QUALITY OF SHALLOW GROUND WATER AT SELECTED SITES IN THE DRY CREEK OIL FIELD, FRANKLIN COUNTY, MISSISSIPPI, 1999

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ABSTRACT

In 1999, the U.S. Geological Survey conducted an investigation of possible brine contamination of shallow ground water in the Dry Creek oil field in the Homochitto National Forest in southwestern Franklin County, Mississippi. Eleven wells were drilled in or near a brine-disposal evaporation pit. Concentrations of chemical constituents in water from one well (southwest of the evaporation-pit area) were near background levels. Concentrations in water from the other 10 wells were brine-affected (more than 25 years after the last known activity at the study site). Dissolved solids concentrations ranged from 1,560 to 9,880 milligrams per liter; sodium, from 510 to 3,100 milligrams per liter; and chloride from 800 to 5,500 milligrams per liter. Based on median chloride concentrations, the brine-affected ground water in the study area is less than 5 percent brine, but the median chloride concentration is more than 16 times that recommended for drinking water.

INTRODUCTION

Large quantities of brine are withdrawn from the subsurface in conjunction with the production of petroleum. Since 1939, when petroleum production began in Mississippi, disposal of brine has resulted in brine contamination of ground water and streams. In the early years of oil production in Mississippi, brine was discharged onto the ground or into nearby streams. Later, in an effort to avoid surface-water contamination, producers pumped brine into evaporation ponds or pits. This disposal practice led to the brine contamination of shallow ground water. In 1978, these disposal methods were prohibited in the State (Mississippi Oil and Gas Board, 1985), but it was several years later before these methods of disposal were actually discontinued.

Under the National Environmental Policy Act, the U.S. Department of the Interior, Bureau of Land Management (BLM), must complete an environmental analysis and document potential impacts prior to making leasing decisions concerning applications to conduct oil and gas production in National forests. Many of the areas in National forests managed by the U.S. Forest Service (USFS) that are being considered for leasing/development are within recharge areas of aquifers used for primary or secondary drinking-water supplies for nearby communities. Concerns about water quality are repeatedly raised when leasing and development proposals are considered. Water-quality data are needed to address impacts to water quality in a quantitative manner.

The Dry Creek oil field, containing approximately 1,120 acres in the Homochitto National Forest in Franklin County, is considered representative of oil fields in National forests in southwestern Mississippi that are managed by the USFS. Oil and gas wells located in the Dry Creek oil field have produced oil since 1963 when the oil field was formally delineated. Presently, there are approximately 35 oil and gas wells in the vicinity of the Dry Creek oil field. Federal leases covering approximately 800 acres in the Dry Creek oil field were issued during the 1960's and mid-1980's. In 1989, the BLM issued additional leases for 320 acres.

As of 1977, when federally authorized surface disposal was officially discontinued, about 18,000,000 barrels of saltwater (from all sources) had been produced from the Dry Creek oil field. Since that time, all brines produced from federally leased areas in this oil field have been required to be disposed in class 2 approved injection wells. The last known pit disposal of brines in the Dry Creek oil field occurred in 1983 on privately (non-federal) leased land. Little information is available on shallow ground water in the area. The results reported by Slack and Darden (1991) of three aquifer tests conducted in Franklin County were from much deeper aquifers (well depths ranging from 237 to 345 feet).

In 1999, the U.S. Geological Survey (USGS), in cooperation with the USFS and BLM, conducted an investigation of possible brine contamination of shallow ground water in the Dry Creek oil field in the Homochitto National Forest in Franklin County, Mississippi. This report describes the site selection criteria and site information, methods of sampling and analysis, and results of that study.

SITE SELECTION CRITERIA AND SITE INFORMATION

BLM, USFS, and USGS personnel selected a site in southwestern Franklin County for the study (fig. 1). The site selection criteria were as follow:

- Being on land managed by the USFS
- Being in the Dry Creek oil field.
- Being in the vicinity of historical brine evaporation pits
- Being accessible for well drilling and ground-water sampling.

The site selected is southeast of Forest Service road 101 in NE1/4NE1/4 sec. 21, T. 5 N., R. 1 E., of the Washington Meridian (fig. 1).

During June 1999, two test holes were drilled in the vicinity of an evaporation-pit area in the Dry Creek oil field in Franklin County, Mississippi. These holes were drilled by the National Resources Conservation Service (NRCS), using a dry-rotary technique. The test holes were cased with 2-inch polyvinyl chloride casing with a 3-foot well point. Due to equipment limitations, these holes were shallow (test hole 1 was 20 feet deep and produced water; test hole 2 was 36 feet deep and dry). Test hole 1 is labeled "2-inch test hole" on figure 2 (test hole 2 is not shown).

During August-September 1999, 11 additional test holes were drilled in or near an evaporation-pit area in the Dry Creek oil field in Franklin County, Mississippi. These 11 test holes were drilled by the Mississippi Department of Environmental Quality, Office of Geology (MDEQ-OG), using mud-rotary equipment. Water-quality samples were collected from the 11 MDEQ-OG shallow monitoring wells (locations for these sites, and for NRCS test hole 1 at which water-level measurements were made, are shown on fig. 2). An effort was made to construct wells to sample water representing water-table conditions, and to install 4-inch polyvinyl chloride casing (with slots cut in the bottom 5 or 10 feet) in the unconsolidated Miocene sediments. Water levels were measured and surveyed using an assumed datum. Site information for the 11 MDEQ-OG shallow monitoring wells is listed in table 1.

Most of the wells were selected to be downgradient (based on the land-surface topography) of the evaporation-pit area (fig. 3); this was done by assuming that the shallow water-level gradient would be a subdued image of the land surface. Well L053 was drilled in the evaporation-pit area. Well L054 is located across Forest Service Road 101 from the pit and is roughly north-northwest of the evaporation-pit area. The rest of the wells were believed (on the basis of land-surface contours) to be downgradient of the evaporation-pit area.

METHODS OF SAMPLING AND ANALYSIS

To obtain samples that closely represent shallow ground water in the water-bearing unit, the wells were pumped with a submersible pump prior to sampling long enough to withdraw at least twice the volume of water in the casing. Water temperature, pH, and specific conductance were monitored until they stabilized.

The water samples were analyzed at the USGS Water-Quality Service Unit in Ocala, Florida. Laboratory procedures used to analyze the water samples for this study were similar to the procedures used in previous studies by Kalkhoff (1985) and by Slack and others (1996). The Water-Quality Service Unit used methods described by Fishman and Friedman (1989). The detection limits of these techniques for selected constituents or properties are listed in table 2.

RESULTS

Concentrations of chemical constituents in water from one well (L049) were near background levels. Although sodium was the predominant cation and chloride was the predominant anion in water from all 11 wells, dissolved solids (residue on evaporation at 180 degrees Celsius), sodium, and chloride concentrations were low in well L049: 195, 13, and 26 milligrams per liter, respectively (table 3).

Water from 10 of the 11 wells had elevated concentrations of sodium and chloride indicating that the ground water in vicinity of the evaporation pits is contaminated by brine more than 25 years after the last known activity at the study site (table 3). Dissolved solids concentrations for the 10 brine-affected sites ranged from 1,560 to 9,880 milligrams per liter, with a median concentration of 8,080 milligrams per liter. Sodium concentrations for the 10 sites ranged from 510 to 3,100 milligrams per liter, with a median concentration of 2,000 milligrams per liter. Chloride concentrations for the 10 sites ranged from 800 to 5,500 milligrams per liter, with a median concentration of 4,100 milligrams per liter. Interestingly, the median sodium:chloride ratio of water from these 10 sites was 0.53, compared to a median sodium:chloride ratio of 0.61 for analyses of seven selected brine samples collected in 1963 from oil-productive formations in the vicinity of the study area (table 4). Median concentrations of total solids (stoichiometrical analysis), sodium, and chloride concentrations in the seven brine samples collected in 1963 were 139, 569; 51,850; and 85,100 milligrams per liter, respectively (table 4, data from Hawkins, Jones, and Pearson, 1963).

The dissolved solids (residue on evaporation at 180 degrees Celsius):specific conductance relation for the 11 samples was fairly uniform (fig. 4). The equation for the relation was as follows:

$$DS = 0.67 * SC,$$

Where DS is dissolved solids (in milligrams per liter) and SC is specific conductance (in microsiemens per centimeter at 25 degrees Celsius). The r-squared value for this relation is 0.98. The median dissolved solids:specific conductance ratio was 0.66.

The areal distribution of brine-affected water (water with elevated specific conductance values and elevated concentrations of dissolved solids, sodium, and chloride) was mixed (see table 3. The highest chloride concentrations were measured in samples from wells south and southwest of the evaporation-pit area, whereas the lowest chloride concentrations were measured in samples from wells west of the pit area. However, water sampled from well L054 northwest of the evaporation-pit area was substantially brine-affected, and the only freshwater sampled was from well L049 southwest of the pit area.

The data indicate that substantial dilution of the original brine water from the evaporation pit has occurred. For example, the median chloride concentration in the 11 brine-affected samples was 4,100 milligrams per liter, whereas the median chloride concentration in the seven brine samples from oil-productive formations was 85,100 milligrams per liter. Thus, based on median chloride concentrations, the brine-affected ground water in the study area was less than 5 percent brine. Nonetheless, the median chloride concentration in the brine-affected water was 16.4 times the 250-milligram-per-liter secondary standard recommended for drinking water (U.S. Environmental Protection Agency, 2000)—more than 25 years after the evaporation-pit area was last used.

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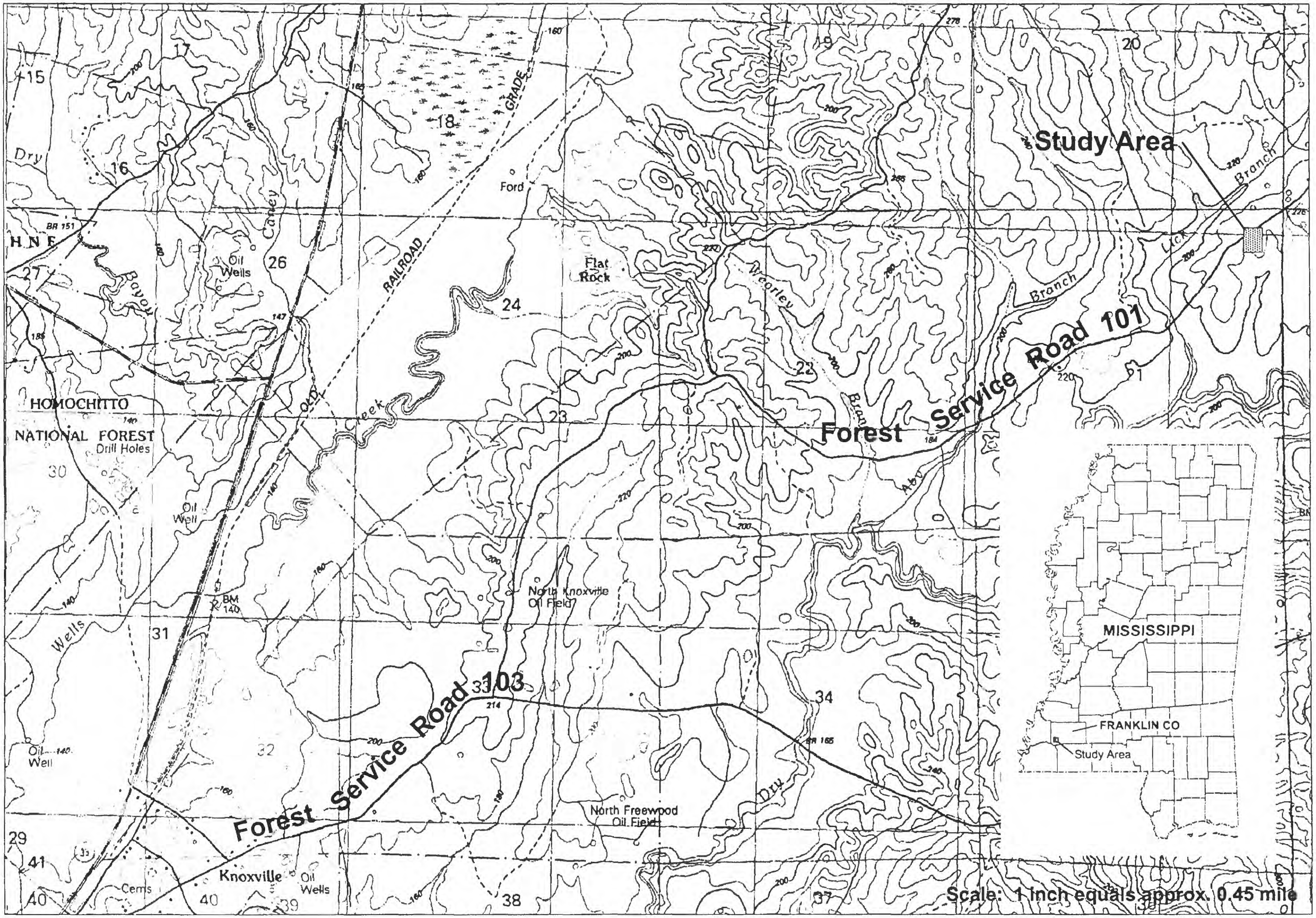


Base from U.S. Geological Survey
Knoxville Quad, 1988

Figure 1. Location of study area, Franklin County, Mississippi.

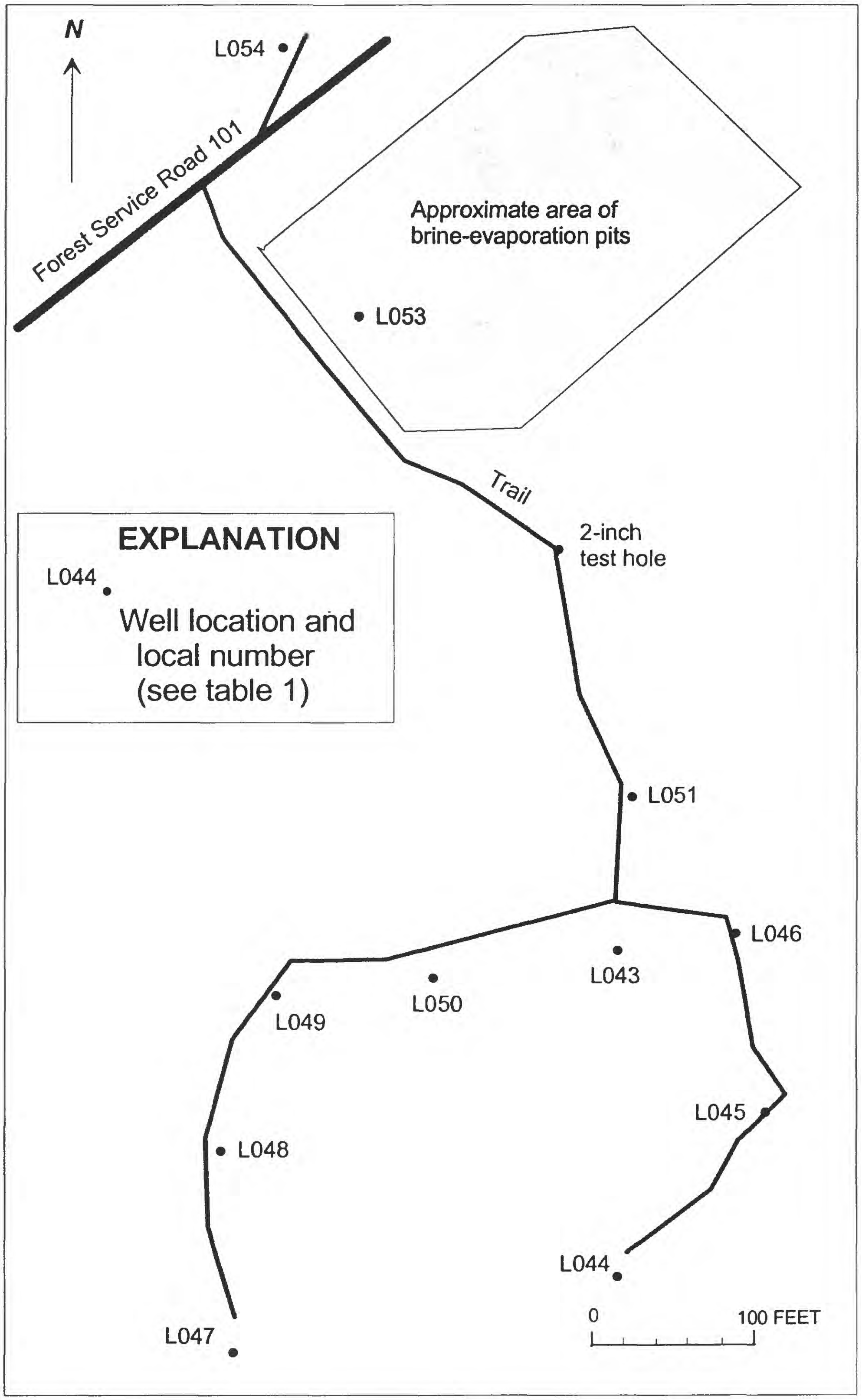
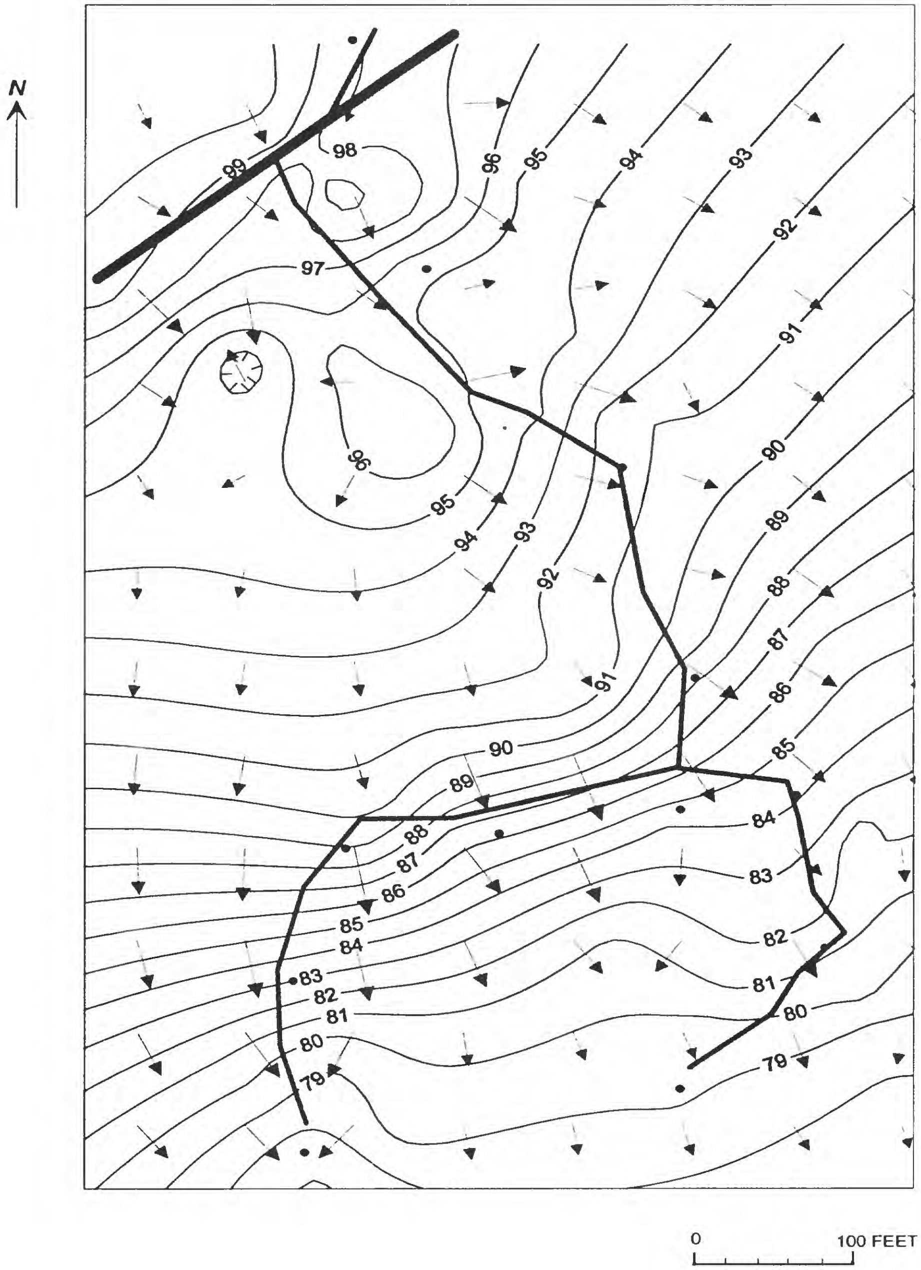


Figure 2. Location of ground-water sampling sites (wells) in the study area, Franklin County, Mississippi.



EXPLANATION

— 85 — Topographic contour-- Shows approximate elevation of land surface in feet above arbitrary datum (summer 2000)

• Well location (See fig. 2 and table 1)

Arrow represents general direction of decreasing land surface altitude

Figure 3. Land-surface contours in the study area, Franklin County, Mississippi.

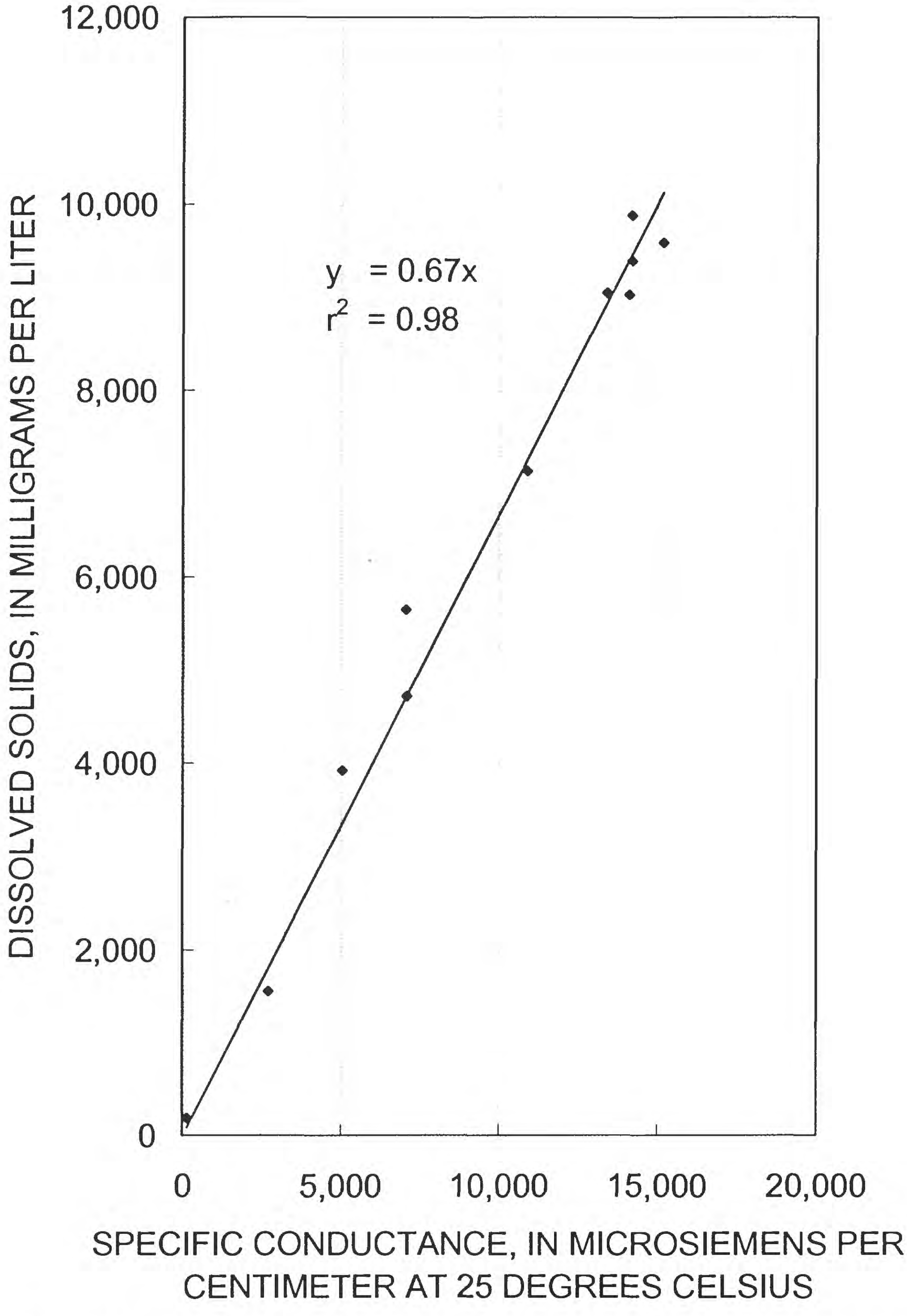


Figure 4. Relation of dissolved solids (residue on evaporation at 180 degrees Celsius) and specific conductance of water from selected wells in the Dry Creek oil field, Franklin County, Mississippi.

Table 1. Site information for selected wells in the Dry Creek oil field, Franklin County, Mississippi
[LSD, land surface datum. All wells are in sec. 21, T. 5 N., R. 1 E.]

Local number	Latitude	Longitude	Open interval (feet below LSD)	Water level (feet below LSD)	Water level (date measured)
L043	31°24′17″	091°03′35″	110-115	53	08-24-99
L044	31°24′15″	091°03′35″	79-84	43	08-25-99
L045	31°24′16″	091°03′33″	69-74	50	08-26-99
L046	31°24′17″	091°03′34″	100-105	52	08-30-99
L047	31°24′14″	091°03′37″	78-83	48	09-09-99
L048	31°24′16″	091°03′37″	76-81	53	09-14-99
L049	31°24′17″	091°03′37″	112-117	57	09-05-99
L050	31°24′17″	091°03′36″	63-68	55	09-07-99
L051	31°24′18″	091°03′34″	100-105	55	09-09-99
L053	31°24′21″	091°03′36″	78-83	40	09-09-99
L054	31°24′22″	091°03′36″	64-75	65	09-16-99

Table 2. Detection limits for water-quality data for selected wells in the Dry Creek oil field, Franklin County, Mississippi
[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter. ROE, residue on evaporation at 180 degrees Celsius]

Parameter code	Property or constituent	Detection limit
90095	Specific conductance (lab)	1.0 μS/cm
00403	pH (lab)	0.1 standard pH unit
70300	ROE	1.0 mg/L
00915	Calcium	1.0 mg/L
00925	Magnesium	1.0 mg/L
00930	Sodium	1.0 mg/L
00940	Chloride	1.0 mg/L
00945	Sulfate	1.0 mg/L

Table 3. Water-quality data for selected wells in the Dry Creek oil field, Franklin County, Mississippi

[Specific conductance in microsiemens per centimeter at 25 degrees Celsius; all other constituents in milligrams per liter. ROE, residue on evaporation at 180 degrees Celsius; Sum, sum of constituents; Ca, calcium; Mg, magnesium; Na, sodium; Cl, chloride; SO_4, sulfate]

Local number	Date	Specific conductance	ROE	Sum	Ca	Mg	Na	Cl	SO_4
L043	09-13-99	14,200	9,390	8,510	260	88	3,000	5,100	4.6
L044	09-14-99	5,050	3,930	2,770	190	68	760	1,700	6.8
L045	09-14-99	7,060	5,650	4,130	270	102	1,200	2,500	6.6
L046	09-14-99	14,200	9,880	8,940	280	91	3,000	5,500	4.4
L047	09-14-99	13,400	9,050	7,360	500	191	2,100	4,500	6.2
L048	09-14-99	10,900	7,140	6,100	320	116	1,900	3,700	5.6
L049	09-14-99	135	195	107	7.3	2.7	13	26	3.2
L050	09-14-99	14,100	9,020	8,000	300	124	2,700	4,800	6.1
L051	09-14-99	15,200	9,590	.8,690	240	80	3,100	5,200	4.4
L053	09-14-99	2,730	1,560	1,400	26	9.5	510	800	2.2
L054	09-16-99	7,100	4,720	3,750	350	116	910	2,300	4.9
Summary, all 11 sites									
Maximum		15,200	9,880	8,940	500	191	3,100	5,500	6.8
Mean		9,461	6,375	5,432	249	90	1,745	3,284	5.0
Median		10,900	7,140	6,100	270	91	1,900	3,700	4.9
Minimum		135	195	107	7.3	2.7	13	26	2.2
Summary, brine sites only (10 sites)									
Maximum		15,200	9,880	8,940	500	191	3,100	5,500	6.8
Mean		10,394	6,993	5,965	274	99	1,918	3,610	5.2
Median		12,150	8,080	6,730	275	96	2,000	4,100	5.3
Minimum		2,730	1,560	1,400	26	9.5	510	800	2.2

Table 4. Characteristics of brine from oil-producing formations in the vicinity of the Dry Creek oil field, Franklin County, Mississippi

[Constituents in milligrams per liter. Ca, calcium; Mg, magnesium; Na, sodium; Cl, chloride; SO_4, sulfate; Total solids, stoichiometrical; Na/Cl, sodium:chloride ratio. Modified from Hawkins, Jones, and Pearson, 1963]

Field	Ca	Mg	Na	Cl	SO_4	Total solids	Na/Cl
Freewoods, N.	1,750	290	34,800	57,600	<0.1	94,561	0.60
Freewoods, N.	2,000	300	40,800	67,200	<0.1	110,526	0.61
Knoxville	1,920	380	46,500	76,200	<0.1	125,078	0.61
Knoxville	2,000	730	57,300	94,000	<0.1	154,125	0.61
Knoxville, N.	1,900	870	57,200	94,000	<0.1	154,060	0.61
Knoxville, N.	1,920	630	58,100	94,700	<0.1	155,470	0.61
Richardson Creek	1,100	650	32,200	53,400	<0.1	87,649	0.60
Maximum	2,000	870	58,100	94,700	<0.1	155,470	0.61
Mean	1,807	593	48,683	79,917	<0.1	131,151	0.61
Median	1,920	640	51,850	85,100	<0.1	139,569	0.61
Minimum	1,100	300	32,200	53,400	<0.1	87,649	0.60