# GROUND-WATER HYDROLOGY AND THE EFFECTS OF VERTICAL LEAKAGE AND LEACHATE MIGRATION ON GROUND-WATER QUALITY NEAR THE SHELBY COUNTY LANDFILL, MEMPHIS, TENNESSEE

By Michael W. Bradley

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DIVISION OF SOLID WASTE MANAGEMENT

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*For additional information write to:*

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U.S. Geological Survey, WRD
810 Broadway, Suite 500
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# CONTENTS



# ILLUSTRATIONS

## TABLES

# CONVERSION FACTORS, VERTICAL DATUM, AND WELL-NUMBERING SYSTEM

| *Multiply* | *By* | *To obtain* |
|---|---|---|
| inch (in.) | 2.54 | centimeter |
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |
| square mile ($mi^2$) | 2.590 | square kilometer |
| gallons per minute (gal/min) | 0.06309 | liters per second |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second |

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*Sea Level*: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NVGD of 1929)--a geodetic datum derived from general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

*Well-Numbering System*: Wells are identified according to the numbering system used by the U.S. Geological Survey throughout Tennessee. The well number consists of three parts: (1) an abbreviation of the name of the county in which the well is located; (2) a letter designating the 7 $^1/_2$-minute quadrangle or 7 $^1/_2$-minute quadrant of the 15-minute quadrangle, on which the well is plotted; and (3) a number generally indicating the numerical order in which the well was inventoried. The number SH:P-99, for example, indicates the well is located in Shelby County on the "P" quadrangle and is identified as well 99 in the numerical sequence. Quadrangles are lettered from left to right, beginning in the southwest corner of the county.

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## ABSTRACT

*An investigation of potential leakage of leachate from the Shelby County landfill near Memphis, West Tennessee, was conducted during 1986-87. The migration of leachate from the landfill to the shallow alluvial aquifer system and the potential leakage to the deeper confined Memphis aquifer of Tertiary age were investigated. A network of observation wells was drilled to determine water levels and aquifer properties in the shallow and deep aquifers as well as in the confining layer. Water samples were collected to define potential leachate occurrence.*

*A depression in the water table within the shallow alluvial aquifer was defined from the water-level data. Drawdowns within the cone of depression are as much as 14 feet lower than the adjoining Wolf River. Recharge from the river and leachate from the landfill moves toward the depression. The presence of leachate within the shallow aquifer was confirmed from determinations of dissolved solids and dissolved chloride concentrations and comparisons with areas away from the affected zone. Leakage from the water-table aquifer to the Memphis aquifer was confirmed from chemical analyses and hydraulic-head data. Dissolved-solids concentrations in water samples from the upper Memphis aquifer near the landfill are higher than in samples from the Memphis aquifer in unaffected areas. Tritium activities in water samples from the upper Memphis aquifer were as high as 34 picoCuries per liter indicating recent recharge to the Memphis aquifer.*

*The presence of synthetic organic compounds and elevated concentrations of dissolved solids, chloride, and trace metals indicate the leachate has affected water quality in the alluvial aquifer. Vertical migration of ground water could transmit leachate down to the Memphis aquifer. Although water-quality data indicate that water is leaking from the alluvial aquifer to the Memphis aquifer, most of the data do not indicate the occurrence of leachate in the Memphis aquifer. Chemical data from one well in the Memphis aquifer near the landfill indicates a slightly elevated dissolved-chloride concentration, but the data are limited.*

## INTRODUCTION

The Memphis aquifer is the major source of water for municipal, industrial, and commercial uses in West Tennessee. The City of Memphis uses the Memphis aquifer as its only source of water and pumped about 190 million gallons per day from the Memphis aquifer in 1988 (S. Hutson, U.S. Geological Survey, written commun., 1989). The potential for this resource to be endangered by the possible downward migration of contaminants is a major concern to the City of Memphis, Shelby County, and the State of Tennessee.

In the Memphis area, the Memphis aquifer is overlain and confined by the Jackson-upper Claiborne confining layer. The confining layer separates the Memphis aquifer from the shallow water-table aquifer occurring at land surface. Movement of water down to the Memphis aquifer was thought to be prevented by clay layers in the Jackson-upper Claiborne confining layer. However, an investigation by Graham and Parks (1986) identified general areas in Shelby County where water could possibly migrate down from the water-table aquifer to the Memphis aquifer. Investigations by the Division of Solid Waste Management of the Tennessee Department of Health and Environment (P.M. Garman, written commun., 1978; J.L. Ashner, written commun., 1986) for the proposed expansion of the Shelby County Landfill indicated the occurrence of possible downward leakage to the Memphis aquifer at a specific site. If leakage were occurring, leachate from the landfill could possibly move toward and into the Memphis aquifer.

The U.S. Geological Survey (USGS), in cooperation with the Shelby County Department of Public Works and the Tennessee Department of Health and Environment, Division of Solid Waste Management, conducted a hydrologic investigation in the vicinity of the landfill during 1986 to 1987. The investigation was designed to determine if leakage down the Memphis aquifer is occurring and whether leachate from the landfill is reaching or affecting water quality in the Memphis aquifer. If a relatively small, specific area of vertical leakage could be identified, the hydrologic and geochemical methods could be applied to other areas in Shelby County and West Tennessee to identify areas where the water-table aquifer is recharging the Memphis aquifer and areas where the Memphis aquifer may be susceptible to contamination.

### PURPOSE AND SCOPE

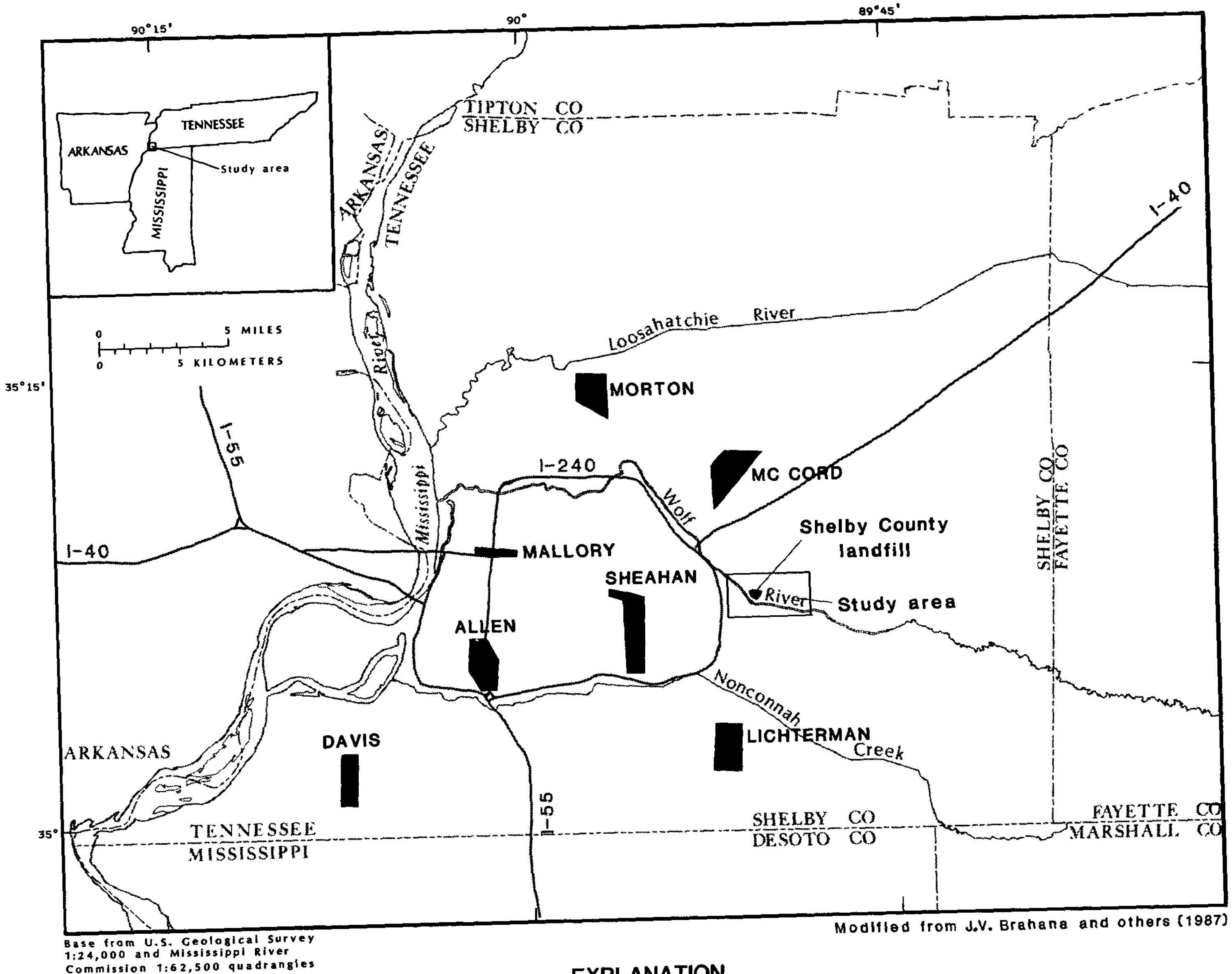
This report summarizes the findings of the hydrologic investigation at the Shelby County landfill. The objectives of that investigation were to determine:

(1) If vertical leakage from the alluvial aquifer to the Memphis aquifer is occurring near the landfill.

(2) The extent of any leachate migration from the landfill to the alluvial aquifer.

(3) If leachate has migrated to the Memphis aquifer.

The study area included the landfill and its immediate vicinity (fig. 1). The landfill proper occupies an area of about 60 acres south of the Shelby County Penal Farm east of Memphis (fig. 1). Existing and new wells in the alluvial aquifer and Memphis aquifer were used in the study. The segment of the Wolf River adjacent to the landfill was included in the study area to determine whether the stream recharges the aquifer or receives water from the aquifer.




EXPLANATION

DAVIS — MEMPHIS LIGHT, GAS AND WATER DIVISION WELL FIELD

Figure 1.--Location of the Shelby County landfill and Memphis Light, Gas and Water Division well fields in the Memphis area, Tennessee.

## APPROACH

The approaches used to meet the objectives of the investigation were as follows:

(1) A network of 37 observation wells were drilled in the vicinity of the landfill. These included 28 wells in the alluvial aquifer, 5 wells in the confining layer, and 4 wells in the Memphis aquifer. The network was supplemented with existing wells.

(2) Ground-water levels and hydrogeologic data for the alluvial and Memphis aquifers were collected from the wells. Aquifer tests were conducted at two sites to determine the effects of pumpage from the Memphis aquifer on water levels in the alluvial aquifer.

(3) Water samples were collected from 18 wells completed in the alluvial and Memphis aquifers. Chemical and physical analyses of the samples were made to define the quality of the water and the potential occurrence of leakage of leachate from the landfill.

(4) Streamflow measurements were made along the Wolf River during periods of low flow. The measurements were used to determine if recharge from the river, or discharge from the shallow aquifer, occurs near the landfill.

## ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance during this investigation of Mr. Ronald W. Lawler who arranged for access to and allowed the installation of wells on Agricenter International property. Mr. David C. Newsome, Manager of the Shelby County landfill, also is gratefully acknowledged for providing extensive information about the landfill and its operation. Special thanks are expressed to Mr. Ronnie James and his crew at the landfill who prepared drilling sites and access roads, supplied a water truck during drilling, and provided needed assistance during the drilling operations.

## SITE DESCRIPTION

The Shelby County landfill is located on the Wolf River flood plain on the east side of Memphis (fig. 1). The landfill area is about 4 miles south of the McCord well field operated by the Memphis Light, Gas and Water Division (MLGW) of the City of Memphis, and about 5 miles east of the Sheahan well field also operated by MLGW. The Wolf River flood plain is relatively flat with some levees, drainage ditches, and intermittent streams. Agricultural land, including the Shelby County Penal Farm (Penal Farm), is adjacent to the landfill to the north and east (fig. 2). The landfill lies north of the Wolf River, which flows west to its junction with the Mississippi River at Memphis. Land-surface altitudes in the area range from about 250 feet above sea level in the flood plain to more than 300 feet above sea level in the uplands northeast of the landfill.

The Shelby County landfill has been built above the adjacent Wolf River flood plain. The surface of the landfill is 290 feet above sea level, or about 40 to 45 feet higher than the surrounding flood plain. The water-surface elevation of the Wolf River at Walnut Grove Road was about 230 feet above sea level during average flow conditions in 1988 and about 248 feet above sea level during peak flow conditions in 1988 (U.S. Geological Survey, 1989).

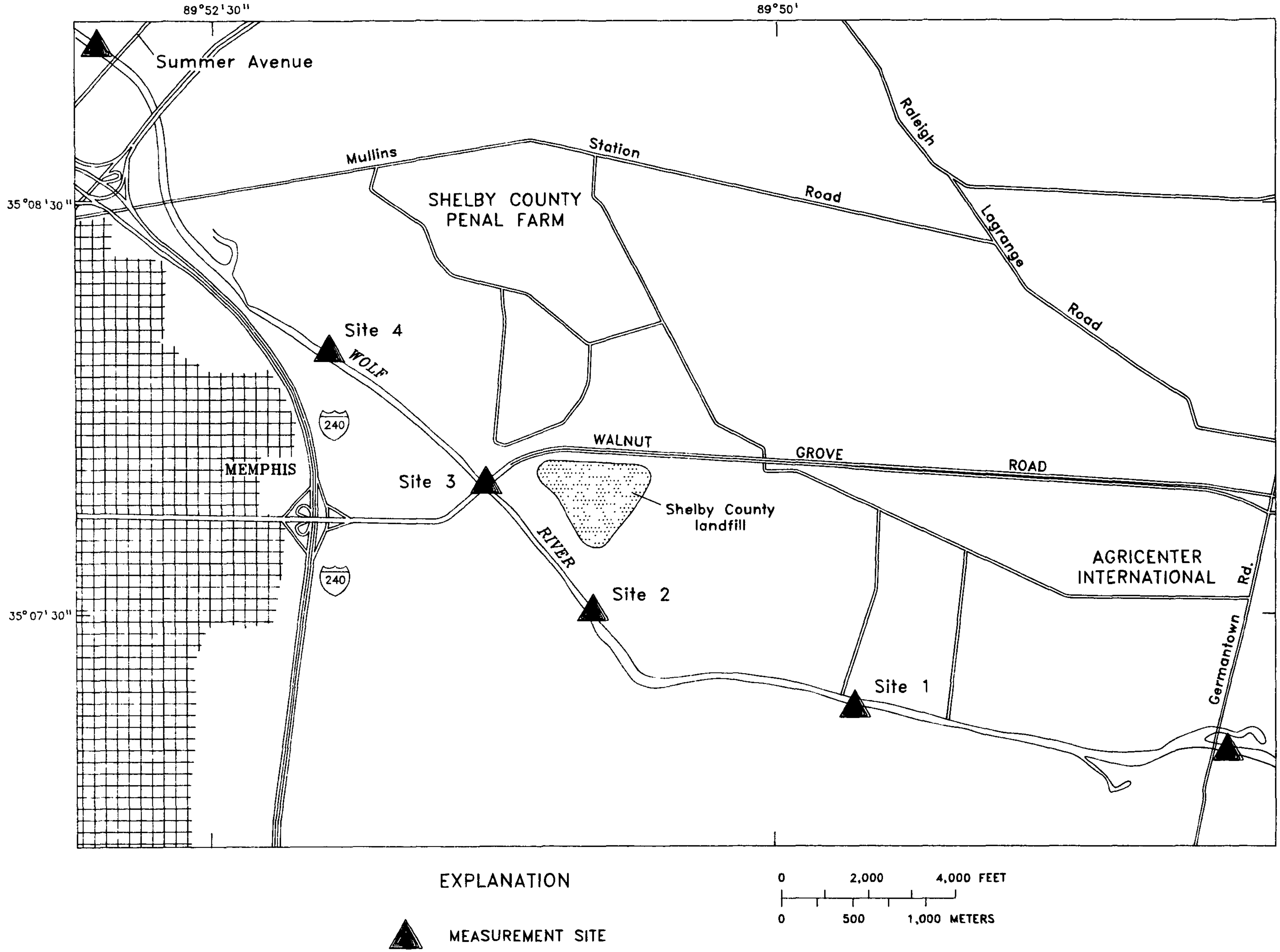



Figure 2.--Low-flow measurement sites on the Wolf River.

## GEOLOGY

The study area is located within the north-central part of the Mississippi embayment, and is underlain by several thousand feet of unconsolidated Cretaceous, Tertiary, and Quaternary age sediments (Cushing and others, 1964). The formations of interest to this study are the alluvium beneath the Wolf River flood plain and the fluvial deposits of Quaternary age in the adjacent uplands and the Cockfield and Cook Mountain Formations and the Memphis Sand of Tertiary age (fig. 3).

The upper part of the alluvium in the study area consists of about 10 to 15 feet of silty clay and clay. The lower part of the alluvium is composed of 20 to 40 feet of sand and gravel with minor clay and silt (Bradley, 1988). The sand is predominantly medium to coarse grained and is locally iron stained. The fluvial deposits occur beneath the uplands and valley slopes north and east of the landfill area. These deposits consist of sand and gravel with some minor amounts of clay. The fluvial deposits are in contact with the alluvium near the edge of the Wolf River flood plain.

The alluvium and fluvial deposits are separated from the underlying Memphis Sand by a confining layer, which includes strata equivalent to the Jackson Formation and the Cockfield and Cook Mountain Formations of the upper Claiborne Group of Tertiary age. Because of the similarity in lithology, these formations have not been subdivided and the confining layer is referred to as the Jackson-upper Claiborne confining layer (Graham and Parks, 1986). The Jackson-upper Claiborne confining layer consists predominantly of clay, silt, and silty or fine-grained sand and is highly variable in thickness.

Individual beds within the Jackson-upper Claiborne confining layer are not areally extensive in this area. The clay or silt layers are lenticular and may pinch out rapidly or grade laterally into silty-sand or sand layers. For example, a clay layer occurring at about 60 to 70 feet below land surface at well MS-2 pinches out laterally and is not present at well MS-1 about 50 feet away (fig. 4).

The Memphis Sand of the Claiborne Group underlies the Jackson-upper Claiborne confining layer. The upper part of the Memphis Sand consists predominantly of sand with some interbedded silt and clay (fig. 3). The upper sand of this formation occurs at about 70 to 135 feet below land surface in the study area (Bradley, 1988). The Memphis aquifer is a term used to distinguish the hydrologic unit from the geologic Memphis Sand formation. The Memphis aquifer consists of the saturated sands of the Memphis Sand.

## STREAMFLOW

The area around the Shelby County landfill is drained by intermittent streams and ditches. All of these intermittent streams and ditches discharge to the Wolf River, a major stream with an average annual discharge of about 1,000 $ft^3/s$ (USGS, 1980-89).

The Wolf River exerts an important role in the hydrology in the vicinity of the landfill. Streamflow data collected since 1962 indicate that in some reaches water infiltrates from the stream into the shallow aquifer with the reverse occurring in other reaches. Discharge measurements made at two sites on the Wolf River during October 1962 showed a streamflow loss of 13 $ft^3/s$ (table 1). Streamflow of the Wolf River was 353 $ft^3/s$ upstream of the landfill area at Germantown Road and 340 $ft^3/s$ downstream of the area at Summer Avenue (fig. 2, table 1). During this investigation, additional discharge measurements were made to determine if the reach of the Wolf River

| | Stratigraphic column | Stratigraphic unit | Thickness, in feet | Lithology and hydrologic significance |
|---|---|---|---|---|
| QUATERNARY | | Alluvium | 0–175 | Sand, gravel, silt, and clay. Underlies the Mississippi Alluvial Plain and alluvial plains of streams in the Gulf Coastal Plain. Thickest beneath the Alluvial Plain, where commonly between 100 and 150 feet thick; generally less than 50 feet thick elsewhere. Provides water to domestic, farm, industrial, and irrigation wells in the *Mississippi Alluvial Plain.* |
| QUATERNARY | | Loess | 0–65 | Silt, silty clay, and minor sand. Principal unit at the surface in upland areas of the Gulf Coastal Plain. Thickest on the bluffs that border the Mississippi Alluvial Plain; thinner eastward from the bluffs. Tends to retard downward movement of water providing recharge to the fluvial deposits. |
| QUATERNARY | | Fluvial deposits (terrace deposits) | 0–100 | Sand, gravel, minor clay and ferruginous sandstone. Generally underlie the loess in upland areas, but are locally absent. Thickness varies greatly because of erosional surfaces at top and base. Provides water to many domestic and farm wells in rural areas. |
| TERTIARY | | Jackson Formation and upper part of Claiborne Group, includes Cockfield and Cook Mountain Formations (capping clay) | 0–360 | Clay, silt, sand, and lignite. Because of similarities in lithology, the Jackson Formation and upper part of the Claiborne Group cannot be reliably subdivided based on available information. Most of the preserved sequence is the Cockfield and Cook Mountain Formations undivided, but locally the Cockfield may be overlain by the Jackson Formation. Serves as the upper confining bed fo the Memphis aquifer. |
| TERTIARY | | Memphis Sand ("500-foot" sand) | 500–890 | Sand, clay, and minor lignite. Thick body of sand with lenses of clay at various stratigraphic horizons and minor lignite. Thickest in the southwestern part of the Memphis area; thinnest in the northeastern part. Principal aquifer providing water for municipal and industrial supplies east of the Mississippi River; sole source of water for the City of Memphis. |

Modified from D.D. Graham and W.S. Parks (1986)

Figure 3.--Stratigraphic column and general geohydrology of the Memphis area.

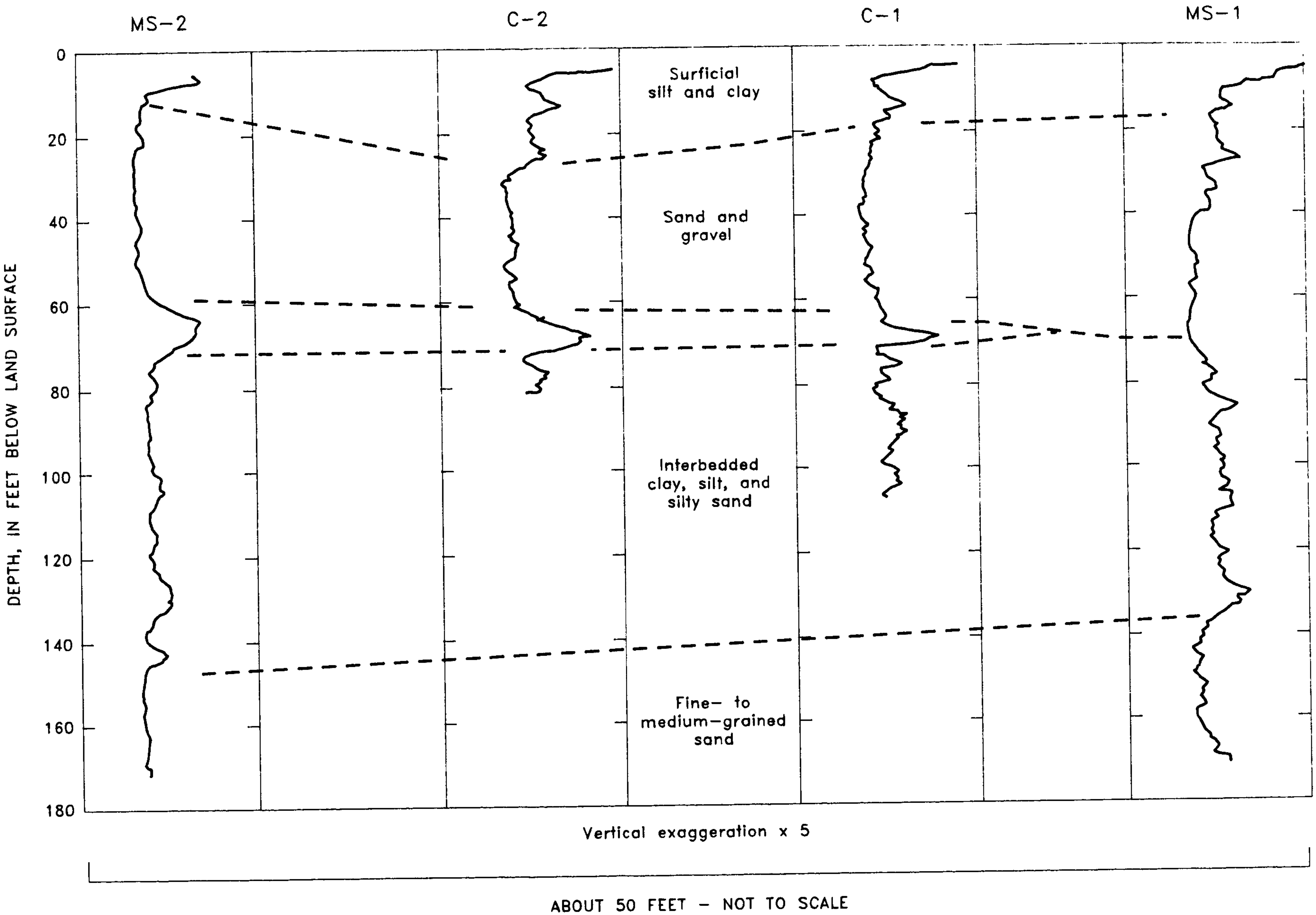



Figure 4.--Generalized lithology and gamma logs from well MS-2 to well MS-1.

Table 1.—*Streamflow measurements for the Wolf River near the Shelby County landfill*

[Streamflow measurements in cubic feet per second;
RM - River mile, miles upstream of river mouth; --, No data]

| Measurement date | Germantown Road RM18.90 | Site 1 RM17.50 | Site 2 RM16.20 | Walnut Grove Road RM15.40 | Site 3 RM14.45 | Summer Avenue RM13.00 |
|---|---|---|---|---|---|---|
| Oct. 26,1962 | 353 | -- | -- | -- | -- | 340 |
| Aug. 22,1986 | 224 | -- | -- | 228 | -- | 235 |
| Nov. 4,1986 | -- | 271 | 265 | 255 | 284 | -- |

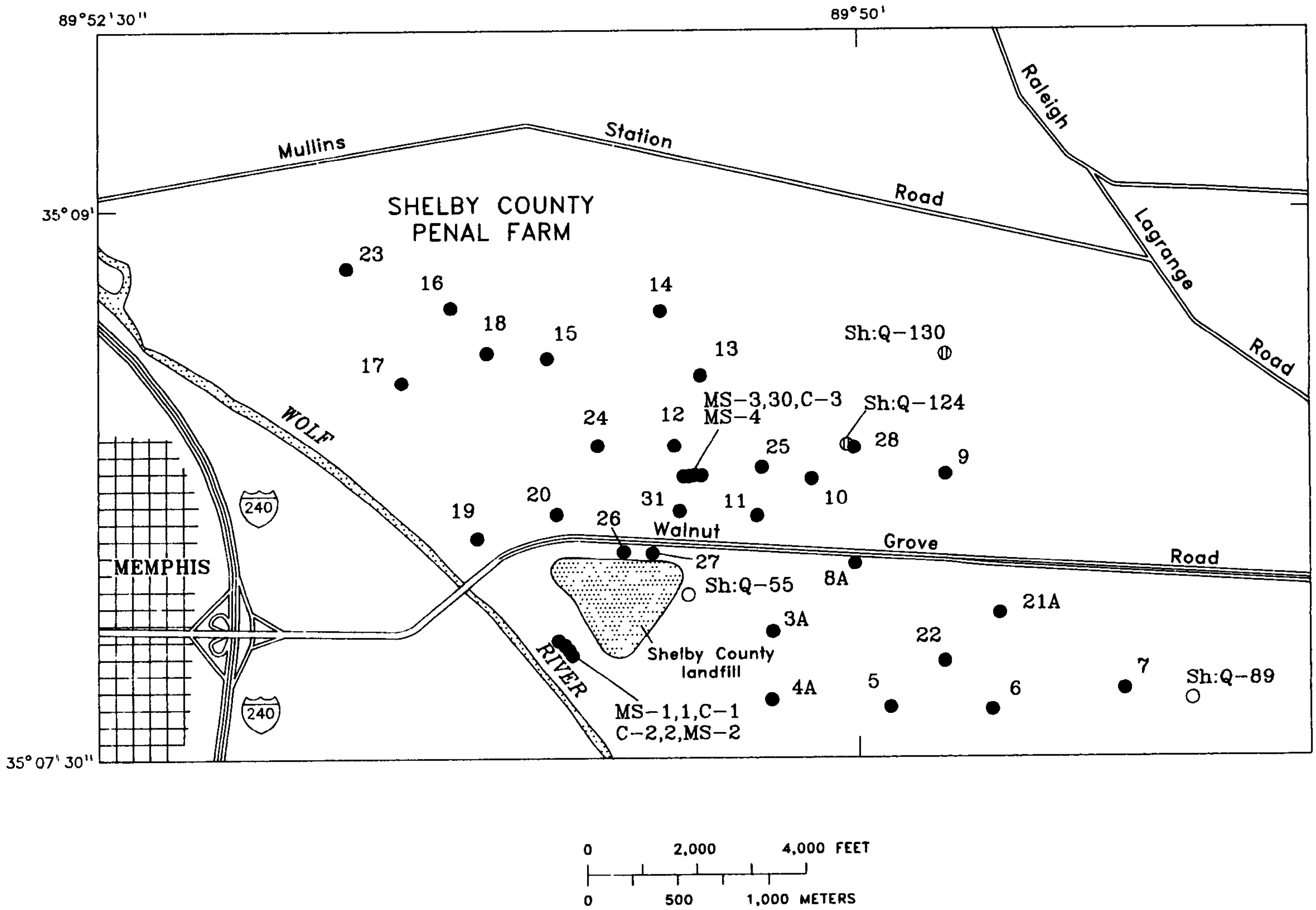
near the landfill was losing water to the alluvial aquifer. Measurements made at Germantown Road, Walnut Grove Road, and Summer Avenue (fig. 2) in August 1986 indicated a general increase in flow from upstream to downstream sites. The discharge was 224 $ft^3/s$ at Germantown Road, 228 $ft^3/s$ at Walnut Grove Road, and 235 $ft^3/s$ downstream of Summer Avenue (table 1). However, because the sites are about 2 to 3 miles upstream and downstream from the landfill, closer sites were later selected for additional discharge measurements.

Four discharge measurements were made on November 4, 1986 (table 1), at Walnut Grove Road and at about 1-mile intervals upstream and downstream (fig. 2). Sites 1 and 2 are upstream of Walnut Grove Road, and site 3 is about 1 mile downstream. Discharge decreased from 271 $ft^3/s$ at site 1 to 255 $ft^3/s$ at Walnut Grove Road (table 1). The Wolf River lost 16 $ft^3/s$ in this 2.1-mile reach. This reach of the river is adjacent to the landfill and Penal Farm area. Below Walnut Grove Road, the Wolf River gained 29 $ft^3/s$, increasing from 255 to 284 $ft^3/s$ at site 3 (table 1).

The loss in flow of the Wolf River from site 1 to Walnut Grove Road is only 16 $ft^3/s$ or about 6 per-cent of the total flow of 271 $ft^3/s$. Because of the low percentage involved, some of this difference could be measurement error. However, the general trend of decreasing flow adjacent to the project area indicates a loss of water to the alluvial aquifer was occurring. This is consistent with conclusions based on ground-water levels and direction of ground-water flow in the alluvial aquifer.

## WELL CONSTRUCTION

During July 1986 and June 1987, 37 observation wells were installed in the landfill area (fig. 5). Twenty-eight wells were completed in the alluvial aquifer. Five wells were completed in the confining layer. Four wells were completed in the upper part of the Memphis aquifer. Two test holes, SH:Q-124 and SH:Q-130, were drilled to depths of 200 and 217 feet, respectively, for stratigraphic information (fig. 5). These two wells were plugged.




EXPLANATION

19 ● OBSERVATION WELL AND PROJECT NUMBER

Sh:Q-130 ◍ STRATIGRAPHIC TEST HOLE AND USGS LOCAL NUMBER

Sh:Q-55 ○ OBSERVATION WELL AND USGS LOCAL NUMBER OF WELL EXISTING PRIOR TO THIS STUDY

Figure 5.--Location of observation wells and stratigraphic test holes at the Shelby County landfill.

Groups of wells were installed at two sites. One group of wells is located southwest of the landfill near the Wolf River and consists of six wells: 1, 2, C-1, C-2, MS-1, and MS-2 (fig. 5). These wells were completed at 35.8 and 48.3 feet below land surface in the alluvial aquifer (wells 1 and 2); 108 and 83.5 feet below the surface in the confining layer (wells C-1 and C-2); and 170 and 180 feet below land surface in the upper Memphis aquifer (wells MS-1 and MS-2). The second group of wells: 30, C-3, MS-3, and MS-4 (fig. 5), is located in a field north of the landfill. This group consists of one well completed at 38.7 feet below land surface in the alluvial aquifer (well 30), one at 55.3 feet below land surface in the confining layer (well C-3), and 100 feet and 97.7 feet below land surface in the upper Memphis aquifer (wells MS-3 and MS-4).

Construction data are summarized in table 2; more detailed information is given in a report by Bradley (1988). All of the wells were constructed with polyvinyl chloride (PVC) casing and screen. Two existing wells in the study area (SH:Q-55 and SH:Q-89) used for collecting water-quality samples are also listed in table 2.

The wells constructed for this investigation were assigned a project number during the drilling (for example MS-1) and later assigned a formal USGS local number, for example, SH:Q-98. Throughout this report, wells constructed for the project will be identified by the project number. Those wells that were not constructed during this investigation are identified by the USGS local number.

## GROUND-WATER HYDROLOGY

The aquifers of concern near the Shelby County landfill are the alluvial aquifer and the Memphis aquifer. These units are separated by the Jackson-upper Claiborne confining layer.

### ALLUVIAL AQUIFER

The alluvial aquifer consists of 30 to 50 feet of sand and gravel with some interbedded layers of silt and clay. Water levels in the alluvial aquifer fluctuated about 1 foot during October 1986 to June 1987 (fig. 6). These fluctuations were probably in response to changes in recharge and evapotranspiration. Water levels were generally lowest during October and November. Recharge during winter and early spring typically caused water levels to rise to their highest levels in March, April, and May (fig. 6). Decreased recharge and increased evapotranspiration during the summer caused water levels in the alluvial aquifer to steadily decline from May through October (fig. 6). There is currently (1989) no ground-water use from the alluvial aquifer in the study area.

The ground-water-level data from the observation wells in the alluvial aquifer confirmed the occurrence of a depression in the water table north of the landfill. Water-table altitudes in the alluvial aquifer ranged from about 216 to 240 feet above sea level. The water-level measurements were used to define a generalized map of the water table (fig. 7). The lowest altitudes in the water table occur north of the landfill in a broad elliptical depression. The closed depression is similar to water levels surrounding a pumped well with significant drawdown. At this location there is no pumpage, drain, or similar activity that could account for the depressed water levels.

Typically, in a West Tennessee setting similar to the Shelby County landfill area, ground water from the uplands moves through the alluvial aquifer and discharges along the

Table 2.—*Construction data for wells near the Shelby County landfill*

[Al, Alluvial aquifer; CL, Jackson-upper Claiborne confining layer; MS, Memphis aquifer; --, no data or project number not assigned]

| Well number USGS | Well number Project | Latitude | Longitude | Altitude of land surface (feet) | Hydro-logic unit | Well depth (feet below land surface) | Screen length (feet) |
|---|---|---|---|---|---|---|---|
| SH:Q- 55 | -- | 350757 | 0895027 | 262 | Al | 66 | -- |
| SH:Q- 95 | 1 | 350749 | 0895058 | 247 | Al | 35.8 | 5 |
| SH:Q- 96 | 2 | 350749 | 0895058 | 247 | Al | 48.3 | 5 |
| SH:Q- 97 | 3A | 350750 | 0895017 | 253 | Al | 50 | 5 |
| SH:Q- 98 | 4A | 350739 | 0895017 | 254 | Al | 52.5 | 5 |
| SH:Q- 99 | 5 | 350737 | 0894955 | 251 | Al | 33.4 | 5 |
| SH:Q-100 | 6 | 350732 | 0894930 | 254 | Al | 30 | 5 |
| SH:Q-101 | 7 | 350741 | 0894909 | 258 | Al | 37.7 | 5 |
| SH:Q-102 | 8A | 350803 | 0894959 | 262 | Al | 53.7 | 5 |
| SH:Q-103 | 9 | 350814 | 0894943 | 275 | Al | 44.3 | 5 |
| SH:Q-104 | 10 | 350816 | 0895009 | 267 | Al | 44 | 5 |
| SH:Q-105 | 12 | 350822 | 0895040 | 252 | Al | 43.7 | 5 |
| SH:Q-106 | 13 | 350833 | 0895030 | 264 | Al | 43.8 | 5 |
| SH:Q-107 | 14 | 350844 | 0895032 | 264 | Al | 42.3 | 5 |
| SH:Q-108 | 15 | 350836 | 0895032 | 260 | Al | 43.8 | 5 |
| SH:Q-109 | 16 | 350845 | 0895121 | 257 | Al | 44.7 | 5 |
| SH:Q-110 | 17 | 350833 | 0895121 | 255 | Al | 44.2 | 5 |
| SH:Q-111 | 18 | 350838 | 0895113 | 259 | Al | 43.3 | 5 |
| SH:Q-112 | 19 | 350807 | 0895111 | 247 | Al | 44.4 | 5 |
| SH:Q-113 | 20 | 350812 | 0895059 | 248 | Al | 43.2 | 5 |
| SH:Q-114 | 21A | 350753 | 0894933 | 260 | Al | 45 | 5 |
| SH:Q-115 | 22 | 350745 | 0894945 | 255 | Al | 54.2 | 5 |
| SH:Q-116 | 23 | 350853 | 0895140 | 246 | Al | 28.3 | 5 |
| SH:Q-117 | 24 | 350817 | 0895053 | 250 | Al | 42.7 | 5 |
| SH:Q-119 | 26 | 350804 | 0895041 | 260 | Al | 65.1 | 5 |
| SH:Q-120 | 27 | 350804 | 0895035 | 262 | Al | 65.2 | 5 |
| SH:Q-121 | 28 | 350822 | 0895003 | 273 | Al | 27.5 | 5 |
| SH:Q-128 | 30 | 350817 | 0895035 | 250 | Al | 38.7 | 5 |
| SH:Q-129 | 31 | 350810 | 0895035 | 249 | Al | 39 | 5 |
| SH:Q- 91 | 11 | 350808 | 0895021 | 262 | CL | 88.7 | 5 |
| SH:Q-118 | 25 | 350717 | 0895019 | 262 | CL | 79 | 5 |
| SH:Q-122 | C-1 | 350749 | 0895058 | 247 | CL | 108 | 5 |
| SH:Q-123 | C-2 | 350749 | 0895058 | 247 | CL | 83.5 | 5 |
| SH:Q-127 | C-3 | 350817 | 0895035 | 250 | CL | 55.3 | 2 |
| SH:Q- 89 | -- | 350737 | 0894856 | 259 | MS | 320 | -- |
| SH:Q- 90 | MS-1 | 350749 | 0895058 | 247 | MS | 170 | 30 |
| SH:Q- 92 | MS-2 | 350749 | 0895058 | 247 | MS | 180 | 30 |
| SH:Q-124 | -- | 350822 | 0895003 | 275 | MS | 200 | -- |
| SH:Q-125 | MS-3 | 350817 | 0895035 | 250 | MS | 100 | 20 |
| SH:Q-126 | MS-4 | 350817 | 0895035 | 250 | MS | 97.7 | 29 |
| SH:Q-130 | -- | 350835 | 0894941 | 320 | MS | 217[1] | -- |

[1]Stratigraphic test hole. Hole was plugged and abandoned after running geophysical logs.

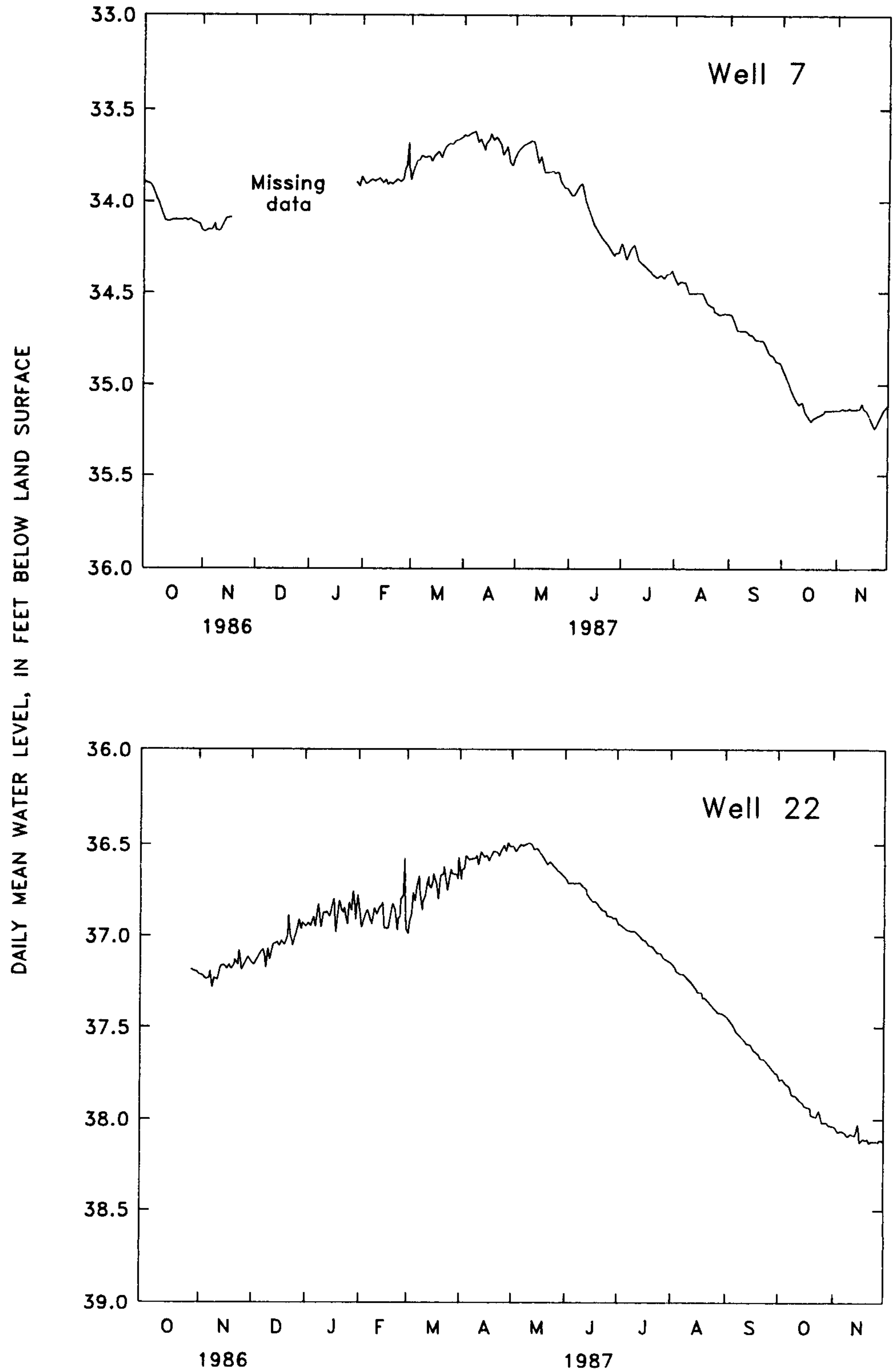
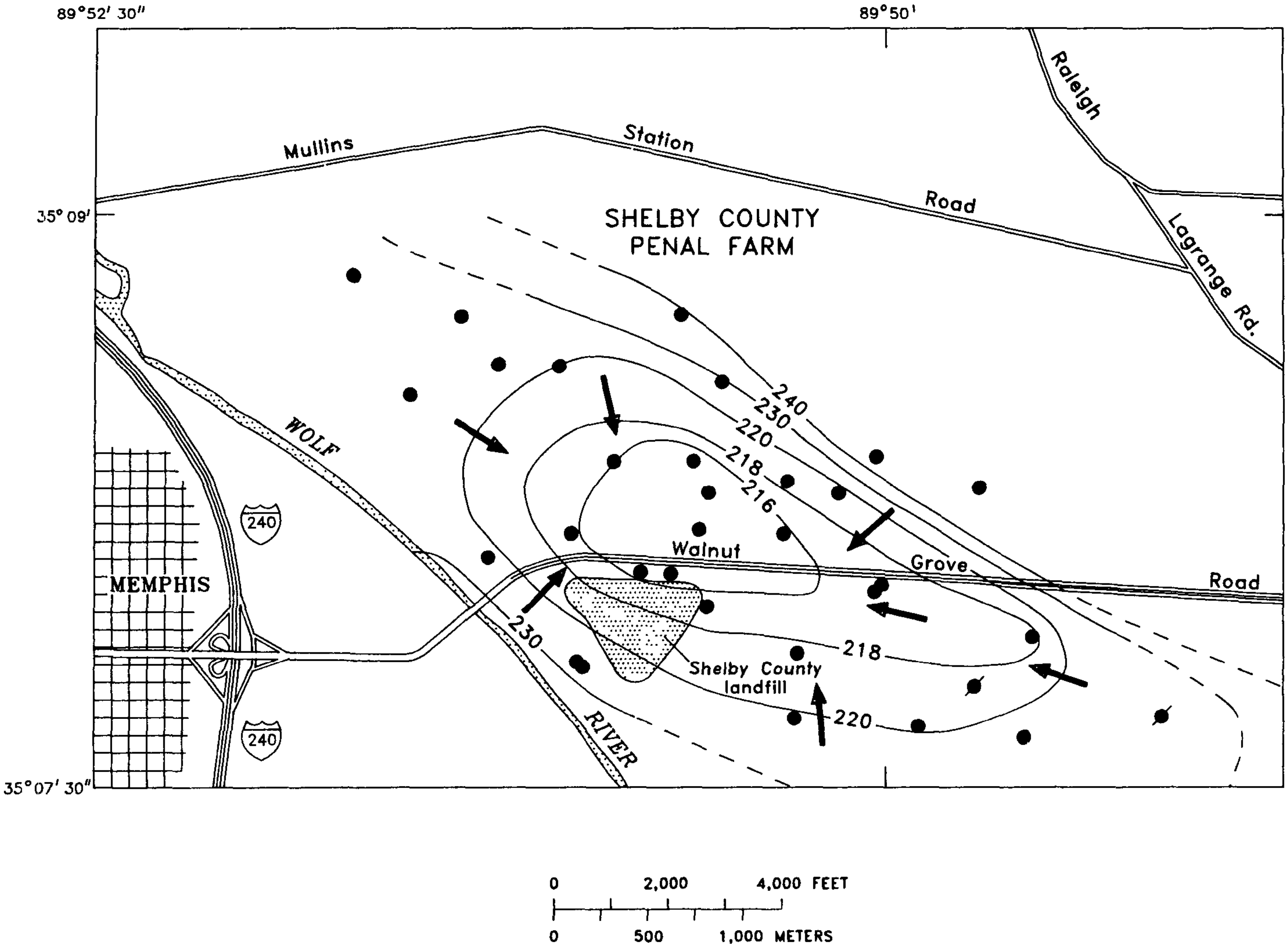



Figure 6.--Water levels in the alluvial aquifer, October 1986 through November 1987.




EXPLANATION

——230—— WATER-TABLE CONTOUR--Shows altitude of the water table in the alluvial aquifer, July 1987. Contour interval 10 feet. Supplemental contours 2 feet. Dashed where approximately located. Datum is sea level

GENERAL DIRECTION OF GROUND-WATER FLOW

● OBSERVATION WELL

OBSERVATION WELL WITH WATER-LEVEL RECORDER

Figure 7.--Water table in the alluvial aquifer, July 1987.

channels of major streams like the Wolf River (fig. 8a). However, in the landfill area, ground water appears to be diverted toward the depression in the water table (fig. 8b). The depression in the water table indicates that the downward movement of water is occurring from the alluvial aquifer to the upper part of the Memphis aquifer. Downward leakage could occur only through a discontinuity or fault in the confining layer separating the alluvial and Memphis aquifers (fig. 8b). Seeps identified along the sides and base of the landfill indicated perched water-table conditions may occur at times within the landfill and contribute flow to the alluvial aquifer.

### MEMPHIS AQUIFER

The Memphis aquifer consists of about 500 to 900 feet of sand with minor clay lenses of the Memphis Sand. Water levels fluctuate in the Memphis aquifer in response to natural conditions and pumping at the well fields (Graham, 1982). Water levels generally are highest during the spring months and decline during the summer as a result of increased evapotranspiration, increased pumpage, and decreased recharge. Low water levels occurred in the Memphis aquifer during September through November, with water-level fluctuations of approximately 2 feet in MS-1 during 1986 and 1987 (fig. 9).

Ground-water flow in the Memphis aquifer in the study area is toward Sheahan and McCord well fields to the west and northwest. The potentiometric surface of the Memphis aquifer ranges from an altitude of about 235 feet above sea level to slightly less than 210 feet above sea level in the study area (fig. 10). Water levels in the wells screened in the Memphis aquifer near the landfill are generally 35 to 37 feet below land surface (fig. 9). These water levels are at lower altitudes than the water table in the alluvial aquifer. Therefore, a downward hydraulic gradient exists to potentially allow water to flow vertically from the alluvial aquifer down to the Memphis aquifer.

Vertical leakage of ground water into the Memphis aquifer from the overlying alluvial and fluvial deposits and the underlying Fort Pillow aquifer were investigated by Graham and Parks (1986). These investigations found that the movement of ground water down from the alluvial and fluvial (water-table) aquifers to the Memphis aquifer occurs where the confining bed is thin or absent and a downward gradient exists. Downward leakage near the southern part of Sheahan well field has been documented from water-quality data, declines in the water-table altitude, and isotope analyses showing recent water in wells Sh:K-73 and Sh:K-74 in the Memphis aquifer (Graham and Parks, 1986). The potential for upward migration of water from the underlying Fort Pillow aquifer into the Memphis aquifer also exists, but between these formations, the amount of leakage is small (Graham and Parks, 1986)

## AQUIFER TESTS AND RESULTS

Aquifer tests were conducted at two sites at the Shelby County landfill to estimate the amount of vertical leakage from the alluvial aquifer down to the Memphis aquifer. Wells were installed at each site to monitor water levels in the alluvial aquifer, the confining layer, and the Memphis aquifer. The pumped well at each site was screened in the upper part of the Memphis aquifer. The southern group of wells is located on the southwestern side of the landfill near the Wolf River (fig. 5). Wells 1 and 2 are screened in the alluvial aquifer, C-1 and C-2 in the confining layer, and MS-1 and MS-2 in the upper Memphis aquifer (table 2). MS-2 was the pumped well at this site. The second group is located in a field north of the Shelby County landfill (fig. 5). In the

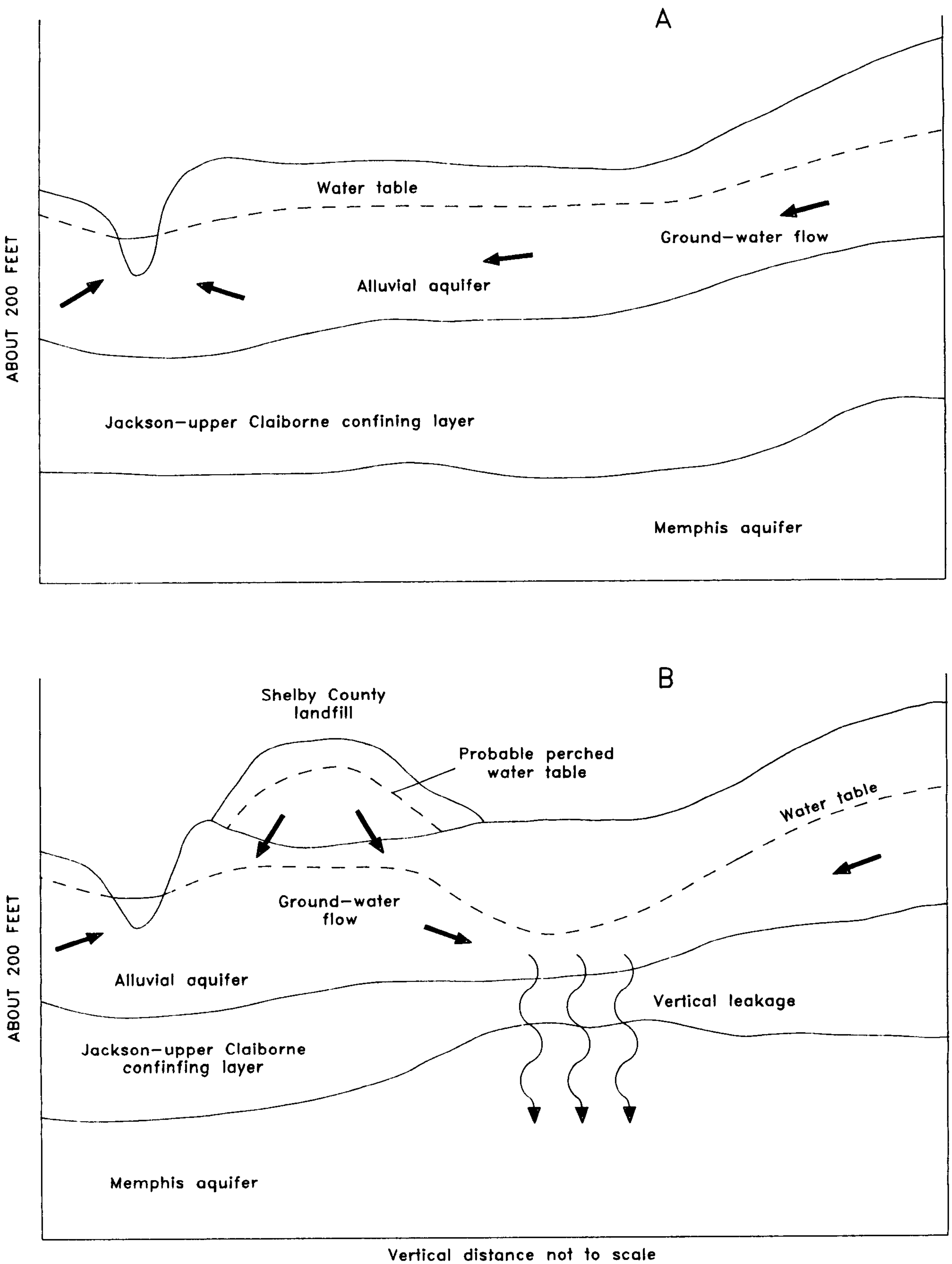



Figure 8.--Conceptual diagrams showing ground-water flow in (A) a typical West Tennessee flood plain and (B) at the Shelby County landfill.

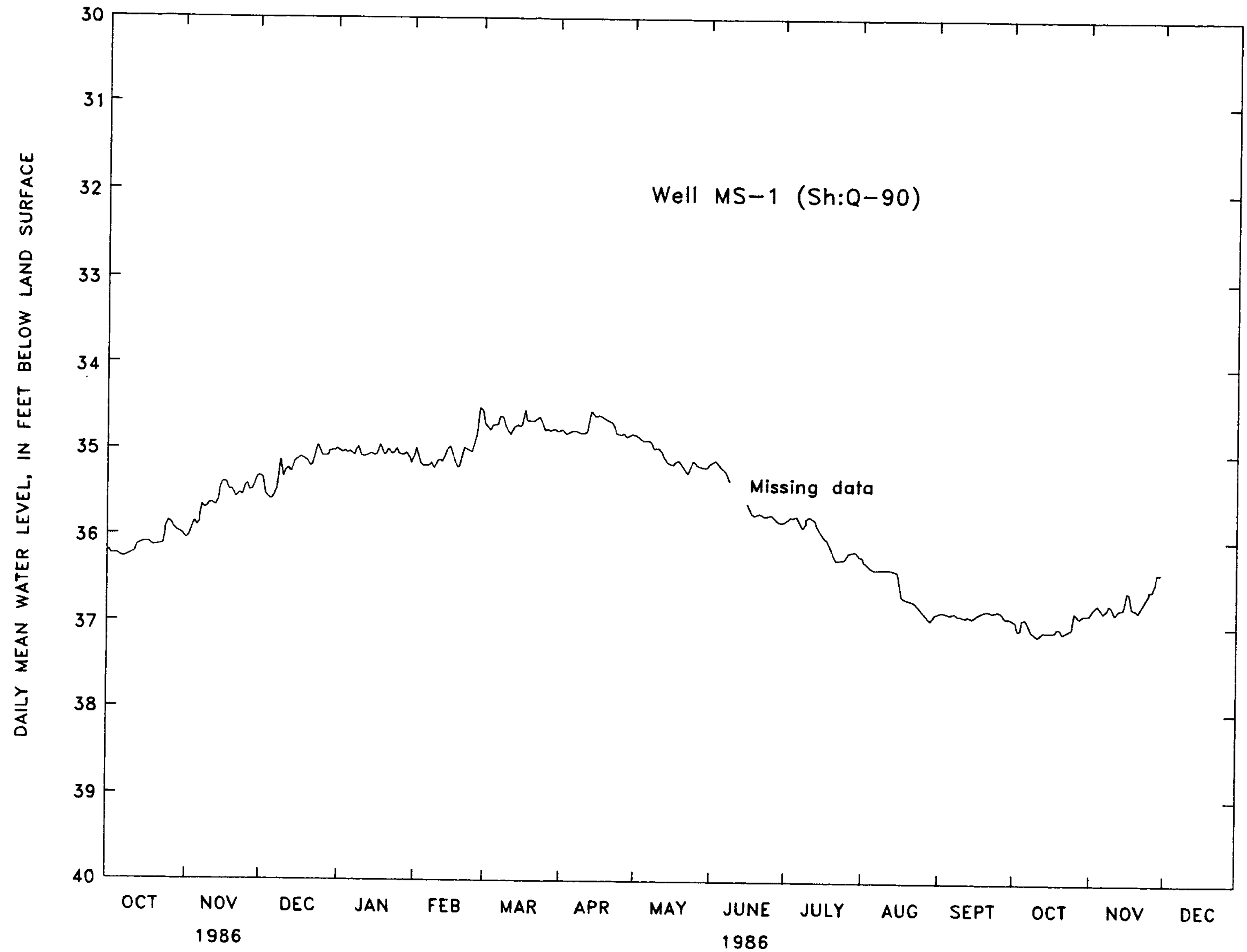
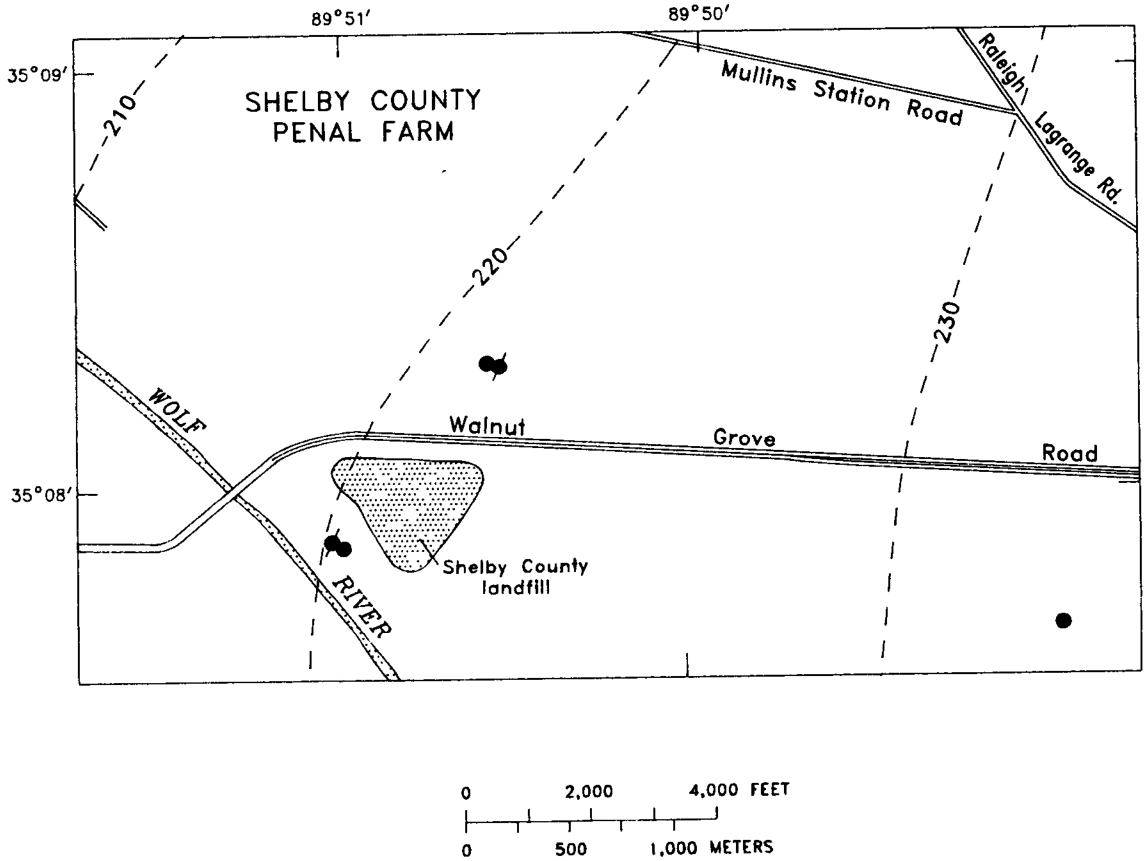



Figure 9.--Water levels in the Memphis aquifer, October 1986 through November 1987.




EXPLANATION

— —220— — POTENTIOMETRIC CONTOUR--Shows altitude at which water level stood in wells completed in the Memphis Sand aquifer. Dashed where approximately located. Contour interval 10 feet. Datum is sea level (Modified from D.D. Graham, 1982.)

● OBSERVATION WELL

OBSERVATION WELL WITH WATER-LEVEL RECORDER

Figure 10.--Potentiometric surface of the Memphis aquifer at the Shelby County landfill, July 1987.

northern group, well 30 is screened in the alluvial aquifer, well C-3 in the confining layer, and wells MS-3 and MS-4 in the Memphis aquifer. Well MS-3 was the pumped well during this test.

The aquifer test at the south group started on July 7, 1987, and continued for 72 hours. Water levels in the wells and the pumping rate were monitored throughout the test (fig. 11). The initial pumping rate was more than 20 gal/min, but this rate was reduced to 12 gal/min when the water level approached the pump intake at about 120 feet after 5 minutes. This pumping rate, with two exceptions, was maintained throughout the test. Initial drawdowns were observed in all of the observation wells (1, 2, C-1, and MS-1) after the start of the test (fig. 11). Water level in the pumped well was 39.69 feet below the measuring point prior to the start of the test and about 105 feet below the measuring point at the end of the test. Water levels in the observation wells showed little drawdown during the rest of the test but did respond relatively quickly to changes in pumping (fig. 11). Changes in the pumping rate during the night of July 8 caused water-level fluctuations in wells 1, 2, C-2, and MS-1. Maximum drawdown in the observation wells were: 0.16 foot in well MS-1, 0.09 foot in C-1, 0.17 foot in C-2, 0.11 foot in well 1, and 0.09 foot in well 2.

The data collected during this aquifer test were inadequate to quantify vertical leakage at this site. Because of the natural fluctuations in water levels and the relatively small amount of drawdown at the observation wells, the data could not be used for reliable calculations. Water levels in the confining layer and the alluvial aquifer responded to changes in the pumping rate in the Memphis aquifer. This indicates that the alluvial aquifer is *hydraulically connected* to the Memphis aquifer.

Well MS-3 in the northern group was pumped for about 31 hours during July 14 and 15, 1987. The pumping rate was 10 gal/min (fig. 12). About 4 hours after the test started, the pump was shut off briefly and then pumping resumed at 10 gal/min. Only the pumped well and the observation well MS-4 in the Memphis aquifer responded significantly to pumping. Maximum drawdown at the end of the test was 31.34 feet in well MS-3 and 0.54 foot in observation well MS-4. Water levels in both wells 30 and C-3 fluctuated only about 0.05 foot during the aquifer test (fig. 12). Any drawdown that may have occurred in wells 30 or C-3 could not be separated from natural fluctuation or measurement error. About 30 feet of relatively dense clay is present in the confining layer separating the alluvial aquifer from the Memphis aquifer at this site (Bradley, 1988). The northern group of wells is located in the depression in the water-table surface, and water levels were expected to respond to pumping. Evidently, the pumping stress in the Memphis aquifer was not great enough to affect water levels in the alluvial aquifer or the confining layer.

## WATER QUALITY

### SAMPLING AND ANALYSES

During the study, water samples were collected from 14 wells completed in the alluvial aquifer and 4 wells completed in the Memphis aquifer. Samples were analyzed for major and trace inorganic constituents, total organic carbon, and selected volatile organic compounds. A scan for the presence of semivolatile organic compounds using a gas chromatograph equipped with a flame ionization detector (GC/FID) was also conducted on samples from each well.

Samples from the alluvial aquifer were collected after purging the wells with a 2-inch,

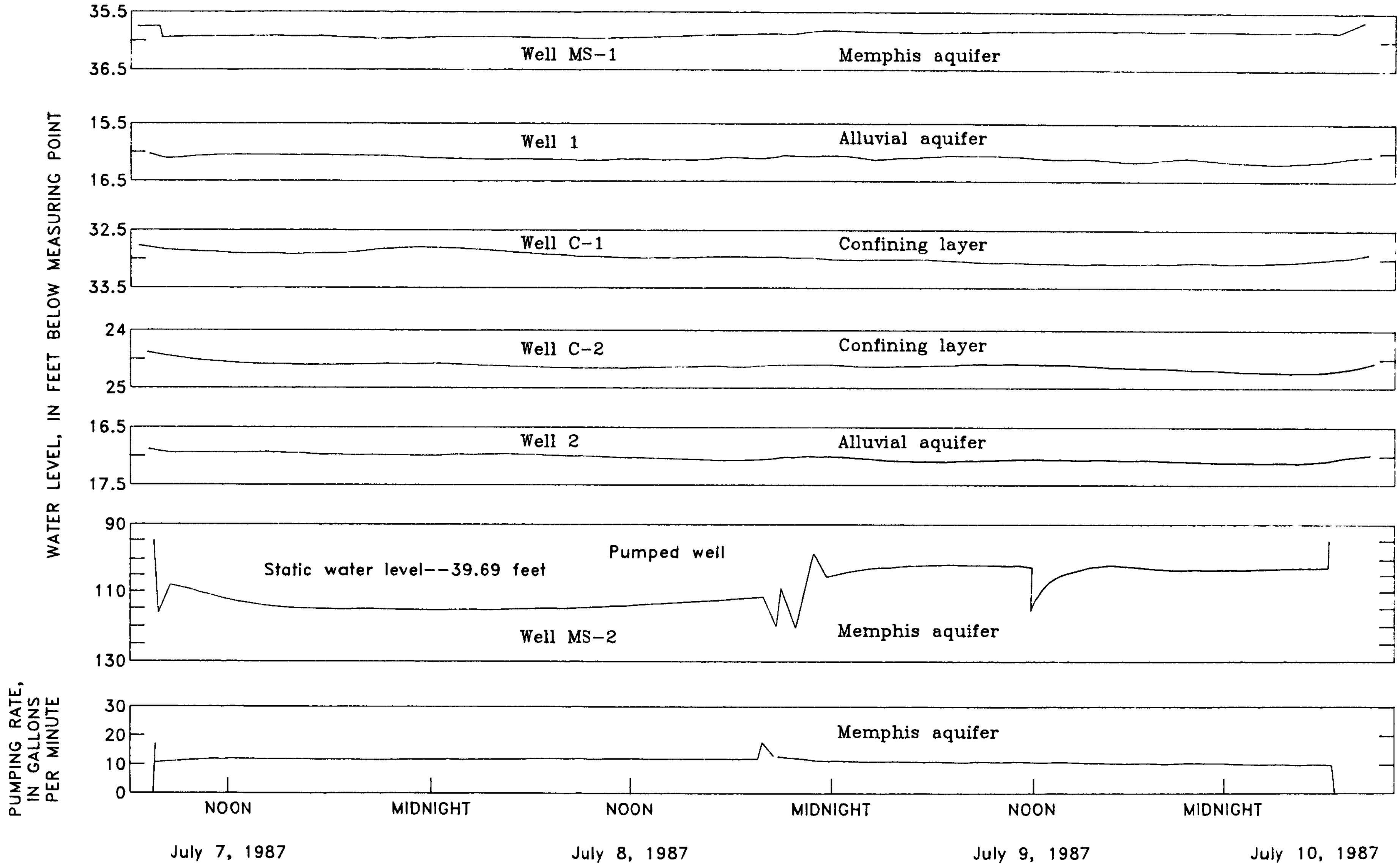



Figure 11.--Water-level change during an aquifer test at well MS-2, July 7-10, 1987.

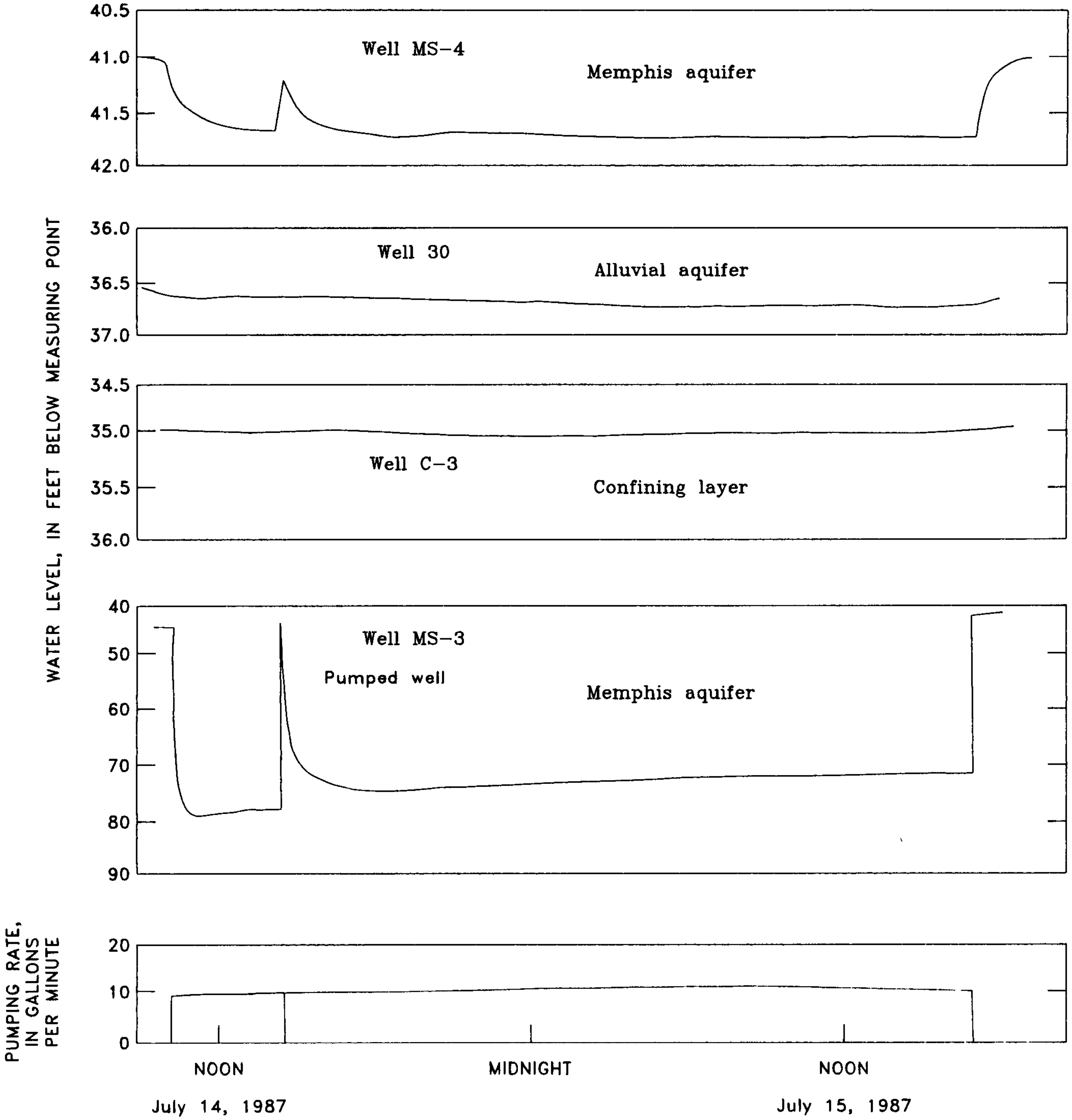



Figure 12.--Water-level change during an aquifer test at well MS-3, July 14-15, 1987.

stainless-steel, submersible pump. A minimum of five casing volumes of water was purged and sampling was conducted after temperature, pH, and specific conductance stabilized. Standard procedures for the collection of the samples were followed to ensure that samples represented water from the aquifers sampled (Claassen, 1982). Water-quality analyses of these samples were performed at the USGS National Laboratory in Denver, Colorado, using standard methods (Brown and others, 1970; Wershaw and others, 1987). Analyses of water from other selected wells were conducted by the Tennessee Department of Health and Environment, Division of Solid Waste Management.

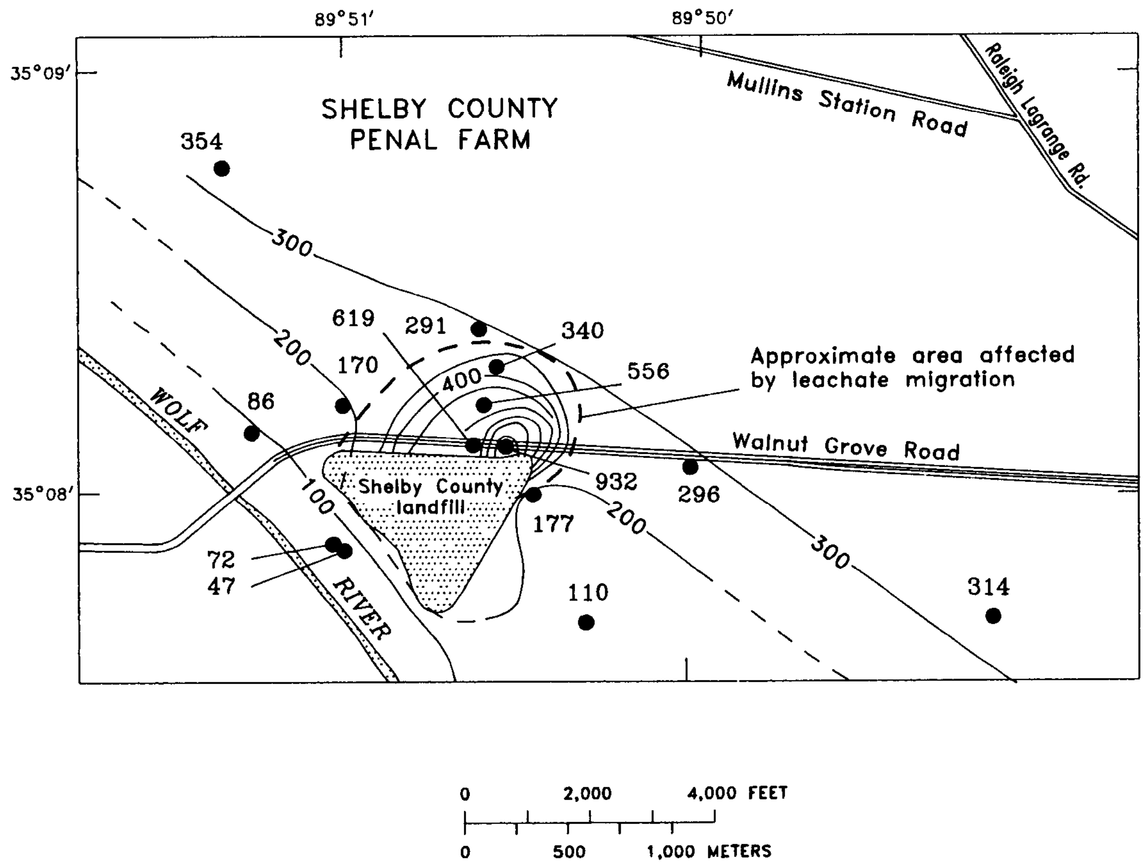
## ALLUVIAL AQUIFER

Natural water quality in the alluvial aquifer in Shelby County is variable due to the heterogeneous nature of the deposits. The water quality is affected by the occurrence and type of clay layers, the presence and decomposition of organic material, and the occurrence of ferrugineous sand. The alluvial aquifer in the Memphis area generally contains a calcium-bicarbonate water with dissolved-solids concentrations ranging from 197 to 652 milligrams per liter (mg/L) and a median concentration of 314 mg/L (Brahana and others, 1987). The water from the alluvial aquifer is typically very hard, having a median hardness value of 285 mg/L as $CaCO_3$. Dissolved-iron concentrations in 11 water samples from Shelby County wells in the alluvial aquifer ranged from 200 to 24,000 $\mu$g/L with a median concentration of 5,200 $\mu$g/L (Brahana and others, 1987).

The concentrations of dissolved solids in the alluvial aquifer in the study area ranged from 47 to 932 mg/L (fig. 13, table 3). The distribution of the dissolved-solids concentrations shows the effect of surface-water infiltration and leachate migration from the Shelby County landfill (fig. 13). The concentrations of dissolved solids in parts of the alluvial aquifer unaffected by the leachate ranged from less than 100 mg/L near the Wolf River to more than 300 mg/L to the north and southeast of the landfill. In areas affected by leachate migration, dissolved-solids concentrations ranged from 340 to 932 mg/L. Dissolved-chloride concentrations in ground water in unaffected areas generally ranged from about 3 mg/L to about 9 mg/L. Concentrations of dissolved chloride ranged from 7.5 to 91 mg/L where the ground water is affected by leachate migration from the landfill (fig. 14).

Concentrations of trace inorganic constituents also indicate leachate migration north from the landfill into the alluvial aquifer. Concentrations of dissolved barium were 120 to 610 $\mu$g/L in the areas north of the landfill; and were generally less than 100 $\mu$g/L south and east of the landfill (fig. 15, table 3).

Anomalously high concentrations were detected in water from some wells which, based on estimated flow direction, would not be affected by leachate migration. These concentrations were detected in water from wells 8A and 16 (fig. 5). Water from these wells had relatively high concentrations of sodium, chloride, and barium (table 3). These wells may have been affected by localized, nonpoint sources of contamination. Very high concentrations of iron and manganese (31,000 $\mu$g/L and 1,300 $\mu$g/L, respectively), were detected in water from well 4A (table 3). The source of these high concentrations is uncertain, but may have been from the ferrugineous sands encountered during drilling. Iron concentrations in the alluvial aquifer in other parts of Shelby County are as high as 24,000 $\mu$g/L (Brahana and others, 1987).




EXPLANATION

——100— — LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION--
Dashed where approximately located. Interval
100 milligrams per liter

47
● WELL AND DISSOLVED-SOLIDS CONCENTRATIONS IN
MILLIGRAMS PER LITER--Value represents
dissolved-solids concentration in samples
collected in November 1986 or July 1987
(See table 3)

Figure 13.--Distribution of dissolved-solids concentrations in water in the alluvial aquifer.

Table 3.—*Water-quality data for wells near the Shelby County landfill*

[mg/L, milligrams per liter; μg/L, micrograms per liter; μS/cm, microseimens per centimeter; <, concentration is less than indicated detection limit; NO2 + NO3, nitrite plus nitrate; --, Project number not assigned]

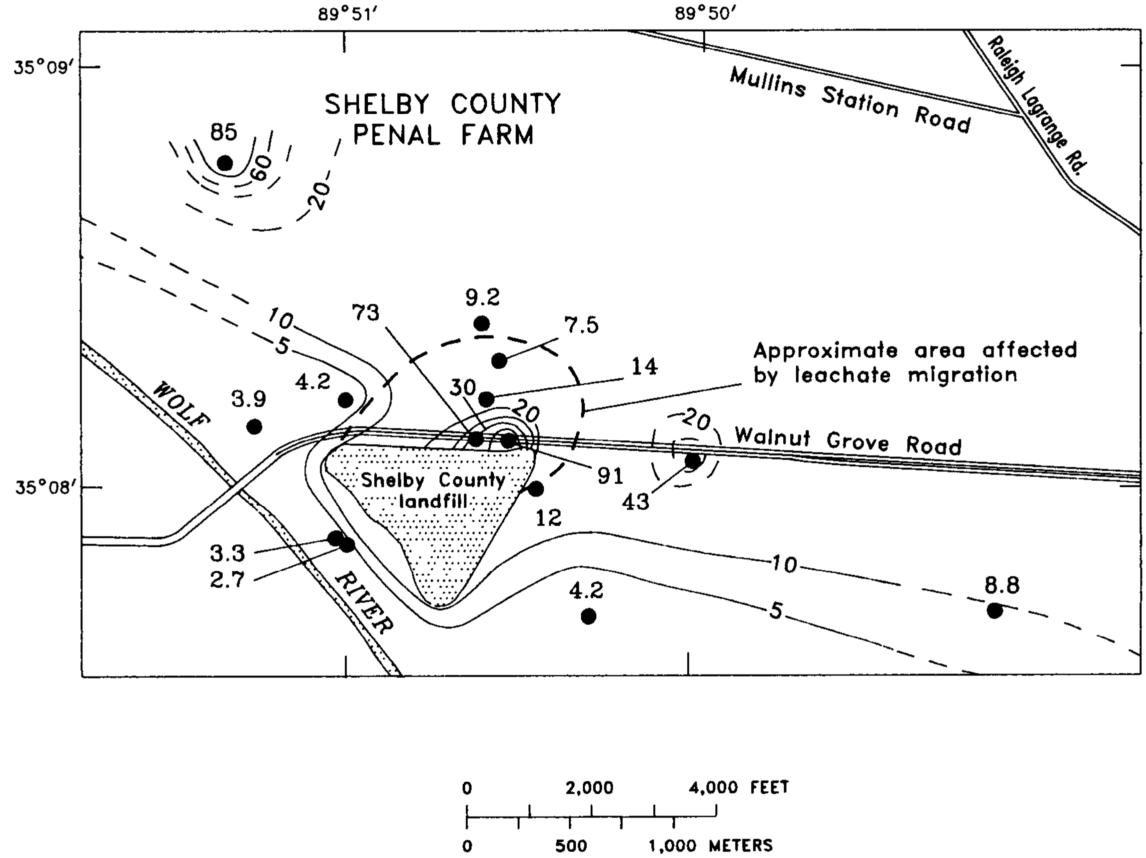
| Well number | | Date sampled | pH (standard units) | Hardness, total (mg/L as $CaCO_3$) | Calcium, dissolved (mg/L as Ca) | Magnesium, dissolved (mg/L as Mg) | Sodium, dissolved (mg/L as Na) | Potassium, dissolved (mg/L as K) | Chloride, dissolved (mg/L as Cl) | Sulfate, dissolved (mg/L as $SO_4$) | Fluoride, dissolved (mg/L as F) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| USGS | Project | | | | | | | | | | |
| SH:Q- 55 | -- | 11-18-86 | 6.6 | 120 | 28 | 13 | 13 | 4.2 | 12 | 20 | 0.10 |
| SH:Q- 95 | 1 | 07-16-87 | 5.7 | 23 | 5.9 | 2.1 | 9.8 | 1.9 | 3.3 | 9.4 | .10 |
| SH:Q- 96 | 2 | 07-16-87 | 5.6 | 20 | 6.8 | .82 | 4.2 | 1.2 | 2.7 | 3.2 | < .10 |
| SH:Q- 98 | 4A | 11-18-86 | 6.0 | 37 | 10 | 3.0 | 3.5 | 3.7 | 4.2 | 40 | < .10 |
| SH:Q-101 | 7 | 11-17-86 | 6.2 | 160 | 38 | 16 | 34 | 1.4 | 8.8 | 140 | < .10 |
| SH:Q-102 | 8A | 11-18-86 | 6.3 | 130 | 32 | 12 | 48 | 1.7 | 43 | 64 | < .10 |
| SH:Q-105 | 12 | 11-17-86 | 6.2 | 150 | 35 | 14 | 32 | 1.6 | 9.2 | 130 | < .10 |
| SH:Q-109 | 16 | 11-17-86 | 6.0 | 140 | 33 | 15 | 54 | 1.3 | 85 | 30 | .10 |
| SH:Q-112 | 19 | 11-19-86 | 6.0 | 43 | 9.7 | 4.4 | 5.6 | 1.8 | 3.9 | 2.2 | .20 |
| SH:Q-113 | 20 | 11-18-86 | 5.8 | 88 | 22 | 8.1 | 12 | 1.2 | 4.2 | 79 | < .10 |
| SH:Q-119 | 26 | 11-19-86 | 6.4 | 360 | 91 | 33 | 62 | 15 | 73 | 4.4 | .20 |
| SH:Q-120 | 27 | 11-19-86 | 6.4 | 510 | 140 | 39 | 82 | 46 | 91 | 7.6 | .30 |
| SH:Q-128 | 30 | 07-17-87 | 6.8 | 91 | 20 | 9.8 | 70 | .80 | 7.5 | 79 | .30 |
| SH:Q-129 | 31 | 07-16-87 | 6.6 | 140 | 36 | 12 | 110 | 3.7 | 14 | 54 | .30 |
| SH:Q- 89 | -- | 07-16-87 | 5.7 | 25 | 6.3 | 2.3 | 5.0 | .40 | 2.3 | 2.4 | < .10 |
| SH:Q- 92 | MS-2 | 07-07-87 | 6.5 | 41 | 11 | 3.4 | 5.5 | 1.0 | 2.5 | 5.8 | < .10 |
| | | 07-10-87 | 6.3 | 38 | 9.5 | 3.4 | 3.5 | .90 | 2.5 | 5.1 | < .10 |
| SH:Q-125 | MS-3 | 07-15-87 | 6.4 | 78 | 21 | 6.2 | 20 | .80 | 17 | 23 | .40 |
| SH:Q-126 | MS-4 | 07-13-87 | 6.8 | 65 | 20 | 3.7 | 8.6 | 1.4 | 3.3 | 4.1 | .10 |
| | | 07-13-87 | 7.1 | 84 | 24 | 5.7 | 11 | 1.0 | 4.1 | 15 | .20 |

Table 3.—*Water-quality data for wells near the Shelby County landfill*—Continued

| Well number USGS | Well number Project | Date sampled | Dissolved solids, residue at 180 deg. C (mg/L) | Alkalinity, field (mg/L as $CaCO_3$) | Specific conductance lab (μS/cm) | Silica, dissolved (mg/L as $SiO_2$) | Arsenic, dissolved (μg/L as As) | Barium, dissolved (μg/L as Ba) | Cadmium, dissolved (μg/L as Cd) | Chromium, dissolved (μg/L as Cr) | Copper, dissolved (μg/L as Cu) | Iron, dissolved (μg/L as Fe) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH:Q- 55 | -- | 11-18-86 | 177 | 127 | 301 | 12 | <1 | 29 | <1 | <10 | <10 | 360 |
| SH:Q- 95 | 1 | 07-16-87 | 72 | 35 | 105 | 12 | 2 | 61 | 1 | <10 | <10 | 4 |
| SH:Q- 96 | 2 | 07-16-87 | 47 | 27 | 70 | 11 | 19 | 41 | 2 | 20 | <10 | 4,600 |
| SH:Q- 98 | 4A | 11-18-86 | 110 | 67 | 222 | 22 | <1 | 83 | 3 | <10 | <10 | 31,000 |
| SH:Q-101 | 7 | 11-17-86 | 314 | 68 | 454 | 17 | <1 | 70 | <1 | <10 | <10 | 338 |
| SH:Q-102 | 8A | 11-18-86 | 296 | 99 | 459 | 21 | <1 | 180 | 1 | <10 | <10 | 16 |
| SH:Q-105 | 12 | 11-17-86 | 291 | 69 | 421 | 17 | 1 | 120 | <1 | <10 | <10 | 1,100 |
| SH:Q-109 | 16 | 11-17-86 | 354 | 82 | 546 | 38 | <1 | 210 | 1 | <10 | <10 | 31 |
| SH:Q-112 | 19 | 11-19-86 | 86 | 60 | 108 | 13 | 1 | 130 | <1 | <10 | <10 | 5,500 |
| SH:Q-113 | 20 | 11-18-86 | 170 | 34 | 255 | 17 | <1 | 81 | 2 | 10 | <10 | 3,900 |
| SH:Q-119 | 26 | 11-19-86 | 619 | 642 | 1,030 | 13 | 1 | 340 | 8 | <10 | <10 | 92,000 |
| SH:Q-120 | 27 | 11-19-86 | 932 | 924 | 1,650 | 14 | 1 | 610 | 8 | <10 | <10 | 83,000 |
| SH:Q-128 | 30 | 07-17-87 | 340 | 200 | 456 | 28 | 2 | 170 | 3 | <10 | <10 | 4 |
| SH:Q-129 | 31 | 07-16-87 | 556 | 325 | 709 | 16 | 1 | 160 | 8 | 20 | <10 | 310 |
| SH:Q- 89 | -- | 07-16-87 | 43 | 28 | 78 | 12 | <1 | 17 | 16 | <10 | <10 | 36 |
| SH:Q- 92 | MS-2 | 07-07-87 | 75 | 50 | 108 | 11 | 1 | 28 | <1 | <10 | <10 | 310 |
| | | 07-10-87 | 61 | 36 | 96 | 10 | 1 | 18 | <1 | <10 | <10 | 450 |
| SH:Q-125 | MS-3 | 07-15-87 | 146 | 68 | 258 | 15 | <1 | 46 | <1 | <10 | <10 | 3 |
| SH:Q-126 | MS-4 | 07-13-87 | 100 | 70 | 170 | 14 | <1 | 47 | <1 | <10 | <10 | <3 |
| | | 07-13-87 | 123 | 88 | 218 | 13 | <1 | 66 | 1 | 20 | <10 | 10 |

Table 3.—*Water-quality data for wells near the Shelby County landfill*—Continued

| Well number USGS | Well number Project | Date sampled | Lead, dis-solved (µg/L as Pb) | Manga-nese, dis-solved (µg/L as Mn) | Silver, dis-solved (µg/L as Ag) | Stron-tium, dis-solved (µg/L as Sr) | Zinc, dis-solved (µg/L as Zn) | Sele-nium, dis-solved (µg/L as Se) | Nitro-gen, NO2+NO3, dis-solved (mg/L as N) | Phos-phorous, dis-solved (mg/L as P) | Carbon, organic total (mg/L as C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SH:Q- 55 | -- | 11-18-86 | <10 | 2,800 | <1.0 | 120 | 14 | <1 | <0.100 | <0.010 | 1.5 |
| SH:Q- 95 | 1 | 07-16-87 | <10 | 1 | <1.0 | 40 | 31 | <1 | < .100 | .010 | 13 |
| SH:Q- 96 | 2 | 07-16-87 | <10 | 340 | <1.0 | 30 | 11 | <1 | < .100 | .010 | 2.1 |
| SH:Q- 98 | 4A | 11-18-86 | <10 | 1,300 | <1.0 | 46 | 16 | <1 | < .100 | < .010 | 2.7 |
| SH:Q-101 | 7 | 11-17-86 | <10 | 15 | <1.0 | 99 | 15 | 2 | .680 | < .010 | 1.5 |
| SH:Q-102 | 8A | 11-18-86 | <10 | 380 | <1.0 | 91 | 15 | 5 | 1.50 | < .010 | 1.1 |
| SH:Q-105 | 12 | 11-17-86 | <10 | 1,400 | <1.0 | 80 | 28 | 9 | 1.90 | < .010 | 5.4 |
| SH:Q-109 | 16 | 11-17-86 | <10 | 5 | <1.0 | 210 | 22 | 2 | 7.90 | .020 | 1.7 |
| SH:Q-112 | 19 | 11-19-86 | <10 | 220 | <1.0 | 86 | 12 | <1 | < .100 | .020 | 3.2 |
| SH:Q-113 | 20 | 11-18-86 | <10 | 190 | <1.0 | 62 | 24 | <1 | < .100 | < .010 | 2.0 |
| SH:Q-119 | 26 | 11-19-86 | 20 | 1,900 | <1.0 | 320 | 5 | <1 | < .100 | < .010 | 18 |
| SH:Q-120 | 27 | 11-19-86 | 20 | 2,500 | <1.0 | 980 | <3 | <1 | < .100 | < .010 | 18 |
| SH:Q-128 | 30 | 07-17-87 | <10 | 3,200 | <1.0 | 160 | 45 | 9 | 1.30 | .040 | 99 |
| SH:Q-129 | 31 | 07-16-87 | <10 | 590 | <1.0 | 330 | 24 | <1 | .100 | .020 | 8.0 |
| SH:Q- 89 | -- | 07-16-87 | <10 | 8 | 1.0 | 16 | 8 | <1 | < .100 | < .010 | .2 |
| SH:Q- 92 | MS-2 | 07-07-87 | <10 | 29 | <1.0 | 5 | 55 | <1 | < .100 | .100 | .3 |
| | | 07-10-87 | <10 | 14 | <1.0 | 33 | 85 | <1 | -- | -- | -- |
| SH:Q-125 | MS-3 | 07-15-87 | <10 | 9 | 1.0 | 40 | 74 | 2 | -- | -- | -- |
| SH:Q-126 | MS-4 | 07-13-87 | <10 | 44 | <1.0 | 42 | 700 | <1 | -- | -- | .4 |
| | | 07-13-87 | <10 | 81 | <1.0 | 75 | 640 | <1 | < .100 | .020 | 1.0 |

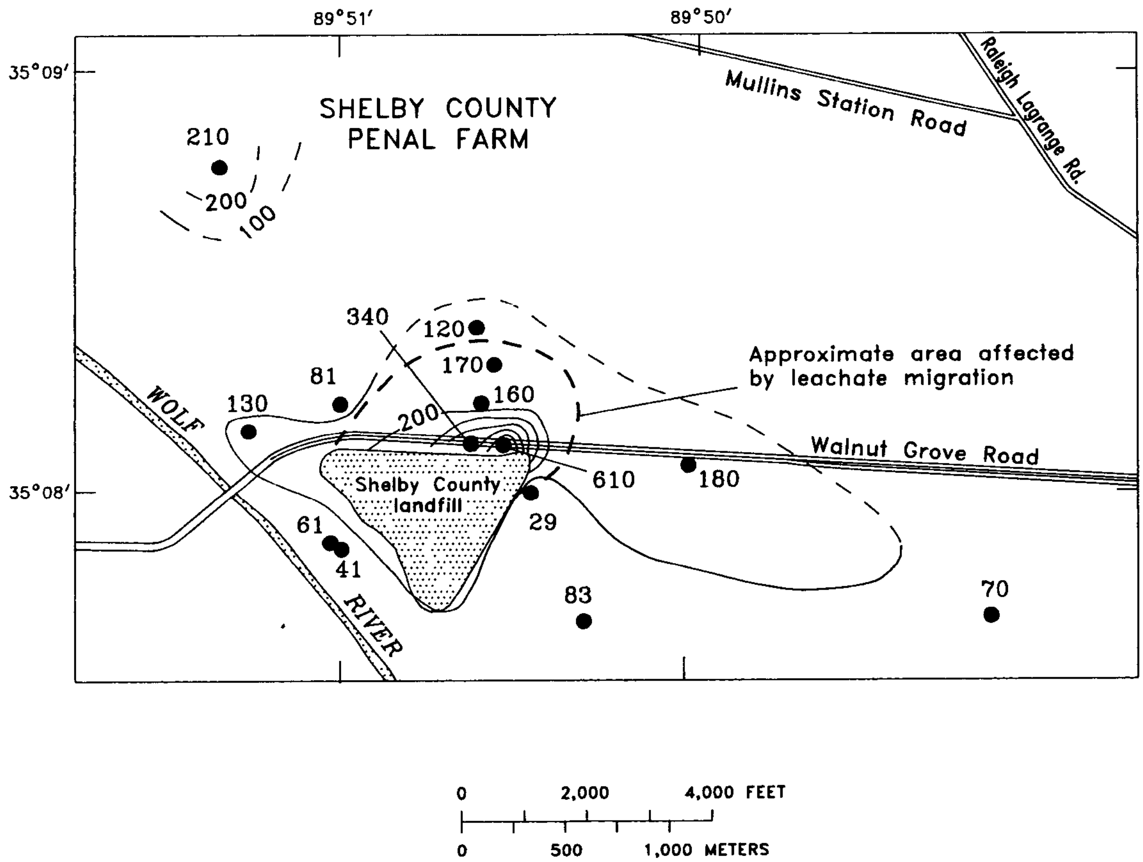



EXPLANATION

—— 5 — — LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION--Dashed where approximately located. Interval 20 milligrams per liter. Supplemental interval 5 milligrams per liter

4.2 ● WELL AND DISSOLVED-CHLORIDE CONCENTRATION IN MILLIGRAMS PER LITER--Value represents dissolved-solids concentration in samples collected in November 1986 or July 1987 (See table 3)

Figure 14.--Distribution of dissolved-chloride concentrations in water in the alluvial aquifer.




## EXPLANATION

——100— — LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION--Dashed where approximately located. Interval 20 milligrams per liter. Supplemental interval 5 milligrams per liter

83 ● WELL AND DISSOLVED-BARIUM CONCENTRATION IN MILLIGRAMS PER LITER--Value represents dissolved-solids concentration in samples collected in November 1986 or July 1987 (See table 3)

Figure 15.--Distribution of dissolved-barium concentrations in water in the alluvial aquifer.

## MEMPHIS AQUIFER

Water in the Memphis aquifer in the Memphis area is generally a calcium bicarbonate type with dissolved-solids concentrations ranging from 32 to 333 mg/L and a median of 83 mg/L (Brahana and others, 1987). The water quality in the Memphis aquifer varies areally. Dissolved-solids concentrations generally increase toward the west and north. The dissolved-solids concentrations in water from the Memphis aquifer in the area around the Shelby County landfill range from 43 to 122 mg/L (table 4) with an average concentration of 70 mg/L and a median concentration of 68 mg/L.

Water-quality samples were collected from four wells completed in the Memphis aquifer in the vicinity of the Shelby County landfill (table 3). Three of these wells, MS-2, MS-3, and MS-4, were installed during this study, and the fourth well (SH:Q-89) is an irrigation well east of the landfill (fig. 5).

Table 4.—*Dissolved-solids and dissolved-chloride concentrations in water from wells completed in the Memphis aquifer*

[Well depth, in feet below land surface; dissolved-solids and dissolved-chloride concentrations in milligrams per liter, mg/L; Data source: U, U.S. Geological Survey unpublished water quality records; D, U.S. Geological Survey, 1980-1989]

| Well number | Date sampled | Depth of well, total (feet) | Dissolved solids, residue at 180 deg. C (mg/L) | Chloride, dissolved (mg/L as Cl) | Data source |
|---|---|---|---|---|---|
| SH:K- 21 | 09-30-81 | 459 | 73 | -- | U |
| SH:K- 72 | 09-30-81 | 292 | 76 | -- | U |
| SH:K- 73 | 08-26-87 | 273 | 122 | 7.9 | D |
| SH:K- 87 | 04-22-82 | 402 | 77 | -- | U |
| SH:K- 94 | 09-17-79 | 550 | 76 | 6.0 | D |
| SH:K-120 | 04-28-82 | 273 | 66 | -- | U |
| SH:K-126 | 06-09-80 | 302 | 65 | 4.5 | D |
| SH:K-131 | 04-23-82 | 315 | 60 | -- | U |
| SH:L- 36 | 08-25-87 | 567 | 50 | 1.4 | D |
| SH:L- 37 | 08-28-86 | 382 | 59 | 4.7 | D |
| SH:L- 82 | 09-29-81 | -- | 69 | -- | U |
| SH:L- 83 | 02-25-85 | 622 | 54 | 1.7 | D |
| SH:P-124 | 06-11-80 | 466 | -- | 3.0 | D |
| SH:P-125 | 10-01-81 | 458 | 79 | -- | U |
| SH:P-134 | 08-11-88 | 460 | 68 | 2.1 | D |
| SH:P-145 | 06-17-82 | 540 | 84 | -- | D |
| SH:Q- 40 | 08-09-88 | 516 | 66 | 5.5 | D |
| SH:Q- 60 | 02-26-85 | 491 | 62 | 3.7 | D |
| SH:Q- 64 | 08-29-84 | 734 | 76 | 3.3 | U |
| SH:Q- 78 | 09-30-81 | -- | 73 | -- | U |
| SH:Q- 81 | 02-26-85 | 509 | 63 | 4.3 | D |
| SH:Q- 89 | 07-16-87 | 320 | 43 | 2.3 | D |

Concentrations of dissolved solids generally increase from about 44 mg/L to about 84 mg/L toward the west (fig. 16). The dissolved-solids concentrations are highest in water from wells in the southern part of Sheahan well field and from wells just north of the Shelby County landfill. In these two areas, dissolved-solids concentrations are greater than 100 mg/L (fig. 16).

The concentration of dissolved chloride in the Memphis aquifer can also be used as an indicator of potential leakage from the alluvial aquifer. Dissolved-chloride concentrations in water from wells in the Memphis aquifer within a 10-mile radius of the landfill generally were less than 28 mg/L. Dissolved-chloride concentrations were 17 mg/L in water from well MS-3 just north of the landfill (fig. 17).

The water quality of the Memphis aquifer near the Shelby County landfill indicated a significant difference in dissolved-solids concentrations between the upper and lower parts of the Memphis aquifer. Samples from wells drilled into the upper part of the aquifer just below the confining layer (MS-2, MS-3, MS-4) had dissolved-solids concentrations that ranged from 61 to 146 mg/L. In comparison, a sample from the deeper irrigation well (SH:Q-89) contained a dissolved-solids concentration of 43 mg/L (table 3). Higher dissolved-solids concentrations in the upper part in the Memphis aquifer could be due to vertical leakage from the alluvial aquifer. This comparison, however, is based on only one analysis from the deeper well.

## POTENTIAL EFFECTS OF VERTICAL LEAKAGE

Vertical leakage downward from the alluvial aquifer could affect the water quality of the underlying Memphis aquifer. In Shelby County dissolved-solids concentrations are, on the average, about four times higher in water from the alluvial aquifer than in water from the Memphis aquifer (314 mg/L in the alluvial aquifer and 83 mg/L for the Memphis aquifer, Brahana and others, 1987). The downward movement of water from the alluvial aquifer could, therefore, increase the dissolved-solids concentrations in the upper part of the Memphis aquifer. Leachate from the landfill, which could have an even higher dissolved-solids concentrations than water from the alluvial aquifer, could have a more pronounced effect on the quality of water in the Memphis aquifer. A statistical test can be applied to determine if the difference in dissolved-solids concentrations between water from the alluvial aquifer in the upper Memphis aquifer near the landfill and the Memphis aquifer in other areas are significant. The Wilcoxon-Mann-Whitney test for two populations was used for this purpose (Iman and Conover, 1983).

The Wilcoxon-Mann-Whitney test is a non-parametric statistical analysis that can be used to compare the differences between two populations at a given significance level. The first test was conducted to determine if there is a significant difference between the dissolved-solids concentrations in the upper Memphis aquifer near the landfill (wells MS-2, MS-3, and MS-4) and the dissolved-solids concentrations for the Memphis aquifer in areas not affected by vertical leakage. Wells MS-2 and MS-4 were each sampled twice (table 3). For the purpose of the statistical analyses described below, the dissolved-solids concentrations of samples collected at the end of the aquifer tests were used (61 mg/L for MS-2 and 123 mg/L for well MS-4). Dissolved-solids concentrations for the Memphis aquifer in areas unaffected by leakage were those of samples from wells outside the Shelby County landfill area and away from South Sheahan well field where slightly elevated concentrations were found (fig. 16; table 4).

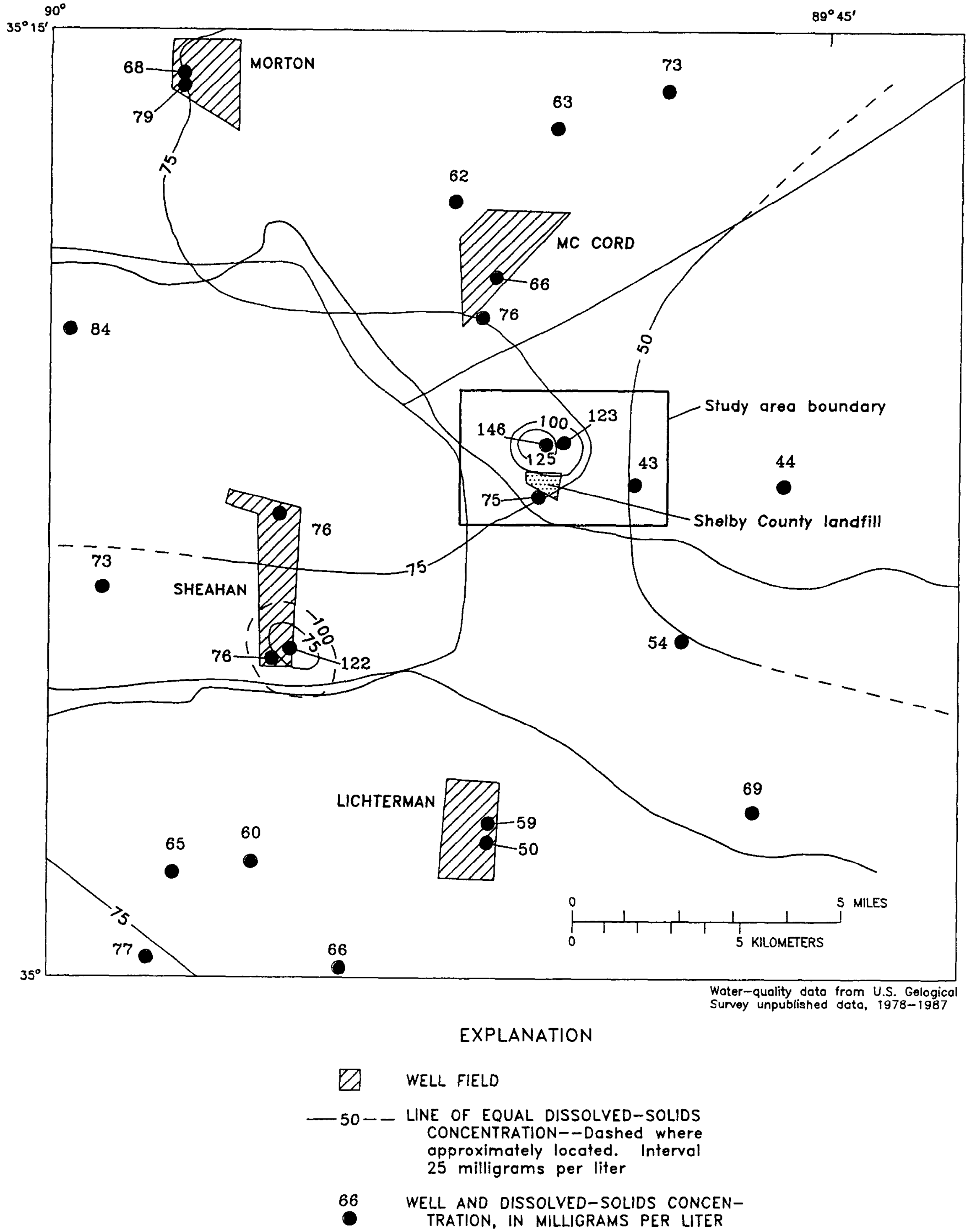
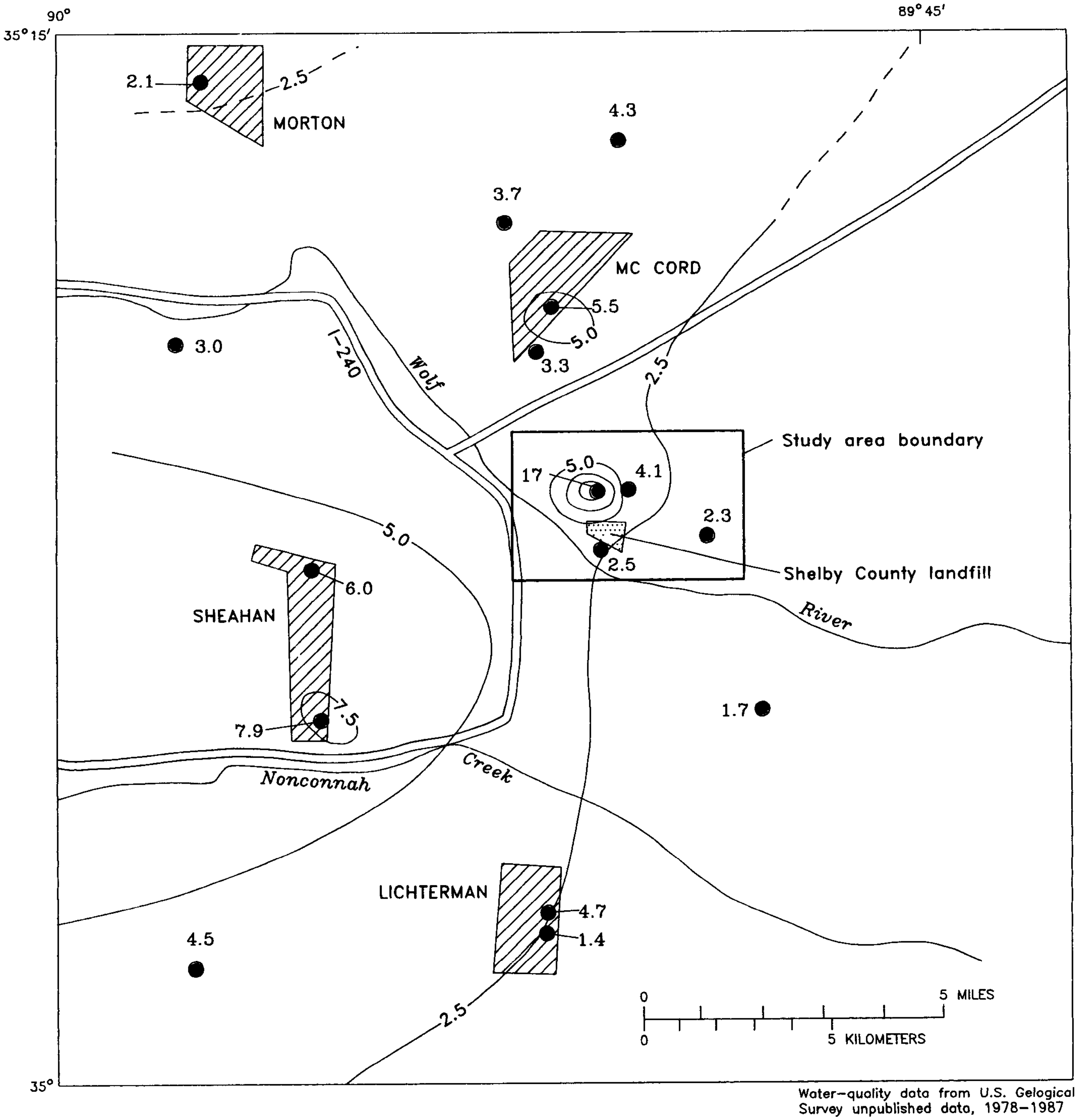



Figure 16.--Distribution of dissolved-solids concentrations in water in the Memphis aquifer.




EXPLANATION

WELL FIELD

——2.5— — LINE OF EQUAL DISSOLVED-CHLORIDE CONCENTRATION--Dashed where approximately located. Interval 5 milligrams per liter. Supplemental interval 2.5 milligrams per liter

4.5 ● WELL AND DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER

Figure 17.--Distribution of dissolved-chloride concentrations in water in the Memphis aquifer.

By use of the procedure described in Iman and Conover (1983) a test statistic (T) was calculated for the data sets and compared to a test value (t) based on the level of significance selected. A comparison of the two data sets for the Memphis aquifer indicated that the test statistic (T) was 1.90 and the test value (t) at a 0.05 level of significance was 1.708. At the 0.05 level of significance, $T > t$, and the hypothesis that the data sets are similar is rejected (Iman and Conover, 1983). The Wilcoxon-Mann-Whitney test indicates that there is a significant difference between dissolved-solids concentrations in water from the wells representing background conditions in the Memphis aquifer and those in the upper part of the Memphis aquifer near the Shelby County landfill. It should be noted, however, that this analysis is based on data from only three wells completed in the upper Memphis aquifer. Consequently, the results of the analysis cannot be considered as conclusive.

A second test was conducted to determine if the dissolved-solids concentrations in the area of the alluvial aquifer unaffected by the landfill and those in the upper part of the Memphis aquifer near the landfill were significantly different. Wells selected in the alluvial aquifer were 1, 2, 4A, 7, 19, and 20. Values determined by the Wilcoxon-Mann-Whitney test were, $T = 1.02$ and $t = 1.81$ at a 0.05 significance level. Because $T < t$, the null hypothesis is accepted that there is no significant difference between dissolved-solids concentrations in water in the alluvial aquifer and in the upper part of the Memphis aquifer near the Shelby County landfill. As with the previous analysis, however, this conclusion was based on a small number of wells.

Another indication of vertical leakage is evidence of recent recharge to the upper Memphis aquifer. The relative age of the recharge water can be roughly dated by an analysis of tritium activity in ground water. Tritium is a radioisotope of hydrogen that occurs in water from both man-made and natural processes. Beginning in 1953, large quantities of tritium were released as the result of atmospheric testing of nuclear weapons (Freeze and Cherry, 1979). The testing effectively 'tagged' the precipitation that recharged the ground-water system with high quantities of tritium. Water that entered the ground-water system prior to 1953 is expected to have a tritium activity generally less than 1 picoCurie per liter (pCi/L), because of the relatively low quantities of naturally occurring tritium in precipitation and the short half-life of tritium.

Samples for tritium analyses were collected from two wells in the alluvial aquifer (wells 1 and 30), three wells in the upper part of the Memphis aquifer (wells MS-2, MS-3, and MS-4), and one well in the lower part of the Memphis aquifer (well SH:Q-89) (table 5). The measured tritium activities were 29 and 30 pCi/L in the alluvial aquifer, 2.2 to 34 pCi/L in the upper part of the Memphis aquifer, and less than 0.3 pCi/L in the lower part of the Memphis aquifer (table 5).

The tritium data confirms the occurrence of recent ground-water recharge to the upper Memphis aquifer, an indication of leakage from the alluvial aquifer down to the Memphis aquifer near the Shelby County landfill. In water from the well group south of the landfill, the tritium activity was 29 pCi/L in the alluvial aquifer at well 1 and 34 and 31 pCi/L in two samples from well MS-2 in the upper part of the Memphis aquifer. This indicates that recent water (post-1953) has percolated downward from the alluvial aquifer into the Memphis aquifer at the well site south of the landfill. Tritium activity in the alluvial aquifer at the northern well group was 30 pCi/L in well 30 (table 5). In the upper part of the Memphis aquifer at the northern group, the tritium activities are 15 and 2.2 pCi/L in wells MS-3 and MS-4, respectively. The

Table 5.—*Tritium activity of water from wells completed in the alluvial and Memphis aquifers near the Shelby County landfill*

[Well depth is feet below land surface; total tritium activities are in picoCuries per liter, pCi/L; --, project number not assigned]

| Well number USGS | Well number Project | Date sampled | Well depth (feet) | Tritium, total (pCi/L) | Aquifer |
|---|---|---|---|---|---|
| SH:Q- 95 | 1 | 07-16-87 | 35.8 | 29 | Alluvium |
| SH:Q-128 | 30 | 07-17-87 | 38.7 | 30 | Alluvium |
| SH:Q- 89 | -- | 07-16-87 | 320 | < .3 | Memphis Aquifer |
| SH:Q- 92 | MS-2 | 07-07-87 | 180 | 34 | Memphis Aquifer |
| SH:Q- 92 | MS-2 | 07-10-87 | 180 | 31 | Memphis Aquifer |
| SH:Q-125 | MS-3 | 07-15-87 | 100 | 15 | Memphis Aquifer |
| SH:Q-126 | MS-4 | 07-13-87 | 97.7 | 2.2 | Memphis Aquifer |

water from wells MS-3 and MS-4 appears to be a mixture of alluvial aquifer water that has migrated vertically downward and water in the Memphis aquifer. Water from well SH:Q-89 completed deeper in the Memphis aquifer had tritium activity less than 0.3 pCi/L. The low tritium activity in this water indicates the water in the well occurred as recharge prior to 1953 and is not affected by the vertical leakage of recent water. A conceptual diagram of the distribution of tritium activities at the Shelby County landfill is shown in figure 18.

## LEACHATE MIGRATION

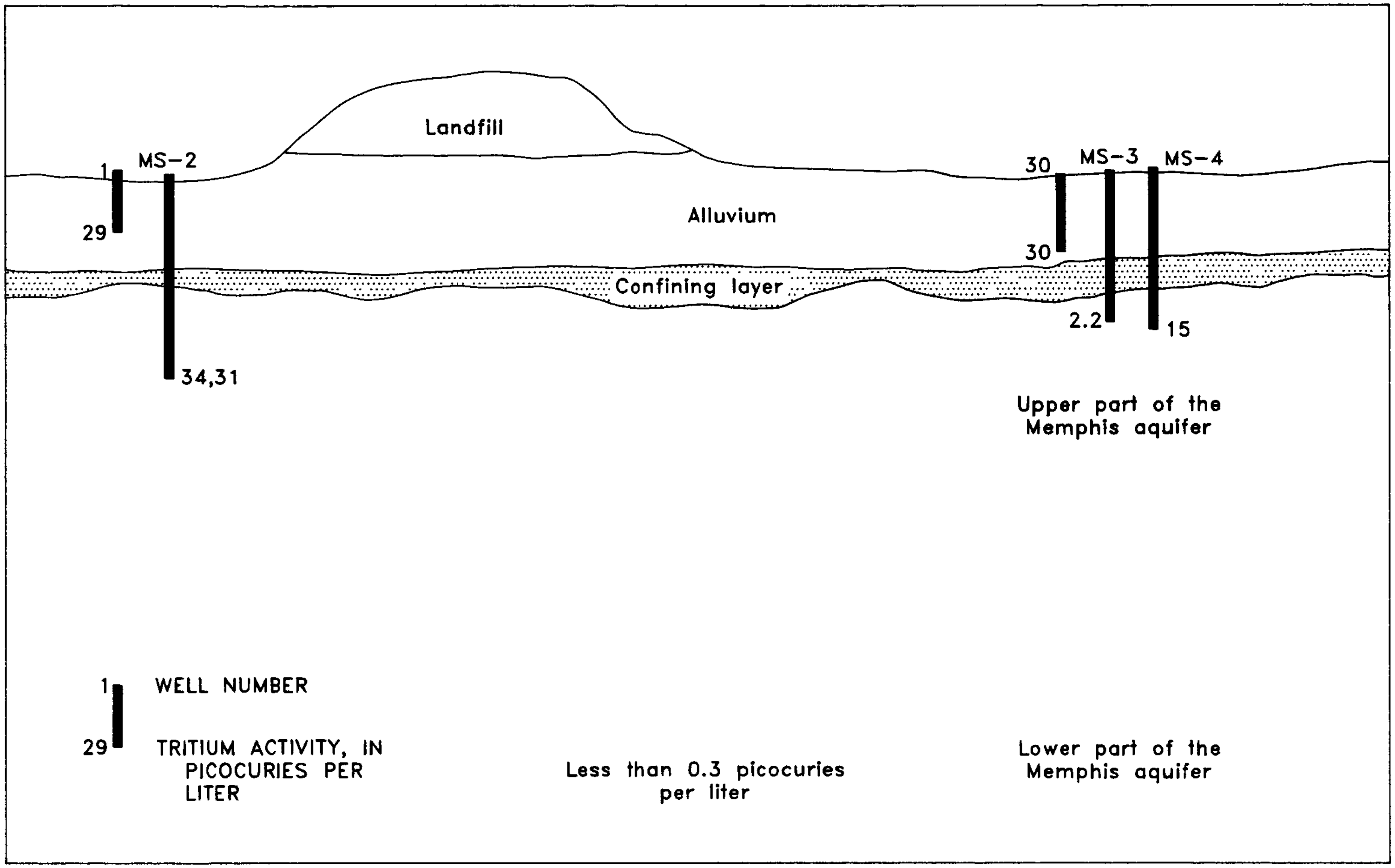
The migration of leachate from the landfill to the alluvial aquifer was determined from data collected from the shallow wells. This was an important element of the study because the potential for leakage from the alluvial aquifer to the Memphis aquifer had been demonstrated. The occurrence of leachate was documented from analyses of water samples from wells in the alluvial aquifer that indicate high concentrations of dissolved solids, trace elements, and synthetic organic compounds. These results were as follows:

- Water samples from wells 26, 27, 30, and 31 in areas affected by leachate migration (fig. 13, table 3), had dissolved-solids concentrations ranging from 340 to 932 mg/L. Other wells in unaffected areas had lower dissolved-solids concentrations ranging from 47 to 354 mg/L.

- Dissolved-chloride concentrations in samples from some wells affected by leachate range from 7.5 to 91 mg/L. Chloride concentrations in other wells unaffected by leachate ranged from about 3 to about 9 mg/L.

- Evidence showing leachate migration to the Memphis aquifer is not conclusive. A relatively high concentration of dissolved chloride (17 mg/L) in well MS-3 in the upper part of the Memphis aquifer may be due to the effect of leachate, but the data are not conclusive.

- Wells drilled into the Memphis aquifer on the south side of the landfill do not contain any chemical constituents associated with leachate migrations, but do show evidence of downward leakage from the alluvial aquifer, based on the tritium analyses.




Not to scale

Figure 18.--Conceptual diagram showing tritium activities in water in the aquifers near the Shelby County landfill.

- Determinations of total organic carbon (TOC) in most of the samples did not show evidence of leachate migration to the Memphis aquifer. The water samples from wells drilled into the alluvial aquifer had TOC concentrations that ranged from 1.1 to 99 mg/L, but most were less than 5 mg/L (table 3, fig. 19). In samples from the Memphis aquifer, TOC concentrations did not exceed 1.0 mg/L.

- Water samples from 16 wells (14 alluvial aquifer wells and 2 Memphis aquifer wells) were scanned for the presence of semivolatile organic compounds (table 6). The scans for organic compounds utilized a gas chromatograph with flame-ionization detection (GC/FID) to qualitatively determine the presence and relative concentration of organic compounds (Wershaw and others, 1987). The presence of this group of organic compounds is indicated by nonblank peaks on a chromatograph (fig. 20). The chromatograph for water from the alluvial aquifer in an area affected by leachate (well 27) had a greater number of peaks than the chromatograph of water in an unaffected area (well 7).

- The area under the curve of the chromatograph was used to estimate concentrations of organic compounds present in the ground water (table 6). The estimated concentrations ranged from 5 to 161 μg/L but generally were less than 20 μg/L (fig. 21). Estimated concentration were highest in wells 26 and 27 with 130 and 161 μg/L, respectively (table 6, fig. 21). The estimated concentrations generally decreased away from the landfill (fig. 21). Estimated concentrations in the Memphis aquifer were 12 μg/L at MS-2, and 14 and 17 μg/L at MS-4.

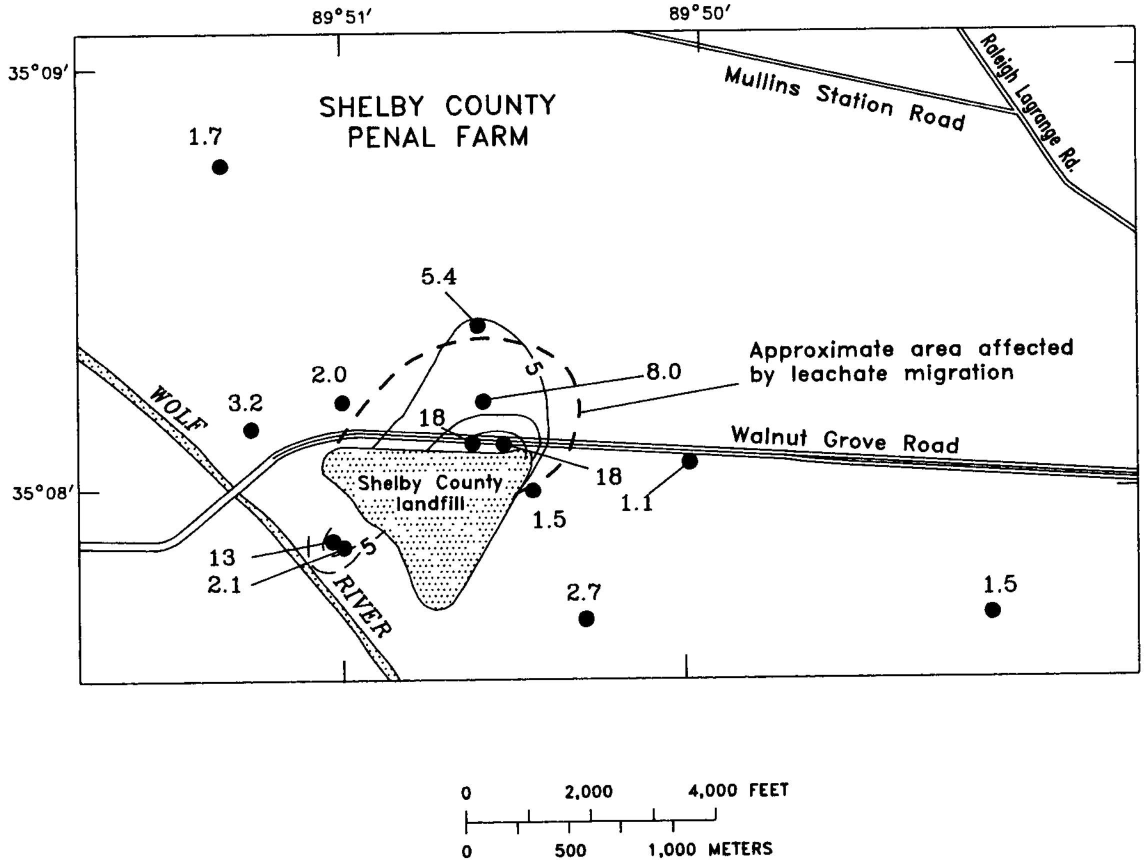
- Water samples from two wells completed in the alluvial aquifer were analyzed for volatile organic compounds (VOC's) (table 7). Concentrations generally were below detection limits of either 1.0 or 3.0 μg/L. Some organic compounds were detected in water at wells 26 and 31, located downgradient from the landfill. Samples from well 26 contained 3.6 μg/L benzene, 1.1 μg/L chlorobenzene, 1.9 μg/L vinyl chloride, and 1.0 μg/L xylene. The VOC's detected in water from well 31 included 5.0 μg/L methylene chloride, 6.3 μg/L tetrachloroethylene, 3.6 μg/L 1,1-dichloroethane, and 4.5 μg/L 1,2-transdichloroethylene (table 7).

- Water from well MS-4 in the Memphis aquifer did not have VOC's at concentrations higher than the detection limits (table 7). Results of analyses of samples from well MS-3 also were negative (Tennessee Department of Health and Environment, Division of Solid Waste Management, written commun., 1987).

## SUMMARY AND CONCLUSIONS

The area near the Shelby County landfill is underlain by the alluvial aquifer, the Jackson-upper Claiborne confining layer, and the Memphis Sand. The confining layer separates and hydraulically isolates the alluvial aquifer from the underlying Memphis aquifer. In some areas, the confining layer may be thin, absent, or contain a high percentage of sand. If a downward vertical gradient exists, water from the alluvial aquifer may recharge the upper part of the Memphis Sand.

Preliminary investigations indicated an area near the Shelby County landfill where vertical leakage down to the Memphis aquifer could be occurring. There was considerable

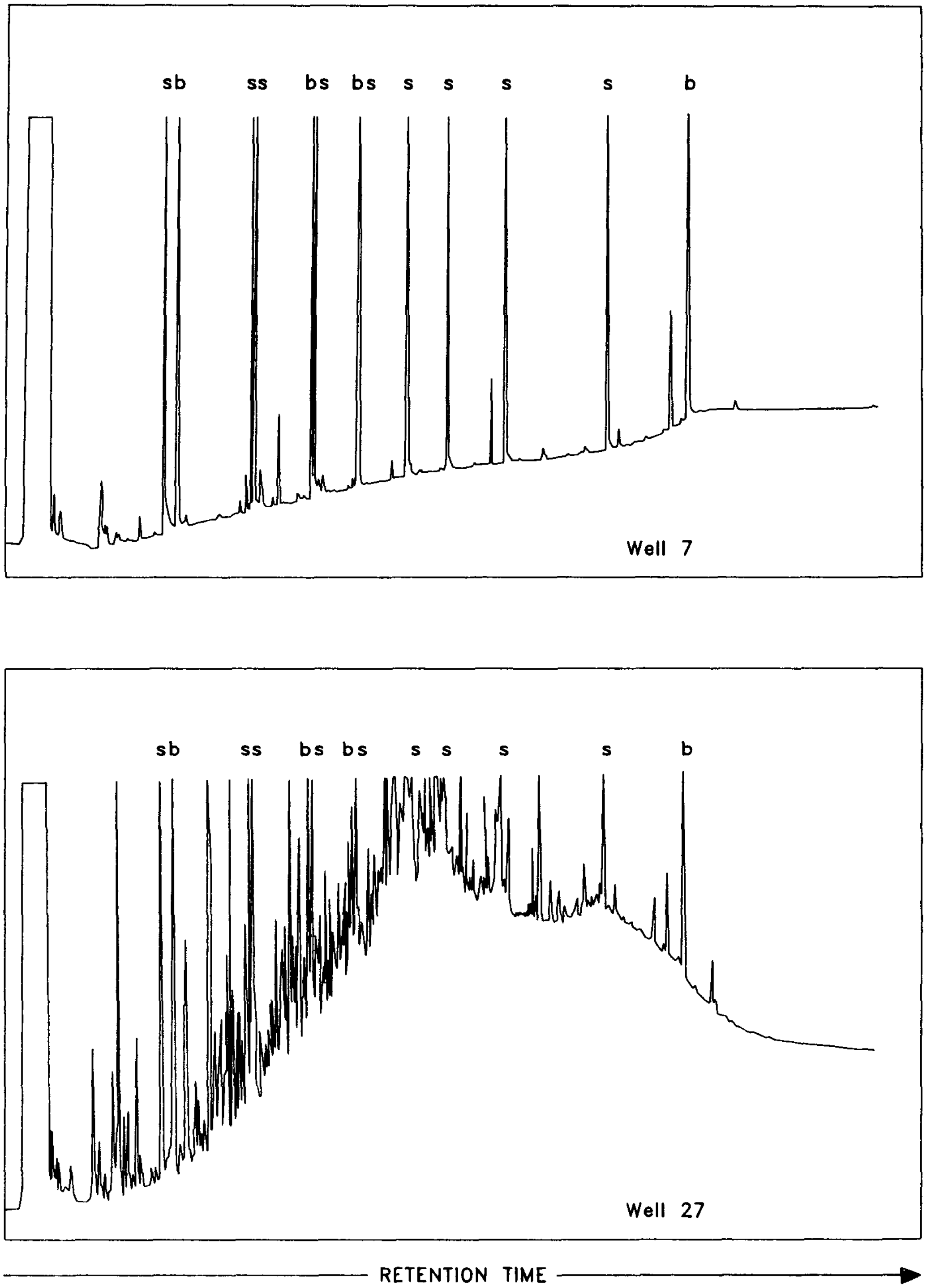



EXPLANATION

—— 5 — — LINE OF EQUAL TOTAL ORGANIC CARBON CONCENTRATION-- Dashed where approximately located. Interval 5 milligrams per liter

3.2 ● WELL AND TOTAL ORGANIC CARBON CONCENTRATION, IN MILLIGRAMS PER LITER--Value represents total organic carbon concentration in samples collected in November 1986 or July 1987

Figure 19.--Distribution of total organic carbon concentrations in water in the alluvial aquifer.

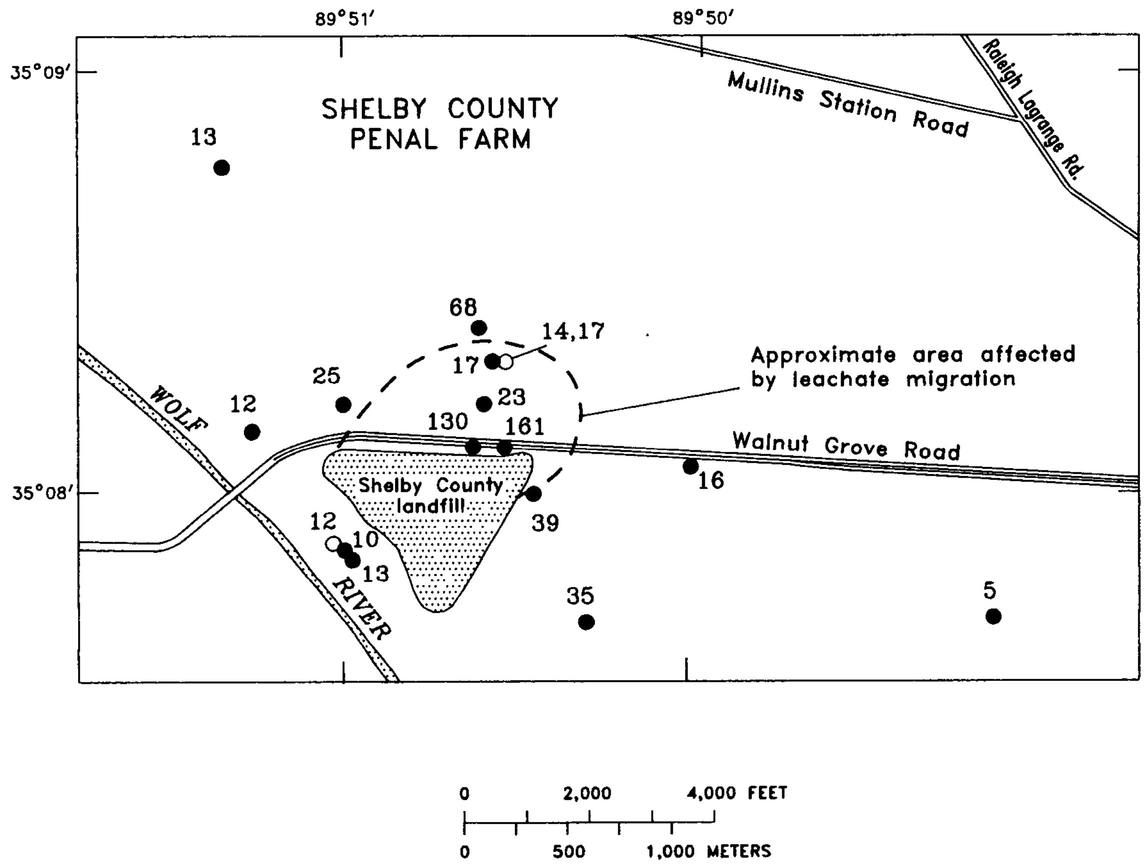



EXPLANATION

s STANDARD OR SURROGATE COMPOUND ADDED BY LABORATORY PRIOR TO ANALYSIS

b COMPOUND ALSO DETECTED IN BLANK SAMPLE

Figure 20.--Gas chromatographs showing response of gas chromatograph/flame-ionization detection scans of water from wells 7 and 27.




EXPLANATION

13 ● WELL AND ESTIMATED CONCENTRATION OF ORGANIC COMPOUNDS, IN MICROGRAMS PER LITER, FOR WATER FROM THE ALLUVIAL AQUIFER--Samples collected in November 1986 and July 1987

12 ○ WELL AND ESTIMATED CONCENTRATION OF ORGANIC COMPOUNDS, IN MICROGRAMS PER LITER, FOR WATER FROM THE MEMPHIS AQUIFER--Samples collected in November 1986 or July 1987

Figure 21.--Estimated concentrations of organic compounds as determined by gas chromatograph/flame-ionization detection scans of ground water near the Shelby County landfill.

Table 6.—*Concentrations of organic compounds as estimated from gas chromatograph/flame-ionization detection scans for the presence of semivolatile organic compounds in ground water near the Shelby County landfill*

[Concentration of organic compounds, in micrograms per liter (μg/L), is estimated from total area of all peaks on the chromatograph minus the peaks detected in the blank sample]

| Well number | | Date sampled | Number of peaks | Concentration of organic compounds (μg/L) |
|---|---|---|---|---|
| USGS | Project | | | |
| SH:Q- 55 | -- | 11-18-86 | 13 | 39 |
| SH:Q- 95 | 1 | 07-16-87 | 15 | 10 |
| SH:Q- 96 | 2 | 07-16-87 | 14 | 13 |
| SH:Q- 98 | 4A | 11-18-86 | 26 | 35 |
| SH:Q-101 | 7 | 11-17-86 | 10 | 5 |
| SH:Q-102 | 8A | 11-18-86 | 20 | 16 |
| SH:Q-105 | 12 | 11-17-86 | 32 | 68 |
| SH:Q-109 | 16 | 11-17-86 | 20 | 13 |
| SH:Q-112 | 19 | 11-19-86 | 17 | 12 |
| SH:Q-113 | 20 | 11-18-86 | 18 | 25 |
| SH:Q-119 | 26 | 11-19-86 | 132 | 130 |
| SH:Q-120 | 27 | 11-19-86 | 137 | 161 |
| SH:Q-128 | 30 | 07-17-87 | 40 | 17 |
| SH:Q-129 | 31 | 07-16-87 | 43 | 23 |
| SH:Q- 92 | MS-2 | 07-07-87 | 17 | 12 |
| SH:Q-126 | MS-4 | 07-13-87 | 24 | 17 |
| | | 07-13-87 | 19 | 14 |

concern that leachate from the landfill could possibly migrate downward to the upper part of the Memphis aquifer. An investigation of the possible vertical movement of water downward to the Memphis aquifer and potential leachate migration from the landfill indicated that:

(1) Leakage from the alluvial aquifer down to the Memphis aquifer is occurring through a more permeable zone in the Jackson-upper Claiborne confining layer near the Shelby County landfill.

(2) Leachate from the landfill has affected water quality in the alluvial aquifer and could potentially enter the Memphis aquifer by leakage.

(3) The vertical leakage of water through the confining layer down to the Memphis aquifer is indicated by a depression in the water table and changes in the water quality of the Memphis aquifer north of the landfill. The water table in the alluvial aquifer north of the landfill shows a broad, closed depression at an elevation of about 216 feet above sea level, or about 14 feet lower than the Wolf River. The flow of water in the alluvial aquifer is toward the depression from all sides and then down to the Memphis aquifer.

(4) The water quality in the upper Memphis aquifer near the Shelby County landfill has been affected by vertical leakage from the alluvial aquifer. Dissolved-solids concentrations at 3 wells in the upper part of the Memphis aquifer near the landfill (61 to 146 mg/L) are similar to concentrations in the alluvial aquifer in areas not affected by leachate migration (47 to 354 mg/L).

Table 7.—*Concentrations of volatile organic compounds in ground water near the Shelby County landfill*

[Values are total recoverable concentration in micrograms per liter, µg/L; < less than indicated detection limit]

| Well number USGS | Well number Project | Date | Di-chloro-bromo-methane (µg/L) | Carbon-tetra-chlo-ride (µg/L) | 1,2-Di-chloro-ethane (µg/L) | Bromo-form (µg/L) | Chloro-di-bromo-methane (µg/L) | Chloro-form (µg/L) | Toluene (µg/L) | Benzene (µg/L) | Chloro-benzene (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SH:Q-126 | MS-4 | 07-13-87 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 |
| SH:Q-129 | 31 | 07-16-87 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 |
| SH:Q-119 | 26 | 07-17-87 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | 3.6 | 1.1 |

| Well number USGS | Well number Project | Chloro-ethane (µg/L) | Ethyl-benzene (µg/L) | Methyl-bromide (µg/L) | Methyl-chlo-ride (µg/L) | Methyl-ene chlo-ride (µg/L) | Tetra-chloro-ethyl-ene (µg/L) | Tri-chloro-fluoro-methane (µg/L) | 1,1-Di-chloro-ethane (µg/L) | 1,1-Di-chloro-ethyl-ene (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| SH:Q-126 | MS-4 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 |
| SH:Q-129 | 31 | <3.0 | <3.0 | <3.0 | <3.0 | 5.0 | 6.3 | <3.0 | 3.6 | <3.0 |
| SH:Q-119 | 26 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |

| Well number USGS | Well number Project | 1,1,1-Tri-chloro-ethane (µg/L) | 1,1,2-Tri-chloro-ethane (µg/L) | 1,1,2,2 Tetra-chloro-ethane (µg/L) | 1,2-Di-chloro-benzene (µg/L) | 1,2-Di-chloro-propane (µg/L) | 1,2-Transdi chloro-ethyl-ene (µg/L) | 1,3-Di-chloro-propane (µg/L) | 1,3-Di-chloro-benzene (µg/L) | 1,4-Di-chloro-benzene (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| SH:Q-126 | MS-4 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 |
| SH:Q-129 | 31 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | 4.5 | <3.0 | <3.0 | <3.0 |
| SH:Q-119 | 26 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |

| Well number USGS | Well number Project | 2-Chloro-ethyl-vinyl-ether (µg/L) | Di-chloro-di-fluoro-methane (µg/L) | Trans-1,3-di-chloro-propene (µg/L) | CIS 1,3-di-chloro-propene (µg/L) | 1,2-dibromo ethyl-ene (µg/L) | Vinyl chlo-ride (µg/L) | Tri-chloro-ethyl-ene (µg/L) | Styrene (µg/L) | Xylene water whole (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| SH:Q-126 | MS-4 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 |
| SH:Q-129 | 31 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 |
| SH:Q-119 | 26 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | 1.9 | <1.0 | <1.0 | 1.0 |

(5) A statistically significant difference exists (0.05 significance level) between the dissolved-solids concentrations in water in the upper part of the Memphis aquifer near the landfill and those in wells in the Memphis aquifer in areas not affected by leakage. Dissolved-chloride concentrations also were elevated in water from some wells in the upper part of the Memphis aquifer near the landfill and are similar to concentrations for water in the alluvial aquifer.

(6) Tritium activities are approximately 30 pCi/L in the alluvial aquifer and 2.2 to 34 pCi/L in the upper part of the Memphis aquifer near the landfill. The similarity between activities present in the upper part of the Memphis aquifer and the alluvial aquifer is evidence of the presence of recent water in the Memphis aquifer due to downward leakage from the alluvial aquifer.

(7) Leachate migration from the landfill has affected the water quality in the alluvial aquifer. The effect of leachate migration is indicated by elevated concentrations of dissolved solids (340 to 932 mg/L), dissolved chloride (7.5 to 91 mg/L), and dissolved barium (120 to 610 µg/L).

(8) Estimated concentrations of synthetic organic compounds in the alluvial aquifer were 5 to 68 µg/L in areas not affected by leachate and 17 to 161 µg/L in affected areas.

(9) The quality of water in the Memphis aquifer near the landfill has been affected by water from the alluvial aquifer. Water-quality data from this investigation, however, do not conclusively indicate the migration of leachate down to the Memphis aquifer from the landfill. The occurrence of dissolved chloride at a concentration of 17 mg/L in samples of water from a well drilled into the Memphis aquifer could be the result of leachate migration.

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