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WATER INFORMATION FOR NORTHWESTERN MISSOURI:

A PLANNING DOCUMENT

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 82-27

Prepared in cooperation with the
Missouri Department of Natural Resources,
Division of Geology and Land Survey

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16. Abstract (Limit: 200 words)

Water supplies are limited in much of northwestern Missouri, and water-resources data also are limited. The report presents a summary of hydrologic data and an evaluation of areas where future hydrologic investigations would be most useful.

The largest and most dependable surface-water supplies that can be obtained without storage from tributary streams are from the lower Grand, Nodaway, and Chariton Rivers. The sources of ground water in order of quantities available are the Missouri River alluvium, glacial drift, tributary stream alluvium, and Pennsylvanian bedrock. Irrigation and industry are concentrated along the Missouri River where alluvial ground water is abundant.

Areas that have the greatest potential for future cooperative studies by the Missouri Division of Geology and Land Survey and the U.S. Geological Survey include the lower Grand and Thompson River basins, the Missouri River alluvial aquifer, the Nodaway-Tarkio-One Hundred and Two River basins, the Chariton River basin, and the 19 counties where surface-mineable coal reserves make coal-related industrial expansion possible.

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1982

Rolla, Missouri

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WATER INFORMATION FOR NORTHWESTERN MISSOURI--A PLANNING DOCUMENT

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ABSTRACT

Water supplies are limited in much of northwestern Missouri, and water-resources data also are limited. This report presents a summary of hydrologic data and an evaluation of areas where additional hydrologic data are needed to provide a data base suitable for use in making decisions regarding future water development.

The largest and most dependable surface-water supplies that can be obtained without storage from tributary streams, as indicated by the 30-day low flow with recurrence interval of 10 years, potentially are available from the lower Grand River (15 to 30 million gallons per day) and the Nodaway and Chariton Rivers (5 to 10 million gallons per day). Flow of the Missouri River is greater than 1,300 million gallons per day at all points in Missouri. Surface water is primarily a calcium bicarbonate type with dissolved-solids concentration less than 400 milligrams per liter.

Sources of water in surficial deposits are the Missouri River alluvium (well yields as much as 2,000 gallons per minute), glacial drift (well yields of 30 to 500 gallons per minute), and alluvium of tributary streams (well yields exceed 50 gallons per minute in large basins). The Pennsylvanian bedrock yields only a few gallons per minute to wells. The Cambrian and Ordovician formations are not evaluated because data are few, and there are no water wells open to these units. Water from the alluvium is a hard, calcium bicarbonate type that commonly has relatively large iron concentrations and typically has dissolved-solids concentrations of less than 500 milligrams per liter. Water from the glacial-drift and bedrock generally is a mixed calcium bicarbonate sodium sulfate type, is hard, has relatively large iron concentrations, and some of it is classified as saline.

Areas where additional hydrologic data are needed to provide a data base suitable for use in making decisions regarding future water development include the lower Grand and Thompson River basins, the Missouri River alluvial aquifer, the Nodaway-Tarkio-One Hundred and Two River basins, the Chariton River basin, and the 19 counties where surface-mineable coal reserves make coal-related industrial expansion possible.

INTRODUCTION

In northwestern Missouri, adequate supplies of water are becoming increasingly difficult to obtain where agricultural, municipal, or industrial water use has increased during the past decade. Streamflow and well yields are variable in time and space and suitable sites for water storage few. Although water supplies are limited, the area's water resources can sustain further economic development, but additional water-resources data will be required to fully assess the potential for development.

The purposes of this study were: (1) To update and summarize hydrologic data for northwestern Missouri and determine areas where water demand may be increasing because of municipal, irrigation, industrial, and energy development; and (2) to evaluate areas where additional hydrologic data are needed to provide a data base suitable for use in making decisions regarding future water development.

The area described in this report, approximately 14,000 square miles, is shown in figure 1. Approximate boundaries of the area are the Little Chariton River basin on the east, the Missouri River on the south and west, and the Missouri-Iowa border on the north.

Hydrologic information for northwestern Missouri was summarized in a hydrologic atlas by Gann and others (1973) that describes approximately the same area as the current (1980) study. The atlas contains information about aquifers, streamflow, glacial-drift thickness, aquifer tests, and an extensive list of selected references to other hydrologic reports about the area.

Conversion of Units

Conversion of inch-pound units to International System (SI) units:

Multiply inch-pound units	By	To obtain SI units
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
mile	1.609	kilometer
square mile	2.590	square kilometer
acre	0.4047	hectare
acre-foot	1233	cubic meter
cubic foot per second	0.02832	cubic meter per second
million gallons per day	0.04381	cubic meter per second
gallon per minute	6.31×10^{-5}	cubic meter per second
gallon per minute per foot	20.7×10^{-5}	cubic meter per second per meter
ton (short)	0.9072	metric ton
ton per square mile	0.3502	metric ton per square kilometer

Definition of Terms

1. Aquifer - A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

2. Cubic foot per second - One cubic foot per second is the rate of discharge of a stream having a cross-sectional area of 1 square foot and an average velocity of 1 foot per second. One cubic foot per second =7.48 U.S. gallons per second=0.646 million U.S. gallons per day.

3. Hydraulic conductivity - The volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

4. Low flow - The part of stream discharge that is derived primarily from ground-water outflow.

5. Recurrence interval - The average interval in years between occurrences of flow less than that indicated by the data. A 10-year drought has a probability of 0.10, or a 10 percent chance, of occurring during any given year.

6. Specific capacity - The rate of discharge of water from a well divided by the drawdown of water level in the well.

7. Standard deviation - A measure of the variation of a group of values around the mean of the group, based on the deviation of each value from the mean.

8. Storage coefficient - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

9. Transmissivity - The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

10. X-day Q_n - The average minimum flow for X consecutive days that has a recurrence interval of n years. For example, the 30-day Q_{10} is the 30-day average minimum flow with a recurrence interval of 10 years.

11. National Geodetic Vertical Datum of 1929 (NGVD of 1929) - A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level."

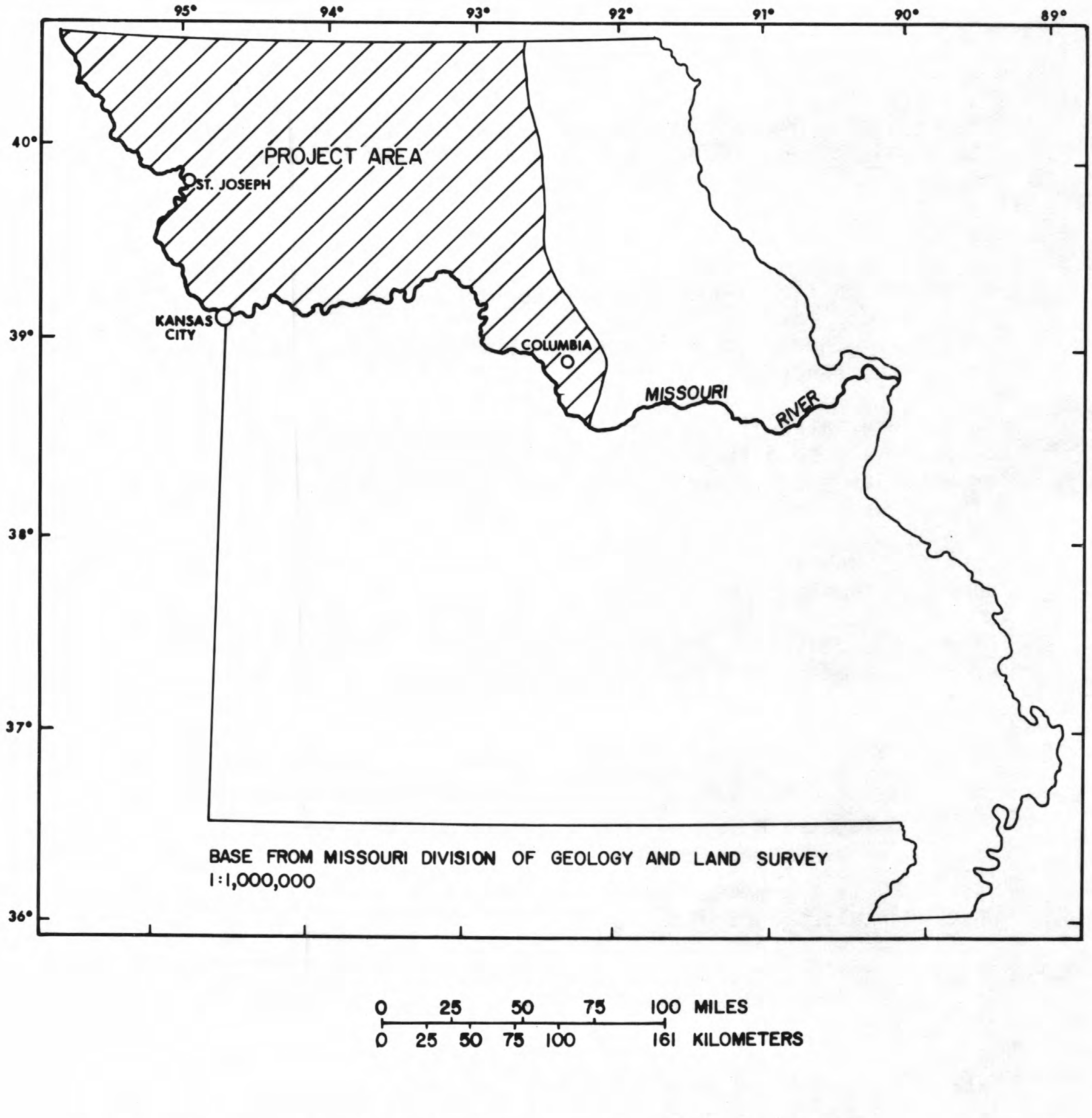

Figure 1.--Location of project area.

DESCRIPTION OF AREA

Geology

A report by Gann and others (1973) presents maps showing the geological and structural features of northwestern Missouri. In addition, the distribution, thickness, and texture of the glacial deposits are described in county reports (Fuller and others, 1956-60).

The geologic-time units and rock types in the area are shown in table 1. A large part of the study area is mantled by unconsolidated clay, silt, sand, gravel, and boulders of Pleistocene and Holocene age. The Pleistocene sediments consist of glacial deposits that mantle the uplands, valley fill in buried valleys, and the deeper part of the fill in the bordering Missouri River valley. Holocene deposits of clay, silt, sand, and gravel fill the modern valleys, whose drainage pattern has little relation to the buried valleys.

Pennsylvanian shale, sandstone, coal, and minor beds of limestone underlie the unconsolidated deposits and are exposed on the uplands where glacial deposits are thin and in the banks and beds of some streams. The Pennsylvanian bedrock formations listed in table 1 dip at the rates of 8 to 15 feet per mile northwest toward the Forest City basin in western Missouri (McCracken, 1971). The rocks are bowed into gentle folds whose axes generally strike northwest.

Rocks older than Pennsylvanian age are listed in table 1. However, they will not be discussed in detail because of a lack of data.

Physiography and Drainage

The study area is in the Dissected Till Plains Section of the Central Lowland Physiographic Province of the Interior Plains Physiographic Division (Fenneman, 1946). The land surface is mostly rolling hills with greatest relief occurring in the northwestern sections. Land-surface altitudes range from 1,220 feet in the northwestern part of the area to 620 feet in the southeastern part.

Major streams (fig. 2) originate outside the study area. With the exception of the Missouri River, the headwaters of all major streams are in Iowa. All the streams flow in a southerly or southeasterly direction. All runoff from the land surface eventually reaches the Missouri River through a network of tributary streams that forms a dendritic drainage pattern. The flood plains of the streams range from less than 1 mile in some areas to as much as 11 miles wide along the Missouri River.

Table 1.--Geologic-time units for northwestern Missouri showing rock type

[Time (in years) listed under period names is length of time for each unit; number in top righthand corner of each period name is cumulative time, in millions of years from the present (1980). Data from U.S. Geological Survey, Geologic Names Committee, 1980.]

Era	Period	Epoch	Rock type
Cenozoic		Holocene	Glacial deposits and loess mainly north of the Missouri River; silt, sand, and gravel in modern streams and rivers throughout the study area.
Cenozoic	Quaternary 2,000,000 years	Pleistocene	
Paleozoic	290 Pennsylvanian 40,000,000 years		Shale, limestone, sandstone, clay, and coal. Discontinuous outcrops in study area where drift is thin or absent.
Paleozoic	330 Mississippian 30,000,000 years		Predominantly limestone, some shale.
Paleozoic	360 Devonian 50,000,000 years		Predominantly limestone.
Paleozoic	410 Silurian 25,000,000 years		Predominantly limestone.
Paleozoic	435 Ordovician 65,000,000 years		Dolomite (magnesian limestone), limestone, sandstone, and shale.
Paleozoic	500 Cambrian 70,000,000 years		Dolomite, sandstone, and shale.
Precambrian	570		Igneous and metamorphic rocks.

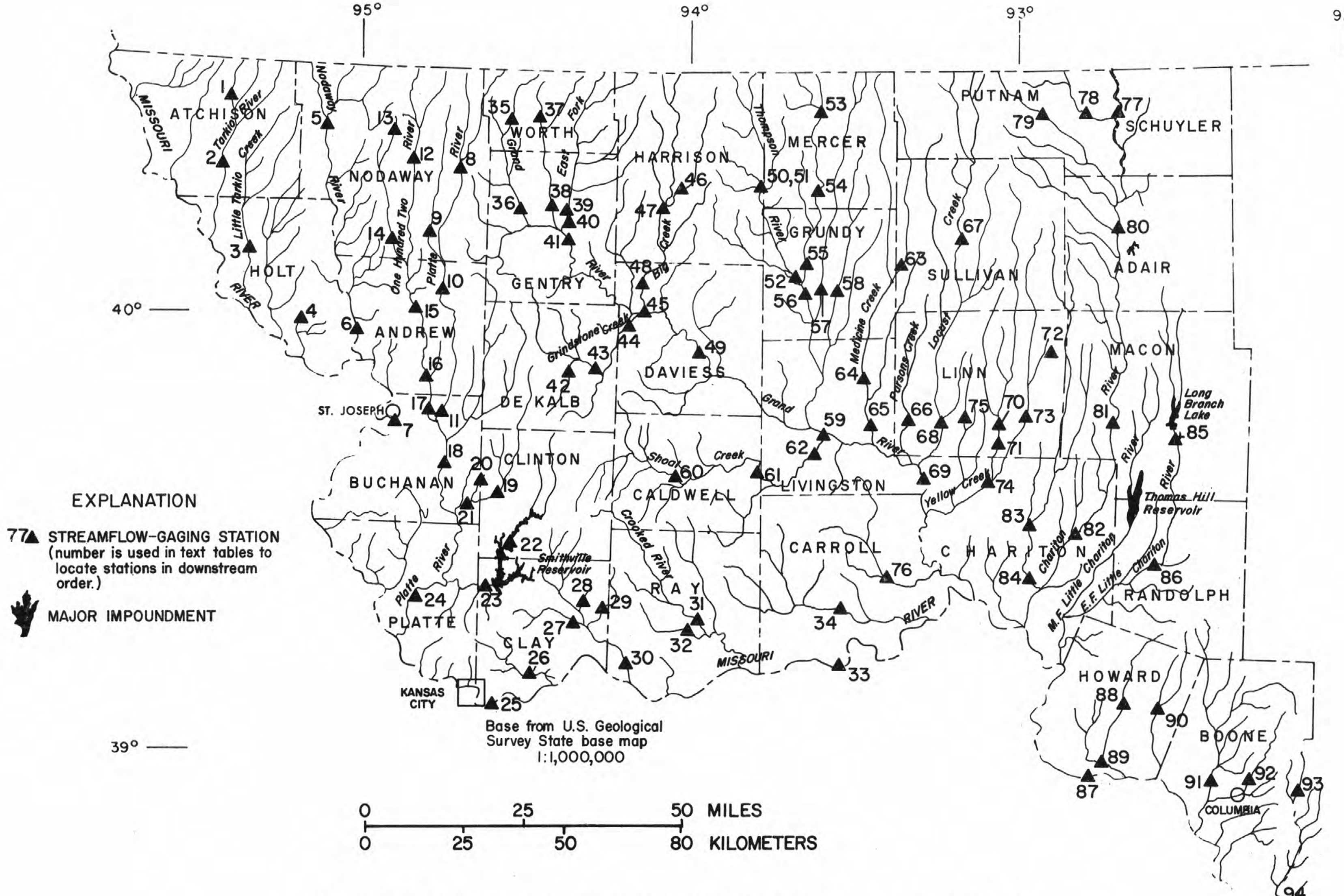

Figure 2.--Drainage pattern and network of streamflow-gaging stations.

Man has altered the natural drainage in several parts of the area. Extensive channelization has been done in some areas to decrease local flooding problems and improve the chances for successful agricultural operations. There are hundreds of small farm ponds that impound storm runoff from small drainage basins; a number of impoundments provide surface water for municipal supplies; and three large reservoirs (see fig. 2) provide flood control, water supply, recreation, and cooling water for electric-power generation. Many miles of levees have been constructed to protect agricultural, municipal, and industrial areas, especially along the Missouri River and its major tributaries.

Population Trends

A projection of population trends is one basis for determining the need of acquiring hydrologic data. Therefore, data for 1980-2000 from the Missouri Office of Administration (1977) and the Missouri Division of Geology and Land Survey (Jim Vandike, written commun., 1980) were used in this report to analyze population trends.

Projected population changes between 1980 and 2000 are shown by county in figure 3. Thirteen of the 29 counties are expected to lose population, which should reduce water use for domestic-municipal purposes in these areas. Nine of the 13 counties losing population are in the Grand River basin, which is primarily an agricultural area. Three of the losing counties are located in the northwestern part of the area, also a farming region. The counties near Kansas City and Columbia and those in the Chariton River basin are expected to increase in population during 1980-2000 because of urbanization, coal mining, and energy-related activities.

WATER-SUPPLY AVAILABILITY AND QUALITY

Surface Water

Continuous-record and low-flow partial-record streamflow-gaging stations are used for surface-water interpretive studies in northwestern Missouri (table 2 and fig. 2). The data from these stations show that approximately 19 percent of the average annual precipitation appears as streamflow. The remaining 81 percent is lost primarily to evapotranspiration. Although ground-water storage may vary from year to year, the long-term change in storage is assumed to be zero. The amount of underflow into and from the area is not known, but is assumed to be negligible in comparison to runoff and evapotranspiration (Gann and others, 1973).

The minimum flows of streams are a limiting factor in their potential use for industry, agriculture, municipalities, and waste dilution. In some basins of northwestern Missouri, there are significant amounts of surface water available, even during times of serious drought. The data in table 3 show the approximate limits of potential supplies from streams without

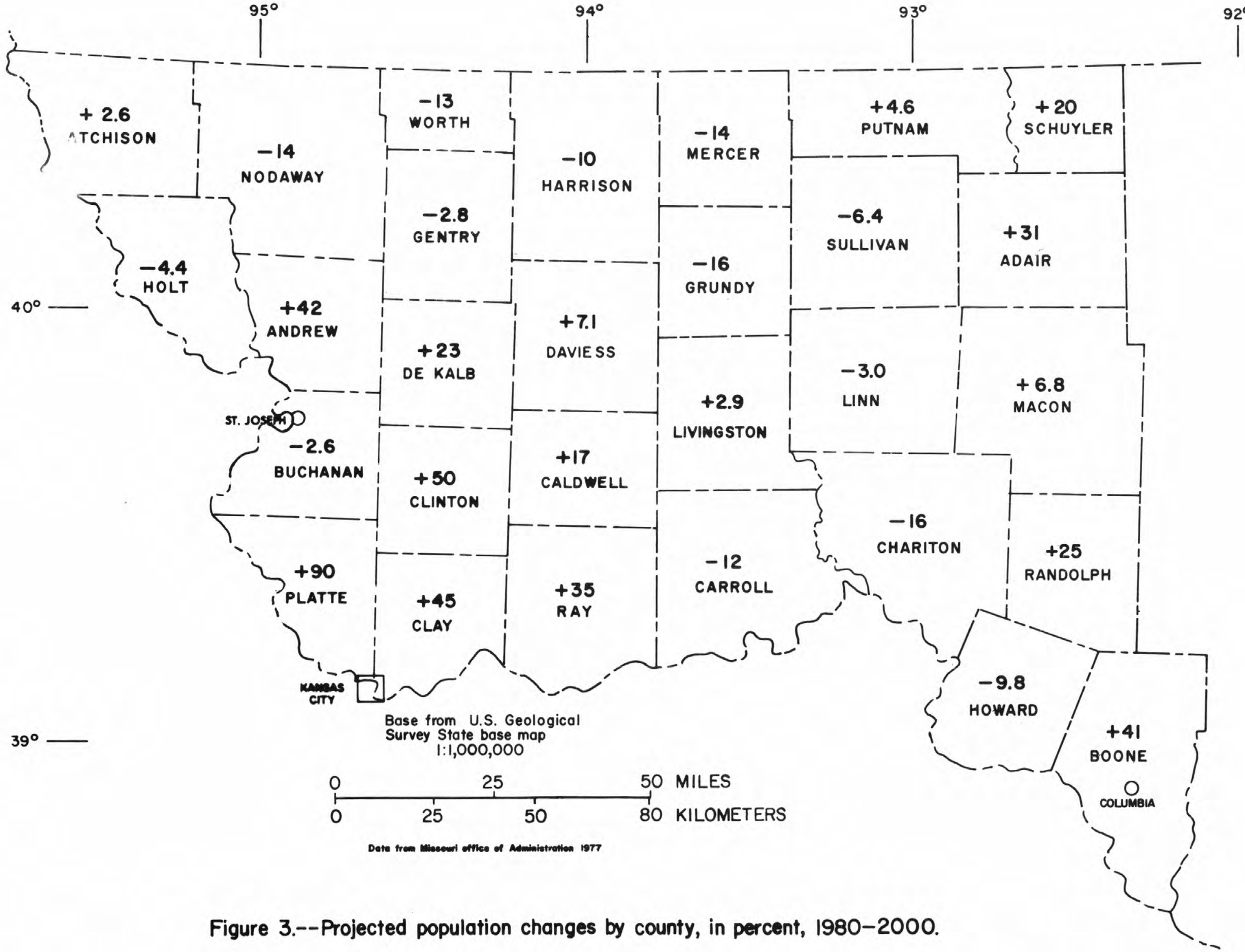

Figure 3.--Projected population changes by county, in percent, 1980-2000.

significant reservoir storage during a 30-day low-flow period with a recurrence interval of 10 years. The most dependable and largest supplies from tributary streams can be obtained from the lower Grand River (15 to 30 million gallons per day) and the Nodaway and Chariton Rivers (5 to 10 million gallons per day). Other streams and reaches with significant low-flow potential (1 to 5 million gallons per day) are the upper Grand River; the lower reaches of the Platte, Tarkio, and Weldon Rivers; and the Thompson River. The low-flow potential of streams in the area is discussed in more detail in a report by Skelton (1976), which presents a statistical analysis of low-flow information for Missouri streams.

Across much of northwestern Missouri, the seasonal and annual variability of streamflow make it necessary to provide storage reservoirs to insure a dependable supply. The data in table 4 show storage requirements for selected streamflow-gaging stations to provide a general idea of carryover storage required to provide indicated sustained draft rates. A report by Skelton (1971) presents additional carryover storage requirements for draft rates as much as 94 percent of the mean flow for streamflow-gaging stations in northwestern Missouri. That report also includes regional draft-storage curves that can be used to estimate storage requirements at sites where long-time continuous streamflow records are not available.

Table 2.--Streamflow-gaging stations in northwestern Missouri

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
1	West Tarkio Creek near Westboro, Atchison County	1934-39	105
2	Tarkio River at Fairfax, Atchison County	1922-80	508
3	Little Tarkio River near Mound City, Holt County	1962-65 1967-70	---
4	Mill Creek at Oregon, Holt County	1952-76	4.90
5	Nodaway River near Burlington Junction, Nodaway County	1922-80	1,240
6	Nodaway River near Oregon, Holt County	1942-43 1946 1962-64 1967, 1970	---
7	Missouri River at St. Joseph, Buchanan County	1930-80	424,300
8	Platte River at Ravenwood, Nodaway County	1921-25 1928-32 1958-71	486
9	Long Creek near Guilford, Nodaway County	1942-43, 1946 1962-64	---
10	Platte River at Whitesville, Andrew County	1964-65 1967 1969-70	---
11	Platte River near St. Joseph, Buchanan County	1962-65 1967, 1971	---

Table 2.--Streamflow-gaging stations in northwestern Missouri--continued

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
12	One Hundred and Two River at Maryville, Nodaway County	1933-80	500
13	White Cloud Creek near Maryville, Nodaway County	1949-70	6.06
14	White Cloud Creek near Barnard, Nodaway County	1942-43 1946 1962-64	---
15	One Hundred and Two River at Rosendale, Andrew County	1964-65 1967 1969-70	---
16	One Hundred and Two River at Avenue City, Andrew County	1942-43 1962-65 1967, 1971	---
17	One Hundred and Two River near St. Joseph, Buchanan County	1962-65 1967, 1971	---
18	Platte River near Agency, Buchanan County	1933-80	1,760
19	Castile Creek near Gower, Clinton County	1942-43 1946 1962-64	---
20	Jenkins Branch at Gower, Clinton County	1952-76	2.72
21	Castile Creek near Edgerton, Buchanan County	1962-65 1967	---
22	Little Platte River near Trimble, Clinton County	1962-64	---

Table 2.--Streamflow-gaging stations in northwestern Missouri--continued

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
23	Little Platte River at Smithville, Clay County	1942-43 1946, 1962 1964-80	234
24	Platte River at Platte City, Platte County	1962-65 1967-71	---
25	Missouri River at Kansas City, Jackson County	1930-80	489,200
26	Shoal Creek near Liberty, Clay County	1962, 1964 1967, 1970	----
27	Fishing River at Mosby, Clay County	1962-65 1967	---
28	Williams Creek near Mosby, Clay County	1962-64	---
29	East Fork Fishing River at Excelsior Springs, Clay County	1952-72	20
30	Fishing River near Orrick, Ray County	1962-65 1967	---
31	Crooked River near Richmond, Ray County	1948-70	159
32	West Fork Crooked River at Richmond, Ray County	1943 1945-46 1953, 1962	---
33	Missouri River at Waverly, Lafayette County	1930-80	491,200
34	Wakenda Creek at Carrolton, Carroll County	1948-70	248

Table 2.--Streamflow-gaging stations in northwestern Missouri--continued

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
35	Grand River near Grant City, Worth County	1962-70	---
36	Grand River near Stanberry, Gentry County	1943 1946-47 1953 1962-70	---
37	Middle Fork Grand River at Grant City, Worth County	1943, 1946 1962-65 1967 1969-70	---
38	Middle Fork Grand River near Albany, Gentry County	1943, 1946 1953 1962-64 1967-68 1970	---
39	East Fork Grand River at Albany, Gentry County	1943, 1946 1953 1962-70	---
40	Thompson Branch near Albany, Gentry County	1957-72	5.58
41	Grand River near Darlington, Gentry County	1929-31 1962-65 1967 1970-71	---
42	West Fork Lost Creek at Maysville, DeKalb County	1943 1945-46 1962-64	---
43	Lost Creek near Weatherby, DeKalb County	1943 1945-47 1962-64	---

Table 2.--Streamflow-gaging stations in northwestern Missouri--continued

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
44	Grindstone Creek near Pattonsburg, Daviess County	1962-64	---
45	Grand River near Pattonsburg, Daviess County	1958 1960-64 1967-68 1970-71	---
46	East Fork Big Creek near Bethany, Harrison County	1935-72	95
47	Big Creek at Bethany, Harrison County	1934, 1943 1946, 1953 1962-65	---
48	Big Creek near Pattonsburg, Daviess County	1964-65 1967, 1971	---
49	Grand River near Gallatin, Daviess County	1921-80	2,250
50	Thompson River at Mt. Moriah, Harrison County	1960-77	891
51	Panther Creek at Mt. Moriah, Harrison County	1962-64	---
52	Thompson River near Trenton, Grundy County	1962-69	---
53	Weldon River near Mercer, Mercer County	1940-58	246
54	Weldon River at Mill Grove, Mercer County	1930-72	494
55	Weldon River near Trenton, Grundy County	1961-65 1967	---

Table 2.--Streamflow-gaging stations in northwestern Missouri--continued

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
56	Thompson River at Trenton, Grundy County	1929-80	1,670
57	Muddy Creek at Trenton, Grundy County	1962-64 1967	---
58	Honey Creek near Trenton, Grundy County	1962-65 1967	---
59	Grand River at Chillicothe, Livingston County	1934, 1936 1957-58 1961-65 1967	4,850
60	Shoal Creek at Kingston, Caldwell County	1942-43 1945-46 1962-64 1967	---
61	Shoal Creek near Braymer, Caldwell County	1958-77	391
62	Shoal Creek near Chillicothe, Livingston County	1942-43 1945-46 1962-65 1967	---
63	Medicine Creek near Galt, Sullivan County	1930-75	225
64	Medicine Creek near Sturges, Livingston County	1930-33 1962-65 1967, 1971	368
65	Medicine Creek near Wheeling, Livingston County	1942-43 1945-47 1962-65 1967	---

Table 2.--Streamflow-gaging stations in northwestern Missouri--continued

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
66	Parson Creek at Meadville, Linn County	1942-43 1945-47 1962-64	---
67	Locust Creek near Milan, Sullivan County	1923-32 1971	225
68	Locust Creek near Linneus, Linn County	1929-72	550
69	Grand River near Sumner, Chariton County	1925-80	6,880
70	West Yellow Creek near Brookfield, Linn County	1959-77	135
71	West Yellow Creek below Brookfield, Linn County	1942-43 1945-47 1953 1962-64	---
72	Hamilton Branch near New Boston, Linn County	1955-72	2.51
73	East Yellow Creek near Brookfield, Linn County	1942-43 1945-47 1953 1962-64	---
74	Yellow Creek near Rothville, Chariton County	1929-32 1949-51	405
75	Turkey Creek near Laclede, Linn County	1942-43 1945-47 1953 1962-64	---
76	Big Creek near Bosworth, Carroll County	1962-64	---

Table 2.--Streamflow-gaging stations in northwestern Missouri--continued

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
77	Chariton River at Livonia, Putnam County	1963-71	---
78	Shoal Creek near Hartford, Putnam County	1963-66, 1968	---
79	Blackbird Creek near Unionville, Putnam County	1942-43 1945-48 1962-64	---
80	Chariton River at Novinger, Adair County	1931-51 1955-80	1,370
81	Chariton River near Callao, Macon County	1964-65 1969, 1971	---
82	Chariton River near Prairie Hill, Chariton County	1930-80	1,870
83	Mussel Fork near Musselfork, Chariton County	1948-51 1962-80	267
84	Mussel Fork at Keytesville, Chariton County	1942-43 1946, 1953 1962-65	---
85	East Fork Little Chariton River near Macon, Macon County	1971-80	112
86	East Fork Little Chariton River near Huntsville, Randolph County	1962-80	220
87	Missouri River at Boonville, Cooper County	1927-80	505,700
88	Bonne Femme Creek at Fayette, Howard County	1942-43 1946, 1953 1962-64	---

Table 2.--Streamflow-gaging stations in northwestern Missouri--continued

Map no. (fig. 2)	Station name and location	Period of record	Drainage area (square miles)
89	Bonne Femme Creek at New Franklin, Howard County	1962-64	---
90	Moniteau Creek near Fayette, Howard County	1949-69	81
91	Perche Creek near Columbia, Boone County	1962-64	---
92	Hinkson Creek at Columbia, Boone County	1942-43 1945-46 1952-53 1962-64 1966-80	70.2
93	Cedar Creek near Columbia, Boone County	1964-75	44.8
94	Cedar Creek near Cedar City, Callaway County	1962-64 1965	---

Table 3.--Approximate limits of potential supplies from streams without storage[1]

[Data from Skelton, 1976]

Approximate range of minimum flow for 30 consecutive days during a 10-year drought (million gallons per day)	Streams where indicated average minimum flow is potentially available
20 to 30	Grand River downstream from Sumner.
15 to 20	Grand River downstream from mouth of Thompson River to vicinity of Sumner.
5 to 10	Chariton River[2].
	Grand River from Gallatin to confluence with Thompson River.
	Nodaway River.
1 to 5	Grand River from Iowa line to Gallatin.
	Platte River downstream from mouth of One Hundred and Two River.
	Tarkio River downstream from vicinity of Fairfax.
	Thompson River.
	Weldon River from vicinity of Tindall to mouth.
0.1 to 1	Big Creek in Daviess County.
	Fishing River in Ray County.
	Locust Creek downstream from East Locust Creek.
	Medicine Creek downstream from Galt.
	One Hundred and Two River.
	Platte River upstream from mouth of One Hundred and Two River.
	Shoal Creek in Livingston County.
	Tarkio River upstream from vicinity of Fairfax.

Table 3.--Approximate limits of potential supplies from streams without storage--continued

Approximate range of minimum flow for 30 consecutive days during a 10-year drought (million gallons per day)	Streams where indicated average minimum flow is potentially available
0.1 to 1---------------------	Wakenda Creek downstream from mouth of Turkey Creek. Weldon River from Mill Grove to vicinity of Tindall. Yellow Creek downstream from Rothville.

[1]Flow of the Missouri River, a regulated stream, is greater than 1,300 million gallons per day at all points in Missouri.

[2]Flow partly regulated by Rathbun Reservoir in Iowa since 1969. Minimum release from Rathbun during low-flow season is about 10 cubic feet per second.

Table 4.--Storage requirements for selected sites

[Data from Skelton, 1971]

Map no. (fig. 2)	Stream name	Drainage area (square miles)	Storage required to maintain indicated sustained draft during multi-year drought with recurrence interval of 10 years. (Not corrected for reservoir evaporation, sedimentation, and seepage.)	
			Storage (thousands of acre-feet)	Draft (million gallons per day)
2	Tarkio River at Fairfax	508	30	40
5	Nodaway River near Burlington Junction	1,240	12	42
12	One Hundred and Two River near Maryville	500	30	32
18	Platte River near Agency	1,760	18	42
20	Jenkins Branch at Gower	2.7	2.5	1
29	East Fork Fishing River at Excelsior Springs	20	21	6
31	Crooked River near Richmond	159	74	40
34	Wakenda Creek at Carrollton	248	45	40
46	East Fork Big Creek near Bethany	95	72	27
49	Grand River near Gallatin	2,250	40	85
50	Thompson River at Mt. Moriah	891	27	60
53	Weldon River near Mercer	246	42	40
54	Weldon River at Mill Grove	494	45	50
56	Thompson River at Trenton	1,670	40	75
63	Medicine Creek near Galt	225	68	50
68	Locust Creek near Linneus	550	40	50
69	Grand River near Sumner	6,880	90	230
70	West Yellow Creek near Brookfield	135	24	25
74	Yellow Creek near Rothville	405	36	50
80	Chariton River at Novinger	1,370	30	58
82	Chariton River near Prairie Hill	1,870	50	105
90	Moniteau Creek near Fayette	81	25	17

Selected streamflow statistics and flow-variability data for continuous-record streamflow-gaging stations in the study area are presented in table 5 so that planners and water managers will have streamflow statistics in a form that they can adapt to their needs.

Computations for annual data in table 5 were made on the basis of two different annual periods: (1) Lowest annual mean values for 7 consecutive days are computed on a climatic year basis (April 1-March 31) so that low-flow periods during the summer and fall are not divided and (2) highest mean values, annual means, flow-duration data, and statistical data are shown on a water year basis (October 1-September 30).

Additional statistical data for each streamflow-gaging station are on file in the district office of the U.S. Geological Survey at Rolla, Mo. Reports also are available that include analyses of peak-flow data for rural and urban areas (Hauth, 1974; Gann, 1971), and flood-volume data (Skelton, 1973).

A summary of selected chemical constituents and pH of surface water collected at two sites on streams with similar chemical and physical characteristics in northwestern Missouri for periods of low flow during the late 1960's and late 1970's (table 6), shows that dissolved-solids concentration generally was less than 400 milligrams per liter. The water is primarily a calcium bicarbonate type but significant amounts of magnesium and sulfate also were present. The median values of the recent analyses indicate that the chemical and physical characteristics remain relatively unchanged from the late 1960's, although most concentration values were somewhat smaller during 1976-78.

As reported by Gann and others (1973), the estimated sediment yield for streams draining 100 square miles or more ranges from 300 to about 6,000 tons per square mile per year (fig. 4). Sediment yields are largest where slopes are steep and in areas of greatest loess thickness in the western part of the area.

Surface-water quality in some parts of northwestern Missouri, primarily small basins in the eastern counties, has been affected by coal strip-mining operations. The statistical data shown in table 7 are from a report by Vaill and Barks (1980) and were selected to illustrate the impacts of strip mining on surface-water quality in a typical northwestern Missouri river basin.

The East Fork Little Chariton River upstream from Macon is not affected by mining activities and thus is an ideal site to use for background or reference-station data. Between Macon and the streamflow-gaging station near Huntsville, drainage into the river is affected by past and present (1980) large-scale mining activity. The data collected at the Huntsville station, when compared with that shown for the station near Macon, indicate significant changes in the characteristics of surface-water quality due to runoff from the strip-mined areas. These are the types of changes that can be expected in surface-water quality when significant strip-mining activities occur in other northwestern Missouri basins.

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations

[All units in cubic feet per second, unless otherwise indicated]

ANNUAL STATISTICAL DATA

Map no. (fig. 2)	Station name and location	Drainage area (square miles)	Period of record	Lowest mean discharge for 7 consec-utive days	Highest mean discharge for 7 consec-utive days	Average annual discharge	Discharge exceeded for indicated percentage of time: 90	50	10	Standard deviation of annual means
1	West Tarkio Creek near Westboro	105	1934-39	0.1	7,400	234	2.3	22	300	94
2	Tarkio River at Fairfax	508	1922-79	0	4,480	192	7.9	55	410	143
4	Mill Creek at Oregon	4.90	1952-76	0	87	2.2	0	0.9	4.2	1.7
5	Nodaway River near Burlington Junction	1,240	1922-79	1.4	15,700	551	25	130	1,300	402
7	Missouri River at St. Joseph[1]	424,300	1930-79	3,330	324,000	39,200	14,000	35,000	68,000	10,700
8	Platte River at Ravenwood	486	1921-25, 1928-32 1958-71	3.2	2,990	261	7.8	50	520	144
12	One Hundred Two River at Maryville	500	1933-79	0	7,150	213	2.6	26	420	151

See footnotes at end of table.

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

MONTHLY STATISTICAL DATA

Month	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average monthly flow	Discharge exceeded for indicated percentage of time: 90	50	10	Standard deviation of monthly means	Percentage of average annual flow
Jan.	1.0	384	28	1.2	7.4	36	39	1.2
Apr.	4.2	1,330	105	5.5	34	150	129	4.6
July	0.1	1,410	183	0.7	12	210	254	8.0
Oct.	0.8	730	69	1.8	5.4	47	82	3.0
Jan.	1.0	1,900	97	5.4	36	220	137	4.4
Apr.	2.5	2,570	220	15	78	540	259	9.6
July	0	3,580	241	6.4	72	430	323	10.5
Oct.	0.19	3,660	128	4.6	37	270	212	5.6
Jan.	0	6.3	1.2	0	0.6	2.9	1.5	4.6
Apr.	0	19	2.3	0.2	1.2	4.6	2.0	8.6
July	0	26	2.6	0	1.0	3.9	2.8	10.1
Oct.	0	31	1.5	0	0.7	2.5	2.5	5.9
Jan.	7.1	7,200	258	16	61	610	450	3.9
Apr.	9.9	9,190	753	45	250	1,900	877	11.3
July	1.6	5,640	519	25	180	1,100	564	7.8
Oct.	9.0	11,700	320	20	71	580	647	4.8
Jan.	3,300	74,500	17,100	8,000	16,000	27,000	7,050	3.6
Apr.	16,000	324,000	56,700	28,000	45,000	110,000	31,600	12.0
July	16,100	166,000	53,200	32,000	47,000	84,000	18,500	11.2
Oct.	8,600	141,000	35,800	14,000	35,000	57,000	14,700	7.6
Jan.	2.9	4,580	152	5.1	23	210	310	4.8
Apr.	6.9	2,000	344	39	130	850	236	11
July	6.9	2,150	234	10	44	340	302	7.4
Oct.	3.9	2,010	131	6.3	41	230	174	4.2
Jan.	0	4,830	106	1.5	15	140	229	4.2
Apr.	0.4	3,430	308	11	77	690	350	12.1
July	0	2,460	177	2.5	23	280	262	6.9
Oct.	0.2	7,150	137	1.5	8.4	170	367	5.4

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

ANNUAL STATISTICAL DATA

Map no. (fig. 2)	Station name and location	Drainage area (square miles)	Period of record	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average annual discharge	Discharge exceeded for indicated percentage of time 90	50	10	Standard deviation of annual means
13	White Cloud Creek near Maryville	6.06	1949-70	0	85	3.2	0	0.3	3.4	2.4
18	Platte River near Agency	1,760	1933-79	0	30,700	903	18	160	2,000	645
20	Jenkins Branch at Gower	2.72	1952-76	0	75	1.6	0	0.2	2.4	1.2
23	Little Platte River at Smithville	234	1965-79	0	6,330	158	1.9	30	330	112
25	Missouri River at Kansas City[1]	489,200	1930-79	2,140	401,000	48,400	16,000	40,000	88,000	15,100
29	East Fork Fishing River at Excelsior Springs	20	1952-72	0	737	12	0.01	1.6	20	9.0
31	Crooked River near Richmond	159	1948-70	0	5,380	99	0.4	14	160	66

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

MONTHLY STATISTICAL DATA

Month	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average monthly flow	Discharge exceeded for indicated percentage of time: 90	50	10	Standard deviation of monthly means	Percentage of average annual flow
Jan.	0	67	1.5	0	0.2	2.2	3.8	3.9
Apr.	0	46	3.8	0.1	0.9	5.8	4.0	10.0
July	0	82	5.0	0	0.2	2.8	9.0	13.0
Oct.	0	49	1.7	0	0.01	1.8	3.4	4.7
Jan.	1.4	11,200	393	10	84	610	763	3.6
Apr.	3.5	15,700	1,390	68	370	3,600	1,750	12.8
July	0.06	21,300	804	23	160	1,600	1,290	7.4
Oct.	0	30,700	670	7.3	85	1,000	1,520	6.2
Jan.	0	10	0.7	0	0.1	1.4	1.0	3.4
Apr.	0	16	2.0	0	0.7	3.7	2.0	10.1
July	0	75	2.2	0	0.2	1.7	4.3	11.1
Oct.	0	46	1.6	0	0.06	2.7	3.0	8.2
Jan.	0.06	538	73	1.7	30	190	75	3.5
Apr.	7.1	1,580	240	17	81	550	211	11.5
July	0.3	8,330	242	1.7	16	270	544	11.7
Oct.	0	3,970	157	0.5	9.7	310	297	7.6
Jan.	2,140	95,700	20,600	9,000	18,000	32,000	9,630	3.5
Apr.	17,700	328,000	67,800	31,000	51,000	130,000	38,100	11.7
July	17,400	401,000	66,900	36,000	56,000	110,000	32,600	11.5
Oct.	9,430	240,000	43,000	17,000	40,000	68,000	20,800	7.4
Jan.	0	50	5.5	0	1.8	12	7.5	3.4
Apr.	0.01	227	22	0.6	8.1	43	22	13.6
July	0	737	26	0	0.8	18	53	16.2
Oct.	0	157	10	0	0.4	13	16	6.2
Jan.	0	472	46	0.4	12	98	60	3.9
Apr.	1.1	1,130	149	6.3	60	310	130	12.7
July	0	5,380	179	1.3	10	140	363	15.2
Oct.	0	819	55	0.07	3.5	77	81	4.7

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

ANNUAL STATISTICAL DATA

Map no. (fig. 2)	Station name and location	Drainage area (square miles)	Period of record	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average annual discharge	Discharge exceeded for indicated percentage of time: 90	50	10	Standard deviation of annual means
33	Missouri River at Waverly[1]	491,200	1930-79	2,070	420,000	48,900	16,000	40,000	90,000	15,800
34	Wakenda Creek at Carrolton	248	1948-70	0.2	3,560	141	1.4	12	210	92
40	Thompson Branch near Albany	5.58	1957-72	0	82	2.8	0.02	0.2	3.4	2.1
46	East Fork Big Creek near Bethany	95	1935-72	0	1940	48	0	3.7	80	30
49	Grand River near Gallatin	2,250	1921-79	2.6	42,400	1,140	24	200	2,300	770
50	Thompson River at Mount Moriah	891	1960-77	8.0	8,460	516	26	130	1,200	303
53	Weldon River near Mercer	246	1940-58	0	4,260	138	0.3	9.5	200	101

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

MONTHLY STATISTICAL DATA

Month	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average monthly flow	Discharge exceeded for indicated percentage of time 90	50	10	Standard deviation of monthly means	Percentage of average annual flow
Jan.	2,070	98,500	21,000	9,400	19,000	33,000	10,300	3.6
Apr.	18,200	325,000	70,100	32,000	52,000	130,000	40,000	11.9
July	17,800	420,000	69,000	35,000	58,000	110,000	35,300	11.7
Oct.	9,760	231,000	43,000	17,000	38,000	69,000	21,600	7.3
Jan.	0.2	889	69	1.6	9.4	120	100	4.0
Apr.	0.5	1,200	168	2.1	50	320	151	9.8
July	0.4	3,560	223	1.5	9.3	410	363	13.1
Oct.	0.3	3,350	142	1.1	5.5	160	237	8.3
Jan.	0	20	1.0	0.01	0.09	2.2	1.7	3.0
Apr.	0	29	3.1	0.06	0.7	5.0	3.3	9.0
July	0	82	3.1	0.01	0.09	3.1	6.7	9.2
Oct.	0	71	2.7	0.01	0.09	2.0	4.9	7.9
Jan.	0	1,000	24	0	1.8	32	48	4.2
Apr.	0	932	69	2.0	14	150	78	12.0
July	0	1,010	32	0	1.9	44	56	5.6
Oct.	0	494	25	0	0.8	34	40	4.3
Jan.	3.0	13,800	539	16	120	820	981	3.9
Apr.	5.8	21,600	1,780	120	470	4,200	2,090	12.9
July	6.0	25,600	1,070	34	170	1,700	1,680	7.8
Oct.	2.6	30,700	864	13	90	1,500	1,670	6.3
Jan.	8.0	2,800	271	13	70	660	373	4.4
Apr.	57	6,800	912	96	350	2,300	807	14.7
July	12	4,400	405	35	110	760	546	6.5
Oct.	12	7,230	337	19	87	550	575	5.4
Jan.	0	3,370	66	0.06	4.4	77	181	4.0
Apr.	0.1	2,070	220	5.6	42	400	253	13.2
July	0	1,460	95	0.3	6.9	90	141	5.7
Oct.	0	633	54	0.2	2.4	67	88	3.2

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

ANNUAL STATISTICAL DATA

Map no. (fig. 2)	Station name and location	Drainage area (square miles)	Period of record	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average annual discharge	Discharge exceeded for indicated percentage of time: 90	50	10	Standard deviation of annual means
54	Weldon River at Mill Grove	494	1930-72	0	7,420	246	2.6	31	410	167
56	Thompson River at Trenton	1,670	1929-79	1.7	27,900	937	25	190	2,100	624
61	Shoal Creek near Braymer	391	1958-77	0	6,300	243	1.6	39	460	139
63	Medicine Creek near Galt	225	1930-75	0	5,590	136	2.1	21	230	87
67	Locust Creek near Milan	225	1933-32	0.2	2,270	153	2.5	25	320	84
68	Locust Creek near Linneus	550	1929-72	0	11,400	313	4.1	44	590	195
69	Grand River near Sumner	6,880	1925-79	12	98,200	3,700	110	870	9,200	2,360

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

MONTHLY STATISTICAL DATA

Month	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average monthly flow	Discharge exceeded for indicated percentage of time 90	50	10	Standard deviation of monthly means	Percentage of average annual flow
Jan.	0	5,910	136	1.3	19	210	266	4.6
Apr.	0.1	3,790	378	22	94	730	394	12.8
July	0.01	3,620	163	3.3	21	230	239	5.5
Oct.	0	2,280	137	1.1	13	210	208	4.6
Jan.	4.0	15,000	493	16	100	890	864	4.4
Apr.	4.4	14,600	1,590	110	480	4,100	1,620	14.1
July	2.2	12,100	649	34	170	1,300	834	5.8
Oct.	5.8	13,800	600	17	79	1,100	986	5.3
Jan.	0	2,020	167	1.2	39	320	225	5.7
Apr.	3.6	2,130	394	24	130	1,000	317	13.4
July	0.4	3,360	223	2.3	15	320	365	7.6
Oct.	0.1	3,810	158	0.3	11	250	243	5.4
Jan.	0	1,430	74	1.5	17	130	105	4.5
Apr.	0.7	3,210	247	14	66	500	248	14.9
July	0	3,130	114	2.6	15	120	198	6.9
Oct.	0.4	1,660	93	1.4	9.3	150	142	5.6
Jan.	1.4	1,430	77	2.3	17	150	127	4.2
Apr.	12	1,910	283	21	61	880	247	15.4
July	0.6	1,640	102	1.9	9.5	150	191	5.6
Oct.	1.0	1,720	171	1.9	19	520	176	9.3
Jan.	1.0	3,980	190	3.1	41	340	267	5.0
Apr.	3.3	6,640	589	35	170	1,400	555	15.4
July	0	8,780	284	3.7	27	320	587	7.4
Oct.	0.7	3,150	169	2.4	15	270	270	4.4
Jan.	19	54,500	1,960	64	530	3,500	3,250	4.4
Apr.	44	66,600	6,270	560	2,200	18,000	6,350	14.0
July	25	66,200	3,010	170	770	7,000	4,540	6.7
Oct.	29	56,800	2,720	76	400	7,000	4,210	6.1

ANNUAL STATISTICAL DATA

Map no. (fig. 2)	Station name and location	Drainage area (square miles)	Period of record	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average annual discharge	Discharge exceeded for indicated percentage of time: 90	50	10	Standard deviation of annual means
70	West Yellow Creek near Brookfield	135	1959-77	0	2,980	101	0.08	8.3	170	72
72	Hamilton Branch near New Boston	2.51	1955-72	0	79	2.2	0.02	0.1	2.2	1.4
74	Yellow Creek near Rothville	405	1929-32 1949-51	0.4	3,850	221	1.2	42	560	40
80	Chariton River at Novinger[2]	1,370	1931-51 1955-79	0.3	16,200	771	14	150	2,200	502
82	Chariton River near Prairie Hill[2]	1,870	1930-79	4.8	19,800	1,120	32	270	3,100	695
83	Mussel Fork near Musselfork	267	1948-51 1962-79	0	7,340	212	2.1	28	510	154
85	East Fork Little Chariton River near Macon	112	1971-79	0	2,370	123	0	13	310	101

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

MONTHLY STATISTICAL DATA

Month	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average monthly flow	Discharge exceeded for indicated percentage of time 90	50	10	Standard deviation of monthly means	Percentage of average annual flow
Jan.	0	999	87	0.06	11	170	121	7.2
Apr.	3.9	2,560	220	8.9	40	570	254	18.2
July	0	2,980	81	0.2	1.6	38	208	6.7
Oct.	0	2,150	64	0.03	1.6	62	132	5.3
Jan.	0	27	1.4	0.02	0.2	1.6	2.3	5.4
Apr.	0	30	4.0	0.08	0.6	5.2	4.4	15.4
July	0	79	2.7	0.01	0.06	0.5	5.9	10.4
Oct.	0	36	1.7	0.01	0.07	0.8	2.7	6.3
Jan.	0.9	2,520	256	1.6	36	550	341	8.3
Apr.	26	3,810	505	43	160	1,300	461	16.4
July	3.7	1,110	178	6.5	33	500	139	5.8
Oct.	0.2	934	118	0.4	2.7	370	171	3.8
Jan.	2.0	9,030	485	11	110	1,300	697	5.2
Apr.	2.0	13,300	1,400	110	510	3,800	1,380	14.9
July	1.3	6,620	596	17	96	1,600	745	6.3
Oct.	0.6	8,470	418	6.0	44	1,200	675	4.4
Jan.	6.4	12,200	728	21	210	1,600	984	5.4
Apr.	11	19,800	2,050	210	820	5,400	1,920	15.2
July	6.1	17,500	959	40	210	2,200	1,220	7.1
Oct.	8.9	15,900	615	20	90	1,600	990	4.6
Jan.	0.3	1,850	186	1.2	22	440	241	7.3
Apr.	14	7,340	512	26	130	1,600	577	20.1
July	0.9	4,140	148	3.4	13	290	306	5.8
Oct.	0	3,140	135	0.3	9.9	230	230	5.3
Jan.	0	717	82	0	17	210	112	6.1
Apr.	1.4	2,270	282	14	42	640	316	21
July	0	314	47	0	2.9	110	57	3.5
Oct.	0	1,770	79	0	1.8	160	150	5.9

Table 5.--Annual and monthly statistical streamflow data for continuous-record stations--continued

ANNUAL STATISTICAL DATA

Map no. (fig. 2)	Station name and location	Drainage area (square miles)	Period of record	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average annual discharge	Discharge exceeded for indicated percentage of time: 90	50	10	Standard deviation of annual means
86	East Fork Little Chariton River near Huntsville	220	1962-79	0	5,880	181	1.2	28	510	133
87	Missouri River at Boonville[1]	505,700	1927-79	2,140	440,000	58,500	18,000	45,000	110,000	20,100
90	Moniteau Creek near Fayette	81	1949-69	0	1,020	37	0.05	3.0	63	22
92	Hinkson Creek at Columbia	70.2	1966-79	0	993	54	0.3	7.9	95	36
93	Cedar Creek near Columbia	44.8	1964-75	0	960	41	0.1	3.3	51	31

[1]Stream regulated by reservoirs and diversions.
[2]Flow partially regulated by Rathbun Reservoir in Iowa since November 1969.

Table 5.--*Annual and monthly statistical streamflow data for continuous-record stations--continued*

MONTHLY STATISTICAL DATA

Month	Lowest mean discharge for 7 consecutive days	Highest mean discharge for 7 consecutive days	Average monthly flow	Discharge exceeded for indicated percentage of time: 90	50	10	Standard deviation of monthly means	Percentage of average annual flow
Jan.	0.2	1,250	157	1.0	22	500	182	7.2
Apr.	4.8	5,880	428	20	130	1,200	505	19.7
July	0	3,210	154	0.4	10	260	306	7.1
Oct.	0	2,480	142	0.2	11	340	211	6.5
Jan.	2,140	148,000	26,600	11,000	23,000	42,000	14,800	3.8
Apr.	21,400	390,000	86,700	34,000	62,000	170,000	52,800	12.3
July	18,900	440,000	79,600	37,000	64,000	140,000	44,400	11.3
Oct.	10,800	268,000	49,800	19,000	41,000	80,000	27,600	7.1
Jan.	0	429	32	0.06	3.3	68	47	7.3
Apr.	0	475	63	1.5	18	130	52	14.5
July	0	1,020	50	0.08	1.7	42	86	11.5
Oct.	0	461	22	0.02	0.4	18	32	5.0
Jan.	0.3	458	47	0.7	5.8	93	60	7.4
Apr.	3.9	709	97	6.3	27	190	80	15.2
July	0.1	717	46	0.5	2.3	58	83	7.3
Oct.	0	993	41	0.09	1.7	46	78	6.5
Jan.	0.01	351	44	0.3	3.9	81	51	9.3
Apr.	0.6	354	74	1.9	11	170	61	15.4
July	0	766	32	0.06	0.8	17	73	6.7
Oct.	0	960	34	0.01	0.7	14	78	7.2

Table 6.--Summary of selected chemical constituents and pH in water from Grand River near Sumner (sta. 69, fig. 2) and Chariton River near Prairie Hill (sta. 82, fig. 2) during low flow, 1968-70 and 1976-78

[Analyses of all samples collected during periods of low flow during 1968-70 and 1976-78. Results in milligrams per liter, except as indicated]

Constituent and pH	Minimum		Median		Maximum	
	1968-70	1976-78	1968-70	1976-78	1968-70	1976-78
Calcium (Ca)	21	26	64	50	104	72
Bicarbonate (HCO_3)	68	100	214	158	352	268
Magnesium (Mg)	4.2	5.3	14	9.5	24	15
Sulfate (SO_4)	20	15	52	33	146	40
Dissolved solids (residue at 180°C)	122	120	288	212	470	319
pH (standard unit)	6.7	7.6	7.6	8.1	8.9	8.3

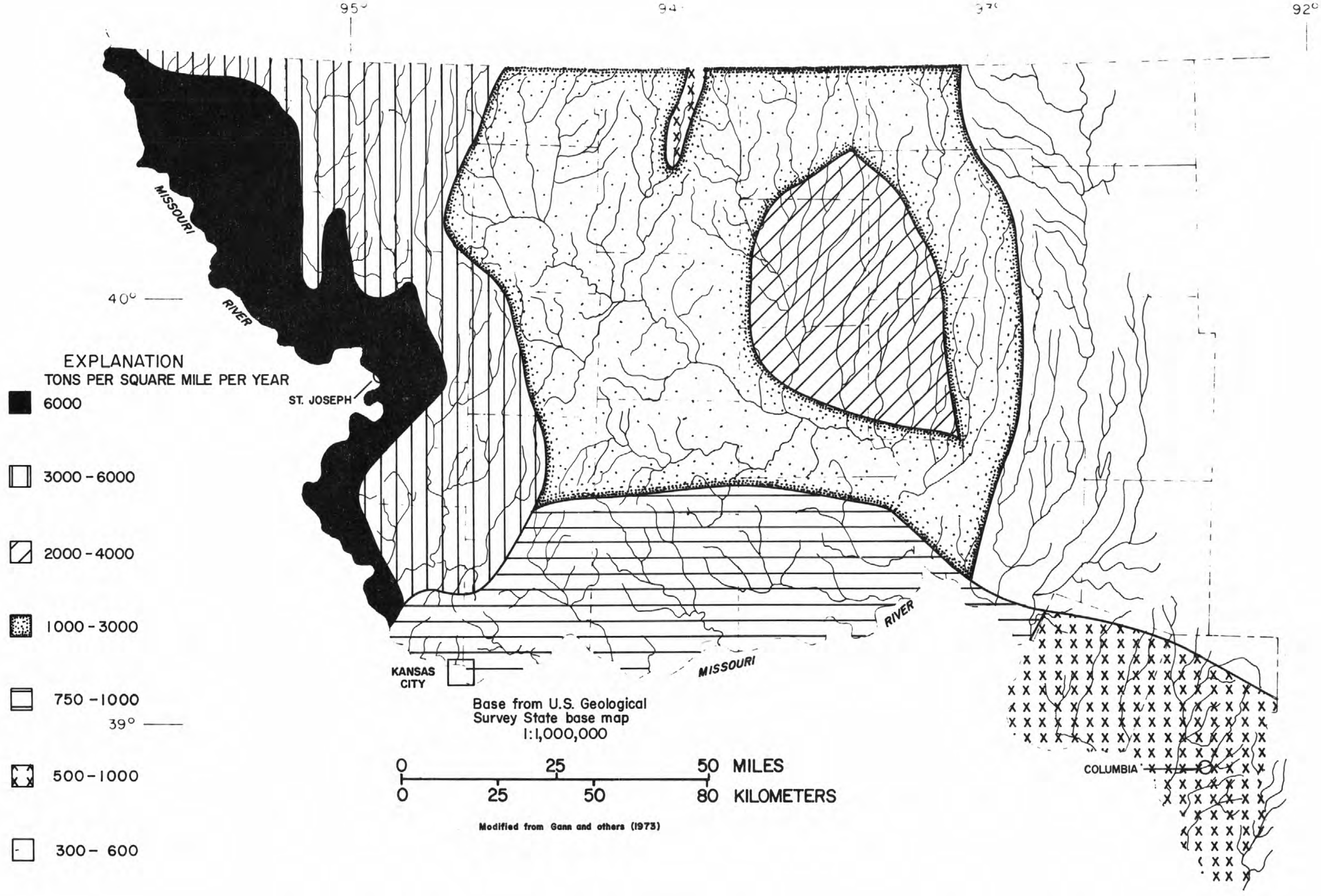

Figure 4.--Estimated sediment yield for drainage areas greater than 100 square miles.

Table 7.--Statistical relationships of discharge, specific conductance, pH, and selected chemical constituents for East Fork Little Chariton River near Macon and Huntsville (from Vaill and Barks, 1980)

[Results in milligrams per liter, except as indicated; ft^3/s=cubic feet per second; µmho/cm at 25°C=micromho per centimeter at 25 degrees Celsius; µg/L=micrograms per liter]

	Sample size	Mean	Standard deviation	Range
East Fork Little Chariton River near Macon, station 85, figure 2 (Drainage area, 112 square miles)				
Discharge (ft^3/s)	36	153	297	0 - 1250
Specific conductance (µmho/cm at 25°C)	36	309	123	120 - 670
pH (standard units)	36	---	---	7.1 - 8.1
Dissolved calcium (Ca)	36	36	15	13 - 75
Dissolved magnesium (Mg)	36	8.4	4.3	3.0 - 23
Bicarbonate (HCO_3)	36	115	49	32 - 218
Dissolved sulfate (SO_4)	36	49	25	19 - 120
Dissolved iron (Fe) [µg/L]	36	170	170	10 - 950
Dissolved manganese (Mn) [µg/L]	36	240	170	30 - 800
Dissolved solids (residue at 180°C)	36	195	76	76 - 104

Table 7.--Statistical relationships of discharge, specific conductance, pH, and selected chemical constituents for East Fork Little Chariton River near Macon and Huntsville (from Vaill and Barks, 1980)--continued

	Sample size	Mean	Standard deviation	Range
East Fork Little Chariton River near Huntsville, station 86, figure 2 (Drainage area, 220 square miles				
Discharge (ft^3/s)	92	244	560	0 - 3250
Specific conductance (μmho/cm at 25°C)	92	918	454	90 - 2180
pH (standard units)	92	---	---	2.6 - 7.9
Dissolved calcium (Ca)	92	110	59	9.2 - 300
Dissolved magnesium (Mg)	92	49	32	2.2 - 140
Bicarbonate (HCO_3)	91	76	44	0 - 180
Dissolved sulfate (SO_4)	92	450	300	16 - 1400
Dissolved iron (Fe) [μg/L]	22	380	630	20 - 2500
Dissolved manganese (Mn) [μg/L]	92	3300	4400	0 - 23,000
Dissolved solids (residue at 180°C)	89	738	458	63 - 2100

Ground Water

The aquifer characteristics for significant ground-water sources in northwestern Missouri are summarized in table 8. The source of ground water in order of quantities available are the Missouri River alluvium, glacial drift, alluvium of tributary streams, and the Pennsylvanian bedrock (used only for small rural domestic supplies and not considered further in this report).

Wells completed in the alluvium along the Missouri River yield as much as 2,000 gallons per minute and are sustained at these levels by induced infiltration if they are located near the river. The thickness of the alluvium is as much as 120 feet and specific capacities are as much as 330 gallons per minute per foot of drawdown.

The glacial drift is the most variable of the units shown in table 9 because it contains lenses of outwash deposits and buried valley deposits that differ considerably in thickness and permeability. Quantities available from the glacial drift vary from 30 to 800 gallons per minute and specific capacities are as much as 40 gallons per minute per foot of drawdown. The thickness of the glacial drift varies from zero where bedrock is at the surface to as much as 350 feet in the northwestern part of the area.

Yields of wells completed in alluvium along tributary streams are somewhat variable, depending on thickness and permeability of the deposits, but exceed 50 gallons per minute in part of the Grand, Nodaway, Chariton, Thompson, and Tarkio River valleys. The alluvium of the tributary valleys is fairly uniform in the valleys where data are available. Generally, the thickness of the valley fills ranges from 30 to 40 feet, but there are instances where thicknesses may reach 60 feet.

Both water-table and artesian conditions exist in all of these aquifers, depending on thickness of overlying fine-grained material. Water-table conditions are more common in alluvial deposits than in glacial-drift deposits because of greater thicknesses of fine-grained materials overlying sand and gravel units in the drift.

Transmissivities of unconsolidated aquifers in the area range from 800 to 33,000 feet squared per day. Values for the glacial drift and tributary alluvium are much smaller than those for the Missouri River alluvium (see table 8).

Bedrock formations in northwestern Missouri are not shown in table 8 because data are few, and there are few water wells completed in these units in the project area. Stratigraphic and water-quality data for the Mississippian and Cambrian formations are limited to data derived from oil tests. That information indicates that water from those formations is saline; dissolved-solids concentrations range from 2,000 to 20,000 milligrams per liter for most of the area (Gann and others, 1973). In that part of Iowa adjacent to the study area, the dissolved-solids concentration of water from the Cambrian and Ordovician aquifers exceeds 2,000 milligrams per liter (Horick and Steinhilber, 1978).

Table 8.--Summary of aquifer characteristics based on data from wells completed in alluvium and glacial drift

[(1) number of values available, (2) median value, (3) range in values; Missouri River alluvium data from Emmett and Jeffery, 1968, 1969a, 1969b, 1970]

Source of water	Well depths (feet)			Aquifer thickness (feet)			Well yield (gallons per minute)			Specific capacity (gallons per minute per foot of drawdown)			Storage coefficient			Transmissivity (feet squared per day)			Hydraulic conductivity (feet per day)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Glacial Drift	32	75	30-209	17	14	5-67	34	60	4-785	28	5.7	0.5-40	2	---	0.002-0.00008	5	3,300	240-3,600	5	110	60-167
Missouri River alluvium.	44	84	52-118	44	75	30-118	37	1,000	60-3,000	37	67	8.4-330	4	0.15	0.001-0.20	4	28,000	24,000-33,000	1	400	---
Tarkio River alluvium.	1	---	42.5	1	---	17.5	1	---	100	1	---	13	---	---	---	1	---	3,100	1	---	180
Nodaway River alluvium.	5	40	36-65	4	16	15-18	5	80	15-120	4	9	7-10	---	---	---	1	---	2,500	1	---	150
One Hundred and Two alluvium.	3	28	24-32	2	8	7-9	3	30	30-100	3	6.2	3-20	---	---	---	---	---	---	---	---	---
Grand River alluvium.	5	40	38-60	4	17	12-22	3	67	30-152	2	16	9-23	---	---	---	---	---	---	---	---	---
Weldon River alluvium.	2	40	39-41	---	---	---	2	140	80-205	2	14	8.6-20	---	---	---	---	---	---	---	---	---
Medicine Creek alluvium.	3	29	28-32	3	12	9-19	3	39	23-64	3	5.6	5-6.1	---	---	---	---	---	---	---	---	---
Platte River alluvium.	7	30	23-61	4	11	6-18	7	30	13-175	7	4.1	1.2-18	---	---	---	---	---	---	---	---	---
Middle Chariton River alluvium.	2	55	42-69	1	---	19	2	115	94-136	2	7.6	3.3-12	---	---	---	1	---	1,200	1	---	28
Chariton River alluvium.	3	48	45-49	2	22	14-29	3	100	72-267	3	7.1	4.0-15	1	---	0.002	1	---	2,000	1	---	70
Shoal Creek alluvium.	1	---	50	1	---	18	1	---	152	1	---	5.4	---	---	---	---	---	---	---		---
Mussel Fork alluvium.	1	---	42	1	---	22	1	---	130	1	---	8.1	---	---	---	1	---	760	1	---	34

Table 9.--Median values of well depths and constituents from chemical analyses for three sources of ground water in northwestern Missouri

[Results in milligrams per liter, except as indicated]

	Glacial drift[1]	Tributary alluvium[1]	Missouri River alluvium[2]
Well depths (feet)-----	80	40	90
Number of samples------	33	32	54
Silicia (S_iO_2)---------	23	23	27
Iron (Fe)--------------	1.4	6.9	2.8
Manganese (Mn)---------	.08	.55	.64
Calcium (Ca)-----------	80	78	125
Magnesium (Mg)---------	21	18	30
Sodium (Na)------------	53	24	18
Potassium (K)----------	2.1	1.4	5.2
Bicarbonate (HCO_3)	377	247	505
Sulfate (SO_4)----------	50	40	36
Chloride (Cl)----------	19	12	3.5
Fluoride (F)-----------	.2	.2	.3
Nitrate (NO_3)----------	.7	.2	.2
Dissolved solids------- (residue at 180°C)	474	436	510
Hardness as $CaCO_3$			
Calcium, Magnesium---	287	265	438
Noncarbonate---------	0	36	13

[1]Gann and others, 1973.

[2]Emmett and Jeffery, 1968, 1969a, 1969b, 1970.

The chemical quality of the water from the three principal sources of fresh ground water is similar although considerable variation occurs in extreme values. The data in table 9 show median values for the principal chemical constituents in water and well depths for the three ground-water sources.

Water in the Missouri River alluvium generally is more mineralized and harder than water from the glacial drift and tributary alluvium (Gann and others, 1973). This is mainly due to the greater concentrations of calcium and magnesium bicarbonate. Sodium and chloride concentrations in water from the glacial drift and alluvium generally are small. Sodium concentrations range from 18 to 53 milligrams per liter, and chloride concentrations range from 3.5 to 19 milligrams per liter. Sulfate concentrations are moderate--36 to 50 milligrams per liter. Extreme concentrations of these constituents are probably caused by leakage of water from the underlying Pennsylvanian sandstone and shale or slow movement of water through the formations.

A pattern in the distribution of varying concentrations of sulfate in water from the alluvial and glacial deposits may be partly explained by the occurrence of coal deposits, which were eroded by glacial and stream action. Pyrite-bearing coal and clay fragments incorporated in the glacial and alluvial deposits commonly are observed in exposures along streams and road cuts.

A study of the distribution of dissolved-solids concentrations and bicarbonate, chloride, and sulfate concentrations showed that gross differences exist in different geographic areas (table 10). For example, south of the latitude of St. Joseph (see fig. 2), 35 percent of the values of dissolved-solids concentrations in water from the glacial drift exceed the median value for the entire area, and north of that latitude 67 percent of the values exceed the median. This difference indicates more recharge in the southern part than in the northern part or that there is less contribution from the underlying Pennsylvanian rocks than in the northern part.

The water from the alluvium does not show such a distinctive difference based on a north-south distribution. Rather, they have an east-west difference. The western tributaries, the Tarkio, Nodaway, One Hundred and Two, and Platte Rivers have only 37 percent of their values exceeding the median for the entire area. The eastern tributaries, the Grand and Chariton River systems, have 53 percent of their values exceeding the median. The reason for this difference is not apparent. Percentages computed for chloride and sulfate are similar to those for dissolved solids, while bicarbonate shows an opposite relationship (see table 10).

Table 10.--Percentage of selected chemical-constituent concentrations that are greater than the median for all ground-water samples from the alluvium and glacial drift

Location	Dissolved solids	Chloride	Sulfate	Bicarbonate
GLACIAL DRIFT				
South of latitude of St. Joseph	35	41	28	61
North of latitude of St. Joseph	67	60	85	36
ALLUVIUM				
Western tributaries (Tarkio, Nodaway, One Hundred and Two, Platte Rivers)	37	37	41	59
Eastern tributaries (Grand and Chariton Rivers)	53	67	60	36

WATER USE

The estimated use of ground water and surface water in northwestern Missouri during 1980 is shown in table 11. About 88 percent of the water withdrawn was used for cooling purposes in electric powerplants, which pump water from the Missouri River or from impoundments. Most of this water is returned to the source after use. Approximately 96 percent of the water used in the area during 1980 came from surface-water sources, but about 92 percent of this water was used for electric-powerplant cooling.

Gann and others (1973) reported water use in northwestern Missouri for 1966. The only significant changes in water use during 1966-80 were in the thermoelectric power and livestock categories. The amount of water used for thermoelectric power increased by about 55 percent, and water used for livestock increased by about 60 percent. This is reflective of the increase in livestock production reported during the period (Missouri Crop and Livestock Reporting Service, written commun., 1976), and the increasing use of electric power throughout the area. A continuation of these trends depends on many socioeconomic factors, but it is unlikely that a significant increase in most uses of water will occur during 1980-2000.

Irrigation

Irrigation is used to improve crop yields and to reduce the chances of crop failure in northwestern Missouri. It is a supplemental water source only, because rainfall during average years generally is sufficient for most agricultural uses.

Areas where irrigation is significant or a potentially significant practice are shown in figure 5. At the present time (1980) most of the irrigated farmland is located in the Missouri River alluvial plain; the irrigation water is supplied by shallow wells. In the tributary areas, water for irrigation is supplied almost entirely from streams or from off-channel impoundments.

During 1977 there were about 21,000 acres irrigated in northwestern Missouri, mostly in the areas outlined in figure 5. By 1985 it is estimated that about 36,000 acres will be irrigated in the same areas, and by 2000 the total is projected to increase to about 100,000 acres (U.S. Department of Agriculture, Soil Conservation Service, written commun., 1979).

Thus during the 1980's and 1990's, supplemental irrigation will be increasing in northwestern Missouri. However, this will occur only in areas where surface flow and terrain are suitable for impoundments and in the vicinity of extensive alluvial deposits or deposits in the buried valleys that can supply adequate ground water.

Table 11.--Estimated water use in northwestern Missouri during 1980, in million gallons per day

[Data from L. F. Emmett, U.S. Geological Survey, written commun., 1980]

Type of use	Surface water	Ground water	Total	Percentage of total
Thermoelectric power---	1,060	1.7	1,061.7	88.2
Livestock--------------	34.3	11.4	45.7	3.8
Public supply[1]---------	30.0	15.0	45.0	3.7
Self-supplied---------- industrial	23.9	15.6	39.5	3.3
Rural domestic---------	3.8	6.1	9.9	.9
Irrigation-------------	.3	1.0	1.3	.1
Total--------	1,152.3	50.8	1,203.1	100

[1]Public supply does not include water pumped from the Missouri River by Kansas City.

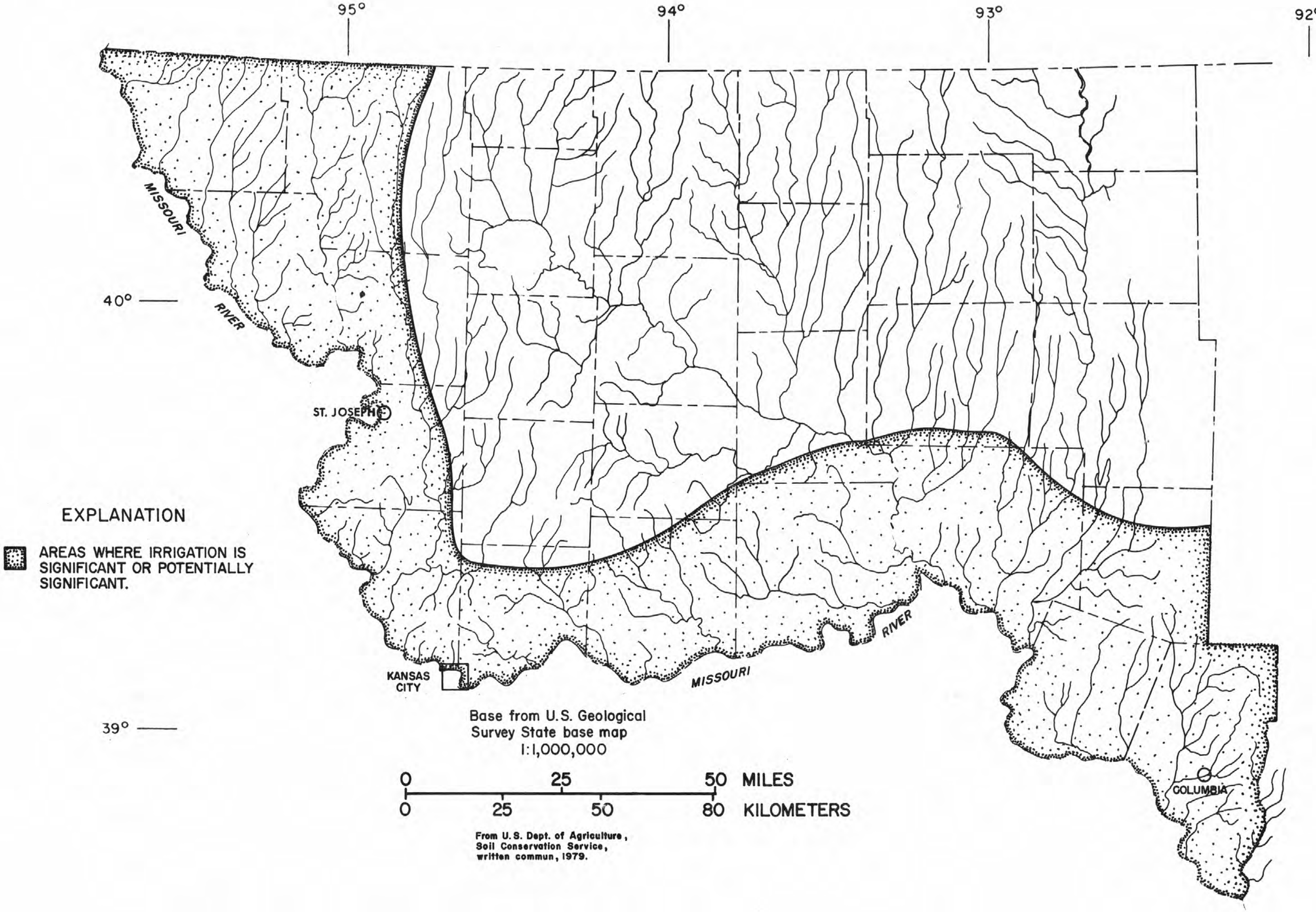

Figure 5.--Areas in which irrigation is considered to be a major agricultural practice.

Industrial Growth and Potential

During 1979 new and expanding industry in Missouri resulted in nearly 14,000 additional jobs statewide (Missouri Division of Community Economic Development, written commun., 1980). However, only about 15 percent of the jobs (2,100) were located in the northwestern Missouri project area.

More than one-half of the additional northwestern Missouri jobs (63 percent) were located in the Kansas City area. Other towns (see fig. 2) where industrial expansion produced new jobs (their percentage of the industrial job growth is in parenthesis) were Columbia (7 percent), Excelsior Springs (2 percent), Maryville (9 percent), Rock Port (7 percent), St. Joseph (9 percent), and Trenton (3 percent). None of these industries have been reported to need significant new sources or amounts of water.

Based on these data plus interviews and telephone conversations with personnel of the Missouri Division of Community and Economic Development and the Department of Natural Resources, the authors consider it unlikely that significant amounts of additional water will be necessary to supply industrial development (other than coal-related development) in northwestern Missouri during 1980-2000.

Coal-Gasification Plants

Of all the processes and industries in Missouri making use of coal, the one that will probably require the most hydrologic data and planning is the coal-gasification process. Coal resources in a number of locations in northwestern Missouri (fig. 6) probably are sufficient to support coal gasification or other coal-conversion plants. At the present time (1980), there are proposals for two coal-gasification plants to be located in the area (Steve Hencey, Missouri Department of Natural Resources, oral commun., 1980). Proposed locations of the two plants are shown in figure 6; one at Reger on Locust Creek and the other near Yates in the southeastern part of the area. The Reger plant would use an impoundment on Locust Creek for its water supply and the Yates plant would use water from the Missouri River, which is about 20 miles away.

There is some variation in the estimated water requirements for coal-gasification plants. A summation of available information on water use for one coal-gasification plant is presented in table 12. It is assumed that this range of water requirements would be sufficient for most coal-gasification plants.

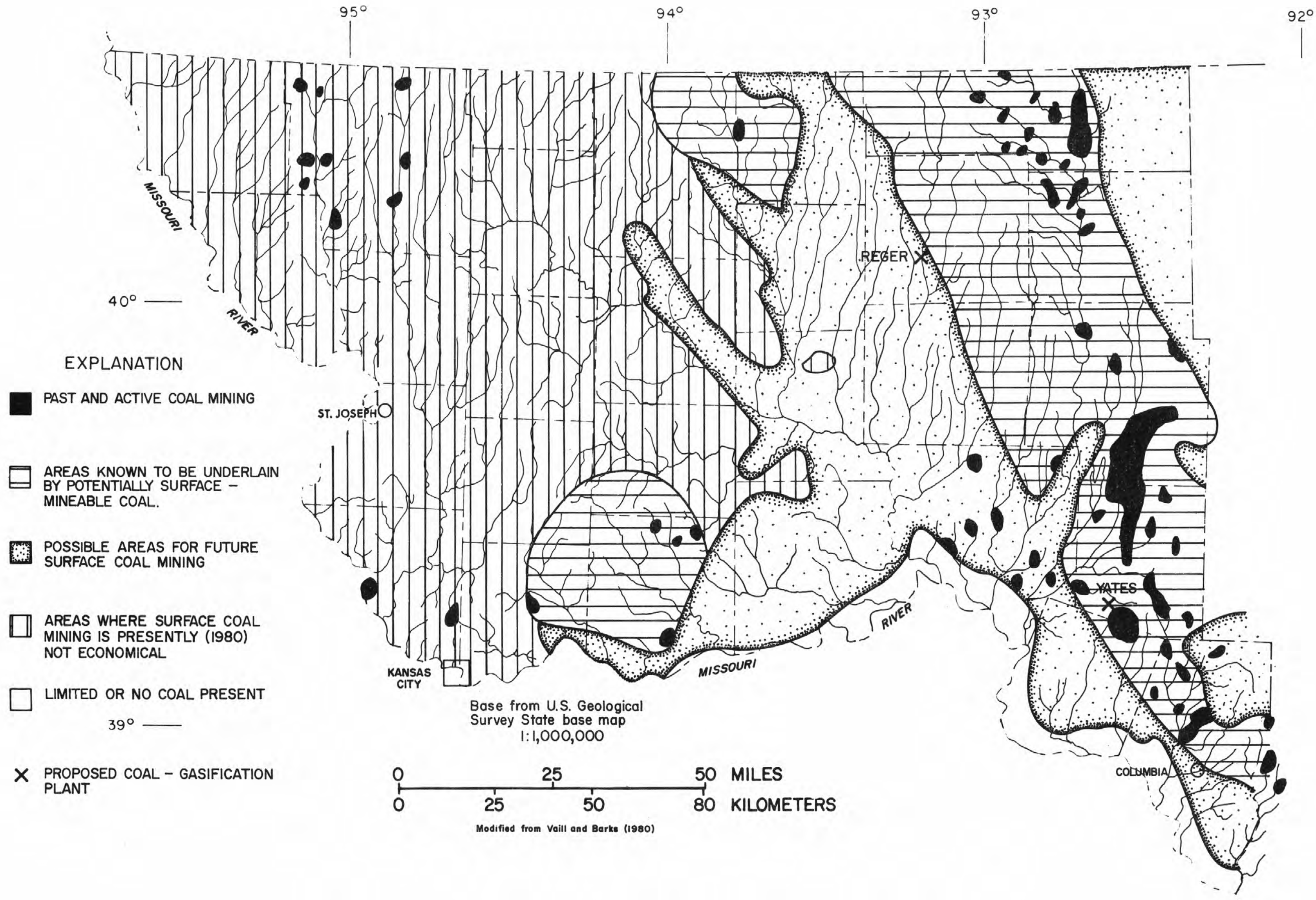

Figure 6.--Location of coal resources and coal-mining areas.

Table 12.--Range in volumes of water needed by one coal-gasification plant

[From Western Gasification Company, 1973; production 250 million standard cubic feet per day of synthetic natural gas]

Level of use	Gallons per minute	Cubic feet per second
Very low (extreme conservation measures)	4,000	9
Low	10,000	22
Medium	20,000	45
High	50,000	111

Potential Areas for Future Studies

One of the purposes of this report was to evaluate areas in northwestern Missouri where additional hydrologic data are needed to provide a data base suitable for use in making decisions regarding future water development. Previous sections of the report have included background hydrologic and economic data that affect the selection of potential study areas.

The following areas and types of study are presented as the authors' estimate of the most viable work that can be done in northwestern Missouri during the next 10 to 15 years to obtain the needed hydrologic data. The order of presentation is not necessarily significant; the authors believe that any of these studies would be useful to many people, industries, and agencies throughout northwestern Missouri.

The lower Grand and Thompson River basins (see fig. 2) are one of the most promising areas for future hydrologic studies. The area is semicircular with a radius of 30 to 40 miles, and probably is the area with greatest potential for ground-water development except for the Missouri River alluvium. The relation between the alluvial valley of the Grand River and an adjacent buried glacial valley is shown by the lithologic sections presented in figure 7. At Gallatin (section A-A') the alluvial valley and the buried valley are not coincident and the top of the sand and gravel is separated from the alluvium by relatively impervious bedrock. At Chillicothe (section B-B') the two deposits partly coincide and about 26 feet of glacial drift, silt, and clay intervene. At Bosworth (section C-C') the alluvium and glacial drift are undifferentiated, and there is no continuous body of impervious material separating the two deposits. Therefore, the downstream areas, where wells can produce as much as 800 gallons per minute, are most amenable to future hydrologic studies that may be directed toward analyses that are useful in investigating conjunctive uses of water. This would include the quantitative analysis of the alluvial fill, glacial fill, and surface streamflow. A digital-simulation model could be used to predict the effects of pumpage for assumed industrial or agricultural expansions on streamflow and potentiometric surfaces. This study could encompass an area extending from the mouth of the Grand River to Chillicothe and include the Thompson River in Livingston County and a buried preglacial valley that joins the Grand River buried preglacial valley downstream from Chillicothe. To model the buried preglacial valley aquifer and its hydraulic relation to the Grand River alluvial aquifer, test-drilling and aquifer-test data would be needed for each aquifer. Before the modeling effort, preparation of potentiometric maps of the alluvial and glacial-drift aquifers and additional surface-water data also would be required. The results of the study could aid industrial development and would be useful to water developers and planners.

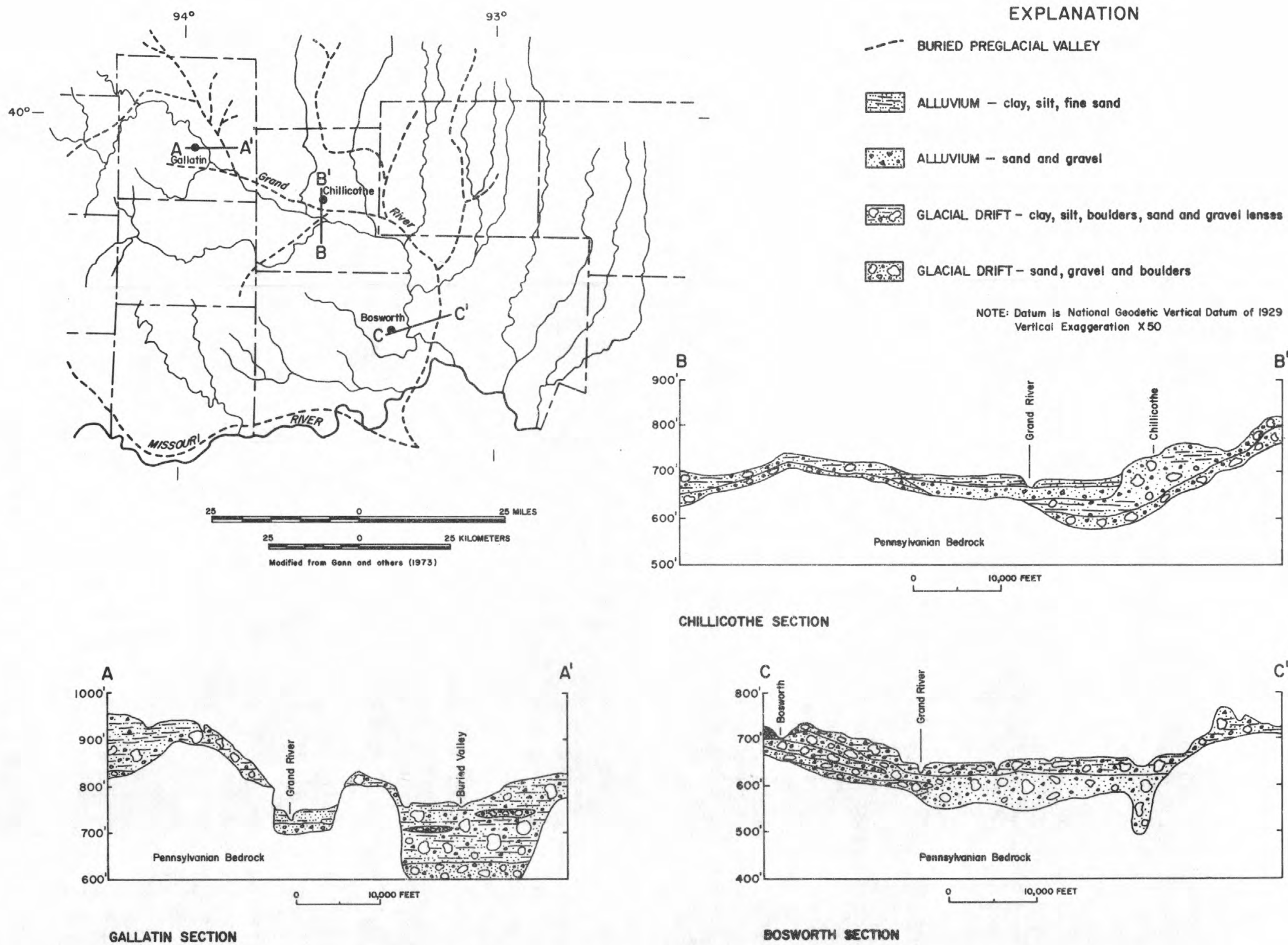

Figure 7.--Relationship between the Grand River alluvial valley and the buried preglacial valley.

The most abundant source of water in northwestern Missouri is the Missouri River and its alluvial flood plain. A useful study would be an analysis of the effects of present (1980) and proposed upstream diversions and changes in the river regimen on future water-resources development along the river in Missouri. Modeling techniques could be used to determine the effects of pumpage from the alluvial aquifer before and after projected changes in the streamflow pattern. Background information for the alluvial aquifer is available from a series of reports by Emmett and Jeffery (1969, 1969a, 1969b, 1970). However, additional data collection such as ground-water levels in relation to river stages, aquifer characteristics, and present and projected water use would be necessary before the model study. It also would be necessary to make studies for selected segments of the river other than the entire reach bordering northwestern Missouri. Segments of the river that might be studied first would be in the vicinity of the large urban centers (St. Joseph, Kansas City, and Columbia). These are the areas where present (1980) and potential industrial water use is greatest.

The Nodaway-Tarkio-One Hundred and Two River basins (see fig. 2) are areas where future hydrologic studies might be useful in attracting water-using developments, although significant expansion of industry, agriculture, and population is not expected during the next 10 to 20 years. Existing ground-water data appear to be sufficient, and additional test drilling probably is not needed because of the availability of data collected by the Missouri Division of Geology and Land Survey during the late 1950's (Fuller and others, 1956-60). The buried preglacial valleys in the area are not likely to be a factor in water supply and availability because the limited width and thickness of this aquifer limits its usefulness. The mineralization of the water also is greater than that of the glacial drift, alluvium, and surface water. Seepage-run data are needed for these basins to supplement available surface-water information from continuous- and partial-record streamflow-gaging stations. Low-flow data (table 3) show that there probably are aquifers of some potential in the Nodaway River basin even though they are thin (table 8). The value of a hydrologic study in this area is limited because the economy of the area is not expected to expand significantly; however, additional published information on water availability could spur development in parts of the area where there is greatest potential.

Except in downstream reaches near the Missouri River, the Chariton River basin (see fig. 2) is an area where ground-water resources are undependable because of the limited thickness of alluvium and glacial drift (about 15 to 30 feet). Ground- and surface-water supplies are adequate for municipal use and no major industrial expansion is forecast for the next 10 to 20 years. Strip mining of coal is increasing in the basin, but this activity should not require significant increases in water use. Surface-water supplies should be adequate for most needs, especially where the terrain is suitable for storage facilities to be constructed. Hydrologic studies are in progress in coal-mining areas of the basin (Vaill and Barks, 1980) and no significant industrial or agricultural expansion is forecast. However, as shown in figure 3, population increases are projected for a large part of the basin, and the data in table 3 show that ground-water outflow to the river in the downstream reaches of the basin is significant in comparison with other basins in the region. Thus the hydrologic data that would be collected during a comprehensive study in the Chariton River basin would serve a useful purpose in describing an area of potential for conjunctive development of ground water and surface water.

The areas where coal resources are adequate and mining is feasible (see fig. 6) need additional hydrologic studies. These areas include all or parts of the following counties: Adair, Boone, Caldwell, Carroll, Chariton, Clay, Clinton, Daveiss, Grundy, Harrison, Howard, Linn, Livingston, Macon, Mercer, Putnam, Randolph, Ray, and Sullivan. One of the primary reasons for these studies is the possibility of coal-related industrial expansion in these areas, especially the construction of coal-gasification plants and associated industrial parks in addition to those proposed for the Reger and Yates areas. The first hydrologic studies need to include appraisals of quantity and quality of the surface- and ground-water supply and need to provide information for model studies to predict the impact of water-resource development on the hydrologic system in these areas.

An important factor that needs to be considered in all proposed projects is water quality, especially the nitrate concentration of water in the shallow aquifers. The nitrate concentration (as NO_3) of ground water in municipal supplies in northwestern Missouri is greater than in other parts of the State (Missouri Divsiion of Environmental Quality, 1977). Nine of 14 municipal ground-water supplies in the State with nitrate concentration in excess of 10 milligrams per liter, and 17 of 39 supplies in excess of 5 milligrams per liter occur in the project area. The source of nitrate in this area may be the abundant use of fertilizers in agricultural activities. Fourteen of the 17 supplies with nitrate concentration greater than 5 milligrams per liter have shown increases between 1966-77, so it is apparent that this trend and its cause needs to be investigated by additional sampling of private wells as a part of all the projects mentioned previously.

SUMMARY AND CONCLUSIONS

Increases in water use may occur in northwestern Missouri because of agricultural activities, coal development, industrial expansion, and population increases in some areas. Water supplies are limited in much of the area, as are adequate evaluations of the water resource.

The minimum flow of streams is a limiting factor in their potential use, but in some basins significant amounts of surface water are available without storage, even during times of serious drought. The most dependable and largest supplies, as indicated by the 30-day low flow with recurrence interval of 10 years, can be obtained form the lower Grand River (15 to 30 million gallons per day) and the Nodaway and Chariton Rivers (5 to 10 million gallons per day).

Dissolved-solids concentration of surface water generally is less than 400 milligrams per liter. The water is primarily a calcium bicarbonate type. Sediment yields, which are largest in areas of greatest loess thickness near the Missouri River in the western part of the area, range from 300 to 6,000 tons per square mile per year for drainage areas greater than 100 square miles.

The unconsolidated aquifers are the most important source of ground water. Wells completed in the alluvium along the Missouri River can yield 1,000 to 2,000 gallons per minute. Well yields in the glacial drift and tributary alluvium vary from a few gallons per minute to 800 gallons per minute. Most municipal supplies are obtained from wells completed in alluvium (although a few large cities obtain most of their supplies from surface-water sources). Water from the alluvium is a calcium bicarbonate type and has dissolved-solids concentrations of less than 1,000 milligrams per liter. Water from glacial drift is a mixed calcium bicarbonate sodium sulfate type, is hard, and has large iron concentrations. Some of the water from glacial drift is saline (greater than 1,000 milligrams per liter dissolved-solids concentration).

Irrigation and industry are concentrated along the Missouri River where ground-water supplies from the alluvium are abundant. The largest use of water (about 78 percent of the water withdrawn during 1975) was for cooling purposes by electric powerplants, which pump water from the Missouri River or from impoundments.

Coal-gasification plants are proposed at two sites at present (1980). However, coal resources in a number of areas probably are sufficient to support coal-gasification or other coal-conversion plants.

Areas where additional hydrologic data are needed to provide a data base suitable for use in making decisions regarding future water development include the following: The lower Grand and Thompson River basins, the Missouri River alluvial aquifer, the Nodaway-Tarkio-One Hundred and Two River basins, the Chariton River basin, and the 19 counties where there is a possibility for coal-related industrial expansion because of potentially surface-mineable coal.

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