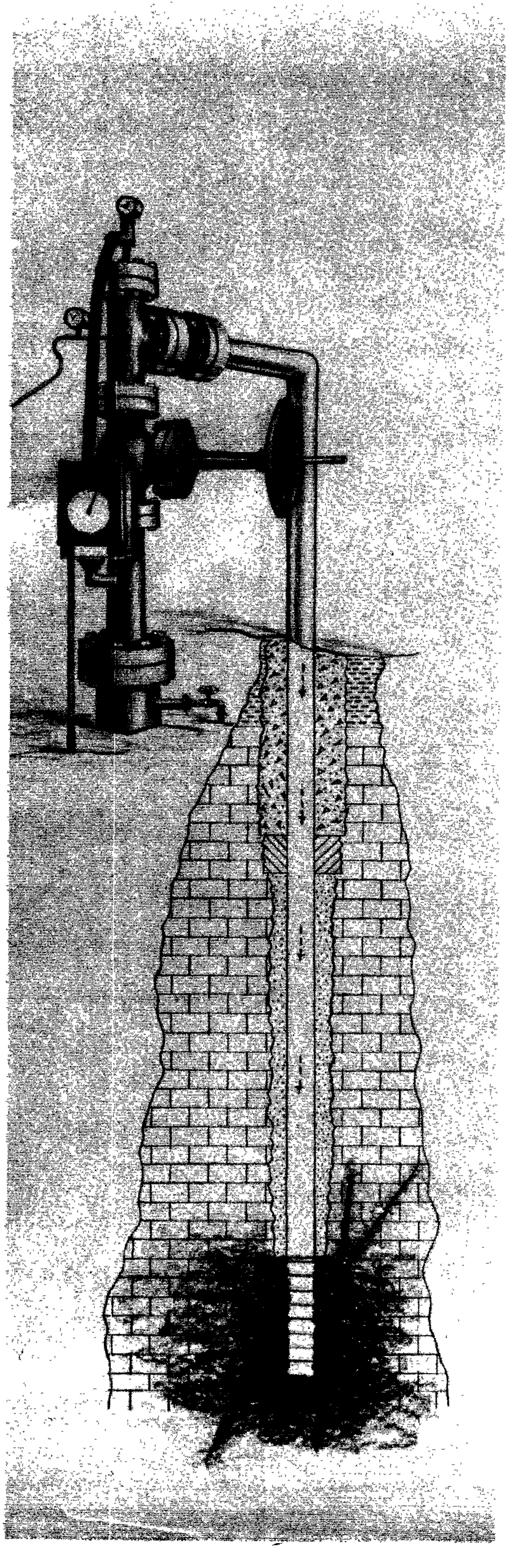
WATER-RESOURCES INVESTIGATIONS REPORT 84-4103



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PRELIMINARY EVALUATION OF THE CENTRAL BASIN 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

U.S. GEOLOGICAL SURVEY

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Nashville, Tennessee
1985

UNITED STATES DEPARTMENT OF THE INTERIOR

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

PRELIMINARY EVALUATION OF THE CENTRAL BASIN AQUIFER SYSTEM IN TENNESSEE FOR RECEIVING INJECTED WASTES

Michael W. Bradley

ABSTRACT

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

The Central Basin aquifer system in Tennessee consists of Ordovician to Devonian carbonate rocks and it occurs from the Valley and Ridge province to west of the Tennessee River. This aquifer system is currently used for drinking water in the Central Basin and western Highland Rim, but is not used for drinking water in the northern Highland Rim nor the Cumberland Plateau provinces.

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 manage underground injection, EPA needs to identify and protect aquifers that are drinking water sources and to identify the aquifers or parts of aquifers which are not used as drinking water sources.

Under part 146.04 of the Federal Underground Injection Control program (EPA, 1981), an underground source of drinking water is protected from receiving injected wastes. The EPA, however, may allow the injection of wastes into an aquifer or part of 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 and less than 10,000 million gallons per liter (mg/L) and it is not reasonably expected to supply a public water system.

There are 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 with all of 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.

The Tennessee Department of Public Health (1982) has proposed regulations to prohibit the injection of wastes in parts of Tennessee. These regulations state that wastes will not be injected through the unconsolidated sediments of West Tennessee. Because of these regulations, this report will deal with the Central Basin aquifer system which is east of the unconsolidated sediments of West Tennessee.

The purpose of this study is to identify any areas in the Central Basin aquifer system that may be allowed to receive injected wastes under the State and Federal (EPA) Underground Injection Control programs. The areal extent of parts of the aquifer system that may be used for waste injection will be delineated in this report. The report also shows areas where there are little or no data to evaluate the aquifer system. Generalizations on hydrology and water quality have been made because of limited data in some areas, and the need for additional data has been emphasized.

HYDROGEOLOGY

The Central Basin aquifer system underlies most of Tennessee west of the Valley and Ridge province (fig. 1). This aquifer system crops out in the Central Basin and parts of the Sequatchie Valley and western Highland Rim. The Central Basin aquifer system occurs in the subsurface in the Cumberland Plateau, most of the Highland Rim, and part of the Coastal Plain in west Tennessee.

The Central Basin aquifer system is composed of Devonian to Ordovician limestones, with some calcareous shales (table 1) that are generally flat lying and dip gently away from the Central Basin. In some areas, these formations have been broken by vertical fractures and faults. In the Highland Rim, the Central Basin aquifer system is separated from the overlying Highland Rim aquifer system by the Chattanooga Shale (fig. 2). In the Cumberland Plateau, the Central Basin and Highland Rim aquifer systems are overlain by the Pennington Formation and by the Cumberland Plateau aquifer system (fig. 2).

Ground water in the Central Basin aquifer system occurs primarily in solution enlarged bedding planes and, to a lesser extent, enlarged joints and faults. The formations of this aquifer system have low intergranular permeability to transmit water. Ground water in the aquifer system is unconfined in the Central Basin and the Sequatchie Valley (figs. 1 and 2). Groundwater flow is from outcrop areas (areas of recharge) to nearby discharge points at springs, along streams, and to wells. As a result of a more active flow system, the formations in the outcrop areas generally transmit water more readily than other areas of the Central Basin aquifer system. Although most circulation is in the upper 200 feet, some ground water moves downward through fractures and faults to the underlying Knox Group.

Water in the Central Basin aquifer system occurs under confined conditions beneath the Highland Rim and Cumberland Plateau. The upper confining layer is the Chattanooga Shale, a relatively impermeable fissile shale. It hydraulically separates the Central Basin aquifer system from the overlying Highland Rim aquifer system (fig. 2). In places along the Highland Rim escarpment, the Chattanooga Shale is fractured and ground water from the Highland Rim aquifer system may move downward into the Central Basin aquifer system.

The geology and hydrology of the Central Basin aquifer system is described in more detail in the following reports: Piper, 1932; Theis, 1936; Newcome, 1958; Moore and others, 1969; Moore and Wilson, 1972; Zurawski, 1978; and Brahana and Bradley, 1985.

APPLICATION OF CRITERIA

Drinking Water Use

The Central Basin aquifer system is an important source of drinking water throughout the Central Basin, Sequatchie Valley, and parts of the Highland Rim (fig. 3). Many public supply systems in the Central Basin and Sequatchie Valley use water from this aquifer system (table 2, fig. 3). The formations of the Central Basin aquifer system are not currently used as a source of drinking-water supplies in the northern and eastern Highland Rim and in the Cumberland Plateau (fig. 3). The Highland Rim aquifer system provides drinking water in these areas of the Highland Rim. The Cumberland Plateau aquifer system provides drinking water for domestic and municipal use in the Cumberland Plateau.

Mineral and Hydrocarbon Resources

Several formations of the Central Basin aquifer system contain mineral resources such as phosphates, fluorite, and hydrocarbons. Fluorite was once mined in the northern Central Basin (Miller and others, 1970). Phosphate is currently mined in the western Central Basin (fig. 4). Oil and gas are being produced from Ordovician formations in parts of the Highland Rim and the Cumberland Plateau (fig. 4).

Water Quality

Water from the Central Basin aquifer system is generally fresh (Robinove and others, 1958) throughout most of the Central Basin and the western Highland Rim, with dissolved-solids concentrations usually less than 1,000 mg/L (fig. 5 and table 3). Ground water with more than 3,000 mg/L dissolved solids, however, occurs in small pockets in the Central Basin and western Highland Rim, and dissolved-solids concentrations may exceed 10,000 mg/L in Wilson, Bedford, Williamson, and Lewis Counties (fig. 5, and table 3).

Water from the Central Basin aquifer system with dissolved-solids concentrations less than 1,000 mg/L is primarily a calcium bicarbonate type (fig. 5). The more mineralized water is a calcium sulfate, sodium sulfate, or sodium chloride water type. Where the dissolved-solids concentrations are greater than 10,000 mg/L, the water is most often a sodium chloride type. Water type is shown in figure 5 by Stiff diagrams.

In a Stiff diagram, the chemically equivalent concentrations (milliequivalents per liter) of the eight major constituents, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, and chloride are plotted. The plotted points are connected forming a distinctive pattern for the different water types. The resulting patterns can be used to illustrate water composition differences or similarities (Hem, 1970). The width of the pattern indicates the degree of mineralization. For example, water from a well in Bedford County is a highly mineralized (dissolved-solids concentration is 30,830 mg/L), sodium chloride type; the corresponding Stiff diagram is very wide with large peaks for sodium and chloride (fig. 5). Water from another well in the same county is a calcium bicarbonate type with 476 mg/L dissolved solids. The Stiff diagram for this well is much narrower and has a different shape with peaks for calcium and bicarbonate (fig. 5).

Few data are available on the water quality of the Central Basin aquifer system beneath much of the eastern Highland Rim and all of the Cumberland Plateau (fig. 5). Additional data are needed to define the ground-water quality of the Central Basin aquifer system in these areas.

Contamination

The Central Basin aquifer system is contaminated at small localized sites (fig. 6 and table 4) in the Central Basin. A shallow landfill in Davidson County has contaminated ground water in the Nashville Group. In south Nashville, several springs have been contaminated with diesel fuel. Near Williamsport, Maury County, a tailings pond collapsed and phosphatic mud appeared as far as 1 mile away. Ground-water contamination due to the effluent from closely spaced septic tanks has been documented in the cities of Hendersonville, LaVergne, and Mount Juliet (Tennessee Division of Water Quality Control, written commun., 1981). Contamination at each site is very localized and does not appear to have spread to nearby areas of drinking water supplies.

Part of the outcrop area of the Central Basin aquifer system is an area with karst features (fig. 6). These features include sinkholes, caves, and disappearing streams. The Central Basin aquifer system is susceptible to contamination by the rapid movement of fluids through sinkholes into the ground-water system.

AQUIFERS POTENTIALLY SUITABLE FOR WASTE INJECTION

Parts of the Central Basin aquifer system in the Highland Rim and Cumberland Plateau may be allowed to receive injected wastes under the Federal (EPA) UIC program (fig. 7). The Central Basin aquifer system is not being used as a source of drinking water in the northern and eastern Highland Rim and the Cumberland Plateau. In these areas, the formations of the Central Basin aquifer system lie below other sources of drinking water. In parts of the Cumberland Plateau, the Central Basin aquifer system is not currently used as a source of drinking water and will not be used as a source of drinking water because of hydrocarbon resources. However, the proposed State program would prohibit the injection of wastes in the areas with hydrocarbon resources.

There are very little data on the Central Basin aquifer system in the Cumberland Plateau and the northern and eastern Highland Rim. Additional work is needed to define the hydrology and water quality of the Central Basin aquifer system in these areas.

The formations of the Central Basin aquifer system contain phosphate resources in the western Central Basin. The phosphate mining areas are underlain by formations that are used as sources of drinking water in nearby areas.

Small, isolated contamination sites occur in the Central Basin, and isolated pockets of highly mineralized water with more than 10,000 mg/L dissolved solids are present. The contamination sites and pockets of highly mineralized ground water are very small, isolated areas that occur in the area of use of this aquifer system as a source of drinking water.

Table 1.—Geologic formations of the Central Basin aquifer system

Devonian System	Upper Devonian		Chattanooga Shale
	Middle Devonian		Pegram Formation
	Lower Devonian		Camden Chert
			Harriman Formation
			Flat Gap Limestone
			Ross Formation
Silurian System	Middle Silurian		Decatur Limestone
			Brownsport Formation
			Dixon Formation
			Logo Limestone
			Waldron Shale
			Laurel Limestone
			Osgood Formation
	Lower Silurian		Brassfield Limestone
Ordovician System	Upper Ordovician		Mannie Shale
			Fernvale Limestone
			Sequatchie Formation
			Arnheim Limestone
			Leipers Formation
			Inman Formation
	Middle Ordovician	Nashville Group	Catheys Formation
			Bigby and Cannon Limestones
			Hermitage Formation
		Stones River Group	Carters Limestone
			Lebanon Limestone
			Ridley Limestone
			Pierce Limestone
			Murfreesboro Limestone
			Pond Spring Formation

Modified from Miller, 1974.
The stratigraphic nomenclature follows the usage of the Tennessee Division of Geology and does not necessarily follow the usage of the U.S. Geological Survey.

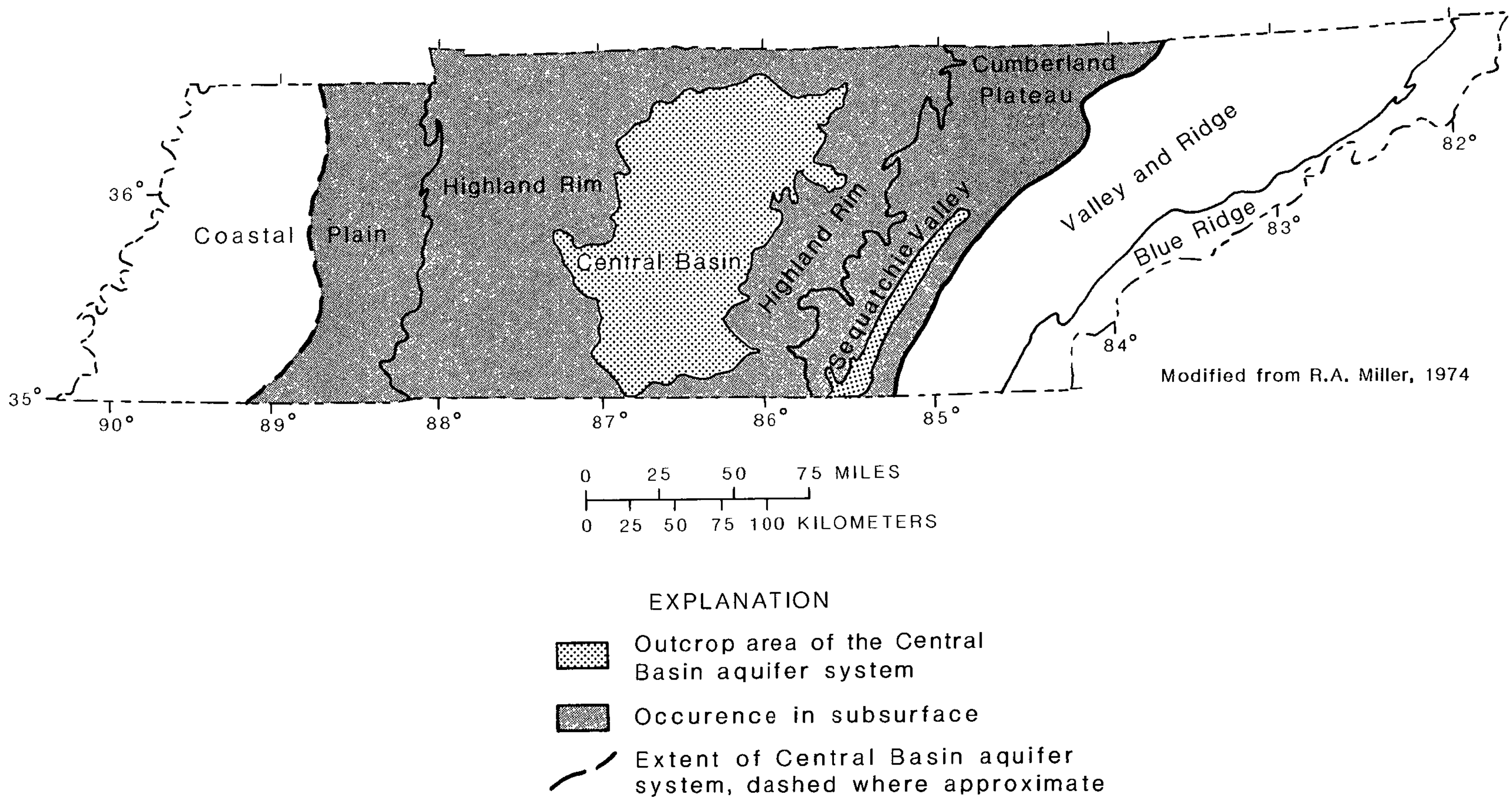
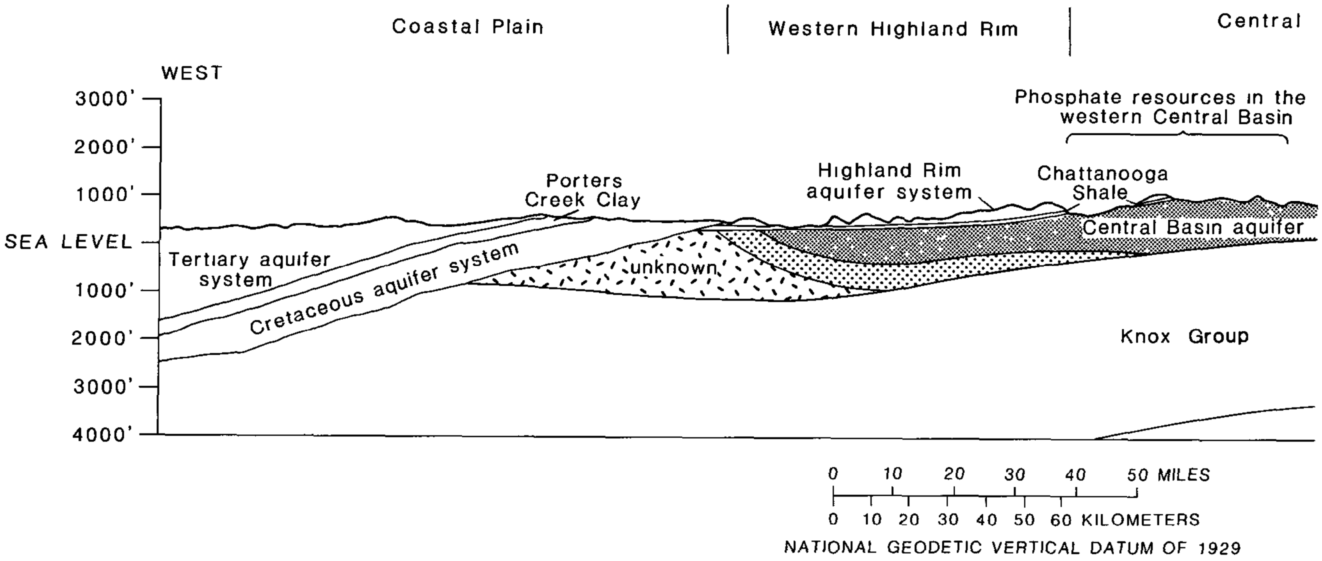


Figure 1.-- Areal extent of the Central Basin aquifer system.

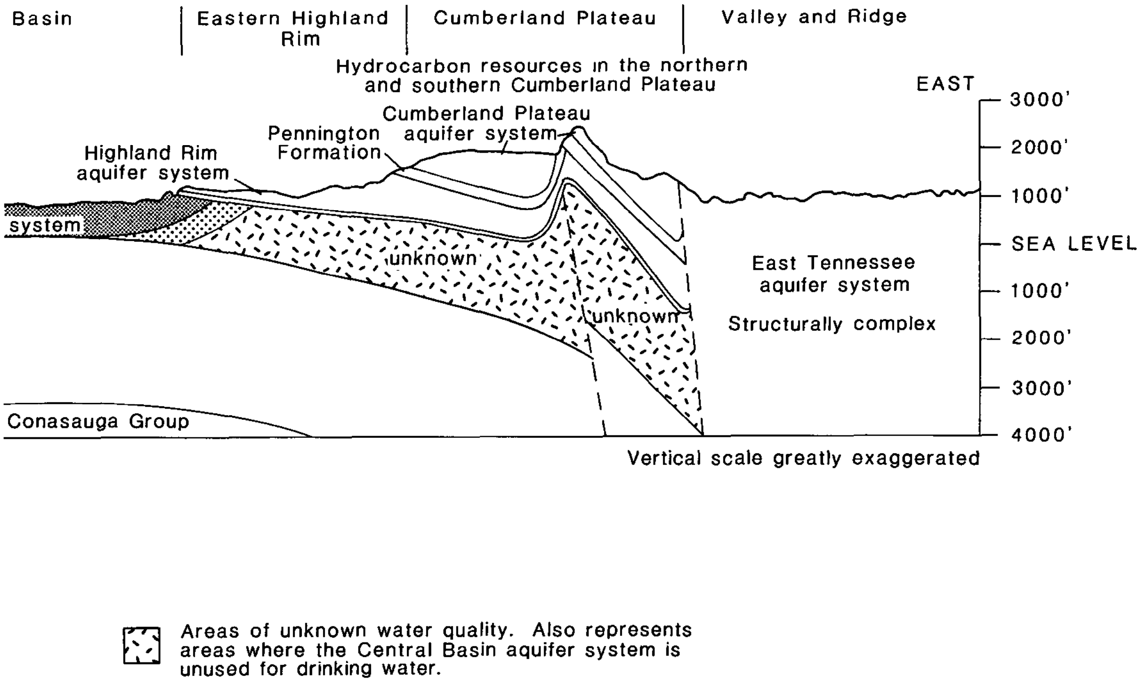


EXPLANATION

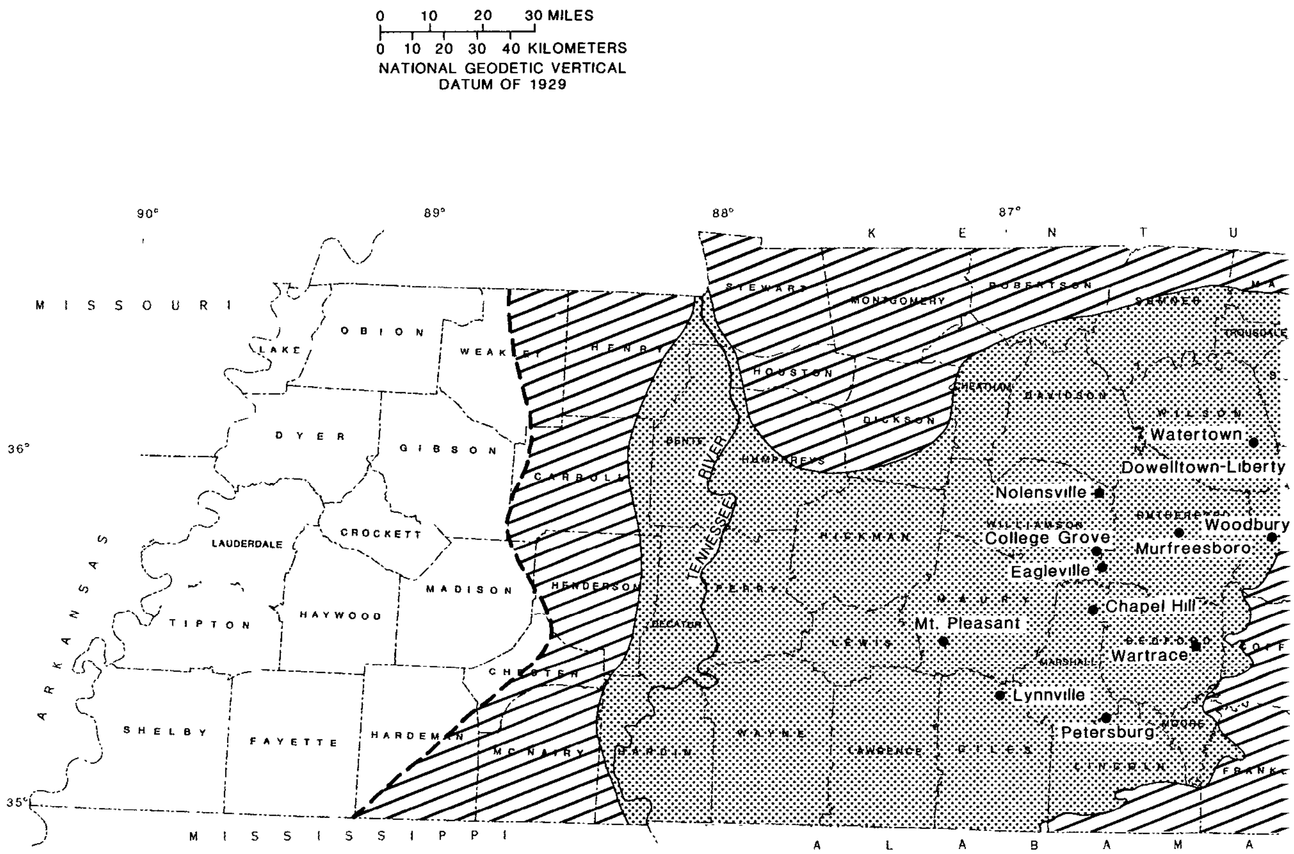
Dissolved-solids concentrations are less than 1 000 milligrams per liter. Isolated pockets with concentrations greater than 1 000 milligrams per liter exist in some areas. Represents the area of use of the Central Basin aquifer system for drinking water.

Few data. Estimated dissolved-solids concentrations are greater than 1 000 milligrams per liter. May be greater than 10 000 milligrams per liter dissolved solids with depth.

Figure 2.-- Generalized cross section of the Central Basin aquifer

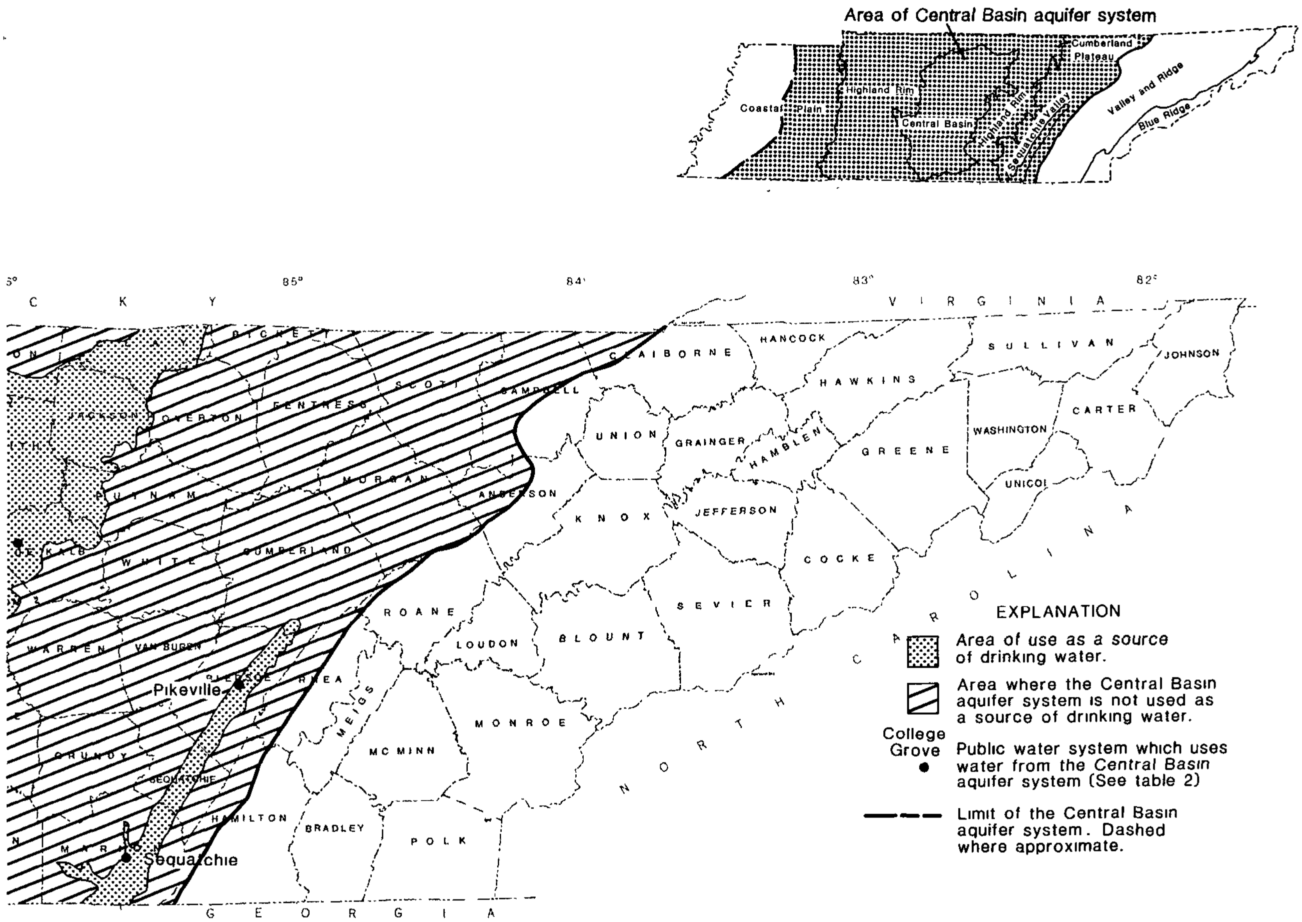


system showing water quality and use.



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

Figure 3.-- Areas of drinking water use



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

in the Central Basin aquifer system.

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

[Data source codes: 1, Tennessee Division of Water Resources; and 2, Tennessee Division of Water Quality Control]

System	County	Data source
Chapel Hill	Marshall	1, 2
College Grove	Williamson	1, 2
Dowelltown-Liberty	DeKalb	1, 2
Eagleville	Rutherford	1, 2
Lynnville	Giles	1
Mount Pleasant	Maury	1
Murfreesboro	Rutherford	1, 2
Nolensville	Williamson	1, 2
Petersburg	Marshall	1, 2
Pikeville	Bledsoe	1, 2
Sequatchie	Marion	1, 2
Wartrace	Bedford	1, 2
Watertown	Wilson	1, 2
Woodbury	Cannon	2

Table 3.--Dissolved-solids concentrations in water from selected wells and springs in the Central Basin aquifer system

[Data sources: 1, Piper (1932); 2, Wells (1933); 3, Theis (1936); 4, Newcome (1958); 5, Rima and Goddard (1979); 6, Smith (1962)]

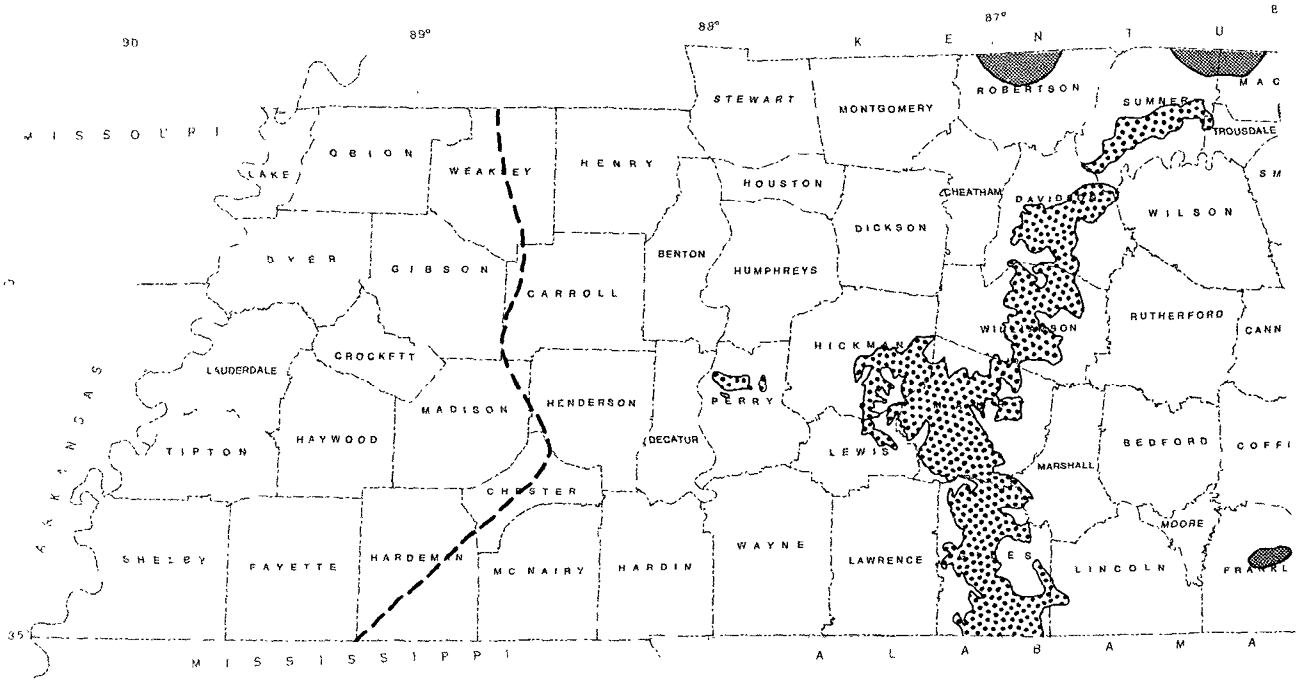
County	Location	Depth (feet)	Water bearing formation or system	Dissolved solids (milligrams per liter)	Data source
Bedford	Bell Buckle 1.5 mi S	36	Carters	10,813	3
	Haley	155	Lebanon	30,830	3
	Shelbyville 11 mi N	102	Ridley	384	3
	Shelbyville	120	Lebanon	476	3
	Wartrace	185	Lebanon	1,103	3
Benton	Big Sandy	11	Camden	128	2
	Camden 5.1 mi E	22	Devonian rocks	106	2
Carroll	Bruceton	298	Devonian rocks	276	2
Cheatham	Pegram 0.5 mi N	79	Silurian rocks	70	1
Davidson	Ashland City 8 mi SE	Spring	Silurian rocks	178	1
	Bellevue 1.25 mi W	144	Catheys	6,474	1
	Nashville 4.5 mi S	125	Carters	469	1
	Whites Creek 2 mi S	63	Leipers	412	1
	Brentwood 0.5 mi N	90	Bigby and Cannon	1,960	4
Decatur	Bath Springs	60	Decatur	276	2
	Decaturville 0.5 mi SE	107	Decatur	516	2
	Decaturville	30	Harriman	224	2
	Perryville	72	Decatur	609	2
Franklin	Winchester 5 mi W	Spring	Silurian rocks	141	3
Giles	Aspen Hill	185	Lebanon	286	3
	Campbellsville 3 mi N	Spring	Catheys	152	3
	Lynnville	37	Carters	424	3
	Minor Hill	619	Ordovician rocks	130	6
	Tarpley 1 mi E	Spring	Hermitage	190	3
Hardin	Savannah	128	Hermitage	98	2
Hickman	Centerville 1.5 mi SE	Spring	Leipers	56	3
	Coble 2.5 mi NW	Spring	Brownsport	97	3
	Pinewood	100	Leipers	1,614	3
Humphreys	Denver 4.25 mi S	Spring	Silurian rocks	160	1

Table 3.--Dissolved-solids concentrations in water from selected wells and springs in the Central Basin aquifer system--Continued

County	Location	Depth (feet)	Water bearing formation or system	Dissolved solids (milligrams per liter)	Data source
Lewis	Gordonsburg 5.5 mi NE	84	Catheys	19,160	3
	Gordonsburg 6.5 mi NE	50	Leipers	257	3
Lincoln	Belleville	66	Hermitage	7,724	3
	Delrose 0.5 mi NE	Spring	Fernvale	110	3
	Fayetteville 4 mi S	Spring	Bigby and Cannon	106	3
	Howell	Spring	Fernvale	193	3
	Petersburg	40	Carters	434	3
Marshall	Chapel Hill 2.5 mi S	96	Lebanon	270	3
	Chapel Hill	540	Murfreesboro	236	4
	Lewisburg 2 mi SE	21	Carters	609	3
Macon	Lafayette 3.5 mi SW	63	Leipers	435	4
	Lafayette 6 mi S	30	Bigby and Cannon	310	4
Maury	Carters Creek 1 mi E	29	Hermitage	200	3
	Columbia 3.5 mi SW	70	Hermitage	311	3
	Kettle Mills	83	Bigby and Cannon	1,300	4
	Mount Pleasant 6 mi SE	85	Lebanon	290	3
	Springhill 4 mi SE	73	Lebanon	955	3
	Match 5 mi E	75	Lebanon	3,283	3
Moore	Lynchburg 2 mi NE	Spring	Bigby and Cannon	138	3
	Lynchburg 1 mi W	25	Bigby and Cannon	280	4
Perry	Beardstown	137	Brownsport	3,121	3
	Beardstown 3 mi E	Spring	Ross	79	3
	Linden	Spring	Ross	118	3
	Linden 0.5 mi S	202	Silurian rocks	185	6
	Pope 9 mi SE	Spring	Brownsport	108	3
Rutherford	Christiana 9 mi W	Spring	Lebanon	300	1
	Eagleville 2 mi E	Spring	Lebanon	256	1
	Halls Hill	115	Ridley	357	5
	Murfreesboro 2.5 mi W	175	Murfreesboro	1,240	1
	Murfreesboro 0.75 mi NW	217	Murfreesboro	356	1
	Murfreesboro 6 mi SE	253	Ridley	282	5
	Rucker	--	Ridley	297	5
	Rocky Ford 0.25 mi W	112	Lebanon	367	5
Smith	Kempville	123	Bigby and Cannon	300	4

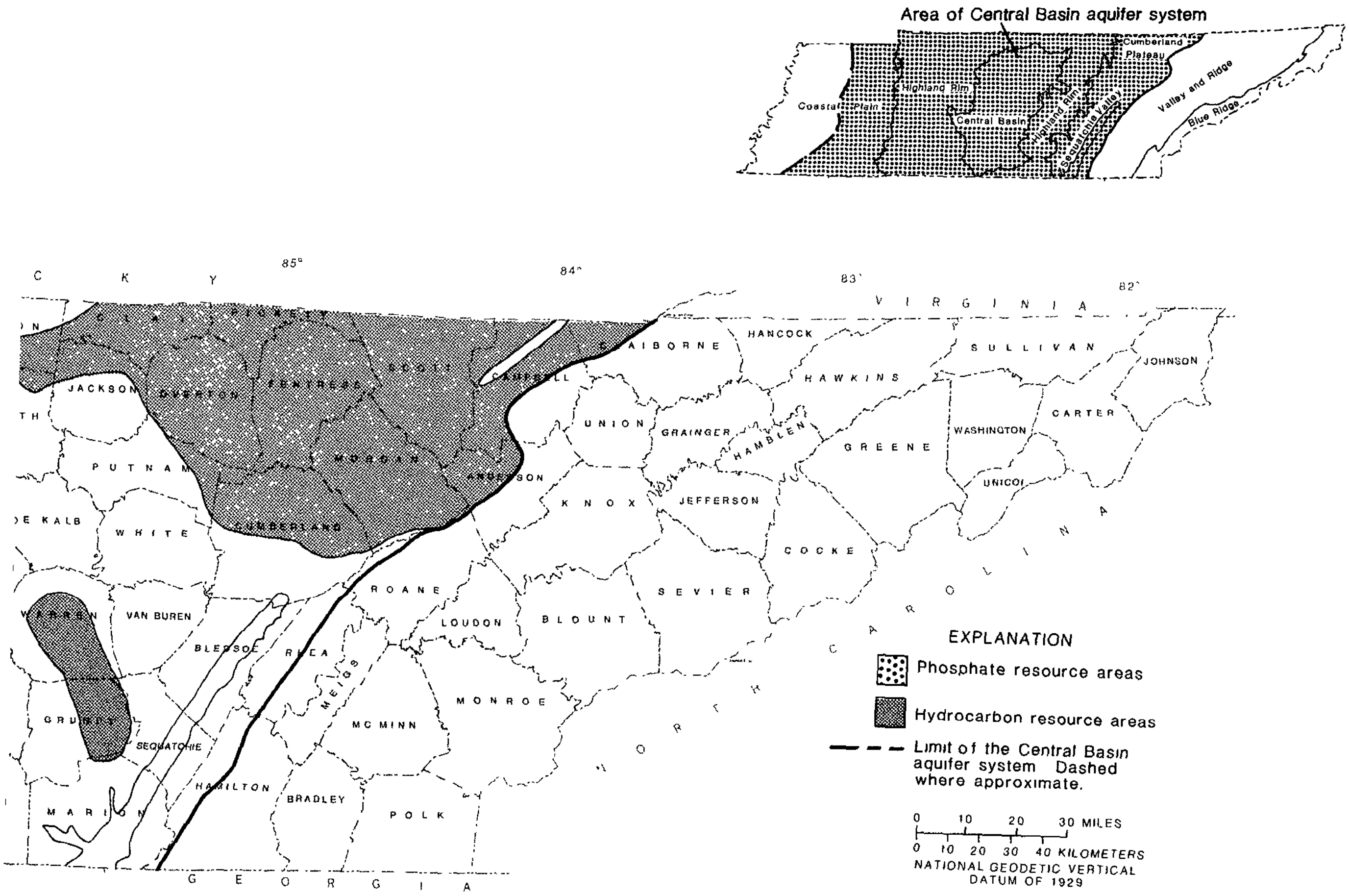
Table 3.--Dissolved-solids concentrations in water from selected wells and springs in the Central Basin aquifer system--Continued

County	Location	Depth (feet)	Water bearing formation or system	Dissolved solids (milligrams per liter)	Data source
Sumner	Castalian Springs	Spring	Bigby and Cannon, Hermitage	3,497	1
	Cottontown	60	Leipers	292	1
	Gallatin	300	Bigby and Cannon	262	1
	Hendersonville	315	Bigby and Cannon	262	5
	Millersville 2 mi S	35	Bigby and Cannon	377	5
	Saundersville	50	Leipers	628	1
Wayne	Clifton 3 mi NE	42	Silurian rocks	481	3
	Collinwood 5 mi NW	Spring	Brownsport	170	3
	Riverside 5 mi SW	Spring	Silurian rocks	78	3
Wilson	Gladeville 0.75 mi E	28	Lebanon	1,152	1
	Horn Springs	Spring	Hermitage	3,880	1
	Lebanon 9 mi NE	118	Lebanon	382	1
	Lebanon	205	Ridley	379	1
	Mount Juliet	47	Carters	312	1
	Norene 5.5 mi S	152	Lebanon	26,410	1
	Watertown 0.5 mi W	251	Ridley	319	1
	Woods Ferry	60	Lebanon	261	5
Williamson	Boston 5 mi E	45	Bigby and Cannon	10,920	1
	Boston 4.75 mi SE	105	Catheys	2,296	1
	Franklin	150	Carters	216	5
	Franklin 1 mi S	Spring	Hermitage	192	1
	Nolensville	160	Ridley	342	1
	Fairview 5 mi SE	Spring	Fernvale	241	1



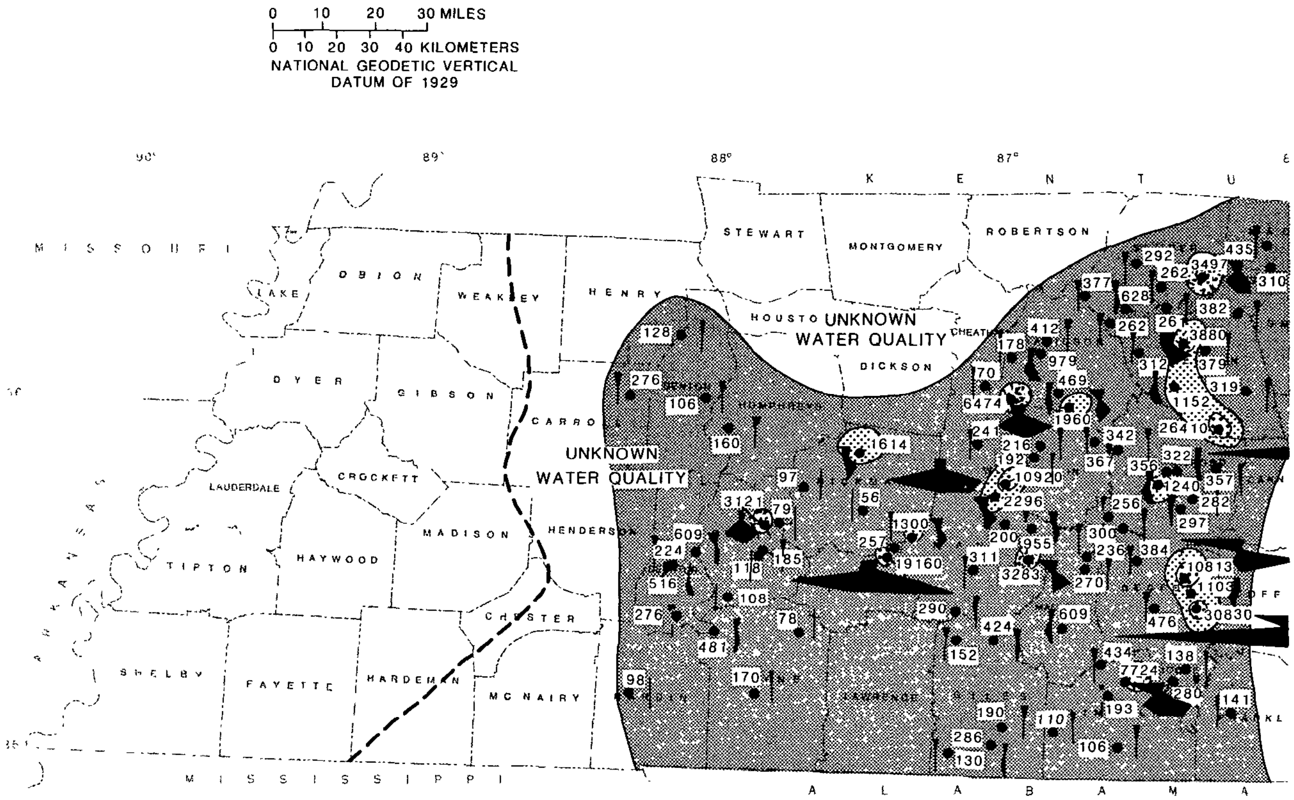
Base from U.S. Geological Survey
State base map, 1:1,000,000 1957,
revised 1973

Figure 4.-- Phosphate and hydrocarbon



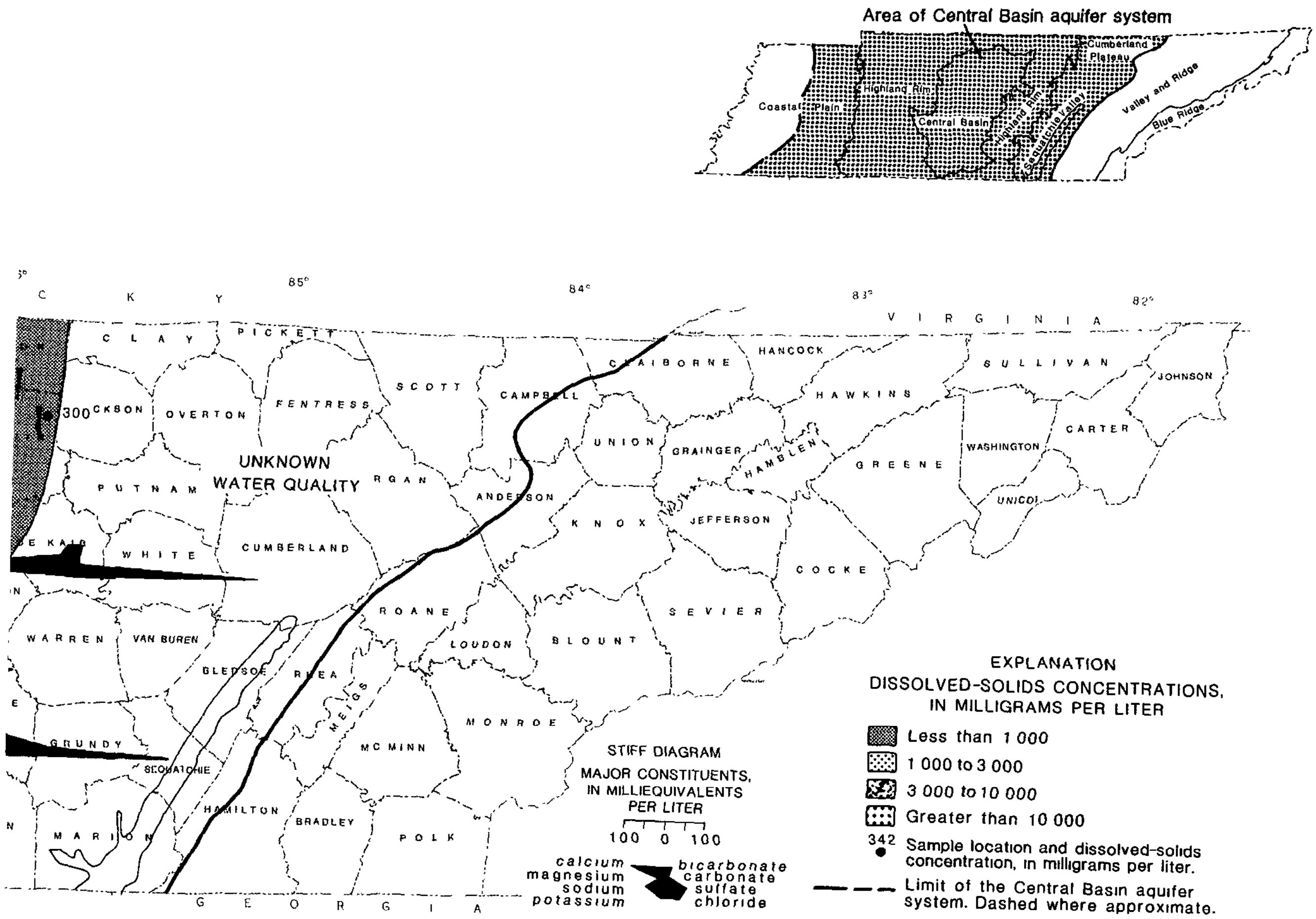
resources in the Central Basin aquifer system

Modified from R.A Miller, J.M Fagan, R.C. Hale, W.D Hardeman, and R.W Johnson, 1970



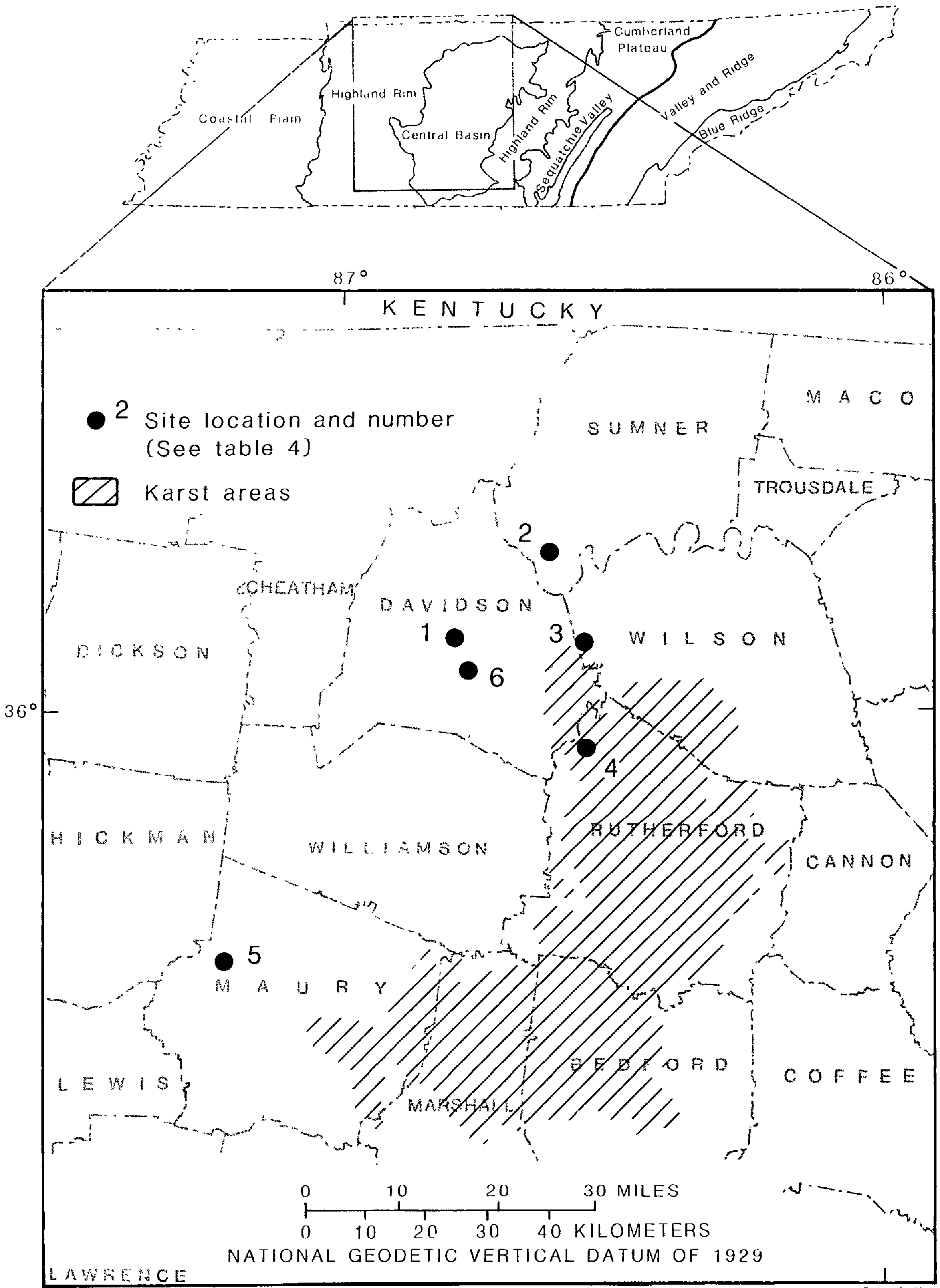
Base from U.S. Geological Survey State base map 1:1,000,000 1957 revised 1975

Figure 5.-- Dissolved-solids concentration and



water type in the Central Basin aquifer system.

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



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

Karst features from R.A. Miller
and P.D. Sitterly, 1977

Figure 6.-- Contamination sites and karst areas in the Central Basin aquifer system.

Table 4.--Description of contamination sites

[Site location and number are given in figure 6]

Site identification No.	Location	Type of contamination	Data source	Stratigraphic interval contamination	Comments
1	Bordeaux landfill, Davidson County.	Muncipal waste	Residual waste study, Tennessee Division of Water Quality Control.	Perched water in the alluvium and water within the bedrock of the Nashville Group.	Noticeably higher hardness, higher biological oxygen demand, and higher concentrations of dissolved solids. A petroliferous odor was noticed in one well. Monitoring to be continued throughout the life of the landfill.
2	Hendersonville, Sumner County.	Domestic waste	Tennessee Division of Water Quality Control.	The regolith and bedrock of the Upper Ordovician formations.	The contamination at sites 2, 3, and 4 is due to the effluent from the large number of septic tanks under most municipal areas.
3	Mount Juliet, Wilson County.	Domestic waste	do	The regolith and bedrock of the Carters Limestone.	Do.
4	LaVergne, Rutherford County.	Domestic waste	do	The regolith and bedrock of the Lebanon Limestone.	Do.
5	Williamsport, Maury County.	Industrial waste	do	The water-table aquifer within the Leipers to Catheys Formation.	The bottom of a phosphate tailings pond collapsed and phosphate mud was found in springs one-half to 1 mile away.
6	Croft farm, Nashville, Davidson County.	Industrial waste		The regolith and bedrock of the Bigby and Cannon Limestones.	Diesel fuel has contaminated several springs at this south Nashville site.

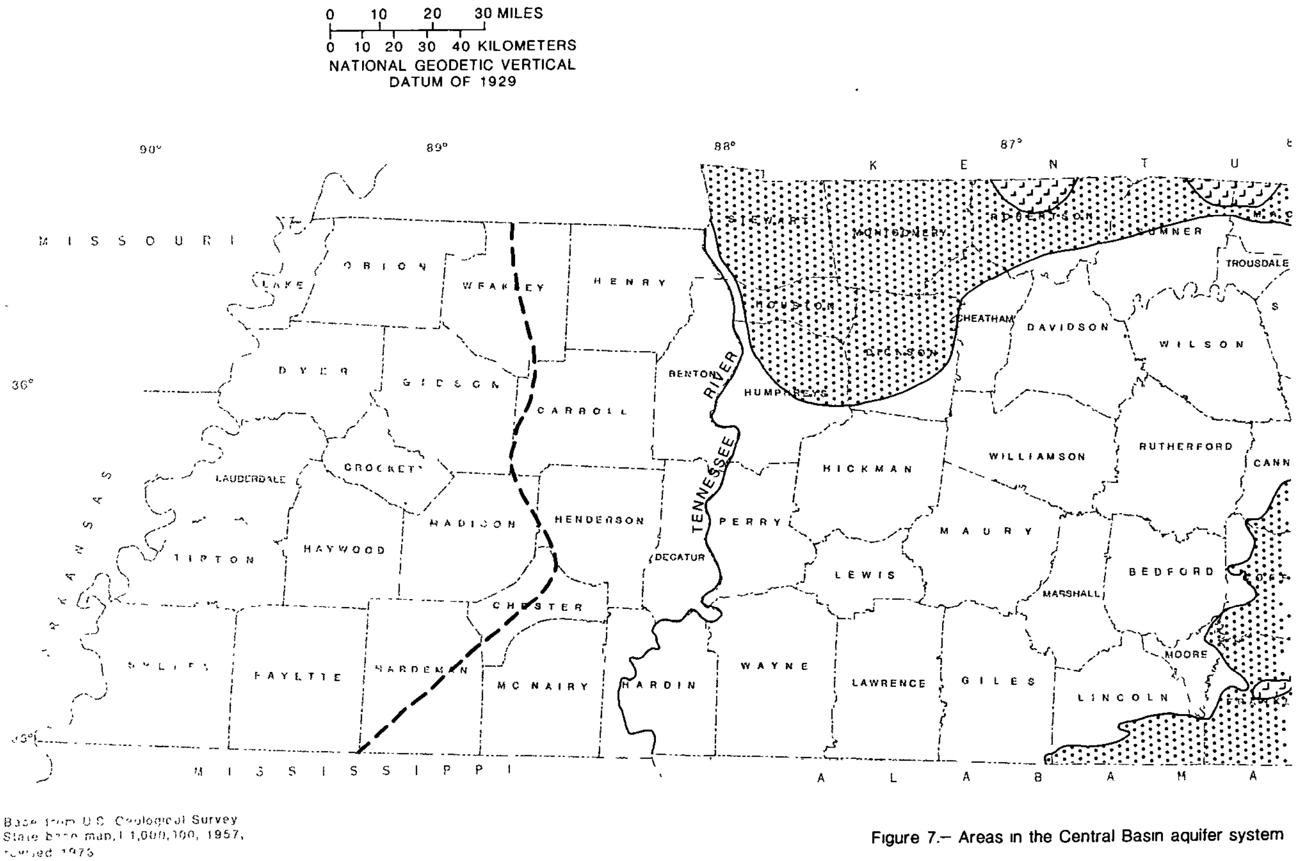
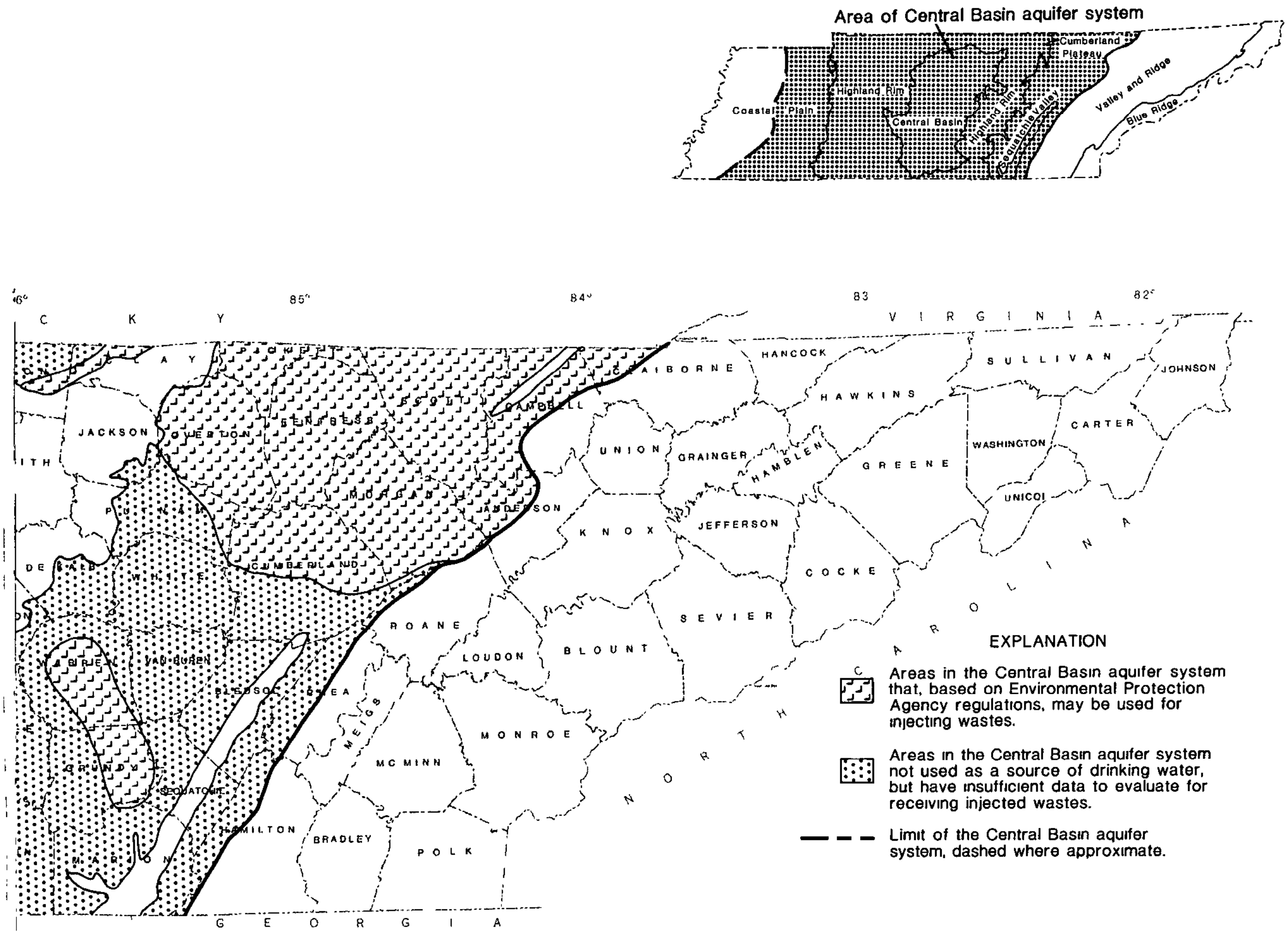


Figure 7.– Areas in the Central Basin aquifer system



that may be used for receiving injected wastes.

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