

**WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL
SURVEY IN MISSOURI, 1991-92**

Compiled by Katherine L. Jenkins-Bartle

U.S. GEOLOGICAL SURVEY

Open-File Report 92-626

Rolla, Missouri

1992

U.S. DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

DALLAS L. PECK, Director



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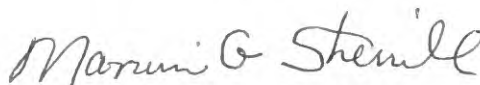
Message from the District Chief

The U.S. Geological Survey, Water Resources Division has a long history of cooperation with State, local, and Federal agencies in providing water information for the benefit of the citizens of Missouri and the Nation. I am a relatively new resident of the State, but I look forward to a continued close working relationship with these agencies in studying and evaluating the critical water resources of Missouri. The data-collection activities and water resources investigations currently underway in Missouri are briefly described in this Activities Report.

Our last Activities Report was completed during 1989. Since then, several of the activities described in that report have been completed and results reported; other, newer studies have been initiated. Examples of our most recent interpretive studies include an evaluation of ground-water flow and quality in the Missouri River alluvium near Kansas City using a Geographic Information System and flow model to store and analyze the data. Two studies at the U.S. Department of Agriculture's Management System Evaluation Area near Centralia also were begun. One involves using nitrogen and oxygen isotopes to measure nitrogen-cycle processes in claypan soils and glacial-drift aquifers; the other will determine the role of macropores in water and nitrogen transport through claypan soils. The Ozark Plateaus study, a part of the National Water-Quality Assessment (NAWQA) Program, also was recently started. Eventually, the NAWQA Program will include 60 different offices that will study and report on the status and trends in the quality of the Nation's surface and ground water.

The hydrologic data-collection program continues to be the backbone of our District operations. Extensive quantities of surface-water, ground-water, and water-quality data are being collected and reported in our Annual Data Report series. The District has made a major effort to get this report published expediently so that the valuable information it contains is available sooner to its many users.

The District also is making a concentrated effort in the area of our interpretive reports. Quality technical reports produced in a timely manner will be a primary goal of the Missouri District.

A handwritten signature in dark ink, reading "Marvin G. Sherrill". The signature is written in a cursive, flowing style.

Marvin G. Sherrill

ORIGIN AND MISSION OF THE U.S. GEOLOGICAL SURVEY

The U.S. Geological Survey was established by an act of Congress on March 3, 1879, to provide a permanent Federal agency to conduct the systematic and scientific “classification of the public lands, and examination of the geological structure, mineral resources, and products of national domain.” An integral part of that original mission includes publishing and disseminating the earth-science information needed to understand, to plan the use of, and to manage the Nation’s energy, land, mineral, and water resources.

Since 1879, the research and fact-finding role of the U.S. Geological Survey has grown and been modified to meet the changing needs of the Nation it serves. As part of that evolution, the U.S. Geological Survey has become the Federal Government’s largest earth-science research agency, the Nation’s largest civilian mapmaking agency, the primary source of data on the Nation’s surface- and ground-water resources, and the employer of the largest number of professional earth scientists. Today’s programs serve a diversity of needs and users. Programs include:

- Conducting detailed assessments of the energy and mineral potential of the Nation’s land and offshore areas.
- Investigating and issuing warnings of earthquakes, volcanic eruptions, landslides, and other geologic and hydrologic hazards.
- Conducting research on the geologic structure of the Nation.
- Studying the geologic features, structure, processes, and history of the other planets of our solar system.
- Conducting topographic surveys of the Nation and preparing topographic and thematic maps and related cartographic products.
- Developing and producing digital cartographic data bases and products.
- Collecting data on a routine basis to determine the quantity, quality, and use of surface and ground water.
- Conducting water-resources appraisals to describe the consequences of alternative plans for developing land and water resources.
- Conducting research in hydraulics and hydrology, and coordinating all Federal water-data acquisition.
- Using remotely sensed data to develop new cartographic, geologic, and hydrologic research techniques for natural resources planning and management.
- Providing earth-science information through an extensive publications program and a network of public access points.

Along with its continuing commitment to meet the growing and changing earth-science needs of the Nation, the U.S. Geological Survey remains dedicated to its original mission to collect, analyze, interpret, publish, and disseminate information about the natural resources of the Nation--providing Earth Science in the public service.

MISSION AND PROGRAM OF THE WATER RESOURCES DIVISION

The mission of the Water Resources Division is to provide the hydrologic information and understanding needed for the optimum utilization and management of the Nation's water resources for the overall benefit of the people of the United States.

This is accomplished, in large part, through cooperation with other Federal and non-Federal agencies by:

- Collecting, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources.
- Conducting analytical and interpretive water-resources appraisals describing the occurrence, availability, and physical, chemical, and biological characteristics of surface and ground water.
- Disseminating the water data and the results of these investigations and research through reports, maps, computerized information services, and other forms of public releases.
- Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground water.
- Providing scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the Department of State.

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CONVERSION FACTORS

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inch	25.40	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	0.4047	hectare
square mile	2.590	square kilometer
gallon	3.785	liter
cubic yard	0.7646	cubic meter
cubic foot per second	0.02832	cubic meter per second
gallon per minute	0.06308	liter per second

WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY

IN MISSOURI, 1991-92

Compiled by

Katherine L. Jenkins-Bartle

ABSTRACT

Water-resources activities of the U.S. Geological Survey in Missouri consist of collecting hydrologic data and making interpretive studies. Hydrologic studies in Missouri are made through three basic types of projects: hydrologic data-collection programs, local or areal hydrologic investigations, and statewide or regional studies. These projects are funded through cooperative joint-funding agreements with State and local agencies, transfer of funds from other Federal agencies, and direct Federal funds. The data and the results of the investigations are published or released by either the U.S. Geological Survey or by cooperating agencies. This report describes the hydrologic data-collection programs, local or areal hydrologic investigations, and statewide or regional studies in Missouri for 1991-92 and provides a list of selected water-resources references for Missouri.

MISSOURI DISTRICT

A District Office of the U.S. Geological Survey was established in Rolla, Missouri, during 1921, when a cooperative program was begun with the Missouri Bureau of Geology and Mines (now the Missouri Department of Natural Resources, Division of Geology and Land Survey). The Missouri District, with field headquarters in Rolla, Independence, and Olivette, and a project office in Independence (fig. 1), investigates the occurrence, quantity, quality, distribution, and movement of surface and ground water in Missouri.

Hydrologic data-collection programs and interpretive studies in Missouri are conducted by two operating sections and three support sections (fig. 2). The two operating sections are responsible for the implementation and execution of District projects assigned to project chiefs.

Operating Sections

The Hydrologic Surveillance and Analysis Section designs, constructs, operates, and maintains all hydrologic-data networks in the State. The Section manages the collection and analysis of the hydrologic data for the State network, prepares water-resources data for the annual water-data report, and provides quality control of results for field and office methods. The Hydrologic Studies Section plans, executes, and reports on water-resources projects, including multidiscipline appraisal studies, and conducts hydrologic and hydraulic investigations. These investigations include ground-water hydraulics and mathematical modeling of aquifer systems, environmental concerns, hydraulics affected by manmade structures, magnitude and frequency of

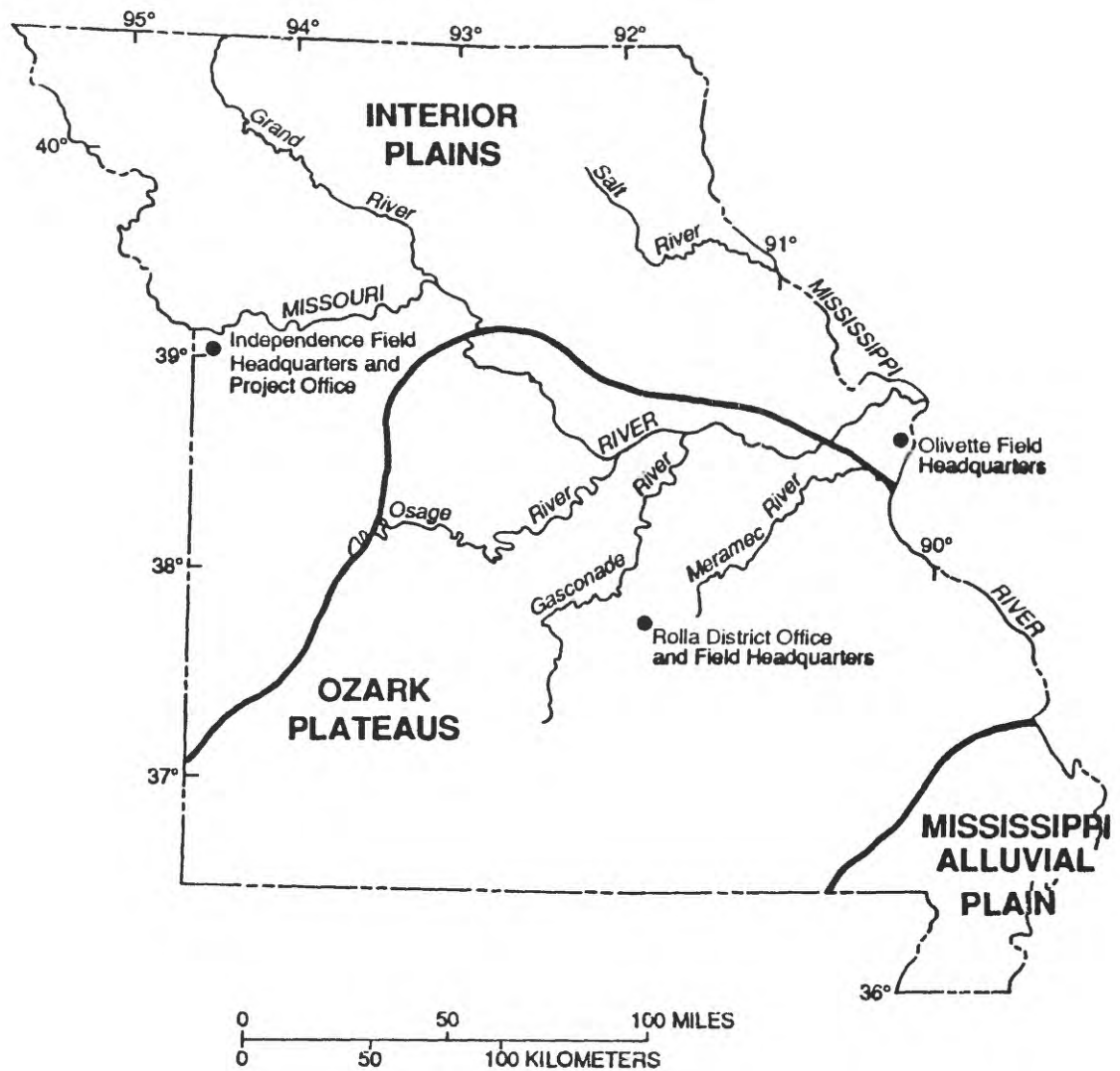
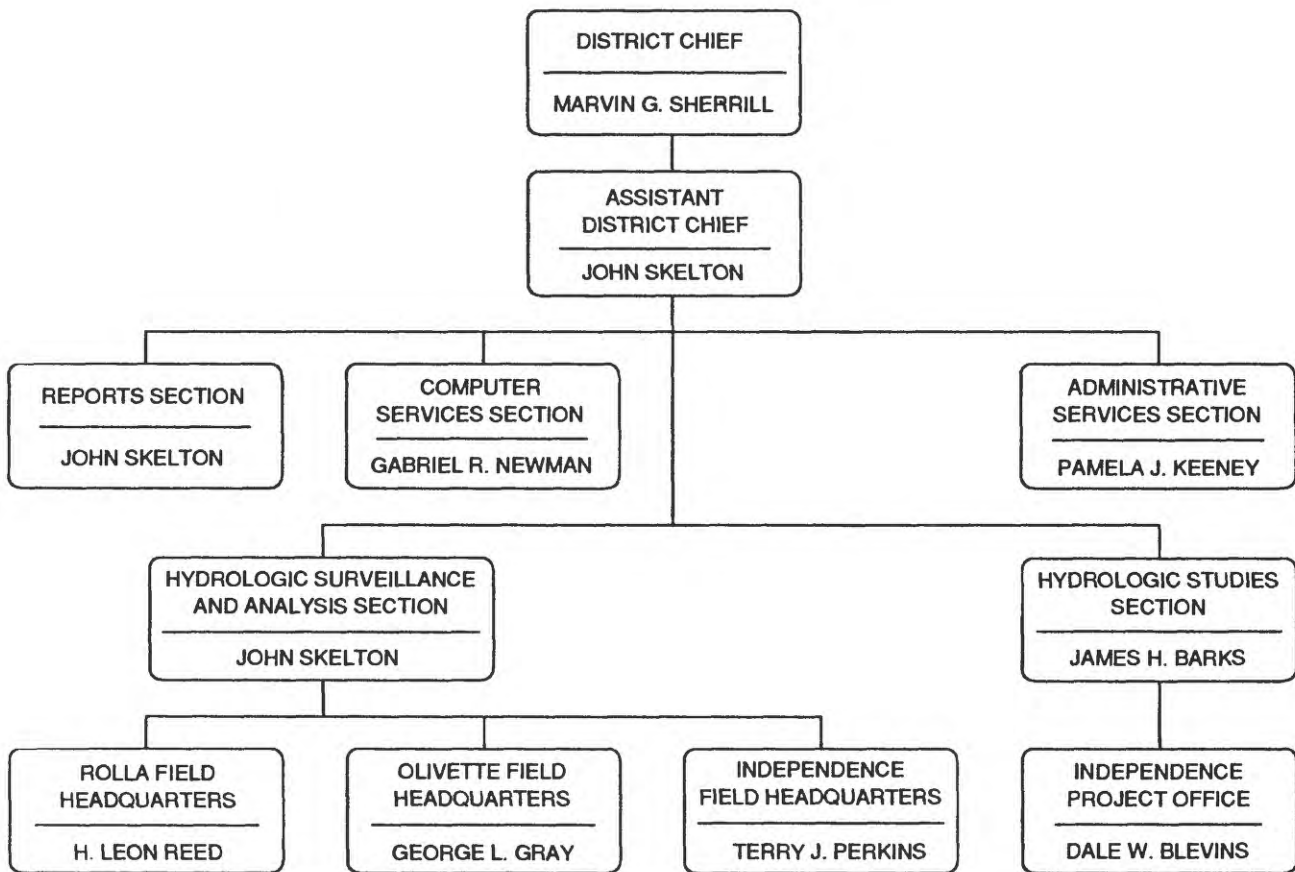


Figure 1.--Location of offices of the U.S. Geological Survey in Missouri.



Rolla Field Headquarters
H.L. Reed, SupvHydroITech
(314) 341-0843
1210 Homelife Plaza
Rolla, MO 65401

DISTRICT OFFICE
(314) 341-0824
1400 Independence Road
Mail Stop 200
Rolla, MO 65401

Olivette Field Headquarters
G.L. Gray, SupvHydroITech
(314) 567-7077
Dielman Industrial Center
9351 Dielman Industrial Drive
Olivette, MO 63132

Independence Field Headquarters
T.J. Perkins, Lead HydroITech
(816) 254-7272
Room 223, Federal Building
301 West Lexington
Independence, MO 64050

Independence Project Office
D.W. Blevins, Hydrologist
(816) 254-5824
Room 219, Federal Building
301 West Lexington
Independence, MO 64050

Figure 2.--Missouri District organization, office addresses, and telephone numbers.

floods and droughts, hydrology of urban areas, analysis of the effects and assessment of hazardous waste and historical and ongoing mineral mining on the hydrologic system, and traveltime and dispersion studies.

Support Sections

The Reports Section maintains records of technical and hydrologic-data reports; reviews project annotated outlines; and edits, types, assembles, verifies, and prepares manuscripts and illustrations for publication. The Section advises and updates District personnel on current report-writing procedures.

The Computer Services Section manages and maintains the District's computer system, and coordinates processing, storage, and retrieval of data for the District and National Computer files. The Section helps design, implement, and maintain the computer program software necessary for District operation.

The Administrative Services Section provides administrative support for the District, including programming, budgeting, accounting, management of personnel, property inventory, travel records, vehicle management, and related services.

COOPERATION AND PROGRAM FUNDING

The Missouri District and agencies of the State of Missouri have had cooperative agreements for the systematic collection of streamflow records since 1921. About 90 percent of the hydrologic data collected by the U.S. Geological Survey in Missouri is in cooperation with local, State, or other Federal agencies. Collection of surface-water data was begun at a few selected sites during 1903; collection of ground-water data in cooperation with the Missouri Department of Natural Resources, Division of Geology and Land Survey, was begun during 1963; and collection of water-quality data was begun during 1962 in cooperation with the Missouri Water Pollution Control Program (now a part of the Missouri Department of Natural Resources, Division of Environmental Quality). Surface-water data primarily are collected cooperatively with other Federal agencies, whereas the ground-water and water-quality data primarily are collected in cooperation with selected divisions of the Missouri Department of Natural Resources. These types of data are needed for the continuing determination and evaluation of the quantity, quality, and use of Missouri's water resources.

Moneys for program operation of the U.S. Geological Survey in Missouri come from joint-funding agreements with local and State agencies, transfer of funds from other Federal agencies, and direct Federal funds. Distribution of funding for program operation during fiscal year 1992 is shown in figure 3.

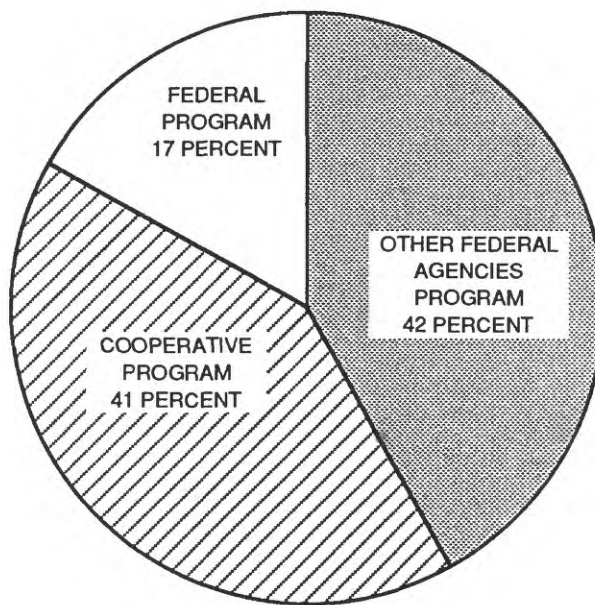


Figure 3.--Distribution of funding for water-resources programs of the U.S. Geological Survey in Missouri, fiscal year 1992.

WATER CONDITIONS

Sufficient water for present demands is available in many parts of Missouri during most years. Annual precipitation ranges from 34 inches in the northwest to 46 inches in the southeast, according to the National Oceanic and Atmospheric Administration (1990; fig. 4), but in some years precipitation has been as much as 15 inches less than normal.

Surface-water supplies generally are adequate for most uses (fig. 5). However, variation in availability occurs within and among the State's three major physiographic regions: the Interior Plains, the Ozark Plateaus, and the Mississippi Alluvial Plain (fig. 6). Some small communities in the Plains region, for example, can have water-supply shortages during droughts because many of the public-water supply districts serve large areas and cannot meet increased demands during extreme low-flow periods. Ozark streams generally have the best-sustained low flows because of the contribution of ground water from extensive solution cavities in the carbonate aquifers. Low flows in the Mississippi Alluvial Plain region are second in magnitude to those of the Ozarks and are sustained by ground-water contributions from the extensive alluvial deposits.

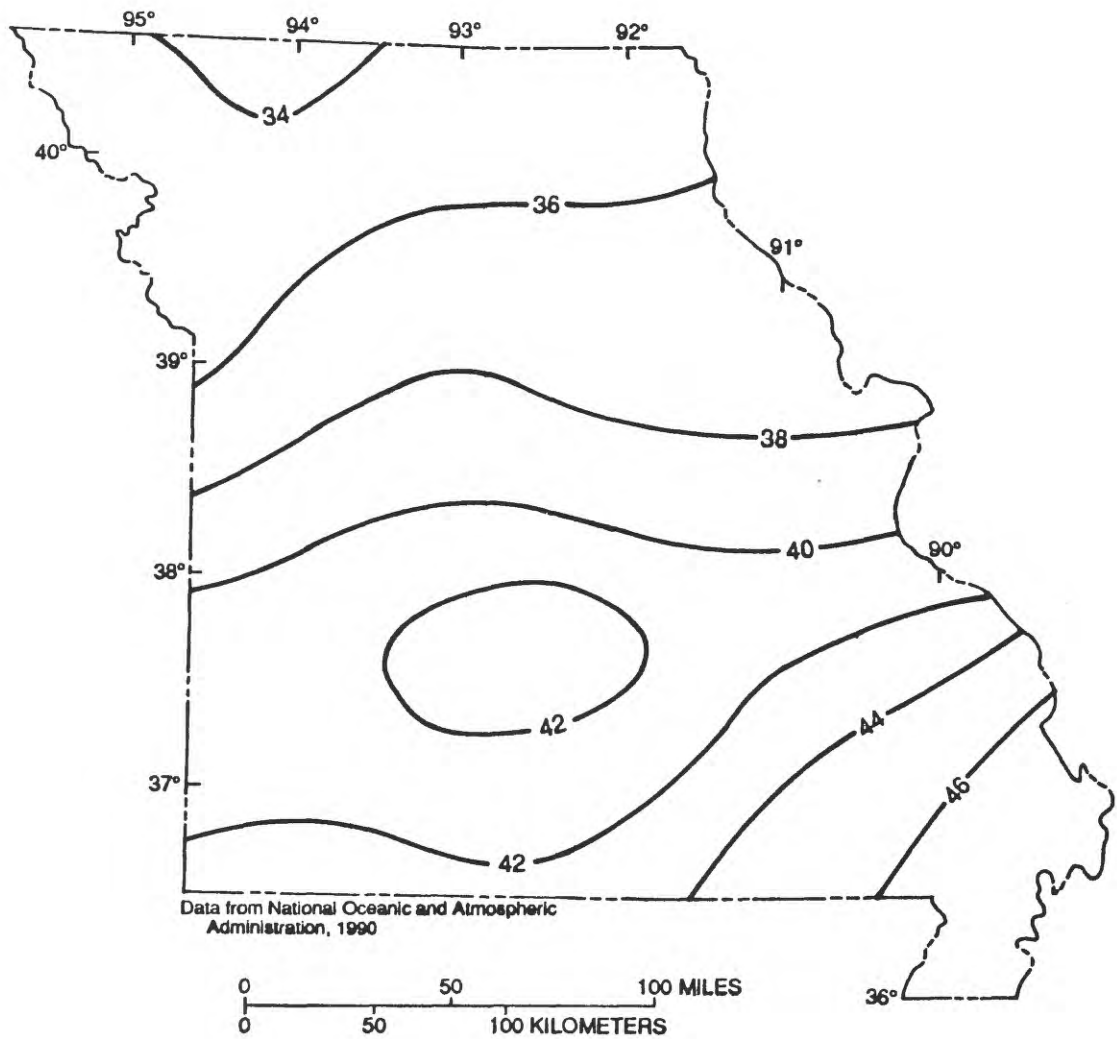
More communities depend on ground water than on surface water, but larger quantities of surface water are withdrawn because most of Missouri's large cities have surface-water supplies. The southeastern two-thirds of the State is underlain by freshwater aquifers (Harris, 1979).

Large quantities of saline ground water are available in the northwestern one-third of Missouri (fig. 7). However, without desalination, this water is unsuitable for most purposes. In local areas of the State, the increased use of ground water for farmland irrigation has lowered ground-water levels.

Generally, water quality in Missouri streams and aquifers is adequate for most uses (Missouri Division of Geology and Land Survey, 1967). However, water-quality concerns in Missouri include stream erosion that is among the largest in the United States; carbonate rocks in the Ozarks region that contain solution-enlarged cracks and crevices allowing contaminants, such as sewage-lagoon effluent, to directly enter the shallow ground-water system; and many obsolete sewage-treatment plants in the State that adversely affect the water quality of streams.

NATIONAL HYDROLOGIC-DATA NETWORKS AND PROGRAMS

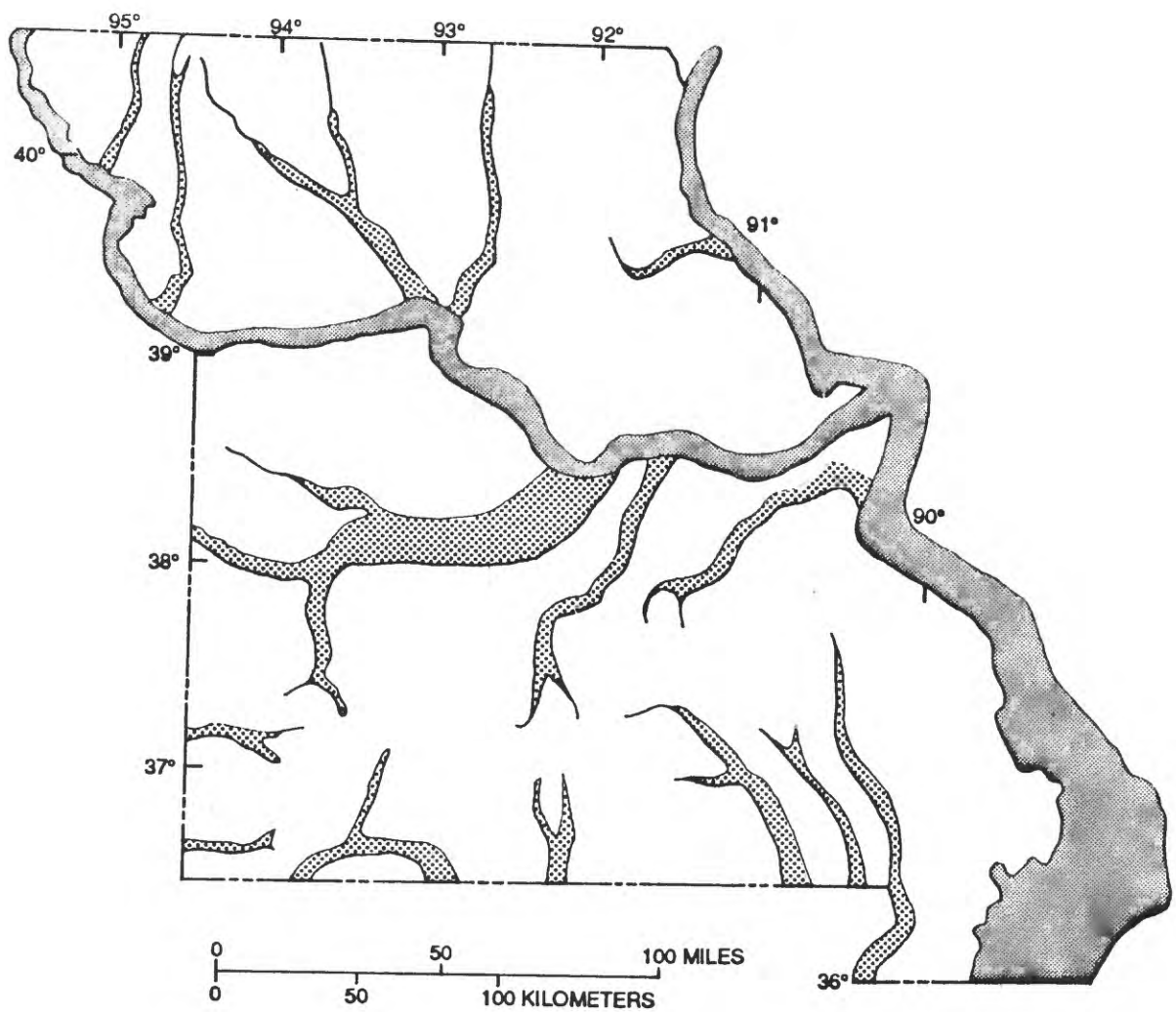
A significant quantity of stream water-quality data is collected in Missouri as part of the National Stream Quality Accounting Network (NASQAN). NASQAN is a data-collecting effort for obtaining consistent regional nationwide overviews of the quality of streams. The primary objectives of the network are to: (1) account for the quantity and quality of water moving within and from major river basins in the United States; (2) depict areal variability; (3) detect changes in stream quality; and (4) provide data for future assessments of changes in stream quality. Ten NASQAN stations are included in the Missouri District's hydrologic data-collection program.



EXPLANATION

— 34 — LINE OF EQUAL PRECIPITATION—
Interval 2 inches

Figure 4.--Mean annual precipitation.



EXPLANATION

WIDTH OF RIVER INDICATES AVERAGE DISCHARGE,
IN CUBIC FEET PER SECOND

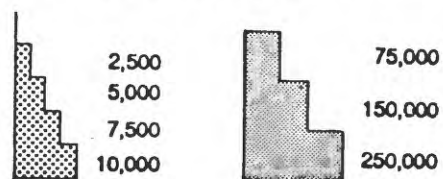


Figure 5.--Average discharge of the principal rivers.

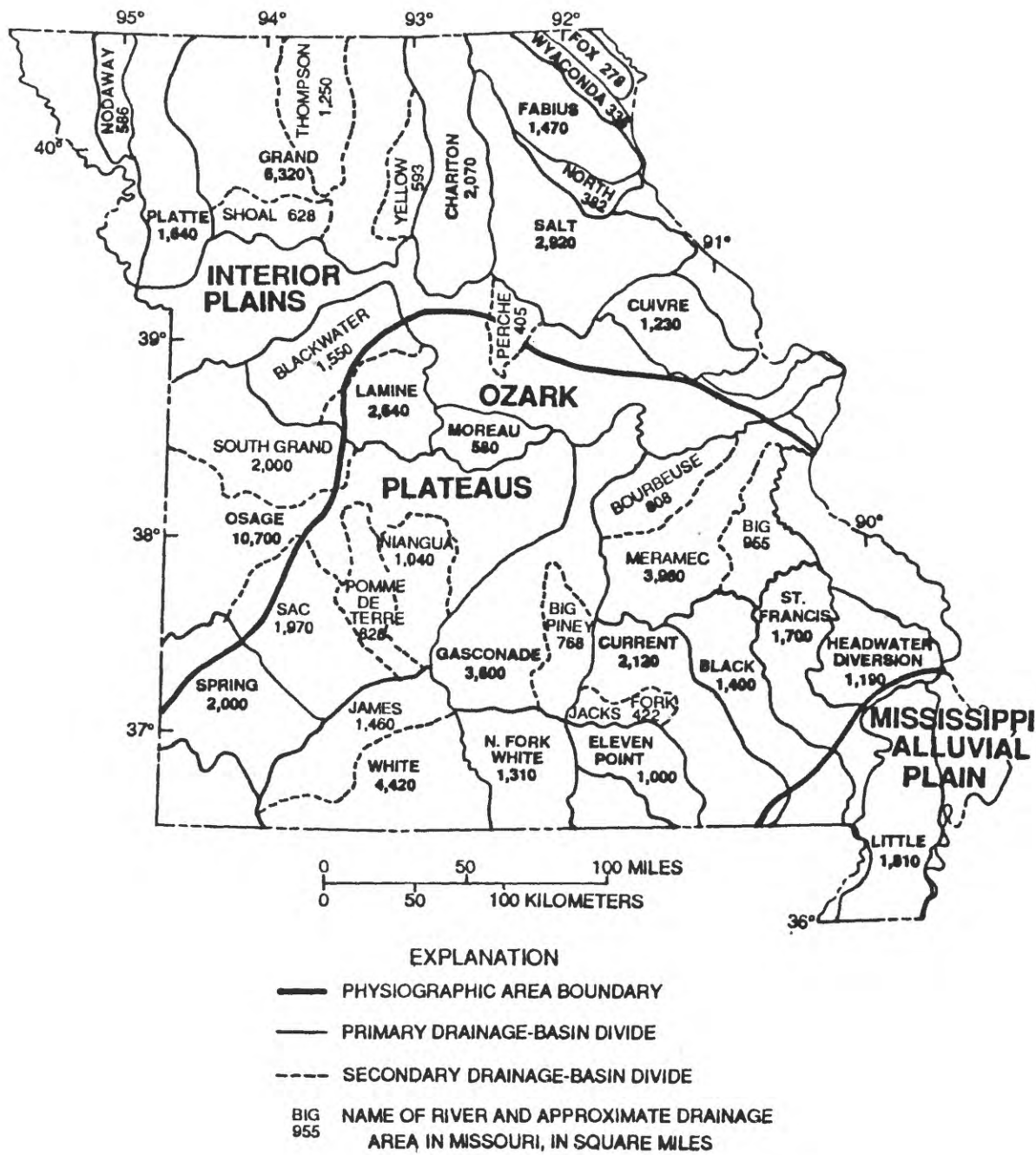


Figure 6.--Physiographic divisions and major drainage basins.

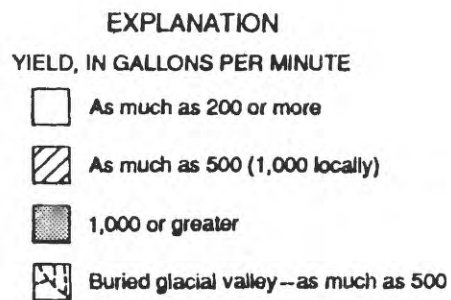
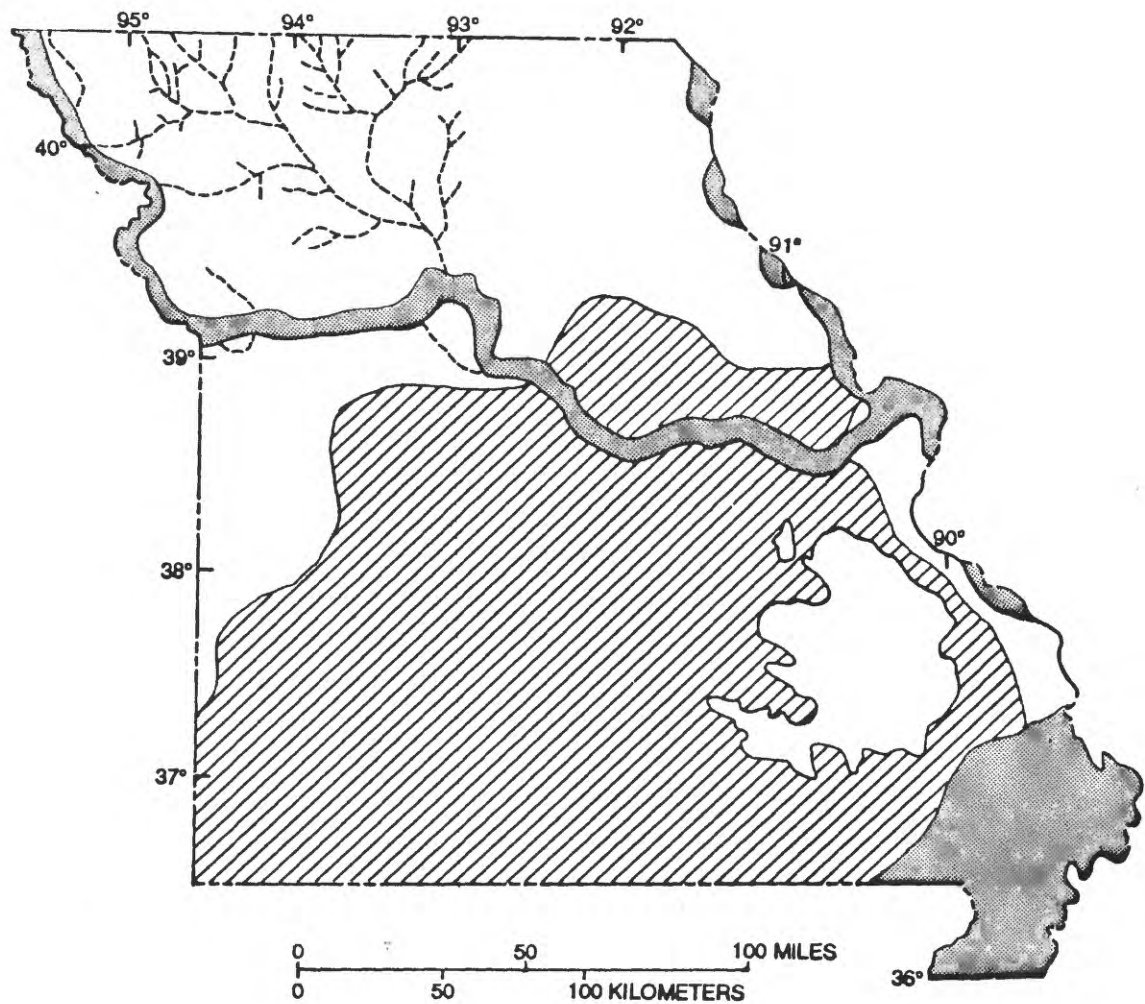


Figure 7.--Availability of ground water.

The National Water-Use Information Program of the U.S. Geological Survey is a Federal-State cooperative program designed to collect, store, and disseminate water-use information both nationally and locally. The program was begun during 1978 to develop a single source of uniform information on water use. The water-use information from this program complements long-term U.S. Geological Survey data on the availability and quality of the Nation's water resources. Information on the National Water-Use Information Program and its data bases can be obtained from the District Office in Rolla.

District Chief
U.S. Geological Survey
Water Resources Division
1400 Independence Road, Mail Stop 200
Rolla, Missouri 65401

As part of the U.S. Geological Survey's program of releasing water data to the public, a large-scale computerized system is used for the storage and retrieval of water data. Presently (1992), all primary U.S. Geological Survey water-resources data are maintained on the National Water Data Storage and Retrieval System (WATSTORE) at the central computer facilities in Reston, Virginia. These data also are stored and are available on District minicomputer files using the Distributed Information System (DIS). The DIS configuration provides easier dissemination and access of data that pertain to a given State. These data are available for water planning and management in machine-readable form, computer-printed tables or graphs, statistical tabulations, and digital plots. Information about the availability of specific types of data, the acquisition of data or products, and user charges can be obtained from the District Office in Rolla.

A Master Water Data Index (MWDI) was developed by the Office of Water Data Coordination (OWDC) and is managed by the National Water Data Exchange (NAWDEX) Program Office to assist users of water data to identify, locate, and acquire needed data. The U.S. Geological Survey, through OWDC, coordinates the water-data-acquisition activities of the U.S. Geological Survey and other Federal agencies. This information is made available to all users of water data by means of a national network of assistance centers. In Missouri, NAWDEX services can be obtained from the District Chief, Rolla, Missouri.

The U.S. Geological Survey outlines flood-prone areas on topographic maps as part of a nationwide Federal program for managing flood losses. Studies of the frequency and extent of flooding in Missouri have resulted in delineation of the 100-year flood boundary on selected topographic quadrangle maps (fig. 8). These maps are available on request from the Missouri District Office in Rolla.

HYDROLOGIC DATA-COLLECTION PROGRAMS

Hydrologic data-collection stations are maintained by the U.S. Geological Survey throughout Missouri to obtain records of stream discharge or stage, lake and reservoir storage, spring discharge, ground-water levels, and the quality of surface and ground water. Major drainage basins in Missouri and approximate areas in square miles are shown in figure 6. Daily discharge and surface-water quality data-collection stations in operation during 1991-92 are listed

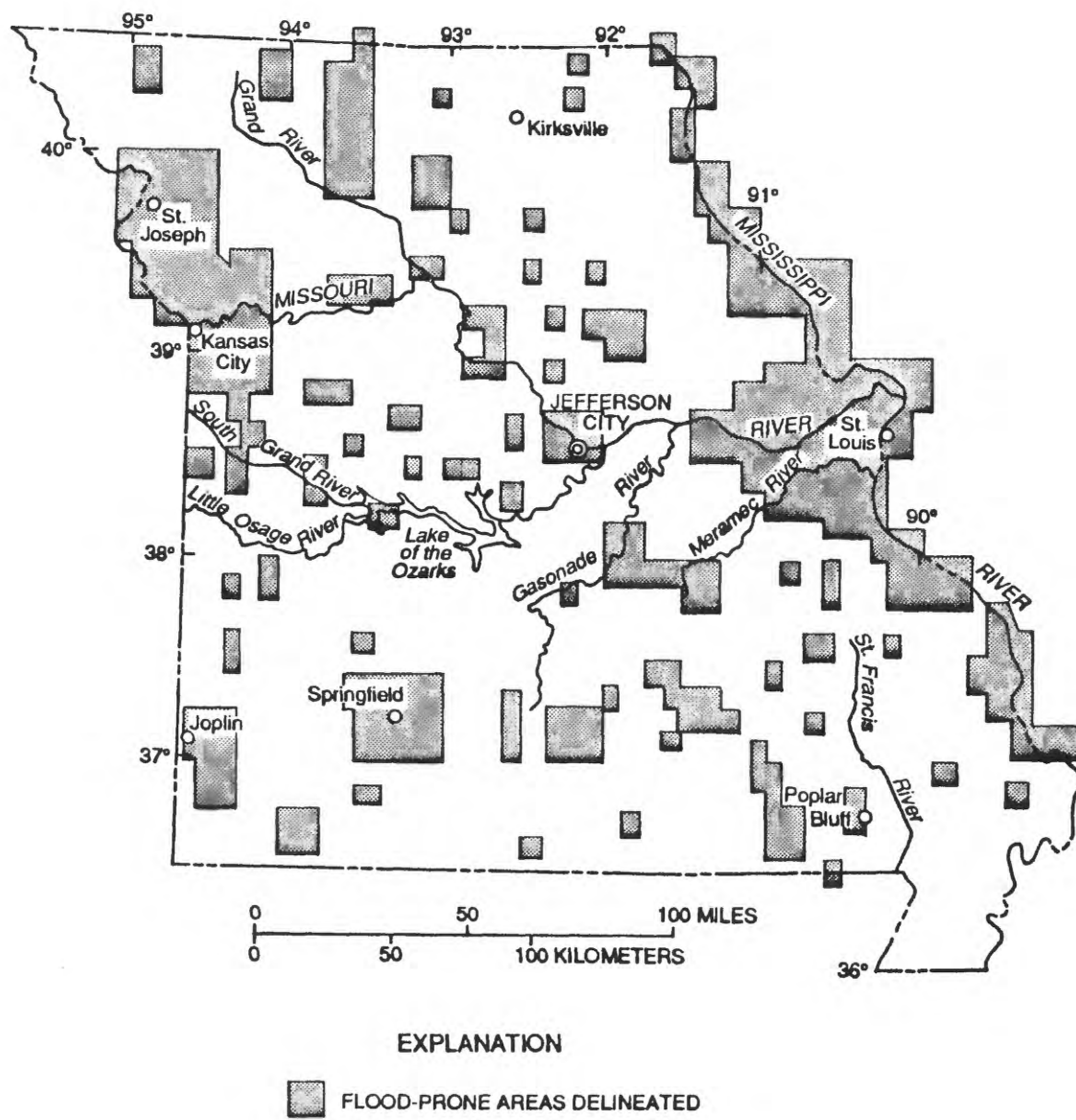


Figure 8.--Flood-prone area maps completed in Missouri.

in downstream order in table 1, which also includes the cooperating agency and type of data collected. In addition to these stations, the Missouri District collects data from several hundred low-flow partial-record stations, peak-flow partial-record stations, and observation wells throughout the State.

Hydrologic data collected in Missouri as part of the data-collection network are published annually in a report entitled "Water Resources Data, Missouri, Water Year 19__" (the water year is from October 1 of each year to September 30 of the following year). These data represent most of the water-resources data collected in Missouri in cooperation with local, State, and other Federal agencies. Reports for each year are released the following year. Water-data reports are available for inspection at the U.S. Geological Survey in Rolla, Missouri, or may be purchased from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia 22161.

Table 1.--Daily discharge, stage, and surface-water quality stations in operation during 1991-92

Station number	Station name	Cooperation ¹	Type of data ¹
05490600	Des Moines River at St. Francisville	CE RI	C,M,S
05495000	Fox River at Wayland	CE RI	D
05496000	Wyaconda River above Canton	CE RI	D
05497000	North Fabius River at Monticello	CE RI	D
05498000	Middle Fabius River near Monticello	CE RI	D
05500000	South Fabius River near Taylor	CE RI	D
05501000	North River at Palmyra	CE RI	D
05502000	Bear Creek at Hannibal	CE RI	D
05502300	North Fork Salt River at Hagers Grove	CE STL	D
05502500	North Fork Salt River near Shelbyna	CE STL	D,S
05503800	Crooked Creek near Paris	CE STL	D
05504800	South Fork Salt River above Santa Fe	CE STL	D
05506500	Middle Fork Salt River at Paris	CE STL	D,S
05506800	Elk Fork Salt River near Madison	CE STL	D
05507600	Lick Creek at Perry	CE STL	D
05507795	Salt River below Cannon Dam	CE STL	St
05507800	Salt River near Center	CE STL	D
05508000	Salt River near New London	CE STL	D,S
05508805	Spencer Creek below Plum Creek near Frankford	CE STL	D
05514500	Cuivre River near Troy	CE STL, DEQ	C,D,M
05587450	Mississippi River at Grafton, Illinois	CE STL	D
05587455	Mississippi River below Grafton, Illinois	NONE	C,M,S
05587498	Mississippi River at Alton, Illinois	CE STL	St
05587795	Mississippi River at Hartford	CE STL	St
06813000	Tarkio River at Fairfax	DGLS	D
06817700	Nodaway River near Graham	CE KC	D
06818000	Missouri River at St. Joseph	CE KC, DEQ	C,D,M,S
06819500	One Hundred and Two River at Maryville	DGLS	D
06820500	Platte River near Agency	CE KC	D
06821140	Smithville Reservoir near Smithville	CE KC	D
06821150	Little Platte River at Smithville	CE KC	D
06821190	Platte River at Sharps Station	CE KC	C,D,M
06893000	Missouri River at Kansas City	CE KC	D,S
06893500	Blue River near Kansas City	CE KC	D
06893590	Blue River at 12th Street in Kansas City	CE KC	St

**Table 1.--Daily discharge, stage, and surface-water quality stations in operation
during 1991-92--Continued**

Station number	Station name	Cooperation ¹	Type of data ¹
06893791	Longview Reservoir at Kansas City	CE KC	R
06893793	Little Blue River below Longview Dam at Kansas City	CE KC	D
06893880	Lake Jacomo near Blue Springs	CE KC	St
06893885	Blue Springs Reservoir near Blue Springs	CE KC	St
06893890	East Fork Little Blue River near Blue Springs	CE KC	St
06894000	Little Blue River near Lake City	CE KC	D
06895500	Missouri River at Waverly	CE KC	D
06897500	Grand River near Gallatin	CE KC	D
06899500	Thompson River at Trenton	CE KC	D
06899680	Grand River at Chillicothe	CE KC	D
06900000	Medicine Creek near Galt	DGLS	D
06902000	Grand River near Sumner	CE KC, DEQ	C,D,M
06904050	Chariton River at Livonia	CE KC	D
06904500	Chariton River at Novinger	CE KC	D
06905500	Chariton River near Prairie Hill	CE KC	D
06906000	Mussel Fork near Musselfork	CE KC	St
06906190	Long Branch Reservoir near Macon	CE KC	R
06906200	East Fork Little Chariton River near Macon	CE KC	D
06906300	East Fork Little Chariton River near Huntsville	CE KC, DEQ	C,D,M
06906500	Missouri River at Glasgow	CE KC, DEQ	C,D,M
06906800	Lamine River near Otterville	DC	D
06908000	Blackwater River at Blue Lick	CE KC	D
06909000	Missouri River at Boonville	CE KC	D
06910230	Hinkson Creek near Columbia	DC	D,T
06910410	Cedar Creek near Columbia	DC	D,T
06910450	Missouri River at Jefferson City	UE	St
06916664	Marais des Cygnes River at Rich Hill	CE KC	St
06916670	Miami Creek near Butler	CE KC	St
06917060	Little Osage River near Horton	CE KC	St
06918065	Marmaton River near Nevada	CE KC	St
06918070	Osage River above Schell City	CE KC	C,D,M,S
06918330	Clear Creek near Eldorado Springs	CE KC	St
06918335	Monegaw Creek at Monegaw Springs	CE KC	St
06918440	Sac River near Dadeville	CE KC	D
06918460	Turnback Creek above Greenfield	CE KC	D

Table 1.--Daily discharge, stage, and surface-water quality stations in operation during 1991-92--Continued

Station number	Station name	Cooperation ¹	Type of data ¹
06918740	Little Sac River near Morrisville	CE KC	D
06918990	Stockton Lake near Stockton	CE KC	R
06919000	Sac River near Stockton	CE KC	St
06919020	Sac River below Stockton	CE KC	D
06919500	Cedar Creek near Pleasant View	CE KC	D
06919900	Sac River near Caplinger Mills	CE KC	D
06920500	Osage River at Osceola	CE KC	St
06921070	Pomme de Terre River near Polk	CE KC, DGLS	D
06921200	Lindley Creek near Polk	CE KC	D
06921350	Pomme de Terre River near Hermintage	CE KC	D
06921760	South Grand River near Clinton	CE KC	D,S
06922075	Tributary to Middle Fork Tebo Creek near Leeton	DEQ	C
06922190	West Fork Tebo Creek near Lewis	CE KC	C,M
06922440	Harry S. Truman Reservoir at Warsaw	CE KC	R
06922450	Osage River below Truman Dam at Warsaw	CE KC	D
06922500	Osage River at Warsaw	CE KC	St
06922550	Osage River below Warsaw	CE KC	St
06922560	Lake of the Ozarks at Oar House Marina	CE KC	St
06922790	Lake of the Ozarks above Buffalo Creek	CE KC	St
06922900	Lake of the Ozarks at Rainy Creek	CE KC	St
06923250	Niangua River near Windyville	DEQ	C,M
06923500	Bennett Spring at Bennett Springs	DGLS, DEQ	C,D,M
06925500	Lake of the Ozarks near Bagnell	UE	R
06926000	Osage River near Bagnell	UE	D
06926500	Osage River near St. Thomas	UE	D
06926510	Osage River below St. Thomas	FED	C,M
06930000	Big Piney River near Big Piney	FED	D
06930800	Gasconade River above Jerome	DEQ	C
06932000	Little Piney Creek at Newburg	FED	D
06933500	Gasconade River at Jerome	FED	D
06934000	Gasconade River at Rich Fountain	CE KC	D
06934500	Missouri River at Hermann	CE KC, DEQ	C,D,M,S,T
06935965	Missouri River at St. Charles	CE STL	St
07010000	Mississippi River at St. Louis	CE STL	D,S,T
07013000	Meramec River near Steelville	CE STL	D

**Table 1.--Daily discharge, stage, and surface-water quality stations in operation
during 1991-92--Continued**

Station number	Station name	Cooperation ¹	Type of data ¹
07014500	Meramec River near Sullivan	CE STL	D
07015720	Bourbeuse River near Highgate	CE STL	D
07016500	Bourbeuse River at Union	CE STL	D
07017020	Meramec River at Pacific	CE STL	St
07017200	Big River at Irondale	CE STL	D
07018100	Big River near Richwoods	CE STL	D
07018500	Big River near Byrnesville	CE STL	D
07019000	Meramec River near Eureka	CE STL	C,D,M
07019280	Meramec River at Paulina Hills	DEQ	C,M
07019300	Meramec River at Arnold	CE STL	St
07020500	Mississippi River at Chester, Illinois	CE STL	D,S
07020850	Mississippi River at Cape Girardeau	CE STL	St
07021000	Castor River at Zalma	DGLS	D
07022000	Mississippi River at Thebes, Illinois	CE STL	C,D,M,S
07034000	St. Francis River near Roselle	CE STL	D
07035000	Little St. Francis River near Fredericktown	CE STL	D
07035800	St. Francis River near Mill Creek	CE STL	D
07036100	St. Francis River near Saco	CE STL	D,S
07037000	Big Creek at Des Arc	CE STL	D
07037500	St. Francis River near Patterson	CE STL	D
07039000	Wappapello Lake at Wappapello	CE STL	R
07039500	St. Francis River at Wappapello	CE STL	D
07042500	Little River Ditch 251 near Lilbourn	DGLS	D
07043500	Little River Ditch 1 near Morehouse	DGLS	D
07050700	James River near Springfield	CU	D
07052500	James River at Galena	CE LR	D
07053400	Table Rock Lake near Branson	CE LR	R
07053450	White River below Table Rock Dam near Branson	CE LR	C,T
07053500	White River near Branson	CE LR	D
07053600	Lake Taneycomo at College of the Ozarks	CE LR	C,St,T
07053700	Lake Taneycomo at Branson	DEQ	C,M
07053820	Lake Taneycomo at Powersite Dam	CE LR	St
07057500	North Fork River near Tecumseh	CE LR	D
07061500	Black River near Annapolis	CE LR	D
07062000	Clearwater Lake near Piedmont	CE LR	R

**Table 1.--Daily discharge, stage, and surface-water quality stations in operation
during 1991-92--Continued**

Station number	Station name	Cooperation ¹	Type of data ¹
07062500	Black River at Leeper	CE LR	D
07063000	Black River at Poplar Bluff	CE LR	D
07063500	Cane Creek at Harviell	CE LR	St
07064400	Montauk Springs at Montauk	NPS	C
07064440	Current River below Montauk State Park	NPS	C
07064530	Welch Spring near Akers	NPS	C
07064555	Pullite Spring near Round Spring	NPS	C
07065000	Round Spring at Round Spring	NPS	C
07065500	Alley Spring at Alley	NPS	C
07066000	Jacks Fork at Eminence	DGLS	D
07066110	Jacks Fork above Two Rivers	NPS	C
07066510	Current River above Powder Mill	NPS	C
07066550	Blue Spring near Eminence	NPS	C
07067000	Current River at Van Buren	CE LR	D
07067500	Big Spring near Van Buren	FED, NPS	C,D
07067800	Current River below Hawes Campground	NPS	C
07068000	Current River at Doniphan	CE LR	D
07071000	Greer Spring at Greer	DGLS	D
07071500	Eleven Point River near Bardley	CE LR	D
07186000	Spring River near Waco	CE TU	D
07186400	Center Creek near Carterville	DGLS	D
07187000	Shoal Creek above Joplin	CE TU	D
07189000	Elk River at Tiff City	CE TU	D

¹Explanation of abbreviations:

Cooperation

CE KC	U.S. Army Corps of Engineers, Kansas City
CE LR	U.S. Army Corps of Engineers, Little Rock
CE RI	U.S. Army Corps of Engineers, Rock Island
CE STL	U.S. Army Corps of Engineers, St. Louis
CE TU	U.S. Army Corps of Engineers, Tulsa
CU	City Utilities of Springfield
DEQ	Missouri Division of Environmental Quality
DGLS	Missouri Division of Geology and Land Survey
UE	Union Electric Company of Missouri
NPS	National Park Service
LRC	Missouri Land Reclamation Commission
DC	Missouri Department of Conservation
FED	Federal

Type of Data

C	Chemical
D	Discharge--continuous record of stage and discharge
M	Microbiological
R	Reservoir content or elevation
S	Sediment
St	Stage only
T	Temperature

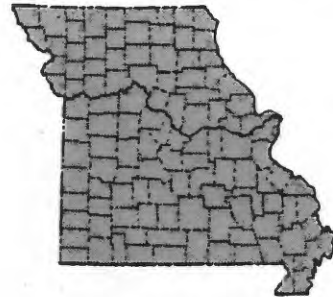
Collection of Surface-Water Data (MO 00-001)

in cooperation with

Union Electric Company of Missouri
Missouri Highway and
Transportation Commission
Missouri Department of Natural Resources,
Division of Geology and Land Survey

National Park Service
City Utilities of Springfield
U.S. Army Corps of Engineers
City of Cape Girardeau
Missouri Department of Conservation

John Skelton, Project Chief



NEED FOR STUDY

Surface-water information is needed for surveillance, planning, design, hazard warning, and operation and management in water-related fields, such as water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, contamination abatement, flood-plain management, waste disposal, and water-resources development.

OBJECTIVES

(1) Collect surface-water data sufficient to satisfy needs for current-purpose uses, such as assessment of water resources; operation of reservoirs or industries; forecasting, disposal of wastes, both common and nuclear; contamination controls; discharge data to accompany water-quality measurements; compact and legal requirements; and research or special studies. (2) Collect data necessary for analytical studies and define the trends and statistical properties of streamflow.

APPROACH

Standard methods of data collection will be used as described in the series *Techniques of Water-Resources Investigations of the U.S. Geological Survey*.

ACTIVITIES DURING 1991

The 1990 annual water-data report was completed and submitted to the U.S. Government Printing Office in March 1991; printed copies were distributed to cooperators and other Federal agencies.

Collection of Surface-Water Data (MO 00-001)--Continued

PLANNED ACTIVITIES DURING 1992

Data collection will continue, and a date of April 1992 is anticipated for completion of the 1991 water-data report.

REPORT

Reed, H.L., Hatten, D.O., Perkins, T.J., Gray, G.L., and Davis, J.V., 1991, Water-resources data, Missouri, water year 1990: U.S. Geological Survey Water-Data Report MO-90-1, 304 p. (published annually).

Collection of Ground-Water Data (MO 00-002)

in cooperation with

Missouri Department of Natural Resources,
Division of Geology and Land Survey

Michael J. Kleeschulte, Project Chief



NEED FOR STUDY

Ground-water information is needed to evaluate the effects of climatic variations on recharge to and discharge from the aquifer systems, to provide a data base for measuring the effects of development, to assist in the prediction of future supplies, and to provide data for management of the resources.

OBJECTIVES

(1) Collect sufficient data to provide a long-term data base so that the general response of the hydrologic system to natural climatic variations and induced stresses is known to allow for proper planning and management of potential concerns in the State. (2) Provide a data base from which the short-term records acquired in areal studies can be analyzed.

APPROACH

Evaluation of regional geology allows a broad, general definition of aquifer systems and their boundary conditions. Within this framework, data will be collected to help define stresses on the systems and the hydrologic properties of the aquifers. The data-collection network will be refined as records accumulate and detailed areal studies of the ground-water system more closely define the aquifers, their properties, and the stresses to which they are subjected.

ACTIVITIES DURING 1991

Continuous ground-water level data were collected and processed for about 50 wells throughout the State. The data were published in "Water Resources Data, Missouri" (published annually).

PLANNED ACTIVITIES DURING 1992

Data collection for all but 3 of the about 50 wells in the ground-water monitoring program will be returned to the Missouri Department of Natural Resources.

Collection of Ground-Water Data (MO 00-002)--Continued

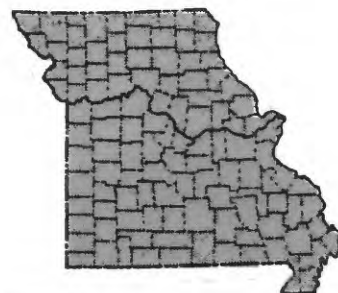
REPORT

Reed, H.L., Hatten, D.O., Perkins, T.J., Gray, G.L., and Davis, J.V., 1991, Water-resources data, Missouri, water year 1990: U.S. Geological Survey Water-Data Report MO-90-1, 304 p. (published annually).

Collection of Quality-Water Data (MO 00-003)

in cooperation with

Missouri Department of Natural Resources, Land Reclamation
Commission, and Division of Environmental Quality
Missouri Department of Conservation
National Park Service
U.S. Army Corps of Engineers
Illinois Environmental Protection Agency



Emmit C. Witt, Project Chief

NEED FOR STUDY

Water-resources planning and water-quality assessment require a statewide and nationwide base of relatively standardized information. For planning and assessment of the water resources, the chemical and physical quality of the rivers and streams needs to be defined and monitored.

OBJECTIVES

(1) Collect sufficient data to provide a long-term data base so that the general water quality of the hydrologic system is known to allow for proper planning and management of potential concerns in the State. (2) Collect data necessary for analytical studies and define the trends and statistical properties of water-quality conditions.

APPROACH

A network of quality-water stations will be operated to measure chemical conditions, loads, and time trends as required by planning and management agencies.

ACTIVITIES DURING 1991

The Missouri District water-quality network included 10 NASQAN stations. Seven stations were sampled bimonthly and three were sampled quarterly for major constituents, nutrients, and trace elements; one was sampled daily for temperature and specific conductance. Samples for major constituents, nutrients, and trace elements were collected monthly at five stations operated in cooperation with the Missouri Department of Natural Resources. Samples for specific conductance were operated at four stations; two for the U.S. Army Corps of Engineers, one for the Missouri Department of Natural Resources, and one for the Missouri Department of Conservation.

Collection of Sediment Data (MO 00-004)

in cooperation with

U.S. Army Corps of Engineers

Robert R. Holmes Jr., Project Chief



NEED FOR STUDY

Water-resources planning and water-quality assessment require a nationwide base level of relatively standardized information. Sediment concentrations and discharges in Missouri's rivers and streams need to be defined and monitored.

OBJECTIVE

Provide sediment data for use in comprehensive State and Federal planning and action programs, including State and Federal management of interstate and international waters.

APPROACH

A network of sediment stations will be established and operated to provide spatial and temporal averages and trends of sediment concentration, sediment discharge, and particle size of sediment being transported by rivers and streams.

ACTIVITIES DURING 1991

The operation of 10 daily suspended-sediment data sites, 7 partial record suspended sediment sites, and 1 bedload site continued, and the data were published in "Water Resources Data, Missouri" (published annually). Historical suspended-sediment data for the Missouri River at Hermann were entered into the data base. The sediment computation program SEDCALC was evaluated on two Missouri sediment stations.

PLANNED ACTIVITIES DURING 1992

Data collection at the 10 suspended-sediment data sites, 7 partial record suspended-sediment sites, and 1 bedload site will continue. Historical sediment data will be entered into the data base for three Missouri River stations.

Collection of Quality-Water Data (MO 00-003)--Continued

PLANNED ACTIVITIES DURING 1992

NASQAN samples for major constituents, nutrients, and trace elements will be collected at seven stations bimonthly and three stations quarterly; one station will be sampled daily for temperature and specific conductance. Stations operated in cooperation with the Missouri Department of Natural Resources will include three where samples will be collected monthly for major constituents, nutrients, and trace elements. Samples for major constituents, nutrients, and trace elements will be collected biannually at 11 stations for the National Park Service. Continuous water-quality monitors measuring temperature, temperature and dissolved oxygen, or pH and specific conductance will be operated at two stations.

REPORT

Reed, H.L., Hatten, D.O., Perkins, T.J., Gray, G.L., and Davis, J.V., 1991, Water-resources data, Missouri, water year 1990: U.S. Geological Survey Water-Data Report MO-90-1, 304 p. (published annually).

Collection of Sediment Data (MO 00-004)--Continued

REPORT

Reed, H.L., Hatten, D.O., Perkins, T.J., Gray, G.L., and Davis, J.V., 1991, Water-resources data, Missouri, water year 1990: U.S. Geological Survey Water-Data Report MO-90-1, 304 p. (published annually).

Water-Use Data-Collection and Reporting Program (MO 00-007)

in cooperation with

Missouri Department of Natural Resources,
Division of Geology and Land Survey

Loyd A. Waite, Project Chief



NEED FOR STUDY

As population increases and industry expands to meet the needs of that population, demand for and use of water will increase. This places a two-fold stress on the water supply. The increased demand may exceed the supply, and increased use accelerates the potential for degradation of the water quality.

OBJECTIVES

(1) Systematically collect data for the estimation of the withdrawal and return of water for all types of water uses. (2) Provide a comprehensive data base from which many types of analyses can be made. (3) Provide a greater knowledge of the general hydrologic effects of increased withdrawals from the water system. (4) Provide data to the national water-use data base to assist in the national water-resources management.

APPROACH

Water-use data will be collected by category on a statewide basis. Existing data will be compiled from State files, stored in the U.S. Geological Survey Prime computer system, and entered into the U.S. Geological Survey aggregated data base. Data-collection methods and sampling strategies will be devised to acquire additional data. Statistical summaries will be included in the annual water-data report.

ACTIVITIES DURING 1991

Water-use data were collected for public supply, commercial, domestic, industrial, fossil fuel, nuclear, mining, livestock, animal specialities, irrigation, hydroelectric, sewage treatment, and reservoir evaporation. These data were compiled and entered into the Water Use Data System (WUDS) to be used for the 5-year compilation report "Estimated Water Use in the United States during 1990."

PLANNED ACTIVITIES DURING 1992

Data-collection activities will continue, and the data will be entered into the WUDS computer program.

Water-Use Data-Collection and Reporting Program (MO 00-007)--Continued

REPORT

Reed, H.L., Hatten, D.O., Perkins, T.J., Gray, G.L., and Davis, J.V., 1991, Water-resources data, Missouri, water year 1990: U.S. Geological Survey Water-Data Report MO-90-1, 304 p. (published annually).

HYDROLOGIC INVESTIGATIONS

Hydrologic investigations include multidiscipline appraisal studies and hydrologic and hydraulic investigations. These investigations include ground-water hydraulics and mathematical modeling of aquifer systems, environmental problems, effects of manmade structures on hydraulics, magnitude and frequency of floods and droughts, urban hydrology, analyses of the effect of hazardous wastes and historical and ongoing mineral mining on the hydrologic system, and traveltime and dispersion of water and floodwaves.

Hydrologic information collected during these investigations is published in technical and basic-data reports. These reports are available for inspection at the U.S. Geological Survey District Office in Rolla, Missouri, or may be purchased from the sources shown in a later section of this report, "Sources of Water Resources Division Publications and Information."

***Discharge Ratings for Tainter and Roller Gates at Lock and Dam Nos. 24 and 25
on the Mississippi River (MO 00-00102)***

in cooperation with

U.S. Army Corps of Engineers

Terry W. Alexander, Project Chief



NEED FOR STUDY

The development of stage-discharge relations for all flow-regulating structures within the Mississippi River basin is needed to assist in the water-control management of the basin. Lock and Dam No. 24 (at Clarksville) and No. 25 (near Winfield) are 2 of the 29 flow-regulating structures maintained and operated by the U.S. Army Corps of Engineers. Only theoretical discharge ratings for the tainter and roller gate flow-controls located at these two structures are available for use.

OBJECTIVES

To develop stage-discharge relations for the 15 tainter gates at Lock and Dam No. 24, and the 14 tainter and 3 roller gates at Lock and Dam No. 25.

APPROACH

Current-meter discharge measurements will be made in the forebays of selected tainter gates at Dam No. 24, and at selected tainter and roller gates at Dam No. 25. These discharge measurements will be used to develop discharge coefficient relations and equations of discharge for all possible flow regimes. Discharge ratings will be given for discrete combinations of headwater-tailwater elevations for normal operational limits when each dam is the control.

ACTIVITIES DURING 1991

Lock and Dam No. 24: Current-meter discharge measurements were completed, and a coefficient of discharge was completed for each discharge measurement. From the computed coefficients, a straight-line coefficient of discharge and orifice-submergence ratio logarithmic relation was graphically determined. Submerged orifice flow is the predominate flow regime at Dam No. 24.

Lock and Dam No. 25: Collection of current-meter discharge measurement needed for the study analyses continued. Submerged-orifice flow is the predominate flow regime at Dam No. 25.

***Discharge Ratings for Tainter and Roller Gates at Lock and Dam Nos. 24 and 25
on the Mississippi River (MO 00-00102)--Continued***

PLANNED ACTIVITIES DURING 1992

Lock and Dam No. 24: Using the discharge coefficient relation previously developed, the equations of discharge for submerged-orifice flow under the 15 tainter gates at Lock and Dam No. 24 will be developed. From these equations, a discharge rating table will be computed for the normal navigation pool operational limit of 445.50 to 449.00 feet.

Lock and Dam No. 25: The current-meter discharge measurements will be completed. A coefficient of discharge relation for the 14 tainter and the 3 roller gates will be graphically determined. Using these relations, the equations of discharge for submerged-orifice flow under the tainter and the roller gates will be developed. From the equations of discharge, discharge rating tables (tainter and roller gates) will be computed for the normal navigation pool operational limits of 429.70 to 434.00 feet.

The final reports will be prepared and published as two U.S. Geological Survey Water-Resources Investigations Reports.

REPORTS

Alexander, T.W., 1992a, Discharge rating for tainter gates at Lock and Dam No. 24 on the Mississippi River at Clarksville, Missouri: U.S. Geological Survey Water-Resources Investigations Report 92-4054, 16 p.

_____ 1992b, Discharge ratings for tainter and roller gates at Lock and Dam No. 25 on the Mississippi River near Winfield, Missouri: U.S. Geological Survey Water-Resources Investigations Report 92-4118, 20 p.

Stormwater Data Collection and Modeling for the City of Cape Girardeau,

Missouri (MO 00-00103)

in cooperation with

City of Cape Girardeau

Robert R. Holmes, Jr., Project Chief



NEED FOR STUDY

Flooding in urbanized areas has long been a concern for the city of Cape Girardeau. Because the population of Cape Girardeau continues to increase, a way to assess the effects of increasing urbanization is needed.

OBJECTIVES

Establish a network of hydrologic instruments to collect rainfall-runoff data in urbanized areas and areas of potential urbanization. Construct an urban runoff model of Cape Girardeau for assessing stormwater effects.

APPROACH

A stormwater data collection network will be designed and operated by the U.S. Geological Survey. A model will be calibrated and validated as soon as sufficient data become available.

ACTIVITIES DURING 1991

Rainfall-runoff data were collected for seven storms. Streamflow ratings are one-half complete.

PLANNED ACTIVITIES DURING 1992

The upper end of streamflow ratings by indirect hydraulic methods will be completed. Basin geometry will be entered into the rainfall-runoff model and preliminary calibration of the model will be completed.

Agricultural Chemicals in Ground Water (MO 00-00203)

in cooperation with

Missouri Department of Health,
Bureau of Environmental Epidemiology

Donald Wilkinson, Project Chief



NEED FOR STUDY

Data are needed to determine the occurrence and distribution of pesticides and nitrate in domestic-water supplies from ground water in the agricultural areas of Missouri.

OBJECTIVES

(1) Collect data to provide information on concentrations of commonly used pesticides and nitrate in ground water from various aquifers in Missouri overlain by agricultural land. (2) Collect the data necessary to describe and interpret the possible causes of pesticide and nitrate occurrence in ground water.

APPROACH

Domestic-water supplies will be sampled to measure the concentrations of pesticides and nitrate in water from different aquifers in areas of intense agricultural activity. Pertinent well, land-use, and agricultural chemical use information will be collected to assist in interpretation of the chemical data.

A representative sampling of all of the aquifers in Missouri will be completed. During 1986-87, wells in the Mississippi River alluvium in southeastern Missouri were sampled. During 1988-89, wells in the Missouri River alluvium in northwestern and west-central Missouri were sampled.

ACTIVITIES DURING 1991

Water samples from 120 domestic-supply wells completed in aquifers in rocks of Pennsylvanian, Mississippian, and Ordovician age, 7 surface-water sites, and 3 springs were analyzed for concentrations of 7 common pesticides, nitrite plus nitrate, and gross alpha and gross beta radioactivity. All the sampling sites were in Bates, Cass, St. Clair, and Vernon Counties, west-central Missouri. During 1991, 100 domestic-supply wells, 3 springs, and 2 surface-water sites were resampled in Bates, Cass, and Vernon Counties to quantify changes in concentrations of pesticides and nitrate since the previous sampling. Samples were field screened for concentrations of pesticides and if any pesticides were detected, the samples were

Agricultural Chemicals in Ground Water (MO 00-00203)--Continued

analyzed at the laboratory. All water samples were analyzed for concentrations of nitrite plus nitrate. Samples of water from 18 wells with pesticides detected were analyzed to determine the average age of the ground water. Samples from 22 wells with nitrite plus nitrate concentrations exceeding 10 milligrams per liter were analyzed for the ratio of nitrogen-15 to nitrogen-14. Land-use information also was collected.

During 1991, water samples from more than 130 domestic-supply wells completed in glacial drift and in aquifers in rocks of Pennsylvanian age were analyzed for concentrations of pesticides and nitrite plus nitrate. The wells were in Caldwell, Clinton, Daviess, Gentry, and Nodaway Counties, northwestern Missouri. Land-use information also was collected in this area.

PLANNED ACTIVITIES DURING 1992

Water samples from about 150 domestic-supply wells in Audrain, Clark, Lewis, Monroe, Scotland, and Shelby Counties, northeastern Missouri will be analyzed for concentrations of pesticides and nitrite plus nitrate. Plans include sampling wells in the Des Moines and Mississippi River alluviums, glacial drift, and aquifers in rocks of Pennsylvanian and Mississippian age.

Drafts of U.S. Geological Survey Open-File Reports listing the results of the Missouri River alluvium sampling during 1988-89 and of the west-central Missouri sampling during 1990-91 will be completed by September 1992.

REPORT

Mesko, T.O., and Carlson, G.M., 1988, Occurrence of pesticides, nitrate, volatile organic compounds, and trace elements in ground water and streams, southeastern Missouri, 1986-87: U.S. Geological Survey Open-File Report 88-495, 73 p.

***Extent and Magnitude of Contamination of the Water Resources in the Vicinity of
the Weldon Spring Radioactive Waste-Disposal Sites, St. Charles County,
Missouri (MO 87-071)***

in cooperation with

U.S. Department of Energy

Michael J. Kleeschulte, Project Chief



NEED FOR STUDY

Chemical analyses indicate that water in the shallow bedrock aquifer contains large concentrations of calcium, lithium, magnesium, nitrate, sodium, strontium, sulfate, and uranium in the vicinity of four low-level radioactive waste-disposal pits near Weldon Spring, Missouri. A spring 1.5 miles north of the site also has increased lithium, nitrate, and uranium concentrations, but monitoring wells between the pits and spring do not indicate a contamination plume. The areal and vertical extent and magnitude of contamination and the transport routes for the contaminants in this karst environment need to be defined.

OBJECTIVE

To define the extent, magnitude, and transport routes of contamination near the Weldon Spring radioactive waste-disposal sites.

APPROACH

Ground-water flow in St. Charles County will be simulated using a ground-water flow model. Continuous water-level recorders on wells will monitor ground-water fluctuations with changes in climatic conditions and the possible movement of the ground-water divide. Water-quality minimonitors at one contaminated spring and at the outflow from two contaminated ponds that drain into losing streams will record water-quality variations with climate and time. Selected monitoring wells will be sampled, and water levels will be measured quarterly. An interpretive report will be completed in the third year of the project. Water-quality conditions during remedial action will be monitored during the last 6 years of the project.

ACTIVITIES DURING 1991

A U.S. Geological Survey Open-File Report was published. An interpretive report defining the areas of surface- and ground-water contamination and the results of a three-dimensional finite difference ground-water flow model was begun. The U.S. Department of Energy has requested additional work to determine background water quality in the Missouri

***Extent and Magnitude of Contamination of the Water Resources in the Vicinity of
the Weldon Spring Radioactive Waste-Disposal Sites, St. Charles County,
Missouri (MO 87-071)--Continued***

River and the Missouri River alluvium near Weldon Spring. Sampling of the Missouri River was begun to determine background water quality in the river during low-base, high-base, and runoff flow conditions.

PLANNED ACTIVITIES DURING 1992

The interpretive report will be finished, approved, and published. Basic data collection, including quarterly water-level measurements, operation of stream-gaging and minimonitor equipment at Burgermeister spring, and biannual water-quality sampling will continue. Water-quality sampling of the Missouri River and the Missouri River alluvium near Weldon Spring will be completed. The results from the Missouri River and the Missouri River alluvium sampling will be compiled and published in a U.S. Geological Survey Open-File Report.

REPORTS

- Kleeschulte, M.J., 1991, Geohydrology of bedrock aquifers and public supply and domestic water use, 1962-85, in St. Charles County, Missouri, in Proceedings of the Geosciences Workshop: U.S. Department of Energy, Oak Ridge Operations Office, p. 41-74.
- Kleeschulte, M.J., and Cross, P.W., 1990, Hydrologic data for the Weldon Spring Chemical Plant Site and vicinity property, St. Charles County, Missouri--1986-89: U.S. Geological Survey Open-File Report 90-552, 117 p.

***Investigation of Bridge-Scour Processes Occurring at Selected Sites on Missouri
Streams (MO 88-076)***

in cooperation with

Missouri Highway and Transportation Commission

Lawrence D. Becker, Project Chief



NEED FOR STUDY

Adequate definition of potential scour at bridge piers is essential to proper design, construction, and maintenance of hydraulic structures. Reasonably accurate estimates of scour depth are needed for safe, cost-effective bridge design. Although many scour estimating equations have been developed based on laboratory work, site-specific data have not been collected to verify the accuracy of these equations and techniques and their applicability to Missouri streams.

OBJECTIVES

To investigate bridge-pier scour processes at selected sites on Missouri streams, collect data relative to bridge-pier scour during floods, evaluate existing scour prediction techniques and equations, and possibly develop depth-of-scour estimation techniques applicable to Missouri in whole or part.

APPROACH

The scope of this study is statewide, but will be limited to regions where pier scour can be expected to be a significant consideration in bridge design. Approximately 12 sites will be selected for data collection relative to extent of scour, sediment and bed material, and flow velocities and directions during and following flood events. Collected data will be used in verification or development of methods to predict scour effects at ungaged or site-specific locations.

ACTIVITIES DURING 1991

Fourteen bridge-scour data collection sites were operated. Site descriptive data were collected, field training was completed, and scour measurement techniques were refined. Portable fathometers were tested and used to measure scour at eight sites during floods of 2- to 10-year recurrence intervals.

***Investigation of Bridge-Scour Processes Occurring at Selected Sites on Missouri
Streams (MO 88-076)--Continued***

PLANNED ACTIVITIES DURING 1992

Scour data will be collected at as many sites and for as many floods as possible. Preliminary analysis on collected scour data will be done. Various scour equations will be used to compare measured scour depths with estimated scour depths.

The Effect of Sinkholes and Related Karst Features on Shallow Water Flow and Ground-Water Quality in Greene County, Missouri (MO 89-077)

in cooperation with

Watershed Committee of the Ozarks, Inc.

Loyd A. Waite, Project Chief



NEED FOR STUDY

The well-developed karst environment of Greene County, Missouri, and lack of integrity of the confining unit that separates the shallow karst aquifer from the underlying aquifer used for municipal supply can allow the rapid movement of contaminants from the land surface into the shallow aquifer, and subsequently into the deep aquifer. Greene County (and the city of Springfield) is on top of a regional ground-water divide, and all water pumped from wells in the county ultimately comes from infiltration of precipitation within the county.

OBJECTIVE

To develop a comprehensive Geographic Information System (GIS) data base of karst features, surface-water hydrologic data, and shallow ground-water hydrologic data.

APPROACH

Collect and digitize available data on karst features, karst hydrology, and geologic factors that may affect karst features. Data layers include the location of sinkholes, caves, streams and springs, bedrock geology, and potentiometric surfaces. These data bases will be combined with existing cultural data layers to make the data base useful in an emergency, such as a chemical spill.

ACTIVITIES DURING 1991

The GIS data base is progressing in accordance with the project work plan. Several of the data layers have been submitted to the cooperator. Work has begun on a final report, and regular meetings with the cooperator were held to assign writing sections and set final goals for the completion of the project.

PLANNED ACTIVITIES DURING 1992

The data base will be completed and submitted to the cooperator. The U.S. Geological Survey Water-Resources Investigations Report will be completed; Director's approval is planned before the end of 1992.

***Uptake and Release of Contaminants by Overburden Soil Minerals in the Vicinity
of the Raffinate Pits, Weldon Spring Chemical Plant, St. Charles County,
Missouri (MO 89-078)***

in cooperation with

U.S. Department of Energy
U.S. Army Corps of Engineers

John G. Schumacher, Project Chief



NEED FOR STUDY

The Weldon Spring chemical plant processed uranium ore concentrates and scrap into uranium trioxide, uranium tetrafluoride, and uranium metal. The 207-acre plant is situated on the eastern part of a 17,232-acre tract formerly owned by the U.S. Army known as the Weldon Spring Ordnance Works. The ordnance works produced explosives between 1941 and 1945. During the operation of the chemical plant between 1957 and 1966, the plant processed more than three times its design capacity. Additionally, some thorium also was processed. Wastes from these operations (referred to as raffinate) were pumped into four large pits. These pits were constructed by removing contaminated soils from unconsolidated regolith at the site. The pits contain various quantities of magnesium, sulfate, fluoride, nitrate, uranium, thorium, and other elements. The raffinate pits have been determined to be leaking and sulfate, nitrate, lithium, uranium, and various trace elements have been detected in ground water and surface water both on and off site.

In addition to contamination from the chemical plant operations, ground water and soils also contain various quantities of nitroaromatic compounds, such as trinitrotoluene (TNT), 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT), and nitrobenzenes related to the production of TNT at the former Weldon Spring Ordnance Works. Most of the soil contamination is restricted to a 1,655-acre tract owned by the U.S. Army known as the Weldon Spring training area. Large quantities of TNT (up to several percent by weight) have been detected in surficial soils in the training area. Small concentrations of nitroaromatic compounds have been detected in 17 of the 34 monitoring wells in the training area. Before the construction of wastewater treatment plants during 1943, wastewater from the chemical plant, which contained large quantities of nitroaromatic compounds, was discharged into lagoons and vicinity streams.

***Uptake and Release of Contaminants by Overburden Soil Minerals in the
Vicinity of the Raffinate Pits, Weldon Spring Chemical Plant, St. Charles County,
Missouri (MO 89-078)--Continued***

OBJECTIVES

(1) Determine the geochemical controls on contaminant migration from the raffinate pits. (2) Determine the physical, chemical, and mineralogic properties of the various overburden units on the U.S. Department of Energy and U.S. Army properties. (3) Investigate the attenuation of contaminants within the various overburden units. (4) Determine the geochemical controls on contaminant migration within the shallow bedrock aquifer. (5) Determine if contaminated surficial soils on the U.S. Army property are a source of the nitroaromatic compounds detected in the ground water.

APPROACH

Representative samples of raffinate sludge and interstitial water will be collected and analyzed for physical properties, trace elements, and radionuclides. Phase associations of contaminants in the raffinate sludge will be determined by X-ray diffraction, fission-track radiography, and scanning electron microscopy. Soil samples will be collected from the U.S. Department of Energy and U.S. Army sites for chemical and mineralogic characterization. Laboratory experiments will be used to evaluate the sorption of contaminants by the various overburden units. Results of laboratory sorption experiments will be compared to water-quality data from the unsaturated zone to develop geochemical models for contaminant migration through the overburden.

ACTIVITIES DURING 1991

The geochemical controls on migration of uranium and other contaminants within the overburden and shallow bedrock aquifer were determined. Uranium is not attenuated in the raffinate pits but attenuated within the overburden by sorption onto iron oxides. Significant differences exist in the attenuation of uranium between various overburden units; this is mainly a function of pH value and carbonate concentration of the solution, and oxide content of the overburden. Mass balance models were constructed, indicating sources of contaminants in the overburden. An interpretive paper on geochemical controls on migration of molybdenum, uranium, and other contaminants at the U.S. Department of Energy site was published and a draft U.S. Geological Survey Water-Resources Investigations Report was written. Investigations have now moved to the adjacent U.S. Army property (a former ordnance production facility). Water-quality samples were collected from monitoring wells on the U.S. Army site and lysimeters were installed to collect water samples from the unsaturated zone beneath TNT-contaminated surficial soils.

***Uptake and Release of Contaminants by Overburden Soil Minerals in the Vicinity
of the Raffinate Pits, Weldon Spring Chemical Plant, St. Charles County, Missouri
(MO 89-078)--Continued***

PLANNED ACTIVITIES DURING 1992

Additional lysimeters and ground-water monitoring wells will be installed on the U.S. Army site. Water samples will be collected from the lysimeters and monitoring wells and analyzed for TNT, TNT breakdown products, and other nitroaromatic compounds. A U.S. Geological Survey Open-File Report on the Weldon Spring training area site will be written. The U.S. Geological Survey Water-Resources Investigations Report for the U.S. Department of Energy site will be approved. Soil samples will be collected to determine the variability of TNT and organic carbon concentrations with depth. Additional studies will be initiated to investigate the microbial degradation of TNT within the unsaturated zone, if breakdown products are detected in samples from the lysimeters.

REPORTS

- Schumacher, J.G., 1990, Geochemical data for the Weldon Spring chemical plant site and vicinity property, St. Charles County, Missouri--1989-90: U.S. Geological Survey Open-File Report 90-351, revised in 1991, 47 p.
- Schumacher, J.G., Lindley, C.E., and Anderson, F.S., in press, Migration of nitroaromatic compounds in unsaturated soil at the abandoned Weldon Spring Ordnance Works, St. Charles County, Missouri: 16th Annual Army Environmental R&D Symposium, Williamsburg, Va., 1992, Proceedings.
- Schumacher, J.G., and Stollenwerk, K.G., 1991, Geochemical controls on the migration of molybdenum, uranium, and other constituents at the Weldon Spring chemical plant site, in Proceedings of the Geosciences Workshop: U.S. Department of Energy, Oak Ridge Operations Office, p. 87-140.

Comprehensive Assessment of the Potential Hydrologic and Biological Impact of Lead and Zinc Mining in the Mark Twain National Forest of Southern Missouri

(MO 89-079)

in cooperation with

Missouri Department of Natural Resources,
Division of Geology and Land Survey
National Park Service



Michael J. Kleeschulte, Project Chief

NEED FOR STUDY

The U.S. Forest Service has issued two preference right leases for exploratory drilling and road construction for lead and zinc prospecting in the Mark Twain National Forest. Lead and zinc mining could potentially affect the water resources in the area by degrading water quality or decreasing the ground-water flow, or both. Declining water levels could cause domestic wells to go dry and contribute to land subsidence in the karst terrane. Changes in water quality and quantity could adversely affect flora and fauna, including some threatened and endangered species, as well as the large tourist industry.

OBJECTIVES

The overall objective is to provide a technical basis for estimating the probable environmental effects of lead and zinc mining in the hydrologically and biologically sensitive Mark Twain National Forest.

APPROACH

The study has been divided into three phases that generally coincide with mine development. Phase 1 will include an extensive literature search, installation of monitoring equipment on wells, inventory of existing wells, sampling of ground and surface water and bed material for chemical analyses, water-level measurements, and monitoring stream discharge. If mineralization warrants further exploration and mine development, phase 2 will include continued collection of and analyses of water and sediment, preparation of a geologic map, core analyses, aquifer testing, and construction of a ground-water flow model. Phase 3 will include comparison of data collected from earlier phases and data from monitoring in this phase to determine if resources are being affected by mining.

***Comprehensive Assessment of the Potential Hydrologic and Biological Impact of
Lead and Zinc Mining in the Mark Twain National Forest of Southern Missouri***

(MO 89-079)--Continued

ACTIVITIES DURING 1991

Continuous recorders were operated on three wells, one precipitation gage, and one spring flow gage. Mass water-level measurements were made in the spring and fall. Water samples were collected from a network of stream, spring, and ground-water sites in the spring and fall and analyzed for major inorganic constituents, nutrients, and trace elements. Bed-material samples were collected at stream and spring sites and analyzed for trace elements.

PLANNED ACTIVITIES DURING 1992

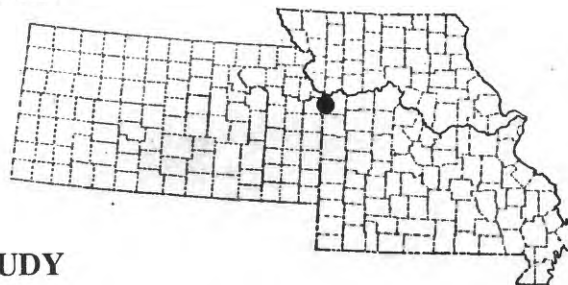
Data collection will continue at all monitoring sites. Data compilation will be completed and preparation of the final report will begin.

Ground-Water Flow and Quality in the Missouri River Alluvium near Kansas City, Missouri and Kansas (MO 90-081)

in cooperation with

Mid-America Regional Council

Brian P. Kelly, Project Chief



NEED FOR STUDY

The Missouri River alluvium is the only aquifer near Kansas City that can produce more than 20 gallons of water per minute. The aquifer is used for public supply, industry, and irrigation. The aquifer is threatened by urban and rural activities. To protect this aquifer, background data on flow and quality are required.

OBJECTIVE

(1) Develop a regional GIS for the hydrogeology of the Missouri River alluvium that incorporates existing data and can be updated as more data are collected. (2) Determine ground-water levels in the Missouri River alluvium in different seasons and stages of the Missouri River. This determination would help delineate the zones of contribution around municipal well fields in the Kansas City area. (3) Identify areas of the alluvial aquifer most susceptible to contamination from the land surface. (4) Establish a water-quality and water-level monitoring network.

APPROACH

All existing hydrogeologic data for the Missouri River alluvium will be entered into a GIS data base. Wells will be drilled where data are lacking. Water-level measurements will be used to map zones of contribution to well fields. Water samples will be collected to characterize present conditions. A map depicting susceptibility to surface contamination also will be prepared.

ACTIVITIES DURING 1991

All pertinent data available from the U.S. Geological Survey, as well as a significant quantity of data from other sources, have been compiled.

PLANNED ACTIVITIES DURING 1992

Location and entry of hydrogeologic data in the GIS data base will be completed, and a monitoring network will be designed. Water-level and water-quality data will be collected. Potential ground-water contamination areas will be identified, and the final water-level map will be prepared.

Urban Stormwater Data Collection and Modeling for the City of Rolla, Missouri

(MO 90-082)

in cooperation with

City of Rolla

Robert R. Holmes, Jr., Project Chief



NEED FOR STUDY

The city of Rolla is a rapidly growing municipality. Urban development adds to the stormwater runoff. Presently (1992), Rolla has no systematic method to mitigate the adverse effects of increased urbanization.

OBJECTIVE

(1) Establish data collection network to collect background flow quantity and rainfall data at selected locations and to provide calibration data for a storm water management model. (2) Construct an urban runoff model of Rolla to use for stormwater management.

APPROACH

A stormwater data collection network will be designed and implemented by the U.S. Geological Survey. The model will be used as soon as sufficient data become available. Continuation of some data sites may occur after completion of project to provide calibration data for the model.

ACTIVITIES DURING 1991

Five stream-gaging stations, four recording rain gages, and three total-catch rain gages were installed. Streamflow ratings for all stream gages were completed. Low-flow water-quality samples were collected at two sites. Continuous streamflow and rainfall data were collected for 1 year at all sites. Reduction of basin hydraulic geometry was completed and entered into the model. Preliminary calibration of the model was begun.

PLANNED ACTIVITIES DURING 1992

Rainfall and streamflow data collection will continue. The U.S. Environmental Protection Agency's Stormwater Management Model (SWMM) will be calibrated and validated. High-flow water-quality samples will be collected, and compilation of a U.S. Geological Survey Water-Resources Investigations Report will begin.

***Hydrochemical Investigations of the St. Francois County Landfill, St. Francois
County, Missouri (MO 91-084)***

in cooperation with

St. Francois County Environmental Corporation

John G. Schumacher, Project Chief



NEED FOR STUDY

The St. Francois County Landfill is located in an abandoned lead and zinc mine tailings pile. The 550-acre tailings pile is located within a meander bend of the Big River. Numerous unplugged exploratory boreholes are present beneath the landfill and tailings pile. These boreholes extend into underlying abandoned flooded mine cavities that are used as a local drinking-water supply for several communities. There are little data on direction of ground-water flow at the site, quality of ground water, or possible mobilization of trace elements within the mine tailings by landfill leachate. The tailings pile has been nominated by the U.S. Environmental Protection Agency to the National Priority List as a Superfund site.

OBJECTIVES

(1) Determine the direction of regional ground-water flow in the vicinity of the site. (2) Assess the extent and magnitude of contamination from landfill leachate within the mine tailings, shallow bedrock, and mine cavity system. (3) Determine the relation between the original land surface and abandoned boreholes to the migration of contaminants from the landfill. (4) Determine if landfill leachate is mobilizing substantial quantities of trace elements from the mine tailings.

APPROACH

A potentiometric map will be prepared for the area using water-level data collected during a well inventory. The ground-water/surface-water relations will be determined by conducting a seepage run along the Big River and various tributaries in the vicinity of the landfill. A ground-water monitoring network will be installed to collect water-quality data of water from the tailings, shallow bedrock, and mine cavities near the site. Exploration maps and auger drilling were used to delineate the original topography beneath the landfill and tailings pile.

Hydrochemical Investigations of the St. Francois County Landfill, St. Francois

County, Missouri (MO 91-084)--Continued

ACTIVITIES DURING 1991

A well monitoring network was completed and a potentiometric map was drawn. Water-quality samples have been collected from tailings seeps and vicinity wells to determine the direction and extent of leachate migration. Relation between the abandoned boreholes, mine cavities, and original land surface beneath the tailings to the landfill has been determined and GIS maps have been completed. A monitoring network has been designed. Preliminary data indicate migration from the landfill is controlled by the original buried topography. Monitoring wells near the Big River contain increased concentrations of sodium, chloride, nitrate, and arsenic. Concentrations of other trace elements seem within the ranges expected from lead and zinc mine tailings seeps, indicating landfill leachate may not be mobilizing large quantities of trace elements from the tailings; however, no laboratory studies have been made.

PLANNED ACTIVITIES DURING 1992

The ground-water monitoring network will be installed during the summer of 1992, and additional water-quality samples will be collected. Laboratory leaching tests will be conducted to determine the potential for landfill leachate to mobilize trace elements from the tailings.

Use of Nitrogen and Oxygen Isotopes to Measure Nitrogen-Cycle Processes in Claypan Soils and Glacial-Drift Aquifers (MO 91-085)

Dale W. Blevins, Project Chief



NEED FOR STUDY

Nitrate concentrations in water under claypan soils in northern Missouri frequently are greater than the Missouri drinking water supply standard of 10 milligrams per liter. However, the source, including the contribution of nitrogen fertilizers, of the concentrations is not known. Previous studies have not used nitrogen-15 and oxygen-18 to determine the contribution of nitrogen fertilizers to nitrate concentrations in ground water and field runoff.

OBJECTIVE

(1) Determine the effects of nitrogen fertilizers on concentrations of nitrate in ground water and runoff from clay-rich soils and aquifers using nitrogen and oxygen isotopes in nitrate. (2) Identify hydrogeochemical factors that have significant roles in the speciation and transport of nitrogen in a claypan soil and underlying glacial deposits. (3) Test and refine new methods for isolation and isotopic analysis of oxygen isotopes in nitrate. (4) Refine and develop field methods for concentrating nitrate in water samples for nitrogen isotopic analysis.

APPROACH

Existing isotopic signatures and fertilizer spiked with nitrogen-15 will be used to trace nitrogen fertilizers in the soil, and ground water will be analyzed for nitrogen-15 and oxygen-18 to trace the fertilizer. Changes in isotopic signatures are expected to reveal the extent of nitrification and denitrification. New laboratory methods will be developed and tested for the determination of oxygen-18 in nitrate and to substantially decrease the cost of nitrogen-15 analyses to make them an affordable tool in nitrogen studies.

ACTIVITIES DURING 1991

Project planning, including proposal, work plan, and procedures for testing preconcentration of nitrate for isotope analyses, were completed. Instrumentation of a 0.1-acre tracer plot is 90 percent complete. Instrumentation included a flume and continuous recorder, a refrigerated automatic sampler, six monitoring wells (one with a continuous recorder), six lysimeters, two tile drains, six tensiometers, and a berm with a 30-inch subsurface barrier bordering the plot. Corn was planted with high nitrogen inputs during spring 1991, and 18 ground-water samples and 1 surface-water sample were collected to determine background concentrations of nitrogen species, tracer concentrations, and isotope ratios of nitrogen and

***Use of Nitrogen and Oxygen Isotopes to Measure Nitrogen-Cycle Processes in
Claypan Soils and Glacial-Drift Aquifers (MO 91-085)--Continued***

oxygen. Preliminary results indicate concentrations of nitrate ranged from 20 to 30 milligrams per liter and dissolved oxygen ranged from 2 to 6 milligrams per liter in ground water. Nitrite and ammonium concentrations were near detection limits. The water table is only 4 to 6 feet below the land surface within the range of corn roots and near the bottom of the claypan. At least two of the wells seem to be connected by cracks observed in cores taken from glacial materials. These cracks may be the conduits for dissolved oxygen detected near the bottom of the glacial till at 50 feet deep.

PLANNED ACTIVITIES DURING 1992

Background concentrations of tracers will continue to be established during winter 1992. Corn will be planted on the tracer plot during spring 1992 and fertilizer spiked with nitrogen-15, bromide, and rhodamine WT will be applied to the tracer plot next spring. Samples of rainfall, runoff, ground water, soil water, and grain will be analyzed for the tracers. Tracer concentrations will be compared with background concentrations to follow the tracers through the hydrologic system.

REPORT

Blevins, D.W., 1991, Planned studies of movement of nitrogen species and herbicides on claypan soils at the Management Systems Evaluation Area in Missouri, in Mallard, G.E., and Aronson, D.A., Proceedings of the Technical Meeting of the U.S. Geological Survey Toxic Substance Hydrology Program: Monterey, Calif., March 11-15, 1991, U.S. Geological Survey Water-Resources Investigations Report 91-4034, p. 240-242.

***Water-Quality Characteristics of Lake Jacomo, Prairie Lee Lake, and
Harrisonville Lake in Jackson and Cass Counties, Missouri (MO 91-086)***

in cooperation with

Jackson County Parks and Recreation Department
City of Independence
Cass County Soil and Water Conservation District

David C. Heimann, Project Chief



NEED FOR STUDY

Lake Jacomo, Prairie Lee Lake, and Harrisonville Lake are located in a rapidly growing urban area in the Kansas City metropolitan area. Development of the lake drainage areas has caused sediment and nutrient loading of the lakes. Harrisonville Lake also receives drainage from agricultural areas. The existing water quality needs to be characterized to develop water-quality protection and remediation plans for the lakes.

OBJECTIVE

(1) Characterize the water quality and microbiology of Lake Jacomo, Prairie Lee Lake, and Harrisonville Lake. (2) Identify source areas for selected constituents detected in Lake Jacomo, Prairie Lee Lake, and Harrisonville Lake.

APPROACH

Lake samples will be collected about 3 feet below the lake surface and about 3 feet above the bottom at three locations on all lakes. Samples will be analyzed for specific conductance, pH, bacteria, alkalinity, suspended solids, nutrients, algae, chlorophyll a, and suspended sediment. Temperature and dissolved oxygen profiles will be obtained at each site. Samples will be collected every other week from May through September and monthly from October through April. A bottom sediment sample will be collected at each site and analyzed for pesticides, nutrients, trace elements, and total organic carbon. Composite storm runoff samples will be collected at three sites and analyzed for sediment, nutrients, and volatile suspended solids.

PLANNED ACTIVITIES DURING 1992

A bathymetric and bottom sediment survey will be done for all lakes in the spring of 1992.

Determination of Stormwater Runoff Quality in Independence,

Missouri (MO 92-087)

in cooperation with

City of Independence

Gregory K. Schalk, Project Chief



NEED FOR STUDY

Stormwater quality of streams, the stormwater systems, and the relation of stormwater quality to different land uses in Independence are unknown.

OBJECTIVES

(1) Characterize the quantity and quality of discharge from storm-sewer outfalls during dry weather. (2) Characterize the quantity and physical, chemical, and bacteriological quality of stormwater in streams and channels draining land with five specific uses. (3) Estimate annual, seasonal, and event mean loads for selected constituents for each storm-sewer outfall in the city. (4) Based on the estimates of storm-sewer outfalls, evaluate the effects of stormwater from Independence on larger receiving streams in the area.

APPROACH

Land-use data will be compiled and storm-sewer outfalls will be located during characterization of dry weather water quality. Existing hydrologic data and precipitation data will be compiled. Based on existing data and results of the dry weather reconnaissance, five gaging sites will be selected and instrumentation will be installed. Water samples will be manually collected three times at each gage and analyzed for constituents on the U.S. Environmental Protection Agency's primary pollutant list. Based on results from the first three storms, selected constituents will be analyzed from an additional three storms. Seasonal, annual, and storm-event mean loads will be calculated from discharge, precipitation, water-quality, and land-use data by using regression analysis.

ACTIVITIES DURING 1991

Dry-weather screening for chlorine, copper, anionic detergents, and phenols was completed for more than 380 sites. Many sites had concentrations of chloride greater than 0.2 milligram per liter. Copper and phenols were not detected at any sites. Anionic detergents were

Determination of Stormwater Runoff Quality in Independence,

Missouri (MO 92-087)--Continued

detected at one site. The GIS coverages of land-use basins, roads, and dry-weather screening sites were compiled. Five stream-gaging sites have been selected and instrumentation has been installed.

PLANNED ACTIVITIES DURING 1992

Sample collection will begin during the spring of 1992. All sampling will be completed. Constituents loads will be calculated and evaluated. A draft U.S. Geological Survey Water-Resources Investigations Report will be written.

The Role of Preferential Flow in the Transport of Agricultural Chemicals in Claypan Soils (MO 92-088)

Brian P. Kelly, Project Chief



NEED FOR STUDY

Claypan soils cover about 16,000 square miles of the central United States. Claypan soils have low intrinsic permeabilities, yet macropores form in claypan soils from shrinkage cracks and biologic activity. Once formed, these macropores may transmit recharge and agricultural chemicals to the underlying aquifers. Knowledge of the effects and processes of water flow and chemical transport in claypan soils is crucial to understanding the larger concerns of water contamination from agricultural sources because of the large areal extent of these soils.

OBJECTIVES

(1) Determine the rate of water flow through macropores in a claypan soil compared to the transport of nitrate, nitrogen-15 in nitrate, and bromide. (2) Determine the rate of water flow, and the transport of nitrate, nitrogen-15 in nitrate, and bromide through macropores compared to flow and transport through the soil matrix.

APPROACH

A 0.1-acre plot will be used as the study area. Conventional methods of corn production and herbicide application will be used on and around the plot. Tracers such as nitrogen-15 (in nitrate) and bromide will be applied with the fertilizer. Water samples from rainfall, surface runoff, the unsaturated zone, interflow, and ground water will be analyzed to follow nitrate tracers and water from the ground surface through the unsaturated zone and into the ground water beneath the study plot.

PLANNED ACTIVITIES DURING 1992

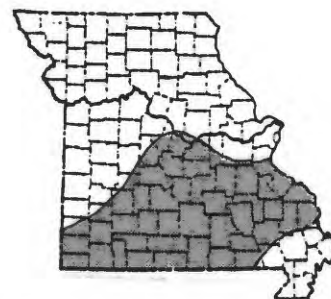
(1) All instrumentation will be completed on the study plot before spring 1992. (2) Nitrogen-15 and bromide will be applied to the study plot during spring 1992. (3) Rainfall, surface runoff, interflow, and ground water sampling will be done periodically. (4) Water and nitrogen budgets will be developed. (5) Soil staining and soil physical properties experiments will be completed.

Land-Use and Climatic Effects on the Stream Geomorphology and Physical Aquatic Habitat in the Ozark Highlands (MO 92-089)

in cooperation with

Missouri Department of Conservation

Robert B. Jacobson, Project Chief



NEED FOR STUDY

Ozarks stream channels are characterized by extensive, unvegetated gravel bars, rapidly shifting channels, and extensive eroding cut banks. It is not known if these conditions are natural or unnatural, whether they are getting better or worse, and what their effects have been on stream ecology. Management of aquatic ecosystem resources in the Ozarks of Missouri requires a predictive understanding of how streams and physical habitat attained their present condition and how they will respond to future land use and climate changes.

OBJECTIVES

(1) Determine how stream channels in the Ozarks achieved their present state of instability. (2) Assess the effect of channel disturbance on physical habitat. (3) Develop a predictive understanding of how future regional and global changes are likely to affect physical habitat of streams in the Ozarks using the record of past responses to disturbance. (4) Synthesize results of this study with results of channel disturbance studies in different geographic areas to develop a general model of processes and controls on channel disturbance and aquatic ecosystem disturbance.

APPROACH

The study will integrate stratigraphic, pedogenic, dendrochronologic, photogrammetric, historical, and channel monitoring data collected for this project with existing hydrologic and climatic data. A variety of physical hydraulic models will be used to model changes in aquatic habitat. Data and results will be synthesized with coordinated studies by other researchers involved in the National Park Service Global Change Research Program, including researchers in aquatic ecosystems, dendroclimatology, and regional-scale modeling.

PLANNED ACTIVITIES DURING 1992

(1) Channel-geometry monitoring cross sections will be installed at all sites and resurveyed at least once. (2) Hydraulic and habitat characterization data (depths, velocities, gradients, and bed material particle size characteristics) will be collected at all sites. (3) A geomorphically based aquatic habitat classification system will be refined and used to map low-flow habitat at all sites. (4) Digital photogrammetric methods will be refined and employed in continued photogrammetric mapping of sites using historical aerial photography. (5) Stratigraphic

Land-Use and Climatic Effects on the Stream Geomorphology and Physical

Aquatic Habitat in the Ozark Highlands (MO 92-089)--Continued

drilling of some sites will be initiated. (6) Regional stratigraphic reconnaissance sampling will continue. Data on physical characteristics of habitat units will be collected in coordination with aquatic ecology sampling; these data will be used to evaluate statistically the ability of the geomorphically based habitat classification to describe the spatial distribution of aquatic organisms. In addition, historical, census, and oral-history data on changes in Ozarks land use since 1800 will be combined into a U.S. Geological Survey Water-Resources Investigations Report evaluating the potential for land-use changes to destabilize streams.

REPORTS

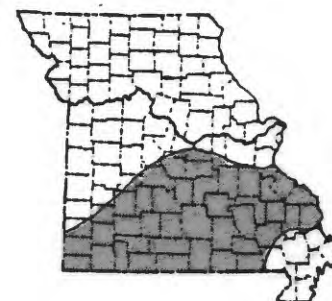
- Jacobson, R.B., in press, Geographic Information System analysis of landslides on shale slopes, Pendleton County, West Virginia [abs.]: The Geological Society of America 1992 Annual Meeting--Abstracts with Programs, v. 24.
- Jacobson, R.B., and Pugh, A.L., 1992, Effects of land use and climate shifts on channel disturbance, Ozark Plateaus, U.S.A.: Proceedings of the workshop on the effects of global climate change on hydrology and water resources at the catchment scale, Japan-U.S. Committee on Hydrology, Water Resources and Global Climate Change, p. 423-444.
- Pugh, A.L., and Jacobson, R.B., 1992, Recent geomorphic evolution of Little Piney Creek, Phelps County, Missouri [abs.]: Program and Abstracts of the Missouri Academy of Science Annual Meeting, Geology and Geophysics Section, Rolla, Missouri, April 25, 1992.
- Rabeni, C.F., and Jacobson, R.B., in press, Geomorphic and hydraulic controls on the abundance and distribution of centrarchids in streams in the Ozarks region, USA: Polish Archives of Hydrobiology.

National Water-Quality Assessment Program: Ozark Plateaus Study Unit--

Missouri Subproject (MO 92-090)

David A. Freiwald, Project Chief

Jerri V. Davis, Missouri Sub-Project Chief



NEED FOR STUDY

The extensive karst features of the Ozark Plateaus create a complex hydrologic system that results in rapid interactions between ground and surface water. Poultry, cattle, and swine production along with septic tanks and sewage-treatment plants have affected the water quality with large concentrations of nitrate, ammonia, and bacteria. Serious degradation has occurred in the surface and ground water because of abandoned lead and zinc mines in the Tri-State District of Kansas, Missouri, and Oklahoma, and recent lead mining in southeastern Missouri. Increased concentrations of radionuclides have been detected in numerous wells throughout the area, and highly saline ground water along the western boundary has caused some wells to be abandoned.

OBJECTIVE

Describe the status and trends in the quality of the ground- and surface-water resources of the Ozark Plateaus study unit. Provide an understanding of the natural and human factors that affect the quality of these resources. Integrate study unit results with regional and national synthesis activities that will provide a base to assess specific water-quality issues of the Nation.

APPROACH

Compile and review available water-quality information for both surface- and ground-water resources in the first 2 years. Intensively sample and analyze the water resources of the study unit for a wide array of physical, chemical, and biological properties for a period of about 3 years. Create computer data bases of water-quality and ancillary information to effectively interpret and report the results. Intermittently monitor the water quality of the study unit for about 5 years to establish trends using statistical and deterministic techniques.

PLANNED ACTIVITIES DURING 1992

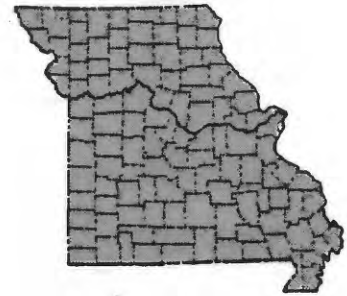
Continue water-quality and biological retrospective data analysis with emphasis on pesticide data. Create computer data bases and GIS coverages as needed. Write the first draft of a pesticide retrospective report and the second phase of the draft work plan. Perform water-quality and biological reconnaissance sampling within the study unit.

Evaluation of Potential Bridge Scour in Missouri (MO 92-091)

in cooperation with

Missouri Highway and Transportation Department

Loyd A. Waite, Project Chief



NEED FOR STUDY

The Federal Highway Administration requires all State highway agencies to evaluate the bridges on highways within the Federal Aid System for susceptibility to scour-related failure. There are about 4,700 bridges within the Federal Aid System requiring screening for scour susceptibility in Missouri.

OBJECTIVES

Evaluate the potential for scour at bridges and identify bridges that are observably scour critical (a bridge with abutment or pier foundations that are rated unstable).

APPROACH

Scour-susceptible bridges will be identified. Methodologies for quality assurance, calculation of stream-stability index, and field data collection also will be provided. Ten bridges will be selected from a list of observably scour-critical bridges, and a detailed analyses will be done for each one, including flood frequency relations. Step-backwater computations will be used to provide surface-water profiles and parameters necessary to calculate potential scour.

PLANNED ACTIVITIES DURING 1992

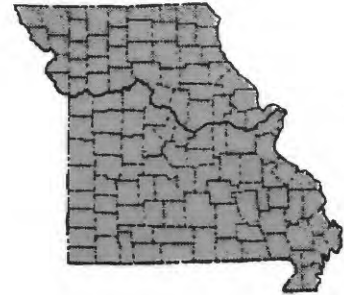
A methodology for evaluating bridge scour in Missouri will be developed.

Peak-flow Frequency for Rural Unregulated Streams in Missouri (MO 92-092)

in cooperation with

Missouri Highway and Transportation Department

Terry W. Alexander, Project Chief



NEED FOR STUDY

The Missouri Highway and Transportation Department has a need for updated flood frequency relations to assist them in future highway planning and design of bridges, road embankments, and culverts. For example, the 500-year flood frequency relation is needed for channel scour analyses at bridges.

OBJECTIVE

The existing 2-, 5-, 10-, 25-, 50-, and 100-year flood frequency relations will be updated for unregulated rural streams in Missouri. The 500-year flood frequency relation will be developed for use in bridge scour studies.

APPROACH

The basin characteristics and peak-flow files will be updated. The 2-, 5-, 10-, 25-, 50-, 100-, and 500-year discharges for individual stations will be computed and entered into the basin characteristics file. The generalized least squares regression approach will be used to develop the 2- to 500-year estimating equations for rural streams in Missouri.

PLANNED ACTIVITIES DURING 1992

Peak-flow and basin characteristics files will be transferred to a local data base. State boundary discontinuities will be determined. Peak-flow and basin characteristics files will be updated, including the addition of new stations.

Hydrologic Monitoring of the Columbia/Eagle Bluffs Wetland Complex

(MO 92-093)

in cooperation with

Missouri Department of Conservation

Joseph M. Richards, Project Chief



NEED FOR STUDY

Wetland areas are sensitive to chemical and physical changes in the hydrologic environment. An effective hydrologic monitoring network is needed to provide data that can be used to evaluate these changes and to analyze water-quality trends. Trend analysis will be an invaluable tool to identify changes before they become widespread or irreversible. The ability to evaluate changes is especially necessary because treated sewage effluent will be used as a major source of water for wetland management on the Eagle Bluffs Wildlife Area.

OBJECTIVE

Evaluate changes in surface- and ground-water flow and quality as the result of the construction of the effluent-wetland treatment system.

APPROACH

Fourteen new monitoring wells will be installed. Two automatic data recorders will be installed on two existing sand point wells. Twenty-three wells and two surface-water sites will be sampled for inorganic and organic constituents to characterize the pre-inundation water quality. After inundation, quarterly sampling of the monitoring network will be performed to provide data for water-quality trend analysis. Two sediment sites will be sampled annually to provide organic compound and trace-element data. All data will be synthesized into a GIS data base.

PLANNED ACTIVITIES DURING 1992

A literature search will be completed. Creation of a GIS data base integrating tabular and spatial data will be started. A base map showing location of all wells with attributes will be created and distributed to cooperators. Fourteen monitoring wells will be installed in the Eagle Bluffs Wildlife Area and upgradient of the area. Particle size and bulk mineralogy of the aquifer material at each of the 14 well sites will be determined, and the wells will be developed for sample collection. Two automatic data recorders will be installed on two existing wells in the wetland. The monitoring network, which includes 23 wells, Perche Creek, and 1 small area of impounded water, will be sampled quarterly. Sediment samples will be collected and analyzed annually.

SOURCES OF WATER RESOURCES DIVISION PUBLICATIONS AND INFORMATION

Selected references on water resources in Missouri are listed on the following pages, and many of these publications are available for inspection at:

U.S. Geological Survey, WRD
Missouri District
1400 Independence Road
Mail Stop 200
Rolla, Missouri 65401

and

Missouri Division of Geology and Land Survey
Fairgrounds Road
Rolla, Missouri 65401

Current releases are described in a monthly pamphlet, "New Publications of the Geological Survey," and may be obtained from:

Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, Colorado 80225

Professional Papers, Bulletins, Water-Supply Papers, Techniques of Water-Resources Investigations, Earthquake Information Bulletins, and popular leaflets, pamphlets, and booklets may be purchased from Books and Open-File Reports Section, Denver, Colorado (address above); additional information is given in "Guide to Obtaining U.S. Geological Survey Information," U.S. Geological Survey Circular 900, which is available without cost from Books and Open-File Reports Section, Denver, Colorado.

Open-File and Water-Resources Investigations Reports for Missouri are available for inspection at the Missouri District Office, and may be purchased from:

Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, Colorado 80225

To obtain information on maps, write:

U.S. Geological Survey
Map Distribution
Federal Center
Box 25286
Denver, Colorado 80225

For additional information write:

Earth Science Information Center
Mid-Continent Mapping Center
1400 Independence Road
Mail Stop 231
Rolla, Missouri 65401

Public Inquiries Offices (PIOs) provide general information about the programs of the U.S. Geological Survey and its reports and maps. The PIOs answer inquiries made in person or by mail and refer requests for specific technical information to the appropriate people. Direct inquiries for Missouri to:

Public Inquiries Office
U.S. Geological Survey
1028 General Services Administration Building
19th and F Streets, NW
Washington, D.C. 20244

REFERENCES CITED

- Harris, Barbara, 1979, Water in Missouri: Rolla, Missouri Division of Geology and Land Survey Educational Series 5, 28 p.
- Missouri Division of Geology and Land Survey, 1967, Water resources, in Mineral and Water Resources of Missouri: Rolla, Missouri Division of Geology and Land Survey, v. 43, ser. 2, p. 254.
- National Oceanic and Atmospheric Administration, 1990, Climatological data, annual summary, Missouri, 1990: Asheville, N.C., 20 p.

SELECTED REFERENCES FOR MISSOURI

Contact the Missouri District office for information regarding the availability of these publications.

- Alexander, T.W., 1990a, Delineation of flooding within the Ozark National Scenic Riverways in southeastern Missouri--Akers and Alley Spring: U.S. Geological Survey Hydrologic Investigations Atlas HA-712-A, 3 sheets.
- _____, 1990b, Delineation of flooding within the Ozark National Scenic Riverways in southeastern Missouri--Round Spring and Powder Mill: U.S. Geological Survey Hydrologic Investigations Atlas HA-712-B, 3 sheets.
- _____, 1990c, Analysis of alternative modifications for reducing backwater flooding at the Honey Creek coal strip mine reclamation in Henry County, Missouri: U.S. Geological Survey Water-Resources Investigations 90-4068, 22 p.
- _____, 1992a, Discharge rating for tainter gates at Lock and Dam No. 24 on the Mississippi River at Clarksville, Missouri: U.S. Geological Survey Water-Resources Investigations Report 92-4054, 16 p.
- _____, 1992b, Discharge ratings for tainter and roller gates at Lock and Dam No. 25 on the Mississippi River near Winfield, Missouri: U.S. Geological Survey Water-Resources Investigations Report 92-4118, 20 p.
- Barks, J.H., 1976, Water-quality characteristics of six small lakes in Missouri: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 33, 42 p.
- _____, 1977, Effects of abandoned lead and zinc mines and tailing piles on water quality in the Joplin area, Missouri: U.S. Geological Survey Water-Resources Investigations Report 77-75, 49 p.
- _____, 1978, Water quality in the Ozark National Scenic Riverways: U.S. Geological Survey Water-Supply Paper 2048, 57 p.
- Barks, J.H., and Berkas, W.R., 1979, Water quality in the proposed Prosperity Reservoir area, Center Creek basin, Missouri: U.S. Geological Survey Water-Resources Investigations Report 79-22, 26 p.S
- Barks, J.H., Mesko, T.O., Bohm, R.A., Meier, D.H., and Williams, J.H., 1983, Geology, water movement, and sediment characteristics of the Spring River upstream from La Russell, southwestern Missouri: Rolla, Missouri Division of Geology and Land Survey Open-File Report 83-21-WR, 33 p.
- Becker, L.D., 1985, How the U.S. Geological Survey provides flood-estimating methods and conducts flood measurement [abs]: Jefferson City, Mo., Proceedings of the 1985 Stormwater Conference, p. 4-5.

SELECTED REFERENCES FOR MISSOURI--Continued

- Becker, L.D., 1986, Techniques for estimating flood-peak discharges from urban basins in Missouri: U.S. Geological Survey Water-Resources Investigations Report 86-4322, 38 p.
- _____, 1990, Simulation of flood hydrographs for small basins in Missouri: U.S. Geological Survey Water-Resources Investigations Report 90-4045, 40 p.
- Becker, L.D., Alexander, T.W., and Waite, L.A., 1983, Floods in Kansas City, Missouri, and vicinity, August 12-13, 1982: U.S. Geological Survey Water-Resources Investigations Report 83-4141, 35 p.
- Berkas, W.R., 1980, Effects of urban runoff and wastewater effluent on Wilsons Creek and James River near Springfield, Missouri: U.S. Geological Survey Water-Resources Investigations Report 80-27, 31 p.
- Berkas, W.R., 1982, Streamflow and water-quality conditions, Wilsons Creek and James River, Springfield area, Missouri: U.S. Geological Survey Water-Resources Investigations Report 82-26, 38 p.
- _____, 1983, Suspended-sediment data in the Salt River basin, Missouri: U.S. Geological Survey Open-File Report 83-275, 38 p.
- _____, 1987a, Traveltime, reaeration, and water-quality characteristics during low-flow conditions in Wilsons Creek and the James River near Springfield, Missouri: U.S. Geological Survey Water-Resources Investigations Report 87-4074, 32 p.
- _____, 1987b, Water-quality assessment of Peruque Creek, St. Charles County, Missouri, July 1983 and July 1984: U.S. Geological Survey Water-Resources Investigations Report 87-4079, 45 p.
- _____, 1989, Sedimentation of Lake Taneycomo, Missouri, 1913-1987: U.S. Geological Survey Water-Resources Investigations Report 89-4160, 80 p.
- Berkas, W.R., and Barks, J.H., 1980, Effects of the proposed Prosperity Reservoir on ground water in lower Center Creek basin, Missouri: U.S. Geological Survey Water-Resources Investigations Report 80-88, 29 p.
- Berkas, W.R., Endicott, Cynthia, and Cross, P.W., 1989, Groundwater level data for Missouri 1985-1986: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 37, 78 p.
- Berkas, W.R., Femmer, S.V., Mesko, T.O., and Thompson, B.W., 1987, Surface-water hydrology of the Little Black River basin, Missouri and Arkansas, before water-land improvement practices: U.S. Geological Survey Water-Resources Investigations Report 87-4076, 54 p.

SELECTED REFERENCES FOR MISSOURI--Continued

- Berkas, W.R., and Lodderhose, J.R., 1985, Water-quality assessment and wastewater-management alternatives for Dardenne Creek in St. Charles County, Missouri: U.S. Geological Survey Water-Resources Investigations Report 85-4120, 51 p.
- Bevans, H.E., Skelton, John, Kenny, J.F., and Davis, J.V., 1984, Hydrology of Area 39, Western Region, Interior Coal Province, Kansas and Missouri: U.S. Geological Survey Water-Resources Investigations Open-File Report 83-851, 83 p.
- Blevins, D.W., 1985, Quality of stormwater runoff in the Blue River basin, Missouri and Kansas, July-October 1981 and April-July 1982: U.S. Geological Survey Water-Resources Investigations Report 84-4226, 131 p.
- ____ 1989, Sources of coal-mine drainage and their effects on surface-water chemistry in the Claybank Creek basin and vicinity, north-central Missouri, 1983-84: U.S. Geological Survey Water-Supply Paper 2305, 38 p.
- ____ 1991a, Hydrology and water chemistry of an abandoned surface coal mine, southwestern Henry County, Missouri--1984-86: U.S. Geological Survey Water-Resources Investigations Report 90-4047, 52 p.
- ____ 1991b, Planned studies of movement of nitrogen species and herbicides on claypan soils at the Management Systems Evaluation Area in Missouri, in Mallard, G.E., and Aronson, D.A., Proceedings of the Technical Meeting of the U.S. Geological Survey Toxic Substance Hydrology Program: Monterey, Calif., March 11-15, 1991, U.S. Geological Survey Water-Resources Investigations Report 91-4034, p. 240-242.
- Blevins, D.W., and Chafin, D.T., 1988, Determination of chemical processes in coal mine spoil in west-central Missouri using sulfur and oxygen isotopes: Lexington, Ky., Proceedings of the 1988 Symposium on Mining, Hydrology, Sedimentology and Reclamation, p. 53-57.
- Blevins, D.W., and Ziegler, A.C., 1992, Hydrogeology, water chemistry, and subsidence of underground coal mines at Huntsville, Missouri--July 1987 to December 1988: U.S. Geological Survey Water-Resources Investigations Report 92-4001, 56 p.
- Bowie, J.E., 1971, Temperature of Missouri streams: U.S. Geological Survey, 350 p.
- Bowie, J.E., and Gann, E.E., 1967, Floods of July 18-23, 1965, in northwestern Missouri: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 21, 103 p.
- Bowie, J.E., and Petri, L.R., 1969, Travel of solutes in the lower Missouri River: U.S. Geological Survey Hydrologic Investigations Atlas HA-332, 1 sheet.
- Brahana, J.V., and Mesko, T.O., 1988, Hydrogeology and preliminary assessment of regional flow in the upper Cretaceous and adjacent aquifers in the northern Mississippi embayment: U.S. Geological Survey Water-Resources Investigations Report 87-4000, 65 p.

SELECTED REFERENCES FOR MISSOURI--Continued

- Brahana, J.V., Mesko, T.O., Busby, J.F., and Kraemer, T.F., 1985, Ground-water quality data from the northern Mississippi embayment--Arkansas, Missouri, Kentucky, Tennessee, and Mississippi: U.S. Geological Survey Open-File Report 85-683, 15 p.
- Chin, E.H., Skelton, John, and Guy, H.P., 1976, The 1973 Mississippi River basin flood--Compilation and analysis of meteorologic, streamflow, and sediment data: U.S. Geological Survey Professional Paper 937, 137 p.
- Davis, J.V., and Schumacher, J.G., 1992, Water-quality characterization of the Spring River basin, southwestern Missouri and southeastern Kansas: U.S. Geological Survey Water-Resources Investigations Report 90-4176, 112 p.
- Dean, T.J., Barks, J.H., and Williams, J.H., 1976, Guide for the geologic and hydrologic evaluation of small lake sites in Missouri: Rolla, Missouri Division of Geology and Land Survey Water-Resources Report 31, 50 p.
- Detroy, M.G., Skelton, John, and others, 1983, Hydrology of Area 38, Western Region, Interior Coal Province, Iowa and Missouri: U.S. Geological Survey Water-Resources Investigations Open-File Report 82-1014, 85 p.
- Emmett, L.F., 1985, Missouri ground-water resources in National Water Summary 1984--Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, p. 277-284.
- Emmett, L.F., and Imes, J.L., 1984, Ground-water resources of Audrain County, Missouri: U.S. Geological Survey Open-File Report 84-245, 55 p.
- Emmett, L.F., and Jeffery, H.G., 1968, Reconnaissance of the ground-water resources of the Missouri River alluvium between St. Charles and Jefferson City, Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-315, 1 sheet.
- Emmett, L.F., and Jeffery, H.G., 1969a, Reconnaissance of the ground-water resources of the Missouri River alluvium between Kansas City, Missouri, and the Iowa border: U.S. Geological Survey Hydrologic Investigations Atlas HA-336, 1 sheet.
- _____, 1969b, Reconnaissance of the ground-water resources of the Missouri River alluvium between Jefferson City and Miami, Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-340, 1 sheet.
- _____, 1970, Reconnaissance of the ground-water resources of the Missouri River alluvium between Miami and Kansas City, Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-344, 1 sheet.

SELECTED REFERENCES FOR MISSOURI--Continued

- Emmett, L.F., Skelton, John, Luckey, R.R., and Miller, D.E., 1978, Water resources of the Springfield area, Missouri: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 34, 150 p.
- Feder, G.L., 1979, Geochemical survey of waters of Missouri: U.S. Geological Survey Professional Paper 954-E, 78 p.
- Feder, G.L., and Barks, J.H., 1972, A losing drainage basin in the Missouri Ozarks identified on side-looking radar imagery, in Geological Survey Research 1972: U.S. Geological Survey Professional Paper 800-C, p. C249-C252.
- Feder, G.L., Skelton, John, Jeffery, H.G., and Harvey, E.J., 1969, Water resources of the Joplin area, Missouri: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 24, 97 p.
- Gann, E.E., 1971, Generalized flood-frequency estimates for urban areas in Missouri: U.S. Geological Survey Open-File Report, 18 p.
- Gann, E.E., Harvey, E.J., Barks, J.H., and Fuller, D.L., 1973, Water resources of northwestern Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-444, 4 sheets.
- Gann, E.E., Harvey, E.J., Barks, J.H., Fuller, D.L., and Miller, D.E., 1974, Water resources of west-central Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-491, 4 sheets.
- Gann, E.E., Harvey, E.J., Jeffery, H.G., and Fuller, D.L., 1971, Water resources of northeastern Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-372, 4 sheets.
- Gann, E.E., Harvey, E.J., and Miller, D.E., 1976, Water resources of south-central Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-550, 4 sheets.
- Hall, D.C., 1986, A description of the hydrologic system and the effects of coal mining on water quality in the East Fork Little Chariton River and the alluvial aquifer between Macon and Huntsville, north-central Missouri: U.S. Geological Survey Water-Resources Investigations Report 86-4160, 66 p.
- _____, 1987, Hydrogeochemical data of coal strip-mine spoil near Macon in north-central Missouri: U.S. Geological Survey Open-File Report 87-119, 18 p.
- Hall, D.C., and Berkas, W.R., 1988, Comparison of instream and laboratory methods of measuring sediment oxygen demand: Water-Resources Bulletin, v. 24, no. 3, p. 571-575.
- Hall, D.C., and Davis, R.E., 1986, Ground-water movement and effects of coal strip mining on water quality of high-wall lakes and aquifers in the Macon-Huntsville area, north-central Missouri: U.S. Geological Survey Water-Resources Investigations Report 85-4102, 102 p.

SELECTED REFERENCES FOR MISSOURI-- Continued

- Hall, D.C., and Steelman, S.H., 1990, Missouri water supply and demand, in National Water Summary 1987--Selected hydrologic events and water supply and demand: U.S. Geological Survey Water-Supply Paper 2350, p. 329-336.
- Harvey, E.J., 1980, Ground water in the Springfield-Salem Plateaus of southern Missouri and northern Arkansas: U.S. Geological Survey Water-Resources Investigations Report 80-101, 66 p.
- Harvey, E.J., and Emmett, L.F., 1980, Hydrology and model study of the proposed Prosperity Reservoir, Center Creek basin, southwestern Missouri: U.S. Geological Survey Water-Resources Investigations Report 80-7, 50 p.
- Harvey, E.J., and Skelton, John, 1968, Hydrologic study of a waste-disposal problem in a karst area at Springfield, Missouri in Geological Survey Research 1968: U.S. Geological Survey Professional Paper 600-C, p. C217-C220.
- Harvey, E.J., Skelton, John, and Miller, D.E., 1983, Hydrology of carbonate terrane--Niangua, Osage Fork, and Grandglaize basins, Missouri: Rolla, Missouri Division of Geology and Land Survey Water-Resources Report 35, 132 p.
- Harvey, E.J., Williams, J.H., and Dinkel, T.R., 1977, Application of thermal imagery and aerial photography to hydrologic studies of karst terrane in Missouri: U.S. Geological Survey Water-Resources Investigations Report 77-16, 58 p.
- Hauth, L.D., 1973a, Rainfall-runoff data for small drainage areas of Missouri: U.S. Geological Survey Open-File Report, 171 p.
- ____ 1973b, Selected storm events in 5-minute increments, from Missouri rainfall stations at Kansas City, St. Louis, Springfield, and Columbia: U.S. Geological Survey Open-File Report, 191 p.
- ____ 1974a, Technique for estimating the magnitude and frequency of Missouri floods: U.S. Geological Survey Open-File Report, 19 p.
- ____ 1974b, Model synthesis in frequency analysis of Missouri floods: U.S. Geological Survey Circular 708, 16 p.
- ____ 1980, Evaluation of peak-flow data network of small streams in Missouri: U.S. Geological Survey Water-Resources Investigations Report 80-87, 38 p.
- ____ 1982, Flow-duration data for Missouri streams: U.S. Geological Survey Open-File Report 81-1189, 26 p.
- Hauth, L.D., and Carswell, W.J., Jr., 1978, Floods in Kansas City, Missouri and Kansas, September 12-13, 1977: U.S. Geological Survey Water-Resources Investigations Report 78-63, 36 p.

SELECTED REFERENCES FOR MISSOURI-- Continued

- Hauth, L.D., Carswell, W.J., Jr., and Chin, E.H., 1981, Floods in Kansas City, Missouri and Kansas, September 12-13, 1977: U.S. Geological Survey Professional Paper 1169, 47 p.
- Hauth, L.D., and Spencer, D.W., 1969, Floods in Gravois Creek basin, St. Louis County, Missouri: U.S. Geological Survey Open-File Report, 14 p.
- 1971, Floods in Coldwater Creek, Watkins Creek, and River des Peres basins, St. Louis County, Missouri: U.S. Geological Survey Open-File Report, 36 p.
- Hedman, E.R., Skelton, John, and Freiwald, D.A., 1987, Flow characteristics for selected springs and streams in the Ozark subregion, Arkansas, Kansas, Missouri, and Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-688, 4 sheets.
- Holmes, Jr., R.R., Westphal, J.A., and Jobson, H.E., 1990, Mudflow rheology in a vertically rotating flume, *in* French, R.H., ed., Proceedings of the International Symposium Hydraulics/Hydrology of Arid Lands: San Diego, Calif., July 30-August 2, 1990, p. 212-217.
- Imes, J.L., 1985, The ground-water flow system in northern Missouri with emphasis on the Cambrian-Ordovician aquifer: U.S. Geological Survey Professional Paper 1305, 61 p.
- 1988, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma--Basement confining unit: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-B, 1 sheet.
- 1989a, Analysis of the effect of pumping on ground-water flow in the Springfield Plateau and Ozark aquifers near Springfield, Missouri: U.S. Geological Survey Water-Resources Investigations Report 89-4079, 63 p.
- 1989b, Compilation of geohydrologic data collected as part of the areal appraisal of ground-water resources near Branson, Missouri: U.S. Geological Survey Open-File Report 89-401, 24 p.
- 1989c, Geohydrology and hydrochemistry of the Ozark Plateaus aquifer system, *in* Swain, L.A., and Johnson, A.I., eds., Regional Aquifer Systems of the United States, Aquifers of the Midwestern Area: American Water Resources Association Monograph Series, no. 13, p. 165-178.
- 1990a, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-A, 1 sheet.
- 1990b, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma--St. Francois aquifer: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-C, 2 sheets.

SELECTED REFERENCES FOR MISSOURI--Continued

- Imes, J.L., 1990c, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma--St. Francois confining layer: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-D, 3 sheets.
- ____ 1990d, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma--Ozark aquifer: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-E, 3 sheets.
- ____ 1990e, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma--Ozark confining layer: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-F, 3 sheets.
- ____ 1990f, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma--Springfield Plateau aquifer: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-G, 3 sheets.
- ____ 1990g, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma--Western Interior Plains confining system: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-H, 3 sheets.
- ____ 1991, Water quality, seasonal water-level changes, 1988-89, and simulated effects of increased water use from the Ozark aquifer near Branson, Missouri: U.S. Geological Survey Water-Resources Investigations Report 91-4057, 54 p.
- Imes, J.L., and Davis, J.V., 1990a, Water type and concentration of dissolved solids, chloride, and sulfate in ground water from the St. Francois aquifer in Missouri, Arkansas, Kansas, and Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-J, 1 sheet.
- ____ 1990b, Water type and concentration of dissolved solids, chloride, and sulfate in ground water from the Springfield Plateau aquifer in Missouri, Arkansas, Kansas, and Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-L, 2 sheets.
- ____ 1991, Water type and concentration of dissolved solids, chloride, and sulfate in ground water from the Ozark aquifer in Missouri, Arkansas, Kansas, and Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-K, 4 sheets.
- Imes, J.L. and Emmett, L.F., in press, Geohydrology and modeling analysis of the Ozark Plateaus Aquifer System in parts of Missouri, Arkansas, Oklahoma, and Kansas: U.S. Geological Survey Professional Paper 1414-F.
- Imes, J.L., and Smith, B.J., 1990, Areal extent, stratigraphic relation, and geohydrologic properties of regional geohydrologic units in southern Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-I, 3 sheets.

SELECTED REFERENCES FOR MISSOURI--Continued

- Jacobson, R.B., in press, Geographic Information System analysis of landslides on shale slopes, Pendleton County, West Virginia [abs]: The Geological Society of America 1992 Annual Meeting--Abstracts with Programs, v. 24.
- Jacobson, R.B, and Pugh, A.L., in press, Effects of land use and climate shifts on channel disturbance, Ozark Plateaus, U.S.A.: Proceedings of the orkshop on the effects of global climate change on hydrology and water resources at the catchment scale, Japan-U.S. Committee on Hydrology, Water Resources and Global Climate Change, p. 423-444.
- Jenkins, K.L. (compiler), 1989, Water-resources activities of the U.S. Geological Survey in Missouri, fiscal year 1989: U.S. Geological Survey Open-File Report 89-621, 54 p.
- Jorgensen, D.G., Helgesen, J.O., and Imes, J.L., in press, Regional aquifers in Kansas, Nebraska, and parts of Arkansas, Colorado, Missouri, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming--Geologic framework: U.S. Geological Survey Professional Paper 1414-B.
- Jorgensen, D.G., Signor, D.C., and Imes, J.L., 1989a, Accounting for intracell flow in models with emphasis on water table recharge and stream-aquifer interaction--I. Problems and concepts: Water Resources Research, v. 25, no. 4, p. 669-676.
- _____ 1989b, Accounting for intracell flows in models with emphasis on water table recharge and stream-aquifer interaction--II. A procedure: Water Resources Research, v. 25, no. 4, p. 677-684.
- Kleeschulte, M.J., 1991, Geohydrology of bedrock aquifers and public supply and domestic water use, 1962-85, in St. Charles County, Missouri, in Proceedings of the Geosciences Workshop: U.S. Department of Energy, Oak Ridge Operations Office, p. 41-74.
- Kleeschulte, M.J., and Cross, P.W., 1990, Hydrologic data for the Weldon Spring chemical plant site and vicinity property, St. Charles County, Missouri--1986-89: U.S. Geological Survey Open-File Report 90-552, 117 p.
- Kleeschulte, M.J., and Duley, J.W., 1985, Geology, water movement, and sediment characteristics of the Sugar, Romaine, and Rock Creek basins, with a section on Surficial material, by J.W. Whitfield: Rolla, Missouri Division of Geology and Land Survey Open-File Report 85-30-EG, 49 p.
- Kleeschulte M.J., and Emmett, L.F., 1986a, Compilation and preliminary interpretation of hydrologic data for the Weldon Spring radioactive waste-disposal sites, St. Charles County, Missouri--A progress report: U.S. Geological Survey Water-Resources Investigations Report 85-4272, 71 p.
- _____ 1986b, Surface and ground-water interaction in the vicinity of a radioactive waste-disposal site, Weldon Spring, Missouri [abs]: Midwest Ground Water Conference, 31st, Little Rock, Ark., 1986, Proceedings, p. 12-13.

SELECTED REFERENCES FOR MISSOURI--Continued

- Kleeschulte, M.J., and Emmett, L.F., 1987, Hydrology and water quality at the Weldon Spring radioactive waste-disposal sites, St. Charles County, Missouri: U.S. Geological Survey Water-Resources Investigations Report 87-4169, 65 p.
- Kleeschulte, M.J., Emmett, L.F., and Barks, J.H., 1986, Hydrologic data for the Weldon Spring radioactive waste-disposal sites, St. Charles County, Missouri--1984-1986: U.S. Geological Survey Open-File Report 86-488, 61 p.
- Kleeschulte, M.J., Mesko, T.O., and Vandike, J.E., 1985, Appraisal of the ground-water resources of Barton, Vernon, and Bates Counties, Missouri: Rolla, Missouri Division of Geology and Land Survey Water-Resources Report 36, 74 p.
- Kratzer, W.M., and Jenkins, K.L. (compilers), 1985, Water-resources activities of the U.S. Geological Survey in Missouri, fiscal year 1985: U.S. Geological Survey Open-File Report 85-188, 57 p.
- Luckey, R.R., 1985, Water resources of the southeast lowlands, Missouri, with a section on Water quality, by D.L. Fuller: U.S. Geological Survey Water-Resources Investigations Report 84-4277, 78 p.
- Luckey, R.R., and Fuller, D.L., 1980, Hydrogeologic data for the Mississippi embayment of southeastern Missouri: U.S. Geological Survey Open-File Report 79-421, 199 p.
- Marikos, Mark, and Skelton, John, 1982, Estimated water use in Missouri, 1980: Rolla, Missouri Division of Geology and Land Survey Open-File Map Report, 1 sheet.
- Maxwell, J.C., and Harvey, E.J., 1965, Use of abandoned mines as a potential water resource, Joplin district, Missouri [abs]: Mining Engineering, v. 17, no. 8, p. 51.
- Mesko, T.O., 1986, Geohydrology of the Tiger Mine area near Worland, Bates County, Missouri [abs]: Midwest Ground Water Conference, 31st, Little Rock, Ark., 1986, Proceedings, p. 14-15.
- _____, 1987, Geohydrology of a coal-mining area, southwestern Bates County, Missouri: U.S. Geological Survey Water-Resources Investigations Report 87-4204, 57 p.
- _____, 1988, Subsurface geology of Paleozoic, Mesozoic, and Cenozoic units of southeast Missouri: U.S. Geological Survey Miscellaneous Investigations Series I-1875, 3 sheets.
- _____, 1990, Geohydrology and water quality of Cenozoic and Mesozoic units in southeast Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-719, 2 sheets.
- Mesko, T.O., and Berkas, W.R., 1988, Missouri ground-water quality, in National Water Summary 1986--Selected hydrologic events and ground-water quality: U.S. Geological Survey Water-Supply Paper 2325, p. 329-337.

SELECTED REFERENCES FOR MISSOURI--Continued

- Mesko, T.O., and Carlson, G.M., 1988, Occurrence of pesticides, nitrate, volatile organic compounds, and trace elements in ground water and streams, southeastern Missouri, 1986-87: U.S. Geological Survey Open-File Report 88-495, 73 p.
- Mesko, T.O., and Imes, J.L., in press, Discharge of ground water along the Ozark escarpment in southeastern Missouri and northeastern Arkansas in Selected Papers in the Hydrologic Sciences, 1988-90: U.S. Geological Survey Water-Supply Paper 2340.
- Miller, D.E., Emmett, L.F., Skelton, John, Jeffery, H.G., and Barks, J.H., 1974, Water resources of the St. Louis area, Missouri: Rolla, Missouri Division of Geology and Land Survey Water-Resources Report 30, 114 p.
- Peterson, M.S., 1965, Floods of June 17th and 18th, 1964, in Jefferson, Ste. Genevieve, and St. Francois Counties, Missouri: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 19, 20 p.
- Pugh, A.L., and Jacobson, R.B., 1992, Recent geomorphic evolution of Little Piney Creek, Phelps County, Missouri [abs.]: Program and Abstracts of the Missouri Academy of Science Annual Meeting, Geology and Geophysics Section, Rolla, Missouri, April 25, 1992.
- Rabeni, C.F., and Jacobson, R.B., in press, The relation of fluvial geomorphology to fish habitat in low-gradient streams, Ozark Plateaus, U.S.A.: Freshwater Biology.
- _____ in press, Geomorphic and hydraulic influences on the abundance and distribution of stream centrarchids in Ozark U.S.A. streams: Polish Archives of Hydrobiology.
- Reed, H.L., Hatten, D.O., Perkins, T.J., Gray, G.L., and Davis, J.V., 1991, Water-resources data, Missouri, water year 1990: U.S. Geological Survey Water-Data Report MO-90-1, 304 p. (published annually).
- Sandhaus, E.H., and Skelton, John, 1968, Magnitude and frequency of Missouri floods: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 23, 276 p.
- Schumacher, J.G., 1990, Geochemical data for the Weldon Spring chemical plant site and vicinity property, St. Charles County, Missouri--1989-90: U.S. Geological Survey Open-File Report 90-351, revised in 1991, 47 p.
- Schumacher, J.G., Lindley, C.E., and Anderson, F.S., in press, Migration of nitroaromatic compounds in unsaturated soil at the abandoned Weldon Spring Ordnance Works, St. Charles County, Missouri: 16th Annual Army Environmental R&D Symposium, Williamsburg, Va., 1992, Proceedings.
- Schumacher, J.G., and Stollenwerk, K.G., 1991, Geochemical controls on the migration of molybdenum, uranium, and other constituents at the Weldon Spring chemical plant site, in Proceedings of the Geosciences Workshop: U.S. Department of Energy, Oak Ridge Operations Office, p. 87-140.

SELECTED REFERENCES FOR MISSOURI--Continued

- Signor, D.C., and Imes, J.L., 1989, Geohydrology of regional aquifer systems in Cretaceous and older rocks underlying the central United States, in Swain, L.A., and Johnson, A.I., eds., Regional Aquifer Systems of the United States, Aquifers of the Midwestern Area: American Water Resources Association Monograph Series, no. 13, p. 149-163.
- Skelton, John, 1966, Low-flow characteristics of Missouri streams: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 20, 95 p.
- Skelton, John, 1968, Storage requirements to augment low flows of Missouri streams: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 22, 78 p.
- _____ 1970, Base-flow recession characteristics and seasonal low-flow frequency characteristics for Missouri streams: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 25, 43 p.
- _____ 1971, Carryover storage requirements for reservoir design in Missouri: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 27, 56 p.
- _____ 1973, Flood-volume design data for Missouri streams: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 28, 28 p.
- _____ 1974, Estimating low-flow frequency for perennial Missouri Ozarks streams: U.S. Geological Survey Water-Resources Investigations Report 59-73, 19 p.
- _____ 1976, Missouri stream and springflow characteristics--Low-flow frequency and flow duration: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 32, 76 p.
- _____ 1977, Streamflow characteristics of the Joplin area, Missouri: U.S. Geological Survey Open-File Report 77-605, 32 p.
- Skelton, John, and Harvey, E.J., 1968, Structural controls on streamflow in the North Fork River and Bryant Creek basins, Missouri, in Geological Survey Research 1968: U.S. Geological Survey Professional Paper 600-C, p. C153-C157.
- Skelton, John, Harvey, E.J., and Miller, D.E., 1982, Water information for northwestern Missouri--A planning document: U.S. Geological Survey Water-Resources Investigations Report 82-27, 58 p.
- Skelton, John, and Homyk, Anthony, 1970, A proposed streamflow data program for Missouri: U.S. Geological Survey Open-File Report, 44 p.
- Smith, B.J., 1988, Assessment of water quality in non-coal mining areas of Missouri: U.S. Geological Survey Water-Resources Investigations Report 87-4286, 50 p.

SELECTED REFERENCES FOR MISSOURI--Continued

- Smith, B.J., 1988, Water fact sheet--U.S. Geological Survey ground-water studies in Missouri: U.S. Geological Survey Open-File Report 88-161, 2 p.
- Smith, B.J., and Imes, J.L., 1991, Correlation of regional geohydrologic units to geological formations in southern Missouri: U.S. Geological Survey Hydrologic Atlas HA-711-M, 2 sheets.
- Smith, B.J., and Jenkins, K.L. (compilers), 1988, Water-resources activities of the U.S. Geological Survey in Missouri, fiscal year 1987: U.S. Geological Survey Open-File Report 88-99, 66 p.
- Smith, B.J., and Schumacher, J.G., 1991, Hydrochemical and sediment data for the Old Lead Belt, southeastern Missouri--1988-89: U.S. Geological Survey Open-File Report 91-211, 98 p.
- Southard, R.E., 1986, An alternative basin characteristic for use in estimating impervious area in urban Missouri basins: U.S. Geological Survey Water-Resources Investigations Report 86-4362, 21 p.
- Spencer, D.W., 1971, Computed flood profile--River des Peres, Groby Street to 82nd Boulevard, University City, St. Louis County, Missouri: U.S. Geological Survey Open-File Report, 14 p.
- Spencer, D.W., and Alexander, T.W., 1978, Technique for estimating the magnitude and frequency of floods in St. Louis County, Missouri: U.S. Geological Survey Water-Resources Investigations Report 78-139, 23 p.
- Spencer, D.W., and Hauth, L.D., 1968, Floods in Maline Creek basin, St. Charles County, Missouri: U.S. Geological Survey Open-File Report, 12 p.
- U.S. Geological Survey, 1982, Water-resources investigations of the U.S. Geological Survey in Missouri: 1 sheet.
- U.S. Geological Survey, and Missouri Division of Geology and Land Survey, 1967, Mineral and water resources of Missouri: U.S. 90th Congress, 1st Session, Senate Document 19, 399 p.; also Missouri Geological Survey and Water Resources, v. 43, 2d ser., 399 p.
- Vaill, J.E., and Barks, J.H., 1980, Physical environment and hydrologic characteristics of coal-mining areas in Missouri: U.S. Geological Survey Water-Resources Investigations Report 80-67, 33 p.
- Vineyard, J.D., and Feder, G.L., 1974, Springs of Missouri: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 29, 266 p. (reprinted 1982).
- Waite, L.A., 1984, Data uses and funding of the stream-gaging program in Missouri: U.S. Geological Survey Open-File Report 84-868, 32 p.

SELECTED REFERENCES FOR MISSOURI--Continued

- Waite, L.A., 1987, Cost effectiveness of the stream-gaging program in Missouri: U.S. Geological Survey Water-Resources Investigations Report 87-4254, 38 p.
- _____, 1991, Missouri floods and droughts, with sections on General climatology, by W.L. Decker and Water management, by S.A. McIntosh, in National Water Summary 1988-89--Hydrologic events and floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 361-368.
- Waite, L.A., and Alexander, T.W., 1987, Floods of December 1982 in southeastern Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA-689, 1 sheet.
- Waite, L.A., Davis, J.V., Reed, H.L., Perkins, T.J., and Hatten, D.O., 1989, Water resources data, Missouri, water year 1988: U.S. Geological Survey Water-Data Report MO-88-1, 290 p. (published annually).
- Waite, L.A., and Skelton, John, 1986, Missouri surface-water resources, in National Water Summary 1985--Hydrologic events and surface-water resources: U.S. Geological Survey Water-Supply Paper 2300, p. 301-308.