Water Quality in the Ozark National Scenic Riverways, Missouri

By JAMES H. BARKS

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MISSOURI

Canoeists on the Current River. Tourism is a rapidly growing industry in the Riverways.
Photo courtesy of the National Park Service.

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ABSTRACT

The Current River and its principal tributary, Jacks Fork, are the Ozark National Scenic Riverway's primary natural features. About 60 percent of the baseflow in the two streams is derived from the seven largest springs in the basin. The springs are supplied by diffuse contributions from the regional aquifer system and discrete inflows from sinkholes and losing streams, some of which are outside the Current River basin. Because the streams and springs are the primary attractions to the park, preservation of the physical, chemical, and biological quality and aesthetic appeal of the waters is important.

From April 1973 to May 1975, water samples were collected from 19 wells, 7 large springs, 14 sites on the Current River, 7 sites on the Jacks Fork, and 5 tributaries to the Current River and Jacks Fork. Calcium, magnesium, and bicarbonate composed more than 90 percent of the total ionic composition of dissolved material in springs and streams and more than 95 percent in ground water, reflecting the dolomitic composition of the rocks. Dissolved-solids concentrations averaged 276 mg/L (milligrams per liter) in ground water and less than 200 mg/L in springs and streams. Total nitrate concentrations as N averaged 0.22 mg/L in ground water, 0.42 mg/L in springs, and less than 0.65 mg/L in streams. Minor element concentrations were generally low, but on one occasion anomalously high concentrations of total barium, lead, silver, and zinc were found in Blue Spring and the four stream-index stations. The only pesticides detected were 0.03 ug/L (micrograms per liter) of 2,4-D, and 0.03 ug/L of 2,4,5-T, and these were in the Current River below Montauk State Park during storm runoff. The streams were relatively free of sediment, except during periods of storm runoff. Fecal coliform and fecal streptococcus densities as high as 2,000 and 2,100 col/100 ml (colonies per 100 milliliters), respectively, were measured in the Jacks Fork downstream from horseback riding activities. Fecal coliform and fecal streptococcus densities of about 4,000 and 22,000 col/100 ml, respectively, were measured in the Current River during storm runoff. Otherwise, bacteria densities averaged less than 100 col/100 ml for fecal coliforms and 200 col/100 ml for fecal streptococci and appear to be relatively unaffected by swimming, camping, canoeing, and other recreational activities in and along streams. The aquatic biota in the Current River and Jacks Fork indicate that the streams generally are unaffected by pollution.

INTRODUCTION

On August 25, 1974, Congress designated 134 miles of the Current River and Jacks Fork, and about 65,000 acres of adjoining land as the Ozark National Scenic Riverways (hereafter referred to as "the Riverways.") The establishing act, Public Law 88-492, stated that the Riverways was created for the purpose of "* * * conserving and interpreting unique scenic and other natural values and objects of historic interest, including preservation of portions of the Current River and Jacks Fork River in Missouri as free-flowing streams, preservation of springs and caves, management of wildlife, and provision for the use and enjoyment of the outdoor recreation resources * * *."

The Riverways is located in the Current River basin in southeastern Missouri (pl. 1). It is mainly in Shannon and Carter Counties with small parts in Dent and Texas Counties. At present (1977), the park boundary encompasses approximately 100 miles of the Current River, 34 miles of the Jacks Fork, 60,000 acres of land owned by the Federal government, and 20,000 acres of State and private lands and scenic easements. It is within an easy 1-day drive of two large metropolitan centers; 150 miles south of St. Louis and 250 miles southeast of Kansas City, yet it remains "off the beaten path."

The Riverways region was explored by the Spanish in the 16th century and was sparsely populated by French trappers in the 18th century. French trappers probably named the Current River, which they called "La Riviere Courante" or "The Running River." The United States acquired the areas from France as a part of the 1803 Louisiana Purchase, and systematically displaced the native Osage Indians who ceded their southern Missouri lands to the United States in 1808. Settlers from Tennessee, Kentucky, and other eastern states arrived in the area in the early 19th century. Many of the original settlers were from Appalachia and their mountain way of life eventually evolved into the distinct, but related, Ozark culture (Natl. Park Service, 1960, p. 23-28).

Counties and principal towns were established between 1833 and 1859, but settlement was slow. The region remained relatively unaffected by outside change until 1870, when the advent of railroads and the development of a regional lumber industry stimulated economic growth. By 1900, the Doniphan area was the nation's leading producer of railroad ties. By 1930, the era of widespread exploitation of the virgin pine and hardwood forests had come to an end. However, increased interest in the recreation potential of the Ozarks roughly coincided with the decline of the timber industry. Conservation practices were instituted and State parks were established at Alley, Montauk, and Round Springs between 1924 and 1927. The Federal government later supplemented these initial State efforts with the establishment of the 800,000 acre Clark National Forest (now part of the Mark Twain National Forest) north and east of the Riverways.

Even during the lumbering boom, the immediate Riverways area retained a largely river-oriented society in which subsistence agriculture and cattle raising were principal occupations. Schools, churches, and other structures continued to be built along the rivers, which provided the principal access to them. Because roads were unnecessary, few were constructed in the river valleys during the early settlement period. When the automobile became regionally important, ridgetop roads were constructed, thereby preserving the aesthetic quality of the river valleys.

In 1955, the Viburnum Trend ore deposits were discovered in the Black River basin about 20 miles northeast of the Riverways. Production of lead and smaller quantities of zinc, copper, and silver began in 1960. Since 1970, the Viburnum Trend has been the world's largest lead-producing district.

At present (1978), tourism is a rapidly growing industry in the Riverways area (frontispiece). Future economic growth will depend on efforts by the National Park Service and private individuals to develop tourist services and recreational support facilities, while preserving the environment the tourists come to enjoy.

PURPOSE AND SCOPE

In 1973, at the request of the National Park Service, the U.S. Geological Survey began a water-quality study of the Riverways area. The study area includes most of the Current River basin, but the sampling program was designed to determine the quality of water in the Riverways. The main purpose of the study was to determine existing physical, chemical, and biological conditions of the ground, spring, and surface waters, with emphasis on surface water. This information would constitute a baseline for comparison with future conditions.

Four sites (stream-index stations) on the Current River and Jacks Fork were sampled repetitively to delineate variations in common inorganic constituents, major nutrients, minor elements, pesticides, sediment, and aquatic biota with time, runoff, and water uses. Several other sites on the two streams were sampled at least once to show any progressive downstream changes in water quality. Samples were collected upstream and downstream from communities, large campgrounds, and areas of extensive recreational activities such as swimming and horseback riding to assess changes in bacteria and nutrients during the recreation season. The major tributaries to the Current River and Jacks Fork and the seven largest springs that contribute water to the Riverways were also sampled. Water-quality data were collected from 19 wells distributed throughout the area.

This report presents results of the water-quality study of the Riverways region and makes suggestions for future monitoring of water quality in the Riverways.

The author expresses appreciation to the National Park Service, and especially to Dr. Leo F. Marnell, research biologist, for assistance rendered in the completion of this investigation.

PREVIOUS INVESTIGATIONS

Clifford (1966) described the physical, chemical, and biological conditions of six Ozark streams including the Current River and Jacks Fork. His report contains data collected monthly from March to November 1961, at five sites on the Current River, one site on the Jacks Fork, and Montauk Springs, Round Spring, Big Spring, and Alley Spring.

"Springs of Missouri," (Vineyard and Feder, 1974) contains a generalized description of the Current River Basin and a detailed description of the major springs in the basin. A short discussion of the quality of spring water is accompanied by a tabulation of chemical analyses made by the Missouri Geological Survey and Water Resources (now Missouri Division of Geology and Land Survey) during the period 1925-66.

Physical setting, water budget, hydrologic relationships, surface-water availability and quality, ground-water availability and quality, flooding, water use, sewage-treatment and water-development guidelines are topics considered in the Hydrologic Investigations Atlas HA-550 "Water Resources of South-Central Missouri," (Gann and others, 1976). Because the Current River basin is located near the center of the Hydrologic Investigations Atlas study area, the atlas is useful for comparing water resources of the Current River basin with water resources of surrounding basins.

In 1967, the U.S. Department of Agriculture, Forest Service, began collecting water-quality data from Big and Sinking Creeks, tributaries to the Current River that originate in the Mark Twain National Forest. Between August 1967 and May 1969, approximately 43 samples from each of the two stream-monitoring stations were analyzed for several physical, chemical, and biological characteristics and constituents. The results, presented in a report by Tryon (1970), indicate that water in Big and Sinking Creek basins is of excellent quality. A copy of the report and additional data collected since 1969 are on file at the Mark Twain National Forest headquarters in Rolla, Mo.

A benthic invertebrate study of five Ozark streams, including the Current River and Jacks Fork, was made by the Missouri Department of Conservation in 1974 (R. M. Duchrow, written commun., 1975). Data from four of the sampling sites are used later in this report. It is anticipated that the results of the entire study are to be presented by Richard M. Duchrow in a forthcoming Missouri Department of Conservation report.

The U.S. Geological Survey collected water-quality samples monthly from the Current River at Van Buren from October 1962 to June 1963, and bimonthly from the Current River near Doniphan from July 1969 to June 1975. Sinking Creek at Round Spring and Jacks Fork near Mountain View were each sampled once in 1964; Pigeon Creek at

Montauk State Park was sampled once in 1965. Analyses of these samples and those of springs sampled after 1966 are included in the U.S. Geological Survey annual reports, "Water Resources Data for Missouri."

Much of the aforementioned data are used in this report to compare with or supplement data collected during this investigation.

DESCRIPTION OF THE REGION

TOPOGRAPHY

The topography of the Riverways area is typical of the Ozarks. Long, sinuous ridges are alined with corresponding steep-walled valleys, called "hollows." The hollows are drained by swiftly flowing streams that are often flanked by near vertical bluffs. Karst features such as caves, sinkholes, and springs are plentiful throughout the area. (See cover and frontispiece.)

Ridgetop altitudes above mean sea level generally range from 1,000 to 1,200 feet along the Jacks Fork and the upper Current River, and from 700 to 1,000 feet in the lower part of the park. Streambed elevations for the Current River range from about 900 feet at the upstream park boundary to 380 feet at the downstream boundary for an average slope of 5.0 ft/mi (feet per mile). The Jacks Fork drops 7.2 ft/mi from 860 feet at the upstream boundary to 560 feet at the mouth.

GEOLOGY

Josiah Bridge mapped and described in detail the geology of the Eminence and Cardareva quadrangles, which includes most of the Riverways area (Bridge, 1930). The Riverways is situated on the southwest slope of the St. Francois Mountains and includes some of the most ancient rocks on the North American continent. These are the Precambrian igneous knobs that crop out east of Eminence near the center of the Riverways (pl. 2). The 40 or more masses of igneous rocks range in size from a square yard up to 5 or 6 square miles and occur within approximately a 9 mile by 14 mile rectangular area. Some of the larger masses form the highest summits in the region. The igneous rocks are mainly rhyolite, a dense, fine-grained to porphyritic rock that is generally red, but may be gray or green. Other igneous rock types that are generally less common in the area are granite, volcanic ash, and tuff.

Streams and orifices of large springs in the Riverways are in the Gasconade Dolomite of Early Ordovician age and the Eminence and Potosi Dolomites of Late Cambrian age. These cherty dolomites are generally several hundred feet thick, light gray to brown in color, and very soluble. Solution-enlarged openings throughout the formations store and transport large quantities of water. Soils produced from weathering of the dolomitic rocks are deep red clays with numerous small chert fragments.

The Roubidoux Formation overlies the Gasconade and caps the divides between most of the streams. It is composed of interbedded sandstones and dolomites. The dolomites of the Roubidoux are extremely cherty, and weathered slopes in the lower part of the formation are generally strewn with a mixture of this material and sandstone blocks.

Historically, deposits of copper, iron, and manganese have been mined in the Current River-Jacks Fork watershed, but extraction of these minerals is presently not economically feasible. Large quantities of lead are mined from the Viburnum Trend in an adjacent watershed. Mineral exploration continues in the Current River basin and mining for base metals is possible in the future. Limestone, granite, and sandstone have been quarried on a limited scale. Sand and gravel deposits are abundant in major streams and tributaries, and sand and gravel production occurs at Eminence and Van Buren.

HYDROLOGY

The average flow of the Current River at Doniphan, Mo., is 2,720 ft^3/s (cubic feet per second); 445 ft^3/s is the average flow of the Jacks Fork at Eminence, Mo., (U.S. Geol. Survey, 1976). A seepage run made by the U.S. Geological Survey in 1966 and subsequent discharge measurments of the large springs, Current River, and Jacks Fork show that about 60 percent of the baseflow of the two streams is derived from the seven largest springs in the basin. Numerous smaller springs also contribute to the flow of the streams. Thus, the quality of water in the streams is greatly influenced by what enters and flows through the hydrologic system that supplies the springs.

Porous surficial material composed of cherty sand or gravel permits the rapid percolation of precipitation into the aquifer system. Large quantities of water are stored in the rocks and are transported through an extensive interconnected system of solution-enlarged fractures and bedding-plane openings. In the vicinity of the springs, large horizontal channels radiate in several directions which generally coincide with the regional joint pattern (Skelton and Harvey, 1968). During extended dry periods most of the springflow is supplied by the regional aquifer system. However, following intense rainfall, water flows into nearby sinkholes and losing stream valleys and is rapidly transported through the conduits to the springs. As a result, the large springs generally respond to intense rainfall within hours, almost as quickly as nearby streams.

Transwatershed ground-water movement occurs in many parts of the Riverways region. Aley (1975) has shown through dye tracing that part of the water discharged from Big Spring originates as much as 40 miles to the west in the Eleven Point River watershed. Feder and Barks (1972) traced water to Blue Spring from Logan Creek about 15 miles to the northeast in the Black River watershed. In both instances the dye traveled at an average rate of better than 1 mi/d (mile per day), indicating rapid subsurface flow in these areas. The vulnerability of large springs in the Riverways to contamination from surface sources outside the basin is well illustrated by these field experiments.

METHODOLOGY

Samples were collected and analyzed for minerals and gases according to Brown and others (1970), for organic substances according to Goerlitz and Brown (1972), for biologic and microbiologic growths according to Slack and others (1973), and for suspended sediment according to Guy (1969), and Guy and Norman (1970). Unless indicated otherwise, laboratory analyses were made at U.S. Geological Survey laboratories. Field techniques used in this study are described briefly in the following paragraphs.

Depth-integrated water samples were collected at one point in the stream cross-section by lowering bottles to the bottom and raising them to the surface at a constant rate. These samples may not be representative of the entire cross-section.

Wells were pumped several minutes prior to collection of ground-water samples, and whenever possible the samples were collected before the water entered a pressure tank.

Sediment samples were collected in glass bottles using a Model DH-48 depth-integrating suspended-sediment sampler. Pesticide, detergent, and DOC (dissolved organic carbon) samples were taken in specially cleansed glass bottles. All other water samples were collected in polyethylene bottles.

Chemical constituents referred to as "total" were determined from unfiltered samples. Samples for DOC were filtered at the time of collection by forcing the water through a 0.45 μm (micrometer) silver filter from a stainless steel chamber, using compressed nitrogen as the pressure source. All other chemical constituents were determined from samples that were filtered through 0.45 μm membrane filters from a polyvinyl chloride chamber, using a tire pump as the pressure source.

Samples to be analyzed for cations were acidified with double-distilled, analytical-grade nitric acid to a pH of less than 3 to prevent chemical precipitation and adsorption onto the walls of the containers. Nitrogen, phosphorus, COD (chemical oxygen demand), detergent, and DOC samples were chilled to approximately 4°C (degrees Celsius) to deter decomposition.

Samples for determining bacteria were collected in sterilized large-mouth polyethylene bottles. Samples were generally processed upon collection and never held longer than 4 hours before preparation and incubation.

Phytoplankton samples were collected in 1-liter polyethylene bottles using the same procedure as for other water samples. The samples were preserved by adding a formaldehyde-cupric sulfate solution.

Polyethylene strips (fig. 1) were used to collect periphyton. The strips were fastened to submerged roots, logs, and other objects in moving water near the point where water samples were collected. They were sufficiently exposed to sunlight for photosynthesis to take place. The strips were usually near the water surface, although depth below the surface was not ciritcal because of the clarity of the water. The strips remained in the water approximately 30 days, which was sufficient for good colonization of the periphyton. They were collected at the time other samples were taken and were placed in a formaldehyde-cupric sulfate preservative.

Figure 1.—Polyethylene strip used for the collection of periphyton.

A semiquantitative method was used to collect benthic invertebrates. Because the sampling methods are selective, precautions were taken to make sure all the collections were made in a uniform way. Multi-plate samplers (fig. 2) were secured to the stream bottom in a riffle near the point where water samples were collected. The samplers were located at the same places each time. They remained in the water approximately 30 days (the same as for periphyton) and were removed at the time other samples were taken. The samplers, along with the benthic organisms, were placed in a sample container with 40-percent isopropyl alcohol preservative. Those organisms retained by a No. 70 sieve (0.210-mm mesh openings) were identified.

Figure 2.—Multi-plate sampler used for the collection of benthic invertebrates.

Water temperature, specific conductance, pH, alkalinity, dissolved oxygen, fecal coliform, fecal streptococcus, and stream or spring discharge were determined in the field. Water temperature was measured with a mercury thermometer to the nearest 0.5°C. Specific conductance was measured using a portable conductivity meter with temperature compensation designed to express readings in micromhos per centimeter at 25°C. The potentiometric method was used to measure both the pH and alkalinity. The inflection points in the titration for alkalinity with 0.01639 N H_2SO_4 were 8.3 for carbonates and 4.5 for bicarbonates. The azide modification of the Winkler method was used for dissolved oxygen determinations. Bacteria were measured using the membrane filter method.

Wherever U.S. Geological Survey stream gages were present, discharges were determined from the gage-height record. In other areas discharges were computed from measurements made using a wading rod and current meter following procedures outlined in Buchanan and Somers (1969).

WATER QUALITY

Water does not remain pure in its movement through the hydrologic system. It receives natural impurities from the atmosphere and lithosphere as well as the impurities contributed by man.

Natural quality of water varies from place to place, with the season of the year, with the climate, and with the kinds of rocks and soils through which the water moves. As moisture condenses and falls through the atmosphere, it absorbs gases and picks up dust, bacteria, and other particles. Consequently, as precipitation reaches the earth it carries small quantities of dissolved and suspended matter. As the water moves over and through the earth's crust it dissolves minerals from rocks and soil, percolates through organic materials such as roots and leaves, and reacts with living things such as microscopic organisms. Water quality is altered by wind- or stream-transported sediment. It is modified by temperature, by soil bacteria, and by evaporation. These and other environmental factors determine the natural quality of water.

Activities of man (municipal, industrial, agricultural, and recreational) generate many types of wastes that may end up in streams or ground water. Sewage and livestock wastes contain substantial amounts of nutrients, bacteria, and oxygen-demanding organic material. Fertilizer applied to agricultural land is a potential source of nutrients. Pesticides are used in the management of agricultural and forest lands. Gravel operations, construction, and timber-cutting activities produce sediment. Wastes from mining operations may contain large amounts of dissolved solids, including minor elements. Landfills contain many types of wastes such as nutrients, bacteria, toxic metals, and pesticides. These are examples of wastes that can degrade water quality and affect users of the water and aquatic life.

Most natural processes contributing dissolved and suspended material to water are beyond man's control, but the activities of man are, to varying degrees, controllable.

From April 1973 to May 1975, approximately 52 sites (pl. 1) were sampled to determine water quality in the Riverways. A summary and discussion of the ground-water, spring, and surface-water data are presented according to common inorganic constituents, major nutrients, minor elements, pesticides, sediment, bacteria, and aquatic biota.

GROUND WATER

The location and description of the 19 wells sampled during this study are given on plate 1 and in table 1, respectively. The wells are distributed throughout the Riverways and are located within 0.5 mile of the Current River or Jacks Fork.

Round Spring, Big Spring, and Alley Spring recreation areas are the most developed and intensively used in the Riverways. Spray-irrigation sewage-treatment facilities have been constructed at each of these

Table 1.—*Description of wells sampled in the Current River Basin*

Map No	Name	Coordinates: Latitude	Coordinates: Longitude	County	Depth (ft)	Depth cased (ft)	Year drilled	Formation open to well
1	Montauk Lodge	37°27′02″	91°41′02″	Dent	500	340	1964	Potosi Dolomite.
2	Welch Spring Lodge	37°23′17″	91°34′23″	Shannon	...	...	1957	
3	Akers Campsite	37°22′36″	91°33′15″	..do	500	300	1974	Potosi Dolomite.
4	Pulltite Campsite	37°20′00″	91°28′39″	..do	310	205	1968	Eminence and Potosi Dolomites.
5	Carr Store	37°17′15″	91°24′32″	..do	69	30	1956	Eminence Dolomite.
6	Round Spring	37°16′45″	91°24′28″	..do	400	200	1970	Potosi Dolomite.
7	Jerktail Campsite	37°13′53″	91°18′36″	..do	400	180	1975	Eminence Dolomite.
8	Two Rivers 1	37°11′17″	91°16′32″	..do	350	100	1969	Eminence and Potosi Dolomites.
9	Powder Mill Campsite	37°10′48″	91°10′31″	..do	307	202	1968	Potosi Dolomite.
10	Austin House	37°02′31″	91°04′00″	Carter	250	150	1969	Eminence and Potosi Dolomites.
11	Big Spring 1	36°56′51″	90°59′31″	..do	250	120	1934	Potosi Dolomite.
12	Big Spring 2	36°57′32″	90°59′25″	..do	475	200	1961	Do.
13	Big Spring	36°56′44″	90°59′55″	..do	520	370	1970	Do.
14	Cardinal Acres	37°03′22″	91°39′47″	Texas	106	41	1957	Lower part of Gasconade Dolomite.
15	Bunker Hill Ranch	37°03′52″	91°33′20″	Shannon	330	205	1962	Do.
16	Alley Spring Maintenance Building.	37°09′05″	91°26′40″	..do	434	306	1933	Eminence Dolomite.
17	Alley Spring Store	37°08′39″	91°26′36″	..do	...	...	1948	Do.
18	Alley Spring	37°08′29″	91°26′45″	..do	650	301	1970	Do.
19	Shawnee Maintenance Building	37°09′26″	91°17′50″	..do	250	180	1973	Potosi Dolomite.

areas and are scheduled to begin operation in 1976. The spray fields that receive the liquid sewage are located in grass or forested areas that are about 0.5 mile from either the Current River or Jacks Fork, and 0.2 to 2.0 miles from the new well and major spring in each area. Because of the heavy use of these areas and because of the proximity of the new sewage systems to the streams, wells, and springs, two wells were sampled at the Round Spring area, three at the Big Spring area, and three at the Alley Spring area. These included a new well at each of the areas which will replace the old wells and become the primary water supplies for these areas. Analyses of samples from the new wells were made by the Division of Geology and Land Survey, Missouri Department of Natural Resources. The Carr Store well at Round Spring and the Alley Spring Store well at Alley Spring were sampled twice; all other wells were sampled once, for a total of 21 samples. The analyses for these samples are shown in tables 2 and 3 (p. 44 and 46) in the back of the report.

COMMON INORGANIC CONSTITUENTS

The kinds and proportions of ions in the ground water reflect the chemical composition of the predominately dolomite aquifers. Calcium, magnesium, and bicarbonate constituted more than 95 percent of the total ionic composition in water from all the wells except Jerktail (no. 7, table 1). Calcium and magnesium were present in approximately chemically equivalent amounts. The Jerktail well had anomalously high concentrations of sodium (100 mg/L), sulfate (99 mg/L), and chloride (91 mg/L), which probably are caused by contact with sulfide mineral deposits. The remaining wells had maximum sodium, sulfate, and chloride concentrations of 2.5, 14, and 3.8 mg/L, respectively.

Dissolved-solids concentrations, representing the total mineralization of the water, ranged from 177 to 571 mg/L and averaged 276 mg/L. The maximum value is for water from the Jerktail well.

Hardness of water has been classified with respect to calcium carbonate according to the following (Brown and others, 1970, p. 95):

Hardness ($mg/L\ CaCO_3$)	*Classification*
0- 60	Soft
61-120	Moderately hard
121-180	Hard
>180	Very hard

Hardness of ground water in the Riverways ranged from 190 to 350 mg/L as $CaCO_3$ and averaged 259 mg/L for the 21 well samples.

Alkalinity, consisting entirely of bicarbonate, ranged from 187 to 354 mg/L with an average of 258 mg/L.

MAJOR NUTRIENTS

Only low levels of nitrogen and phosphorus were detected in the ground water. Total nitrate concentrations as N ranged from 0.00 to 1.4 mg/L, with an average of 0.22 mg/L. Total phosphorus concentrations as P ranged from 0.01 to 0.04 mg/L.

MINOR ELEMENTS

Maximum concentrations of minor elements were all below the recommended drinking water standards (U.S. Public Health Service, 1962). (See table 4.) Relatively high total zinc concentrations can probably be attributed to the solution of zinc from casings, piping, and pressure tanks. Feder and others (1969) showed by analyses of a few comparative samples collected directly from wells and from faucets receiving water from pressure tanks that 35 to 100 percent of the zinc content may come from the galvanized plumbing.

Table 4.—*Comparison of maximum concentrations of selected minor elements in 18 well samples with the recommended or mandatory drinking-water standards*

[Results in micrograms per liter]

Element	Drinking water standard (U.S. Public Health Service, 1962)	Maximum observed (unfiltered samples)	Element	Drinking water standard (U.S. Public Health Service, 1962)	Maximum observed (unfiltered samples)
Arsenic	10	1	Lead	50	<100
Barium	1,000	100	Mercury	5	2.2
Cadmium	10	<10	Selenium	10	1
Chromium	50	0	Silver	50	<10
Copper	1,000	30	Zinc	5,000	2,800

BACTERIA

Any occurrence of fecal coliforms in water is evidence of contamination by wastes from warm-blooded animals. As fecal coliform densities increase, the potential health hazards become greater (Committee on Water Quality Criteria, 1972, p. 57).

The only fecal coliforms found in ground water were densities of 3 and 23 col/100 ml in water from two wells in the Big Spring area. Ground water in the Big Spring area may have some local contamination, but other constituents do not verify that a problem exists.

SPRINGS

The seven largest springs that contribute flow to the Current River and Jacks Fork are Big, Welch, Alley, Blue, Montauk, Pulltite, and Round Springs (pl. 1). All references to Blue Spring in this report are to Blue Spring on the Current River and not to the smaller Blue Spring on the Jacks Fork. Daily discharge records are available from 1921 to the present (1977) for Big Spring, and from 1929 to 1939 and 1965 to the present for Alley and Round Springs. Occasional discharge measurments are available from the 1920's to the present for the other springs. From these continuous and occasional measurments, the approximate relative size of the springs is shown in table 5. The order of magnitude is changed from that given by Vineyard and Feder (1974, p. 13) because of the use of longer records. It should be noted that the maximum discharge shown for Alley Spring is much higher than the actual maximum for the period of record because the measurement included substantial runoff upstream from the spring. Also, because peak flows are of short duration, those shown for springs that were measured occasionally may be considerably lower than actually occurred during the period of record.

Table 5.—*Discharges of the seven largest springs in the Current River basin*

Name of spring	Maximum discharge		Minimum discharge		Average discharge
	Cubic feet per second	Date	Cubic feet per second	Date	
Big	1,300	June 1928	236	Oct. 6, 1956	433
Welch	500	Apr. 2, 1973	70	Aug. 24, 1964	164
Alley	[1]2,750	Apr. 22, 1974	54	Oct. 15-18, 1934	133
Blue	510	Dec. 11, 1971	59	Nov. 1, 1971	119
Montauk	199	May 10, 1973	39	Jan. 10, 1956	85
Pulltite	164	June 18, 1973	5.9	Oct. 14, 1932	65
Round	520	May 14, 1933	10	Dec. 10-12, 1937	45

[1]Peak flows affected by runoff upstream from spring after heavy rains.

Big, Alley, Montauk, Pulltite, and Round Springs have associated large campgrounds; the Welch and Blue Spring areas are relatively undeveloped.

Montauk Spring was sampled once and the other six springs were sampled four or five times during the study. Minor elements were analyzed for four samples collected from Blue Spring. The following discussion of the quality of spring water is based on these analyses and the historical data available for the springs, which are shown in table 6 (in pocket) and table 7 in the back of the report.

COMMON INORGANIC CONSTITUENTS

Ions in the spring water occured in about the same proportions as in the well water with calcium, magnesium, and bicarbonate composing more than 90 percent of the total. Spring water was less mineralized than the well water presumably because of less exposure to soluble rocks. Ionic concentrations generally decreased with increased spring discharge because the greater the spring discharge the larger the proportion that is derived from surface runoff through sinkholes and losing streams.

A comparison of the range in dissolved-solids concentrations, hardness, and alkalinity for the seven largest springs (table 8) indicates a high degree of chemical uniformity among the springs.

Table 8.—*Dissolved-solids concentrations, hardness, and alkalinity for the seven largest springs in the Current River basin*

[Results in milligrams per liter]

Name of spring	Dissolved solids			Hardness as $CaCO_3$			Alkalinity as $CaCO_3$		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Montauk	203	123	156	180	113	143	164	108	136
Welch	204	118	169	209	98	161	202	97	157
Pulltite	183	105	161	176	94	148	166	85	143
Round	215	105	165	197	95	161	195	91	158
Alley	194	97	149	172	83	142	168	79	136
Blue	186	70	146	184	52	131	182	46	121
Big	208	114	168	200	108	164	192	98	160

MAJOR NUTRIENTS

One indication of spring-water contamination is high nitrogen concentrations. The sources of nitrogen may be decaying organic matter, legume plants, sewage, nitrate fertilizers, nitrates in soil and rock, or deposits of bat droppings in caves.

Nitrogen concentrations for springs in the Current River basin are considerably less than for springs in most other river basins in Missouri (Vineyard and Feder, 1974, p. 22). Total nitrate concentrations as N for 60 samples collected from 27 springs in the Current River basin during the period 1925 to 1966 averaged 0.25 mg/L. During the same period total nitrate concentrations in 28 samples collected from 21 springs in the upper White River basin averaged 3.3 mg/L or about 13 times more than in the Current River basin. The upper White River basin drains a highly developed area with widespread dairy farming and stock raising in the vicinity of Springfield. The Current River basin drains a relatively undeveloped area with scattered stock raising. This comparison illustrates that extensive land development in the recharge areas of springs can have significant long-term effects on their quality. Tryon (1976) in a study of variations in ground-water quality in Phelps County, about 40 miles north of the Riverways, similarly showed that nitrate concentrations increased with increased agricultural (pasture and livestock) land use. He also showed that adverse effects of land use on ground-water quality was more severe in intensely developed karst areas (characterized by losing streams, sinkholes, caves, and springs) than in less intensely developed karst areas. Lowest nitrate concentrations generally occurred in heavily forested areas.

Total nitrate concentrations for the 120 analyses shown in table 6 averaged 0.42 mg/L compared to 0.22 mg/L for the 21 well samples. The higher average for the springs is attributed to their being more subject to contamination from the surface by rapid drainage of runnoff through sinkholes and losing streams.

Total nitrate data are summarized for each of the springs in table 9. Average concentrations were about two times higher in springs in the Jacks Fork and upper Current River basins than in springs in the lower Current River basin. This trend may be caused by slightly different land-use practices in the recharge areas for the springs, but insufficient information about the recharge areas are available to show such a relationship. The maximum total nitrate concentrations generally occured during periods of high flow and the minimum values occured during low flow. All values for 1973 were higher than the averages because of excessive rainfall and high base flows of the springs throughout the year. Total nitrate data are considered to be insufficient to establish any long-term trends.

Table 9.—*Total nitrate concentrations for the seven largest springs in the Current River basin*

[Results in milligrams per liter as N]

Name of Spring	Maximum	Minimum	Mean	Name of spring	Maximum	Minimum	Mean
Montauk	0.92	0.04	0.59	Alley	0.78	0.14	0.52
Welch	.97	.00	.55	Blue	.63	.11	.35
Pulltite	.68	.11	.43	Big	.50	.00	.28
Round	1.1	.00	.26				

Of the 64 total phosphorus values shown in table 6, 37 are 0.00 mg/L and only one is greater than 0.05 mg/L (0.10 mg/L at Big Spring). The higher concentrations generally correspond to higher springflows as indicated by the higher values during 1973.

MINOR ELEMENTS

Blue Spring was sampled for minor elements because of its susceptibility to contamination by wastes discharged from a lead mining and milling operation in the Black River basin (Feder and Barks, 1972).

Four samples were collected from Blue Spring for minor element analyses. Concentrations were low except for the August 1, 1973, sample which had anomalously high concentrations of total barium, lead, silver, and zinc (table 7). Comparatively high concentrations of minor elements, particularly lead, also occured at the four stream-index stations for the July 30-August 2, 1973, samples. This indicates that the high values in Blue Spring were probably a result of antecedent conditions, rather than pollution from the mining operation. For 2 months prior to July 23 there had been only minor amounts of rainfall and streams were at a low-flow condition. On July 23 and 24 more than 3 inches of rain fell on the upper Current River basin and on July 24 more than 4.5 inches fell on the upper Logan Creek basin. The Current River at the gage near Eminence increased from about 930 ft^3/s on July 22 to a peak of 24,200 ft^3/s on July 24. The high minor element concentrations in the late July to early August samples were probably the result of heavy rainfall washing dust from the air, leaching metals from oxidized rocks, and stirring up bottom sediments in streams after an extended dry period.

BACTERIA

Until recent years little consideration was given to the bacterial content of spring water in the Ozarks. The clear, cold water which issued from the ground was assumed to be "pure." However, recent interest has been generated by a greater awareness of the potential for spring contamination from surface sources and by high fecal coliform and fecal streptococcus densities observed in some Ozark springs. For instance, high fecal coliform densities (several hundred col/100 ml) have been observed in several large springs in the upper White River basin. The main sources of the bacteria are sewage effluents, septic tanks, landfills (especially in sinkholes), and high livestock concentrations.

The sanitary significance of fecal coliforms in the environment has been well documented by Geldriech (1966). Fecal streptococci are also being used as indicators of significant contamination of water because, like fecal coliforms, the normal habitat of these organisms is the intestine of man and animals. Fecal streptococcal data supplement fecal coliform data by providing additional information concerning the recency and probable origin of pollution (Slack and others, 1973, p. 50). The origin of contamination can be interpreted from fecal coliform to fecal streptococcus ratios (Geldreich, 1966, p. 103) as follows:

Greater than 4 ...	Pollution derived entirely or predominantly from human origin.
Less than 0.6	Pollution derived entirely or predominantly from animal origin.
Four to 0.6	Uncertain; higher ratios suggestive of predominantly human origin and lower ratios suggestive of predominantly animal origin.

Because of differences in the rates of die off of the two bacterial groups, the original numerical relationships may be obscured if the source of pollution is too remote. Ratios with the greatest reliability are for samples taken not more than 24 hours flow time from the origin of pollution.

Fecal coliforms and fecal streptococci were present in each of the seven springs. Ratios were nearly all below 0.6, indicating animal wastes as the primary source. Fecal coliform densities ranged from less than 1 to 260 col/100 ml and fecal streptococci ranged from less than 1 to 990 col/100 ml. The higher densities can generally be associated with storm runoff preceded by warm, dry weather, as shown by the July 30 to August 3, 1973, values. Fecal coliform and fecal streptococcus densities considerably higher than those shown in table 6 can occur during the early part of storm runoff as shown by the July 23, 1973, determinations for the Current River upstream and downstream from Montauk State Park.

SURFACE WATER

Samples were collected at 14 sites on the Current River, at 7 sites on the Jacks Fork, and from near the mouths of 5 tributaries (pl. 1). Big Creek near Round Spring was not sampled because of inaccessibility and because results of water-quality monitoring by the Forest Service (Tryon, 1970) indicate that Big Creek basically is free of pollution. Three stream-index stations on the Current River and one on the Jacks Fork were sampled 10 times to show variations in quality with time, runoff, and use. Results of analyses of stream samples are shown in table 10 (in pocket) and tables 11-15 in the back of the report. The impact of visitor use was studied by comparing conditions upstream and downstream from camping, horseback riding, swimming, and other activities.

COMMON INORGANIC CONSTITUENTS

Like the wells and springs, ionic properties of streams in the Riverways reflect the dolomitic composition of the rocks. Calcium and magnesium are present in almost chemically equivalent amounts and together with bicarbonate make up more than 90 percent of the total ions. The concentration of sulfate is usually about 5 mg/L, and sodium, potassium, and chloride are each less than 5 mg/L.

The U.S. Geological Survey sampled the Current River near Doniphan, Mo. (map no. 53, pl. 1), bimonthly from July 1969 to July 1975. This site is about 25 miles downstream from the National Park Service boundary. No significant amount of inflow occurs between the two points, and therefore, characteristics related to the major ionic composition of the water are considered to be similar for the two sites.

Ranges in dissolved-solids concentrations, hardness, and alkalinity are summarized for the four stream-index stations and for the Current River near Doniphan in table 16. Springs account for a large proportion of the flow in the Current River and Jacks Fork most of the time. Therefore, mineralization of water in the streams is similar to that in the springs (table 8).

The dissolved-solids concentration and the specific conductance of water are closely related, and either can be used to express the degree of mineralization of water. The relation of dissolved-solids concentration to specific conductance for the Current River and Jacks Fork is shown in figure 3. The dissolved-solids concentration can be approximated from

Table 16.—*Dissolved-solids concentrations, hardness, and alkalinity for the Current River and Jacks Fork*
[Results in milligrams per liter]

Station	Number of samples	Dissolved solids			Hardness as $CaCO_3$			Alkalinity as CaCo3		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Current River below Montauk State Park ..	10	149	96	132	150	84	121	141	80	129
Jacks Fork above Two Rivers	10	190	134	162	190	130	159	185	130	156
Current River above Powder Mill	10	182	126	157	190	120	153	177	118	151
Current River below Hawes Campground ..	10	187	125	156	190	120	152	180	115	149
Current River near Doniphan	37	193	112	159	197	100	154	187	98	152

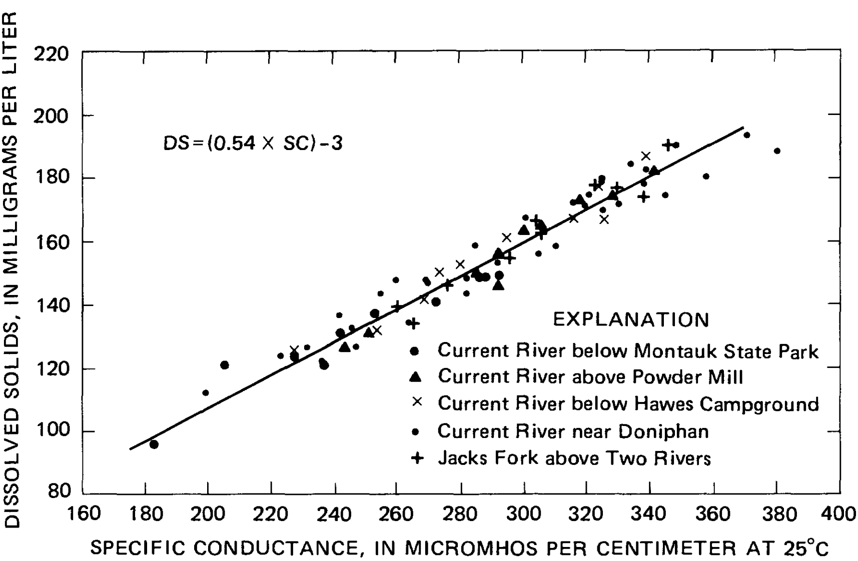

Figure 3.—Relation of specific conductance (SC) to dissolved solids (DS) for the Current River and Jacks Fork.

the specific conductance by use of the graph, or by the equation,

$$\text{Dissolved solids} = (0.54 \times \text{specific conductance}) - 3.$$

Dissolved-solids concentrations used in illustrations in this report were calculated from the sum of various dissolved constituents.

The U.S. Geological Survey measured specific conductance at approximately 100 sites on the Current River, Jacks Fork, and their tributaries during seepage runs of October-November 1966 (U.S. Geol. Survey, 1967, p. 189-197). The results of measurements on the mainstems are shown in figure 4. Abrupt increases and decreases in specific conductance were the result of inflow from large springs and tributaries.

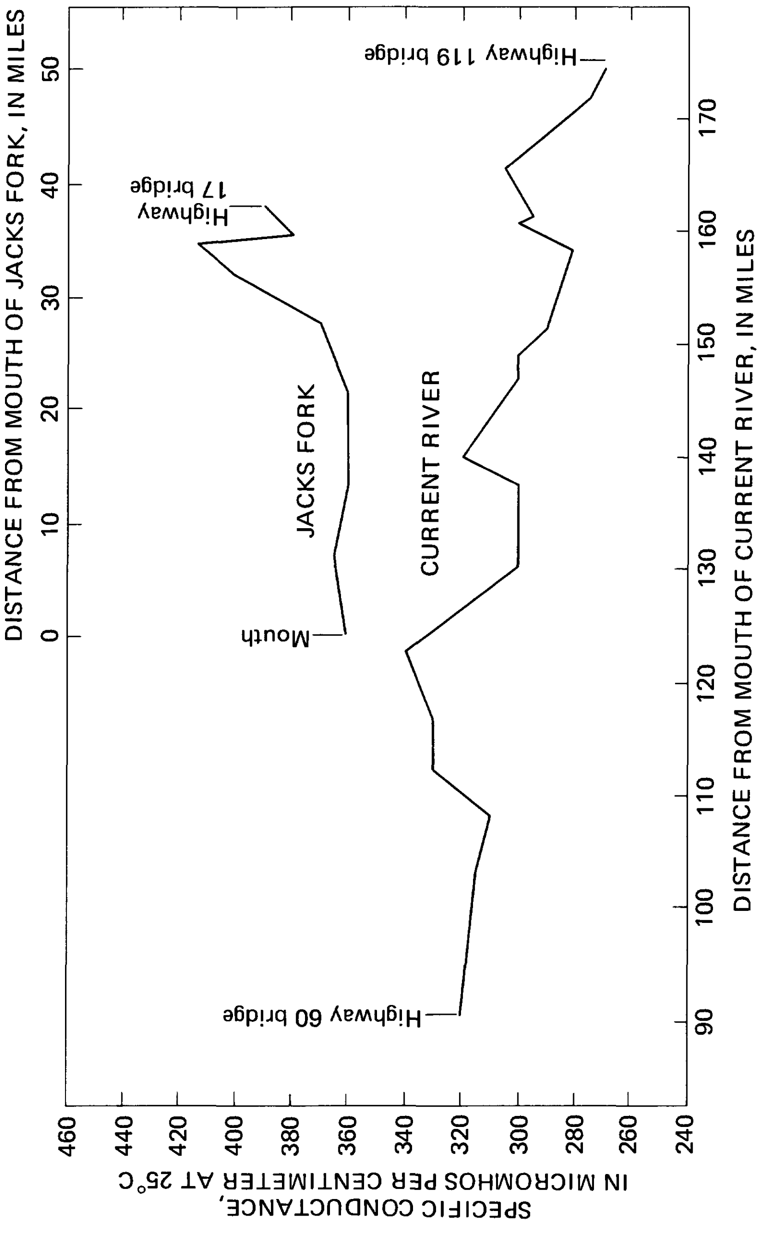

Figure 4.—Relation of specific conductance to distance from mouths of the Current River and Jacks Fork during October-November 1966.

Along the Jacks Fork specific conductance declined from over 400 μmhos/cm (micromhos per centimeter at 25°C) in the headwaters to 360 μmhos/cm at the mouth. The headwaters are cut into the Cotter and Jefferson City Dolomites which are siltier and thinner bedded than the underlying formations into which the lower reach is cut. Ground-water movement is slower through these upper formations and contact time between the rock and the percolating water is longer, resulting in higher mineralization of the water.

Specific conductance of water in the Current River averaged about 295 μmhos/cm upstream from the Jacks Fork and 325 μmhos/cm downstream. The greatest change was an increase of about 40 μmhos/cm caused mainly by inflow of the Jacks Fork.

Near the mouth of the Jacks Fork water from several small tributaries and springs had values of specific conductance of 550 and 600 μmhos/cm which are considered anomalously high. This area contains several igneous knobs and was the locus of copper mining enterprises during the 19th century. The high specific conductance values probably reflect weathering of small quantities of sulfides disseminated through the rocks on the flanks of the igneous knobs.

Like most streams, the concentration of dissolved minerals in the Current River varies inversely with water discharge. During periods of low discharge, concentrations are higher because most of the flow is from springs and ground water that has had close contact with the mineral material for a long time. At higher flows and during floods the concentrations are diluted by surface runoff. Figure 5 shows the relation of dissolved solids to water discharge for the Current River near Doniphan.

MAJOR NUTRIENTS

Nitrogen and phosphorus concentrations were consistently low in the Current River, Jacks Fork, and their tributaries. The low values indicate natural sources such as leaching from soil and rocks, rather than contributions from cities, agriculture, and recreation.

Total nitrate concentrations in the Current River and Jacks Fork were influenced primarily by inflows from the springs. Concentrations in the major tributary streams were slightly, but consistently, lower than in the mainstems. Total nitrate concentrations as N in the Current River decreased from an average of 0.65 mg/L below Montauk State Park to 0.27 mg/L below Hawes Campground. The higher concentrations in the headwaters were caused by higher concentrations in Montauk and Welch Springs (table 9). Total nitrate concentrations in the Jacks Fork increased from an average of about 0.2 mg/L upstream from Alley Spring to about 0.4 mg/L downstream from Alley Spring because of higher concentrations in Alley Spring.

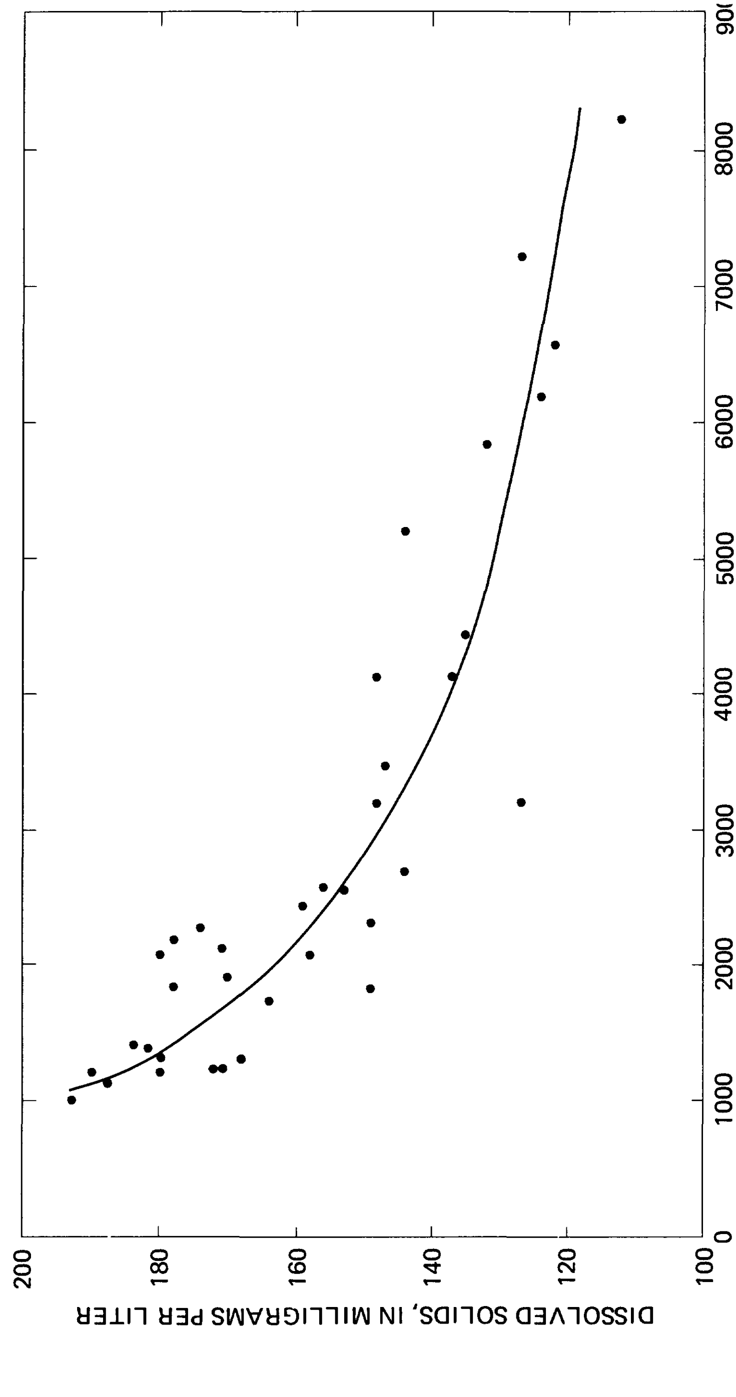

Figure 5.—Relation of dissolved solids to water discharge for the Current River near Doniphan.

The influence of the large springs and the apparent lack of influence by cities and agricultural and recreational activities on total nitrate concentrations in the Current River and Jacks Fork are shown by the example in figure 6. Samples were collected upstream and downstream from potential point sources of nitrogen during the period July 30 to August 2, 1973. Only Montauk Springs and Alley Spring contributed water with total nitrate concentrations significantly higher than in the receiving streams. Welch Spring helped sustain the higher concentrations in the upper Current River caused by Montauk Springs.

No detectable increase in nitrogen due to non-point sources such as floating, camping along gravel bars, and application of agricultural fertilizers is apparent. Although not documented during this study, nitrogen concentrations probably increase during periods of storm runoff.

Total phosphorus concentrations were low in the springs, tributaries, and mainstems. The average concentrations as P for the four stream-index stations were 0.04 mg/L for the Current River below Montauk State Park and 0.02 mg/L for the Current River above Powder Mill, the Current River below Hawes Campground, and the Jacks Fork above Two Rivers. The maximum total phosphorus concentration observed in any well, spring, or stream water was 0.13 mg/L for the Current River below Montauk State Park on October 21, 1974.

MINOR ELEMENTS

Minor element samples were collected quarterly from April 1973 to April 1975 at the four stream-index stations. Unfiltered samples were analyzed to obtain total concentrations in the water-sediment mixture. Because suspended-sediment concentrations at the stream-index stations were low (maximum of 58 mg/L, but usually less than 20 mg/L), the total minor element concentrations were probably not much higher than dissolved concentrations.

In order to show the relative magnitude of minor element concentrations in the Current River basin with respect to streams in undeveloped drainage basins, a comparison is made in table 17 between the Current River basin and 45 nationwide bench-mark stations. The 45 bench-mark samples were among more than 720 samples collected nationwide during October and November 1970 by the U.S. Geological Survey in cooperation with the U.S. Bureau of Sports Fisheries and Wildlife in response to the growing need for data on minor elements in water (Durum and others, 1971). The samples were filtered through 0.45 μm filters and analyzed for arsenic, cadmium, chromium (hexavalent), cobalt, lead, and zinc. Total mercury was also measured.

Considering that the bench-mark samples were filtered (except mercury) and the Current River basin samples were unfiltered, the range in concentrations for the Current River basin stream-index

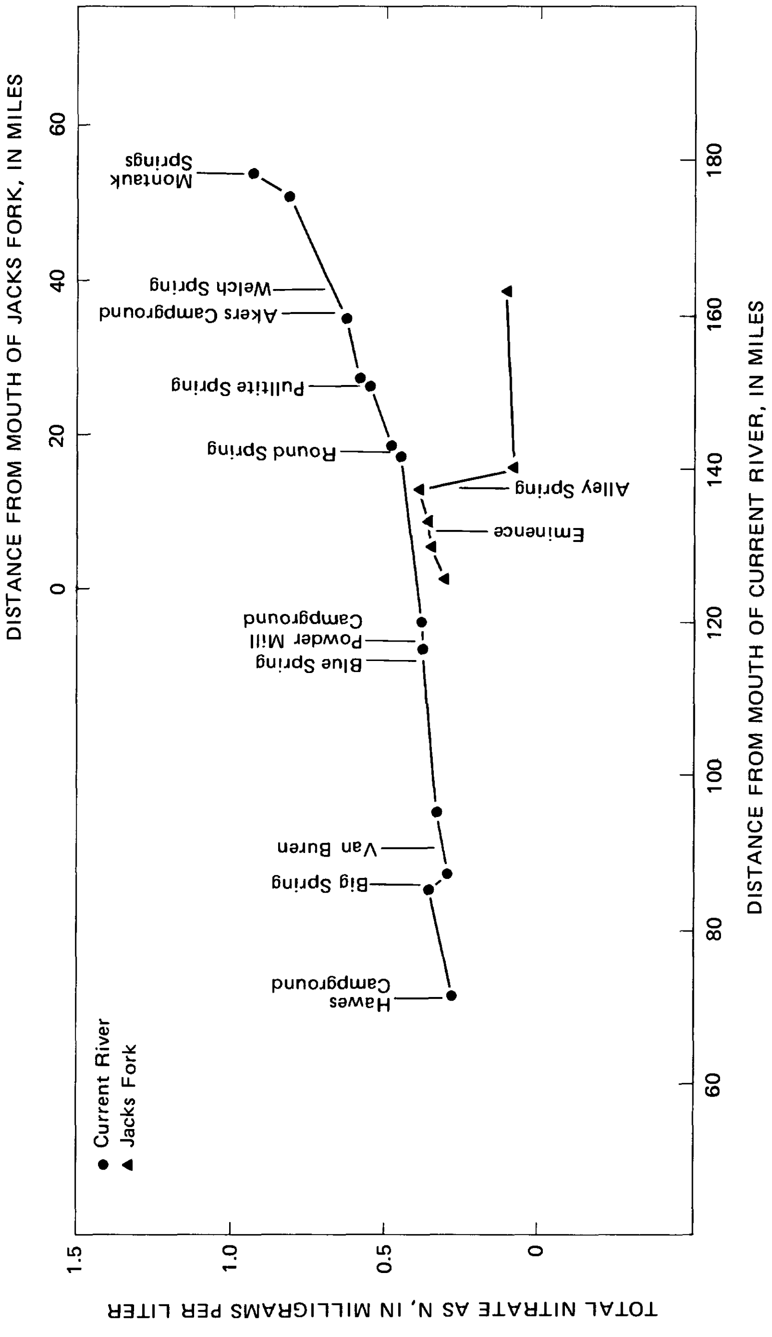

Figure 6.—Relation of total nitrate to distance from mouths of the Current River and Jacks Fork, July 30-August 2, 1973.

Table 17.—*Concentrations of selected minor elements for the four stream-index stations in the Current River basin and 45 nationwide bench-mark stations*

[Results in micrograms per liter]

Current River basin (36 samples)	Total arsenic	Total cadmium	Total chromium	Total cobalt	Total lead	Total zinc	Total mercury	Total barium	Total copper	Total nickel	Total silver
Maximum	6	20	<10	100	550	480	0.7	200	30	100	290
Minimum	0	0	0	3	0	10	.0	0	0	0	0
Mean	1	2	0	10	41	84	.0	17	4	17	13

Nationwide bench-mark stations (45 samples)	Dissolved arsenic	Dissolved cadmium	Dissolved chromium	Dissolved cobalt	Dissolved lead	Dissolved zinc	Total mercury
Maximum	60	10	4	35	84	790	6.0
Minimum	<10	<1	<1	<1	<1	<10	<.5
Mean	4	2	<1	2	6	50	<.5

stations appears to be similar to the range for the bench-mark stations. However, total lead concentrations were anomalously high in the Current River basin in the July 30 to August 2, 1973 samples. As previously explained in the discussion on minor elements in Blue Spring, the higher concentrations were probably caused by the antecedent conditions of heavy rainfall after an extended dry period which washed dust from the air, leached metals from oxidized rocks, and stirred up bottom sediments.

Wentz (1974, p. 27), in his analysis of the effect of mine drainage on the quality of streams in Colorado, summarized criteria which could be applied to Colorado waters used for cold-water fisheries. These criteria are based primarily on the minimum concentrations of metals known to be toxic to fish and other aquatic life as reviewed by McKee and Wolf (1963), the Federal Water Pollution Control Administration (1968), Schneider (1971), the Great Lakes Laboratory (1971), and on the minimum MATC (Maximum Acceptable Toxic Concentration) values recommended by Goettl and others (1971, 1972, 1973). The maximum concentrations of minor elements that occurred at the stream-index stations in the Riverways are compared with Wentz's criteria and criteria suggested by the Committee on Water Quality Criteria (1972) in table 18. The criteria suggested by the Committee on Water Quality Criteria are minimum concentrations considered to be safe for the reproduction, growth, and other natural processes of the aquatic community. The criteria suggested by Wentz compare rather well with those suggested by the Committee on Water Quality Criteria. The maximum concentrations observed at the stream-index stations are

Table 18.—*Comparison of maximum concentrations of selected minor elements for the four stream-index stations in the Current River basin with stream criteria for fish and other aquatic life*

[Results in micrograms per liter]

Minor element	Maximum suggested by Committee on Water Quality Criteria (1972)	Maximum suggested by Wentz (1974)	Maximum observed (unfiltered) samples)
Arsenic	-----	1,000	6
Cadmium	30	10	20
Chromium	50	50	<10
Cobalt	-----	500	100
Copper	[1]20	10-20	30
Lead	30	5-10	550
Mercury	.2	1	.7
Nickel	[1]100	50	100
Silver	-----	0.1	290
Zinc	[1]40	30-70	480

[1]Estimate.

generally close to the criteria, except for total lead, silver, and zinc, which greatly exceeded the criteria. Because the maximum concentrations of total lead, silver, and zinc appear to be anomalously high, additional sampling for these metals, as suggested later in the report, is required before the biological implications of their concentrations in the Current River and Jacks Fork can be determined. Criteria for barium were not determined by Wentz or the Committee on Water Quality Criteria.

PESTICIDES

Pesticide analyses were made of unfiltered samples collected at the four stream-index stations in April, June, July-August, and October 1973, and July 1974. In addition, a storm-runoff sample was collected from the Current River below Montauk State Park on July 23, 1974. Aldrin, chlordane, DDD, DDE, DDT, dieldrin, endrin, heptachlor, epoxide, lindane, 2,4-D, silvex, 2,4,5-T, and PCB's were determined for all the samples. Toxaphene, diazinon, ethion, malathion, methyl parathion, methyl trithion, parathion, and trithion were determined for the July 1974 samples only. The only pesticides detected were 0.03 μg/L of 2,4-D and 0.03 μg/L of 2,4,5-T in the storm-runoff sample. These low concentrations were probably caused by spraying herbicides on timber in the upper part of the watershed.

SEDIMENT

The amount of sediment transported by a stream is very important from a water-quality standpoint. Sediment influences the amount of sunlight available for photosynthesis and determines the type of substrates (clean or sediment covered) available for aquatic organisms. Certain water constituents such as nutrients, minor elements, and organic compounds are transported in streams sorbed to sediment particles and are available to become part of the food chain of the aquatic community.

Sediment is derived mainly from the rocks and soils of the drainage area. A stream transports sediment in suspension, or along the bottom as bed material. Sediment production from a drainage area depends on such factors as soils, topography, land use, and climate. Activities such as logging, land grading, highway construction, farming, and overgrazing, which destroy vegetal cover and expose bare, disturbed soil to the erosion process, may increase sediment yields from local areas by a factor of 10 to 100 (Gann and others, 1976). Gravel operations in the streambed temporarily increase suspended sediment downstream.

The Current River and Jacks Fork contain unusually low amounts of suspended sediment during baseflow because of the large proportion of the water that is derived from relatively sediment-free springs. During storm runoff large amounts of sediment are transported by the streams. However, the high percentage of vegetal cover and the prevailing land-use practices in the Current River and Jacks Fork drainage areas limit erosion considerably.

Gann, Harvey, and Miller (1976) estimated the average annual sediment yields for the period 1922-67 for the Current River near Eminence, at Van Buren, and at Doniphan to be 47, 70, and 106 t/mi^2 (tons per square mile), respectively.

Suspended-sediment samples were collected at the stream-index stations each time other samples were collected. None was collected during storm runoff. Concentrations of suspended sediment ranged from 2 to 58 mg/L and averaged 11 mg/L for the Current River below Montauk State Park, 17 mg/L for the Current River above Powder Mill, 15 mg/L for the Current River below Hawes Campground, and 16 mg/L for the Jacks Fork above Two Rivers.

BACTERIA

Fecal coliform and fecal streptococcus densities were determined each time a site was sampled. In addition to the routine measurement of bacteria densities upstream and downstream from potential sources such as towns and recreation areas, short-term studies were made to determine the effects of storm runoff, swimming, and horseback riding on bacteria densities. Except for the July 23, 1973, storm-runoff samples, the streams were considered unaffected by recent storm runoff at the time of sampling.

Bacterial data collected for the Current River, Jacks Fork, major tributaries, and large springs during the period April 1973 to April 1975 are summarized in table 19. Results of the July 23, 1975, storm runoff sampling are excluded from the summary. Fecal coliform and fecal streptococcus densities averaged 56 and 160 col/100 ml, respectively, for the 35 samples from the Current River upstream from the Jacks Fork

Table 19.—*Bacteria densities for the Current River, Jacks Fork, tributaries, and springs*

[Results in colonies per 100 milliliters]

Station	Number of samples	Fecal coliforms			Fecal streptococci		
		Max	Min	Mean	Max	Min	Mean
Current River:							
Upstream from Jacks Fork	35	290	<2	56	780	6	160
Downstream from Jacks Fork	35	27	<1	10	160	3	35
Jacks Fork	30	240	2	57	560	10	130
Tributaries	17	480	9	86	350	13	160
Springs	27	260	<1	46	990	11	170

and 10 and 35 col/100 ml, respectively, for the 35 samples downstream from the Jacks Fork. Average densities for the 30 samples from the Jacks Fork were 57 col/100 ml for fecal coliforms and 130 col/100 ml for fecal streptococci. The higher average bacteria densities in the upper Current River and the Jacks Fork correlate with higher total nitrate concentrations for these areas, and are probably caused by occasional high densities in the springs and tributaries and the higher visitor use such as canoeing, swimming and horseback riding per unit volume of water. Ratios of fecal coliform to fecal streptococcus were generally less than 0.6, indicating that numbers and distribution of livestock probably influence bacteria densities in the streams and springs.

Routine sampling upstream and downstream from Eminence, Van Buren, and the major recreation areas showed no increases in bacteria densities that could be attributed to sources at these points. No seasonal patterns are evident from the 10 bacteria measurements at each of the four stream-index stations, which indicate there are no significant overall increases in bacteria densities during the summer recreation seasons.

To illustrate that much higher bacteria densities occur during storm runoff, samples were collected upstream and downstream from Montauk State Park soon after a storm on July 23, 1973, deposited about 2.5 inches of rain on the area in a short period of time. Fecal coliform and fecal streptococcus densities were about 4,000 and 22,000 col/100 ml, respectively, at both sites. A week after the storm, densities were still higher than average at most of the sites.

A diel bacteria study was made on the Jacks Fork upstream and downstream from the Alley Spring camping complex during a 24-hour heavy-use period in August 1974. Fecal coliform and fecal streptococcus analyses were made every 2 hours for a total of 13 analyses at each site. Over 100 swimmers were estimated to be in the water between the sampling sites at various times during the sampling period. Fecal coliforms averaged 21 col/100 ml upstream and 29 col/100 downstream and fecal streptococci averaged 150 col/100 ml upstream and 200 col/100 ml downstream. These data are somewhat inconclusive, but indicate that bacteria densities are increased only slightly by swimming in the streams.

A cross-country trail ride was held August 11-17, 1974, on the Jacks Fork about 1.5 miles downstream from Alley Spring. About 1,300 people and 500 horses participated in the activities which centered along a 1-mile reach of the river. Fecal coliform and fecal streptococcus samples were collected immediately upstream and downstream from the trail ride on August 14. Fecal coliform, fecal streptococcus, and nitrogen samples were collected upstream and downstream from the trail ride and at Eminence, about 4 miles downstream from the trail ride, on August 16. Also, samples for nitrogen analyses were collected from the Jacks Fork upstream from the trail ride and at Eminence, and from the Current River at Powder Mill on August 17 during a period of storm runoff and again August 18, 20, and 22.

Results of the August 14 and August 16 bacteria analyses were very similar and the August 16 results are shown in figure 7. Fecal coliform and fecal strepotcoccus densities were consistently low upstream from the trail-ride activities and consistently high immediately downstream. The highest densities of bacteria occurred about midmorning when the maximum number of horses were observed in the water. Maximum densities of 2,000 fecal coliform col/100 ml and 2,100 fecal streptococcus col/100 ml were measured on August 14. The low ratios of fecal coliform to fecal streptococcus suggest that the increased numbers of bacteria downstream from the trail ride were caused mainly by animal wastes. Judging from the graphs, most of the indicator bacteria died by the time the water reached Eminence.

The recommended limit for primary contact recreational use is 200 fecal coliform col/100 ml of water (Federal Water Pollution Control Administration, 1968, p. 12). People were observed swimming, bathing, and brushing their teeth in the river immediately downstream from the trail ride when the fecal coliform density was 1,000 col/100 ml, five times the recommended limit.

No consistent or significant increases in nitrogen were observed downstream from the trail ride, even during the period of storm runoff.

From June 30 to July 4, 1972, the U.S. Geological Survey in cooperation with the University of Missouri at Rolla repetitively determined bacteria densities in the vicinity of Eminence, Van Buren, and the major campgrounds in the Riverways. The purpose of the short-term study was to determine the effects, if any, of an increased number of visitors during a summer holiday weekend (Independence Day). The results (Maxwell, 1974) show that prior to a large increase in visitors, fecal coliform and fecal streptococcus densities were generally in the range of 0 to 25 and 10 to 70 col/100 ml, respectively. A large increase in the number of visitors resulting in considerable use of the

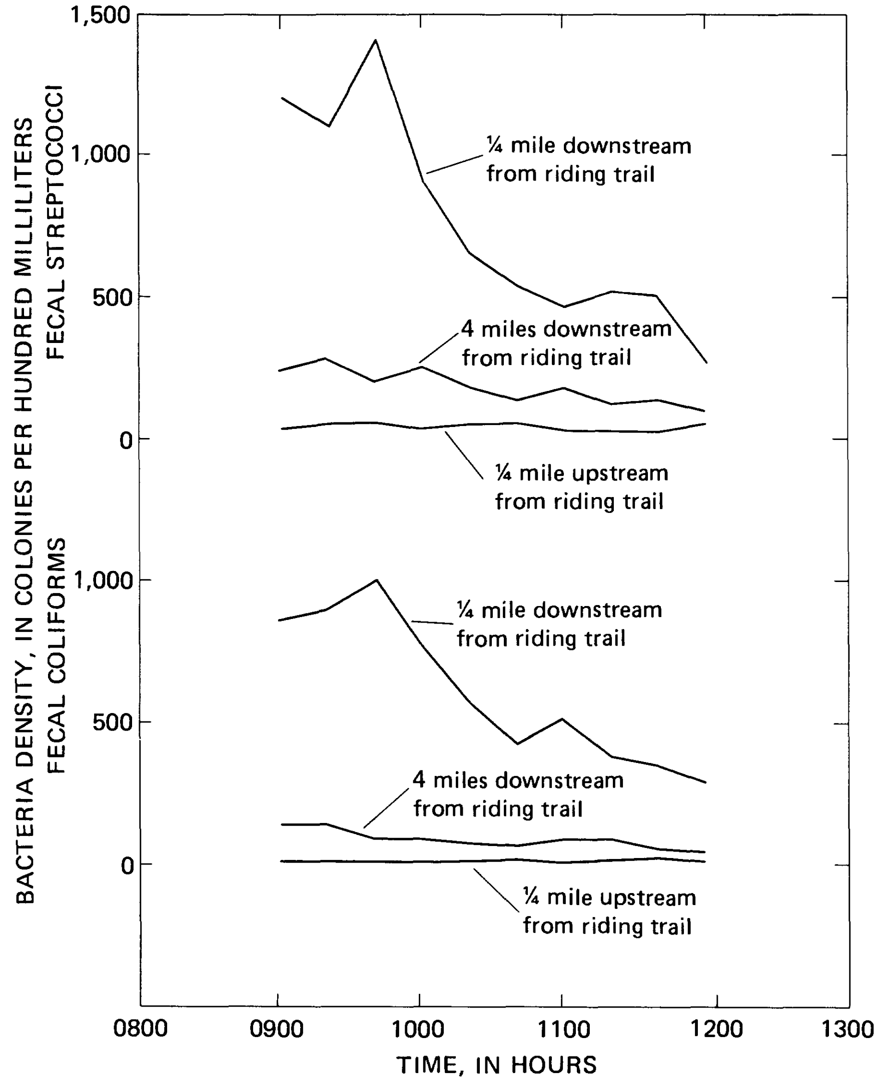

Figure 7.—Bacteria densities in the Jacks Fork on August 16, 1974, near the site of horseback riding activities.

rivers for swimming, especially near Alley Spring, was accompanied by a general doubling to tripling of bacteria densities. Rain showers probably contributed significantly to this increase. Higher densities also were observed on the Jacks Fork where horses were crossing and recrossing the river during a trail ride. Later in the study, runoff from heavier rainfall caused additional increases in bacteria.

AQUATIC BIOTA

Physical, chemical, and bacteriological determinations indicate the water-quality conditions only at the time of sampling. Because aquatic organisms respond continually to water-quality factors, their types and populations reflect stream conditions over a longer period of time. Clean streams tend to have moderate populations of many types of organisms, whereas polluted streams restrict the number of types of organisms, which may increase to large populations because of the lack of competition. If toxic conditions occur, most or all of the organisms are eliminated.

Three groups of aquatic organisms were determined at the four stream-index stations—phytoplankton, periphyton, and benthic invertebrates.

Phytoplankton, because they float passively with the currents, are indicative of quality conditions of the mass of water in which they are contained. The phytoplankton population represents, in part, the nutrient supplying capability of that mass of water.

Periphyton also provide an indication of the nutrient supply in the water, and, in addition, because of their stationary existence, represent an integration of the physical and chemical conditions of water passing the point of their location.

Benthic invertebrates are excellent indicators of stream conditions, primarily because they are restricted to the area in which they are found. Because of their varying environmental requirements, benthic invertebrates form communities characteristic or associated with particular chemical and physical conditions. For example, mayflies, caddisflies, and stoneflies usually characterize clean water. The presence of sludge-worms, midges, air-breathing snails, and aquatic earthworms is indicative of oxygen-consuming organic materials. Relative absence of benthic invertebrates may indicate toxic materials in the water.

PHYTOPLANKTON

Phytoplankton samples were collected on a seasonal (April, July, October, January) basis from April 1973 to April 1975. The cells were identified to genus, and a genus was considered codominant if in excess of 15 percent of the total cell count. The total cell counts, codominant genera, and number of other genera identified in each sample are listed in table 13.

Twenty different codominant genera, predominantly diatoms, were present at the four index stations. On occasion, green algae and blue-green algae were also codominant genera. The blue-green algae occurred mostly in the Current River below Hawes Campground.

Several common types of organisms were present in each sample, but two or three genera usually dominated. *Navicula, Cymbella,* and *Achnanthes* were the most common genera at the Current River below Montauk State Park and Current River above Powder Mill stations. *Cymbella, Navicula,* and *Nitzchia* were the most common genera at the Jacks Fork above Two Rivers and Current River below Hawes Campground stations. Without any apparent reason a significantly high density (2 million cells/ml (cells per milliliter)) of the blue-green algae, *Microcystis,* occurred in the April 1973 sample for the Current River below Hawes Campground.

Total phytoplankton cell counts varied considerably with time, but without any consistent seasonal pattern (fig. 8). Likewise, densities varied between stations, but without much pattern. Densities averaged 523 cells/ml cells per millimeter for the Current River below Montauk State Park compared to less than 300 cells/ml for the other index stations, excluding the two anomalously high counts at Hawes Campground. The higher densities at the upstream station are probably caused by slightly higher nutrient levels.

The numbers of phytoplankton present at the four stream-index stations indicate sufficient nutrients to sustain moderate populations. With the exception of the anomalously high density of blue green algae that was observed below Hawes Campground on one occasion, the types of phytoplankton present indicate that the Current River and Jacks Fork are relatively free of pollutants.

PERIPHYTON

Periphyton was sampled seven times at the Jacks Fork and upper Current River stations and five times at the two downstream Current River stations. The dry and ash weights, codominant genera, and number of other common algal genera identified are shown in table 14. The volatile or organic weight of the periphyton can be determined by subtracting the ash weight from the dry weight.

Fifteen different codominant genera, mainly diatoms, were identified for the four stream-index stations. Like phytoplankton, two or three genera usually dominated the community. The most common genera for the Current River were *Navicula* and *Achnanthes* below Montauk State Park; *Gomphonema, Achnanthes, Cocconeis,* and *Cymbella* above Powder Mill; and *Achnanthes* below Hawes Campground. *Cymbella, Achnanthes, Gomphonema* and the blue-green algae, *Lyngbya,* were the most common genera identified at the Jacks Fork station.

Periphyton biomass varied considerably, but no seasonal trends or trends between stations are indicated. These data may be insufficient to show biomass trends because several of the artificial substrates were lost to high water and vandalism.

The types of organisms and their biomass generally indicate clean-water conditions for each of the stream-index stations.

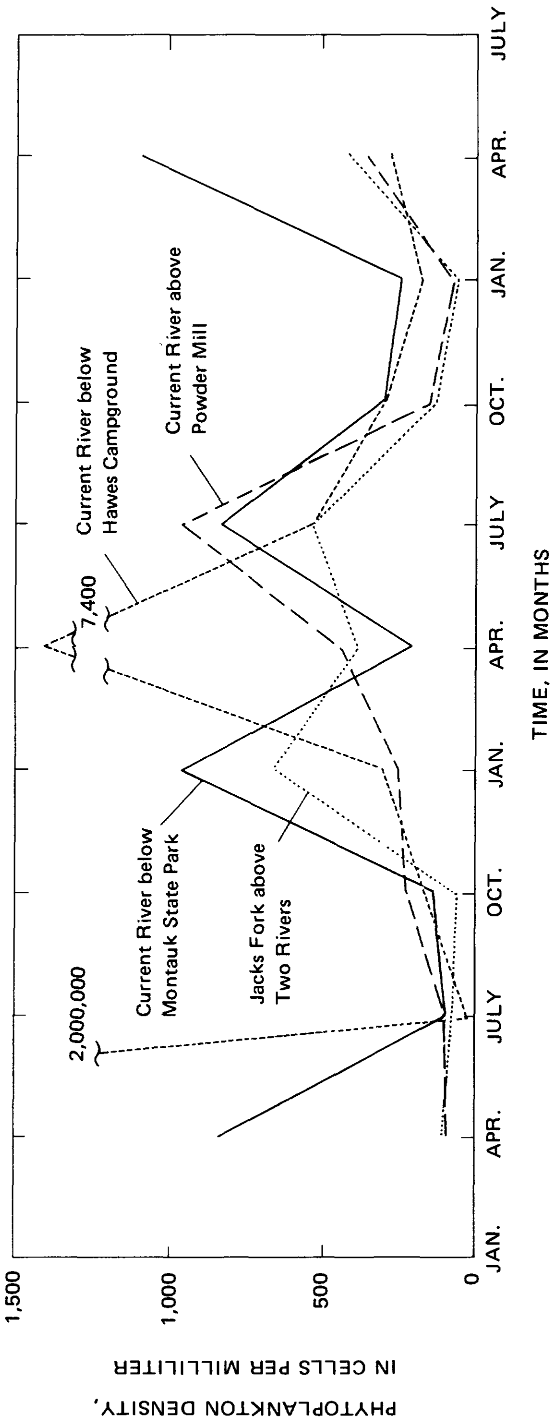

Figure 8.—Graphs showing seasonal changes in phytoplankton densities in the Current River and Jacks Fork, April 1973 to April 1975.

BENTHIC INVERTEBRATES

The types and numbers of organisms identified in samples collected at the four stream-index stations are shown in table 15. Use of the data is limited to a general appraisal of the community type and abundance of organisms colonized on multi-plate artificial substrates and identified only to family. Use of multi-plate samplers is a simple, standardized method of showing changes from place to place or time to time. However, this method is selective for organisms adapted to hard surfaces and restricts the sampling to a small area.

A concurrent benthic invertebrate study, which included the stream-index stations, was made by the Missouri Department of Conservation. Winter, spring, summer, and fall samples were collected from each station during 1974. Each sample was a composite of 8 to 20 square-foot samples (depending on stream width) collected with a nylon bottom net with 20 strands per inch by "working" the riffle substrate immediately upstream from the net to a depth of 4 to 6 inches with a three-pronged garden tool. The current carried the dislodged organisms into the net. Mayflies, caddisflies, and stoneflies were identified to species when possible and other organisms were identified to genus or a higher taxonomic level.

A comparison of the results obtained by the two methods (artificial substrate at one point in the riffle versus natural substrate at several points in the riffle) shows that sampling the natural substrate and identifying the organisms to a low taxonomic level gives a much better assessment of the types and abundance of organisms present and, consequently, a better indication of the water-quality conditions.

At each station Diptera, primarily the midge Chironomidae, composed more than 50 percent of the number of organisms colonized by the artificial substrates. Mayflies (Ephemeroptera) and caddisflies (Trichoptera) were also present in moderate abundance. By comparison Diptera composed less than 20 percent of the organisms present in the natural substrate. Apparently, Diptera are more adaptable to the multi-plate samplers than most of the other organisms.

The natural substrate sampling showed that caddisflies dominated the bottom fauna at the Current River below Montauk State Park and mayflies were dominant at the other three sites. Midges (Diptera) and beetles (Coleoptera) were also present in moderate numbers at all four sites. The diversity and abundance of organisms are summarized for each site in table 20. The higher average number of organisms in the Current River below Montauk State Park were caused by a greater abundance of Trichoptera and Diptera. The high diversity of organisms and the large number of mayfly and stonefly taxa present at each site indicate that the streams are basically unaffected by pollution.

Table 20.—*Diversity and abundance of benthic invertebrates collected from the Current River and Jacks Fork by the Missouri Department of Conservation, 1974*

[Data from R.M. Duchrow (written commun., 1975)]

Stream	Average number of organisms per square foot	Total number of taxa identified	Number of mayfly and stonefly taxa identified
Current River below Montauk State Park	327	44	14
Current River Above Powder Mill	34	58	21
Current River below Hawes Campground	61	48	19
Jacks Fork above Two Rivers	74	61	21

SUGGESTIONS FOR FUTURE MONITORING OF WATER QUALITY

In order to safeguard the quality of waters in the Riverways, additional information and a routine monitoring program are needed.

A better knowledge of the location and extent of the recharge areas and hydrologic systems that supply water to the large springs is needed for more sensitive detection of pollution sources within the recharge areas. The National Park Service is presently attempting to fill this need by locating sources of Welch, Pulltite, Round, and Alley Springs.

Based upon the results of this study the following sampling programs are suggested as a minimum for future water-quality monitoring in the Riverways.

1. Ground water.—Each year near the beginning and near the end of the summer recreation season, sample wells near the spray-irrigation sewage-treatment sites and make the following determinations:

Field	*Laboratory*
Temperature	Nitrogen
Specific conductance	Phosphorus
Dissolved oxygen	Chloride
pH	Organic carbon
Alkalinity	
Fecal coliforms	
Fecal streptococci	

2. Springs.—Each year near the beginning and near the end of the summer recreation season, sample the major springs (Big, Welch, Alley, Blue, Montauk, Pulltite, and Round) and make the following determinations:

Field	*Laboratory*
Temperature	Nitrogen
Specific conductance	Phosphorus
Dissolved oxygen	Cadmium

2. Springs.—Continued

Field	*Laboratory*
pH	Lead
Alkalinity	Silver
Fecal coliforms	Zinc
Fecal streptococci	

3. Surface water.—Each year near the beginning and near the end of the summer recreation season, sample the four stream-index stations used in this study and make the following determinations:

Field	*Laboratory*
Temperature	Nitrogen
Specific conductance	Phosphorus
Dissolved oxygen	Cadmium
pH	Lead
Alkalinity	Silver
Fecal coliforms	Zinc
Fecal streptococci	Phytoplankton

A stream-invertebrate study of the Current River and Jacks Fork in 1984 similar to the one made by the Missouri Department of Conservation in 1974 would indicate long-term changes in stream conditions.

It would be desirable to sample storm runoff from the sewage spray-irrigation fields infrequently and analyze for the same characteristics and constituents listed for ground water.

Examples of possible future activities that could adversely affect water quality in the Riverways are mining operations within the Current River basin, large-scale pesticide applications, increased agricultural fertilization, changed land-use practices, increased removal of gravel from the streambeds, new or changed sewage-treatment facilities, and sharp increases in population that may overload existing sewage-treatment facilities. The influence of such activities on water quality should be promptly evaluated as they occur by measuring the pertinent characteristics and constituents that may be affected.

SUMMARY

GROUND WATER

Dissolved-solids concentrations averaged 276 mg/L in the 19 wells sampled. Calcium, magnesium, and bicarbonate make up more than 95 percent of the total ionic composition, reflecting the dolomitic characteristics of the rocks. Hardness averaged 259 mg/L, and alkalinity averaged 285 mg/L.

Total nitrate concentrations as N averaged 0.22 mg/L and total phosphorus concentrations as P ranged from 0.01 to 0.04 mg/L.

Maximum concentrations of selected minor elements were all below the recommended drinking water standards (U.S. Public Health Service, 1962).

Ground water in the Riverways area is presently of good quality. However, it would be useful to monitor ground-water quality in areas of new development, such as the three new spray-irrigation sewage-treatment sites for indications of water-quality problems.

SPRINGS

Ions in the spring water occur in about the same proportions as the ground water, but the spring water is less mineralized, presumably because of less exposure to the soluble rocks. Dissolved-solids concentrations averaged 159 mg/L for the seven largest springs in the Riverways. Hardness and alkalinity averaged 150 and 144 mg/L, respectively.

The average total nitrate concentration for 120 analyses available for the seven largest springs was 0.42 mg/L. Higher nitrogen concentrations generally correspond to higher springflows.

Of the 64 total phosphorus analyses available for the springs, 37 were 0.00 mg/L and only one was greater than 0.05 mg/L.

Blue Spring was sampled for minor elements on four occasions because of the proximity of its recharge area to the lead and zinc-mining operations in the Black River basin. Comparatively high concentrations of total barium (400 μg/L), lead (650 μg/L), and zinc (1,400 μg/L were measured in one of the samples. The higher concentrations were attributed to antecedent hydrologic conditions, rather than direct pollution from mining operations because high concentrations of some of these metals also occurred at the stream-index stations during the same sampling period.

Fecal coliform densities ranged from less than 1 to 260 col/100 ml and fecal streptococcus densities ranged from less than 1 to 990 col/100 ml for the seven largest springs. The higher densities can generally be associated with storm runoff preceded by warm, dry weather.

Because the Current River basin is mostly undeveloped, the springs at the present time (1977) are relatively unaffected by the activities of man. By comparison, nitrogen concentrations and bacteria densities in springs in the upper White River basin are several times higher than in springs in the Current River basin due to greater development including widespread dairy farming and stock raising. The quality of spring waters in the Current River basin is subject to quick deterioration as a result of increased levels of activity or changes in the activities of man in the spring recharge areas because of the rapidity of transport of water from the recharge areas to the spring effluents.

SURFACE WATER

Because the major springs account for a large proportion of the flow in the Current River and Jacks Fork, mineralization of water in the streams is similar to that in the springs. Dissolved-solids concentrations, hardness, and alkalinity averaged 159, 154, and 152 mg/L, respectively, for the Current River near Doniphan, Mo. The surface water is generally chemically uniform throughout the basin. However, water in small tributaries and springs near the mouth of the Jacks Fork is more mineralized because of weathering of small quantities of sulfides that are disseminated through the rocks on the flanks of the igneous knobs that are prevalent in the area.

Total nitrate in the Current River decreased from an average of 0.65 mg/L below Montauk State Park to 0.27 mg/L below Hawes Campground. The higher concentrations in the headwaters were caused by higher concentrations in Montauk and Welch Springs. Total nitrate concentrations in the Jacks Fork increased from an average of about 0.2 mg/L upstream from Alley Spring to about 0.4 mg/L downstream from Alley Spring because of higher concentrations in Alley Spring. Total phosphorus concentrations averaged 0.04 mg/L for the Current River below Montauk State Park and 0.02 mg/L for the Current River above Powder Mill, Current River below Hawes Campground, and Jacks Fork above Two Rivers. Samples collected at numerous sites along the Current River and Jacks Fork and from tributaries showed no detectable increase in major nutrients due to wastes from cities, agricultural fertilization, or recreational activities such as camping, canoeing, and swimming.

Minor-element concentrations were generally low in the nine samples collected at each of the four stream-index stations. However, on at least one occasion, total barium, lead, silver, and zinc concentrations were relatively high, probably due to antecedent hydrologic conditions.

The only pesticides detected were 0.03 μg/l of 2,4-D and 0.03 μg/L of 2,4,5-T, which occured below Montauk State Park during storm runoff.

Because much of the streamflow in the Current River basin comes from springs and because the basin is heavily vegetated and lightly developed, sediment concentrations are very low in streams except during heavy storm runoff. Suspended-sediment concentrations averaged 16 mg/L for samples collected at the four stream-index stations during baseflow conditions.

Fecal coliform and fecal streptococcus densities averaged 56 and 160 col/100 ml, respectively, for the Current River upstream from the Jacks Fork; 10 and 35 col/100 ml for the Current River downstream from the Jacks Fork; and 57 and 130 col/100 ml for the Jacks Fork. The higher average densities in the Jacks Fork and upper Current River were probably caused by occasional high densities in some of the springs and tributaries and by more visitor use such as camping, swimming, and horseback riding per unit volume of water. Routine sampling upstream and downstream from cities and major campgrounds showed no attributive increases in bacteria densities. Sampling at the stream-index stations showed no patterns of increased bacteria densities during the summer recreation seasons. A diel bacteria study made upstream and downstream from a swimming area on the Jacks Fork near Alley Spring indicates that bacteria densities are increased slightly by large numbers of swimmers in reaches of the streams that have relatively low flows. Fecal coliform and fecal streptococcus densities as high as 2,000 and 2,100 col/100 ml, respectively, were measured downstream from horseback riding activities (trail ride) on the Jacks Fork below Alley Spring. Maximum densities measured upstream from the trail ride were 24 col/100 ml for fecal coliforms and 56 col/100 ml for fecal streptococci. Most of the increased indicator organisms died by the time the water had traveled about 4 miles downstream from the trail-ride activities. Fecal coliform and fecal streptococcus densities of about 4,000 and 22,000 col/100 ml, respectively, were measured in summer storm-runoff samples collected from the Current River upstream and downstream from Montauk State Park.

Phytoplankton, periphyton, and benthic invertebrate data collected at the four stream-index stations indicate that the streams are basically unaffected by pollution. Nutrient levels appear to be high enough to sustain moderate plant populations, but low enough to prevent nuisance conditions. The rocky substrates support moderate populations of a diversity of benthic organisms including a large number of mayfly and stonefly taxa.

Repetitive and infrequent (as needed) sampling of ground, spring and surface waters in the Riverways is suggested as a future monitoring program to detect changes in water quality caused by the activities of man.

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BASIC-DATA TABLES

Table 2.—*Water-quality data for selected wells in the Current River basin*

[Results in milligrams per liter except as indicated]

Map No.	Date of collection	Silica (SiO_2)	Iron (Fe) (μg/L)	Manganese (Mn) (μg/L)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Total ammonia nitrogen (N)	Total organic nitrogen (N)	Total nitrate (N)	Total nitrogen (N)
1	05-14-75	7.8	0	5	41	27	2.2	0.8	244	11	---	0.0	0.00	0 01	0 03	0.04
2	05-14-75	7 5	20	10	56	36	1.6	6	356	6.1	1 1	.0	00	.01	.15	.16
3	05-14-75	7.9	70	5	59	37	2.5	7	356	14	1.9	.1	.00	.05	.00	.06
4	05-14-75	8.4	30	10	51	31	1 6	9	312	2.5	1.7	.0	.00	.01	32	34
5	10-21-74	9.1	10	0	73	40	1.6	.3	410	6.5	2.0	.0	.00	01	.22	.23
5	05-14-75	8.4	30	50	70	43	2.3	7	432	6 4	3 3	0	00	.02	.32	.34
6[1]	11-24-70	10	[1]70	[1]0	34	26	2 3	2 2	264	4.8	3.7	0	---	---	.09	---
7	04-25-75	9.7	50	30	55	42	100	2.0	328	99	91	1 4	.06	.54	08	68
8	05-15-75	10	0	5	57	41	1.6	.7	386	4.5	1 8	.0	.00	.01	.44	.46
9	05-15-75	7 1	20	10	42	24	1.8	8	244	2.6	1 9	0	.00	01	07	.08
10	05-15-75	5.0	60	5	66	38	1.9	1 5	384	9.2	2.2	.1	00	.01	58	.60
11	05-15-75	8.2	10	10	54	31	1.6	6	324	3.6	2.5	1	00	01	.03	.04
12	10-22-74	11	0	0	62	41	2 1	5	400	3.1	3.8	0	.04	.00	.09	.10
13[1]	12-18-70	9 1	[1]60	[1]10	57	28	1.2	6	315	1.0	3 2	0	---	---	.00	---
14	05-16-75	7.5	20	10	38	23	2.0	9	228	3.2	8	.0	.00	01	09	10
15	05-16-75	7.7	10	10	37	23	1.9	7	232	1.9	9	.0	00	.01	.04	.06
16	05-16-75	7.5	40	10	45	26	1.6	6	270	1 3	.8	0	00	.02	.08	.10
17	10-21-74	9.6	10	0	47	22	1.5	1 4	246	4.3	1 8	.0	.02	.00	21	.23
17	05-16-75	7 3	0	10	44	20	1.4	1 0	234	3 6	1.8	0	.00	.01	35	37
18[1]	11-03-70	11	[1]210	[1]14	54	20	1 5	7	281	3.8	2.2	8	---	---	09	---
19	05-15-75	7.6	30	5	57	36	2.3	.9	352	4.8	2 8	1	.00	.02	1.4	1.4

Table 2.—*Water-quality data for selected wells in the Current River basin*—Continued

Map No.	Date of collection	Dissolved phosphours (P)	Total phosphorus (P)	Dissolved solids (residue at 180°C)	Total hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Specific conductance (μmhos/cm at 25°C)	pH (units)	Temperature (°C)	Color (platinum cobalt units)	Detergents (MBAS)	Dissolved organic carbon	Chemical oxygen demand	Carbon dioxide	Fecal coliforms (col/100ml)
1	05-14-75	0.01	0.01	369	210	13	200	408	7.6	15	0	0.0	0.3	1	9.8	<1
2	05-14-75	.01	.01	267	290	0	292	538	7.9	15	0	0	2	3	7.2	<1
3	05-14-75	02	02	290	300	8	292	555	7 5	15	0	.0	3.6	4	18	<1
4	05-14-75	.01	01	235	260	0	256	480	7 7	14	0	0	.1	5	10	<1
5	10-21-74	.01	.01	376	350	11	336	610	7.4	15	3	0	.2	0	26	<1
5	05-14-75	01	02	338	350	0	354	675	7 4	15	1	0	7.0	6	28	<1
6[1]	11-24-70	---	---	210	192	0	216	370	---	13	--	---	---	--	---	--
7	04-25-75	.01	04	571	310	41	269	1,000	7 5	15 5	3	---	---	9	17	--
8	05-15-75	01	01	292	310	0	317	580	7.4	15	0	0	4	1	25	<1
9	05-15-75	01	01	177	200	4	200	373	7.8	15.5	0	0	1	2	6.2	<1
10	05-15-75	01	01	306	320	6	315	585	7 4	15.5	0	.0	.5	1	24	<1
11	05-15-75	.01	.01	248	260	0	266	480	7 2	13	0	0	1.4	1	33	3
12	10-22-74	00	.02	366	320	0	328	610	7 3	16	0	0	---	0	32	23
13[1]	12-18-70	---	---	257	257	0	258	490	---	14	--	---	---	--	---	--
14	05-16-75	01	01	180	190	3	187	353	7.6	16 5	0	.0	8 5	4	9 2	<1
15	05-16-75	.01	01	178	190	0	190	355	7 6	15	0	0	.5	3	9.3	<1
16	05-16-75	01	01	200	220	000	221	310	7 7	15	0	.0	.8	3	8 6	<1
17	10-21-74	01	02	246	210	6	202	388	7 4	18 5	0	0	5	0	16	<1
17	05-16-75	01	01	179	190	0	192	335	7.7	14	0	0	2	2	7 5	<1
18[1]	11-03-70	---	---	235	218	0	230	380	7.8	15	--	---	---	--	---	--
19	05-15-75	01	.01	282	290	2	289	555	7 4	16	0	.0	.3	2	22	<1

[1] Analyses by Division of Geology and Land Survey, Department of Natural Resources.
[2] Total

Table 3.—*Total minor element analyses of samples from selected wells in the Current River basin*

[results in micrograms per liter]

Map No.	Date of collection	Arsenic (As)	Barium (Ba)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Selenium (Se)	Silver (Ag)	Zinc (Zn)
1	05-14-75	0	0	< 10	0	< 10	< 100	0.0	0	< 10	0
2	05-14-75	0	0	10	0	10	100	.4	1	10	160
3	05-14-75	0	0	10	0	10	100	.1	0	10	2 800
4	05-14-75	0	0	10	0	10	100	.5	0	10	130
5	10-21-74	1	< 100	10	0	10	100	0	--	10	100
5	05-14-75	0	100	10	0	10	100	.0	0	10	20
7	04-25-75	0	0	10	0	10	100	.0	0	10	200
8	05-15-75	0	0	10	0	30	100	.2	1	10	1,800
9	05-15-75	0	0	10	0	10	100	.1	0	10	170
10	05-15-75	0	0	10	0	10	100	.3	0	10	810
11	05-15-75	0	0	10	0	10	100	.0	0	10	120
12	10-22-75	0	< 100	10	0	10	100	.0	--	10	160
14	05-16-75	1	0	10	0	10	100	---	0	10	480
15	05-16-75	0	0	10	0	10	100	.0	0	10	320
16	05-16-75	0	0	10	0	10	100	2 2	0	10	20
17	10-21-74	1	< 100	10	0	10	100	.0	--	10	130
17	05-16-75	0	0	10	0	10	100	.4	1	10	130
19	05-15-75	0	0	10	0	10	100	.2	0	10	1,700

Table 7.—*Total minor element analyses of samples form Blue Spring*

[Results in micrograms per liter]

Date of collection	Arsenic (As)	Barium (Ba)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Nickel (Ni)	Silver (Ag)	Zinc (Zn)
Apr. 6, 1973	<10	0	0	<10	6	0	2	<.5	6	1	30
Aug. 1, 1973	5	400	<10	20	<25	10	650	.0	<25	200	1,400
Oct. 17, 1973	0	0	<10	0	<25	<10	<50	.0	<25	<10	80
July 10, 1974	1	0	<10	0	<50	<10	<100	.0	<50	<10	10

Table 11.—*Total minor element analyses of samples from the Current River and Jacks Fork*

[Results in micrograms per liter]

Date	Arsenic (As)	Barium (Ba)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Nickel (Ni)	Silver (Ag)	Zinc (Zn)
Map No. 29—Current River below Montauk State Park (lat 37°27′01″ long 91°29′41″)											
1973											
Apr. 2	<10	0	0	<10	3	0	1	<.5	0	0	30
July 30	0	0	<10	0	<25	<10	250	.0	<25	100	80
Oct. 15	2	0	<10	0	<25	<10	<50	.0	<25	<10	80
1974											
Jan. 18	2	0	20	0	50	<10	<100	.0	<50	<10	30
Apr. 17	5	0	10	0	<50	<10	<100	.0	100	<10	480
July 9	1	0	<10	0	<50	<10	<100	.0	<50	<10	10
Oct. 21	0	<100	<10	0	<50	<10	<100	.0	<50	<10	60
1975											
Jan. 22	0	200	<10	0	50	30	<100	.0	<50	20	10
Apr. 15	1	100	10	0	<50	<10	<100	.2	50	<10	10
Map No. 45—Jacks Fork above Two Rivers (lat 37°10′53″ long 91°17′36″)											
1973											
Apr. 5	<10	0	0	<10	4	0	7	<.5	0	1	50
Aug. 1	6	0	<10	0	<25	20	350	.7	<25	<10	170
Oct. 17	2	--	<10	0	25	10	<50	.0	<25	<10	80
1974											
Jan. 18	0	0	<10	0	<50	<10	<100	.0	<50	<10	30
Apr. 17	1	0	<10	0	<50	<10	<100	.0	100	<10	260
July 10	1	0	<10	0	<50	<10	<100	.0	<50	<10	20
Oct. 22	1	<100	<10	0	<50	<10	<100	.0	<50	<10	240
1975											
Jan. 21	0	<100	<10	0	<50	10	<100	.0	<50	10	30
Apr. 15	1	<100	10	0	<50	10	<100	.2	50	<10	10

Map No 46—Current River above Powder Mill (lat 37°10′32″ long 91°12′48″)											
1973											
Apr. 5	<10	0	1	<10	4	0	7	.5	7	0	160
Aug. 1	6	0	<10	0	<25	20	550	.0	<25	<10	190
Oct. 17	2	0	<10	0	25	10	<50	.1	<25	<10	70
1974											
Jan. 18	0	0	10	0	50	<10	<100	.0	<50	<10	30
Apr. 17	1	0	<10	0	<50	<10	<100	.0	50	<10	230
July 10	2	0	<10	0	<50	<10	<100	.0	<50	--	30
Oct. 22	1	<100	<10	0	<50	<10	<100	.0	<50	<10	50
1975											
Jan. 21	0	<100	<10	0	100	10	<100	.0	50	10	30
Apr. 15	1	100	<10	0	<50	10	<100	--	50	290	10
Map No 52—Current River below Hawes Campground (lat 36°49′08″ long 90°56′48″)											
1973											
Apr. 6	<10	0	0	<10	6	0	0	<.5	6	1	50
Aug. 2	0	0	<10	0	<25	<10	300	.0	<25	<10	40
Oct. 18	2	0	<10	0	<25	<10	<50	.0	<25	<10	80
1974											
Jan. 17	1	0	10	0	50	<10	<100	.0	<50	<10	30
Apr. 18	1	0	10	0	<50	<10	<100	.0	100	<10	210
July 10	2	0	<10	0	<50	<10	<100	.0	<50	<10	30
Oct. 23	1	<100	<10	0	<50	<10	<100	.0	<50	<10	70
1975											
Jan. 21	0	<100	<10	0	<50	30	<100	.0	<50	10	30
Apr. 15	1	200	10	0	<50	<10	<100	.2	50	10	10

Table 12.—*Total pesticide analyses of*

[Results in

Date	Aldrin	Chlordane	DDD	DDE	DDT	Dieldrin	Endrin	Heptachlor	Heptachlor epoxide	Lindane
Map No. 29—Current River below Montauk State Park (lat 37°27′01″ long 91°29′41″)										
1973										
Apr. 2	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June 18	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
July 23	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
July 30	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Oct. 15	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
1974										
July 9	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Map No. 45—Jacks Fork above Two Rivers (lat 37°10′53″ long 91°12′48″)										
1973										
Apr. 5	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June 20	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Aug. 1	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Oct. 17	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
1974										
July 10	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Map No. 46—Current River above Powder Mill (lat 37°10′32″ long 91°12′48″)										
1973										
Apr. 5	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June 20	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Aug. 1	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Oct. 17	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
1974										
July 10	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Map No. 52—Current River below Hawes Campground (lat 36°49′08″ long 90°56′48″)										
1973										
Apr. 6	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June 22	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Aug. 2	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
Oct. 18	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00
1974										
July 10	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00

Samples from the Current River and Jacks Fork
micrograms per liter]

Toxaphene	Diazinon	Ethion	Malathion	Methyl parathion	Methyl trithion	Parathion	Trithion	2,4-D	2,4,5-T	Silvex	PCB
Map No. 29—Current River below Montauk State Park (lat 37°27'01" long 91°29'41")—Continued											
--	--	--	--	--	--	--	--	0.00	0.00	0.00	0.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
--	--	--	--	--	--	--	--	.03	.03	.00	.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00	.00	.00	.0
Map No. 45—Jacks Fork above Two Rivers (lat 37°10'53" long 91°12'48")—Continued											
--	--	--	--	--	--	--	--	0.00	0.00	0.00	0.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00	.00	.00	.0
Map No. 46—Current River above Powder Mill (lat 37°10'32" long 91°12'48")—Continued											
--	--	--	--	--	--	--	--	0.00	0.00	0.00	0.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00	.00	.00	.0
Map No. 52—Current River below Hawes Campground (lat 36°49'08" long 90°56'48")—Continued											
--	--	--	--	--	--	--	--	0.00	0.00	0.00	0.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
--	--	--	--	--	--	--	--	.00	.00	.00	.0
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00	.00	.00	.0

Table 13.—*Codominant genera and populations of phytoplankton in the Current River and Jacks Fork*

Date	Total count (cells/ml)	Codominant genera								Number of other genera identified
		Organism	Percent	Organism	Percent	Organism	Percent	Organism	Percent	
Current River below Montauk State Park										
Apr. 2, 1973	840	*Ankistrodesmus*	84	--	--	--	--	--	--	--
July 30, 1973	85	*Achnanthes*	25	*Navicula*	25	*Cymbella*	17	*Cocconeis*	17	--
Oct. 15, 1973	130	*Navicula*	31	*Cymbella*	17	*Ankistrodesmus*	17	--	--	--
Jan. 18, 1974	960	*Navicula*	46	*Achnanthes*	24	--	--	--	--	--
Apr. 17, 1974	200	*Navicula*	40	*Cymbella*	20	--	--	--	--	4
July 9, 1974	840	*Navicula*	41	*Cymbella*	21	--	--	--	--	6
Oct. 21, 1974	300	*Nitzschia*	52	*Navicula*	15	--	--	--	--	5
Jan. 22, 1975	250	*Navicula*	28	*Achnanthes*	24	--	--	--	--	7
Apr. 15, 1975	1,100	*Nitzschia*	26	*Achnanthes*	23	*Navicula*	17	--	--	5
Current River above Powder Mill										
Apr. 5, 1973	90	*Fragilaria*	43	*Synechococcus*	29	--	--	--	--	--
Aug. 1, 1973	99	*Cocconeis*	39	*Cymbella*	29	--	--	--	--	--
Oct. 17, 1973	230	*Achnanthes*	38	*Cocconeis*	18	*Navicula*	17	--	--	--
Jan. 18, 1974	250	*Gomphonema*	29	*Navicula*	26	*Cymbella*	18	--	--	--
Apr. 17, 1974	440	*Navicula*	53	*Cymbella*	27	--	--	--	--	4
July 10, 1974	960	*Cymbella*	49	*Navicula*	31	--	--	--	--	5
Oct. 22, 1974	150	*Epithemia*	38	*Nitzschia*	15	*Gomphonema*	15	*Achnanthes* *Navicula*	15 15	--
Jan 21, 1975	72	*Achnanthes*	40	*Navicula*	27	*Nitzschia*	20	--	--	2
Apr. 15, 1975	350	*Cymbella*	33	*Navicula*	19	--	--	--	--	7

Current River below Hawes Campground										
Apr. 6, 1973	(1)	*Microcystis*	99	--	--	--	--	--	--	--
Aug. 2, 1973	28	*Cocconeis*	63	*Navicula*	25	--	--	--	--	--
Oct. 18, 1973	160	*Achnanthes*	34	*Cocconeis*	32	--	--	--	--	--
Jan. 17, 1974	300	*Achnanthes*	22	*Scenedesmus*	16	*Navicula*	16	--	--	--
Apr. 18, 1974	7,400	*Cymbella*	72	--	--	--	--	--	--	5
July 10, 1974	530	*Cymbella*	45	*Navicula*	26	--	--	--	--	4
Oct. 23, 1974	300	*Oscillatoria*	37	*Nitzschia*	22	*Anabaena*	15	--	--	3
Jan. 21, 1975	170	*Cymbella*	31	*Anacystis*	15	*Nitzschia*	15	--	--	5
Apr. 15, 1975	270	*Nitzschia*	32	*Gomphonema*	18	*Navicula*	18	--	--	6
Jacks Fork above Two Rivers										
Apr. 5, 1973	100	*Fragilaria*	38	*Cymbella*	25	--	--	--	--	--
Aug. 1, 1973	74	*Cocconeis*	29	*Navicula*	33	--	--	--	--	--
Oct. 1, 1973	49	*Gomphonema*	21	*Navicula*	21	*Cocconeis*	21	--	--	--
Jan. 18, 1974	660	*Meridion*	15	*Lyngbya*	60	--	--	--	--	--
Apr. 17, 1974	380	*Nitzschia*	30	*Cymbella*	30	*Crucigenia*	17	--	--	3
July 10, 1974	540	*Cymbella*	36	*Achnanthes*	29	--	--	--	--	5
Oct. 22, 1974	130	*Cyclotella*	36	*Navicula*	27	*Achnanthes*	18	--	--	2
Jan. 21, 1975	54	*Nitzschia*	43	*Scenedesmus*	29	--	--	--	--	2
Apr. 15, 1975	410	*Nitzschia*	35	*Cymbella*	23	*Diatoma*	15	--	--	3

[1]2,000,000

Table 14.—*Codominant genera and*

Date	Biomass		Organism
	Dry weight (g/m^2)	Ash weight (g/m^2)	
Current River below Montauk State Park			
Apr. 2, 1973	3.3	0.83	*Achnanthes*
July 7, 1973	28	9.2	*Cocconeis*
Oct. 15, 1973	22	5.8	*Stigeoclonium*
Jan. 18, 1974	36	11	*Navicula*
July 9, 1974	25	5.4	*Achnanthes*
Oct. 21, 1974	25	16	*Nitzschia*
Jan. 22, 1975	24	23	*Achnanthes*
Current River above Powder Mill			
Oct. 17, 1973	20	8	*Lingbya*
Jan. 18, 1974	18	14	*Meridion*
April 17, 1974	--	--	*Achnanthes*
July 10, 1974	12	5.4	*Cymbella*
Oct. 22, 1974	3.1	2.3	*Cocconeis*
Current River below Hawes Campground			
Aug. 2, 1973	--	--	*Gongrosira*
Oct. 18, 1973	41	24	*Stigeoclonium*
Jan. 17, 1974	36	25	*Synedra*
July 10, 1974	120	89	*Cymbella*
Oct. 23, 1974	6.9	3.9	*Achnanthes*
Jacks Fork above Two Rivers			
Apr. 4, 1973	33	8	*Cymbella*
Aug. 1, 1973	31	8	*Stigeoclonium*
Oct. 17, 1973	--	--	*Lyngbya*
Jan. 18, 1974	8.3	8.3	*Meridion*
Apr. 17, 1974	--	--	*Cymbella*
July 10, 1974	3.8	2.3	*Cymbella*
Oct. 22, 1974	35	21	--

biomass of periphyton in the Current River and Jacks Fork

Codominant genera			Number of other common alga forms identified
Organism	Organism	Organism	
Current River below Montauk State Park—Continued			
Gomphonema	--	--	4
Navicula	--	--	4
Navicula	*Cocconeis*	--	4
Ulothrox	--	--	4
Nitzchia	--	--	12
Navicula	--	--	14
Fragilaria	--	--	13
Current River above Powder Mill—Continued			
Stigeoclonium	*Cocconeis*	*Gomphonema*	4
Gomphonema	*Navicula*	--	3
Cymbella	*Gomphonema*	--	15
--	--	--	15
Achnanthes	--	--	12
Current River below Hawes Campground—Continued			
Cocconeis	*Oscillatoria*	--	3
Achnanthes	*Cymbella*	--	3
Navicula	*Nitzschia*	--	3
--	--	--	11
--	--	--	14
Jacks Fork above Two Rivers—Continued			
Gomphonema	*Synedra*	--	3
Gongrosira	*Lyngbya*	--	3
--	--	--	--
Diatoma	*Gomphonema*	*Achnanthes*	4
--	--	--	--
Achnanthes	*Lyngbya*	--	11
--	--	--	16

Table 15.—*Types and abundance of benthic*

[Results in organisms

				Current River below Montauk State Park					
Phylum	Class	Order	Family	10-15-73	1-17-74	4-17-74	7-9-74	10-21-74	1-22-75
Arthropoda	Insecta	Diptera	Chironomidae	3	35	230	106	21	90
			Simuliidae	3	---	3	693	6	---
			Tipulidae	---	---	---	---	---	1
			Ceratopogonidae	---	---	---	---	---	---
			Empididae	---	---	---	---	---	---
		Ephemeroptera		2	106	190	90	8	20
		Trichoptera		25	---	50	201	26	220
		Plecoptera		---	---	7	---	---	---
		Neuroptera		---	---	---	---	---	---
		Coleoptera	Elmidae	---	---	---	---	---	7
		Collembola		---	---	---	---	---	---
	Crustacea	Cyclopoida		---	---	2	---	---	---
	Arachnoidea	Hydraecarina		---	1	3	---	---	---
Mollusca	Gastropoda	Pulmonata	Lymnaeidae	---	---	---	1	---	---
			Ancylidae	---	---	---	---	---	---
		Ctenobranchiata	Bulimidae	---	---	---	---	---	---
			Pleuroceridae	---	---	---	---	---	---
Annelida	Oligochaeta			---	---	---	---	---	---
Total count				33	142	485	1,091	61	338

invertebrates in the Current River and Jacks Fork

per multi-plate sampler]

Current River above Powder Mill				Current River below Hawes Campground				Jacks Fork above Two Rivers			
10-17-73	4-17-74	7-10-74	10-22-74	10-18-74	10-18-73	7-10-74	10-23-74	10-17-73	4-17-74	7-10-74	10-22-74
---	61	465	162	2	25	315	126	---	216	577	468
---	---	12	---	1	3	764	---	4	2	7	---
---	---	---	---	---	---	---	3	---	---	---	---
---	---	---	---	---	---	---	---	6	---	---	---
---	---	---	---	---	---	---	---	---	---	---	3
22	42	102	3	12	42	95	9	8	85	37	18
---	9	25	---	2	---	41	67	3	6	37	10
---	---	5	3	6	6	---	4	2	---	2	12
---	---	1	---	---	---	---	---	1	---	---	1
---	---	2	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	1	---	---	---	---
---	---	---	---	--	1	---	---	---	---	---	---
---	---	2	---	---	2	2	---	---	3	1	---
2	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	2
---	1	---	---	---	---	---	---	---	---	---	---
---	---	---	1	---	---	---	---	---	---	---	32
1	---	---	---	---	---	---	---	---	100	---	---
25	113	614	169	23	79	1,217	210	24	412	661	546

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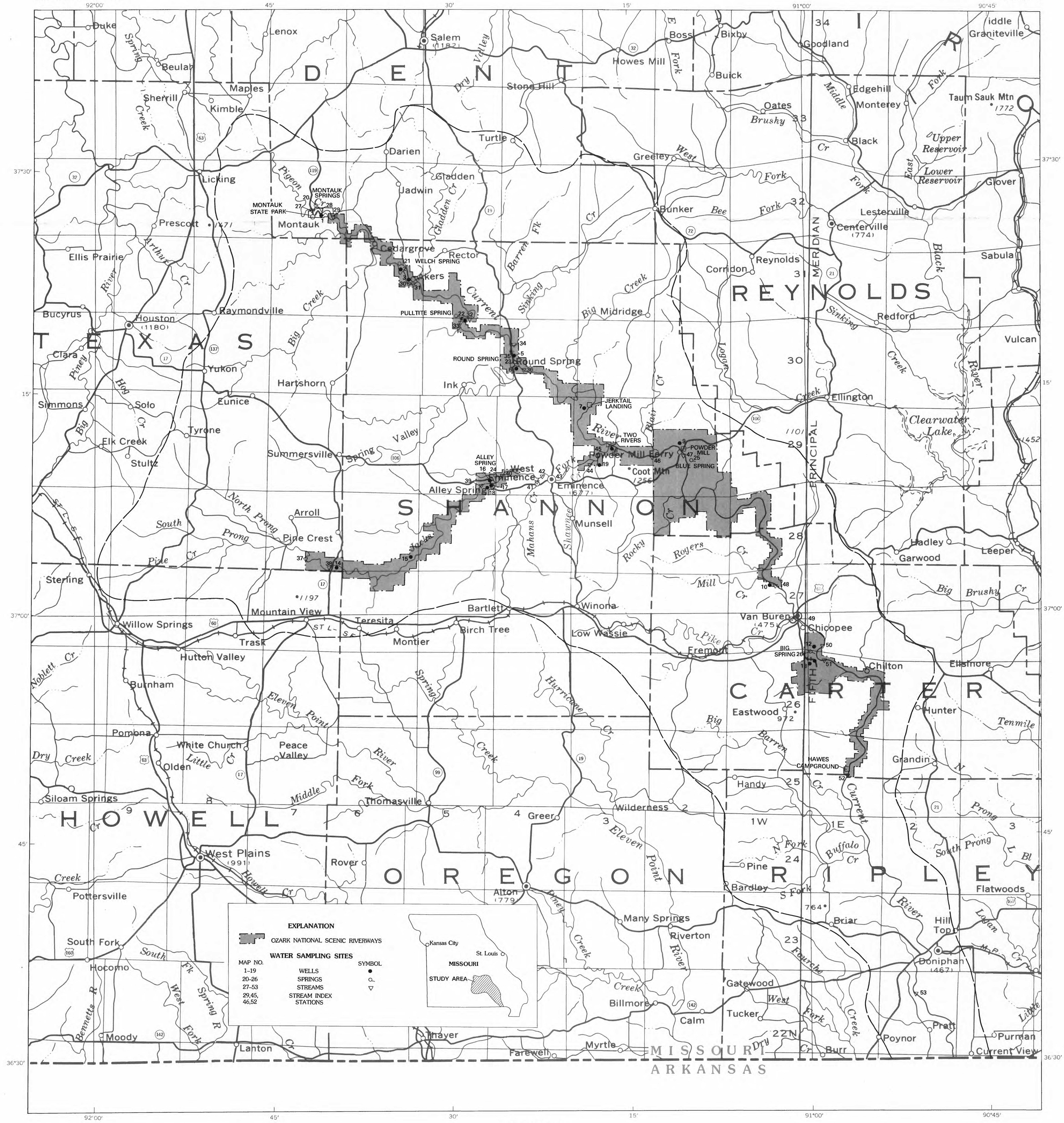
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



Modified from Geologic Map of Missouri, 1961

SCALE 1:250 000

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LOCATION OF THE OZARK NATIONAL SCENIC RIVERWAYS AND ASSOCIATED WATER SAMPLING SITES

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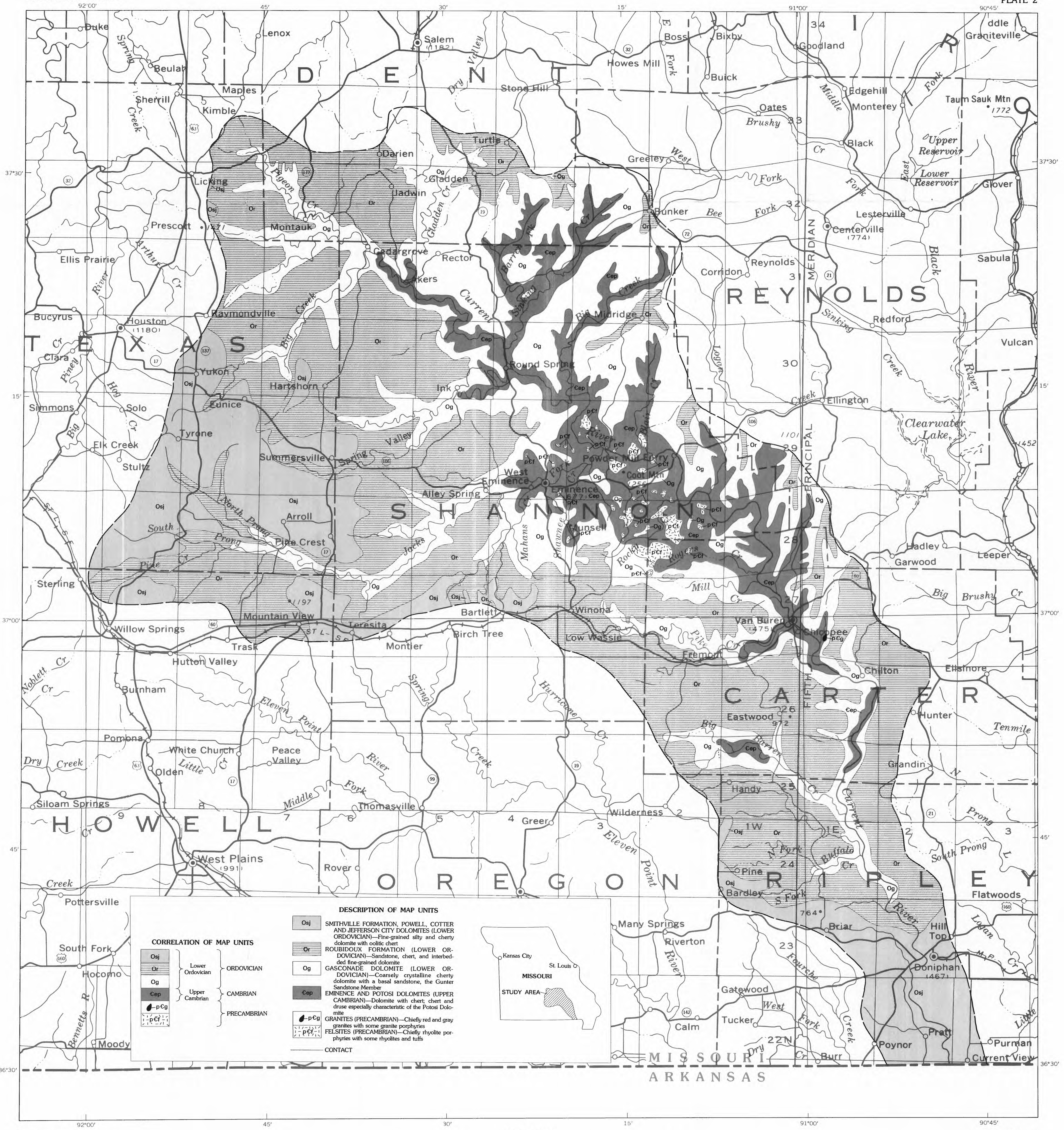

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SCALE 1:250 000

5 0 5 10 15 MILES

Modified from McCracken, 1961

GEOLOGIC MAP OF THE CURRENT RIVER BASIN

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