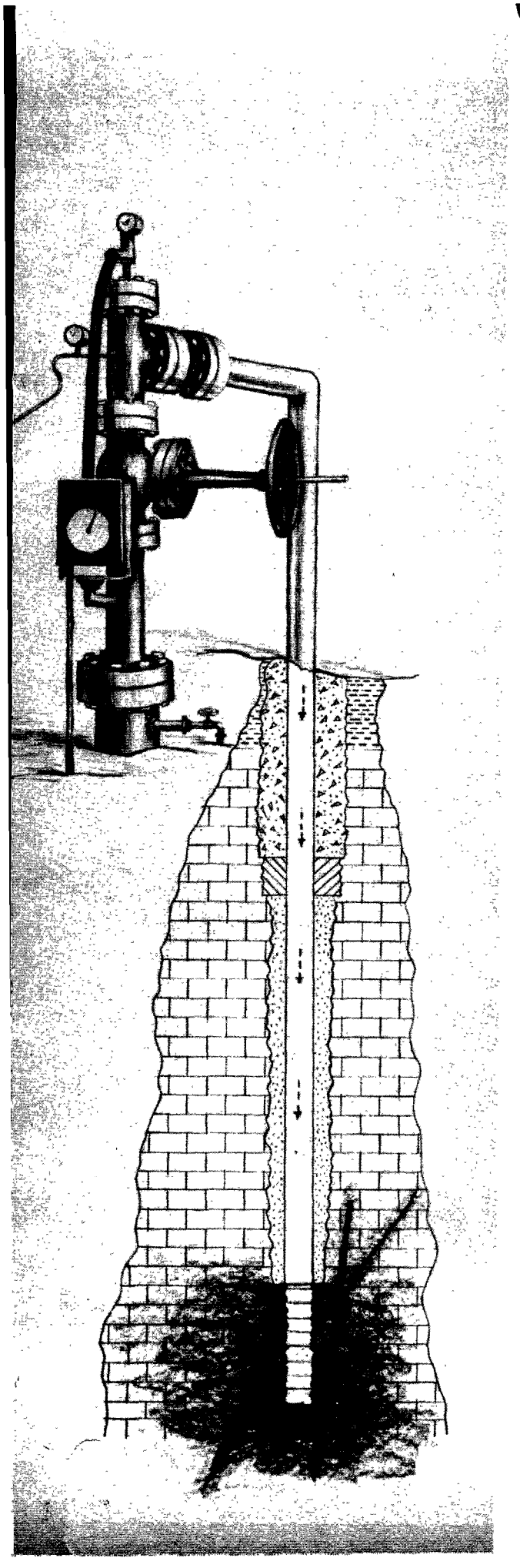
WATER-RESOURCES INVESTIGATIONS REPORT 85-4252



PRELIMINARY EVALUATION OF THE THE HIGHLAND RIM AQUIFER SYSTEM IN TENNESSEE FOR RECEIVING INJECTED WASTES

Prepared by
U.S. GEOLOGICAL SURVEY
in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

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By Michael W. Bradley

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Nashville, Tennessee
1986

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

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Factors for Converting Inch-Pound Units to
International System of Units (SI)

For the convenience of readers who may want to use International System of Units (SI), the data may be converted by using the following factors:

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	0.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon per minute (gal/min)	0.00006309	cubic meter per second (m^3/s)

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. NGVD of 1929 is referred to as sea level in this report.

PRELIMINARY EVALUATION OF THE HIGHLAND RIM AQUIFER SYSTEM IN TENNESSEE FOR RECEIVING INJECTED WASTES

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ABSTRACT

The U.S. Environmental Protection Agency has authority under the Safe Drinking Water Act to protect underground sources of drinking water from contamination by deep well injection. An aquifer, however, may be exempted from protection and used for injected wastes where the aquifer meets criteria established in the Agency's Underground Injection Control program.

The Highland Rim aquifer system in Tennessee consists of Mississippian age carbonate rocks and occurs from the Valley and Ridge of East Tennessee to west of the Tennessee River. This aquifer contains potable water and is an important source of drinking water for municipal and domestic supplies on the Highland Rim. The Highland Rim aquifer system under parts of the Cumberland Plateau is not currently used as a source of drinking water and is not expected to be used in the future. These areas meet parts of the Environmental Protection Agency's Underground Injection Control criteria for exempting aquifers to receive injected waste.

INTRODUCTION

Part C of the Safe Drinking Water Act (Public Law 93-523) authorized the U.S. Environmental Protection Agency (EPA) to establish regulations to assure that the underground injection of waste will not endanger existing or potential sources of drinking water. In order to regulate underground injection, EPA needs to identify and protect aquifers that are existing or potential drinking-water sources and to identify the aquifers or parts of aquifers that are not and will not be used as drinking-water sources.

Under part 146.04 of the Federal Underground Injection Control program (U.S. Environmental Protection Agency, 1981), an underground source of drinking water is protected from receiving injected wastes. However, EPA may exempt an aquifer or part of an aquifer and allow the injection of wastes into an aquifer if:

(A) It does not currently serve as a source of drinking water; and

(B) It cannot now and will not in the future serve as a source of drinking water because:
   (1) It is mineral, hydrocarbon, or geothermal energy producing;
   (2) It is situated at a depth or location which makes recovery of water for drinking-water purposes economically or technologically impractical;

(3) It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or
(4) It is located over a class III well mining area subject to subsidence or catastrophic collapse; or

(C) The total dissolved solids content of the ground water is more than 3,000 mg/L and less than 10,000 mg/L and it is not reasonably expected to supply a public water system."

In addition to meeting these criteria, an aquifer will be exempted only after public notice, a public hearing, and final approval by the Administrator of EPA.

Under current technology and present economic conditions, it will be considered economically or technologically impractical to recover drinking water from an aquifer with the following characteristics.

(a) The aquifer contains water of inferior quality to existing, alternate sources of drinking water, and treatment to make it potable would be uneconomical;
(b) The aquifer lies below a source of drinking water that is adequate to supply present and future needs;
(c) Interflow is imperceptible between the aquifer and existing drinking-water sources.

A dissolved-solids concentration of 10,000 milligrams per liter (mg/L) will be considered to be the limit above which demineralization would be uneconomical. The EPA does not consider an aquifer with water containing more than 10,000 mg/L dissolved solids to be an underground source of drinking water.

Purpose and Scope

The purpose of this study is to evaluate areas in the Highland Rim aquifer system that meet the exemption criteria and can be used to receive injected wastes as defined by State and Federal (EPA) Underground Injection Control programs. The areal extent of the parts of this aquifer system that may be used for waste injection are delineated in this report. Areas where data are insufficient to evaluate the aquifer are also identified. Generalizations on hydrology and water quality have been made because of limited data.

GEOHYDROLOGY

The Highland Rim aquifer system occurs west of the Valley and Ridge physiographic province (fig. 1). This aquifer system is composed of Mississippian carbonate rocks including, in descending order, the Bangor Limestone, Hartselle Formation, Monteagle and Ste. Genevieve Limestones, St. Louis Limestone, Warsaw Limestone, and the Fort Payne Formation (table 1). These formations crop out in the Highand Rim physiographic province and occur in the subsurface of the Cumberland Plateau and part of the Coastal Plain of West Tennessee. This aquifer system has been removed by erosion from the Central Basin and most of the Sequatchie Valley (figs. 1 and 2).

Below the Cumberland Plateau, the Highland Rim aquifer system is overlain by the Pennington Formation (fig. 2). This formation acts as an upper confining layer that separates the Highland Rim aquifer system from the overlying Cumberland Plateau aquifer system. The Highland Rim aquifer system is at or near land surface in the rest of the area of occurrence and does not have an upper confining layer. The Highland Rim aquifer system is confined from below by the Maury Shale and the Chattanooga Shale (table 1; fig. 2).

Ground water in the Highland Rim aquifer system occurs in the regolith above bedrock and in solution-enlarged bedding-plane openings and fractures in the rock (Burchett and Hollyday, 1974; Bradley, 1984). The rocks comprising the Highland Rim aquifer system generally have low primary porosity and permeability. Solution and fracture openings provide zones of secondary permeability for movement and storage of ground water. In parts of the southeastern Highland Rim, the Fort Payne Formation weathers to a regolith with permeable zones of gravel-sized chert fragments above the bedrock (Burchett and Hollyday, 1974).

Most of the ground-water flow in the Highland Rim aquifer system is within 300 feet of land surface. The ground-water reservoir is recharged from precipitation occurring over the outcrop area. Ground water then moves through solution openings and regolith to local discharge points at springs and along streams.

APPLICATION OF CRITERIA TO THE HIGHLAND RIM AQUIFER SYSTEM

Drinking-Water Use

The Highland Rim aquifer system is used as a source of drinking water for 35 municipal water systems in central Tennessee (table 2; fig. 3). This aquifer system also supplies drinking water for most of the rural domestic and non-community use in the Highland Rim.

The aquifer system is not currently used as a source of drinking water in the Cumberland Plateau. The Cumberland Plateau aquifer system overlies the Highland Rim aquifer system (fig. 2) and can supply adequate amounts of ground water for drinking-water use throughout the Plateau.

Hydrocarbon Resources

The formations of the Highland Rim aquifer system are producing hydrocarbon resources (oil and gas) in the northern Cumberland Plateau (fig. 4). Exploration is taking place in other areas in the Cumberland Plateau. There are no current mineral uses, other than construction material, and no geothermal resource uses of the formations of this aquifer system.

Water Quality

Most of the ground water in the outcrop area of the Highland Rim aquifer system is a calcium bicarbonate type. Dissolved-solids concentrations are generally less than 1,000

mg/L (table 3; fig. 5). In the northwestern Highland Rim, the presence of evaporite minerals in the Fort Payne Formation or Warsaw Limestone probably causes higher mineralization of the ground water, with dissolved-solids concentrations being more than 1,000 mg/L in some areas. In this part of the Highland Rim aquifer system, ground water is primarily a calcium sulfate type.

Water type has been illustrated by Stiff diagrams (fig. 5) which show chemically equivalent concentrations (milliequivalents per liter) of calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, and chloride. The diagrams form a distinct pattern for different water types (Hem, 1970). The degree of mineralization is indicated by the width of the pattern. For example, water in a well in Dickson County is a mineralized calcium sulfate water type with about 3,200 mg/L dissolved solids. The corresponding Stiff diagram is wide with large peaks for calcium and sulfate (fig. 5). Water from another well in the same county is a calcium bicarbonate type with 195 mg/L dissolved solids. The Stiff diagram is narrower, has a different shape, and has small peaks for calcium and bicarbonate (fig. 5).

In the Cumberland Plateau, very little quantitative water-quality information for the Highland Rim aquifer system is available. Driller's reports generally describe the water qualitatively as "fresh," "sulfur water," or "salty." Dissolved-solids concentrations in water from the Mississippian formations in the northern Cumberland Plateau probably are more than 1,000 mg/L. One oil well in Morgan County produced water having dissolved-solids concentrations greater than 100,000 mg/L (fig. 5).

Water-quality data in the southern Cumberland Plateau are limited to two points near the Sequatchie Valley. Ground water at both sites had less than 1,000 mg/L dissolved solids. Additional data are needed to define the quality of the water and the hydrology of the Highland Rim aquifer system in the Cumberland Plateau.

Contamination

Contamination of the Highland Rim aquifer system is documented in several localized areas (table 4; fig. 6). At two sites, landfill leachate has contaminated nearby wells and springs, and at three sites contamination involved dumping of wastes into sinkholes (table 4).

The Highland Rim aquifer system is vulnerable to contamination through sinkholes in areas of karst terrain (fig. 6). In these areas, sinkholes channel surface runoff and any contaminants that may be present directly into the subsurface (Miller and Sitterly, 1977). The relatively rapid movement of waste through sinkholes and solution openings can contaminate surface water as well as ground water.

AQUIFERS POTENTIALLY SUITABLE FOR WASTE INJECTION

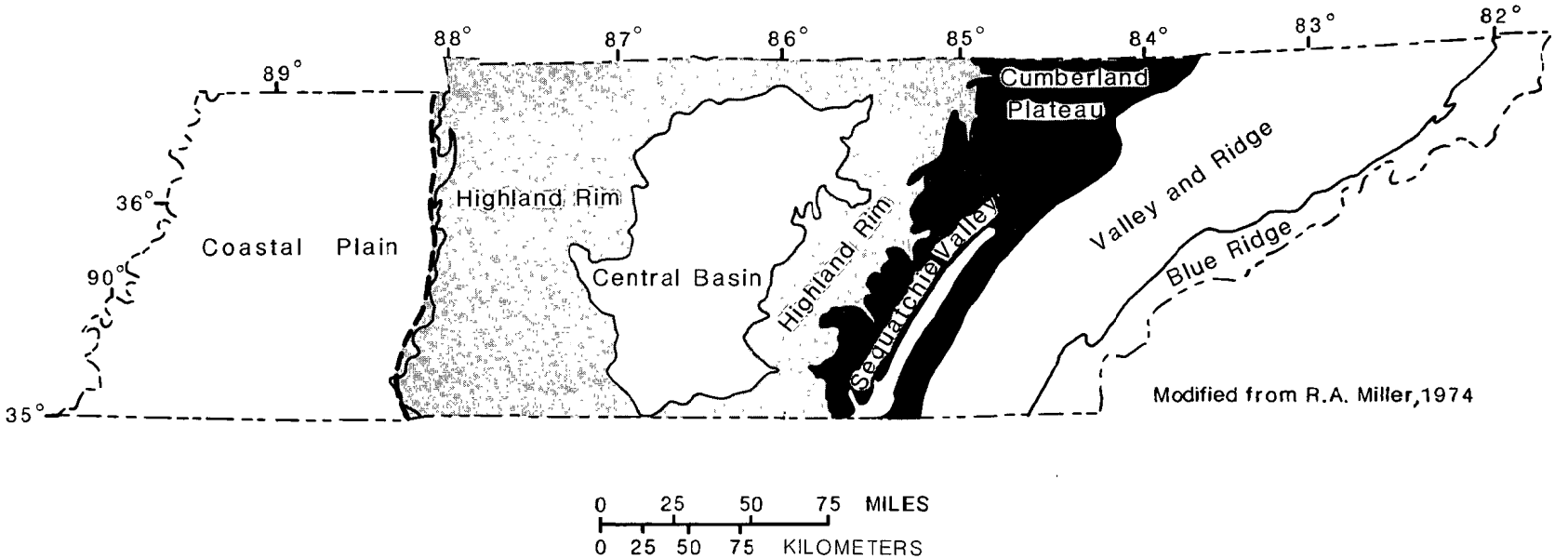
The Highland Rim aquifer system is not currently used as a source of drinking water in the Cumberland Plateau; and in the northern Plateau, the aquifer system is not expected to serve as a source of drinking water because of the presence of hydrocarbon resources (fig. 7). Although this area meets some of the EPA criteria for exemption, the Tennessee Department of Public Health has proposed regulations that would prevent the subsurface injection of wastes into aquifers that contain extractable energy related resources.

At some sites, dissolved-solids concentrations in water from the Highland Rim aquifer system exceeds 3,000 mg/L. There are also some sites of local contamination in the Highland Rim aquifer system. The pockets of mineralized ground water and the contamination sites, however, are small, isolated occurrences in the outcrop area, with the aquifer system being used as a source of drinking water in the area surrounding these sites. Consequently, injection of wastes at these shallow sites could cause contamination of nearby drinking-water supplies.

Table 1.--Geologic formations of the Highland Rim aquifer system, and confining units

Mississippian System	Upper Mississippian	Pennington Formation (confining unit) Bangor Limestone Hartselle Formation Monteagle and Ste. Genevieve Limestones St. Louis Limestone Warsaw Limestone
	Lower Mississippian	Fort Payne Formation Maury Shale (confining unit)
Devonian System	Upper Devonian	Chattanooga Shale (confining unit)

Modified from Miller, 1974.



0 25 50 75 MILES

0 25 50 75 KILOMETERS

EXPLANATION

Outcrop area of the Highland Rim aquifer system

Area of occurrence in the subsurface

Extent of the Highland Rim aquifer system. Dashed where approximate

Figure 1.-- Areal extent of the Highland Rim aquifer system and physiographic provinces in Tennessee.

Table 2.--Summary of public-water systems that use the Highland Rim aquifer system as a source of drinking water

[Data sources: 1, Tennessee Division of Water Resources - Unpublished data; 2, Tennessee Division of Water Quality Control - Unpublished data; 3, Reported from other unpublished sources]

System	County	Data source
Ardmore	Giles	1,2
Belvidere Utility District	Franklin	1,2
Big Sandy	Benton	1,2
Bon Aqua - Lyles Utility District	Hickman	1,2
Collinwood	Wayne	1
Cowan	Franklin	1,2,3
Cumberland City	Stewart	2
Cunningham	Montgomery	2
Dechard	Franklin	1,2
Dickson	Dickson	3
Erin	Houston	1,2
Estill Springs	Franklin	1,2
Fairview	Williamson	1,2
Fayetteville	Lincoln	1,2
Franklin	Williamson	1,2
Harpeth Utility District	Dickson	1
Hohenwald	Lewis	1,2
Huntland	Franklin	1,2
Lafayette	Macon	1,2
Lawrenceburg	Lawrence	1,2
Leoma	Lawrence	1,2
Loretto	Lawrence	1,2
Manchester	Coffee	1,2
McEwen	Humphreys	1,2
Orlinda	Robertson	1,2
Red Boiling Springs	Macon	1,2
Sherwood	Franklin	1,2
St. Joseph	Lawrence	1,2
Summertown	Lawrence	1,2
Taft	Lincoln	3
Tennessee Ridge	Houston	1,2
Tullahoma	Coffee	1,2
Vanleer	Dickson	1
Waverly	Humphreys	1,2
West Point Utility District	Lawrence	1,2

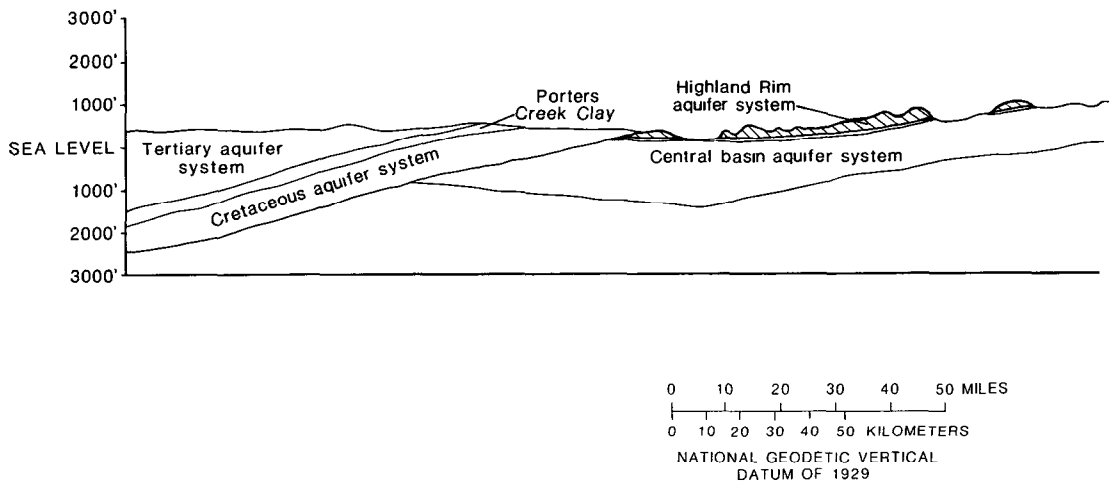
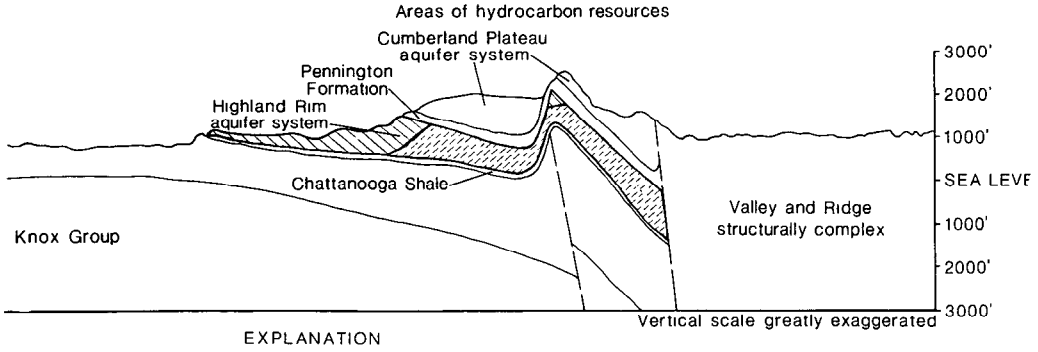


Figure 2.--Generalized geologic section of the



EXPLANATION

Dissolved-solids concentrations are less than 1 000 milligrams per liter. Isolated pockets with more than 1 000 milligrams per liter may occur in some areas Represents the area where the aquifer system is used as a source of drinking water

Few data Estimated dissolved-solids concentrations more than 1 000 milligrams per liter, may be more than 10,000 milligrams per liter. Represents areas where the aquifer system is not used as a source of drinking water

Highland Rim aquifer system showing water quality and use.

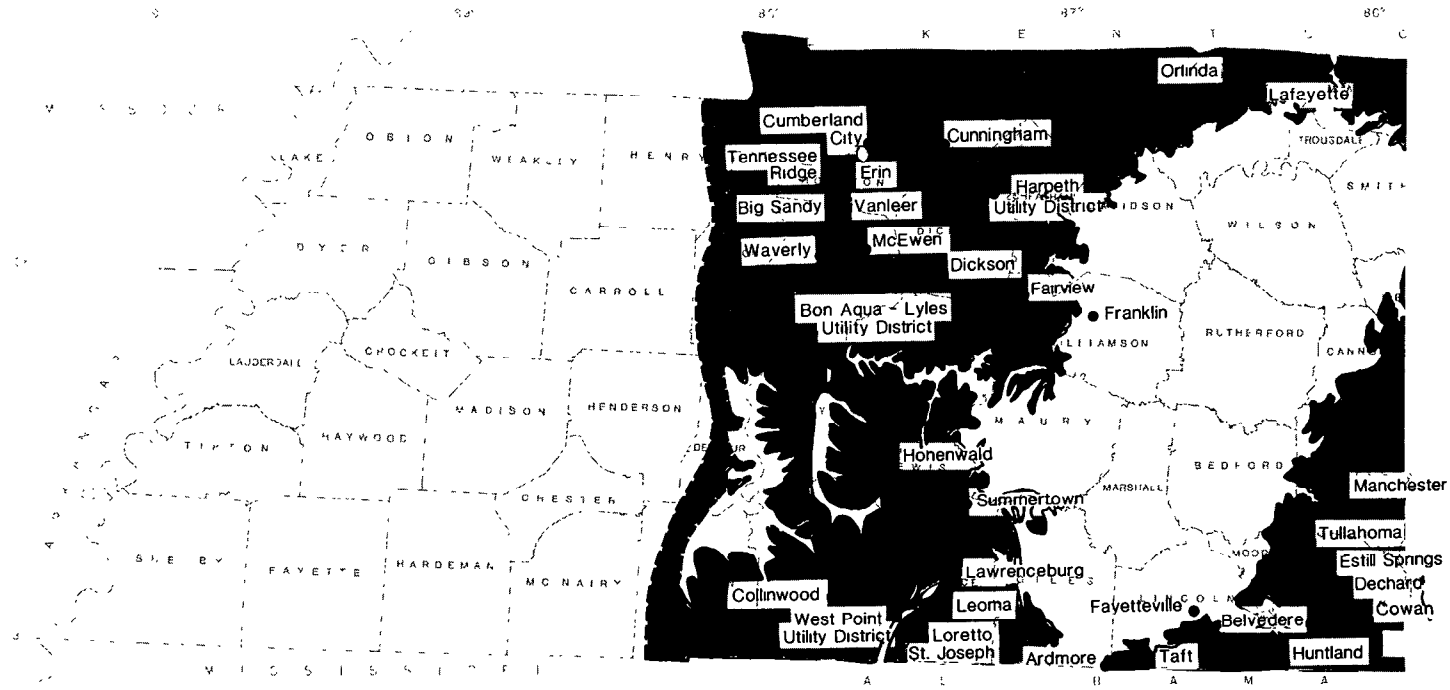
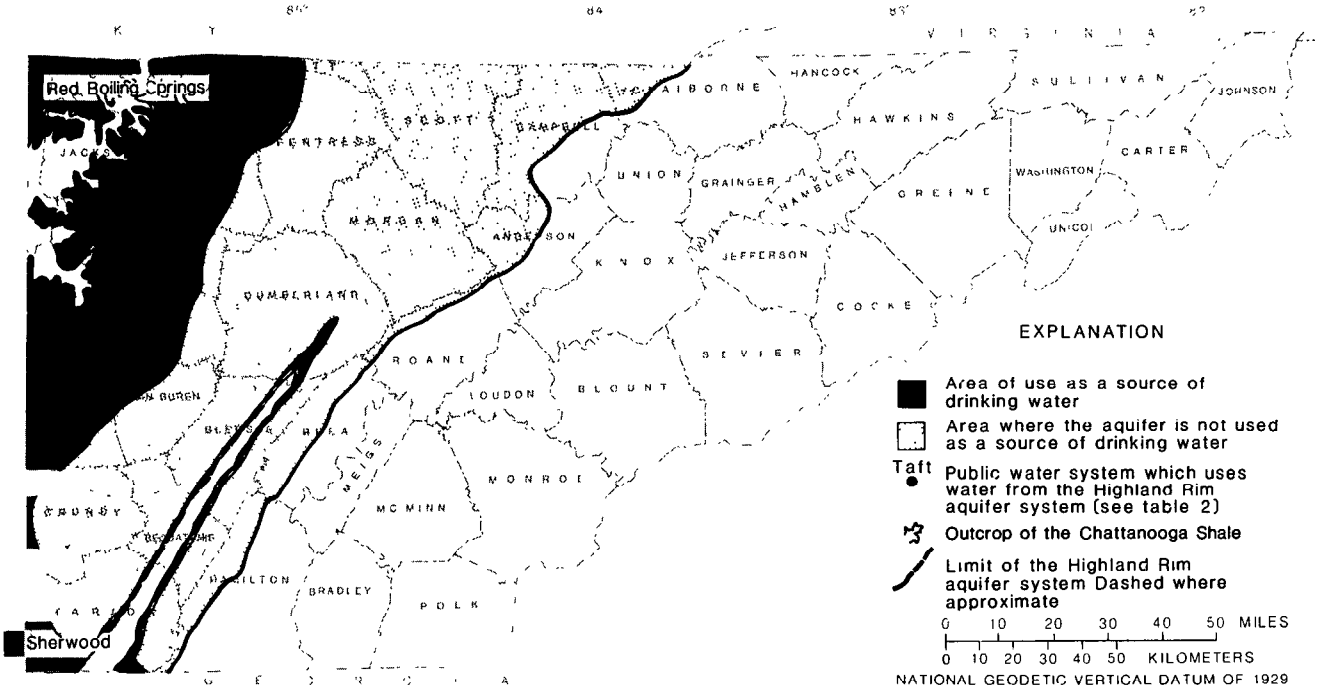


Figure 3.--Areas where the Highland Rim aquifer system is used



as a source of drinking water.

Table 3.--Dissolved-solids concentrations of water from selected wells and springs in the Highland Rim aquifer system

[Data sources: 1, Piper (1932); 2, Smith (1962); 3, Theis (1936); 4, Rima and Goddard (1979); 5, Wells (1933); 6, Unpublished USGS files; 7, Newcome and Smith (1958); 8, Marcher, Bingham, and Lounsbury (1964)]

County	Location	Well depth, in feet	Water-bearing formation	Dissolved solids concentrations, in milligrams per liter	Data source
Benton	Faxon	18	Fort Payne	57	5
Bledsoe	Brayton 7 mi W	57	St. Louis	62	7
Cannon	Woodbury 6 mi SE	105	Warsaw	395	2
Cheatham	Ashland City 1.75 mi S	120	Fort Payne	10,688	1
	Ashland City 6 mi NE	105	Fort Payne Warsaw	1,130	2
	Kingston Springs 0.5 mi S	Spring	Fort Payne	401	1
	Neptune 1.75 mi NE	165	St. Louis	274	1
Clay	Moss 1 mi SE	135	Warsaw	231	2
Coffee	Manchester 4 mi N	85	Warsaw	210	2
	Manchester 3 mi NW	97	Fort Payne	57	2
Cumberland	Crab Orchard	160	St. Louis	333	7
Davidson	Joelton 2 mi S	230	Fort Payne	488	2
	Whites Creek 2.75 mi W	Spring	Chattanooga	844	1
	Joelton	238	Fort Payne	282	4
Decatur	Sugartree	20	Fort Payne	42	5
Dekalb	Smithville 3 mi NW	61	Warsaw	86	2
Dickson	Cumberland Fur. 2.5 mi N	140	Fort Payne	742	2
	Dickson	427	St. Louis Warsaw	256	1
	Vanleer 5 mi W	65	Fort Payne	3,195	1
	Burns 8 mi SW	215	Fort Payne	1,620	6
	Dickson 2.75 mi SW	200	Warsaw	135	4,8
	White Bluff 2 mi W	102	Fort Payne	196	4,8
Franklin	Belvidere 1.5 mi N	118	Warsaw	1,212	3
	Belvidere	65	Fort Payne	182	3
	Cowan	Spring	Warsaw	296	3
	Decherd	112	Fort Payne	239	3
	Sherwood	Spring	Warsaw	214	3
	Winchester	Spring	Fort Payne	156	3

Table 3.--Dissolved-solids concentrations of water from selected wells and springs in the Highland Rim aquifer system--Continued

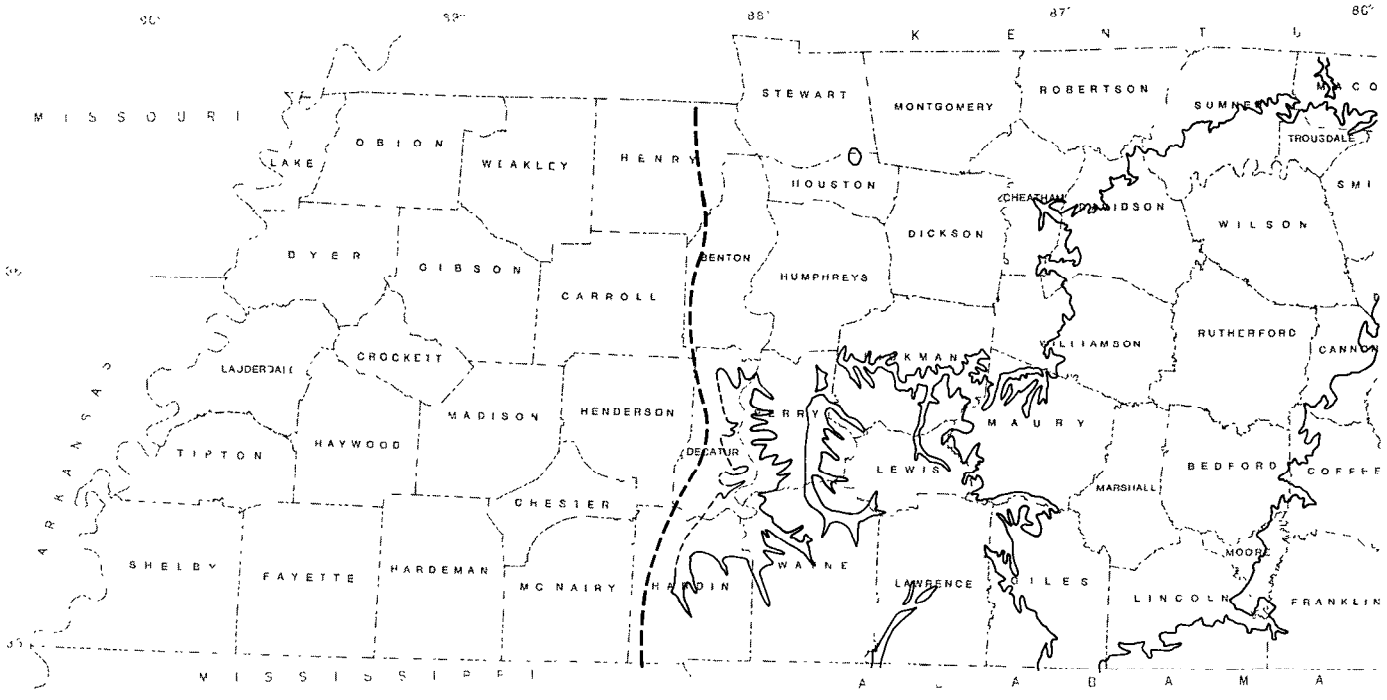
County	Location	Well depth, in feet	Water-bearing formation	Dissolved solids concentrations, in milligrams per liter	Data source
Giles	Ardmore 1.5 mi NE	Spring	Fort Payne	43	3
Hardin	Olive Hill	30	Fort Payne	74	5
Hickman	Aetna 6 mi W	Spring	Fort Payne	198	3
	Bon Aqua 0.5 mi SE	Spring	Fort Payne	841	3
	Nunnelly 2 mi W	Spring	Fort Payne	156	3
	Wrigley 2.5 mi S	212	Fort Payne	144	2
	Wrigley 7 mi NE	130	Warsaw	184	2
Houston	Erin 9.25 mi SE	64	Fort Payne	226	1
	Erin 6.5 mi SW	160	Fort Payne	172	1
	Erin 0.6 mi W	Spring	St. Louis	186	1
	Stewart 1 mi W	Spring	St. Louis Warsaw	97	1
Humphreys	Bold Spring	Spring	St. Louis	156	1
	Denver 4.75 mi E	Spring	Fort Payne	160	1
	McEwen 0.5 mi NE	217	St. Louis	166	1
	Waverly 6.25 mi N	Spring	St. Louis	140	1
Lawrence	Ethridge 6 mi NE	Spring	St. Louis	57	3
	Iron City	Spring	Fort Payne	75	3
	Iron City	200	Fort Payne	3857	2
	Lawrenceburg 1 mi W	Spring	Fort Payne	70	3
	Lawrenceburg 7 mi N	120	Fort Payne	60	2
Lewis	Hohenwald 2 mi N	Spring	St. Louis	55	3
	Hohenwald 5 mi NW	Spring	Fort Payne	81	3
	Hohenwald 0.5 mi E	97	Fort Payne	34	2
	Hohenwald 2 mi SW	167	Warsaw	35	2
Lincoln	Elora 0.5 mi S	Spring	St. Louis	189	3
	Flintville	80	Fort Payne	42	2
Macon	Layfayette 6 mi NW	87	Fort Payne	62	2
	Layfayette 7 mi SW	137	Fort Payne	108	2
Maury	Santa Fe 3 mi N	80	Fort Payne	95	3
	Theta	Spring	St. Louis	74	3

Table 3.--Dissolved-solids concentrations of water from selected wells and springs in the Highland Rim aquifer system--Continued

County	Location	Well depth, in feet	Water-bearing formation	Dissolved solids concentrations, in milligrams per liter	Data source
Montgomery	Clarksville 10 mi NE	195	Warsaw	326	2
	Clarksville 4.25 mi E	162	St. Louis Warsaw	1948	1
	Clarksville 9 mi SE	140	Fort Payne	2288	2
	Louise 5 mi SE	65	Fort Payne	1238	1
	Woodlawn 5 mi NW	136	St. Louis	262	1
	Oakwood 0.5 mi E	126	St. Louis	235	4
	Southside 1.75 mi E	80	Warsaw	215	4
Overton	Livingston 2 mi N	210	Fort Payne Warsaw	115	2
	Rickman	65	Fort Payne	182	2
Perry	Flatwoods 6 mi NE	Spring	Fort Payne	58	3
	Linden 4 mi S	90	Warsaw	53	2
Pickett	Byrdstown 2 mi SW	100	Fort Payne	208	2
Putnam	Cookville 4 mi NW	105	Fort Payne	595	2
	Goffton 1 mi S	150	Fort Payne	125	2
Robertson	Adams 7 mi S	202	Warsaw	185	2
	Cedar Hill 9.25 mi S	119	St. Louis Warsaw	1158	1
	Orlinda 4.75 mi SW	54	St. Louis	362	1
	Springfield 3 mi W	Spring	St. Louis	146	1
	Springfield 10 mi N	71	St. Louis Warsaw	2101	1
	Springfield 2 mi S	96	Fort Payne	180	2
Stewart	Dover 5.75 mi NW	75	Gravel	198	1
	Dover 6 mi SE	111	Warsaw	198	2
	Indian Mound	55	St. Louis	220	1
	Model 5.5 mi W	Spring	Fort Payne	50	1
	Mulberry Hill 3 mi NE	182	Fort Payne	202	2
Sumner	Portland 2 mi NE	Spring	St. Louis Warsaw	162	1
	Westmoreland 0.5 mi E	65	Fort Payne	214	1
	Westmoreland 5 mi W	100	Fort Payne/ Chattanooga	4502	1
	White House	56	Warsaw	204	2
Warren	McMinnville 1 mi SE	105	Fort Payne	386	2
	McMinnville 3 mi NW	133	Fort Payne	125	2

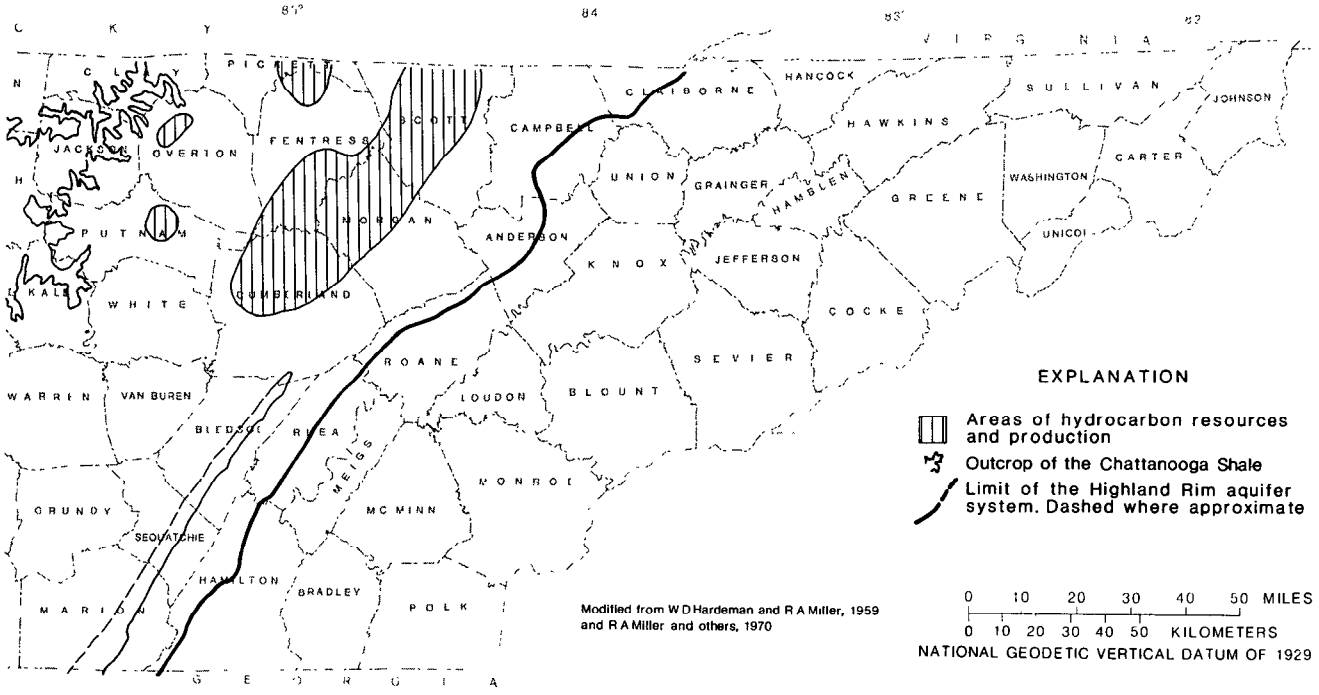
Table 3.--Dissolved-solids concentrations of water from selected wells and springs in the Highland Rim aquifer system--Continued

County	Location	Well depth, in feet	Water-bearing formation	Dissolved solids concentrations, in milligrams per liter	Data source
Wayne	Waynesboro	Spring	Fort Payne	43	3
	Waynesboro 10 mi N	82	Fort Payne	38	2
	Waynesboro 10 mi NE	122	Warsaw	24	2
	Westpoint 7 mi NW	Spring	Fort Payne	104	3
White	Cassville 3 mi W	82	Fort Payne	215	2
	Spring Hill 3 mi SW	140	Warsaw	185	2
Williamson	Boston 6.25 mi N	Spring	Fort Payne	168	1
	Boston 2.25 mi W	54	St. Louis	77	1
	Fairview	206	Fort Payne	946	6

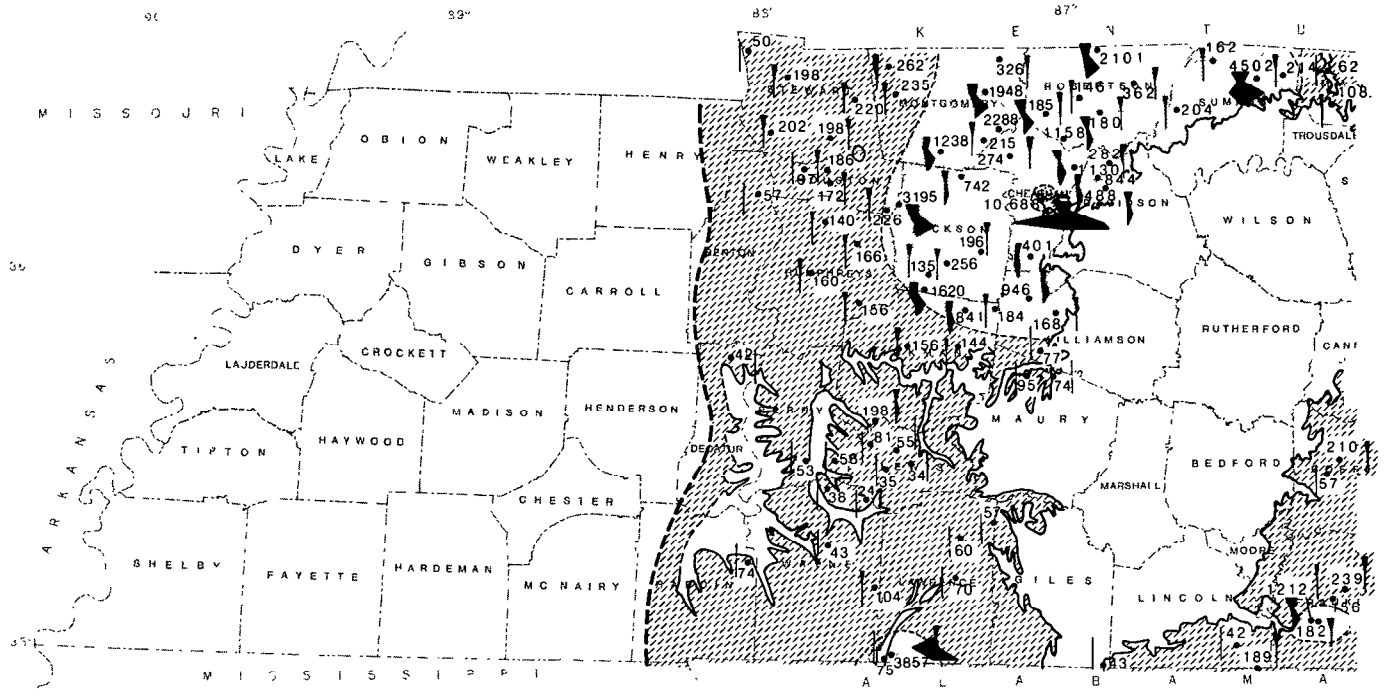


Base from U.S. Geological Survey State Base Map 1:500,000 1967 Revised 1973

Figure 4.--Hydrocarbon resources of the Highland

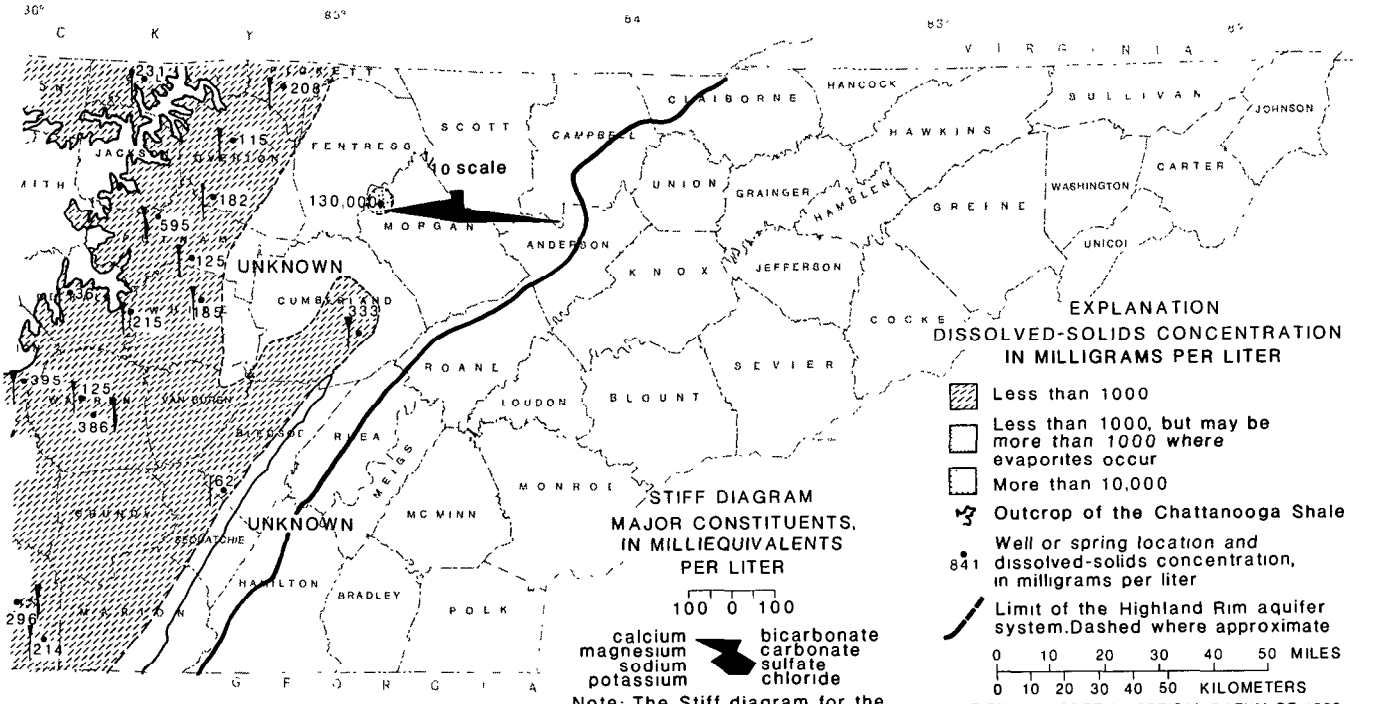


Rim aquifer system.



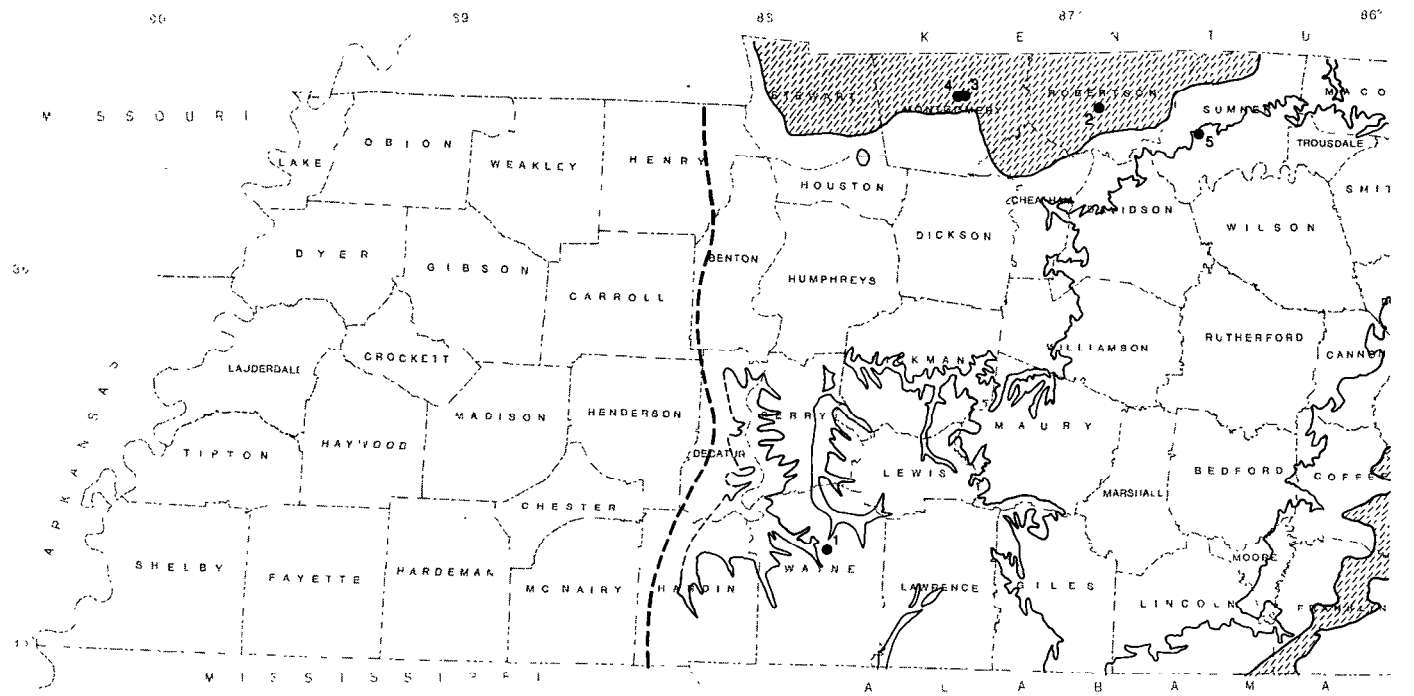
Base from U.S. Geological Survey
State base, 1:1,000,000, 1957
revised 1973

Figure 5.--Dissolved-solids concentrations and water type



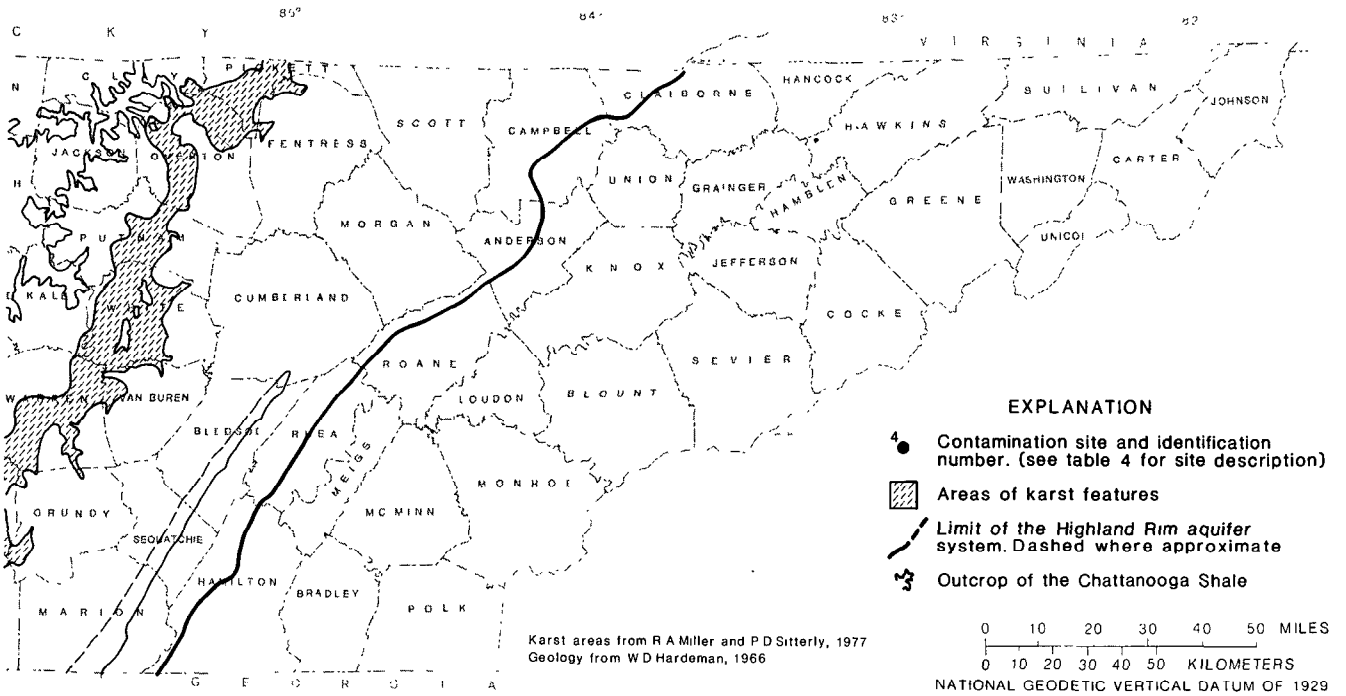
in the Highland Rim aquifer system

Note: The Stiff diagram for the Morgan County well is at one-tenth scale.



Base from U.S. Geological Survey State Base Map, 1:500,000, 1967, revised 1973

Figure 6.--Contamination sites and karst areas in the Highland



Rim aquifer system.

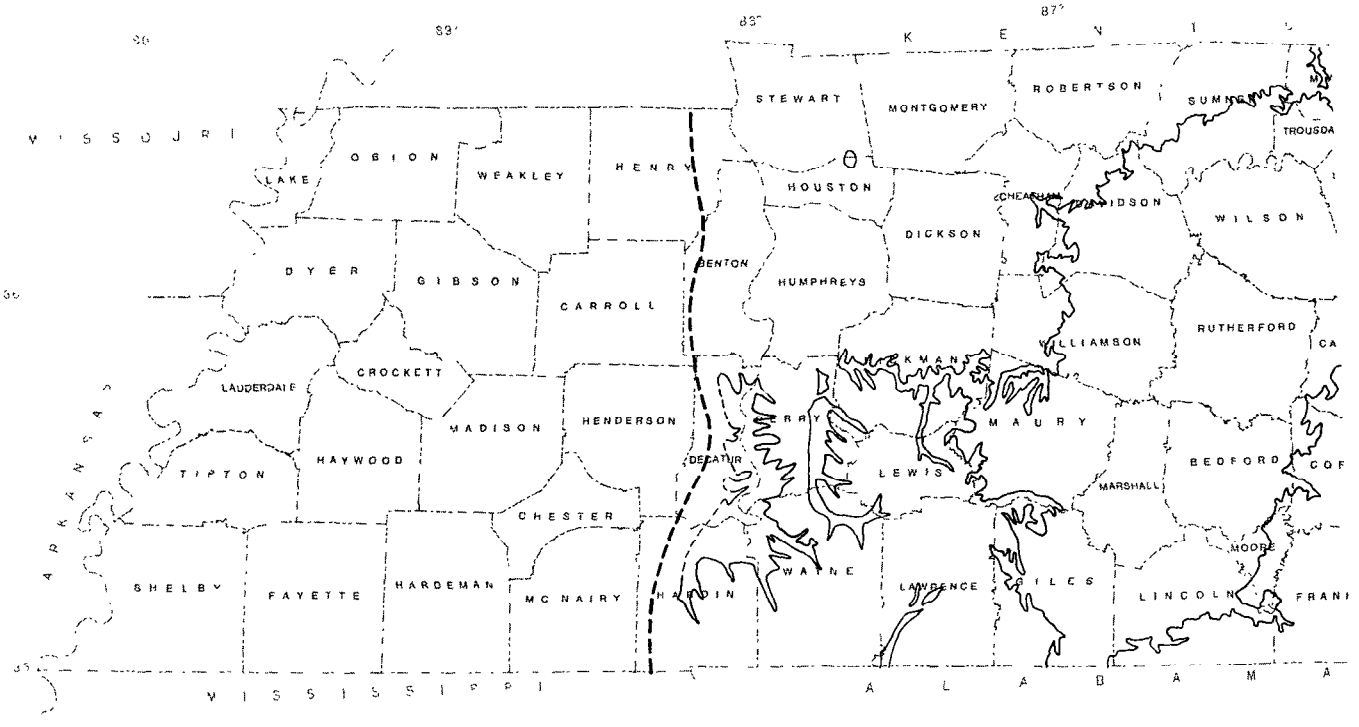
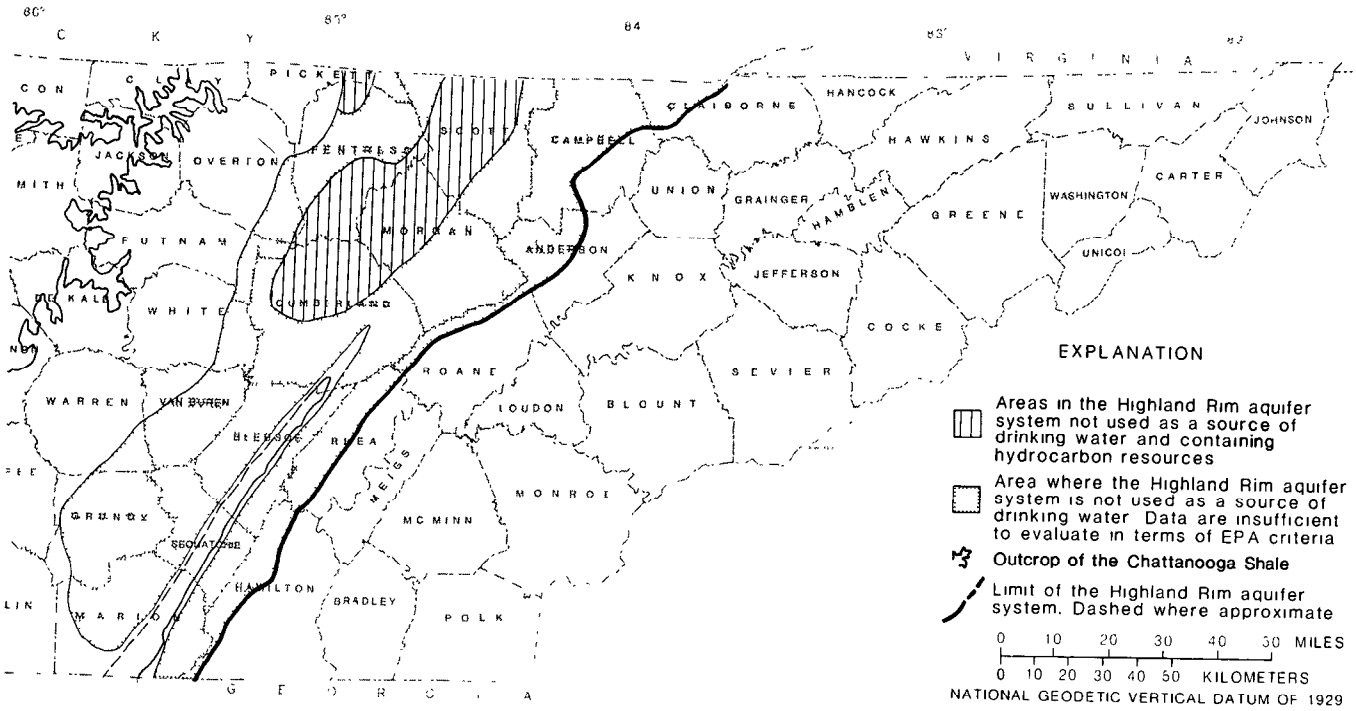


Figure 7.--Areas in the Highland Rim aquifer system that meet EPA criteria for exemption



and may be used for receiving injected waste.

Table 4.--Contamination sites in the Highland Rim aquifer system

Site identification No.	Location	Type of contamination	Data source	Stratigraphic interval contamination	Comments
1	Waynesboro City Dump, Wayne Co.	Open dump	Residual Waste Study, Tennessee Department of Health and Environment.	Fort Payne Formation	In 1970-1972 waste capacitors and rags containing polychlorinated biphenyls were deposited. Impact on ground water unknown, remedial action taken to clean up the area.
2	Springfield, Robertson County	Industrial wastes	Unpublished data, Tennessee Department of Health and Environment.	St. Louis Limestone	Sulphuric acid and alum dumped into a depression appeared in a spring 1/2 mile away.
3	Clarksville, Montgomery County	Industrial wastes	do	St. Louis Limestone	Heavy metals dumped into a sinkhole emerged at a spring.
4	Clarksville Montgomery County	Waste petroleum	do	St. Louis Limestone	Petroleum products were used to wash out asphalt trucks. The waste was dumped into a sinkhole and appeared at a spring about 1/2 mile away.
5	Landfill Sumner County	Open dump	Unpublished data, Tennessee Division of Solid Waste Management.	Fort Payne Formation	Large amounts of iron, manganese, zinc, and chloride have appeared in nearby springs. Organics including chloroethanes, methylene chloride, and toluene have also been detected.

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