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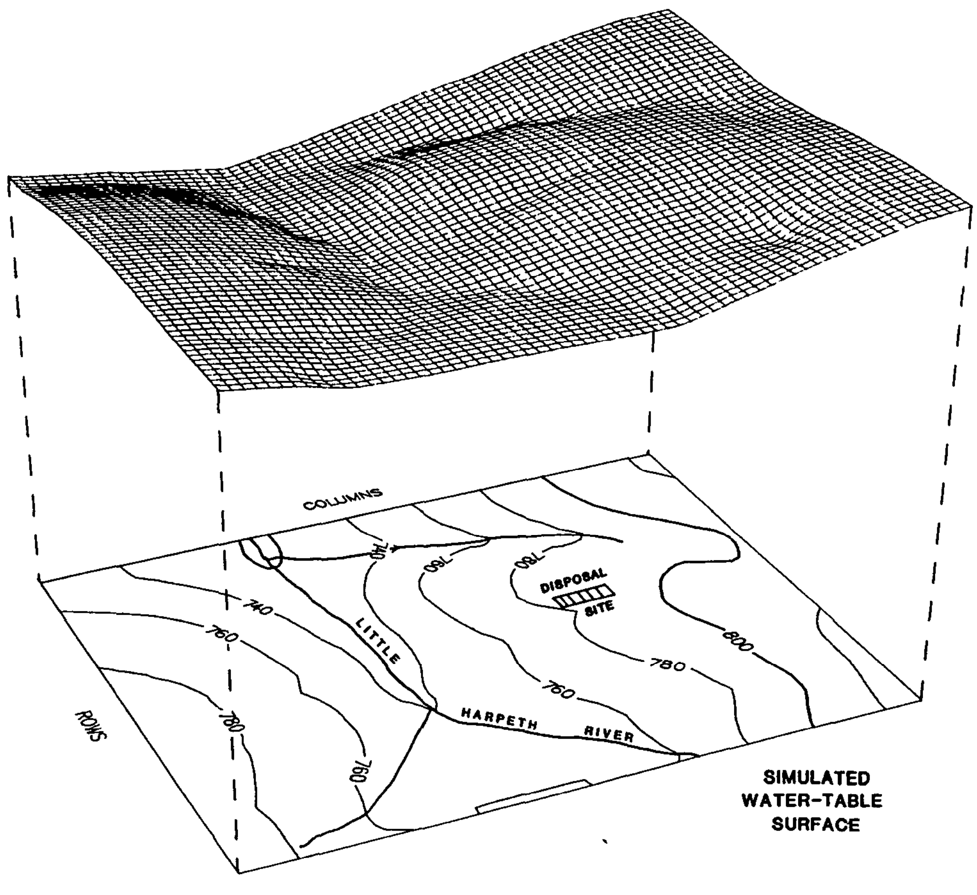
HYDROGEOLOGY OF A HAZARDOUS-WASTE DISPOSAL SITE NEAR BRENTWOOD, WILLIAMSON COUNTY, TENNESSEE



Prepared by the
U.S. GEOLOGICAL SURVEY

in cooperation with the
TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT, DIVISION OF SUPERFUND

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By Patrick Tucci, Dorothea Withington Hanchar, and Roger W. Lee

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TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT,
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Nashville, Tennessee
1990

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

For those readers who may prefer to use metric units rather than inch-pound units, conversion factors for terms used in this report are listed below:

Multiply inch-pound units	By	To obtain metric units
inch (in.)	25.4	millimeter (mm)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	30.48	centimeter per day (cm/d)
foot per day per foot [(ft/d)/ft]	30.48	centimeter per day per centimeter [(cm/d)/cm]
square foot (ft^2)	0.0929	square meter (m^2)
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
gallons per minute (gal/min)	0.0631	liters per second (L/s)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$^{\circ}C = (^{\circ}F-32)/1.8$$

Sea level: In this report "sea level" refers to the 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 Sea Level Datum of 1929.

HYDROGEOLOGY OF A HAZARDOUS-WASTE SITE NEAR BRENTWOOD, WILLIAMSON COUNTY, TENNESSEE

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ABSTRACT

Approximately 44,000 gallons of industrial solvent wastes were disposed in pits on a farm near Brentwood, Tennessee, in 1978. Contaminants associated with these wastes were reported in the soil and shallow ground water on the site in 1985. In order to enable the State to evaluate possible remedial-action alternatives, an 18-month study was conducted to define the hydrogeologic setting of the disposal site and surrounding areas.

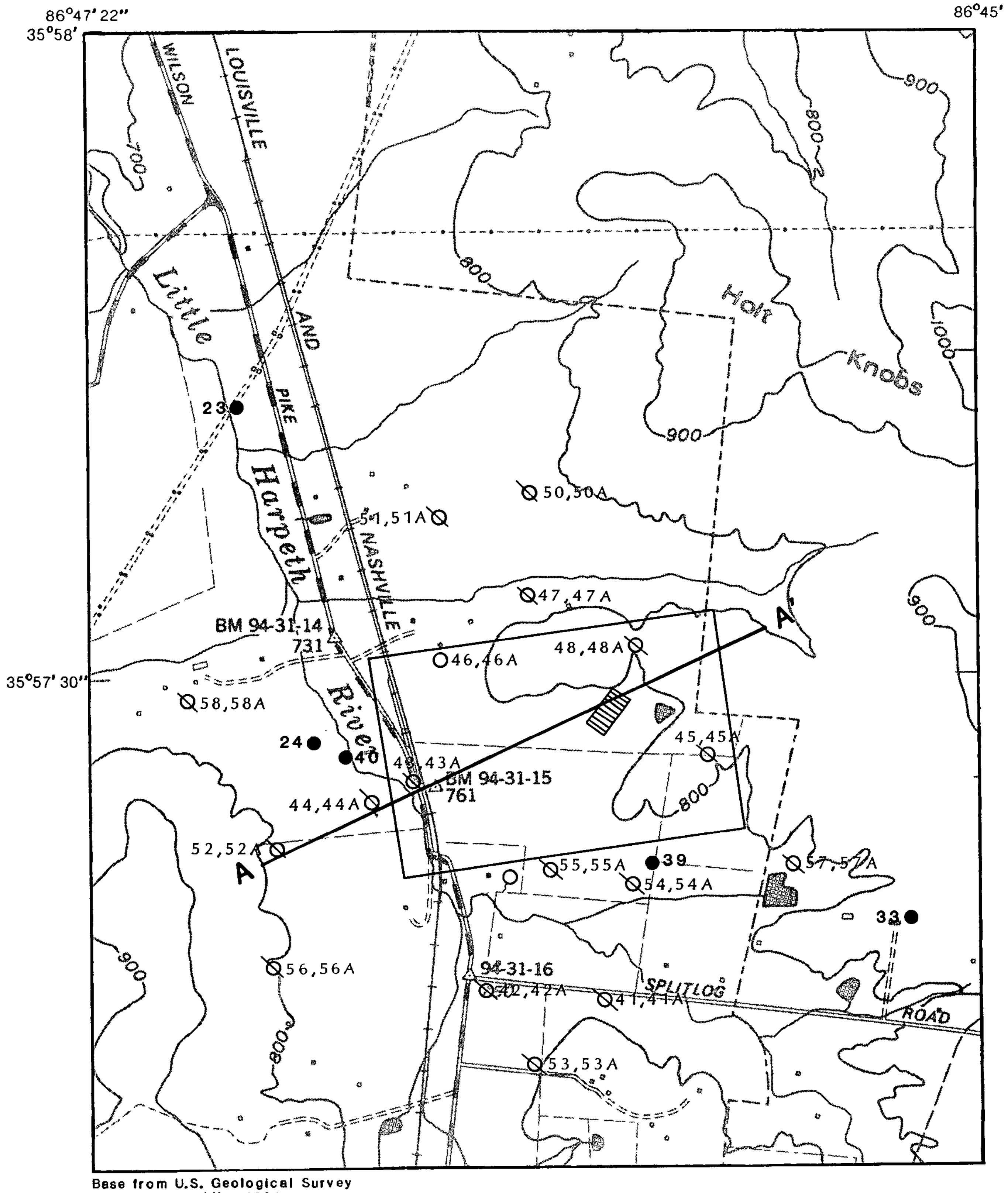
The area is underlain by four hydrogeologic units: (1) an upper aquifer consisting of saturated regolith, Bigby Limestone, Cannon Limestone, and weathered Hermitage Formation, (2) the Hermitage confining unit, (3) a lower aquifer consisting of the Carters Limestone, and (4) the Lebanon confining unit. Wells tapping these aquifers generally are low yielding (less than 1 gallon per minute), although locally yields may be as much as 80 gallons per minute. Aquifer test results indicate that the lower aquifer is anisotropic, and transmissivity of this aquifer is greatest in a northwest-southeast direction.

Recharge to the ground-water system is primarily from precipitation, and estimates of average annual recharge rates range from 6 to 15 inches per year. Discharge from the ground-water system is primarily to the Little Harpeth River and its tributaries. Ground-water flow at the disposal site is mainly to a small topographic depression that drains the site.

Geochemical data indicate several distinct water types related to four zones of circulating ground water: (1) a shallow zone of rapid circulation; (2) a deeper zone (greater than 100 feet) of rapid circulation; (3) a shallow zone of slow moving circulation, and (4) a deeper zone of slow circulation. Both the geochemical data and a numerical ground-water flow model of the study area support the concept of two aquifers separated by a low permeability confining unit. Results of the numerical model indicate that most of the ground-water flow is in the upper aquifer, and that less than 1 percent of the recharge to the upper aquifer flows down to the lower aquifer.

INTRODUCTION

In 1978, approximately 44,000 gallons of industrial solvent wastes were disposed in pits on a farm in Brentwood, Tennessee (figs. 1 and 2).

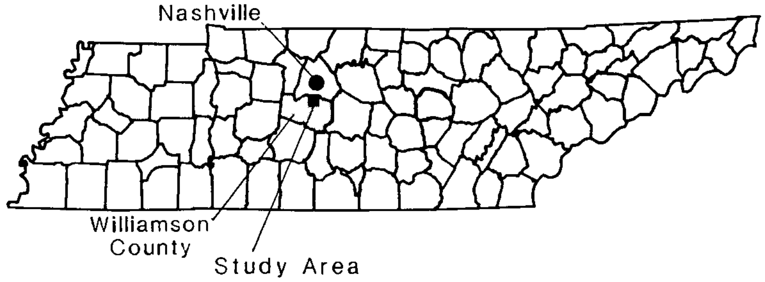


Base from U.S. Geological Survey 1:24,000, Franklin, 1981

0 0.5 MILE

CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

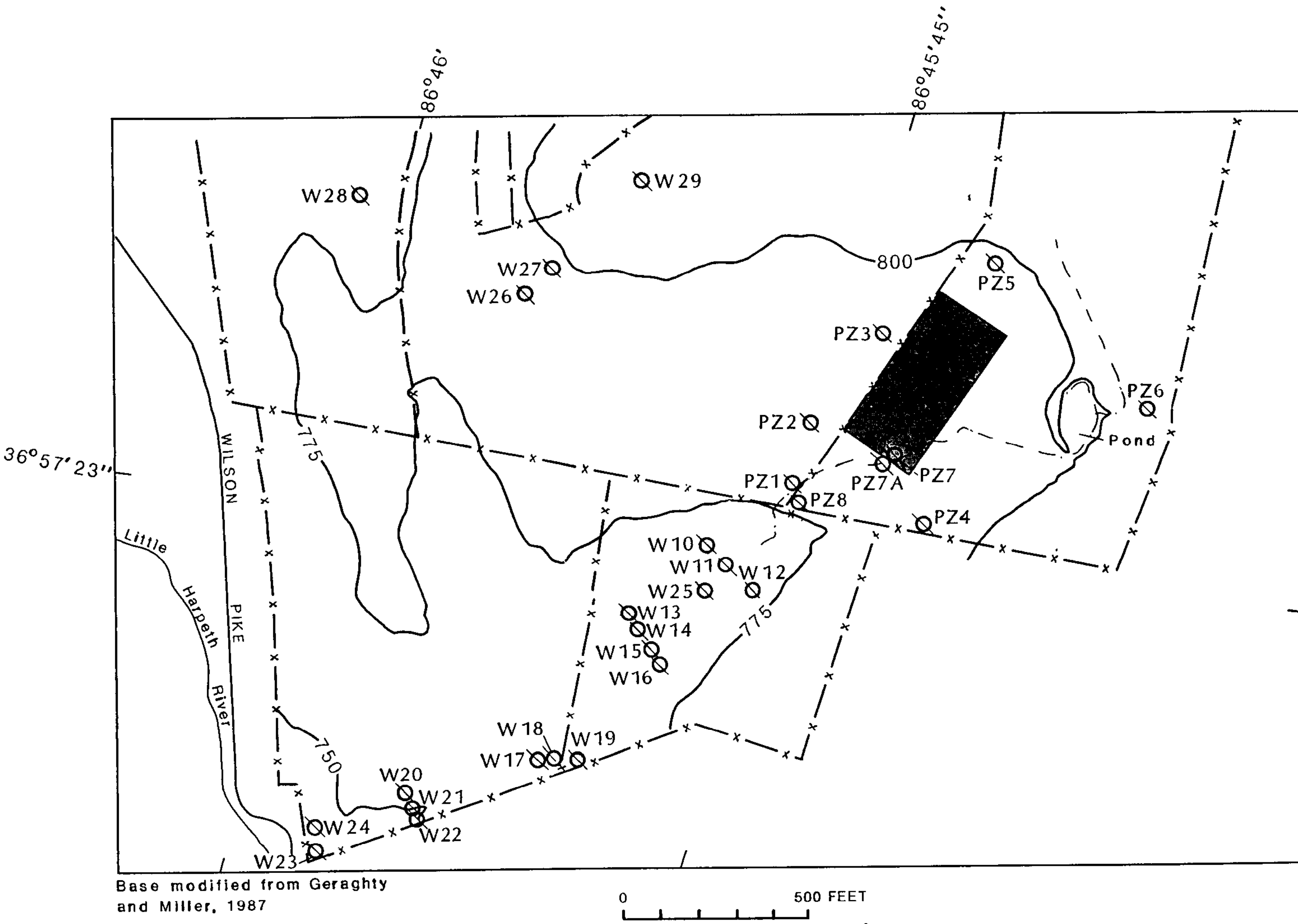
Location Map



EXPLANATION

[hatched box]	DISPOSAL SITE
A—A'	LINE OF SECTION
53,53A	OBSERVATION WELL AND NUMBER--Full well identification includes the prefix WM:N-##. See text
39 ●	DOMESTIC WELL AND NUMBER
	HACKETT'S SPRING

Figure 1.--Location of study area, disposal site, and observation and domestic wells.



Base modified from Geraghty and Miller, 1987

CONTOUR INTERVAL 25 FEET

DATUM IS SEA LEVEL

EXPLANATION

- DISPOSAL SITE--Shown in figure 1
- —x— FENCE
- --···— INTERMITTENT STREAM
- - - - - DISPOSAL PIT BOUNDARY
- W27 SHALLOW OBSERVATION WELL AND NUMBER

Figure 2.--Details of disposal site and observation wells.

The waste products consisted of rubber solvents, hexane, acetone, toluene, chloroethylene, organic fillers, and water soluble adhesives (Geraghty and Miller, Inc., 1986). The waste products, principally liquids, were poured into open pits dug into a former phosphate strip mine. Preliminary investigations in 1985 by the State of Tennessee determined the presence of many of these organic compounds in soil and shallow ground water on the site (Geraghty and Miller, Inc., 1986). Organic compounds were also found in water from two domestic wells in the area and in Hackett's Spring (fig. 1). The U.S. Geological Survey, in cooperation with the Tennessee Department of Health and Environment, Division of Superfund, began an 18-month study of the hydrogeology of the disposal site and surrounding area in 1986.

PURPOSE AND SCOPE

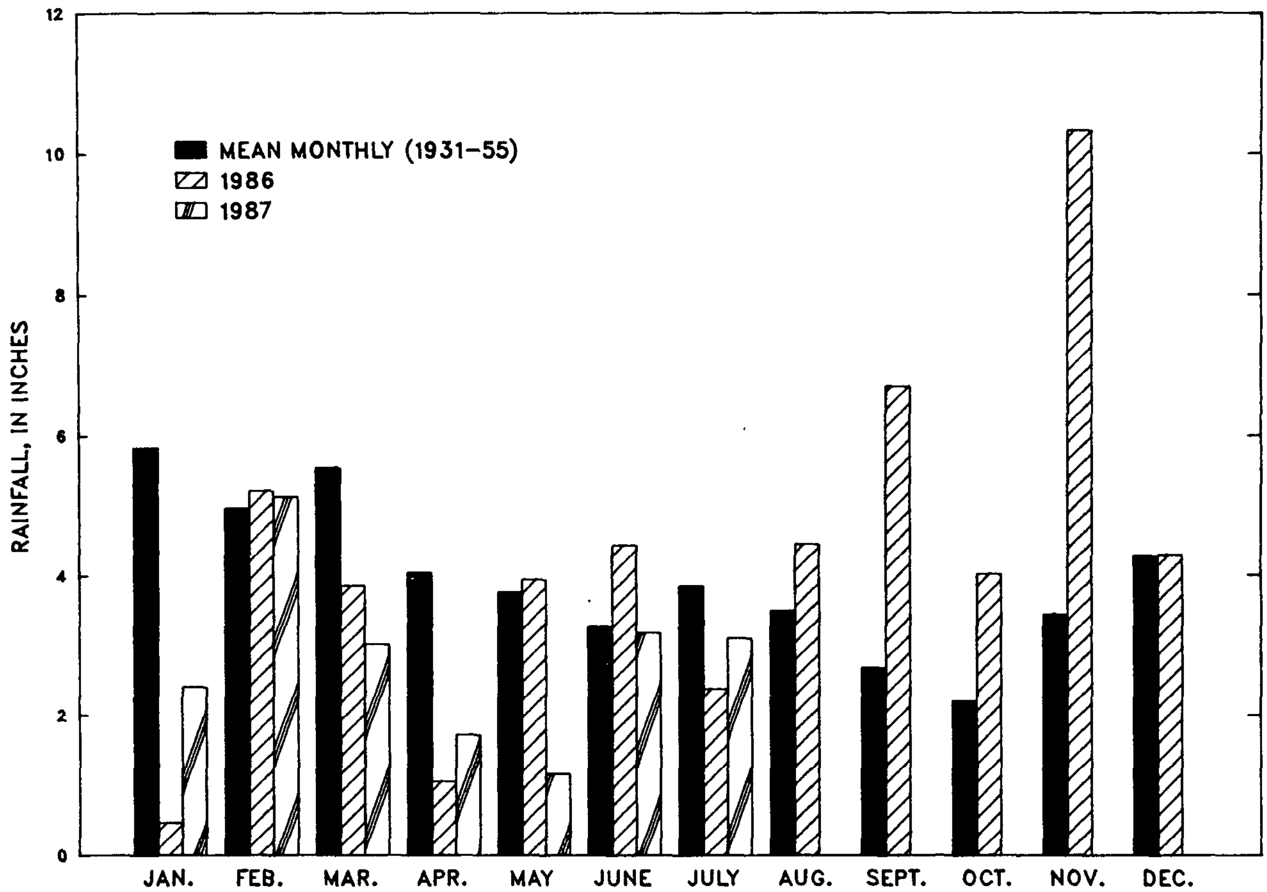
The purpose of the investigation was to (1) develop an understanding of the geology and ground-water hydrology of the site and surrounding area in order to determine potential contaminant pathways, and (2) to provide sufficient geologic and hydrologic information to enable the State to evaluate remedial-action alternatives and subsequent monitoring of the area. This report documents the results of the investigation, and includes information on geology and hydraulic characteristics of the subsurface materials and on the surface- and ground-water systems of the study area. The report also provides geochemical data and interpretations, and documents the results of a numerical ground-water flow model.

Hydrologic data collected in support of the study include discharge measurements of the Little Harpeth River and pertinent tributaries (fig. 1) to determine ground-water seepage, and measurement of water levels in 34 observation wells installed at 17 sites surrounding the disposal site (fig.1) (Hanchar, 1989). In addition to these observation wells, water levels were measured in 5 domestic wells (fig. 1) and 30 shallow observation wells previously installed by a consulting firm at the disposal site (fig. 2). Subsurface geologic information describing the geometry of the aquifers and confining units was obtained from lithologic descriptions and borehole-geophysical logs of observation and domestic wells in the area. Eight geochemical samples of ground water were collected to aid in the conceptualization of the flow system. A numerical model of the ground-water flow system was used to better understand the quantities and distribution of ground-water flow.

LOCATION, PHYSICAL FEATURES, AND CLIMATE

The study area is located in Middle Tennessee, about 15 miles south-southeast of Nashville, in the southeast corner of the city of Brentwood, in Williamson County (fig. 1). The study area covers about 3.4 mi^2 and includes the approximate 7-acre disposal site in the center of the area (fig. 1). The setting of the area has historically been rural; however, several residential subdivisions are presently (1989) under construction within $^1/4$ mile of the disposal site. The disposal site is in a broad valley flanked by hills or "knobs" with as much as 350 feet of relief. The valley is drained by the Little Harpeth River, a perennial stream, and several intermittent streams (fig.1).

The climate of the study area is temperate. Climatological data for Franklin (National Oceanic and Atmospheric Administration, 1974), which is about 7 miles south of the study area, indicates a mean annual air temperature of 59 ^oF. Average annual rainfall for Franklin is about 47 in/yr; however, during 1986 rainfall was 51 inches (fig. 3). Rainfall for the first half of 1987 was about 11 inches below normal.



Data from National Oceanic and Atmospheric Administration, 1974, 1986, and 1987

Figure 3.—Mean monthly and monthly rainfall for the period January 1986 to July 1987 for Franklin, Tennessee.

ACKNOWLEDGMENTS

The authors wish to acknowledge the cooperation of landowners in the study area for granting access to domestic wells and for permission to install observation wells. We also wish to acknowledge Geraghty and Miller, Inc., for providing supplementary geologic and hydrologic information from the disposal site.

GEOLOGY AND HYDRAULIC CHARACTERISTICS

GEOLOGY

Regionally, the study area is located along the northwestern dipping flank of the Nashville Dome and is underlain by limestone of

Ordovician age. Previous work in the area has identified four formations at or within 300 feet of the land surface (Wilson and Miller, 1963). From oldest to youngest these formations are: the Lebanon Limestone and the Carters Limestone of the Stones River Group, and the Hermitage Formation and the correlative Bigby and Cannon Limestones (locally referred to in this report as the Bigby-Cannon Limestone as defined by Wilson, 1949) of the Nashville Group (fig. 4). These formations have been previously described in detail by Wilson (1949), and descriptions of the lithologies encountered during drilling for the study are presented by Hanchar (1989). Bedding in the formations is nearly horizontal; however, some small-scale folding of the Carters and Lebanon Limestones is present, (Hanchar, 1988, p. 15).

Locally, the study area is overlain by 3 to 15 feet of regolith, consisting of soil and weathered rock. Regolith is generally thickest on the hillsides and thinnest in the valley. Bigby-Cannon Limestone and the Hermitage Formation underlie the regolith in the study area. Thickness maps of these two formations show that both have been modified by erosion to the extent that the Bigby-Cannon Limestone is missing from the valley (fig. 5) and the Hermitage Formation is greatly thinned (fig. 6). The Bigby-Cannon Limestone ranges in thickness from 0 to 41 feet (fig. 5), and the Hermitage Formation ranges in thickness from 26 to 103 feet (fig. 6). The Carters Limestone is more uniform in thickness and ranges from 65 to 77 feet thick.

Both the Bigby-Cannon and the Carters Limestone are predominantly silt-free limestones with solution openings. In contrast, the Hermitage Formation and the Lebanon Limestone are laminated argillaceous limestones, interbedded with shale partings.

HYDRAULIC CHARACTERISTICS

Hydraulic characteristics of the rocks in the study area are highly variable. Wells completed in rocks that are unweathered or lack fractures and solution openings have very low yields and low aquifer transmissivity values. Wells that are completed in weathered zones or that intercept fractures and solution openings, however, have higher yields and aquifer transmissivity values.

Well yields from each formation were estimated during drilling. For the 17 shallow wells completed in the Bigby-Cannon Limestone, the Hermitage Formation, or the Carters Limestone, yields generally were less than 1 gal/min. The approximate yield of one shallow well, Wm:N-041, ranged between 5 and 10 gal/min. Two of the shallow wells (Wm:N-043 and Wm:N-044) constructed in the valley of the Little Harpeth River, where the Hermitage Formation is thin (fig. 6), were completed into the upper part of the Carters Limestone. Yields of both of these wells were less than 1 gal/min.

The 17 deep wells were completed either in the lower part of the Carters Limestone or in the Lebanon Limestone. Yields of these wells were variable, ranging from less than 1 to 80 gal/min. The major water-bearing zone in well Wm:N-044A, which has a yield of 80 gal/min, appears to be a solution opening at the base of the Carters Limestone.

Transmissivity was determined at well Wm:N-050, which is completed in the Bigby-Cannon Limestone, by analysis of specific-capacity test data using a method described by Theis and others (1963). Using this method, a transmissivity value of 10 ft^2/d was calculated.

Slug-test results reported by Geraghty and Miller (1987, table 11) indicate an average horizontal hydraulic conductivity of 4.4 ft/d for 15 wells completed in the Bigby-Cannon Limestone and weathered parts of the Hermitage

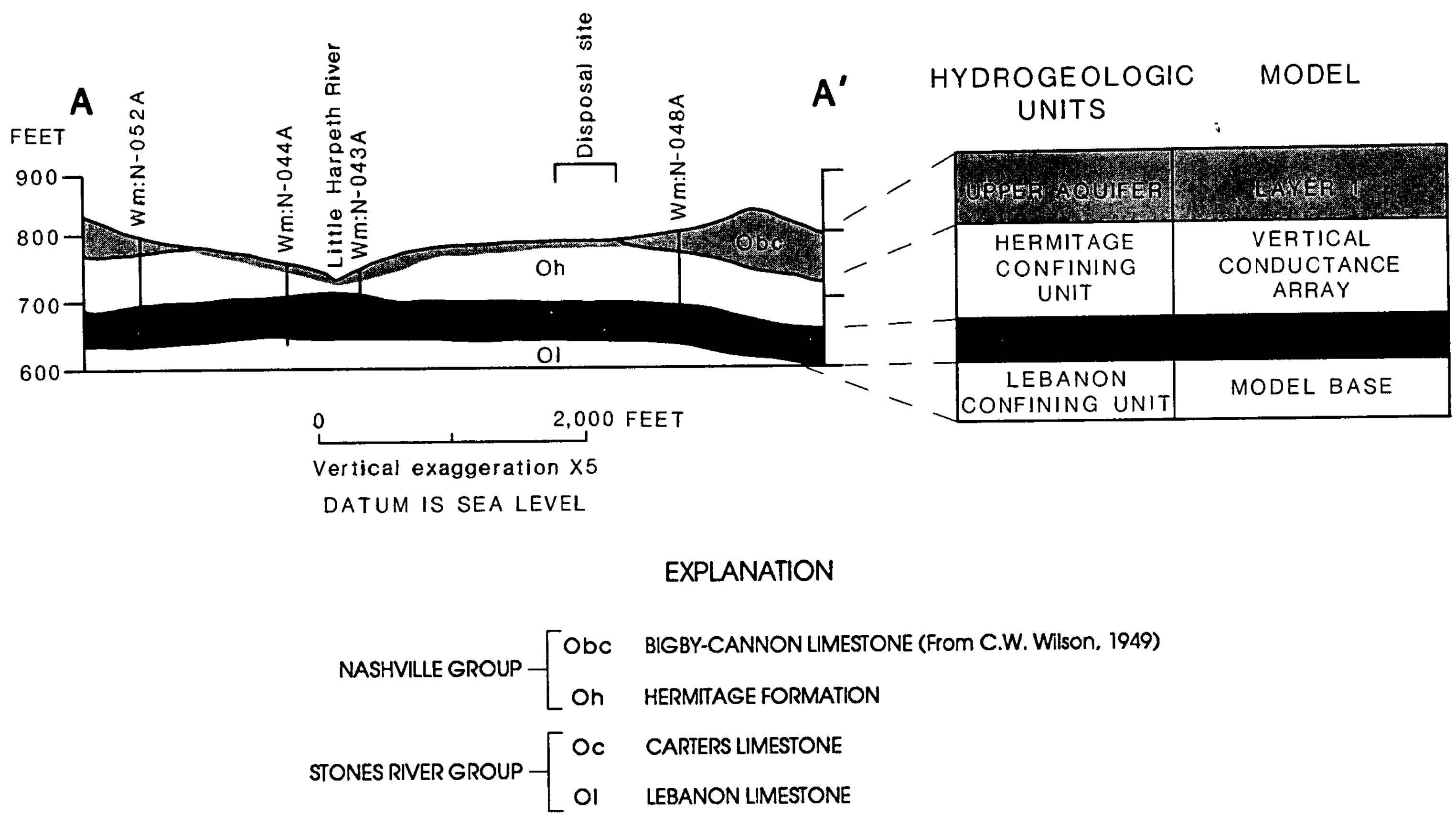
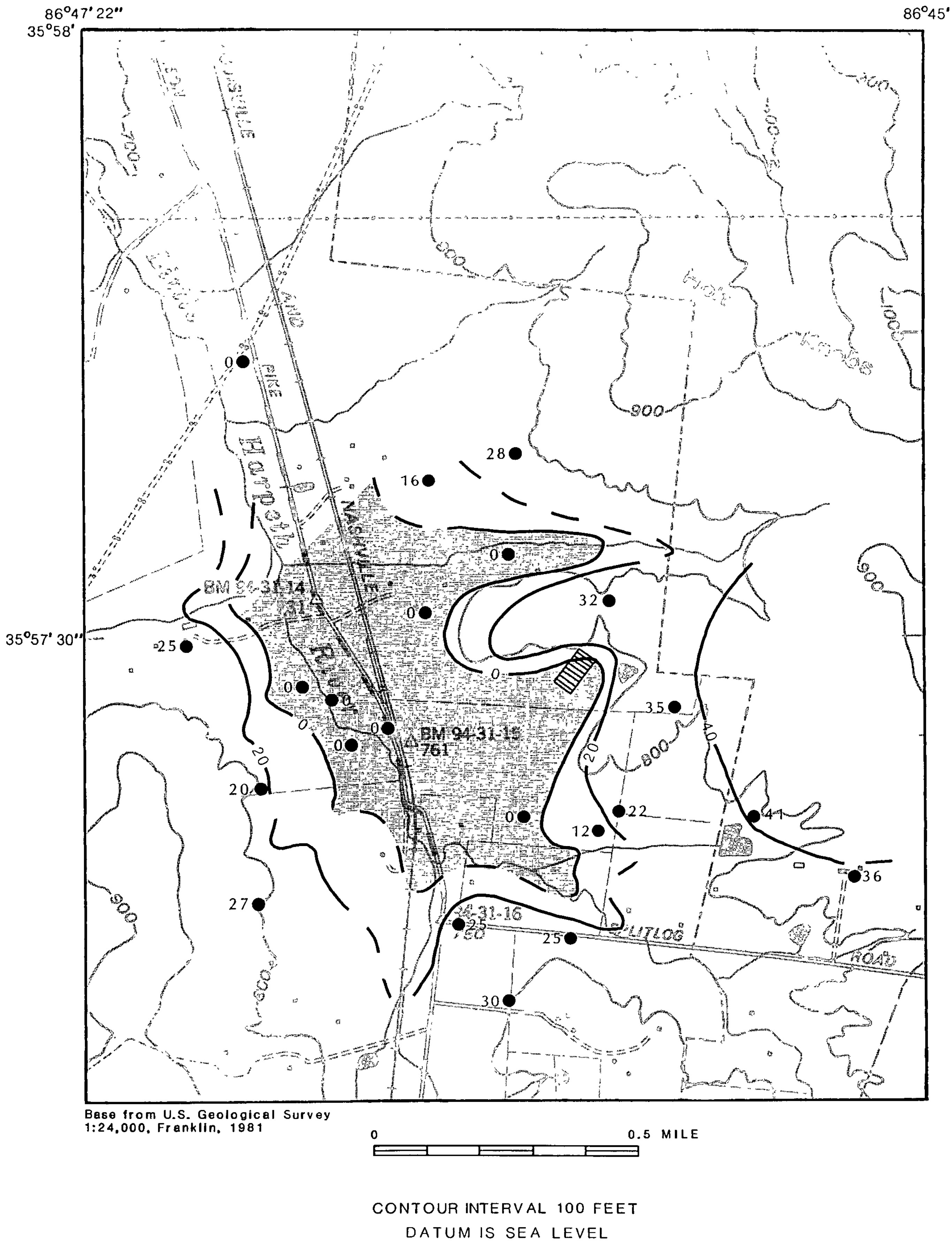


Figure 4.--Relation between geologic and hydrogeologic units, and model layers and boundaries.


86°47'22"
86°45'
35°58'
35°57'30"
BM 94-31-14
BM 94-31-15
761
94-31-16
NASHVILLE
PIKE
Harpeth River
Holt Knobs
LITLOG
ROAD
900
800
700
1000
0
16
28
0
32
0
25
0
0
0
0
35
20
22
12
41
27
0
36
25
25
30
20
40
Base from U.S. Geological Survey
1:24,000, Franklin, 1981
0
0.5 MILE
CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

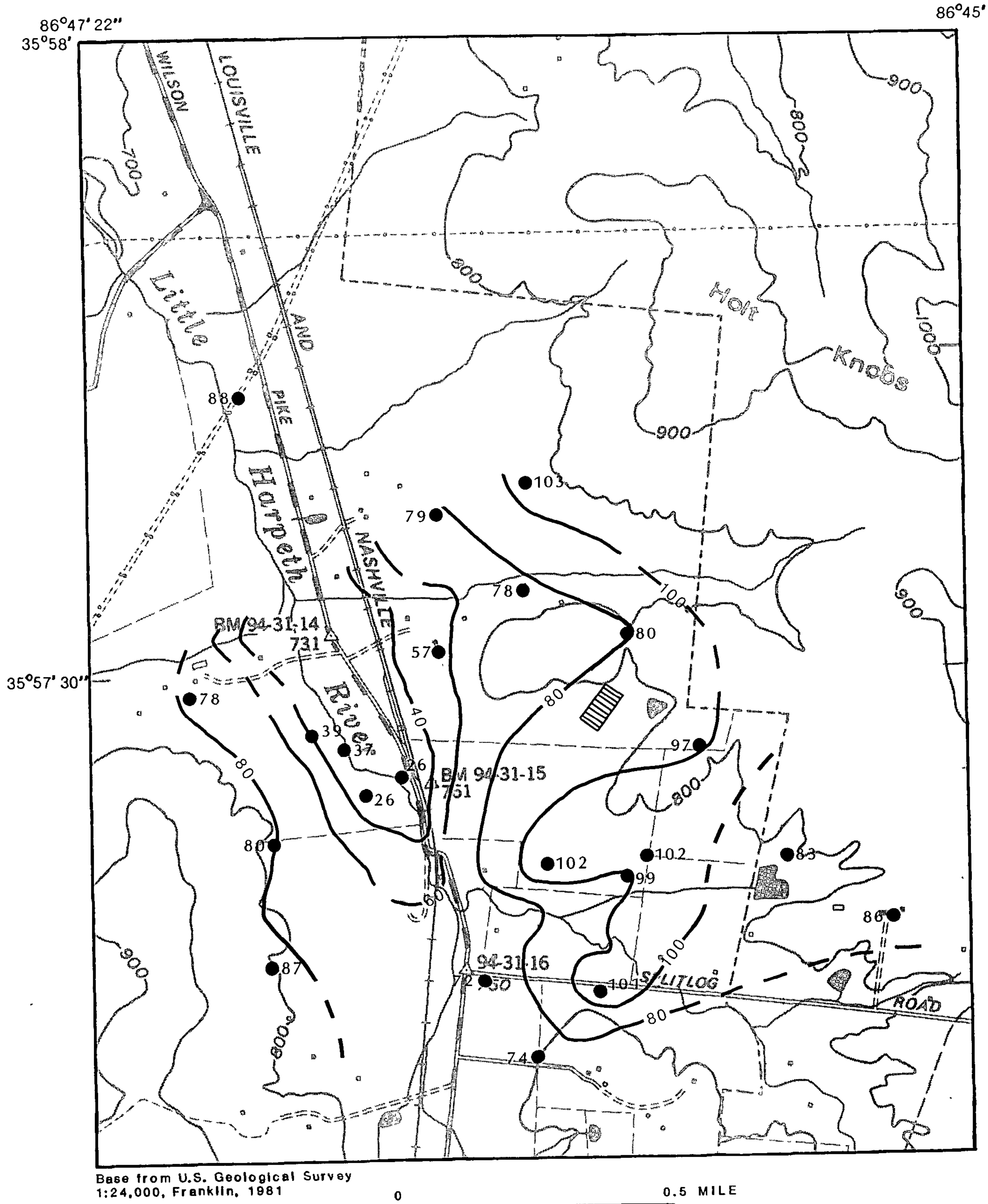
DISPOSAL SITE

AREA OF HERMITAGE FORMATION OUTCROP

20 — LINE OF EQUAL THICKNESS OF THE BIGBY-CANNON LIMESTONE--Dashed where approximately located. Interval 20 feet. Datum is sea level

25 ● WELL LOCATION AND THICKNESS OF THE BIGBY-CANNON LIMESTONE, IN FEET

Figure 5.--Thickness of the Bigby-Cannon Limestone.



CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

DISPOSAL SITE

80 — LINE OF EQUAL THICKNESS OF THE HERMITAGE FORMATION--Dashed where approximately located. Interval 20 feet. Datum is sea level

26 ● WELL LOCATION AND THICKNESS OF THE HERMITAGE FORMATION, IN FEET

Figure 6.--Thickness of the Hermitage Formation.

Formation in the vicinity of the disposal site. Tests at seven of the wells, completed only in the Hermitage Formation, indicated an average hydraulic conductivity value of 0.17 ft/d. Based on the average hydraulic conductivity values (4.4 ft/d) and the average saturated thickness in the disposal site area (15 feet), the average transmissivity in the area is 66 ft^2/d. Using the average saturated thickness of 15 feet, transmissivity values range from 0.5 to 426 ft^2/d. The largest hydraulic conductivity values were from slug tests conducted on wells completed in an "unconsolidated zone" or that were close to the contact of the Bigby-Cannon Limestone and the Hermitage Formation. None of the wells tested appear to be completed only in the Bigby-Cannon Limestone.

Regional transmissivity values for the shallow ground-water system were estimated in the drainage basin upstream of the Harpeth River at Franklin (A.B. Hoos, U.S. Geological Survey, written commun., 1986) using the streamflow recession method of Rorabaugh and Simons (1966). Data from this basin were used because it contains the gaging station closest to the study area and includes a similar geologic setting. An estimate of transmissivity can be made by this method using the equation:

$$T = \frac{0.933\, a^2 S}{Ri}$$

where

- T = transmissivity, in feet squared per day;
- S = storage coefficient (unitless);
- a = average distance from stream to hydrologic divide, in feet; and
- Ri = streamflow recession index, in days.

For the Harpeth River at Franklin: a = 1,032 feet as determined from stream density, Ri = 32 days as determined from hydrograph-separation analysis, and S = 0.003, resulting in a calculated transmissivity value of 93 ft^2/d. The equation and resulting transmissivity value are sensitive to the value chosen for storage coefficient. For example, use of S = 0.01 in the equation would result in a calculated transmissivity value of 310 ft^2/d. The value for storage coefficient (0.003) was calculated as the ratio between base flow in the stream per unit area to a corresponding decline in water level in a nearby well during the streamflow recession (Olmsted and Hely, 1962). Because wells in the area generally are low yielding, a transmissivity value of 93 ft^2/d for the shallow ground-water system is considered a reasonable estimate.

An aquifer test was conducted at well Wm:N-044A, which is completed in the Carters Limestone. The well was pumped for 4.5 hours at about 50 gal/min. Drawdown was measured in the pumped well and in 13 observation wells in the vicinity. Measurable drawdowns were observed in only three of seven wells completed in the Carters Limestone (fig. 7). The effects of pumping were not observed in any of the six shallow wells. The shape of the cone of depression is elongated northwest to southeast (fig. 7), indicating that the transmissivity of the Carters Limestone is anisotropic and is greater in a northwest-southeast than in a northeast-southwest direction. Analysis of the aquifer test data indicate transmissivity values of 180 ft^2/d at the pumped well and from 130 to 160 ft^2/d at the three observation wells in which measurable drawdowns were obtained (R.E. Faye, U.S. Geological Survey, written commun., 1988).

Slug-test results reported by Geraghty and Miller (1987, table 11) indicate an average hydraulic conductivity of 0.34 ft/d for the upper part of the Carters Limestone. Multiplying this average hydraulic conductivity value by an average thickness of the Carters Limestone of 72 feet results in an average transmissivity value of about 25 ft^2/d. An average value of 2×10^{-4} ft/d for "vertical permeability" of the Hermitage Formation is also reported by Geraghty and Miller (1987, table 6).

HYDROLOGY

SURFACE WATER

The Little Harpeth River is the primary stream in the study area (fig. 1) and is perennial. Most of the tributaries to the river are intermittent streams and are dry for much of the year. The drainage basin of the Little Harpeth River has a total area of 22 mi^2, but the drainage area within the study area is only 6 mi^2. Flow measured at a station 9 miles north of the study area shows a range in discharge from 0.05 to 9,260 ft^3/s from 1978 to 1986. Data are not available for the average discharge of the river; however, in the study area the Little Harpeth River probably averages less than 10 ft^3/s.

Discharge measurements were made at 20 sites on the Little Harpeth River and its tributaries (fig. 8) on April 20, 1987, during high base flow to determine streamflow gains from and losses to the ground-water system. During this seepage investigation, the Little Harpeth River was a gaining stream for its entire length; however, a small tributary to the southwest, which heads in a stock pond, lost about 0.2 ft^3/s to the ground-water system (fig. 8). Total discharge of the Little Harpeth River for the 6 mi^2 drainage area was about 4.5 ft^3/s during this seepage investigation.

Several stock ponds, which contain water most of the year, are also present in the study area; and springs, such as Hackett's Spring (fig. 1), commonly are present at the Bigby-Cannon Limestone and Hermitage Formation contact.

GROUND WATER

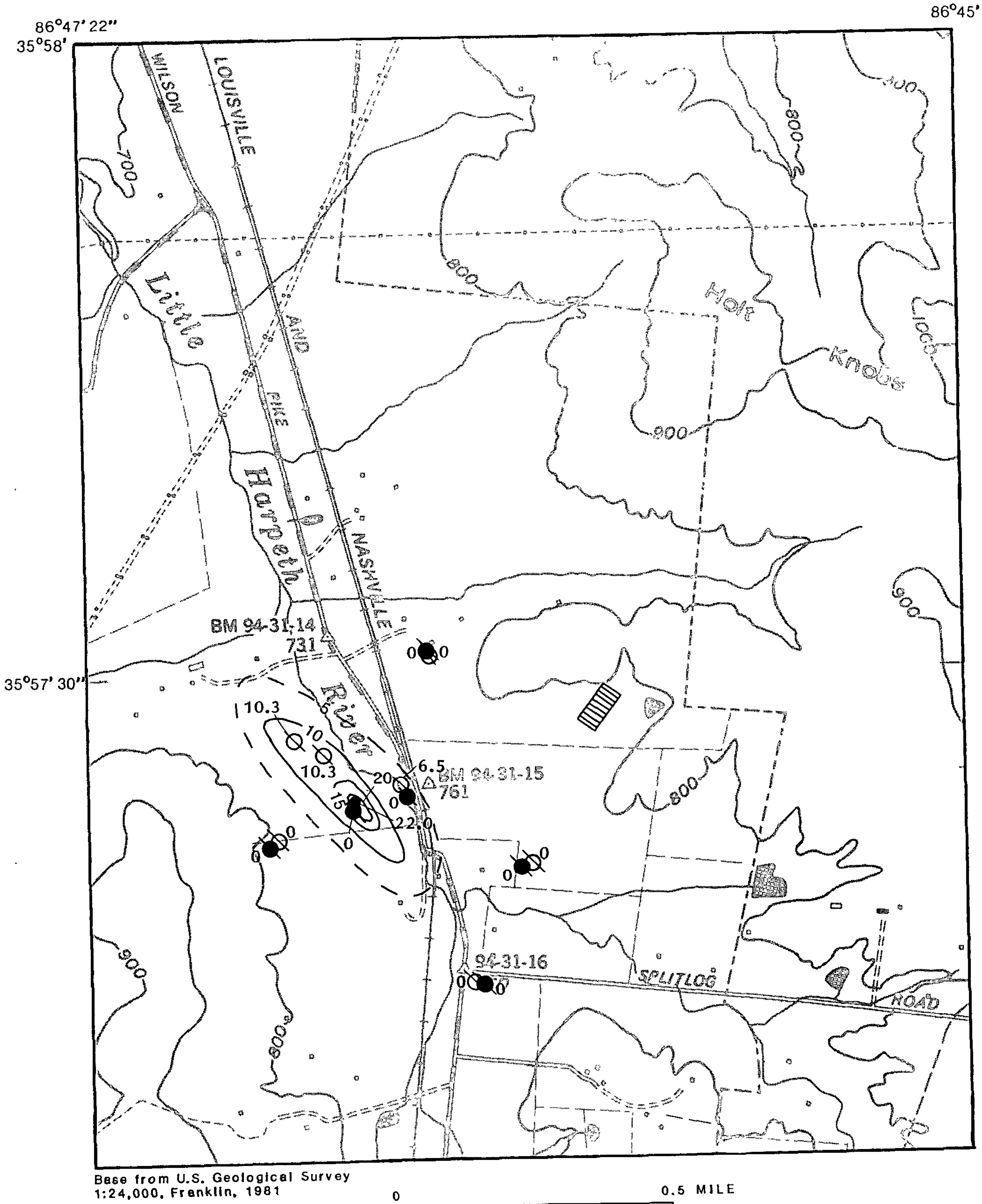
The ground-water system of the study area consists of two aquifers and two confining units. The upper aquifer includes the regolith, Bigby-Cannon Limestone, and the upper, weathered part of the Hermitage Formation, where the Bigby-Cannon has been removed by erosion (fig. 4). Because of the gradual decrease in weathering and the consequent decrease in hydraulic conductivity of the Hermitage Formation with depth, the bottom of the upper aquifer is not well defined. Lithologic samples obtained during drilling indicate that the depth of weathering is shallow in the Hermitage outcrop area, and that the upper aquifer is probably less than 20 feet thick in those areas.

The lower aquifer corresponds to the Carters Limestone. This aquifer generally yields 1 gal/min or less to wells over most of the study area; however, well Wm:N-044A produced 80 gal/min from the lower aquifer. The lower aquifer is a source of water for several domestic wells within the study area.

The upper and lower aquifers are separated by the Hermitage confining unit, which consists of the unweathered parts of the Hermitage Formation. Available water-level and water-quality data, which will be discussed in more detail in subsequent sections, indicate that this unit effectively isolates the two aquifers. The Lebanon confining unit, which consists of the Lebanon Limestone, separates the lower aquifer from deeper formations that are used locally as sources of water for domestic wells. The Lebanon confining unit is considered the lower boundary of ground-water flow of interest to this study. Both the Hermitage and Lebanon confining units contain abundant interbedded shale, which restricts vertical ground-water flow.

RECHARGE AND DISCHARGE

Recharge to the ground-water system is primarily from infiltration of precipitation, although some recharge probably occurs from losing reaches of the Little Harpeth River during periods of high stream stage. Most recharge



CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

DISPOSAL SITE

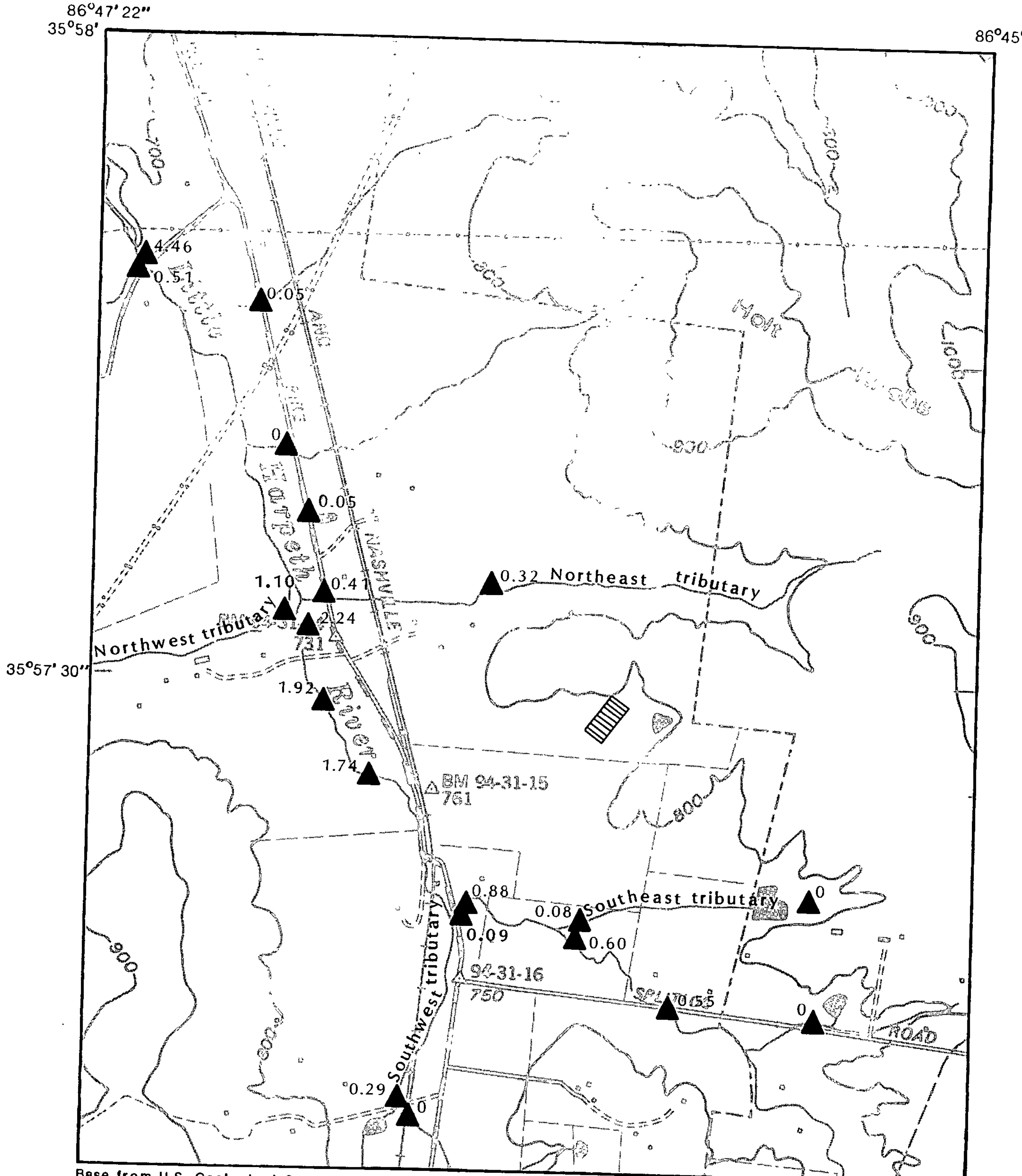
5 — LINE OF EQUAL DRAWDOWN--Dashed where approximately located. Interval 5 feet. Datum is sea level

22.0 — PUMPED WELL (Wm:N-044A) AND DRAWDOWN, IN FEET

6.5 — DEEP OBSERVATION WELL AND DRAWDOWN, IN FEET

0 — SHALLOW OBSERVATION WELL AND DRAWDOWN, IN FEET

Figure 7.-- Cone of depression for aquifer test at well Wm:N-044A.



Base from U.S. Geological Survey 1:24,000, Franklin, 1981

0 — 0.5 MILE

CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

DISPOSAL SITE

STOCK POND

4.46 DISCHARGE-MEASUREMENT SITE--
Amount of discharge, in cubic
feet per second

Figure 8.--Discharge-measurement sites and amount of discharge for seepage investigation, April 20, 1987.

probably occurs during the late fall, winter, and early spring months (November to April), when precipitation is high and plants are mostly dormant. Ground water also enters the lower aquifer as underflow from the southern part of the study area. Discharge from the ground-water system primarily occurs as seepage to streams. Evapotranspiration and underflow out of the study area are only minor components of ground-water discharge.

Direct measurements of average annual recharge are not available for the study area. Data are available from Franklin, approximately 7 miles south of the study area, and these data may provide some insight into general recharge rates. Hydrograph-separation techniques (Rorabaugh, 1964; Daniel, 1976) for streamflow data for the Harpeth River at Franklin yield estimates of recharge of 3.7, 6.0, and 7.7 in/yr for dry, normal, and wet years, respectively (A.B. Hoos, U.S. Geological Survey, written commun., 1986). Zurawski and Burchett (1980, p. 12) state that an average annual recharge rate for the Franklin area of 8 in/yr "may be a low estimate," and that up to an additional 7 in/yr may be entering the ground-water system, for a maximum average-annual recharge rate of 15 in/yr.

Estimates of recharge can also be made based on measurements of base flow to streams, assuming steady-state conditions (recharge is equal to discharge) are valid. Discharge measurements were made for the Little Harpeth River and its tributaries on April 20, 1987 (fig. 8). Total discharge for the 6-mi^2 drainage area at this time was 4.5 ft^3/s (fig. 8). If steady-state conditions are assumed, recharge is estimated to be about 5 inches for the entire drainage area. Discharge within the smaller, 1.4 mi^2, model area (discussed in a subsequent section) is estimated to be 2.0 ft^3/s, which is equal to about 9 inches of recharge for that area. A recharge of 9 inches is equal to about 33 percent of reported precipitation from November 1986 through April 1987 at Franklin (27 inches). It is important to note that these estimates are made for stream discharge at high base-flow conditions, so that they represent recharge rates that are greater than average-annual recharge. Estimated recharge values based on measurements made on April 20, 1987, may also be somewhat higher than actual recharge for the November 1986 to April 1987 period, because discharge on that day was probably somewhat higher than baseflow. Continuous-discharge measurements for the Harpeth River at Franklin indicate that streamflow was still receding from rainfall that had occurred about a week prior to the April 20 discharge measurements (fig. 9).

GROUND-WATER FLOW

A network of 69 wells (figs. 1 and 2), completed in both the upper and lower aquifers, was used to construct a water-table map of the upper aquifer (fig. 10) and a potentiometric-surface map of the lower aquifer for April 20, 1987 (fig. 11). From these maps, the general direction of ground-water movement can be inferred (figs. 10 and 11).

Flow in the upper aquifer generally is from the hills on the east and west towards the Little Harpeth River, and towards the north along the river (fig. 10). Ground water in the upper aquifer leaves the study area in a narrow zone under the Little Harpeth River. Ground-water flow at the disposal site is toward a small topographic depression that drains the site.

Flow directions in the lower aquifer can only be generally inferred from the potentiometric-surface map because of the anisotropic nature of the lower aquifer. Anisotropy causes flow to be skewed in the direction of the main transmissivity tensor, which is oriented northwest-southeast in the study area. Water in the lower aquifer generally flows from the south, southeast, and west toward an area that is approximately parallel to the river, and north out of the

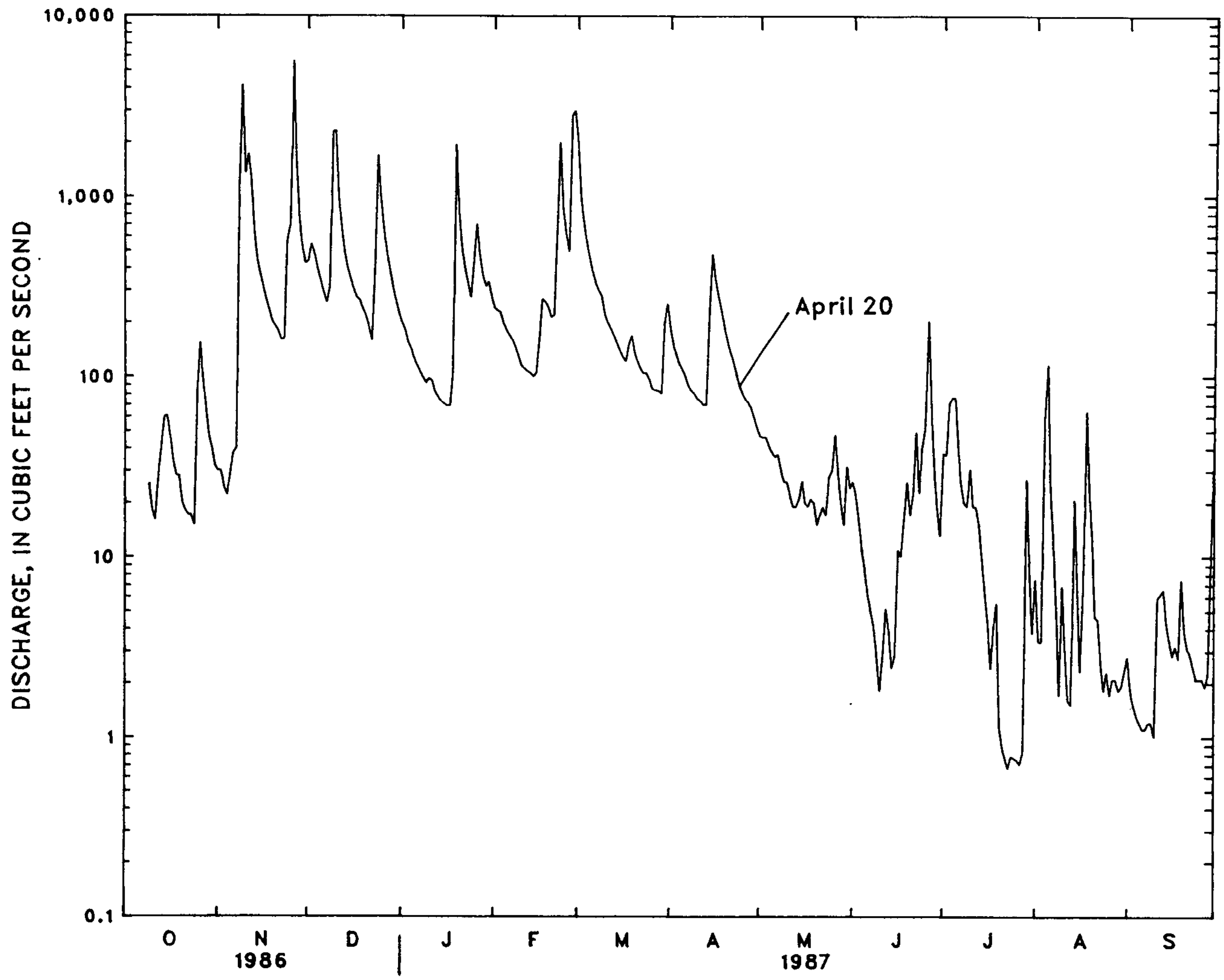
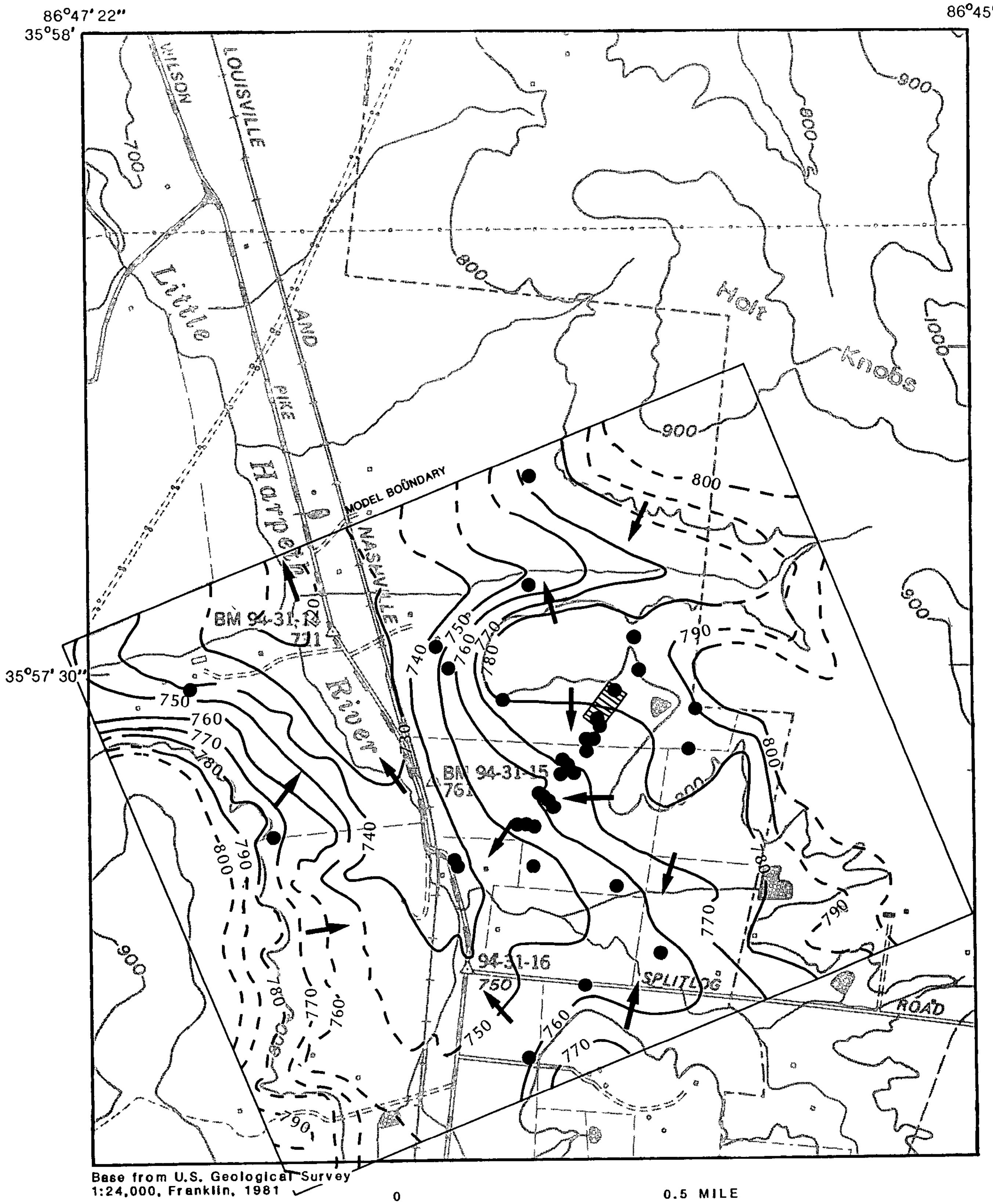


Figure 9.--Mean daily discharge for the Harpeth River at Franklin, Tennessee

study area (fig. 11). Although water levels in both the upper and lower aquifers may fluctuate up to 5 feet annually, the general patterns of lateral ground-water flow remain the same throughout the year.

The potential for vertical movement of water between the aquifers can be assessed by comparing water levels in each aquifer at a site. For example, water levels are higher in the upper aquifer (well Wm:N-051) than the lower aquifer (well Wm:N-051A, fig. 12a) at a site on the hill near the disposal site. This difference in water levels indicates a potential for downward flow of ground water to the lower aquifer. This downward gradient exists over much of the study area. At two sites at lower elevations, ground-water levels were higher in the lower aquifer (well Wm:N-058A) than in the upper aquifer (well Wm:N-058, fig. 12b) during the winter and spring of 1987. During that time, there was a potential for some upward flow from the lower aquifer. Although potential for interaquifer flow exists in the study area, water-level differences between the aquifers of as much as 50 feet indicate that the intervening Hermitage confining unit is effective in isolating the upper and lower aquifers.

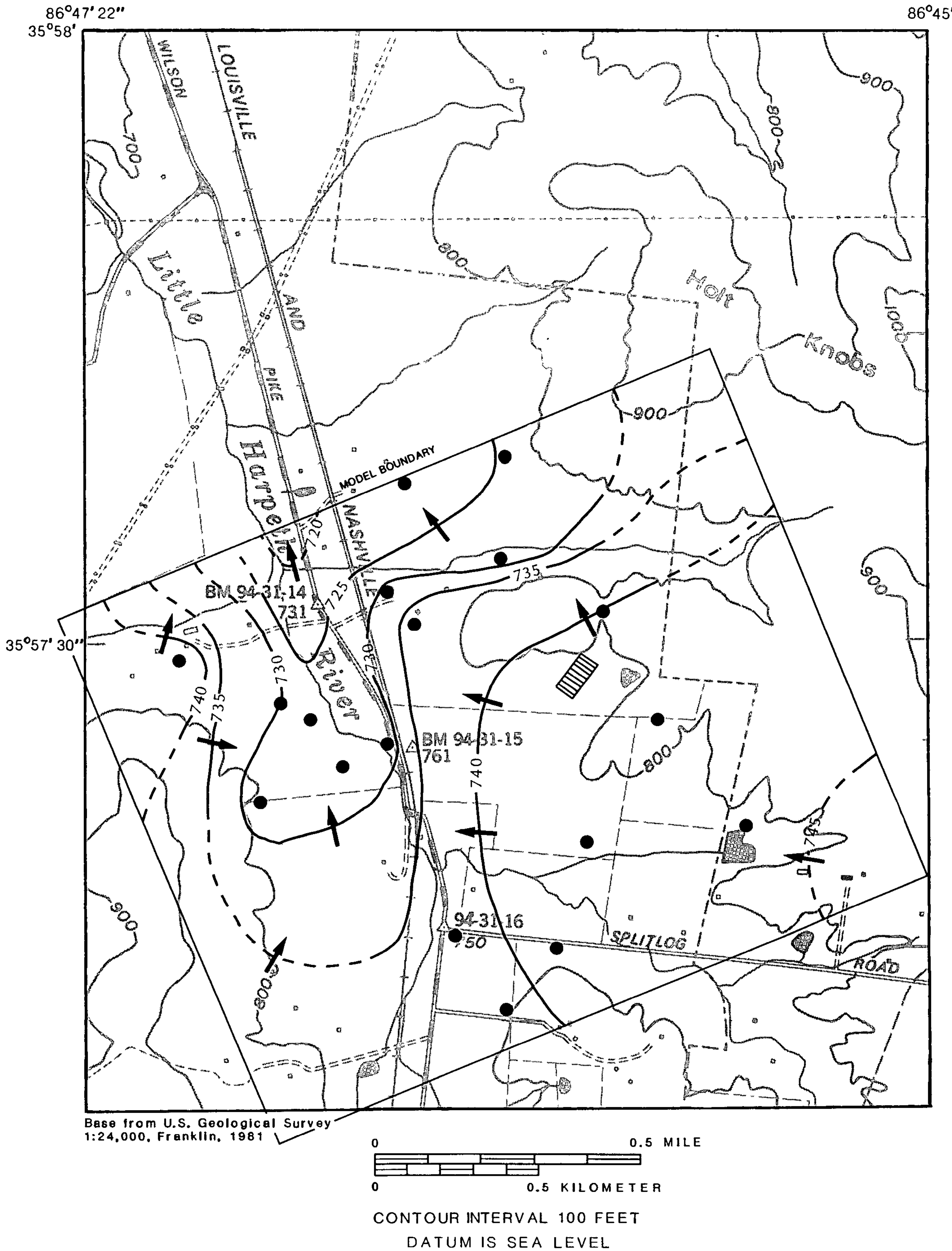


CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

	DISPOSAL SITE
—— 800 – –	WATER LEVEL CONTOUR--Shows altitude of water level. Dashed where approximately located. Contour interval 10 feet. Datum is sea level
	GENERALIZED DIRECTION OF GROUND-WATER FLOW
●	WELL

Figure 10.--Water levels and generalized directions of ground-water flow for the upper aquifer, April 20, 1987.


86°47'22"
86°45'
35°58'
35°57'30"
WILSON
LOUISVILLE
AND
NASHVILLE
PIKE
Little
Harpeth
River
Holt
Knobs
MODEL BOUNDARY
BM 94-31-14
731
BM 94-31-15
761
94-31-16
750
SPLITLOG
ROAD
700
720
725
730
735
740
800
900
1000
Base from U.S. Geological Survey
1:24,000, Franklin, 1981
0
0.5 MILE
0
0.5 KILOMETER
CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

DISPOSAL SITE

— 740 — — WATER LEVEL CONTOUR--Shows altitude of water level. Dashed where approximately located. Contour interval 5 feet. Datum is sea level

GENERALIZED DIRECTION OF GROUND-WATER FLOW

WELL

Figure 11.--Water levels and generalized direction of ground-water flow for the lower aquifer, April 20, 1987.

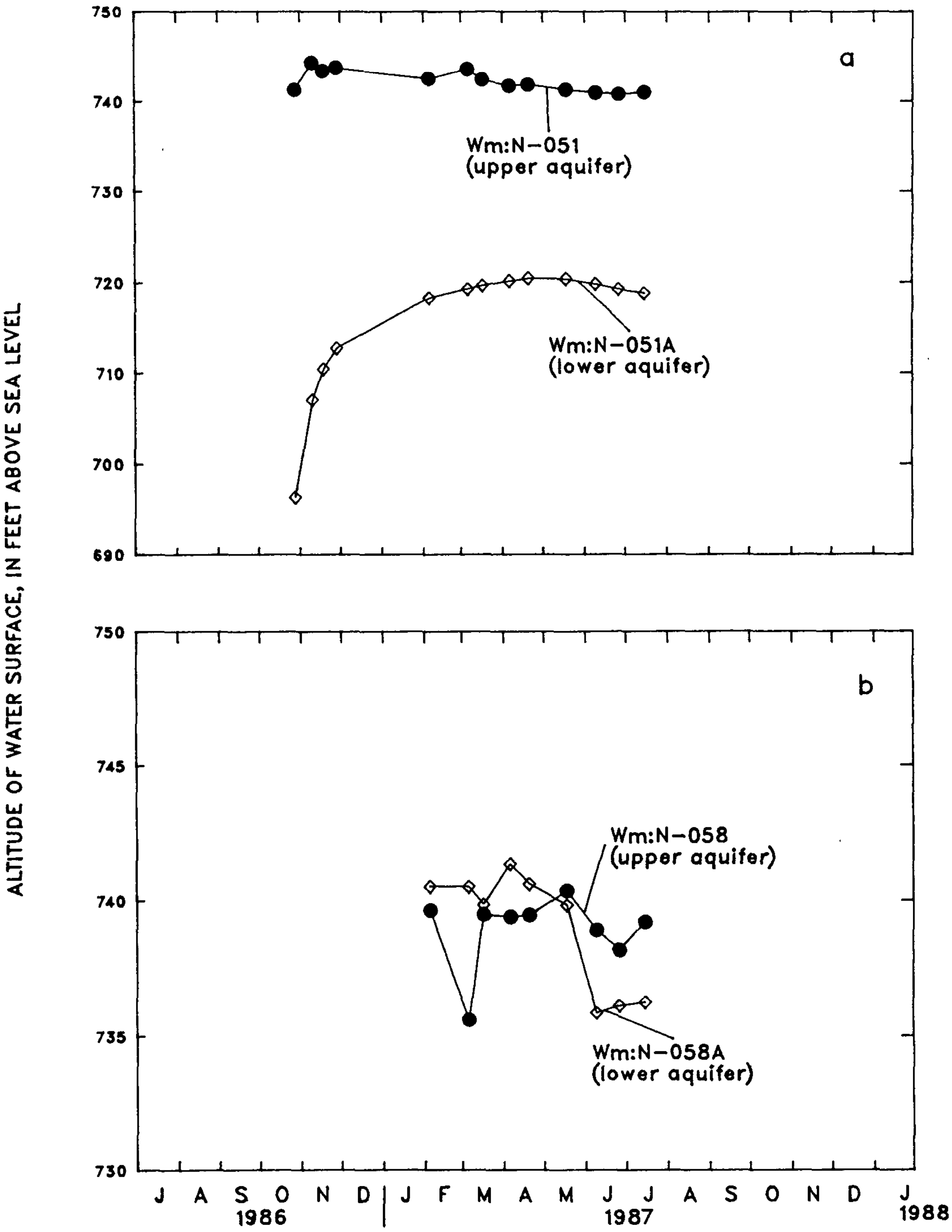


Figure 12.--Comparison of water levels in the upper and lower aquifers.

GROUND-WATER CHEMISTRY

Ground water from wells and springs in the study area contains solutes typical of carbonate rock aquifers in Middle Tennessee (Rima and Goddard, 1979). Although some of the wells are open to both the Hermitage Formation and Carters Limestone, the geologic unit supplying water (table 1) to each well was determined during drilling operations. Hackett's Spring appears to be a contact spring in the Bigby-Cannon Limestone above the Hermitage Formation. Samples of ground water from seven wells and one spring (table 1) had concentrations of dissolved solids ranging from 228 to 1,220 mg/L, and averaging about 720 mg/L. Three distinctive water chemistries were determined for this study area based on the principal dissolved constituents (fig. 13) identified by using Piper diagram analysis (Piper, 1953). Water from the Hermitage Formation has a calcium magnesium bicarbonate sulfate composition in wells Wm:N-044 and Wm:N-052, and a calcium magnesium sulfate bicarbonate composition in well Wm:N-055. Chemistry of water from the Carters Limestone is sodium sulfate bicarbonate dominated from wells Wm:N-052A and Wm:N-055A. Water from well Wm:N-043A is similar, but is sodium bicarbonate sulfate in chemical character. Waters from well Wm:N-044A and from Hackett's Spring are both calcium bicarbonate dominated.

Three different water compositions were identified (fig. 13). Chemical compositions of water from the Hermitage Formation and the Carters Limestone comprise two of the three solute chemistries. Well Wm:N-044A, completed in the Carters Limestone, and Hackett's Spring are chemically similar although from different geologic units. The chemistry of water from well Wm:N-044A does not resemble the chemistry of other water from the Carters Limestone, but is chemically similar to water from Hackett's Spring. This chemical difference from other water from the Carters Limestone indicates that water in well Wm:N-044A occurs in deep fractures or solution openings in the Carters Limestone that are hydraulically connected to shallow circulating water that is similar to water at Hackett's Spring.

Well yield from Wm:N-044A was approximately 80 gal/min, whereas other wells completed in the Carters Limestone produced less than 1 gal/min. This larger well yield suggests higher hydraulic conductivity and rapid circulation of ground water near well Wm:N-044A. Rapid circulation of ground water would result in less dissolution of the limestone aquifer. Thus, the chemistry of rapidly circulating water in the Carters Limestone could resemble rapidly circulating water in the Bigby-Cannon Limestone, rather than the chemistry of water of limited circulation in the Carters Limestone.

The chemical composition of water from the Little Harpeth River, collected in April 1987, under high base-flow conditions, was also plotted on the Piper diagram. The plotted points are tightly clustered and indicate a calcium bicarbonate dominated water, which is similar to that in well Wm:N-044A and Hackett's Spring.

Other chemical data of ground water also show the same three hydrogeologic distinctions. Concentrations of dissolved sodium range from 18 to 37 mg/L in water from the Hermitage Formation. Dissolved-sodium concentrations in water from the Carters Limestone are greater, ranging from 190 to 350 mg/L. The waters from well Wm:N-044A and Hackett's Spring contain 4.3 mg/L and 1.2 mg/L dissolved sodium, respectively. The differences are graphically illustrated in figure 14a.

Similar geochemical distributions occur for dissolved lithium (fig. 14a) and for dissolved chloride and fluoride (fig. 14b). In each case, these solute concentrations were highest in samples from the three wells in the Carters Limestone, somewhat less in samples from the

Table 1.--*Ground-water quality in the disposal site area*

[All constituents are dissolved and in milligrams per liter unless otherwise specified. The values of temperature, pH, bicarbonate, and carbonate are field determinations unless otherwise noted. (*) denotes lab determination of bicarbonate. ROE = residue on evaporation at 180 °C; TOC = total organic carbon]

Well No.	Wm:N044	Wm:N052	Wm:N055	Wm:N043A	Wm:N052A	WM:N055A	WM:NO44A	Hackett's Spring
Geologic unit	Hermitage Formation	Hermitage Formation	Hermitage Formation	Carters Limestone	Carters Limestone	Carters Limestone	Carters Limestone	Bigby-Cannon Limestone
Open interval (feet below land surface)	5-34	19.5-35	5.8-30	15-102	33-132	26-77	20-102	Land surface
Date of sample	6-2-87	6-2-87	6-5-87	5-28-87	5-28-87	6-5-87	10-16-87	6-5-87
Temperature (°C)	16.0	16.0	17.0	17.0	15.5	16.0	15.0	16.5
Specific conductance (microsiemens per centimeter)	670	840	2,200	1,280	1,820	1,600	380	450
pH (units)	7.40	7.30	7.40	7.70	7.70	7.61	7.50	7.38
Solids (ROE at 180 °C)	410	551	1,120	820	1,220	1,150	228	269
Ammonium	.02	.03	.13	.69	.77	1.2	.12	.01
Calcium	64	120	190	37	39	72	66	89
Magnesium	26	24	70	31	24	50	13	4.6
Sodium	37	36	18	190	350	220	4.3	1.2
Potassium	6.5	2.3	1.6	8.3	10	10	1.1	.3
Bicarbonate	*306	*375	251	409	442	314	261	267
Carbonate	0	0	0	0	0	0	0	0
Chloride	3.0	10	8.8	29	51	31	4.4	6.0
Sulfate	99	140	580	300	530	580	24	15
Fluoride	.7	1.3	1.4	3.1	3.9	3.1	.6	.2
Silica	7.9	9.3	12	8.8	11	8.8	9.0	6.6
Total organic carbon	1.0	3.0	1.3	1.0	1.0	.5	4.0	1.1
Nitrite and nitrate	.56	.34	.06	.021	.021	.021	.02	.7
Bisulfide	--	--	45	79	38	38	--	--
Barium (µg/L)	< 100	< 100	< 100	< 100	< 100	< 100	200	< 100
Boron (µg/L)	690	100	190	520	870	590	--	30
Iron (µg/L)	10	< 10	140	20	170	60	760	< 10
Lithium (µg/L)	70	10	20	300	540	340	--	< 10
Manganese (µg/l)	110	30	70	< 10	20	< 10	140	< 10
Strontium (µg/L)	10,000	6,000	4,900	10,000	3,600	8,200	1,500	210

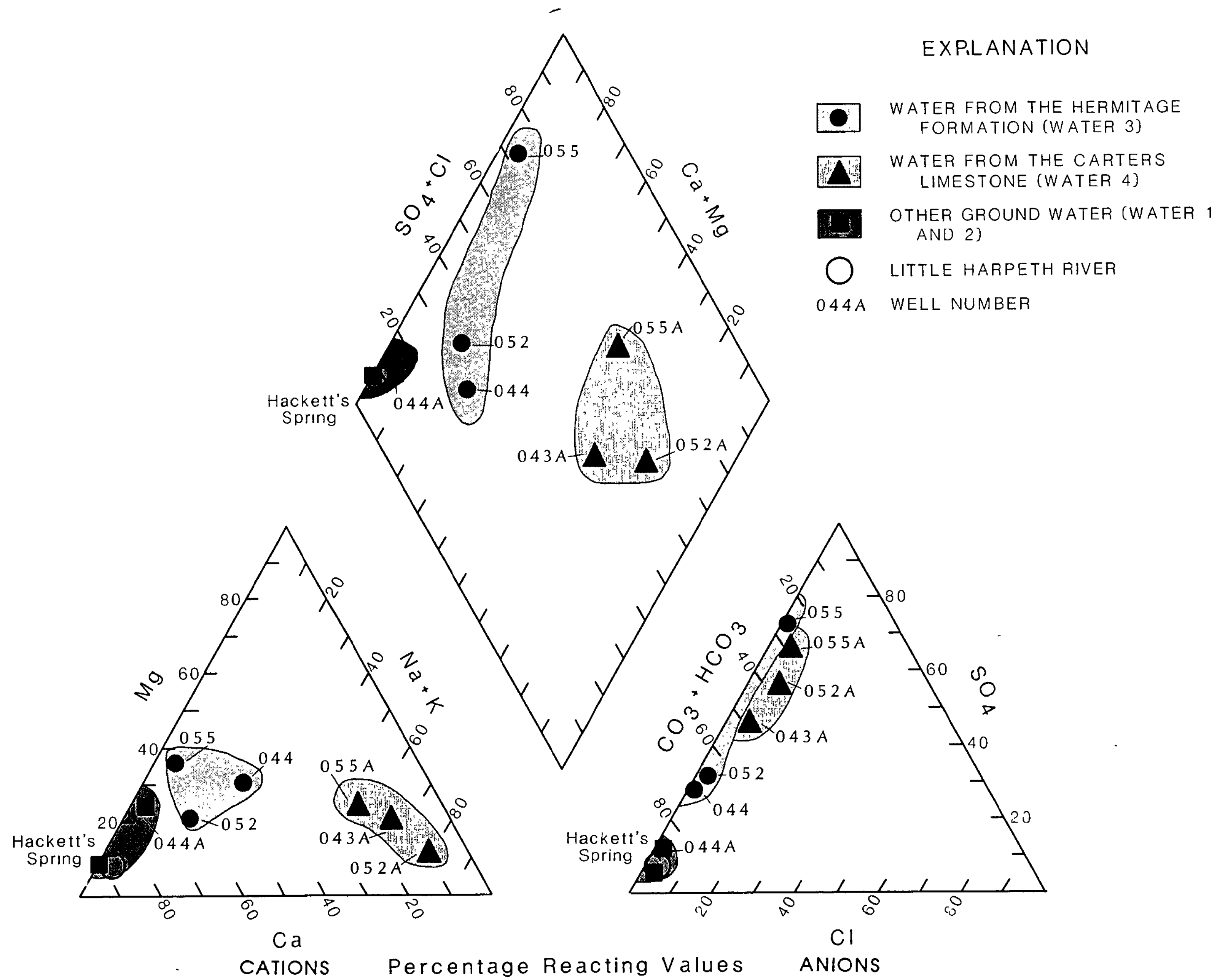


Figure 13.--Piper diagram of chemistry of ground water and surface water.

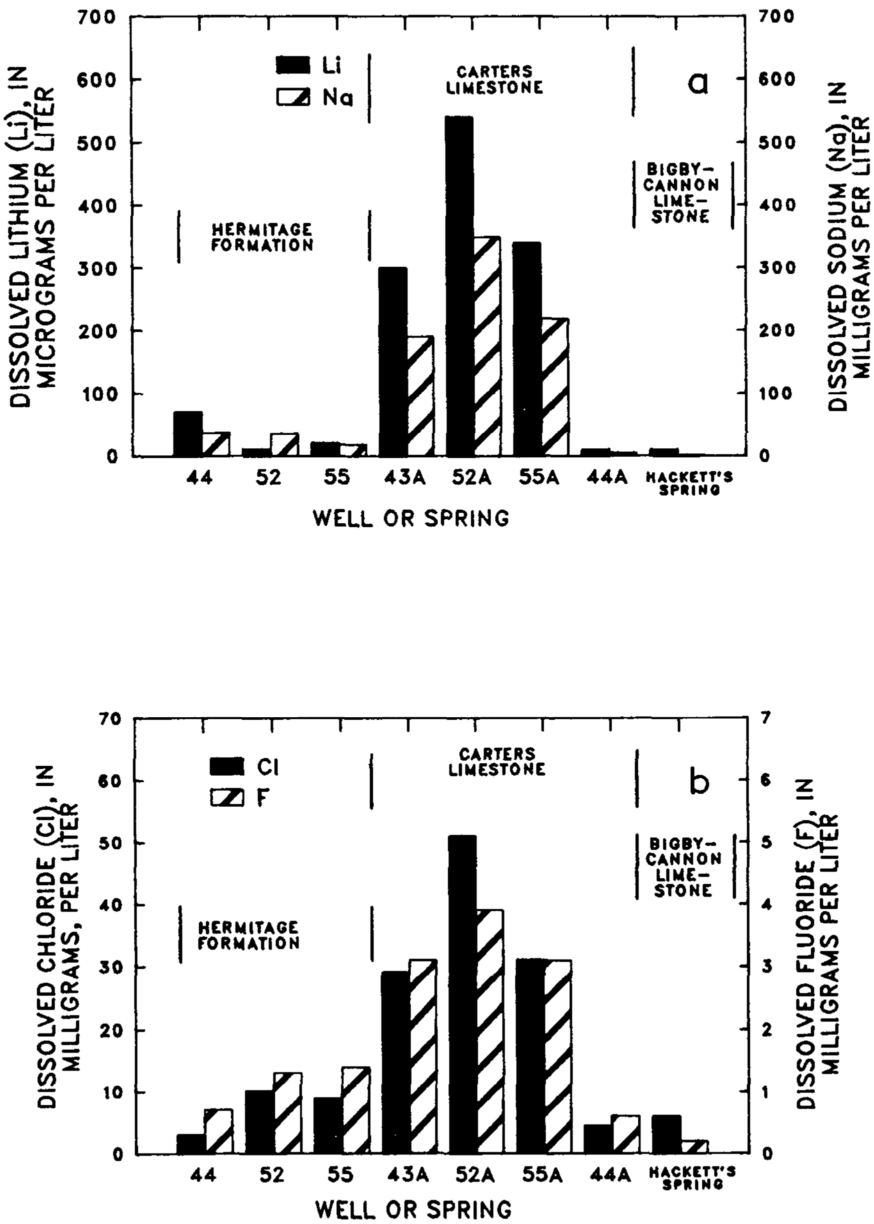


Figure 14.--Concentrations of (a) dissolved sodium and dissolved lithium, and (b) dissolved chloride and dissolved fluoride in ground water.

three wells completed in the Hermitage Formation, and generally lowest in samples from well Wm:N-044A and Hackett's Spring. The concentration of dissolved chloride is lower in water from well Wm:N-044, however, than in water from Wm:N-044A and Hackett's Spring.

Other solutes demonstrating hydrogeologic distinctions are dissolved sulfate, boron, and strontium. Concentrations of these constituent are similar for water from the Hermitage Formation and Carters Limestone (sulfate--99 to 580 mg/L; boron--100 to 870 μg/L; strontium--3,600 to 10,000 μg/L); however, these constituents are significantly different from corresponding concentrations in water from well Wm:N-044A and Hackett's Spring (sulfate--24 and 15 mg/L; boron--20 and 30 μg/L; strontium--1,500 and 210 μg/L, respectively). Although geochemical data do not fully distinguish water from both the Hermitage Formation and Carters Limestone, differences between water from the Carters Limestone and waters from well Wm:N-044A and Hackett's Spring are discernible. Some geochemical distinction between water from well Wm:N-044A and Hackett's Spring is evident from dissolved-strontium concentrations; however, more chemical data are required to explain this observation.

The geochemical data combined with the present understanding of the hydrogeology in the study area suggest a ground-water flow system consisting of four hydrogeochemical regimes (fig. 15). The four regimes are described as water 1 through water 4 (fig. 13).

Water 1 is best defined by the chemistry of water from Hackett's Spring. This regime probably represents water which has circulated only in the shallow bedrock system for a short time without dissolving much of the rock matrix.

Water 2 is best defined by the chemistry of water from well Wm:N-044A. Here the ground water has circulated rapidly to depth (more than 100 feet) along permeable zones without dissolving much of the rock matrix. The water chemistry is similar to water 1, although it is acquiring the chemical character of its aquifer environment as indicated by greater concentrations of trace metals, iron, manganese, barium, and strontium.

Water 3 is defined by its aquifer environment, the weathered part of the Hermitage Formation. This water has not circulated deeply but is contained in the upper part of the Hermitage Formation near the regolith-bedrock contact.

Water 4 is generally defined by its aquifer environment, the Carters Limestone. Water 4 has circulated deeply but is contained in less permeable parts of the aquifer than water 2 and, therefore, has achieved a water chemistry considerably different from water 2.

The occurrence of these four hydrogeochemical regimes is consistent with the ground-water flow concepts developed from the hydrogeologic part of this investigation; that is, two distinct aquifers separated by an effective confining unit are indicated. Other flow patterns such as mixing of ground water with recharge water or cross-formational flow and mixing of ground waters is not indicated by geochemical data in the area around the disposal site. A summary of the chemical and hydrogeologic classifications is given in table 2.

GROUND-WATER FLOW MODEL

MODEL CONSTRUCTION

A numerical ground-water flow model was used to provide a better understanding of the workings of the flow system in the study area. Models are useful tools for this purpose because they incorporate all of the major components that affect ground-water flow, and allow for the

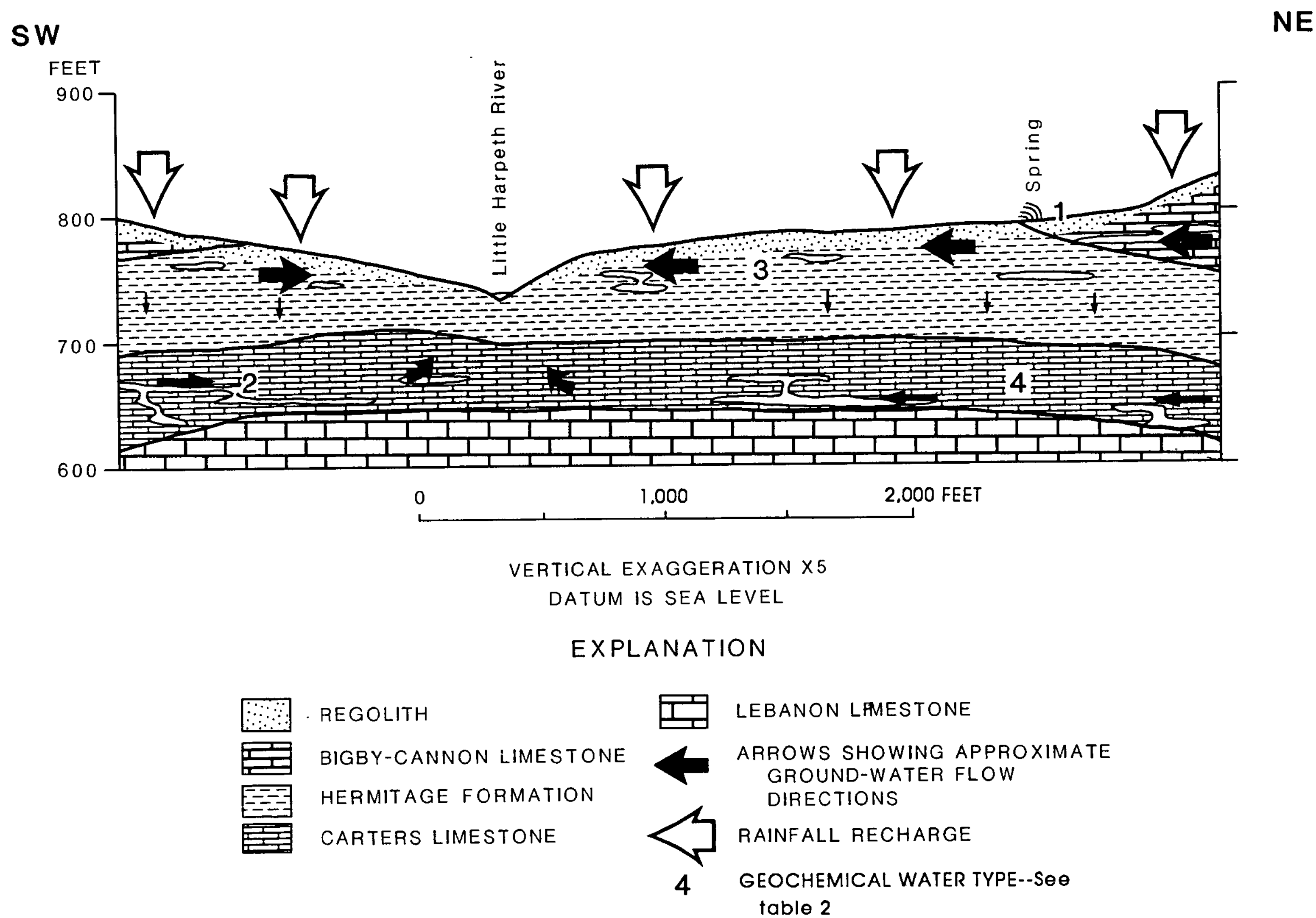


Figure 15.--Conceptual model of the ground-water flow system and geochemical water types.

Table 2.--*Chemical and hydrogeological classification of ground water in the disposal site area*

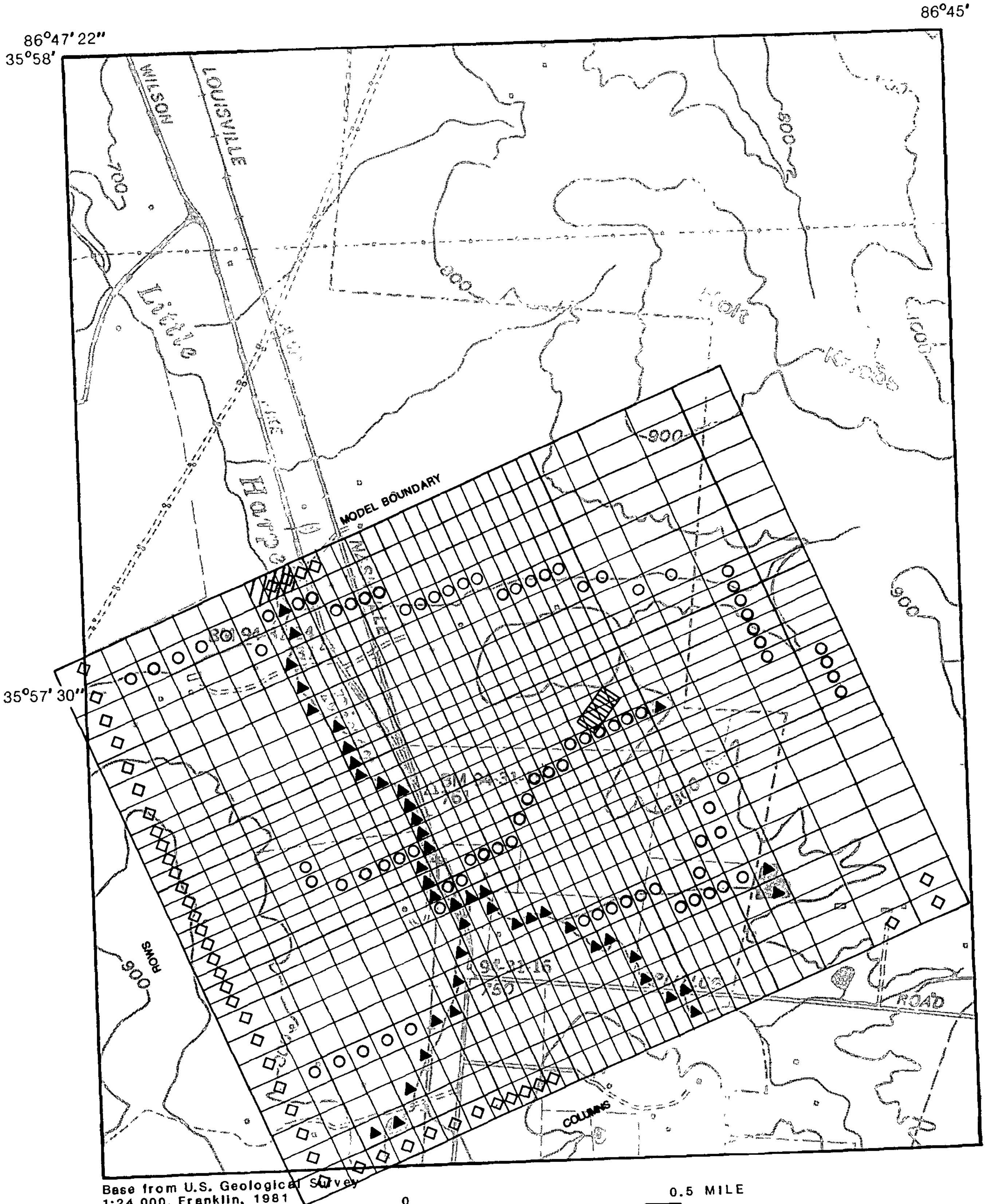
Water type	Chemical classification	Dissolved solids	Sodium	Chloride	Formation	Comments
1	$Ca\text{-}HCO_3$	<300 mg/L	<10 mg/L	<10 mg/L	Bigby-Cannon Limestone	Spring sample only, rapid circulation.
2	$Ca\text{-}HCO_3$	<300 mg/L	<10 mg/L	<10 mg/L	Carters Limestone	Wm:N-044A only sample, rapid circulation.
3	$Ca,Mg\text{-}HCO_3,SO_4$ $Ca,Mg\text{-}SO_4,HCO_3$	400-1,200 mg/L	20-40 mg/L	30-50 mg/L	Hermitage Formation	Shallow, slow circulation.
4	$Na\text{-}HCO_3,Cl$	800-1,000 mg/L	200-400 mg/L	<10 mg/L	Carters Limestone	Low well production, deep slow circulation, high lithium and fluoride.

evaluation of the interactions of the various components. The flow model of this study area, however, was not designed or intended for use as a predictive tool or to assess site-specific remedial-action alternatives.

A computer program to simulate three-dimensional ground-water flow (McDonald and Harbaugh, 1984) was used to simulate flow in the study area. Finite-difference techniques are used by the program to solve the ground-water flow equation for three-dimensional, steady or non-steady flow in an anisotropic, heterogeneous medium. The quasi-three-dimensional model, which simulates horizontal flow in aquifers and only vertical flow in confining units, was used for this investigation to simulate vertical flow and differences in hydraulic properties between hydrogeologic units.

The model was used to simulate steady-state conditions in which water levels remain constant and water is neither entering nor leaving storage during the simulation period. Hydrologic conditions for April 1987 are considered to represent steady-state conditions and were simulated by the model. Although this time period does not represent an average steady-state condition, by April 1987 ground-water levels had achieved a winter-time maximum and had stabilized or declined slightly, and streamflow was approaching high base-flow conditions (fig. 9). Ground-water levels and base flow to streams measured in April 1987 reflect recharge to the ground-water system that occurred during the previous 6 months (November 1986 through April 1987). Water levels in most of the wells completed in the lower aquifer had recovered from drilling operations by that time. Ground-water levels and streamflow were measured on April 20, 1987, and were assumed to be representative of high base flow, steady-state conditions and were compared to model output during calibration.

The model area is approximately 1.4 mi^2 and includes the central part of the study area (fig. 16). The model grid consists of variable grid-block sizes that range in area from about 22,000 to 122,500 ft^2. Because the area around



CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

DISPOSAL SITE

GRID BLOCK SIMULATING:

CONSTANT HEAD IN LAYER 1

CONSTANT HEAD IN LAYER 2

RIVER NODE

DRAIN NODE

Figure 16.--Model grid and boundary types.

the disposal site is of major interest to the study, the smallest blocks were used in that area. The alignment of the grid along a northwest-southeast direction was chosen in order to properly simulate the anisotropy in the lower aquifer, and to best simulate the alignment of the streams.

The model consists of two layers (fig. 4) representing the upper aquifer (layer 1) and the lower aquifer (layer 2). Vertical flow between the layers is simulated in the model by a leakance array that represents the Hermitage confining unit.

Layer 1 includes the saturated parts of the regolith, Bigby-Cannon Limestone, and weathered parts of the Hermitage Formation. Transmissivity of layer 1 ranged from 78 ft^2/d in areas underlain by the Hermitage Formation to 235 ft^2/d in areas underlain by the Bigby-Cannon Limestone. The rationale behind this distribution is that the aquifer is thinnest in the valleys due to erosion, and that the Hermitage is less permeable because of its high shale content. The aquifer is thickest in areas underlain by the Bigby-Cannon and has a greater hydraulic conductivity in those areas because of the presence of solution cavities within the unit. Values for transmissivity were derived during model calibration, but are within a range of values derived from data reported by Geraghty and Miller (1987), and discussed in the "*Hydraulic Characteristics*" section. Values for areas underlain by the Hermitage are similar to the regional transmissivity values obtained by the streamflow-recession analysis method discussed in the "*Hydraulic Characteristics*" section.

Transmissivity of layer 2 ranges from about 0.4 to 180 ft^2/d and averages about 35 ft^2/d. For most of the model area, transmissivity of layer 2 was calculated by multiplying the thickness of the Carters Limestone by an assumed hydraulic conductivity of 0.5 ft/d, which is close to the average value reported by Geraghty and Miller (1987, table 11). Steep potentiometric gradients in t lower aquifer measured north and west of t disposal site (fig. 10) indicate lower transm sivity values in that general area. In order better simulate these gradients with the mod a zone of low transmissivity in layer 2 (0.4 ft^2/ was included for this area during calibratic The maximum transmissivity value (180 ft^2/ was used in the area near the aquifer test si Results of the aquifer test conducted in t Carters Limestone indicate that the aquifer anisotropic (fig. 7). Transmissivity is greater i northwest-southeast direction than a northea southwest direction. The northwest-southe transmissivity tensor was simulated at five tin that of the northeast-southwest tensor, and t multiplication factor was considered to produ the best overall model results.

Ground-water flow within the Hermita confining unit is not simulated in the mod because the amount of lateral flow within t confining unit is assumed to be negligible. T primary influence of the confining unit is in t restriction of ground-water flow between t upper and lower aquifers. The model simula vertical flow with a "vertical-leakance arra Vertical leakance is defined as vertical hydrau conductivity divided by the thickness of the co fining unit (McDonald and Harbaugh, 19 p. 144). A vertical hydraulic conductivity va for the Hermitage of 1×10^{-4} ft/d produced t best model results and is similar to the avera value of 2×10^{-4} ft/d reported by Geraghty a Miller (1987, table 6). Using this value for ve cal hydraulic conductivity, vertical leakance v calculated, and ranged from 9.8×10^{-8} to $\times 10^{-7}$ (ft/d)/ft.

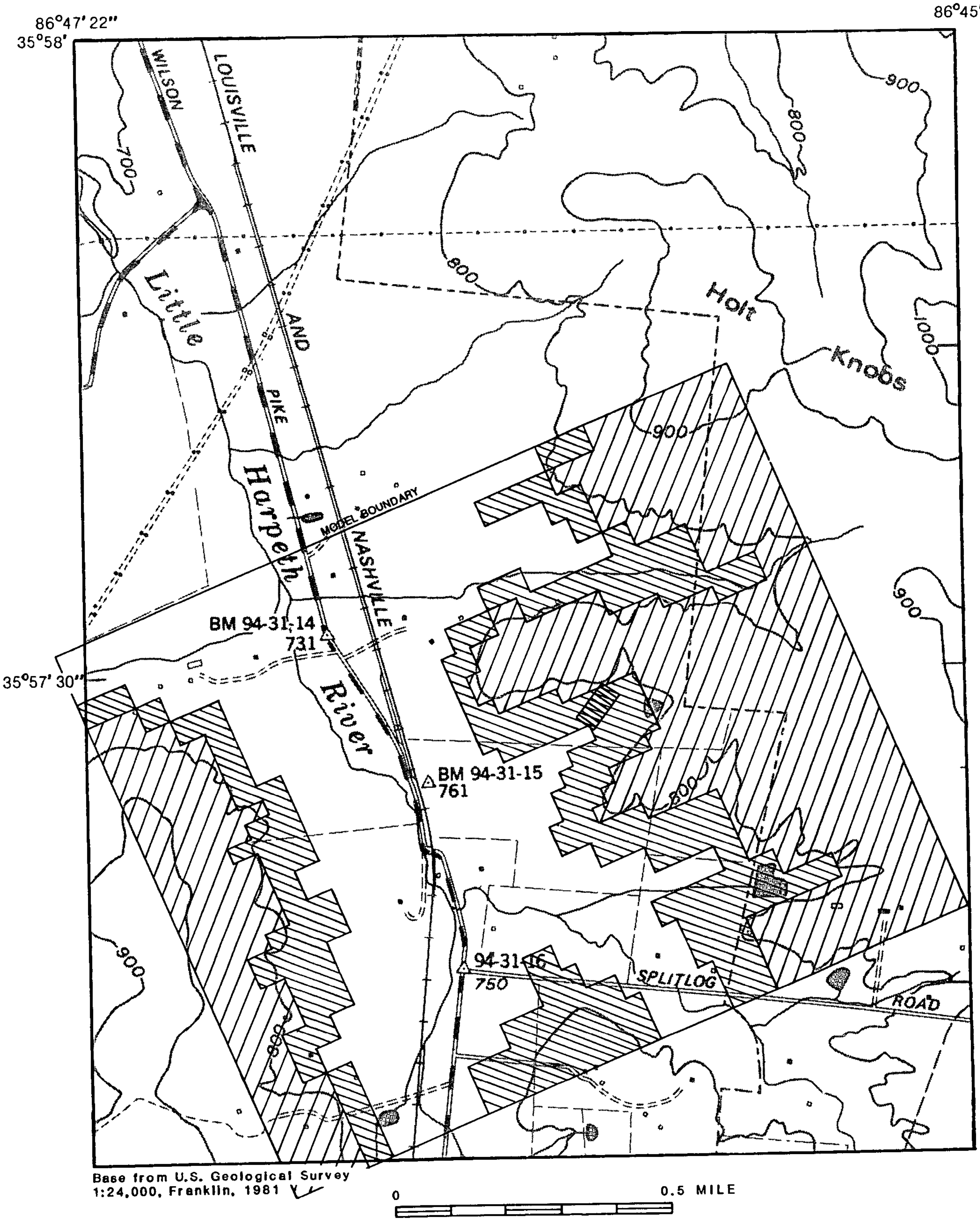
Boundaries around the edges of the mo were simulated as either no-flow or const heads. Boundaries around layer 1 were no-fl except for a small area beneath the Little H peth River, where constant heads were usec simulate underflow out of the model a (fig. 16). No-flow boundaries were used for m of layer 1 because the model boundaries coincide with or are within 1,000 feet of topographical divides (fig. 16), which are assumed to coincide with ground-water divides in the upper aquifer. No-flow boundaries were used along the east side of layer 2, and along most of the north and south sides (fig. 16). Constant heads were used to simulate possible underflow into the study area on the southeast, southwest, and west sides of layer 2, and to simulate underflow out of the study area beneath the Little Harpeth River (fig. 16). Water-level data for layer 2 are sparse on the west and southwest sides of the model area, so that underflow into the model in these areas cannot be determined with certainty. The effects of the assumed boundary conditions for both layers are discussed in the "*Model Limitations*" section. The top of the Lebanon confining unit is assumed to be the impermeable base of the model.

The Little Harpeth River and the tributary entering the river from the southwest were simulated as "river" nodes (fig. 16), which will either provide water to or take water from the ground-water system depending on the stream stage and the water-table elevation. During high streamflow conditions, the river does provide some recharge to the ground-water system, and during the April 1987 seepage investigation, the southwest tributary lost water to the ground-water system. Stock ponds within the model area were simulated in the same manner. All other tributary streams were simulated as "drain" nodes (fig. 16), which will only accept water from the aquifer. These streams appear to be gaining streams within the study area – no losing reaches have been observed. Both river and drain nodes are simulated only in layer 1.

The model requires a conductance value, which is the product of streambed hydraulic conductivity and cross-sectional area of flow divided by streambed thickness, for each river and drain node. Streambed thickness is meaningless in the study area, because the streams mainly flow directly on bedrock. Uniform values of 1 ft/d and 1 foot were assumed for streambed hydraulic conductivity and streambed thickness, respectively. The average stream widths used in the model were 5.5 feet for the river nodes and 2 feet for the drain nodes. Values for stream stage and stream-bottom elevations were estimated from topographic maps of the study area.

As discussed previously, direct measurements of recharge for the study area are not available. The recharge value estimated for the model area (9 inches) based on discharge measurements obtained on April 20, 1987, is somewhat higher than that estimated for wet years (7.7 inches) by hydrograph-separation techniques. A recharge of 9 inches is probably a slight overestimate, because the streamflow on which the estimate is based was slightly above high baseflow. Although an average recharge of 9 inches for November 1986 through April 1987 was initially used in the model, that value was reduced to 7.2 inches during model calibration. The reduction in recharge is discussed further in the "*Model Results*" section.

Recharge from precipitation is simulated only in layer 1. Recharge was applied only to the upland areas, and not to areas near the Little Harpeth River (fig. 17). This distribution is consistent with the theoretical distribution of recharge in water-table aquifers presented by Toth (1963) and Freeze and Witherspoon (1967) in which recharge occurs in upland areas and discharge occurs in lowland areas. Recharge was greatest (15 inches for November through April) at the highest elevations (greater than 800 feet above sea level) and lower (7 inches for November through April) in a zone between the uplands and the river (between 760 and 800 feet above sea level). The average recharge rate for the entire model area was about 7.2 inches for November through April. It is important to note that these recharge rates are probably not representative of average-annual conditions, because the model was calibrated to high base-flow conditions that



CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

DISPOSAL SITE

SIMULATED RECHARGE FOR NOVEMBER 1986 - APRIL 1987, IN INCHES

0

7

15

Figure 17.--Areal distribution of simulated recharge rates.

resulted from recharge that occurred from November 1986 through April 1987.

Model-input data are included in the appendix. Readers are referred to McDonald and Harbaugh's (1984) documentation of the computer program for model-input instructions and explanations of the program and input data.

MODEL RESULTS

Simulated water levels were compared to measured water levels for April 20, 1987, in wells located within 34 model grid blocks in layer 1 and 18 grid blocks in layer 2. Model-calculated rates of ground-water seepage to streams were compared to measured seepage to the Little Harpeth River and its tributaries for April 20, 1987.

Simulated water levels in layer 1 are within ± 10 feet of measured water levels at 27 of the 34 comparison points, and within ± 5 feet in 15 of the comparison points (fig. 18). The maximum difference between simulated and measured water levels at a comparison point is on the hill southwest of the disposal site, where simulated water levels are 14 feet higher than measured levels. Although simulated water levels generally are greater than measured water levels, the simulated pattern of ground-water level contours (fig. 18) is similar to the observed pattern and simulated flow directions are similar to actual directions. Simulated flow in layer 1 is primarily towards the Little Harpeth River and its tributaries, and flow at the disposal site is to the topographic low that drains the site.

Simulated water levels in layer 2 closely match measured water levels. Sixteen of the 18 comparison points are within ± 5 feet (fig. 19). The maximum difference between simulated and measured water levels is 6 feet on the west side of the model area and north of the disposal site. The simulated pattern of water-level contours for layer 2 (fig. 19) approximates the observed pattern. Simulated ground-water flow is from the southeast and west toward the Little Harpeth River and north out of the model area. Flow beneath the disposal site in layer 2 is to the west and north.

The model-calculated water-budget components indicate that most of the ground-water flow is in the upper aquifer (table 3). The major water-budget components are recharge to layer 1 and discharge to streams. Although total measured seepage for streams in the study area is 4.5 ft^3/s, an estimated 2.5 ft^3/s of this flow originates outside the model area. Total seepage for the model area, therefore, is 2.0 ft^3/s. Because streamflow measured on April 20, 1987, was somewhat above high base flow, the estimated seepage for the model area (2.0 ft^3/s) is considered as an upper limit for comparison to model-calculated seepage. An average simulated recharge of 9 inches for November 1986 through April 1987 resulted in model-calculated seepage that was equal to estimated seepage; however, the maximum recharge rate that was

Table 3.--*Model-calculated water-budget components*

[Values in cubic feet per second]

Layer 1	
Inflow:	
Areal recharge	1.6
Recharge from streams	<.01
Outflow:	
Discharge to streams	1.6
Boundary flow (constant heads)	.01
Flow to layer 2	<.01
Layer 2	
Inflow:	
Boundary flow (constant heads)	0.02
Flow from layer 1	<.01
Outflow:	
Boundary flow (constant heads)	.02

applied to upland areas to produce this average rate was considered to be unacceptably high. The value chosen for maximum recharge (15 inches) in upland areas is equal to about 55 percent of November 1986 through April 1987 precipitation, and is considered to be the maximum acceptable rate. Use of this lower maximum rate resulted in an average recharge of 7.2 inches for the model area and a model-calculated seepage to streams of 1.6 ft^3/s (table 3). The model-calculated seepage is 20 percent less than the estimated seepage and is probably more representative of high base flow.

Less than 1 percent of simulated recharge to the upper aquifer flows down to the lower aquifer, and is indicative of the effectiveness of the Hermitage confining unit in restricting flow between the two aquifers. Most ground-water flow in the lower aquifer enters the system as underflow from the northwest, south near the Little Harpeth River, and southeast, and discharges as underflow to the north. Virtually no ground-water flow in the lower aquifer discharges to the upper aquifer, although water levels measured during this investigation in both aquifers indicated the potential for upward flow at two sites during certain times of the year.

Although simulated ground-water conditions generally match observed or estimated conditions, the model is only a generalized representation of the ground-water system. Because of the generally close agreement between simulated and observed water levels and between model-calculated and estimated seepage to streams, the model can be considered a reasonable representation of the ground-water system for the November 1986 through April 1987 calibration period. However, because the model was calibrated to high base-flow conditions for a specific period of time (November 1986 through April 1987), the model is not considered to be representative of average-annual conditions. Further discussion on limitations or use of the model is presented in the "*Model Limitations*" section. Model results support the conceptual model of the flow system and the observed geochemical data that indicate two distinct aquifers separated by an effective confining unit.

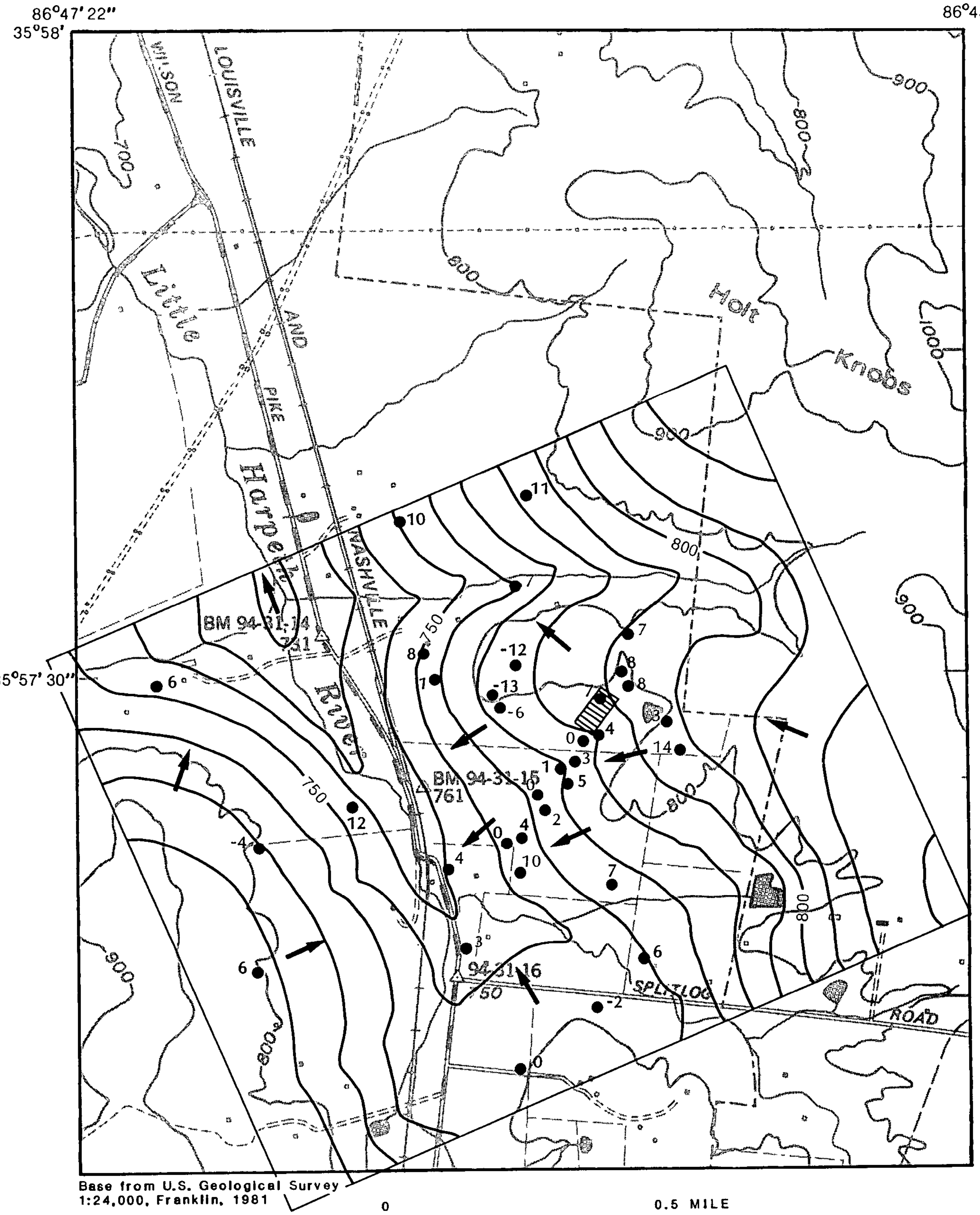
SENSITIVITY ANALYSES

The response of the model, in terms of simulated water levels and flows, to changes in various model-input parameters was evaluated by sensitivity analysis. The relative sensitivity of a model to these changes indicates the degree of importance of individual parameters to the simulation of ground-water flow, and where additional data-collection efforts may be worthwhile. In other words, if the model is insensitive to changes in transmissivity, then additional aquifer testing to refine knowledge of aquifer transmissivity would do little to improve model results.

The parameters tested in this sensitivity analysis were row-to-column anisotropy, recharge, transmissivity of the upper aquifer, transmissivity of the lower aquifer, vertical leakance, and river and drain conductance. Except where noted in the following discussion, each parameter was adjusted uniformly over the entire model area, while all other parameters were held constant.

Differences between simulated and measured water levels were used as an indication of the sensitivity of the model to adjustments of a parameter. The root mean square error (RMSE) was calculated for simulated and measured water levels by

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (h_i^m - h_i^c)^2}{N}}$$



0 0.5 MILE

0 0.5 KILOMETER

CONTOUR INTERVAL 100 FEET

DATUM IS SEA LEVEL

EXPLANATION

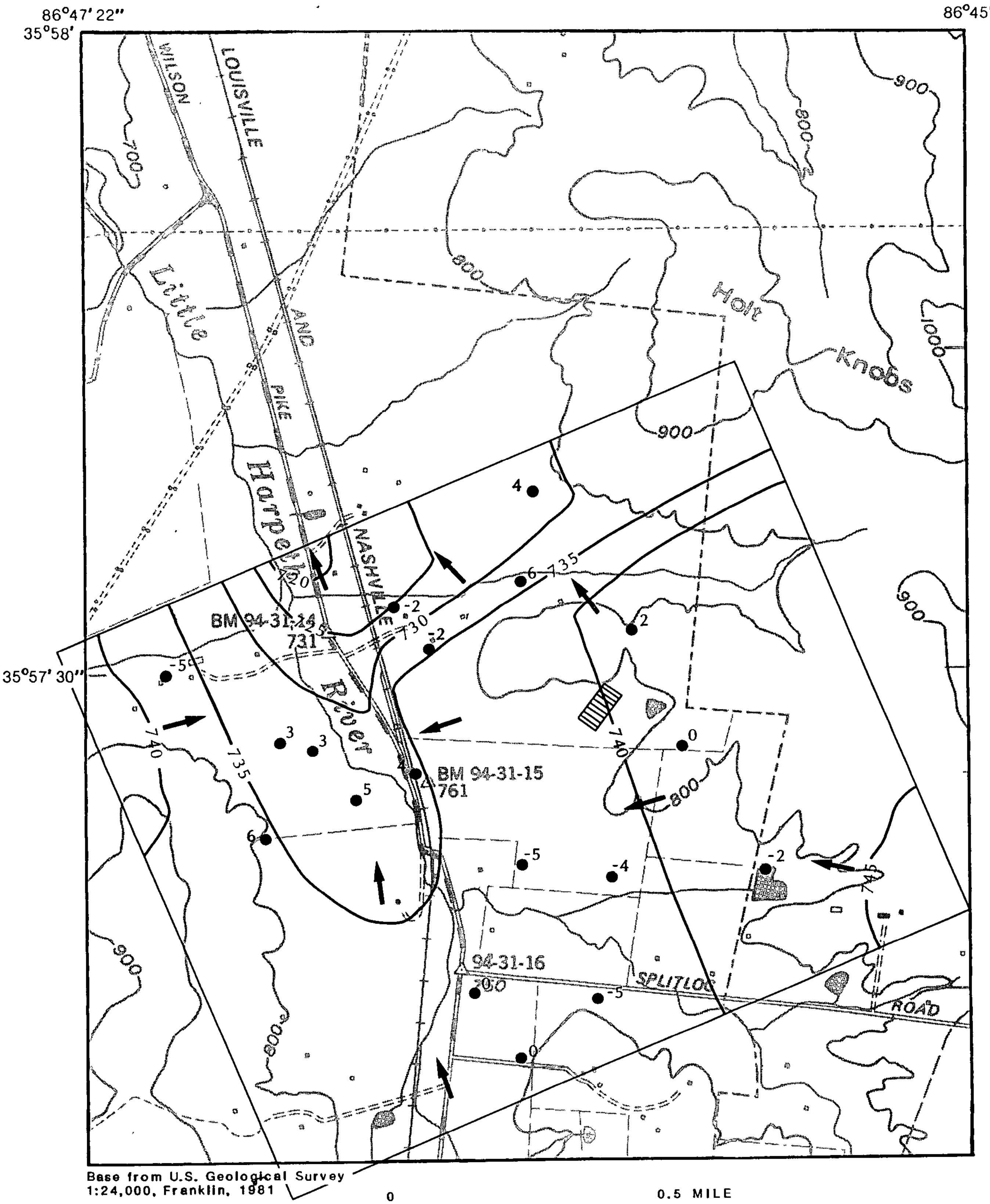
DISPOSAL SITE

800 WATER-LEVEL CONTOUR--Shows simulated water-level altitude. Contour interval 10 feet. Datum is sea level

GENERALIZED DIRECTION OF GROUND-WATER FLOW

7 WATER-LEVEL DIFFERENCE CALCULATED AT THE MODEL NODE--Values are rounded to the nearest foot

Figure 18.--Simulated water levels, generalized directions of ground-water flow, and difference between simulated and measured water levels for layer 1.



CONTOUR INTERVAL 100 FEET

DATUM IS SEA LEVEL

EXPLANATION

	DISPOSAL SITE
—— 740 ——	WATER-LEVEL CONTOUR--Shows simulated water-level altitude. Contour interval 5 feet. Datum is sea level
←	GENERALIZED DIRECTION OF GROUND-WATER FLOW
●3	WATER-LEVEL DIFFERENCE CALCULATED AT THE MODEL NODE--Values are rounded to the nearest foot

Figure 19.--Simulated water levels, generalized directions of ground-water flow, and difference between simulated and measured water levels for layer 2.

where

N = number of observations;

h_i^m = the measured water level, in feet; and

h_i^c = the simulated water level, in feet.

RMSE for all parameters used in the calibrated model is 6.8 feet for layer 1 and 3.7 feet for layer 2. Comparison of model-calculated to estimated seepage to streams was also evaluated during the sensitivity analysis of recharge.

Row-to-column anisotropy values for layer 1 were adjusted from 0.3 to 10.0, and from 0.5 to 30.0 for layer 2 (fig. 20). The calibrated values for anisotropy were 1.0 (isotropic) for layer 1, and 5.0 for layer 2. The model is sensitive to changes in anisotropy for layer 1 but not for layer 2. Simulated water levels were about the same (RMSE = 7.0 feet) as calibrated water levels using an anisotropy of 2.0 for layer 1, however, model-calculated seepage to the Little Harpeth River was less than seepage using the calibrated value of anisotropy. Use of greater-than-calibrated anisotropy values for layer 1 was, therefore, considered unacceptable. Model results were relatively unaffected by changes in anisotropy for layer 2 (fig. 20), however, the calibrated value (5.0) produced the best overall model results. Use of anisotropy values from 2.0 to 10.0 could be considered as equally acceptable.

In evaluation of model sensitivity to changes in recharge rate, the total model-calculated seepage to streams was considered to be equally important to the evaluation as simulated water levels, and is plotted along with RMSE in figure 20. Recharge rates were varied from 0.25 to 2.0 times the calibrated value for the sensitivity analysis. Simulated water levels in layer 1 were very sensitive to increases in recharge rate, but less sensitive to decreases in recharge rate (fig. 20). Model-calculated seepage to streams was also sensitive to changes in recharge rate (fig. 20), but simulated water levels in layer 2 were unaffected by changes in recharge. Use of an average recharge of 9 inches for November 1986 through April 1987 (1.25 times the calibrated value) resulted in model-calculated seepage to stream equal to measured seepage (2.0 ft^3/s); however simulated water levels for layer 1 were not as close to measured water levels for the calibrated value of recharge (RMSE = 8.6 feet). While these model results may have been considered acceptable, the maximum rate used in that situation was considered unrealistically high. Simulated water levels in layer 1 were improved over calibrated water levels using recharge rates of 0.75 times the calibrated value, however, total model-calculated seepage to streams for those lower recharge rates was considered unacceptably low.

Use of a uniform recharge rate of 7.2 inches for November 1986 through April 1987 was also tested as a part of the sensitivity analysis. Model results were not as good with a uniform recharge rate (RMSE = 7.8 feet) as with a variable recharge rate. Simulated water levels in layer 1 were generally too high near the Little Harpeth River and too low on the uplands using a uniform recharge rate.

Model results were sensitive to decreases in layer 1 transmissivity values, but relatively insensitive to increases in layer 1 transmissivity (fig. 21). Calibrated transmissivity values for layer 1 are generally greater than reported transmissivity values for the upper aquifer, but because of the insensitivity of model results to increases in layer 1 transmissivity, use of transmissivity values of two to three times the calibrated values also may be acceptable.

Use of a uniform layer 1 transmissivity value of 157 ft^2/d was also evaluated as part of the sensitivity analysis. This value is simply the average of the calibrated transmissivity values for the areas underlain by the Hermitage Formation and the Bigby-Cannon Limestone. Model results using a uniform transmissivity value were not as good (RMSE = 8.0 feet) as for the calibrated variable transmissivity values.

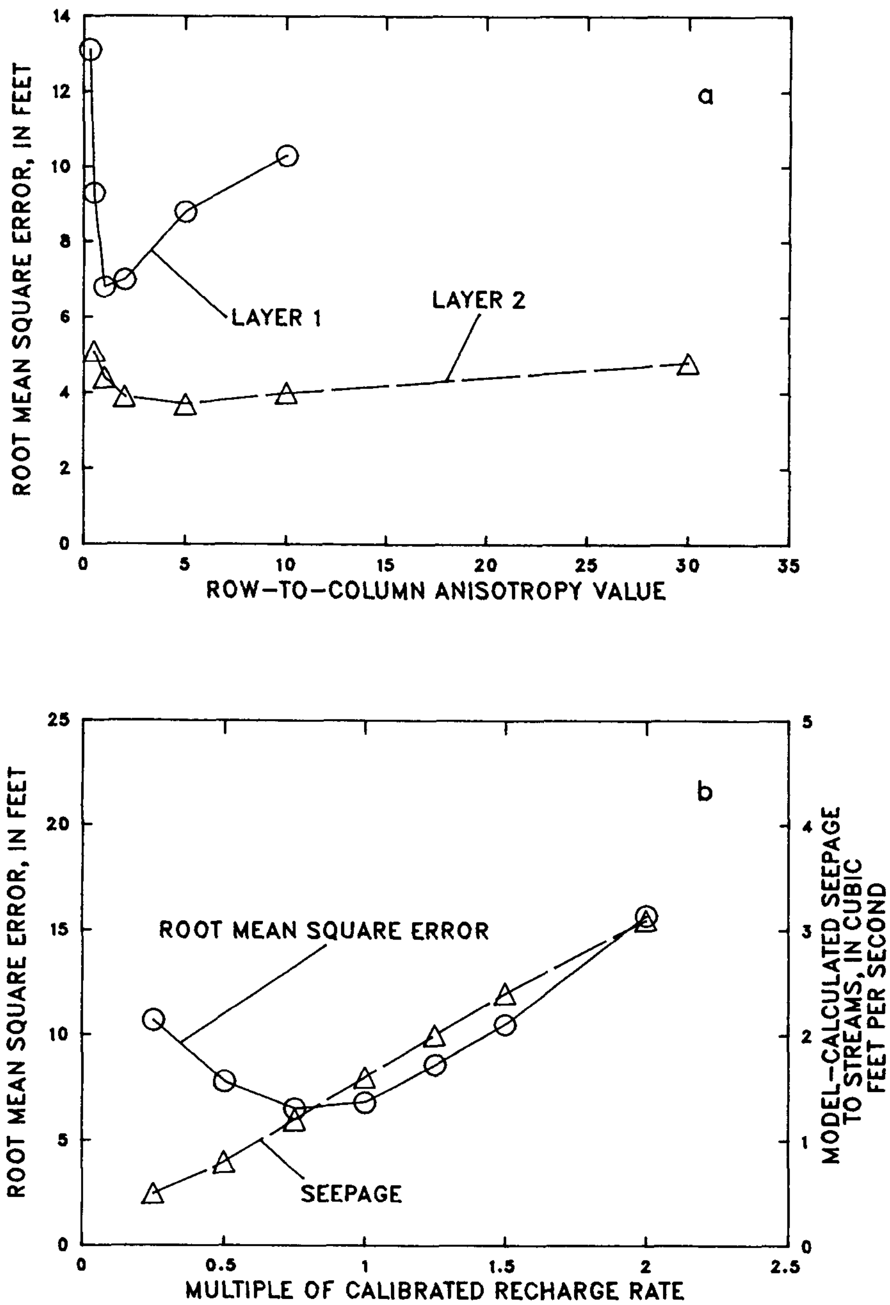


Figure 20.--Model sensitivity to changes in (a) row-to-column anisotropy and (b) recharge rates.

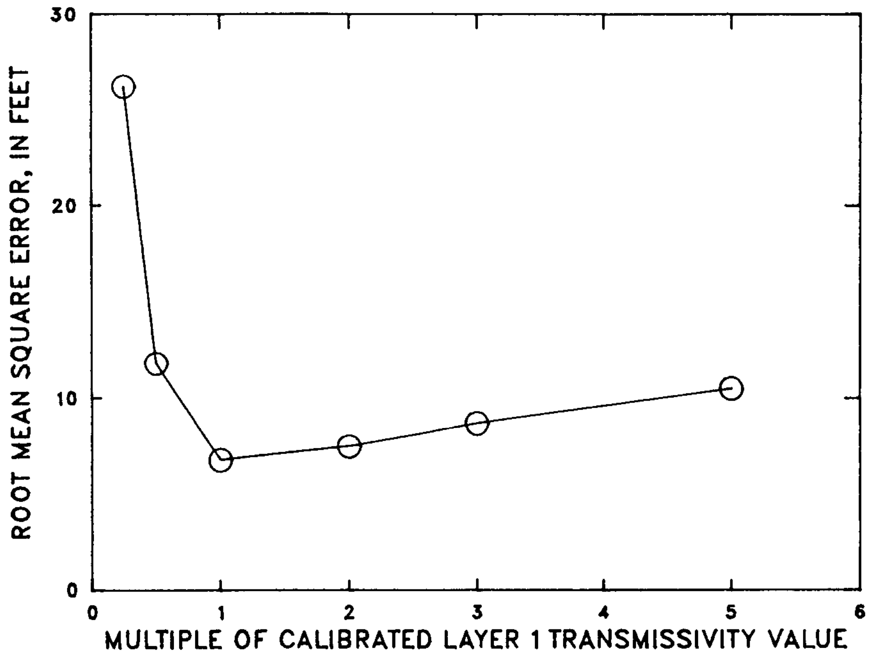


Figure 21.--Model sensitivity to changes in transmissivity of layer 1.

Adjustments to the transmissivity of layer 1 had no effect on model results for layer 2.

The model was sensitive to decreases in river and drain conductance values, but insensitive to increases in these values (fig. 22). River and drain conductance values were varied simultaneously in the sensitivity analysis, because changes in either parameter alone had no effect on model results. Increasing river and drain conductance values by an order of magnitude or more resulted in a slightly better overall match between simulated and measured water levels for layer 1 (RMSE = 6.2 feet), and slightly increased model-calculated seepage to streams. Although use of conductance values of up to 10 times the calibrated values might still be considered acceptable, conductance values greater than 10 times the calibrated values are considered unacceptable.

River and drain nodes provide the main outlet for water entering layer 1, so that decreasing the river and drain conductance values reduces the rates at which water is discharged from layer 1 and produces unacceptable model results (RMSE = 9.8 feet). Adjustments to river and drain values had no effect on model results for layer 2.

The model was insensitive to changes in layer 2 transmissivity values and vertical leakance. These parameters could be varied over more than two orders of magnitude before model results were significantly affected (fig. 22).

Increases in transmissivity values of layer 2 from 1 to 100 times the calibrated values had no effect on the model results, and decreasing the transmissivity values by 0.1 increased the RMSE of layer 2 from 3.7 to 6.8 feet (fig. 22). Decreasing the transmissivity values by 0.01 times the calibrated values significantly increased the RMSE of layer 2 to 19.8 feet. These adjustments to layer 2 transmissivity values had no effect on

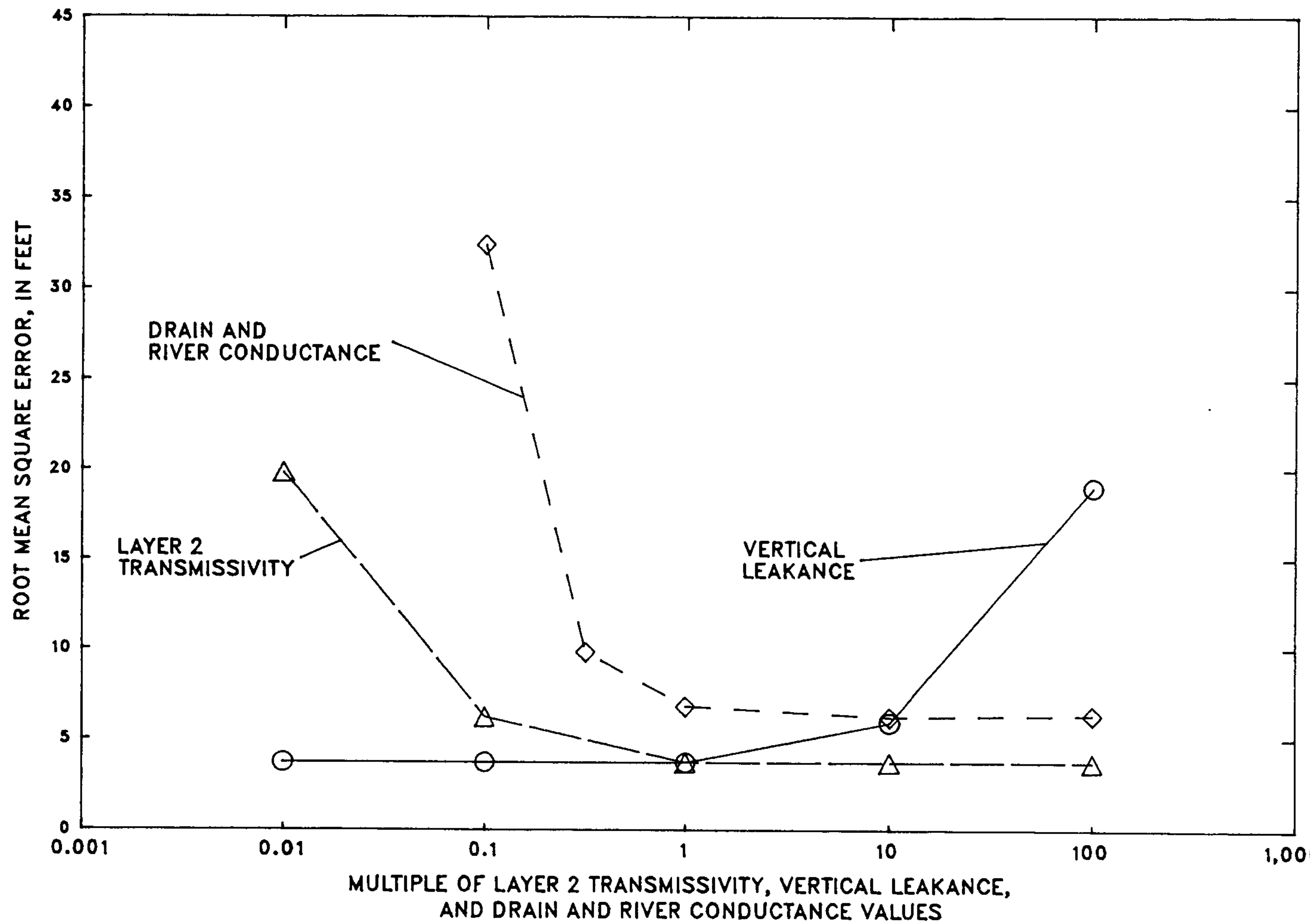


Figure 22.--Model sensitivity to changes in layer 2 transmissivity, vertical leakance, and drain and river-conductance values.

model results for layer 1. In fact, removing layer 2 from the simulation (transmissivity = 0.0 ft^2/d) had no effect on model results for the upper layer. According to this analysis, the amount of water flowing through the lower aquifer is so small that simulation of the lower aquifer is not necessary for accurate simulation of ground-water flow in the upper aquifer.

Decreasing the vertical leakance values from 1 to 0.01 times the calibrated values had no effect on model results (fig. 22). Increasing these values by 10 times the calibrated value increased the RMSE of layer 2 from 3.7 to 6.2 feet, and increasing the values by 100 times significantly increased the RMSE to 19.4 feet (fig. 22). Adjustments to vertical leakance values had no effect on model results for layer 1.

The sensitivity analyses provided additional insight into the conceptualization of the ground-water flow system. The concept of a relatively impermeable confining unit separating two distinct aquifers is supported by the sensitivity analysis, because variations in layer 1 parameters have virtually no effect on layer 2 and variations in layer 2 parameters have no effect on layer 1. Trying to force more interaction between the two layers by increasing the vertical leakance values produces unacceptable model results.

MODEL LIMITATIONS

Models by their very nature are not exact replicas of natural systems. They are limited by such factors as scale, inaccuracies in estimating hydraulic characteristics and representing boundary conditions, and underlying model assumptions. The model constructed for this study is no exception. For example, the minimum grid block size for the model is about 22,000 ft^2, an area much too large to accurately simulate ground-water flow through individual fractures or solution openings. The model is based on the assumption that flow through fractures and solution openings, common in limestone aquifers, can be approximated as flow through an anisotropic porous media. Inaccuracies in the model results could be caused by deviations of existing hydrologic conditions from this assumption. The focus of this section is on limitations of the model, and specific additional data needed to minimize these limitations.

Selection of model boundary conditions can greatly influence model results. Model boundaries should closely correspond to natural hydrologic boundaries whenever possible. Model boundaries for layer 1 generally coincide with or are within 1,000 feet of topographic divides, and the water table generally reflects the topography. Ground-water divides, therefore, should correspond to topographic divides so that no-flow boundaries along ground-water divides in layer 1 are appropriate. Areas between the model boundaries and the topographic divides that were not simulated in the model would actually contribute some water to layer 1 as underflow. Not simulating this underflow required that some other source of water be provided to layer 1. The additional water was provided by recharge to layer 1. In order to compensate for the unknown amount of underflow that was not simulated, the recharge rate used near the model boundary may be greater than actual recharge during the calibration period.

Boundary conditions for layer 2 are much more uncertain, particularly on the west and southwest sides of the model area. These boundaries were simulated as constant heads in order to allow for underflow that was assumed, based on sparse potentiometric data, to occur in these areas. It is equally likely that ground-water divides for the lower aquifer may coincide with topographic divides, so that no-flow boundaries might also be appropriate to use. Model results indicate that flow from the constant-head boundaries on the west and southwest sides of the model was small (less than 0.01 ft^3/s). Simulating these boundaries primarily as no-flow boundaries had no effect on the simulated steady-state potentiometric surface or model-calculated water-budget components. Because the amount of flow in layer 2 is so slight compared to the flow in layer 1, and because of the effectiveness of the confining layer in isolating the aquifer, errors in simulation of layer 2 boundaries will have minimal effect on model results. In order to better define the natural boundaries of the ground-water flow system, additional wells and water-level data are needed near the topographic divides.

High base-flow, steady-state conditions are assumed to be valid for April 20, 1987, although discharge of the Little Harpeth River was probably somewhat above high base flow. Use of measured seepage to streams as a calibration criterion required use of maximum recharge rates that were unacceptably high. The rate chosen as a maximum "acceptable" rate was somewhat arbitrarily selected, but it is believed to be a reasonable rate for high base-flow conditions. Sensitivity analysis indicated that use of lower overall recharge rates may produce better model results; however, without discharge measurements at actual high base-flow conditions to compare to model-calculated seepage to streams, the actual recharge rate for these conditions remains uncertain. Because variations in simulated recharge rates have essentially no effect on layer 2, use of slightly overestimated or underestimated recharge rates in the model does not affect the model-supported concept that the upper and lower aquifers are hydraulically separated by an effective confining unit.

Simulation of high base-flow conditions requires use of recharge rates and transmissivities for the upper aquifer that are greater than those required to simulate average-annual, steady-state conditions. The average recharge used in the model (7.2 inches) is greater than that estimated for average-annual conditions for the Harpeth River basin above Franklin (6 inches). Average-annual water levels and streamflow will be somewhat lower than those that occur under high base-flow conditions. However, without long-term hydrologic data, the amount of difference between average-annual and high base-flow conditions cannot be quantified.

The model used in this study is, therefore, calibrated only for one set of hydrologic conditions (April 1987). Use of the model to evaluate changes in hydrologic conditions from long-term, average conditions would be inappropriate.

Model results were about the same with use of transmissivity values for layer 1 greater than the calibrated values. Although the model is not very sensitive to increased layer 1 transmissivity values, additional information on aquifer characteristics for the upper aquifer would help to justify use of larger transmissivity values. Most data on aquifer characteristics for the upper aquifer were obtained in areas underlain by the Hermitage Formation, so that additional data would be most useful in areas underlain by the Bigby-Cannon Limestone.

Despite the limitations discussed in this section, the model provided useful insights into the workings of the hydrologic system of the study area. Model results support the conceptual model of the ground-water flow system in that the upper and lower aquifers are effectively isolated by the Hermitage confining unit. The model should not be used for predictive purposes until further long-term hydrologic data are available to define average-annual conditions. Additional data are also needed to further define hydrologic boundaries if the model is to be used for predictive purposes.

SUMMARY

Approximately 44,000 gallons of industrial solvent wastes were disposed in pits on a farm in Brentwood, Tennessee, in 1978. Organic compounds were found in soil and shallow ground water on the site and in two domestic wells and a spring in the area of the disposal site. The U.S. Geological Survey, in cooperation with the Tennessee Department of Health and Environment, Division of Superfund, began a study in 1986 (1) to develop an understanding of the hydrogeology of the site and surrounding area in order to determine potential contaminant pathways, and (2) to provide information to the State to evaluate remedial-action alternatives.

Four geologic units underlie the area (from oldest to youngest): Lebanon Limestone, Carters Limestone, Hermitage Formation, and Bigby-Cannon Limestone. The thickness of individual formations ranges from 0 to 103 feet. These formations are overlain by 3 to 15 feet of regolith. The formations are grouped into four hydrogeologic units: (1) an upper aquifer comprised of saturated regolith, Bigby-Cannon Limestone, and weathered Hermitage Formation; (2) the Hermitage confining unit, which consists of the unweathered parts of the Hermitage Formation; (3) a lower aquifer consisting of the Carters Limestone; and (4) the Lebanon confining unit, which is considered the lower boundary of the flow system. Wells tapping these aquifers generally yield less than 1 gal/min, although locally the aquifers may yield as much as 80 gal/min. Transmissivity estimates for the aquifers based on various hydraulic analyses range from 0.5 to 180 ft^2/d. The lower aquifer is anisotropic, and transmissivity is greatest in a northwest-southeast direction.

The Little Harpeth River and smaller streams in the area generally are gaining streams. Streamflow measured on April 20, 1987, at about high base flow was 4.5 ft^3/s for the entire study area. Springs, which often occur at the Bigby-Cannon Limestone and Hermitage Formation contact, are common in the area.

Recharge to the ground-water system is primarily from precipitation, and estimates of average-annual recharge rates range from 6 to 15 in/yr. Discharge from the ground-water system is primarily to the Little Harpeth River and its tributaries. A minor amount of ground water enters and leaves the study area as underflow in the lower aquifer. The direction of ground-water flow in the upper aquifer is from the hills on the east and west sides of the study area to the Little Harpeth River. Ground-water flow at the disposal site is mainly to a small topographic depression that drains the site. The direction of ground-water flow in the lower aquifer generally is from the south, southeast, and west to an area that approximately coincides with the Little Harpeth River, and north out of the study area. Water levels generally are higher in the upper aquifer than the lower aquifer, indicating a potential for downward flow of ground water; however, the Hermitage confining unit is effective in restricting vertical flow between the aquifers.

Geochemical data indicate several distinct water types: (1) water in a zone of rapid, shallow circulation that has not had time to dissolve much of the aquifer rock matrix; (2) water of similar composition, but that has a deeper flow path (greater than 100 feet); (3) shallow, slow-moving ground water that has had time to react with the rock matrix; and (4) deep, slow-moving ground water, defined by its aquifer environment. The geochemical data support the concept of a generally tight confining unit (Hermitage) separating the upper and lower aquifers.

A numerical ground-water flow model was used to simulate hydrologic conditions for April 1987, which are assumed to be representative of high base-flow, steady-state conditions. Two model layers represented the upper and lower

aquifers, separated by the Hermitage confining unit. The top of the Lebanon confining unit is assumed to be the impermeable base of the model. Transmissivity values were varied areally to correspond to variable geologic conditions. The lower aquifer transmissivity is simulated as five times greater in a northwest-southeast direction than in a northeast-southwest direction, as indicated by analysis of the aquifer test for this aquifer. Model calibration indicated that recharge is also variable across the model area and is greater on the hills than the valleys. The average areal recharge rate over the model area for the November 1986 through April 1987 calibration period is about 7.2 inches.

Model results support the concept of two aquifers separated by an effective confining unit. Simulated ground-water levels were similar to measured levels in both the upper and lower aquifers. Model-calculated ground-water seepage to streams was less than the total seepage measured in the model area; however, measured seepage is believed to be somewhat higher than the high base-flow conditions simulated by the mode. Model results indicate that most of the ground-water flow occurs in the upper aquifer. Nearly all recharge to the upper aquifer discharges to streams, and less than 1 percent of this recharge flows down to the lower aquifer.

Because the model was calibrated to high base-flow conditions, additional long-term hydrologic data would be needed to simulate average-annual hydrologic data. Additional data needed to refine the model include water-level data near topographic divides, and transmissivity data for the upper aquifer. The model should not be used for predictive purposes because the model was calibrated for a specific set of hydrologic conditions (April 1987) rather than average-annual conditions.

SELECTED REFERENCES

Daniel, J.F., 1976, Estimating ground-water evapotranspiration from streamflow records: Water Resources Research, v. 12, no. 3, p. 360-364.

Freeze, R.A., and Witherspoon, P.A., 1967, Theoretical analysis of regional ground-water flow: 2. Effect of water-table configuration and subsurface permeability variation: Water Resources Research, 3, p. 623-634.

Geraghty and Miller, Inc., 1986, Plan for investigation of the Kennon site, Brentwood, Tennessee: Oak Ridge, Tennessee, Geraghty and Miller, Inc., 142 p.

----- 1987, Hazard evaluation and remedial alternatives for the Kennon site, Brentwood, Tennessee, v. 1 — Hazard evaluation: Oak Ridge, Tennessee, Geraghty and Miller, Inc., 108 p.

Hanchar, D.W., 1988, Geology of an area near Brentwood, Williamson County, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 88-4176, 24 p.

----- 1989, Construction, geologic, and water-level data for observation wells near Brentwood, Williamson County, Tennessee: U.S. Geological Survey Open-File Report 87-248, 27 p.

Hantush, M.S., 1960, Modification of the theory of leaky aquifers: Journal of Geophysical Research, v. 65, no. 11, p. 3713-3725.

McDonald, M.G., and Harbaugh, A.W., 1984, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 83-875, 528 p.

National Oceanic and Atmospheric Administration, 1974, Climates of the States, v. 1, Eastern States: Port Washington, New York, Water Information Center, Inc., p. 370-384.

----- 1986, Climatological data, Tennessee, January-December, 1986: Asheville, North Carolina, National Environmental Satellite Data and Information Service, National Climatic Data Center, v. 91, no. 1-12.

----- 1987, Climatological data, Tennessee, January-July, 1987: Asheville,North Carolina, National Environmental Satellite Data and Information Service, National Climatic Data Center, v. 92, no. 1-7.

Olmsted, F.H., and Hely, A.G., 1962, Relation between ground water and surface water in Brandywine Creek Basin, Pennsylvania: U.S. Geological Survey Professional Paper 417-A, 21 p.

Piper, A.M., 1953, A graphic procedure in the geochemical interpretation of water analysis: U.S. Geological Survey Ground-Water Note 12, 14 p.

Rima, D.R., and Goddard, P.L., 1979, Groundwater resources in the metropolitan region of Nashville, Tennessee: U. S. Army Corps of Engineers, Nashville District, 44 p.

Rorabaugh, M.I., 1964, Estimating changes in bank storage and ground-water contribution to streamflow: International Association of Scientific Hydrology Publication 63, p. 432-441.

Rorabaugh, M.I., and Simons, W.D., 1966, Exploration of methods relating ground water to surface water, Columbia River Basin—Second phase: U.S. Geological Survey Open-File Report, 62 p.

Theis, C.V., Brown, R.H., and Meyer, R.R., 1963, Estimating transmissivity of aquifers from the specific capacity of wells, *in* Benthall, Ray, Methods of determining permeability, transmissibility, and drawdown: U.S. Geological Survey Water-Supply Paper 1536-I, p. 331-341.

Toth, J.,1963, A theoretical analysis of groundwater flow in small drainage basins: Journal of Geophysical Research, 68, p. 4795-4812.

Wilson, C.W., Jr., 1949, Pre-Chattanooga stratigraphy in central Tennessee: Tennessee Division of Geology Bulletin 56, 407 p.

Wilson, C.W., Jr., and Miller, R.A., 1963, Geologic Map of Franklin Quadrangle, Tennessee: Tennessee Division of Geology, GM 63-NE, scale 1:24,000.

Zurawski, Ann, and Burchett, C.R., 1980, Ground water in the carbonate rocks of the Franklin area, Tennessee: U. S. Geological Survey Open-File Report 80-410, 37 p.

APPENDIX

MODEL-INPUT DATA FOR STEADY-STATE CALIBRATION

Basic Module Data

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***** BRENTWOOD HAZARDOUS-WASTE SITE MODEL DATA FOR STEADY-STATE CALIBRATION.
TWO LAYERS, 28 ROWS, 32 COLUMNS. *****
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-2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
-2-2-2-2-2-2-2-2-2-2-2-2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2-2
      9999
```

5 1 (16F5.0) 4 (STARTING HEADS LAYER 1)

748	740	738	735	732	728	723	720	717	720	723	725	727	732	735	737
740	742	745	747	750	755	760	765	770	773	777	782	790	820	830	850
739	738	734	730	726	725	723	715	714	718	722	723	725	727	728	733
735	739	742	745	749	753	758	762	767	771	774	780	785	800	819	850
752	754	743	733	725	725	718	718	720	721	722	724	726	727	728	730
733	737	740	743	747	750	754	758	763	767	769	775	785	798	805	830
771	762	752	744	735	727	721	722	723	724	724	725	726	727	728	731
733	735	737	739	743	747	752	755	758	760	763	767	775	785	796	808
800	769	761	752	742	731	725	724	723	724	725	726	728	730	733	736
739	741	749	750	753	754	755	756	756	756	758	764	768	778	789	795
800	776	767	759	748	738	726	725	724	725	726	728	730	735	740	746
752	760	762	764	765	765	764	764	763	760	759	758	763	771	782	790
800	778	773	764	751	740	729	728	726	725	726	728	731	739	748	755
763	765	770	775	779	779	779	778	777	774	770	767	767	768	777	782
801	779	774	767	756	743	730	727	726	725	726	728	735	744	752	757
763	770	777	782	790	791	790	791	790	784	779	775	774	770	776	781
803	800	775	770	760	745	733	728	727	727	729	730	737	745	753	758
764	771	780	783	785	785	786	787	787	786	783	787	780	777	777	780
804	801	776	772	760	747	733	728	728	728	730	735	740	749	754	760
763	768	775	781	782	783	784	785	786	785	785	786	782	771	778	782
805	802	777	774	762	750	734	728	729	733	734	737	742	752	755	759
764	766	770	774	777	779	781	783	784	785	785	785	785	785	779	785
805	802	777	775	763	750	737	727	727	732	735	738	742	750	753	757
762	765	768	769	774	773	775	776	778	783	785	785	786	790	780	785
804	800	775	770	762	750	740	728	728	732	735	737	743	750	754	756
760	764	765	767	768	770	772	773	777	780	782	784	787	792	785	786
801	778	774	767	758	750	743	735	730	733	734	738	744	750	754	755
757	760	762	763	765	766	769	772	775	779	782	785	788	793	787	787
802	777	772	765	756	748	744	736	733	734	735	737	743	748	753	754
756	757	758	760	762	765	767	770	772	778	781	784	788	794	790	787
801	776	771	764	755	747	744	737	736	735	736	737	742	745	752	753
754	756	758	761	763	764	766	768	771	777	780	783	786	792	793	788
802	777	771	762	755	748	744	738	737	736	735	736	739	743	749	752
754	757	760	762	763	764	766	768	770	773	776	781	784	787	794	789
800	776	770	761	756	750	745	739	738	737	735	733	736	744	747	751
752	757	761	763	764	765	766	767	769	772	775	777	778	781	795	793
779	775	768	760	755	749	745	739	737	736	735	737	749	744	746	748
753	756	760	762	763	764	765	767	768	770	772	774	777	785	795	793
778	774	766	759	754	748	744	740	737	735	737	741	742	743	744	745
747	754	757	761	763	764	765	766	767	768	771	774	775	787	793	794
776	773	765	757	753	747	744	740	736	736	739	742	743	744	745	747
748	751	755	757	761	762	763	764	765	766	767	770	777	784	789	795
774	769	761	756	751	746	742	739	736	736	739	742	743	744	745	747
749	751	754	755	751	760	762	763	764	765	766	768	778	785	790	795
772	764	757	754	747	746	743	738	736	735	737	741	742	744	746	748
751	752	753	754	756	757	758	761	763	764	766	769	775	783	790	790
773	763	755	748	746	745	743	742	740	740	743	745	747	747	748	749
751	752	753	754	754	756	758	760	762	764	765	767	780	782	784	791
770	760	754	748	746	744	741	736	735	737	738	741	744	745	746	748
751	752	753	754	754	756	758	769	762	764	765	770	780	782	784	791
775	765	757	750	747	746	746	746	746	750	751	754	755	755	757	757
753	753	754	755	756	756	757	759	763	764	768	773	775	779	784	788
774	765	756	752	748	747	747	749	753	756	757	760	761	762	763	763
760	758	756	756	757	757	758	769	762	765	769	774	777	785	790	789
780	772	762	757	755	754	756	757	758	760	765	770	773	775	775	773
770	768	767	765	763	762	763	765	767	770	773	777	782	790	800	815

5 1 (16F5.0) 4 (STARTING HEADS LAYER 2)

741	738	736	733	730	728	725	722	720	718	718	719	720	721	721	721
721	721	721	722	722	723	723	724	725	726	726	727	728	729	731	732
741	740	737	735	730	729	728	727	726	725	723	723	723	723	723	722
722	722	722	722	723	722	720	719	718	718	717	716	717	720	723	725
742	742	741	740	735	730	728	727	726	724	723	723	722	723	723	723
724	724	724	724	724	724	723	723	722	722	720	720	720	723	725	727
743	744	741	740	735	730	728	727	726	724	724	724	724	725	725	725
725	726	726	727	726	725	725	724	723	722	722	722	724	725	727	729
743	744	742	740	735	729	728	727	726	726	726	726	727	727	730	730
732	731	730	730	729	729	729	729	728	728	727	728	728	728	730	735
742	743	740	735	733	729	728	727	727	727	728	729	730	731	733	736
737	737	737	736	735	735	735	735	735	735	735	735	736	736	736	736
741	740	737	735	730	729	728	727	726	727	728	729	732	734	736	737
737	737	737	738	738	738	737	737	737	737	737	738	738	738	738	739
741	738	735	732	729	728	727	726	726	728	729	730	733	735	737	737
738	738	738	738	738	738	738	738	738	738	738	738	738	739	739	740
740	737	735	731	729	728	727	726	726	728	729	730	733	735	737	738
738	738	739	739	739	739	739	739	739	739	739	739	739	740	740	740
739	736	733	730	728	727	727	727	727	727	728	728	729	734	736	737
738	738	739	739	739	740	740	740	740	740	740	740	740	740	740	740
738	735	732	729	727	727	727	728	728	728	728	729	735	737	738	739
739	739	740	740	740	740	740	740	740	740	740	740	740	740	741	741
737	735	732	729	727	727	727	728	728	728	729	735	737	738	739	739
740	740	740	740	740	740	740	740	740	740	740	740	740	740	741	741
737	734	731	729	727	728	728	728	728	728	729	730	735	737	739	739
740	740	740	740	740	740	740	740	741	741	741	741	741	741	741	741
737	733	731	729	729	729	729	729	729	729	730	731	736	738	739	739
740	740	741	741	741	741	741	741	741	741	741	741	741	741	741	742
737	734	732	730	730	730	730	730	730	731	731	733	737	738	739	740
740	741	741	741	741	741	741	742	742	742	741	741	741	741	742	742
737	733	732	731	731	731	731	731	731	732	732	735	737	738	739	740
740	741	741	741	742	742	742	742	742	742	742	742	742	742	742	742
737	734	733	732	732	732	732	732	732	733	734	736	737	739	740	740
741	741	742	742	742	742	742	742	742	742	742	742	742	742	742	743
737	734	733	733	732	732	732	733	733	734	735	736	738	739	740	741
742	742	742	742	743	743	743	743	743	743	743	743	743	743	743	743
737	734	733	733	733	733	733	734	734	734	736	737	738	739	740	741
742	742	742	742	743	743	743	743	743	743	743	743	743	743	743	743
737	734	733	733	733	733	733	734	734	735	736	737	738	739	741	742
742	742	742	742	743	743	743	743	743	743	743	743	743	743	743	743
737	734	734	733	733	733	734	734	735	736	737	738	739	740	741	742
742	742	742	743	743	743	743	743	743	743	743	743	743	743	744	744
737	734	734	733	733	733	734	735	735	736	737	738	739	740	741	742
742	743	743	743	743	743	743	743	743	743	743	743	743	744	744	744
737	734	734	733	733	734	734	735	736	737	738	739	739	741	742	742
742	742	743	743	743	743	743	743	743	744	744	744	744	744	744	744
737	734	734	734	734	734	734	735	736	737	738	739	739	741	742	742
743	743	743	743	743	743	743	744	744	744	744	744	744	744	744	745
737	735	734	734	734	734	734	735	735	736	737	738	740	741	742	743
743	743	743	743	743	743	743	743	744	744	744	744	744	744	744	744
737	736	735	735	734	734	734	736	736	736	736	738	740	741	742	743
743	743	743	743	743	743	743	744	744	744	744	744	744	744	744	744
737	736	735	735	735	736	736	736	736	736	736	737	739	740	742	742
743	743	743	743	743	743	743	744	744	744	744	744	744	744	745	746
738	737	737	737	737	737	737	737	737	737	737	737	738	740	741	742
742	743	743	743	743	743	743	743	743	744	744	744	744	745	746	746

1 1 1

Block-Centered Flow Module Data

```
         1         20
0 0
         7          1 (2F5.0)                     6
  1.    5.
         7          1 (20F4.0)                    7  (DELR)
495 248 247 248 247 248 247 149 148 149 148 149 148 149 148 149 148 149 148 149
148 149 148 149 148 149 148 248 247 495 495 495
         7          1 (20F4.0)                    7  (DELC)
248 247 248 247 248 247 248 148 149 148 149 148 149 148 149 148 149 148 149 148
248 247 248 247 248 247 248 247
         7      157.0 (20F4.0)                    7  (TRANSMISSIVITY LAYER 1)
1.5 1.5 1.5 1.5 001 0.8 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.8 0.8 0.8
0.8 0.8 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5
1.5 1.5 001 001 001 0.8 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.8 0.8 0.8 0.8
0.8 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5
1.5 1.5 1.5 001 001 001 0.8 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.8 0.8
0.8 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5
1.5 1.5 1.5 001 001 001 0.8 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.8 0.8
0.5 0.8 0.8 0.8 0.8 1.5 1.5 1.5 1.5 1.5 1.5 1.5
1.5 1.5 1.5 1.5 001 0.8 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.8 0.8 1.5 1.5 1.5 1.5 1.5
1.5 1.5 1.5 1.5 1.5 0.8 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.8 0.8 0.8
0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8 1.5 1.5 1.5
1.5 1.5 1.5 1.5 1.5 0.8 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1.5 1.5 1.5 1.5
1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5
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```

7 0.00001 (8F10.6) 0 (VCONT)

0.011765	0.011765	0.012195	0.013333	0.015873	0.020000	0.026316	0.033333
0.040000	0.040000	0.028571	0.022222	0.016667	0.014706	0.013333	0.012821
0.012048	0.011494	0.012195	0.010638	0.010417	0.010204	0.010000	0.009804
0.009804	0.009709	0.009524	0.009091	0.009091	0.009091	0.009091	0.009091
0.011765	0.011765	0.012195	0.013333	0.015873	0.022222	0.033333	0.037037
0.040000	0.040000	0.050000	0.023810	0.019231	0.016667	0.014286	0.013333
0.012821	0.012195	0.011765	0.011111	0.010870	0.010638	0.010417	0.010204
0.010000	0.009804	0.009524	0.009091	0.009091	0.009091	0.009091	0.009091
0.011494	0.011765	0.012048	0.012821	0.015385	0.020000	0.033333	0.040000
0.040000	0.031250	0.028571	0.025000	0.020833	0.018182	0.016129	0.015385
0.014286	0.013333	0.012500	0.011765	0.011364	0.011111	0.010870	0.010638
0.010417	0.010204	0.010000	0.009709	0.009524	0.009091	0.009091	0.009091
0.011111	0.011494	0.011765	0.012195	0.014286	0.018182	0.028571	0.040000
0.040000	0.030303	0.028571	0.026316	0.022222	0.020000	0.018182	0.016667
0.015873	0.014925	0.014286	0.013333	0.012500	0.012048	0.011765	0.011364
0.011111	0.010870	0.010526	0.010000	0.009709	0.009524	0.009091	0.009091
0.010870	0.011364	0.011765	0.012048	0.013889	0.018182	0.028571	0.040000
0.040000	0.031250	0.028571	0.027027	0.023810	0.021277	0.018868	0.018182
0.016667	0.015873	0.014925	0.014286	0.013889	0.013333	0.012821	0.012500
0.012048	0.011765	0.011111	0.010526	0.010000	0.009524	0.009091	0.009091
0.010526	0.011111	0.011364	0.011765	0.013333	0.018182	0.028571	0.040000
0.040000	0.033333	0.030303	0.028571	0.025000	0.022222	0.020000	0.018182
0.016667	0.014706	0.013889	0.013333	0.013333	0.013333	0.013333	0.013333
0.012821	0.012500	0.012048	0.011364	0.010753	0.009709	0.009091	0.009091
0.010526	0.010526	0.011111	0.011765	0.012821	0.019231	0.033333	0.040000
0.040000	0.037037	0.030303	0.028571	0.027027	0.023256	0.020000	0.017544
0.015385	0.014286	0.013333	0.012500	0.012500	0.012500	0.012500	0.012500
0.012658	0.012821	0.012821	0.012048	0.011111	0.010000	0.009524	0.009091
0.010000	0.010526	0.010870	0.011765	0.012500	0.017241	0.027027	0.037037
0.040000	0.037037	0.033333	0.030303	0.027027	0.023810	0.019231	0.016667
0.014925	0.013889	0.012987	0.012195	0.011765	0.011765	0.011765	0.011765
0.011765	0.012048	0.012500	0.012500	0.011364	0.010000	0.009524	0.009091
0.010000	0.010526	0.010870	0.011765	0.012500	0.016667	0.025000	0.037037
0.040000	0.040000	0.037037	0.031250	0.028571	0.023810	0.018868	0.016129
0.014925	0.013699	0.012987	0.012500	0.012500	0.012346	0.012346	0.012195
0.012195	0.012195	0.012821	0.012821	0.011364	0.010000	0.009524	0.009091
0.010000	0.010526	0.010753	0.011494	0.012500	0.016667	0.025000	0.037037
0.040000	0.040000	0.037037	0.031250	0.028571	0.022222	0.018182	0.015873
0.014706	0.013699	0.013333	0.012987	0.012987	0.012987	0.012987	0.012821
0.012500	0.012500	0.012821	0.012658	0.011364	0.010000	0.009524	0.009091
0.010000	0.010526	0.010753	0.011494	0.012500	0.015385	0.022222	0.035714
0.040000	0.040000	0.037037	0.033333	0.025000	0.020833	0.017544	0.015385
0.014286	0.013699	0.013333	0.013333	0.013333	0.013333	0.013333	0.013333
0.013333	0.013333	0.013333	0.012500	0.011236	0.010000	0.009524	0.009091
0.010000	0.010526	0.010870	0.011494	0.012500	0.014925	0.021277	0.035714
0.040000	0.040000	0.040000	0.028571	0.023810	0.020000	0.017241	0.015385
0.014286	0.013699	0.013333	0.013333	0.013333	0.013333	0.013333	0.013333
0.013333	0.012987	0.012658	0.011765	0.011111	0.009709	0.009524	0.009091
0.010000	0.010526	0.011111	0.011765	0.012500	0.014286	0.020000	0.033333
0.037037	0.037037	0.033333	0.025000	0.022222	0.018182	0.017241	0.015385
0.014286	0.013699	0.013333	0.013333	0.013333	0.013333	0.013333	0.013333
0.012987	0.012821	0.012195	0.011494	0.010526	0.009709	0.009346	0.009091
0.010000	0.010526	0.011364	0.011765	0.012821	0.014286	0.018868	0.027027
0.028571	0.028571	0.025000	0.022222	0.020000	0.018868	0.016667	0.014925
0.013889	0.013333	0.013333	0.013333	0.013333	0.013158	0.012821	0.012500
0.012048	0.011765	0.011364	0.011111	0.010526	0.009709	0.009346	0.009091
0.010000	0.010753	0.011494	0.012048	0.013333	0.014286	0.018868	0.022222
0.025000	0.023256	0.021277	0.020000	0.018182	0.016667	0.015385	0.014706
0.013889	0.013333	0.012987	0.012500	0.012195	0.012048	0.011765	0.011364
0.011111	0.010870	0.010526	0.010309	0.010000	0.009524	0.009091	0.009091
0.010526	0.011111	0.011765	0.012500	0.013699	0.015385	0.018182	0.021277
0.022222	0.022222	0.020833	0.018182	0.016667	0.015385	0.014286	0.013333

0.012500	0.012195	0.011765	0.011494	0.011111	0.010870	0.010526	0.010526
0.010526	0.010526	0.010309	0.010000	0.009709	0.009524	0.009091	0.009091
0.010526	0.011364	0.012048	0.012821	0.013699	0.015385	0.017241	0.019231
0.021277	0.021277	0.019231	0.016667	0.014706	0.013699	0.012987	0.012500
0.011765	0.011111	0.010870	0.010638	0.010417	0.010204	0.010000	0.010000
0.009709	0.009709	0.009709	0.009709	0.009709	0.009524	0.009091	0.009091
0.010870	0.011765	0.012195	0.012987	0.013699	0.015385	0.016667	0.018182
0.019231	0.019231	0.016667	0.014286	0.013333	0.012500	0.011765	0.011111
0.010526	0.010204	0.010000	0.009709	0.009709	0.009709	0.009709	0.009709
0.009709	0.009524	0.009524	0.009524	0.009524	0.009524	0.009091	0.009091
0.011111	0.011765	0.012195	0.012987	0.013889	0.015385	0.016667	0.018182
0.019231	0.015873	0.015385	0.013333	0.012500	0.011765	0.010870	0.010204
0.010000	0.009709	0.009709	0.009709	0.009709	0.009709	0.009709	0.009709
0.009709	0.009524	0.009524	0.009524	0.009524	0.009091	0.009091	0.009091
0.011364	0.011765	0.012500	0.013333	0.014286	0.015385	0.016129	0.017544
0.015873	0.015385	0.014286	0.013333	0.011765	0.011111	0.010000	0.009804
0.009709	0.009709	0.009709	0.009709	0.009709	0.009709	0.009709	0.009709
0.009709	0.009524	0.009524	0.009524	0.009524	0.009091	0.009091	0.009091
0.011494	0.012048	0.012821	0.013333	0.014286	0.014925	0.015873	0.015385
0.013699	0.013699	0.013333	0.013333	0.012821	0.011765	0.010753	0.010526
0.010000	0.009709	0.009709	0.009709	0.009709	0.009709	0.009709	0.009709
0.009709	0.009524	0.009524	0.009524	0.009524	0.009091	0.009091	0.009091
0.011765	0.012195	0.012987	0.013333	0.014286	0.014925	0.014925	0.014286
0.012500	0.011111	0.011765	0.011765	0.011765	0.011765	0.011765	0.011494
0.011111	0.010753	0.010526	0.010309	0.010101	0.009709	0.009709	0.009709
0.009709	0.009524	0.009524	0.009524	0.009524	0.009091	0.009091	0.009091
0.012048	0.012500	0.013333	0.013699	0.014706	0.015385	0.014925	0.013333
0.011494	0.010309	0.010309	0.010526	0.010526	0.010526	0.010526	0.010526
0.010526	0.010526	0.010309	0.010204	0.009901	0.009709	0.009709	0.009709
0.009709	0.009709	0.009524	0.009524	0.009524	0.009091	0.009091	0.009091
0.012048	0.012500	0.013333	0.013889	0.014925	0.015385	0.013333	0.011765
0.010753	0.010526	0.010000	0.009709	0.009709	0.009709	0.009709	0.009709
0.009709	0.010000	0.010000	0.009709	0.009709	0.009709	0.009709	0.009709
0.009709	0.009709	0.009524	0.009524	0.009524	0.009091	0.009091	0.009091
0.012048	0.012500	0.012987	0.013889	0.014925	0.015385	0.014706	0.013699
0.012821	0.011765	0.011111	0.010526	0.010204	0.010000	0.009709	0.009709
0.009709	0.009709	0.009709	0.009709	0.009709	0.009709	0.009709	0.009709
0.009709	0.009709	0.009709	0.009709	0.009709	0.009524	0.009524	0.009524
0.011765	0.012195	0.012987	0.013889	0.014706	0.015385	0.014925	0.014706
0.013333	0.012987	0.012195	0.011765	0.011364	0.011111	0.010753	0.010526
0.010204	0.010000	0.010000	0.010000	0.010000	0.010000	0.010000	0.010000
0.010000	0.010000	0.010204	0.010204	0.010204	0.010000	0.010000	0.010000
0.011765	0.012195	0.012987	0.013699	0.014706	0.014925	0.015385	0.014925
0.014706	0.014286	0.013889	0.013333	0.012987	0.012500	0.012195	0.011905
0.011765	0.011628	0.011364	0.011111	0.010870	0.010870	0.010753	0.010753
0.010638	0.010526	0.010526	0.010526	0.010526	0.010753	0.011111	0.011111
0.012048	0.012500	0.012987	0.013699	0.014286	0.014925	0.015385	0.015385
0.015385	0.014925	0.014925	0.014706	0.014286	0.013889	0.013514	0.013333
0.013158	0.012821	0.012500	0.012500	0.012195	0.012048	0.012048	0.011765
0.011765	0.011765	0.011765	0.011494	0.011494	0.011494	0.011765	0.011765

7 0.50 (16F5.0) 7 (TRANSMISSIVITY LAYER 2)

73	73	72	72	72	72	72	72	72	72	72	72	70	70	70	70
70	70	70	70	70	70	70	70	71	71	71	71	72	72	73	73
73	73	72	71	70	70	70	70	70	68	68	68	68	68	68	68
69	69	69	69	69	69	69	69	69	69	70	70	70	70	70	70
72	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
69	69	69	68	68	68	68	68	68	68	69	69	69	69	69	69
70	70	71	72	73	75	75	75	75	75	73	.7	.7	.7	.7	.7
.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7
70	72	71	75	77	79	80	80	80	80	80	.7	.7	.7	.7	.7
.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7
72	72	72	75	77	80	80	80	80	80	80	.8	.8	.8	.8	.8
.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7
72	72	72	75	76	360	360	360	360	77	76	.8	75	75	75	74
73	71	71	70	69	68	67	67	68	69	70	70	70	70	75	70
72	72	72	74	75	360	360	360	360	76	76	.7	76	75	74	72
70	70	69	68	67	66	67	68	70	76	78	80	80	80	75	70
72	72	72	73	73	360	360	360	360	74	74	.7	74	73	72	70
69	68	67	66	66	66	68	70	70	71	71	71	71	71	71	70
72	72	72	72	71	360	360	360	360	72	72	.7	70	70	70	69
68	67	67	66	65	65	66	70	72	72	72	72	72	71	71	70
72	71	71	70	70	360	360	360	360	70	70	68	69	69	68	67
66	66	66	65	65	64	65	70	71	71	71	71	71	71	71	70
72	71	71	68	69	360	360	360	360	68	67	67	67	66	66	66
65	65	65	65	65	65	65	70	72	72	72	72	71	71	71	70
72	70	69	68	67	360	360	360	360	66	66	67	66	65	65	65
65	65	65	65	65	65	70	73	72	71	71	71	71	71	71	70
72	70	69	68	67	360	360	360	360	66	65	65	65	65	65	65
65	65	65	63	65	68	70	75	78	75	72	72	71	71	71	70
72	70	69	68	67	66	65	64	65	65	65	65	65	65	65	65
65	63	65	65	67	70	75	75	73	73	73	73	73	73	72	70
72	71	70	68	66	65	65	65	65	65	65	65	65	65	65	67
64	65	67	70	70	76	76	74	73	72	71	71	71	71	71	70
72	71	70	69	67	65	65	66	66	66	66	66	66	66	66	67
65	67	70	70	72	74	72	71	71	71	71	71	71	71	71	70
72	71	71	70	68	65	66	65	65	65	65	65	66	67	65	65
70	70	70	71	73	73	72	72	72	72	71	71	71	71	71	70
72	70	71	71	70	67	66	65	65	65	65	66	67	67	67	70
70	70	71	72	73	72	72	72	72	72	72	72	72	72	71	70
72	70	70	71	71	70	65	65	65	65	65	65	65	70	70	70
71	71	71	72	73	74	73	72	72	72	71	71	71	71	71	70
72	70	70	70	70	73	70	70	70	70	70	70	70	70	71	71
71	71	72	72	73	73	74	75	75	75	75	75	75	75	75	70
75	72	72	72	73	74	70	70	70	70	71	71	71	71	71	71
71	71	71	71	70	70	70	70	70	70	70	70	70	70	70	70
73	73	73	73	73	73	72	70	68	69	69	69	69	69	69	69
69	69	69	69	69	68	69	69	69	68	67	66	66	70	70	70
73	73	72	72	72	72	72	71	70	69	68	68	68	68	68	68
67	68	69	69	69	69	70	70	70	70	70	70	68	68	70	70
73	73	72	72	72	72	72	71	70	69	68	68	68	68	68	70
70	70	70	70	70	70	68	70	70	70	70	70	71	71	71	70
71	71	71	71	71	71	70	70	69	68	67	68	68	69	68	68
68	68	70	70	70	70	70	70	72	73	74	73	71	71	71	70
73	73	73	72	72	72	71	70	69	68	68	68	69	70	70	70
72	72	73	72	72	72	73	72	71	71	71	71	71	71	72	70
75	75	74	73	72	70	70	68	68	68	68	70	70	70	70	70
70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70

River Module Data

45	20				
45					
1	2	9	716.5	1400.	716.
1	3	9	717.5	1360.	717.
1	4	8	719.5	1360.	719.
1	5	8	720.5	1360.	720.
1	6	8	722.5	1360.	722.
1	7	9	724.5	1360.	724.
1	8	9	725.5	820.	725.
1	9	9	726.5	820.	726.
1	10	9	727.5	820.	727.
1	11	10	728.5	1090.	728.
1	12	11	729.5	820.	729.
1	13	11	730.5	820.	730.
1	14	11	731.5	820.	731.
1	14	28	797.5	6000.	795.
1	15	11	732.5	820.	732.
1	16	11	733.5	820.	733.
1	17	10	734.5	820.	734.
1	18	10	735.5	820.	735.
1	19	10	736.5	820.	736.
1	20	11	737.5	820.	737.
1	20	12	741.5	820.	741.
1	20	13	742.5	550.	742.
1	21	11	739.5	820.	739.
1	21	13	743.5	1500.	743.
1	22	10	741.5	200.	741.
1	22	14	744.5	1090.	744.
1	22	15	745.5	820.	745.
1	22	16	746.5	1090.	746.
1	23	9	743.5	490.	743.
1	23	17	747.5	1360.	747.
1	24	7	748.5	200.	748.
1	24	8	746.5	200.	746.
1	24	18	751.5	1360.	751.
1	24	19	753.5	1090.	753.
1	24	29	782.5	6000.	780.
1	25	6	753.5	490.	753.
1	25	29	782.5	8000.	780.
1	25	20	754.5	1360.	754.
1	26	5	757.5	490.	757.
1	26	20	755.5	1360.	755.
1	27	4	761.5	8000.	760.
1	27	5	758.5	490.	758.
1	27	21	757.5	820.	757.
1	27	22	758.5	1360.	758.
1	28	22	759.5	1360.	759.

Drain Module Data

86	15			
86				
1	2	2	740.	490.
1	2	3	738.	490.
1	2	4	735.	490.
1	2	5	727.	490.
1	2	6	725.	490.
1	2	8	717.	100.
1	2	10	720.	150.
1	2	11	722.	100.
1	3	7	718.	490.
1	3	12	725.	150.
1	3	13	728.	150.
1	3	14	729.	150.
1	3	15	731.	100.
1	4	16	733.	150.
1	4	17	735.	150.
1	4	18	737.	150.
1	4	19	739.	150.
1	4	20	741.	150.
1	4	21	744.	150.
1	5	22	747.	150.
1	5	23	749.	150.
1	5	24	753.	150.
1	5	25	756.	150.
1	5	26	759.	150.
1	6	27	762.	150.
1	6	28	765.	270.
1	7	29	768.	150.
1	7	30	771.	400.
1	8	31	774.	100.
1	9	31	777.	150.
1	10	31	780.	150.
1	11	31	783.	150.
1	12	31	786.	150.
1	13	31	793.	150.
1	14	5	775.	100.
1	14	22	770.	150.
1	14	23	773.	150.
1	14	24	776.	150.
1	14	25	780.	150.
1	14	26	785.	150.
1	14	27	790.	150.
1	14	31	795.	150.
1	15	5	768.	490.
1	15	19	760.	200.
1	15	20	762.	150.
1	15	21	765.	150.
1	15	32	806.	150.
1	16	6	755.	490.
1	16	7	747.	490.
1	16	8	744.	150.
1	16	9	740.	150.
1	16	10	737.	150.
1	16	18	758.	200.
1	16	32	811.	150.
1	17	17	754.	200.
1	17	32	813.	150.
1	18	13	745.	150.
1	18	14	748.	150.
1	18	15	749.	150.
1	18	16	749.	150.
1	18	32	818.	150.
1	19	11	739.	150.
1	19	12	743.	150.
1	20	10	742.	150.
1	20	29	790.	490.

1	21	15	748.	100.
1	21	28	780.	270.
1	22	28	775.	270.
1	22	27	775.	150.
1	23	26	772.	150.
1	23	18	749.	150.
1	23	19	754.	150.
1	23	20	758.	150.
1	23	21	759.	150.
1	23	22	761.	150.
1	23	23	762.	150.
1	24	2	778.	490.
1	24	3	770.	490.
1	24	4	765.	490.
1	24	5	760.	490.
1	24	6	755.	490.
1	24	24	764.	150.
1	24	25	766.	150.
1	24	26	769.	150.
1	24	27	772.	150.
1	24	28	775.	150.

Recharge Module Data

```
         1        20
         1         1
        10 66.50E-04 (20F4.0)                   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0  00  00  00  00  00 0.5 0.5 1.5 1.5 1.5
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0  .5  .5  .5  .5  .5 1.5 1.5 1.5 1.5 1.5
 ..5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0  .5  .5 1.5 1.5 1.5 1.5
 1.5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0  .5 1.5 1.5 1.5 1.5
 1.5 1.5  .5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  .5  .5  .5   0   0   0   0   0  .5 1.5 1.5 1.5
 1.5 1.5 1.5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0  .5  .5  .5
 1.5 1.5  .5  .5  .5  .5  .5  .5  .5  .5 1.5 1.5
 1.5 1.5 1.5  .5   0   0   0   0   0   0   0   0   0   0   0   0  .5  .5 1.5 1.5
 1.5 1.5 1.5 1.5 1.5 1.5 1.5  .5  .5  .5 1.5 1.5
 1.5 1.5 1.5  .5   0   0   0   0   0   0   0   0   0   0   0   0  .5 1.5 1.5 1.5
 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5  .5  .5 1.5
 1.5 1.5 1.5  .5  .5   0   0   0   0   0   0   0   0   0   0   0  .5 1.5 1.5 1.5
 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5  .5 1.5
 1.5 1.5 1.5 1.5  .5   0   0   0   0   0   0   0   0   0   0   0  .5  .5 1.5 1.5
 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5 1.5 0.5  .5  00   0   0   0   0   0   0   0   0   0   0  .5  .5  .5  .5
  .5  .5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5 0.5  .5  .5  00   0   0   0   0   0   0   0   0   0   0  .5  .5  .5  .5
  .5  .5  .5  .5  .5  .5  .5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5 1.5  .5  .5  00   0   0   0   0   0   0   0   0   0   0   0  .5  .5  .5
  .5  .5  .5  .5  .5  .5  .5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5 1.5  .5  .5  00   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0  .5  .5  .5  .5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5 1.5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0  .5  .5  .5  .5  .5  .5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5 1.5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  .5  .5  .5  .5  .5  .5 1.5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5 1.5  .5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0  00  .5
  .5  .5  .5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5
 1.5 0.5 0.5  .5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0  00  .5
  .5  .5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5
 1.5 0.5  .5  .5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0  .5  .5
  .5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 0.5 1.5 1.5 1.5
 1.5 0.5  .5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0   0  .5  .5
  .5  .5  .5  .5 1.5 1.5 1.5 0.5 0.5 1.5 1.5 1.5
 1.5 1.5  .5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  .5  .5  .5  .5  .5  .5  .5  .5 1.5 1.5 1.5 1.5
 1.5 1.5  .5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0  .5  .5  .5  .5  .5 1.5 1.5 1.5 1.5
 1.5  .5  .5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0  .5 1.5 1.5 1.5 1.5
 1.5  .5   0   0   0   0   0   0   0   0   0   0   0  .5  .5   0   0   0   0   0
   0   0  .5  .5  .5  .5  .5  .5  .5 1.5 1.5 1.5
 1.5 1.5  .5   0   0   0   0   0   0   0   0   0   0  .5  .5  .5   0   0   0   0
   0   0   0  .5  .5  .5  .5  .5  .5  .5 1.5 1.5
 1.5 1.5  .5   0   0   0   0   0   0   0  .5  .5  .5  .5  .5  .5  .5  .5   0   0
   0   0   0  .5  .5  .5  .5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5  .5   0   0   0   0  .5  .5  .5  .5  .5  .5  .5  .5  .5  .5  .5  .5   0
   0   0   0   0  .5  .5  .5 1.5 1.5 1.5 1.5 1.5
 1.5 1.5  .5   0   0   0   0  .5  .5  .5  .5  .5  .5  .5  .5  .5  .5  .5  .5   0
   0   0   0   0  .5  .5  .5 1.5 1.5 1.5 1.5 1.5
```

Strongly Implicit Procedure Module Data

```
       100         5
       1.0      0.10         1    0000000
```