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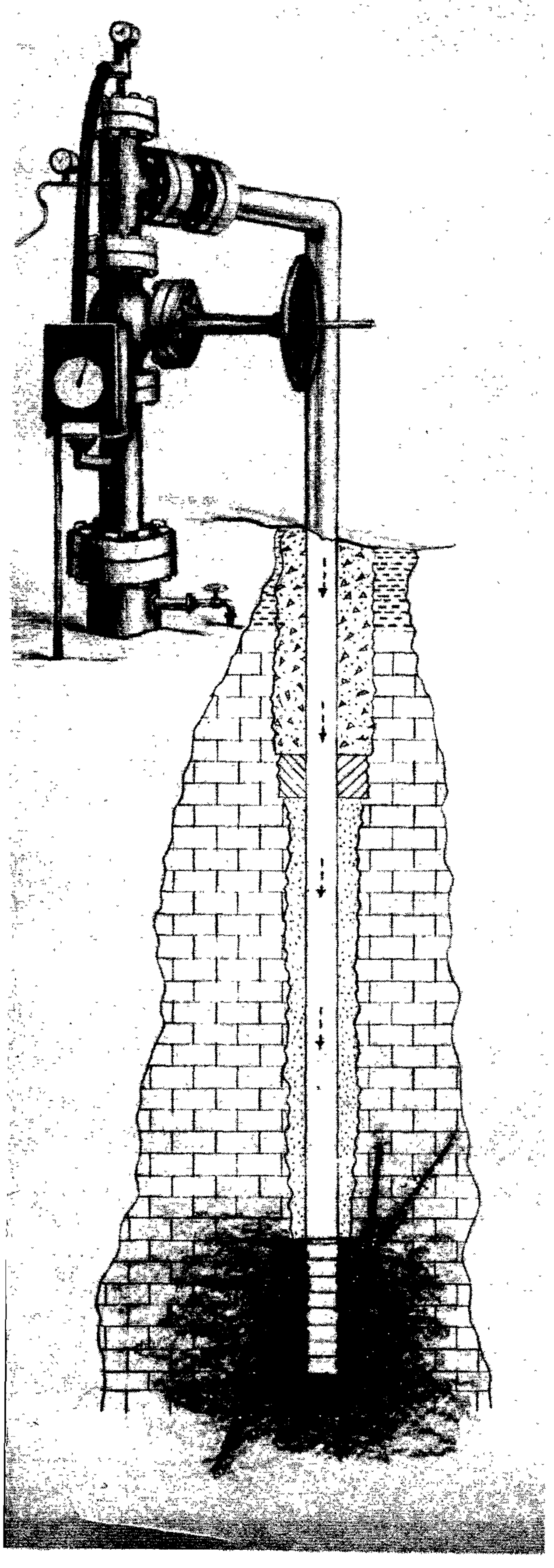

PRELIMINARY EVALUATION OF THE KNOX GROUP IN TENNESSEE FOR RECEIVING INJECTED WASTES

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

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Michael W. Bradley

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Nashville, Tennessee

1986

UNITED STATES DEPARTMENT OF THE INTERIOR

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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)	1.609	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."

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ABSTRACT

The U.S. Environmental Protection Agency is authorized under the Safe Drinking Water Act to protect underground sources of drinking water from contamination. However, an aquifer may be exempted from protection and used for injected wastes where the aquifer meets criteria established in the U.S. Environmental Protection Agency's Underground Injection Control program.

The Knox Group in Middle and West Tennessee occurs primarily in the subsurface, and the top of the Knox Group ranges from about 350 to 3,000 feet below land surface. The upper part of the Knox Group (upper Knox aquifer) is an important source of drinking water in parts of the Central Basin and the Highland Rim provinces. The lower part of the Knox Group is currently being used for injected wastes at New Johnsonville on the western Highland Rim and at Mount Pleasant in the Central Basin.

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 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 existing or potential drinking-water sources and to identify the aquifers or parts of aquifers that are not and will not be used as sources of drinking water.

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. The EPA, however, may exempt an aquifer or part of an aquifer and allow the injection of wastes into the 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 and less than 10,000 milligrams per liter (mg/L) and it is not reasonably expected to supply a public water system.

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

There were no class III well mining areas in Tennessee in 1983.

Under current technology and present economic conditions, it will be considered economically or technologically impractical to recover drinking water from an aquifer that contains water of inferior quality to existing, alternate sources of drinking water, and the aquifer lies below a source of drinking water that is adequate to supply present and future needs. A dissolved-solids concentration of 10,000 mg/L will be considered 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.

The Tennessee Department of Public Health (1982) has proposed regulations to prohibit the injection of wastes into the ground-water system in parts of Tennessee. These regulations state that waste injection will not be permitted into the rocks underlying unconsolidated sediments in the Coastal Plain of West Tennessee.

Purpose and Scope

The purpose of this report is to provide a preliminary geohydrologic evaluation of the Knox Group and to identify areas that meet the criteria for exemption to receive injected wastes under the State and Federal (EPA) Underground Injection Control programs. This study also identifies areas where there are limited or no data to evaluate the aquifer and emphasizes the need for additional data. Generalizations on hydrology and water quality have been made because of limited data.

GEOHYDROLOGY

The Knox Group west of the Valley and Ridge province occurs in the subsurface through most of Tennessee (fig. 1). The Knox Group consists of a sequence of Lower Ordovician and Upper Cambrian dolomite and dolomitic limestone approximately 3,000 to 5,000 feet thick. The Knox Group crops out in the Wells Creek structure in the northwestern Highland Rim and in the Sequatchie Valley. The Knox Group overlies the Conasauga Group and is unconformably overlain by limestone of the Central Basin aquifer system and Cretaceous sediments in West Tennessee (fig. 2). Depth to the top of the Knox Group below land surface ranges from about 350 feet in the Central Basin to more than 2,000 feet in West Tennessee and more than 3,000 feet in the Cumberland Plateau. Structurally, the Knox Group dips away from the Central Basin in all directions.

The rocks of the Knox Group are generally impermeable except for zones of secondary permeability such as solution openings and vertical fractures. For the purpose of this report, the Knox Group has been separated into the upper 200 to 300 feet of the Knox Group, which hereafter will be referred to as the upper Knox aquifer, and the remaining several thousand feet of the Knox Group (fig. 2; table 1), which hereafter will be referred to as the lower part of the Knox Group. Nearly all of the data available for the Knox Group is for the upper Knox aquifer. Data for the lower part of the Knox Group is limited to a few waste-injection wells and deep oil test wells. The available data are not sufficient to areally define the hydrologic nature of the lower part of the Knox Group.

Ground water in the upper Knox aquifer is under confined conditions, except in the outcrop areas. Regional ground-water flow in the upper Knox aquifer is primarily toward the west, with discharge occurring along the Tennessee River. In the Central Basin, recharge to the upper Knox aquifer appears to come from areas that are topographic highs, and discharge from the aquifer may occur along the Cumberland, Stones, and Duck Rivers (Newcome and Smith, 1962). The vertical movement of water into and out of the upper Knox aquifer probably occurs along vertical fractures in the overlying formations. In Middle Tennessee, drillers report that more than 90 percent of the wells completed in the upper Knox aquifer yield 5 to 10 gal/min. Below the upper Knox aquifer, the Knox Group is saturated but has much lower permeability.

The hydrology of the lower part of the Knox Group and the amount of vertical flow between the upper and lower Knox along joints and fractures are unknown. Neutron porosity logs and porosity analyses indicate that the lower part of the Knox Group generally has less than 10 percent porosity. However, there are thin zones of high porosity (20 to 25 percent) at depths of more than 2,000 feet below the top of the Knox Group.

APPLICATION OF CRITERIA FOR RECEIVING INJECTED WASTES

Drinking-Water Use

The upper Knox aquifer, which generally contains water having dissolved-solids concentrations less than 10,000 mg/L, is used as a source of drinking water in the Central Basin province and the Sequatchie Valley (figs. 2 and 3). In the western Highland Rim province, the upper Knox aquifer is only slightly used as a source of drinking water for domestic supplies (fig. 3). While the upper Knox aquifer is an important source of drinking water where the overlying formations do not yield enough water for domestic supplies, no public supplies currently use water from the upper Knox aquifer. The lower part of the Knox Group is not used as a source of drinking water because of the depth and availability of generally better quality water in the overlying formations.

Mineral and Hydrocarbon Resources

The rocks of the Knox Group are currently being mined for zinc at the Elmwood Mine in Smith County, Tenn. (fig. 4). The zinc ore was deposited along zones of increased permeability that were formed by dissolution in the Knox Group (Fischer, 1977). Ground water in the Knox Group at this site occurs along zones of increased permeability similar to those which allowed the movement of the ore-bearing solution.

The Knox Group is being investigated for hydrocarbon resources in the Coffee, Franklin, and Lincoln County area of the southeastern Highland Rim province and has yielded some hydrocarbons in that area (fig. 4). The potential for hydrocarbon resources in the Knox Group has not been extensively investigated beneath the Cumberland Plateau.

Water Quality

Quality of water is believed to vary considerably throughout the 3,000- to 5,000-foot thickness of the Knox Group. Most of the ground-water-quality data available, however, are from the upper Knox aquifer. Concentrations of dissolved solids in water from the upper Knox aquifer are generally less than 1,000 mg/L in the Central Basin and less than 3,000 mg/L in the western Highland Rim (table 2; fig. 5). The dissolved-solids concentration in water from the upper Knox aquifer increases away from the Central Basin to more than 4,000 mg/L in the northeast Coastal Plain and extreme northern Central Basin and to more than 10,000 mg/L in parts of the northern and eastern Highland Rim (fig. 5).

The quality of water in the upper Knox aquifer in the Cumberland Plateau and northwestern Highland Rim is unknown (fig. 5). Dissolved-solids concentrations greater than 3,000 mg/L may be present in water in the upper Knox aquifer, estimated from resistivity logs, but additional information is needed for verification.

Table 3 lists major cations and anions in water from nine wells open to the upper Knox aquifer. Dissolved-solids concentrations were less than 1,000 mg/L in water from the upper Knox aquifer in Maury County in the Central Basin and Cheatham and Hickman Counties in the western Highland Rim. In Henry County in the northeastern part of the Coastal Plain, water from a well open to the upper Knox aquifer contained 4,320 mg/L dissolved solids and had relatively high sodium and chloride concentrations. Dissolved-solids concentrations were 9,990 mg/L in water from a well in Lincoln County in the eastern Highland Rim.

The quality of water in the lower part of the Knox Group is defined by only four sites. These data show that dissolved-solids concentrations in water from the lower part of the Knox Group range from 1,100 to 16,600 mg/L, depending upon depth and location (table 4). However, some of these data may be questionable because of drilling and sampling techniques, and may not represent the natural formation fluid. Because of the limited data, ground-water quality for the lower Knox Group is essentially unknown.

Contamination

There is no known contamination of the upper Knox aquifer. In Tennessee, contamination of the lower part of the Knox Group is known at three waste-injection well sites (table 5). The injection wells at these sites are open from the lower part of the Knox Group to the Precambrian basement. Ground-water-quality data from observation wells penetrating the upper Knox aquifer at the injection sites in Maury County (see My:F-11 and My:F-13 in table 3) did not show high concentrations of sodium or chloride that would be associated with the primarily sodium-chloride wastes at those sites.

AREAS POTENTIALLY SUITABLE FOR WASTE INJECTION

In the southeastern Highland Rim province, the upper Knox aquifer is not currently used as a source of drinking water and is not expected to be used because it has produced hydrocarbons (fig. 6). Although this area meets some of the EPA criteria for exemption, the Tennessee Department of Public Health and Environment has proposed regulations to prohibit the subsurface injection of wastes into aquifers that contain extractable energy-related resources.

The upper Knox aquifer in the northern and eastern Highland Rim (fig. 6) currently is not used and probably will not be used as a source of drinking water because of the high dissolved-solids concentrations (more than 10,000 mg/L). The upper Knox aquifer in the northern part of the Coastal Plain and the extreme northern part of the Central Basin (fig. 6) is not used as a source of drinking water and is not expected to supply a public water system. Dissolved-solids concentrations range from 3,000 to 10,000 mg/L in the upper Knox aquifer in these areas. The Tennessee Department of Public Health (1982) proposed regulations, however, would prevent the underground injection of wastes west of the Tennessee River.

The upper Knox aquifer in parts of the Highland Rim and Cumberland Plateau may contain water having dissolved-solids concentrations more than 3,000 mg/L or, in some places, more than 10,000 mg/L (fig. 6). Additional data are needed to define the water quality and hydrology of the upper Knox aquifer in these areas.

In Tennessee, the lower part of the Knox Group currently is not used as a source of drinking water and is not expected to be used in the future because of the depth, the uncertainty about yield and water quality, and the availability of water from overlying aquifers and surface-water sources. The general water quality of the lower part of the Knox Group, however, is essentially unknown. Parts of the lower part of the Knox are already contaminated at the three waste-injection sites in Tennessee (fig. 6).

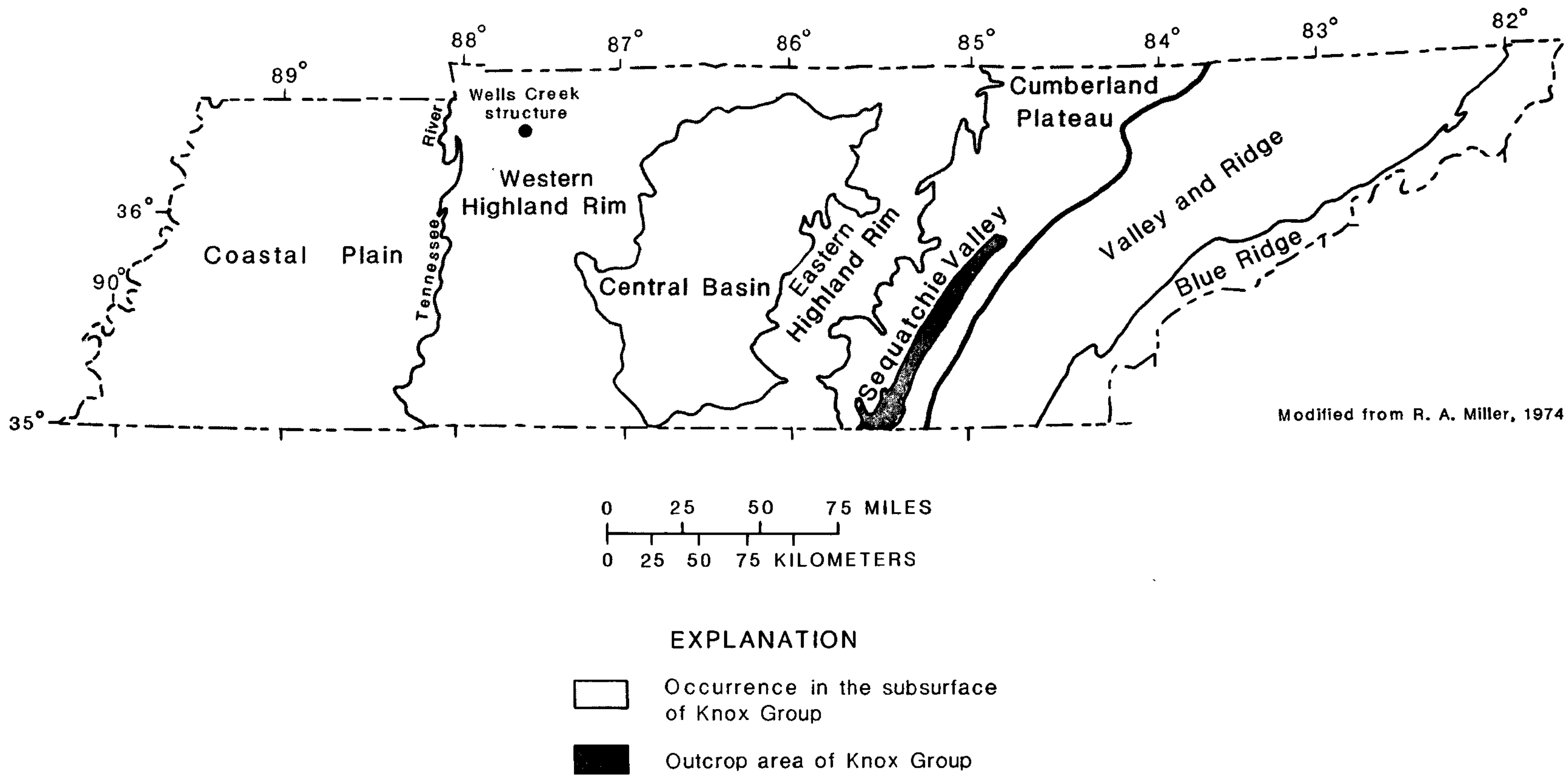
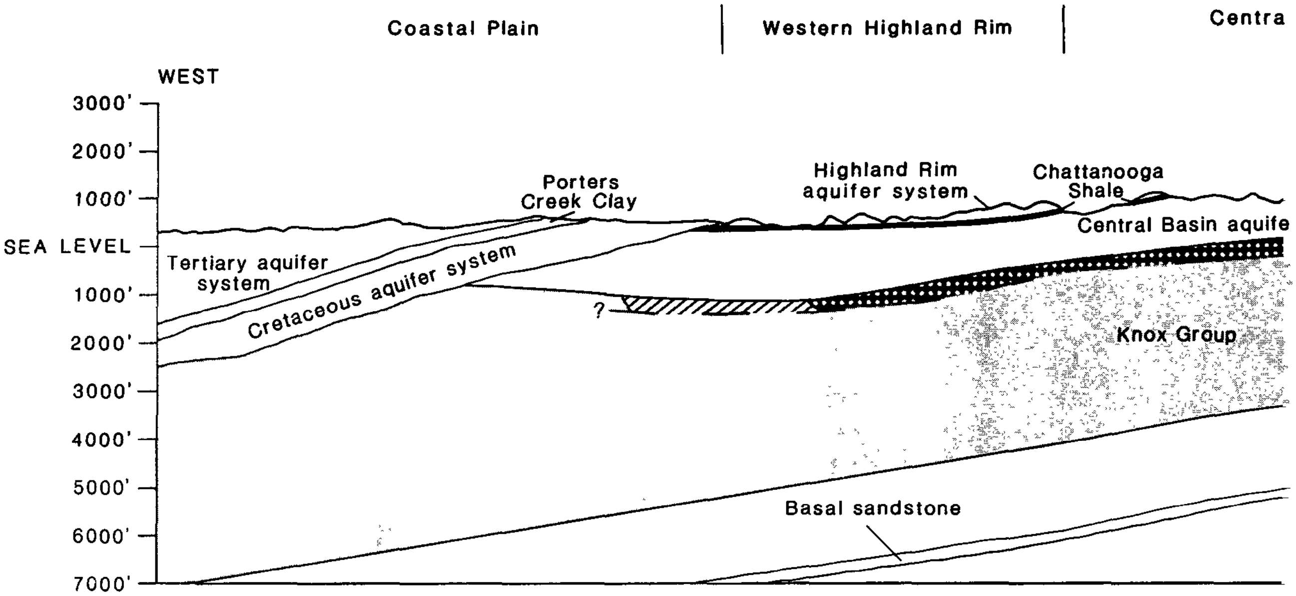


Figure 1.--Physiographic provinces and areal extent of the Knox Group in Middle and West Tennessee.

Table 1.--Geologic units of the Knox Group

[Modified from Miller, R.A. (1974); Schwalb, H.R. (1982)]

System	Series	Group	Formations	Hydrology
Ordovician	Lower Ordovician	Knox Group	Mascot Dolomite Kingsport Formation Longview Dolomite Chepultepec Dolomite	The upper Knox aquifer, the upper 200 to 300 feet of the Knox Group contains water in zones of secondary permeability. Consists of dolomite and dolomitic limestone. The lower part of the Knox Group, the remaining several thousand feet of the Knox Group, consists of dolomite and dolomitic limestone with some thin zones of higher porosity separated by thick sequences of rock with very low porosity. The type of boundary between the upper Knox aquifer and lower part of the Knox Group is essentially unknown.
Cambrian	Upper Cambrian		Copper Ridge Dolomite	



EXPLANATION

WATER QUALITY AND USE

Dissolved-solids concentrations are less than 1000 milligrams per liter. Knox Group may be used as a source of drinking water

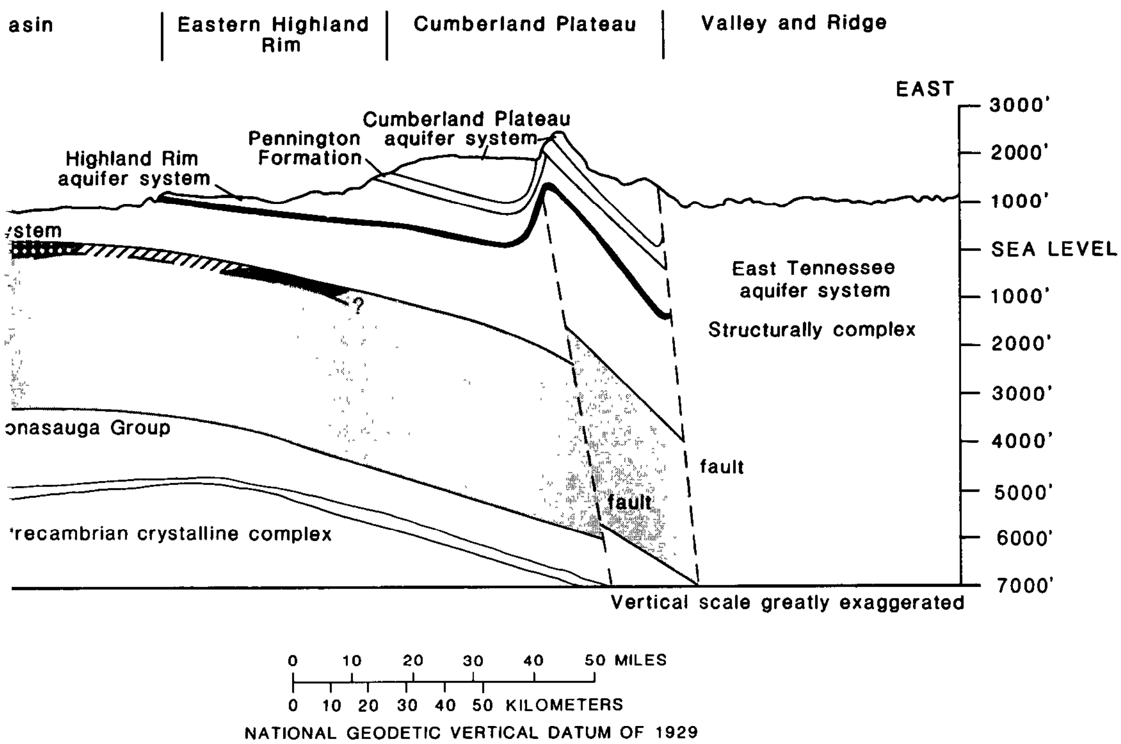
Dissolved-solids concentrations are more than 10,000 milligrams per liter. Knox Group is not used as a source of drinking water

Dissolved-solids concentrations are 1000 to 10,000 milligrams per liter

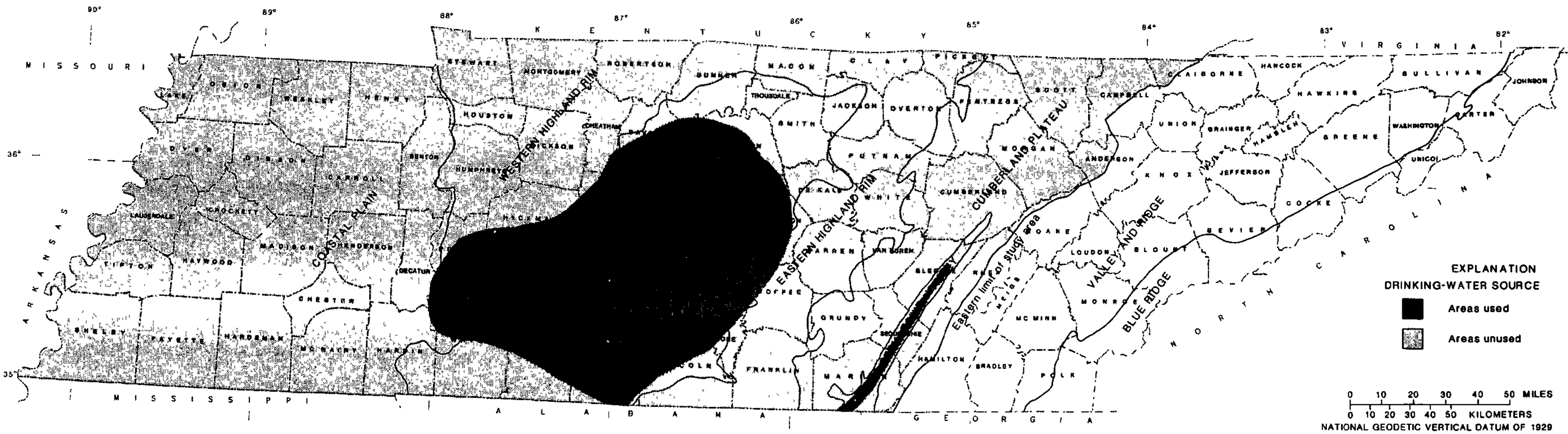
Very few data, water quality is unknown. Dissolved-solids concentrations are estimated to be more than 1000 milligrams per liter and may be more than 10,000 milligrams per liter. Knox Group is not used as a source of drinking water

?—— ——? Conceptual boundary between the upper Knox aquifer and lower part of the Knox Group. Exact location and nature are unknown

Figure 2.--Generalized hydrogeologic section of the Knox

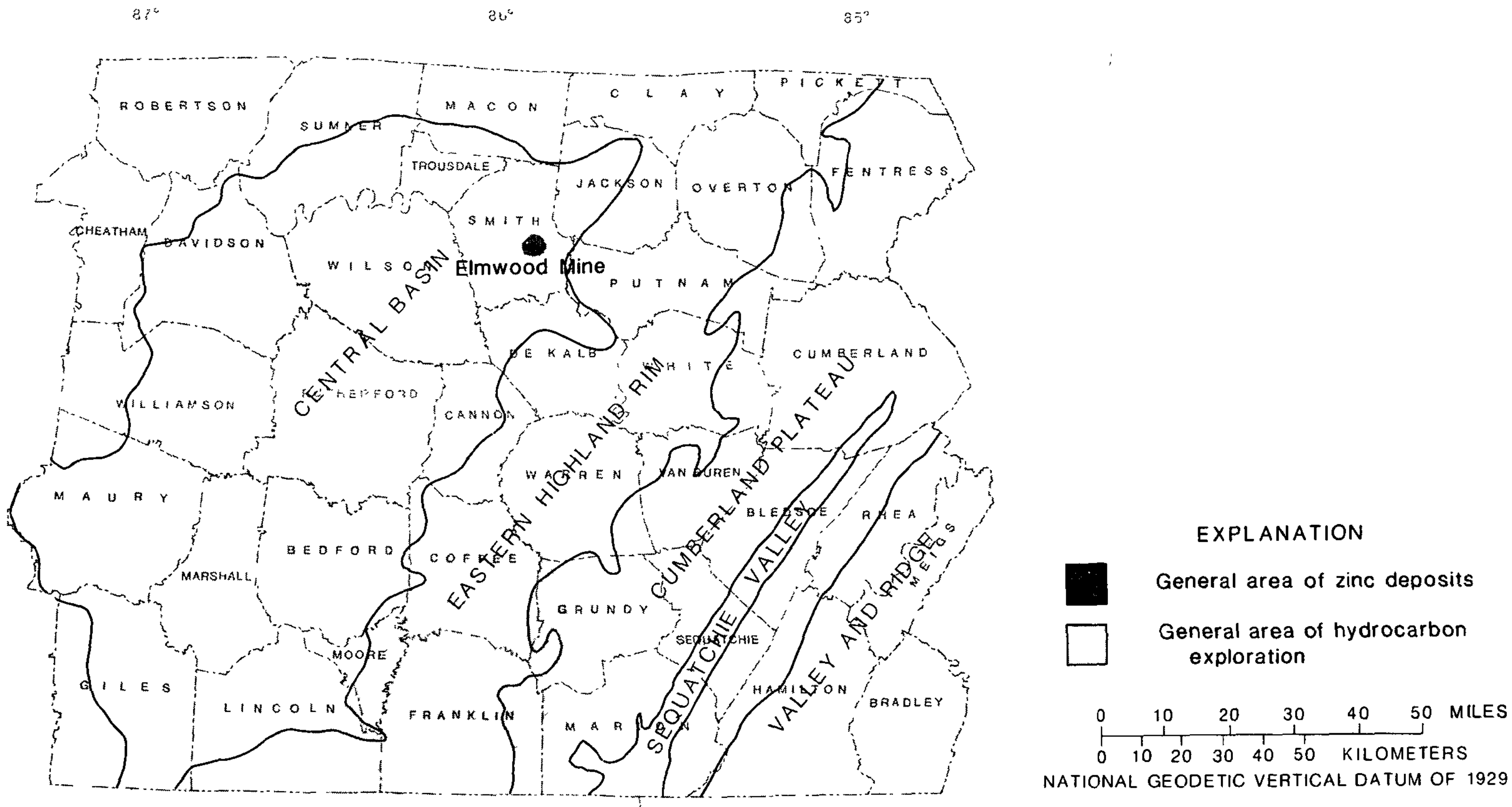


Group showing water quality and use.



From J V Brahana and M W Bradley, 1985

Figure 3.--Areas where the upper Knox aquifer is used for drinking water.



From J. V Brahana and M W. Bradley, 1985

Figure 4.--Hydrocarbon resources and zinc mining in the Knox Group.

Table 2.--Dissolved-solids concentrations in water from selected wells in the upper Knox aquifer

[A, Estimate based on calculation from concentration of major constituents; C, Estimate based on average of more than one analysis. Data sources: 1, Newcome and Smith (1962); 2, Tennessee Division of Water Resources, unpublished records; 3, Tennessee Division of Geology, unpublished records; 4, Tennessee Division of Water Quality Control; 5, U.S. Geological Survey, unpublished records; 6, Newcome (1958); 7, Fischer and Hoagland (1970)]

County	Location	Depth to the top of the Knox Group, in feet	Well or sample depth, in feet	Dissolved-solids concentrations, in milligrams per liter	Data source
Bedford	Farmington 3 mi E	718	746	610	1
	Shelbyville 0.5 mi N	795	858	602	1
	Wheel	780	817	428	1
	Unionville 1.75 mi NW	668	694	2,450 C	1
Cannon	Woodbury 8.5 mi SW	744	1005	1,100 C	1
Davidson	Nashville 6 mi N	1050	1095	2,620	5
	Forest Hills	1010	1110	1,003	1
	Nashville	1135	1149	2,064	1
	Old Hickory 3 mi SW	980	1057	6,552	1
	Brentwood 2.5 mi W	1042	1300	524	1
	Bellevue 3 mi W	1352	1600	570 C	1
	Madison	1060	1095	3,248	1
	LaVergne 1.5 mi NW	730	937	576	6
	Nashville	794	859	2,350	6
DeKalb	Alexandria	746	1385	1,100 C	1
Dickson	White Bluff 1 mi NE	1414	1551	1,450 C	1
Gibson	Dyer 3.4 mi NW	2220	2309-4450	4,500 C	3
Giles	Good Spring	---	705	1,416	5
	Lynnville	860	1084	1,257	1
	Ardmore 3 mi NW	918	957	468	1
	Pulaski 3.5 mi W	860	874	270	1
	Pulaski	882	931	720	1
	Campbellsville	796	1000	1,159	1
Humphreys	New Johnsonville	1620	1980-2196	1,250	2,3,4
		1662	1584-1690	1,496	2,3,4
Jackson	Gainesboro 9 mi W	930	1465	4,520	6
	Gainesboro 6 mi ESE	957	1034	14,898	1
Lincoln	Ardmore 3 mi NE	1040	1050	16,170	1

Table 2.--Dissolved-solids concentrations in water from selected wells in the upper Knox aquifer--Continued

County	Location	Depth to the top of the Knox Group, in feet	Well or sample depth, in feet	Dissolved-solids concentrations, in milligrams per liter	Data source
Marshall	Cornersville	---	940	3,002	5
	Lewisburg 4.75 mi WNW	805	830	1,060	1,6
	Verona 3 mi NE	562	595	960 C	1
	Lewisburg	780	835	750 C	1
	Caney Spring 2 mi NE	774	788	507	1
Maury	Columbia 4.5 mi SW	870	922	685	1
	Spring Hill 0.5 mi SE	880	970	302	1
	Culleoko 3.5 mi E	739	800	1,619	1
	Berlin 4.25 mi NW	508	545	627	1
	Jameson 1.5 mi SW	956	1047	1,550 C	1
	Columbia 4 mi NE	959	990	990 C	1
Perry	Beardstown 1.5 mi SW	1295	1625	860 C	1
	Linden	---	1320	2,762	1
Pickett	Byrdstown 4.5 mi NE	1800	2101	20,383	1
Rutherford	Lascassas 1 mi NE	444	584	2,314	1
	Smyrna 3.5 mi NE	559	632	2,225	1
	Smyrna 2 mi SE	500	513	432	1
	Double Springs 0.5 mi SE	696	852	1,185	1
	Concord 1.75 mi W	668	760	518	1
	Pinnacle Hill 2.25 mi NE	470	493	300	1
Smith	Elmwood 1 mi W	---	---	4,550 C,A	7
Sumner	Bethpage	1372	1415	18,768	1
	Saundersville 2 mi N	986	1133	6,577	1,6
Trousdale	Hartsville 5 mi SW	859	1300	2,530	1
Wayne	Clifton 3 mi NE	895	1125	804	1
	Waynesboro 6 mi SE	1383	3003	1,551	1
Williamson	Bingham 3 mi N	965	1020	1,440	1,6
	Brentwood 1.5 mi S	940	1002	556	1
	Ewingville 1 mi NE	874	912	1,330	1
	Franklin 1.4 mi W	1305	1338	1,968	1
	Kirkland	856	916	700	1
	Nolensville 2 mi SE	431	1135	1,428	1
	Thompson Sta. 3 mi NE	777	906	545	1
Wilson	Lebanon 2 mi E	665	2003	1,175 C	1
	Green Hill 1 mi W	900	1004	1,632	1

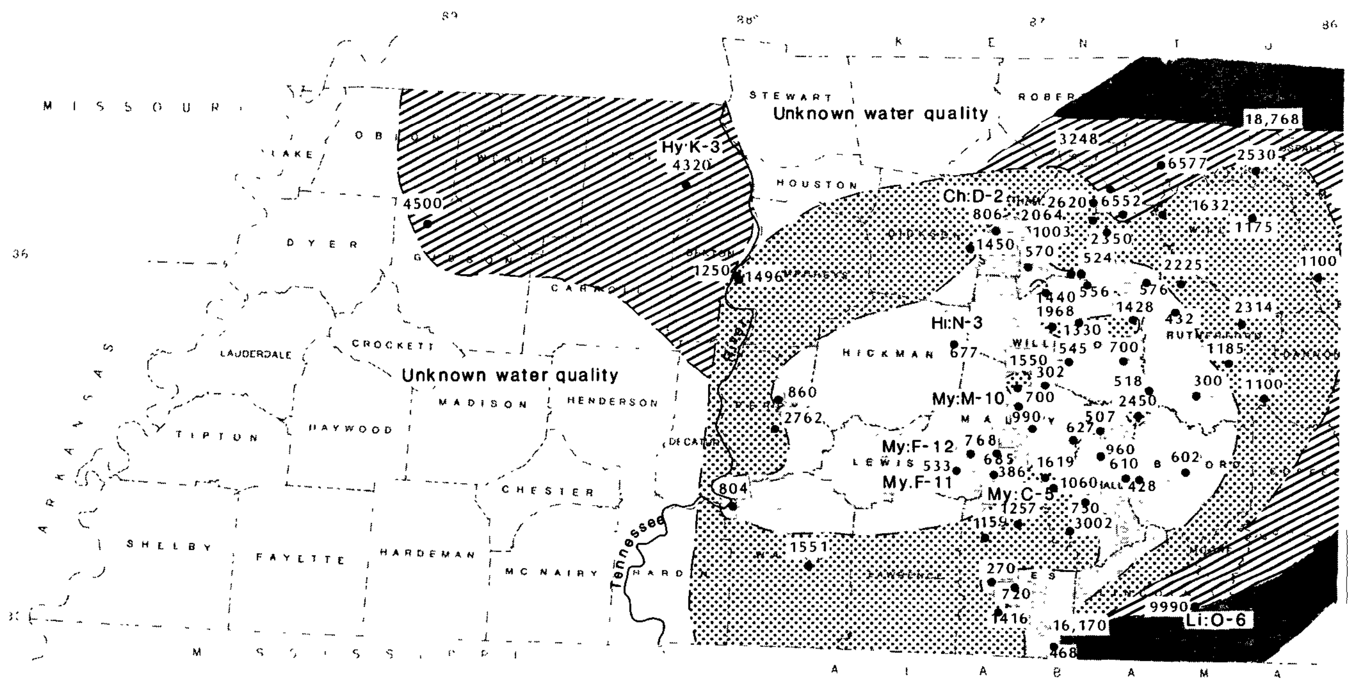
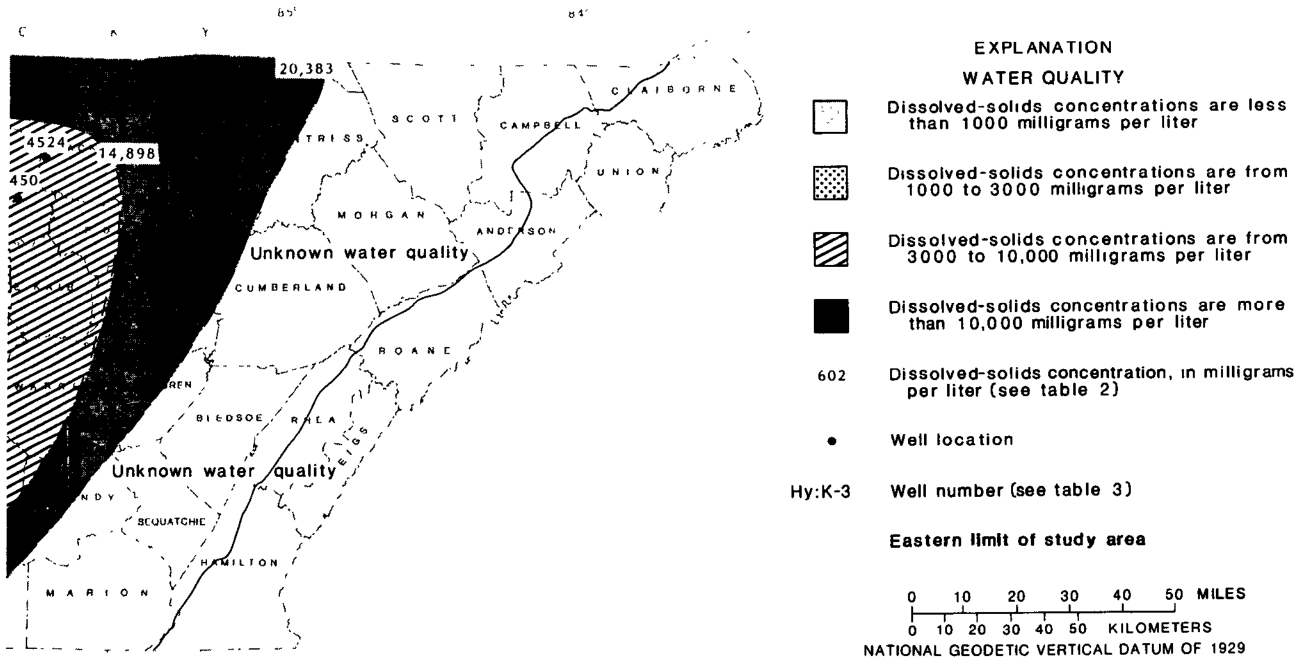


Figure 5.--Dissolved-solids concentrations



Modified from J. V. Brahana and M. W. Bradley, 1985

in water from the upper Knox aquifer.

Table 3.--Quality of ground water from the upper Knox aquifer

[mg/L, milligrams per liter]

Well No.	Latitude	Longitude	Depth (feet)	Date sampled	pH units	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Dissolved solids (mg/L)
								Cheatham County							
Ch:D-2	36°09'05"	87°07'02"	1424	8/30/82	8.0	89	22	8.3	240	11	260	200	120	9.0	806
								Henry County							
Hy:K-3	36°16'49"	88°09'10"	2240	8/23/82	7.2	540	120	58	1500	43	299	570	1900	4.0	4320
								Hickman County							
Hi:N-2	35°50'20"	87°13'25"	1200	11/ 1/82	7.9	260	55	30	110	5.0	150	200	150	8.0	677
								Lincoln County							
Li:O-6	35°07'37"	86°25'09"	1150	10/29/82	7.6	1300	300	140	3000	51	174	1100	4800	6.2	9990
								Maury County							
My:C-5	35°29'56"	87°07'10"	875	8/19/82	7.9	180	36	23	58	8.1	186	120	15	5.4	386
My:F-11	35°30'44"	87°11'45"	2100	8/20/82	8.2	97	23	9.7	150	8.4	231	71	91	8.7	533
My:F-12	35°33'48"	87°09'53"	1100	8/20/82	7.6	180	35	23	190	13	271	200	130	5.7	768
My:F-13	35°31'25"	87°14'31"	2600	12/ 1/82	9.4	24	3.4	3.7	75	6.6	150	10	23	5.4	233
My:M-10	35°40'35"	87°00'59"	905	8/12/82	8.0	120	23	14	200	10	277	200	71	6.9	700

Table 4.--Dissolved-solids concentrations in water from the lower part of the Knox Group

[Data from unpublished files with the Tennessee Division of Geology and Department of Health and Environment]

County	Location	Depth to the top of the Knox Group, in feet	Well or sample depth, in feet	Dissolved-solids concentrations, in milligrams per liter
Davidson	Old Hickory	1070	2806	[a]3,000+
			3287	7,370
			3953-4142	[b]16,600
Humphreys	New Johnsonville	1620	2450-2673	1,440
			3220-3400	3,100
			3538-3628	2,500
			4657-6735	4,280
	New Johnsonville	1662	2695-2880	1,100
			5000-6340	[c]12,860
Maury	Mount Pleasant 1.5 mi SE	910	5064-5079	4,700

[a]Estimate based on calculation from concentration of major constituents.
[b]Estimate based on average of more than one analysis.
[c]Represents influence of intercepted wastes.

Table 5.--Contamination sites in the lower part of the Knox Group

[Data from Tennessee Division of Geology and Tennessee Department of Public Health, open file records]

Site No.	Location	Comments
1	New Johnsonville	Contamination due to injection of industrial waste. The waste is primarily an iron chloride with a pH of less than 1.
2	Mount Pleasant 1.5 mi SE.	Contamination due to injection of industrial waste. The wastewater is primarily a sodium chloride (176,000 million gallons per liter) with a pH of 12.5.
3	Mount Pleasant 1.5 mi SW.	Contamination due to injection of industrial waste. The wastewater is primarily a sodium chloride.

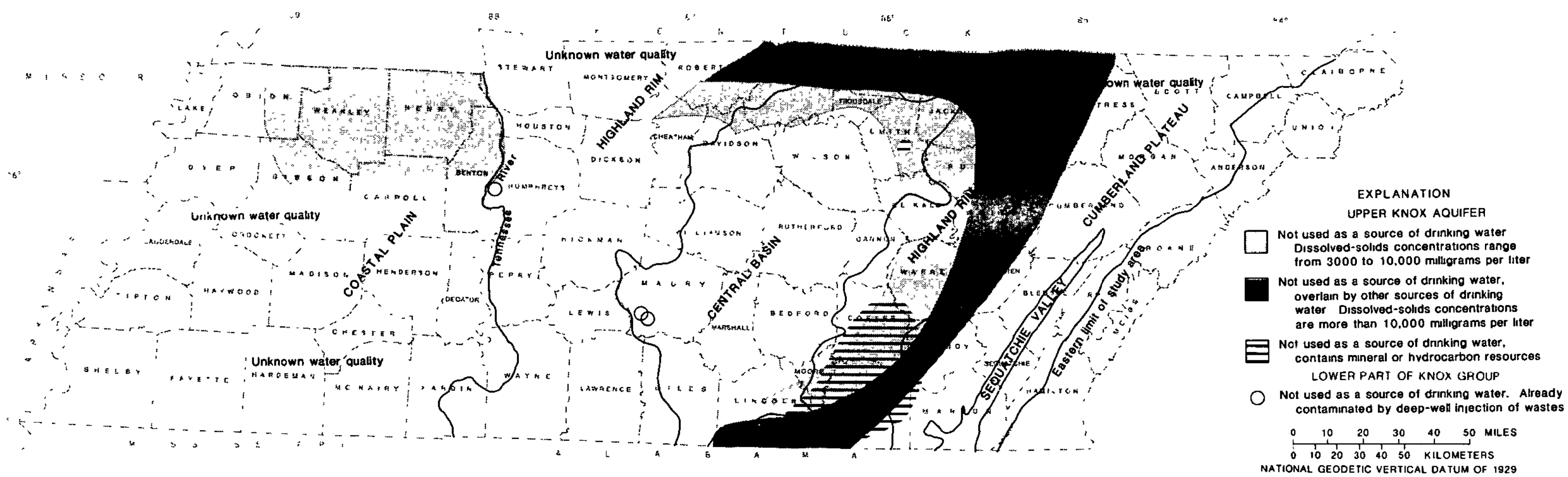


Figure 6.--Areas in the Knox Group that may be used for receiving injected wastes.

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