SPRINGS OF MISSOURI

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Stratigraphic nomenclature is that of the Missouri Geological Survey and Water Resources and not necessarily that of the U.S. Geological Survey.

SPRINGS OF MISSOURI

The old red mill at Alley Spring, clothed in a new coat of paint, stirs memories of the days when spring water-powered mills were as common as one-room schoolhouses in the Ozark hill country. Few of the picturesque mills remain, but the springs that powered them have not diminished. Photo by Jerry D. Vineyard.

By Jerry D. Vineyard
and Gerald L. Feder

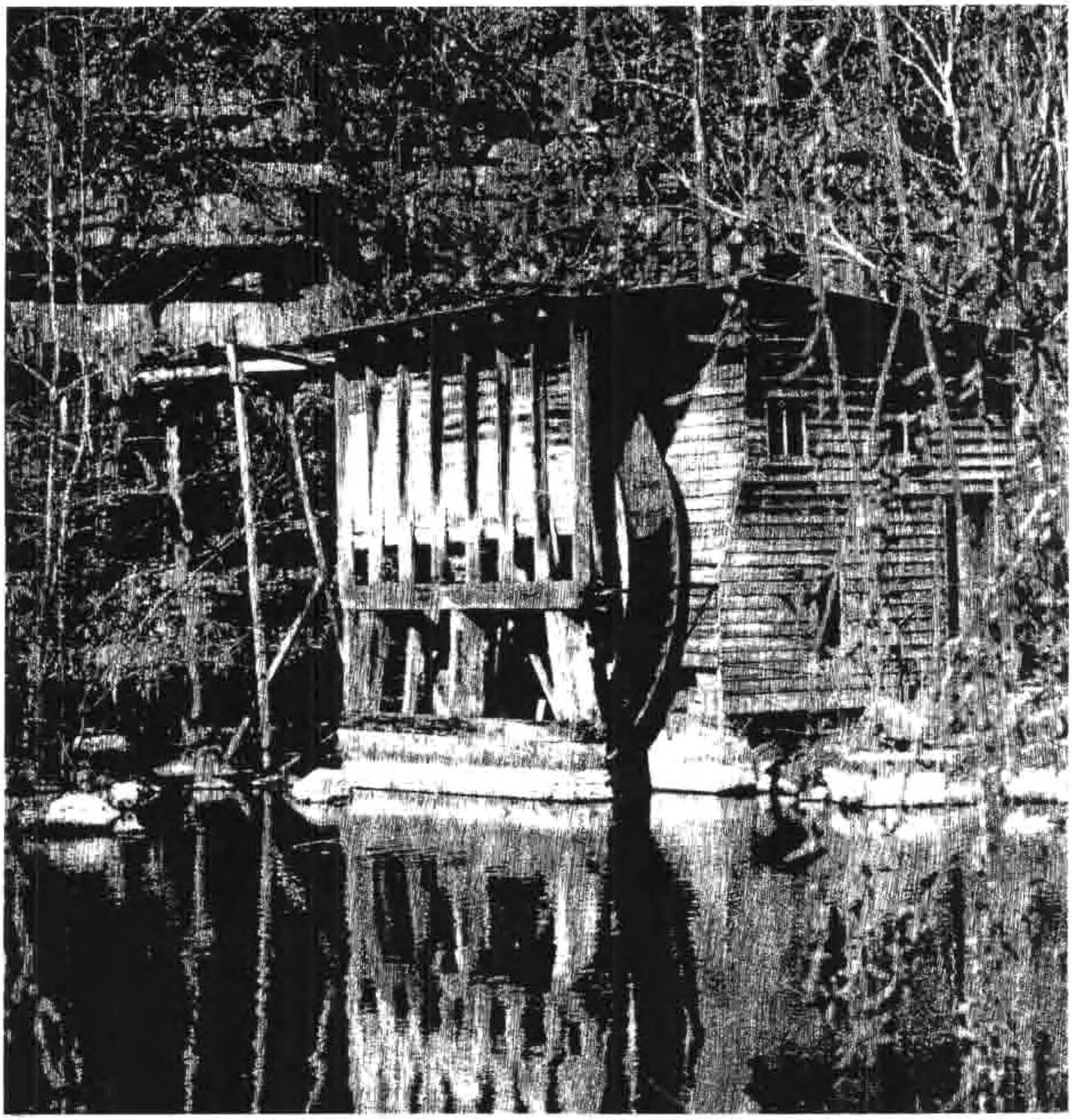


Figure 1

Falling Spring Mill in Mark Twain National Forest had an overshot water wheel that harnessed the power of a spring that gushes from openings in the face of a bluff. Today, it's a reminder of a way of life that time has passed by.

INTRODUCTION

Springs have been of great interest and extreme fascination for mankind since the very beginning of the human race. They occur in great variety, with many spectacular features. Their origin has appeared mysterious and at times providential; they are surrounded with the greenness and freshness of growing vegetation; they give rise to the living streams; and for ages they have been the source of the cleanest and most attractive water supplies available to man. The lore of the healing properties of spring waters is of ancient origin and is deepseated in human thought.

Missouri is blessed with an abundance of springs that have played a major role in the settlement and development of the state. Their yields range from a few gallons of water per day to yields capable of supplying the needs of a large metropolitan area. The Missouri Ozarks comprises one of the nation's greatest concentrations of springs. The waters are generally of good quality, but the ability of highly permeable soils and solution channels in limestone bedrock to rapidly transport contaminated water to the springs makes them highly susceptible to pollution. Therefore, before approving the use of spring water for drinking, the Missouri Division of Health requires adequate treatment of the water. In an average day more than a billion gallons of water flow from the ten largest springs in Missouri.

During the earliest years of Missouri's development, one of the most important uses made of mineralized spring waters was to provide pioneer settlements with their salt needs, particularly from the salt springs of Saline, Howard, and Perry Counties. Later, improved communication and transportation made it more economical to transport salt from other areas. During the late 19th century many of the mineral springs, believed to have beneficial medicinal qualities, were developed into spas with large capital investment in hotels, pools, bath houses, and clinics. In 1892 Paul Schweitzer described the mineral springs, their purported medicinal qualities, and the development of the health resorts.

During the early settlement and development of the Ozarks, (where there are no salt springs), springs were used as domestic and stock water supplies; many springs also became the sites of grist mills, which were the hub of many community activities. Though some picturesque old mills remain, most are brought to mind only by mossy mill ponds and crumbling foundations. But the springs remain much as they were generations ago, an exceedingly pleasant and valuable water resource for Missourians.

Today only a fraction of the spring water is being used for municipal and domestic supply. At a few springs the grist mills have been preserved or have been restored and are operating for their esthetic charm; for example, Hodgson Mill advertises "Stone Buhr Ground Corn Meal Since 1885." A few spas at the salt-water springs are still in existence but most of the spas have ceased operation. Although only a small part of the water is used for municipal and domestic supplies, medicinal purposes, or grist milling, the springs do contribute indirectly to the economy by sustaining the flow of streams and by serving as focal points for a thriving and expanding recreation industry. Many of the large springs have been acquired by governmental agencies to be preserved in their natural state for future generations to enjoy. Others are used for the spawning and raising of fish, mainly trout and bass, most of which are released in spring branches for the benefit of fishermen or for marketing to restaurants and frozen food distributors. At some springs fish bait is raised and shipped to many fishing areas in the Midwest.

An interesting feature of Ozark springs is the unusual plant and animal life they contain. Many of the plants found in the springs are rare species restricted to springs. The vegetation is uniform and appears as a natural, distinct unit in the vegetation of the state. At one or two springs, some of the species found have been cultivated and marketed for use in aquariums or for replanting in home gardens. Water cress is cultivated in springs in the St. Louis area for the local market. Most springs contain abundant animal life, but because the organisms are small and secretive in nature they are rarely seen. Among the most common animals found in springs are fish, salamanders, flatworms, amphipods, isopods, snails, and insects (see the section on fauna beginning on p. 31). Some animals show unique adaptations to the spring environment, such as blindness and loss of pigmentation. Blind, white organisms such as fish, crayfish, and salamanders as well as other forms may spend their entire life cycles in the world of eternal darkness of the water-filled caves that supply water to the springs.

Missouri springs, in one of the most scenic sections in the nation and easily accessible by good highways, are visited by hundreds of thousands of tourists and sportsmen each year. Truly they are one of Missouri's most important natural assets.

PURPOSE AND SCOPE

The popular publication *THE LARGE SPRINGS OF MISSOURI* (Beckman and Hinchey, 1944) presented information on the large springs of the Ozark region of the state. Since the publication of this report, a wealth of additional information has been collected concerning the quantity and quality of springflow, not only in the Ozarks but in other regions also. In addition, much has been learned about the hydrogeology of springs.

Most of the significant springs in Missouri and probably all large springs—10 cfs (cubic feet per second) or more—have been measured and sampled. Data on 585 springs are contained in this report, but there are more than 1,100 springs currently on record. However, many springs in the Ozarks still remain unrecorded, unmeasured, and unsampled. In addition, the environment of some springs has been altered over the years by commercial development or, in some cases, by neglect.

It is the purpose of this report to present available quantitative and qualitative information about springflow in Missouri and to illustrate and describe the physical and cultural changes in the spring environs.

This additional information will be of interest to those charged with the management of the state's water resources (particularly in the recreation field) and to homeowners, farmers, and those city dwellers seeking country retreats. Information and records collected for this report, which are expected to stimulate further contributions to karst hydrology, also will be used for an interpretive study of the movement of water in the limestone and dolomite that underlie the Ozarks.

ACKNOWLEDGMENTS AND COOPERATION

The information contained herein was collected by the staffs of the Missouri Geological Survey and Water Resources, under the direction of Dr. Thomas R. Beveridge, State Geologist and Director, succeeded by Dr. William C. Hayes, succeeded by Dr. Wallace B. Howe; and the U.S. Geological Survey, under the direction of Anthony Homyk, district chief, Missouri district.

The writers acknowledge the valuable assistance given in the collection of data for the report. The Missouri State Park Board furnished the services of gage readers for springs in state parks and the Missouri Department of Conservation furnished the services of gage readers for springs at their fish hatcheries.

Several underwater diving clubs and individual divers contributed valuable information on the water-filled supply systems of springs. The St. Louis Underwater Recovery Team investigated numerous springs, and the Aqua Rays Diving Club of Chicago, Ill. aided in the study of the Cave Spring system in Shannon County. The assistance of an individual cave diver, Donald N. Rimbach, is gratefully acknowledged.

Through the years the accumulation of data on springs has depended on the cooperation and assistance of hundreds of individuals, including landowners, outdoor enthusiasts, scientists, and government officials. The list of names of those who aided in various ways is too long for inclusion here, but the authors and the agencies they represent appreciate each courtesy extended during the preparation of this report.

PHYSICAL SETTING

Missouri has a more varied geologic and physiographic character than might be expected from its position near the center of the United States, far from the mountainous areas of the East and West. The physiography reflects Missouri's geologic history through a remarkably long period of time.

CLIMATE

The climate of Missouri is continental. The average annual temperature ranges from 60°F in the southeast corner of the state to about 53°F in the northwest corner. Average annual precipitation is about 48 inches in the southeast and 32 inches in the northwest. Figure 3 shows the distribution of precipitation in Missouri. On the average about 40 percent of the precipitation occurs during the period May to August, inclusive. Evapotranspiration over the state averages about 28 inches.

PHYSIOGRAPHY

Missouri has three distinct physiographic regions (fig. 4): in the north and west, a plain or prairie; in the extreme southeast, a lowland; and between them, the Ozark uplift (McCracken, 1971, p. 3).

PLAINS– (or Prairies) embrace almost all the area north of the Missouri River (shown as the Dissected Till Plain) and a large area south of the Missouri River in the west-central part of the state (shown as the Osage Plains). The plains north of the Missouri River were covered by two major glaciers. A third glacier entered Missouri from Illinois and covered only eastern St. Charles and St. Louis Counties. Elevations in the Plains range from about 1,200 feet above mean sea level in the extreme northwest to 600 feet in the northeast. Springs in this area are few, have a relatively small flow, and many are highly mineralized.

OZARKS–The principal spring region of Missouri is the Ozarks province. It is an area characterized by deep, narrow valleys and sharp ridges in the eastern part, the Salem Plateau, and a gently rolling landscape in the western part, the Springfield Plateau. Separating the two plateaus in the vicinity of Springfield is the Eureka Springs escarpment, a narrow belt of scenic

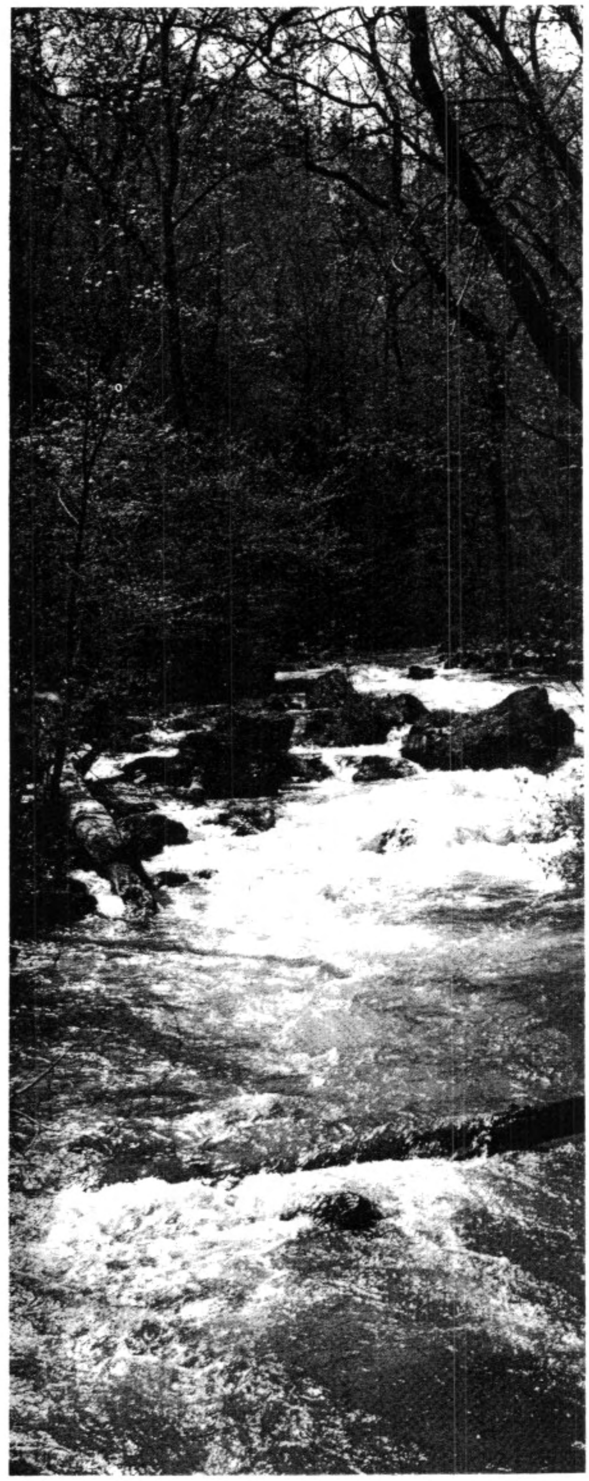


Figure 2
A "spring branch" is a haven from the cares of a busy life. Photo by Jerry D. Vineyard.

hills extending from the Osage Plains on the north to the Arkansas state line on the south. Upland elevations range from 1,000 to 1,700 feet above mean sea level and the relief in some areas is as much as 700 feet. Springs with appreciable year-round flow occur at altitudes as high as 1,500 feet above mean sea level. Many springs exist in the Springfield Plateau, but they are not as large or as abundant as the springs in the Salem Plateau. The geologic formations in the plateaus are capable of storing and transmitting large quantities of water through spring outlets. Consequently, the streams in the Ozarks have the highest sustained flows in the state.

SOUTHEASTERN LOWLANDS– The Southeastern Lowlands is a relatively flat region comprising about 3,000 square miles. Elevations in this region range from 230 to 300 feet above mean sea level. Crowleys Ridge, about 500 feet above sea level, lies diagonally across the area. This section of Missouri was once swampland, but extensive drainage and removal of the forests have converted the area into excellent farmland. Only a few small springs are in this area

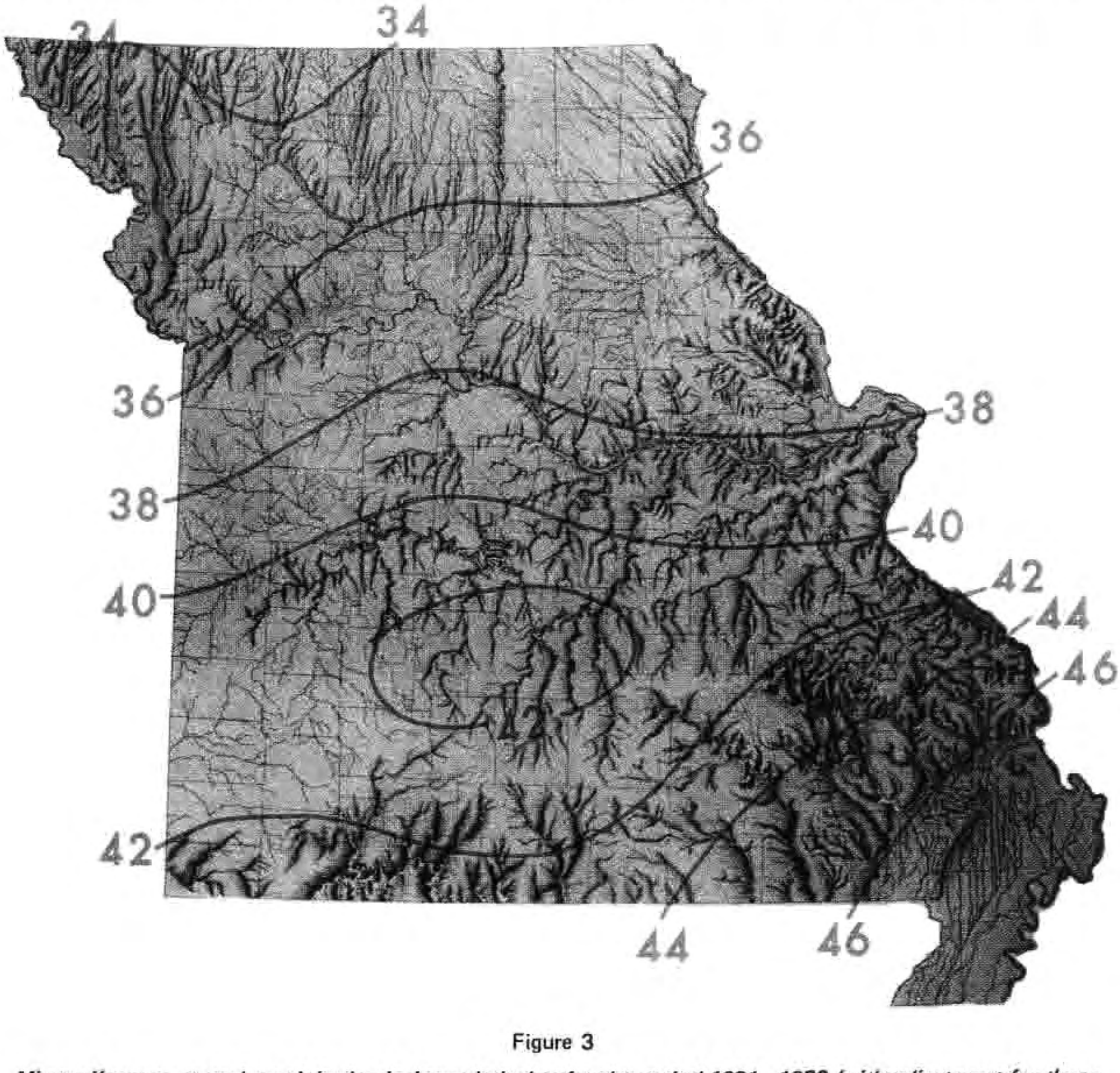


Figure 3

Missouri's mean annual precipitation is shown in inches for the period 1931 - 1960 (with adjustment for those stations that have 1941 - 1970 summaries). Data from National Weather Service.

GEOLOGY

Springs occur in all sections of Missouri but the dolomitic rock of the Salem Plateau is the locality of the greatest number and the largest springs in Missouri (fig. 5). The uplands of the Salem Plateau are covered for the most part by the Jefferson City Dolomite and the Roubidoux Formation; valleys are floored chiefly by the Gasconade Dolomite. In part of the Current River valley and on the flanks of the St. Francois Mountains, the Eminence and Potosi Dolomites are exposed. Most of the large springs discharge from openings in the Gasconade, Eminence, and Potosi Dolomites.

Dolomitic rocks are by far the most common in the sequence from which the large springs issue and it is the soluble character of these rocks that made possible the extensive cave and spring systems for which the Ozarks is noted. The mass of 1,000 to 2,000 feet of dolomite which is present in the Ozarks affords a tremendous storage volume for precipitation in the area. Some concept of the capacity of the dolomite aquifers can be gained by considering the number of caves in the region, many of which sustain large springs. Of a total of nearly 3,000 known caves in Missouri, more than 2,500 are in the Ozarks.

The Ozark uplift is a broad asymmetric arch (McCracken, 1971, p. 3) whose eastern and south-

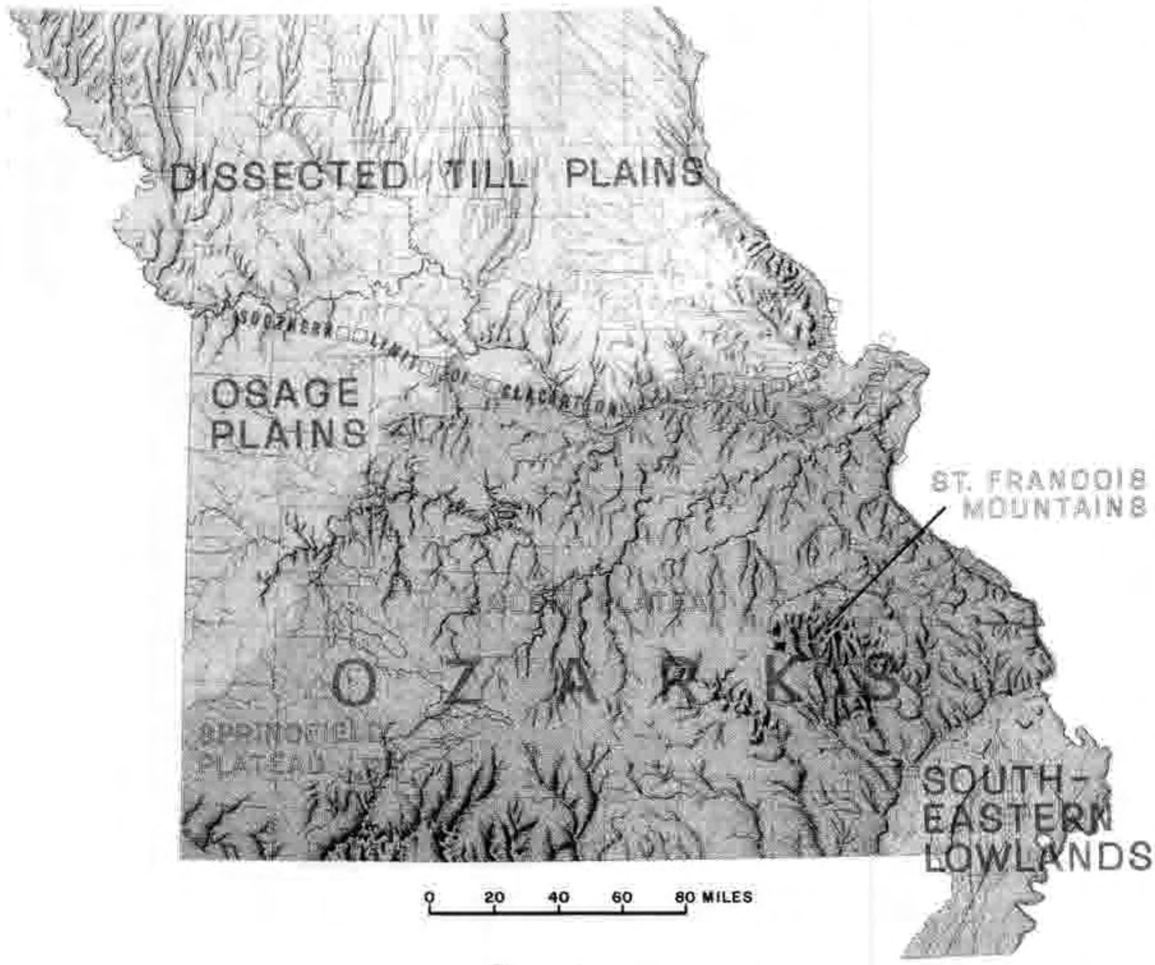


Figure 4

The physiographic divisions of Missouri include the rugged Ozarks in the south and the glaciated plains of the north, with the alluvial plains of the Southeastern Lowlands forming the Bootheel. The Osage Plains of western Missouri have low relief because they are underlain by easily eroded sedimentary rocks, whereas the St. Francois Mountains have developed on resistant igneous rocks.

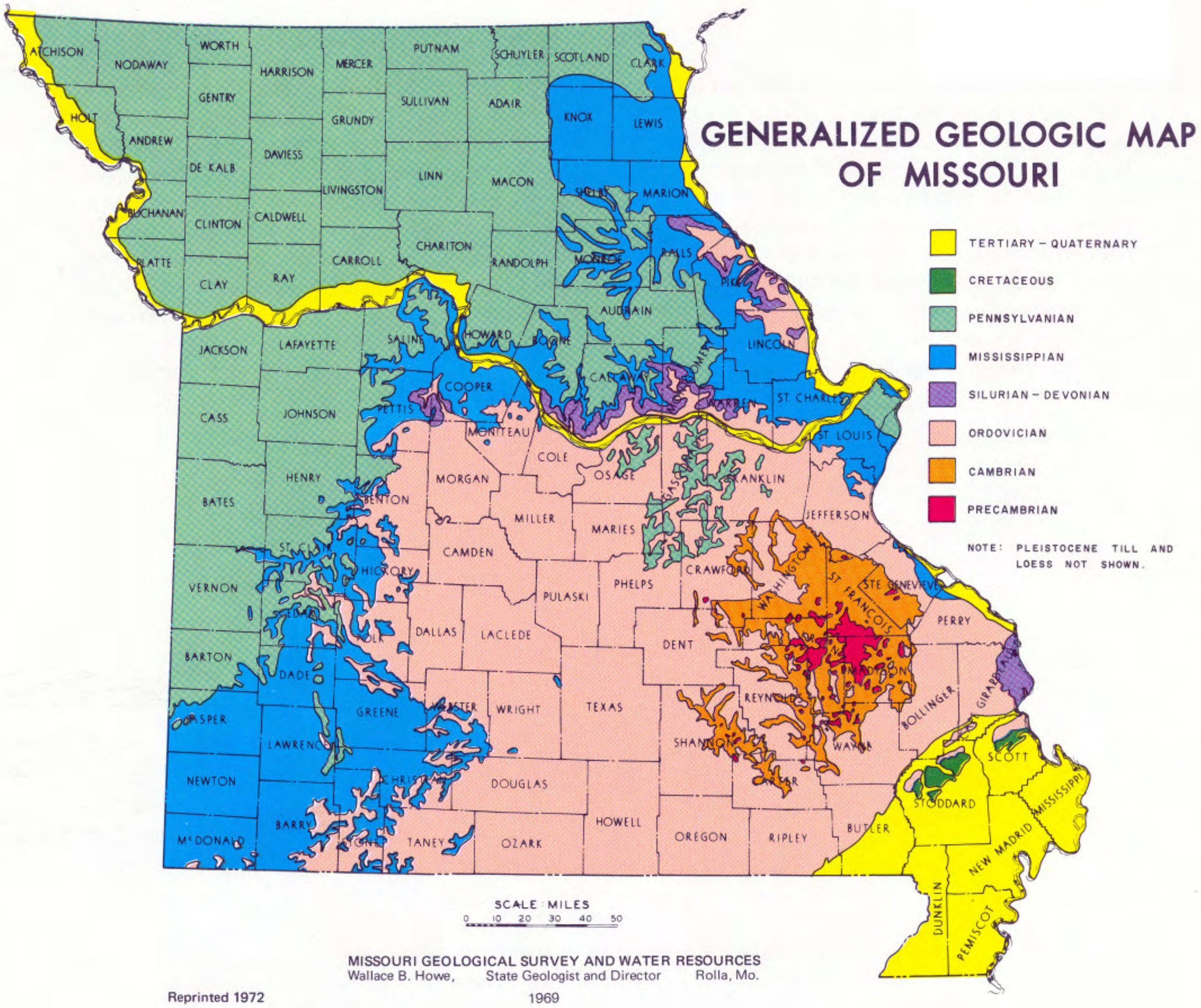


Figure 5

This generalized geologic map shows the distribution of rock formations in Missouri. The state's largest springs are in rocks of Cambrian and Ordovician age. A number of springs are also to be found in rocks of Mississippian age.

eastern flanks are steep by comparison with the gently sloping northern and western flanks. The axis of the uplift has a southwest trend extending from the St. Francois Mountains into southwestern Missouri. The trend of the major axis generally follows the divide that crosses the state.

The rocks have steeper dips on the eastern flank than on the western flank so that outcrop areas of the important spring formations are broader on the west and the collecting systems of conduits are more extensive. Faulting and fracturing of the carbonate rocks in the Ozarks have had an important effect on the movement of ground water. Numerous tracing studies using rhodamine or fluorescein dye have shown that water may flow in a surface stream until it reaches a cavernous zone where it will sink underground and follow the zone of solution for many miles before issuing from a spring—–sometimes in a different drainage basin.

Bordering the Salem Plateau on the west is the Springfield Plateau where the second most important group of springs in the state is located. Limestone of Mississippian age is exposed at the surface in much of this area and it is from these rocks that the springs issue. The gentle westward dip of the rocks on the Salem Plateau continues into the Springfield Plateau where the Ordovician dolomite passes beneath the Mississippian limestone which underlies the Springfield Plateau. At the western edge of the Springfield Plateau the Mississippian limestone, in turn, gives way at the surface to Pennsylvanian sandstone and shale.

Springs on the Springfield Plateau are not as large as those of the Salem Plateau but many small perennial springs exist. They become smaller and fewer toward the boundary with the Pennsylvanian rocks of the Osage Plains.

In the remaining areas of Missouri only small springs of generally intermittent character are found. The Osage Plains west of the Springfield Plateau have Pennsylvanian sandstone and shale on the surface. Springs issuing from the beds of sandstone are small and relatively few in number. Beds of Pennsylvanian limestone which become quite thick in the vicinity of Kansas City have dissolved sufficiently along joints and bedding planes to afford storage for water, and a few small springs occur in this area.

The Southeastern Lowlands is a part of the Mississippi alluvial plain which is underlain by 100 to 200 feet of sand and gravel. In the northern part of the Lowlands, Crowleys Ridge, Benton Hills, and Bloomfield Hills rise as much as 170 feet above the adjacent plain. Small outliers of Ordovician rocks flanked by Cretaceous and Tertiary formations are exposed in the hills. Springs emanating principally from Tertiary sand and gravel are infrequent and small by comparison with those in the Ozarks to the northwest.

The occurrence of springs has been reported from time to time on the alluvial plain where water seeps from the alluvium into swales or ditches. That these should be called springs in the sense that the word is used in this report is questionable. The flow of streams draining the Lowlands is quite substantial due to streams and ditches intersecting the water table in the highly permeable aquifers. The Lowlands is an area of high discharge of ground water, but it should not be considered a prominent spring area of the state.

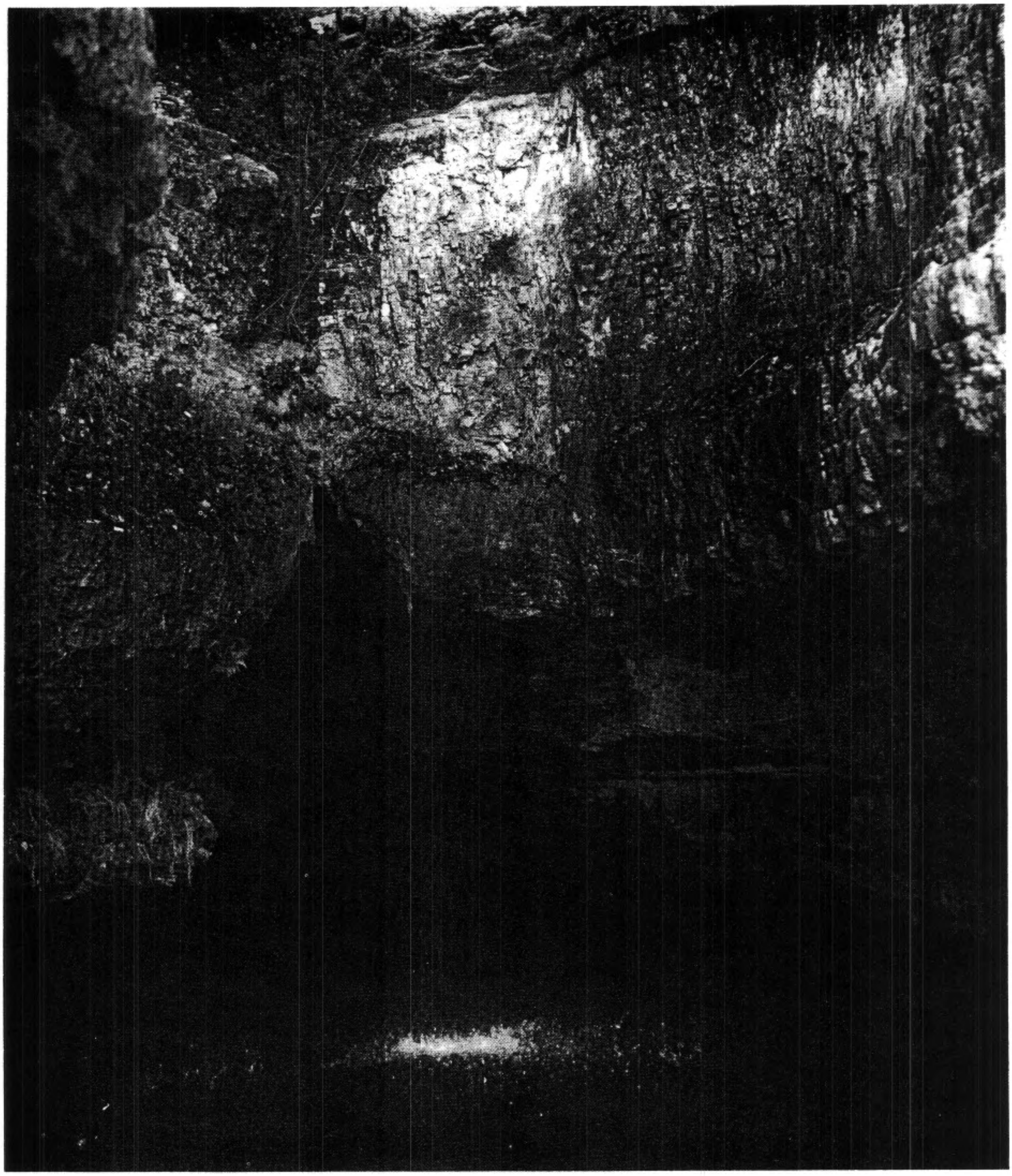


Figure 6

Part of the watercourses of tubular springs may be determined by fractures or faults (faults are actually fractures along which differential movement has occurred). Note the fault in the center left of the picture, which determines the orientation of Roaring River Spring near Cassville. Photo by Jerry D. Vineyard.

CHARACTERISTICS OF SPRINGS

The conditions that produce springs are many and varied and may be related to combinations of geologic, hydrologic, topographic, hydraulic, or climatic controls. A spring is defined as any natural discharge of water from rock or soil onto the surface of the land or into a body of surface water.

CLASSIFICATION OF SPRINGS

Numerous specific descriptive terms for springs have arisen and no single basis of classification of springs has satisfied the need of common usage. The most common classifications are based on the type of aquifer, chemical characteristics of the spring water, temperature of the water, magnitude of discharge, and hydraulic characteristics. The following classification of springs according to their yield or discharge was suggested by Meinzer (1927, p. 2) as convenient for use in the United States, although it is recognized that this classification may be inappropriate for countries that have other units of discharge.

MAGNITUDE	DISCHARGE
First	100 cfs (cubic feet per second) or more
Second	10 to 100 cfs
Third	1 to 10 cfs
Fourth	100 gpm (gallons per minute) to 1 cfs (448 gpm)
Fifth	10 to 100 gpm

According to their temperatures springs may be divided into thermal and non-thermal. Non-thermal springs have temperatures that are approximately the same as the mean annual temperature of the air of the region in which they are found. Thermal springs are classified as hot springs or warm springs. Hot springs are those having a temperature higher than 98°F. Warm springs are those whose temperatures are higher than the local mean annual temperature of the atmosphere but lower than 98°F. All springs in Missouri can be classified as non-thermal springs.

With respect to the character of the openings through which the water issues, springs may be divided into three general classes: seepage or filtration springs, fracture springs, and tubular springs. A seepage spring, or filtration spring, is one in which water percolates from numerous small openings in permeable material. The term "seepage spring" is often limited to springs with small discharge; the term "filtration spring" may be applied without limitation to yield. Any considerable area in which water is seeping to the surface is called a seepage area. Seepage springs occur in all sections of Missouri.

Fracture springs (fig. 6) and tubular springs are springs whose water flows from relatively large openings in the rocks and these springs are abundant in the Ozarks of Missouri. The term "fracture spring" is used when the opening or openings consist of joints or other fractures. Fracture springs can be further subdivided into joint springs, fissure springs, or fault springs according to the extent of the fracture, and the amount of relative movement on either side of the fracture. In the Ozarks several distinct springs may be found along a single fault trace. The term "tubular spring" is used if the openings or opening consist of more or less rounded channels such as solution passages in limestone. Excellent examples of this type of spring are found in the Missouri Ozarks. A common type of spring in the Ozarks is the bedding-plane spring. The openings in these springs are enlarged in the direction of bedding planes in the surrounding rocks.

Another basis for classification of springs is hydraulic characteristics. Springs are either artesian or nonartesian. A spring boil in the orifice is often an indication that pressure exists in the spring reservoir system that causes the water to discharge at the surface with noticeable vigor. The artesian spring is similar in this respect to the flowing artesian well. The nonartesian spring is one which discharges by gravity drainage from the surrounding hills. This classification is the most difficult to use in describing the Ozark springs because only the orifice of the spring can be seen or investigated in many instances.

SIZE AND RANK OF SPRINGS

Through the years records of the rate of flow of the large springs of the Ozark region of Missouri have been collected. Daily records are available from 1921 to present (1972) for Big Spring in Carter County and Greer Spring in Oregon County. Records for several years are also available for other large springs. Occasional measurements of discharge are available at most springs. From these continuous and occasional measurements it is possible to determine only an approximation of the relative size of the springs. Table 1 shows the relative size of the large springs in the Ozarks. This order of magnitude has been

Table 1

*DISCHARGES OF LARGE SPRINGS IN MISSOURI****

(In gallons per day)

Name of Spring	County	Location	Average Discharge	Maximum Measured		Minimum Measured	
				Discharge	Date	Discharge	Date
Big	Carter	SW¼NE¼ sec. 6, T. 26 N., R. 1 E.	276,000,000	840,000,000	June 1928	152,000,000	Oct. 6, 1956
Greer	Oregon	SE¼SW¼ sec. 36, T. 25 N., R. 4 W.	214,000,000	583,000,000	May 26, 1927	67,000,000	Nov. 16-19, 1956
Double	Ozark	NE¼NE¼ sec. 32, T. 24 N., R. 11 W.	*100,000,000	150,000,000	Apr. 7, 1965	30,000,000	Nov. 16, 1964
Bennett	Dallas	SE¼NW¼ sec. 1, T. 34 N., R. 18 W.	100,000,000	**		36,000,000	Nov. 13, 1934
Maramec	Phelps	NW¼SE¼ sec. 1, T. 37 N., R. 6 W.	96,000,000	420,000,000	1927-28	36,000,000	Aug. 1, 1934
Blue	Shannon	NE¼SE¼ sec. 21, T. 29 N., R. 2 W.	* 90,000,000	153,000,000	Apr. 24, 1964	40,000,000	Oct. 10, 1932
Alley	Shannon	NW¼SE¼ sec. 25, T. 29 N., R. 5 W.	81,000,000	**		35,000,000	Oct. 1934
Welch	Shannon	SE¼SE¼ sec. 14, T. 31 N., R. 6 W.	* 75,000,000	214,000,000	June 22, 1924	45,000,000	Aug. 24, 1964
Boiling	Pulaski	SE¼NW¼ sec. 33, T. 37 N., R. 10 W.	* 68,000,000	45,000,000	Oct. 26, 1963	36,000,000	Jan. 21, 1964
Blue	Oregon	NW¼SE¼ sec. 16, T. 22 N., R. 2 W.	* 61,000,000	65,000,000	July 18, 1935	35,000,000	Aug. 13, 1936
Montauk	Dent	SE¼NE¼ sec. 22, T. 32 N., R. 7 W.	* 53,000,000	79,000,000	May 15, 1939	25,000,000	Aug. 13, 1934
Hahatonka	Camden	NE¼SW¼ sec. 2, T. 37 N., R. 17 W.	48,000,000	123,000,000	June 19-20, 1924	28,000,000	Feb. 23, 1923
North Fork	Ozark	SW¼SW¼ sec. 28, T. 24 N., R. 11 W.		49,000,000	July 6, 1966	43,000,000	Apr. 8, 1966
Round	Shannon	SW¼NW¼ sec. 20, T. 30 N., R. 4 W.	26,500,000	336,000,000	May 1933	6,500,000	Dec. 1937
Hodgson Mill	Ozark	SW¼SE¼ sec. 34, T. 24 N., R. 12 W.	* 24,000,000	29,000,000	Aug. 18, 1934	15,000,000	Aug. 29, 1926

*Estimated.
**Peak flows affected by runoff upstream from spring, after heavy rains.
***Source: Table 41, p. 317, Mineral and Water Resources of Missouri, 1967.

Table 2

SELECTED LIST OF LARGEST SPRINGS IN THE WORLD

Name of Spring	**Location**	**Discharge (In cubic feet per second)**			**Type of Aquifer**	**Source of Data**
		Maximum	**Minimum**	**Average**		
Big Spring	Missouri, U.S.A.	1,300 (est.)	236	427	Limestone	U.S. Geol. Survey, 1968
Fontaine de Vaucluse	France	5,300	160	800	Limestone	Meinzer, 1927
Ras el 'Ain	Syria			1,362	Limestone	Burden and Safadi, 1963
Stella Spring	Italy			1,292	Limestone	Burden and Safadi, 1963
Silver Springs	Florida, U.S.A.	1,280	539	813	Limestone	U.S. Geol. Survey, 1963
Spring on Rio Maule River	Chile			1,000 (est.)	Basalt	Davis and DeWiest, 1966
Malade Springs	Idaho, U.S.A.			1,000*	Basalt	Meinzer, 1927
Rainbow Springs	Florida, U.S.A.	1,020	487	700	Limestone	Stringfield, 1966
Giant Springs	Montana, U.S.A.			600 (est.)	Sandstone	Meinzer, 1927

*Approximate figure. Spring consists of many outlets along Snake River. There are several other groups of springs discharging from basalt bluffs along the Snake River whose combined discharge is greater than Big Spring.

revised from that given by Beckman and Hinchey (1944, p. 16) because of the availability of longer records. Blue Spring in Wayne County has been omitted because of its inundation by Wappapello Reservoir, and Mammoth Spring is not included because its orifice is in Arkansas.

Many times we are asked how the large springs of Missouri compare with those of other states and of other countries. According to the strict definition of a spring (any natural discharge of water from rock or soil onto the surface of the land or into a body of surface water), the largest springs in the world probably occur at the termini of glaciers during warm seasons. Many of these springs in Greenland have never been measured because of the hazards involved, but their flow has been estimated to be many thousands of cfs. In table 2 are listed some of the largest springs in the world. There are many submarine springs in many parts of the world, but their discharges are not accurately known. Some of the more famous ones occur off the coast of Florida and along the north shore of the Mediterranean Sea.

EBB-AND-FLOW SPRINGS

Periodic or "ebb-and-flow" springs are of little economic value but they have been, and still are, of considerable scientific interest. It has been suggested that the miracle-working waters described in the Bible—John (KJV) 5: 2-9, was an ebbing-and-flowing spring:

> *"Now there is in Jerusalem by the sheep market, a pool, which is called in Hebrew tongue Bethesda, having five porches.*
>
> *In these lay a great multitude of impotent folk of blind, halt, whichever, waiting for the moving of the water.*
>
> *For an angel went down of a certain season into the pool, and troubled the water; whosoever then first after the troubling of the water stepped in, was made whole of whatsoever disease he had."*

In 1724 the periodic action of ebb-and-flow springs was ascribed by J.T. Desaguliers to natural siphons in the rock. To date there is no evidence to disprove the theory. Recent studies of spring supply systems have shown that siphons are often present in spring systems in a transitional stage from completely water-filled solution channels to air-filled caves.

The total number of known ebb-and-flow springs is very small, only about 26 in the United States, and it is believed a comparable number in other parts of the world. The total number in existence may be greater, but they are rare and unusual features.

Of 23 ebb-and-flow springs known in the United States in 1944 (Beckman and Hinchey, 1944, p. 44), five were in Missouri. Since 1944 three additional ones have been discovered in the state. It is believed that more ebb-and-flow springs will be found as more continuous-flow records on Missouri springs become available.

Recent studies of ebb-and-flow springs have not revealed the mechanism of periodicity, but observations suggest that periodicity is a function of spring discharge. Critical discharge ranges probably exist for each spring, outside of which the spring will flow normally.

Recording gages have been installed on several springs in Missouri in order to obtain a record of the periodic fluctuations in the stage and discharge. Reproductions of these charts are shown in figure 7. Notice the differences in the periodicity of the fluctuations in these springs. Apparently each ebb-and-flow spring has its own pattern of fluctuations. Due to the limited period of continuous records for these springs the complete patterns of fluctuations are not known. Nevertheless one can compare the stage hydrographs shown in figure 7 and see the distinctive nature of each ebb-and-flow spring's fluctuation pattern. The stage hydrograph of Rymer Spring indicates that both above and below certain discharges the spring does not ebb and flow. The fact that the available continuous record for Miller Spring shows that it only stops ebbing and flowing above a critical discharge does not mean it might not stop ebbing and flowing below some critical discharge. The short continuous record for Schumer Spring does not show stages either above or below which the spring fails to ebb and flow. However, a longer period of continuous record may reveal such stages.

The development and refinement of techniques in underwater exploration of spring systems in Missouri suggests that the riddle of ebb-and-flow springs—unsolved since 1724—may soon yield to scientific scrutiny. Some Missouri springs, notably Emerald Spring (p. 104) have been observed to ebb and flow, and appear to be accessible to divers.

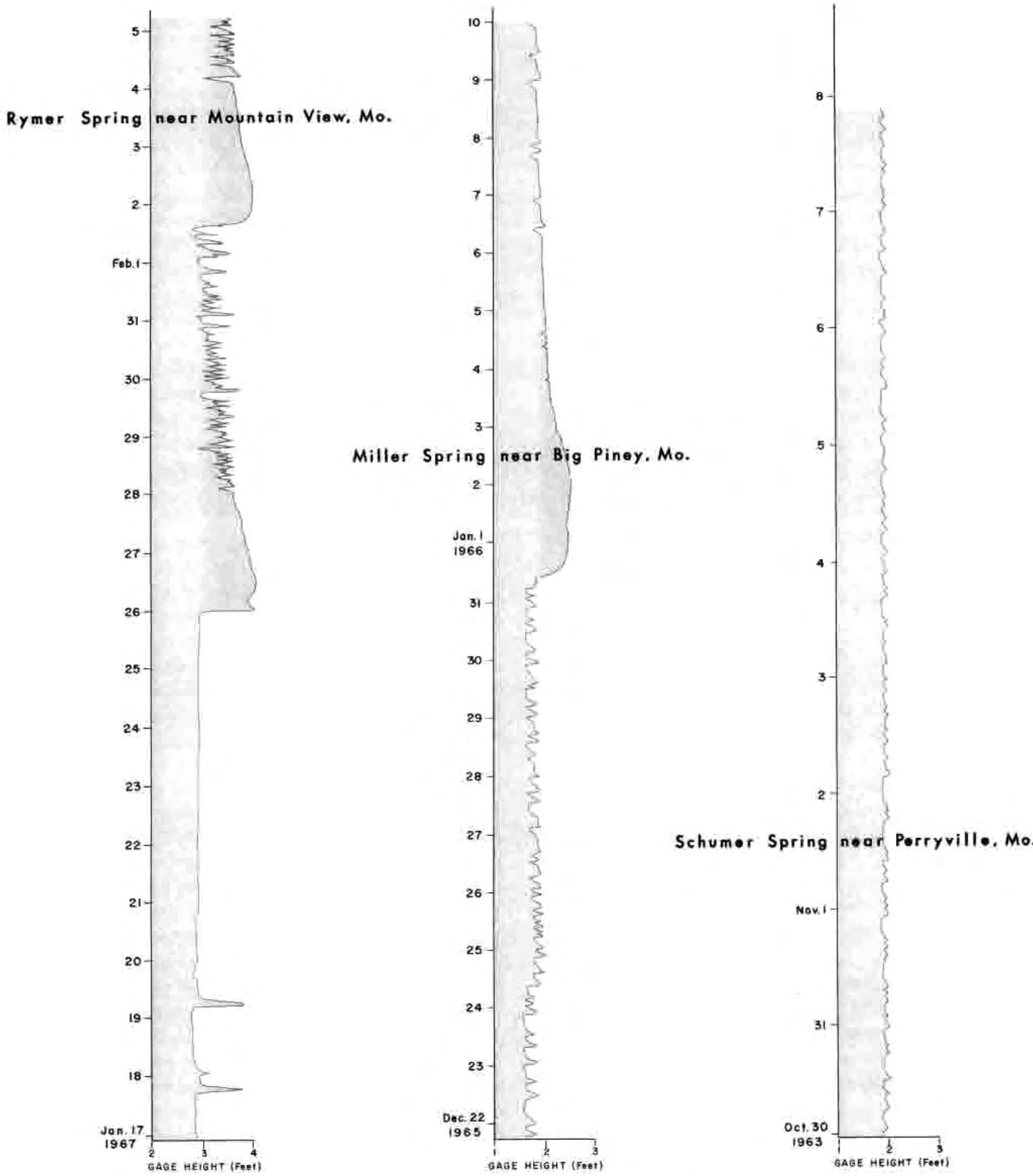


Figure 7

These stage hydrographs for three ebb-and-flow springs in Missouri show variations in periodicity and character of discharge patterns.

MEASUREMENT OF SPRING DISCHARGE

The discharge of springs is generally measured by means of a current meter and wading-rod (fig. 8), and a ruled tape. The springflow channel is divided into vertical sections of measured width and depth, and the average velocity in each section is measured with the current meter. The discharge of each portion of the stream cross section is computed by multiplying the width times depth times velocity. The discharges of all the sections are totaled to obtain the total discharge of the spring. Buchanan and Somers (1969) give a more detailed description of techniques and equipment for measuring spring discharge.

During periods of high water many springs are flooded by nearby streams making discharge measurements difficult or impossible. For this reason the maximum discharges of many springs are not accurately known. Estimates of spring discharge during floods can be made by measuring the discharge of the receiving stream above and below the spring inflow, and using the difference as the estimate.

Spring discharge measurements are given in this report in terms of gallons per day (gpd) or cubic feet per second (cfs). Discharge measurements are routinely made in terms of cfs, then converted to gpd when considered desirable. One cfs is a measure of volume and means one cubic foot of water passing a fixed point in one second. One cfs is equivalent to 646,000 gallons per day (gpd). Thus, to convert measurements in cfs to gpd, one simply multiplies the cfs figure by 646,000. Occasionally discharge measurements are needed in other terms. Conversion factors to other units of volume are:

1 cfs = 449 gallons per minute
646,000 gallons per day
1.98 acre-feet per day
28.3 liters per second

QUALITY OF SPRING WATER

Spring water in the Ozarks is generally of good quality. On the flanks of the Ozarks the mineral content is higher, corresponding in a general way with the higher mineral content exhibited by water from deep wells and streams. Owing to the facility with which water can penetrate the surface in the vicinity of springs, considerably more variation in quality is evident in springs than in deep wells. The relative ease by which contaminants can enter a spring system makes them highly vulnerable to pollution. Many clear, cool, inviting springs in Missouri are polluted and contain high concentrations of fecal coliform. The Missouri Division of Health will not approve spring water for drinking unless it is adequately treated. The effects of urbanization on springs in metropolitan and industrial sections of the state are reflected in the higher mineral content of the spring water. Spring water usually has a uniform temperature. Most springs in Missouri have a temperature about equal to the mean annual temperature of 59°F. Streams fed by large springs generally have dampened daily and annual temperature cycles. The source and significance of dissolved-mineral constituents and properties of water are given in table 3.

Basically two types of water discharge from the springs of the Ozarks. On the Salem Plateau, where the aquifers are dolomite and sandstone, calcium-magnesium bicarbonate water predominates and the chemical characteristics of water from wells and from springs are similar. However, the dissolved-solids content of well waters is generally 25 to 50 percent higher owing to the greater time the water is in storage within the aquifer system. On the Springfield Plateau, springs that issue from the Mississippian limestone are of the calcium bicarbonate type. The relation between chemical quality of well and spring water in this area is similar to that which exists on the Salem Plateau. The spring water is the same type as that from wells in the Mississippian limestone but different from that in the Ordovician and Cambrian dolomitic rocks beneath the limestone.

Springs outside the Ozarks are generally higher in dissolved-solids content and exhibit chemical features characteristic of the areas in which they are located. Springs north of the Missouri River are moderately mineralized (but more mineralized than those of the Ozarks) and they contain considerably more sulfate. However, spring water in northern Missouri, in most instances, is not as mineralized as well water from the same strata.

There is a noteworthy concentration of salt springs in Saline County which gives the Blackwater River a noticeably higher natural mineral content than any other stream in Missouri. The geochemistry and origin of the saline ground waters in that county are described by Carpenter and Miller (1969), and Miller (1971). They conclude that the springs are discharges of connate water mixed with varying amounts of locally derived meteoric water. Saline springs are also known in other areas of the state. Springs having concentrations of several thousand

milligrams per liter (mg/l) dissolved solids are known in Marion, Pike, Jefferson, Perry, Pettis, St. Clair, and Clay Counties.

The dissolved-mineral content of spring water generally increases as the discharge of the spring declines seasonally. Seasonal variations in chemical quality are due to land use in the recharge area of the spring, kind of rock, and the length and character of the conduits through which the water travels to its orifice.

Because most spring systems are relatively shallow in comparison to the depth at which many wells obtain their water, springs are more subject to contamination from the surface and, even though the water may be less mineralized, it may not be as free of contaminants. A recent study of springs and shallow wells on the Springfield Plateau showed that the nitrate content (an indication of suspected pollution) of individual shallow wells may greatly exceed (maximum, 277 mg/l NO_3) that of springs (maximum, 18 mg/l NO_3), but the median value for all springs sampled was double that of all wells sampled. On the basis of one analysis a spring may appear to be of satisfactory bacteriological quality, but it may be unsafe on another day, another time of the year, or in later years.

Concentrations of nitrate that are much greater than the local average may suggest pollution. The source of the nitrate may be decaying organic matter, legume plants, sewage, nitrate fertilizers, nitrates in soil and rock, and deposits of bat droppings in caves. Practically all springs sampled in the Ozarks showed some nitrate content, which is normal. Generally, the content was less than 10 mg/l. However (as shown at right) in certain areas of Missouri the nitrate content of a majority of the springs exceeds 10 mg/l. Rarely does the concentration exceed 45 mg/l.

The Drinking Water Standards (U.S. Public Health Service, 1962b) recommend that the nitrate content not exceed 45 mg/l because there is evidence that higher concentrations may cause methemoglobinemia (blue baby) in infants.

Springs on the Springfield Plateau have abnormally high nitrate concentration. The area, which is drained principally by the White, Sac, Spring, and Osage Rivers, is gently rolling with extensive areas of karst topography. Sinkhole drainage, however, increases the possibility of pollution from surface sources and with dairy farming and stock raising widespread, all the ingredients for pollution are present. This is well demonstrated by the sharp contrast in the occurrence of nitrate in spring water on the Springfield and Salem Plateaus.

Two basins – the Spring River, which drains limestone terrane on the Springfield Plateau, and the Current River, which drains dolomite terrane on the Salem Plateau are considered representative of the two areas of the Ozarks. Spring water from limestone varies more in hardness, nitrate, and total dissolved solids, is generally softer, and has about the same total mineralization as spring water from dolomite.

Basin	No. of Samples	Percent of Samples Having More Than 10 mg/1 NO_3
White River	22	68
Sac River	27	63
Spring River	40	35
Osage River	4	25
Pomme de Terre-Niangua Rivers	20	10
Eleven Point River	24	4
North Fork River	28	4
Gasconade River	72	3
Meramec River	69	3
Black-St. Francis Rivers	31	0
Current River	52	0

Iron content of spring water in the two basins is low and no significant difference was noted. Total iron ranged from 0.0 to 1.5 mg/l with most analyses showing less than 0.10 mg/l. Summaries of some of the chemical characteristics of spring water (in milligrams per liter) in the two basins are given below.

Basins	No. of samples	Hardness (mg/l)			Nitrate (mg/l)			Total dissolved solids (mg/l)		
		Max.	Min.	Median	Max.	Min.	Median	Max.	Min.	Median
Spring River	31	397	92	146	17.0	0.0	8.9	520	123	184
Current River	29	315	129	188	5.8	0.0	0.3	301	136	183

Figure 8

Spring discharge is measured with a current meter and tape line. Drawing by Douglas R. Stark.

Table 3

*SOURCE AND SIGNIFICANCE OF DISSOLVED-MINERAL CONSTITUENTS AND PROPERTIES OF WATER**

Constituent or property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 mg/l High concentrations, as much as 100 mg/l, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high-pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 mg/l of soluble iron in surface waters generally indicates acid wastes from mine drainage or other sources.	More than about 0.3 mg/l stains laundry and utensils reddish brown. Objectionalbe for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. USPHS (1962) **drinking-water standards state that iron should not exceed 0.3 mg/l. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Manganese (Mn)	Dissolved from some rocks and soils. Not so common as iron. Large quantities often associated with high iron content and acid waters.	Same objectionable features as iron. Causes dark brown or black stain. USPHS (1962) drinking-water standards state that manganese should not exceed 0.05 mg/l.
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all rocks and soils, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see Hardness). Waters low in calcium and magnesium desired in electroplating, tanning, and dyeing and in textile manufacturing.
Sodium (Na) and potassium (K).	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers, and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium they cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives a bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. USPHS (1962) drinking-water standards recommend that the sulfate content should not exceed 250 mg/l.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial wastes.	In large amounts in combination with sodium gives salty taste to water. In large quantities increases the corrosiveness of water. USPHS (1962) drinking-water standards recommend that the chloride content not exceed 250 mg/l.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, the amount of water consumed, and the susceptibility of the individual. The maximum concentration of fluoride recommended by the USPHS (1962) varies with the annual average of maximum daily air temperatures and ranges downward from 1.7 mg/l for an average maximum daily temperature of 10.0°C to 0.8 mg/l for an average maximum daily temperature of 32.5°C. Optimum concentrations for these ranges are from 1.2 to 0.7 mg/l.

*Source: Table 3, p. 20, WR 24—WATER RESOURCES OF THE JOPLIN AREA, MISSOURI, 1969.

**"Public Health Service Drinking Water Standards," revised 1962, apply to drinking water and water-supply systems used by carriers and others subject to Federal quarantine regulations.

Table 3 *(continued)*

Constituent or property	Source or cause	Significance
Nitrate (NO_3)	Decaying organic matter,legume plants, sewage, nitrate fertilizers and nitrates in soils.	Concentration much greater than the local average may suggest pollution. USPHS (1962) drinking-water standards suggest a limit of 45 mg/l. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing the intercrystaline cracking of boiler steel. It encourages the growth of algae and other organisms which may cause odor problems in water supplies.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils.	USPHS (1962) drinking-water standards recommend that the dissolved solids should not exceed 500 mg/l. However, 1,000 mg/l is permitted under certain circumstances. Waters containing more than 1,000 mg/l of dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters, nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Waters of hardness up to 60 mg/l are considered soft; 61-120 mg/l moderately hard; 121-180 mg/l hard; more than 180 mg/l very hard.
Specific conductance (micromhos at 25°C).	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. It varies with the concentrations and degree of ionization of the constituents, and with temperature.
Hydrogen-ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 denote increasing acidity. pH is a measure of the activity of hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline water may also attack metals.
Color	Yellow-to-brown color of some water usually is caused by organic matter extracted from leaves, roots, and other organic substances. Color in water also results from industrial wastes and sewage.	Water for domestic and some industrial uses should be free from perceptible color. Color in water is objectionable in food and beverage processing and many manufacturing processes.
Temperature	Climatic conditions, use of water as a cooling agent, industrial pollution.	Affects usefulness of water for many purposes. Most users desire water of uniformly low temperature. Seasonal fluctuations in temperature of surface waters are comparatively large depending on the volume of water.
Suspended sediment	Erosion of land and stream channels. Quantity and particle-size gradation affected by many factors such as form and intensity of precipitation, rate of runoff, stream channel and flow characteristics, vegetal cover, topography, type and characteristics of soils in drainage basin, agricultural practices, and some industrial and mining activities. Largest concentrations and loads occur during periods of storm runoff.	Sediment must generally be removed by flocculation and filtration before water is used by industry or municipalities. Sediment deposits reduce the storage capacity of reservoirs and lakes and clog navigable stream channels and harbors. Particle-size distribution is a factor controlling the density of deposited sediment and is considered in the design of filtration plants. Sediment data are of value in designing river-development projects, in the study of biological conditions and fish propagation, and in programs of soil conservation and watershed management.

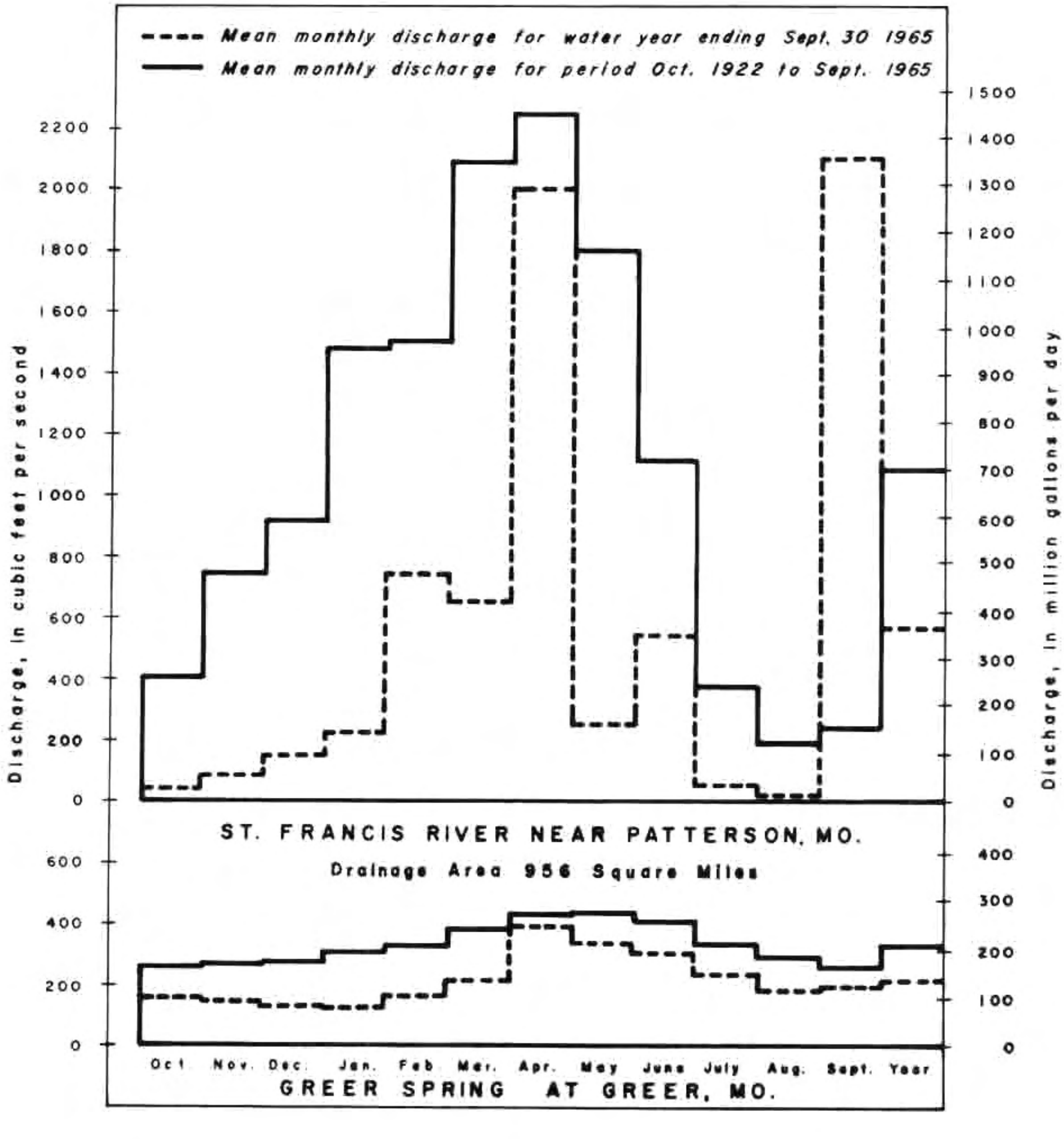


Figure 9

Discharge of Greer Spring at Greer, Mo. compared with that of the St. Francis River near Patterson, Mo.

RELATION OF SPRINGFLOW TO STREAMFLOW

The rate of flow of springs is relatively uniform when compared to that of streams. This can be demonstrated by comparing Greer Spring and the St. Francis River at Patterson (fig. 9). The two stations were selected because the Greer Spring outlet is never inundated by high water from the Eleven Point River and the St. Francis River, in the same general area as Greer Spring, reflects surface runoff conditions from the basin upstream. Records of flow have been collected since 1921 at both Greer Spring and the St. Francis River.

The spring waters of the state have a direct and important effect on the streams into which they flow. Although the spring waters are seldom used, they contribute directly to the value of some streams by providing them with a high sustained base flow. In fact, the base flow of many streams in the Ozarks is almost entirely derived from springs, with some of them having the highest sustained base flows in Missouri.

Just as springflow may increase the flow of a stream, so also a stream may lose water to underground channels only to reappear in springs downstream or in springs in adjacent drainage basins. Among the many examples of stream losses are Logan Creek in the Black River basin, Dry Fork in the Meramec River basin, and a reach on the Gasconade which will be described later.

The temperatures of springs reflect the mean annual air temperature of this area, or about 58°F. The annual temperature cycles of streams receiving spring waters are somewhat dampened and have less range in temperature than streams that are not spring-fed. Because of the constant, cool temperatures of Missouri springs, many were once used as a means of refrigeration for food (fig. 10).

The clear waters of streams of the Ozarks can be attributed to the springs which flow into them. This clear, constantly cool, and sustained flow of water is a natural habitat for many species of cold-water game fish, particularly the trout and small-mouth bass. Much of the plant life found along the spring-fed streams is attributed to spring waters.

During minor flood events the peak discharges of many spring-fed streams are lower than on streams not fed by springs. This is due to the large amount of drainage into sinkholes and the numerous losing tributaries common to spring areas. Though most peak discharges of spring-fed streams are lower, the annual runoff from these streams is generally greater than from streams which are not spring-fed. During periods of record floods spring-fed streams and non-spring-fed streams have similar runoff characteristics.

RELATION OF SPRINGFLOW TO WELL YIELD

In areas where the surface rock formation is the same as the aquifer supplying water to wells, some general correlation may exist between the yields to the wells and springs. Many of the large springs of the Current River valley have their source in the Eminence and Potosi Dolomites. Generally, in southern Missouri, it is the Potosi Dolomite that yields much of the water to the larger capacity municipal and industrial wells. The Jefferson City Dolomite is the source for many springs, but they have much smaller yields. Similarly, wells which obtain their water from the Jefferson City Dolomite usually yield only sufficient water for domestic water supplies.

On the Springfield Plateau, where limestone of Mississippian age is the surface formation and municipal wells are drilled to the Ordovician and Cambrian rocks, there is no correlation between well and spring yields. The correlation in this area is between wells and springs in the Mississippian limestone. While a few springs have large yields, most are small. Similarly, most wells have yields that are only adequate for domestic water supplies, even though a few medium-capacity wells have been drilled. It is anticipated that wells drilled into solution channels could supply water in volumes commensurate with spring yields.

USE OF SPRING WATER

The springs of Missouri have figured importantly in the history and development of the state as indicated by the fact that 62 towns contain the word "spring" in their names. Three overlapping periods in Missouri's development can be distinguished in the use of spring water. In pioneer days, springs served as a source of water for people and stock as they moved westward and, perhaps more importantly, certain springs served as sources of salt when availability of salt depended on local manufacture at the salt springs. Salt is no longer obtained commercially from saline springs in Missouri.

After this earliest use of water, the larger fresh-water springs became important as a source of power

Figure 10

Missouri has thousands of tiny springs that were once widely used as a means of refrigeration for rural families. Practically everyone had a springhouse where cream, meat, vegetables, and other products were stored. This small spring flows from beneath one of the state's few remaining log springhouses. Photo by Jerry D. Vineyard.

for grist mills and other manufacturing as well as for mining establishments in rural Missouri. Within the past two decades most of the grist mills have ceased operation and today only three are still in business.

After the decline in the importance of saline springs as a source of salt, they gained importance because of the medicinal qualities of their water. This was the era of the great spas when large hotels, pools, and bath houses (fig. 11) were built at many of the mineral springs (Schweitzer, 1892). The only spa of importance remaining in Missouri today is Excelsior Springs, 20 miles northeast of Kansas City, where people still come in anticipation of the beneficial effects of spring water.

With the increase in recreational and commercial fishing, trout and bait hatcheries have been increasing production and facilities. Resorts have been built, not for the medicinal qualities of the mineral waters, but to afford recreation to trout fishermen. Many impoundments have been built in the Ozarks to utilize the high sustained flow of the streams for hydroelectric power and water-based recreation.

The principal use of spring water at the source is for rearing trout and other game fish, and bait. Owing to the uniform temperature and good quality of the water, springs are ideal for both sport fishing and commercial fisheries. Information on some of the fish-rearing establishments open to the public and details on the springflow are given in table 4; figure 12 shows the location of these springs. It is estimated from a recent study that about 100 million gallons of water a day are used at the hatcheries and fishing facilities. This quantity does not include the total springflow at the largest hatcheries, but represents

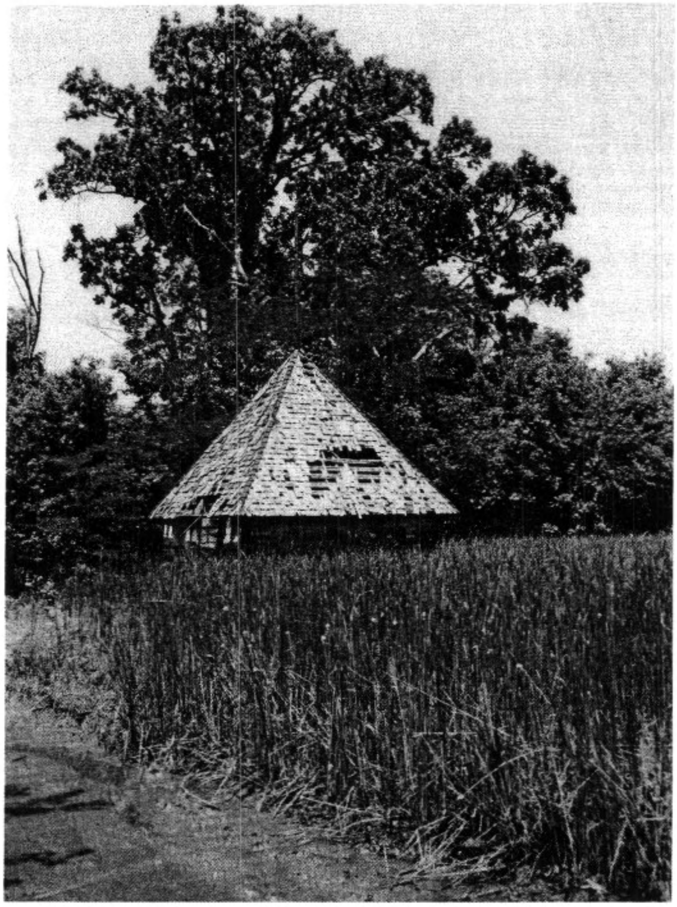


Figure 11

This small "gazebo" in Saline County is one of the few remaining signs that the waters of mineralized springs were once widely used for medicinal purposes. Photo by Jerry D. Vineyard.

only 5 to 30 percent of individual flows of some of the larger springs.

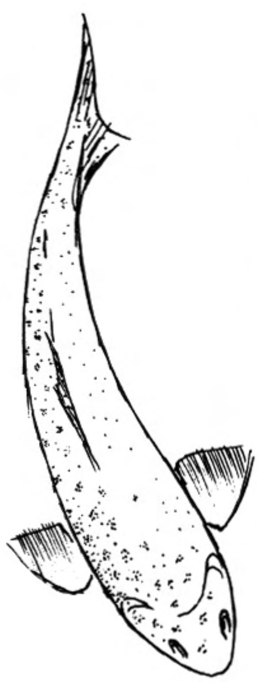
Today, the town of Mill Spring in Wayne County is the only community in Missouri solely dependent on a spring for its water supply. Arcadia in Iron County and Springfield in Greene County have springs incorporated in their water-supply systems which are drawn on intermittently or which supplement water from other sources. However, springs did determine the locations of numerous towns in the days when Missouri was first being settled. Rich Fountain, a small town in Osage County, grew around a small spring which today is used only for watering stock. Generally there was a grist mill at the larger springs with the spring serving as a water supply and a source of power. Meramec Spring in Phelps County provided the water and power supply for the first successful iron works west of the Mississippi River, established in 1829 (Norris, 1964). Scotland Spring in Jasper County is today an important source of water for the complex of chemical industries located east of Joplin.

An important use of the springs of Missouri is stock water. Many cattle ranches in the Ozarks have one or more springs that serve as a water supply for stock and, when dammed and stocked with trout, also serve as private fishing lakes.

Table 4

REPRESENTATIVE WATER DEMAND FOR SPRINGS USED IN THE FISHING INDUSTRY OF MISSOURI

COUNTY	OWNERSHIP	NAME OF SPRING OR SPRINGS	DEMAND OR SPRINGFLOW (million gallons per day)
Barry	Private	Crystal	5 – 11
Barry	State of Missouri	Roaring River	6 – 8
Camden	"	Wet Glaize	5 – 8
Christian	"	Montague	2
Crawford	"	McDade	1
Crawford	"	Westover	7
Dallas	"	Bennett	19 – 25
Dent	"	Montauk	5 – 6
Douglas	Private	Bryant	0.5 – 1
Douglas	"	Crystal	7 – 10
Iron	"	Speer	0.75
Lawrence	State of Missouri	Chesapeake	1 – 2
Lawrence	Private	Spring River	3
Morgan	"	Gravois Mills	3
Newton	U.S. Government	Hearrell, Elm, Bartholic, and McMahon	3
Newton	Private	Ozark Trout Farm	1
Ozark	"	Rockbridge and Morris	7 – 15
Phelps	"	Maramec	2 – 4
Phelps	"	Yancy Mills	0.5 – 2
Stone	"	Brown	6 – 7



Springs are ideal for commercial and sport fisheries.

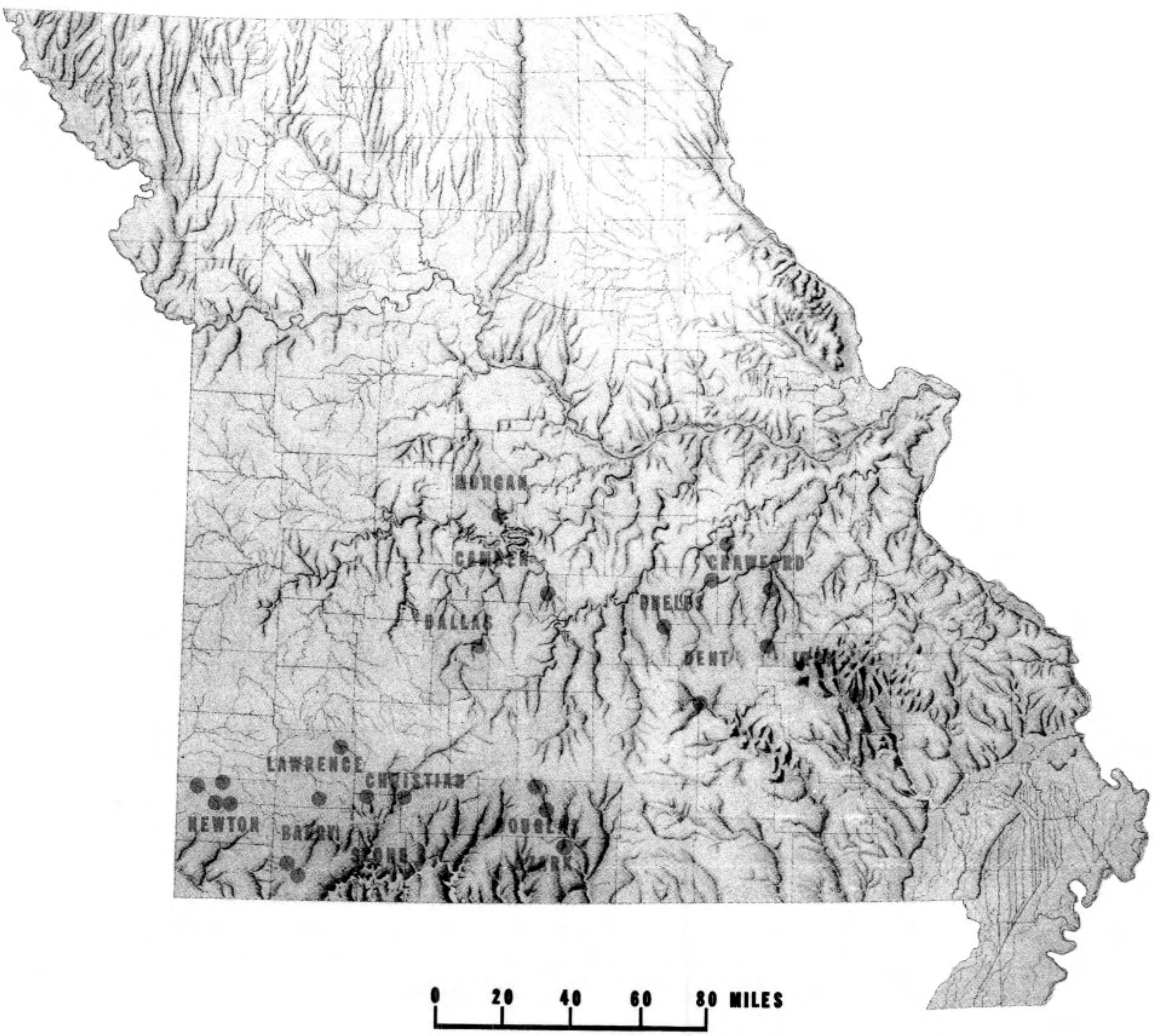


Figure 12

A number of springs in Missouri are used for fish hatcheries and rearing ponds. Locations of these springs are noted here.

SUMMARY

The importance of springs to the future of Missouri lies in their fairly uniform mineral content, generally low suspended-solids content, uniform cool temperature (56° to 59°F), attractive settings, and large quantities of water available. The chief drawback to their widespread use at the source is the inaccessibility of many of them.

Studies made in other states have shown that springs can provide adequate and reliable water supplies of good quality for municipal and industrial uses (Gurnee and others, 1961; Sun and others, 1963). The use of springs as water supplies must be accompanied by adequate water-treatment facilities and delineation and protection of the spring recharge areas to minimize pollution hazards. A spring flowing 1 cubic foot per second (cfs) can supply a city of 6,500 population, assuming average per capita water use of 100 gallons per day (gpd). Missouri has 165 known springs that have minimum flows of 1 cfs (646,000 gpd) or more.

The absence of surface flow in a stream valley does not indicate that springs of considerable magnitude may not exist upstream. Some springs discharge and flow in the spring branch or stream valley for a short distance only to disappear into the ground at faults, in subterranean cavities in the carbonate rocks, or into the coarse gravel fill of an alluviated valley.

Photo (right) — *A trout fisherman "tries his luck" at Bennett Spring near Lebanon, Mo. Numerous large trout can be seen in the clear waters of the spring. The submerged entrance to the large, water-filled cave from which the spring flows can also be seen in front of the fisherman. Catching-size trout are regularly stocked in several large springs by the Missouri Department of Conservation.*

Photo by Jerry D. Vineyard.

FAUNA
OF
MISSOURI SPRINGS

BY WILLIAM L. PFLIEGER

INTRODUCTION

To the casual observer, a clear spring in the Missouri Ozarks may appear to be largely devoid of animal life. But this is an illusion, resulting because the common animals of the spring community are, for the most part, small and secretive. Though the fauna of springs is not diverse in comparison with flowing waters generally, the species present are sometimes almost unbelievably abundant. Densities exceeding several hundred individuals per square foot are not uncommon for certain invertebrates. Flatworms, amphipods, isopods, snails, and certain insects are the dominant invertebrates; fish and salamanders are the principal vertebrates. Few of the species characteristic of Missouri springs make much of a showing in other aquatic habitats and, consequently, the spring fauna presents a very distinctive aspect.

The spring environment is characterized by great stability in certain factors. Of these, temperature seems to be most important in limiting the distribution of animals that comprise the spring fauna. Because the water of a typical Missouri spring at its source is near 58°F. year-around, such a spring is much cooler during summer than other natural waters. As the spring flows away from the point where it issues from the ground, it comes more and more under the influence of the prevailing air temperature, and ultimately acquires a temperature differing little from that of nearby warm-water streams. The distance involved in achieving this change varies depending on factors such as the volume of flow, the shape of the spring branch channel, and the degree of shading by streamside vegetation. Many Missouri springs join a warm-water stream long before equilibrium with the air temperature is reached and, as a result, the change in temperature is abrupt. Some springs are so large that they have a profound effect on the temperature regimen of the streams they feed.

Detailed information is lacking concerning the temperature requirements of most animals in the Missouri spring fauna. However, cold-spring inhabitants in general are known to have narrow limits of tolerance for this factor and do not thrive where temperatures go much above 70°F. Temperature tolerances of this sort probably account for restriction of the fauna typical of Missouri springs to a rather narrow zone below the spring source. Downstream, this fauna becomes more diverse, consisting of species with broader temperature tolerances and a more general distribution in flowing waters. Streams that receive one or more large springs may remain cool enough to support a typical spring fauna for many miles.

Salamanders are commonly found in springs.

The fauna of Missouri springs is augmented at the spring source by species otherwise known only from subterranean waters. These species are members of the same taxonomic groups that are dominant in the surface waters of springs. Subterranean species all exhibit more or less similar adaptations for subterranean life, even though they belong to widely divergent taxonomic groups. Most notable among these adaptations are an overall whitish or translucent color, reflecting the absence of pigment, and the reduction or loss of eyes. Some species from surface springs occur as self-sustaining populations in subterranean waters, even though they exhibit no special adaptations for life in that habitat. A few species, such as the snail *Amnicola aldrichi*, occur in typical form in the surface waters of springs but are represented by a blind, white form in subterranean waters. Since subterranean species are such a persistent element in the fauna of Missouri springs, and no clear line of demarcation exists between the fauna of Missouri springs and that of their subterranean sources, both are treated in this report.

With respect to general distribution, the Missouri spring fauna exhibits a high degree of endemism. No less than 38 species from springs and subterranean waters are restricted to the Ozark region of Missouri and adjacent states. Some are known from only a single spring or cave stream. The distribution of most wide-ranging species extends northeastward from Missouri. Of special interest are northern animals having populations in the Ozarks that are broadly disjunct from the main body of the species range. These disjunct Ozark populations have been interpreted as glacial relicts. According to this interpretation, occurrence in the Ozarks dates from one of the Pleistocene ice advances, when a cooler and moister climate favored southward dispersal across regions where the species cannot now survive. Persistence of the relict populations in the Ozarks is favored by the numerous cool springs which provide conditions like those of northern waters. Ozark glacial relicts among insects and fishes have been cited and discussed by Ross (1965) and Pflieger (1971).

The fauna of Missouri springs is not well known. To date, no detailed survey has been made of the fauna of even a single spring. Lists of invertebrates have been provided for a few large Ozark springs (Clifford, 1966; Missouri Water Pollution Board, 1964), but these are useful only in a general way, because identifications were not carried to the species level in most groups. Useful compilations of species from subterranean waters have been provided by Nicholas (1960) for the United States and by Hubricht (1950) for the Ozark region. Occasional references to species from Missouri springs are scattered through the taxonomic literature of various animal groups.

ACKNOWLEDGMENTS

The following individuals provided information or suggestions that were incorporated in this section of this report: Carl C. Childers, William J. Clench, John R. Holsinger, Leslie Hubricht, William E. Ricker, and Herbert H. Ross.

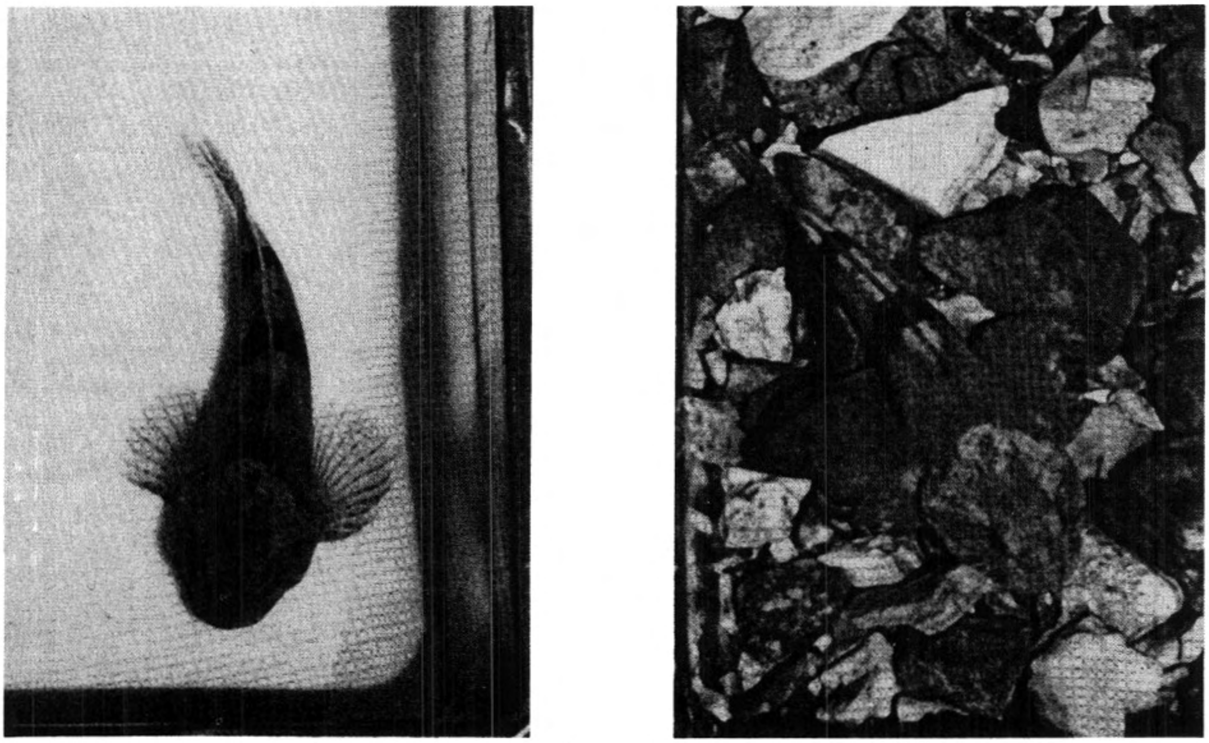


Figure 13

Some creatures that live in springs, such as the sculpin pictured above, are remarkably adapted to their environment. The same fish is shown first against a white background (left, above), and then against a background of the typical chert gravel found in springs. Photos by Jerry D. Vineyard.

ANNOTATED LIST OF SPECIES

The following is a list of some of the animals known to be in Missouri springs and their subterranean sources. It is based largely on a review of the pertinent literature and includes 69 species. Only those that are especially characteristic of spring habitats are listed. Species of more general distribution that have been incidentally reported from these habitats are not included. Since Missouri springs have received little study, future investigations will doubtless reveal additional species. For each animal listed, an indication of its habitat and distribution is given along with the authority for including it on the list.

FREE-LIVING FLATWORMS (TURBELLARIA)

Flatworms are among the most common and characteristic invertebrates in cold-spring habitats. Of the five species listed below, three are widely distributed in surface springs of the eastern United States; two are subterranean forms with very limited distributions.

Dugesia doratocephala **(Woodworth).** This wide-ranging flatworm may occur in springs and spring-fed streams throughout the Ozarks, but the only published report is for Valle Spring, Ste. Genevieve County (Kenk, 1970).

Macrocotyla glandulosa **Hyman.** This flatworm has been placed in a distinct genus, known only from one locality – the cave stream at Rock Bridge, Rock Bridge State Park, Boone County (Hyman, 1956).

Phagocata gracilis **(Haldeman).** A wide-ranging flatworm that has been reported in caves and springs of the eastern Ozarks (Kenk, 1970).

Phagocata veleta **(Stringer).** Missouri is within the range of this flatworm, but there are no published records. Springs and spring-fed waters are its preferred habitat (Hyman, 1951).

Speophyla hubrichti **Hyman.** A cave-adapted flatworm, known only from cave streams and springs of eastern Missouri and adjacent Illinois (Hyman, 1951).

CRUSTACEA

Three groups of crustaceans commonly occur in Missouri springs: amphipods, isopods, and crayfish. Amphipods are very abundant in many springs. The principal species in surface waters are *Crangonyx forbesi, Gammarus minus, G. pseudolimnaeus,* and *G. troglophilus.* These species are also known from cave streams. Ten species of blind, white amphipods have been reported from subterranean waters as well as the outlets of springs. Six species of isopods are known from Missouri springs. The common species are *Asellus brevicauda, Lirceus garmani,* and *Lirceus hoppinae.* Crayfish are not well represented in springs. Two blind, white species are restricted to the subterranean waters of southern Missouri. Other stream-dwelling crayfish occur occasionally in springs and cave streams, but none are especially characteristic of those habitats.

The crustaceans of Missouri springs are rather well known compared to other invertebrate groups. Williams (1954) presented a comprehensive review of Ozark crayfish, and Holsinger (1972) recently published a guide to North American amphipods that treats all species presently known from Missouri.

AMPHIPODS

Allocrangonyx hubrichti **Holsinger.** Presently known only from two cave streams in Phelps and Pulaski Counties (Holsinger, 1971).

Apocrangonyx subtilis **Hubricht.** This blind, white amphipod is known from cave streams and spring seeps of eastern Missouri and adjacent Illinois (Holsinger, 1969).

Bacturus brachycaudus **Hubricht and Mackin.** Known from numerous cave streams and spring seeps of eastern Missouri and adjacent Illinois (Hubricht, 1943).

Bacturus muacronatus **(Forbes).** Reported from spring seeps and caves in the southern Ozarks (Hubricht, 1943).

Crangonyx forbesi **(Hubricht and Mackin).** This is one of the commonest amphipods in springs and cave streams of east-central Missouri. A closely related form that is still technically undescribed occupies similar habitats in the central and southwestern Ozarks (Holsinger, 1972).

Gammarus minus **Say.** A common species in springs and cave streams of the eastern and southern Ozarks (Cole, 1970; Holsinger, 1972).

Gammarus pseudolimnaeus **Bousfield.** Common and widely distributed in springs and cave streams of the Ozarks (Holsinger, 1972).

Gammarus troglophilus **Hubricht and Mackin.** Common in springs and cave streams of counties bordering the Mississippi River in Missouri and Illinois (Hubricht, 1943; Holsinger, 1972).

Stygobromus heteropodus **Hubricht.** Known only from the type locality: Pickle Springs, Ste. Genevieve County (Hubricht, 1943).

Stygobromus onondagaensis **(Hubricht and Mackin).** Known authentically from cave streams and pools and a few surface seeps in south-central Missouri (Holsinger, 1972).

Stygonectes alabamensis alabamensis **(Stout).** This wide-ranging amphipod occurs in spring seeps and cave streams of the central and southern Ozarks (Holsinger, 1967).

Stygonectes barri **Holsinger.** Reported only from spring seeps and a small creek in the southeastern Ozarks of Missouri (Holsinger, 1967).

Stygonectes clantoni **(Creaser).** Known from springs, wells, and cave streams of west-central Missouri and Kansas (Holsinger, 1967).

Stygonectes ozarkensis **Holsinger.** Restricted to spring seeps and caves of the southwestern Ozarks (Holsinger, 1967).

ISOPODS

Asellus antricolus **(Creaser).** Known from cave streams of southern Missouri and northern Arkansas (Steeves, 1966).

Asellus brevicauda brevicauda **Forbes.** This wide-ranging isopod occurs in springs, spring-fed streams, and occasionally in cave streams of east-central Missouri (Mackin and Hubricht, 1938; Williams, 1970).

Asellus dimorpha **(Mackin and Hubricht).** Known only from two localities: a spring seep in Wayne County, Missouri, and a spring in Jackson County, Arkansas (Mackin and Hubricht, 1940).

Lirceus garmani **Hubricht and Mackin.** An inhabitant of springs and intermittent streams of the western Ozarks (Hubricht and Mackin, 1949).

Lirceus hoppinae **(Faxon).** Two subspecies are recognized from springs and cave streams of the central and southwestern Ozarks (Hubricht and Mackin, 1949).

Lirceus megapodus **Hubricht and Mackin.** Known only from a few springs in the St. Francois Mountains of southeastern Missouri (Hubricht and Mackin, 1949).

CRAYFISH

Cambarus hubrichti **Hobbs.** This blind, white crayfish is known from cave streams of the upper Eleven Point and Current stream systems (Hobbs and Barr, 1960), and from Maramec Spring, Phelps County. See figure 14, page 32 (specimen identified by Dr. H.H. Hobbs, Jr.).

Cambarus setosus **Faxon.** Another blind, white crayfish, known only from subterranean waters of southwestern Missouri (Hobbs and Barr, 1960).

INSECTS

Insects are less numerous in springs than in other aquatic habitats of Missouri. However, the aquatic insects of Missouri springs are not well known, and the following list is far from complete. Caddisflies are better represented in the spring habitat than other insect groups. Beetles commonly occur in springs, but I have seen no published reports of the species.

CADDISFLIES

Agepetus artesus **Ross.** Known only from Greer Spring, Oregon County (Ross, 1938).

Glossosoma intermedium **(Klapalek).** This northern caddisfly occurs as a glacial relict in spring-fed streams of the Missouri Ozarks (Ross, 1965).

Glyphopsyche missouri **Ross.** Restricted to spring-fed streams of the Missouri Ozarks (Ross, 1965).

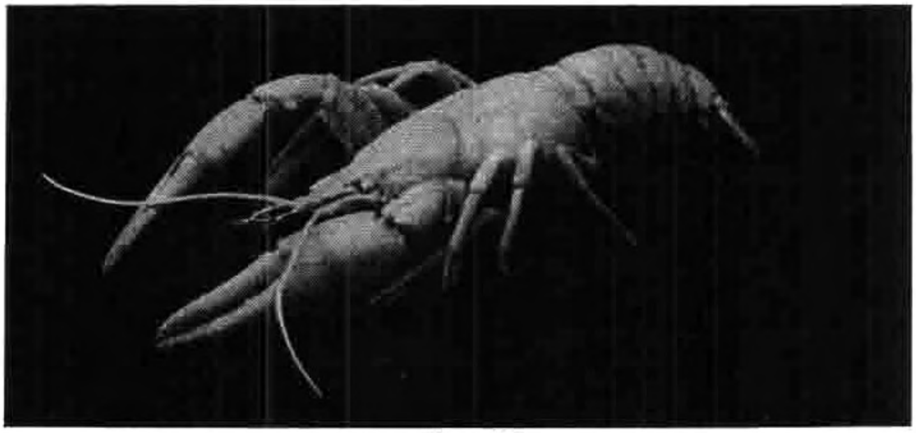


Figure 14

Blind, white crayfish that live in the darkness of spring supply systems occassionally venture into the twilight of spring rise basins. They are so rare that few people are aware of their existence. The specimen pictured (Cambarus hubrichti Hobbs) is from Maramec Spring near St. James. Photo by Henry M. Groves.

Hydropsyche piatrix **Ross.** Mouths of large springs in Missouri and Arkansas (Ross, 1944).

Microsema ozarkana **Ross and Unzicker.** Large springs of southern Missouri and northern Arkansas (Ross and Unzicker, 1965).

Ochrotrichia contorta **(Ross).** Described from specimens collected at Greer Spring, Oregon County (Ross, 1941).

Pycnopsyche subfasciata **(Say).** A northern species, occurring as a glacial relict in spring-fed streams of the Missouri Ozarks (Ross, 1965).

Setodes vernalia **Banks.** This northern caddisfly occurs as a glacial relict in spring-fed streams of the Missouri Ozarks (Ross, 1965).

MAYFLIES

Baetisca obesa **(Say).** Recorded in the Meramec basin only from one station on the Meramec River, where its presence was attributed to cool inflow from Maramec Spring (Missouri Water Pollution Board, 1964).

Ephemerella invaria **(Walker).** Recorded in the Meramec basin only from one station on the Meramec River, where its presence was attributed to cool inflow from Maramec Spring (Missouri Water Pollution Board, 1964).

STONEFLIES

Allocapnia pygmaea **(Burmeister).** A northern species, occurring as a glacial relict in spring-fed streams of the Missouri Ozarks (Ross, 1965).

TRUE FLIES

Culicoides variipennis australis **Wirth.** Larvae of this insect are the dominant animal macro-organism in Booneslick Salt Spring, Howard County, where larval concentrations sometimes exceed 20,000 per square foot (Childers and Wingo, 1968).

SNAILS (GASTROPODA)

Snails are exceedingly abundant in many springs, especially those with rocky substrata or abundant submergent vegetation. ***Goniobasis potosiensis*** is the most common and widespread species.

Amnicola stygia **Hubricht.** Known only from the type locality: Tom Moore Cave in Perry County (Hubricht, 1971).

Antrobia culveri **Hubricht.** Known only from the type locality: Tumbling Creek Cave in Taney County (Hubricht, 1971).

Fontigens aldrichi **(Call and Beecher).** Present in springs and cave streams of the eastern Ozarks. Specimens from springs are pigmented and have well developed eyes, whereas those from caves are unpigmented and blind (Hubricht, 1940).

Fontigens antrocoetes **(Hubricht).** A blind, unpigmented snail, known from only three caves of the eastern Ozarks (Hubricht, personal communication).

Fontigens proserpina **(Hubricht).** Present in cave streams of counties bordering the Mississippi River (Hubricht, 1940).

Goniobasis potosiensis **Lea.** Common and widespread in rocky streams and spring branches of the Ozarks.

Physa remingtoni **Clench.** Reported from Round Spring, Shannon County (Clench, 1930).

SALAMANDERS AND FROGS

Six species of salamanders inhabit springs and underground streams in Missouri. The grotto salamander is one of the more interesting members of this group. Larvae and adults of this species exhibit a marked contrast in appearance and habit. The larvae, which are most often found in springs and spring-fed streams, are darkly pigmented and have well developed, functional eyes. Adults are unpigmented and have eyes that show only as dark spots beneath fused or partially fused lids. As might be surmised from these adaptations, the adults are restricted to subterranean waters.

The only frog that is at all common in Missouri springs and caves is the pickerel frog. Tadpoles of some other species occur occasionally in spring branches, but are less abundant there than in other habitats.

The following list of amphibians was compiled largely from Wiley (1968).

Cryptobranchus alleghenienisis bishopi **Grobman, Ozark hellbender.** This large salamander is endemic to spring-fed streams of the southern Ozarks.

Eurycea longicauda melanopleura **Cope, dark-sided salamander.** This subspecies is widespread in the Ozarks, intergrading with ***E. 1. longicauda*** Green in eastern Missouri. Typically an inhabitant of the twilight zone of caves, it also occurs in spring brooks (Mittleman, 1950).

Eurycea lucifuga **Rafinesque, cave salamander.** A widespread salamander in spring-fed streams and the twilight zone of moist Ozark caves (Mittleman, 1950).

Eurycea multiplicata griseogaster **Moore and Hughes, gray-bellied salamander.** An inhabitant of spring branches and cave streams of the southwestern Ozarks.

Eurycea tynerensis **Moore and Hughes, Oklahoma salamander.** Reported from seeps, springs and spring-fed streams of the southwestern Ozarks.

Typhlotriton spelaeus **Stejneger, grotto salamander.** Larvae of this salamander are typically found in springs and spring-fed creeks, while adults are restricted to subterranean waters. Endemic to the southern Ozarks.

Rana palustris **Le Conte, pickerel frog.** In the Ozarks this frog is most often found near spring branches and in the twilight zone of caves.

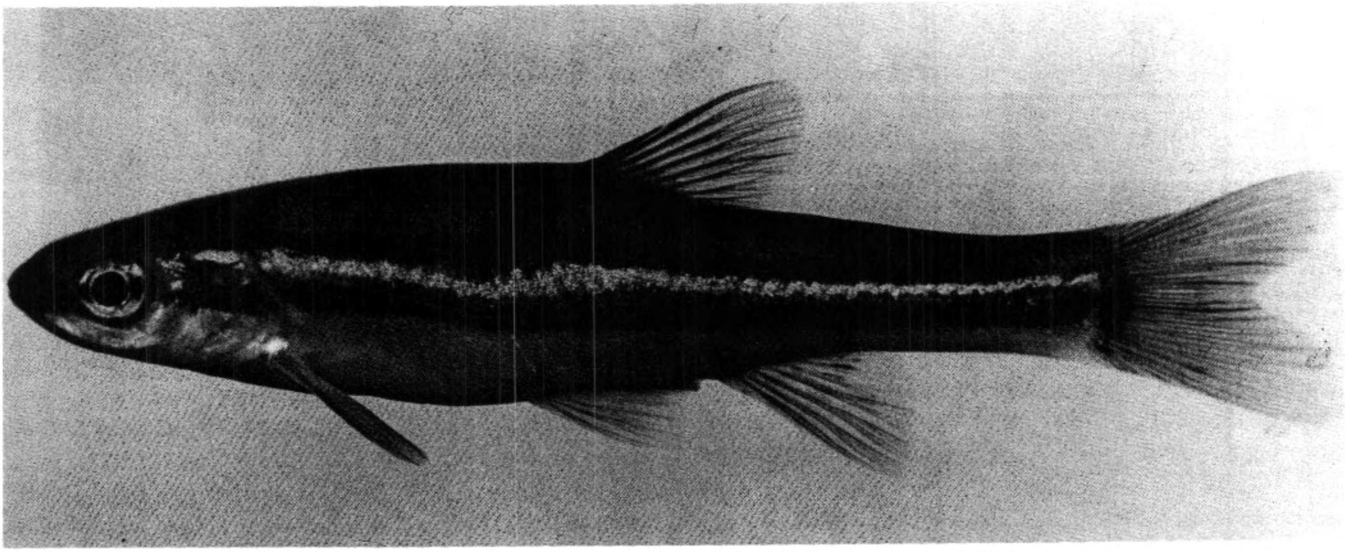


Figure 15

The southern redbelly-dace (Phoxinus erythrogaster), here shown about three times life size, is a species that is common in spring habitats. This one came from Miller County. Photo by James R. Whitley.

FISHES

The fish fauna of Missouri springs and subterranean waters is quite limited. The two most characteristic and widespread species in springs and spring-fed streams are the mottled sculpin and banded sculpin. Other common species in spring habitats are the redbelly dace (fig. 15), creek chub, white sucker, and stippled darter. The goldstripe darter, known only from a small spring in Butler County, has the most restricted distribution of any Missouri fish. Two species of amblyopsid cavefishes occur in subterranean waters of the Ozarks.

Certain fish that are not especially characteristic of the spring habitat at other times of the year utilize large Ozark springs as wintering areas. A notable example is the rock bass, which forms large aggregations in deep springs such as Cave Spring on Current River.

Species in the following list have been treated in greater detail elsewhere (Pflieger, 1971).

LAMPREYS *(Petromyzontidae)*

Lampetra aepyptera **(Abbot), least brook lamprey.** This small lamprey is locally common in springs of the eastern Ozarks.

TROUTS (Salmonidae)

Salmo gairdneri **Richardson, rainbow trout.** This trout is not native to Missouri, but has been widely stocked in spring branches and cool, spring-fed streams. Few self-sustaining populations have been established.

MINNOWS (Cyprinidae)

Phoxinus erythrogaster **(Rafinesque), southern redbelly dace.** One of the most common and generally distributed fishes in Ozark springs and spring-fed creeks.

Semotilus atromaculatus **(Mitchell), creek chub.** The creek chub occurs in a variety of habitats, but in the Ozarks is restricted primarily to springs and spring-fed creeks.

SUCKERS (Catostomidae)

Catostomus commersoni **(Lacepede), white sucker.** This species is a common associate of the creek chub, and exhibits a similar distribution.

CAVEFISHES (Amblyopsidae)

Amblyopsis rosae **(Elgenmann), Ozark cavefish.** The Ozark cavefish is endemic to subterranean waters of the southwestern Ozarks.

Typhlichthys subterraneus **Girard, southern cavefish.** Restricted to subterranean waters of the central and southeastern Ozarks.

KILLIFISHES (Cyprinodontidae)

***Fundulus sciadicus* Cope, plains topminnow.** A common species in clear, heavily vegetated spring pools of the central and southwestern Ozarks.

***Fundulus kansae* Garman, plains killifish.** The most abundant fish in Salt Creek and Booneslick Salt Spring, Howard County. Typically an inhabitant of saline or alkaline waters.

PERCHES (Percidae)

***Etheostoma cragini* Gilbert, Arkansas darter.** Restricted in Missouri to springs and small, spring-fed creeks of the southwestern Ozarks.

***Etheostoma microperca* Jordan and Gilbert, least darter.** A very abundant darter in vegetated spring pools and spring seeps of the northern and western Ozarks.

***Etheostoma parvipinne* Gilbert and Swain, goldstripe darter.** Known in Missouri only from a small spring in Butler County.

***Etheostoma punctulatum* (Agassiz), stippled darter.** A common darter in springs and spring-fed creeks of the northern and western Ozarks.

SCULPINS (Cottidae)

***Cottus bairdi* Girard, mottled sculpin.** One of the most common and widely distributed fishes in Ozark springs and spring-fed streams.

***Cottus carolinae* (Gill) banded sculpin.** This sculpin is similar in distribution to the mottled sculpin, but is less restricted to spring-fed waters.

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FLORA OF MISSOURI OZARK SPRINGS

Water cress (right foreground) is common in many of Missouri's springs, particularly in the smaller ones. Years ago before refrigeration, small "springhouses" such as this were frequently built over springs and used for cold storage of perishables. Thus, the cool, constant temperature of spring water that encourages growth of water cress and other aquatic plants was put to practical use. Photo by Jerry D. Vineyard.

BY ROBERT G. LIPSCOMB

Figure 16

Missouri springs, such as Greer Spring in Oregon County, have long been noted for their distinctive vegetation and beauty. Photo by Gerald Massie, Division of Commerce & Industrial Development.

INTRODUCTION

One of the striking features of the springs in southern Missouri is their distinctive aquatic vegetation. These springs have long been known for their beauty which, no doubt, has been greatly enhanced by the plant life they contain. The esthetic value of such springs for sources of recreation has increased rapidly within recent years.

Water temperature is an important factor in the habitat of plants found in the springs. The water of the springs averages about 58°F., much cooler than that of the rivers and streams in the area. Growing in this cooler water are a limited number of species of plants that are rarely found outside of the spring environment. These species do exist in nearby streams, but are found only within the influences of incoming springflow and are, therefore, an index to that occurrence. Distribution within the springs is mostly influenced by such factors as depth of water, velocity of current, and the type of substratum. The springs are so consistently and remarkably clear that the effects of light and turbidity can be considered negligible.

SPERMATOPHYTES

The vegetation of the springs which is so distinctive has been extensively investigated by Steyermark (1941). He studied those seed-producing species or flowering plants (the phanerogams of the time – the more popular term used today is spermatophytes) found growing in the waters of the largest of the springs or in their branches.

Of the 60 species listed by Steyermark, 16 were common to most of the springs. Of those, the three commonly found were water milfoil *(Myriophyllum heterophyllum* Michx.), water cress *(Nasturtium officinale* var. *officinale*, formerly *Rorippa Nasturtium – aquaticum* (L.) Schinz and Thell.), and water starwort *(Callitriche heterophylla* Pursh amend. Darby var. *heterophylla*, formerly *Callitriche heterophylla* Pursh).

Water cress is the species most frequently observed in these springs (fig. 17). It must not be assumed, however, that it is also the dominant species in the flora. It is recorded as dominant in Alley Spring, but most often its occurrence in large springs is minimized by the abundance of the next most frequently occurring species, water milfoil, water starwort, and waterweed *(Anacharis Nuttallii* Planch., formerly *Anacharis occidentalis* (Pursh) Victorian). Water cress appears to be better suited to shallow water, a gravelly substratum, and a rather medium-flowing current, conditions which prevail in smaller springs and in spring branches. One would expect, therefore, to find it to be the dominant and common species of the many smaller springs. It usually grows in colonies or mats of several plants.

Water milfoil is typically a deep, quiet-water plant which grows in colonies or beds of numerous plants, and does best on a substratum of mud, sand, and gravel mixture. Water starwort grows best as a solitary plant in water which has a gentle current and a muddy substratum. Characteristically, it will be found in the cold water of the springs, but it may also be found in the water of ponds and streams which have been warmed appreciably by late summer. It is one of the few species found in springs which is tolerant of a wide range of temperature.

Figure 17

Water cress (Nasturtium officinale) was formerly gathered from the wild but is now cultivated as a commercial crop. It requires a carefully selected site and a supply of clear, uncontaminated water. Line drawing by Phillip Streamer.

**Names preceding former names after Steyermark (1962).

GEOGRAPHIC DISTRIBUTION OF SPECIES

A number of species inhabiting the springs are rarely found outside of cool water. The distribution of those species in Missouri is limited generally to the Ozark region. While they do not appear elsewhere in the state many of them do have a rather wide geographic distribution with ranges in the eastern and northeastern parts of the United States and southeastern Canada.

They include shining pondweed *(Potamogeton illinoensis* Morong., formerly *Potamogeton lucens* L.), large-leaved pondweed *(Potamogeton amplifolius* Tuckerm.), waterweed, water cress, and water speedwell *(Veronica comosa* Richter, formerly *Veronica connata* Raf.). Two of the species, bur–reed *(Sparganium americanum* Nutt.) and water milfoil, have ranges which extend generally east of the 100th meridian. The final species listed, spring cress *(Cardamine bulbosa* f. *fontinalis* Palmer & Steyerm., formerly *Cardamine bulbosa* (Schreb.) BSP., f. *fontinalis* Palmer & Steyermark), is known only in Missouri.

Most of the species which are common to the springs, but which are not limited to them, have a general distribution within Missouri. They, too, have a rather wide geographic distribution with ranges extending generally throughout the United States. Included in this group is one of the three species most commonly found in the springs, water starwort, which has its range predominantly in the East.

Some species found in the springs have a very limited distribution in Missouri. A good example is the rare star duckweed *(Lemna trisulca* L.) or ivy-leaved duckweed as it is sometimes called. Its range is more northerly.

BRYOPHYTES

The mosses and liverworts are somewhat less conspicuous in the springs than are the spermatophytes. They will be observed growing mostly in mats attached to submerged or partly submerged rocks and boulders in swiftly flowing water in and around the edges of spring pools. The most commonly found species capable of withstanding this rigorous habitat is one of the mosses, *Fissidens debilis* Schw. (formerly *Fissidens julianus* (Mont.) Schimp.), which quite often grows in association with *Marchantia*, a liverwort. *Fontinalis*, another moss of swiftly flowing water, is found on limestone outcrops.

Steyermark recorded the existence of these and other species of nonflowering plants whenever they were unusually abundant or were in close association with species of spermatophytes. In shallow, quiet water, and particularly along the edges of such water, he sometimes found mosses and liverworts growing attached to submerged rocks and mud substrata amidst an association of flowering plants which were also present. These species included a moss, ***Drepanocladus aduncus*** (Hedw.) Warnst., and two liverworts, *Porella pinnata* L., and *Riccia fluitans* L. On occasion he also encountered *Ricciocarpus natans* (L.) Corda, the purple-fringed liverwort which floats and resembles duckweed.

ALGAE

Algae are plants which lack true roots, stems, and leaves and include the smallest of the chlorophyll-bearing organisms consisting of but a single cell as well as multicelled organisms ranging in size up to several hundreds of feet in length in the marine environment.

Steyermark noted the presence of the following three forms in the springs which range in size well within these two extremes. *Batrachospermum* is a red alga (the genus belongs to the Rhodophyta) which may be easily observed with the unaided eye. The most common species are found attached as individual plants or in large patches over stones in flowing water. The plants will not appear red but gray-green or blue-green, or sometimes olive in color, and are slimy to the touch.

Nitella and *Chara* are green algae (these genera belong to the Chlorophyta) which are also clearly visible to the unaided eye. They occur most frequently in slow-flowing or quiet water. Species of *Nitella* usually grow in deeper water than *Chara*, and often have a glistening or translucent appearance.

Species of *Chara* resemble *Nitella* structurally, but the stem-like and leaf-like structures of plants may be encrusted with lime giving them a coarse appearance, thus giving rise to the common name of "stonewort."

The presence of filamentous green and blue-green (Cyanophyta) algae in springs is shown by the appearance of a filmy or slime-like growth attached to other aquatic plants and objects in the water. Species of blue-green algae commonly occur on bedrock or rocky substrata making wading hazardous, sometimes impossible, even in very shallow water when velocities are high. The growth will appear dark as contrasted with that of certain of the species in another group of algae, the diatoms (Bacillariophyceae), which may also be responsible for a slippery substratum.

PRESENT CONSTITUENTS IN THE FLORA OF MISSOURI OZARK SPRINGS

During the week of September 9, 1968, some of the springs in Missouri were investigated to determine if the more conspicuous elements present in the springs were previously reported by Steyermark (1941). Since 1941, there have been no additional publications of the scope of his work made of the flowering vegetation of the springs so by now there may have been some significant changes. Sixteen of the largest springs were visited from which 59 specimens representing 19 different species of flowering plants were collected. None has been checked against herbarium specimens.

In the data derived from this study two species are listed as new, not only for the springs from which they were collected, but also for the counties in which the springs are located. One species is from Maramec Spring in Phelps County, and the other species is from Alley Spring in Shannon County. Single species which have been previously recorded for the respective counties but which are new for the springs were found at Chesapeake, Greer, Blue (Oregon County), Mill, Big (Carter County), and Welch Springs. Alley Spring has three species previously recorded for the county but listed as new for the spring. Those species that are new for the counties and for the springs are listed below.

Species	Spring	County
Lemna minor (Lesser Duckweed)	Maramec	*Phelps
Leersia virginica (White Grass)	Alley	*Shannon
Myriophyllum heterophyllum (Water Milfoil)	Chesapeake	Lawrence
Polygonum punctatum (Smartweed)	Greer	Oregon
Nasturtium officinale var. ***officinale*** (Water Cress)	Blue Mill	Oregon Wayne
Vallisneria americana (Eel Grass)	Big	Carter
Potamogeton illinoensis (Shining Pondweed)	Welch	Shannon
Eleocharis acicularis var. ***acicularis*** f. ***acicularis*** (Spike Rush)	Alley	Shannon
Potamogeton pectinatus (Fennel-leaved Pondweed)	Alley	Shannon
Hypericum mutilum (Dwarf St. John's-wort)	Alley	Shannon

*New for the county

This was a very cursory investigation when compared with the effort and time required to conduct the original survey. Certainly a more thorough evaluation of the flowering plants of the springs would require that they be investigated throughout the growing season, an effort which would, as did the original survey, extend over a number of years.

The environment of each spring tends to be stable, as does the flora which it supports. Individual springs have unique plant communities which remain virtually unchanged for long periods because many of the species adaptable to the particular environment simply are not introduced. Animals, birds, and man are probably the important vectors for species invading the individual spring environment. The appearance of new species and the removal of old ones in the community, therefore, do not necessarily reflect environmental change but may simply be occurrences incidental to a stabilized community.

The data derived from this study illustrate the point very well. New species of plants are reported for 11, or slightly more than two-thirds of the springs investigated. According to Steyermark (1941), some of those species are common to most of the springs in the Ozarks, and occur in many of the springs where the number of genera is relatively large. The general composition of the plant communities in the springs today appear to be varied also, which indicates a normal development for the environment. The new species, therefore, should be considered nothing more than a part of that development.

It appears from the recently obtained data that the flora of the springs has remained essentially unchanged since Steyermark's investigation. While the results of the recent study have shown the occurrence of new species in several of the springs since the earlier survey, they are not of sufficient detail to lead to any conclusions regarding previously recorded species not found. In a more thorough investigation of the springs, one would expect omissions to become more meaningful. As long as a varied composition of the plant communities is maintained, any omissions should be considered (as with the new species) nothing more than a part of normal development. Reintroduced, a species should again become an established component in the plant community.

REFERENCES

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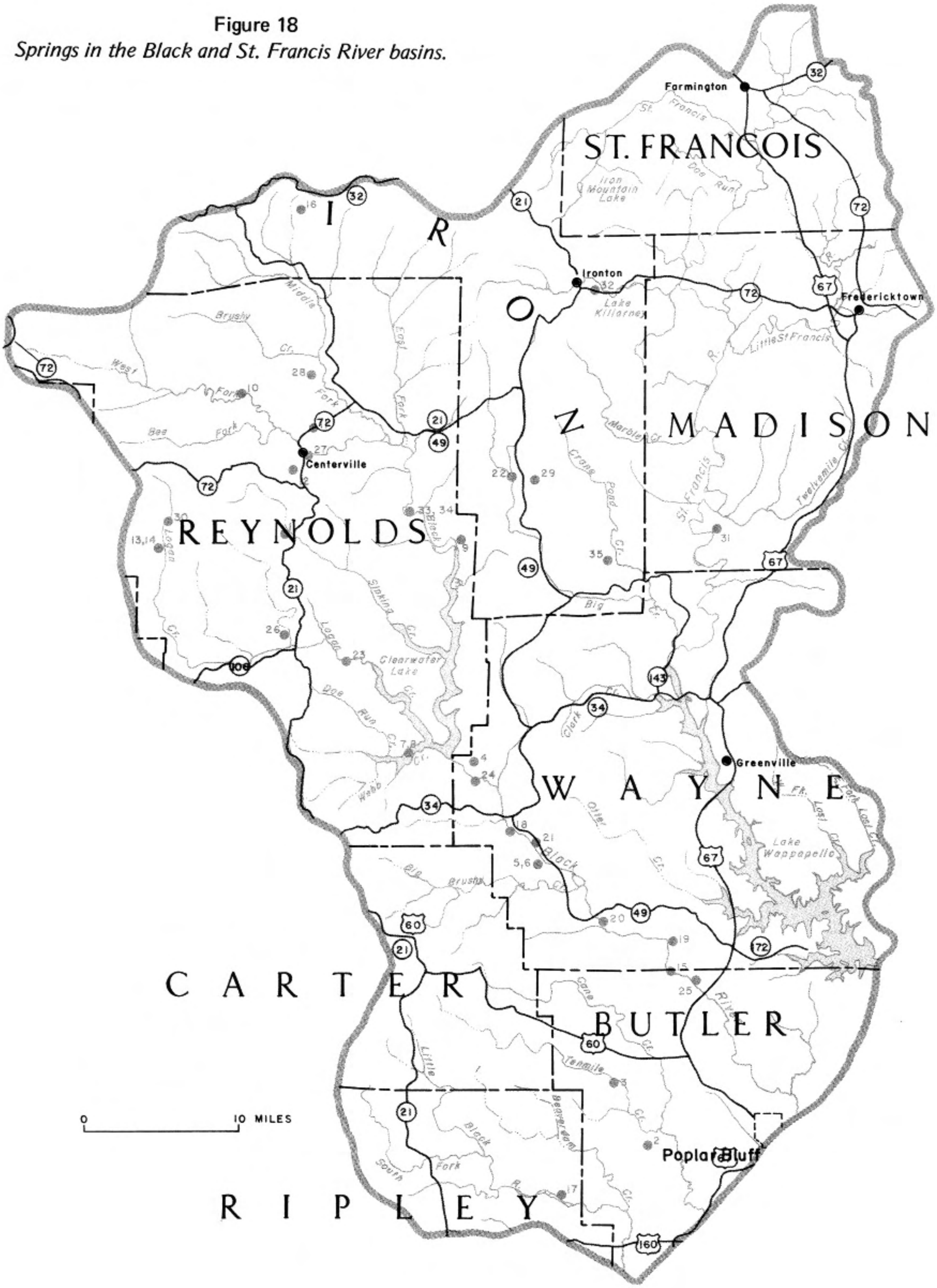
Photo (right) — A late winter snow mantles the old mill at Falling Spring in Oregon County. While seasonal and diurnal air. temperatures vary through a wide range, spring water temperatures remain nearly constant throughout the year.

Photo by Jerry D. Vineyard.

DESCRIPTION
OF
INDIVIDUAL SPRINGS

BY JERRY D. VINEYARD
AND GERALD L. FEDER

Figure 18
Springs in the Black and St. Francis River basins.



DESCRIPTION OF INDIVIDUAL SPRINGS

SPRINGS IN THE OZARK AREA (BY BASIN)

BLACK AND ST. FRANCIS RIVER BASINS

BASIN DESCRIPTION

The Black and St. Francis River basins lie on the southern flank of the St. Francois Mountains. The land is rugged and picturesque, especially in the mountainous areas. Taum Sauk Mountain, the highest point in Missouri, is 1,772 feet above sea level. Rivers flowing out of the Ozarks into the Southeastern Lowlands descend about 1,400 feet to an elevation of 360 feet above sea level. Along their courses many small springs (0.1 to 1 cfs) occur. There are a few large springs, but there are not as many as in the Current River basin on the west. Table 5 gives the discharges for springs in the Black and St. Francis River basins; locations of measured springs are shown in figure 18.

The oldest rocks in Missouri form the St. Francois Mountains in the northern half of the St. Francis River basin and the northeastern part of the Black River basin. These rocks, of Precambrian age, consist of felsitic volcanic rocks, granite and granite porphyry, and basic intrusions of gabbro (Tolman and Robertson, 1969). Springs are few in this area and most are little more than seeps. In the valleys between the igneous knobs and in the western and southern parts of the basins, the dolomitic rocks and sandstones are more porous than the igneous rocks. Springs in these areas are more abundant and larger than those in the mountainous area. The dry-weather flows of the streams draining the varied rock types of the basins are an indication of the abundance or absence of springs. The drainage basin of the Black River upstream from Annapolis is chiefly on dolomite. The drainage basin of the St. Francis River upstream from Roselle is chiefly of igneous rocks and some sedimentary rocks that are not easily dissolved by the action of ground water. In these areas the dry-weather flow of the Black River is about 40 times the flow of the St. Francis River on a per-square-mile basis. Downstream from Roselle where the St. Francis River drains dolomitic rocks, such as those in the Black River basin, large springs exist but some of them have been inundated by Lake Wappapello. Blue Spring, in Wayne County, one of the 15 largest springs in the Ozarks, discharges into the reservoir and can no longer be seen.

Mining, recreation, lumbering, and agriculture are the principal enterprises in the basins. Although mining has been carried on in the area for many years, recent developments of iron and lead deposits have increased capital expenditures and income manyfold. The New Lead Belt in Iron and Reynolds Counties is a massive undertaking that includes the development of six new mines and concentrating plants, and two new lead smelters. This development has enabled Missouri to become the world's largest lead-producing district (Vineyard, 1971, p. 22-23).

The recreational facilities of these basins are being expanded continuously. Chief among them are Clearwater Lake in the Black River basin and Lake Wappapello in the St. Francis River basin. Picnic areas have been built around Markham Spring in Wayne County and Cook Spring in Reynolds County, both in Clark National Forest.

As much of the basin is forested, lumbering is one of the chief sources of income for the area. The river bottoms and lower slopes of the hills are the only areas farmed to any extent. Springs often furnish the water supply for cattle farms and domestic water supply.

The abundance of scenic forested lands and clear streams and springs makes this one of the most popular recreational areas of the state.

QUALITY OF WATER

Water from most springs in the Black and St. Francis River basins is a moderately mineralized calcium magnesium bicarbonate type. Table 6 gives the chemical analyses for selected springs in the Black and St. Francis River basins. Excluding Sunny Slope Spring, the dissolved-solids content ranges from 55 to 277 mg/l. Water from Sunny Slope Spring contains 620 mg/l dissolved solids. It has chemical characteristics similar to other spring water, except that it has more sodium chloride. The source of the sodium chloride is not known. Hardness of the waters ranges from 49 to 319 mg/l. Of the 39 samples with hardness determinations, one is classed as soft, six are moderately hard, 16 are hard, and 16 are very hard (see table 3). The iron content of the waters ranges from 0.00 to 0.3 mg/l, with 32 of the 39 determinations showing less than the 0.3 mg/l recommended limit. The nitrate content ranges from 0.00 to 3.0 mg/l.

Table 5
Discharges of springs in the Black and St. Francis River basins
[A = less than 0.01 cfs]

Location No. (fig. 18)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
1	Amsden	Centerville	Reynolds	SESE 19,31,1E	2.50	1,620	-	8-1-25	
					.53	342	59	8-6-36	
					1.70	1,100	55	1-22-64	
					1.96	1,270	58	8-25-64	
					.76	491	-	11-30-64	
2	Bay	Poplar Bluff	Butler	SESE 5,24,5E	.04	26	-	6-6-66	Domestic
3	Branscum	Poplar Bluff	Butler	SWNE 13,25,4E	2.06	1,330	61	6-6-66	Stock
4	Brewer Bay	Piedmont	Wayne	SWNW 5,28,3E	2.09	1,350	58	8-11-36	
					3.27	2,110	-	9-19-48	
					2.50	1,620	-	9-17-53	
					2.36	1,520	59	1-22-64	
					2.30	1,490	57	8-26-64	
					1.84	1,190	57	12-3-64	
5	Bunyard No. 1	Mill Spring	Wayne	SENW 6,27,4E	5.17	3,340	58	1-23-64	Stock
					7.05	4,550	-	8-26-64	
					7.53	4,864	61	12-3-64	
6	Bunyard No. 2	Mill Spring	Wayne	SENW 6,27,4E	.50	323	-	8-26-64	Domestic
					.45	291	-	12-3-64	
7	Carter No. 1	Piedmont	Reynolds	SESW 34,29,2E	1.49	963	-	8-1-25	
					.91	588	58	8-11-36	
					1.78	1,150	57	8-26-64	
					1.66	1,070	54	12-3-64	
8	Carter No. 2	Piedmont	Reynolds	SWNW 3,28,2E	.72	465	-	8-26-64	
9	Champion	Annapolis	Reynolds	SENW 19,31,3E	2.10	1,360	-	5-19-53	Stock
10	Cook	Centerville	Reynolds	NESE 3,32,1W	.50	323	-	6-19-61	Recreation, U. S. Forest Service
					.60	388	57	9-14-66	
11	Faulkenberry	Lesterville	Reynolds	NENW 16,32,1E	.92	594	-	7- -25	
					.35	226	58	8-24-64	Domestic
12	January	Centerville	Reynolds	SESE 29,32,1E	.24	155	-	10-18-63	
					.21	136	55	8-24-64	
					.34	220	57	9-14-66	
13	John Beck	Corridon	Reynolds	NWSW 36,31,2W	A	A	-	8-24-64	
14	Joe Beck	Corridon	Reynolds	SENE 26,31,2W	.39	252	-	9-17-56	Domestic
					.59	381	-	12-19-56	
					.40	258	57	8-24-64	
15	Keener	Williamsville	Wayne	SESE 4,26,5E					
	(Average of 10 measurements)				22.0	14,200	-	1925-1966	
	(Maximum discharge measured)				43.0	27,800	58	3-18-35	
	(Minimum discharge measured)				14.0	9,040	59	8-10-36	
16	Keith	Bixby	Iron	NENE 8,34,1E	.02	13	59	9-13-66	Recreation, forest
17	King Bee	Fairdealing	Ripley	SWSW 20,24,4E	3.25	2,100	-	6-18-40	Stock
					5.51	3,560	58	8-25-64	
					8.66	5,590	58	12-2-64	
18	Leeper	Leeper	Wayne	SENE 27,28,3E	.46	297	-	8- -25	
					.17	110	-	4-8-32	
					.04	26	-	8-11-36	
					.04	26	57	8-26-64	
					.03	19	50	12-2-64	
19	Lord	Williamsville	Wayne	NESE 28,27,5E	.43	278	-	10-30-32	Domestic
					.58	375	-	8-10-36	
					.11	70	-	10-17-63	
					.27	174	55	8-27-64	
					.50	323	57	10-9-64	
					.66	426	56	12-2-64	
20	Markham	Williamsville	Wayne	SWNW 23,27,4E					
	(Average of 15 measurements)				7.52	4,860	-	1925-1965	
	(Maximum discharge measured)				10.2	6,590	57	4-9-65	
	(Minimum discharge measured)				5.54	3,580	60	8-10-36	
21	Mill	Mill Spring	Wayne	NENW 36,28,3E					
	(Average of 15 measurements)				11.9	7,690	-	1922-1966	Used for municipal water supply
	(Maximum discharge measured)				29.2	18,900	56	5-13-66	
	(Minimum discharge measured)				8.99	5,810	58	10-15-63	
22	Mitchell	Sabula	Iron	SWSW 35,32,3E	.28	181	57	1-30-64	Domestic for resort
					.24	155	-	8-25-64	
23	Morris	Ellington	Reynolds	SENW 36,30,1E	5.00	3,230	-	7-27-56	Stock
					4.33	2,800	-	10-18-63	
					3.88	2,510	-	8-25-64	
					4.04	2,610	55	12-4-64	
24	Pittman	Piedmont	Wayne	NWNW 8,28,3E					
	(Average of 15 measurements)				32.4	20,900	-	1942-1966	
	(Maximum discharge measured)				38.1	24,600	57	7-21-66	
	(Minimum discharge measured)				24.5	15,800	58	1-30-64	
25	Pryor	Poplar Bluff	Butler	NESE 11,26,5E	.14	90	-	7-6-66	
26	Randolph	Ellington	Reynolds	SWSW 20,30,1E	1.04	672	-	8-1-25	
					.03	19	58	1-22-64	Fish rearing
					.02	13	-	12-3-64	

Table 5 *(continued)* . . . . .

Location No. (fig. 18)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
27	Reeds	Centerville	Reynolds	NESW 28,32,1E	7.52	4,680	-	7-3-25	
					15.1	9,750	-	6-17-26	
					6.78	4,380	57	8-5-36	
					2.86	1,850	56	10-18-63	
					6.28	4.060	55	8-24-64	
					5.90	3,810	55	12-4-64	
28	Ringo	Black	Reynolds	NENW 33,33,1E	1.06	685	54	5-4-66	Fish raising
29	Speer	Sabula	Iron	SESE 35,32,3E	1.12	724	58	1-8-63	Private, fishing allowed
					1.26	814	58	8-25-64	
					1.29	833	58	6-10-65	
					1.02	659	-	8-24-65	
					1.28	827	58	5-13-66	
30	Spout	Corridon	Reynolds	SESW 13,31,2W	.02	13	-	9-17-56	Domestic
					.01	6	-	12-19-56	
					.11	71	57	8-24-64	
31	Stillhouse	Annapolis	Madison	SENW 23,31,5E	.15	97	58	8-26-66	
32	Sunny Slope	Ironton	Iron	SWSW 3,33,4E	A	A	60	9-13-66	
33	Unnamed	Lesterville	Reynolds	NWNE 9,31,2E	.44	284	58	7-21-66	
34	Warner Bay	Lesterville	Reynolds	NWNW 9,31,2E	16.0	10,300	-	7-31-25	
					16.3	10,500	-	8-16-36	
					19.0	12,300	57	1-22-64	
					17.5	11,300	56	8-25-64	
					17.3	11,200	56	12-4-64	
35	Weeping Willow	Des Arc	Iron	SWNE 34,31,4E	1.50	969	59	9-13-66	

DESCRIPTIONS OF SELECTED SPRINGS

COOK SPRING, *Reynolds County, Corridon 7½-minute quadrangle, NE¼ SE¼ sec. 3, T. 32 N., R. 1 W.*

The U.S. Forest Service has built a picnic area at Cook Spring about ½ mile north of the West Fork of Black River. The spring discharges from a series of small solution openings in dolomite along a bedding plane extending for about 75 feet along the spring branch. The main stream channel flows along the base of the east bluff of the hollow and is dry, except after heavy rain; the spring rises at the base of the west bluff and the branch leading from the spring flows continuously. During dry weather the flow declines to about 300,000 gpd, but it never ceases to flow. The spring contributes to the attractiveness of the picnic area. Water cress is abundant in the spring branch.

FULTON SPRING, *Wayne County, Patterson 7½-minute quadrangle, SE¼ NW¼ NW¼ sec. 12, T. 29 N., R. 4 E.*

Fulton Spring occupies an unusual topographic setting in a basin-like lowland flanked by Precambrian knobs (fig. 19). The spring rises in alluvium along the valley of a tributary to Camp Creek, which in this area flows southward between Frenchman Hill on the west and Mudlick Mountain on the east. The spring flows quietly from a basin approximately 25 feet in diameter (fig. 20) on the grounds of the old Fulton homestead. Surrounding lands are under cultivation.

The basin of Fulton Spring, when measured in 1964, was 13 feet deep. Local legend implies that the spring was once much deeper and that it has been filled over the years by debris, logs, and rock. There may be some truth to the story that the spring was much deeper than it is now; it flows from Cambrian bedrock, which is not exposed at the surface. The source of water for Fulton Spring is the basin between Frenchman Hill and Mudlick Mountain.

JANUARY SPRING, *Reynolds County, Centerville 7½-minute quadrangle, SE¼ SE¼ sec. 29, T. 32 N., R. 1 E.*

January Spring is in Centerville, a small town on the West Fork of Black River in Reynolds County. The spring bubbles up through sand inside a small stone enclosure and flows through the town to join West Fork about 1,500 feet away. The spring has been measured only three times and the measurements have all been made during the summer and autumn months. That supply, amounting to from 130,000 to 220,000 gpd, is used only to water a few cattle.

Table 6
CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE BLACK AND ST. FRANCIS RIVER BASINS

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 18)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (NA)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
																			Calcium Magnesium	Noncarbonate				
1	Amsden	8-25	2.50	--	4.8	0.66	29	16	0.5		151	10	0.0	3.4	--	0.1	--	138	136	0	---	--	-	-
		4-52	--	53	3.8	.18	17	11	2.4		97	0	3.0	1.0	0.0	1.5	--	94	86	7	---	7.4	-	-
		8-64	1.96	58	3.4	.14	28	17	3.4		171	0	1.9	2.3	.2	.0	--	146	141	0	---	7.4	-	-
3	Branscum	6-66	2.06	61	9.1	1.30	46	24	2.0	.8	256	0	4.0	1.4	.2	.0	--	226	214	4	386	7.4	5	-
4	Brewer Bay	8-64	2.30	57	1.0	.05	38	21	2.0		209	0	2.3	2.5	.0	.0	--	180	183	12	---	7.2	-	<1
5	Bunyard No. 1	5-64	--	56	--	--	--	--	--	--	98	0	.9	2.5	.1	.0	--	98	---	--	170	7.2	-	-
7	Carter No. 1	8-25	1.49	--	8.6	.22	37	18	2.2		188	13	11	2.9	--	.7	--	176	167	0	---	--	-	0
		8-64	1.78	57	1.2	.14	39	22	2.3		218	0	3.0	2.3	.0	.0	--	188	188	9	---	7.2	-	4
10	Cook	9-66	.60	57	9.0	.00	43	13	1.0	.5	192	0	1.6	1.7	.2	.0	--	166	161	3	305	7.6	2	-
11	Faulkenberry	7-25	.92	--	7.4	.66	36	20	.5		186	13	.0	2.6	--	.0	--	171	172	0	---	--	-	0
		8-64	.35	58	3.0	.03	40	22	1.5		222	0	3.1	2.8	.0	.0	--	200	193	12	---	7.4	-	1
12	January	9-66	.34	57	7.6	.00	26	14	.9	.6	150	0	1.4	.6	.1	.8	--	132	119	0	236	7.6	2	-
14	Joe Beck	8-64	.40	57	.4	.03	33	19	2.8		186	0	2.5	3.0	.0	.0	--	158	160	8	---	8.2	-	<1
15	Keener	4-52	--	55	5.0	.15	19	11	4.6		106	0	3.5	2.0	.0	.3	--	102	95	8	---	7.5	-	3
		8-64	23.0	57	.0	.03	40	22	1.3		214	0	3.7	3.3	.0	.0	--	185	188	12	---	7.5	-	<1
17	King Bee	8-64	5.31	58	4.2	.04	36	20	.3		198	0	3.0	3.5	.0	.0	--	177	171	9	---	7.3	-	1
18	Leeper	8-25	.46	--	9.0	.83	34	31	.1		270	19	.0	3.4	--	.4	--	250	264	11	---	--	-	0
		4-52	--	57	5.8	.06	48	28	6.1		272	0	3.7	2.8	.0	2.7	--	235	237	4	---	7.6	-	2
		8-64	.04	57	.8	.25	60	32	1.3		321	0	4.7	3.0	.1	.0	--	277	282	18	---	8.2	-	1
19	Lord	8-64	.27	55	.4	.05	47	27	1.4		268	0	3.0	2.8	.0	.0	--	218	226	7	---	7.2	-	<1
20	Markham	8-25	7.38	--	21	.21	38	20	7.1		210	12	5.3	3.2	--	.2	--	210	177	0	---	--	-	0
		4-52	--	60	5.0	.13	34	21	7.5		206	0	1.9	1.8	.0	.2	--	180	173	4	---	8.0	-	4
		8-64	6.90	62	4.6	.08	42	24	2.3		243	0	2.3	3.3	.1	.0	--	205	205	7	---	7.4	-	-
21	Mill	8-25	11.1	--	7.8	.70	35	20	.6		179	12	.0	2.7	--	.3	--	167	169	1	---	--	-	0
		4-52	--	53	3.2	.28	15	8.7	3.3		78	0	3.9	1.5	.1	1.1	--	86	73	10	---	7.6	-	6
		8-64	9.18	57	.8	.04	40	23	.9		230	0	2.7	3.0	.1	.0	--	187	195	6	---	7.8	-	<1
		11-65	9.43	57	8.8	.00	36	21	1.5	.4	213	0	1.8	1.2	.0	1.0	--	176	177	2	324	7.7	1	-
24	Pittman	8-64	30.2	57	2.8	.04	34	19	1.2		191	0	2.6	2.8	.1	.0	--	162	164	7	---	8.1	-	<1
26	Randolph	8-25	1.04	--	6.0	.24	55	16	2.5		186	10	1.4	2.7	--	2.2	--	169	156	0	---	--	-	0
27	Reeds	7-25	7.52	--	6.2	.66	24	13	2.3		129	16	.0	2.2	--	.3	--	128	115	0	---	--	-	0
		4-52	--	--	4.4	.25	10	5.9	4.1		51	0	3.0	.5	--	.7	--	55	49	7	---	7.5	-	6
		8-64	6.28	55	1.8	.05	27	15	2.0		148	0	2.7	2.0	.0	.0	--	127	128	7	---	7.3	-	<1
29	Speer	5-66	1.28	58	9.6	.06	46	20	2.4	.5	236	0	3.0	2.3	.1	.1	--	200	214	20	358	7.8	0	-
30	Spout	8-64	.11	--	.4	.00	45	25	3.3		255	-	2.8	3.3	.0	.0	--	213	217	9	---	7.2	-	<1
31	Stillhouse	8-66	.15	58	9.3	.22	35	24	1.1	.5	216	0	3.8	1.0	.2	.0	--	181	186	9	332	7.6	2	-
32	Sunny Slope	9-66	A	60	13	.02	75	32	110	4.9	333	0	25	186	.2	3.0	--	620	319	46	1,120	7.1	8	-
34	Warner Bay	7-25	16.0	--	7.4	.77	28	16	0		148	8	.2	2.2	--	.0	--	134	134	0	---	--	-	0
		4-52	--	54	4.6	.19	15	8.9	5.7		80	0	3.7	1.5	.0	1.3	--	81	75	9	---	7.7	-	6
		8-64	17.5	56	2.4	.03	34	17	1.3		173	0	2.7	2.8	.1	.0	--	147	156	14	---	7.6	-	<1
35	Weeping Willow	9-66	1.50	59	8.9	.00	49	19	1.3	.4	248	0	.8	1.2	.1	.0	--	203	200	0	373	7.5	4	

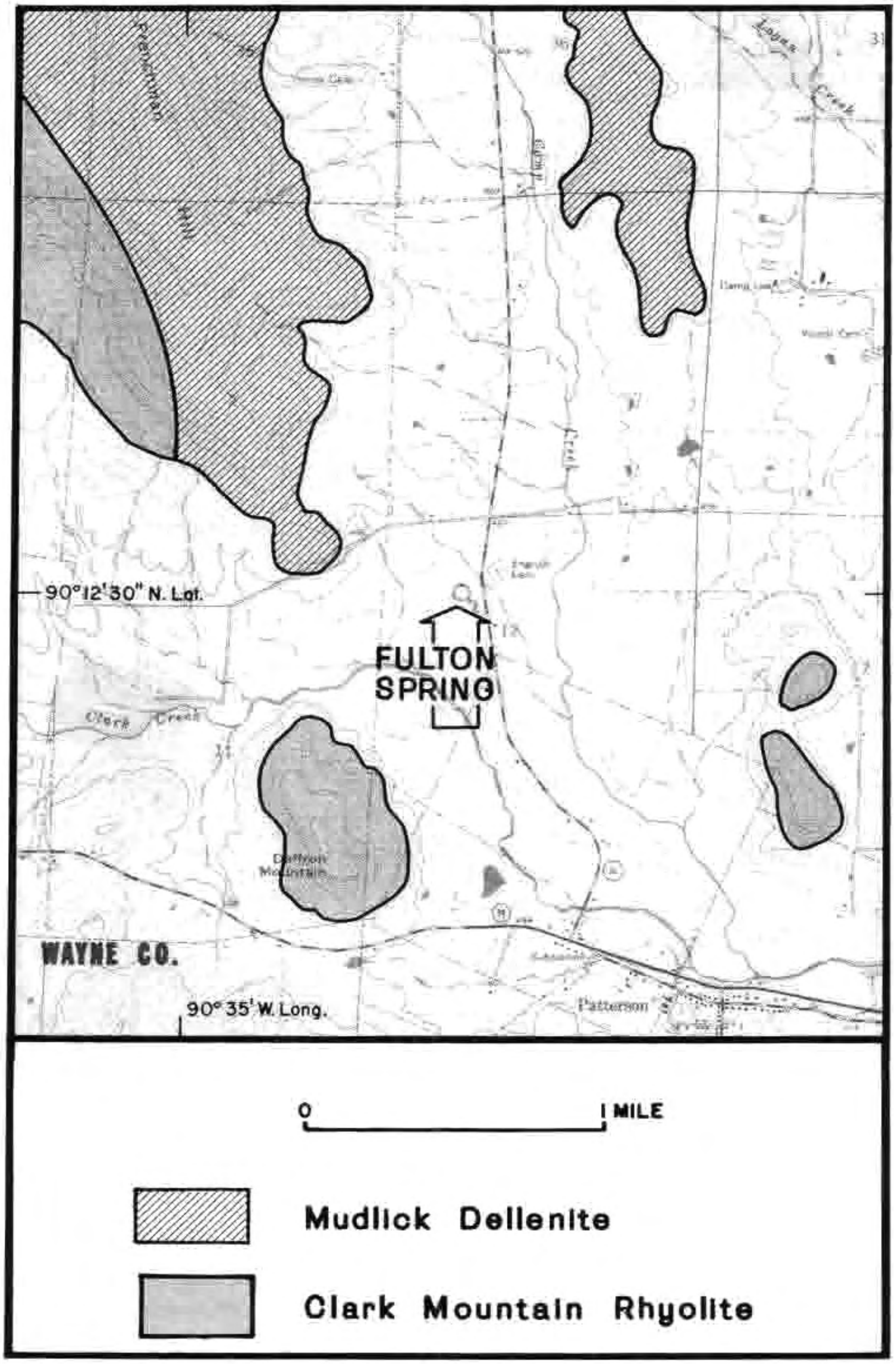


Figure 19

Fulton Spring flows from Upper Cambrian dolomite between Precambrian igneous knobs. Topography from U.S. Geological Survey. Patterson 7½-minute quadrangle; geology from Tolman and Robertson (1969).

Figure 20

Fulton Spring rises in a nearly circular pool about 13 feet deep. Source of the water is in Cambrian dolomite filling basinal areas between Precambrian igneous knobs (see fig. 19) of the St. Francois Mountains in southeastern Missouri. Photo by Jerry D. Vineyard.

KEENER SPRING, *Wayne County, Williamsville 15-minute quadrangle, SE¼ SE¼ sec. 4, T. 26 N., R. 5 E.*

Keener Spring, one of the larger springs in the Black River basin, is part of a privately owned development for tourists and fishermen. The spring pools are stocked with trout for fee fishing. The spring consists of two principal openings in the Roubidoux connected by a lake about 600 feet long, which stands several feet above the Black River at normal stages. The water discharges from openings along a bedding plane in the sandstone and dolomite that form the bluff at this place. The water flows through a spillway in an earthen dam and the spring branch joins the Black River about 600 feet downstream. Variations in the descriptions of the spring indicate that many changes in the vicinity of the spring have been made over the years. Plant growth is abundant in the lake and along the spring branch, which was described by Steyermark (1941, p. 581-2).

The spring rises on the south flank of a gentle anticlinal fold trending west-southwest. The crest of the fold is at Keener Cave a few hundred feet north of the spring. This small fold is probably the result of "solution sapping" in the dolomite beds of the Roubidoux and underlying Gasconade Dolomite.

Water tracing experiments during the summer of 1972 showed that surface water enters the Keener Spring system through a losing reach of Cane Creek about 5 miles west-southwest of the spring (fig. 21). A reach of Cane Creek about 1 mile long comprises a water loss zone that was discovered and delineated by personnel of Clark National Forest (Charles Tryon, oral comm. 1970). Subsequent tracing work by Hoffman and Vineyard established the connection

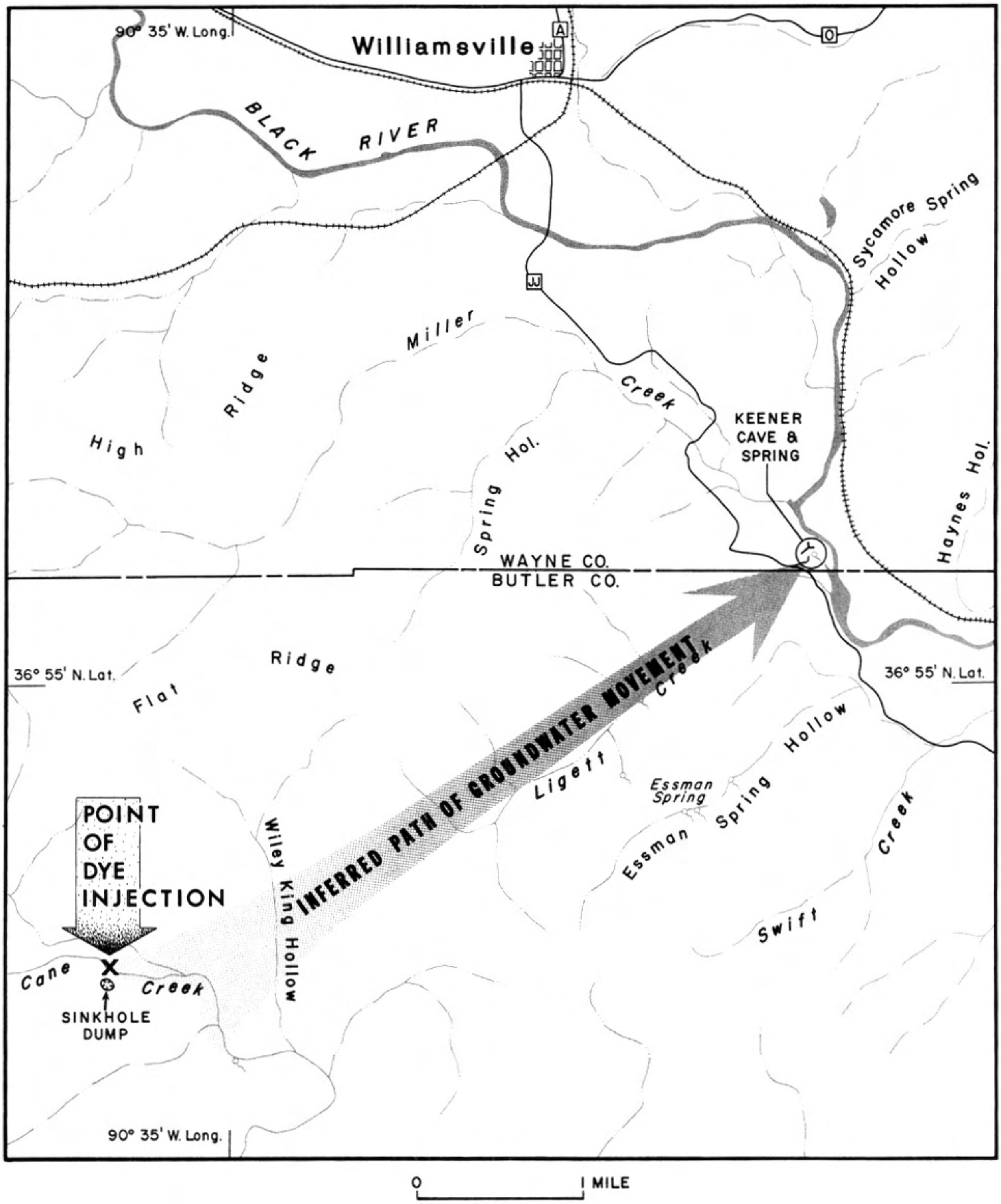


Figure 21

Keener Spring in relation to Cane Creek and other elements of the spring supply system. Base map from U.S. Geological Survey, Williamsville 15-minute quadrangle.

between the losing reach of Cane Creek and Keener Spring, with a travel time of less than three weeks.

It is noteworthy that the inferred path of groundwater movement between Cane Creek and Keener Spring passes beneath the valley of Ligett Creek, the only small valley in the area shown as a permanent stream on the Williamsville 15-minute topographic map.

Subsequent to the water tracing experiments, Vineyard found a sinkhole in NW¼ SE¼ sec. 23, T. 26 N., R. 4 E. that may aid in defining the zone of water movement from Cane Creek to Keener Spring (fig. 21). This sinkhole, long used as a dumping ground, is inferred to be contributory to the Keener Spring system, but no tracing work has been attempted with the sinkhole as an injection point.

A window into the supply system of Keener Spring may be examined by visiting Keener Cave. The cave has developed in the upper part of the Gasconade Dolomite immediately beneath the massively bedded sandstone in the lower part of the Roubidoux that forms the cave's roof and covers the outlet of Keener Spring. The entrance to Keener Cave was formerly a small sinkhole on a steep hillside, but the owners have bulldozed talus away from the entrance to provide parking space and a level walk into the cave so visitors may view an underground lake. The cave consists of a single south-southwest trending passage determined by rock structure. The major feature in the cave is the underground lake with a water depth (over fill) of 35 feet. The water has no observable motion, but fluorescein dye introduced in the cave lake reappeared in Keener Spring.

MARKHAM SPRING, *Wayne County, Williamsville 15-minute quadrangle, SW¼ NW¼ sec. 23, T. 27 N., R. 4 E.*

Markham Spring is one of the larger sustained springs in the Black River basin. Its flow averages about 5 million gallons per day and the minimum that has ever been measured, in the drought of the 1930's, is 3.5 million gallons per day. Recently the spring has been improved by the U.S. Forest Service, Clark National Forest, and is the center of attraction in the camping and picnic area built around the spring. The spring and mill wheel are at the base of a steep hill of Eminence Dolomite. The spring rises in a pool formed by an embankment built to contain the flow of the spring which operated a grist mill. In former years the pool was stocked with trout for the recreation of the owners. The spring is easily reached by improved roads since the establishment of the camping area.

Steyermark (1941, p. 583-584) described the flora in the pool and in the branch in considerable detail. Because of the varied habitats a large variety of plants is described. Steyermark listed 13 species of which a few are not commonly found in Missouri springs.

MILL SPRING, *Wayne County, Mill Spring 7½-minute quadrangle, NE¼ NW¼ sec. 36, T. 28 N., R. 3 E.*

Mill Spring is one of the few springs in Missouri that is still used for a municipal water supply (fig. 22). Its average flow of almost 8 million gallons per day is many times the average daily use – 22,000 gallons – of the town's 230 inhabitants. The spring discharges from a water-filled cave at the foot of a bluff of Eminence Dolomite a few hundred feet south of the town. Just west of the spring is a low cave entrance that leads to a pool of water representing backwater from the spring. In periods of high discharge, the cave fills and water flows from the entrance. The spring branch passes under the tracks of the Missouri Pacific Railroad and enters the Black River about ½-mile downstream.

Steyermark (1941, p. 585-586) examined the plants growing along the spring branch and found, among other species, patches of peppermint which give off a pleasant odor around the spring.

PITTMAN SPRING, *Wayne County, Ellington SE 7½-minute quadrangle, NW¼ NW¼ sec. 8, T. 28 N., R. 3 E.*

Pittman Spring is the largest spring known in the Black and St. Francis River basins that has not been covered by an impoundment. The spring has an average flow of about 20 million gallons per day and seems to vary between 15 and 25 million gallons per day. The spring has several outlets along a branch in a distance of about 60 feet. One of the openings is a collapsed cave in Eminence Dolomite. More water is added in boils near the edge of the bluff and from solution openings in the bluff at the water's edge. The bluff is honeycombed with solution openings in the vicinity of the main outlets. The water is clear and cold, and the surroundings are wooded, making this an attractive place for picnics and camping. One of the notable features of the spring and the branch is the sparse plant growth. Although it is submerged when the river is high, the branch has a clean gravel bottom.

The spring is easily reached by boat from the left bank or by a short walk from the end of a logging road on the river bank.

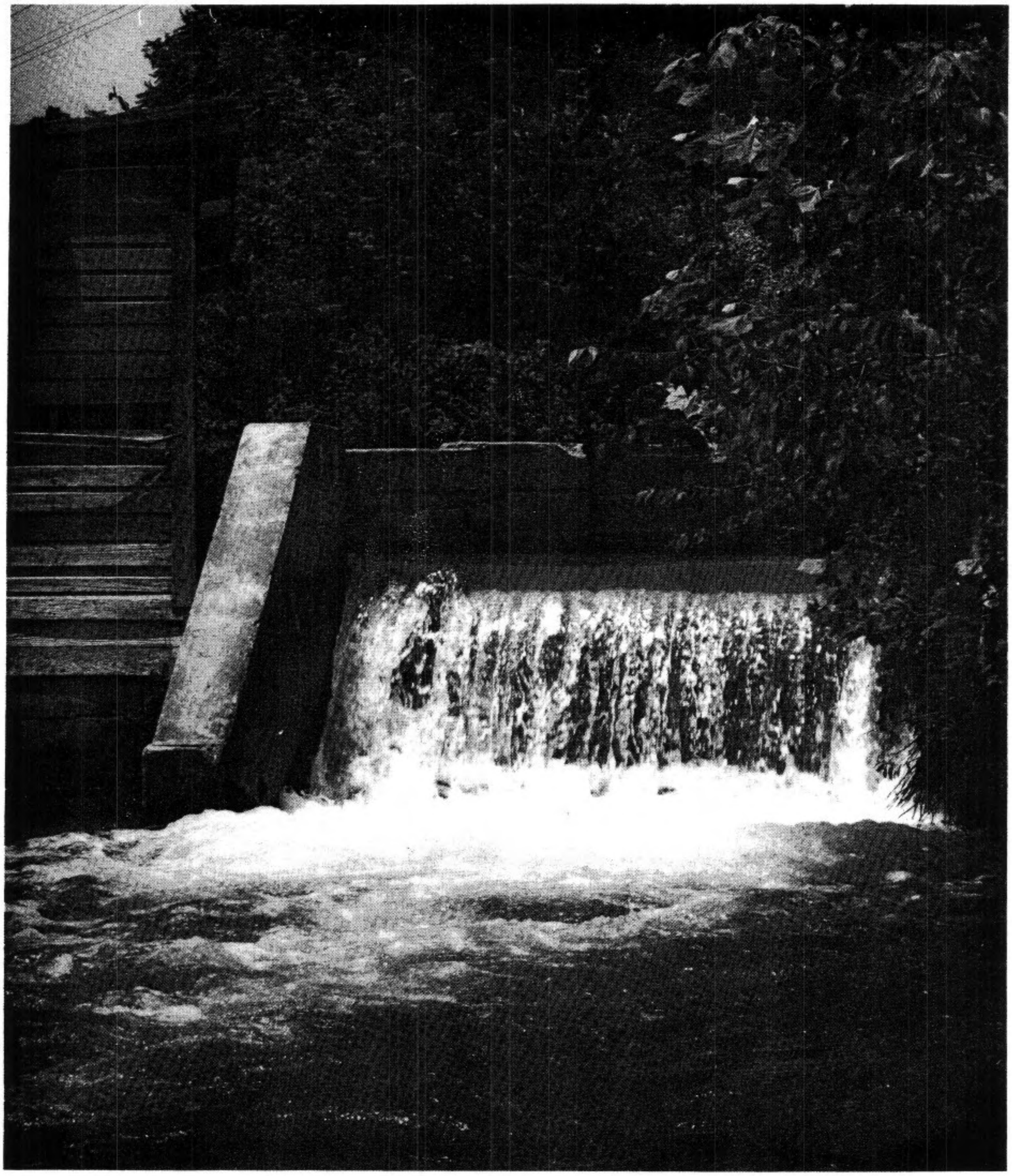


Figure 22

Mill Spring water cascades over a dam formerly used to provide water power for a millwheel to pump water uphill to a storage tank. An electric pump now does the work and the millwheel works is falling into disrepair. Photo by David Hoffman.

REEDS SPRING, *Reynolds County, Centerville 7½-minute quadrangle, NE¼ SW¼ sec. 28, T. 32 N., R. 1 E.*

Reeds Spring is about ½-mile east of Centerville along the West Fork of Black River. It is a sizable spring, flowing 3 to 5 million gallons per day. This spring, in earlier years, operated an ice plant, grist mill, and generator which furnished electricity for Centerville and a nearby resort. The mill and generating plant were dismantled in 1939 and the mill wheel was sent to the 1939 New York World's Fair for display. The spring is privately owned and formerly had been developed as a tourist attraction. It rises in a small artificial basin, passes through five pools and a series of dams and enters the river after a total fall of about 15 feet. The series of pools and waterfalls enhance the scenery and the setting for the houses built around the spring pools. The elevation is high enough above the river to make it safe from most floods.

Near the bank of the Black River, a second spring with a smaller flow discharges directly to the river from cavernous openings in dolomitic limestone and is probably part of the same system of openings feeding Reeds Spring.

SPEER SPRING, *Iron County, Glover 7½-minute quadrangle, SE¼ SE¼ sec. 35, T. 32 N., R. 3 E.*

Near the town of Sabula along Highway 49, a small trout fishing resort has been built using the water from Speer Spring. The spring rises in a clear circular pool in a broad, gravel-filled valley surrounded by hills of Cambrian dolomite. From the rise pool the spring branch carries the water through successive rearing pools separated by gates. In these pools trout are raised for sport fishing. The flow of the spring averages about 700,000 gpd. The spring branch enters Big Creek, a tributary of the St. Francis River, about 1 mile downstream from the spring pool.

WARNER BAY SPRING, *Reynolds County, Lesterville 7½-minute quadrangle, NW¼ NW¼ sec. 9, T. 31 N., R. 2 E.*

Warner Bay Spring, one of the larger springs in the Black River basin, is one of the least accessible. It is on private property bordering the Black River about 6 miles south of Lesterville. The spring issues from cavernous openings at the foot of a rocky cliff of Cambrian dolomite rock, and flows a quarter of a mile in a slough to the Black River. The caves extend about 50 feet along the bluff and water discharges from numerous openings. The floor and roof of the spring orifice are very irregular due to solution activity along a bedding plane and along vertical joints, which are prominent and intersect at the places where most of the water discharges. The pools in the cave entrance are probably as much as 10 to 15 feet deep and the deep parts coincide with the major joints. The clear blue spring and the rocky openings enhance the beauty of the rugged, undisturbed wilderness. The flow of the spring exceeds 10 million gallons per day; it is not used but contributes substantially to the flow of the Black River. Steyermark described the plant species (1941, p. 613-614).

CURRENT AND ELEVEN POINT RIVER BASINS AND WARM FORK OF SPRING RIVER

BASIN DESCRIPTION

One of the most picturesque sections of Missouri is the "Big Springs Country" of the Current-Eleven Point River basins, and the Warm Fork of the Spring River. It lies on the southern border of the state; its headwaters reach up toward the St. Francois Mountains on the east and the high divide in Texas County on the west. The northern boundary is formed by the Gasconade and Meramec River basins. Areas of rugged and scenic countryside border the Current River and its tributaries in contrast to the divide areas on the north and west which are gently rolling. The altitude of the divides around the perimeter range from 1,000 to 1,400 feet above sea level. The Current River descends from 1,000 feet in its headwaters in Dent County to 300 feet above sea level at the Missouri-Arkansas line with an average gradient of 5 feet per mile.

Since the establishment of the Ozark National Scenic Riverways on the Current River and Jacks Fork, accessibility to many parts of the area has been improved.

In the 1860's much of the basin was covered by mixed yellow pine and hardwood forests and logging was a big industry. By 1899, 700 million board feet of lumber were cut in one year. This marked the peak of logging operations and from that time to 1931 logging declined to a point where only 75,000 board feet were cut in that year. From that time on interest in reforestation mounted. Today large tracts of land are included in state and federally managed forests. The total area shown on figure 23 is about 4,200 square miles. Of this total about 850 square miles is presently included within national forest

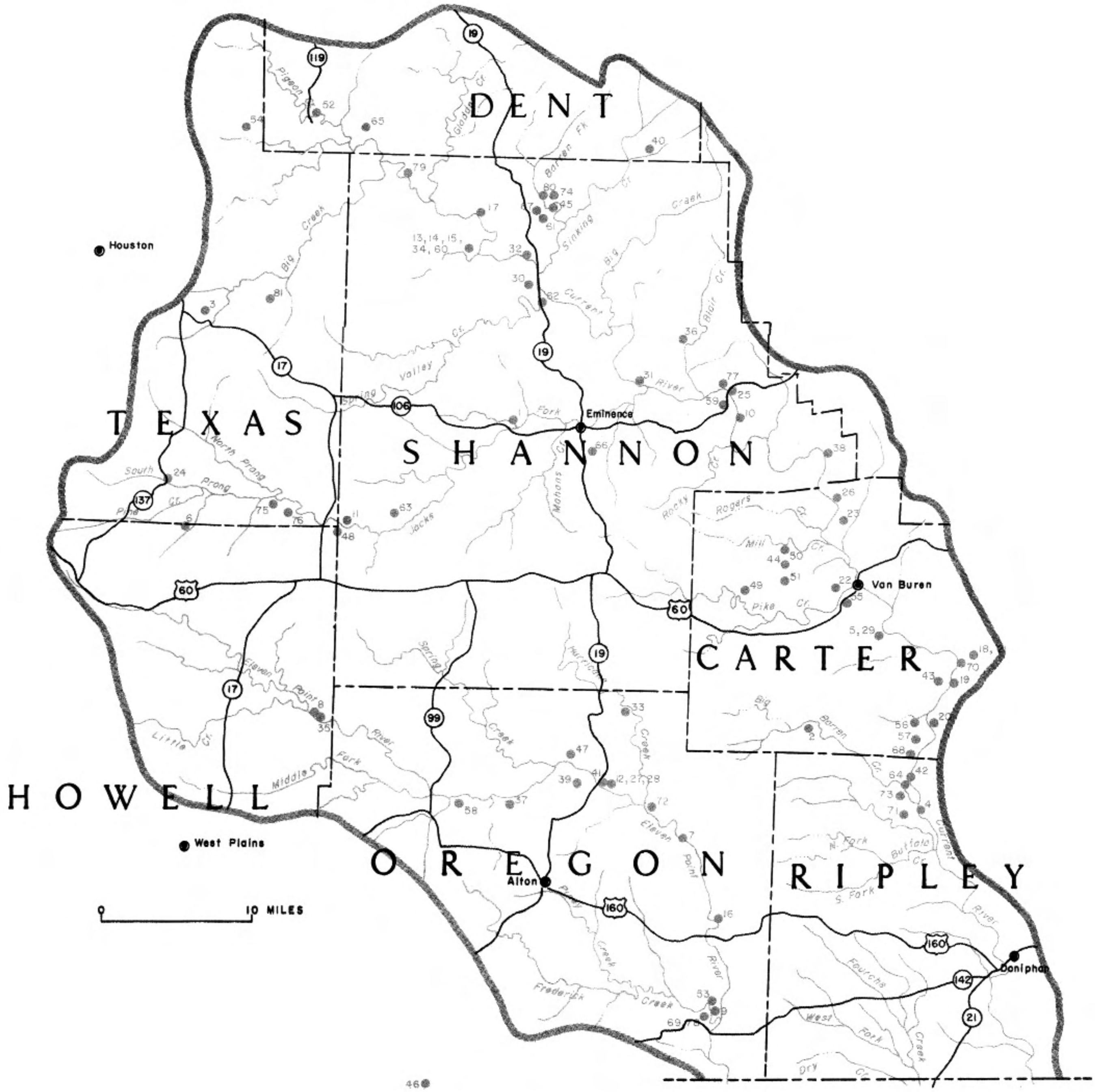


Figure 23
Springs in the Current and Eleven Point River basins and Warm Fork of the Spring River.

boundaries and more than 100 square miles in state forest lands.

The Ozark National Scenic Riverways was established in 1964. It was formally dedicated June 10, 1972 to preserve the natural conditions of the Current River and Jacks Fork and to increase the area's utility as a recreational area for fishermen, floaters and campers. Numerous campsites and put-in points for canoeists have been constructed along the two rivers and at points of interest in the basin.

Josiah Bridge mapped and described the geology of the Eminence and Cardareva quadrangles so that the geology of this part of the Current-Jacks Fork area is well known (Bridge, 1930). Practically all the formations at the surface in the three basins crop out in the area mapped by Bridge. The area is on the southwest slope of the St. Francois Mountains; the formations dip generally southwestward. The oldest rocks occur in the Precambrian igneous knobs in the vicinity of Eminence; most of these are west of the Current River. The igneous rocks are mainly rhyolite, a dense, fine-grained to porphyritic rock that is generally red but sometimes is gray or green. Other igneous rock types, which are generally rarer in the area, are granite, volcanic ash and tuff (Bridge, 1930; Tolman and Robertson, 1971).

A thick sequence of dolomite and sandstone of Ordovician and Cambrian age encloses the spring systems. Most of the large springs are along the Current River and their orifices are in the Eminence and Potosi Dolomites. The outcrop of the Eminence and Potosi forms a nearly straight band through which the Current River flows from its headwaters to mid-Carter County. The direction of this outcrop belt and the stream that traverses it is northwest and corresponds with a major joint system of the Ozarks. The joint system, the alinement of many of the streams, and the location of the big springs of the Current-Jacks Fork area are closely related.

Many minerals used in industry occur in these basins, but at present little income is derived from their extraction. Iron and manganese deposits have been prospected or worked in the past. Noteworthy among these are the brown iron ore deposits of the West Plains area, which extend into the Eleven Point River basin. Near the mouth of Jacks Fork is an area of igneous knobs where copper was mined in earlier days. The history of copper mining dates back to the early part of the 19th century when it was first investigated by Joseph Slater, a Cornish miner (Bridge, 1930). Although only a small quantity of copper has been produced, occurrences (which seem to be related to deposition on the steep flanks of the igneous knobs) are common in the Eminence area. Though the occurrences of manganese are widespread in the eastern part of the Current River basin, little manganese has been extracted since it was first mined in 1872.

Two springs of interest in connection with the mining industry are Slater Spring near Eminence in Shannon County and Midco Spring in Carter County. Slater Spring was used in the 19th century as a water supply when the copper deposits were being mined. Midco Spring, north of Fremont in Carter County, furnished water to the former town of Midco and to the Mid-Continent Iron Company, which smelted brown iron ore from the region. The ruins of the old Midco Iron Works still exist.

In November 1966, a seepage run of the Current River and Jacks Fork was made to determine if there were any losses of consequence along either stream. Measurements were made of all tributaries and springs entering the two rivers. The seepage run showed that seepage losses were negligible on the main stems and that the bulk of the flow of the Current River is made up of the discharges of the large springs and the principal tributaries. The seepage run also showed that tributary streams entering from the east contributed more flow to the Current River than tributaries entering from the west (Jacks Fork not included). This is due to the larger number of springs in the eastern side of the basin and perhaps also to the better development of underground drainage in the western part of the basin.

It has long been recognized that many surface streams in the vicinity of large springs have little or no flow except during rainstorms. Precipitation in the stream basins goes into the ground to enter the channels and feeders of the springs and reappears as spring discharge. Table 7 gives the discharge for springs in the Current and Eleven Point River basins and the Warm Fork of the Spring River.

No discussion of the spring systems of the Ozarks would be complete without mentioning Mammoth Spring in Arkansas, the second largest spring in the Ozark province of Missouri and Arkansas (Beckman and Hinchey, 1944, p. 90-91). The orifice of Mammoth Spring is a short distance across the Missouri-Arkansas line at the head of the Spring River, but it is probable that nearly all of the entire drainage area

Table 7
DISCHARGES OF SPRINGS IN THE CURRENT AND ELEVEN POINT RIVER BASINS AND THE WARM FORK OF THE SPRING RIVER

[A = discharge less than 0.01 cfs]

Location No. (fig. 23)	Spring	Nearest Town	County	Land Line Location	Rate of Flow: Sec. Ft. (cfs)	Rate of Flow: 1000 gal. day	T °F.	Date	Remarks
1	Alley	Alley Spring	Shannon	NWSE 25,29,5W	(See page 81 for data on flow)				NPS*
2	Barren Creek	Fremont	Carter	NESW 4,25,1W	.06	39	-	9-23-53	
3	Bear Claw	Yukon	Texas	SENE 33,30,8W	2.02	1,300	56	7-7-50	Stock
					.67	433	58	8-27-64	
4	Bee Bluff	Bennett	Ripley	SWNE 34,25,1E	.92	594	-	8-11-46	
					.91	589	57	12-1-64	
5	Big	Van Buren	Carter	SENW 6,26,1E	(See page 83 for data on flow)				NPS*
6	Big	Willow Springs	Howell	SWNW 4,27,8W	1.41	911	56	6-6-66	
7	Bliss	Wilderness	Oregon	NWNE 18,24,2W	.80	517	57	9-20-64	
8	Blowing	Mountain View	Howell	NWNE 11,25,7W	.98	633	56	6-6-66	
9	Blue	Alton	Oregon	NWSE 16,22,2W					
	(Average of 10 measurements)				72.0	46,500	-	1925-1966	Aquatic plant farming
	(Maximum discharge measured)				100	64,600	58	7-8-35	
	(Minimum discharge measured)				52.0	33,600	59	12-1-64	
10	Blue	Eminence	Shannon	SENE 21,29,2W					
	(Average of 19 measurements)				107	69,100	-	1923-1965	NPS*
	(Maximum discharge measured)				236	152,000	54	4-24-64	
	(Minimum discharge measured)				62.0	40,100	57	10-10-32	
11	Blue	Mountain View	Shannon	NESE 31,28,6W	7.87	5,080	-	9-25-27	NPS*
					2.00	1,290	-	10- -32	
					6.61	4,270	60	8-20-36	
					18.5	12,000	58	8-24-64	
					3.53	2,280	60	12-1-64	
12	Blue Hole	Greer	Oregon	NWSW 32,25,3W	8.84	5,710	-	10-18-46	
					9.80	6,330	60	8-25-64	
					4.59	2,970	58	12-2-64	
13	Boiling Sand (1)	Round Spring	Shannon	NWNE 4,30,5W	.50	323	58	1-17-64	NPS*
14	Boiling Sand (2)	Round Spring	Shannon	NWNE 4,30,5W	12.1	7,820	58	1-17-64	NPS*
					12.9	8,330	54	8-24-64	
					12.7	8,200	57	11-30-64	
15	Boiling Sand (3)	Round Spring	Shannon	NWNE 4,30,5W	3.41	2,200	58	1-17-64	NPS*
					3.72	2,400	58	8-24-64	
					3.92	2,530	57	11-30-64	
16	Boze Mill	Bardley	Oregon	SESE 9,23,2W					
	(Average of 10 measurements)				23.0	14,900	-	1925-1966	
	(Maximum discharge measured)				46.0	29,700	59	7-20-66	
	(Minimum discharge measured)				13.0	8,400	-	8-13-25	
17	Cave	Akers	Shannon	SWSE 28,31,5W	72.5	46,800	-	6-22-24	NPS*
					25.4	16,400	58	11-30-39	
					15.7	10,100	58	8-24-64	
					15.9	10,300	57	11-30-64	
18	Cave	Chilton	Carter	NWNW 8,26,2E	1.25	808	-	5-14-54	Stock
					1.85	1,200	57	11-30-64	
19	Cave	Hunter	Carter	SWNW 19,26,2E	2.14	1,380	57	7-26-34	Picnic area, old dam and mill, stock, NPS*
					1.17	756	58	8-11-36	
					1.34	866	58	1-24-64	
					1.88	1,210	57	8-27-64	
					2.53	1,630	56	11-30-64	
20	Cedar	Grandin	Carter	SWSE 2,25,1E	.58	375	-	8-11-46	NPS*
					1.75	1,130	60	8-26-64	
					.96	620	58	12-1-64	
21	Cement	Hunter	Carter	SWNE 8,26,2E	.68	439	57	5-14-54	Private club, trout fishing lake
22	Clark	Van Buren	Carter	SWSW 23,27,1W	.57	368	61	10-24-63	
					.41	265	60	8-26-64	
23	Clear	Van Buren	Carter	SWNW 36,28,1W	.96	620	-	11-14-42	Stock
					.09	58	61	10-24-63	
					.11	71	60	8-26-64	
					.13	84	59	11-30-64	
24	Clear	Willow Springs	Texas	SENE 19,28,8W	.89	575	59	12-3-35	Domestic
					1.15	743	59	8-20-36	Stock
					.78	504	-	12-2-64	
25	Cove	Eminence	Shannon	NESW 9,29,2W	3.7		-	-	Stock, NPS*
					.02	2,390	-	11-18-42	
					no flow	13	56	8-25-64	
							-	12-3-64	
26	Dazey	Van Buren	Carter	NWSE 22,28,1W	1.27	820	57	11-19-42	NPS*
					.19	123	59	8-26-64	
					.25	162	58	11-30-64	
27	Dennig (lower)	Greer	Oregon	SESW 32,25,3W	7.38	4,770	58	10-18-46	Stock
					15.0	9,690	60	8-25-64	
					8.87	5,730	58	12-2-64	
28	Dennig (upper)	Greer	Oregon	SWSE 32,25,3W	3.06	1,980	59	10-18-46	
					2.76	1,780	59	8-25-64	Stock
					2.76	1,780	58	12-2-64	
29	Ebb and Flow	Van Buren	Carter	NWSE 6,26,1E	.41	265	56	5-19-39	NPS*

Table 7 *(continued)* . . . . .

Location No. (fig. 23)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
	Ebb and flow (cont.)				A	A	-	9-29-64	
30	Ebb and Flow	Eminence	Shannon	SWSW 19,30,4W	no flow	-	-	12-2-64	Stock, NPS*
31	Ebb and Flow	Eminence	Shannon	NWSW 9,29,3W	.14	90	-	11-18-42	Stock
					.04	26	-	10-25-63	
					.05	32	57	8-25-64	
					.02	13	57	12-3-64	
32	Emerald	Round Spring	Shannon	SWNW 7,30,4W	.04	26	-	-	NPS*
					.12	78	57	8-24-64	
33	Falling	Greer	Oregon	NWNW 4,25,3W	.14	90	-	9-8-44	
					.29	187	57	8-27-64	
					.16	103	55	12-2-64	
34	Fire Hydrant	Round Spring	Shannon	NWNE 4,30,5W	2.00	1,290	-	1-17-64	Camping, NPS*
					4.08	2,640	58	1-31-64	
					5.39	3,480	58	8-24-64	
					5.49	3,550	58	11-30-64	
35	Flat	Mountain View	Howell	SENW 12,25,7W	.31	200	56	6-6-66	
36	Gang	Eminence	Shannon	Lot 8, NW 1,29,3W	.77	497	-	11-18-42	Stock
					.74	478	60	8-25-64	
					.78	504	59	12-3-64	
37	Graham	Thomasville	Oregon	NE 6,24,4W	.30	194	-	8-15-25	
38	Gravel	Eminence	Shannon	C 4,28,1W	15.0	9,690	-	6-1-34	Camping, fishing, NPS*
					30.0	19,400	-	8-7-36	
					12.0	7,750	58	10-24-63	
					13.8	8,910	58	8-26-64	
					13.2	8,530	58	12-1-64	
39	Greer	Greer	Oregon	SESW 36,25,4W	(See page 105 for data on flow)				Private lodge
40	Highly	Bunker	Dent	NESE 33,32,3W	3.51	2,270	-	10-13-32	Stock
					3.84	2,250	58	8-6-36	
					3.90	2,520	-	8-24-64	
					4.46	2,880	56	12-4-64	
41	Huff	Greer	Oregon	SESE 31,25,3W	.78	504	-	10-18-46	Domestic
					.50	323	58	8-25-64	Stock
42	Jakes Valley	Doniphan	Ripley	SWSE 27,25,1E	.60	388	-	12-17-45	Stock
					.57	368	-	8-11-46	
43	Jordan	Hunter	Carter	NESW 24,26,1E	11.8	7,620	-	7-26-34	Stock, NPS*
					7.66	4,950	60	8-11-36	
					11.5	7,430	61	1-24-64	
					13.4	8,660	-	8-27-64	
					15.5	10,000	57	11-30-64	
44	Little Mill Cr.	Van Buren	Carter	SWNE 7,27,1W	.82	530	59	10-25-63	
					.97	627	60	8-27-64	
45	Lone Elm	Round Spring	Shannon	NENW 20,31,4W	.15	97	60	8-26-64	Stock
46	Mammoth	Mammoth Spring	Arkansas		240	155,000	-	12-11-24	Electricity
					310	200,000	-	6-11-26	
					431	278,000	-	4-28-42	
					281	182,000	60	8-28-64	
47	McCormack	Winona	Oregon	SENE 23,25,4W	.16	103	56	10-12-65	Picnic area
					.12	78	57	12-10-65	Forest Service
48	McCubben	Mountain View	Shannon	E½W½Lot 1, NW 6,27,6W	2.37	1,530	-	9-25-27	NPS*
					.78	504	-	10-16-32	
					.40	258	59	8-30-36	
					.12	78	59	8-23-64	
					.72	465	57	12-1-64	
49	Midco	Fremont	Carter	SESE 22,27,2W	2.70	1,740	-	6-23-28	Domestic
					.25	162	58	8-27-64	Stock
50	Mill Creek	Van Buren	Carter	NWSE 6,27,1W	40.4	26,100	-	11-20-42	Stock
					no flow			11-2-43	
					no flow			10-25-63	
					no flow			11-30-64	
51	Mint	Van Buren	Carter	NENE 19,27,1W	.01	6	-	10-24-63	Stock
52	Montauk	Montauk State Park	Dent	NESE 22,32,7W					
	(Average of 17 measurements)				63.3	40,900	-	1923-1965	State fish hatchery
	(Maximum discharge measured)				123	79,500	-	5-15-39	
	(Minimum discharge measured)				38.2	24,700	58	8-13-34	
53	Morgan	Alton	Oregon	SENE 16,22,2W					
	(Average of 12 measurements)				32.0	20,700	-	1925-1966	Aquatic plant farming
	(Maximum discharge measured)				58.0	37,500	59	7-18-35	
	(Minimum discharge measured)				14.0	9,040	59	10-25-32	
54	Mounty	Licking	Texas	NWSE 25,32,8W	.02	13	-	11-26-63	Stock
					.02	13	-	8-27-64	
55	Onyx	Van Buren	Carter	SWNE 26,27,1W	no flow	-	-	10-24-63	
					no flow	-	-	8-27-64	
56	Panther	Hunter	Carter	SESE 34,26,1E	.61	394	-	8-11-46	Picnic area, NPS*
					.27	174	59	8-26-64	

Table 7 – *DISCHARGES OF SPRINGS (continued) . . . . .*

(Current and Eleven Point River Basins and the Warm Fork of the Spring River)

Location No. (fig. 23)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
57	Phillips	Van Buren	Carter	NWSE 15,25,1E	8.81	5,690	-	8-15-25	Camping, NPS*
					9.00	5,810	59	8-7-36	
					19.3	12,500	-	8-11-46	
					18.3	11,800	60	8-26-64	
					18.6	12,000	59	12-1-64	
58	Posy	Thomasville	Oregon	NENE 3,24,5W					
	(Average of 17 measurements)				1.89	1,220	-	1950-1963	
	(Maximum discharge measured)				4.05	2,620	-	6-22-61	
	(Minimum discharge measured)				.38	245	57	10-22-63	
59	Powder Mill	Eminence	Shannon	NENW 16,29,2W	2.44	1,580	-	11-18-42	NPS*
					5.10	3,290	58	10-25-63	
					6.50	4,200	58	8-25-64	
					6.55	4,230	58	12-3-64	
60	Pulltite	Round Spring	Shannon	SWSE 33,30,5W	30.8	19,900	-	10-3-23	Camping
					142	91,700	-	6-22-24	NPS*
					5.90	3,810	-	10-14-32	
					8.85	5,720	58	1-18-64	
					18.4	11,900	58	8-24-64	
					10.5	6,780	58	11-30-64	
61	Roaring	Round Spring	Shannon	SWSE 20,31,4W	.59	381	58	8-26-64	Stock
62	Round	Round Spring	Shannon	SWNW 20,30,4W	(See page 109 for data on flow)				NPS*
63	Rymer	Mountain View	Shannon	NENE 35,28,6W	.24	155	55	12-1-64	Private club, NPS*
					.48	310	56	10-7-65	
64	Sandboil	Doniphan	Ripley	SWNW 27,25,1E	.65	420	-	12-17-45	
					.61	394	-	8-11-46	
65	Shaffer	Montauk	Dent	SWSE 20,32,6W	3.52	2,270	-	12-17-48	Fish raising
					1.43	923	70	8-27-64	
					1.16	749	47	12-8-64	
66	Slater	Eminence	Shannon	NWNE 1,28,4W	.10	65	-	11-19-42	Stock
					.12	78	59	12-2-64	
67	Smith	Round Spring	Shannon	NENW 20,31,4W	.51	329	58	8-26-64	Domestic, stock
68	Spring Hollow	Grandin	Carter	SENW 15,25,1E	2.50	1,620	-	8-11-46	NPS*
					2.34	1,510	58	12-1-64	
69	Sullivan	Alton	Oregon	NWSE 16,22,2W	5.23	3,380	-	11-6-63	Aquatic plant farming
					6.44	4,160	60	8-28-64	
					6.15	3,970	58	12-1-64	
70	Tile	Grandin	Carter	NWSW 7,26,2E	.22	142	-	5-14-54	Stock
71	Tucker Bay	Doniphan	Ripley	SENW 3,24,1E	36.8	23,800	-	12-18-45	
					47.2	30,500	-	4-19-48	
					34.4	22,200	-	8-11-46	
					30.4	19,600	-	10-15-47	
					33.4	21,600	60	8-25-64	
					32.3	20,900	57	12-1-64	
72	Turner Mill	Alton	Oregon	NESE 3,24,3W					
	(Average of 8 measurements)				2.30	1,490	-	1924-1965	
	(Maximum discharge measured)				3.00	1,940	58	8-25-64	
	(Minimum discharge measured)				1.70	1,100	57	10-5-32	
73	Twin	Doniphan	Ripley	SESE 33,25,1E					
	(Average of 8 measurements)				10.0	6,460	-	1945-1964	Forest Service,
	(Maximum discharge measured)				22.0	14,200	-	4-14-46	recreation
	(Minimum discharge measured)				5.10	3,290	-	6-23-52	
74	Twin	Round Spring	Shannon	SWSW 16,31,4W	12.1	7,820	58	8-26-64	Stock
					9.82	6,340	58	12-2-64	
75	Unnamed	Arroll	Texas	NWNE 29,28,7W	.07	45	59	8-22-64	Stock
					.04	26	56	10-31-66	
76	Unnamed	Arroll	Texas	NW 34,28,7W	.01	6	57	8-23-64	Stock
77	Unnamed	Eminence	Shannon	NESW 9,29,2W	.24	155	-	11-18-42	NPS*
78	Vaugt	Couch	Oregon	16,22,2W	.40	258	-	8-11-25	
79	Welch	Akers	Shannon	SESE 10,31,6W					
	(Average of 10 measurements)				121	78,200	-	1923-1965	Private recreation, NPS*
	(Maximum discharge measured)				331	214,000	-	6-22-24	
	(Minimum discharge measured)				70.0	45,200	58	8-24-64	
80	Whaley	Round Spring	Shannon	SWSE 17,31,4W	.31	200	59	8-26-64	Stock
81	Yoga	Eunice	Texas	NENW 29,30,7W	1.96	1,270	55	3-30-51	Stock

* Administered by National Park Service

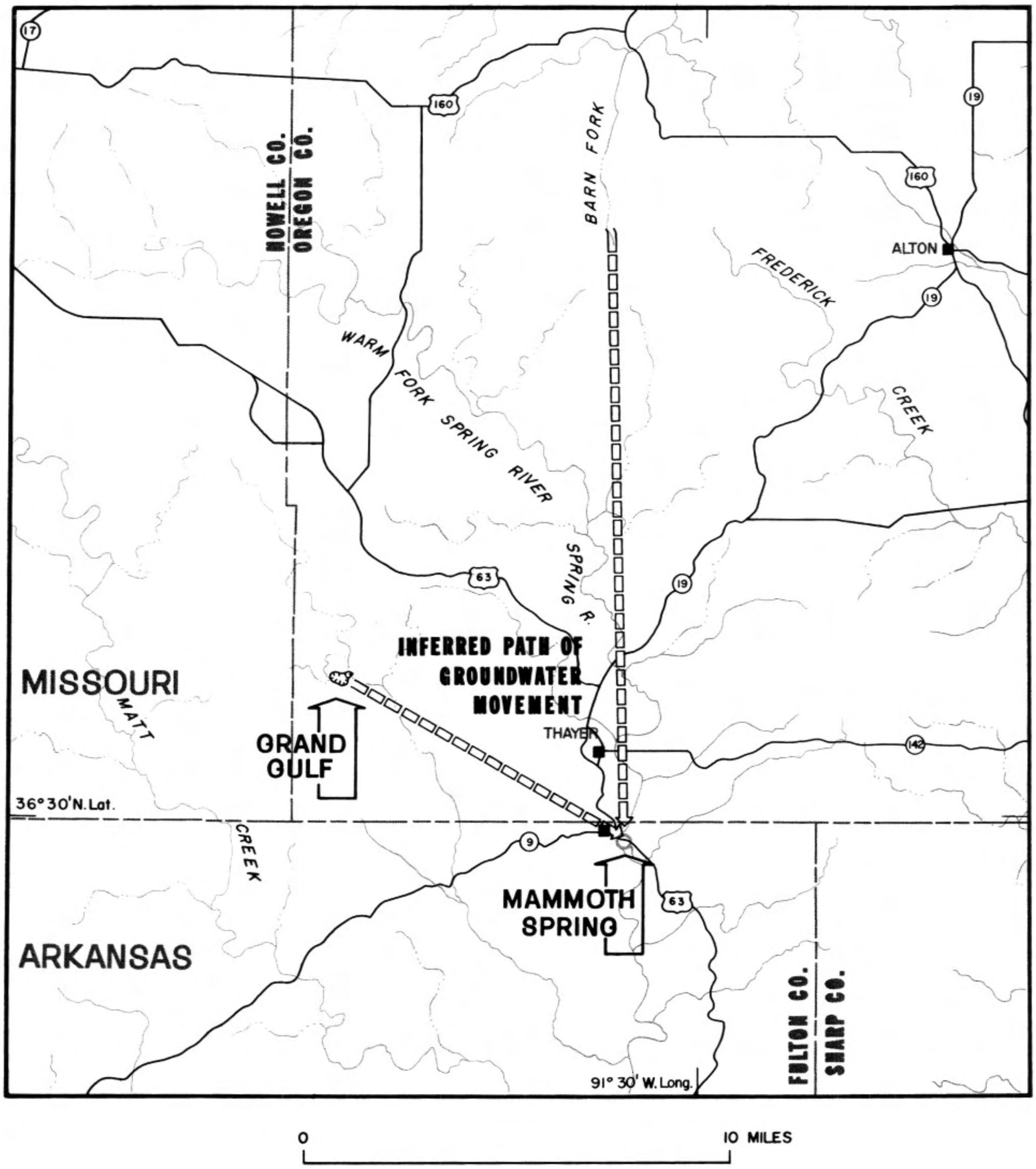


Figure 24

Water-tracing experiments show that Mammoth Spring in Arkansas derives most of its flow from sources in Missouri. Base map from U.S. Geological Survey, Poplar Bluff 1:250,000 scale map.

of the spring lies in Missouri. Beckman and Hinchey discussed the probable recharge area of Mammoth Spring and recounted local stories of water tracing by cornstalks and straw dumped into Grand Gulf near Thayer, Missouri. In 1966 fluorescein dye was traced from Grand Gulf to Mammoth Spring by Toney Aid in a test monitored by Vineyard (Aid, unpub. rept., 1966). Subsequently Aley (written comm., 1972) also traced water from a Missouri locality into Mammoth Spring. The results of these water tracing experiments are shown in figure 24.

Grand Gulf (fig. 25) is one of the most spectacular surface karst features of the Ozark region; it was recently (1972) acquired by a private foundation for eventual donation to a state or federal agency for the enjoyment of the public. Owen (1898; 1970, p. 95-101) gave a colorful description of Grand Gulf as it was in the mid-1880's. At that time it was possible to enter and explore a large underground stream by boat — the same stream that emerges some 9 miles away as Mammoth Spring. Always a careful observer, geologist Owen mentioned (p. 100) the blind white fish in the stream: ***"The small eyeless fish had been noticeable in the water everywhere but now came swimming about the boat in an astonishing multitude, and as unconscious of any possible danger as bees in a flower garden. Having no eyes, they were naturally undisturbed by the light, so the candle could be held close to the water for a satisfactory examination of the happy creatures."***

This fascinating underground river is no longer accessible; according to Hedden (1970, p. 119), a severe storm in the early 1920's washed large trees and other debris into Grand Gulf, effectively closing the river access. In recent years the immense karst valley has impounded water after local rainfall to form a temporary lake for several weeks at a time.

Figure 25

Aerial view of Grand Gulf in dry weather shows an extensive karst valley. The farmland on the upper right is part of the former surface course of Bussell Branch, which now drains into Grand Gulf and thence to Mammoth Spring in Arkansas. After heavy rains Grand Gulf may fill to depths of 50 to 75 feet and remain a temporary lake for weeks at a time. Photo by Jerry D. Vineyard.

QUALITY OF WATER

Springs in the Current and Eleven Point River basins yield a moderately mineralized calcium magnesium bicarbonate water reflecting the dolomitic character of rocks in the basin. The dissolved-solids content of the water ranges from 107 to 301 mg/l (table 8). Variations in dissolved solids are related to changes in spring discharge and are caused by changes in the amounts of calcium, magnesium and bicarbonate in the water. The concentrations of other constituents is fairly low. Hardness of spring waters in the basins ranges from 94 to 315 mg/l. Of the 80

Table 8

CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE CURRENT AND ELEVEN POINT RIVER BASINS AND THE WARM FORK OF THE SPRING RIVER

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[Values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 23)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (NA)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
1	Alley	5-25	88.6	--	5.4	0.17	30	18	4.6		160	4	1.4	5.0	--	0.9	--	148	150	13	---	--	--	5
		6-52	--	58	3.2	.08	32	19	2.1		178	0	2.3	2.8	--	2.8	--	156	158	12	---	7.6	--	3
		6-64	85.7	58	--	--	--	--	--	--	176	0	--	--	--	.0	--	167	---	--	---	7.6	--	-
		8-65	81.5	--	3.8	.05	34	21	1.3		199	0	1.9	3.2	0.0	.6	--	179	170	7	---	8.0	--	1
		2-66	78.4	57	8.0	.03	25	14	1.3	.4	144	0	4.6	1.5	.1	3.0	--	129	120	2	234	7.6	0	0
		5-66	281	57	8.3	.05	21	10	.9	.8	112	0	3.2	.5	.1	2.1	--	107	94	2	190	7.4	3	-
3	Bear Claw	8-64	.67	58	3.3	.10	44	24	2.3		237	0	3.8	3.3	.1	3.7	--	222	210	16	---	8.1	--	-
5	Big	8-25	281	--	6.0	.36	40	22	4.9		225	0	1.0	2.1	--	.3	--	188	192	7	---	--	--	0
	(Carter Co.)	4-52	--	56	5.4	.18	26	16	4.4		150	0	1.1	1.5	.0	1.8	--	138	130	7	---	7.5	--	8
		8-65	287	--	4.2	.06	40	23	1.6		234	0	1.2	3.5	.0	.0	--	201	196	3	---	8.2	--	1
		2-66	306	58	7.9	.02	33	19	1.2	.2	192	0	2.2	.9	.2	.3	--	159	161	3	299	7.5	0	0
		5-66	734	57	7.9	.03	25	11	.7	.7	125	0	3.0	.6	.1	1.9	--	114	108	5	200	7.6	3	-
6	Big(HowellCo.)	6-66	1.41	56	9.5	.02	29	16	1.2	1.2	173	0	5.4	.8	.2	.0	--	158	139	0	279	7.5	0	-
9	Blue	8-25	66.6	--	7.4	.33	53	29	3.5		303	0	1.8	2.4	--	1.1	--	248	253	4	---	--	--	0
	(Oregon Co.)	6-52	--	59	6.8	.10	48	27	3.7		270	0	1.6	2.3	.1	3.3	--	238	232	10	---	7.7	--	5
		8-64	76.3	59	--	.00	51	28	1.6	.8	274	8	2.0	3.0	.0	4.1	.00	247	242	4	454	--	0	2
10	Blue	6-25	--	--	5.6	.32	29	18	3.8		161	6	.4	3.7	--	.5	--	146	146	4	---	--	--	5
	(Shannon Co.,	5-52	--	55	2.6	.05	24	13	3.9		128	0	2.5	1.8	.0	1.7	--	116	114	9	---	7.6	--	4
	nr. Eminence)	8-65	73.6	--	2.6	.06	33	20	3.3		192	0	6.1	9.0	.0	.9	--	182	164	7	---	8.2	--	2
11	Blue (Shannon Co. nr. Mtn. View)	8-64	18.5	58	6.0	1.20	27	15	2.8		134	0	8.6	.8	.1	.1	--	136	129	20	---	7.6	--	-
12	Blue Hole	8-64	9.80	60	1.3	.14	46	26	.8		250	0	6.6	2.0	.0	.0	--	204	222	17	---	7.7	--	-
14	Boiling Sand	1-64	12.1	--	8.2	--	39	17	2.7	.8	199	0	1.2	3.0	.0	1.0	--	178	168	4	314	8.0	5	-
	(No. 2)	8-64	12.9	54	10	.02	32	21	2.1	1.0	193	0	3.8	4.0	.0	1.9	.00	171	167	8	317	7.8	5	0
16	Boze Mill	8-25	12.8	--	8.6	.50	48	26	3.1		273	0	1.2	1.7	--	1.4	--	224	228	4	---	--	--	0
		6-52	--	59	4.4	.05	41	24	5.7		234	0	1.8	2.3	.0	4.7	--	203	201	10	---	7.8	--	3
17	Cave	7-35	--	--	7.6	.07	42	23	4.7		241	0	1.4	1.8	.0	.2	--	223	197	0	---	--	--	-
		6-52	--	57	1.4	.05	37	22	2.0		214	0	2.3	2.3	.0	1.6	--	183	184	8	---	7.7	--	3
		8-64	15.7	58	1.3	.09	44	24	3.9		228	0	9.1	1.0	.0	.0	--	196	207	20	---	8.2	--	-
23	Clear	8-64	.11	60	4.7	.04	60	34	2.3		334	0	2.0	4.5	.0	.0	--	300	290	16	---	7.0	--	2
25	Cove	8-64	.02	56	4.0	.10	53	32	1.6		309	0	3.7	3.7	.0	.0	--	261	264	11	---	7.4	--	2
26	Dazey	8-64	.19	59	1.0	.05	42	25	1.1		250	0	2.4	2.3	.0	.0	--	209	209	4	---	8.0	--	<1
28	Dennig(upper)	8-64	2.76	59	.7	.06	45	24	.6		246	0	7.4	.5	.1	.0	--	212	213	10	---	8.1	--	-
31	Ebb and Flow	8-64	.05	57	5.0	.04	62	38	1.4		347	0	1.6	3.5	.0	.0	--	301	315	31	---	7.3	--	1
33	Falling	8-64	.29	57	--	.05	40	21	1.1	.6	220	0	.4	2.1	.1	.4	.01	187	187	6	346	8.0	3	2
34	Fire Hydrant	1-64	2.00	--	9.7	--	38	18	1.7	1.2	189	8	4.0	4.5	.0	.6	--	183	169	0	318	8.4	5	-
		8-64	5.39	58	7.0	.06	35	21	2.3		199	0	2.5	4.5	.0	1.8	--	184	173	11	---	7.8	--	1

Table 8 – *CHEMICAL ANALYSES (continued) . . . . .*

(Current and Eleven Point River Basins and the Warm Fork of the Spring River)

Location No. (Fig. 23)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (NA)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
35	Flat	6-66	.31	56	9.2	.01	36	21	1.4	1.0	216	0	1.2	1.0	.3	3.5	--	185	177	0	338	7.5	0	-
37	Graham	8-25	.30	--	13	.62	38	21	.0		214	0	.0	1.9	--	1.6	--	182	183	7	---	--	--	1
38	Gravel	8-64	13.8	58	5.4	.04	41	23	1.6		231	0	.7	2.7	.0	.0	--	191	196	6	---	7.3	--	1
39	Greer	8-25	158	--	6.8	.33	39	21	.0		222	0	1.4	1.9	--	1.9	--	182	184	2	---	--	--	0
		9-50	437	--	4.6	.19	36	21	2.3		202	0	3.4	1.9	--	--	--	170	174	8	---	7.4	--	20
		6-52	443	58	3.0	.11	34	20	3.1		192	0	1.4	2.3	.0	3.4	--	170	167	10	---	7.5	--	10
		8-65	174	--	5.2	.04	40	23	3.1		210	12	2.0	4.2	.0	.0	--	201	197	4	---	8.3	--	2
		2-66	265	57	8.6	.02	30	16	1.2	.8	167	0	3.0	.4	.0	3.7	--	159	141	4	262	7.6	0	0
		5-66	584	56	8.7	.09	24	10	.7	1.0	119	0	1.8	1.1	.2	3.1	--	115	101	4	200	7.4	4	-
40	Highly	8-64	3.90	--	.2	.05	46	23	2.6		226	0	3.0	2.0	.0	.0	--	190	211	25	---	7.6	--	<1
41	Huff	8-64	.50	--	1.3	.05	52	28	1.0		290	0	9.5	.8	.0	.0	--	256	246	7	---	8.0	--	-
47	McCormack	2-66	.42	55	8.2	.02	46	26	1.0	0.1	273	0	2.6	0.9	0.2	0.0	--	224	222	0	400	7.8	0	0
		5-66	4.40	55	8.7	.01	38	20	.6	.6	213	0	2.2	.6	.1	.1	--	176	177	2	310	7.6	3	-
52	Montauk	6-25	--	--	2.4	1.3	31	18	5.2		165	8	.2	4.8	--	2.0	--	153	151	3	---	--	--	5
		5-52	--	58	3.5	.07	28	17	6.1		162	0	3.3	3.3	.0	3.4	--	149	139	7	---	7.6	--	2
		8-64	--	57	4.7	.07	38	20	4.1		200	0	4.7	3.8	.0	.2	--	203	180	16	---	8.0	--	-
		11-65	44.1	58	9.2	.00	31	17	2.2	.7	178	0	4.0	2.3	.0	3.4	--	157	148	2	288	7.6	2	-
53	Morgan	8-25	26.0	--	6.6	.38	53	29	1.7		297	0	1.6	2.0	--	1.2	--	242	252	9	---	--	--	10
		5-52	--	60	5.8	.07	47	27	2.8		265	0	2.0	2.0	.0	4.1	--	235	230	12	---	7.8	--	5
		8-65	32.0	--	5.0	1.50	53	30	2.5		301	0	2.4	2.2	.0	1.4	--	262	254	7	---	7.9	--	-
57	Phillips	8-65	8.81	--	5.4	.50	39	22	1.7		222	0	1.6	2.1	--	.0	--	182	188	5	---	--	--	0
		5-52	--	57	3.6	.04	32	19	3.3		185	0	2.4	1.8	.0	.8	--	161	157	6	---	7.6	--	2
		8-64	18.3	60	10	.08	39	22	1.6		221	0	3.0	3.2	.0	.0	--	205	188	6	---	8.0	--	1
59	Powder Mill	8-64	6.50	58	5.7	.04	44	24	7.8		238	0	5.7	9.7	.0	.1	--	227	210	14	---	7.2	--	2
60	Pulltite	7-25	--	--	7.4	.25	33	19	1.4		188	2	.4	2.2	--	.5	--	158	158	0	---	--	--	0
		6-52	--	58	2.8	.09	32	19	2.8		170	0	2.3	2.8	.0	2.0	--	157	156	17	---	7.7	--	5
		1-64	8.85	58	9.1	--	37	17	1.8	.9	195	4	3.2	3.5	.0	1.0	--	180	163	0	322	8.3	5	-
		8-64	18.4	58	11	.02	34	22	2.0	.8	195	0	3.8	4.0	.0	1.2	.01	175	176	16	318	7.8	5	5
61	Roaring	8-64	.59	58	2.7	.16	53	30	2.4		291	0	4.4	1.8	.1	0	--	258	254	16	---	7.3	--	-
62	Round	6-25	--	--	7.2	.28	33	20	4.1		191	6	.6	2.4	--	.5	--	168	165	0	---	--	--	5
		5-52	--	56	4.0	.12	32	19	3.9		185	0	2.7	1.3	.0	1.2	--	162	157	5	---	7.7	--	5
		8-65	14.7	58	1.6	.07	38	22	.9		220	0	1.6	2.7	.0	.0	--	187	185	4	---	8.1	--	2
		2-66	18.0	57	7.5	.01	29	16	1.1	.3	168	0	3.0	1.0	.1	1.5	--	142	139	1	264	7.8	0	0
		5-66	114	56	8.8	.02	26	12	.8	.7	139	0	3.0	.8	.2	1.1	--	127	115	0	220	7.4	0	-
67	Smith	8-64	.51	58	1.3	.09	39	23	2.4		218	0	6.4	2.3	.1	2.7	--	199	192	14	---	7.4	--	-
71	Tuckers	8-64	33.4	60	2.2	.11	36	20	1.4		202	0	2.1	2.5	.0	.0	--	178	173	8	---	7.2	--	1
72	Turner Mill	8-64	2.35	--	7.8	.32	44	24	.0		222	13	1.0	2.7	--	.4	--	201	208	4	---	--	--	40
		6-52	--	57	3.0	.03	42	24	3.2		236	0	.6	2.3	.0	1.0	--	200	202	9	---	7.7	--	1
		8-65	3.00	--	3.8	.03	44	25	1.1		257	0	.6	3.5	.0	.0	.00	217	213	2	---	8.1	--	1
73	Twin (Ripley Co)	8-64	8.30	58	2.0	.14	40	21	2.0		202	0	2.3	2.5	.0	.0	--	182	·185	19	---	7.4	--	2
74	Twin (Shannon Co)	8-64	12.1	--	4.7	.06	41	24	6.5		240	0	4.5	2.3	.0	.0	--	205	202	6	---	7.3	--	-
78	Vaugt	8-25	.40	--	5.0	1.4	42	24	4.5		239	0	2.7	2.5	--	1.3	--	200	202	5	---	--	--	0
79	Welch	6-25	--	--	2.2	.57	36	20	1.2		191	11	.2	4.1	--	1.3	--	171	173	0	---	--	--	5
		6-52	--	57	3.2	.08	35	20	3.1		200	0	1.8	2.0	.0	2.5	--	173	172	8	---	8.0	--	4
		8-64	70.2	58	3.3	.09	44	24	2.3		247	0	6.2	.5	.0	.0	--	204	209	6	---	8.2	--	-

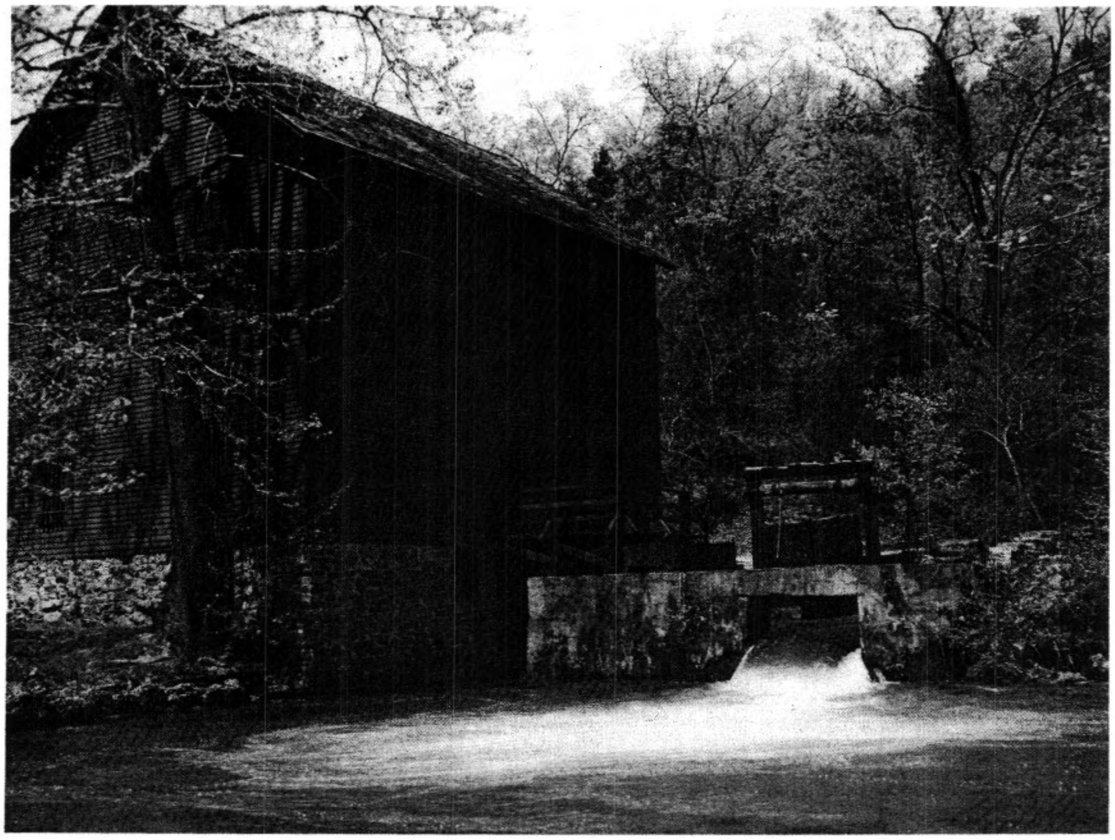


Figure 26

The old red mill at Alley Spring is a well-preserved reminder of pioneer days when spring water-powered mills were numerous in the Ozarks. The waters of Alley Spring, impounded by a rock dam, spin a turbine to power the mill's stone buhrs, which today grind corn and wheat for the enjoyment of visitors to the Ozark National Scenic Riverways. Photo by Jerry D. Vineyard.

hardness determinations, 6 are classed as moderately hard, 34 as hard, and 40 as very hard (see table 3). Iron content of the water ranges from 0.00 to 1.5 mg/l with 63 of the analyses showing less than the 0.3 recommended limit and 14 analyses containing iron in excess of the 0.3 mg/l limit. The nitrate content of spring water throughout the basin is low, ranging from 0.00 to 5.8 mg/l.

DESCRIPTIONS OF SELECTED SPRINGS

ALLEY SPRING, *Shannon County, Alley Spring 7½-minute quadrangle, NW¼ SE¼ sec. 25, T. 29 N., R. 5 W.*

Alley Spring rises in a deep basin at the base of a bluff of Eminence Dolomite and flows past the turbine-well of the Alley Spring mill before discharging into Jacks Fork, about ½-mile away. The spring and grounds formerly were Alley Spring State Park, but are now part of the Ozark National Scenic Riverways.

The old red mill at Alley Spring was used for grinding meal and flour, cattle feed, operating a saw mill, and furnishing electrical power for nearby houses (fig. 26). In recent years the mill served as a concession stand for the park. The National Park Service plans to restore the mill to partial operation to produce stone buhr-ground corn meal and flour for sale to visitors.

Beckman and Hinchey (1944), Bretz (1956), and others have given detailed descriptions of Alley Spring. Bridge (1930) reported that the spring was

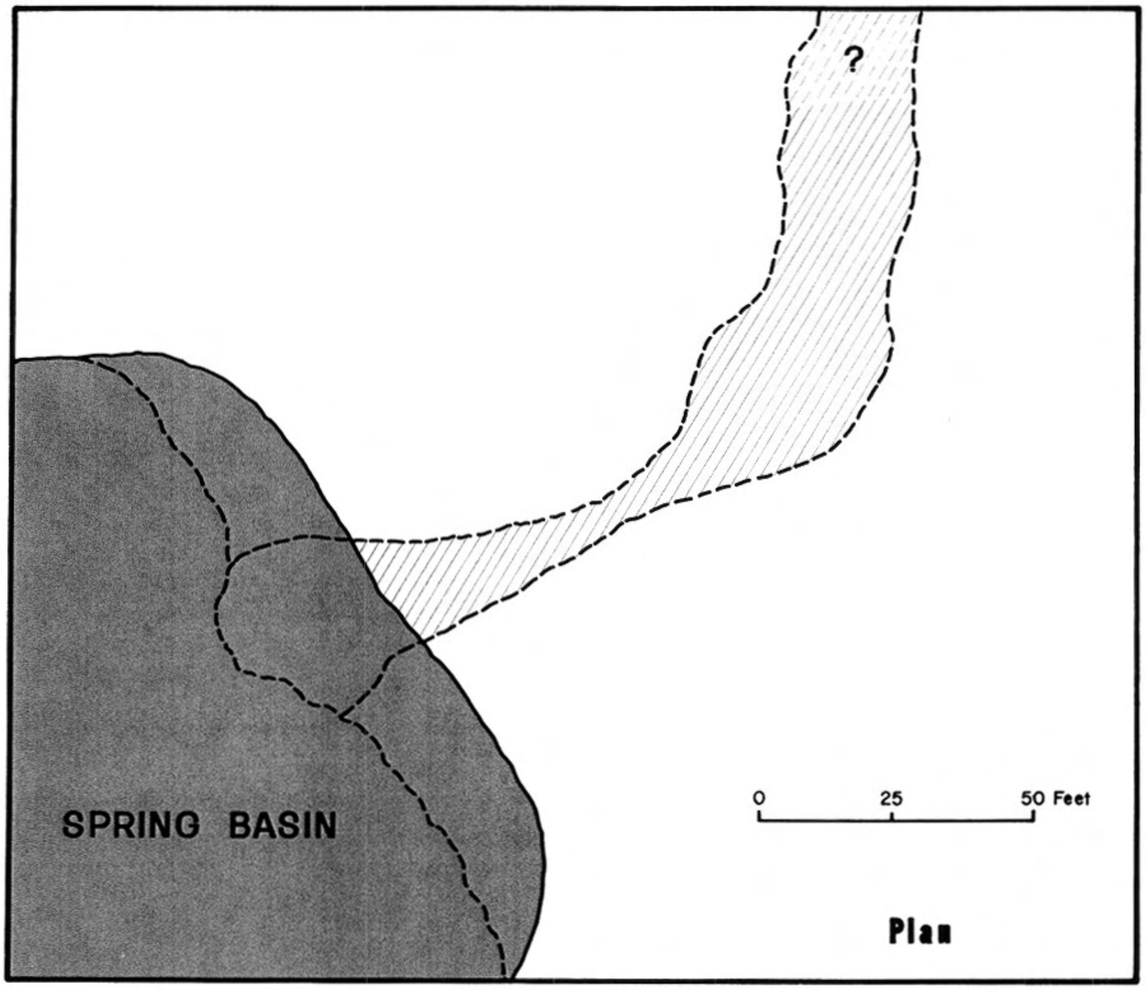


Figure 27a

Plan drawing of Alley Spring prepared by the St. Louis Underwater Recovery Team showing the spring basin, normally the only part of the spring visible to visitors.

once observed to cease flowing for about 12 hours. The water level decreased rapidly and sank to about 5 feet below normal pool level. After about 12 hours the water level rose and flow resumed, but the spring was quite muddy for several days thereafter. At approximately the same time a large sink formed in the upland about 15 miles northwest of the spring. Bridge does not record the date of the temporary interruption of the flow, nor the location of the sink, but it was generally supposed that the problem was caused by temporary blockage of the spring supply channel by the sinkhole collapse.

The St. Louis Underwater Recovery Team explored Alley Spring in April 1960 (Dr. R.W. Shelby, written comm.). They reported the deepest part of the spring basin to be 32 feet deep. At this point they found an opening to the spring conduit and were able to descend to a depth of 100 feet in a horizontal distance of about 150 feet. The opening to the spring conduit was measured as 15 feet wide and 10 feet high, it is floored by well-worn chert gravel. The tubular channel descends at an angle of about 25 degrees. Diagrams produced by the Underwater Recovery Team are shown as figure 27.

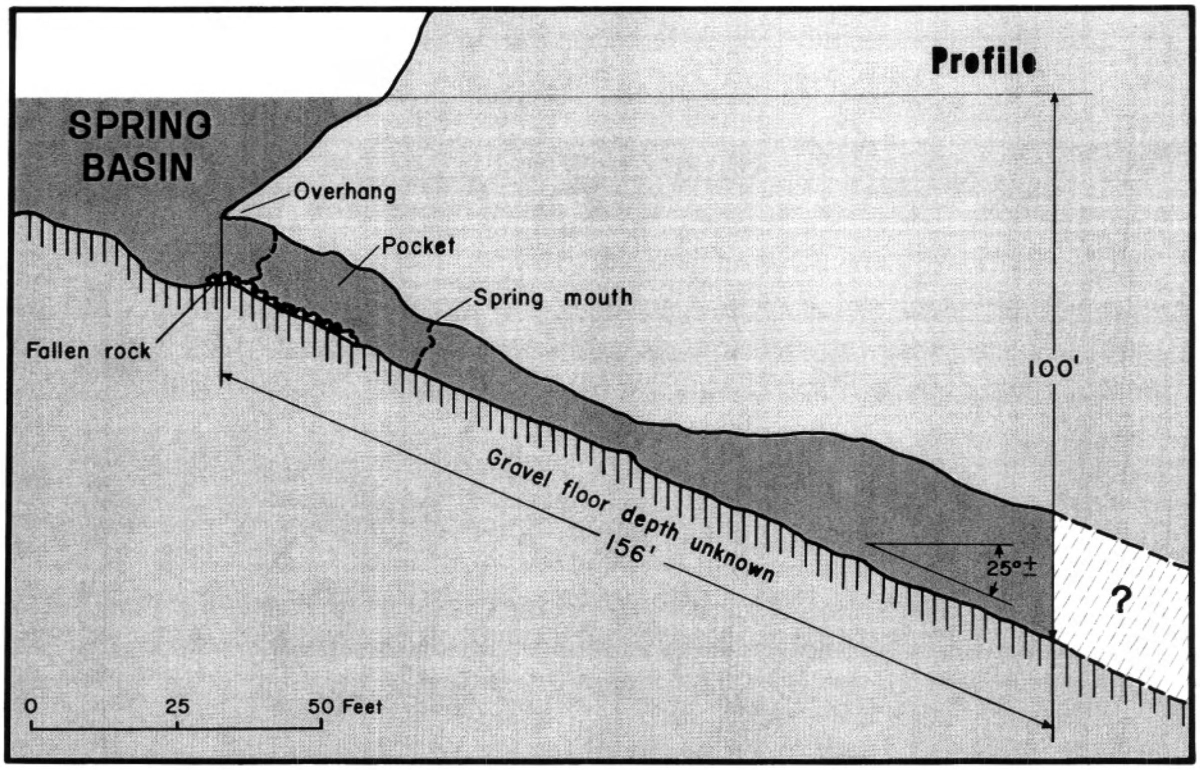


Figure 27b

Profile drawing of Alley Spring prepared by the St. Louis Underwater Recovery Team showing the relationship of the spring basin to the tubular channel that supplies water to the spring.

Records of daily flow of the spring have been collected from October 1928 to September 1939, and from October 1965 to the present. During this period the average flow has been as follows:

	Date	cfs	Gallons per day
Maximum	March 11, 1935	1,060	685,000,000
Minimum	October 15-18, 1934	54	35,000,000
Average	16-year record	125	81,000,000

BIG SPRING, *Carter County, Big Spring 7½-minute quadrangle, NW¼ NE¼ sec. 6, T. 26 N., R. 1 E.*

The name is hardly necessary; the normal appearance of Big Spring is inspiring in its power and magnitude, and in flood it is awesome (fig. 28). Boiling upward from the wreckage of the cave outlet, the waters of Big Spring emerge as a river and flow about 1,000 feet to join the Current River. Big Spring is the largest spring in the Ozark region of Missouri and Arkansas. Its ranking in comparison with other large springs of the world is shown on table 2.

Records of daily flow of the spring have been collected since 1921. During this period (1921-1970) the flow has been as follows:

	Date	cfs	Gallons per day
Maximum	June, 1928	1,300 (est.)	840,000,000
Minimum	October 6, 1956	236	152,000,000
Average	49-year record	428	276,000,000

Big Spring was for many years the pride of Missouri's state park system, included in a 5,836-acre park that offered abundant and varied recreational opportunities. In 1971 the state transferred Big Spring, Alley Spring and Round Spring State Parks to the Federal government to be included in the nation's first national scenic riverway. The Ozark National Scenic Riverways was formally dedicated at Big Spring on June 10, 1972, by Tricia Nixon Cox, daughter of the President, who "christened" the park by tossing a bouquet of flowers into the surging waters of Big Spring.

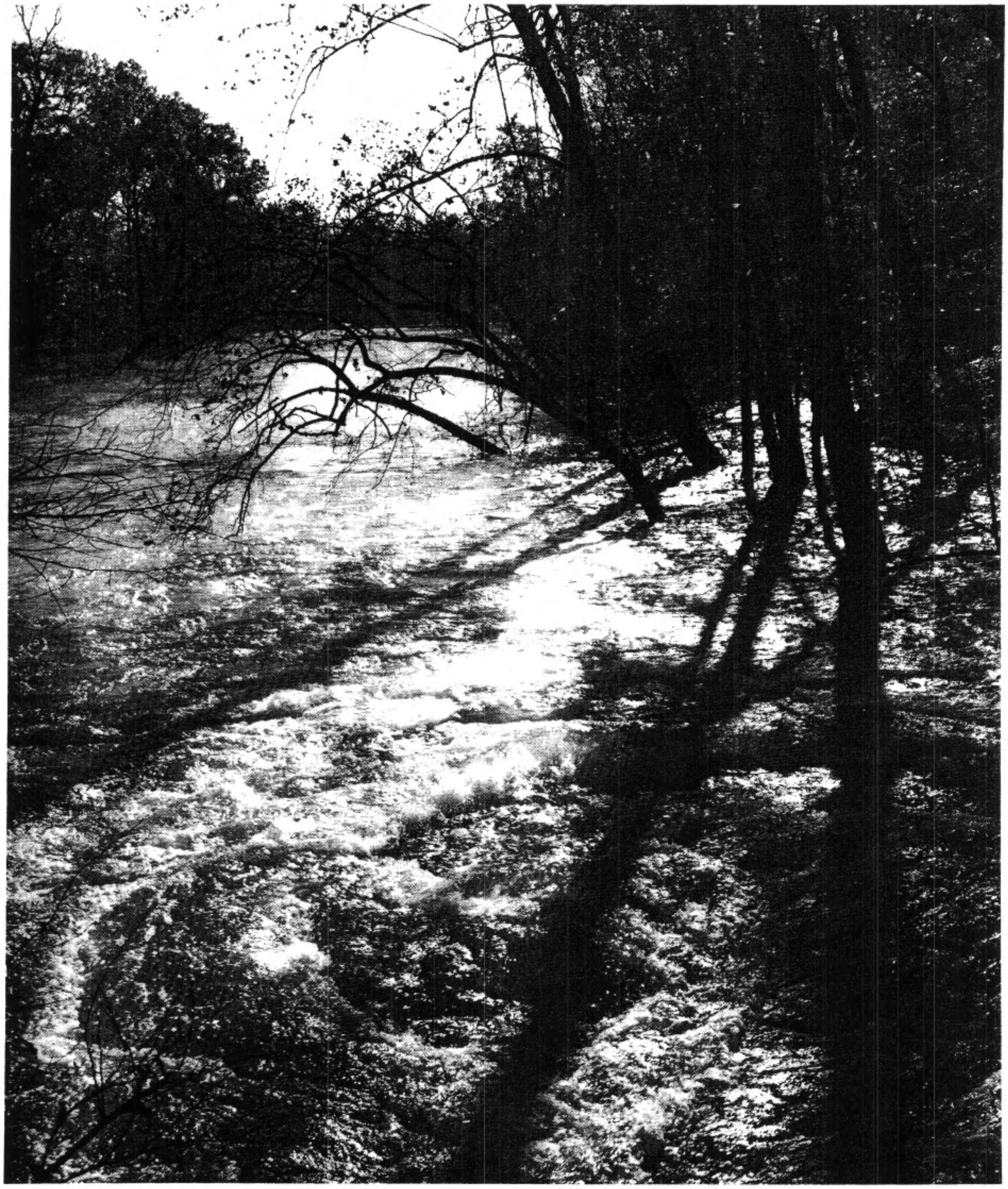


Figure 28

Big Spring during the flood of November 1972. Backwater from the Current River covers the spring but fails to suppress the boils. Because of the backflooding, peak discharge of Big Spring can only be estimated. Photo by Jerry D. Vineyard.

Big Spring rises from the Eminence Dolomite through a jumble of giant boulders that forces the water to flow through the openings between the rocks, thus causing the dramatic "boil" at the spring orifice. A closer look at the springhead area shows that a massive collapse has occurred. Ramparts of what may once have been an enormous underground rise chamber remain as bluffs immediately north and just south of the spring, but between the bluffs there is a westward trending slope of jumbled boulders and talus that Bretz (1956, p. 130) termed "cave wreckage" (fig. 29).

About one-third of the way up the slope, amidst large breakdown boulders, is the entrance to a small pit cave (now closed to visitors) that can be entered with the aid of ropes giving access to a small room through which part of the Big Spring river flows. Here the water is quiet, but it moves swiftly toward the orifice; the roar of emerging waters can be heard inside the cave. Divers of the St. Louis Underwater Recovery Team entered Big Spring through this relatively quiet pool to explore the conduit system channeling water to the spring orifice. They also descended into the main boil area of the spring, searching carefully for "dead spots" in the powerful current. Neither effort was successful in getting past the breakdown into the undisturbed conduit system of the spring, though one diver reported a tantalizing glimpse of immense caverns beyond. The water and air-filled caves beyond the spring orifice must be very large. Grawe (1945, p. 181) calculated that, during an average day, Big Spring removes in solution about 175 tons of calcium carbonate, the chemical constituent of limestone. Therefore, in a year's time enough bedrock (640,000 tons) is removed to form a cave passage 30 feet high by 50 feet wide and 1 mile long. Of course this material is not removed as a unit, but is distributed throughout the ramifying system of solution channels that comprise the "total" spring. It is instructive to note that the Big Spring system is now larger than it has ever been in the past and that the rate of growth is also greater than ever before, simply because each year the feeder system grows larger by the removal of rock by groundwater solution and, each year, more rock is exposed to the dissolving action of groundwater. Vineyard (1965) used the term "cave factory" to emphasize the concept of contemporary development of cavern systems by the deep springs of the Ozarks.

There has been much speculation about the source of waters flowing from Big Spring. Though it has long been recognized that the water is from relatively local sources, little work had been done until recent years to identify specific sources. Bridge (1930, p. 40) reported the contamination of the spring from chemical wastes discharged into the dry valley of Davis Creek from the Midcontinent Iron Company at Midco, a few miles north of Fremont and about 10 miles from Big Spring. The iron furnace and chemical plant ceased operation in 1921 and the spring soon cleansed itself. Bridge's further remarks concerning sinkholes that might contribute to the flow of the spring encouraged speleologists to hunt for air-filled parts of the supply system, in optimistic contrast to Bretz's remark (1956, p. 41): *"Not for many centuries yet will any human enter this aqueduct — not until the Current River has deepened its valley enough to drain the cave, or conducting 'tube' for the huge spring."*

The most meaningful efforts to delineate the Big Spring underground watershed have been by the use of water tracers by Tom Aley, Forest Hydrologist with the Mark Twain National Forest. In the mid-1960's the Hurricane Creek Barometer Watershed was established by the U.S. Forest Service to study the hydrological dynamics of a forested watershed in carbonate terrane. Early in the development and instrumentation of the barometer watershed, a water balance study utilizing U.S. Geological Survey stream gaging data showed that the Eleven Point River (to which Hurricane Creek is a tributary) was a deficient stream in terms of runoff that would be expected from its drainage basin. In contrast, the Current River appeared to be delivering more water than would be expected. The difference in discharge between the two basins could approximately be accounted for by the discharge of Big Spring.

A study of the structural geology of the Hurricane Creek watershed (Hilliard, Mark Twain National Forest Memorandum No. 2540, July 1967) revealed prominent joint systems trending approximately N. 70° E. Extending the trend from the central part of the watershed leads to Big Spring. Instrumentation of the watershed had also shown that about 70 percent of the runoff expected from Hurricane Creek was being lost. With this data in mind, Aley began water tracing experiments in 1968 (Mark Twain National Forest Memorandum, July 8) that are continuing to pinpoint sources of water entering Big Spring.

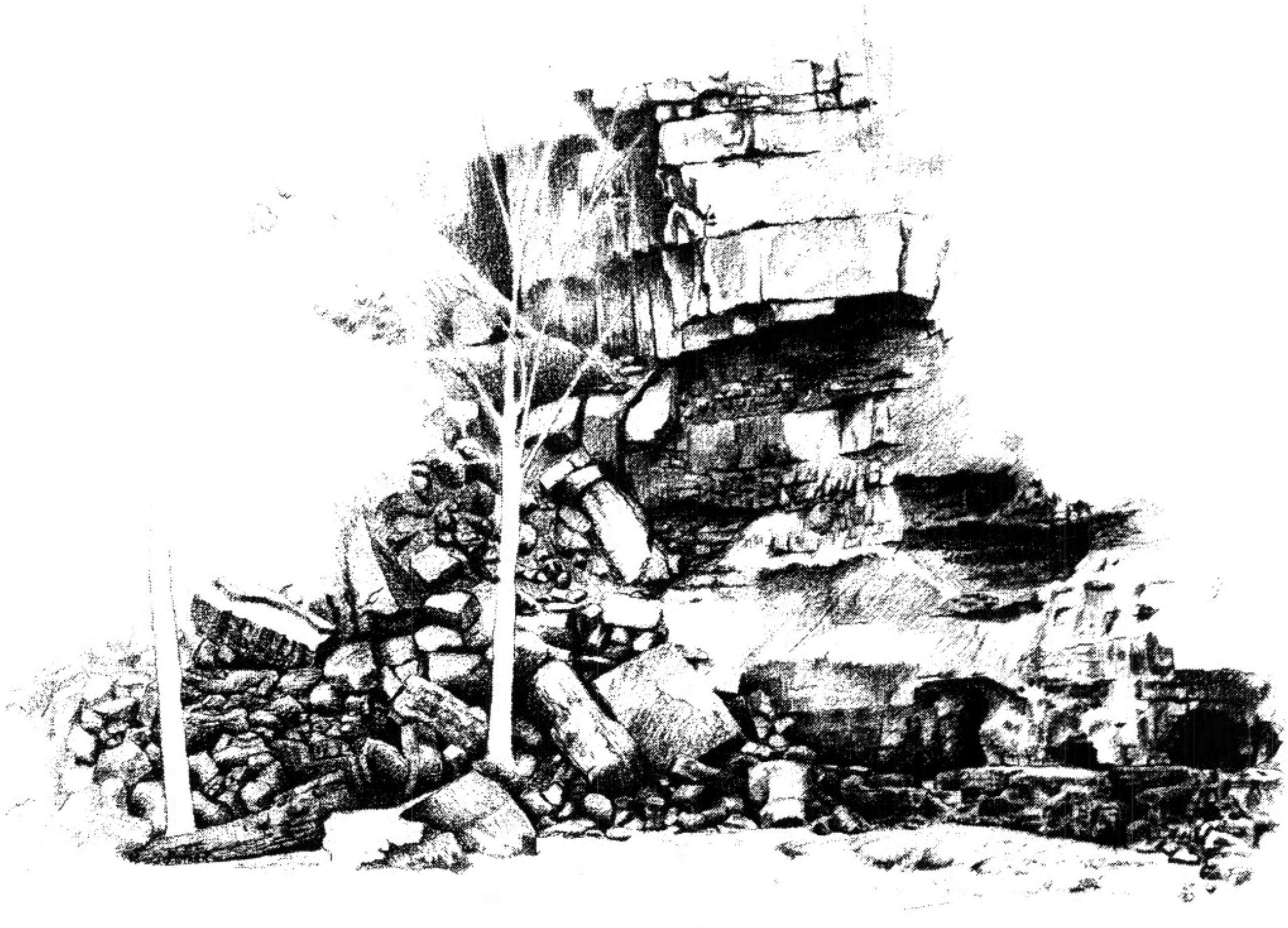


Figure 29

Big Spring rises through a jumble of boulders that comprise the wreckage of the spring orifice. Though most of the flow comes from the main boil, there is a second orifice about 150 feet downstream from the major rise, and during wet seasons several other small springs have been observed rising from the toe of a second talus slope a few hundred feet downstream from Big Spring. Drawing by Douglas R. Stark.

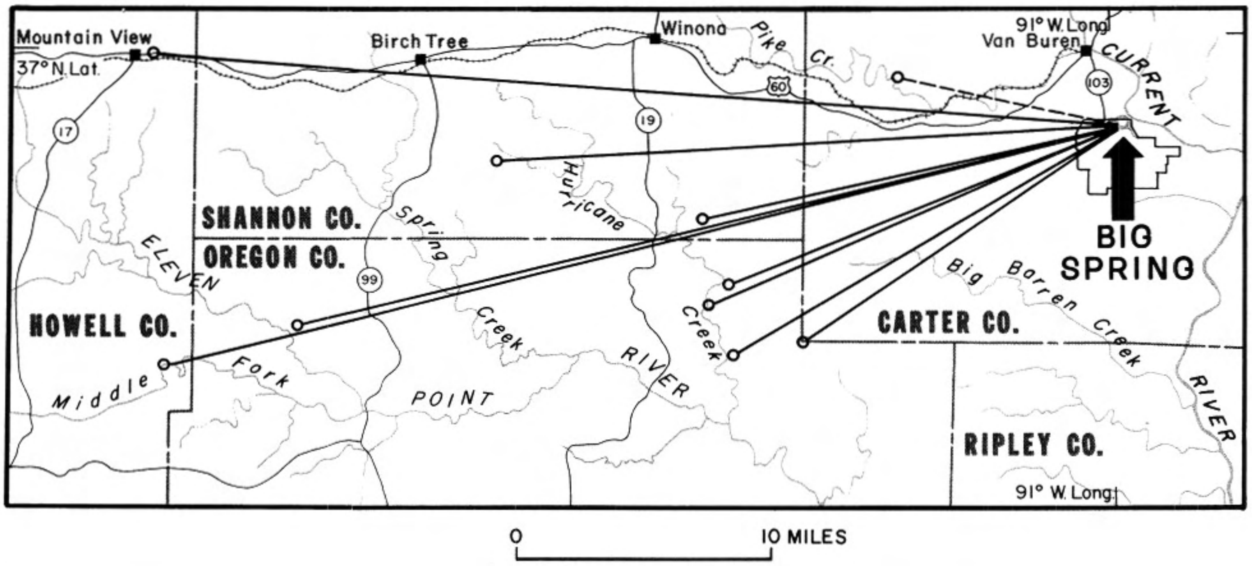


Figure 30

Water tracing experiments by Thomas J. Aley of Mark Twain National Forest, using fluorescein dyes and Lycopodium spores, show that water flows through subterranean channelways to Big Spring from as far as 40 miles away. Solid lines represent successful traces by Alley; the dashed line at the top of the illustration is the contamination reported by Bridge (1930) from the Midco Furnace. Base map from U.S. Geological Survey, Poplar Bluff 1:250,000 scale map.

Aley's water tracing experiments are summarized in figure 30. His first successful traces utilized fluorescein dye, which required 7 to 14 days to travel 17 miles. Subsequent traces have been performed by Aley and his associates. Most recently (1971), *Lycopodium* spores have successfully been used as tracers, proving the vulnerability of Big Spring to bacteriologic contamination (Aley, Mark Twain. National Forest Memorandum, 20 December 1971). In the words of Aley, " . . . *essentially no filtration occurs in the system connecting the two points (Blowing Spring estavella and Big Spring) and that viruses, bacteria, and many protozoans can readily traverse the straight line distance of 17.5 miles.*"

Figure 30 shows that ground water moves toward Big Spring from as far as Mountain View and Hutton Valley – about 40 miles – and that the travel time through the solution channels in dolomite is relatively rapid. Surface stream divides are not coincident with groundwater divides, nor is stratigraphic control a significant factor in groundwater movement. Helwig (1963, p. 35) pointed out that the Big Spring supply system cuts through about 500 feet of rock, including at least one formational boundary, because the structural dip is southwestward off the flank of the Ozark uplift.

Although most of the definitive work on the drainage area of Big Spring has concentrated on areas to the south and west, there remains a large area north and northwest of the spring that probably contributes to the flow. With the concept of a spring as an underground drainage system in mind, it becomes apparent that land management and waste disposal practices in the watershed over a spring system are critically important to the quality of water flowing from the spring orifice.

BLUE SPRING *near Mountain View, Shannon County, Jam Up Cave 7½-minute quadrangle, NE¼ SE¼ sec. 31, T. 28 N., R. 6 W.*

Blue Spring rises from a deep pool in a short cave beneath a high bluff of Gasconade Dolomite on the north bank of Jacks Fork (fig. 31). The name of the spring obviously comes from the deep blue color of the water in the spring basin. The cave entrance is about 75 feet wide and 20 feet high, and during

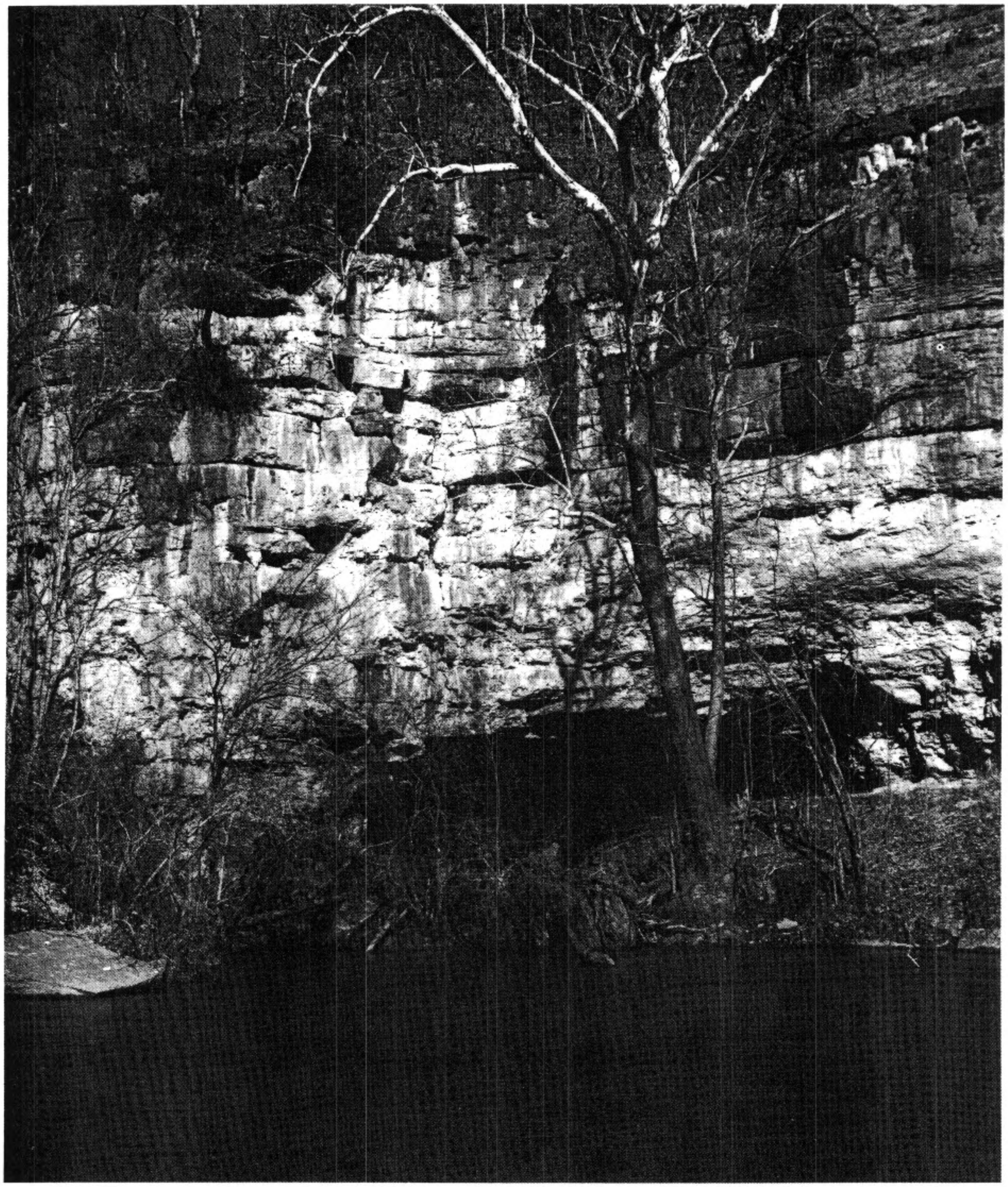


Figure 31

Blue Spring rises in a cave at the base of a high bluff along Jacks Fork. The Gasconade-Roubidoux contact is near the top of the bluff. Discharge measurement is difficult because the spring enters Jacks Fork through the boulders and flood debris to the left of the sycamore tree. Photo by Jerry D. Vineyard.

Figure 32

Blue Spring near Owls Bend in Shannon County, the state's deepest and bluest spring, is said to have been called the "Spring of the Summer Sky" by Indians. Photo by Jerry D. Vineyard.

morning hours the entire cave is lit by sunlight, thereby enhancing the blue color of the water.

A small concrete dam was built across the outflow of Blue Spring in September 1937, according to notations scribed in the concrete of the 4-foot high dam. Since that time, however, about a 15-foot section of the dam has broken down and the spring water flows through a jumble of boulders and logs, the latter washed in by floods on Jacks Fork.

Most of the spring basin is floored by mud and there is no evidence suggesting that the spring flows with great vigor. However, during periods of high water the spring undoubtedly discharges a considerable quantity of water. The catchment area for Blue Spring must lie on the sinkhole-pocked uplands north of the spring.

There is very little water cress in Blue Spring, but blue-green algae forms mats on the floor of the spring and can be observed breaking away and floating to the surface. The presence of the blue-green algae suggests that Blue Spring may be contaminated.

Possible ancestral outlets for Blue Spring are the numerous caves in the vicinity of the spring. Just downstream, there is a small cave opening at river level from which a small spring emerges. Upstream, in the isolated hill that forms a near-island on the north bank of the river, there is a small cave with an entrance near the top of the rock, with a northward trending passage. The area between this isolated rock and Blue Spring Cave is typical of cave wreckage. A large sinkhole seems to have developed, pirating water from a surface valley through ancestral Blue

Spring to emerge at river level in Jacks Fork. This sinkhole developed over a period of time and the rock intervening between the lost hill and Blue Spring Cave was eroded away, leaving behind a narrow cleft in the bluff. Evidence of extensive solution work is present in the cleft, whose walls are lined with spongework. Several caves in the east and north walls of this sinkhole-like opening may once have been outlets for Blue Spring. There is still another cave entrance slightly higher than Blue Spring, between Blue Spring Cave and the cleft in the bluff mentioned earlier.

BLUE SPRING *near Owls Bend, Shannon County, Powder Mill Ferry 7½-minute quadrangle, SE¼ NE¼ sec. 21, T. 29 N., R. 2 W.*

There are many Blue Springs in Missouri, but this is the largest and the bluest spring with that name in the state. It is also the deepest known spring in the Ozark region, with an explored depth of 256 feet (Paul Laws, pers. comm.). Ranking sixth in size with an average flow of 90,000,000 gpd, Blue Spring is in a remote and picturesque setting (fig. 32) south of Owls Bend on the Current River. The spring rises quietly beneath a bluff of Eminence Dolomite and flows swiftly toward the Current about ¼-mile away.

Many divers, notably members of the St. Louis Underwater Recovery Team, have explored Blue Spring. The tubular orifice of the spring plunges at a steep angle beneath the bluff. It is this steep angle and extremely deep water that heightens the deep blue color of the spring. The maximum depth reached by divers may not represent the total depth of the spring; divers report that only the technical problems of descending to such depths prevent further exploration of the conduit system that feeds Blue Spring.

Bridge (1930, p. 40) suggested on the basis of his field work and observations from local inhabitants that Blue Spring would rise following rain in the Logan Creek watershed, but not after rains in the valley of Carr Creek, and that much of its flow came from Logan Creek several miles northeast of the spring. Feder and Barks (1972) confirmed Bridge's supposition by injecting dye at the beginning of a losing reach of Logan Creek near the Latter Day Saints Church in NE¼ sec. 14, T. 30 N., R. 2 W., and recovering it in Blue Spring.

The vulnerability of large springs to contamination from surface sources is extremely well illustrated by this trace. The entire flow of Logan Creek is pirated to underground channels through sinkholes and other karst features in the bed of the stream. Therefore, any contaminants introduced into Logan Creek can easily be transported beneath the surface divide into Blue Spring (fig. 33).

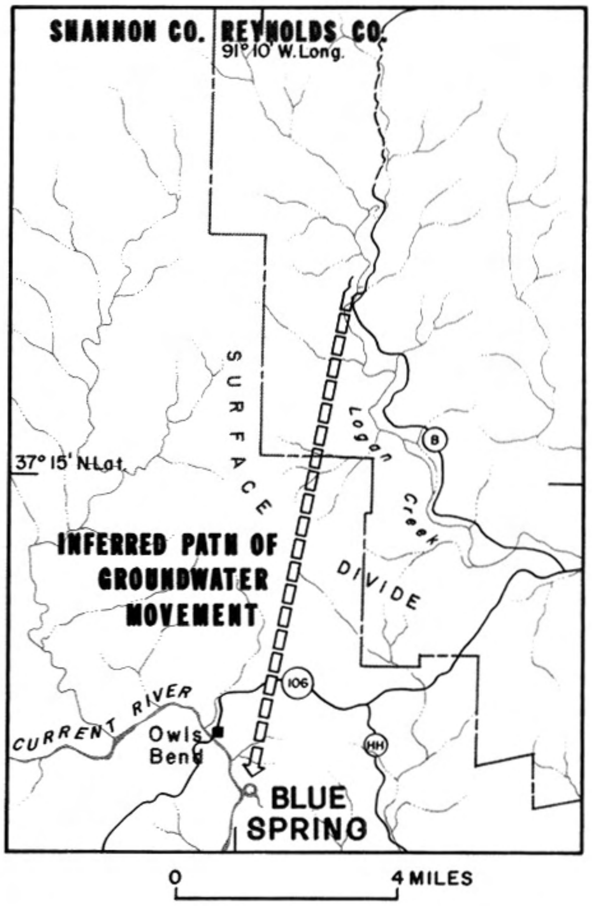


Figure 33

Water tracing experiments have shown that water lost in the bed of Logan Creek travels beneath a surface divide to reappear in Blue Spring. Therefore, land management and waste disposal practices in the valley of Logan Creek can have a direct effect on the water quality of Blue Spring.

CAVE SPRING *near Akers, Shannon County, Round Spring 7½-minute quadrangle, SE¼ SW¼ sec. 28, T. 31 N., R. 5 W.*

Bretz (1956, p. 441-444) first suspected the true nature of Cave Spring and its supply system. He examined the spring orifice in detail but he erred in measuring the true depth of the spring, apparently because his sounding line struck a rock ledge about

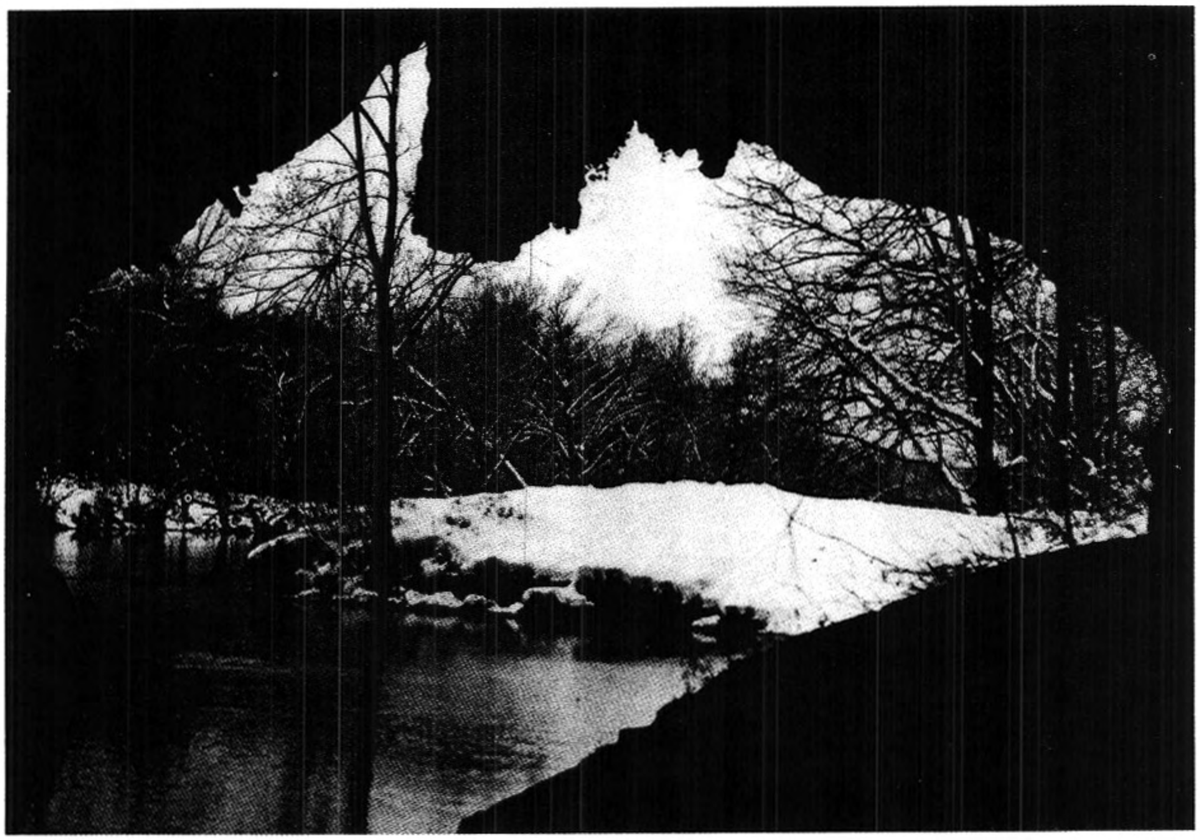


Figure 34

Cave Spring, a winter haven for Current River fish, is also called Fishing Spring. Floods on the Current River sometimes completely fill the cave part of the spring orifice. Photo by Jerry D. Vineyard.

77 feet below the surface. Divers later found the ledge and passed beneath it to the bottom of the spring. Bretz considered the spring an excellent, functioning example of cave origin in the phreatic zone.

Cave Spring issues from a large, near-vertical shaft that leads down to the subterranean conduits channeling ground water to the spring orifice. This natural well permits access, with underwater breathing apparatus, to the water-filled supply network of the spring. Access is also available through a large sinkhole called Devils Well and through a small cave known as Wallace Well. The two wells and other similar, but hypothetical, features serve as direct routes and as reservoirs for surface water entering the spring system.

The fortuitous development of Cave Spring (fig. 34) and its environs has permitted the observation of a cave system in transition from the deep phreatic zone beneath the water table into the vadose zone above the water table. This transition period is the stage of functioning as a spring. Cave Spring rises at the back of a short, discontinuous cave, from a vertical conduit about 30 feet in diameter and 155 feet deep (fig. 35).

Bretz (1956, p. 441) described the orifice of the spring and Vineyard (1959, 1963, and 1968) added the results of speleological and hydrological investigations of the system. Divers, using self-contained underwater breathing apparatus, have penetrated to the bottom of the spring (William Cate, oral comm.) and have entered the conduits bringing water to the orifice. The upwelling water in the shaft rises with a slight current but it does not hamper diving operations.

The bottom of the shaft is covered with clean quartz sand. In addition to the sand, there are waterlogged sticks, logs and other organic material. It is not clear whether the organic material was intro-

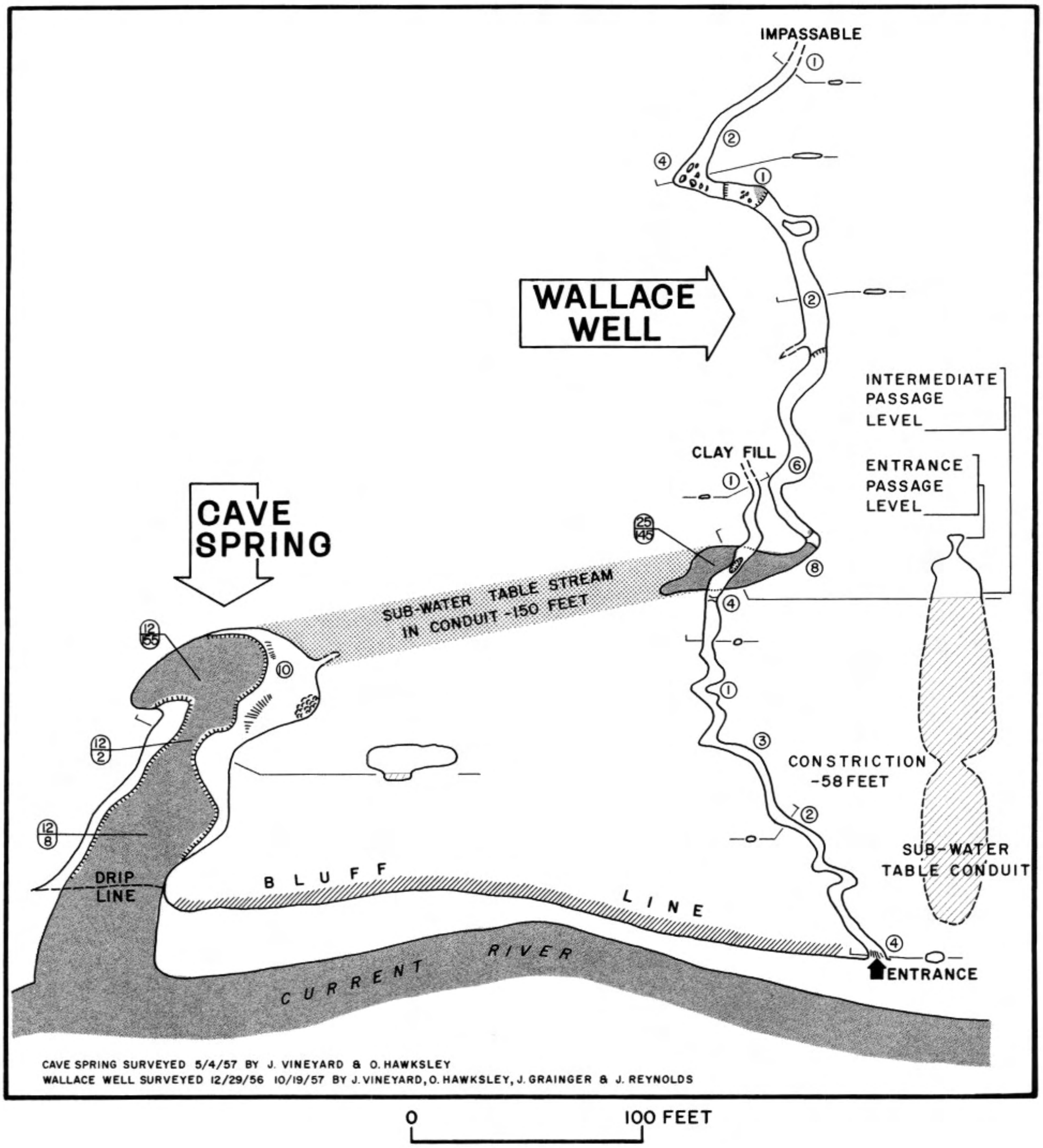


Figure 35

Map of Cave Spring and Wallace Well. Circled numbers are ceiling heights. Symbols $\frac{12}{8}$ indicate ceiling height over water depth. Modified from Vineyard (1963).

Figure 36

Access to the large underground lake known as Devils Well, part of the supply system for Cave Spring, is by electric winch and bosun's chair. A diver is shown here making the 100-foot vertical descent from the bottom of Devils Well sinkhole to the surface of the underground lake. The lake is 400 feet long and impounds more than 20 million gallons of water. Photo by Michael R. Tatalovich.

duced through the spring orifice or through another part of the system such as Devils Well. In 1964, what is thought to be part of a dugout canoe was recovered by divers from the Aqua-Rays Diving Club of Chicago. The wooden object is now in the Archaeological Museum of the University of Missouri at Columbia.

The shaft retains approximately the same dimensions from top to bottom. There are several ramifying passages leading away from the base of the shaft. The dolomite is rapidly being dissolved away, with solution occurring primarily along grain boundaries. Primary, porous chert stands in relief on cave walls as the dolomite matrix is dissolved away. At the base of the shaft a definite current can be felt coming from the direction of Wallace Well, and divers have been successful in swimming between the two features (William Cate, written comm., 1972).

The spring attracts several kinds of aquatic life, probably because of its relatively constant year-round water temperature. Divers have reported seeing hundreds of river fish in the spring during cold weather, and the author has observed bass swimming into the orifice and into the depths of the spring. Sculpins (see p. 40) have been seen in Wallace Well and there are unconfirmed sightings of river fish in Devils Well. Small leopard frogs occasionally swim into Wallace Well via Cave Spring. River salamanders (Hellbenders) are seen in large numbers in the spring during the summer, along with common crayfish. River fish apparently avoid the spring during the summer months.

As it is now known, the spring system appears to derive most of its flow from conduits leading in from the north. It is not known whether water enters the orifice area from south of the Current River. A passage extends beneath the river (William Cate, pers. comm.), but it has not been explored by divers.

The key to the Cave Spring system was discovered in 1956 when the senior author investigated a small, tube-like cave with an entrance only 300 feet downstream from Cave Spring. This small cave, named Wallace Well, enabled investigators to enter an Ozark spring supply system, heretofore generally considered to be completely filled and thus inaccessible except to divers. A hole in the floor of Wallace Well opens into the supply system feeding Cave Spring.

The entrance to Wallace Well is in the same bluff of Eminence Dolomite from which the spring emerges. The entrance elevation is about 10 feet above the Current River and the cave passage rises an additional 10 feet or more before the well room is reached.

The cave is tubelike in character with its largest dimensions at the entrance and in the well room. At the entrance the passage is about 6 feet wide and 4 feet high, but these dimensions decrease rapidly until the cave becomes a crawlway of 2 or 3 feet in width and 1 to 2 feet in height. The crawlway retains approximately the same dimensions for about 300 feet until the passage is abruptly disrupted by a slotlike hole in the floor. Nearly 20 feet down in this hole is a deep lake which apparently has no free-surface outlet.

Beyond this hole in the floor (which can be by-passed), the passage becomes constricted by a rising clay fill. It can be traversed with difficulty for about 50 feet but then red clay fill occupies more than two-thirds of the passage and further progress must wait removal of the fill. The fill does not appear to be a stream deposit, but rather seems to have been laid down in quiet water. The entire cave received a partial clastic fill, but most of the fill has been removed, except that part beyond the collapse area.

Further progress in Wallace Well is possible only by descent on a cable ladder to the surface of the lake in Wallace Well. The lake is drained and replenished through a conduit at the bottom of the lake which links it on the upstream side with Devils Well and on the downstream side with Cave Spring. With a boat it is possible to go from the cable ladder to an intermediate-level passage that leads from the north end of the lake. Another small passage enters the lake from the west wall.

The intermediate-level passage enters the lake chamber approximately at water level. It trends in a general northerly direction and can be traversed for about 200 feet. Unlike the upper-level passage, which is dry and partially filled, the second passage does not seem to have undergone filling; it may be almost entirely vadose in origin. The intermittent cave stream, which flows through the passage during wet weather, apparently derives its flow from water leaking into the system from the permeable bed of the dry valley just north of Cave Spring.

The lake in Wallace Well is about 60 feet long, 30 feet wide and 150 feet deep. Walls of the room appear to diverge beneath the water surface, creating the bottle-shaped profile shown in figure 35. There is a ledge or constriction in the chamber about 60 feet below water level. Wallace Well, with its deep lake, acts as a collection reservoir for Cave Spring, and although only a very small percentage of the flow of Cave Spring comes from the vadose passages of the cave, it is indeed supplying part of the flow.

Devils Well is a large, conical sinkhole about 150 feet in diameter and 40 feet deep which opens into a large chamber containing an underground lake. The awesome Well was entered in early 1955, after the former owner built a heavy timber platform in the neck of the sinkhole and installed a hand-powered winch to which he attached a quarter-inch steel cable and bosun's chair (figs. 36 and 37). The senior author first visited Devils Well in March 1956 for preliminary mapping and reconnaissance. The sinkhole has remained stable long enough for large trees to grow on its inner slopes. A small spring enters the sinkhole from the west, flowing over a chert layer before discharging into the Well. The spring entering the sinkhole contributes a very small part to the total flow of Cave Spring (fig. 38). In dry periods the spring dwindles to a trickle, but it may discharge from 1 to 2 cfs in wet weather.

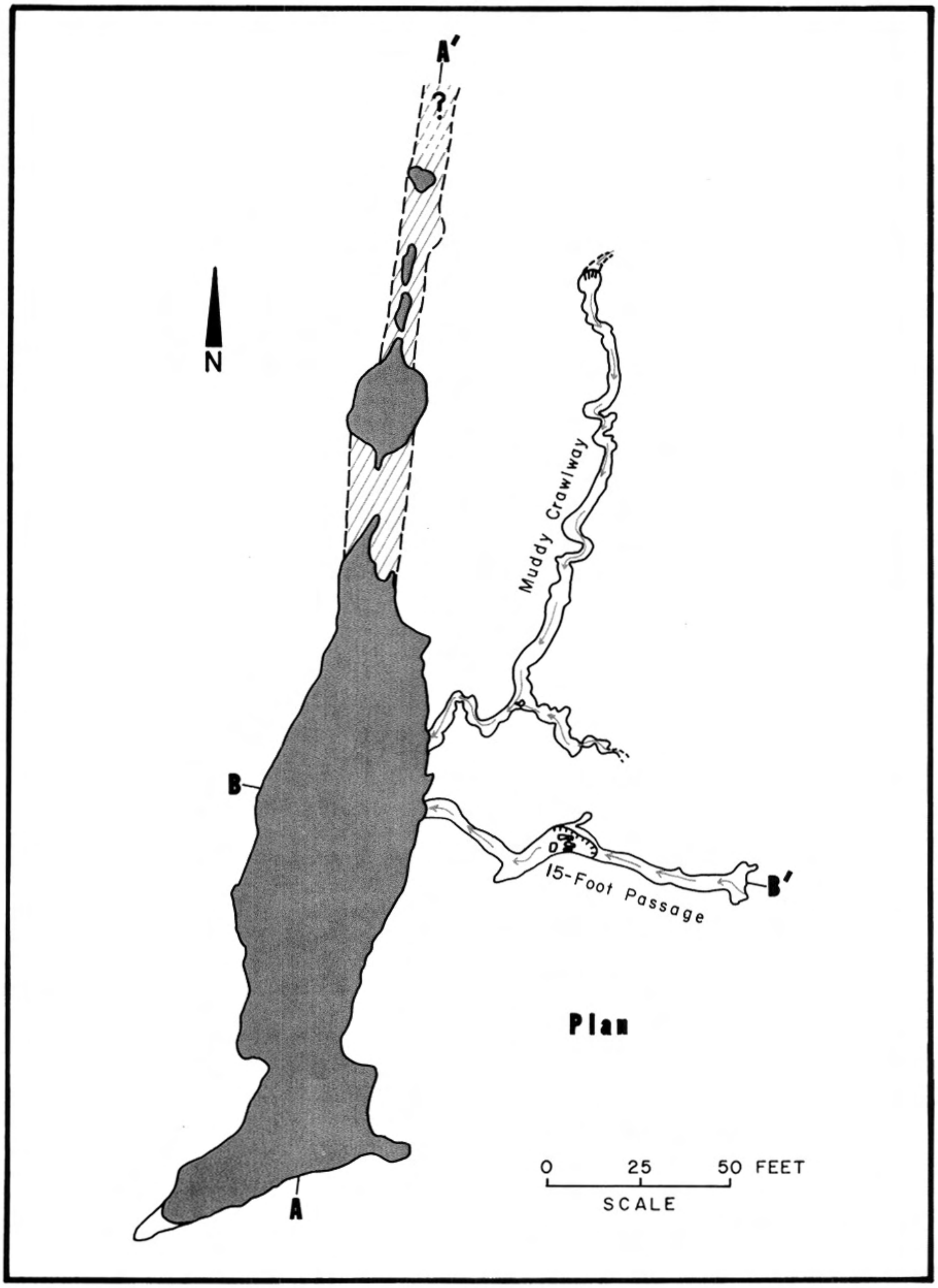
The Gasconade Dolomite crops out in several ledges around the perimeter of the entrance sinkhole. The Gunter Sandstone Member of the Gasconade is exposed in the lower part of the sinkhole and the Eminence Dolomite begins immediately beneath the small rock span at the base of the sinkhole. The Eminence is exposed for about 100 feet downward to the water table and is accessible to divers for an additional 200 feet.

A vertical fault with 2 feet of displacement cuts across the Well, striking due east, displacing the lower part of the Gunter and the underlying Eminence. The fault dies out, however, in the thin, incompetent shale and dolomite beds of the upper part of the Gunter. The opening at the bottom of the conical sinkhole is joint determined, and water from the previously mentioned spring has carved a steplike profile along the opening. A sturdy steel-reinforced timber platform rests over the last step, making a convenient point for entering the Well. Beneath the platform is an immense underground chamber, far larger and deeper than the surface sinkhole above it.

Beneath the entrance slot in the bottom of Devils Well, the walls of an underground chamber diverge to form a bell-shaped profile. This chamber is about 400 feet long and 100 feet wide, with a total vertical range of approximately 300 feet. Water is continually being added to the supply in the lake by four or more waterfalls entering the Well from various points in the ceiling and walls.

The water in Devils Well appears bright green in reflected light. Visibility through the water is often very good with strong lights penetrating from 30 to 50 feet below the surface. The cavity beneath the lake's surface is much larger than the air-filled cavern above the lake. Indeed, the largest part of the Well, the conduit leading to Cave Spring, lies to the southwest of the lake chamber.

The surface of the lake in the Well is actually the local water table. As such, the lake level fluctuates with the groundwater supply. Water marks on the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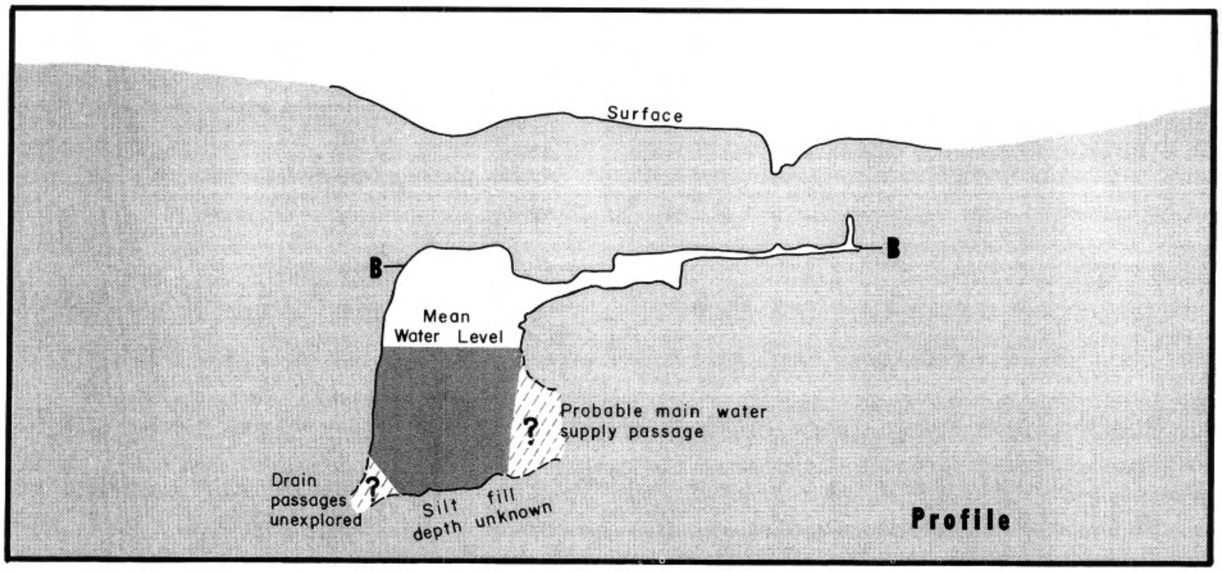


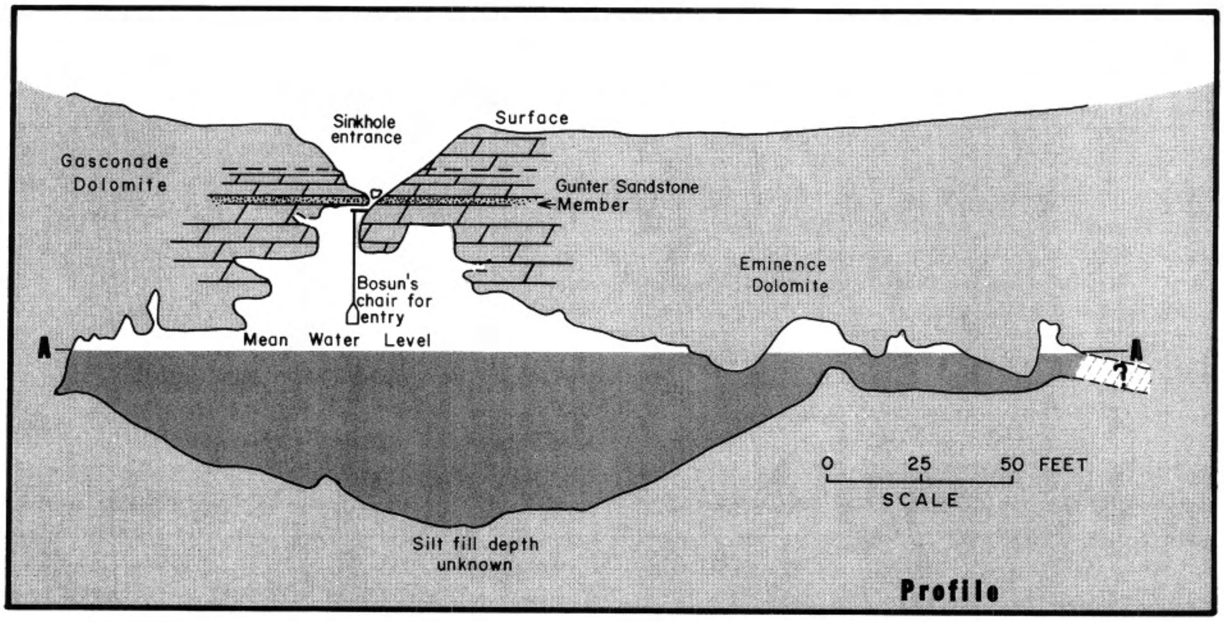


Figure 37

Map and cross sections of Devils Well, showing lake rooms discovered by divers. Entrance to the Well is by electric winch and bosun's chair through the bottom of a large sinkhole. Original survey after Vineyard (1963), with additions and cross sections by Donald N. Rimbach and Michael Tatalovich, Ozark Spring Studies (1973).

walls of the Well and debris collected in various places attest to the frequent changes of water level. Fluctuations of 8 to 10 feet apparently are common with one rise of 30 feet being reported. Turbidity of the water varies over a wide range. After heavy rains the water is understandably turbid because of the influx of sediment and debris from largely unfiltered surface streams. After prolonged periods of dry weather, however, the water becomes remarkably clear.

Water enters the Well from a number of sources above the water table and from unknown sources below the water table. Four waterfalls enter the Well at all times and additional ones appear after heavy rains. These four sources, however, provide only token percentages of the total flow of the spring system. An estimate of one second-foot for the combined flow of the four sources does not seem too large. The remainder of the water to sustain an average spring flow of about 35 cfs comes from other sources. Fluorescein dye introduced into Devils Well in December 1961 reappeared in Cave Spring within one week.

There are nine known cave passages leading from the Well chamber, but only two have been entered. Entrances to the other seven passages are high on the walls of the room, accessible only to those with rock climbing skills or boat-mounted ladders. All of these passages appear to be small. Muddy Crawlway is so named because it is a tight, narrow channel that is half filled with gritty clay and silt over which a stream flows. It can be traversed with considerable difficulty to a canyon section about 400 feet from the entrance in the Well chamber. The canyon section of Muddy Crawlway developed by waterfall recession. The small stream enters the passage over a series of waterfalls. The highest of these, about 15 feet high, can be climbed with the aid of rock climbing equipment. The passage continues above the first fall to a second waterfall, where exploration ceased. Muddy Crawlway and its vadose canyon section comprise a collector channel for water entering the system from a nearby intermittent stream.

In 1960 Vineyard suggested that the Cave Spring supply system was dominated by a series of large subterranean reservoirs of solution-collapse origin. Two of these features, Devils Well and Wallace Well, were known and enterable at the time. The first of the hypothetical reservoir chambers was discovered in 1961 when a diver swam under the north end of Devils Well and into a large chamber similar in size and development to the one from which he had dived. Underwater exploration has also uncovered a vast cavity immediately west of the Well chamber, but diving operations have not progressed far enough to disclose the true size and nature of the cavity.

The south end of Devils Well has a fill of clay and silt which rises to the surface of the lake, forming a small beach. Slow circulation of lake water seems to cause deposition in this area.

Cave Spring and other similar large springs of the Ozarks are often cited as type examples of deep phreatic caves emerging from their zone of origin into the vadose zone, where they are altered by free-surface streams and eventually destroyed. Bretz (1942, p. 752) wrote, *"Subwater-table streams, the result of integration and concentration of drainage somewhat below the water table of droughts, have been the chief agents of cave-making in the Ozarks."* There is no question but that the subwater-table streams (springs) are actively excavating caves and that the present episode of cave-making may be the most intense in the geologic history of the area.

Abundant evidence for an older progression or progressions of cave development occurs elsewhere in the Ozark region. The Tri-State Lead-Zinc district abounds with filled caves, sinks and channels, many of which are mineralized. McQueen (1943) described the filled sink deposits of the fireclay region of east-central Missouri, in which Pennsylvanian fire clays are found in sinks that developed during a pre-Pennsylvanian erosion interval.

Undoubtedly the Eminence Dolomite was subjected to these same pre-Pennsylvanian cave making epochs; caves and sinks must also have developed in the Eminence, although perhaps to a lesser extent than elsewhere. Some of the solution features that developed probably survived subsequent repeated uplifts and submergence until initiation of the present geomorphic cycle.

The greater part of Cave Spring and its supply system are now in the phreatic zone, undergoing enlargement by solution and filling by deposition. The main conduit linking Cave Spring, Wallace Well and Devils Well lies approximately 150 to 200 feet below the water table. It grows larger as the acidulated waters of the spring dissolve away the dolomite of the walls and ceiling of the tube. Filling is in progress in those parts of the spring system where current velocity is very low. The system grows upward and laterally, but not downward. Insoluble

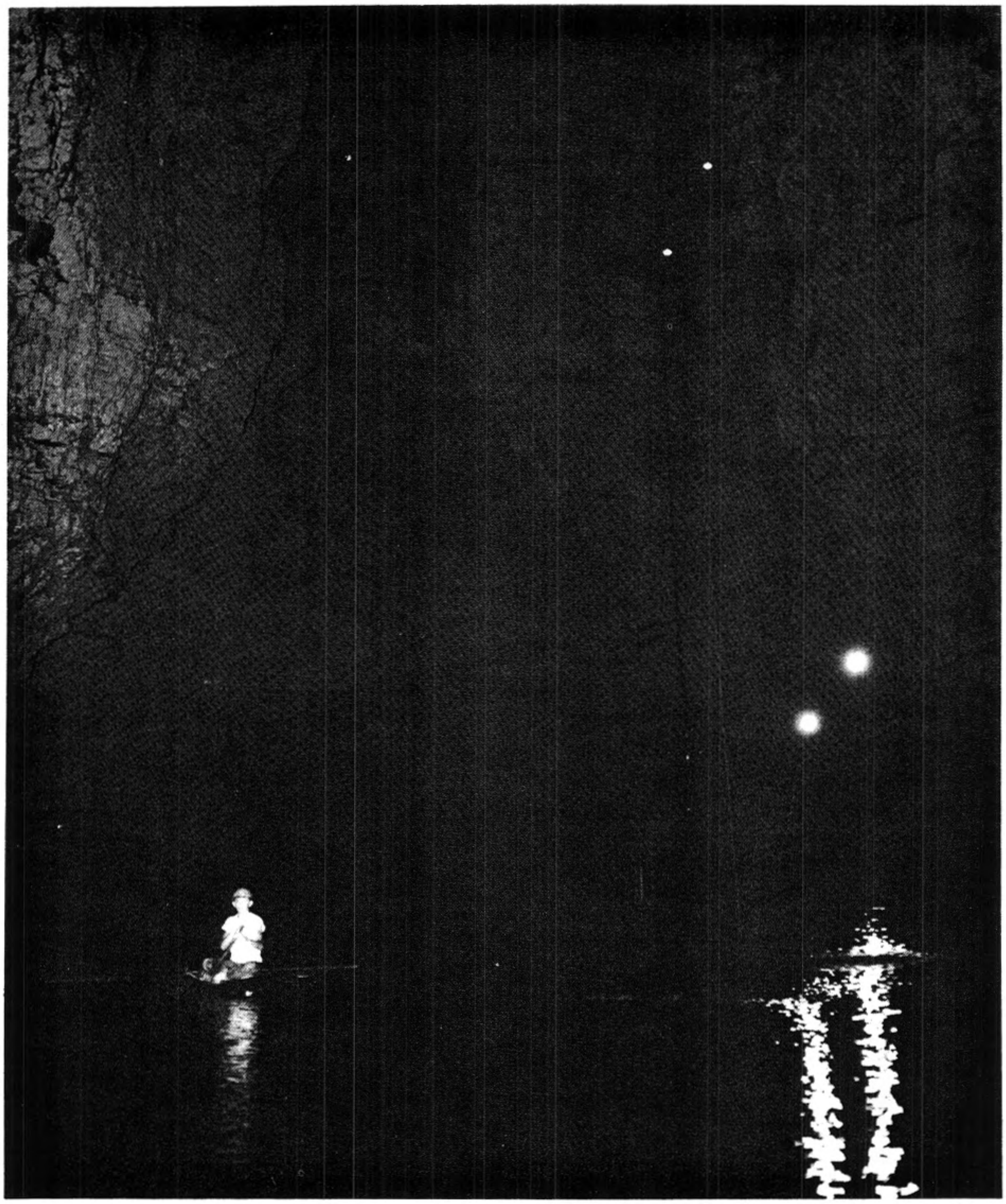


Figure 38

Devils Well is one of the largest cave lakes in the nation. More than 400 feet long and reaching depths of over 200 feet, Devils Well is a major feature of the Cave Spring supply system. Photo by Jerry D. Vineyard.

residual products from the weathering of the host rock accumulate on the floor, protecting it from solution. This upward growth implies the retention of the original gradient of the system. Deposits now being made in the spring consist of: (a) residual material from weathering of the host rock, (b) breakdown from the walls and ceilings of the phreatic conduits and (c) material introduced from the surface through sinkholes and enlarged joints.

The huge chambers so characteristic of the Cave Spring system have grown to their great size in the deep phreatic zone, enlarging upward by the companion processes of solution and breakdown. The smaller tubes of the system, such as the upper passages of Wallace Well and Muddy Crawlway in Devils Well, have developed in the upper part of the phreatic zone, at or very near the water table. Indeed, the two passages mentioned as examples are at very nearly the same elevation (fig. 39). The gentle gradients of these passages reflect the position of the water table when it was slightly higher than at present; they have a shallow phreatic origin much like that postulated by Thrailkill (1961) for similar passages in Fulford Cave, Colorado.

The Cave Spring system is now undergoing the most rapid growth in its history. Data cited by Beckman and Hinchey (1944, p. 39) suggest that the limestone springs of the Ozarks are rapidly enlarging their subwater-table supply systems. This process will continue as long as the greater part of the system remains in the phreatic zone.

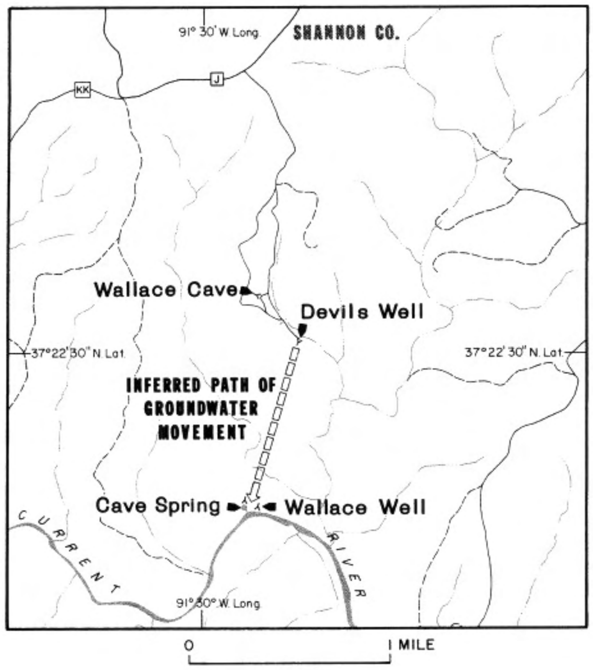


Figure 39

Relation of the Cave Spring-Devils Well system to local topography. Base map from U.S. Geological Survey, Cedargrove, Gladden, Lewis Hollow, and Round Spring 7½-minute quadrangles.

COVE SPRING, *Shannon County, Powder Mill Ferry 7½-minute quadrangle, NE¼ NE¼ SW¼ sec. 9, T. 29 N., R. 2 W.*

Cove Spring issues from the mouth of a cave in Powder Mill Creek valley near Powder Mill Ferry on the Current River. The cave and spring are in the Eminence Dolomite, which forms a prominent outcrop at the cave entrance.

Cove Spring is the exit of an unusually long and interesting cave stream. The cave, known as Powder Mill Creek Cave, has been explored for a distance of several miles. Trend of the cave passages is north-northeast, extending beneath the forested uplands of the Current River area. The topography in this region is highly dissected with deep hollows, residuum-covered hill slopes and long, narrow ridges. Most of the surface streams are ephemeral and sustained flow is maintained only on the lower reaches of streams, or where springs augment the normal flows.

Powder Mill Creek Cave has a long, spacious main passageway with few intersecting side passages. The spring may be followed for a long distance by wading in water that sometimes reaches depths of several feet. About 4,000 feet from the entrance it is necessary to crawl in a low part of the passageway to gain entrance to the further extensions of the cave. About 1 mile from the entrance, the main passage splits into several smaller passages but the water flow at this point is only slightly less than the flow at the cave entrance, indicating that most of the flow of Cove Spring comes from a much greater distance.

The nature of Cove Spring and its supply system extending through more than a mile of cave passage is instructive in considering cave-spring genesis and functioning. From paleontological evidence one can assume that Cove Spring has existed for an unusually long time and may have been accessible through other entrances. Bones of Pleistocene bears and wolves (Galbreath, 1964), along with smaller mammals, have

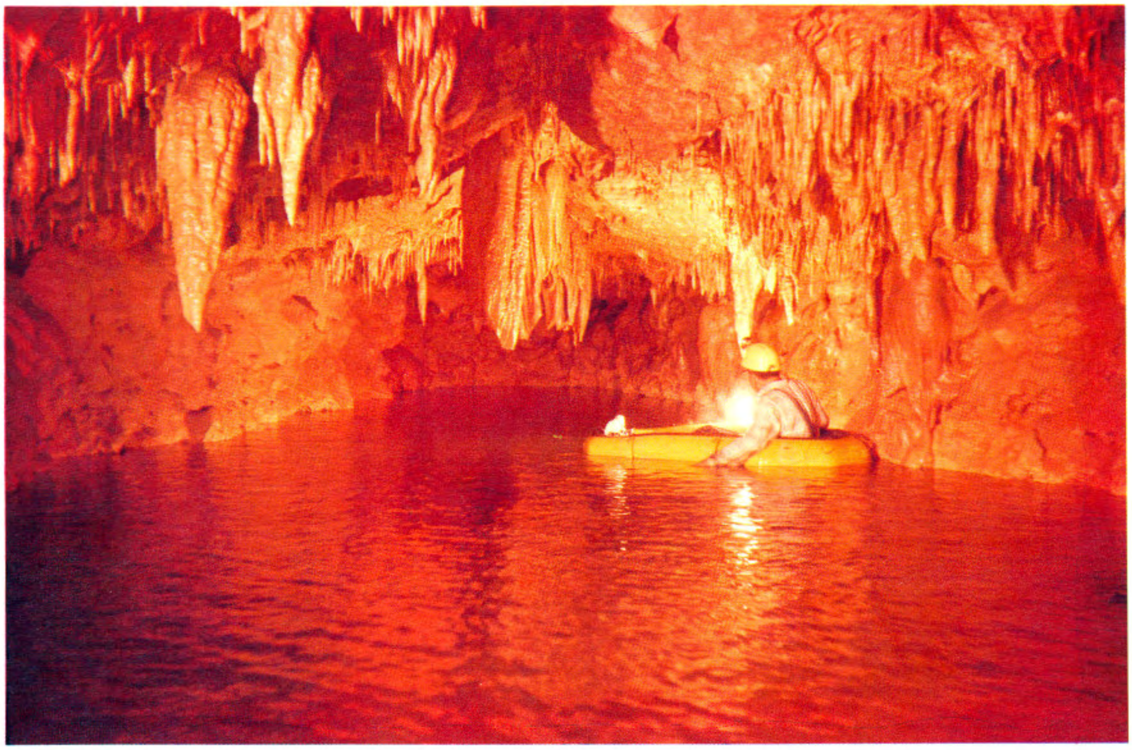


Figure 40

The rise pool of Emerald Spring. The feeder channel is at the bottom of the 10-foot deep pool, to the left of the figure in the rubber boat. Photo by Jerry D. Vineyard.

been found more than a mile from the entrance. It is thought that, in order for these animals to be in that part of the cave in which their bones were found, they would have had to enter by an opening other than the one now in existence.

Part of the flow of Cove Spring must be derived from water entering the cave system through high domepits. There are several of these in the headward portions of the cave system; one is estimated to be 50 feet high and receives a continuous stream of water through a small crevice in the top of the domepit. Other similar domepits, though smaller, also contribute increments of flow to Cove Spring.

EMERALD SPRING, *Shannon County, Round Spring 7½-minute quadrangle, SW¼ NW¼ sec. 7, T. 30 N., R. 4 W.*

Emerald Spring is unusual because the spring basin can be seen only after traversing approximately 1,000 feet of cave passage in Little Gem Cave in Shannon County. It is also unusual in that it exhibits a periodicity of flow which places it in the exclusive group known as ebb-and-flow springs. The name of the spring comes from its beautiful deep green color as exhibited in the spring rise pool (fig. 40). Emerald Spring rises in a pool about 10 feet deep, 50 feet long and 25 feet wide, at the explored end of Little Gem Cave. The cave and spring are in the Eminence Dolomite of Cambrian age.

On May 5, 1957, Vineyard observed Emerald Spring in a period of high flow. On this date, at about 11:00 a.m. the spring began to rise rapidly. The water level in the stream near the cave entrance rose for 13 minutes, then fell for 17 minutes until it had nearly reached the stage it had been before the rise. Peak flow of the spring was 1,440 gallons per minute, or the equivalent of 2,073,600 gallons per day. This peak flow lasted but a few minutes; normal flow on this date was probably only 1/6th as large as this peak flow. This periodicity in flow has been observed at the spring only one other time since the May 1957 observation. However, a continuous recorder was installed on the stream in Little Gem Cave on October 9, 1963, and remained in

Figure 41

The upper (cave) outlet of Greer Spring as it appeared in the 1880's; it is little changed today. This photograph was made from an uncredited 6 x 9 inch glass negative in the files of the Missouri Geological Survey.

operation until October 24, 1963. During this period, the spring exhibited an unusually constant flow pattern, with no periodic fluctuations of the flow. During the period of record, the spring exhibited a gradual decrease in flow, but a decrease so slight as to be almost unnoticable to the observer. The average discharge during this period was 0.04 cfs. There was no rainfall during the period of record.

It is probable that the periodic nature of Emerald Spring is delicately balanced with respect to discharge. That is, above a critical mean discharge, the spring will function periodically, or as an ebb-and-flow spring. Below this critical discharge, the siphons governing the periodic flow of the spring are broken and the spring functions normally. An opportunity has not yet arisen to place a recorder on the spring for an extended period of time to possibly determine the periodic nature of the spring and the critical discharge limits.

The rise pool of Emerald Spring normally contains water of high clarity, and a water-filled conduit may be seen on the south wall of the spring basin. This conduit presumably leads into the supply system of the spring where siphons produce the periodic flow of the spring.

GREER SPRING, *Oregon County, Birch Tree 15-minute quadrangle, SE¼ SW¼ sec. 36, T. 25 N., R. 4 W.*

Missouri's second largest spring may be unsurpassed in the beauty of its wilderness setting, so colorfully described by Owen (1898, p. 82-93) and little changed in 75 years. In the days when water power was the wave of the future, engineers dreamed of taming the wild Greer Spring branch, with a flow said to be *". . . two hundred and eighty yards per minute, with no appreciable variation,"* by building a dam across the precipitous gorge carved by the spring branch. However, Miss Owen showed foresight far in advance of her time when she said, *"The high walls of Greer Spring gorge will, of course, far more than double the value it would otherwise possess, when it becomes desirable to control and turn to practical account the power now going so cheerily to waste, but the artistic loss will be proportionately severe."* Fortunately for this generation and others to come, those who have owned the spring since it was named for Captain Greer nearly a hundred years ago, appreciated its beauty and no dam was ever built in the gorge. Greer Spring is as wild and beautiful today as it was in the 1880's. It is now slated to become part of the Eleven Point National Scenic River.

Records of the daily flow of the spring have been collected since 1929. During this period the flow has been as follows:

	Date	cfs	Gallons per day
Maximum	May 26, 1927	903	583,000,000
Minimum	November 16, 1956	104	67,000,000
Average	49-year record	289	187,000,000

Greer Spring flows from two openings – an upper cave outlet (fig. 41) and a lower orifice in the bed of the gorge. The upper outlet may be explored for several hundred feet, past a waterfall and plunge pool into a low-ceilinged passage in which the air space above water level gradually decreases until the wide, bedding-plane opening becomes completely water-filled, the rise of an underground stream. The lower orifice is a powerful streambed boil (fig. 42) that obscures the conduit in the Gasconade Dolomite that feeds the spring. Divers have been successful in penetrating this opening to a depth of more than 100 feet, despite the powerful current (William Cate, oral comm., 1972).

Attempts, thus far, to outline the drainage area of Greer Spring have been speculative, such as those of Doll (1938) and Beckman and Hinchey (1944, p. 80). There is intense karst topography in the region as well as many dry valleys where surface water is lost to underground spring channels, but delineation of the Greer Spring recharge area remains open for hydrologic study.

The old Greer Spring Mill still stands on a hill on the rim of the gorge, at the start of a trail that leads to the spring. Power to turn the stone buhrs of the mill came from Greer Spring branch through a power transmission system unique to Ozark water mills. The hilltop mill and its machinery are intact, but the power system in the spring branch has fallen victim to time and floods on the spring branch.

An earlier mill was built about 1870 near the spring in the gorge and operated until 1883 (Morman, 1972). Captain Greer built the mill and a dam to regulate power to the turbine waterwheel. The road to the mill was rough and steep, and a team of oxen was trained to make these trips without a driver. About 1883 work was begun on the Greer Roller Mill on a hill above the spring. The building, completed in 1899, still stands.

ROUND SPRING, *Shannon County, Round Spring 7½-minute quadrangle, SW¼ NW¼ sec. 20, T. 30 N., R. 4 W.*

The aptly-named Round Spring is one of the major attractions of the Ozark National Scenic Riverways, having been a popular state park for many years prior to becoming part of the Riverways. The spring rises quietly in a nearly circular basin (fig. 43) formed by the collapse of a cavern roof. Part of the roof remains intact as a natural bridge beneath which the waters of the spring flow toward nearby Current River.

Boulders from the collapse of the cavern roof effectively block the tubular conduit of the spring, limiting divers to a depth of about 55 feet and preventing their access to the water-filled spring supply channels that are accessible in some other springs.

Records of the daily flow of the spring have been collected from October 1928 to September 1939, and continuously since August 1965. During these periods the flow has been as follows:

	Date	cfs	Gallons per day
Maximum	May 14, 1933	520	336,000,000
Minimum	December 10-12, 1937	10	6,460,000
Average	16-year record	40	26,000,000

Figure 42

The lower outlet of Greer Spring is a powerful boil in a scenic setting at the bottom of a steep-walled valley tributary to the Eleven Point River. Photo by Jerry D. Vineyard.

Beckman and Hinchey (1944, p. 116) note unusual characteristics of the flow pattern of the spring: *"During the period that a gaging station was operated on the spring (from 1928 to 1939), appreciable changes in the stage and discharge were observed that could not be accounted for by changes in rainfall. The thought occurred that these changes in stage and discharge might be caused by changes in the atmospheric pressure."*

W.L. Doll, of the U.S. Geological Survey, made a brief study of this subject by using the pressures indicated by the isobar lines on the daily weather map of the U.S. Weather Bureau. His studies, although not very detailed or conclusive, indicated a tendency for the stage of the spring to increase somewhat with a drop in the barometric pressure, and to decrease with a rise in the pressure. The relation between the elevation of the water surface and the barometric pressure has been noted by engineers and geologists (Jacob, 1950) in many wells, especially those in which the water is under artesian pressure.

A major flood on the Current River in October 1969 exposed evidence of use of the Round Spring area by Indians. The source of the waters of Round Spring remains conjectural, though the remarks by Beckman and Hinchey (1944, p. 116) relating heavy rains on Spring Valley southwest of Round Spring to discharge records of the spring are still appropriate.

Figure 43

Round Spring rises from the wreckage of a cavern in the Eminence Dolomite. Part of the former cave roof remains as a rock span (upper left of the picture) through which waters of the spring flow toward the nearby Current River. Photo by Walker, Division of Commerce and Industrial Development.

GASCONADE RIVER BASIN

BASIN DESCRIPTION

The Gasconade River flows in an elongate basin in central Missouri flanking the northwestern Ozarks and enters the Missouri River near the little town of Gasconade in east-central Missouri. The basin lies between the Osage basin on the west and the Meramec basin on the east.

The Gasconade River basin has one of the largest concentrations of big springs in the state. They are found mainly in the central part of the basin where the Gasconade Dolomite floors the valleys and the Roubidoux Formation covers the uplands. In the upper part of the basin, altitudes are high and the Cotter and Jefferson City Dolomites cover most of the area. The Roubidoux forms the valley floors. Springs are abundant in the valleys but are generally small by comparison with those in the central part of the basin. The lower portion of the basin is narrow, and here the summits are covered by Pennsylvanian sandstone and shale. Where the Pennsylvanian formations have been eroded away the Cotter and Jefferson City Dolomites form the divides and hill slopes. Although the Gasconade Dolomite floors the valley through much of the lower part of the basin, springs, with one exception, are very small.

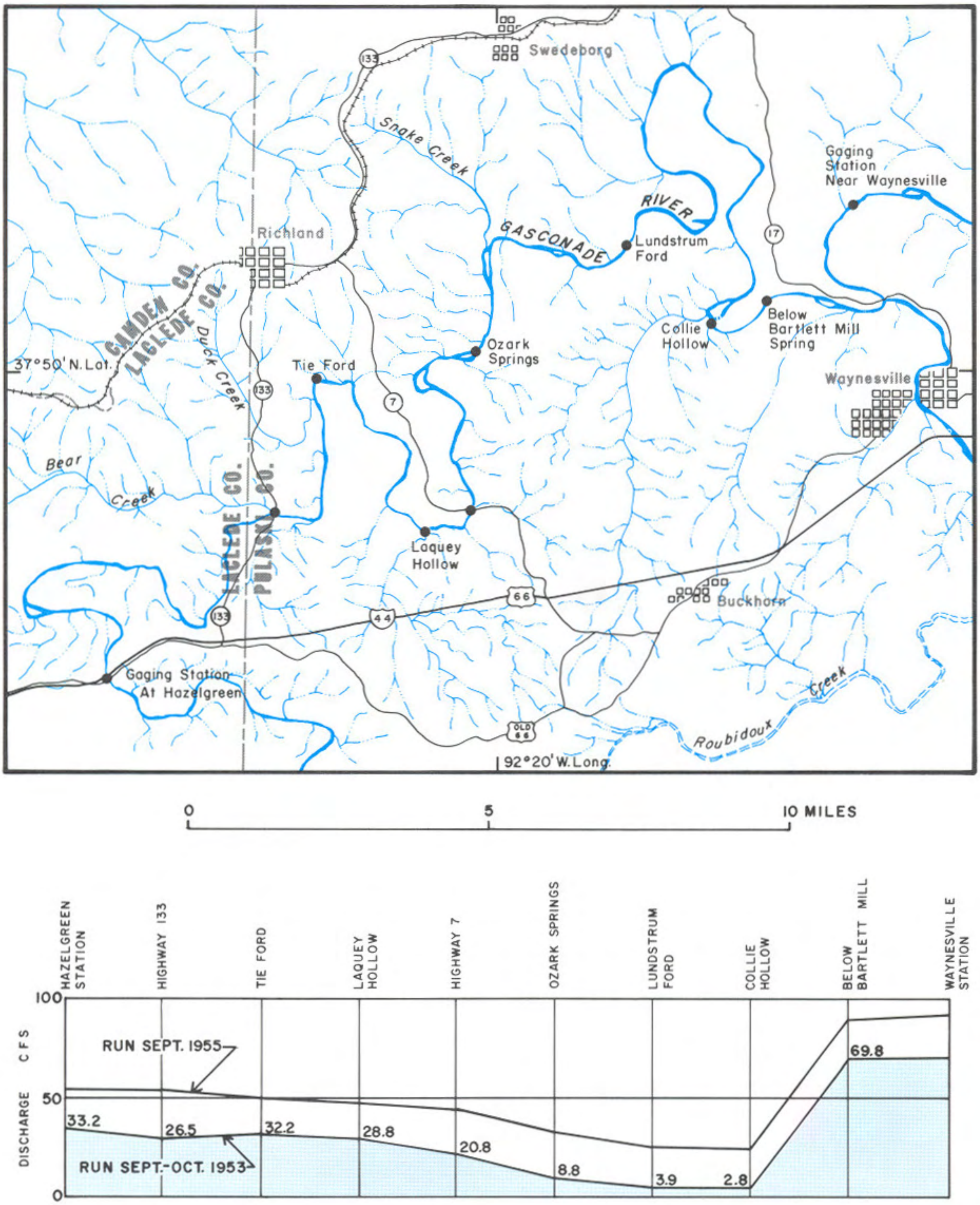


Figure 44

Graphical presentation of low-water flow of the Gasconade River from Hazelgreen to Waynesville, Missouri.

Faulting is not prominent in the basin. Several small faults in the Mansfield fault system cut the southwestern extremity of the basin where Mississippian rocks form the divide. In the lower part of the basin the Gasconade Dolomite, which forms the floor of the valley, comes to an abrupt end at a fault which dropped the Roubidoux Formation opposite the Gasconade Dolomite.

Most of the large springs are concentrated in an area south of the constriction in the basin. This is an area where the Gasconade Dolomite crops out extensively and much of the upland area is covered by the Roubidoux Formation. All the larger springs are in a belt about 20 miles wide trending northwesterly across the basin. The Gasconade River gains water through the accumulation of the discharges of the many springs in the basin so that when it discharges into the Missouri River it has an average discharge of more than 3,000 cfs (almost 2,000 mgd). Although the river gains water from its headwaters to its mouth, it has an important losing reach just before it reaches the heart of the big spring area (fig. 44).

The distribution of the big springs in the basin (those with average discharge exceeding 10 cfs or 6.5 mgd) seems to be influenced by structural features which must be traced into the Niangua and Osage basins on the northwest and the Current River basin on the southeast. The belt of large springs crosses the Gasconade River basin in a northwesterly direction. Extended to the Osage basin it includes a reach of the Osage River that is now a part of the Lake of the Ozarks. In this reach of the Osage, the meandering of the river suggests considerable influence by faulting and jointing. The southwestern margin of the big spring belt is nearly in line with the Red Arrow fault in the lower end of the Niangua River basin (McCracken, 1971, p. 52). The Gasconade River is offset to the northwest along the southwestern margin of the belt for a distance of 10 miles. Similarly, other streams show effects of strong structural control. The very straight course of the Current River and its alinement with the belt indicates that the influence of this structural trend continues into this basin. More than 50 percent of the springs in the Ozarks having an average discharge of 10 cfs or more are located in this belt as it crosses the Osage, Gasconade and Current River basins.

The basin contains 14 springs with average flows of 10 cfs (6.5 mgd) or more which is the same number that occurs in the Current River basin. Boiling Spring, with an average discharge of a little over 100 cfs (68 mgd), is included among the 15 largest springs in Missouri. Seventy-six springs have been measured in the basin. However, there are more springs – unmeasured to date – than are reported on here. Probably all of the larger springs are listed, though. Table 9 gives the measured discharges for springs in the Gasconade River basin. Figure 45 is a map showing the locations of measured springs in the Gasconade River basin.

Most of the springs are used for watering stock, a few furnish domestic supplies and two are used for commercial fishing. Many are unused and most are located on private property. At least six of the springs were used in earlier days for powering grist and woolen mills and some of them were still in use as late as the early 1940's. All of these are now out of operation but many of the foundations can still be seen. The village of Rich Fountain in Osage County grew up around a small spring of the same name and although the discharge is only 27,000 gallons per day it served as the water supply for the town for many years. Today it is used for watering stock and the town depends on a deep well.

Miller Spring is the largest known ebb-and-flow spring in the state and the only one known to exist in the Gasconade basin. The ebb-and-flow character of the spring is readily apparent in comparing the discharges of the spring given in the table.

Steyermark (1941) described the flora in 21 of the springs in the basin. He found that many had lush plant growths and a considerable variety of plant life.

QUALITY OF WATER

Spring water in the Gasconade River basin is a calcium magnesium bicarbonate type reflecting the dolomitic character of rocks in the drainage basin. The waters are moderately mineralized with dissolved-solids content ranging from 132 to 308 mg/l (table 10).

Springs in the belt of high discharge crossing the central part of the basin have a lower dissolved-solids content on the average than those in the upper and lower parts of the basin. This is attributed to the faster movement of water and shorter residence time in the central portion of the basin.

Hardness of the water ranges from 102 to 294 mg/l. On the basis of the hardness classification given in table 3, water in 53 of the samples was very hard; in 23 of the samples, the water was hard; and in 1

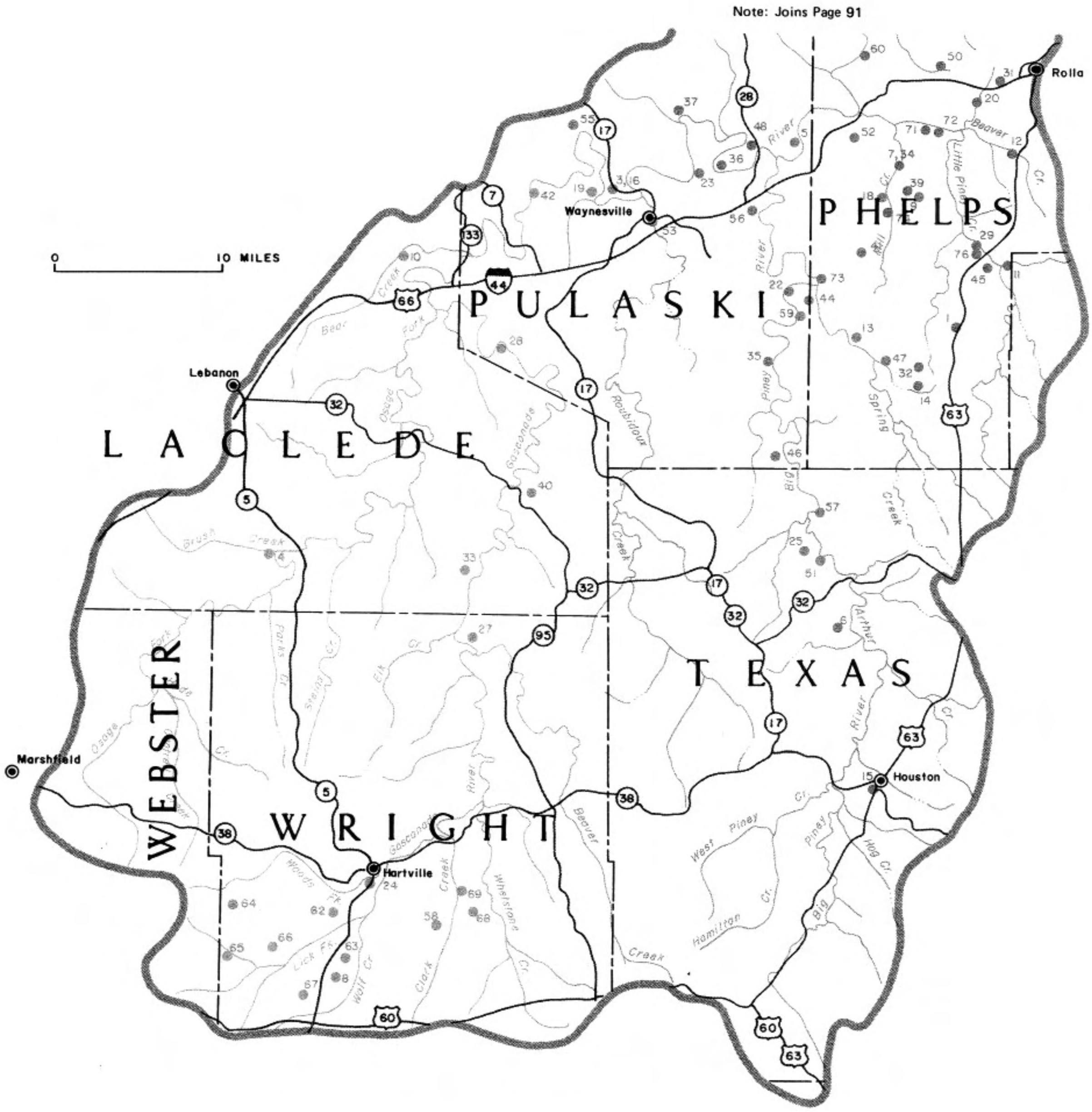
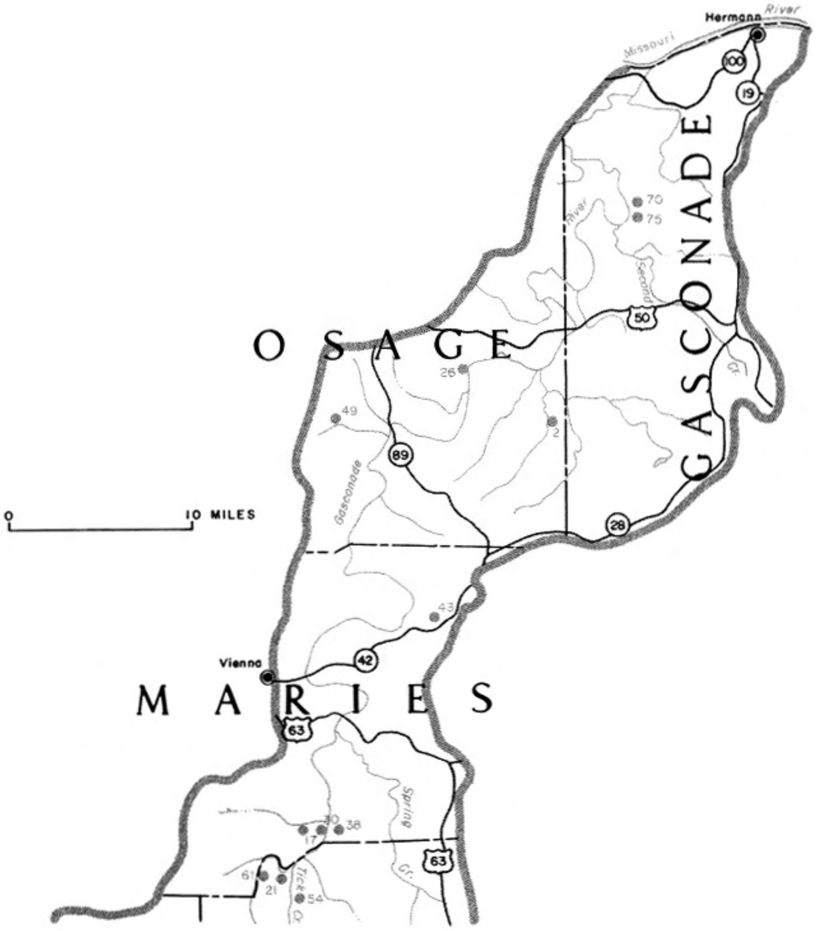


Figure 45
Springs in the Gasconade River basin.



Note: Joins Page 90

Table 9
DISCHARGES OF SPRINGS IN THE GASCONADE RIVER BASIN

[A = less than 0.01 cfs]

Location No. (fig. 45)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
1	Arndt	Edgar Springs	Phelps	NWNW 30,35,8W	.10	65	-	9-6-47	Domestic
					A	A	61	8-25-64	Volumetric
2	Bacon	Mount Sterling	Osage	NESE 11,42,7W	.05	32	60	6-7-66	Stock
3	Bartlett Mill	Waynesville	Pulaski	SWSE 16,36,12W				1926-1966	
	(Average of 16 measurements)				15.6	10,100	-		
	(Maximum discharge measured)				68.4	44,200	55	5-17-66	
	(Minimum discharge measured)				.31	200	-	10-12-32	
					.31	200	-	9-20-56	
4	Big	Morgan	Laclede	NENE 6,32,15W	17.7	11,400	59	9-17-53	
					16.4	10,600	57	11-30-64	
5	Boiling	St. Robert	Pulaski	SENW 33,37,10W	65.0	42,000	-	9-21-23	Camping
					65.0	42,000	-	10-21-32	
					67.0	43,300	-	9-11-54	
					70.2	45,300	58	10-26-63	
					56.0	36,200	58	1-21-64	
					65.0	42,000	57	7-26-64	
6	Boiling	Licking	Texas	SWSW 24,32,10W	12.0	7,750	-	8-18-25	Camping
					18.3	11,800	-	10-8-32	
					31.0	20,000	-	8-14-34	
					15.2	9,820	-	8-14-36	
					2.51	1,620	57	8-26-64	
					1.36	879	57	12-8-64	
7	Cave Trail	Newburg	Phelps	SWNW 4,36,9W	A	A	68	7-26-64	
8	Cave	Mansfield	Wright	NWSE 2,28,15W	.75	484	55	5-11-66	Stock
9	Cedar Cave	Newburg	Phelps	NWNW 15,36,9W	A	A	56	8-8-64	
10	Cliff	Stoutland	Laclede	NENW 9,35,14W	1.40	904	-	11-11-58	
					1.12	724	56	12-3-64	
11	Cold	Yancy Mills	Phelps	SWSE 4,35,8W	.02	13	58	8-26-64	Stock
12	Coolbrook	Rolla	Phelps	NESE 34,37,8W	.20	129		7- -25	Recreation
					.02	13	59	7-24-64	
					A	A	59	8-26-64	
13	Coppedge	Flat	Phelps	NESE 36,35,10W					
	(Average of 7 measurements)				19.4	12,500	-	1923-1964	Mill abandoned
	(Maximum discharge measured)				28.6	18,500	-	5-26-25	Univ. of Mo. owns
	(Minimum discharge measured)				15.4	9,950	-	8-2-34	spring
14	Cox	Edgar Springs	Phelps	NESE 3,34,9W	.02	13	-	7-7-49	Stock
					no flow			8-25-64	
15	Coyle	Houston	Texas	SENW 8,30,9W	.60	388	-	1-25-50	Private estate
					A	A	-	8-27-64	Recreation, stock
16	Creasy	Waynesville	Pulaski	SESW 16,36,12W	27.0	17,400	-	9-10-26	Spring in edge of river
					19.0	12,300	-	10-12-32	
					23.6	15,200	58	6-2-36	
					20.0	12,900	63	9-22-53	
					22.2	14,300	63	8-24-64	
					19.8	12,800	59	12-1-64	
17	Davis	Rolla	Maries	SWNE 34,39,9W	.04	26	-	5-8-36	Stock
					no flow			12-3-64	
18	Elm	Jerome	Phelps	SENW 17,36,9W	.08	52	55	7-24-64	
					.05	32	55	7-26-64	
19	Falling	Waynesville	Pulaski	SWSW 16,36,12W					
	(Average of 8 measurements)				2.10	1,360	-	1925-1964	
	(Maximum discharge measured)				7.40	4,780	-	9-10-26	
	(Minimum discharge measured)				.30	194	59	12-1-64	
20	Gollahon	Rolla	Phelps	SWSW 17,37,8W	.27	174	52	4-1-31	
					.26	168	58	5-5-36	Stock
					.10	65	73	7-24-64	
					.14	904	59	8-28-64	
					.05	32	44	11-30-64	
21	Groover	Rolla	Phelps	SESW 9,38,9W	1.50	969	-	4-26-47	Stock
					A	--	-	8-27-64	Spring submerged
22	Hale Cemetery	Flat	Pulaski	NWNE 17,35,10W	.01	6	50	12-3-64	
23	Harrison	Waynesville	Pulaski	NWNE 8,36,11W	6.00	3,880	-	8-8-47	
					1.29	833	58	8-25-64	
24	Hartville	Hartville	Wright	NESW 6,29,14W	.20	129	-	5-11-66	
25	Hazelton	Hazelton	Texas	SENW 34,33,10W	4.30	2,780	-	8-15-25	Stock
					4.60	2,790	57	10-18-32	
					7.40	4,780	-	8-14-34	
					5.35	3,460	62	8-26-64	
					5.70	3,680	51	12-2-64	
					10.3	6,650	-	8-5-66	
26	Hollenback	Linn	Osage	SESE 30,43,7W	.14	90	57	6-7-66	
27	Kincheloe	Hartville	Wright	NWSE 30,32,13W	2.33	1,510	56	5-11-66	Stock
28	Land	Hazelgreen	Pulaski	SENW 4,34,13W	.18	116	56	11-26-37	Stock
					.12	80	55	8-28-64	
29	Lane	Yancy Mills	Phelps	SWNW 32,36,8W	17.9	11,600	56	10-21-32	Conservation
					4.82	3,110	-	8-2-34	Picnic area
					11.9	7,690	58	8-25-64	

Table 9 *(continued)* . . . . .

Location No. (fig. 45)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
30	Little Gaines Ford	Rolla	Maries	SWNW 35,39,9W	0.03	19	-	5-8-36	
					no flow			12-3-64	
31	Martin	Rolla	Phelps	SWSE 8,37,8W	1.30	840	-	3-13-35	Domestic
					.13	84	-	3-1-46	
					A	A	58	10-26-63	
					.01	6	56	7-26-64	
					.03	19	56	7-24-64	
					.01	6	57	8-26-64	
					.03	19	54	11-30-64	
32	Mathis	Edgar Springs	Phelps	SESE 3,34,9W	.04	26	-	7-7-49	
					no flow	--	-	8-25-64	
33	Mayfield	Competition	Laclede	NWSW 6,32,13W	2.80	1,810	57	9-21-53	Forest Service
					2.32	1,500	57	11-30-64	
34	Mill Creek Camp	Newburg	Phelps	SWNW 4,36,9W	.02	13	57	7-26-64	Forest Service, picnic area
35	Miller	Big Piney	Pulaski	NWNE 6,34,10W	4.85	3,130	-	11-25-23	
					20.2	13,000	-	11-25-23	
					7.21	4,660	-	10-8-43	
					21.2	13,700	-	10-13-43	
					17.7	11,400	-	10-13-43	
					11.4	7,360	-	10-13-43	
					8.70	5,620	-	10-13-43	
					7.87	5,080	-	10-13-43	
					7.73	4,990	-	10-13-43	
					16.9	10,900	-	10-13-43	
					23.6	15,200	-	10-13-43	Ebb & flow spring
					23.2	15,000	-	10-13-43	
					4.37	2,820	58	8-7-64	Stock, irrigation
					4.49	2,900	57	8-25-64	
					4.50	2,910	57	10-6-64	
					4.68	3,020	58	11-6-64	
					16.3	10,500	58	1-11-65	
					6.67	4,310	57	2-1-65	
					33.8	21,800	57	4-15-65	
					36.7	23,700	58	6-7-65	
					5.70	3,680	54	8-17-65	
					6.24	4,030	57	10-4-65	
					15.0	9,690	56	12-2-65	
					15.0	9,690	56	12-7-65	
					9.93	641	-	1-10-66	
					10.6	6,850	-	1-10-66	
					30.3	19,600	56	2-18-66	
					41.1	26,600	55	5-17-66	
36	Mossy	St. Robert	Pulaski	NENW 10,36,11W	1.20	775	-	8-9-47	Stock
					.33	213	56	12-1-64	
37	Murphy Eddy	Crocker	Pulaski	SENE 19,37,11W	1.00	646	-	8-7-47	Recreation
					.42	271	56	8-25-64	
38	Nagogami	Rolla	Maries	SWNW 35,39,9W					
	(Average of 7 measurements)				6.00	3,880	-	1926-1964	Recreation for
	(Maximum discharge measured)				18.3	11,800	-	4-28-26	Country Club
	(Minimum discharge measured)				3.00	1,940	57	9-11-54	
39	Natural Bridge	Newburg	Phelps	NWNE 16,36,9W	A	A	61	9-7-64	
40	Nebo	Nebo	Laclede	SESW 11,33,13W	.58	375	-	10-27-55	Domestic
41	Ousley	Spring Creek	Pulaski	SWSE 36,36,10W	.95	614	-	10-20-32	
					.76	491	57	8-24-64	
					.55	355	51	12-3-64	
42	Ozark	Richland	Pulaski	SWNW 23,36,13W	.01	6	58	9-22-53	Resort, domestic
43	Paydown	Belle	Maries	SWSW 2,40,8W	18.4	11,900	-	9-25-24	Private club
					6.85	4,430	-	10-20-32	
					7.35	4,750	55	9-18-36	
					6.00	3,880	-	10-11-42	
					9.85	6,360	55	12-3-64	
44	Pillman No. 1	Flat	Phelps	NWSW 15,35,10W	11.6	7,490	57	1-23-47	Stock
					4.87	3,150	60	8-24-64	
					9.37	6,050	54	12-3-64	
45	Piney	Yancy Mills	Phelps	SWSE 4,35,8W	5.00	3,230	-	7-24-25	Stock
					.10	65	59	10-20-32	
					A		69	8-26-64	
46	Prewett	Big Piney	Pulaski	SENW 32,34,10W	17.0	11,000	-	7-21-25	Stock
					16.5	10,700	58	10-18-32	
					15.6	10,100	-	8-14-34	
					13.2	8,530	57	8-26-64	
					12.8	8,270	57	12-2-64	
					29.6	19,100	56	8-2-66	
47	Pruett	Edgar Springs	Phelps	SENW 5,34,9W	.15	97	-	1-29-47	Domestic

Table 9 – *DISCHARGES OF SPRINGS (continued)* . . . . .

(Gasconade River Basin)

Location No. (fig. 45)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
48	Pruett	St. Robert	Pulaski	SENW 36,37,11W	1.50	969	-	8-9-47	
					1.26	814	65	8-25-64	
					1.35	872	58	12-1-64	
49	Rich Fountain	Rich Fountain	Osage	SWSW 12,42,9W	.04	26	58	11-8-65	Stock
50	Roach	Newburg	Phelps	NWSW 2,37,9W	.18	116	-	10-16-53	
					.03	19	56	8-27-64	
51	Roaring	Licking	Texas	NENW 35,33,10W	1.45	937	58	8-14-36	Private lodge
					1.69	1,090	57	8-26-64	
					.81	523	58	12-8-64	
52	Rolufs	Jerome	Phelps	SWSW 25,37,10W	.24	155	-	9-16-31	Stock
					.55	355	-	10-2-36	
					.14	90	58	10-16-53	
					.20	129	59	7-24-64	
					1.19	769	58	8-24-64	Stock
53	Roubidoux	Waynesville	Pulaski	NENW 25,36,12W					
	(Average of 14 measurements)				58.3	37,700	-	1924-1970	
	(Maximum discharge measured)				192	124,000	-	10-1-70	
	(Minimum discharge measured)				4.66	3,010	58	9-18-53	
54	Saltpeter	Newburg	Phelps	NWNE 21,38,9W	.22	142	-	4-14-46	Stock
					A	A	60	8-27-64	
55	Schlicht	Swedeborg	Pulaski	SESW 30,37,12W	.92	594	-	8-6-25	Stock
					1.00	646	-	9-12-25	
					.85	549	71	8-24-64	
					.21	136	50	12-1-64	
56	Shanghai	Waynesville	Pulaski	NESW 24,36,11W					
	(Average of 12 measurements)				18.0	11,600	-	1925-1966	
	(Maximum discharge measured)				38.0	24,500	-	5-11-66	
	(Minimum discharge measured)				7.70	4,970	-	8-3-34	
57	Slabtown	Licking	Texas	SESW 15,33,10W					
	(Average of 7 measurements)				14.0	9,040	-	1925-1966	Commercial fishing
	(Maximum discharge measured)				24.0	15,500	-	2-18-66	
	(Minimum discharge measured)				8.50	5,490	56	12-2-64	
58	Sparks	Owensville	Wright	NENW 23,29,14W	.10	64	59	5-11-66	Stock
59	Stone Mill	Flat	Pulaski	NWSW 21,35,10W					Recreation
	(Average of 8 measurements)				29.0	18,700	-	1925-1966	
	(Maximum discharge measured)				53.0	34,200	58	6-3-66	
	(Minimum discharge measured)				17.0	11,000	-	8-2-34	
60	Sugar Tree	Newburg	Phelps	SESE 36,38,10W	1.60	1,030	57	8-27-64	Lodge, recreation
61	Thox Rock	Newburg	Phelps	Sec. 7,38,9W	A	A	-	8-6-25	Stock
62	Unnamed	Hartville	Wright	NESE 14,29,15W	0.50	323	54	5-11-66	Stock
63	Unnamed	Hartville	Wright	NENW 36,29,15W	.05	32	55	5-11-66	
64	Unnamed	Mansfield	Wright	NENE 15,29,16W	.10	65	55	5-11-66	
65	Unnamed	Mansfield	Wright	NENE 34,29,16W	.20	129	54	5-11-66	
66	Unnamed	Mansfield	Wright	SESE 30,29,15W	.10	65	54	5-11-66	
67	Unnamed	Mansfield	Wright	NESE 9,28,15W	.50	232	54	5-11-66	
68	Unnamed	Owensville	Wright	SWNW 17,29,13W	.20	129	55	5-11-66	
69	Unnamed	Owensville	Wright	SWSW 6,29,13W	.30	194	55	5-11-66	
70	Unnamed	Gasconade	Gasconade	NENE 15,44,6W	A	A	58	6-6-66	Stock
71	Unnamed	Newburg	Phelps	NWNW 26,37,9W	.03	19	58	9-7-64	
72	Unnamed	Newburg	Phelps	SENE 26,37,9W	A	A	58	7-26-64	
73	Unnamed	Newburg	Phelps	NWSE 10,35,10W	A	A	59	7-26-64	
74	Wilkins	Newburg	Phelps	NENE 20,36,9W	5.77	3,730	57	8-25-64	
75	Williams	Gasconade	Gasconade	NESW 14,44,6W	.15	97	55	6-6-66	
76	Yancy Mills	Yancy Mills	Phelps	SESW 32,36,8W	1.55	1,000	-	7-24-25	
					3.03	1,960	56	10-20-32	
					1.02	659	-	8-2-34	
					3.04	1,960	58	8-26-64	Commercial fish rearing

sample, it was moderately hard. Iron content of the water ranges from 0.00 to 1.6 mg/l. Of the 77 analyses shown, 61 contained less than the 0.3 mg/l limit for iron recommended for drinking water. Concentrations of other constituents (except bicarbonate) in the water generally are less than 10 mg/l. Nitrate content, which is one indication of contamination, is low in this basin. Only one sample contained nitrate much above the average. This may indicate local or seasonal pollution; however, the high nitrate content was in water from Shanghai Spring and it was higher in 1953 than it was in 1964.

DESCRIPTIONS OF SELECTED SPRINGS

BARTLETT MILL SPRING, *Pulaski County, Ozark Springs 7½-minute quadrangle, SW¼ SE¼ sec. 16, T. 36 N., R. 12 W.*

Bartlett Mill Spring is on private property near the Gasconade River. Rocks in the area consist mostly of the Gasconade Dolomite, which forms the floor and the walls of the valley, and the sandstone and dolomite of the Roubidoux, which caps the hills. The first Bartlett Mill, a three-story frame mill with flour and meal machinery as well as a wood saw, was built about 1850 by Solomon Bartlett. This mill was in operation until 1911 when it was torn down and replaced by a two-story mill built to grind corn only. It used the same stone buhrs until about 1916 when it was duplicated by a third mill that operated until 1947 (Dru L. Pippin, written comm.). This mill was used not only to grind corn but also to power a 5-kilowatt electric generator to light Pippin Place, formerly a lodge near the spring. This installation was the first electricity in Pulaski County and people came daily to view the lights. At present the spring is unused. Water from the Gasconade River backfloods the spring when the river is up.

Bartlett Mill Spring rises from a cave at the bottom of a 60-foot deep pool (Michael Tatalovich, written comm., 1972), where the spring water rises through gravel fill. Solomon Bartlett walled up nearby Falling and Creasy (Bubbling) Springs to increase the flow at Bartlett Mill Spring. History does not record whether his efforts were successful.

Bartlett Mill, Falling and Creasy (Bubbling) Springs are thought to be resurgence points for water which sinks into the bed of the Gasconade River above Ozark Springs (Beveridge, 1963). Water is known to be lost from the Gasconade River, beginning at Ozark Springs, and is not regained until below Bartlett Mill Spring. However, water tracing experiments have not yet confirmed the theory that Bartlett Mill Spring derives part of its flow from the resurgence of Gasconade River water. Solomon Bartlett is reported to have done some primitive water tracing of his own by dumping chicken feathers into the sinkhole at Ozark Springs and noting their appearance in Bartlett Mill Spring sometime thereafter. A cave in the hollow above Bartlett Mill Spring, now cased with a concrete box some 20 feet deep and extending about 4 feet above ground, may have been a former orifice of Bartlett Mill Spring. No water emerges from the cave at the present time, except after excessive floods, when water appears in the cave before the crest of the flood arrives in the Gasconade River (Dru L. Pippin, written comm.).

Michael Tatalovich and Michael Grussemeyer explored Bartlett Mill Spring by means of underwater breathing apparatus in August 1971. At the bottom of the spring basin, at a depth of about 20 feet, they found a small opening partly blocked by gravel. By enlarging the opening they were able to enter a large, downward-sloping passage as much as 55 feet wide (fig. 46). The conduit ended in gravel fill through which the spring water issued. No further exploration was possible; the depth of gravel fill is unknown.

Although the average flow of the spring is 16.4 cfs, the flow is extremely variable and minimum flows of 0.31 cfs were measured during the droughts of the 1930's and 1950's.

Steyermark (1941, p. 540) described an abundant and diversified flora growing in the spring, in the pool formed by the dam, and in the spring branch below the dam.

***BIG SPRING,** near Morgan, Laclede County, Lebanon 15-minute quadrangle, NE¼ NE¼ sec. 6, T. 32 N., R. 15 W.*

Big Spring, near Morgan, emerges in the bed of the Osage Fork of the Gasconade River just above the upper end of an island and is submerged at all times. The waters are deep blue in color and "boil" up with considerable force. Late in the 1880's Davis Mill, a short distance downstream, utilized the spring waters in its milling operations. Today, only remnants of the old mill remain; the waters are unused.

The discharge of Big Spring is sufficient to cool Osage Fork so that water cress grows in the river bed at least ½ mile below the spring.

This is the second largest spring discovered since the Beckman and Hinchey report of 1944.

Table 10

CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE GASCONADE RIVER BASIN

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

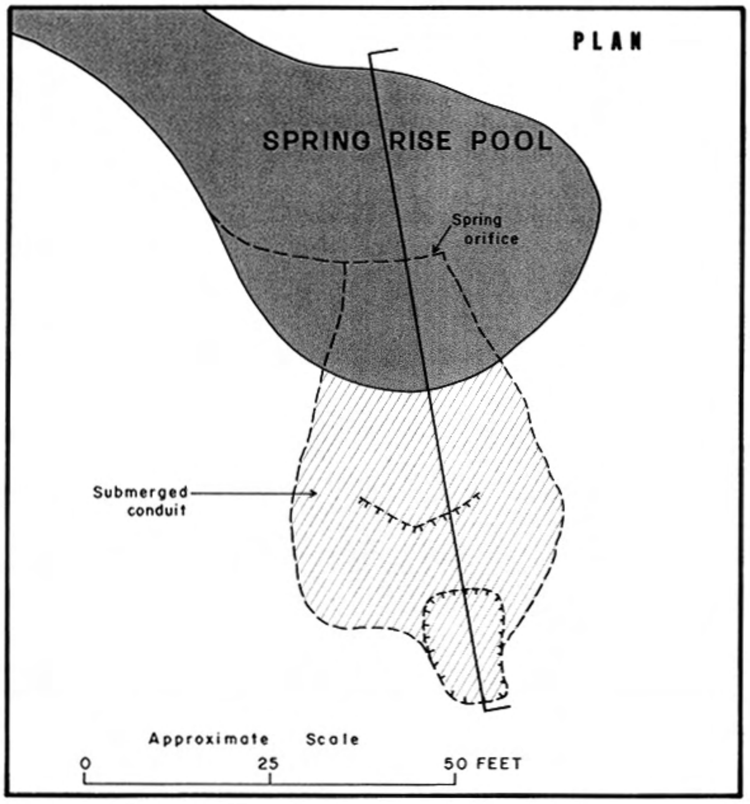
Data in milligrams per liter except as indicated

Location No. (Fig. 45)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved Solids (Residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
3	Bartlett Mill	8-25	---	--	25	0.63	40	22	9.7		218	10	4.1	4.4	--	1.0	---	224	188	0	---	---	--	0
		11-53	---	58	4.8	.14	45	28	3.1		267	0	4.0	2.5	0.2	1.6	---	238	230	12	---	7.4	--	2
		8-64	4.32	62	6.2	.09	30	25	3.1		202	0	6.9	3.8	.1	1.2	---	178	179	13	380	8.0	--	1
4	Big	11-64	16.4	57	3.0	.02	35	27	3.7		219	0	3.1	3.2	.0	.0	---	193	196	16	---	8.1	--	<1
5	Boiling	6-25	---	--	6.8	.21	28	17	5.8		164	1	1.8	2.7	--	2.5	---	145	139	4	---	---	--	-
	(Pulaski Co.)	11-53	---	58	5.2	.09	36	21	4.2		207	0	.7	3.0	.1	3.0	---	188	176	6	---	7.4	--	1
		8-65	---	57	2.8	.06	33	19	3.2		190	0	2.3	3.5	.0	2.1	---	169	161	6	---	7.9	--	2
6	Boiling	8-25	12.0	--	6.8	.30	42	23	4.2		229	0	3.7	2.6	--	.8	---	195	199	11	---	---	--	0
	(Texas Co.)	8-64	2.51	57	5.0	.05	48	25	3.7		249	0	6.2	3.0	.0	.0	---	214	223	19	---	7.3	--	-
8	Cave	5-66	.75	55	10	.02	46	25	1.6	1.0	255	0	3.8	1.9	.4	3.3	---	225	218	8	398	7.6	3	-
10	Cliff	12-64	1.12	56	7.2	.90	47	26	3.6		240	0	9.4	4.7	.0	4.9	---	223	226	28	---	8.1	--	8
12	Coolbrook	7-25	.20	--	9.6	.38	52	30	3.0		268	10	13.0	3.6	--	1.6	---	254	251	15	---	---	--	5
	(Sands)	8-53	---	59	7.8	.08	55	33	6.1		305	0	17.0	5.3	.3	1.1	---	276	274	24	---	8.0	--	1
		8-64	A	59	17	.07	46	30	4.3	1.2	249	7	23.0	6.0	.1	3.0	.01	260	239	23	457	8.4	--	1
13	Coppedge	7-25	---	--	6.6	.29	34	19	2.2		190	2	3.3	2.4	--	.8	---	163	161	2	---	---	--	-
	(Relfe)	8-53	---	58	4.4	.10	35	20	3.5		201	0	2.3	2.8	.1	2.5	---	177	171	6	---	---	--	1
		8-64	16.4	58	14	.00	32	21	1.9	1.8	199	0	3.0	2.5	.0	3.0	.03	177	167	4	324	8.2	0	2
16	Creasy	8-25	---	--	27	.38	39	21	2.5		203	14	4.5	3.2	--	1.2	---	212	183	0	---	---	--	0
		11-53	---	61	5.8	.08	44	28	3.5		264	0	5.3	3.0	.2	.6	---	229	224	8	---	7.4	--	3
		8-64	22.2	63	5.5	.08	42	26	3.1		245	0	6.3	3.8	.1	.1	---	216	212	12	400	7.2	--	2
19	Falling	8-25	---	--	21	.29	39	20	9.1		214	12	4.1	3.3	--	.5	---	214	179	0	---	---	--	0
		11-53	---	61	6.8	.08	44	28	3.5		260	0	4.9	2.5	.2	.9	---	222	223	10	---	7.4	--	2
		8-64	.42	'63	6.0	.16	43	26	2.8		244	0	6.4	3.5	.1	.5	---	217	216	16	390	8.1	--	2
20	Gollahon	8-64	.14	59	13	.00	40	29	2.9	1.2	242	9	9.4	3.5	.2	2.3	.00	230	219	6	415	8.5	0	1
25	Hazelton	8-25	4.30	--	5.6	.30	34	19	.6		172	9	.0	2.8	--	.3	---	156	162	6	---	---	--	0
		12-64	5.70	51	5.0	.14	38	21	2.6		208	0	3.0	2.3	.0	.0	---	183	180	9	---	7.8	--	-
26	Hollenback	6-66	.14	57	9.5	.01	60	35	2.8	1.3	334	0	22.0	1.2	.4	.0	---	309	294	20	526	7.9	0	-
27	Kincheloe	5-66	2.33	56	7.8	.15	31	14	1.5	1.0	161	0	5.4	1.7	.1	1.9	---	144	135	3	260	7.6	4	-
28	Land	8-64	.12	55	4.0	.20	60	35	2.0		318	0	16.0	4.0	.0	1.0	---	290	293	33	500	7.3	--	3
29	Lane	8-64	11.9	58	18	.02	36	19	2.2	.8	181	9	2.6	3.0	.0	3.5	.00	183	168	4	318	8.5	---	3
31	Martin	8-64	.01	57	32	.05	46	28	6.0	1.1	247	7	5.4	12.0	.1	4.7	.01	264	230	16	443	8.4	--	4
33	Mayfield	11-64	2.32	57	3.0	.05	50	28	2.9		276	0	6.8	3.7	.0	.0	---	242	241	15	---	7.4	--	<1
35	Miller	7-25	---	--	10	.52	39	22	8.3		238	7	.8	3.3	--	.9	---	210	189	0	---	---	--	5
		8-53	---	58	10	.03	41	24	2.8		238	0	4.5	2.3	.1	1.4	---	213	202	7	---	---	--	1
		8-64	4.50	57	---	.08	--	--	---		214	0	3.3	1.0	.0	.0	---	225	---	--	370	6.9	--	-
38	Nagogami	8-25	---	--	7.8	.26	48	27	4.4		273	3	6.6	3.4	--	.8	---	235	230	1	---	---	--	5
	(Gaines Ford)	8-53	---	57	6.6	.05	52	33	3.5		---	--	7.6	2.0	.2	.8	---	258	265	14	---	---	--	1
		12-64	3.33	56	4.4	.07	57	34	2.9		313	0	9.3	3.2	--	---	---	272	280	22	---	7.9	--	1

Table 10 – *CHEMICAL ANALYSES (continued)* . . . . .

(Gasconade River Basin)

Location No. (Fig. 45)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved Solids (Residue at 180° C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
																			Calcium Magnesium	Noncarbonate				
41	Ousley	8-25	---	--	36	.36	53	30	12		274	30	2.1	2.5	--	.2	---	301	257	0	---	---	--	-
		8-53	---	58	5.8	.06	52	32	3.6		314	0	2.7	1.5	.1	.1	---	260	263	6	---	8.1	--	1
		8-64	.76	57	14	.00	41	30	1.9	.6	252	9	3.4	2.5	.0	.5	.00	227	226	4	414	8.4	0	0
43	Paydown	6-25	---	--	13	1.00	20	13	4.1		121	4	15.0	2.4	--	1.9	---	132	102	0	---	---	--	15
		11-53	---	58	5.8	.12	39	25	4.9		223	0	17.0	3.3	.3	1.9	---	214	201	19	---	7.4	--	2
		12-64	9.85	55	4.0	.09	48	27	4.6		234	0	21.0	3.7	--	--	---	221	230	38	---	8.0	--	2
45	Piney	7-25	5.00	--	9.6	.04	32	18	5.3		181	4	2.9	3.4	--	1.3	---	165	155	0	---	---	--	5
		8-53	---	--	17	.07	36	22	5.0		209	0	3.0	3.0	.2	.8	---	191	180	9	---	8.1	--	4
46	Prewett	7-25	17.0	--	7.6	1.6	38	21	0.3		219	3	0.2	1.9	--	0.4	---	181	183	0	---	---	--	5
		8-53	---	58	4.8	.07	43	25	3.6		248	0	3.0	2.0	.1	1.1	---	210	211	7	---	8.1	--	<1
		8-64	13.2	57	5.8	.04	45	26	2.9		251	0	4.9	3.0	.1	.9	---	213	220	15	390	7.2	--	<1
50	Roach	8-25	---	--	6.8	.60	39	22	10		228	0	6.2	4.9	--	2.4	---	205	190	3	---	---	--	0
	(Youngs)	8-53	---	56	5.2	.08	50	30	5.1		281	0	4.8	7.8	.2	4.2	---	252	247	16	---	8.1	--	3
51	Roaring	8-64	1.69	57	4.3	.05	35	20	5.2		185	0	2.3	2.5	.0	.4	---	156	171	19	---	7.8	--	-
52	Rolufs	8-64	1.19	58	14	.01	45	34	2.2	.7	288	5	8.0	2.0	.0	.9	.00	253	252	8	461	8.3	0	0
53	Roubidoux	6-25	---	--	4.8	.22	33	20	5.0		188	3	2.0	1.0	--	1.8	---	164	167	8	---	---	--	-
		11-53	---	59	3.8	.08	49	29	3.4		286	0	3.8	2.0	.1	1.6	---	250	242	8	---	7.4	--	1
		8-64	9.98	58	3.6	.05	47	27	2.7		260	0	6.2	3.3	.1	.8	---	226	230	17	410	7.4	--	1
55	Schlicht	8-25	.92	--	22	.24	44	25	6.5		212	15	3.7	5.4	--	.4	---	---	212	13	---	---	--	-
		11-53	---	53	5.6	.13	52	32	6.0		279	0	26	4.3	.3	1.3	---	269	260	32	---	7.7	--	3
		8-64	.85	--	4.5	.42	50	30	4.0		246	0	28	6.3	.2	3.3	---	262	245	44	450	7.2	--	4
56	Shanghai	7-25	12.3	--	7.4	.73	41	19	1.7		204	7	2.5	2.9	--	1.0	---	183	182	3	---	---	--	40
		11-53	---	58	5.4	.10	46	28	14		268	0	6.6	10	.6	14	---	273	231	11	---	7.4	--	2
		8-64	11.0	57	5.0	.07	47	27	11		213	22	9.1	12	.1	4.9	---	246	227	17	450	8.4	--	1
57	Slabtown	7-25	12.8	--	6.6	.23	30	17	1.1		181	2	1.2	1.4	--	.5	---	148	144	0	---	---	--	5
		8-64	9.91	58	5.6	.06	33	19	3.3		191	0	2.9	3.0	.0	.2	---	165	158	2	---	7.9	--	-
59	Stone Mill	9-25	22.8	--	6.4	.31	40	22	7.3		208	16	2.3	3.2	--	2.4	---	201	188	0	---	---	--	-
		8-65	19.2	58	2.6	.12	34	20	4.6		197	0	3.3	2.7	.0	.7	---	180	168	5	300	8.2	--	2
60	Sugar Tree	8-25	---	--	7.4	.52	53	27	7.2		306	0	7.8	3.7	--	.4	---	258	245	0	---	---	--	0
		11-53	---	58	9.0	.09	56	32	3.8		318	0	6.8	2.8	.2	.4	---	274	273	12	---	7.4	--	1
		8-64	1.60	57	18	.02	41	29	2.4	1.0	240	11	8.8	2.5	.0	3.8	---	236	221	6	414	8.5	0	1
61	Thox Rock	8-25	A	--	11	.33	59	32	4.7		337	0	2.3	6.5	--	5.2	---	286	277	0	---	---	--	0
62	Unnamed	5-66	.5	55	11	.01	43	21	3.0	.9	232	0	5.4	2.0	.2	3.6	---	207	194	4	369	7.4	1	-
74	Wilkins	8-64	5.77	57	14	.00	36	21	1.9	.7	191	9	3.4	2.5	.0	2.6	.03	185	177	5	331	8.6	0	1
75	Williams	6-66	.15	55	9.6	.01	45	31	1.9	.8	266	0	15	1.2	.3	1.3	---	237	240	22	429	7.5	0	-
76	Yancy Mills	6-25	---	--	6.8	1.4	33	19	10		175	6	5.4	3.2	--	2.0	---	171	159	6	---	---	--	5
		8-53	---	57	6.8	.07	38	22	3.4		192	10	1.6	2.8	.1	.0	---	180	183	9	---	8.5	--	<1
		8-64	3.04	58	12	.00	35	22	2.0	.7	211	0	3.4	3.0	.0	2.9	.06	185	178	5	344	7.8	0	0



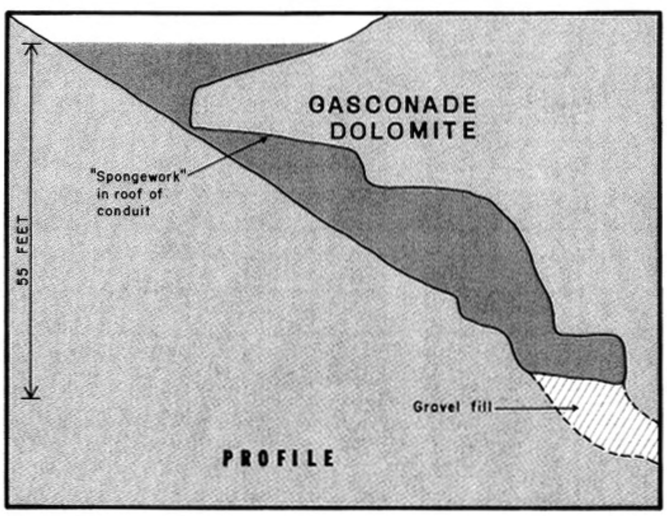


Figure 46

Plan and profile views of the orifice of Bartlett Mill Spring. Adapted from drawings by Michael R. Tatalovich.

BOILING SPRING, *Pulaski County, Dixon 7½-minute quadrangle, SE¼ NW¼ sec. 33, T. 37 N., R. 10 W.*

Boiling Spring, one of the 15 largest springs in Missouri and the largest in the Gasconade basin, rises in the channel of the Gasconade River near the right bank, beneath a high bluff of Gasconade Dolomite. On the surface of the river the spring appears as a very pronounced boil whose height above the surface depends upon the discharge of the spring and that of the river. Unlike the water in some resurgences, where flow lost in upstream reaches reappears downstream, the water in this spring has a bright blue color and its source is in the upland areas east and south of the spring. It is reported that it has been turbid only once in 30 years (Bretz, 1956, p. 412). At low river stage, when the bottom of the pool can be seen, it is filled with gravel continually churned by the rising current.

The spring can be reached by a private road; the owner charges a small admission fee for using the road and viewing the spring. Another private road leads to a lookout point on the bluff where the spring can be viewed from above. Years ago the spring was used as a water supply for a bluff-edge lodge and cabins above the spring. A cable was stretched from the bluff to a point above the spring, and a bucket could be lowered into the spring and water drawn upward to the lodge.

The importance of highly permeable bedrock to the development and continuous functioning of a

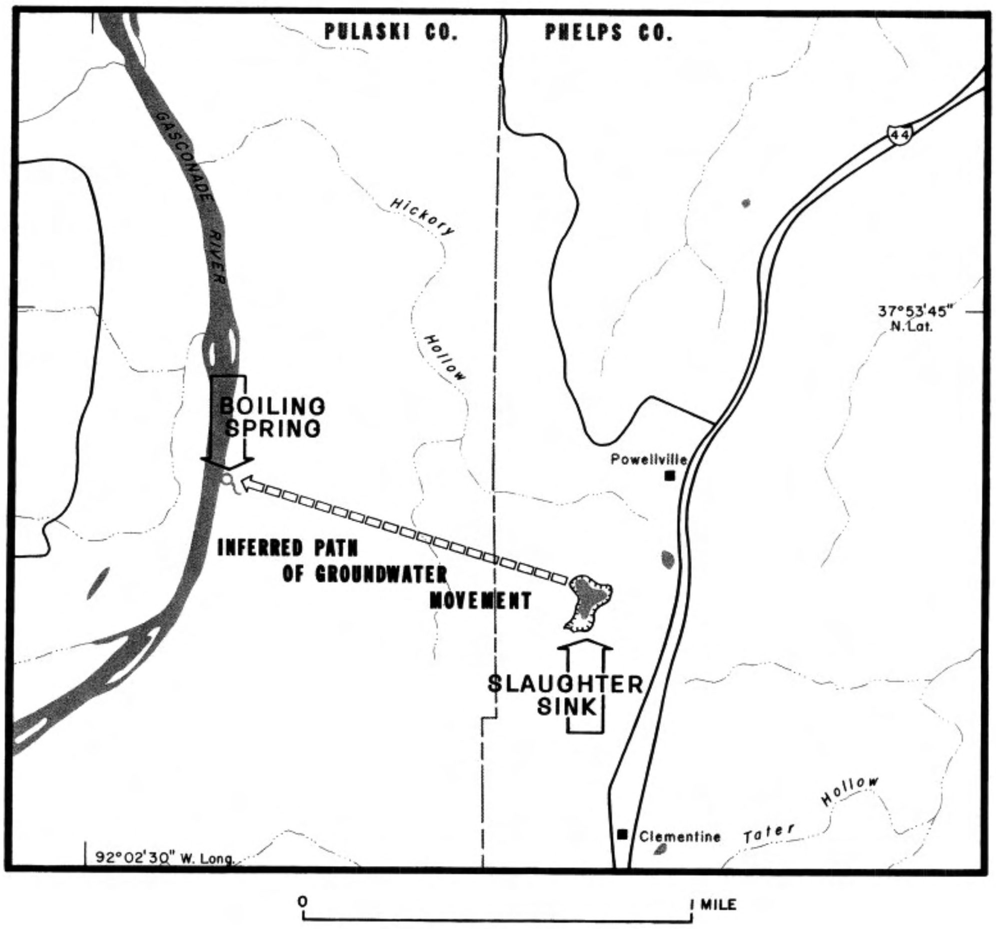


Figure 47

Boiling Spring is a classic example of a karst spring deriving flow from upland sinkholes. Fluorescein dye injected in Slaughter Sink traversed the solution channels to Boiling Spring within two days. Base map from U.S. Geological Survey, Dixon 7½-minute quadrangle.

large spring is extremely well illustrated by Boiling Spring. It is in the midst of an extraordinary concentration of karst features. Using caves as an index of solution activity, within a 1-mile radius of Boiling Spring there are 12 caves. Others probably exist, but may be hidden by hillslope talus. The largest of these is Onyx Cave, high on the hillside approximately 1/3 mile southeast of Boiling Spring. Onyx Cave has more than 2 miles of passages exhibiting cavern development and sedimentational history typical of the area (Bretz, 1956, p. 411-412; and Vineyard, 1964, p. 35-39). The other 11 caves near Boiling Spring are smaller than Onyx Cave, though some are nearly as long.

Approximately 1 mile east-southeast of Boiling Spring is Slaughter Sink, the largest sinkhole in the general area of the spring. Water draining into Slaughter Sink and the adjacent Conical Sink has been traced by fluorescein dye into Boiling Spring (fig. 47). Slaughter Sink has a partial fill of soil and rock accumulated by erosion of the uplands surrounding the depression. Small sinks a few feet in diameter and several feet deep occasionally develop in this fill, indicating that the processes that produced the immense ponor are still operative. The drainage from the large basin of Slaughter Sink is not capable of carrying away all of the water that enters the sink during storm periods; therefore, an intermittent lake forms after heavy rains.

Conical Sink has long been used by local residents as a dumping ground, and has received countless tons of trash, garbage, and debris over the years. Both Conical Sink and Slaughter Sink have been acquired by Clark National Forest and the dumping has been stopped. The U.S. Forest Service expects to develop plans for reclamation of the sinks that will help to restore water quality in Boiling Spring.

Steyermark (1941, p. 553) described the flora growing around the margin of the spring. The plants are not as profuse in the spring because of its location in the bed of the river. Boiling Spring is unused except as a tourist attraction. However, it is reported that the spring is a favorite place to fish when the river is low.

BROOK SPRING, *Phelps County, Maramec Spring 7½-minute quadrangle, SE¼ SW¼ sec. 22, T. 38 N., R. 6 W.*

Brook Spring, near the Administration Building of Boys Town of Missouri, rises in a rock-walled circular basin at the foot of stone steps leading to the building. Before the building was constructed the spring emerged from a cave beneath the house; improvements around the spring area have erased any evidence of the cave. Until 1955 the spring supplied water for Boys Town. At that time the waters turned dark, possibly as a result of pollution, making the development of other sources desirable. Presently the waters are used for recreation only.

COPPEDGE SPRING, *Phelps County, Flat 7½-minute quadrangle, NE¼ SE¼ sec. 36, T. 36 N., R. 10 W.*

Coppedge Spring issues at the side of a county road and flows for about a quarter of a mile into Spring Creek. Presently the spring property is owned by the University of Missouri. At one time a grist mill, woolen mill, and the community of Relfe were on the spring branch. Very little remains of any part of the community. Spring water was used to supply the homes and buildings at one time and the hydraulic ram used to transport the water is still intact. Today no use is being made of the spring water. The dominant plant in the spring branch is water cress. In the lower part of the branch, plants such as water crowfoot and water starwort also occur. Some peppermint grows near the confluence of the spring branch and Spring Creek.

CREASY SPRING *(also known as Bubbling Spring), Pulaski County, Ozark Springs 7½-minute quadrangle, SE¼ SW¼ sec. 17, T. 36 N., R. 12 W.*

Creasy Spring rises in the floodplain on the left bank of the Gasconade River about ½ mile upstream from Bartlett Mill Spring. The geologic settings of the two springs are similar. The spring is submerged whenever the river is high. The spring is unused, but it is an important contributor to the base flow of the Gasconade River. Steyermark (1941) described the plant assemblage of Creasy Spring, the varieties of plants being smaller than those usually found in Ozark springs. This may be because Creasy Spring is often flooded by the Gasconade.

Solomon Bartlett, who built the original Bartlett Mill at nearby Bartlett Mill Spring, constructed a rock wall around Creasy Spring to increase the flow of water for the mill. The old rock dike is no longer apparent, but it has served to partially protect the spring from river floods.

Probably one of the most interesting features of Creasy Spring is its relationship to other springs in the vicinity and to the Gasconade River. Bolon (1963, p. 23-25) described the results of seepage runs

Figure 48

Falling Spring is enclosed by a rock dam built in the hope of increasing the flow of nearby Bartlett Mill Spring to provide more power for Bartlett Mill. History does not reveal whether the attempt was successful since records were not kept during the years prior to construction of the dam. Photo by Jerry D. Vineyard.

made on the Gasconade River between Hazelgreen and Waynesville during the drought of 1953. Figure 44 shows how the flow of the Gasconade River declines in the reach from Laquey Hollow to Collie Hollow. Just below Collie Hollow water boils up in the bed of the Gasconade River and Creasy, Falling and Bartlett Mill Springs increase the Gasconade's discharge so that it is about twice as large at the gaging station below Waynesville than it is above the losing reach. Bolon made the additional observation that the water boiling into the bed of the stream had a temperature of 62°F., which is 5° warmer than normal spring water temperature, indicating that water coming up in the boils is the lost streamflow. The temperature of the water in Creasy, Bartlett Mill and Falling Springs is from 57° to 58°F. The source of this water is the upland areas on either side of the river rather than a resurgence of lost streamflow.

FALLING SPRING, *Pulaski County, Ozark Springs 7½-minute quadrangle, SW¼ SW¼ sec. 16, T. 36 N., R. 12 W.*

Falling Spring rises beneath a steep, near-bluff hill on the right (south) bank of the Gasconade River about ½ mile above Bartlett Mill Spring and ¼ mile above Creasy Spring. The spring would emerge at river level were it not for a 6-foot high rock dam (fig. 48) which was constructed around the spring by

Solomon Bartlett, who built the original mill at nearby Bartlett Mill Spring. Bartlett reasoned that by putting a head on Falling Spring and nearby Creasy Spring he could increase the flow of Bartlett Mill Spring. Unfortunately there are no records to show whether he was successful.

Falling Spring can be reached by boat from Pippin Lodge. For further information on the relationships between Falling Spring, Creasy Spring and Bartlett Mill Spring, refer to Bartlett Mill Spring (p. 119).

HAZELTON SPRING, *Texas County, Slabtown Spring 7½-minute quadrangle, SE¼ NW¼ sec. 34, T. 33 N., R. 10 W.*

Hazelton Spring rises in a swampy section of a large open field and flows for about 600 feet into Piney Creek. A dam was constructed on the branch so that presently the spring opening is submerged in a 5-acre lake. At one time the waters provided power to operate a grist mill, which has disappeared. The lake is stocked with fish. Some of the waters are used for watering stock.

The spring branch is bordered by dense masses of water cress. Other plants found in the spring basin and branch are described by Steyermark (1941).

MILLER SPRING, *Pulaski County, Big Piney 7½-minute quadrangle, SE¼ NE¼ sec. 6, T. 34 N., R. 10 W.*

Miller Spring is one of the larger ebb-and-flow springs in Missouri and the only one known in the Gasconade basin. According to Fowke (1922, p. 58), Indians living in the region named the spring and his translation of their name is "Breathing Spring." Thus, the ebb-and-flow character of springs has been recognized for a long time. The spring is on private property at the end of a farm road on the left bank of Big Piney River. The opening is in a pool at the base of a bluff of Gasconade Dolomite and the spring branch flows about ¼ mile to the Big Piney. During high water on the river, water backs into the spring pool and at these times the ebb-and-flow action is obscured. Also, during rainy periods when the discharge of the spring increases to a high level, even though the river does not back water into the spring, the ebb-and-flow action ceases until the discharge declines. However, the spring has not been observed at such a low stage that the ebb-and-flow action has ceased. Rymer Spring in the Current River basin, on the other hand, ceases to ebb and flow when there is a low rate of discharge during extended dry periods.

The spring is used for watering stock. Steyermark (1941, p. 586) described the flora of the spring and spring branch as abundant and among the more varied of the Ozark springs. He described 13 different species.

NAGOGAMI SPRING, *Maries County, Vienna 15-minute quadrangle, SW¼ NW¼ sec. 35, T. 39 N., R. 9 W.*

Nagogami Spring, formerly called Gaines Ford Spring, emerges from the base of a steep limestone bluff and flows in its branch for about 500 feet into the Gasconade River. The earliest known use of the spring water (about the mid-1800's) was for the purpose of distilling spirits. Situated in a rugged, tree-shaded and picturesque area, the spring and river during the early 1900's became the focal point for a thriving and popular resort known as Nagogami Lodge. Here were found rented cottages, dining facilities, and all forms of water-based recreational facilities. Also during this period a part of the area was owned by the Rolla Country Club whose members maintained summer cottages along the river and around the spring. The spring waters during this time were used for domestic purposes in the lodge and in some of the summer cottages. Today, little remains of the lodge and its facilities; however, the number of well-kept cottages in the country club area has grown considerably.

Steyermark (1941) described the flora found in the spring basin and spring branch in detail in his publication on the flora of Missouri springs.

ROUBIDOUX SPRING *(Waynesville Spring), Pulaski County, Waynesville 7½-minute quadrangle, NE¼ NW¼ sec. 25, T. 36 N., R. 12 W.*

Roubidoux Spring flows from a rocky basin at the base of a high bluff of Gasconade Dolomite along Roubidoux Creek within the city limits in the southern part of Waynesville. A county road passes between the spring and the bluff and is protected by a concrete retaining wall (fig. 49) which prevents undermining of the road by the spring during periods of high discharge. The spring is easily reached from Interstate 44, 3/4 mile south of the spring, and from Business Route 66, ¼ mile north of the spring.

Figure 49

Roubidoux Spring at low flow as viewed from the bluff overlooking the spring basin. Much of the discharge of the spring is the resurgence of Roubidoux Creek water that enters the spring system in a losing reach of Roubidoux Creek some 10 miles south of the spring. The light color of the vegetation results from the use of infrared film. Photo by Jerry D. Vineyard.

Old photographs of Roubidoux Spring show the waters emerging from a shallow, water-filled cave which has since been filled with rocks. In periods of high discharge, the rocks are churned by the surging waters and slowly destroyed by attrition. However, the many visitors to the spring keep the supply of rocks relatively constant by throwing rocks into the spring. Divers have excavated the rock fill sufficiently to enter the water-filled cave from which the spring flows (D.N. Rimbach, oral comm., 1971), but the spring quickly refills the opening with rocks.

Roubidoux Spring is now partly protected from Roubidoux Creek by a low rock dam which raises the level of the spring about 2 feet above that of the creek. When Roubidoux Creek is in flood, the spring may be covered with 8 to 10 feet of water, but even when this occurs the discharge of the spring increases accordingly and is sufficient to produce a mound or boil of water that rises more than 3 feet above the level of flood waters in Roubidoux Creek (fig. 50). The spring has never been measured in periods of peak flow. During high flow, spring water is usually much clearer than Roubidoux Creek water (fig. 51). It is interesting to note that the maximum measured flow of Roubidoux Spring is greater than that of Boiling Spring in Pulaski County, but the minimum flow of Roubidoux Spring is far less than the lowest measurement of Boiling Spring.

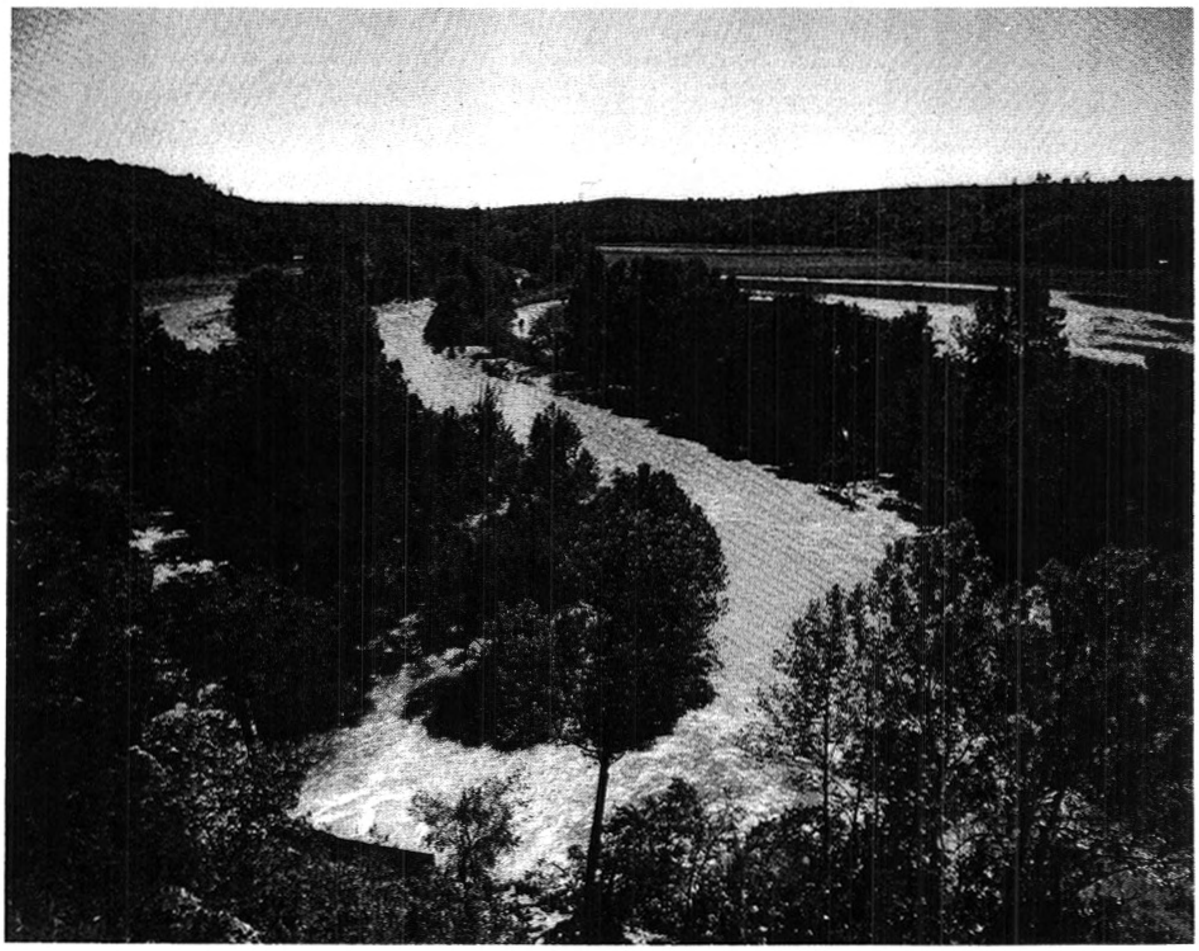


Figure 50

Roubidoux Spring in flood stage, backflooded to a depth of 9 feet by Roubidoux Creek during the flood of January 1969. Downstream is toward the lower right corner of the picture; the spring boil is in the lower left-center. Photo by Jerry D. Vineyard.

Figure 51

Roubidoux Spring at Waynesville during medium to high flow exhibits a common characteristic of Ozark springs; the spring water is strikingly clearer than floodwaters in Roubidoux Creek. The apparent cave in the cliff above the spring marks the Cryptozoon *reef separating Upper and Lower Gasconade Dolomite. Photo taken in April 1972 by Jerry D. Vineyard.*

Recharge for Roubidoux Spring comes from the dry valley of Roubidoux Creek extending south and west for a distance of approximately 10 miles from Roubidoux Spring (fig. 52). Permanent flow begins in Roubidoux Creek about 1 mile southeast of Roubidoux Spring. From this point toward the headwaters of the creek, Roubidoux Creek sinks into a wide gravel bed, and the stream is dry most of the year for a distance of approximately 15 river miles.

SHANGHAI SPRING *(Blue Spring), Pulaski County, Devils Elbow 7½-minute quadrangle, NE¼ SW¼ sec. 24, T. 36 N., R. 11 W.*

Shanghai Spring rises in a circular basin about 25 feet in diameter, at the base of a bluff of Gasconade Dolomite. The spring flows over a riffle, beneath a road and a U.S. Army railroad spur before it empties into the Big Piney River a few hundred feet away. The well-kept grounds in the vicinity of the spring feature a large house with walls constructed principally of thick concrete. Shanghai Spring can be observed from a small wooden bridge carrying a county road across the spring branch.

At the base of the bluff, about 10 feet above the spring pool, there is an entrance to a small cave. This entrance is screened by trees and other vegetation so it is not obvious to the casual observer. However, inside the cave there is a short slope leading downward to a passage about 6 feet wide, trending north-northwest for about 100 feet. The water level of pools inside this cave are the same elevation as the water in the spring pool; the water in the cave is part of the supply system of the spring. It is possible to wade through the first pool (fig. 53), which is about 3 feet deep, and through deep, sticky mud to the end of the cave (fig. 54). At this point the water becomes much deeper and extends beneath a ledge, forming a siphon. This is the deep channel for Shanghai Spring. It is not possible to explore further in this channel without the use of underwater breathing apparatus and this is not really practical because the soft mud is easily disturbed, making the water very turbid.

During periods of extremely high flow, backwater from nearby Big Piney River floods the spring to a depth of several feet. Discharge of the spring on these occasions is sometimes so great that channels feeding the main pool cannot handle the flow so water gushes from the cave entrance (fig. 55).

There is a sinkhole on top of a hill directly above Shanghai Spring that is aligned with the orientation

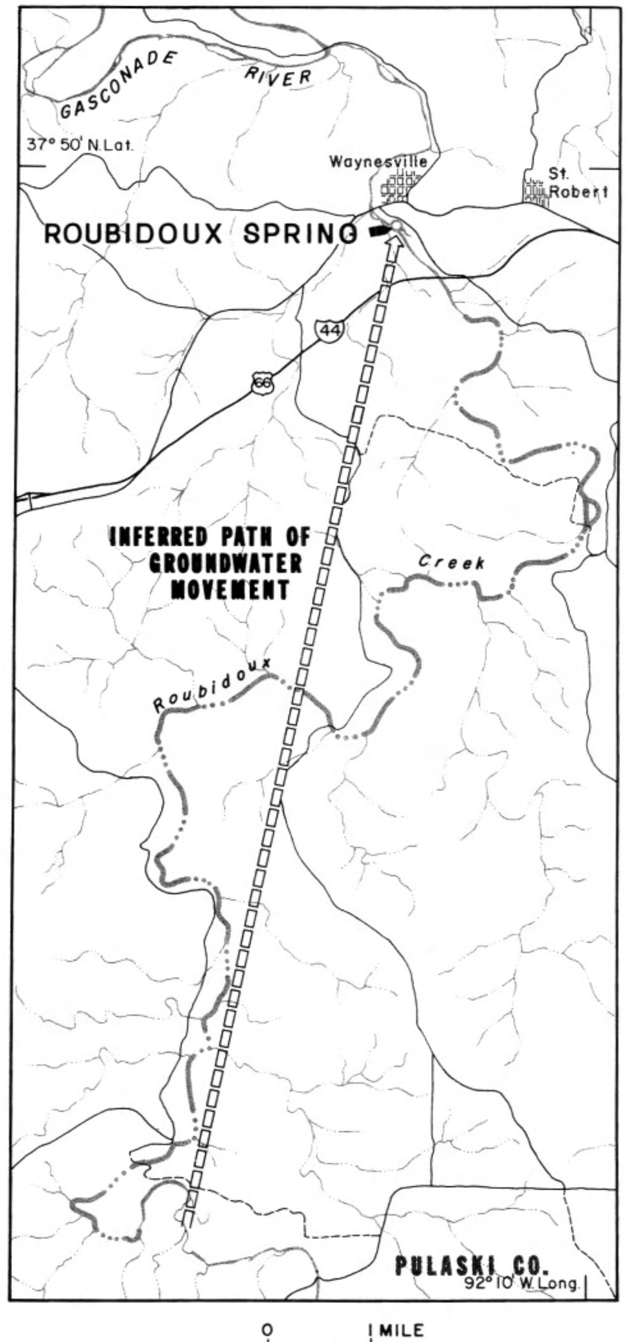


Figure 52

Map showing loss of water in Roubidoux Creek and its resurgence in Roubidoux Spring. Base map from U.S. Geological Survey, Waynesville and Big Piney 15-minute quadrangles.

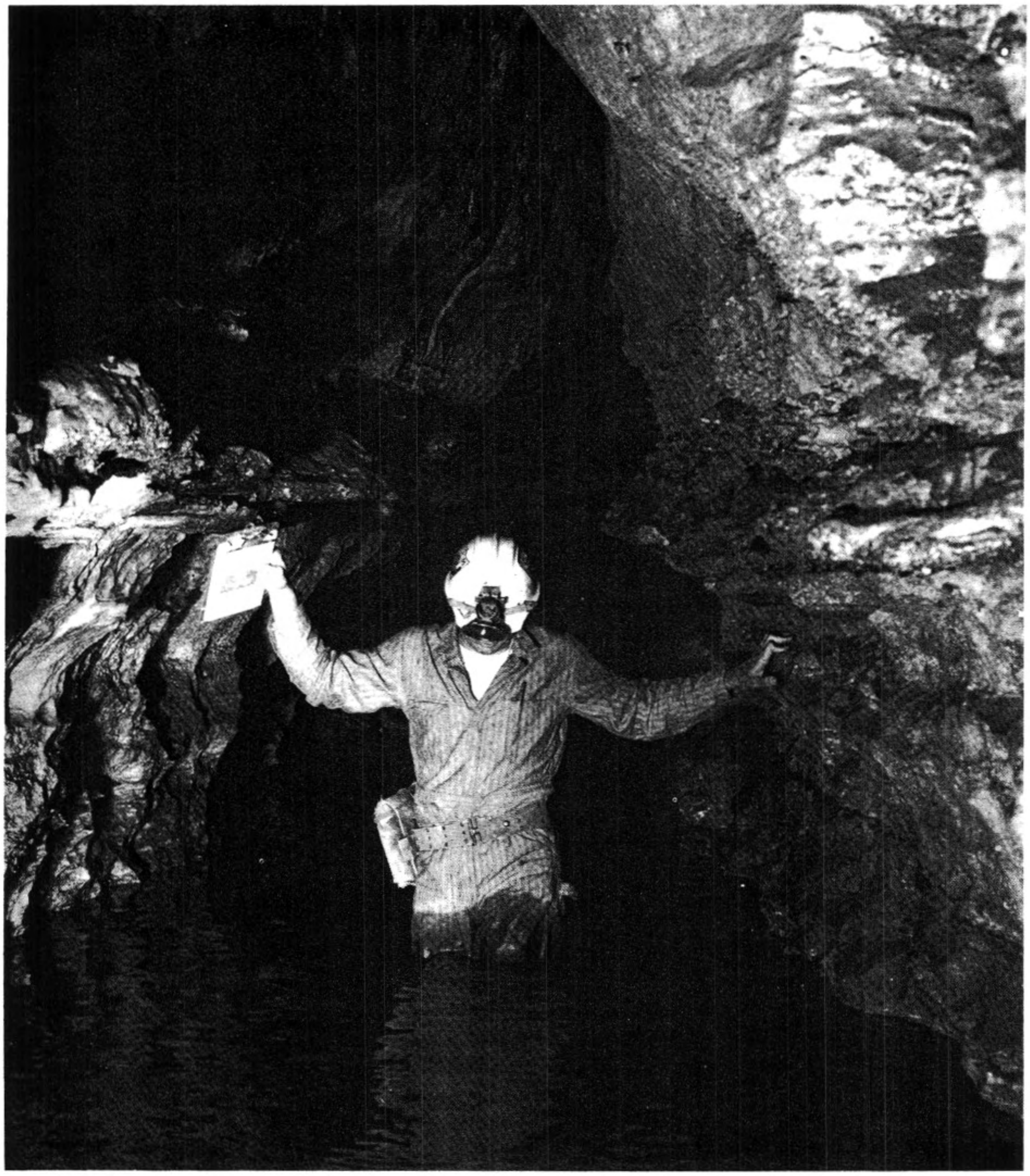


Figure 53

A short part of the Shanghai Spring supply system is exposed in a small cave in a bluff behind the spring. During periods of high flow the cave fills with water which discharges at the cave entrance as a second orifice of Shanghai Spring. Note passage alignment along a prominent joint trending north-northwestward. Photo by Jerry D. Vineyard.

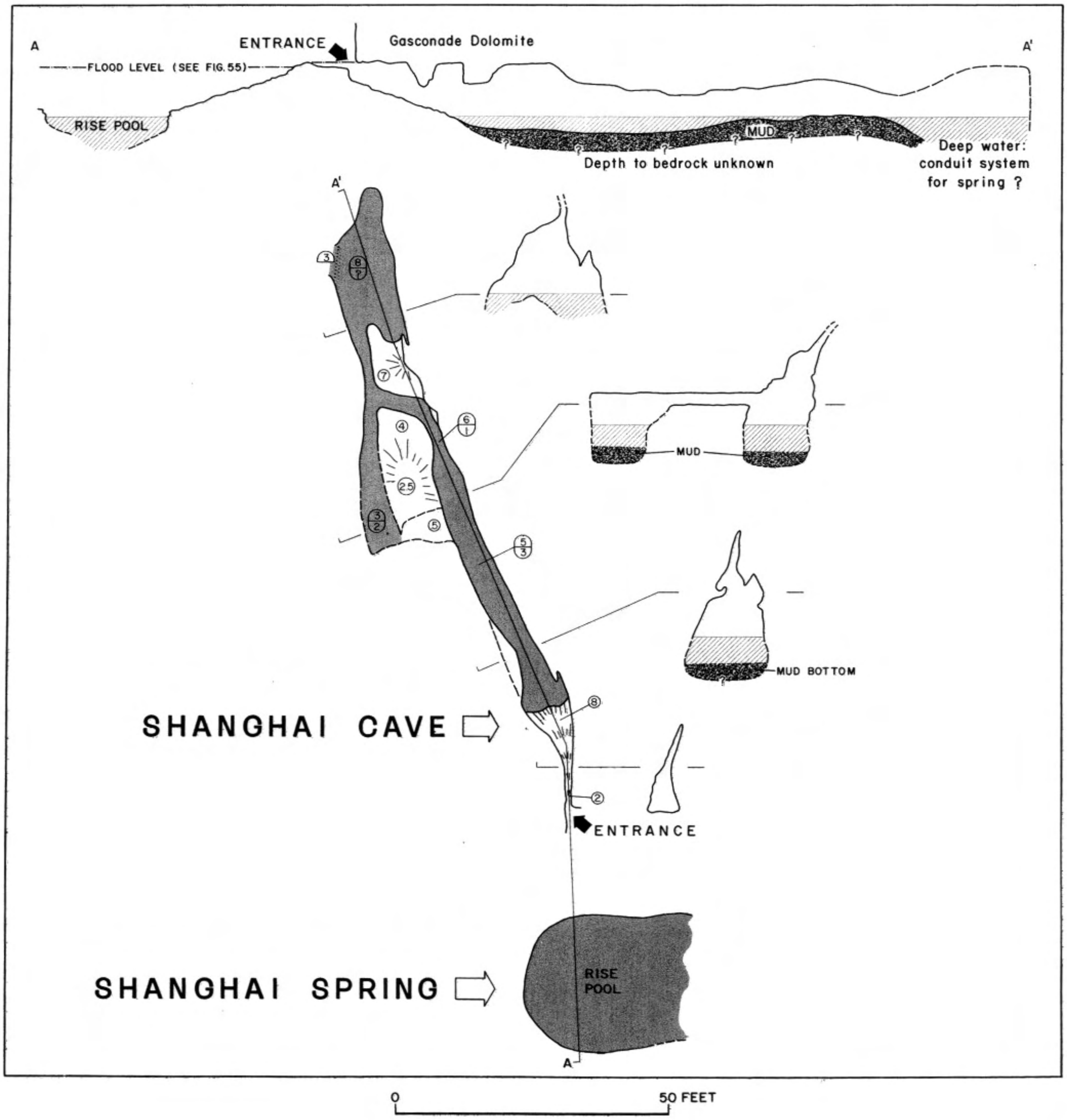


Figure 54

Plan and profile of Shanghai Spring Cave and its relation to Shanghai Spring.

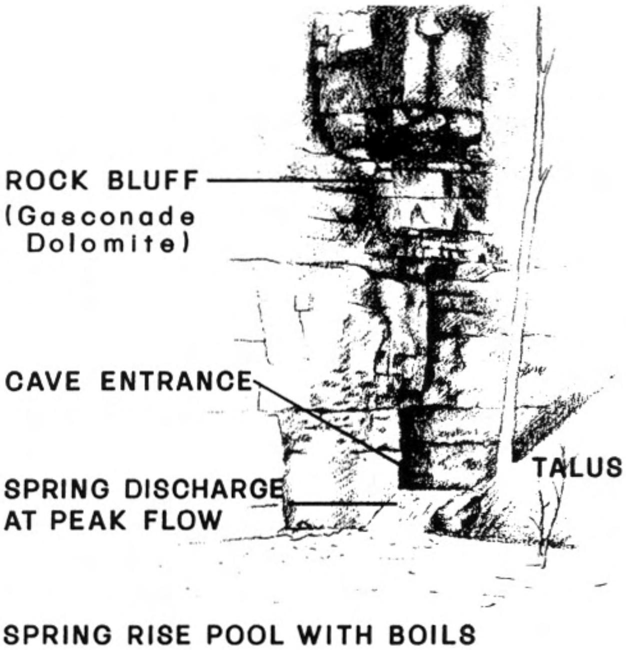


Figure 55

Drawing of Shanghai Spring showing discharge of floodwaters from the entrance to Shanghai Cave, above the spring. Drawing by D.R. Stark, from a photograph taken during the flood of January 1969.

of the cave. There are also several intermittent streams to the northwest of the spring orifice which are dry for the better part of the year. It is probable that most of the flow of Shanghai Spring comes from water lost to the porous bedrock of these dry valleys. Water tracing with fluorescein dyes has also shown that part of the spring flow comes from sinkhole drainage, 7 or 8 miles southwest of the spring; other increments of the flow have been traced to dry valleys draining the town of St. Robert (including its sewage disposal facilities).

As shown in table 10, the nitrate content of Shanghai Spring has varied considerably over a period of years. The high nitrate values obtained in the 1950's are thought to have been caused by sewage disposal practices by upstream users. The most recent (1971) analysis of Shanghai Spring water shows nitrate content about normal for springs in this region.

WILKINS SPRING, *Phelps County, Kaintuck Hollow 7½-minute quadrangle, NE¼ NE¼ sec. 20, T. 36 N., R. 9 W.*

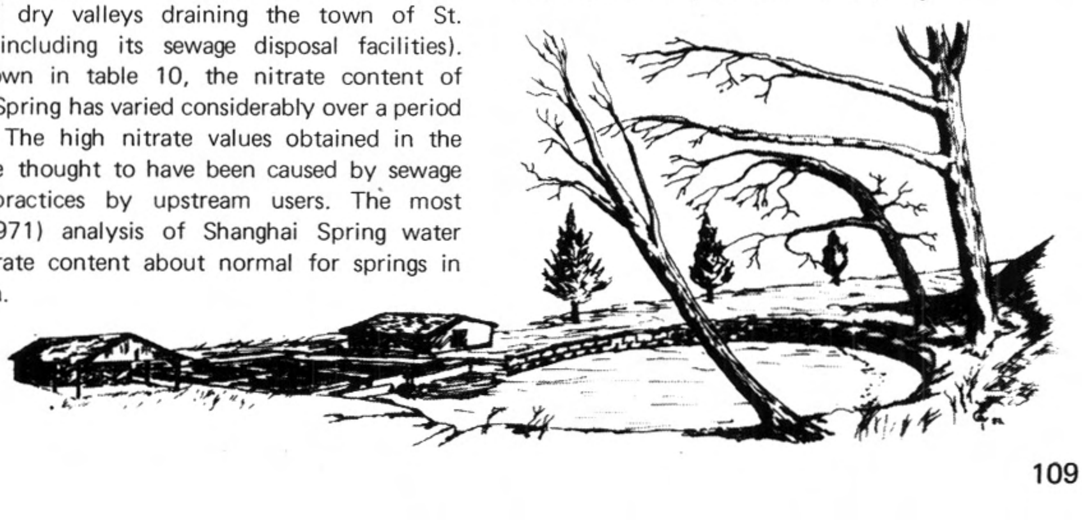
Wilkins Spring rises in a 2-acre lake in an open field on what was formerly Dewitt's Folly Ranch (now part of Clark National Forest). The lake is formed by an earthen dam with a concrete flume spillway. After leaving the spillway, water travels for about 1,000 feet into Mill Creek. The lake is well stocked with trout. The lake and spring branch, amid rustic, hilly surroundings, make Wilkins Spring unusually attractive.

Steyermark (1941) found 10 species of plants in the lake and spring branch.

YANCY MILLS SPRING, *Phelps County, Yancy Mills 7½-minute quadrangle, SE¼ SW¼ sec. 32, T. 36 N., R. 8 W.*

Yancy Mills Spring is on the left bank of the Little Piney River near U.S. Highway 63 about 13 miles south of Rolla. The Gasconade Dolomite is exposed in the bluffs around Yancy Mills but no rock can be seen at the spring opening.

In earlier years a lake, formed by a rock wall around the spring, stored water to operate a grist mill. Recently the spring has been improved with the construction of rearing pools to raise trout. The spring is privately owned and is presently used for fee fishing. The surroundings, the Little Piney River, the high rock bluffs, and the improvements around the spring contribute to the beauty of the area. Steyermark (1941, p. 618) described the lush and varied growth of plant life in the spring.



MERAMEC RIVER BASIN

BASIN DESCRIPTION

The Meramec River basin lies entirely in Missouri and drains approximately 3,980 square miles. The river rises in the Salem Plateau, flows generally northeasterly and enters the Mississippi River 12 miles south of St. Louis. The basin drains a highly dissected plateau with the land surface sloping gently to the north and becoming increasingly more rugged to the south. Surface elevations range from 1,500 feet above mean sea level at its headwaters to about 450 feet at its junction with the Mississippi River. There are many sinkholes in the basin. The many springs in the basin contribute to the high sustained base flow of the Meramec and many of its tributaries. Table 11 gives the discharges for springs in the Meramec basin. Figure 56 is a map showing the locations of measured springs in the Meramec River basin.

The rocks that crop out over much of the basin are principally dolomite and cherty dolomite with some beds of sandstone. In the southeastern part of the basin, granite and associated volcanic rocks of Pre-cambrian age are exposed at the surface. Much of the upland area of the northern part of the basin is capped with shales and clays of Pennsylvanian age which overlie and, in some cases, fill depressions in an ancient karst topography developed on the cherty dolomite and sandstone beds of the Cotter, Jefferson City and Roubidoux formations.

In the western part of St. Louis County and in parts of Jefferson County, St. Peter sandstone and overlying dolomite and limestone beds of Ordovician age are exposed. These strata are seen in the bluffs that make up the valley walls of the Meramec and Big Rivers in the vicinity of Pacific, House Springs and Eureka. Below Valley Park, the Meramec River – as it approaches its mouth – flows across geologically younger beds of limestone of Mississippian age. In the eastern part of St. Louis County these Mississippian beds are covered in places at the surface by shales and thin limestone of Pennsylvanian age.

QUALITY OF WATER

Springs in the Meramec River basin yield moderately mineralized water. Calcium, magnesium and bicarbonate are the predominant constituents dissolved in the water, but sulfate and chloride make

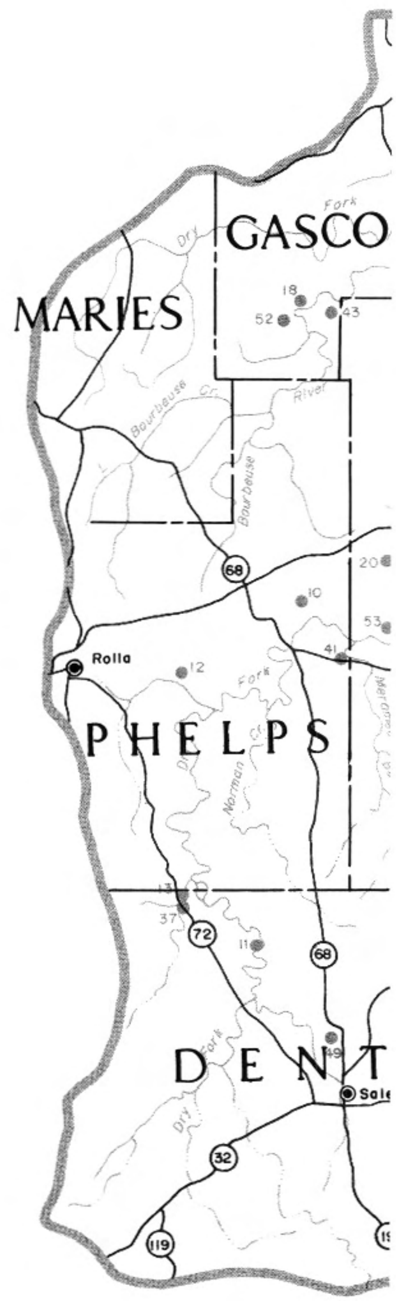


Figure 56

Springs in the Meramec River basin.

Table 11

Discharges of springs in the Meramec River basin

[A = less than 0.01 cfs]

Location No. (fig. 56)	Spring	Nearest Town	County	Land Line Location	Rate of Flow: Sec. Ft. (cfs)	Rate of Flow: 1000 gal. day	T °F.	Date	Remarks
1	Antire	Times Beach	St. Louis	SE 34,44,4E	A	A	57	8-28-64	Boy Scout Camp
2	Antire Farm	Times Beach	St. Louis	NESW 34,44,4E	.02	13	54	8-28-64	
3	Beaumont	Times Beach	St. Louis	NWSE 34,44,4E	.03	19	56	9-6-64	
4	Beaver	Steelville	Crawford	SESW 34,38,5W	.20	129	-	7-6-25	
					.18	116	-	7-7-25	
					.19	123	57	8-11-36	
					.11	71	58	12-13-63	
					.03	19	59	8-28-64	
					.04	26	57	12-2-64	
5	Blue	Bourbon	Crawford	NESW 2,39,3W	4.90	3,170	-	9-3-25	
					7.05	4,550	60	9-29-53	
					5.60	3,620	57	12-10-63	
					5.33	3,440	57	8-25-64	
					6.33	4,090	55	12-4-64	
6	Blue Grass No.1	Eureka	St. Louis	NWSW 34,44,4E	.10	65	58	8-23-34	Wash. Univ.
					.04	26	-	1-1-36	
					1.20	775	-	4-19-37	
					.07	45	-	12-9-63	
					.04	26	63	8-28-64	
					.18	116	54	12-4-64	
7	Blue Grass No.2	Eureka	St. Louis	NWSE 34,44,4E	.03	19	57	8-29-64	
					.02	13	55	10-25-64	
8	Blunt	Bourbon	Crawford	NWSE 21,39,2W	.04	26	-	8-25-64	Domestic
					.06	39	58	9-29-64	
9	Bloch	Viburnum	Iron	SWSE 21,35,1W	.25	162	57	9-13-66	
10	Brook	St. James	Phelps	SESW 22,38,6W	4.69	3,030	58	6-28-35	
					.65	420	57	5-10-36	
					.62	401	-	9-7-39	
					.66	426	56	12-11-64	
11	Brown	Salem	Dent	SENE 17,35,6W	.14	90	-	5-18-36	
					A	A	-	8-27-64	
12	Brown	Rolla	Phelps	NENE 9,37,7W	.09	58	59	9-28-53	
					.06	39	57	8-28-64	
13	Bubbling	Lake Spring	Dent	NENW 3,35,7W	.11	71	54	5-17-49	Private picnic area,
					.09	58	54	5-17-49	stock supply
					.04	26	-	5-12-52	
14	Bunker	Times Beach	St. Louis	NWNW 34,44,4E	A	A	54	10-31-64	
15	Carl	Viburnum	Iron	SENW 21,35,1W	.34	220	57	9-13-66	
16	Cold	Shirley	Washington	SE 4,37,1E	3.30	2,130	55	10-8-26	
					.69	446	55	10-12-32	
					.80	517	55	10-21-63	
					.72	465	52	8-26-64	
					.83	536	52	12-4-64	Lodge
17	Collins	Steelville	Crawford	NWSW 35,38,4W	1.60	1,030	57	10-11-32	
					1.50	969	56	12-13-63	
					1.69	1,090	52	8-24-64	
					1.53	988	58	12-13-64	Domestic
18	Coon Cave	Bland	Gasconade	NWNW 14,40,6W	.20	129	55	6-6-66	Stock
19	Crystal	Babler State Pk.	St. Louis	SENE 29,45,3E	A	A	55	8-15-64	
20	Ebb and Flow	Cuba	Crawford	NESE 8,38,5W	.02	13	56	12-17-36	
					.04	26	57	8-25-65	
21	Elm	Cuba	Crawford	SWSW 9,38,5W	.75	484	56	9-10-36	Fish hatchery
					.70	452	57	12-11-36	
					.28	181	57	8-26-64	
					.63	407	56	12-11-64	
22	Elm	Sullivan	Franklin	NWSW 11,40,2W	1.20	775	-	5-25-37	
					.13	84	58	9-29-53	
					.02	13	56	11-10-63	
					.04	26	57	8-25-64	
					.04	26	54	12-3-64	
23	Evans	Steelville	Crawford	NWNW 2,37,4W	5.30	3,420	-	9-26-24	
					2.60	1,680	-	8-6-30	
					.40	258	-	10-11-32	
					1.40	904	53	12-13-63	
					1.62	1,050	55	8-28-64	
					.97	627	51	12-3-64	
24	Falling	Sullivan	Franklin	NENE 14,40,2W	.08	52	-	5-25-37	
					.02	13	58	9-29-53	
					.01	6	54	12-10-63	
					.02	13	59	8-24-64	
					.07	45	53	12-3-64	
25	Gamlin	Salem	Dent	SESE 5,34,4W	1.48	956	-	11-28-50	Stock
					1.24	801	59	8-28-64	
					1.25	808	56	11-30-64	

Table 11 – *DISCHARGES OF SPRINGS (continued)* . . . . .

(Meramec River Basin)

Location No. (fig. 56)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
26	Gibbs	Steelville	Crawford	NENE 26,38,3W	1.43	924	52	8-26-64	
					1.23	795	56	11-30-64	
27	Glencoe Hollow	Eureka	St. Louis	SWNW 13,44,3E	.01	6	56	9-30-53	
					.04	26	54	8-28-64	
28	Green Cave	Sullivan	Washington	SWSE 24,40,2W	A	A	56	7-27-67	
29	Hamilton Cave	Sullivan	Washington	SESW 20,40,1W	A	A	62	7-27-67	
30	Hopewell	Hopewell	Washington	NENE 33,37,3E					
	(Average of 33 measurements)				.69	446	-	1942-1966	
	(Maximum discharge measured)				2.03	1,310	-	3-9-42	Domestic
	(Minimum discharge measured)				.40	258	57	8-25-65	
31	House Springs	House Springs	Jefferson	NENW 4,42,4E	.77	500	-	9-2-25	Fills ponds
					7.90	5,100	55	5-18-46	
					.02	13	56	9-30-53	
					A	A	-	8-25-64	
					A	A	-	9-7-64	
32	Howes Mill	Howes Mill	Dent	SESW 15,34,3W	8.06	5,210	57	10-13-32	
					7.09	4,580	58	8-5-36	
					3.06	1,980	58	8-10-53	
					2.47	1,600	-	3-12-54	
					1.80	1,160	56	8-27-64	
					2.81	1,820	-	12-3-64	
33	Indian	Steelville	Crawford	SWNW 36,38,5W	.24	155	56	9-11-36	Trout fishing
					.20	129	58	9-24-64	
					.14	90	56	12-13-63	
					.06	39	61	8-27-64	
					.12	78	55	12-2-64	
34	James	Steelville	Crawford	SESE 36,38,3W	2.16	1,400	57	10-12-32	
					3.50	2,260	55	12-13-63	
					3.50	2,260	58	8-26-64	
					3.45	2,230	51	12-4-64	
35	Kratz	Stanton	Franklin	SENW 4,41,2W					
	(Average of 34 measurements)				15.6	10,100	56	1925-1966	Stock
	(Maximum discharge measured)				42.0	27,100	-	5-4-66	
	(Minimum discharge measured)				6.85	4,430	-	9-3-25	
36	LaJolla	Meramec Caverns	Franklin	NWNE 1,40,2W	3.62	2,340	57	10-1-53	
					2.23	1,440	56	12-9-63	
					2.65	1,710	56	8-24-64	
					3.16	2,040	55	12-3-64	
37	Lake	Lake Spring	Dent	SENE 3,35,7W	.09	60	-	7-22-25	
					.02	13	-	5-12-36	
					.12	78	-	12-31-46	
					A	A	57	10-18-63	
					.05	32	55	8-7-64	
					A	A	55	8-27-64	Domestic
					A	A	54	11-30-64	
38	McDade	Cuba	Crawford	NENW 16,39,5W	.80	517	-	9-7-34	Commercial fish hatchery
					1.43	924	57	1-21-64	
					.56	362	59	8-26-64	
					1.19	769	54	12-8-64	
39	McIntosh	Cuba	Crawford	NENE 13,38,5W	1.36	879	-	2-10-35	
					.95	614	57	9-10-36	
					1.01	652	58	12-11-63	
					1.45	937	58	8-26-64	
					1.02	659	57	12-11-64	
40	McNamee	Pacific	Jefferson	Survey 43,3E 1932	A	A	60	9-30-53	
41	Maramec	St. James	Phelps	NWSE 1,37,6W	(See page 155 for data on flow)				Trout raising
42	Mincke	Times Beach	St. Louis	SENE 28,44,4E	A	A	55	10-25-63	
43	Mint	Redbird	Gasconade	NESE 13,40,6W	.01	6	-	12-26-46	
					.05	32	55	6-6-66	
44	Mint	Salem	Dent	NWSE 13,35,5W	.60	388	-	8-27-36	
					.31	200	57	12-12-63	
					.22	142	55	8-28-64	
					.17	110	54	12-3-64	
45	M. L.	Ranken Valley Pk.	St. Louis	NENE 25,44,4E	.05	32	58	9-6-64	
46	Onondaga	Leasburg	Crawford	NWNW 35,39,3W	1.91	1,230	-	9-1-42	
					1.09	704	62	9-29-53	
					1.19	769	56	12-11-63	
					.60	388	54	12-2-64	
47	Plegge	Times Beach	St. Louis	SESW 34,44,4E	.12	78	54	9-6-64	
48	Pratt	Sullivan	Washington	NESW 30,40,1W	.65	420	59	7-27-67	
49	Pulman	Salem	Dent	NWSE 1,34,6W	.02	13	-	7-13-59	
50	Pohlman	Pacific	Jefferson	Survey 43,3E 1932	A	A	-	9-30-53	

Table 11 *(continued)* . . . . .

Location No. (fig. 56)	Spring	Nearest Town	County	Land Line Location	Rate of Flow: Sec. Ft. (cfs)	Rate of Flow: 1000 gal. day	T °F.	Date	Remarks
51	Racing	Shirley	Washington	NESE 21,37,1E	2.28	1,470	-	3-6-41	
					1.78	1,150	56	12-11-63	
					1.37	885	53	8-26-64	
					1.49	963	-	12-4-64	
52	Rhodes	Bland	Gasconade	NENW 22,40,6W	A	A	53	6-6-66	Stock
53	Richart	Cuba	Crawford	NESE 29,38,5W	1.25	808	57	9-10-36	
					1.11	717	58	8-27-64	
					1.67	1,080	56	12-11-64	
54	Roaring	Cuba	Crawford	NENW 22,38,5W	4.10	2,650	58	12-1-32	
					1.80	1,160	53	1-12-64	
					1.42	917	54	12-11-64	
55	Roaring	Stanton	Franklin	NESE 19,41,1W	1.00	646	-	9-3-25	
					2.36	1,520	57	9-4-36	
					2.85	1,840	56	12-9-63	
56	Rock	Allenton	St. Louis	SWNW 14,43,3E	.10	65	-	3-3-35	
					A	A	-	12-9-63	
					A	A	63	8-25-64	
					A	A	56	12-4-64	
57	Rott	Fenton	St. Louis	NESE 23,44,5E	A	A	-	8-12-65	
58	Saranac	Leasburg	Crawford	NWNE 6,38,3W	1.29	833	-	8-12-65	
59	Springling	Sullivan	Crawford	SENW 7,40,1W	.72	465	-	8-13-65	Stock
					.80	517	-	7-27-67	
60	Steelville	Steelville	Crawford	NESE 33,38,4W					
	(Average of 9 measurements)				.50	323	-	1936-1964	
	(Maximum discharge measured)				2.50	1,620	-	5-3-36	
	(Minimum discharge measured)				0	0	-	1936,1956, 1964	
61	Stone	Fertile	Washington	SWNW 36,39,3E					
	(Average of 23 measurements)				1.18	762	-	1964-1966	
	(Maximum discharge measured)				2.42	1,560	-	2-14-66	
	(Minimum discharge measured)				.52	336	-	9-17-64	
62	Twin	Stanton	Franklin	SWSE 19,41,1W					
	(Average of 26 measurements)				1.43	924	-	1963-1966	
	(Maximum discharge measured)				3.86	2,490	55	5-4-66	
	(Minimum discharge measured)				.86	556	52	12-2-65	
63	Unnamed	Steelville	Crawford	SWSE 14,38,4W	2.92	1,890	-	8-12-65	
64	Unnamed	Steelville	Crawford	NWSW 12,38,4W	3.83	2,470	-	8-12-65	
65	Unnamed*	Leasburg	Crawford	NWNE 8,38,3W	.40	258	-	8-12-65	
66	Unnamed*	Meramec Park	Franklin	SESE 12,40,2W	.01	6	-	8-13-65	
67	Sprinkle	Meramec Park	Franklin	SENW 7,40,2W	.72	465	-	8-13-65	
68	Unnamed	Meramec Park	Franklin	NWNW 5,40,1W	.08	52	-	8-13-65	
69	Vandercruyessen	House Springs	Jefferson	NWNE 4,42,4E	10.7	6,910	55	5-18-46	Water cress farm
					.40	258	56	12-4-64	
70	Westover	Steelville	Crawford	SWSE 14,37,3W	12.7	8,200	-	8-23-26	Trout hatchery
					10.0	6,460	-	6-22-32	
					6.30	4,070	-	10-11-32	
					11.1	7,170	56	12-13-63	
					10.0	6,460	56	8-27-64	
					10.9	7,040	55	12-4-64	
71	Woodlock	Davisville	Crawford	SENE 30,36,2W	1.95	1,260	-	10-6-43	
					1.07	691	56	12-12-63	
					1.04	672	50	8-27-64	
					1.19	769	52	12-3-64	

*Sometimes called Camper

up a significant part of the dissolved solids in water from several of the springs. The dissolved-solids content of spring water throughout the basin ranges from 116 to 338 mg/l (table 12). Hardness of the water ranges from 96 to 337 mg/l. Of the 65 hardness determinations, two are classed as moderately hard, 25 are hard, and 38 are very hard (see table 3). Iron content of the water ranges from 0.00 to 0.87 mg/l and usually is low. Fifty-nine of the samples contained less than the 0.3 mg/l recommended limit for drinking water and six contained more than this limit. Nitrate concentrations were higher than usual in two of the springs, possibly the result of contamination. The range in nitrate was from 0.0 to 30 mg/l.

DESCRIPTIONS OF SELECTED SPRINGS

BEAVER SPRING, *Crawford County, Steelville 15-minute quadrangle, NE¼ SW¼ sec. 34, T. 38 N., R. 5 W.*

Beaver Spring issues from the base of a low hill and flows about 100 feet through an artificial, rock-lined canal before entering two lakes (each over an acre in size) forming attractive surroundings for the permanent homes of farm employees. The lakes are stocked with fish for the recreational benefit of the employees. Water from the spring is also used for watering large herds of farm stock. Waterfowl are present in the area to control the growth of vegetation in the spring branch and lakes. Permission must be obtained from a caretaker to visit the spring.

BLUE SPRING, *Crawford County, Sullivan 7½-minute quadrangle, NE¼ SW¼ sec. 2, T. 39 N., R. 3 W.*

Blue Spring rises in a well-developed park and flows through artificial, rock-lined channels to join three smaller springs that form Blue Spring branch. Near the turn of the century a grist mill and general store were located at the spring and during the 1920's and 1930's it was a popular privately-owned resort. Later a trout hatchery utilized the spring waters. Presently the area is owned and operated by the Salvation Army and used as a summer camp for underprivileged urban children. Vegetation found in the spring is described by Steyermark (1941). Of interest in the vegetation found here is the curly-leaved muck-weed, so plentiful at Blue Spring, but very rare in Missouri. Elsewhere in the state it is only known to be in a spring in Newton County.

CATHEDRAL SPRING, *Crawford County, Onondaga Cave 7½-minute quadrangle, NW¼ SE¼ sec. 34, T. 39 N., R. 3 W.*

Cathedral Spring is a classic example of the emergence of a cave stream from a small, narrow and sinuous passage draining a much larger and older cave system beneath upland areas. The spring emerges below water level in the Meramec River.

Following Cathedral Spring upstream through Cathedral Cave is difficult; never is the ceiling more than 12 feet high and, in several places, the ceiling is only 1 foot above the water. However, after traversing 4,500 feet of unpleasant passage one emerges into an immense cavern. A massive flowstone pillar, nearly pure white, towering 25 feet above the stream beneath a vaulted ceiling, is the "Cathedral" after which the spring was named (Bretz, 1956, p. 62-71). The large Cathedral passage runs nearly at right angles to the low stream passage, trending roughly northeast-southwest.

Upstream from the Cathedral, the stream enters the large cavern from a low-ceilinged passage which may be followed with difficulty in a westerly direction. The general trend of the drainage route in Cathedral Cave is west, northwest – east, southeast, but the source of the underground stream remains hidden. Subterranean stream piracy similar to that at Hamilton Cave Spring does not seem to be involved.

Cathedral Cave was once open to the public and an upland entrance was used to gain access to the scenic parts of the cave. The cave is now used as an underground laboratory for the study of karst geomorphology, mineralogy and hydrology under an agreement between the cave owner and the University of Missouri–Rolla Spelunkers Club. The cave is gated and locked. Figure 57 shows Cathedral Cave in relation to local topography.

COLD SPRING, *Washington County, Shirley 7½-minute quadrangle, SW¼ SW¼ sec. 4, T. 37 N., R. 1 E.*

Cold Spring issues from the Gasconade Dolomite and flows down the spring branch with a fall of about 30 feet in the first ¼ mile. The spring is just below Sunnen Lake in Camp Lakewood, a YMCA summer camp, operated for the enjoyment of members and underprivileged children. The rough terrain, wooded hills, spring, and lake form an unusually attractive setting. Spring waters were once used for

Table 12
CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE MERAMEC RIVER BASIN

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 56)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
																			Calcium Magnesium	Noncarbonate				
1	Antire	8-64	A	57	19	0.00	52	12	1.5	.0	177	0	25	24	0.2	3.1	0.66	236	179	34	468	8.2	0	5
2	Antire Farm	8-64	.02	54	23	.01	49	17		.0	195	2	30	5.5	.2	1.8	.02	230	192	28	378	8.3	1	2
4	Beaver	7-25	.20	--	8.2	.24	48	28	5.7		268	5	4.7	2.7	---	1.0	---	236	235	7	---	---	--	5
		11-53	---	58	6.6	.05	52	32	4.2		304	0	3.6	3.8	.2	4.9	---	272	260	10	---	7.4	--	1
		8-64	.03	59	14	.09	54	31	7.1	5.4	294	0	6.2	10	.0	30	1.5	315	262	21	536	7.4	10	0
5	Blue	9-25	4.90	--	6.6	.62	35	18	3.5		174	8	9.0	1.9	---	1.9	---	170	163	7	---	---	--	0
		3-54	---	57	8.6	.08	37	23	3.8		216	0	4.9	2.8	.2	1.7	---	190	187	10	---	7.5	--	1
		8-64	5.33	57	13	.00	39	20	3.0	.8	193	8	7.0	2.1	.1	2.7	.06	180	180	8	340	8.6	2	1
6	Blue Grass No. 1	8-64	.04	63	21	.03	42	19	17	1.2	162	0	23	42	.1	2.3	.04	280	187	50	406	8.1	5	0
8	Blunt	8-64	.04	71	20	.02	56	48	4.4	1.2	390	0	6.0	4.0	.0	1.0	.00	332	337	18	593	7.7	5	0
10	Brook	8-64	A	77	6.1	.11	28	30	12	1.7	164	4	63	10	.2	2.4	.13	248	194	52	416	8.3	0	4
11	Brown	8-64	A	59	3.7	.18	35	20	3.3		201	0	.7	5.2	.0	.0	---	180	170	5	---	7.5	--	4
15	Carl	9-66	.34	57	11	.00	51	29	1.2	.6	300	0	2.0	.9	.1	.6	---	247	246	0	443	7.7	3	-
16	Cold	8-64	.72	52	20	.07	32	16	3.3	1.2	172	4	5.8	3.0	.0	2.2	.08	172	146	0	290	8.4	5	0
17	Collins	8-64	1.69	52	14	.02	34	21	4.6	.7	195	6	1.4	5.5	.0	4.5	.01	188	172	2	337	8.4	5	0
18	Coon Cave	6-66	.20	55	7.0	.02	40	25	7.2	2.0	230	0	26	4.2	.2	2.6	---	235	203	14	410	7.6	0	-
21	Elm (Crawford Co.)	8-64	.28	57	13	.12	22	10	4.2	1.4	106	0	10	5.0	.0	2.8	.09	121	96	9	211	7.7	5	0
22	Elm (Franklin Co.)	8-64	.04	57	16	.00	42	23	5.0	1.1	229	0	4.6	10	.2	6.2	.04	221	200	12	392	8.1	0	3
23	Evans	8-64	1.62	55	9.4	.25	34	19	3.6	.7	179	8	4.8	4.0	.2	1.3	1.7	175	163	3	305	8.5	10	0
24	Falling	8-64	.02	59	18	.03	56	31	4.1	.7	304	0	7.0	7.0	.0	.6	.01	274	267	18	410	8.1	5	0
26	Gibbs	8-64	1.43	52	14	.01	29	24	2.7	.8	191	4	3.8	3.0	.0	1.1	.03	178	171	8	316	8.4	5	0
27	Glencoe Hollow	8-25	---	--	12	.24	87	9.6	11	--	228	5	31	5.1	---	1.9	---	276	257	21	---	---	--	-
		8-64	.04	54	18	.03	75	13	6.7	.6	252	0	25	15	.0	3.3	.03	318	241	34	483	8.0	5	0
30	Hopewell	7-64	.71	55	4.0	.03	66	40	4.9		389	0	6.2	4.3	.0	.7	---	338	332	14	520	7.5	--	-
		11-65	.52	58	11	.00	65	37	3.4	.4	382	0	5.8	3.0	.0	3.1	---	317	314	1	572	7.7	1	-
31	House Springs	9-25	.77	--	9.8	.62	92	12	0		302	0	19	3.6	---	3.0	---	289	282	34	---	---	--	10
		2-54	---	56	9.2	.11	86	15	6.4		296	0	26	3.0	.5	5.0	---	305	274	31	---	7.3	--	3
32	Howes Mill	8-64	1.80	56	15	.04	29	22	3.1	.5	197	0	3.8	4.0	.0	.8	.00	175	163	2	313	8.2	5	0
33	Indian	8-64	.06	61	15	.11	50	27	3.3	1.4	274	0	6.6	5.5	.2	10	.50	254	236	12	457	8.1	0	1
34	James	8-64	3.50	58	44	.08	42	24	3.5	.8	227	6	6.8	4.0	.0	1.2	.05	250	204	8	379	8.3	5	0
35	Kratz	7-25	---	--	8.6	.23	26	15	1.4		137	3	8.0	2.7	---	1.0	---	133	124	6	---	---	--	-
		7-64	16.3	56	2.8	.23	34	20	4.1		197	0	10	3.8	.1	.0	---	186	167	6	---	7.5	--	-
		8-64	13.4	58	14	.04	35	23	4.1	1.3	197	0	11	4.5	.0	2.0	.15	192	182	20	346	7.9	7	0
36	LaJolla	8-64	2.65	56	15	.02	35	21	5.0	1.2	185	0	10	5.0	.0	2.8	.14	186	174	22	341	7.4	5	0
37	Lake	7-25	.09	--	12	.26	42	24	2.2		225	8	.0	4.1	---	.4	---	203	202	4	---	---	--	5
		12-53	---	56	6.0	.12	44	26	3.5		256	0	.7	5.8	.1	3.2	---	230	219	9	---	7.4	--	2
		8-64	A	55	3.0	.03	25	26	1.7		176	0	.8	7.5	.0	.0	---	174	168	23	---	8.2	--	1
38	McDade	8-64	.56	59	13	.03	28	16	3.4	.8	142	8	8.6	3.5	.1	1.5	.00	153	136	6	260	8.5	5	0

Table 12 – *CHEMICAL ANALYSES (continued)*

(Meramec River Basin)

Location No. (Fig. 56)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
39	McIntosh	8-64	1.45	58	12	.03	39	24	3.1	.9	220	3	8.4	4.5	.2	1.9	.00	205	196	11	387	8.3	0	1
41	Maramec	6-25	111	--	6.2	.87	30	18	3.3		163	8	2.7	2.4	---	1.7	---	153	149	1	---	---	--	0
		8-34	86.9	58	--	.30	37	21	5.0		218	1	5.1	2.7	---	1.5	---	259	179	--	---	---	--	-
	Maramec (cont)	11-53	---	58	5.2	.10	39	23	4.1		225	0	2.9	4.0	.1	2.3	---	194	190	6	---	7.5	---	1
		6-64	78.3	53	1.4	.12	32	18	.2		174	0	5.2	3.0	.0	2.1	---	166	154	11	---	7.4	---	-
		8-64	67.4	58	14	.07	37	21	3.4	.9	209	0	4.4	4.0	.1	3.6	.10	191	179	8	346	8.0	1	1
		11-65	63.8	57	9.4	.00	33	18	2.7	.8	187	0	5.2	2.6	.0	3.4	---	167	157	4	306	7.6	1	-
		2-66	75.6	56	8.8	.03	31	17	2.4	.7	171	0	5.6	2.5	.1	2.3	---	154	148	8	280	7.6	1	0
		5-66	290	56	9.9	.04	23	9.6	1.6	1.2	109	0	6.2	1.1	.1	2.8	---	116	97	8	194	7.2	4	-
44	Mint	8-64	.22	59	14	.00	27	22	2.9	.6	170	12	2.2	2.0	.0	1.0	.04	175	158	0	321	8.6	5	2
46	Onondaga	8-25	---	--	8.0	.44	48	25	2.2		231	16	4.3	2.7	--	1.4	---	221	221	5	---	---	---	-
		2-54	---	56	6.6	.10	51	32	3.4		314	0	.9	2.5	.2	.2	---	256	259	2	---	7.9	---	1
		8-64	.01	--	16	.03	46	30	3.6	1.1	288	0	1.4	3.5	.2	1.7	.07	245	239	2	446	8.1	1	9
52	Rhodes	6-66	A	54	12	.05	59	32	4.6	2.4	305	0	29	8.0	.4	4.4	---	302	279	28	520	7.4	0	-
53	Richart	8-64	1.11	58	13	.04	38	22	2.9	1.0	209	0	15	4.5	.2	1.2	.06	201	186	14	355	7.9	0	2
54	Roaring (Crawf. Co.)	8-64	.05	57	13	.02	47	28	3.9	.6	273	0	7.4	3.5	.1	1.5	.29	240	232	8	434	8.0	0	3
55	Roaring (Frank. Co.)	9-25	1.00	--	7.8	.58	36	22	1.9		202	0	10	6.6	--	1.1	---	185	180	15	---	---	---	20
56	Rock	8-64	A	63	27	.07	49	18	9.0	.7	205	0	15	15	.0	.7	.01	235	196	28	396	8.2	5	5
60	Steelville	8-64	.13	57	18	.03	40	21	3.4	.6	209	4	3.8	4.0	.0	2.0	.03	202	187	9	349	8.3	5	0
61	Stone	7-64	1.18	--	2.4	.27	48	28	4.0		270	0	12	5.3	.2	1.0	---	252	239	16	420	8.0	---	-
62	Twin	2-54	---	58	7.2	.12	41	24	3.1		239	0	5.2	2.3	.2	1.0	---	208	201	6	---	8.0	---	4
		7-64	1.28	60	2.8	.12	38	22	1.8		212	0	9.4	2.8	.2	.0	---	194	186	13	320	7.9	---	-
		8-64	1.15	--	16	.02	24	22	3.6	1.1	170	4	9.2	3.0	.0	1.3	.01	168	151	16	289	8.4	5	0
70	Westover	8-64	10.0	56	15	.32	24	22	3.6	.8	156	12	4.6	4.5	.0	2.5	.00	166	151	2	288	8.6	5	0
71	Woodlock	2-54	---	56	8.5	.11	63	38	4.0		368	0	.7	2.8	.1	2.3	---	304	315	14	---	7.4	---	1
		8-64	1.04	50	18	.01	24	34	3.2	.6	237	0	3.8	5.0	.0	2.4	.15	208	200	6	376	8.2	5	0

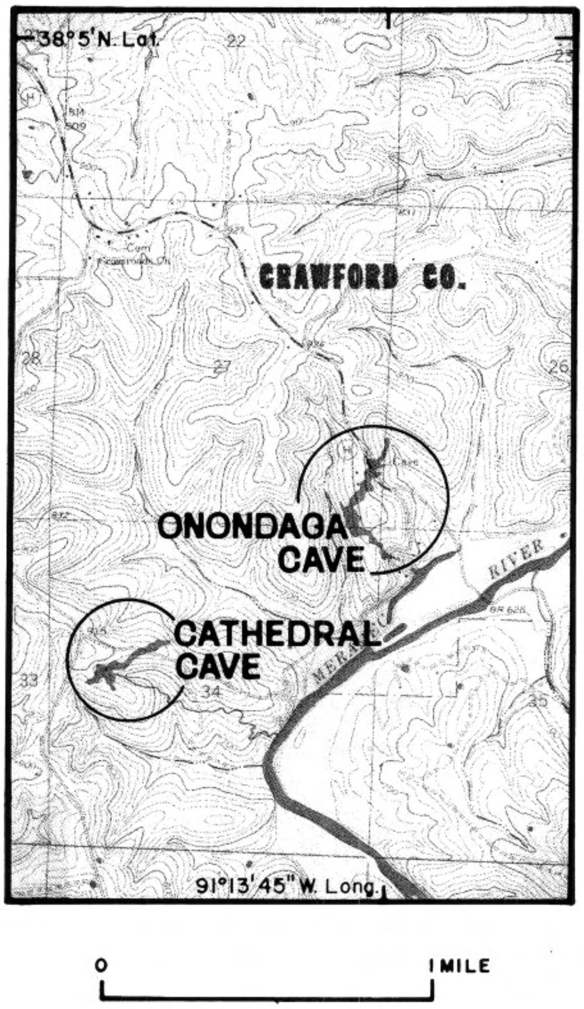


Figure 57

Cathedral and Onondaga Springs flow from large caves along the Meramec River. Ground plans of the two caves, here superimposed on the topography, are typical of caves in the Meramec basin. Topography from U.S. Geological Survey, Onondaga Cave 7½-minute quadrangle.

commercial trout raising, first by a private individual and later by a corporation. Trout raised here were shipped to many metropolitan areas in the Midwest. A large metal water wheel on the spring branch at one time generated electricity and operated a grist mill. It is not operating now although the wheel still remains. The YMCA purchased the spring property in 1946, expanded the land area, and built Sunnen Lake, a 250-acre body of water.

COLLINS SPRING, *Crawford County, Steelville 15-minute quadrangle, NW¼ SW¼ sec. 35, T. 38 N., R. 4 W.*

Collins Spring flows from a gravel bed encased in a concrete spring house. At one time the water was pumped to supply nearby Kelly Mansion. Presently it is being used as stock water in the lower fields of Glen Allen farms. Evans Spring is on the same property. The well-kept farm, amid rustic surroundings, forms an interesting and attractive setting. Permission must be obtained to visit the spring.

ELM SPRING, *Crawford County, Cuba 7½-minute quadrangle, SW¼ NW¼ sec. 9, T. 38 N., R. 5 W.*

Elm Spring emerges in a structure housing a hydraulic ram which furnishes water for a summer home nearby. The remaining water flows into a series of four lakes, which are used to raise fish. The first lake was built about 1880 and was used to raise rainbow trout which were marketed in St. Louis. The springs, lakes and surroundings are well-maintained and form a restful and attractive setting. The spring is on private property.

EVANS SPRING, *Crawford County, Steelville 15-minute quadrangle, NW¼ NW¼ sec. 2, T. 37 N., R. 4 W.*

Evans Spring is on Glen Allen farms near Collins Spring which is on the same property. The water is presently being pumped to Kelly Mansion and to all other farm buildings and farm homes on the property. At one time, a power plant on the spring branch operated a generator to supply electricity for the farm buildings and for a short time supplied power for the community of Steelville. The very well-maintained modern farm, the beautiful mansion, and surrounding countryside are an unusually attractive scene. Permission must be obtained to visit the spring. Vegetation found in the spring is described by Steyermark (1941).

GREEN CAVE SPRING, *Washington County, Meramec State Park 7½-minute quadrangle, SW¼ SE¼ sec. 24, T. 40 N., R. 2 E.*

Green Cave Spring flows from an immense cave opening at the base of Green Cave Bluff on the east bank of the Meramec River. The spring drains Green Cave, which has been surveyed for about 2,000 feet northeasterly from the cave entrance. The sinuous, single-passage cave is spacious and well decorated

except toward the upstream terminus, where the passage becomes low and narrow. The cave passage trends N. 40°E., which carries it beneath a high ridge toward the head of Miller Hollow (fig. 58).

Green Cave is similar in general dimensions and length to Hamilton Cave, but differs in containing less alluvial fill. The reason there are less sediments in Green Cave is that it lies beneath a high ridge and apparently does not pirate a surface stream as is the case at Hamilton Cave. Green Cave should be far less vulnerable to contamination than its larger neighbor to the south.

HAMILTON CAVE SPRING, *Washington County, Meramec State Park 7½-minute quadrangle, SE¼ SW¼ sec. 30, T. 40 N., R. 1 E.*

Hamilton Cave Spring flows from the spacious entrance of Hamilton Cave, a medium-size cavern in the Gasconade Dolomite. This spring should not be confused with Hamilton Spring, which is 3/4 mile east of Hamilton Cave, near the ruins of the Hamilton Iron Furnace. Pratt Spring is about ¼ mile downstream from Hamilton Cave Spring, but drainage areas for the two springs probably are unrelated.

Hamilton Cave Spring is an underground stream draining the southward-trending passage of Hamilton Cave. The first part of the cave is spacious and wide, with ceilings as high as 35 feet. The ceiling is bedding plane-controlled, however, so that as one goes upstream along the rising gradient of the stream, headroom gradually decreases. Toward the upstream terminus of the cave the passage is wide and low; stooping and then crawling are necessary, and eventually there is no room even for crawling.

The alluvial sediments of Hamilton Cave are particularly interesting because they record the history of the cave (Reams, 1968). Superimposing the cave map on the topographic map shows the upstream end of the cave directly under Gamble Hollow, which roughly parallels the valley of Hamilton Creek. This relationship explains the presence in the cave of large quantities of alluvial sediments, ranging from red clay through chert gravel, cobbles and boulders. The clastic sediments are residual from weathering of the dolomite bedrock of the area and entered Hamilton Cave by subterranean stream piracy of Gamble Hollow.

Pratt Spring, which is comparable in magnitude to Hamilton Cave Spring, might be expected to have similar drainage characteristics, but the supply system feeding Pratt Spring is not presently accessible.

HOPEWELL SPRING, *Washington County, Mineral Point 7½-minute quadrangle, NE¼ NE¼ sec. 33, T. 37 N., R. 3 E.*

Hopewell Spring rises in a three-sided concrete box and flows down a natural channel for some 150 feet to Hopewell Creek. About the turn of the century a grist mill operated on Hopewell Creek utilizing water from the spring. Presently some of the people of Hopewell use the spring for their domestic water supply and for watering stock. Nothing remains of the grist mill.

HOWES MILL SPRING, *Dent County, Stone Hill 15-minute quadrangle, SE¼ SW¼ sec. 15, T. 34 N., R. 3 E.*

Howes Mill Spring rises from a rocky bluff just off State Highway 32 and flows into Huzzah Creek. The first known development of the spring was about 1890, when a grist mill and (soon after) a blacksmith shop were built. It was the hub of grain grinding in the vicinity. With the arrival of R.E.A. electricity in the area, the mill ceased operation. Nothing remains of the mill. Today the spring waters are held in approximately 300 ponds where minnows and goldfish are raised for fishing bait. Several millions are shipped each year as bait to various popular fishing areas in the midwest.

KRATZ SPRING, *Franklin County, Stanton 7½-minute quadrangle, SW¼ SE¼ sec. 19, T. 41 N., R. 1 E.*

Kratz Spring emerges from a gravel bed in a wooded area and is the source of Spring Creek, a tributary to the Bourbeuse River. At one time a dam about ½ mile below the spring impounded the waters which were used to operate a girst mill. Remains of the dam are still visible. Presently the property is owned by St. Louis University as a summer camp for faculty members. The pools in the spring branch abound in rainbow trout. The spring is also used for watering stock owned by the camp. Dominant plants in the spring branch are water cress and bur-reed and quantities of moss grow on the rocks in the branch.

LA JOLLA SPRING, *Franklin County, Meramec State Park 7½-minute quadrangle, NW¼ NE¼ sec. 1, T. 40 N., R. 2 W.*

La Jolla Spring rises ignominiously beneath a blanket of blacktop covering the Meramec Caverns parking lot. However, the upstream part of the spring passes through beautifully decorated passages

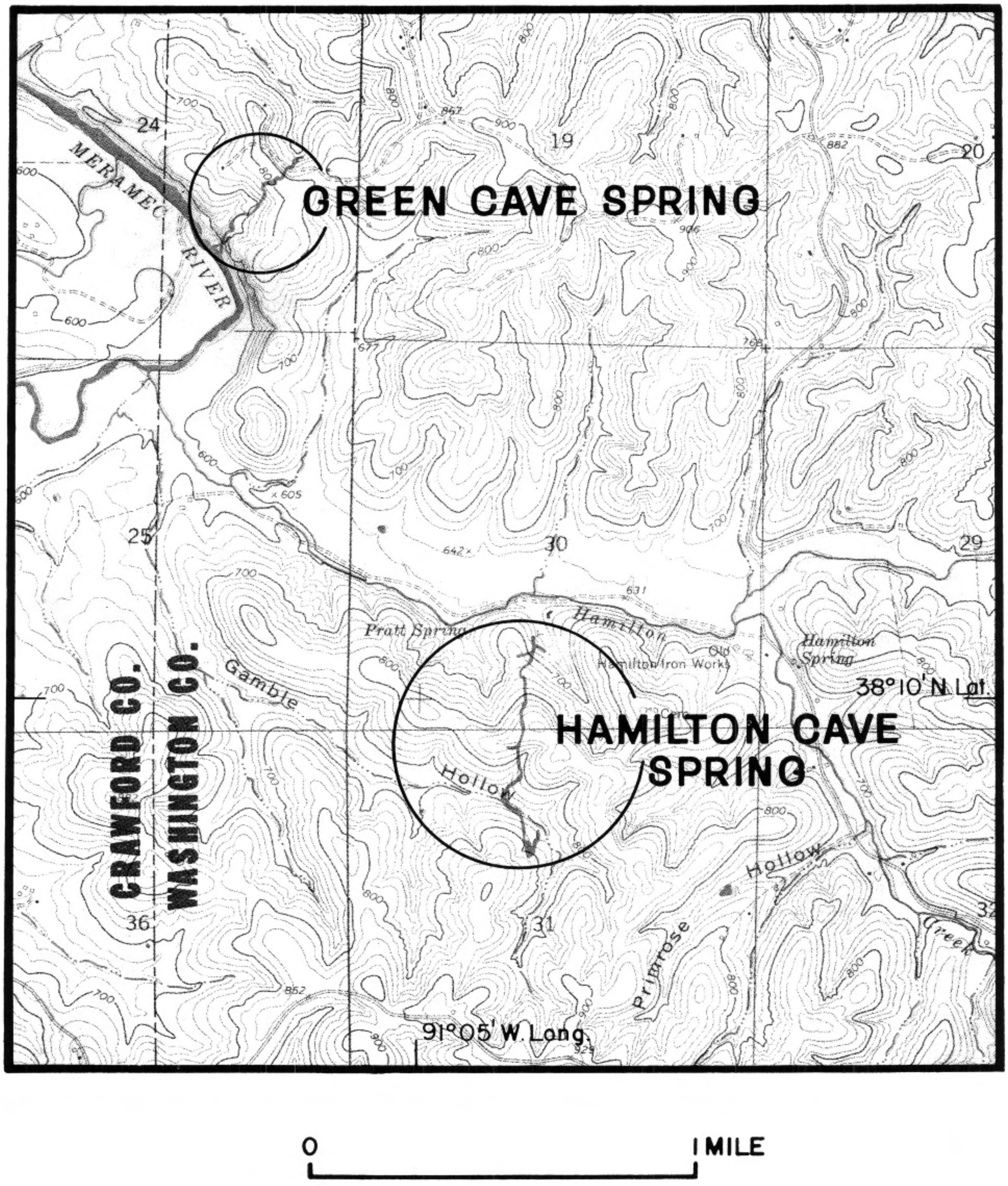


Figure 58

Hamilton Cave Spring and Green Cave Spring differ in their relation to local topography. Note apparent subterranean stream piracy of Gamble Hollow by Hamilton Cave. Topography from U.S. Geological Survey, Meramec State Park 7½-minute quadrangle.

in Meramec Caverns, one of Missouri's outstanding caves. La Jolla Spring is typical of many Ozark springs that issue from caves. Indeed, in the cavernous dolomite terrane of central and southern Missouri most of the springs are cave streams, although in many cases the openings are concealed by hillside talus so that one sees only water emerging through gravel-choked or otherwise inaccessible openings.

The drainage area of La Jolla Spring lies west-northwest of the entrance to Meramec Caverns. The caverns have been mapped for approximately 1 mile. The cave generally follows the trend of the ridge under which it lies (Bretz, 1956, p. 184), and roughly parallels Copper Hollow, which lies ¼ mile to the south. The cave map shows four major tributary passages, all entering the main passage from the north. The apparent alinement of surface and sub-surface drainage routes suggests structural control of valley and cave development (fig. 59).

The headwaters of La Jolla Spring lie beyond the explored limits of Meramec Caverns. The Meramec State Park quadrangle shows a large sink about ¼ mile west of the known end of Meramec Caverns; probably some of the flow enters the underground stream through this sink. In the lower reaches of La Jolla Spring, the underground stream flows on a cave fill composed of red sediment (Bretz, 1956, fig. 87 & 88, p. 176), whereas in the upper reaches it flows on bedrock. Filling of the lower end of the cave has caused the spring to seek a new outlet just north of the present cave entrance.

La Jolla Spring and most of its drainage system, Meramec Caverns, are in the Eminence Dolomite, but the upper levels of the cave may cross the Eminence-Gasconade contact.

McDADE SPRING, *Crawford County, Cuba 7½-minute quadrangle, NW¼ NW¼ sec. 16, T. 39 N., R. 5 W.*

McDade Spring rises in a concrete tank about 12 feet square. There are several concrete tanks in the area to support the commercial trout fishing which is well advertised from I-44 to the spring. Waterfowl are raised in the spring and pond area to control aquatic growth and improve the trout fishing.

McDade Spring issues from joints in dipping sandstone beds of the Roubidoux. The Cuba fault zone, which has a northwest trend, is just east-northeast of the spring and has the younger Jefferson City Dolomite lying opposite the Roubidoux. It is probable that this "fault-line spring" exists because of the creation of a partial barrier to the movement of water through the fault zone allowing the water to surface at McDade Spring.

McINTOSH SPRING, *Crawford County, Cuba 7½-minute quadrangle, NE¼ NE¼ sec. 13, T. 38 N., R. 5 W.*

McIntosh Spring rises in a sand bed in a basin surrounded by trees. The water flows in the spring branch for about 200 feet, empties into Pine Branch, and creates an unusually attractive scene. At one time the spring was diverted through an open ditch for a distance of about 400 feet to fill a small lake created by an earth dam about 300 feet down the valley. From here the water was diverted by another canal for about 50 feet to a point where it was used to operate a water wheel. Presently nothing remains of these structures. The waters are used for stock and the spring grounds are used as a summer retreat by the owner.

MARAMEC SPRING, Phelps County, Maramec Spring 7½-minute quadrangle, NW¼ SE¼ sec. 1, T. 37 N., R. 6 W.

Maramec Spring is the largest spring in the Meramec basin and the seventh largest in Missouri. Waters of the spring rise in a circular basin beneath a high bluff of Gasconade Dolomite. An artificial lake has been created by the damming of the spring branch downstream from the spring orifice. The dam, which raises the water level 8 to 10 feet, was built in the early 1800's to provide water power for a charcoal iron-making industry.

Maramec Spring played an important role in the early development of Missouri. Near the great spring were deposits of the red iron mineral hematite, brown limonite and iron pyrites. Thomas James, an ironmonger from Ohio, came to Missouri in 1826 and began to build the Maramec Iron Works at Maramec Spring. The spring was used for water power, for *"In the never-ending torrents of water lay the requisite power to crank the giant pistons of the air compressors, to lift in endless repetition the heavy refining hammers, or whirl the stone buhrs of the grist and flour mills, and even to activate a sawmill which in turn would provide lumber to build an iron works."* (Norris, 1964, p. 9). For the first 20 years of its existence, the Maramec Works was the largest and sometimes the only local supplier of iron products

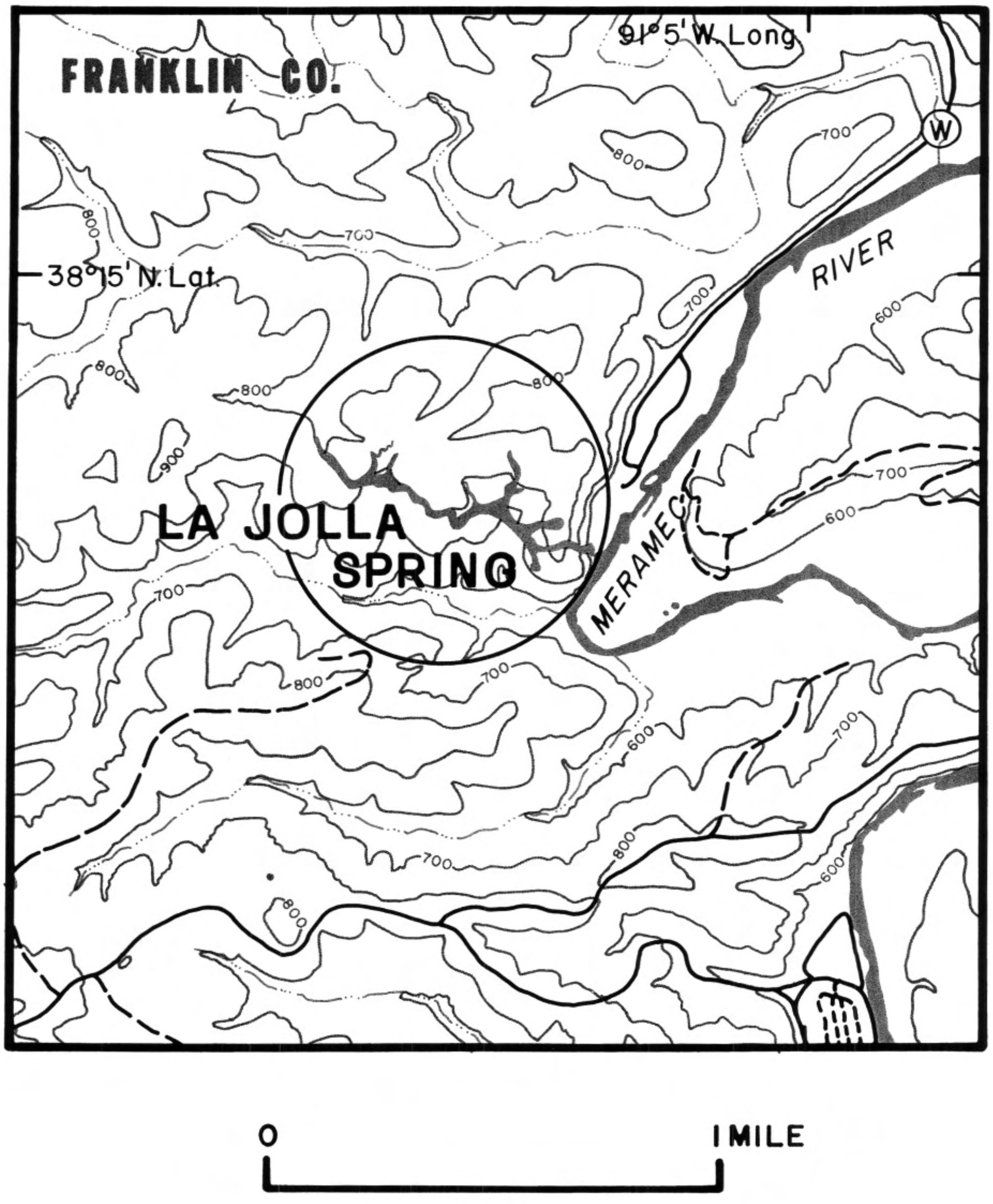


Figure 59

La Jolla Spring drains Meramec Caverns and areas west of the Meramec River beyond the explored limits of the cave system. Topography from U.S. Geological Survey, Meramec State Park and Stanton 7½-minute quadrangles. Redrawn on new topographic base after Bretz (1956, p. 184, fig. 93).

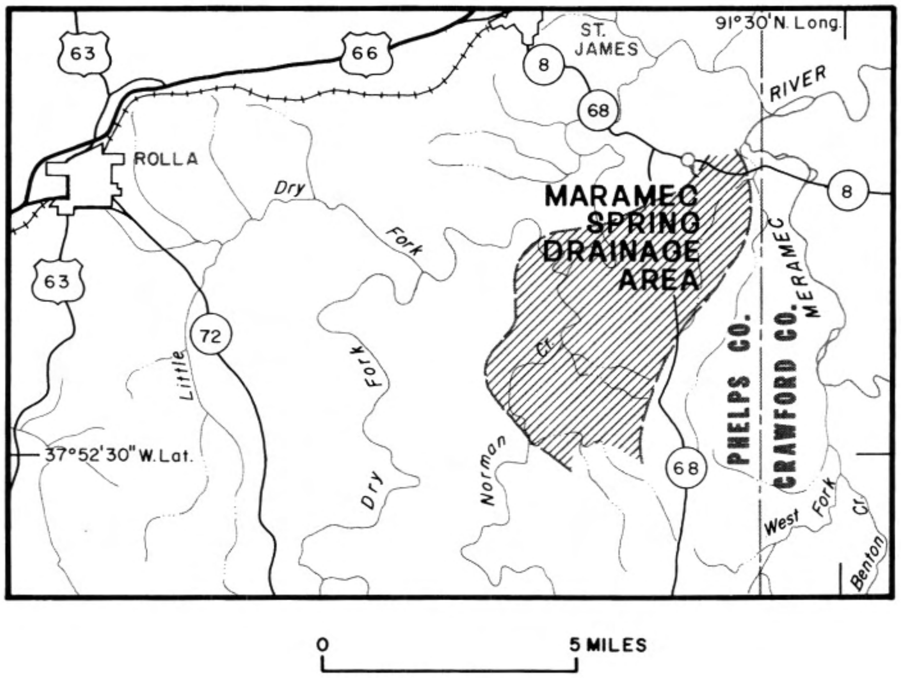


Figure 60

Drainage area of Maramec Spring as determined by low static water levels in domestic water wells. Base map from U.S. Geological Survey, Rolla 1:250,000-scale topographic map.

in the Missouri economy. Maramec iron was shipped to markets across Missouri over primitive "iron roads" that later became routes of Missouri's highway system.

Maramec Spring powered the undershot water wheels of the iron works for half a century, from 1826 to 1876, when advancing technology made the charcoal iron-making industry obsolete. Today the spring and what remains of the Maramec Iron Works are set aside as a privately-owned public park, where the spring, still flowing as vigorously as in the days when its waters powered a frontier iron industry, can be enjoyed by all. The park, operated by the James Foundation of New York, offers trout fishing, playgrounds and an excellent museum. Park benefits are available to visitors; fees are charged for fishing and touring the museum.

Research by Doll (1935) and Williams and Martin (1963, unpublished ms.) has shown that the source of water for Maramec Spring lies to the south and southwest of the orifice. Doll noted that Dry Fork and Norman Creek valleys carry water only for short periods after heavy or prolonged rainfall and reasoned that water, which ordinarily would flow on the surface, was instead flowing through underground channels to Maramec Spring. By comparing the annual discharge of the spring with average annual rainfall for the area, he computed the approximate recharge area needed to supply the spring. Williams and Martin plotted static water levels in domestic water wells of the area and arrived at conclusions similar to those of Doll. The map made by Williams and Martin appears in figure 60. Flow has been as follows:

Date	Discharge	Gallons per day
Maximum: 1927, 1928	650	420,000,000
Minimum: Aug. 1, 1934	56	36,200,000
Average: 1903-1905 1922-1929 Oct. 1965-Sept. 1972	144	93,024,000

The reasons why a large spring rises in a particular area are not completely understood, but consideration of the geology of the Maramec Spring area gives insight into some of the reasons. The upland areas

surrounding Maramec Spring are part of an ancient erosion surface known as the Salem Plateau. Bedrock beneath the plateau is sandstone and dolomite, generally covered by stony soils and residuum derived from the weathering of the bedrock formations. Directly beneath the soils of the plateau are sandstones and some dolomite of the Roubidoux. The Roubidoux weathers to form a thick, permeable residuum. Thick, resistant sandstone beds of the Roubidoux crop out as prominent bluffs along area streams. Beneath the Roubidoux, in layer-cake fashion, are thick dolomite strata of the Gasconade – one of the most cavernous formations in the state. The medium-grained, cherty dolomite of the Gasconade is highly soluble and ground water has greatly increased the permeability of the rock by dissolving caverns, principally by enlargement of openings along joints and bedding planes.

The presence and continuing development of caverns in the Gasconade Dolomite is betrayed on the surface by sinkholes and large, poorly defined sag areas in the Roubidoux cap rock. These random depressions serve as natural funnels that collect rainfall and channel it into the subterranean drainage network in the upper Gasconade Dolomite. In relatively recent geologic time, these solution openings in the limestone became integrated into a subterranean drainage system which surfaces at Maramec Spring. Because water levels beneath upland areas are higher than those beneath lowlands, water is forced from Maramec Spring, under hydraulic pressure, causing the characteristic spring "boil".

The water-filled subterranean conduits feeding Maramec Spring are accessible to divers equipped with self-contained underwater breathing apparatus. In 1964 divers of the St. Louis Underwater Recovery Team explored the orifice of Maramec Spring. The spring basin under the massive overhanging bluff of upper Gasconade Dolomite is 17 feet deep. Before the dam was built, this pool must have been much shallower, perhaps shallow enough to expose the cave opening that serves as the orifice of the spring. This opening is about 10 feet wide and 4 feet high, leading directly back into the hill (southeast) behind the spring basin. Water rushes from this opening with such force that divers can enter only in periods of low flow and, even then, must pull themselves through by clinging to projections on the walls. The force of the water in flood stage is great enough to tumble cobbles of dolomite and even furnace slag, rounding and smoothing them in a natural mill (fig. 61).

Inside the constricted cave opening, the spring "plumbing" enlarges to a vast chamber and current velocity decreases markedly. The floor of the large chamber plunges steeply downward over a boulder-strewn slope. The steeply-dipping tube levels out at about 115 feet below the surface of the spring basin and a smooth-walled, tube-like conduit about 20 feet wide and 5 feet high leads south-southeast toward Asher Hollow and Brown Hollow, both dry valleys.

With better technology it should be possible for divers to follow the supply system of Maramec Spring far from the spring orifice, beneath the sinking streams of Dry Fork and Norman Creek, and to chart with certainty the structure-controlled meanderings of the underground river.

The James Foundation, owner of Maramec Spring, maintains a trout hatchery in Maramec Spring Park with the cooperation of the Missouri Department of Conservation. Hatchery trout are released in the spring downstream from the dam to provide sport for anglers. Rare white cave crayfish ***(Cambarus hubrichti)*** inhabit the subterranean parts of the spring, and may be found in the deepest part of the spring basin. However, they are secretive creatures rarely seen except by divers.

ONONDAGA SPRING, *Crawford County, Onondaga Cave 7½-minute quadrangle, NW¼ NW¼ sec. 35, T. 39 N., R. 3 W.*

Onondaga Spring is the emergence of underground Lost River which flows through Onondaga Cave. A dam about 100 feet downstream from the spring mouth forms a trout-stocked pool for the enjoyment of visitors to the cave. The dam was built in pioneer days for water power and was maintained to provide deep water for visitors to take a boat ride into the larger parts of the cave (Bretz, 1956, p. 197). Popularity of the cave so increased that the boat ride had to be abandoned in favor of an artificial entrance with a wide stairway.

The history of Onondaga Cave and Lost River is extraordinarily interesting to speleologists. Bretz (1956, p. 197-211) described the cave in great detail, postulating at least three different cave streams (which may have emerged as springs in earlier times), several stages of cavern development, and episodes of

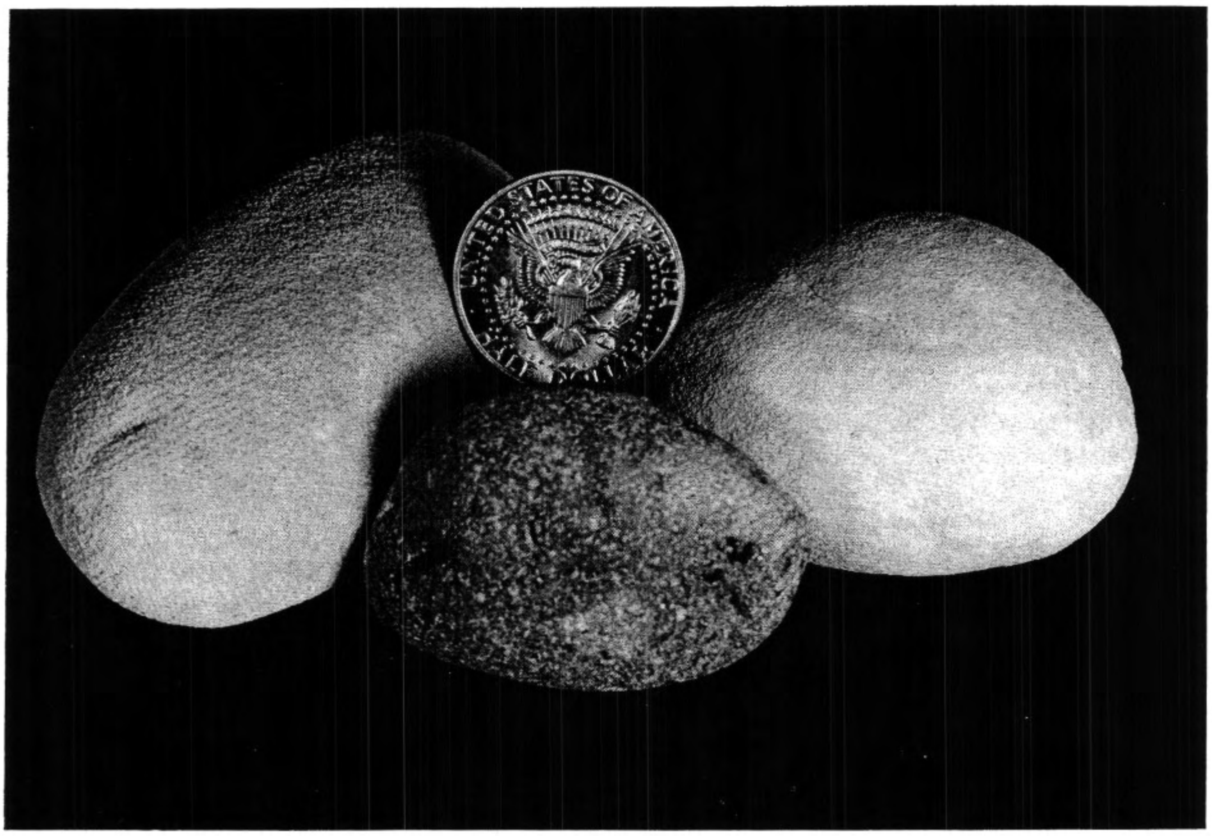


Figure 61

Cobbles of Gasconade Dolomite and a fragment of slag from the Maramec Iron Works, rounded by being tumbled in the strong current of spring water emerging from the orifice of Maramec Spring.

sedimentation and erosion by the several "lost" streams. Bretz led a field trip of the Geological Society of America to the cave in 1958.

The map of Onondaga Cave (fig. 57) shows the major passage orientation to be nearly north-south, but this is the orientation of a large, older section of the cave; the present course of Lost River, as far as it can be followed, is about N. 75°W. Further, the north-south passage, perhaps reflecting a different geomorphic condition, is much larger than the nearly east-west drainage route of Lost River.

The course of Lost River can be followed for about ½ mile in Onondaga Cave. If its east-west course is extended on a topographic map, it would pass at shallow depth beneath a deep, northward-trending hollow west of Onondaga Spring. However, subterranean piracy of this small hollow would not provide the observed discharge of Onondaga Spring; the headwaters of Lost River must lie beyond this small hollow. The next most likely source would be the larger hollow, ½ mile west of the upstream terminus of Lost River in Onondaga Cave.

RACING SPRING, *Washington County, Shirley 7½-minute quadrangle, NE¼ SE¼ sec. 21, T. 37 N., R. 1 E.*

Racing Spring issues from a bluff of the Gasconade Dolomite and flows for about ½ mile into Huzzah Creek. The land on which the spring is located was homesteaded by the Walton family. They constructed a dam and grist mill about ¼ mile below the spring on the spring branch. Later a sawmill was added to the operation. The small community of Shirley was settled around the spring and mill. About 1930 the waters were used to raise trout, but high waters from nearby Huzzah Creek washed out the trout ponds. Another pond was constructed and trout are being

raised today for private use. Nothing remains of the original grist mill and dam. The present owner of the spring stated that the waters of the spring turned milky and remained so for about five days following the March 27, 1964 Alaskan earthquake.

SPRINKLE SPRING, *Franklin County, Meramec State Park 7½-minute quadrangle, SE¼ NW¼ sec. 7, R. 1 E.*

Sprinkle Spring rises in a small cave at the base of a high bluff along the Meramec River in Meramec State Park. The cave entrance is small and low, about 2 feet above average river stage, directly opposite Fisher Cave campgrounds. The small cave opening and the relatively low discharge of Sprinkle Spring belie its significance as one of the most unusual springs in the Meramec basin.

A low passage, with water covering the floor to a depth of about 1 foot, penetrates bedrock of the Eminence Dolomite which has been eroded by the spring water to a rough, pitted surface. About 50 feet inside the entrance, the cave floor slopes steeply downward into a tube which is the spring orifice. Following earlier dives in 1961 by D.N. Rimbach, divers of the St. Louis Underwater Recovery Team explored underwater parts of the spring in 1965. They found a constricted, tortuous maze of jagged-walled crevices which they penetrated to a depth of 45 feet below river level. At one point they were able to surface in a small, air-filled room but the passages supplying water to the spring were not penetrated beyond this air-filled chamber. As at Maramec Spring, better technology may enable divers to study parts of the spring never before accessible to man.

The system of water-filled, tubular passages more than 40 feet below the Meramec River suggests that integrated subsurface voids exist beneath the Meramec River in this area. Confirmation of this hypothesis was obtained by test drilling by the Corps of Engineers along the centerline of the proposed Meramec Park Reservoir (U.S. Army Engineers, 1964, pls. D-10 and D-11). The presence of deepseated Sprinkle Spring downstream from the proposed dam site and the cavernous condition of the bedrock (as determined by test drilling) prompted the moving of the dam site about 1 mile upstream, a locality proven more favorable on the basis of further test drilling (Signaigo and Hood, 1969, p. 10-11).

Sprinkle Spring is in an area of intense cavern development in the Eminence and Gasconade Dolomites. Less than 1 mile northeast of the spring is Lone Hill Onyx Cave, a large cavern which underlies Lone Hill, a knob partly isolated by parallel erosion along Wet Hollow and Silver Hollow. In addition to Lone Hill Onyx Cave, 14 other caves are known within a 2-mile radius of Sprinkle Spring (Vineyard, 1968). William Cate (oral comm., 1972) has traced fluorescein dye into Sprinkle Spring from a swallow hole in a valley about ¼ mile east of the spring.

WESTOVER SPRINGS, *Crawford County, Berryman 15-minute quadrangle, SW¼ SE¼ sec. 14, T. 37 N., R. 3 W.*

Westover Springs rise in many sources in the gravel-bottomed floodplain of Dry Creek. The waters are diverted to a trout hatchery and eventually empty into Dry Creek. Trout are raised here to stock other lakes and streams and fishing in the spring area is available for a fee. During 1966 it was estimated that 500,000 trout were reared here. Waterfowl are kept in the area to control aquatic growth in the lakes and tanks. The water ends at a mill, no longer operating, from which it enters Dry Creek, a tributary to Huzzah Creek.

WOODLOCK SPRING, *Crawford County, Berryman 15-minute quadrangle, SE¼ NE¼ sec. 30, T. 36 N., R. 2 W.*

Woodlock Spring rises at the edge of the narrow floodplain of Davisville Hollow Creek at the foot of a high hill. The spring branch is confined by a 6-foot wide flume made of concrete and native rock. The branch passes under State Highway 49A and runs into another concrete flume to supply a swimming pool and domestic water for Holiday Inn Resort (formerly Woodlock Resort). For about a century, spring water was used to operate a grist mill that was washed out by a flood about 1930. At that time, an overshot wooden water wheel was installed and used for several years to develop electricity for the resort, a school and a store. The wheel, building and old generator are still in place.

NORTH FORK RIVER BASIN

BASIN DESCRIPTION

The North Fork River basin lies at the southern border of Missouri and has typical Ozark topography characterized by high ridges and deep, narrow,

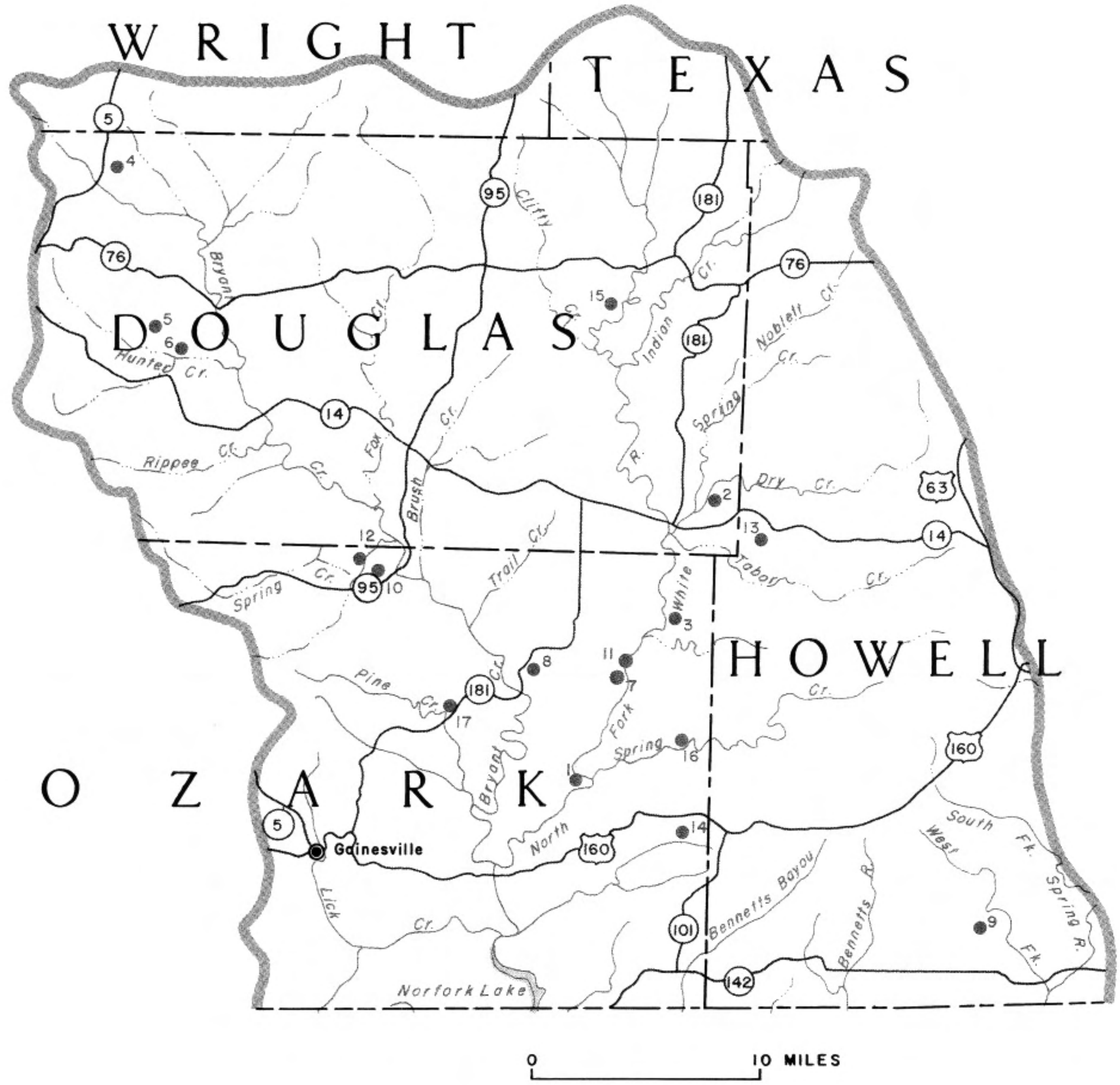


Figure 62

Springs in the North Fork River basin.

canyon-like valleys. Because of the topography, row-crop farming has been carried on here only to a limited degree but much of the basin is used for raising livestock. The only towns in the basin are situated on its perimeter. Many of the points of interest in the basin can be reached by good roads. It is of interest to note that six grist mills were still standing in the North Fork River basin in 1955 with four of these still in operation.

Much of the North Fork River basin is included in the Mark Twain National Forest whereas none of Bryant Creek basin is included. For this reason, some felt that the high flow of the North Fork River was due to the forest cover and the land management practices in the basin. However, it has been demonstrated that the difference in flow of the two basins is due to geologic controls (Skelton and Harvey, 1968).

Table 13
DISCHARGES OF SPRINGS IN THE NORTH FORK RIVER BASIN

Location No. (fig. 62)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
1	Althea	Tecumseh	Ozark	SENE 25,23,12W					
	(Average of 7 measurements)				18.8	12,100	-	1926-1964	Domestic, power plant
	(Maximum discharge measured)				26.5	17,100	58	8-19-26	Private picnic area
	(Minimum discharge measured)				13.3	8,590	58	8-17-36	
2	Big	Dora	Douglas	NWNW 26,25,11W	26.8	17,300	-	9-26-27	
					3.20	2,070	57	10-17-32	
					10.2	6,590	58	8-18-36	
					13.2	8,530	-	8-28-64	
3	Blue	Dora	Ozark	SWSW 14,24,11W	30.0	19,400	-	11-9-26	U. S. Forest Service
					9.50	6,140	-	11-17-32	Camp and picnic area
					12.3	7,950	59	8-18-34	
					11.3	7,300	59	8-18-36	
					11.5	7,430	58	11-6-64	
					10.1	6,520	51	12-7-64	
					16.1	10,400	59	11- -67	
4	Bryant	Ava	Douglas	SWSW 8,27,15W	1.77	1,140	58	8-27-26	Grist mill
					.97	627	-	10-18-32	
					.57	368	-	8-19-36	Fish rearing
5	Crystal	Ava	Douglas	NENE 22,26,15W	17.3	11,200	59	8-19-34	Fish hatchery
					12.1	7,820	60	8-19-36	
					9.67	6,250	-	9-24-54	
					10.2	659	-	8-29-64	
					11.6	7,490	53	12-8-64	
6	Davis	Ava	Douglas	SWNE 26,26,15W	2.00	1,290	-	10-19-64	Domestic
7	Double	Dora	Ozark	NENE 32,24,11W					
	(Average of 27 measurements)				127	82,000	-	1919-1966	
	(Maximum discharge measured)				232	150,000	56	4-7-65	Recreation and
	(Minimum discharge measured)				47.0	30,400	-	11-16-64	fishing
8	Hodgson Mill	Sycamore	Ozark	SWSE 34,24,12W					
	(Average of 15 measurements)				36.4	23,500	-	1926-1966	
	(Maximum discharge measured)				43.8	28,300	57	12-8-66	Grist mill and
	(Minimum discharge measured)				23.6	15,200	58	8-29-26	campsite
9	Lost	West Plains	Howell	NWNE 26,22, 9W	.02	13	-	11-21-34	
					.20	129	58	8-28-64	
10	Morris	Dora	Ozark	NESE 5,24,13W	4.00	2,580	58	8-27-64	Fish hatchery
					3.24	2,090	59	11-15-65	
11	North Fork	Dora	Ozark	SWSW 28,24,11W	68.0	43,900	-	11-16-64	
					66.2	42,800	-	4-8-66	
					75.3	48,600	57	7-6-66	
					68.4	44,200	57	10-6-66	
12	Rockbridge	Dora	Ozark	NWSE 5,24,13W	23.0	14,900	58	8-29-26	Fish hatchery
					24.4	15,800	58	10-17-32	
					15.2	9,820	-	8-18-36	
					11.0	7,110	-	8-27-64	
					21.9	14,100	54	12-8-64	
13	Siloam	Siloam Springs	Howell	32,25,10W	.01	6	-	1892	Originally
					*	*	-	9-7-25	health spa
					no flow			8- -64	
14	Taylor	Caulfield	Ozark	NESE 2,22,11W	.09	65	-	9-6-25	
15	Topaz	Vanzant	Douglas	NESE 12,26,12W	3.66	2,360	59	10-21-64	Private fishing
16	Wilder	Caulfield	Ozark	SWNE 14,23,11W	6.20	3,880	-	9-5-25	Stock
					19.6	12,700	58	8-28-26	
					9.03	5,830	60	8-18-34	
					5.76	3,720	61	8-17-36	
					8.51	5,500	58	11-6-64	
17	Zanoni	Sycamore	Ozark	SWNW 7,23,12W	.30	194	-	10-18-32	Domesti
					.35	226	60	8-18-36	
					1.92	1,240	-	8-27-64	
					.77	497	56	12-4-64	

*Discharge data not available; see Table 14 for water quality data.

Although the North Fork River basin is not large, it has nine large springs (more than 10 cfs) and many smaller ones. The minimum and maximum recorded flows of the nine largest springs in the basin totaled 123 and 323 million gallons per day, respectively. Table 13 gives the discharges for springs in the North Fork River basin. Figure 62 is a map showing the locations of measured springs in the basin.

One of the unusual things about the North Fork River basin is the manner in which the streamflow accumulates. In the dry season of the year the springs in the basin are the source of flow. At Tecumseh, just above the confluence of the North Fork and its principal tributary, Bryant Creek, gaging stations on the two streams measured the discharge of the two basins above that point. The record showed that the flow of the North Fork River in dry weather was twice as great as that of Bryant Creek even though the two basins have equal areas, similar basin shape, climate and topography and, ostensibly, the same geology. Further examination of the basins revealed that the difference in flow in the two basins can be accounted for by Double Spring and North Fork Spring near the lower end of the North Fork River basin and within about 1,000 feet of each other. Their existence attests to a well-developed system of solution channels that does not have a counterpart in the Bryant Creek basin to the west. It is believed that the catchment area for this spring system lies in the eastern part of the basin where a number of sinkholes have developed in a large area. The orientation of the long dimensions of some of the sinkholes and groups of sinkholes parallels that of a prominent joint system in the North Fork River basin.

Bryant Creek and North Fork are good streams for floating, with North Fork the better of the two because of its greater flow.

Bryant Creek, as a perennial stream, begins at Bryant Spring at an altitude of about 1,000 feet above sea level near the contact of the Roubidoux Formation and the Gasconade Dolomite. At its confluence with the North Fork, the altitude is about 560 feet. Bryant Creek is an interrupted stream and its flow sinks into the bed of the stream about 4 miles below Bryant Spring. In a seepage run made in October 1964, surface flow recommenced just above Hunter Creek which joins Bryant Creek from the west. Bryant Creek flows on the Gasconade Dolomite throughout much of its length with the sandstone and dolomite of the Roubidoux forming the valley walls and some of the upland surfaces.

Unlike Bryant Creek, the North Fork does not appear to be an interrupted stream. Continuous flow begins at an altitude of about 960 feet above sea level, also near the contact of the Roubidoux Formation and the Gasconade Dolomite. The flow of the stream does not increase uniformly from its headwaters to its mouth. Rather, its flow increases sporadically whenever springs of considerable magnitude or spring-fed tributaries join the main stem. The North Fork River flows on the Gasconade Dolomite in much of its course except in the reach including Double Spring where the Roubidoux forms the bed of the river for a distance of about 5 miles. The Roubidoux forms the valley walls; the Cotter and Jefferson City Dolomites cover the upland surfaces.

QUALITY OF WATER

Spring water in the North Fork River basin is a moderately mineralized calcium magnesium bicarbonate type reflecting the dolomitic character of rocks in the basin. The dissolved-solids content of spring waters throughout the basin ranges from 168 to 344 mg/l (table 14). Most of the springs yield very hard water, but a few yield water that varies from hard to very hard. Of 39 hardness determinations, six are classed as hard and 28 are classed as very hard (see table 3). Iron content of the water ranges from 0.00 to 0.45 mg/l with only three analyses showing more than 0.3 mg/l. Nitrate content of the water is low and in general does not indicate any serious contamination in the basin. The range in nitrate is from 0.1 to 21 mg/l. Recent studies of several springs in the North Fork River basin indicate counts of fecal coliform up to 220 colonies per 100 ml. These values are higher than observed in most springs.

DESCRIPTIONS OF SELECTED SPRINGS

ALTHEA SPRING, *Ozark County, Cureall NW 7½-minute quadrangle, SE¼ NE¼ sec. 25, T. 23 N., R. 12 W.*

In earlier days Althea Spring was the site of a grist mill and the small hamlet of Althea. The spring is in a scenic area on the left bank of the North Fork River where a picnic area has been established for the use of visitors and float trippers. The present owner has installed a turbine and dam to utilize the flow of Althea Spring. The spring opening cannot be seen as

Table 14
CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE NORTH FORK RIVER BASIN

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 62)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
1	Althea	8-52	--	59	4.3	0.04	52	30	7.0		302	0	3.0	2.0	0.1	1.9	--	249	255	8	---	7.5	-	2
		11-67	27.1	59	11	.04	41	25	1.2	1.3	251	0	3.8	1.4	.0	2.0	0.00	194	205	0	384	7.6	2	-
3	Blue	11-67	16.1	59	10	.02	38	23	1.2	1.3	227	0	3.8	1.6	.0	2.8	.00	202	190	4	354	7.5	2	-
4	Bryant	9-25	2.02	--	5.2	.28	47	19	.0		196	9	8.4	3.9	--	.9	--	191	196	19	---	--	-	0
		8-52	--	58	4.8	.04	51	23	6.7		252	0	8.7	4.0	.2	3.8	--	234	222	15	---	7.6	-	4
		11-67	3.98	57	9.1	.00	46	18	2.2	1.4	214	0	8.2	4.5	.0	2.2	.00	210	189	14	358	7.4	2	-
5	Crystal	9-25	--	--	4.0	.24	55	27	2.5		281	5	3.5	3.2	--	1.2	--	240	248	9	---	--	-	0
		8-52	--	60	1.0	.02	54	29	5.4		294	0	4.1	3.3	.1	3.5	--	251	253	14	---	7.6	-	3
		11-67	14.3	58	9.1	.01	48	27	1.5	1.1	284	0	5.0	2.2	.0	3.5	.00	242	231	0	437	7.7	1	-
7	Double	9-25	82.4	--	4.8	.21	47	25	.0		243	8	3.9	3.7	--	1.1	--	213	221	11	---	--	-	0
		8-52	--	58	2.8	.02	46	25	5.3		250	0	4.7	2.3	.0	3.6	--	218	218	14	---	--	-	1
		2-66	148	57	8.6	.02	41	21	1.4	.7	222	0	4.8	1.8	.2	4.3	--	195	189	6	352	7.8	0	0
		4-66	180	56	9.2	.00	41	21	1.4	.7	222	0	5.0	.8	.0	4.9	--	193	189	6	353	7.7	5	-
8	Hodgson Mill	9-25	--	--	4.8	.33	46	25	.0		247	4	4.3	3.9	--	1.2	--	211	218	9	---	--	-	0
		9-50	--	--	6.2	.07	39	22	1.8		214	0	4.7	2.5	.0	6.1	--	192	185	10	---	7.4	-	8
		8-52	--	58	2.8	.02	45	25	5.9		250	0	4.0	2.3	.0	3.5	--	222	217	12	---	7.4	-	1
		2-66	37.8	57	8.6	.02	39	21	2.0	.7	216	0	5.4	1.8	.1	4.3	--	193	184	7	345	7.6	0	0
		5-66	36.8	58	9.9	.01	34	17	1.3	1.2	180	0	4.0	1.2	.2	4.5	--	168	155	8	295	7.5	5	-
10	Morris	9-25	--	--	5.8	.23	56	28	.0		292	7	1.6	3.7	--	.4	--	245	254	4	---	--	-	0
		8-52	--	58	2.3	.03	53	29	5.3		295	0	2.9	2.5	.1	21	--	244	253	11	---	7.5	-	3
		11-65	3.24	59	9.7	.00	54	27	1.3	.8	306	0	3.4	1.3	.0	2.1	--	250	246	0	458	7.7	3	-
11	North Fork	4-66	66.2	56	9.2	.00	41	21	1.4	.8	220	0	5.0	1.1	.0	4.8	--	192	189	8	353	7.7	4	-
13	Siloam	9-25	--	--	7.2	.45	72	41	5.1		382	10	6.1	8.0	--	6.5	--	344	348	18	---	--	-	5
14	Taylor	9-25	.09	--	8.2	.35	57	39	6.5		319	0	33	3.3	--	.1	--	304	303	41	---	--	-	50
16	Wilder	9-25	6.20	--	7.2	.41	46	28	1.7		248	5	6.4	3.3	--	2.2	--	222	230	18	---	--	-	5
		8-52	--	60	3.0	.04	50	29	4.8		286	0	2.8	1.8	.1	2.6	--	239	244	10	---	7.6	-	2

the dam backs water over the orifice. A spring branch carries water several hundred feet from the spillway of the dam to the river.

BIG SPRING, *Douglas County, Topaz 15-minute quadrangle, NW¼ NW¼ sec. 26, T. 25 N., R. 11 W.*

Big Spring issues from beneath a large pile of Roubidoux sandstone talus at the base of a hill and flows into Spring Creek 60 feet away. The spring is about 400 feet from Big Spring School and the elevation is approximately 730 feet above sea level.

Big Spring ceased to flow some time during the night of March 7, 1956 and did not resume flow until late the following day. The unusual event was verified by Clifford G. Anderson, District Ranger of the Mark Twain National Forest (written comm.). Mr. Anderson reported that the children of Big Spring School, which was still operating as a one-room schoolhouse in 1956, observed the spring running normally on March 7. However, the following day when one of the children went to the spring for water, it was dry. Later in the day of March 8 the spring began to flow again and when observed by Mr. Anderson on March 9 the estimated flow was about 10 percent of what it had been during the dry part of preceding summers. Since this isolated event, the spring has been flowing normally.

Such interruptions in the flow of springs are not uncommon; even springs as large as Alley Spring have had interruptions in their flow, as documented by Beckman and Hinchey (1944, p. 49). It is generally thought that such interruptions in the flow are caused by temporary blockage of spring supply channels by sinkhole collapses, which are relatively common occurrences in the carbonate topography of the Ozarks.

BLUE SPRING *near Dora, Ozark County, Topaz 15-minute quadrangle, SW¼ SW¼ sec. 14, T. 24 N., R. 11 W.*

Blue Spring is one of the larger springs in the North Fork River basin. It has long been a popular recreational area and in recent years the spring and campsite (a few hundred yards upstream from the spring) have been improved as part of Mark Twain National Forest. Blue Spring rises from a cavernous opening in the bottom of a very colorful pool abounding with a variety of plant growth (Steyermark, 1941, p. 547). The rock ledges in the vicinity of the spring are of cavernous, cherty Gasconade Dolomite and they add to the picturesque setting of the spring. The spring boils up at river level and is only a few feet from the edge of the river, so it is submerged whenever the river is up. The spring can still be reached at any time by a pathway built along the side of the bluff from the camping area. The spring is unused except as a point of interest. In earlier days, Hammond Mill was situated in the vicinity of the low-water bridge at the campground.

BRYANT SPRING, *Douglas County, Mansfield 7½-minute quadrangle, SW¼ SW¼ sec. 8, T. 27 N., R. 15 W.*

Bryant Spring, in the headwaters of Bryant Creek, is the beginning of perennial flow although the stream is interrupted several miles downstream from the spring. Formerly the site of a grist mill, the spring now supplies water to a private fish-rearing establishment where visitors may enjoy fishing in a pool formed by the spring. In earlier days, a dam formed the lake now used for fishing and a chute carried the water to the grist mill. Steyermark (1941, p. 555) described the flora – which is quite varied – in the spring pool and branch below where the mill once stood.

CRYSTAL SPRING, *Douglas County, Ava 15-minute quadrangle, NE¼ NE¼ sec. 22, T. 26 N., R. 15 W.*

Crystal Spring flows from beneath a ledge of Roubidoux sandstone at an altitude of about 920 feet. It is the highest spring in the North Fork River basin with a flow of more than 10 cfs. The spring orifice is hidden in a pool formed by a dam. In earlier days the energy of the spring was used as a source of power for operating an ice plant and furnished lights to a nearby resort. Today the spring is the site of a commercial fish hatchery which is also open to tourists for fishing. Fish raised at the hatchery were shipped to the 1963 New York World's Fair.

DOUBLE SPRING (RAINBOW SPRING) AND NORTH FORK SPRING, *Ozark County, Cureall NW 7½-minute quadrangle, SW¼ sec. 28, T. 24 N., R. 11 W.*

Double Spring is also known as Rainbow Spring and is thus shown on the topographic map of the area. Double Spring boils up around large blocks of dolomite and sandstone at the base of a high ridge on

the right bank of the North Fork River. The spring is in the uppermost Gasconade Dolomite. Ledges of sandstone of the Roubidoux are exposed in the bluffs upstream and downstream from the spring, and in the bed of the North Fork at North Fork Spring. The outflow from Double Spring divides into two branches, one leading north and the other south, forming a long island between the spring branch and the North Fork. The south branch carries 70 to 80 percent of the flow. Dams are built across both ends of the island to connect it with the mainland.

Double Spring has been measured 25 times since 1924. Its maximum flow of 150 mgd was measured in April 1965 and its minimum flow of 30.4 mgd was measured in November 1964.

North Fork Spring is about 750 to 1,000 feet upstream from Double Spring. This spring consists

A number of springs have quite varied flora.

of numerous openings on the left bank of the river, in the bed of the river, and in the gravel bar toward the right bank. The openings on the left bank and in the bed of the river are along joints and those in the river form lines of boils extending from the shore to the gravel bar; they are aligned with the joint system in the bank and bed of the river. The rises comprising North Fork Spring extend about 100 feet along the river. North Fork Spring was first measured in November 1964 and four measurements of the spring have been made since that time.

North Fork River flows over a bedrock floor in much of the reach from North Fork Spring to Double Spring. There is a gravel shoal just above the upper end of the gravel bar and North Fork Spring. The major jointing is approximately north-south. At North Fork Spring the major jointing is N. 55° E. In North Fork River in the vicinity of Double Spring, two closely spaced joints were observed in the bed of the river having the same direction as the joints at North Fork Spring. In the reach between the springs, the principal jointing was approximately north-south as mentioned earlier.

In the field about 1,000 feet east of the river is a small sinkhole that had been filled with brush and trees. The level of the water standing in the sinkhole fluctuates rapidly with no apparent pattern. This sinkhole is aligned with the joints in the bed of the river and Double Spring on the west side of the river, suggesting a relationship between the pulsation of the water surface in the sinkhole and the flow of Double Spring.

More difficult to explain are the correlative measurements of the outflow of Double and North Fork Springs. Listed below are measurements of the two springs:

North Fork Spring		Double Spring
November 16, 1964	75.9 cfs	47 cfs
April 8, 1966	66 cfs	180 cfs
July 6, 1966	75.3 cfs	150 cfs
October 6, 1966	68.4 cfs	132 cfs

If the two springs are hydraulically connected, there should be closer correlation between the outflows of the two springs. It is suggested that if the two are hydraulically connected, North Fork Spring has a constricted opening allowing little variation in flow. Double Spring, on the other hand, is able to discharge the greater volumes of water available in

the spring supply system during the winter and spring months. The similarity of the water from North Fork and Double Springs also suggests a common supply system. In April 1966 the springs were sampled and the results, given in table 14, show that their water is almost identical.

A detailed description of the plant life in Double Spring is given by Steyermark (1941, p. 562-566). In his study of Missouri springs he found that Double Spring had 21 species of plants, surpassing all other springs in the Missouri Ozarks in number of species.

Double Spring and the property adjoining it are privately owned and are used by the owners for recreational purposes. The spring branch enclosed by the two dams is stocked with fish. North Fork Spring is unused. The setting around Double Spring is park-like, with the cottages of the owners built near the base of a bluff adjacent to the spring. A large new clubhouse has been erected directly across from Double Spring.

HODGSON MILL SPRING, *Ozark County, Sycamore 7½-minute quadrangle, SE¼ SE¼ sec. 34, T. 24 N., R. 12 W.*

One of the few remaining grist mills operating in Missouri is the Aid-Hodgson Mill at Hodgson Mill Spring. Meal ground on stone buhrs is shipped to all parts of the country and is sold locally. The spring opening is a joint in dolomite and sandstone enlarged by solution and is situated at the base of a high bluff of the Roubidoux. The mill is built over the spring opening so that part of the water is channelled under the mill to the water wheel. The remainder of the water enters a circular pool in front of the mill, passes over a dam and enters the spring branch. The spring branch enters Bryant Creek at a low-water bridge about 600 feet from the spring. The setting is one of the most picturesque in the state. A nearby camping site is maintained by the owners for tourists.

In a bluff behind the old mill, there is an entrance to a cave which developed in the dolomite between sandstone beds of the Roubidoux. The cave entrance is about 7 feet high and its floor is 15 feet above water level in the underlying spring. The cave follows a prominent joint trending N. 67° E. for 72 feet into the hill. Toward the end of the cave, holes in the floor open downward into an underlying passage and then into the lowermost channel occupied by the emerging spring. In the farthest shaft, the spring depth was measured at slightly more than 20 feet. However, the depth may be greater because the sides of the spring-cave slope northwestward. To the writers' knowledge, no divers have explored this spring.

Water tracing experiments by Aley (1972, p. 16-17) have shown not only that Hodgson Mill Spring is receiving contaminants from a sinkhole dump near Dora, 6 miles northeast of the spring (fig. 63), but that the channels linking the sinkhole and the spring are open enough to allow the passage of bacteria as well as dissolved contaminants. Both fluorescein dye and *Lycopodium* spores were used as tracers; they transited the 6 miles in 12 to 20 days. In the words of Aley (p. 17), *"The problems are not unique to the Dora sinkhole dump or Hodgson Mill Spring; probably every major spring in the Missouri karst has similar problems."*

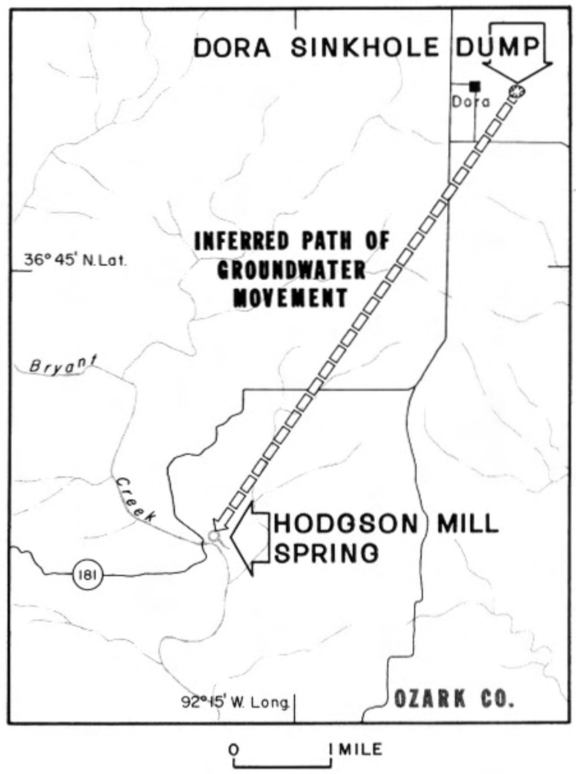


Figure 63

A large sinkhole near the village of Dora, long used as a dumping ground, has been shown by water tracing experiments to be part of the supply system for Hodgson Mill Spring. The dump has recently been closed, but seepage from wastes already in the sinkhole will continue to contaminate the spring water.

Hodgson Mill Spring ranks 15th in size among the springs of Missouri. The uniform discharge of the spring is unusual. Periodic measurements of its discharge have been made since 1926 when the minimum flow of record was measured, 15.2 mgd on August 29. The maximum flow of record, 28.9 mgd occurred on August 18, 1934. Since August 1964, the spring has been measured at regular intervals and the discharge has ranged from 20.6 to 28.1 mgd.

Steyermark (1941, p. 580) described the lush plant life of great variety in the spring and its spring branch.

MORRIS AND ROCKBRIDGE SPRINGS, *Ozark County, Buckhart 15-minute quadrangle, SE¼ sec. 5, T. 27 N., R. 13 W.*

These springs are the site of an old mill, still standing, but used only as part of the scenic setting for a fishing resort and hatchery established around the springs. Rockbridge was a thriving community of another sort in earlier days when it consisted of a grist mill, store, bank, school, etc. Rockbridge Spring is comprised of four springs which rise in the bed of a lake formed by a dam. Morris Spring, a much smaller spring, flows from an opening along a bedding plane in dolomite near the contact between the Gasconade Dolomite and the overlying Roubidoux. This spring forms a small pool whose beauty is enhanced by a variety of plant growth.

Fishermen find the branch below the dam well stocked with fish. The old store has been converted to a restaurant and cottages have been added without destroying the rustic environment that typifies the Ozarks. Water from the springs is used at the commercial hatchery downstream. The springs can be reached by good county roads.

Steyermark (1941, p. 600) described the flora in the lake and the spring branch below the dam.

WILDER SPRING (BREAKUP SPRING), *Ozark County, Cureall NW 7½-minute quadrangle, SE¼ NW¼ sec. 14, T. 23 N., R. 11 W.*

Wilder Spring is also known as Breakup Spring and is shown by that name on the topographic map of the area. The spring is the head of perennial flow of Spring Creek in Ozark County. Water issues from a bedding-plane opening at the base of a bluff of Ordovician dolomite and sandstone and enters Spring Creek directly. The spring is privately owned and is used for watering stock on the ranch. The flora of Spring Creek below the spring has been described by Steyermark (1941, p. 616). A well-sustained spring, its minimum recorded flow of more than 3.5 million gallons a day was measured during the drought of the 1930's.

ZANONI SPRING, *Ozark County, Sycamore 7½-minute quadrangle, SW¼ NW¼ sec. 7, T. 23 N., R. 12 W.*

Zanoni Spring issues from bedding plane openings in the Roubidoux Formation about 20 feet above the valley bottom. A 4-foot high concrete dam forms an impoundment discharging water into a flume leading to the overshot wheel of the old Zanoni Mill. The grist mill, water wheel and equipment are still standing and appear to be in reasonably good condition (fig. 64).

In years past, Zanoni Mill was the focal point of the small community of Zanoni, which boasted a post office and general store, together with several residences. But the old water wheel no longer turns, the general store is closed, and the once-bustling community is now a quiet homestead.

OSAGE RIVER BASIN

BASIN DESCRIPTION

The Osage River basin described in this section includes that part of the Osage River with headwaters in eastern Kansas that drains in a northeasterly direction to the Missouri River. It does not include the Niangua, Pomme de Terre, and Sac River basins. The western part of the basin is in the Osage Plains physiographic province and is underlain by Pennsylvanian sandstone, shales, and limestones which dip gently northwest. This part of the basin contains a few small springs which contribute little to the already low, dry-weather flow of the streams. The remainder of the basin lies in the Ozarks province. This area is underlain by gently dipping rocks of predominantly Ordovician age, with some areas of Mississippian, Pennsylvanian and Cambrian rocks. There are many small faults in the central portion of the region, and the largest springs in the basin line up on a northwest lineation that extends from the Lake of the Ozarks to the Current River basin in southwest Missouri.

The paucity of springs elsewhere in the basin is probably related to the absence of intense fracturing of the rocks and the resulting lack of abundant solution development. The part of the Osage basin

Figure 64

Waters of Zanoni Spring turn the overshot wheel of the old Zanoni grist mill. No longer in use, the mill once was the focal point of the village of Zanoni. Photo by Gerald Massie, Division of Commerce and Industrial Development.

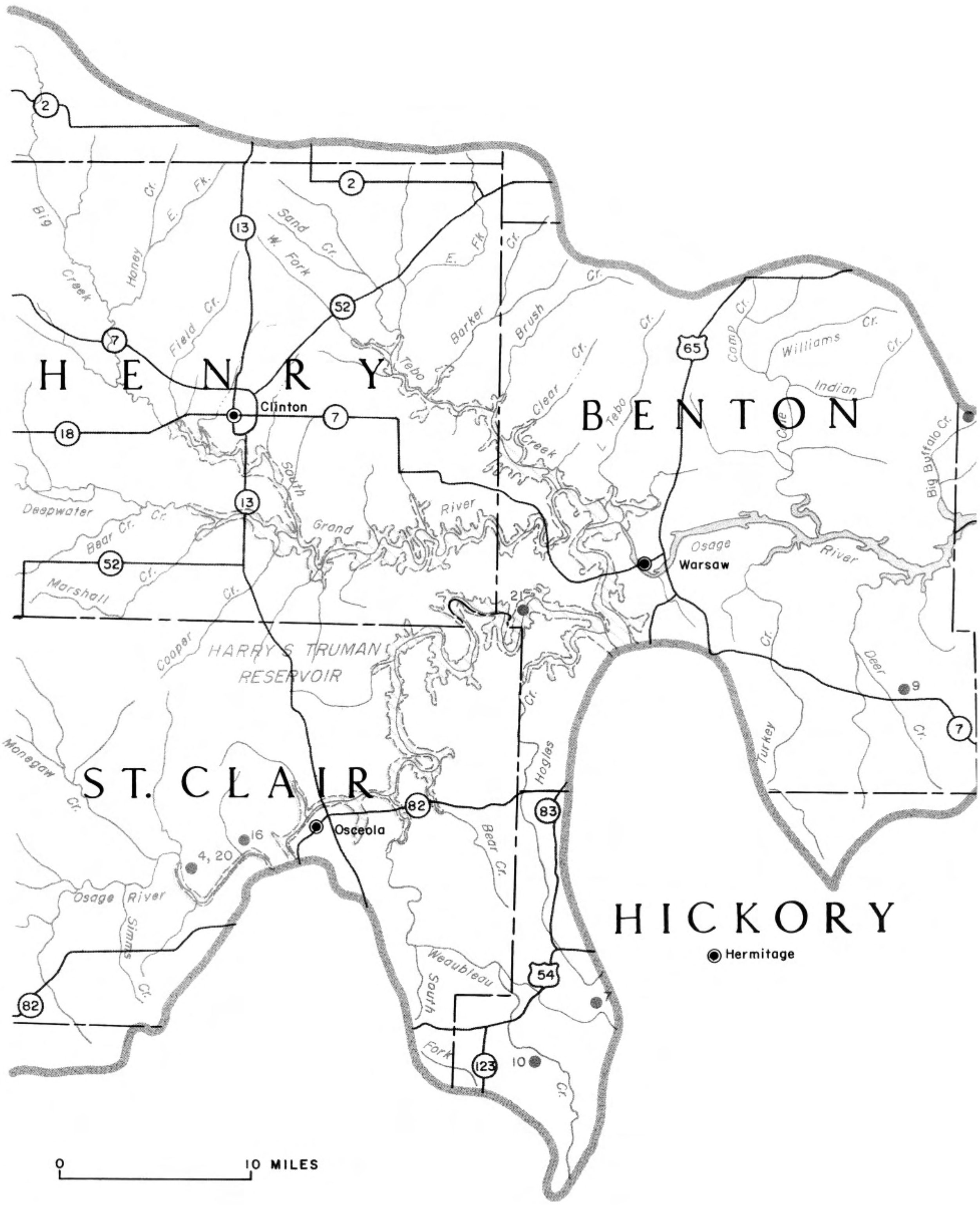


Figure 65

Springs in the Osage River basin.

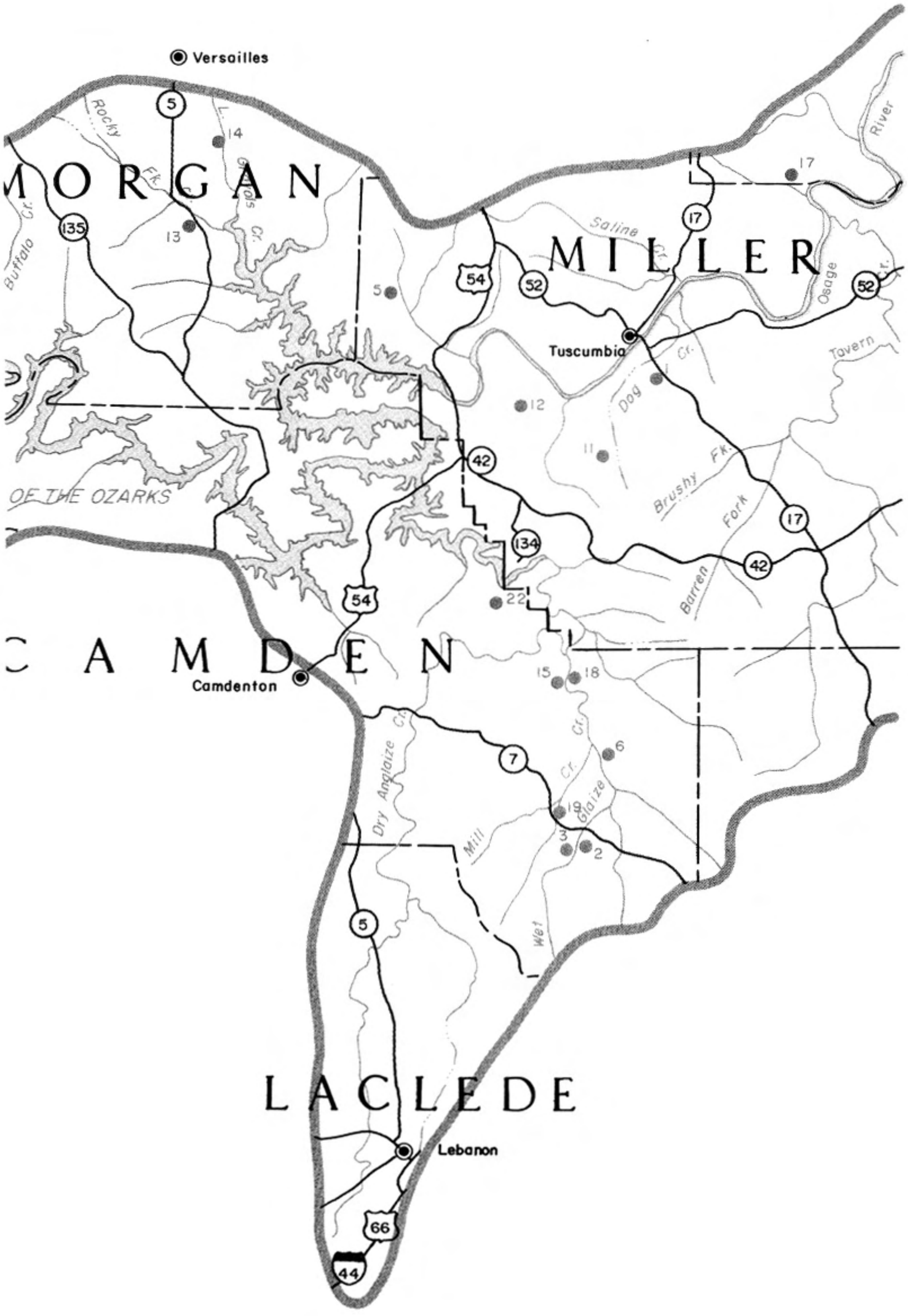

Versailles
MORGAN
MILLER
CAMDEN
LACLEDE
Tuscumbia
Camdenton
Lebanon
OF THE OZARKS
Rocky Fk.
Buffalo Cr.
Saline Cr.
Osage River
Tavern Cr.
Dog Cr.
Brushy Fk.
Barren Fork
Dry Auglaize Cr.
Mill Cr.
Wet Glaize Cr.
5
135
54
52
17
42
134
7
66
44

Table 15

DISCHARGES OF SPRINGS IN THE OSAGE RIVER BASIN

[A = discharge less than 0.01 cfs]

Location No. (fig. 65)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
1	Abbot	Tuscumbia	Miller	NENW 24,40,14W	0.10	65	-	8-20-47	Domestic
2	Armstrong(east)	Stoutland	Camden	SWNW 6,36,14W	40.2	26,000	-	11-18-42	
					9.05	5,850	-	12-8-42	
					4.48	2,890	-	10-8-43	
					1.28	827	-	4-24-56	
					3.30	2,130	55	12-3-64	
3	Armstrong(west)	Stoutland	Camden	NENE 1,36,15W	3.19	2,060	-	11-18-42	
					1.18	762	-	10-8-43	
					.24	155	-	4-24-56	
					no flow			12-3-64	
4	Black Sulphur	Monegaw Springs	St. Clair	SWNW 30,38,26W	.03	19	-	11-6-63	
					.06	39	64	8-27-64	
					.04	26	62	11-11-65	
5	Blue	Bagnell	Miller	NENE 35,41,16W	.08	52	-	6-9-66	
6	Blue Hole	Richland	Camden	NWSE 17,37,14W	6.38	4,120	61	8-28-64	
					7.94	5,130	56	12-2-64	
7	Blue Stem	Wheatland	Hickory	NENE 3,36,23W	.02	13	62	6-14-66	
8	Boylers Mill	Stover	Morgan	SWSW 6,41,19W	1.17	756	-	12-9-26	
					1.10	711	-	10-14-32	
					1.80	1,160	49	12-2-64	
9	Bubbling	Edwards	Benton	SESE 8,39,20W	.08	52	59	6-14-66	
10	Cave	Weaubleau	Hickory	SESE 19,36,23W	.05	32	57	6-14-66	
11	Cave	Ulman	Miller	SENE 5,39,14W	.09	58	62	6-8-66	
12	Elm	Bagnell	Miller	SENE 26,40,15W	.09	58	55	6-8-66	
13	Gravois Mills	Gravois Mills	Morgan	NWNE 19,41,17W					
	(Average of 8 measurements)				6.00	3,880	-	1926-1966	Trout fish
	(Maximum discharge measured)				8.80	5,680	-	5-19-26	hatchery
	(Minimum discharge measured)				4.00	2,580	54	11-7-63	
14	James Mill	Versailles	Morgan	SWNW 28,42,17W	.70	452	58	6-9-66	Fish hatchery
15	Little Toronto	Montreal	Camden	NESE 25,38,15W	.42	271	59	11-18-42	
					.02	13	52	12-1-63	
					no flow		69	8-28-64	
					no flow		44	12-2-64	
16	Magnolia	Osceola	St. Clair	SWNW 27,38,26W	A	A	57	2-14-54	
					.01	6	61	8-27-64	
17	Spring Valley	Henley	Cole	NESE 26,42,13W	A	A	57	6-8-66	
18	Toronto	Montreal	Camden	NWSW 30,38,14W	6.94	4,480	58	11-19-42	
					4.92	3,180	-	10-20-63	
					5.76	3,720	58	8-28-64	
					3.11	2,010	-	12-2-64	
19	Wet Glaize	Stoutland	Camden	NWSW 25,37,15W	12.7	8,200	57	5-25-38	
					8.55	5,520	-	11-18-42	
					8.11	5,240	-	10-7-43	
					3.91	2,530	-	4-24-56	
					1.94	1,250	57	12-3-64	
20	White Sulphur	Monegaw Springs	St. Clair	SWNW 30,38,26W	.01	6	-	2-14-54	
					A	A	66	8-27-64	
21	White Sulphur	Warsaw	Benton	SWSW 32,40,23W	.11	71	-	11-7-63	
					.40	258	62	6-15-66	
22	White Sulphur	Montreal	Camden	SESW 4,38,15W	A	A	57	10-11-64	

east of Bagnell Dam contains rock outcrops as old as Cambrian, yet no springs above 0.1 cfs have been found in this area. Maries River, which drains into the eastern-most portion of the Osage River, has a drainage area of about 300 square miles, yet has a dry-weather flow of less than 2 cfs. For comparison, Jacks Fork in the Current River basin in southwest Missouri has a drainage area of about 400 square miles with a dry-weather flow of over 100 cfs. Due to the low dry-weather flows of streams in this area few springs with flows above 1 cfs can be expected, and certainly no large springs have been overlooked in this study. Table 15 gives the discharges for springs in the Osage River basin. The locations of measured springs are shown in figure 65.

QUALITY OF WATER

Water from springs in the Osage River basin is predominantly a calcium magnesium bicarbonate type reflecting the dolomitic character of rocks

throughout much of the drainage basin. In the western part of the basin, a few springs drain limestone terrain and their waters are a calcium carbonate type. The spring water is moderately mineralized with dissolved-solids contents ranging from 227 to 998 mg/l (table 16) throughout the basin. Hardness of the water ranges from 223 to 389 mg/l with all samples classed as very hard (see table 3). Iron content of the water ranges from 0.02 mg/l to 0.17 mg/l, with none of the samples exceeding the 0.3 mg/l recommended limit. Nitrate content of the water ranges from 0.0 mg/l to 54 mg/l. Of the 15 springs sampled, water from two of them contained more than 10 mg/l nitrate.

DESCRIPTIONS OF SELECTED SPRINGS

CLIMAX SPRING, *Camden County, Climax Springs 7½-minute quadrangle, NW¼ NE¼ sec. 30, T. 39 N., R. 19 W.*

The little village of Climax Springs was founded as a spa in the 1880's to take advantage of the supposed therapeutic qualities of a small spring which now discharges an estimated 50,000 gallons of water per day (Vogel, 1971). According to Vogel, the waters of Climax Spring were reported to cure ills *"varying from scrofula to syphilis, but fortunately for those suffering from such things, very few were exposed to the baths."* There was a resort hotel with several dozen rooms, baths and other attractions, but the little town was as isolated in the 19th Century as it was until the 1950's when hard-surfaced roads and rural electricity reached the area.

Despite the failure of the spa, the little town persisted, until today, according to Vogel, there are more people who would like to live in Climax Springs than there are homes for them.

Climax Spring now flows through a concrete trough constructed to channel the water conveniently for the people who once used it. The area today is in a small, park-like setting and the water is generally unused.

There is a collapse sinkhole about 900 feet from the spring that gives access to a cave partly flooded by a pool of water. Fluorescein dye introduced into this pool in July 1970 reappeared at the nearby spring (fig. 66). The presence of an open sinkhole giving direct access to the underground stream, the numerous homes with septic tanks in the general area, and the signs of reawakening of the town of Climax Springs suggest that the chemical quality of the water in Climax Spring may not all be due to natural causes, and that further development of the area may be accompanied by degradation of water quality in the spring.

TORONTO SPRING, *Camden County, Toronto 7½-minute quadrangle, NW¼ SW¼ sec. 30, T. 38 N., R. 14 W.*

Toronto Spring rises in gravel beds along Wet Glaize Creek. The flow is diffused through gravel beds over a considerable area on the north bank of the creek. The presence of spring rises is betrayed by water cress which grows freely in the cool waters of the spring.

Dye tracing experiments by Vineyard in 1965 proved that the major source of water for Toronto Spring is from Carroll Cave, lying southeast of the spring. Helwig (1965) described the geology of this large cave system which developed in the Gasconade Dolomite of Ordovician age. The system is entered from a cave along Mill Creek from which a spring drains. Following this stream for several miles leads eventually to a second stream called Thunder River. It was so named because of the noise of a waterfall only a short distance downstream, that results from the underground piracy of the Carroll Cave stream by Thunder River. Fluorescein dye introduced into Thunder River reappeared within a period of 10 to 14 days in Toronto Spring.

Toronto Spring is the resurgence of an underground river that can be transited in part through a large cave system. In the lower reaches of the stream there is no air space and confirmation of the source of the flow for Toronto Spring must be by water tracers.

Subterranean stream piracy usually means that an underground stream pirates or beheads a surface stream, but the history of the Toronto Spring system is a record of subterranean stream piracy accomplished entirely underground. At one time, most of the flow that now rises at Toronto Spring flowed southeast and exited through the present entrance to Carroll Cave. However, the then-smaller Toronto Spring channel beheaded the Carroll Cave stream, giving rise to Thunder River, and its waters then flowed to Toronto Spring, greatly increasing its size at the expense of the Carroll Cave stream, which became insignificant in its discharge.

The exploration and study of the Carroll Cave-Toronto Spring system suggests that similar relation-

Table 16

CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE OSAGE RIVER BASIN

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 65)	Spring	Date of Collection	Rate of Flow (Cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180° C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color	Turbidity
4	Black Sulphur	11-65	.04	62	10	0.03	86	36	225	15	261	0	80	400	0.4	4.0	--	998	363	149	1,780	7.6	0	-
5	Blue	6-66	.08	--	9.1	.09	53	25	2.3	1.2	284	0	13	1.9	.1	1.8	--	248	235	2	440	7.8	0	-
6	Blue Hole	12-64	7.94	56	4.8	.11	50	29	2.9		259	7	9.7	4.7	.0	2.8	--	245	244	20	---	--	--	1
7	Blue Stem	6-66	.02	62	12	.06	93	9.2	35	.8	317	0	19	18	.4	54	--	419	270	10	640	7.6	0	-
8	Boylers Mill	12-64	1.80	--	3.6	.07	54	34	3.7		281	12	14	4.7	.0	.9	--	278	275	24	---	--	--	2
9	Bubbling	6-66	.08	59	10	.08	69	33	2.9	1.0	385	0	4.6	1.5	.4	.3	--	324	308	0	565	7.6	0	-
10	Cave (Hickory Co.)	6-66	.05	57	11	.02	99	2.9	2.0	1.0	305	0	13	1.9	.0	1.9	--	286	259	9	480	7.5	0	-
11	Cave (Miller Co.)	6-66	.09	62	12	.02	54	32	3.8	1.9	314	0	8.2	8.6	.1	3.4	--	278	266	8	520	7.6	0	-
12	Elm	6-66	.09	55	13	.02	63	38	2.3	1.0	385	0	6.0	1.3	.2	.0	--	321	313	0	570	7.6	0	-
13	Gravois Mills	6-66	5.31	56	10	.02	48	25	1.6	1.0	273	0	5.0	1.0	.0	.7	--	227	223	0	410	7.7	3	-
14	James Mill	6-66	.70	58	10	.03	61	28	3.1	1.1	294	0	39	1.7	.2	.1	--	289	267	26	560	7.7	0	-
16	Magnolia	8-64	.01	--	1.3	.17	83	34	133		235	0	100	236	.4	.0	--	782	349	--	---	7.8	--	-
17	Spring Valley	6-66	A	57	13	.02	50	28	4.0	1.4	278	0	9.4	5.8	.4	15	--	266	240	12	475	7.5	0	-
18	Toronto	8-64	5.76	58	5.6	.09	49	27	3.8		264	0	5.8	3.5	--	--	--	231	231	15	---	7.2	--	2
21	White Sulphur (Benton Co.)	6-66	.40	62	9.6	.02	98	35	178	5.6	316	0	45	349	.4	.0	--	896	389	130	1,650	7.7	0	-

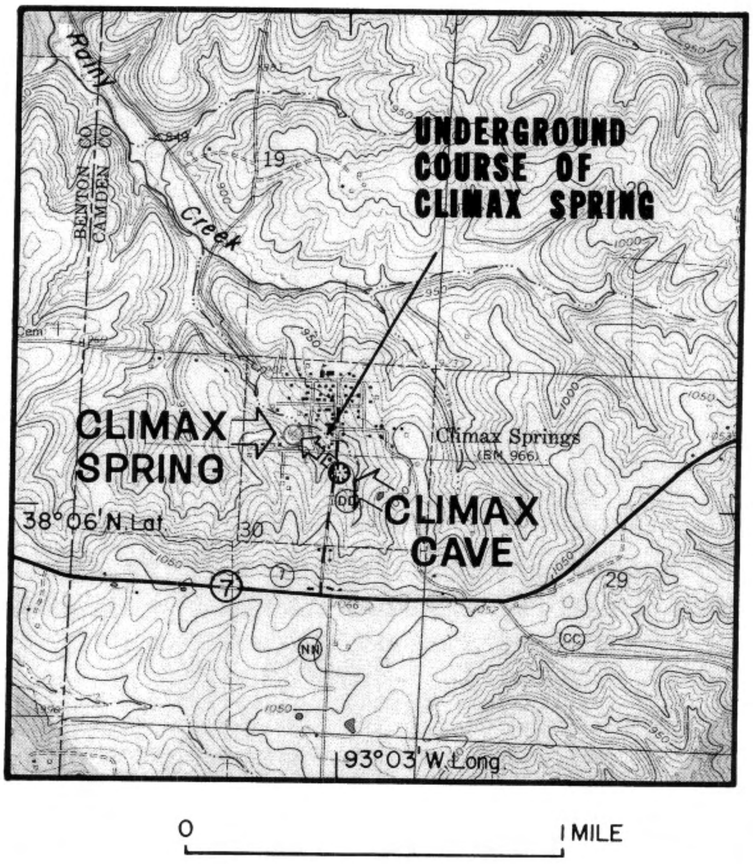


Figure 66

The village of Climax Springs and environs, showing Climax Spring and the cave, as well as upland karst south of the spring, from which the spring probably derives most of its flow. Topography from U.S. Geological Survey, 7½-minute quadrangle.

ships exist in other parts of the Ozark region that are as yet inaccessible to such study. The characteristics of the system emphasize the unpredictability of groundwater movement in limestone terranes and reinforce the points made many times in this report that springs flowing from limestone are highly subject to contamination.

POMME DE TERRE AND NIANGUA RIVER BASINS

BASIN DESCRIPTIONS

The Pomme de Terre and Niangua River basins are in the western part of the Ozarks near the edge of the Springfield Plateau. The Pomme de Terre River flows near the base of the Eureka Springs escarpment in a long, narrow basin mostly underlain by the Cotter and Jefferson City Dolomites. The higher ridges on either side of the river are composed of Mississippian limestone and shale.

Springs in the Pomme de Terre basin are small by comparison with those in the Niangua basin. Few large springs in the Ozarks discharge from openings in the Cotter or Jefferson City Dolomites, the principal formations in the Pomme de Terre basin. Principally, the springs are used for watering stock. In very dry years many of the springs probably stop flowing.

In the Niangua River basin, on the other hand, the streams have cut into the Gasconade Dolomite and along a fault in the northern part of the basin the Eminence Dolomite is exposed. The fault has a northwest trend. Along this trend, several other springs issue from the Gasconade and Eminence Dolomites.

Table 17

DISCHARGES OF SPRINGS IN THE POMME DE TERRE AND NIANGUA RIVER BASINS

Location No. (fig. 67)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
1	Allgire	Tunas	Dallas	SWNW 8,36,18W	4.81	3,110	-	11-19-42	
					5.15	3,330	-	10-7-43	
					4.41	2,850	55	11-8-63	
					4.08	2,640	63	8-26-64	
					4.26	2,750	55	12-1-64	
2	Baumgartner	Springfield	Greene	SESE 23,30,20W	.05	32	59	10-30-64	
3	Bennett	Bennett Spr. St. Pk.	Dallas	NENW 1,34,18W	(See page 185 for data on flow)				
4	Blue	Macks Creek	Camden	NWSW 7,38,18W	4.94	3,190	56	10-18-53	
					4.45	2,870	58	8-25-64	
					3.58	2,310	56	12-1-64	
5	Burnt Mill	Macks Creek	Camden	NENW 10,38,19W	1.50	969	-	10-18-53	
					.81	523	59	8-26-64	
6	Campbell	North View	Webster	SESW 18,30,19W	1.29	833	51	1-14-66	
7	Conn	Bennett Spring State Park	Dallas	SESE 25,35,18W	5.06	3,270	58	8-30-32	
					4.91	3,170	56	1-7-36	
					4.57	2,950	59	11-8-63	
					4.99	3,220	59	8-24-64	
					4.72	3,050	57	11-30-64	
8	Cullen	Camdenton	Camden	SENW 35,38,17W	1.17	756	-	11-19-42	
					.27	174	55	11-8-63	
					.59	381	69	8-27-64	
					1.02	659	57	12-1-64	
9	Eidson	Bolivar	Polk	10,33,22W	*	*		8-8-25	
10	Elm	Fair Grove	Greene	NENE 12,30,21W	.02	13	60	10-30-64	
11	Famous Blue	Bennett Spring State Park	Dallas	SENW 36,35,18W	4.44	2,870	58	9-2-33	
					2.39	1,540	60	11-7-63	
					2.48	1,600	59	8-24-64	
					2.65	1,710	58	12-1-64	
12	Green Ford	Macks Creek	Camden	NENW 27,38,19W	3.39	2,190	58	10-18-53	
					2.86	1,850	-	2-27-67	
13	Hahatonka	Camdenton	Camden	NESW 2,37,17W	(See page 191 for data on flow)				
14	Jordan	Cross Timbers	Hickory	SESE 20,38,20W	.02	13	57	6-14-66	
15	Morrow	Camdenton	Camden	SWNW 29,38,17W	2.53	1,640	58	11-19-42	Domestic
					1.75	1,130	56	11-8-63	Stock
					1.10	711	60	8-27-64	Irrigation
					1.14	736	57	12-1-64	
16	Moulder	Camdenton	Camden	SESE 19,38,17W	.04	26	-	11-19-42	
					.02	13	-	11-8-63	
17	Nigger	Fairfield	Benton	NWSE 18,39,22W	.27	174	61	11-7-63	
					.27	174	63	6-16-66	
18	Sweet Blue	Eldridge	Laclede	SENE 30,36,17W	15.6	10,100	-	9-10-25	
					11.0	7,110	-	10-20-32	
					13.7	8,850	58	9-18-36	
					13.7	8,850	58	11-7-63	
					12.6	8,140	58	8-26-64	
					12.4	8,010	57	12-1-64	
19	Unnamed	Bolivar	Polk	NW 8,33,22W	.01	6	59	8-25-64	
20	Unnamed	Northview	Webster	SESW 20,30,19W	.80	517	53	1-14-66	
					.07	45	58	8-26-64	

*Discharge data not available; see Table 18 for water quality data.

Two of the 15 largest springs in Missouri are in the Niangua basin. Bennett Spring, the fourth largest, has an average discharge of 100 mgd and Hahatonka Spring, the twelfth largest, discharges about 50 mgd. Table 17 gives the discharges of springs in the Pomme de Terre and Niangua River basins. Locations of measured springs are shown in figure 67.

The springs in the Niangua River basin are principally used for camp sites and for feeding stock. Bennett Spring is in Bennett Spring State Park and the Missouri Department of Conservation uses the spring water for a fish hatchery. Bennett Spring State Park is one of the most popular trout fisheries in Missouri.

Structural control seems to be exhibited in the locations of the springs in the Niangua basin. Hahatonka Spring, as mentioned previously, is situated near a northwest-trending fault zone. Bennett Spring is near the mouth of Bennett Spring Creek which is nearly parallel to the fault zone through Hahatonka

Spring, although it is about 15 miles southwest of the fault. Almost in alinement with Bennett Spring Creek is a very straight reach of the Little Niangua River approximately 9 miles to the northwest. Allgire and Sweet Blue Springs, two of the larger springs in the Niangua basin, are similarly situated along a northwest trend lying between the Bennett Spring-Little Niangua line and the fault zone at Hahatonka Spring. The topographic map of the Macks Creek quadrangle shows several other springs on this line and the Niangua River meanders on a course along this line providing evidence of structural control. These zones may represent preferred directions of jointing along which the principal solution channels are developed. In turn, these channels may connect with a set of channels or feeders that intersect at right angles. Stream alinement along a northwest trend and a crude rectangular network of streams seem to indicate such a pattern influences the location of the larger springs in the basin.

QUALITY OF WATER

Water from springs in the Pomme de Terre and Niangua River basins is a calcium magnesium bicarbonate type reflecting the dolomitic character of rocks in the drainage basins. Water from the springs is moderately mineralized with dissolved-solids contents ranging from 150 to 321 mg/l (table 18) throughout the basin. The dissolved-solids content of water in individual springs varies somewhat with changes in concentrations being related to changes in the spring discharge. Hardness of the water ranges from 128 to 331 mg/l with six samples classed as hard and 19 samples classed as very hard (see table 3). Iron content of the water ranges from 0.00 to 1.9 mg/l and it generally is low. Only three of the analyses show iron in excess of the 0.3 mg/l recommended limit. Nitrate content of the water ranges from 0.0 to 11 mg/l.

DESCRIPTIONS OF INDIVIDUAL SPRINGS

BENNETT SPRING, *Dallas County, Long Lane 15-minute quadrangle, NE¼ NW¼ sec. 1, T. 34 N., R. 18 W.*

Bennett Spring is one of the best known and most highly-developed springs in the state. The Missouri State Park Board and the Missouri Conservation Commission have developed it into a beautiful park which offers a wide variety of pastimes to vacationers from all over the country. In addition to facilities for vacationers at the park, the Missouri Department of Conservation maintains a trout hatchery which supplies trout for stream fishing below the hatchery and for stocking fishing areas in other parts of Missouri. In 1965, 260,000 trout were released in Bennett Spring Creek and total production of trout was 87½ tons.

Bennett Spring rises in a circular pool, about 50 feet across, in the bed of Bennett Spring Creek (fig. 68) a short distance from the bluffs on the left bank of the valley. Bedrock in the area is Gasconade Dolomite overlain by sandstone and dolomite beds of the Roubidoux. Bennett Spring Creek above the spring is a deeply-alluviated valley that is ordinarily dry except after heavy rains. About 500 feet below the spring a dam was built many years ago for operating a grist mill which still stands. The water now supplies the trout hatching facility. It is estimated that, of the 100 mgd average flow, only 23 mgd pass through the hatchery. Below the spring the branch flows continuously for 2 miles to its confluence with the Niangua River. Trout fishing is the popular sport of the area, particularly along the spring branch.

In the spring millrace and long spring branch Steyermark (1941) found a large assemblage of plants, with the distribution of the different varieties apparently dependent on the swiftness of the current and the type of material on the bottom.

Bennett Spring is subject to floods in Bennett Spring Creek, which transports large amounts of gravel as bed load material during high water. As a result, the spring basin must be periodically cleaned by a clamshell-equipped crane to remove gravel deposited by the creek.

Following gravel removal from the spring in 1965, the St. Louis Underwater Recovery Team explored the spring basin to a depth of 85 feet before strong currents and constrictions in the feeder conduit prevented further investigation. The divers found a submerged cavern with a rubble floor descending at a steep angle through dolomite bedrock heavily pitted by solution, and typical of the water-filled parts of other Ozark springs. Divers have described the underwater entrance to the spring conduit as being 12 feet high and 30 to 40 feet wide, with a ceiling 22 feet below the surface (Rimbach, oral comm., 1972). Figure 69 shows a cross section of Bennett Spring based on information furnished by the divers.

Concern over a gradual increase in nitrate and phosphate content in the water of Bennett Spring

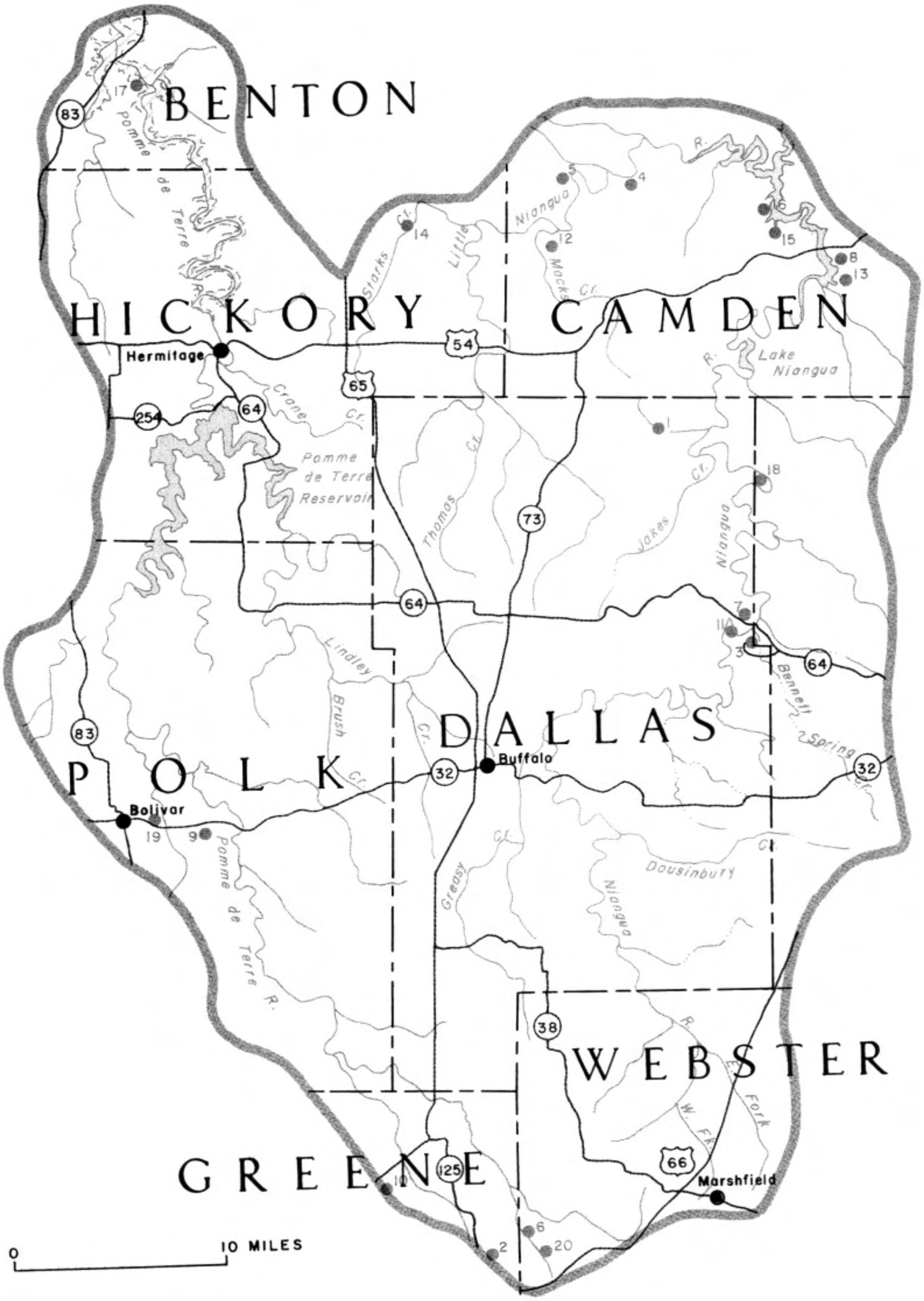


Figure 67

Springs in the Pomme de Terre and Niangua River basins.

Table 18

CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE POMME DE TERRE AND NIANGUA RIVER BASINS

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 67)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
1	Allgire	8-64	4.08	--	2.7	0.04	51	32	3.8		294	0	6.6	3.7	0.0	0.0	--	253	257	17	---	7.6	--	-
3	Bennett	7-25	--	--	5.6	.94	39	22	4.1		204	9	1.4	1.9	--	2.5	--	186	188	6	---	--	--	0
		5-55	--	58	5.6	.13	32	20	4.0		187	0	3.1	1.5	.1	11	--	186	165	11	---	7.3	--	7
		7-64	91.7	58	4.0	.12	40	22	3.3		215	0	4.6	4.3	.0	3.1	--	202	189	12	365	7.4	--	-
		11-65	89.0	59	10	.01	37	21	2.5	.9	210	0	4.4	2.5	.0	5.8	--	187	179	7	341	7.5	0	-
		1-66	91.6	57	9.5	.02	35	18	2.3	.8	190	0	4.6	2.0	.2	5.2	--	178	162	6	311	7.9	0	0
		5-66	173	59	10	.06	28	14	1.8	1.2	144	0	5.6	1.9	.2	5.8	.01	150	128	10	248	7.4	4	-
4	Blue	8-64	4.45	58	4.5	.11	48	27	4.3		264	0	4.5	3.0	.0	2.4	--	230	233	16	---	7.2	--	2
5	Burnt Mill	8-64	.81	59	.8	.04	68	40	3.9		384	0	8.6	3.0	.0	.0	--	321	331	16	---	7.5	--	<1
6	Campbell	1-66	1.29	51	8.3	.00	51	16	2.6	.8	216	0	12	6.6	.1	2.9	--	206	193	16	374	7.7	6	-
7	Conn	8-64	4.99	59	10	.02	49	26	2.9	1.1	265	0	9.4	5.0	.0	.8	.01	234	229	12	427	7.8	5	0
9	Eidson	8-25	--	--	8.2	1.2	48	29	6.3		248	16	3.9	5.8	--	2.5	--	242	239	9	---	--	--	0
11	Famous Blue	8-64	2.48	59	10	.02	47	26	3.0	1.2	261	0	8.4	5.0	.0	1.0	.00	230	224	10	425	7.6	5	-
13	Hahatonka	7-25	64.0	--	7.4	.65	39	24	1.9		220	7	1.6	2.7	--	2.3	--	194	195	3	---	--	--	0
		5-55	--	57	6.0	.21	31	20	3.8		0	0	4.4	.5	.1	10	--	182	160	13	---	7.3	--	10
		8-64	45.5	58	5.5	.08	48	27	3.7		258	0	4.5	5.0	.0	2.1	--	235	228	17	---	7.2	--	-
		11-65	64.5	59	10	.05	37	20	2.5	1.1	207	0	5.0	2.2	.0	4.3	--	184	175	5	335	7.5	3	-
14	Jordan	6-66	.02	57	12	.01	60	28	2.2	.6	312	0	5.0	1.9	.5	8.9	--	273	265	9	567	7.5	0	-
15	Morrow	8-64	1.10	60	5.2	.04	64	36	2.7		351	0	4.5	5.3	--	4.5	--	303	310	22	---	7.0	--	1
17	Nigger	6-66	.27	63	9.2	.01	56	29	4.1	2.0	302	0	20	5.1	.2	.0	--	276	259	11	562	7.8	0	-
18	Sweet Blue	9-25	15.6	--	23	1.9	48	28	5.5		254	20	2.7	4.1	--	.8	--	257	233	0	---	--	--	0
		5-55	--	58	4.8	.15	38	24	4.1		220	0	4.6	2.8	.1	7.3	--	210	195	15	---	7.3	--	2
		8-64	12.6	58	6.7	.05	55	30	2.9		295	0	5.7	4.0	--	.0	--	250	261	19	---	8.0	--	1

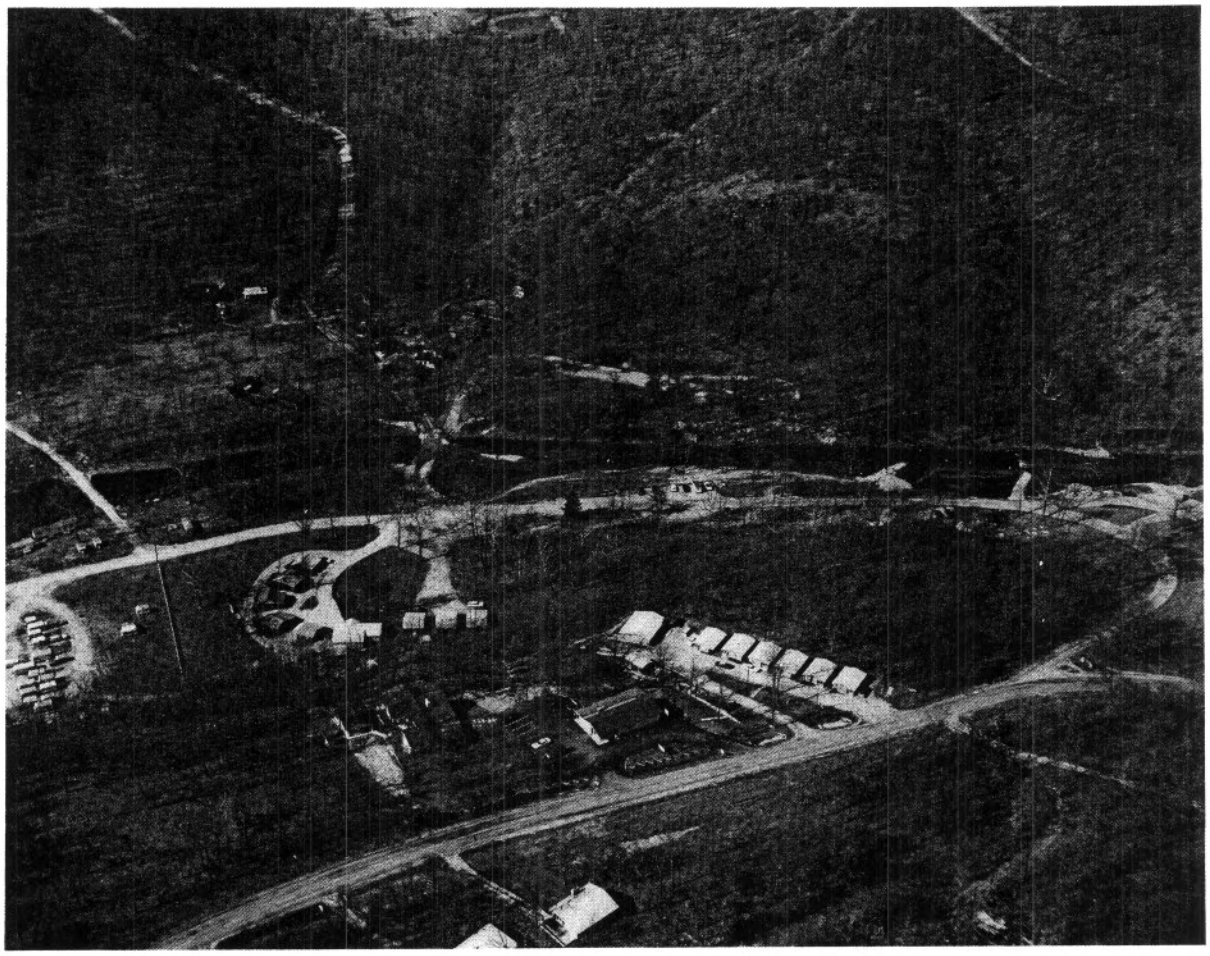


Figure 68

Aerial view of Bennett Spring showing the spring rise pool subject to flooding and consequent gravel deposition by Bennett Spring Creek. Purchase of resort properties adjacent to the spring by the Missouri State Park Board, and the recent installation of a parkwide sanitary sewer system are expected to relieve contamination of the spring from local sources. Photo by Jerry D. Vineyard.

plus an increase in the aquatic growth in the spring branch prompted a study of the spring supply system by the Missouri Geological Survey and the U.S. Geological Survey (Dean, Williams, Lutzen and Vineyard, 1969). A map showing the shallow groundwater relationships in the area was prepared, and dye tracing experiments were conducted to determine the source of nutrients detected in the spring water. A ground water divide was delineated running approximately east-west about 6 miles south of the spring. then trending northeastward from Lebanon toward the Niangua River. A seepage run by U.S. Geological Survey personnel on the Niangua above Bennett Spring showed no detectable water-loss zones in the river. Dye tracing from a zone of water loss in Goodwin Hollow about 2 miles northeast of Lebanon, however, showed that ground water moves westward beneath a surface divide between Goodwin Hollow and the Niangua River, to resurge in Bennett Spring (fig. 70).

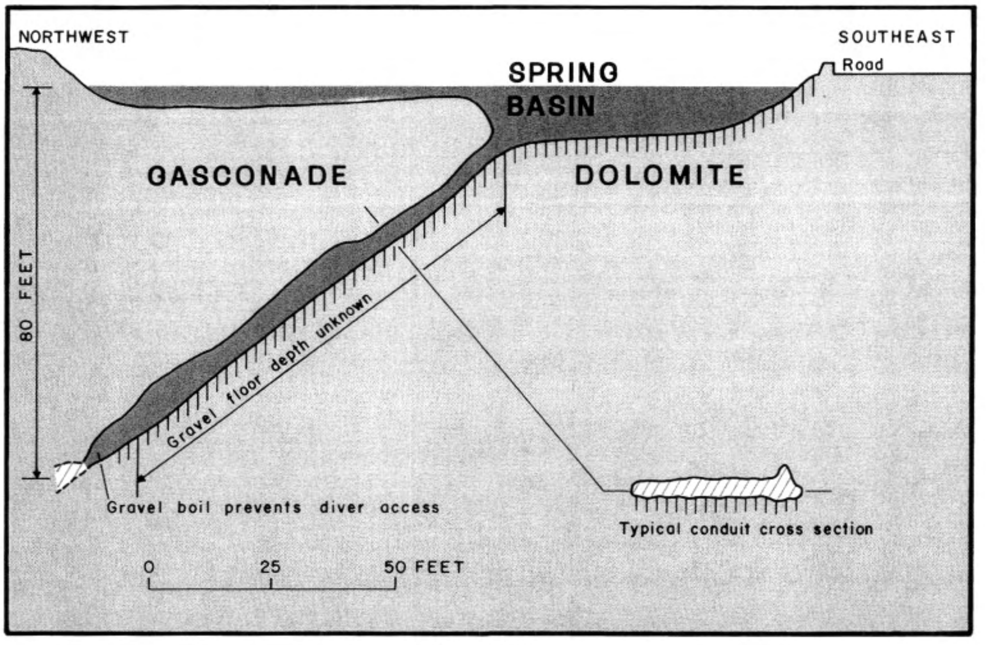


Figure 69

Northwest - southeast longitudinal profile through Bennett Spring from data supplied by Donald N. Rimbach, Michael R. Tatalovich, and M. Grussemeyer.

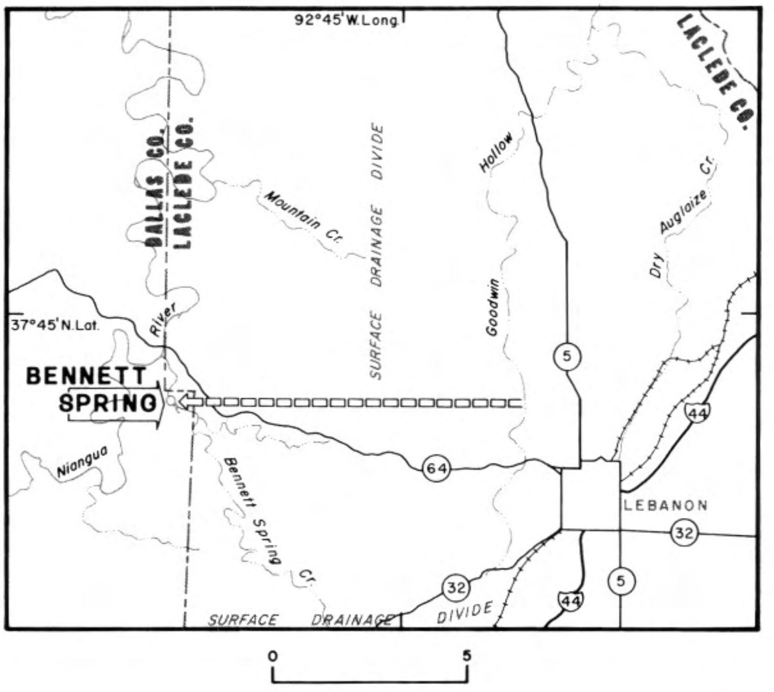


Figure 70

Water tracing experiments by the Missouri Geological Survey have shown that Bennett Spring pirates water from Goodwin Hollow through subterranean conduits beneath the surface divide between Goodwin Hollow and Bennett Spring Creek.

To remove pollution sources nearer the spring, the Missouri State Park Board purchased resort properties immediately upstream from the spring and eliminated the use of septic tanks near the spring by construction of an extensive system of sanitary sewers and treatment facilities.

There is a deposit of polished pebbles and cobbles in a hillside a few hundred feet northeast of the spring that may be an ancestral discharge point for the spring. The deposit is similar to one described by Beveridge (1960, p. 29) near Shanghai Spring in Pulaski County. The mechanism of formation of these highly polished gravels is suggested by the gravel tumbling phenomenon observed in Sweet Blue Spring near Bennett Spring and by Vineyard (1960) from Devils Well, which is part of the supply system for Cave Spring in Shannon County.

Records of daily flow of the spring have been collected during the periods 1916-19, 1928-41, and 1965-70. During this period the flow has been as follows:

	Date	Discharge (cfs)	Gallons per day
Max.	April 30, 1970	1700 (est.)	1,098,000,000
Min.	Nov. 13, 1934	65	36,000,000
Avg.	21-yr. record	149	96,000,000

SWEET BLUE SPRING, *Laclede County, Macks Creek 15-minute quadrangle, SE¼ NE¼ sec. 30, T. 36 N., R. 17 W.*

Blue Spring is on the grounds of a private camping, hunting and fishing resort on the Niangua River. The spring flows from the base of a low cliff of lower Gasconade Dolomite into a basin about 35 feet deep near the east edge of the pool. The Niangua River is close by, and the spring pool is no more than a few feet above normal river level; consequently, the spring is frequently covered by backwater when the river floods. The beautiful blue color of the spring is best displayed on a sunny day when the sun shines directly down into the gravel-floored pool.

Don Rimbach (written comm., 1966) has explored Blue Spring with the aid of underwater breathing equipment. At the bottom of the spring basin there is a cave entrance about 10 feet wide and 5 feet high with a steeply sloping floor. This entrance leads to a circular room about 15 feet in diameter and 12 feet high at the eastern wall. The floor of this room is coarse gravel, and in approximately the center of the room there is an underwater gravel plume which may be unique in Missouri springs. When divers examined the spring in 1966, a strong jet of water was spraying gravel some 3 to 5 feet from the floor of the cave, forming a pulsating plume of ever-changing shape. The noise was similar to pouring gravel on a metal roof. The entire flow of Blue Spring apparently rises in this small, round room. The base of the gravel plume is at a depth of 47 feet, while the ceiling of the room is at a depth of 36 feet.

It is not possible to explore Blue Spring farther than the gravel plume room. Open joints leading away from the room suggest that the catchment basin for Blue Spring lies to the southeast. Examination of the Macks Creek topographic quadrangle map supports this theory. The dry valley of Fishtrap Hollow lies directly south, while Sweet Hollow lies east-southeastward of the orifice of Blue Spring. It is probable that water loss in these valleys contributes to the flow of Blue Spring.

HAHATONKA SPRING, *Camden County, Macks Creek 15-minute quadrangle, Center sec. 2, T. 37 N., R. 17 W.*

Hahatonka Spring (fig. 71) is one of the 15 largest springs in Missouri and has an average discharge of almost 50 mgd. The spring drains an upland area to the south and east, where dry valleys abound, and flows into the Niangua arm of the Lake of the Ozarks. Many features associated with limestone solution occur in the vicinity of Hahatonka Spring; these are described by Bretz (1956, p. 123-132). The abundance of solution features in the area is of interest because of the many indications of strong structural disturbance. Faulting is prominent in the area. Certain stream alinements and the offsetting of other streams suggest additional faulting or intense jointing, much of it still unmapped. Together, these features suggest the development of a large underground storage reservoir that keeps the flow of the spring at a high level.

On top of the bluff from which Hahatonka Spring flows stand the ruins of a mansion of 28 rooms built during the 19th century. It burned before completion and the owner never lived in it. Two dams were constructed below the spring and a mill was built on the south branch from the spring. When Bagnell Dam was built and the Lake of the Ozarks was created, water backed up the Niangua arm to inundate the lake.

Records of the daily flow of the spring were collected from November 1922 to June 1923, and from October 1923 to September 1926. Since that time periodic measurements have been made. During the period of continuous measurement the flow has been as follows:

	Date	Discharge (cfs)	Gallons per day
Max.	Nov. 9, 1925	175	123,000,000
Min.	Feb. 23, 1923	43	28,000,000
Avg.	4-year record	77	50,000,000

Steyermark (1941, p. 578) described the vegetation in the spring and the two branches leading from it.

SAC RIVER BASIN

BASIN DESCRIPTION

The Sac River basin lies in the southwestern part of Missouri. Most of the basin is on the Springfield Plateau and its eastern boundary, which borders the Pomme de Terre basin, approximately coincides with the Eureka Springs escarpment. Valleys basin have been measured only once, it is not known if they stop flowing in dry weather. Generally, it may be concluded that the nearer the spring to a perennial stream and the more abundant the plant growth in the spring branch, the more likely it is that the spring is perennial.

Most of the springs in the basin are used for watering stock. The spring at Valley Water Mills and Fulbright Spring at the city waterworks furnish part of the water supply for the City of Springfield. Chesapeake Spring furnishes water to the State Fish Hatchery. Cove Spring, near Halltown (now in the Mickey Owens Baseball Camp), was formerly a private trout hatchery. A few springs are used for domestic water supplies. Table 19 gives the discharges for springs in the Sac River basin. Some of the springs included in the descriptions of selected springs have not been measured and therefore are excluded from table 19. Locations of measured springs are shown in figure 72.

QUALITY OF WATER

Spring water in the Sac River basin is of two types: calcium bicarbonate water from limestone in the southern part and calcium magnesium bicarbonate water from dolomite in the northern part. Chesapeake Spring rises near the Chesapeake fault zone in the southern part of the basin and chemical analyses indicate that the water is a mixture of water from dolomite along the fault and limestone in the area away from the fault. Other springs along the fault have chemical characteristics similar to Chesapeake Spring. Spring water in the Sac basin is moderately mineralized. The dissolved-solids content ranges from in the eastern part of the basin are floored with Ordovician dolomite. The western and northern parts of the basin are mantled with sandstone and shale of Pennsylvanian age. The remainder of the area is underlain by Mississippian limestone and is the principal spring area of the basin.

Faulting, though common, is not severe in the basin. Generally faults have northwest trends and the nearly rectangular shape of the basin is influenced by the faulting. The long sides of the rectangle parallel the principal direction of faulting.

Solution activity, as indicated by the abundance of sinkholes, is pronounced in Greene County – especially in the vicinity of Springfield. Springs are common in this area. In the remainder of the basin north and west of Springfield, sinkholes are confined to small areas. In these areas, perennial springs are few even though seeps and intermittent springs may be common.

Most of the perennial springs in the basin are in Lawrence and Greene Counties in the area farthest removed from the main outcrop of Pennsylvanian rocks. This is similar to the condition in the Spring River basin. Valleys floored with Cotter Dolomite in the northern and eastern part of the basin have few springs and they are small. Although there are many perennial springs north of Springfield they are not so large as those south of the city in the White River basin or to the west in the Spring River basin. This difference probably is also related to the locations of the spring areas in the three basins in relation to the line of outcrop of Pennsylvanian formations. Because most of the springs in the Sac 185 to 458 mg/l (table 20). Hardness of the water ranges from 156 to 299 mg/l. Of the 31 hardness determinations, three are classed as hard and 28 are classed as very hard (see table 3). Iron content of the water ranges from 0.00 to 0.61 mg/l. Analyses show that four of the springs contain more than 0.3 mg/l of iron. Nitrate content of the water ranges from 1.1

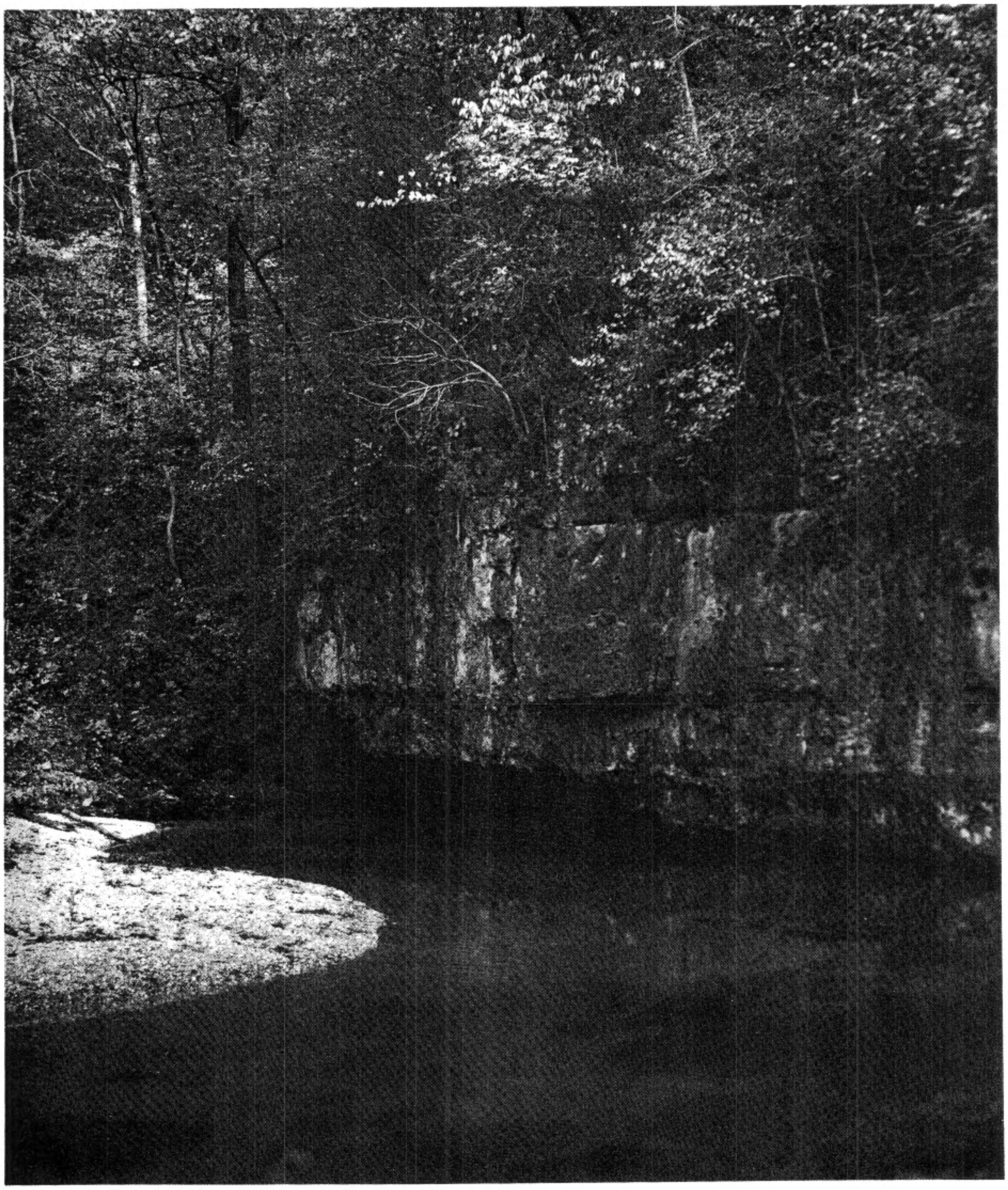


Figure 71

Hahatonka Spring rises beneath a bluff of Gasconade Dolomite and the force of the current is great enough to pile up large quantities of chert gravel. The ability of the spring to move large amounts of gravel suggests that its principal supply channel is shallow rather than deep. Photo by Jerry D. Vineyard.

Table 19
DISCHARGES OF SPRINGS IN THE SAC RIVER BASIN
[A = less than 0.01 cfs]

Location No. (fig. 72)	Spring	Nearest Town	County	Land Line Location	Rate of Flow: Sec. Ft. (cfs)	Rate of Flow: 1000 gal. day	T °F.	Date	Remarks
1	Aunt Maggie	Fair Grove	Greene	NESW 34,31,21W	0.05	32	60	10-29-64	Stock
2	Bigbee	Willard	Greene	NWNE 4,29,23W	.32	207	58	10-27-64	Stock
3	Bob Moore	Chesapeake	Lawrence	NWNE 12,28,26W	A	A	60	8-24-64	
4	Brower	Willard	Greene	NENW 4,29,23W	.33	213	58	10-27-64	
5	Cave	Willard	Greene	SWSE 4,30,23W	.04	26	58	11-5-63	
					.12	76	59	8-25-64	
6	Chesapeake	Chesapeake	Lawrence	SWSW 21,28,25W					
	(Average of 22 measurements)				2.30	1,490	-	1926-1966	Fish hatchery
	(Maximum discharge measured)				9.02	5,830	56	4-6-65	
	(Minimum discharge measured)				.28	181	58	9-2-54	
7	Clear Creek	Springfield	Greene	SWSW 3,29,23W	1.84	1,190	59	9-23-64	Commercial
					1.53	988	58	12-2-64	Park, swimming pool
8	Cove	Halltown	Lawrence	NWSW 36,29,26W	9.00	5,810	-	3-24-50	Fish hatchery
					3.60	2,330	67	8-24-64	
					3.20	2,070	51	12-1-64	
9	Creighton	Bois D'Arc	Greene	NWSW 19,29,23W	.10	65	59	9-23-64	Stock
10	Davis	Springfield	Greene	SESE 2,29,22W	.31	200	58	12-2-64	
11	Dawson (Lower)	Ash Grove	Greene	SENW 30,30,23W	.15	97	58	10-27-64	
12	Dawson (Upper)	Ash Grove	Greene	NESW 30,30,23W	.25	162	58	10-27-64	
13	Dunnegan	Dunnegan	Polk	SESW 5,34,24W	.26	168	59	8-25-64	
14	Fortner	Willard	Greene	SWNW 22,30,23W	.05	32	60	9-25-64	
15	Fulbright	Springfield	Greene	SWNW 2,29,22W	3.35	2,160	58	12-2-64	Springfield waterworks
16	J. B. Gilmore	Willard	Greene	NESW 22,30,23W	.10	65	59	9-24-64	Stock
17	Grace	Willard	Greene	SESE 19,30,22W	A	A	58	10-26-64	Stock
18	Hailey	Dadeville	Dade	NWSE 34,33,25W	.14	90	58	6-13-66	
19	Hammond	Willard	Greene	NWNE 9,30,23W	.08	52	-	11-5-63	
					.38	245	59	8-26-64	
					.22	142	57	9-24-64	
20	J. Hart	Republic	Greene	NWNW 18,28,24W	1.94	1,250	59	9-21-64	Stock
					3.69	2,380	58	12-1-64	
21	Hayes	Springfield	Greene	NESW 19,29,23W	1.52	982	59	9-23-64	Stock
					2.53	1,630	58	12-2-64	
22	Headlee No. 1	Fair Grove	Greene	NWNE 3,30,21W	.10	65	59	10-29-64	Picnic, stock
23	Headlee No. 2	Fair Grove	Greene	NENE 3,30,21W	.10	65	59	10-29-64	Stock
24	Honey Creek	Pennsboro	Dade	NWNW 20,30,26W	.62	401	58	6-13-66	
25	Humansville	Humansville	Polk	NESE 16,35,24W	*	*		8-8-25	
26	Kelley	Ash Grove	Greene	NWSE 15,30,24W	.16	103	58	9-24-64	Stock
27	Leeper	Ash Grove	Greene	NESE 30,30,24W	.22	142	58	9-24-64	Stock
28	Lumlee Mill	Halltown	Lawrence	NWNW 12,29,26W	3.67	2,370	-	10-19-32	Stock
					3.78	2,440	68	8-24-64	
					1.63	1,050	57	12-1-64	
29	Malenosky	Willard	Greene	NESE 31,31,22W	.10	65	59	10-27-64	Domestic, stock
30	Mason	Bois D'Arc	Greene	NWSE 9,29,24W	.76	491	57	9-24-64	Stock
31	Mount Pleasant	Willard	Greene	NWNE 29,30,23W	.10	65	59	9-25-64	
32	Panther	Halltown	Greene	SWNE 19,29,24W	.69	446	59	9-23-64	Stock
33	Parrish	Willard	Greene	SWSW 28,30,22W	.38	245	-	8-26-64	Stock
					.32	207	58	10-26-64	
34	Paxton	Humansville	Polk	NESE 16,35,24W	.69	446	59	8-6-37	Old mill site
					.39	252	-	8-24-64	
35	Pertuche	Springfield	Greene	SESW 28,30,22W	A	A	57	10-26-64	Recreation, stock
36	Ritter No. 1	Springfield	Greene	NESE 4,29,22W	.56	362	58	9-26-53	
					1.24	801	57	10-28-64	
					1.66	1,070	57	12-2-64	
37	Ritter No. 1	Springfield	Greene	SE 4,29,22W	1.18	762	59	10-28-64	
					1.98	1,280	58	12-2-64	
	Ritter No. 2	Springfield	Greene	SWSW 3,29,22W	3.44	2,220	61	9-26-64	
38	Scott	Ash Grove	Greene	NESE 6,29,24W	.15	97	58	9-23-64	Recreation, stock
39	Scott	Everton	Dade	NENE 35,30,25W	.52	336	58	6-13-66	
40	Snider	Willard	Greene	NWNW 34,30,23W	.27	174	60	10-27-64	Stock
41	Sthrom	Chesapeake	Lawrence	NESW 18,28,25W	3.50	2,260	-	3-24-50	
					.03	19	59	8-25-64	
42	Stockton	Stockton	Cedar	Sec. 8,34,26W	*	*		8-7-25	
43	Stoddard	Willard	Greene	NWNW 32,30,22W	.02	13	59	10-26-64	Stock
44	Swift	Willard	Greene	NWNE 29,30,23W	.05	32	59	10-26-64	Stock
45	Trogdon	Republic	Greene	NWNE 21,28,24W	1.32	852	58	9-21-64	Stock
					1.92	1,240	57	12-1-64	
46	Unnamed	Springfield	Greene	NWSE 34,30,22W	.10	65	57	10-28-64	Scout camp
47	Valley Water Mill	Springfield	Greene	NESE 5,29,21W	1.34	866	58	12-3-64	Springfield waterworks
48	Weiland	Springfield	Greene	SESE 21,30,22W	.05	32	58	10-27-64	Stock
49	Williams	Springfield	Greene	NENE 33,30,22W	1.13	730	58	10-28-64	Domestic, stock
					1.37	885	58	12-2-64	
50	Woodward	Ash Grove	Greene	NWNE 15,30,24W	.04	26	59	9-24-64	Stock
51	Young	Ash Grove	Greene	NENE 12,30,24W	.10	65	59	9-25-64	Stock

*Discharge data not available; see Table 20 for water quality data.

Figure 72

Springs in the Sac River basin.

to 33 mg/l, with most of the analyses showing 10 mg/l or more. This area has much farming and dairying so a source of nitrate in the water may be, in part, nitrogen fertilizers used in farming. In some locations, however, the higher nitrate content suggests contamination from barnyards, septic tanks or sewage lagoons.

As in the White River basin to the south, springs in the Sac River basin show the effects of the metropolitan development of Springfield. Measurements of specific conductance made in April 1967 showed that those springs which drain north from Springfield have values more than double those whose sources are south or west of the city. The total dissolved solids in spring water having its source south or west of Springfield ranges from 450 to 525 mg/l compared to 230 to 240 mg/l in springs whose sources are to the north.

DESCRIPTIONS OF SELECTED SPRINGS

BISHOP SPRINGS, *Dade County, South Greenfield 7½-minute quadrangle, NE¼ SE¼ sec. 23, T. 30 N., R. 27 W.*

Bishop Springs rise from two outlets along Limestone Creek about 3½ miles south of South Greenfield. One spring is in alluvial materials on the flood plain of Limestone Creek, and the other spring issues from a limestone outcrop on the west valley wall of the creek. The two streams join and flow through water-cress choked channels to nearby Limestone Creek.

Carrico Cave, about 3/4 mile south-southwest from Bishop Springs, carries a sizeable stream which flows from the southern passages of the cave to an exit in an extremely low northward-trending passage. Fluorescein dye was placed in the Carrico Cave stream and recovered later by charcoal detectors placed in Bishop Springs, confirming the connection between the underground cave stream and the springs (fig. 73).

There are six known caves within a 1-mile radius of Bishop Springs, all in the Burlington Keokuk limestone of Mississippian age. Three of the caves are on the east side of Limestone Creek and, therefore, are not contributory to the flow of Bishop Springs, while the remaining three are on the west side of the creek and undoubtedly contribute to the flow of the springs. The two Carrico Caves shown on the South Greenfield 7½-minute quadrangle are listed by the Missouri Speleological Survey as Carrico Cave (westernmost) and Pump Cave (easternmost). Between

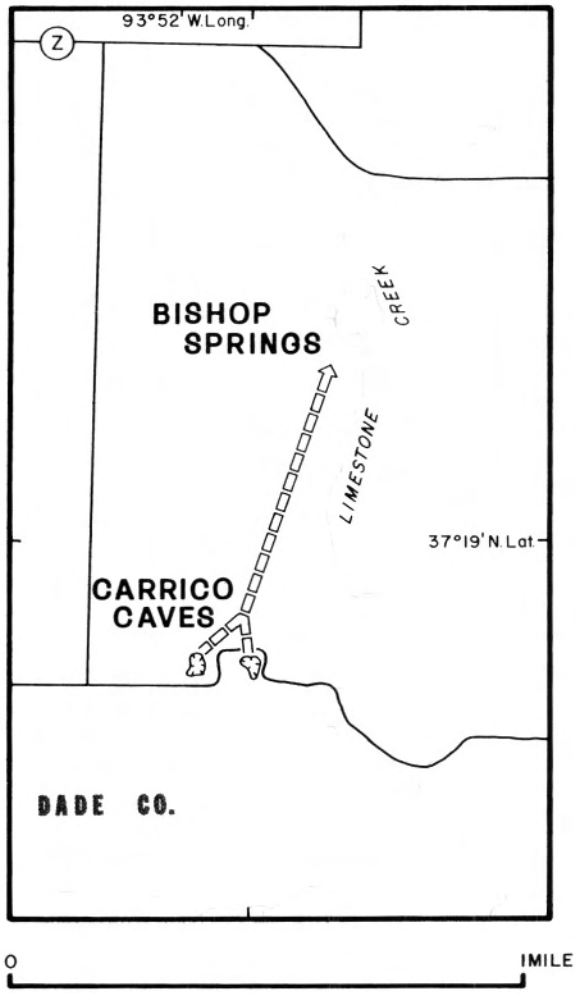


Figure 73

Water that rises in Bishop Springs first passes through Carrico Cave as an underground stream. The hydrologic connection between the cave and springs was determined by water tracing using fluorescein dye. Base map from U.S. Geological Survey, South Greenfield 7½-minute quadrangle.

Carrico Cave, Pump Cave and Bishop Springs there is a pit cave which is also presumed to contribute to the flow of Bishop Springs.

CHESAPEAKE SPRING, *Lawrence County, Chesapeake 7½-minute quadrangle, SW¼ SW¼ sec. 21, T. 28 N., R. 25 W.*

Chesapeake Spring in the village of the same name is in the extreme southern tip of the basin. It rises in the outcrop area of the Cotter Dolomite about 1

Table 20
CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE SAC RIVER BASIN

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 72)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
5	Cave	5-55	--	58	5.8	0.03	85	8.9	4.8		256	0	8.6	5.0	0.1	33	---	286	248	38	---	7.2	--	1
		8-64	.12	58	11	.00	89	9.7	3.0	1.1	284	0	9.8	4.7	.1	20	0.00	288	262	30	508	7.9	1	0
6	Chesapeake	9-26	--	--	9.6	.48	59	19	4.9		224	13	2.7	4.7	--	3.0	---	230	224	19	---	---	--	-
		5-55	--	59	7.0	.10	52	17	5.0		221	0	1.7	5.8	.1	12	---	220	198	17	---	7.4	--	1
		7-64	1.88	59	7.8	.09	53	14	5.6		207	0	4.1	7.8	.1	10	---	218	190	20	385	7.2	--	-
		11-65	1.73	57	11	.00	54	15	4.2	.6	224	0	3.4	6.6	.0	13	---	218	196	12	387	7.7	0	-
		2-66	2.61	55	10	.02	51	14	4.1	.2	211	0	3.8	5.6	.1	12	---	210	185	12	363	7.6	0	0
		7-66	1.74	59	12	.00	50	12	3.6	.7	195	0	4.0	4.6	.2	11	---	202	175	14	340	7.4	5	-
7	Clear Creek	9-64	1.84	59	12	.03	85	2.4	5.5	.6	244	0	8.4	9.0	.0	14	.03	269	222	22	451	8.0	3	0
8	Cove	8-64	3.60	58	9.0	.01	52	6.4	3.8	.8	172	0	5.0	3.1	.0	15	---	185	156	15	303	7.7	0	1
10	Davis	12-64	.31	58	12	.00	108	7.1	40	7.5	288	0	82	44	.0	11	.43	458	299	62	755	7.9	5	0
13	Dunnegan	8-25	--	--	6.8	.61	56	28	7.1		260	15	15	3.7	--	1.1	---	260	254	16	---	---	--	0
		5-55	--	--	4.8	.09	50	27	5.1		262	0	14	3.5	.2	8.3	---	254	236	21	---	7.4	--	1
		8-64	.26	--	11	.03	55	26	3.4	1.0	278	0	20	4.0	.0	1.6	.00	259	244	16	469	7.8	5	0
18	Hailey	6-66	.14	58	14	.05	71	13	1.6	.7	257	0	8.2	3.2	.6	18	---	264	231	20	440	7.5	0	-
19	Hammond	8-64	.38	59	10	.00	82	5.0	2.5	.6	244	0	8.2	3.6	.1	18	.00	250	225	25	439	8.1	1	0
20	Hart	9-64	1.94	59	11	.04	79	2.8	2.5	.5	233	0	2.8	4.5	.0	20	.03	241	209	18	412	7.8	3	0
21	Hayes	9-64	1.52	59	9.2	.00	73	3.4	2.9	.7	211	0	6.0	5.0	.0	20	.02	228	196	22	397	7.6	2	0
24	Honey Creek	6-66	.62	58	13	.02	70	1.1	1.6	.5	202	0	8.6	2.4	.1	12	---	216	179	14	360	7.6	0	-
25	Humansville	8-25	--	--	7.8	.57	57	31	5.8		286	17	8.0	5.3	--	1.2	---	274	270	8	---	---	--	0
		5-55	--	57	6.2	.10	46	27	6.3		241	0	11	4.5	.1	18	---	257	226	28	---	7.2	--	1
28	Lumlee Mill	8-64	3.78	68	11	.00	74	5.2	2.5	1.2	232	0	7.6	5.3	.0	10	---	233	206	16	388	7.9	0	0
30	Mason	9-64	.76	57	9.3	.00	66	4.8	2.2	.4	189	0	6.6	4.6	.0	22	.02	210	184	29	366	7.7	1	0
34	Paxton	8-64	.39	59	11	.05	47	28	4.1	1.5	254	0	15	6.0	.0	5.4	.00	242	232	24	442	7.8	7	0
36	Ritter No. 1	10-64	1.24	57	10	.00	91	3.2	11	.8	254	0	26	15	.0	14	.00	302	240	32	516	8.1	2	2
37	Ritter No. 2	10-64	1.18	59	11	.00	95	2.5	16	3.8	276	0	34	15	.0	9.3	.02	330	247	21	558	8.0	2	1
39	Scott	6-66	.52	58	15	.01	89	1.1	2.4	.5	258	0	5.4	4.2	.0	7.9	---	264	227	15	440	7.6	0	-
41	Sthrom	8-64	.03	59	11	.00	74	7.7	5.1	.8	240	0	8.4	8.4	.0	14	---	251	216	19	419	7.9	0	0
42	Stockton	8-25	--	--	9.0	.45	74	19	8.2		261	17	6.0	8.5	--	16	---	285	262	20	---	---	--	0
45	Trogdon	9-64	1.32	58	10	.00	78	1.9	2.4	.6	221	0	3.6	4.5	.0	18	.03	234	203	22	399	7.7	1	0
49	Williams	10-64	1.13	58	9.4	.00	74	3.5	16	1.0	190	0	34	24	.2	9.8	.01	270	199	44	478	8.1	1	1

mile west of the Chesapeake fault. The spring has a bed of gravel enclosed by a circular rock basin and the water moves through a lined trench beneath Highway 174 to the Chesapeake Hatchery. The hatchery is owned and operated by the Missouri Conservation Commission for the propagation of warm water species of fish such as bass, bluegill and channel catfish. The hatchery raises about one million catfish annually. Recently the propagation of muskies was started at the hatchery to rid fishing lakes and streams of unwanted fish.

There are several springs located in the proximity of the Chesapeake fault and it is believed that faulting is responsible for the occurrence of the springs.

Chesapeake Spring has a moderately uniform flow of about 1.5 mgd and it has never been known to stop flowing. In the dry period of the early 1950's the yield declined to 182,000 gallons per day. A maximum discharge of 5.8 mgd was measured in April 1965 after heavy rains in the area.

Steyermark (1941, p. 558) described the plants in the spring and branch.

FULBRIGHT SPRING, *Greene County, Ebenezer 7½-minute quadrangle, SW¼ NW¼ sec. 2, T. 29 N., R. 22 W.*

Fulbright Spring is at the Springfield Water Works in the northern part of the city. The spring flows from a bedding plane opened by solution of the Burlington Keokuk limestone which forms the bluff on the north side of Pea Ridge Creek. The spring has been completely enclosed by a concrete structure to prevent the entry of surface water as the spring is now used in the Springfield water system. A stream leading away from the spring is lined with water cress; the picturesque setting has been improved by the addition of a park and picnic facilities nearby.

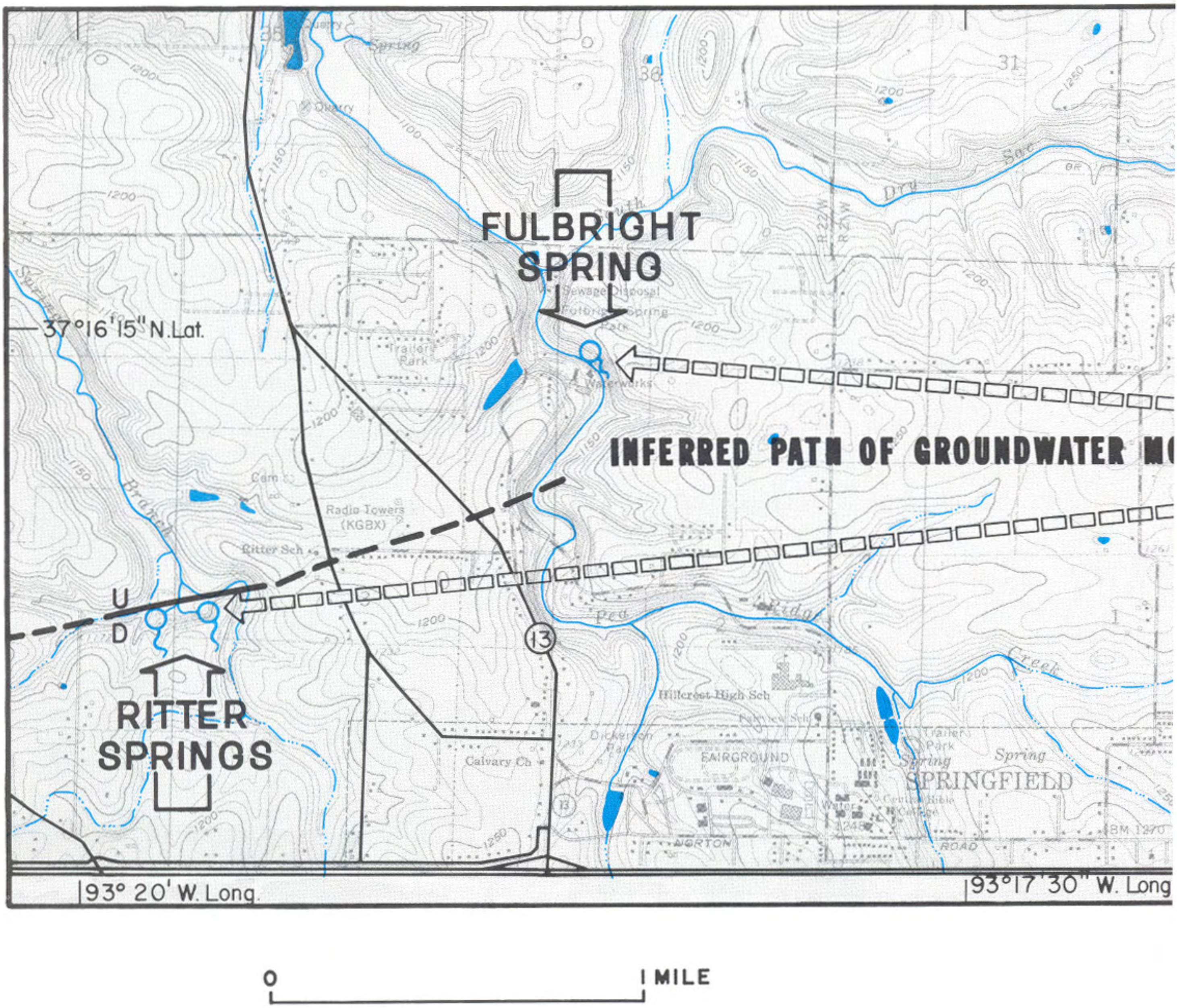
The spring has been measured only one time and it was found, in December 1964, that about 2 mgd was discharging from the spring. Shepard (1898, p. 225) described the spring which, even at that time, was being used by the city. He stated that the spring *"has a flow, in ordinary seasons, of 10,000,000 gallons in twenty-four hours."* It is not known whether Shepard's figure is an estimate or based on a measurement. This difference might suggest a decline in the spring's yield.

To complicate the situation further, the spring at Valley Water Mills (3½ miles east) and Ritter Springs (1½ miles southwest of Fulbright Spring) are hydrologically connected. Beveridge (1963, p. 45-47) discussed the structure of the Valley Mills fault zone and the hydrologic problem involved. Following is his discussion: *"Valley Water Mills reservoir is fed by a large spring at the south end. Water from this reservoir is piped through a ten-inch main into a fissure in the bed of South Dry Sac Creek. Water entering this fissure from the main emerges at Fulbright Spring, three miles to the west, which supplies part of the water to the city water works located at the spring. It had been suspected that not all the flow from Valley Water Mills was emerging at the spring and tracer chemicals were introduced. They showed that part of the water emerged at Ritter Spring, nearly a mile and a half west of Fulbright and four and a half miles west of Valley Water Mills, where there is also a city water supply reservoir."*

Shepard (1898, p. 225-226) discussed the spring known as Sander Spring which is at Valley Water Mills. His discussion follows: *"Sander Spring (T. 29 N., R. 21 W., Sec. 5) just south of the McCracken mill on the South Dry Sac, is another good example of a spring issuing from the base of the Upper Burlington. It flows from the foot of a low bluff into a large basin, and its discharge is probably 8,000,000 gallons in twenty-four hours. A recent attempt to dam this spring has shown that its waters are the chief source of supply for Fulbright Spring, a fact which, in dry times, may be very disadvantageous to the water supply of the city of Springfield. The drainage here, both surface and underground, follows the line of the McCracken-Ritter faulting."*

Bretz (1956, p. 316) discussed Fulbright Spring. His discussion follows: *"The Missouri Water Company, already operating at Fulbright Spring, was dismayed to have its spring entirely fail after the dam had been completed and the millpond back of it was being filled for the first time. They soon found that Fulbright Spring flowed with original volume only when the reservoir at Valley Water Mills was discharging and the spring's flow greatly decreased or ceased altogether when that reservoir had been depleted and its spillway was closed for refilling. The water company's practice for some time was to send grists of corn to Valley Water Mills when the Fulbright flow dropped toward a danger point."*

From the foregoing discussions it would appear that the flow of Fulbright Spring is derived from the spring at Valley Water Mills (fig. 74). Also, the measurement of discharge from the reservoir at


FULBRIGHT SPRING
INFERRED PATH OF GROUNDWATER M
RITTER SPRINGS
U
D
37°16'15" N.Lat.
93° 20' W. Long.
93°17'30" W. Long
Radio Towers (KGBX)
Ritter Sch
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SPRINGFIELD
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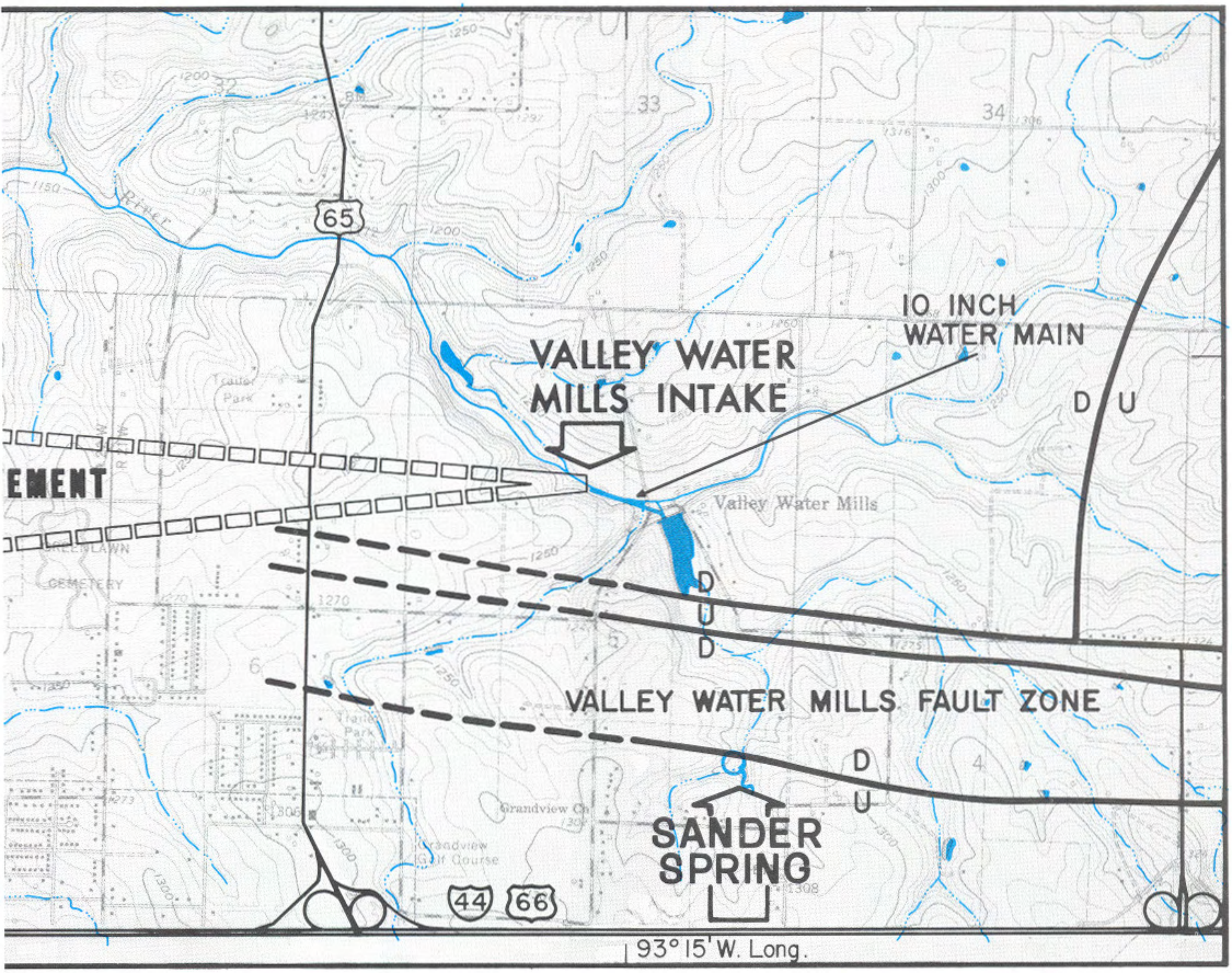


Figure 74

Fulbright Spring and its relationship to the Valley Mills fault zone and to the large spring at the head of Valley Water Mills lake. After Beveridge, 1971, plate 1.

Valley Water Mills made in December 1964 showed that the discharge was about 1 mgd which is much lower than Shepard's figure of 8 mgd.

Shepard (1898, p. 226) stated that the flow of Jones Spring in the White River basin *"has a discharge of about 8,000,000 gallons of water in twenty-four hours."* Modern measurements spaced at 2-month intervals indicate an average flow of 1 mgd, a quantity about equal to that flowing from Valley Water Mills.

Thus, three springs having substantial flows in the 1890's may have declined. The total flow of Fulbright Spring, Valley Water Mills (Sander Spring), and Jones Spring reported by Shepard was 26,000,000 gallons per day. Modern measurements of the three springs total 4,000,000 gallons per day. If the decline in yield of these springs is actual it may be due to a combination of several causes. Deficient precipitation may be one cause. Since 1959 rainfall had been deficient in all years except 1961, and 1964 was the driest year of the 5-year period. Since the springs were measured in December 1964, this is likely to be the principal cause. Another cause may be the urbanization of the Springfield area. Springfield is in a karst area pockmarked with many sinkholes. The sinkholes are being filled as the city expands and precipitation that formerly went into the ground now runs off the surface. A third contributing cause may be the gradual lowering of water levels by pumping from the limestone underlying Springfield.

RITTER SPRINGS, *Greene County, Ebenezer 7½-minute quadrangle, SW¼ SW¼ sec. 3, T. 29 N., R. 22 W.*

Ritter Springs form a scenic area in a ravine about 1 mile northwest of Springfield near the head of Spring Branch, a tributary of Little Sac River. In earlier years a dam was built at the mouth of the ravine, forming a lake. This lake and the dam are gone and the springs have reverted to their natural state. Numerous concrete foundations and ruined buildings in the vicinity attest to the former development centered around the springs.

The east spring rises in a bed of gravel at the base of a rounded bluff of Burlington Keokuk limestone and flows through a spring branch lined with water cress to join the branch leading from the west spring. The spring is unimproved. The west spring is at the base of a low vertical bluff of limestone and is enclosed by stone and concrete retaining walls. The opening of a small cave has developed on a bedding plane in the limestone at the base of the bluff.

Ritter Springs are connected with Valley Water Mills (Sander Spring) and Fulbright Spring as shown by the tracer test described in the discussion of Fulbright Spring (Beveridge, 1963, p. 47).

SPRING AND ELK RIVER BASINS

BASIN DESCRIPTIONS

The Spring River basin lies in the southwestern corner of Missouri. The map of the basin includes Elk River and Buffalo and Lost Creeks which drain McDonald County and flow into the Lake of the Cherokees in Oklahoma. Principal tributaries of Spring River in Missouri are Center, Turkey, and Shoal Creeks. The area in Missouri drained by Spring River and its tributaries is about 2,500 square miles.

Cherty Mississippian limestone is exposed over about 90 percent of the area. Sandstone and shale of the Pennsylvanian System cover Barton County and the northwestern part of Jasper County. Outliers of Pennsylvanian rocks distributed over much of the remaining area indicate that Pennsylvanian deposits were much more extensive than they are today. In McDonald County older rocks belonging to the Silurian and Ordovician Systems crop out along the stream valleys, but do not appear at the surface elsewhere in these basins.

The boundary between the Springfield Plateau and the Osage Plains crosses Jasper and Barton Counties and corresponds with the boundary between the Mississippian limestone and Pennsylvanian shale and sandstone outcrop. The boundary also separates the spring area of the Plateau from the area to the north which is practically devoid of springs. Similarly, streams entering Spring River from the north are intermittent whereas those entering from the south and east have well-sustained flows.

The distribution of springs is related to the geologic history of the area. Formerly the entire area was covered with Pennsylvanian strata. As the Pennsylvanian cover was eroded from southeast to northwest, solution proceeded more rapidly in the exposed Mississippian limestone. As a result of solution of the limestone, movement of water through the rock was made easier with passage of time. The better development of solution openings in the areas away from the Pennsylvanian cover is evidenced by the large number of springs in the Shoal Creek basin. Also, the largest

Figure 75

Springs in the Spring and Elk River basins.

Table 21
DISCHARGES OF SPRINGS IN THE SPRING AND ELK RIVER BASINS

Location No. (fig. 75)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
1	Bartholic	Neosho	Newton	SWSW 7,24,31W					
	(Average of 14 measurements)				0.48	310	-	1960-1964	Fish hatchery
	(Maximum discharge measured)				.83	536	-	6-8-60	
	(Minimum discharge measured)				.29	187	-	10-26-60	
2	Bartkoski	Pioneer	Barry	NENW 3,24,29W	.90	581	59	8-13-64	Domestic, stock
3	Big	Mt. Vernon	Lawrence	SENE 28,28,27W					
	(Average of 16 measurements)				19.0	12,300	-	1925-1966	
	(Maximum discharge measured)				26.4	17,100	57	6-8-65	
	(Minimum discharge measured)				6.05	3,910	58	9-2-54	
4	Big	Neosho	Newton	NESW 19,25,31W					
	(Average of 10 measurements)				1.38	891	-	1925-1964	Neosho City Park
	(Maximum discharge measured)				3.14	2,030	59	4-20-64	Dairy
	(Minimum discharge measured)				.50	323	58	11-6-63	
5	Birch	Neosho	Newton	SWSW 8-25,31W	.26	168	59	8-13-64	Domestic, stock
6	Boy Scout	Joplin	Newton	NWSE 9,26,32W					
	(Average of 8 measurements)				1.61	1,040	-	1964-1966	Boy Scout camp
	(Maximum discharge measured)				7.66	4,950	56	4-6-65	
	(Minimum discharge measured)				.46	297	58	2-2-65	
	Button	Sarcoxie	Newton	NWSE 21,27,29W	3.50	2,260	56	3-24-50	Stock
					.10	65	59	8-4-64	
8	Camp Beaver	Anderson	McDonald	NWNE 12,22,33W					
	(Average of 8 measurements)				2.18	1,410	-	1941-1965	Fish rearing
	(Maximum discharge measured)				4.29	2,770	60	10-5-65	
	(Minimum discharge measured)				.45	291	58	11-6-63	
9	Cave	Fairview	Newton	NENE 12,25,29W	3.00	1,940	-	11-6-63	Stock
					3.40	2,200	-	8-12-64	Fishing
10	Clarkson	Pierce City	Lawrence	SESE 17,27,28W					
	(Average of 11 measurements)				10.4	6,720	-	1925-1964	
	(Maximum discharge measured)				27.1	17,500	-	6-18-63	
	(Minimum discharge measured)				4.57	2,950	59	12-3-63	
11	Ell Lynn	Wentworth	Newton	SESW 23,27,29W	.86	556	55	10-7-53	Stock
					1.96	1,270	-	8-4-64	
					3.11	2,010	56	12-2-64	
12	Elm	Neosho	Newton	SESE 12,24,32W					
	(Average of 13 measurements)				1.20	775	-	1959-1964	Fish hatchery
	(Maximum discharge measured)				3.21	2,070	-	6-8-60	
	(Minimum discharge measured)				.25	162	-	10-26-60	
13	Fly	Wheaton	Barry	SWNW 16,24,28W	3.20	2,070	60	8-11-64	Stock
14	Gibson	Neosho	Newton	SESE 28,25,31W					
	(Average of 13 measurements)				2.85	1,840	-	1959-1964	Stock
	(Maximum discharge measured)				7.97	5,150	-	6-8-60	
	(Minimum discharge measured)				.80	517	60	8-13-64	
15	Great Western	Joplin	Jasper	NESE 6,27,32W	.30	194	-	7-1-64	Recreation
16	Haddock	Sarcoxie	Newton	SWNE 27,27,29W	6.00	3,880	-	3-24-50	Stock
					.80	517	58	8-4-64	
17	Hawkins No. 1	Fairview	Barry	NENW 12,25,29W	1.13	730	-	11-6-63	Fishing, stock
					.37	239	55	12-2-64	
18	Hawkins No. 2	Fairview	Barry	SENW 12,25,29W	1.15	743	-	11-6-63	Fishing, stock
					1.64	1,060	57	12-2-64	
19	Hearrell	Neosho	Newton	NWNE 30,25,31W	1.08	698	-	9-6-43	Fish hatchery
					.51	329	-	3-22-60	
					.51	329	-	6-8-60	
					.26	168	-	7-12-60	
					.80	517	58	8-13-64	
					.89	575	57	12-2-64	
20	Hobo	Neosho	Newton	NWSE 24,25,32W	.65	420	-	6-28-47	
					.20	129	58	8-13-64	
21	Kelley	Goodman	McDonald	SESE 18,23,32W	.41	265	58	3-3-41	
					.90	581	60	8- -64	
					1.00	646	54	12-2-64	
22	Kolkmeyer	Joplin	Newton	NENE 6,26,32W	.10	65	61	9-18-64	Domestic, stock
23	McCullom	Joplin	Jasper	NENW 22,29,32W	1.20	775	-	9-17-64	Stock
24	McMahon	Neosho	Newton	NWSE 28,25,31W					
	(Average of 14 measurements)				3.56	2,300	-	1943-1964	Fish hatchery
	(Maximum discharge measured)				14.6	9,430	-	3-22-60	
	(Minimum discharge measured)				.68	439	-	10-26-60	
25	Monark	Monark Springs	Newton	NWNE 26,25,31W	.10	65	61	8-26-64	Park
26	Morse Park	Neosho	Newton	SENW 19,25,31W	☆	☆	58	5-5-53	Flammable gas
					.30	194	58	8-13-64	
27	Mossy	Joplin	Jasper	NWNW 12,27,31W	3.00	1,940	61	8-4-64	
28	Ozark Trout Fm.	Neosho	Newton	SWNW 28,26,32W	.70	452	-	9-2-54	Fish rearing
					1.04	672	59	8-13-64	
					1.90	1,230	57	12-2-64	
					1.46		60	11-9-65	

Table 21 *(continued)*

Location No. (fig. 75)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
29	Pierce City	Pierce City	Lawrence	SWSW 21,26,28W	*	*		7-2-25	Flows through cave
					*	*	56	5-5-53	beneath house
					0.10	65	59	8-12-64	
30	Pioneer	Pioneer	Barry	NWSE 36,25,29W	.20	129	59	8-11-64	
31	Polk	Marionville	Lawrence	NENW 22,27,25W	1.87	1,210	58	10-6-53	Stock
					3.57	2,310	59	8-25-64	
					6.89	4,450	57	12-3-64	
32	Radar Station	Joplin	Jasper	SESE 10,28,33W	.30	194	59	7-10-64	
33	Rainbow	Wheaton	Barry	SWNE 36,24,29W	2.74	1,770	-	1-21-58	
					.40	258	-	8-11-64	
34	Sagamount	Joplin	Newton	NWNE 5,26,32W	.25	162	59	9-18-64	Recreation
35	Saginaw	Joplin	Newton	SWNE 31,27,32W	.85	549	-	9-18-64	Stock
36	Scotland	Joplin	Jasper	SWNW 1,27,32W	3.08	1,990	-	9-9-47	Industrial
					2.70	1,740	58	8-27-64	
37	Spiva	Joplin	Newton	NWSE 27,27,33W	.31	200	-	9-18-64	Spiva park
38	Spout	Reeds	Jasper	NESW 13,28,30W	.02	13	58	11-6-64	Domestic
39	Spring River	Verona	Lawrence	NWNW 28,26,26W					
	(Average of 8 measurements)				5.10	3,290	-	1953-1964	Fish rearing
	(Maximum discharge measured)				7.70	4,970	-	7-13-60	
	(Minimum discharge measured)				2.80	1,810	-	9-1-54	
40	Sonnywood	Joplin	Jasper	NWSW 15,28,33W	.55	355	62	4- -64	
					.23	149	-	7-6-64	
					.44	284	-	6-8-65	
					.19	123	-	8-18-65	
					.53	342	59	10-5-65	
					.48	310	56	12-8-65	
41	Talbert	Wheaton	Barry	NENE 28,23,28W	.40	258	58	8-11-64	Domestic, stock
42	Unnamed	Wheaton	Barry	SWSW 18,23,28W	.34	220	-	8-11-64	
43	Unnamed	Joplin	Jasper	SESW 15,27,33W	.20	129	-	11-13-64	
44	Unnamed	Ritchey	Newton	NWNE 33,26,29W	.90	581	-	8-12-64	Domestic, stock
45	Unnamed	Ritchey	Newton	NWSE 8,25,29W	.10	65	59	8-12-64	Stock
46	Unnamed	Granby	Newton	NENE 28,26,30W	.20	129	59	8-12-64	Domestic
47	Unnamed	Wheaton	Barry	NESE 25,24,29W	.25	162	-	8-11-64	Stock
48	Unnamed	Joplin	Newton	NENW 9,26,32W	.70	452	59	8-13-64	
49	Unnamed	Joplin	Newton	NWSE 5,26,32W	.05	32	-	8-14-64	Stock
50	Verona	Verona	Lawrence	SESW 17,26,26W	.47	304	-	6-24-60	
					.43	278	-	7-13-60	
					.73	472	-	7-13-60	
					.51	329	-	10-25-60	
					.02	13	-	8-25-64	
51	Wallace	Pioneer	Barry	SWNW 12,25,29W	8.40	5,430	61	8-12-64	Stock
					8.77	5,670	59	8-27-64	Fishing
					6.03	3,900	57	12-2-64	

*Discharge data not available; see Table 22 for water quality data.

springs in the area are in the headwater areas of the streams, the areas farthest from the Pennsylvanian outcrop. Table 21 gives the discharges for springs in the Spring and Elk River basins. Locations of measured springs are shown in figure 75.

Steyermark (1941, p. 544, 545, 558), described the vegetation in Big Spring, Newton County; Big Spring, Lawrence County; and Clarkson Spring, Lawrence County. It is interesting to note that the variety of plant life is less in the springs on the Springfield Plateau than it is in springs on the Salem Plateau. Following is a summary of Steyermark's findings:

Basin	Average number of plant species	Number of springs described
White, Elk, Spring, Sac	3	7
North Fork	10	12
Meramec	7	13
Gasconade	7	21
Black-St. Francis	6	10
Current-Eleven Point	10	21
Pomme de Terre-Niangua	10	2
Osage	6	1

Probably the most significant difference related to plant growth between the White, Elk, Spring, and Sac basins on the one hand and the North Fork, etc., on the other hand is that the springs drain limestone in the first group of basins and dolomite in the other basins.

QUALITY OF WATER

Springs in the Spring River, Shoal Creek and Elk River basins discharge water from limestone terranes and this is reflected by the calcium bicarbonate type of water. Spring water in this area generally contains less dissolved solids than springs in other areas. Excluding Sonny Wood Spring (dissolved solids 520 mg/l, sulfate, 192 mg/l), the range in dissolved-solids content is from 128 to 261 mg/l (table 22). Water in Sonny Wood Spring is affected by abandoned mine workings close by. A few of the other springs in the vicinity of Joplin contain unusually high amounts of sulfate and this, too, may be due to the weathering and solution of sulfide-bearing minerals (Feder and others, 1969, p. 34). Hardness of the water ranges from 96 to 397 mg/l with six samples classed as moderately hard, 31 hard, and four very hard (see table 3). Iron content of the water ranges from 0.00 to 0.77 mg/l with four of the analyses showing more than 0.3 mg/l. Nitrate content of the water ranges from 0.00 to 18 mg/l. Data for a few springs where multiple analyses are available indicate an apparent trend of increasing nitrate content with time. The data are not sufficient, however, to determine if these changes represent a trend or if they represent seasonal variations in the nitrate content of the water.

DESCRIPTIONS OF SELECTED SPRINGS

BARTHOLIC SPRING, *Newton County, Neosho East 7½-minute quadrangle, SW¼ SW¼ sec. 7, T. 24 N., R. 31 W.*

Bartholic, Elm, Hearrell, and McMahon Springs supply water to the U.S. Government Fish Hatchery at Neosho. The flow of these four springs, as it arrived at the hatchery, was about 2,000,000 gallons a day at the time it was measured. Because of its excellent quality the water from Bartholic, Elm, and McMahon Springs is brought several miles by pipeline to the hatchery. Hearrell Spring is at the hatchery which was established in 1888, the oldest of the nearly 100 hatcheries operated by the Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior. Fish produced at the Neosho hatchery are distributed to many sport fishing sites throughout Missouri. Annual production of the hatchery is about 55,000 pounds of trout and 300,000 bass fingerlings – most of which remain in Missouri waters.

BIG SPRING, *Newton County, Neosho East 7½-minute quadrangle, NE¼ SW¼ sec. 19, T. 25 N., R. 31 W.*

Neosho is called the City of Springs. Although the springs are not large there are many of them. The largest is Big Spring in Neosho City Park near the center of town (fig. 76). This spring issues at the base of a high bluff of Mississippian limestone from a series of cavernous openings developed along a bedding plane, flows through the city park and beneath the Big Spring Hotel to Hickory Creek. Part of the flow of Big Spring is used by a creamery.

BIG SPRING, *Lawrence County, Stotts City 7½-minute quadrangle, SE¼ NE¼ sec. 28, T. 28 N., R. 27 W.*

Big Spring in Lawrence County is the largest spring in the Spring River basin. The spring flows from a bedding plane enlarged by solution at the base of a high bluff of Burlington Keokuk limestone known as Baptist Hill and enters Spring River about 200 feet away. The spring branch contains a variety of plants – principally water cress – that thrive well in spring water. The spring is used as a picnic site which is open to the public and easy to reach by car.

The presence of so large a spring at this location presents an interesting aspect of surface and subsurface movement of water. Figure 77 shows that Honey Creek loses all its flow, 8.4 cfs, before it enters Spring River about 3 miles above Big Spring. Spring River loses 0.2 cfs in the reach from Honey Creek to Williams Creek. This suggests that water from Honey Creek might bypass Williams Creek below the ground surface and reappear in Big Spring. However, this has not been proved.

BOY SCOUT SPRING, *Newton County, Tipton Ford 7½-minute quadrangle, NW¼ SE¼ sec. 9, T. 26 N., R. 32 W.*

The spring is in the Richard Childress Boy Scout Camp in a narrow, steep-walled valley at the foot of a high bluff of Mississippian limestone. The picturesque spring opening is along a bedding plane and can be reached by a stairway from the top of the bluff. The opening is enclosed by a rock wall, and the branch is lined with rock to the springhouse and waterfall. The water is used for a swimming pool at the camp.

Table 22
CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE SPRING AND ELK RIVER BASINS

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 75)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved Solids (Residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
1	Bartholic	8-64	0.4	58	10	0.00	46	1.7	2.8	0.2	140	0	3.8	6.3	0.0	2.3	---	147	122	7	244	7.4	0	1
2	Bartkoski	8-64	.90	59	10	.01	63	.7	2.8	.9	176	0	3.6	4.9	.0	15	0.01	201	160	16	317	7.2	5	0
4	Big (Newton Co)	9-25	--	--	10	.73	58	.8	2.8		174	0	3.9	5.3	--	5.9	---	172	148	6	---	---	--	5
		6-26	--	--	6.8	.12	46	1.2	.9		131	0	1.0	2.9	--	.0	---	123	119	12	---	---	--	-
		5-33	--	58	6.0	.09	44	2.5	9.5		112	0	14	7.5	--	8.3	---	170	120	8	---	7.5	--	2
		7-64	2.67	58	7.8	.05	57	2.4	8.2		151	0	13	7.3	.1	13	---	202	152	28	322	7.4	--	2
3	Big (Lawrence County)	9-25	8.6	--	9.4	.29	59	6.0	7.2		193	0	7.4	6.6	--	6.1	---	197	172	14	---	---	--	0
		5-53	--	57	5.8	.15	50	3.5	7.8		145	0	7.0	5.5	--	5.5	---	167	140	21	---	7.2	--	-
		8-64	19.5	59	9.8	.00	58	3.8	5.2	.9	172	0	7.4	9.2	.0	9.7	---	188	160	19	318	7.4	0	0
		5-66	23.5	57	11	.02	55	3.0	3.5	.9	157	0	7.6	5.4	.1	12	---	186	150	21	290	7.3	2	-
6	Boy Scout	8-64	.7	58	8.2	.06	65	2.4	5.1		195	0	2.6	4.8	.0	8.9	---	207	172	12	235	7.3	--	-
8	Camp Beaver	8-64	.89	60	--	.05	54	2.8	4.3	1.3	152	0	8.0	7.5	.0	5.4	.00	176	146	22	293	---	6	0
10	Clarkson	9-25	7.9	--	9.4	.22	54	2.9	1.1		171	0	3.5	5.8	--	7.6	---	169	148	8	---	---	--	-
12	Elm	8-64	.3	59	9.2	.00	46	1.2	4.3	.9	132	0	4.8	7.2	.0	6.4	---	149	120	12	245	7.4	0	0
13	Fly	8-64	3.2	60	10	.00	46	2.7	4.0	.9	136	0	6.6	6.6	.0	11	---	155	126	14	256	7.7	5	0
14	Gibson	8-64	.8	60	9.2	.00	50	1.7	4.0	.9	148	0	8.2	5.9	.0	7.9	---	168	132	11	270	7.4	5	0
15	Great Western	7-64	.3	--	8.6	.08	80	2.4	5.4	1.5	194	0	35	7.2	.0	16	---	252	210	50	434	7.9	2	-
16	Haddock	8-64	.8	58	6.7	.06	60	1.8	8.5		176	0	5.2	4.8	.1	8.9	---	198	156	11	310	7.8	--	-
19	Hearrell	8-64	.8	58	9.0	.00	46	4.6	8.2	1.6	136	0	18	8.8	.1	11	---	184	134	22	296	7.5	5	0
21	Kelly	8-64	.9	60	--	.00	63	2.3	4.4	1.1	168	5	7.0	7.4	.0	17	.16	204	167	20	338	---	5	7
24	McMahon	8-64	1.7	65	11	.05	50	.7	3.3	1.0	140	0	6.2	6.6	.0	9.3	---	157	128	13	260	7.8	5	0
26	Morse Park	5-26	--	--	10	.40	58	1.3	8.5		155	7	.0	7.1	--	4.9	---	173	150	12	---	---	--	-
		5-53	--	58	6.2	.10	53	1.5	7.1		151	0	4.8	4.3	--	6.8	---	175	135	11	---	7.8	--	2
		8-64	.3	58	11	.00	72	3.5	5.1	1.8	196	0	24	13	.0	12	---	254	194	33	406	7.7	0	0
28	Ozark Trout Fm.	8-64	1.04	59	9.8	.00	53	1.0	3.3	.9	154	0	4.8	4.1	.0	4.1	---	170	136	10	283	7.3	0	0
		11-65	1.46	60	10	.00	56	1.4	3.8	.6	158	0	4.0	4.3	.0	18	---	178	146	16	292	7.4	0	-
29	Pierce City	7-25	--	--	10	.77	51	1.3	3.9		115	5	10	9.6	--	12	---	160	132	29	---	---	--	0
30	Pioneer	8-64	.20	59	9.8	.01	58	.4	4.6	.7	168	0	2.6	3.1	.0	8.3	---	187	146	8	301	7.5	0	0
31	Polk	8-64	3.57	59	9.6	.00	63	3.2	3.4	.9	172	0	6.4	9.8	.0	16	---	201	170	29	328	7.4	0	0
32	Radar Station	7-64	.3	59	11	.03	77	3.9	6.1	1.4	184	0	60	4.0	.1	6.8	---	261	208	57	433	7.9	4	0
34	Sagamount	9-64	.25	59	--	.02	31	3.8	2.8	1.0	111	0	4.2	3.0	.1	7.1	---	---	---	2	---	---	0	-
35	Saginaw	9-64	.85	--	--	.00	31	3.7	2.8	.8	110	0	5.2	2.9	.1	4.5	---	---	---	2	---	---	1	-
36	Scotland	8-64	2.7	58	6.4	.06	56	3.8	5.2		165	0	10	4.8	.1	9.9	---	189	154	18	310	7.0	--	-
37	Spiva	9-64	.31	--	--	.06	46	2.9	3.5	.7	140	1	8.0	6.2	.1	9.2	---	169	127	11	272	---	1	-
38	Spout	11-64	.02	58	--	.02	59	.9	4.0	.7	167	0	7.4	4.0	.2	13	---	199	151	14	324	---	1	-
39	Spring River	8-64	4.77	62	9.6	.05	67	2.2	4.7	.8	186	0	5.4	10	.0	12	---	214	176	24	338	7.3	0	0
40	Sonnywood	4-64	.55	62	9.6	.09	147	7.3	10	1.5	253	0	196	9.0	.0	1.3	---	520	397	190	741	7.7	5	-
41	Talbert	8-64	.40	58	9.6	.00	48	2.4	4.8	1.0	140	0	1.2	11	.0	11	---	159	130	15	267	7.6	5	0
50	Verona	9-25	--	--	7.2	.75	56	1.3	.0		141	11	2.7	4.0	--	7.9	---	160	146	12	---	---	--	0
		5-53	--	54	5.2	.22	35	2.2	6.9		90	0	8.1	5.3	--	6.6	---	128	96	22	---	7.1	--	10
51	Wallace	8-64	8.77	59	5.0	.09	55	7.1	5.6		171	0	6.7	7.3	.1	11	---	199	166	26	330	7.9	--	-

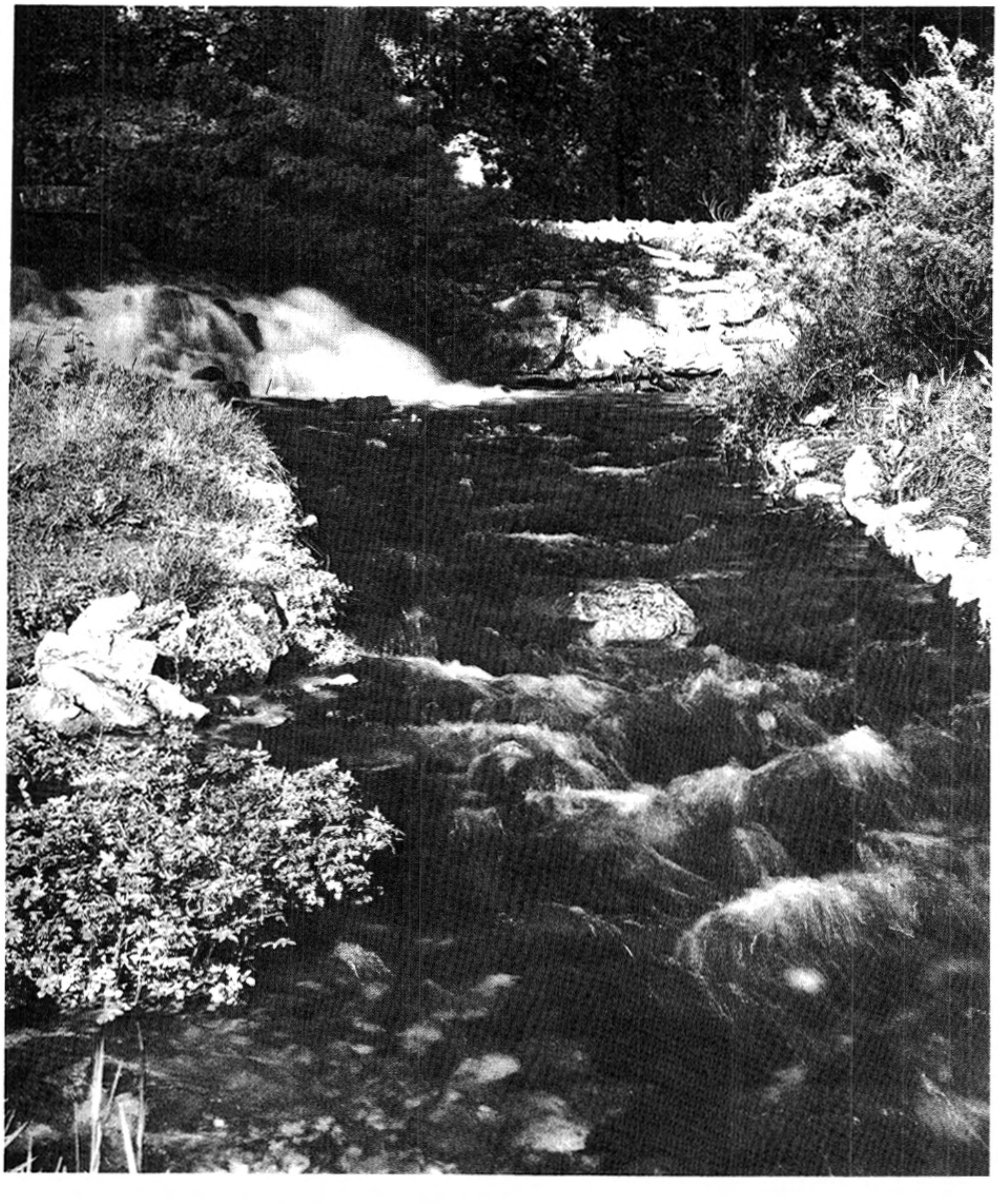


Figure 76

Big Spring at Neosho flows through a well-maintained city park. Part of the flow is also used by a local creamery. Photo by Gerald Massie, Division of Commerce and Industrial Development.

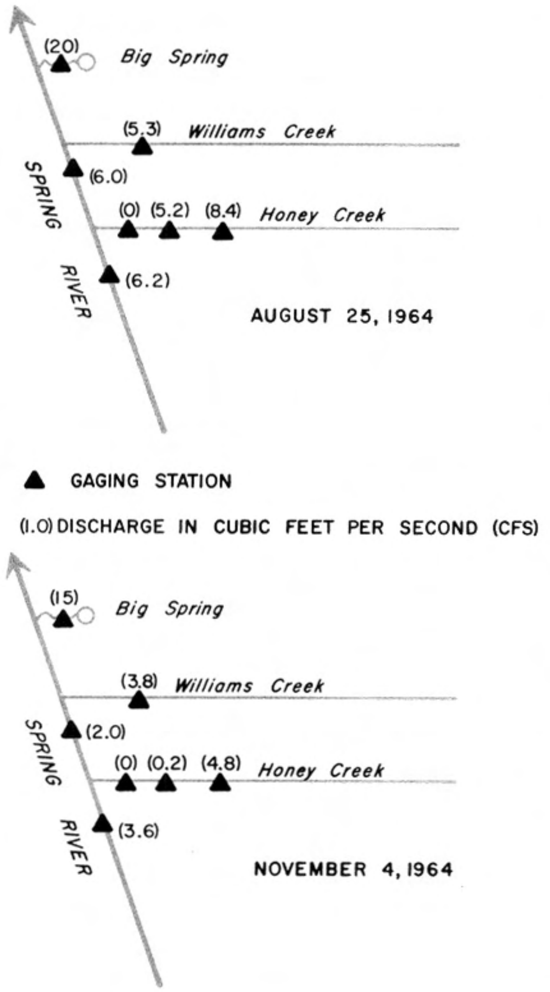


Figure 77

Sketch showing water loss from Honey Creek and Spring River upstream from Big Spring.

CAVE SPRING, *Newton County, Pierce City 7½-minute quadrangle, NW¼ NW¼ sec. 12, T. 25 N., R. 29 W.*

Most of the flow of Capps Creek is derived from a group of four springs, Cave, Hawkins (two), and Wallace Springs about 2 miles above its confluence with Shoal Creek. Cave Spring flows from a bedding plane enlarged by solution at the base of a bluff of Mississippian limestone. The two Hawkins Springs and Wallace Spring rise nearby in a field in the adjoining lowland. Total flow of the four springs in August 1964 was 15 cfs or 9.7 mgd. Capps Creek is stocked with fish and is open to the public for fishing. In 1837 Jolly Mill and a dam were built about ½ mile below the springs; the mill was still grinding grain as recently as 1959. The scenery of the area is enhanced by the mill, dam, creek, and springs. Water from these springs is principally used for watering stock.

CLARKSON SPRING, *Lawrence County, Sarcoxie 7½-minute quadrangle, SE¼ SE¼ sec. 17, T. 27 N., R. 28 W.*

Clarkson Spring is in the headwaters of Center Creek and marks the beginning of perennial flow in the creek. The spring issues from a large, gravel-filled basin walled in at the base of a low bluff of Mississippian limestone and enters Center Creek through a spring branch filled with water cress and other plants. The spring can be reached by road and is used by inhabitants of the area for a picnic site. Water is hauled from the spring by tank truck for construction and other purposes. During the drought of the 1950's considerable water was hauled from the spring for watering stock.

ELM SPRING, *Newton County, Neosho East 7½-minute quadrangle, SE¼ SE¼ sec. 12, T. 24 N., R. 32 W.*

Refer to Bartholic Spring.

HAWKINS SPRING NOS. 1 AND 2, *Barry County, Pierce City 7½-minute quadrangle, NW¼ sec. 12, T. 25 N., R. 29 W.*

Refer to Cave Spring.

HEARRELL SPRING, *Newton County, Neosho East 7½-minute quadrangle, NW¼ NE¼ sec. 30, T. 25 N., R. 31 W.*

Refer to Bartholic Spring.

MCMAHON SPRING, *Newton County, Neosho East 7½-minute quadrangle, NW¼ SE¼ sec. 28, T. 25 N., R. 31 W.*

Refer to Bartholic Spring.

OZARK TROUT FARM SPRING, *Newton County, Tipton Ford 7½-minute quadrangle, SW¼ NW¼ sec. 28, T. 26 N., R. 32 W.*

The spring is on a valley terrace where it flows from an opening within a springhouse. Because the spring is ponded by a low embankment, its orifice cannot be seen. The spring flows about 6/10 mile through a spring branch lined with water cress to Cedar Creek. The trout farm, a commercial enterprise, raises fish for fishermen and for sale to restaurants.

POLK SPRING, *Lawrence County, Chesapeake 7½-minute quadrangle, NE¼ NW¼ sec. 22, T. 27 N., R. 25 W.*

The flow of Polk Spring forms the beginning of perennial flow in Honey Creek and the spring is one of the three largest in the Spring River basin. The orifice of the spring is a bedding plane enlarged by solution at the base of a low ledge of flat-lying Mississippian limestone. The spring branch flows through pastures where it is used for watering stock. It is on private land and unimproved. An abundance of water cress and other plant growth line the spring branch.

SCOTLAND SPRING, *Jasper County, Joplin East 7½-minute quadrangle, NW¼ SW¼ sec. 1, T. 27 N., R. 32 W.*

Scotland Spring forms the beginning of perennial flow in Grove Creek, an important tributary in the lower reaches of Center Creek. The spring opening is a bedding plane in Mississippian limestone at the foot of a 50-foot bluff. The spring is enclosed by a large springhouse and the water is pumped to manufacturing plants on the bank of Grove Creek. None of the water leaves the area unused as it serves as an industrial water supply and the excess helps in diluting plant wastes. The spring is privately owned.

RADIUM SPRING, *Barry County, Cassville 15-minute quadrangle, SW¼ SE¼ NW¼ sec. 23, T. 21 N., R. 27 W.*

Radium Spring has attained a considerable notoriety over the years because of the presence of sufficient radioactivity to register on Geiger counters. On the basis of these indications of natural radioactivity, several attempts have been made either to utilize supposed therapeutic effects of the water, or to mine the minerals producing the radioactivity.

The source of the radioactivity is thought to be from the Noel (Chattanooga) shale which forms the stratigraphic base level for Radium Spring. The source of the spring includes joints, bedding planes, and fractures in the St. Joe Limestone. The spring flows from a hillside, at the contact between the St. Joe Limestone and the underlying black shale. It is not unusual for black shales to exhibit minor radioactivity. On numerous occasions it has been necessary for the State Geologist to discount rumors of mineable quantities of radioactive minerals in the vicinity of Radium Spring.

SPRING RIVER SPRING, *Lawrence County, Verona 7½-minute quadrangle, NW¼ NW¼ sec. 28, T. 26 N., R. 26 W.*

This spring, known as "Head of Spring River", consists of three springs, the largest of which rises in a pool near the base of a bluff of Mississippian limestone. Two smaller springs lie just to the east of it. The flow from all of the springs supplies water to a privately-owned fish hatchery. Since 1950 the hatchery has been a commercial enterprise from which fish are sent out for stocking other private fishing sites and for sale to restaurants. Fee fishing is allowed in the spring pool. It is reported that a nearby spring on the same property flows intermittently, but only after a heavy rain when its flow far exceeds that of Spring River Spring. Although the flow of Spring River Spring increases in wet weather it does not equal the flow of the ephemeral spring nearby.

WALLACE SPRING, *Barry County, Pierce City 7½-minute quadrangle, SE¼ NW¼ sec. 12, T. 25 N., R. 29 W.*

Refer to Cave Spring.

WHITE RIVER BASIN

BASIN DESCRIPTION

The White River basin lies in southwestern Missouri and borders the state of Arkansas. The Eureka Springs escarpment crosses the basin in a southwesterly direction and marks the boundary between the Mississippian and Devonian limestone and shale in the northwestern part and the Ordovician dolomite in the southeast. The escarpment is a steep, east-facing slope that separates the rolling hills of the southern Ozarks from the gently rolling surface of the Springfield Plateau. Along the escarpment some of the ruggedest, most scenic countryside in Missouri makes the White River basin a colorful area.

The southern part of the basin has several large reservoirs. Important among these are Bull Shoals and Table Rock Reservoirs and Lake Taneycomo, all on the White River. There are many springs in the northwestern part of the basin, few in the southern part. Probably many existed in the valleys which are now filled by lakes. Undoubtedly there are many small springs in the southern part that have not been measured but few are shown on topographic maps of the area.

Shepard (1898, p. 225) described Springfield, which is surrounded by springs, as *"the seat of a large and prosperous Indian village long before the appearance of white men in this region."*

Springs are especially common on the Springfield Plateau where the limestone has been dissolved along fractures and water can sink readily below the surface to reappear in springs and seeps. The northern part of the basin is pockmarked by hundreds of sinkholes through which rainfall gains entrance to the cavernous system below the ground. The storage of water in the caverns and small openings serves as a reservoir that maintains the dry-weather flow of streams draining the area, flow which is the accumulation of many springs and seeps.

Dry-weather flows of springs in the White River basin are higher than those in the Shoal Creek basin. Of the 16 springs in the White River basin with maximum discharges more than 1 cfs, and measured more than one time, 10 springs had minimum discharges greater than 1 cfs. In the Shoal Creek basin 25 springs had maximum discharges of more than 1 cfs. Two things may account for this difference – mean annual precipitation decreases to the west so that less water is available for storage to maintain the flow of the springs, and the Spring, Center, and Shoal Creek basins are nearer the Pennsylvanian outcrop and perhaps underground storage is not as well developed. Table 23 gives discharges for springs in the White River basin. Locations of measured springs are shown in figure 78.

QUALITY OF WATER

Springs in the White River basin yield moderately mineralized water of calcium bicarbonate or calcium magnesium bicarbonate type depending on whether

Table 23

DISCHARGES OF SPRINGS IN THE WHITE RIVER BASIN

[A = less than 0.01 cfs]

Location No. (fig. 78)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
1	Beaver Creek	Forsyth	Taney	SESE 15,23,19W	0.10	65	58	11-7-63	
					.22	142	59	8- -64	
2	Bell	Marshfield	Webster	NWNE 4,29,18W	.03	19	54	1-14-66	
3	Blue	Nixa	Christian	NENE 32,28,22W	3.33	2,150	-	10-23-28	
					2.00	1,290	57	10-20-32	
					1.60	1,030	-	7-7-53	
					1.57	1,010	58	10-30-63	
					2.30	1,490	58	8-27-64	
4	Boiling	Rome	Douglas	SENW 5,25,17W	.03	19	-	5-5-48	
					.17	110	59	8- -64	
5	Brown	Hurley	Stone	SENW 12,26,24W	11.0	7,110	-	5-8-31	
					5.12	3,310	59	8-31-64	
					8.94	5,780	51	12-1-64	
6	Camp Cora	Nixa	Greene	NESE 30,28,21W	1.08	698	57	8-30-55	
					.80	517	59	10-29-63	
					2.05	1,320	58	8-28-64	
7	Crystal	Cassville	Barry	NWSW 21,23,27W	11.0	7,110	58	12-11-42	Fish hatchery
					1.68	1,090	49	12-3-64	
8	Danforth No. 1	Stafford	Greene	SWSW 5,29,20W	.37	239	60	10-29-64	Stock
					.69	446	58	12-1-64	Milk cooler
9	Danforth No. 2	Stafford	Greene	SWSW 5,29,20W	.72	465	57	10-29-64	Stock
					.89	575	57	12-1-64	
10	Hunt	Springfield	Greene	SWNW 24,28,21W	.19	123	57	9-22-64	
11	Indian	Battlefield	Greene	SESE 29,28,22W	.20	129	58	9-22-64	
12	Jackson Mill	Ava	Douglas	SESW 35,26,17W	2.39	1,540	-	12-22-43	
					2.24	1,450	58	8-29-64	
					2.38	1,540	56	12-8-64	
13	Jones	Springfield	Greene	SWNE 27,29,21W					
	(Average of 10 measurements)				2.50	1,620	-	1925-1965	
	(Maximum discharge measured)				12.0	7,750	56	4-6-65	
	(Minimum discharge measured)				1.20	775	57	10-4-65	
14	McMurtry	Cassville	Barry	SWNW 6,22,27W	.12	78		10-31-63	
					.44	284	-	8-31-64	
15	Monroe	Springfield	Greene	NWNE 27,29,21W	.71	459	59	8-27-64	
16	Montague	Highlandville	Christian	NESE 27,26,22W	2.81	1,820	56	5-14-41	
					2.71	1,750	54	11-30-64	

Table 23 *(continued)*

Location No. (fig. 78)	Spring	Nearest Town	County	Land Line Location	Rate of Flow		T °F.	Date	Remarks
					Sec. Ft. (cfs)	1000 gal. day			
17	Mountaindale	Seymour	Webster	NESE 23,29,17W	5.46	3,530	55	1-14-66	Stock
					.82	530	56	2-2-66	
					2.49	1,610	55	5-10-66	
18	Mount Sinai	Clever	Christian	NESE 24,27,23W	.44	284	56	6-8-66	
19	Ollie Lasley	Rogersville	Christian	SESE 31,28,19W	1.80	1,160	55	5-10-66	Stock
20	Pruitt	Republic	Greene	NESE 27,28,23W	.15	97	59	9-21-64	
21	Rader	Springfield	Greene	SENW 18,28,22W	16.3	10,500	74	8-4-64	
					15.3	988	64	10-20-64	
					10.5	6,780	54	12-1-64	
					13.4	8,660	49	1-20-65	
					36.3	23,400	-	4-28-65	
22	Reeds	Reeds Spring	Stone	NWSW 25,24,23W					
	(Average of 11 measurements)				.30	194	-	1943-1966	
	(Maximum discharge measured)				.45	291	59	6-9-65	
	(Minimum discharge measured)				.10	65	57	11-7-64	
23	Roaring River	Cassville	Barry	SENE 27,20,27W					
	(Average of 26 measurements)				31.6	20,400	-	1923-1966	
	(Maximum discharge measured)				177	114,000	60	4-6-65	
	(Minimum discharge measured)				8.04	5,190	58	10-31-63	
24	Rock	Ocie	Taney	SESW 24,23,17W	.10	65	59	6-7-66	
25	Roundtree	Springfield	Greene	NWSW 8,28,22W	.13	84	58	8-27-64	
					.09	58	59	9-22-64	
26	Rumfelt	Seymour	Webster	SWSW 23,29,17W	1.67	1,080	53	1-14-66	Stock
27	Sequiota	Springfield	Greene	NENW 9,28,21W	17.1	11,000	-	9-28-36	City park
					7.70	4,970	58	11-12-42	
					.99	640	56	12-4-63	
					2.47	1,600	64	8-27-64	
					2.00	1,290	53	11-30-64	
28	Sherrod	Springfield	Greene	SESE 33,29,22W	.34	220	-	11-23-56	
					.32	207	-	12-13-56	
					.23	149	-	9-29-60	
					.46	297	61	8-27-64	
29	Spout	Nixa	Christian	NESW 18,27,21W	A	A	-	10-30-63	
					.28	181	59	8-28-64	
30	Stutzman	Springfield	Greene	NWSE 25,28,22W	.10	65	56	12-1-64	Stock
31	Tawsemtha	Springfield	Greene	NENW 13,29,21W	.05	32	58	10-29-64	
32	Todd	Fordland	Christian	NWSW 33,28,18W	3.14	2,030	55	5-10-66	Stock
33	Unnamed	Branson	Taney	NWSW 34,24,22W	A	A	57	6-8-66	
34	Unnamed	Springfield	Greene	SESE 14,29,20W	.01	6	-	10-29-64	
35	Unnamed	Ozark	Christian	SWSE 26,26,21W	.20	129	59	6-8-66	
36	Ward	Springfield	Greene	SESE 14,28,22W	1.73	1,120	59	9-22-64	Stock
					1.02	659	58	12-1-64	
37	Wasson	Nixa	Christian	SWNE 25,27,22W	.17	1,100	58	10-30-63	Domestic
					.08	52	59	8-28-64	
38	Welch	Springfield	Greene	SWNW 14,28,22W	.18	116	62	9-22-64	Domestic
39	Winoka	Galloway	Greene	NWNW 22,28,21W	.23	149	55	10-20-32	Private lodge water supply
					3.24	2,090	-	3-7-37	
					6.00	3,880	-	12-14-54	
					.24	155	57	10-29-63	
					.42	271	53	11-30-64	
40	Young	Nixa	Christian	NESE 20,27,22W	.11	71	57	10-30-63	
					.37	239	58	8-27-64	

the spring drains limestone or dolomite. One spring, Roaring River, has its outlet in the Cotter Dolomite but the chemical analyses indicate that the water is recharged in the Mississippian limestone area to the west. The dissolved-solids content of spring water in the basin ranges from 124 to 422 mg/l (table 24), with the maximum value occurring in a spring whose discharge is largely sewage effluent. Iron content of spring water in the basin ranges from 0.00 to 1.0 mg/l, but most of the springs contain less than 0.10 mg/l, and only three of the samples analyzed contained more than 0.3 mg/l. Hardness of the water ranges from 92 to 278 mg/l with three springs classified as moderately hard, seven springs classified as hard, and 14 springs classed as very hard (see table 23). Nitrate content of the water ranges from 0.00 to 81 mg/l. Of the 24 springs sampled, water from 14 of them contained more than

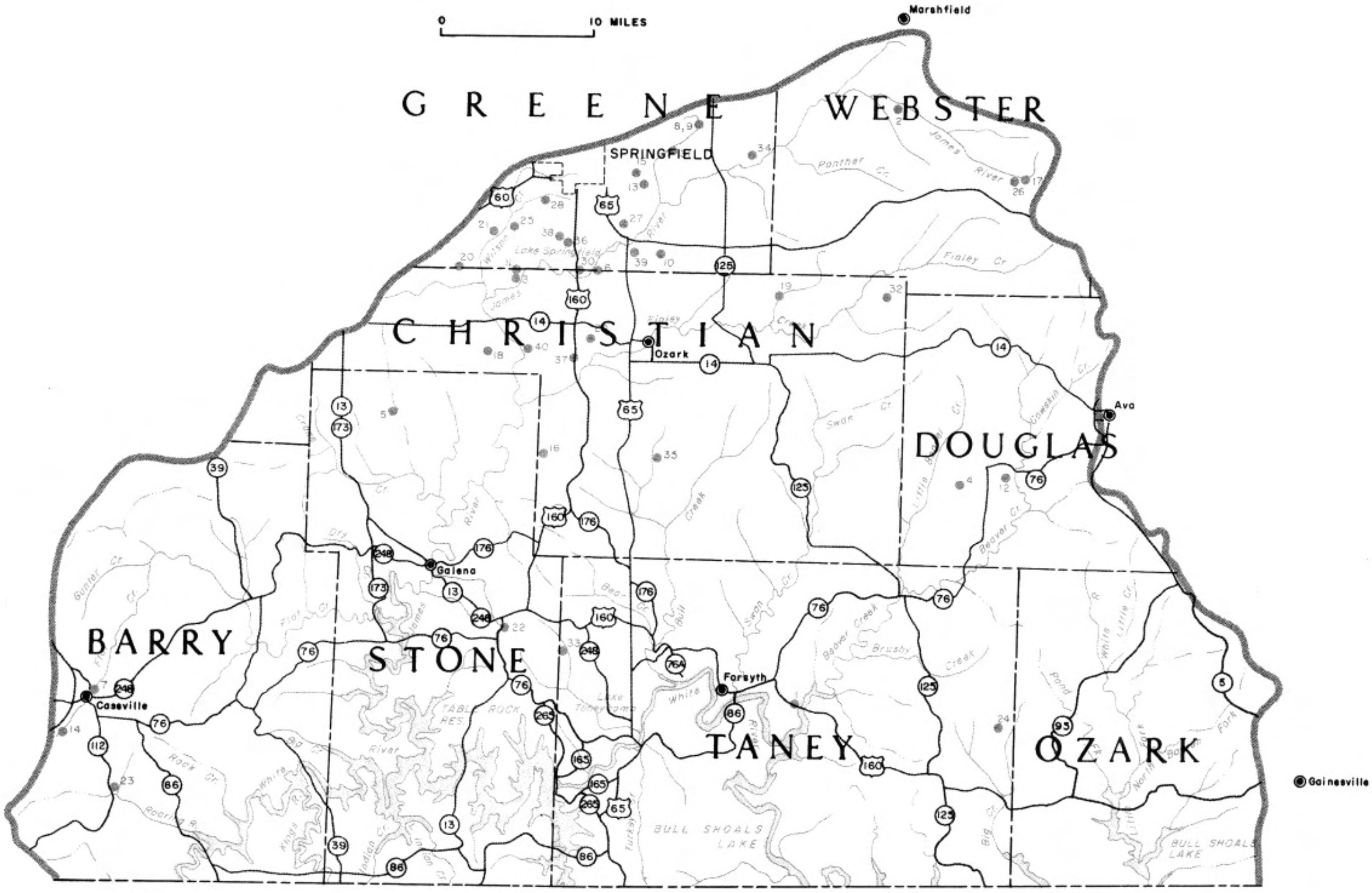


Figure 78

Springs in the White River basin.

Table 24

CHEMICAL ANALYSES OF WATER FROM SPRINGS IN THE WHITE RIVER BASIN

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (Fig. 78)	Spring	Date of Collection	Rate of Flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)	Hardness as $CaCO_3$ Calcium Magnesium	Hardness as $CaCO_3$ Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
3	Blue	8-64	2.30	58	12	0.00	84	1.9	3.3	.8	244	0	2.4	4.9	0.1	17	.00	257	218	18	428	7.8	2	1
4	Boiling	8-64	.17	59	--	.06	48	26	2.6	1.6	235	13	4.8	5.1	.1	5.3	.22	238	227	13	414	8.6	5	2
5	Brown	8-64	5.12	59	--	.00	68	3.8	3.4	1.4	189	4	3.4	5.1	.1	19	.03	218	185	24	366	8.3	2	1
8	Danforth No.1	12-64	.69	57	--	.00	65	5.9	7.1	1.5	210	0	11	7.3	.1	15	.00	227	186	14	404	8.1	2	0
9	Danforth No.2	12-64	.89	58	--	.00	60	6.5	4.6	.7	201	0	6.6	6.8	.0	12	.00	207	176	12	369	8.0	3	0
13	Jones	8-25	1.23	--	9.6	1.0	86	3.5	15		242	0	10	15	--	10	--	269	228	29	---	---	--	0
		11-52	---	57	7.4	.04	91	3.5	16		240	0	---	21	3.2	21	--	312	243	45	---	7.7	--	5
		8-64	1.60	58	--	.01	98	3.0	8.9	2.8	218	0	37	18	4.3	30	--	336	257	78	550	7.2	0	1
14	McMurtry	8-64	.44	59	13	.01	39	.9	1.9	1.5	106	2	2.6	3.7	.0	16	.06	133	101	10	217	8.3	7	10
17	Mountaindale	1-66	5.46	55	10	.01	53	2.2	3.9	.5	159	0	4.6	6.5	.1	8.2	--	171	141	10	298	7.4	3	-
18	Mount Sinai	6-66	.44	56	12	.06	73	4.5	2.3	.8	214	0	6.6	2.9	.1	23	--	235	201	25	396	7.5	7	-
21	Rader	10-64	15.3	64	12	.24	58	9.7	63	9.8	140	0	32	66	.6	81	16	422	185	70	710	7.3	22	28
22	Reeds	9-25	---	--	6.4	.31	63	3.1	4.4		197	0	2.2	4.4	--	1.9	--	183	171	9	---	---	--	25
		11-52	---	58	8.0	.03	63	4.3	8.6		196	0	4.0	10	.2	6.3	--	205	175	15	---	7.5	--	1
		8-64	.30	59	--	.06	63	3.8	5.0	3.6	162	8	9.2	12	.2	16	.22	217	173	26	362	8.5	1	1
23	Roaring River	9-25	---	--	6.4	.91	58	4.0	3.3		186	0	2.1	4.4	--	3.4	--	174	162	9	---	---	--	0
		7-64	22.6	59	6.6	.12	52	2.9	5.0		152	0	4.5	4.5	.0	6.7	--	167	141	16	---	7.1	--	-
		11-65	12.2	58	10	.00	60	2.4	3.0	.7	184	0	3.4	4.0	.0	8.0	--	186	160	8	317	7.6	0	-
		5-66	43.1	57	9.9	.03	54	1.2	2.0	.9	158	0	4.4	1.9	.1	5.8	--	166	140	10	275	7.5	4	-
24	Rock	6-66	.10	59	8.5	.02	52	36	.7	1.0	334	0	8.6	1.0	.1	.0	--	276	278	4	501	7.7	0	-
26	Rumfelt	1-66	1.67	53	9.5	.01	36	3.0	3.0	.5	114	0	4.4	2.5	.1	8.9	--	124	103	9	218	7.3	6	-
27	Sequiota	8-64	2.47	--	7.4	.03	67	3.8	10	1.9	200	0	14	14	.2	7.0	.00	226	183	18	409	7.6	2	1
30	Stutzman	12-64	.10	56	11	.00	77	1.6	2.6	.7	216	0	3.6	4.0	.0	29	.01	247	199	22	405	7.9	2	0
32	Todd	5-66	3.14	55	8.9	.07	35	12	1.9	1.2	160	0	4.6	2.9	.2	2.4	--	161	137	6	265	7.4	1	-
33	Unnamed	6-66	A	57	11	.17	34	2.8	1.9	1.2	106	0	3.8	3.4	.3	7.6	--	134	96	10	205	7.1	15	-
35	Unnamed	6-66	.20	59	11	.04	69	2.8	2.9	1.2	204	0	4.2	8.5	.2	5.2	--	205	184	16	361	7.3	5	-
36	Ward	9-64	1.73	59	9.3	.00	73	2.4	5.1	2.0	207	0	9.2	7.5	.1	21	.05	232	192	22	405	7.8	4	1
39	Winoka	11-64	.42	53	5.2	.20	88	2.1	9.6		237	0	5.7	10	.0	22	--	276	228	33	---	7.4	--	6

10 mg/l of nitrate. Analyses for Reeds Spring and Jones Spring indicate a trend toward an increase in the nitrate content since the first analyses in 1925.

The effect of developments in a metropolitan area is well demonstrated by the level of dissolved solids in spring water. Near Springfield the dissolved-solids content ranges from 205 to 422 mg/l, whereas farther to the south and east, springs have dissolved solids ranging from 124 to 182 mg/l. In all of this area the springs have their source in limestone. In the southeastern part of the basin, ·springs with their source in the Cotter Dolomite, have dissolved-solids contents ranging from 238 to 276 mg/l. This shows that both geology and geographic distribution affect the mineral content of water.

DESCRIPTIONS OF SELECTED SPRINGS

BLUE SPRING, *near Battlefield, Christian County, Nixa 7½-minute quadrangle, NE¼ NE¼ sec. 32, T. 28 N., R. 22 W.*

Blue Spring rises from a small basin formed by enlarged joints in the Burlington-Keokuk limestone bedrock. The spring is nearly surrounded by cultivated fields and flows about 300 feet to its junction with the James River. Blue Spring enters the James just above the old Blue Spring bridge, and is covered by backwater when the river floods.

The Nixa 7½-minute topographic quadrangle map shows a loop in the James River channel at Blue Spring (fig. 79). Blue Spring rises approximately at the nose of this loop, only a few hundred feet from the northwest bank of the river, which here is flanked by limestone bluffs. Ordinarily the valley and floodplain of the James River is approximately 1/4 to 3/8 mile wide, but at this point the valley is restricted to a narrow channel on the northwest side of the floodplain. The remainder of the area is a structural terrace at an elevation of approximately 1,100 feet, beneath which the channel of Blue Spring runs.

South and southeast of Blue Spring there is a large area of karst topography pockmarked with many large sinkholes in the soluble limestone bedrock. The region contains several sinking streams, which flow on the surface for some distance only to be swallowed by large sinkholes, to reappear again in a spring or at some point along the James River. One of these sinking streams, Saunders Valley, heads about 2 miles south-southeast of Blue Spring, near Union Chapel, and takes a north-northwesterly course toward Blue Spring. However, ½ mile southeast of Blue Spring, the Saunders Valley stream enters a swallow hole and disappears. Dye tracing has shown that the stream in Saunders Valley passes beneath the structural terrace previously mentioned and reappears in Blue Spring. Though not proven by tracers, the sinking stream that enters Avin Sink, approximately 2 miles east-southeast of Blue Spring, may also contribute to the flow of Blue Spring.

The intermittent stream in Saunders Valley normally sinks into the cherty and fractured bedrock of the stream channel before it reaches the swallow hole; water flows in the surface channel only during periods when there is too much water to be absorbed into the underground channels which intercept the water before it reaches the swallow hole. The stream plunges beneath a low-ceilinged natural bridge and reappears again momentarily in a karst window, which is an elliptical sinkhole approximately 100 feet long, 30 feet wide, and 20 feet deep. The stream then flows northwestward in a low, winding, tube-like cave passage, which becomes increasingly more difficult to negotiate because of deepening water and lowering ceiling. This stream reappears again at a karst window about 200 feet east of the orifice of Blue Spring. This karst window contains water much of the year, but generally it is standing water. After heavy rains, however, water rushes out of the two entrances to the karst window, travels for about 200 feet, then sinks into a small sinkhole that is generally clogged with debris and reappears in Blue Spring. The main channel of Blue Spring appears to be lower than the karst window, so that water is in the karst window only when the discharge is more than can be accomodated in the subsurface spring system. The Blue Spring rise pool is approximately 6 to 8 feet deep, so far as can be determined by probing. Its main supply channel must lie at or below this elevation.

Directly across the James River from Blue Spring, a few feet upstream from the west abutment of Blue Spring bridge, is a small spring ("Anti-Blue" Spring) rising from crevices in the Burlington-Keokuk bedrock. This spring is normally below river stage and no discharge measurements can be made.

BROWN SPRING, *Stone County, Aurora 15-minute quadrangle, SE¼ NW¼ sec. 12, T. 26 N., R. 24 W.*

Brown Spring consists of two principal springs which form the beginning of perennial flow in

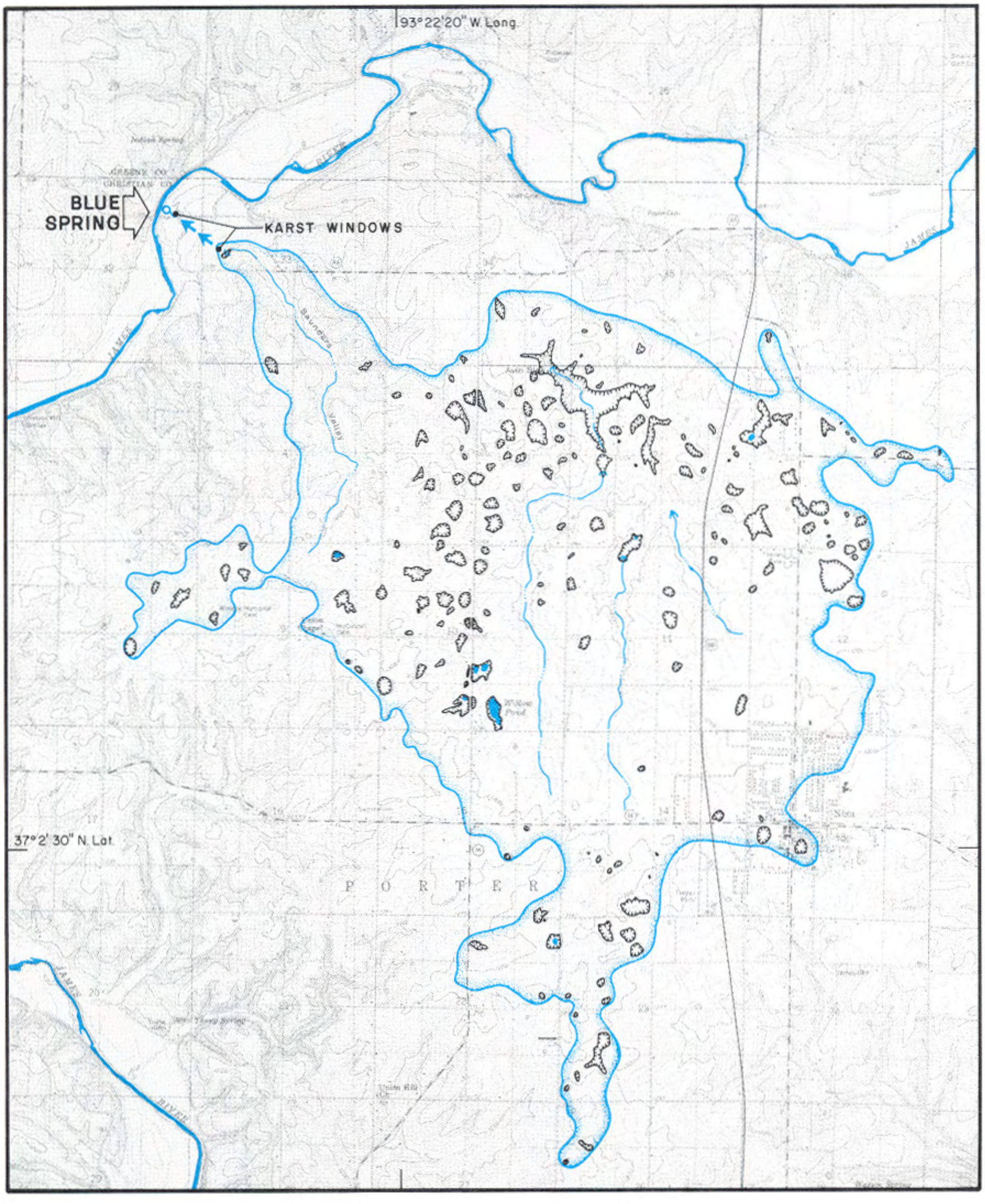


Figure 79

Sinking streams and coalescing sinkhole drainage in the Nixa karst, near Springfield in southwest Missouri. Topography from U.S. Geological Survey, Nixa 7½-minute quadrangle.

Spring Creek, a tributary of the James River. The springs are at the base of a low bluff of weathered and cavernous Burlington-Keokuk limestone. Water flows from bedding-plane openings that are partly hidden by large blocks of limestone slumped from above. The flow of Brown Spring has varied from 3.3 to 7 mgd. Formerly, Brown Spring was a resort and in recent years the springs have been used for rearing trout. The springs are privately owned and are open to the public for fishing. A dam built at Hurley about 1900, 4 miles downstream from Brown Spring, stored the water from these springs and this was the source of power for operation of a mill at the dam.

CRYSTAL SPRING, *Barry County, Cassville 15-minute quadrangle, NW¼ SW¼ sec. 21, T. 23 N., R. 27 W.*

Crystal Spring is on the terrace along Flat Creek just north of Cassville on the Springfield Plateau. Although the spring rises through gravel deposits on the terrace, the source is considered to be the Mississippian limestone below the terrace deposits. The spring has two openings, neither of which can be seen. Embankments surrounding the principal spring form a lake which is used by a commercial fish hatchery. About 50 tons of trout are shipped from the hatchery each year to markets in the eastern half of the country. As the springs do not supply sufficient water for the operation of the hatchery water is pumped from Flat Creek which is only a few hundred feet away.

Only two measurements have been made and these indicate great variation in flow from the spring. The high flow of 7 mgd recorded in December 1942 has not been recorded on subsequent visits. In December 1964, 1 mgd was measured and in October 1966 about the same amount of water was flowing. Probably the very high discharge of 1942 was measured during heavy rains in the recharge area of the spring. Precipitation records are not available for Cassville, but records from other towns in the area indicated a rainy period at the time of the measurement.

JONES SPRING, *Greene County, Ozark SW 7½-minute quadrangle, NE¼ NW¼ sec. 24, T. 28 N., R. 21 W.*

Jones Spring is on private property about 1½ miles east of the Springfield city limits. The spring is in a beautiful setting that has been improved by building small dams along the spring branch. The spring branch is lined with water cress. Outcrops in the vicinity of the spring are in Mississippian cherty limestone (Burlington-Keokuk) and the spring opening is developed along a bedding plane enlarged by solution into a very low cave. The ponds formed by the dams are stocked with trout by the owners.

A limestone wall, still standing near the spring, was built by slaves in 1823 to anchor a flume that directed water into the first grist mill erected west of the Mississippi River *(Springfield News & Leader,* November 3, 1968).

The spring is subject to contamination, and late in 1964 the fish were killed by the application of a chemical in the recharge area west of the spring. About ½ mile west of the spring an area of about 2 square miles is intensely pock-marked by sinkholes. The eastward growth of Springfield is reflected in the increase in nitrate content of the spring. Concentrations of nitrate are as follows:

Date	Amount
August 1929	10 mg/1 NO_3
November 1952	21 mg/NO_3
August 1964	30 mg/NO_3

Other springs in the vicinity of Springfield have abnormally high concentrations of nitrate but Jones Spring is the only one for which historical information is available.

Much of the underground supply system feeding Jones Spring has been outlined by a combination of water tracing using fluorescein dye and speleological methods. About 1 mile northwest of Jones Spring, at the intersection of Cherry Street and Ingram Mill Road, there was a large sinkhole which gave access to Steury Cave (fig. 80). Exploration and mapping of this cave showed a passage extending generally southeast-northwest, both upstream and downstream from the sinkhole entrance. Fluorescein dye placed in the underground stream flowing through the cave system was detected in Jones Spring and also in Bonebreak Spring, approximately ¼ mile north of Jones Spring. Exploration of the cave passage upstream from the sinkhole entrance led investigators to an area beneath some large sinkholes near the residential section between Mill Street and Cherry Street.

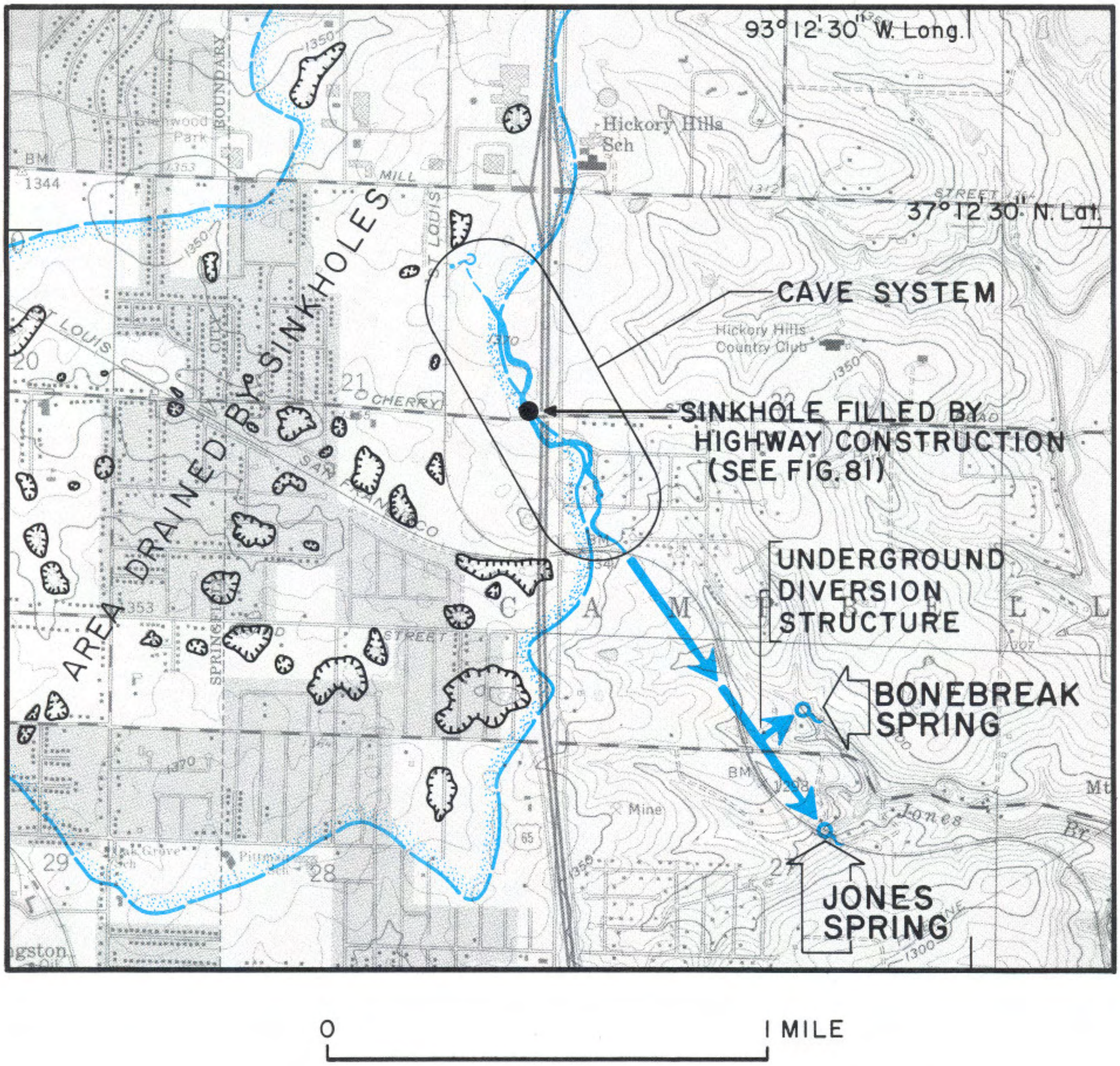


Figure 80

Hydrologic relationships between Jones Spring, Bonebreak Spring, Steury Cave, and U.S. Highway 65 bypass. Arrows indicate inferred subterranean course of the spring feeder channel. After Hayes & Vineyard, 1969, p. 38. Topography from U.S. Geological Survey, Galloway 7½-minute quadrangle.

The Missouri State Highway Department, during construction of the new bypass Highway 65 which generally followed Ingram Mill Road, found it desirable to fill the Steury Cave sinkhole entrance. Upon recommendation from the Missouri Geological Survey, the sinkhole was filled in such a manner as to preserve the drainage characteristics of the sinkhole and to permit underground water to flow past the sinkhole without being dammed by sinkhole fill material (fig. 81). In this manner, the supply system

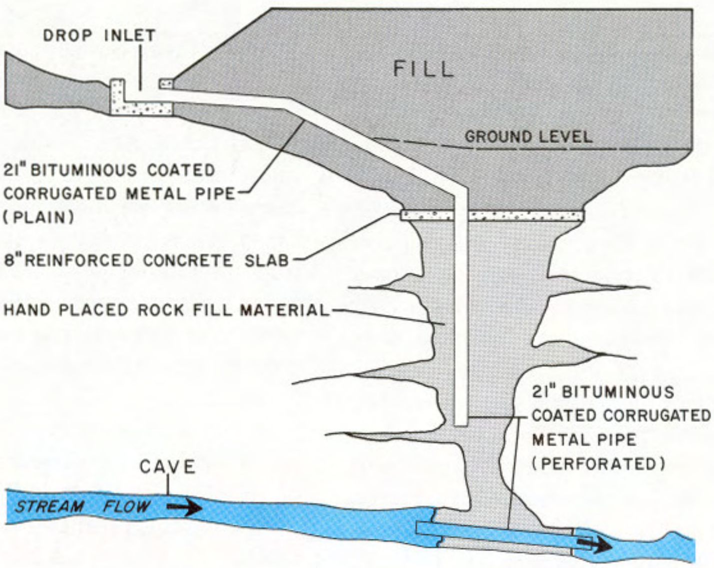


Figure 81

Cross section through the sinkhole entrance to Steury Cave, showing method of filling to preserve underground drainage to Jones and Bonebreak Springs. Adapted from Hayes & Vineyard, 1969, p. 39.

feeding Jones Spring was allowed to continue functioning without interruption (Vineyard, 1968; Hayes & Vineyard, 1969).

In analyzing why the water from Steury Cave should reappear at both Jones Spring and Bonebreak Spring, it was learned that a small sinkhole cave occupied a strategic position for intercepting the flow of Jones Spring and diverting it to Bonebreak Spring. Upon investigation of the cave, it was found that in years past the landowner had constructed a concrete dam underground in the small cave and it was this dam that diverted part of the underground flow from Jones Spring to Bonebreak Spring. This artificial diversion of underground water apparently has had no undesirable effect on either spring, and there is now water enough for both. Bonebreak Spring water now helps to maintain a full pool in a small reservoir formed by damming the ravine downstream from the spring, which flows from a small cave.

MONTAGUE SPRING, *Christian County, Highlandville 7½-minute quadrangle, NE¼ SE¼ sec. 27, T. 26 N., R. 22 W.*

Montague Spring is on the Springfield Plateau near the contact between the Ordovician dolomite and Mississippian limestone. Although the spring is not large, the yield is quite uniform and suitable for raising trout. About 15 tons of trout are raised here annually. The spring is operated as the Ozark Mountain Trout Ranch and is open to the public for fee fishing in one of the lakes formed by the spring.

MOUNTAINDALE SPRING, *Webster County, Fordland 15-minute quadrangle, NE¼ SE¼ sec. 23, T. 29 N., R. 17 W.*

Mountaindale Spring is at an altitude of 1,520 feet above sea level, one of the highest springs in Missouri to have substantial perennial flow. The spring emerges from a low bluff of limestone and flows into a small, walled-in basin. The water forms a spring branch, which is lined with water cress, and enters Finley Creek about 200 yards from the spring. The flow of the spring varies greatly, ranging from ½ to more than 3½ mgd. There are numerous springs in the vicinity of Mountaindale Spring and together they serve as water supplies for cattle. They also help to make the headwater area of Finley Creek very attractive.

RADER SPRING, *Greene County, Brookline 7½-minute quadrangle, SE¼ NW¼ sec. 18, T. 28 N., R. 22 W.*

Rader Spring is on the west bank of Wilson Creek about 5 miles south-southwest of Springfield. The spring issues from a series of openings along

enlarged joints in the Burlington-Keokuk limestone. A pool has developed along the base of a low bluff and the spring branch empties into Wilson Creek a short distance from the spring.

The discharge of Rader Spring ranks third among the springs on the Springfield Plateau and second among those in the White River basin. A description of the spring and its relation to Wilson Creek and karst features of the area is given in a paper by Harvey and Skelton (1968). However, at that time only about one-half the flow of the spring was natural because the discharge of the spring was augmented by treated sewage effluent from the Springfield Southwest Treatment Plant. Subsequent improvements eliminated the effluent loss problem, with a corresponding decrease in the flow of Rader Spring and an improvement in the quality of its water.

Recent hydrologic investigations, including those of Harvey and Skelton (1968), Vineyard and others (1969), and Vineyard (1970), have revealed a remarkable underground drainage system in the Wilson Creek valley south and west of Springfield. Rader Spring is the master resurgence for an extensive area drained by sinkholes. Water tracing by Harvey and Skelton (1968) showed that, prior to the construction of a tertiary treatment lagoon below the Springfield Southwest Treatment Plant, effluent from the plant was lost into a losing reach of Wilson Creek and reappeared in Rader Spring. Results of further dye tracing by Vineyard (1969, p. 25) showed that Rader Spring also receives increments of flow from several other sources on the limestone plateau in the vicinity of Springfield. The results of the several water tracing experiments by various investigators are shown on figure 82.

The City of Springfield occupies an upland region underlain by the Burlington-Keokuk limestone and drained primarily by Wilson Creek and its major tributaries. As shown on figure 82, sinkhole drainage passes through a shallow groundwater system and resurges at Rader Spring. One large sinkhole (Subdivision Sinkhole) drains an area of approximately 200 acres. Storm water drainage is readily accepted by this sinkhole, although occasionally after heavy precipitation it fills with water and floods the surrounding residential area. Fluorescein dye injected into the sinkhole following approximately 2 inches of rainfall during the preceding 24 hours reappeared in Rader Spring – about 5 miles away – within 72 hours.

South Creek is a permanent stream until it begins to lose water in sinkholes in the streambed about a quarter mile above the point where it empties into Wilson Creek. The position of these swallow holes varies from time to time as small subterranean channelways are filled and others are opened by changing conditions imposed by floods on the stream. However, South Creek discharges into Wilson Creek as a surface stream only in times of plentiful rainfall; at other times, the water is pirated underground into channelways that resurge in Rader Spring.

About 4 miles north of Rader Spring is Pfaff Cave, which has a sinkhole entrance about 500 feet east of Wilson Creek. A stream flows through the cave at a level about 25 feet below the bed of nearby Wilson Creek. This stream has been traced to Rader Spring. Fluorescein dye required approximately 39 hours to cover the 4 miles between Pfaff Cave and Rader Spring. This test was conducted during a time of high flow through the system, and during low flow periods the travel time would be expected to be somewhat less.

Harvey and Skelton (1968) recorded a travel time of approximately 5½ hours for treated sewage effluent to travel between the Springfield Southwest Treatment Plant and Rader Spring, a distance of 1.35 miles.

Though water tracing experiments have not yet confirmed the suggestion, it is probable that Rader Spring also receives increments of flow from the extensive sinkhole topography lying west of Wilson Creek and north-northwest of Rader Spring. Sinking streams and sizable caves are known to exist in this area (Thomson, 1970).

Perhaps the most unusual characteristics of Rader Spring and its supply system are the reversible sinkholes or estavellas that occur in the Wilson Creek valley. These curious karst features accept water in drier seasons and discharge water as springs during rainy seasons. They are probably much more common than would be suggested by references to them in literature.

Rader Spring rises along a prominent joint in the Burlington-Keokuk limestone, aligned approximately N. 30° E. About a quarter mile away, in direct line with the joint forming Rader Spring, there is a reversible sink called Rader Resurgence-Sink. This small sinkhole is connected with nearby Wilson Creek through a small channel. During periods of

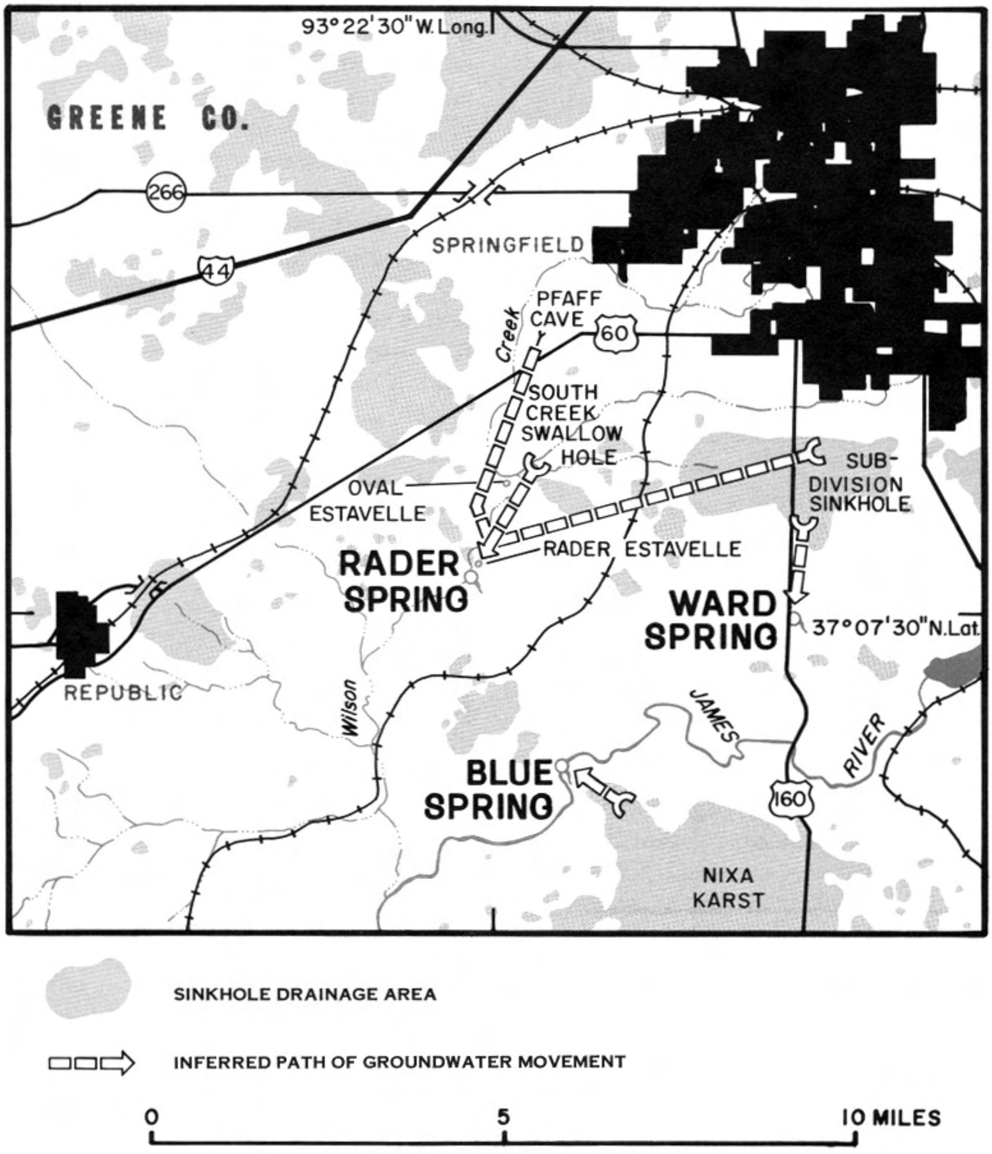


Figure 82

Sinkhole drainage map of Wilson Creek showing Rader Spring recharge area, as defined by water tracing. After Vineyard, 1969 and 1970.

normal flow on Wilson Creek, water flows from the creek down the channel and into Rader Resurgence-Sink, generally forming a small whirlpool. However, during rises on Wilson Creek the flow is reversed, a boil forms in Rader Resurgence-Sink, and water is discharged into Wilson Creek. Similar situations exist with regard to other reversible sinkholes farther upstream. There are two such features in the vicinity of the new tertiary treatment lagoon at the Springfield Southwest Treatment Plant. The most spectacular of these is at the toe of the north dike enclosing the lagoon. This feature is called the Oval Sink, shown in figure 83. Oval Sink, being farther upstream, seldom reverses its flow, but when it does so it produces a sizeable spring that discharges into nearby Wilson Creek. At times of low flow, standing water is always observed in the Oval Sink at about the same level as water in Wilson Creek. That the creek and

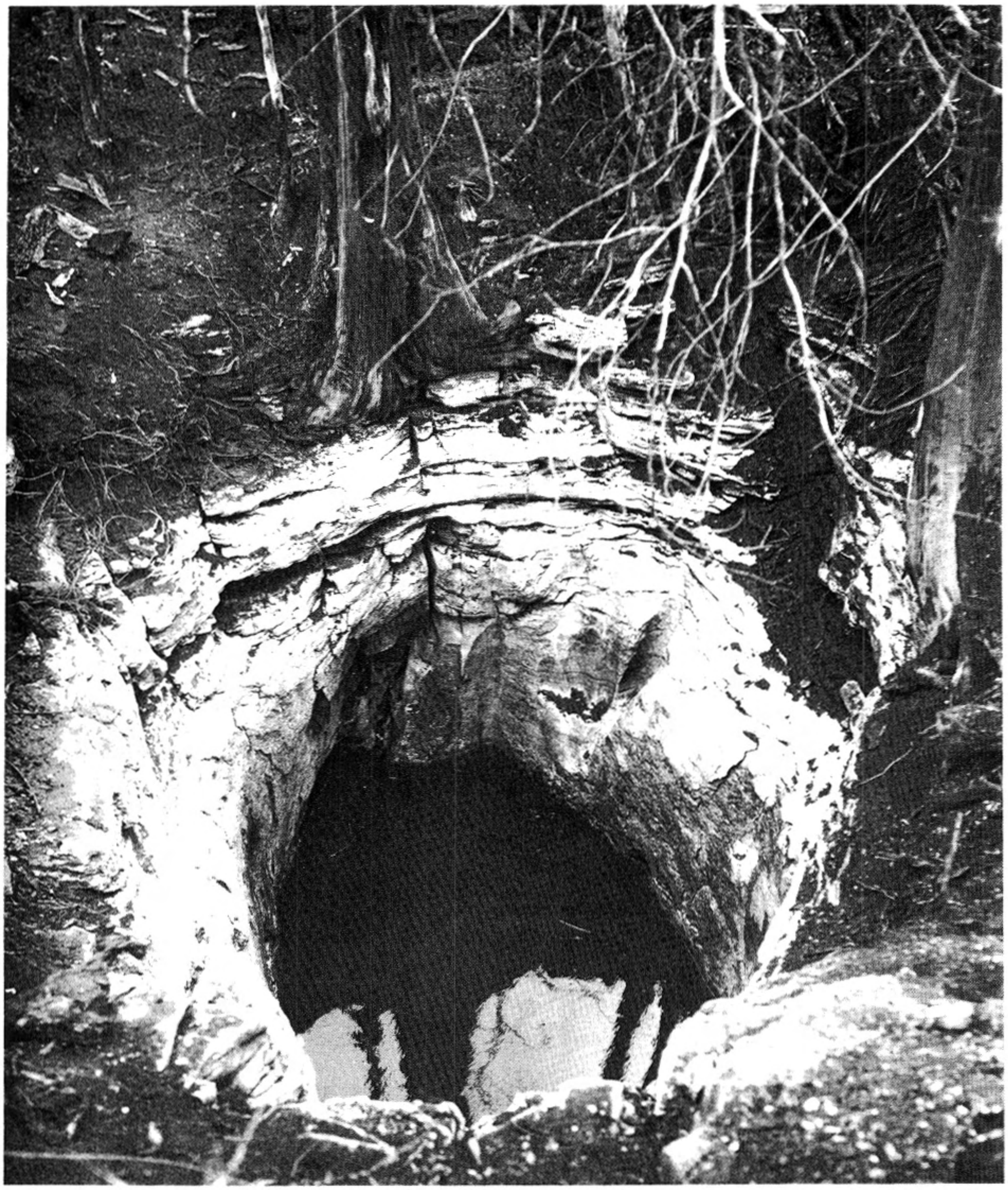
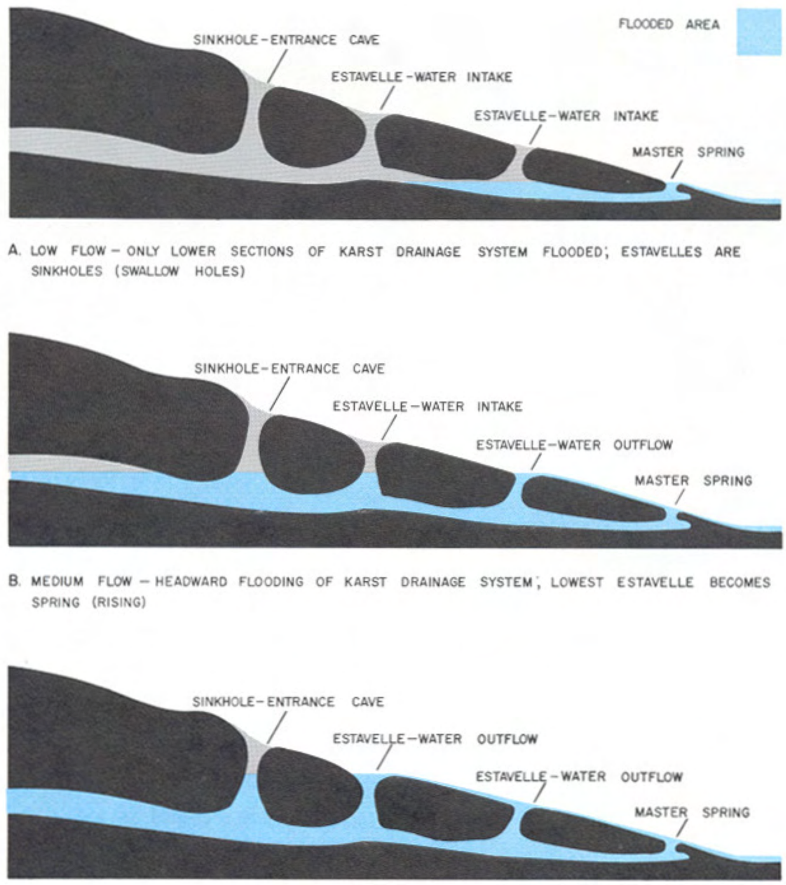


Figure 83

The Oval Sink, a reversible sinkhole (estavelle) near the tertiary treatment lagoon at Springfield's Southwest Treatment Plant. During periods of excessive rainfall the sinkhole reverses and functions briefly as a spring. See figure 84 for a diagrammatic explanation of the reversible action. Photo by Jerry D. Vineyard.



A. LOW FLOW – ONLY LOWER SECTIONS OF KARST DRAINAGE SYSTEM FLOODED; ESTAVELLES ARE SINKHOLES (SWALLOW HOLES)

B. MEDIUM FLOW – HEADWARD FLOODING OF KARST DRAINAGE SYSTEM; LOWEST ESTAVELLE BECOMES SPRING (RISING)

C. HIGH FLOW – STORAGE CAPACITY OF KARST DRAINAGE SYSTEM EXCEEDED; ESTAVELLES BECOME SPRINGS, WATER BACKS UP IN HEADWARD CAVES

Figure 84

Hypothetical stream profile showing sequential reversal of flow in estavelles

Oval Sink are hydrologically connected through relatively open solution channels is shown by the occasional presence of river fish and turtles in the waters of the sink.

Analysis of the flow pattern of Rader Spring and the several reversible sinkholes along Wilson Creek gives insight into the functioning of this groundwater drainage system. The relative openness of the solution channels contributing flow to Rader Spring is shown by the rapid travel time of water traced by fluorescent dyes from various places in the Wilson Creek basin. The capacity or volume of the subterranean channelways can be approximated by considering the sequential reversal of flow in the resurgence sinks. For example, a relatively small rainfall is sufficient to cause reversal of flow in Rader Resurgence-Sink, and this type of reversal is propagated sequentially upstream until the Oval Sink becomes the last in the series to reverse its flow. A large amount of rainfall in a relatively short time is required to cause the Oval Sink to resurge. Pfaff Cave, several miles farther upstream, is a similar feature but it has never been known to reverse flow because it is considerably closer to the headwaters of the stream and is much deeper than the reversible sinkholes in the lower reaches of the Rader Spring supply system.

Figure 84 is a cross section showing the stratigraphic and structural relationships in the Rader Spring supply system. Structure contour maps of the area show the Burlington-Keokuk-Reeds Spring contact to be rising southward toward the Battlefield fault. Rader Spring rises just upstream of the Battle-

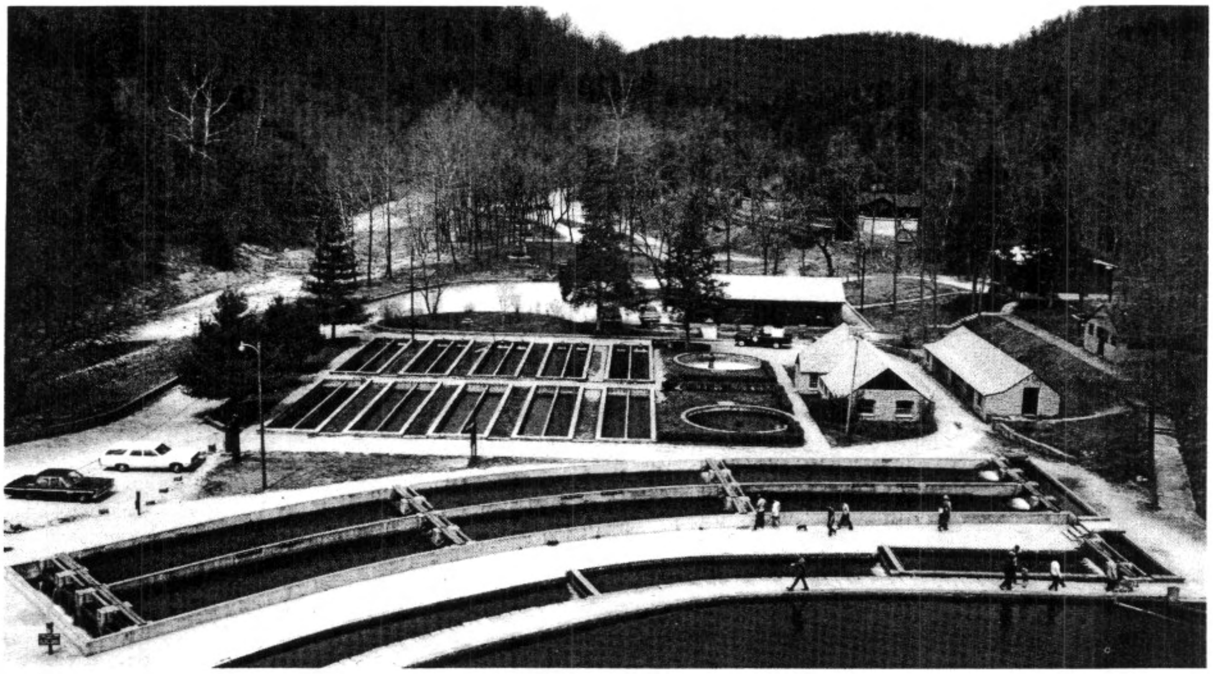


Figure 85

Roaring River Spring supplies water for one of the Missouri Department of Conservation's largest trout hatcheries. Gravity flow from the spring through the rearing pools is normally sufficient, but in dry months some recirculation of the spring water is necessary. The spring basin and retaining dam are in the foreground, with rearing pools adjacent. The dry valley of upper Roaring River Creek is in the background; permanent flow begins below the spring. Photo by Jerry D. Vineyard.

field fault, and it appears that the faulting has caused groundwater to surface along the contact between the cavernous Burlington-Keokuk limestone and the relatively impermeable Reeds Spring cherty limestone. The long-continued solution activity in the Wilson Creek basin above Rader Spring is shown by the depression in the gradient of Wilson Creek, presumably caused by solutional removal of limestone augmenting the removal of rock in normal valley downcutting by the stream.

Situations similar to that of the Rader Spring supply system may be expected in other parts of the Ozarks where similar geologic and hydrologic conditions exist. Further study of the system is likely to reveal more details of the spring supply systems and the functioning of the various segments of the system.

REEDS SPRING, *Stone County, Reeds Spring 7½-minute quadrangle, NW¼ SW¼ sec. 25, T. 24 N., R. 23 W.*

Reeds Spring is centrally located in the town of Reeds Spring. Originally a source of water for the settlement, it later became important to farmers as a source of water in dry periods. Although the spring is not large, its flow is quite uniform, ranging from 65,000 to 291,000 gallons a day. This perennial spring is enclosed by a walled basin extending below the level of the street and is reached by a flight of steps.

ROARING RIVER SPRING, *Barry County, Cassville 15-minute quadrangle, SE¼ NE¼ sec. 27, T. 22 N., R. 27 W.*

Roaring River Spring has been used for many years as a source of water for one of the large state fish hatcheries (fig. 85). It flows from a pool at the base of a high bluff of Cotter Dolomite (fig. 86) in a narrow, canyon-like valley and forms the head of Roaring River.

Roaring River Spring is the largest in that part of the White River basin shown in figure 78. It is not

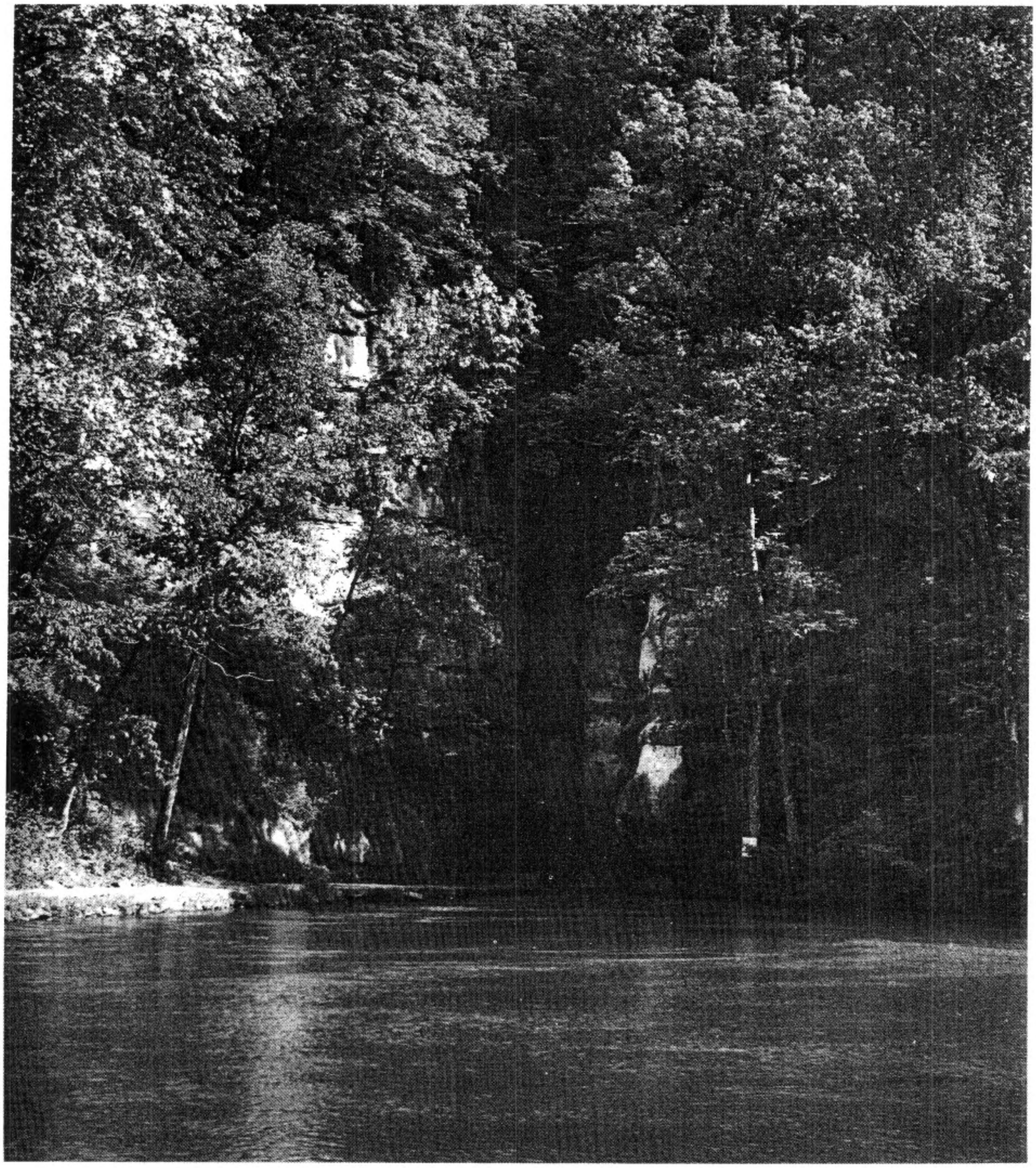


Figure 86

Roaring River Spring rises from Cotter Dolomite (Ordovician), but water quality data indicate that much of the recharge area is in uplands underlain by Mississippian limestone. The bluff re-entrant above the spring follows a small fault and the bluffward recession is augmented by a small Ordovician-Mississippian contact spring discharging from an open joint at the top of the re-entrant. Photo by Gerald Massie.

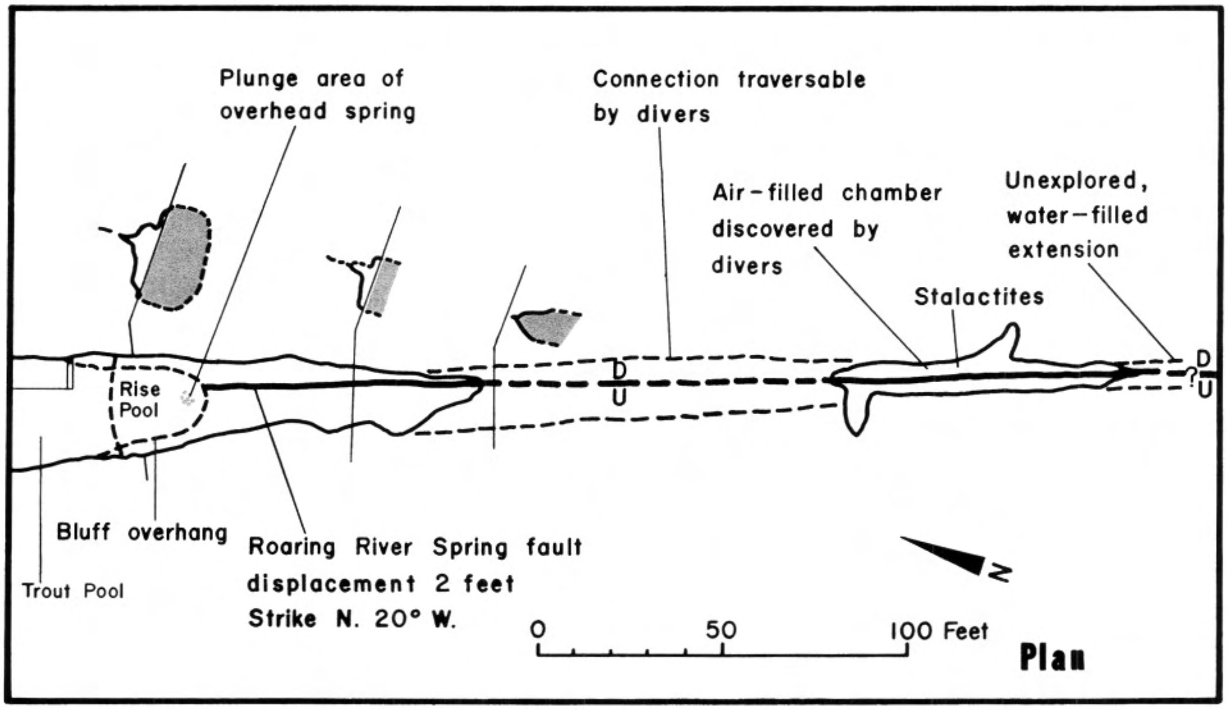


Figure 87a

Sketch map of Roaring River Spring, from information obtained by divers.

large enough to include with the 15 largest springs in Missouri, but it is one of the more important springs in the recreation program of the state. The maximum discharge was measured on April 6, 1965, when the spring flowed at a rate of 144 mgd. The minimum measured discharge is 5,000,000 gallons a day. This does not mean, of course, that higher and lower flows have not occurred.

When the flow of the spring declined in the late summer and fall it was frequently necessary to reuse the water, so pumping facilities were installed when the production of the hatchery increased to the level at which more water was needed.

The spring serves as the nucleus of a resort with dining and lodging facilities that are popular with fishermen who come to fish in the spring branch and lake below the hatchery. Trout are sent throughout the state for stocking lakes and reservoirs. Roaring River State Park consistently ranks high in the number of visitors in the Missouri State Park system.

The environs of Roaring River Spring are pictüresque. Driving from Cassville to the spring one crosses the rolling Springfield Plateau at an altitude of 1,500 feet. In a distance of 3 miles the road drops about 500 feet to the resort area. Probably nowhere in this section of the state is a trip down the slope of an escarpment more spectacular than this one.

Divers of the St. Louis Underwater Recovery Team entered Roaring River Spring in June 1966 and explored part of the waterfilled cave system beyond the rise pool (fig. 87). They entered an airfilled chamber about 200 feet from the stone wall at the spring basin, the same short cave mentioned by Bretz (1956, p. 229). They were also able to descend in the spring channel to a depth of about 100 feet. Bretz presented a detailed analysis of probable areas drained by the spring, relying on accounts by Beckman and Hinchey (1944) of sinkhole collapses and subsequent disturbances in Roaring River Spring. However, with the exception of diving operations in an attempt to discover the depth of solution in the Jefferson City-Cotter Dolomites supplying the spring, no further work has been done in outlining the exact catchment area for the spring.

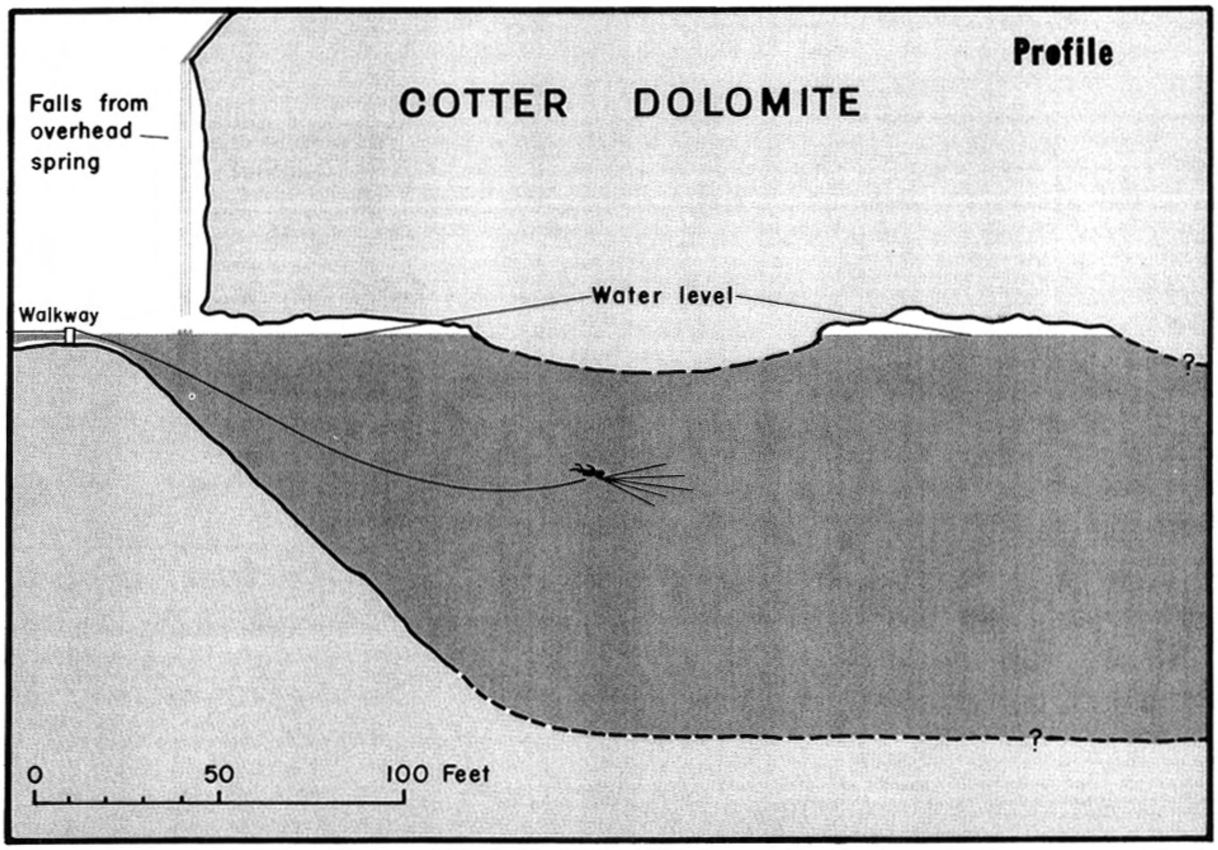


Figure 87b

Cross section of Roaring River Spring. Bathymetry courtesy Donald N. Rimbach.

Roaring River Spring follows a near-vertical fault trending N. 20° W., with a displacement of about 2 feet. This fault may be traced upward through Cotter Dolomite and through the Ordovician-Mississippian contact about 90 feet above the spring. Fault breccia is well exposed, displacing Compton beds above the contact. Curiously, however, a small spring about 50 feet west of the fault issues from an enlarged joint showing no displacement. Water from this small contact spring cascades over the reentrant into Roaring River Spring.

There are at least two other small faults in the immediate vicinity of Roaring River Spring, suggesting that the location of the spring is determined by locally intense faulting.

Steyermark (1941, p. 599) described the species of plants growing in the spring, spring branch and lake.

SEQUIOTA SPRING, *Greene County, Galloway 7½-minute quadrangle, NE¼ NW¼ sec. 9, T. 28 N., R. 21 W.*

Sequiota Spring, also known as Fisher Cave, is one of the larger springs in the Springfield area. It is in a park setting just southeast of the city. The spring flows from a cave developed on a system of joints and widened along a bedding plane. The cave can be followed by boat for a quarter of a mile making right angle turns, caused by strong joint control, every few hundred feet. Bretz (1956, p. 248) gives a complete description of the cave. The limestone in the bluff is the Mississippian Burlington-Keokuk. The spring has been impounded by a dam forming a lake. Flow of the spring varies greatly, having ranged from 0.6 mgd to 11 mgd.

Sequiota Spring and this cave have a long and colorful history. The spring was the site of the first

state fish hatchery – started in 1924 and moved after 35 years to Table Rock Dam. Since 1959, the spring and cave have been owned by the City of Springfield and are a part of the city's park system.

There are three caves at Sequiota Spring, two of which are dry and one which is the spring outlet. It is reported that Major Charles Galloway (for whom the town of Galloway is named) owned the spring following the Civil War. Galloway used the large cave alongside Sequiota Cave as a grocery store for several years. Later the property was bought by a Mr. Fisher, and the cave became known as Fisher Cave. Fisher used the cave for growing mushrooms.

At various times Sequiota Cave was used for boat rides. Fisher built a 4-foot high dam about 200 feet below the opening to store water for the boat rides that took visitors 1,000 feet into the cave.

WINOKA SPRING, *Greene County, Ozark SW 7½-minute quadrangle, NW¼ NW¼ sec. 22, T. 28 N., R. 21 W.*

Winoka Spring is on a bluff of Mississippian limestone south of the James River, 40 feet above the flood plain of the river. The spring consists of a series of openings extending for a distance of about 100 feet. Apparently the openings developed along the same bedding plane because they are at the same altitude. The total flow of all the springs varies considerably because of the height of the openings above river level. In extreme dry weather, storage in the bluffs is depleted and there is little flow. When the springs are flowing well, water cascades down the slopes creating a very pretty sight.

Winoka Spring is privately owned and is used as a water supply for Winoka Lodge.

SPRINGS IN OTHER AREAS

AREA DESCRIPTIONS

Most of the springs in northern Missouri drain areas covered with glacial till which are underlain by limestone, dolomite, sandstone, and shale of Ordovician to Pennsylvanian age. Due to the limited storage in these rocks, the springs in northern Missouri are generally very small.

South of the Missouri River in Saline and Cooper Countiès, numerous saline springs issue from rocks of Mississippian age. According to Carpenter and Miller (1969) and Miller (1971), the salinity of these springs is a result of connate water being gradually flushed out of the enclosing rocks by modern precipitation.

The area east of the St. Francois Mountains contains many small springs. A few of these springs are saline but most contain fresh water. They issue from gently dipping rocks of Cambrian to Mississippian age. There is abundant faulting in this area. Most of the faults are tightly sealed and act as barriers, preventing widespread circulation of large quantities of ground water and the development of abundant storage such as that found to the west of the St. Francois Mountains. Table 25 gives discharges for springs in these areas. Locations of measured springs are shown in figure 88.

QUALITY OF WATER

The chemical characteristics of water discharged by springs generally are related to the types of rocks drained. There is a wide range in chemical characteristics and dissolved-solids content of spring water because of the diversity of rocks in the state. The dissolved-solids content of spring water ranges from 38 to 23,400 mg/l, with the lower value being for a spring draining unconsolidated deposits in southeast Missouri and the higher value being for a mineral spring in Saline County (table 26). Most of the springs yield a hard calcium magnesium bicarbonate or a calcium bicarbonate type of water that contains less than 500 mg/l of dissolved solids. Several springs discharge a highly mineralized sodium chloride type of water that is also enriched with calcium, magnesium and sulfate. Most of these saline springs are located along the freshwater-salt water interface in west-central Missouri and in some areas along the Mississippi River.

Iron content of springs in the statewide area ranges from 0.00 to 18 mg/l, with 17 out of 60 samples showing iron in excess of the 0.3 mg/l recommended limit. Nitrate content of the spring water varies from 0.0 to 103 mg/l, with 18 out of 58 samples containing over 10 mg/l nitrate. The high nitrate content of water from some of the springs indicates contamination. Most of the springs with high nitrate contents occur in the glacial drift of north Missouri.

DESCRIPTIONS OF SELECTED SPRINGS

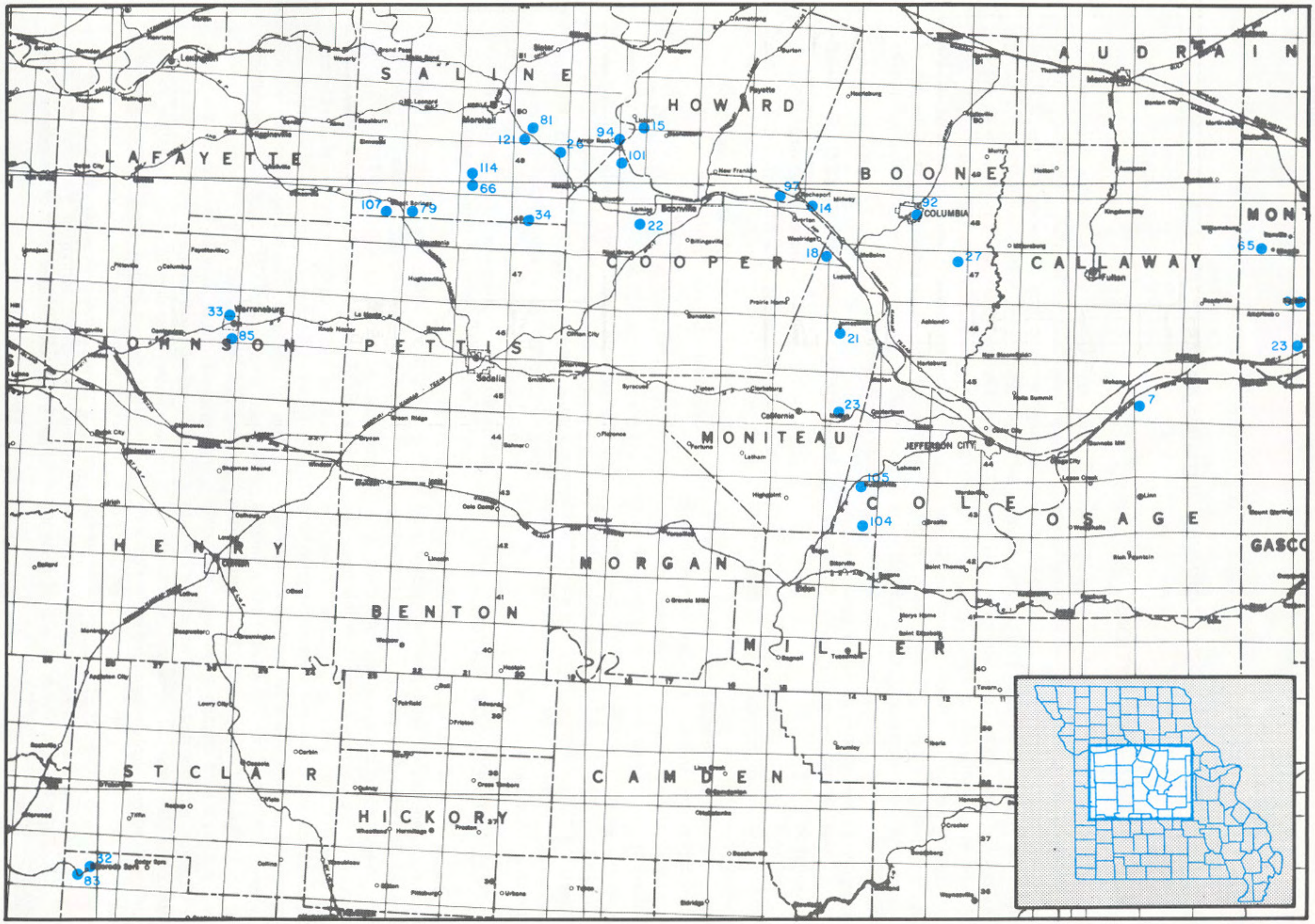
BLUE LICK SPRING, *Saline County, Marshall South 7½-minute quadrangle, SW¼ NE¼ sec. 28, T. 49 N., R. 21 W.*

Miller (1971) reported 19 springs and groups of springs in Saline County, all of which are mineralized and small. Blue Lick Spring rises from alluvium in the valley of West Fork Finney Creek. It is the largest of a group of three springs at this locality. Its shallow basin is strikingly circular (fig. 89) and has a narrow discharge channel.

Typical of the mineralized springs of this area, Blue Lick Spring has an estimated discharge of less than 10 gallons per minute. Its circular rise pool is about 40 feet in diameter. Two smaller springs nearby have rise pools measuring 4 and 5 feet in diameter.

Bedrock from which the mineralized water is derived is the Sedalia dolomitic limestone of Mississippian age. According to Miller (1971, p. 13), the evolution of gases from the spring is slow, with sporadic large bursts of H_2S; the emittance of gases is a characteristic shared by most of the mineralized springs of this area. The spring water has a total dissolved solids content of 14,600 parts per million.

Although mineralized springs today are usually not pleasant places to visit because of the odors accompanying gas discharge and because the mineralized water generally kills the vegetation in the vicinity of such a spring, these waters once were important in the economy of Missouri because of their supposed therapeutic values. Schweitzer (1892) studied mineralized springs of the state at a time when they were at their peak of development and utilization.


SALINE
HOWARD
AUDRAIN
LAFAYETTE
BOONE
COOPER
CALLAWAY
JOHNSON
PETTIS
MONITEAU
COLE
OSAGE
HENRY
MORGAN
BENTON
MILLER
ST CLAIR
CAMDEN
HICKORY
GASCO
MON
Lexington
Marshall
Boonville
COLUMBIA
Fulton
Mexico
Warrensburg
Sedalia
California
JEFFERSON CITY
Clinton
81
121
26
94
15
101
114
66
107
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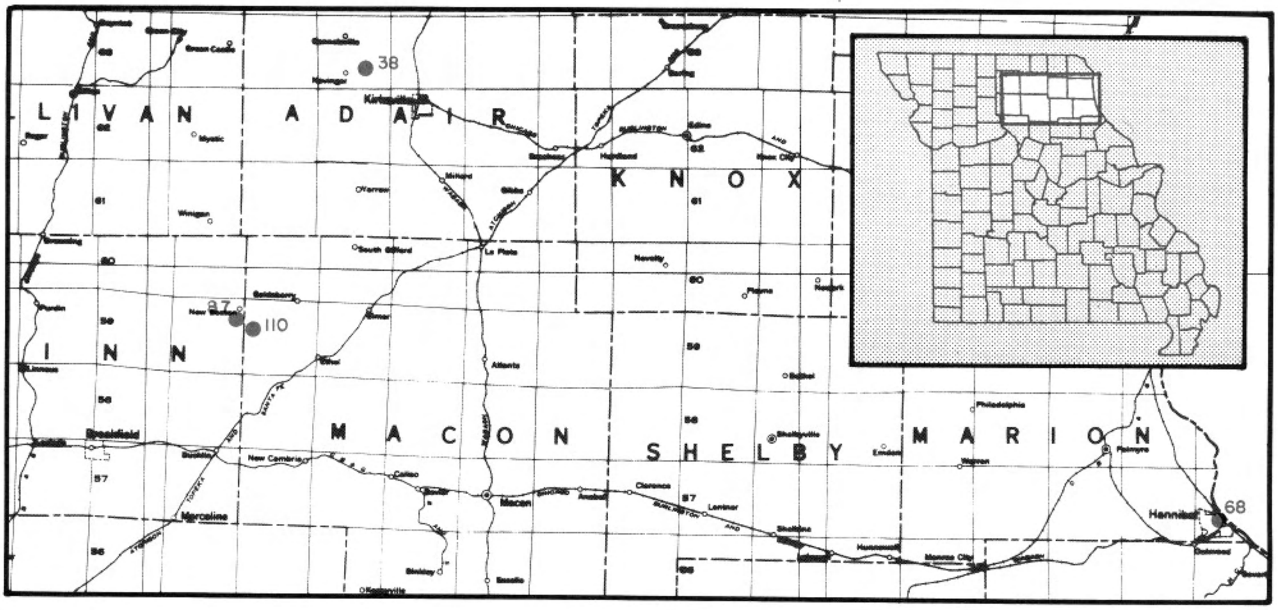
104
32
83



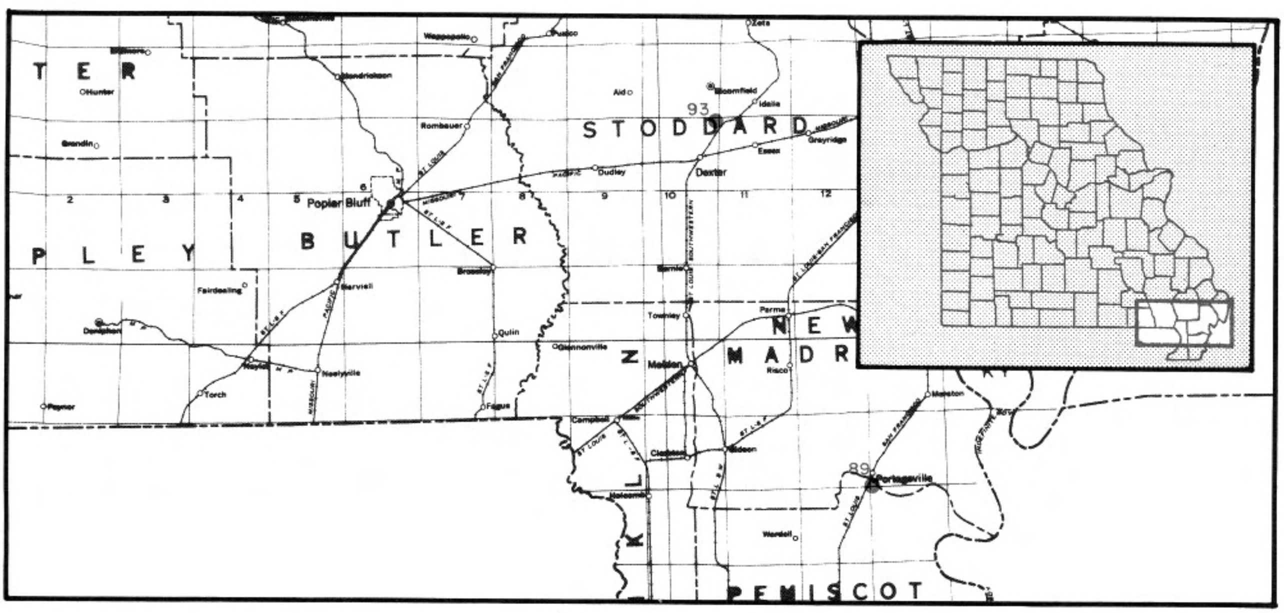


Figure 88

Springs in other areas of Missouri. Those in the central part of the state are on page 186; springs in the north-east part are shown at the top of this page while those in the Bootheel area are indicated in the bottom diagram. *(continued to next page)*

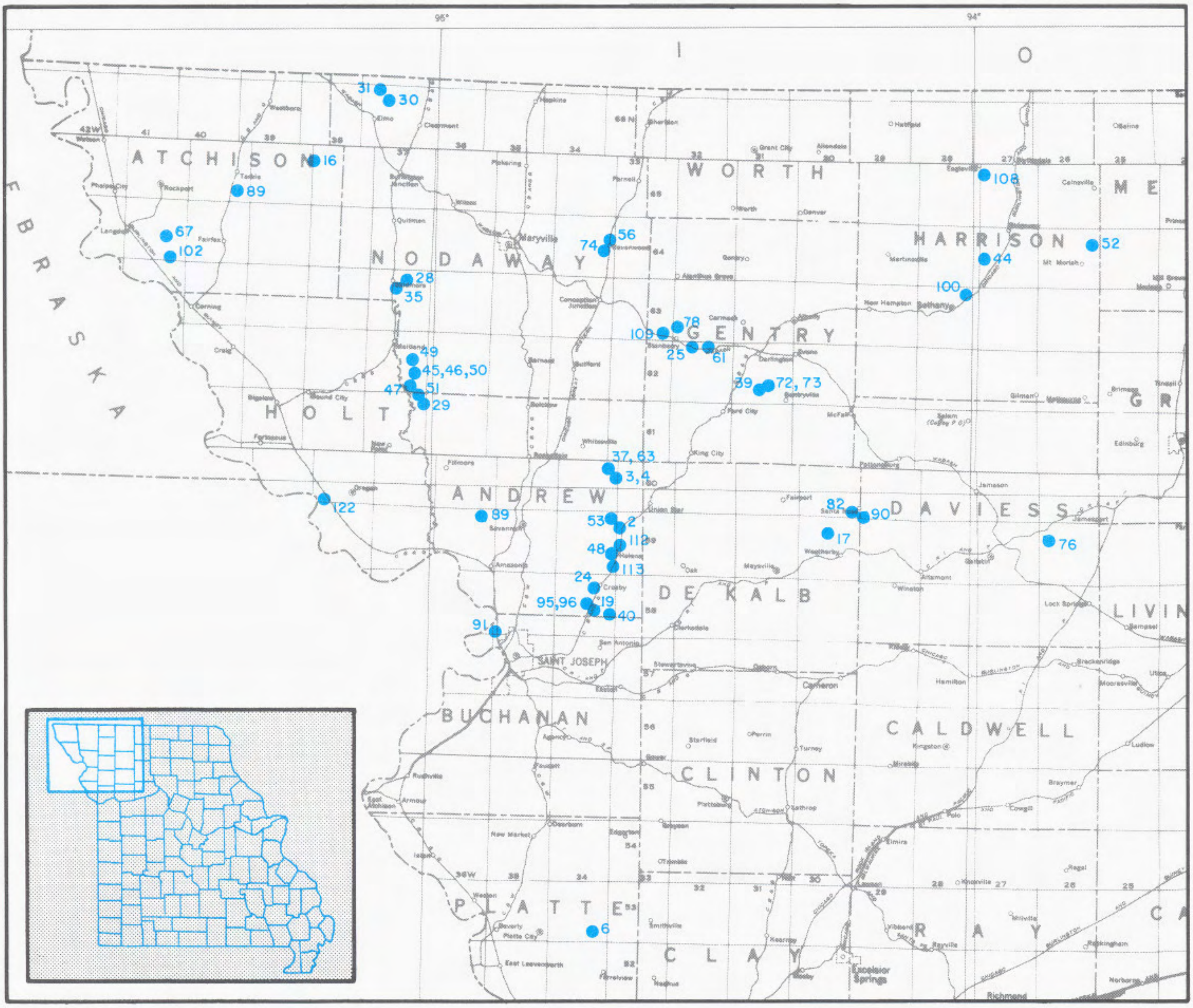


Figure 88 *(continued)*

Springs in northwest Missouri are shown above; those in east-central Missouri are on page 189.

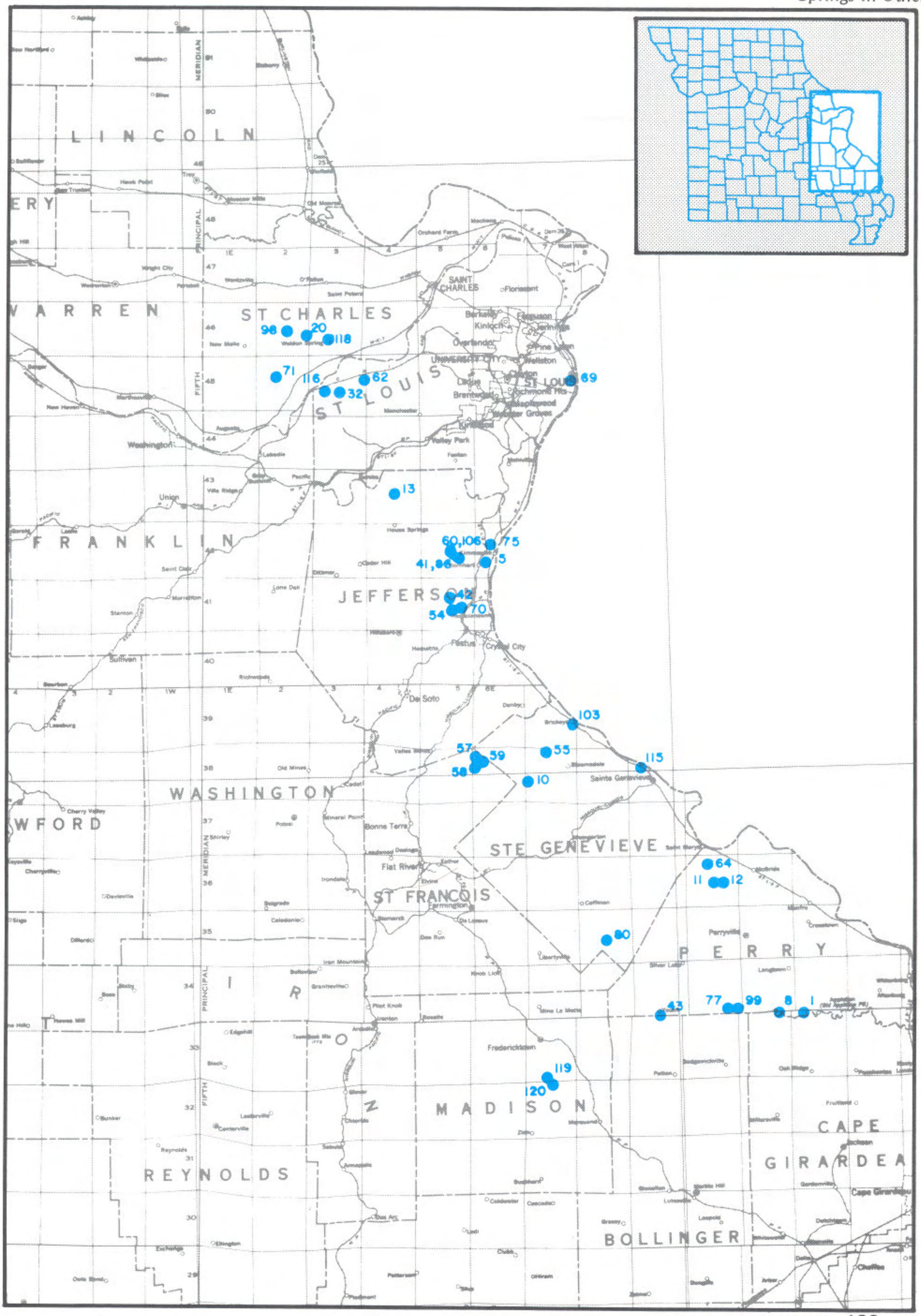

LINCOLN
WARREN
ST CHARLES
ST LOUIS
FRANKLIN
JEFFERSON
WASHINGTON
STE GENEVIEVE
ST FRANCOIS
PERRY
IRON
MADISON
REYNOLDS
BOLLINGER
CAPE GIRARDEAU
SAINT CHARLES
UNIVERSITY CITY
ST LOUIS
Florissant
Kirkwood
Valley Park
Union
Washington
Sullivan
De Soto
Festus
Crystal City
Sainte Genevieve
Bonne Terre
Flat River
Farmington
Perryville
Fredericktown
Potosi
Ironton
98
20
118
71
116
62
32
69
13
60,106
75
41,86
5
42
54
70
103
57
59
58
55
115
10
64
11
12
80
43
77
99
8
1
119
120

Table 25
DISCHARGES OF SPRINGS IN OTHER AREAS OF MISSOURI

[A = less than 0.0 cfs]

Location No. (fig. 88)	Spring	Nearest Town	County	Land Line Location	Rate of Flow: Sec. Ft. (cfs)	Rate of Flow: 1000 gal. day	T °F.	Date	Remarks
1	Abernathy	Old Appleton	Cape Girardeau	NE 5,33,12E	1.00	646	57	6-7-66	Stock
2	Andrews	Helena	Andrew	7,59,33W	A	A	-	8-26-64	
					A	A	54	11-30-64	
3	Armfield No.1	Union Star	Andrew	SENE 24,60,34W	.02	13	-	2-2-64	Stock
					.01	6	-	8-26-64	
					.03	19	-	11-30-64	
4	Armfield No.2	Union Star	Andrew	SENE 24,60,34W	A	A	-	2-24-64	Stock
					A	A	-	8-26-64	
					A	A	54	11-30-64	
5	Barnhart	Barnhart	Jefferson	NWSW 29,42,6E	*	*	-	11--- 40	
6	Basswood	Kansas City	Platte	NENE 27,53,34W	.04	26	44	12-8-66	Bottling
7	Benedict	Chamois	Osage	NWSE 19,45,8W	.02	13	54	6-7-66	
8	Berkbigler	Uniontown	Perry	NENE 2,33,11E	2.83	1,830	60	8-25-66	
9	Big	McKittrick	Montgomery	SWNW 32,47,5W	.02	13	57	10-8-38	
					.02	13	57	8-31-64	
10	Blue	Bloomsdale	Ste. Genevieve	NESW 19,38,7E	.28	18	61	8-23-66	
11	Blue Spring Br.	McBride	Perry	SESE 23,36,10E	.15	97	-	1-4-65	
12	Blue Spring Br.	McBride	Perry	NWSW 24,36,10E	.90	58	56	1-4-65	
13	Boemler	High Ridge	Jefferson	NESW 15,43,4E	.02	13	56	9-20-64	
14	Booneslick	Booneslick Park	Howard	31,50,17W	.06	39	56	11-8-65	
15	Boyer	Tarkio	Atchison	NENW 6,65,38W	.02	13	-	2-5-65	Stock
16	Bray	Weatherby	DeKalb	SW 4,59,30W	A	A	-	8-25-64	Stock
					A	A	-	12-1-64	
17	Bruce Cave	Woolridge	Moniteau	NENE 36,48,15W	.10	65	57	6-10-66	
18	Bunse	Cosby	Andrew	NE 22,58,34W	A	A	-	1-24-64	
					.01	6	-	8-26-64	
					.01	6	-	11-30-64	
19	Burgamaster	Busch Wildlife	St. Charles	NWNW 30,46,3E	.36	23	56	11-8-64	
20	Cave	Jamestown	Moniteau	NW 8,46,14W	.02	13	57	6-9-66	Stock
21	Chouteau	Pilot Grove	Cooper	NWSE 16,48,18W	.04	26	63	6-15-66	
22	Cook	McGirk	Moniteau	SWNW 29,45,14W	.05	32	56	6-10-66	Stock
23	Cosby	Cosby	Andrew	NWNW 11,58,34W	.03	19	-	1-24-64	
					A	A	-	8-26-64	
					.02	13	-	11-30-64	
24	Dawson	Stanberry	Gentry	NW 4,62,32W	A	A	-	3-11-64	Stock
					A	A	-	8-22-64	
					A	A	-	12-4-64	
25	Dennis	Napton	Saline	NWNW 12,49,20W	A	A	55	11-10-65	
26	Devils Icebox	Columbia	Boone	SW 1,47,12W	.05	32	55	8-15-64	
27	Dew	Skidmore	Nodaway	NWSW 3,63,37W	A	A	-	1-16-64	Stock
					A	A	-	8-27-64	
					A	A	-	12-3-64	
28	Drew	Graham	Andrew	NE 1,61,37W	A	A	-	1-28-64	Stock
					A	A	72	8-24-64	
29	Ecker No. 1	Elmo	Nodaway	NENW 8,66,37W	A	A	-	1-14-64	Domestic, stock
					A	A	61	8-25-64	
30	Ecker No. 2	Elmo	Nodaway	SWSW 5,66,37W	A	A	-	1-14-64	Stock
					A	A	57	8-25-64	
31	Eldorado	Eldorado Springs	Cedar	NESW 21,36,28W	.01	6	-	9-3-43	
					A	A	58	2-15-54	
					A	A	-	11-6-63	
					.05	32	62	8-25-64	
32	Electric	Warrensburg	Johnson	SENE 23,46,26W	A	A	-	11-11-65	
33	Elk Lick	Marshall	Saline	NESE 17,48,20W	.05	32	57	11-9-65	
34	Enders	Skidmore	Nodaway	NW 9,63,37W	A	A	-	1-16-64	Stock
					A	A	-	8-27-64	
					A	A	56	12-3-64	
35	Essen	Babler State Pk.	St. Louis	NWSW 22,45,3E	.03	19	-	8-15-64	
					.04	26	56	10-12-64	
					.01	6	56	11-1-64	
36	Flag	Union Star	Andrew	SW 12,60,34W	.03	19	-	2-24-64	Domestic, formerly used
					.04	26	-	11-30-64	for distillery
37	Fountain	Novinger	Adair	SE 22,63,16W	A	A	-	1-22-64	Stock
					A	A	-	8-24-64	
38	Ganaway	Darlington	Gentry	SE 22,62,31W	A	A	-	3-13-64	Stock
					A	A	65	8-25-64	
39	Garbe	Cosby	Andrew	NW 23,58,34W	A	A	-	1-24-64	Stock
					A	A	-	8-26-64	
					A	A	54	11-30-64	
40	Glatts	Otto	Jefferson	23,42,5E	.08	52	56	8-27-64	
41	Glen	Pevely	Jefferson	NENW 10,41,5E	.01	6	55	8-2-64	Girl Scout Camp
42	Hahn	Yount	Bollinger	NENE 3,33,9E	1.01	652	58	6-8-66	Partial domestic
43	Hatten	Ridgeway	Harrison	SW 7,64,27W	A	A	-	2-10-64	Stock
					A	A	61	8-26-64	

Table 25 *(continued) . . . . .*

Location No. (fig. 88)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
44	Hazelett No. 1	Graham	Nodaway	SW 25,62,37W	0.11	71	-	1-28-64	
					.15	97	61	8-24-64	
45	Hazelett No. 2	Graham	Nodaway	SW 25,62,37W	.02	13	-	1-28-64	Stock
					A	A	60	8-24-64	
46	Hazelett No. 3	Graham	Nodaway	SW 25,62,37W	A	A	-	1-28-64	Stock
					A	A	60	8-24-64	
47	Helena	Helena	Andrew	SE 24,59,34W	.01	6	-	2-7-64	Stock
					A	A	-	8-26-64	
					no flow		-	11-30-64	
48	Hill	Graham	Nodaway	NE 23,62,37W	A	A	-	1-28-64	Stock
49	Hoover No. 1	Graham	Nodaway	SE 36,62,37W	A	A	-	1-28-64	Owned by President Hoover
					A	A	70	8-24-64	Stock
50	Hoover No. 2	Graham	Nodaway	SE 36,62,37W	A	A	-	1-28-64	Stock
					A	A	65	8-24-64	
51	Boone Cave	Huntsdale	Boone	NENE 20,48,14W	.33	213	45	3-22-69	
					.02	13	60	8-15-64	
52	Hudson	Mt. Moriah	Harrison	SE 11,64,26W	A	A	-	2-10-64	Stock
					A	A	-	8-24-64	
53	Jackson	Helena	Andrew	NE 1,59,34W	A	A	-	1-7-64	Stock
					A	A	-	8-26-64	
					A	A	54	11-30-64	
54	Jacobsen	Pevely	Jefferson	NWSE 14,41,5E	.01	6	56	8-2-64	
55	Josh Bailey	Bloomsdale	Ste. Genevieve	SWSE 4,48,7E	A	A	64	8-23-63	
56	Joy	Ravenwood	Nodaway	NWSE 12,64,34W	A	A	-	1-16-64	
					.02	13	51	8-25-64	
57	Koester No. 1	Bonne Terre	St. Francois	SENW 7,38,6E	.08	52	56	12-12-63	Domestic
					.07	45	-	8-25-64	
58	Koester No. 2	Bonne Terre	St. Francois	SESW 7,38,6E	.26	168	55	12-12-63	
					.10	65	58	8-25-64	Stock
59	Koester No. 3	Bonne Terre	St. Francois	SWNESW 7,38,6E	.55	355	55	12-12-63	Domestic
					.44	284	57	8-25-64	
					.89	575	55	6-10-66	
60	Kraus	Barnhart	Jefferson	SWNW 23,42,5E	.04	26	57	8-13-64	
61	Kyger	Stanberry	Gentry	NE 4,62,32	A	A	-	3-11-64	Stock
					A	A	-	8-27-64	
					A	A	-	12-4-64	
62	Lewis	Chesterfield	St. Louis	SW 18,45,4E	.11	71	55	8-15-64	
					.02	13	56	10-12-64	
					.02	13	56	11-1-64	
63	Lewis	Union Star	Andrew	NW 12,60,34W	A	A	-	2-24-64	Stock
					A	A	-	8-26-64	
					A	A	-	11-30-64	
64	Lithium	McBride	Perry	SESW 12,36,10E	.17	110	58	1-4-65	
					.04	26	57	6-9-66	
65	Living	Mineola	Montgomery	NE 33,48,6W	A	A	-	12-2-47	
66	Blue Lick	Marshall	Saline	SWNE 28,49,21W	.05	32	-	11-9-65	
67	Luhr	Rockport	Atchison	SENE 22,64,41W	.13	84	-	1-28-64	Stock
					.16	103	-	8-25-64	
68	Mark Twain	Hannibal	Marion	SWNE 28,57,4W	.04	26	54	9-1-64	
69	Market Street	St. Louis	St. Louis	23,45,7E	.06	39	72	9-1-64	
70	Martin	Pevely	Jefferson	NESE 14,41,5E	.01	6	55	8-13-64	
71	Mill	Defiance	St. Charles	SWNW 16,45,2E	.60	388	53	2-6-65	
72	Miller No. 1	Darlington	Gentry	SW 23,62,31W	A	A	-	3-13-64	Stock
					A	A	-	8-25-64	
73	Miller No. 2	Darlington	Gentry	SW 23,62,31W	A	A	-	3-13-64	Stock
					no flow			8-25-64	
74	Miller	Ravenwood	Nodaway	NESE 12,64,34W	A	A	-	1-16-64	
					A	A	-	8-25-64	
75	Montesano	Kimmswick	Jefferson	17,42,6E	*	*	-	6- -34	
76	Mort	Gallatin	Daviess	C 7,59,26W	A	A	-	2-5-64	
					A	A	-	8-25-64	
					A	A	55	12-1-64	
77	Mrs. Murphy	Uniontown	Perry	NESW 36,34,10E	A	A	-	11-9-63	Ebb and flow
					.05	32	58	8-28-64	Stock
78	Myrick	Stanberry	Gentry	SW 30,63,32W	A	A	-	8-27-64	
					A	A	-	12-4-64	
79	McAllister	Houstonia	Saline	SWNE 17,48,22W	A	A	-	11-10-65	
80	Nations Mill	Womack	Ste. Genevieve	NENW 27,35,8E	.15	97	58	8-24-66	
81	Napton	Napton	Saline	NESE 28,50,20W	A	A	56	11-10-65	
82	Nettie Price	Santa Rosa	DeKalb	SESW 25,60,30W	A	A	-	8-25-64	
					A	A	51	12-1-64	
83	9 Wonders	Eldorado Springs	Cedar	SENW 29,36,28W	A	A	-	11-6-63	
					.02	13	62	8-25-64	
84	Patterson	Savannah	Andrew	SWNE 2,59,36W	A	A	-	2-7-64	Stock
					no flow			8-26-64	

Table 25 – *DISCHARGES OF SPRINGS (continued) . . . . .*
(Other Areas of Missouri)

Location No. (fig. 88)	Spring	Nearest Town	County	Land Line Location	Rate of Flow Sec. Ft. (cfs)	Rate of Flow 1000 gal. day	T °F.	Date	Remarks
85	Pertle	Warrensburg	Johnson	NWNW 36,46,26W	0.03	19	56	11-11-65	
86	Pevely	Barnhart	Jefferson	NWSE 23,42,5E	.40	258	56	8-13-64	
					.40	258	56	8-27-64	
87	Polson	New Boston	Linn	SESE 1,59,18W	A	A	-	2-4-64	Stock
					A	A	-	8-24-64	
88	Portage Open Bay	Portageville	New Madrid	SWNW 31,21,13E	2.32	1,500	-	9-24-53	
89	Prather	Tarkio	Atchison	SE 27,65,40W	A	A	-	1-17-64	Stock
					A	A	62	8-25-64	
90	R. C. Price	Santa Rosa	DeKalb	NWNW 25,60,30W	A	A	-	8-25-64	
					A	A	51	12-1-64	
91	Robidoux	St. Joseph	Buchanan	SENW 31,58,35W	.01	6	-	3-10-64	
					A	A	-	8-26-64	
					A	A	55	12-1-64	
92	Rollins	Columbia	Boone	SENW 18,48,12W	.12	78	70	8-27-64	
93	Ross	Dexter	Stoddard	SENE 1,25,10E	.23	149	56	4-9-37	Stock
					.10	65	50	1-29-64	
					.14	90	62	8-27-64	
					.21	136	-	12-2-64	
94	Sante Fe	Arrow Rock	Saline	SENE 36,50,19W	.09	58	-	5-7-37	Historical
					.05	32	-	10-17-62	
					A	A	55	2-17-64	
					.03	19	56	8-28-64	
95	Schlindler No. 1	Cosby	Andrew	SE 15,58,34W	.07	45	-	1-24-64	
					.07	45	-	1-26-64	
					.09	58	-	11-30-64	
96	Schlindler No. 2	Cosby	Andrew	SE 15,58,34W	.06	39	-	1-24-64	Stock
					.04	26	-	8-26-64	
					.05	32	-	11-30-64	
97	Schmidt	Overton	Cooper	SENW 6,48,15W	A	A	59	6-15-66	
98	Schulte	Busch Wildlife	St. Charles	NESW 23,46,2E	.06	39	55	11-15-64	
99	Schumer	Perryville	Perry	NESW 36,34,10E	.01	6	55	10-30-63	Domestic
					.03	19	56	8-28-64	
					.40	258	56	1-4-65	
					.02	13	57	8-25-66	
100	Shepard	Bethany	Harrison	NWNW 2,63,28W	A	A	-	3-12-64	Stock
					A	A	-	8-25-64	
					A	A	-	12-1-64	
101	Slough Creek	Arrow Rock	Cooper	NWSW 6,49,18W	A	A	55	---	Saline Spring, measurement by A. B. Carpenter
102	Sly	Corning	Atchison	NWSE 35,64,41W	.01	6	-	1-17-64	Stock
					A	A	-	8-27-64	
					.01	6	-	12-3-64	
103	Snell Hollow	Bloomsdale	Ste. Genevieve	SENE 24,39,7E	.80	517	57	8-23-66	
104	Steenbargen	Russelville	Cole	SESW 25,43,14W	A	A	59	6-16-66	Stock
105	Strobel	Russelville	Cole	SWSW 35,44,14W	A	A	59	6-16-66	
106	Stuckmeyer	Barnhart	Jefferson	NENW 23,42,5E	A	A	58	8-13-64	
107	Sweet	Sweet Springs	Saline	NWNW 14,48,23W	.02	13	-	8- -25	
					A	A	58	11-10-65	
108	Taylor	Ridgeway	Harrison	NW 6,64,27W	A	A	57	8-26-64	Stock
109	Thomas	Stanberry	Gentry	NENE 35,63,33W	A	A	-	1-20-64	Stock
					A	A	-	8-27-64	
					A	A	-	12-4-64	
110	Thompson	New Boston	Macon	NWSE 7,59,17W	A	A	-	2-4-64	Stock
					A	A	-	8-24-64	
111	Town	Grand Pass	Saline	SWSW 16,51,23W	A	A	55	11-10-65	
112	E. E. Tritten	Helena	Andrew	NE 24,59,34W	A	A	-	2-7-64	Household, stock
					A	A	-	8-26-64	
					A	A	54	11-30-64	
113	J. E. Tritten	Helena	Andrew	NE 25,59,34W	A	A	-	2-7-64	Stock
114	Upper Blue Lick	Marshall	Saline	NWSE 21,49,21W	.08	52	58	11-9-65	
115	Valle	Ste. Genevieve	Ste. Genevieve	Sur. 3255,38, 9E	1.36	879	60	8-24-66	
116	Valley	Babler State Pk.	St. Louis	20,45,3E	A	A	54	8-15-64	
117	Van Meter	Van Meter State Park	Saline	NENW 25,52,22W	no flow	*	48	11-10-65	
						52			
118	Weldon	Weldon Spring	St. Charles	SENW 28,46,3E	.08	90	57	11-8-64	
119	White (Upper)	Fredericktown	Madison	SWNE 2,32,7E	.14	39	57	8-26-66	
120	White (Lower)	Fredericktown	Madison	SWNE 2,32,7E	.06	A	55	8-26-66	
121	Wilton	Napton	Saline	NENE 32,50,20W	A	A	42	11-10-65	Stock
122	Woolsey	Forest City	Holt	NENW 32,60,38W	A		-	2-7-64	Fish rearing, stock

*Discharge data not available; see Table 26 for water quality data.

Figure 89

Blue Lick Spring in Saline County has a nearly circular basin and its waters are mineralized. The spring rises in alluvial deposits along West Fork Finney Creek. Photo by Jerry D. Vineyard.

BLUE SPRING BRANCH: "BALL MILL" AND OTHER RESURGENCES, *Perry County, Lithium 7½-minute quadrangle, SW¼ SW¼ sec. 24, T. 36 N., R. 10 E.*

A group of unusual intermittent springs or resurgences occurs along Blue Spring Branch about 1½ miles south of Lithium. There are five spring rise basins at the base of steep hills along the south bank of Blue Spring Branch. These are properly termed resurgences, defined as points where underground streams rise to become surface streams. Such a term might well be used for most springs in the Ozarks, which for the most part are rises of underground streams. However, in the context used here, a resurgence is more narrowly defined as the intermittent rise of floodwaters gathered by a karst (sinkhole) region.

The Ball Mill Resurgence is so named because of the milling action imparted as karst water rises through an orifice obstructed by cobbles and boulders derived from the local bedrock. Figure 90 illustrates the principle of operation of the Ball Mill Resurgence. When flowing at high discharge, the noise of rocks grinding together in the natural mill is said to be audible for some distance. Examples of the products of the milling action are shown in figure 91.

Table 26
CHEMICAL ANALYSES OF WATER FROM SPRINGS IN OTHER AREAS OF MISSOURI

Analyses by U.S. Geological Survey or Missouri Geological Survey and Water Resources

[A = discharge less than 0.01 cfs; values centered in sodium potassium columns are sodium plus potassium calculated as sodium]

Data in milligrams per liter except as indicated

Location No. (fig. 88)	Spring	Date of collection	Rate of flow (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (Residue at 180°C)
1	Abernathy	6-66	1.00	57	12	0.03	52	22	3.1	0.7	261	0	5.4	1.2	-	1.2	-	236
2	Andrews	11-64	A	54	---	.04	-	-	--	--	384	0	16	8.0	.3	.0	-	365
3	Armfield No.1	11-64	.03	-	---	2.0	-	-	--	--	465	0	46	8.5	.5	5.9	-	509
4	Armfield No.2	11-64	A	54	---	.29	-	-	--	--	265	0	20	17	.4	47	-	390
5	Barnhart	11-40	---	-	6.0	---	311	128	1,300		302	0	205	2,550	-	---	-	5,420
6	Basswood	9-64	---	-	30	.00	94	8.0	6.4	.3	284	0	18	3.2	.2	27	.23	337
7	Benedict	6-66	.02	54	15	.13	64	54	16	1.9	373	0	104	6.4	.3	3.1	-	453
8	Berkbigler	8-66	2.83	60	11	.24	48	25	3.0	.8	264	0	5.2	1.0	.2	.4	-	225
10	Blue (Ste.Gen.)	8-66	.28	61	11	.04	52	21	2.3	1.0	257	0	4.2	1.0	.2	.5	-	220
16	Bray	12-64	A	-	---	.04	-	-	--	--	194	0	63	6.5	.4	1.0	-	296
17	Bruce Cave	6-66	.10	57	13	.93	82	6.5	7.4	4.8	276	0	12	5.1	.1	12	-	287
18	Bunse	11-64	.01	-	---	.36	-	-	--	--	321	0	33	9.0	.3	.0	-	344
20	Cave	6-66	.02	57	14	.19	97	3.5	13	1.8	301	0	21	6.8	.1	19	-	341
21	Chouteau	6-66	.04	63	14	.01	390	137	1,970	42	316	0	376	3,860	1.1	7.4	-	7,410
22	Cook	6-66	.05	56	9.9	.29	78	38	3.2	1.0	367	0	58	1.4	.2	.3	-	375
23	Cosby	11-64	.02	-	---	.64	-	-	--	--	314	0	86	32	.2	22	-	490
27	Dew	12-64	A	-	---	.06	-	-	--	--	179	0	17	4.0	.5	4.2	-	222
31	Eldorado	8-64	.05	62	40	18	16	9.3	26	4.6	0	0	90	43	.0	.3	.01	250
33	Elk Lick	11-65	.05	57	8.6	.03	267	105	1,360	15	304	0	284	2,520	1.0	---	-	4,740
34	Enders	12-64	A	56	---	.05	-	-	--	--	165	0	38	20	.3	70	-	417
36	Flag	8-69	A	61	26.4	.32	81	21	21	.4	375	0	20	8.7	.4	13.1	-	387
39	Garbe	11-64	A	54	---	.15	-	-	--	--	232	0	29	6.0	.3	8.4	-	300
42	Hahn	6-66	1.01	58	9.5	.01	40	21	2.3	.5	224	0	2.6	.9	.2	.0	-	196
53	Jackson	11-64	A	54	---	.03	-	-	--	--	224	0	16	10	.5	27.0	-	378
57	Koester No. 1	8-64	.07	56	16	.04	44	43	3.7	.6	331	4	11	3.0	.0	.9	.01	289
58	Koester No. 2	8-64	.10	58	16	.14	33	30	3.1	.9	244	0	11	3.0	.0	.8	.00	218
59	Koester No. 3	8-64	.44	57	16	.79	29	33	3.5	.7	229	8	13	3.5	.0	.9	.00	221
		6-66	.89	55	11	.02	58	28	3.2	1.2	307	0	21	1.9	.0	.0	-	284
61	Kyger	12-64	A	-	---	.09	-	-	--	--	154	0	44	24	.3	103	-	450
63	Lewis	11-64	.02	-	---	.09	-	-	--	--	306	0	14	7.0	.3	25	-	375
64	Lithium	6-66	.04	57	17	.02	113	38	120	4.6	415	0	36	228	.4	3.7	-	777
68	Mark Twain	9-64	.04	54	17	.00	115	34	14	3.1	398	0	107	16	.2	5.4	.09	524
69	Market Street	8-64	.06	72	36	.05	144	32	76	4.2	201	0	286	119	.3	24	.38	906
75	Montesano	6-34	---	-	8.4	.15	344	146	1,940		283	3	400	3,300	-	.3	-	7,230
76	Mort	12-64	A	55	---	.05	-	-	--	--	478	0	7.9	3.5	.4	1.4	-	419
78	Myrick	12-64	A	-	---	.05	-	-	--	--	381	0	21	5.5	.4	1.9	-	377
80	Nations Mill	8-66	.15	58	9.0	.38	33	17	1.4	.4	182	0	1.8	.6	.5	.0	-	154
82	Nettie Price	12-64	A	51	---	.48	-	-	--	--	220	0	14	5.5	.3	3.0	-	239
85	Pertle	11-65	.03	56	19	4.7	69	19	20	1.5	287	0	49	7.1	.6	.0	-	342
90	R. C. Price	12-64	A	51	---	.36	-	-	--	--	344	0	22	6.0	.3	4.2	-	357
91	Robidoux	12-64	A	55	---	.08	-	-	--	--	504	0	30	12	.1	9.0	-	514
92	Rollins	8-25	---	-	11	.60	145	8.1	23		385	5	79	13	---	8.2	-	482
		8-64	.12	70	2.0	.74	82	42	71		360	29	50	52	.9	1.8	-	508
93	Ross	8-64	.14	62	15	.21	3.1	1.0	2.4	1.0	13	0	1.6	4.5	.0	2.7	.00	38
94	Santa Fe	8-64	.03	56	8.0	.07	85	20	13		343	0	15	9.0	.2	9.1	-	340
95	Schlinder No.1	11-64	.09	-	---	.27	-	-	--		281	0	38	8.5	.2	24	-	374
96	Schlinder No.2	11-64	.05	-	---	.55	-	-	--	--	133	0	39	14	0.3	13	-	247
97	Schmidt	6-66	A	59	24	.02	160	6.4	17	1.0	416	0	39	21	.2	72	-	578
99	Schumer	8-66	.02	57	14	.03	62	23	6.8	1.0	262	0	19	13	.3	3.2	-	279
100	Shepard	12-64	A	-	---	2.8	-	-	--	--	446	0	326	16	.3	2.1	-	930
102	Sly	12-64	.01	-	---	.04	-	-	--	--	509	0	9.7	6.5	.2	.5	-	460
103	Snell Hollow	8-66	.8	57	12	.17	81	12	5.6	1.1	284	0	18	6.6	.3	.5	-	283
104	Steenberger	6-66	A	59	10	.06	64	28	2.6	1.2	325	0	19	1.0	.2	.0	-	295
105	Storbel	6-66	A	59	11	.04	62	25	17	2.9	253	0	41	21	.1	30	-	342
107	Sweet	8-25	.02	-	11	1.3	224	100	740		246	0	112	1,500	-	.2	-	2,900
109	Thomas	12-64	A	-	-	.08	-	-	--	--	470	0	80	14	.4	15	-	580
112	Tritten	11-64	A	54	-	.04	-	-	--	--	307	0	30	20	.3	34	-	396
113	Upper Blue Lick	11-65	.08	58	8.8	1.1	1,120	432	7,000	79	212	0	150	13,300	2.2	-	-	23,400
115	Valle	8-66	1.36	60	20	.34	118	15	33	4.4	376	0	56	39	.5	17	-	488
119	White (Upper)	8-66	.14	57	14	.02	53	20	2.3	1.0	256	0	3.4	1.6	.1	.1	-	220
120	White (Lower)	8-66	.06	55	12	.04	51	5.0	1.6	.9	174	0	4.2	1.0	.0	.0	-	161

Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color	Turbidity
Calcium Magnesium	Noncarbonate				
220	6	400	7.8	0	-
--	--	490	7.1	-	-
--	--	650	7.2	-	-
--	--	490	7.2	-	-
1,300	1,060	---	--	-	-
268	35	534	7.7	2	0
382	76	750	7.2	0	-
203	0	404	7.6	1	-
216	6	399	7.4	8	-
--	--	690	7.8	-	-
231	5	478	7.6	13	-
--	--	430	7.1	-	-
257	10	540	7.3	0	-
1,540	1,280	12,000	7.5	0	-
351	50	630	7.7	0	-
--	--	650	7.0	-	-
--	--	310	6.8	-	-
78	78	408	3.65	5	0
1,100	850	8,070	7.6	1	-
--	--	530	6.8	-	-
290	0	650	7.4	-	-
--	--	400	7.0	-	-
187	3	350	7.7	0	-
--	--	565	7.9	-	-
287	10	524	8.3	5	0
206	6	393	8.2	5	0
208	8	402	8.4	5	0
260	8	500	7.6	0	-
--	--	550	6.5	-	-
--	--	480	7.1	-	-
438	98	1,400	7.5	0	-
427	101	723	7.5	5	2
491	326	1,280	7.8	10	0
1,460	1,230	---	--	-	-
--	--	630	7.0	-	-
--	--	560	7.2	-	-
153	0	284	7.5	2	-
--	--	350	7.2	-	-
250	15	550	7.3	4	-
--	--	540	7.4	-	-
--	--	750	7.1	-	-
397	--	---	--	-	5
380	--	---	--	-	-
12	1	44	7.4	8	5
298	--	---	7.2	-	-
--	--	500	7.1	-	-
--	--	500	7.6	-	-
426	84	869	7.4	0	-
249	34	489	7.3	4	-
--	--	1,200	7.2	-	-
--	--	700	7.2	-	-
252	19	484	7.5	2	-
275	8	540	7.7	0	-
258	50	580	7.2	0	-
969	--	--	-	-	5
--	--	800	7.0	-	-
--	--	540	7.0	-	-
4,580	4,400	35,300	7.0	0	-
356	48	753	7.2	2	-
214	4	399	7.4	0	-
148	5	276	7.3	3	-

The source of the water that occasionally rises in the resurgences along Blue Spring Branch is in the sinkhole plain south of Ball Mill Resurgence. The various areas of sinkhole drainage are integrated into a complex underground drainage system through cave passages trending generally northward toward Blue Spring Branch.

There are doubtless many other resurgences similar to those described here, particularly in the karst areas near Perryville. The recognition and study of such features will be helpful in understanding the origin and development of limestone terranes, and in dealing with environmental problems in such areas.

DEVILS ICEBOX SPRING, *Boone County, Ashland 7½-minute quadrangle, SW¼ sec. 1, T. 47 N., R. 12 W.*

Devils Icebox is the imaginative name of the largest known cave north of the Missouri River in Missouri. It is more than 6 miles long and considered incompletely explored. The passages of the cave system underlie an extensive sinkhole plain developed on the Burlington Limestone of Mississippian age. Runoff water gathered by the depressions on the sinkhole plain are integrated by the cave system and reappear as the cave stream – Devils Icebox Spring. The spring, cave entrance and a large natural bridge are part of Rock Bridge State Park near Columbia.

During dry weather the cave stream is little more than a trickle, but following sustained rainfall the stream rises rapidly and lower passages upstream from the cave entrance may flood completely, thus presenting a hazard to cave explorers. So rapid is the recharge from the sinkhole plain that floodwaters sometimes fill the Big Room, about ½ mile from the entrance, to a depth of several tens of feet, because the passage draining from the Big Room toward the cave entrance is small and incapable of handling the large volume of water.

Rainwater travels from the natural funnels on the sinkhole plain to the stream in Devils Icebox primarily through natural wells or domes (fig. 92) cut in the limestone bedrock by dripping water. A typical shaft is circular in plan and likely to be 40 feet or more in height. The height is determined by resistant chert beds in the upper Burlington Limestone (Hargrove, 1968).

The surface area drained internally by sinkholes to Devils Icebox Cave is shown in figure 93. It is readily apparent that land management and waste

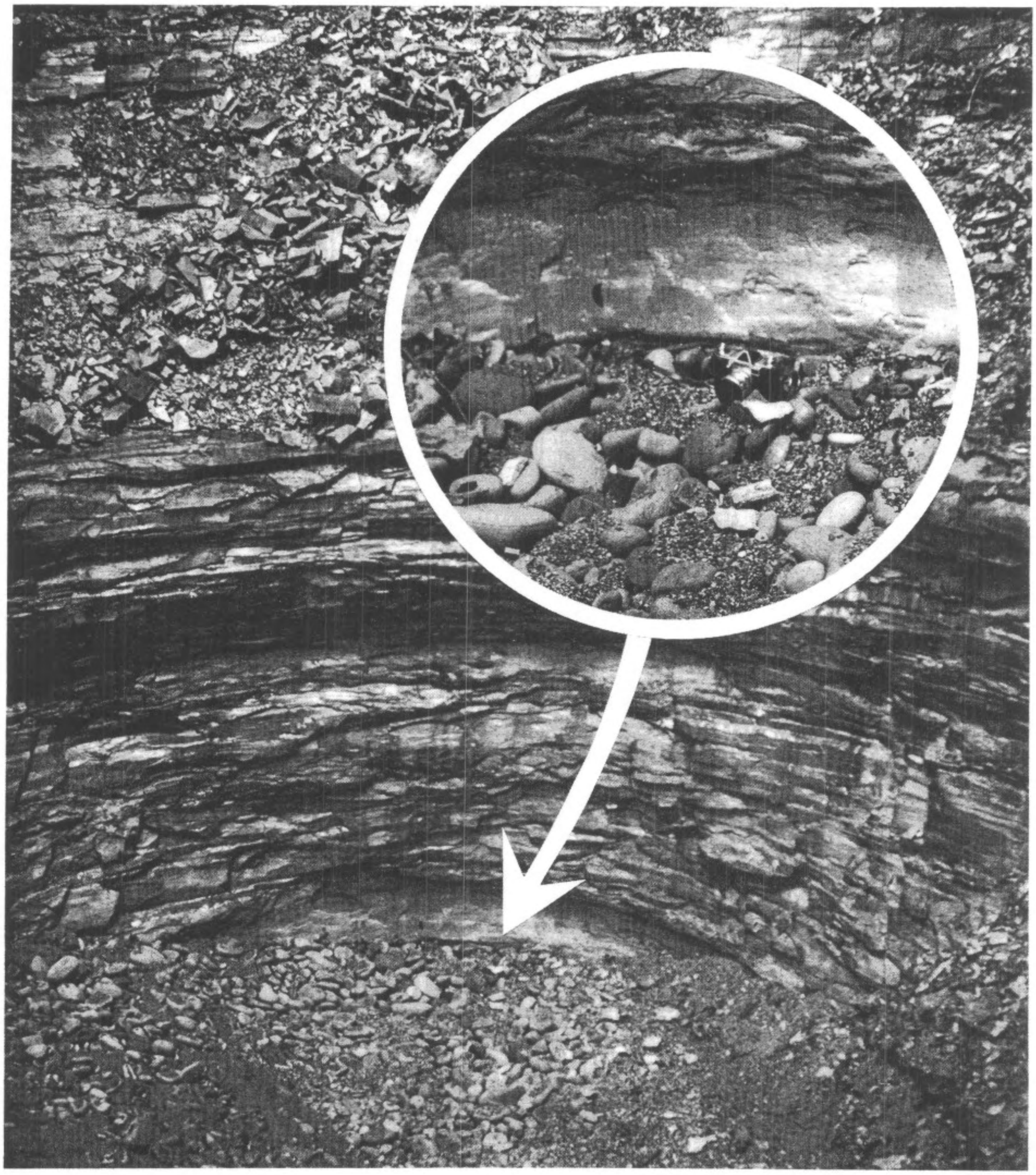


Figure 90

Ball Mill Resurgence is a rise point of stormwaters gathered on the sinkhole plain to the south, and channeled through cave systems to multiple rise points along Blue Spring Branch. The force of the water rising through a choke of broken rock creates a natural milling and tumbling action. The inset shows a closeup of the rocks. Photo by Jerry D. Vineyard.

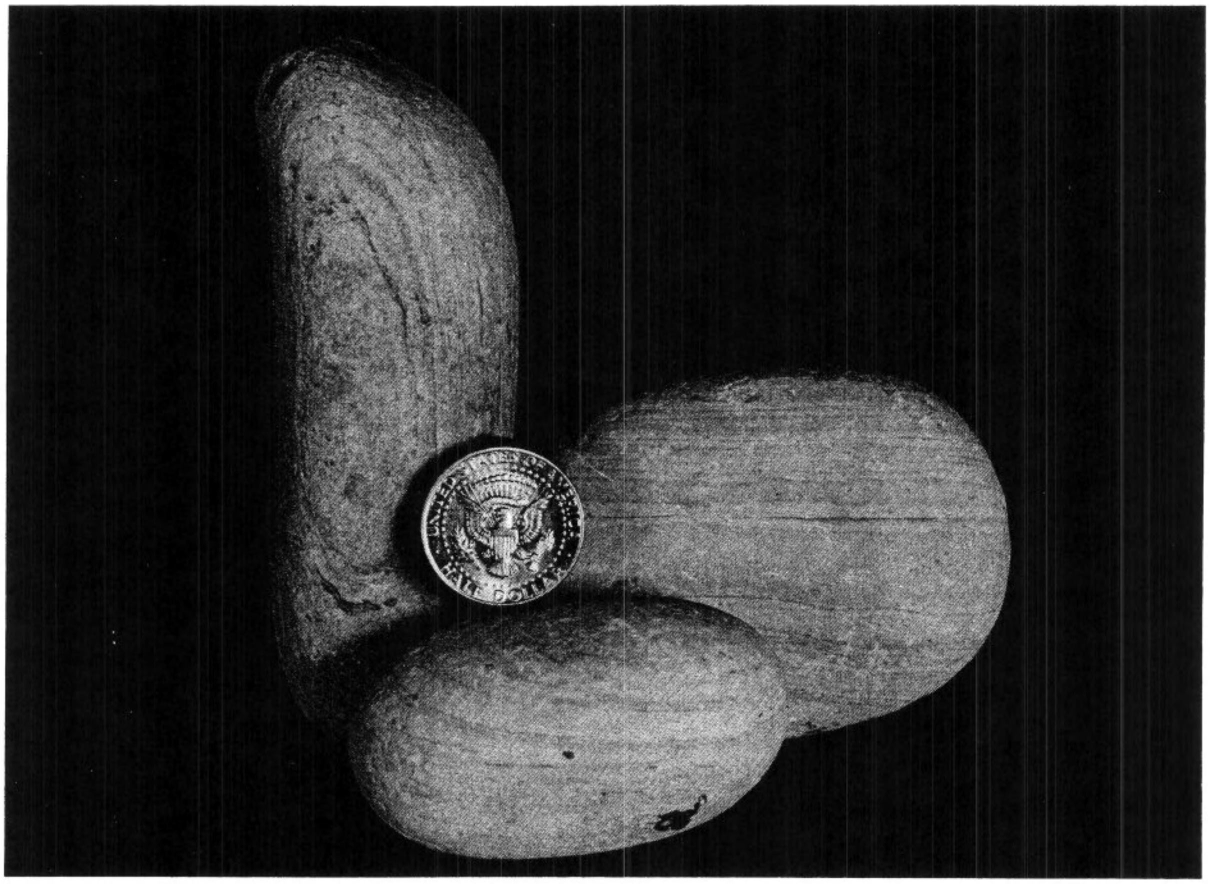


Figure 91

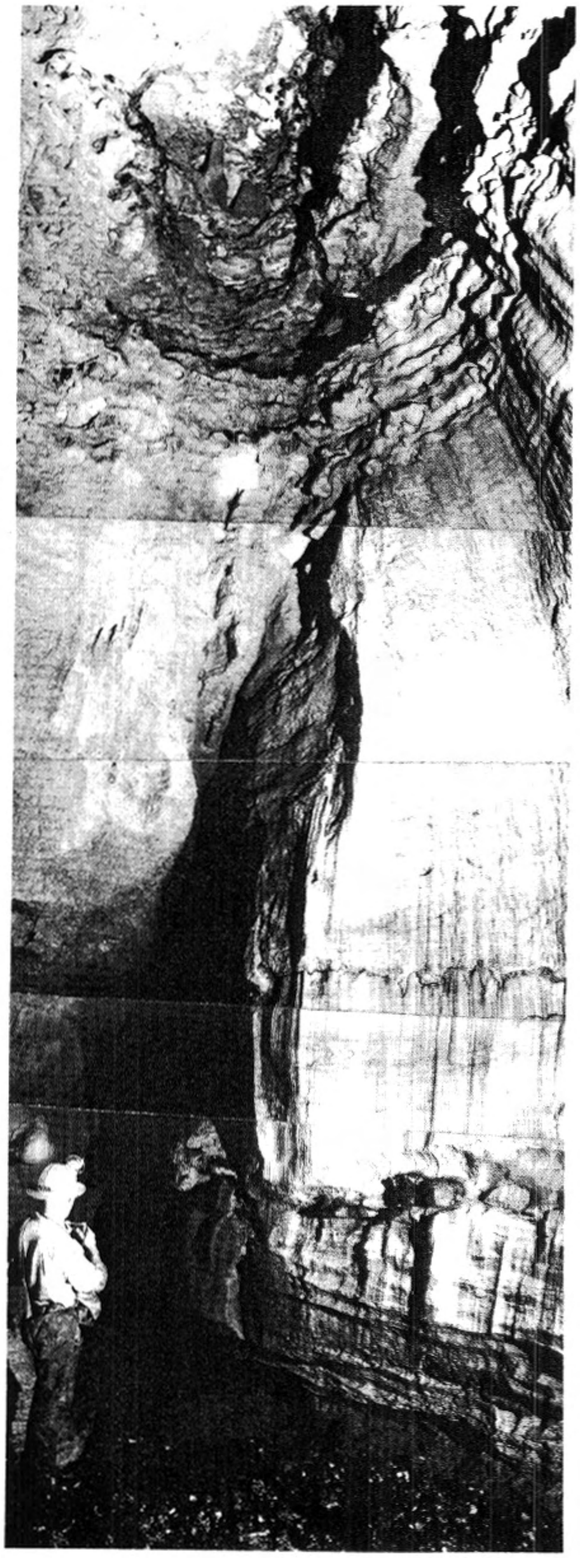
Cobbles of limestone from the basin of Ball Mill Resurgence that have been rounded and smoothed in the natural mill. The "grist" for the mill is constantly replenished by spalling from the cliff above the resurgence, and by the bed load of the karst water stream feeding the resurgence. Photo by Jerry D. Vineyard.

disposal practices on the sinkhole plain, which has only internal drainage and no surface streams, will have direct effects on the spring because its flow comes from the karst area. Residential construction in the area has already resulted in degradation of water quality in Devils Icebox Spring (Vineyard and Williams, 1971, and Middaugh, 1971).

LEWIS AND CLARK SPRING, *Boone County, Rocheport 7½-minute quadrangle, SE¼ NW¼ sec. 24, T. 48 N., R. 12 W.*

According to some authorities, Lewis and Clark camped near Lewis and Clark Spring on their journey up the Missouri River. The spring issues from a cave opening at the base of a bluff along the Missouri River, then passes beneath the roadbed of the M.K.T. railroad which follows the bluffs along the northeast bank of the river.

The catchment area of Lewis and Clark Spring lies north and east of the spring orifice, in a region of intense karst topography. The karst is developed in the Mississippian Burlington Limestone, upon and in which surface and subsurface karst develops. Some of the sinks reach depths of as much as 150 feet and may be more than a quarter mile in diameter. Sinking Creek, which lies about a mile north of Lewis and Clark Spring, drains approximately 4 square miles of karst topography. The drainage passes through Rocheport Cave (now known commercially as Boone Cave), representing subterranean stream



piracy of an entire drainage basin (fig. 94). A similar, though not so far advanced situation exists at Lewis and Clark Spring.

Lewis and Clark Cave, from which the spring flows, may be explored for nearly 1 mile generally east-northeast beneath the karst topography of the uplands. A map of the cave shows the main passage directly beneath a large sinkhole approximately 3/8 mile east-northeast of the spring discharge. Beyond this point there are several other large depressions which probably also drain through the Lewis and Clark system.

Exploration of the spring network is very difficult because of the low ceiling and deep water encountered in several places along the cave passage. It is possible to walk for the first few hundred feet of the passage, but beyond this point it is necessary first to wade in the spring channel, then to proceed in a crouching position, and frequently one must crawl over the rough, cherty gravel floor. The farther one proceeds into the spring-cave, the more unpleasant the trip becomes. Occasionally the low ceiling and cold water of the cave are interrupted by vertical shafts leading upward to sinks above the cave, and by cross-joints that have been enlarged by solution. At these points one may stand, but at other points it is necessary to crawl. At many places along the passage, ceiling heights decrease to less than 1 foot. For most of its length, the cave is developed along bedding planes in the Burlington Limestone, leaving wide passages with a very low ceiling. Toward the explorable limit of the cave, walking passage is encountered for a short distance, but again the cave becomes a low, water-floored, bedding plane passage which may extend for a considerable distance beyond the limit of exploration.

Lewis and Clark Spring is typical of many such springs in the Mississippian limestone terrane of Boone County. Water quality is frequently poor,

Figure 92

Composite photograph of a vertical shaft or dome in Devils Icebox. Note the irregular ceiling formed by chert lenses in the upper Burlington Limestone, and the wall grooves (lapies) cut by water entering the shaft from sinkholes on the surface. Composite photo by Jerry D. Vineyard.

largely because local residents use sinkholes for waste disposal. Discharge of such springs rises dramatically following rains because the upland sinkholes are directly connected with the subterranean cave systems which channel the water beneath upland divides toward a lower-level stream system.

WELDON SPRING, *St. Charles County, Weldon Spring 7½-minute quadrangle, SE¼ NE¼ sec. 28, T. 46 N., R. 3 E.*

Weldon Spring was named for John Weldon who acquired the land from the Spanish in the year 1802. The spring flows from a rocky area at the base of a small hill. It has been improved by a box-like concrete structure which pools the water and the overflow forms a small waterfall.

Weldon Spring is on property owned by Immanuel United Church of Christ; the red brick church, constructed in the year 1874, is on a hill above the spring. The spring and surrounding area is a picturesque and scenic spot that is well maintained by residents of the small community of Weldon Spring.

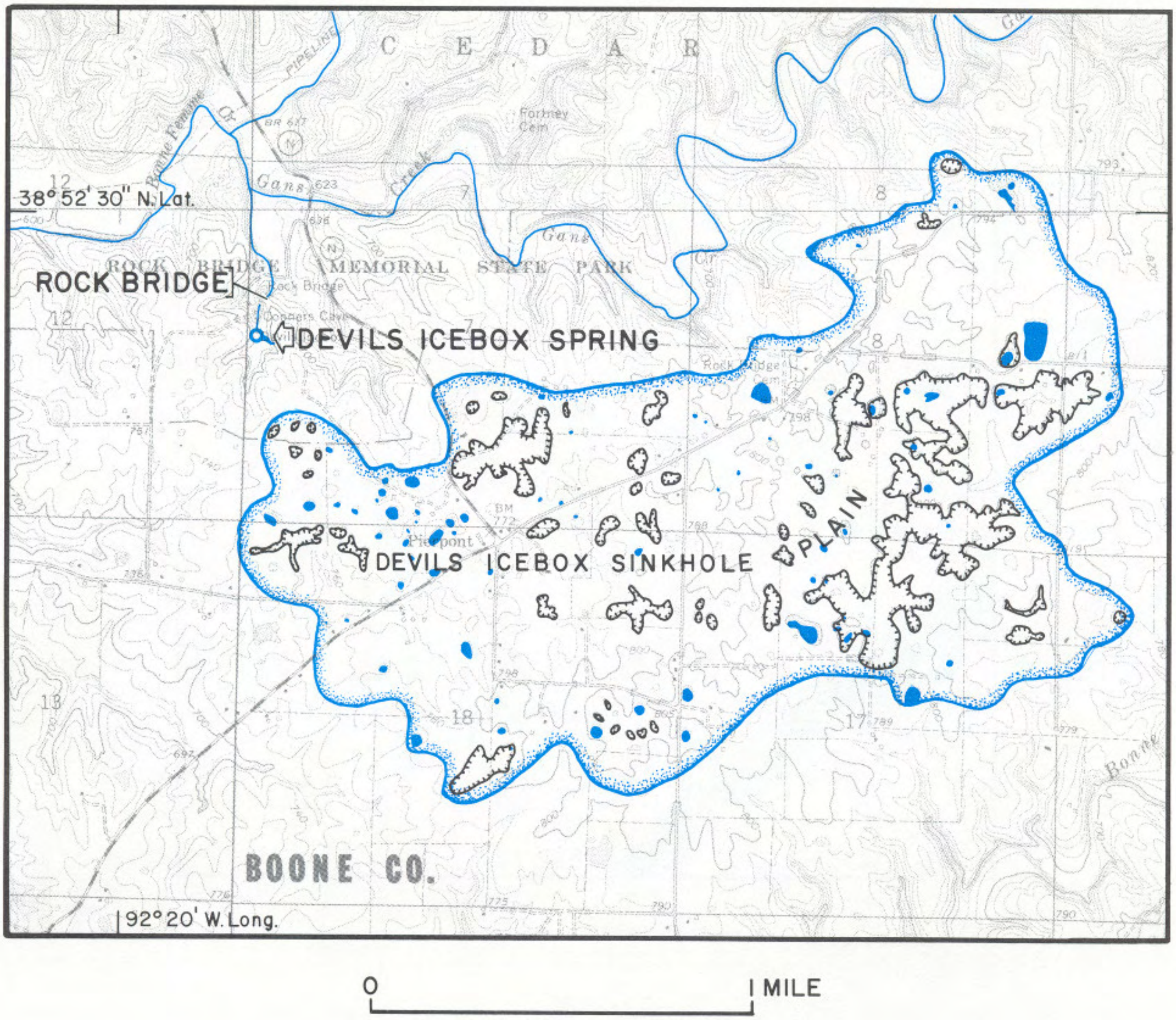


Figure 93

Devils Icebox Spring issues from Devils Icebox through Conners Cave, and its flow comes from water gathered by sinkholes on the uplands south of the cave entrance. Residential waste disposal systems on the sinkhole plain pose a threat to water quality in Devils Icebox Spring. Topography from U.S. Geological Survey, Ashland and Columbia 7½-minute quadrangles.

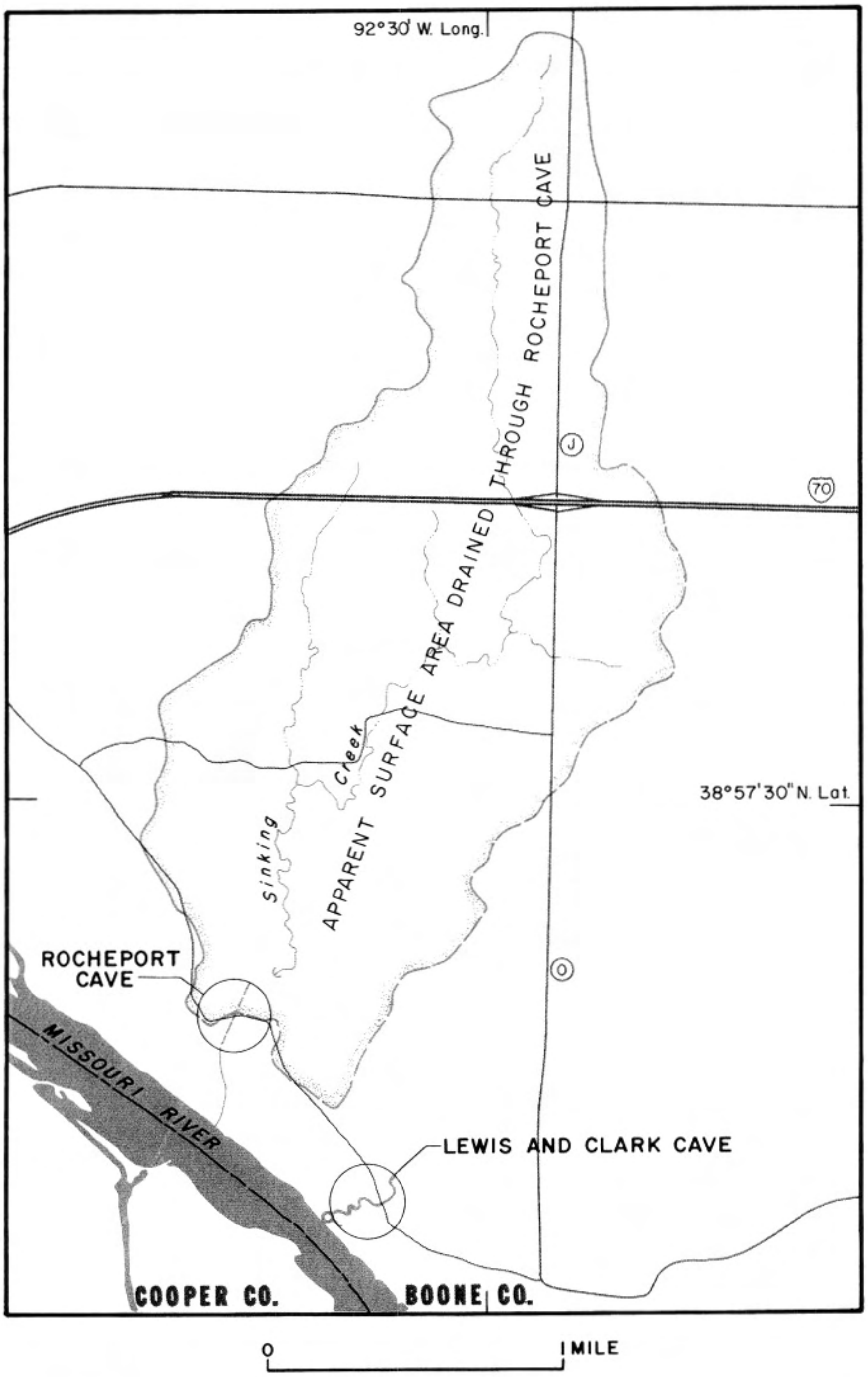


Figure 94

The apparent drainage area of the karst stream passing through Rocheport (Boone) Cave illustrates the nature of springs in limestone terrane. Lewis and Clark Spring, which compares favorably in discharge with Boone Spring, must share the subsurface *drainage area with Sinking Creek. The surface divide is not necessarily coincident with the subsurface divide. Topography from U.S. Geological Survey, Rocheport and Huntsdale 7½-minute quadrangles.*

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