Water-Resources Investigations Report 91-4173

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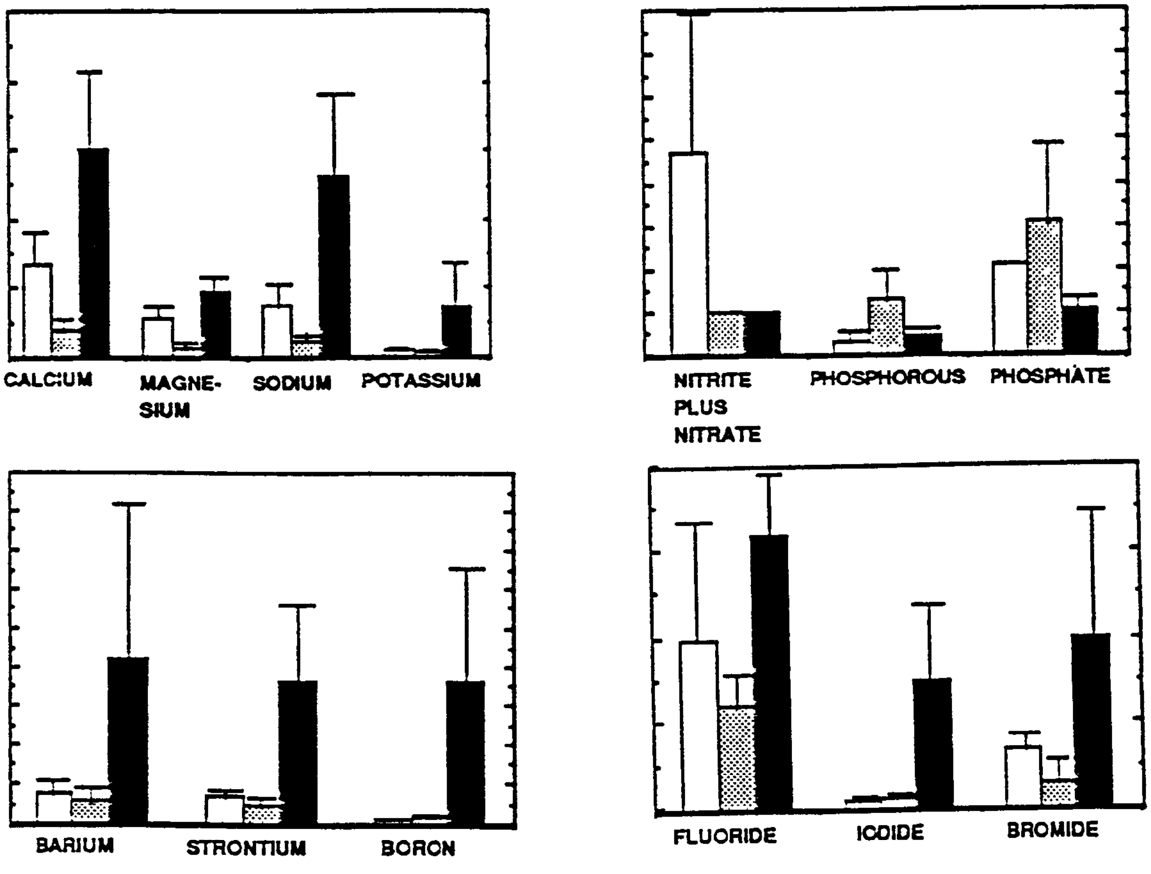

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U.S. GEOLOGICAL SURVEY

in cooperation with the
SHELBY COUNTY DEPARTMENT OF PUBLIC WORKS

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By William S. Parks and June E. Mirecki

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SHELBY COUNTY DEPARTMENT OF PUBLIC WORKS

Memphis, Tennessee

1992

U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY

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Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	0.4047	square hectometer
foot per day (ft/d)	30.48	centimeter per day
gallons per minute (gal/min)	0.06309	liters per second

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum 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.

Well-Numbering Systems: For this investigation, the new wells were assigned project numbers (beginning with 32 for wells screened in the alluvial aquifer and MS-5 for wells screened in the Memphis aquifer) to follow a system begun by Bradley (1988) for the first group of wells installed near the Shelby County landfill. For brevity, these numbers were used as the principal numbers for labeling figures, referencing tables, and identifying wells in the appendices. For location of the schedules, geophysical logs, and water levels in the files, the wells also are identified according to the local numbering system used throughout Tennessee.

Tennessee District well-numbering system: Wells in Tennessee are identified according to this numbering system that is used by the U.S. Geological Survey, Water Resources Division. The well number consists of three parts: an abbreviation of the name of the county in which the well is located; a letter designating the 7 1/2-minute topographic quadrangle on which the well is plotted; quadrangles are lettered from left to right across the county beginning in the southwest corner of the county; and a number generally indicating the numerical order in which the well was inventoried. For example, Sh:Q-132 indicates that the well is located in Shelby County on the "Q" quadrangle and is identified as well 132 in the numerical sequence.

In table 4 of this report, the U.S. Geological Survey site identification numbers used for computer processing of water-quality data are given so that the data for a particular well can be retrieved. This number consists of the latitude and longitude of the well and a sequence number (01, 02, and so forth) to distinguish among several wells located within the same second of latitude and longitude.

Hydrogeology, Ground-Water Quality, and Potential for Water-Supply Contamination near the Shelby County Landfill in Memphis, Tennessee

By William S. Parks *and* June E. Mirecki

ABSTRACT

An investigation was conducted from 1989 to 1991 to collect and interpret hydrogeologic and ground-water-quality data specific to the Shelby County landfill in east Memphis, Tennessee. Eighteen wells were installed in the alluvial and Memphis aquifers at the landfill. Hydrogeologic data collected showed that the confining unit separating the alluvial aquifer from the Memphis aquifer was thin or absent just north of the landfill and elsewhere consists predominantly of fine sand and silt with lenses of clay.

A water-table map of the landfill vicinity confirms the existence of a depression in the water table north and northeast of the landfill and indicates that ground water flows northeast from the Wolf River passing beneath the landfill toward the depression in the water table. A map of the potentiometric surface of the Memphis aquifer shows that water levels were anomalously high just north of the landfill, indicating downward leakage of water from the alluvial aquifer to the Memphis aquifer.

An analysis of water-quality data for major and trace inorganic constituents and nutrients confirms that leachate from the landfill has migrated northeastward in the alluvial aquifer toward the depression in the water table and that contaminants in the alluvial aquifer have migrated downward into the Memphis aquifer.

The leachate plume can be characterized by concentrations of certain major and trace inorganic constituents that are 2 to 20 times higher than samples from upgradient and background alluvial aquifer wells. The major and trace constituents that best characterize the leachate plume are total organic carbon, chloride, dissolved solids, iron, ammonia nitrogen, calcium, sodium, iodide, barium, strontium, boron, and cadmium.

Several of these constituents (specifically dissolved solids, calcium, sodium, and possibly ammonia nitrogen, chloride, barium, and strontium) were detected in elevated concentrations in samples from certain Memphis aquifer wells. Elevated concentrations were detected in samples from the Memphis aquifer beneath the leachate plume where the confining unit is thin or absent.

The distribution of halogenated alkanes (specifically dichlorodifluoromethane and trichlorofluoromethane) and halogenated alkenes (specifically 1,2-trans-dichloroethene and vinyl chloride) in samples from wells screened in both the alluvial and Memphis aquifers is similar to the distribution of major and trace inorganic constituents that characterize the leachate plume.

The ground-water supply most susceptible to contamination from the Shelby County landfill is the Sheahan

well field of the Memphis Light, Gas and Water Division. This well field is about 5 miles downgradient from the landfill in the direction of ground-water flow. Based on an estimated velocity of 0.5 to 1.5 feet per day, ground water would require about 50 to 150 years to travel from the Shelby County landfill to the Sheahan well field. Given the time and distance of transport, any contaminants in the ground water would not likely persist to reach this well field because of the effects of various physical, chemical, and biological processes, including dilution and adsorption.

INTRODUCTION

The Shelby County landfill in east Memphis, Tennessee (fig. 1) was operated as an open dump for 4 years (1968 to 1972) and then as a regulated landfill for 16 years (1972 to 1988). It was closed on October 1, 1988. During its operation as a regulated landfill, waste disposal was limited to domestic and municipal wastes; disposal of hazardous waste was prohibited (D.C. Newsom, Shelby County Department of Public Works, oral commun., 1989).

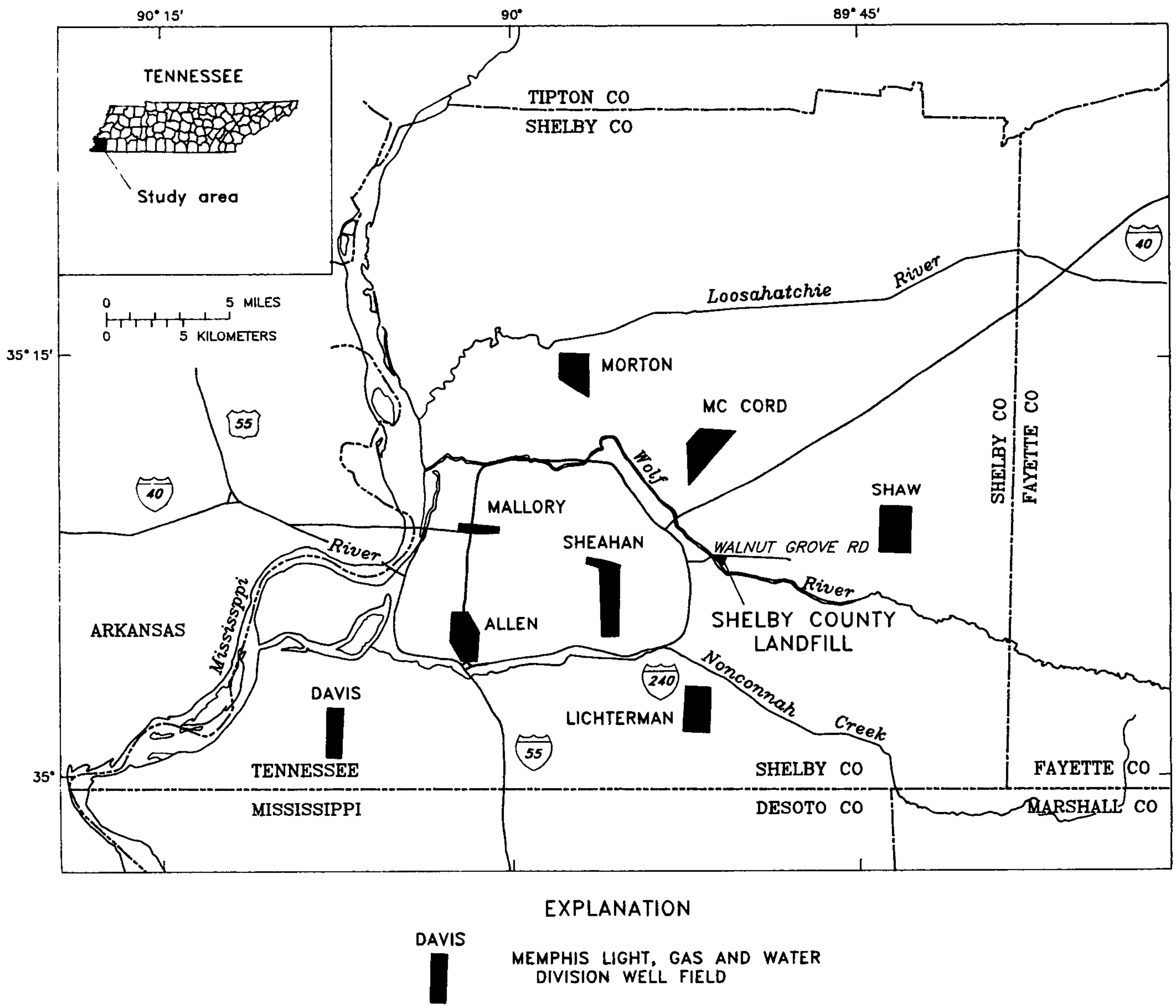


Figure 1.—The Shelby County landfill and Memphis Light, Gas and Water Division well fields.

Proposed expansions of the landfill led to investigations of an area east of the landfill in 1978 (P.M. Garman, Tennessee Department of Health and Environment, written commun., 1978) and north of Walnut Grove Road in early 1986 (J.L. Ashner, Tennessee Department of Health and Environment, written commun., 1986). During the investigation of the area north of Walnut Grove Road, water levels in auger holes and observation wells indicated that the water table was depressed to levels below the low-flow stages of the nearby Wolf River--an anomalous condition (J.L. Ashner, Tennessee Department of Health and Environment, oral commun., 1986).

The USGS subsequently (1986-87) made a study of the ground-water hydrology of the area north and east of the Shelby County landfill with emphasis on determining indications of leakage (M.W. Bradley, U.S. Geological Survey, written commun., 1989). Ground-water data indicated that the depression in the water table was centered north and northeast of the landfill and was as much as 14 feet below the low-flow stages of the Wolf River. Discharge measurements made at low flows indicated that the Wolf River loses water along a stretch that flows past the landfill on the south and west. This local reduction in surface-water flow was interpreted as a loss of water from the Wolf River into the alluvial aquifer (M.W. Bradley, U.S. Geological Survey, written commun., 1989). Thus, the Wolf River may contribute to the north-trending flow of ground water beneath the landfill in the alluvial aquifer.

Water-quality data indicated that contaminants from the landfill had entered the alluvial aquifer and were moving northward in the ground water toward the depression in the water table. The quality of water in the Memphis aquifer beneath the depression indicated that uncontaminated ground water from the alluvial aquifer had moved downward as a result of leakage and had entered the Memphis aquifer (M.W. Bradley, U.S. Geological Survey, written commun., 1989).

In view of these findings, the Tennessee Department of Health and Environment [*Tennessee Department of Environment and Conservation (TDEC) as of 1991*] ordered Shelby County to submit plans (1) for the application of a suitable final cover for the landfill and (2) to conduct a ground-water quality assessment (Tennessee Department of Health and Environment, written commun., 1988). The need to install a monitoring well system around the Shelby County landfill and to determine the types and concentrations of contaminants moving in ground water from the landfill resulted in the investigation reported here. The investigation was conducted by the USGS from 1989 to 1991 in cooperation with the Shelby County Department of Public Works.

Purpose and Scope

This report summarizes information concerning ground-water flow and transport of contaminants in the alluvial aquifer or upper part of the confining unit from the Shelby County landfill toward the depression in the water table north and northeast of the landfill. It also summarizes information concerning downward leakage and transport of contaminants from the alluvial aquifer to the Memphis aquifer. The report documents the construction details of additional wells installed around the Shelby County landfill and presents the geologic, water-level, and water-quality data collected. It also summarizes the field work done and describes the data collection procedures used for this investigation (*Appendix A*).

Acknowledgments

The authors thank Mr. David C. Newsom, Administrator of Shelby County Landfills, whose cooperation and advice significantly aided the efficiency of the field work for the investigation. The authors also thank Mr. Ralph Baker, who operated a county-owned bulldozer and made temporary roads to provide access to difficult-to-reach drilling and sampling sites, as well as, on several occasions, assisted in recovering vehicles or equipment that were stuck.

SITE DESCRIPTION

The Shelby County landfill is located on the Wolf River alluvial plain just south of Walnut Grove Road in east Memphis, Tennessee (fig. 1). The landfill is roughly triangular in shape and covers about 90 acres. It is bounded on the north by Walnut Grove Road and on the southwest by a levee adjacent to the Wolf River. On the southeast, the landfill is surrounded by agricultural land, which belongs to the Shelby County Penal Farm. The Wolf River alluvial plain is relatively flat with some levees, drainage ditches, and intermittent streams.

The surface of the landfill is at an altitude of about 285 to 290 feet above sea level, which is about 40 to 45 feet higher than the surface of the surrounding Wolf River alluvial plain. The landfill comprises two "lifts" (elevations of landfill material and cover) of about 20 to 25 feet each. The southeastern part of the landfill is the oldest part, although it was the last to be covered by the second "lift." In the northern part, the first "lift" adjacent to Walnut Grove Road is being utilized for soccer fields. Near the southeast part of the landfill is a lake, which resulted from the excavation of clay, silt, and sand for cover material during the early operation of the landfill (D.C. Newsom, Shelby County Department of Public Works, oral commun., 1989).

HYDROGEOLOGY

Post-Wilcox geologic units underlying the Shelby County landfill are the alluvium of Quaternary age and the Memphis Sand of Tertiary age (table 1). These units comprise the alluvial and Memphis aquifers. The upper part of the Memphis Sand comprises a confining unit separating the alluvial aquifer from the main body of the Memphis aquifer. This confining unit locally may include clay beds in the Cook Mountain Formation of Tertiary age.

From August to October 1989, 18 wells were installed around the perimeter of the Shelby County landfill and in adjacent areas (table 2). These wells are in addition to 37 wells installed in 1986 for an earlier investigation of a larger area surrounding the landfill (Bradley, 1988). Twelve of the wells are screened in the alluvial aquifer or the upper part of the confining unit separating the alluvium from the main body of the Memphis aquifer (fig. 2). These wells range from 38.5 to 67.3 feet in depth and were installed by auger methods. Six of the wells are screened in the Memphis aquifer (fig. 3). These wells range from 87.5 to 147.5 feet in depth and were installed using the hydraulic-rotary method. Two additional test holes drilled in the Memphis aquifer were abandoned and plugged.

Lithologic descriptions of the alluvium, confining unit, and Memphis Sand encountered in the auger holes and hydraulic rotary test holes drilled in the area of the landfill are given in Bradley (1988) and Appendices B and C of this report. A summary description of lithology and geohydrology of the alluvium (alluvial aquifer), confining unit, and Memphis Sand (Memphis aquifer) follows.

Alluvium

The alluvium of the Wolf River at the Shelby County landfill ranges from about 40 to 70 feet in thickness. The upper 5 to 25 feet generally consist of silty clay or clayey silt, but locally consist of silty fine sand. The lower 25 to 35 feet consist primarily of sand with some gravel. This lower sand

Table 1.- —*Post-Wilcox geologic units underlying the Memphis area and their hydrologic significance*

[Modified from Graham and Parks, 1986]

System	Series	Group	Stratigraphic unit	Thickness	Lithology and hydrologic significance
Quaternary	Holocene and Pleistocene		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.
	Pleistocene		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 and Tertiary(?)	Pleistocene and Pliocene(?)		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	Eocene	?	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 unit for the Memphis Sand.
		Claiborne	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 southeastern 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. Underlain by the Flour Island Formation of the Wilcox Group, which serves as the lower confining unit for the Memphis Sand.

Table 2.- — *Construction data for 18 wells installed at the Shelby County landfill during this investigation*

Well numbers: Project and map	Well numbers: Local USGS for Tennessee	Latutide	Longitude	Altitude of land surface datum, in feet above sea level	Hydrogeologic unit screened	Screened interval, in feet below land surface	Screen diameter, in inches	Date well installed	Installation method A - auger H - Hydraulic rotary
32	Sh:Q-132	350743	0895048	259	Alluvial aquifer	43.5 - 48.5	2	08-08-89	A
33	Sh:Q-133	350749	0895053	264	Alluvial aquifer	42.0 - 47.0	2	08-09-89	A
34	Sh:Q-134	350758	0895101	252	Alluvium aquifer	33.5 - 38.5	2	08-09-89	A
35	Sh:Q-135	350742	0895029	249	Confining unit	35.9 - 40.9	2	08-10-89	A
36	Sh:Q-136	350805	0895106	257	Alluvial aquifer	43.4 - 48.4	2	08-10-89	A
37	Sh:Q-137	350806	0895056	259	Confining unit	58.8 - 63.8	2	08-10-89	A
38	Sh:Q-138	350805	0895049	260	Confining unit	58.8 - 63.8	2	08-11-89	A
39	Sh:Q-139	350804	0895021	260	Confining unit	62.3 - 67.3	2	08-11-89	A
40	Sh:Q-140	350804	0895030	259	Confining unit	60.1 - 65.1	2	08-12-89	A
41	Sh:Q-141	350755	0895029	260	Confining unit	61.9 - 66.9	2	08-12-89	A
42	Sh:Q-142	350738	0895040	261	Alluvial aquifer	36.7 - 41.7	2	08-14-89	A
43	Sh:Q-143	350746	0895035	262	Alluvial aquifer	51.5 - 56.5	2	08-14-89	A
MS-5	Sh:Q-144	350742	0895029	249	Memphis aquifer	110 - 130	4	09-13-89	H
MS-6	Sh:Q-145	350804	0895037	261	Memphis aquifer	casing pulled and hole filled		09-18-89	H
MS-7	Sh:Q-146	350806	0895056	260	Memphis aquifer	88.5 - 108.5	4	09-19-89	H
MS-8	Sh:Q-147	350811	0895047	248	Memphis aquifer	casing pulled and hole filled		09-20-89	H
MS-9	Sh:Q-148	350758	0895101	252	Memphis aquifer	97.5 - 117.5	4	09-28-89	H
MS-10	Sh:Q-149	350749	0895053	264	Memphis aquifer	127.5 - 147.5	4	09-28-89	H
MS-11	Sh:Q-150	350804	0895037	261	Memphis aquifer	107.5 - 127.5		10-03-89	H
MS-12	Sh:Q-151	350811	0895047	248	Memphis aquifer	67.5 - 87.5	4	10-11-89	H

and gravel grades from fine or medium sand in the upper part to coarse or very coarse sand with scattered or thin lenses of gravel in the lower part.

Water-level measurements were made in 33 wells (fig. 4) screened in the alluvial aquifer or upper part of the "confining unit" in the area of the Shelby County landfill during October 1989 (table 3). From these measurements, a map was prepared that shows the altitude of the water table in these units (fig. 5).

This map (fig. 5) indicates that the altitude of the water table in the alluvial aquifer at wells 2, 32, 33, and 34 (fig. 4) approximates river stage at the nearby streamflow-gaging station on the Wolf River at Walnut Grove Road (fig. 5). Just north and northeast of the landfill the map indicates a depression in the water table (fig. 5) centered between wells 12 and 38 (fig. 4). The horizontal component of ground-water flow is along lines perpendicular to the contours shown on the water-table map (fig. 5) from higher altitudes to lower altitudes. Thus, ground-water flow beneath the landfill is generally northeast from the Wolf River towards the depression in the water table. Ground water also flows into this depression from all other directions. In the area of the depression, the alluvial aquifer locally is in direct hydraulic connection with the Memphis aquifer, and water is leaking downward to the Memphis aquifer (M.W. Bradley, U.S. Geological Survey, written commun., 1989).

Confining Unit

The confining unit separating the water-table aquifers (alluvium and fluvial deposits) from the Memphis aquifer in the Memphis area was described previously in several reports. Graham and Parks (1986) considered that part of the stratigraphic section between the base of the water-table aquifers and the top of the first prominent sand in the Memphis Sand to be the "Jackson-upper Claiborne confining bed". This confining unit, the thickness of which was mapped only in the Memphis urban area, was defined by Graham and Parks (1986) to include parts of the Jackson, Cockfield, and Cook Mountain Formations.

Parks (1990), in a study of the larger Memphis area, recognized that the lower part of the "Jackson-upper Claiborne confining bed," as defined by Graham and Parks (1986), locally includes thick intervals of clay, silt, and fine sand that are stratigraphically in the upper part of the Memphis Sand. These fine-grained sediments interfinger with fine to medium or medium to coarse sands in the main body of the Memphis Sand over short lateral distances. Therefore, Parks (1990) re-defined the "Jackson Formation-upper Claiborne Group confining unit" to include only strata in the Jackson, Cockfield, and Cook Mountain Formations, and excluded those strata in the upper part of the Memphis Sand.

The Cook Mountain Formation, which is the lower (and older) of the units comprising the Jackson Formation-upper Claiborne Group confining unit, directly overlies the Memphis Sand (table 1). The Cook Mountain Formation consists primarily of clay, but locally contains varying amounts of fine sand (Parks, 1990). Nevertheless, it comprises the most extensive and persistent clay layer in the Jackson Formation-upper Claiborne Group confining unit in the Memphis area and, therefore, is the principal confining unit for the Memphis aquifer.

Based on the test holes drilled during this investigation, the Cook Mountain Formation probably is thin or absent in the immediate area of the Shelby County landfill. The sequence of fine sand, silt, and clay separating the

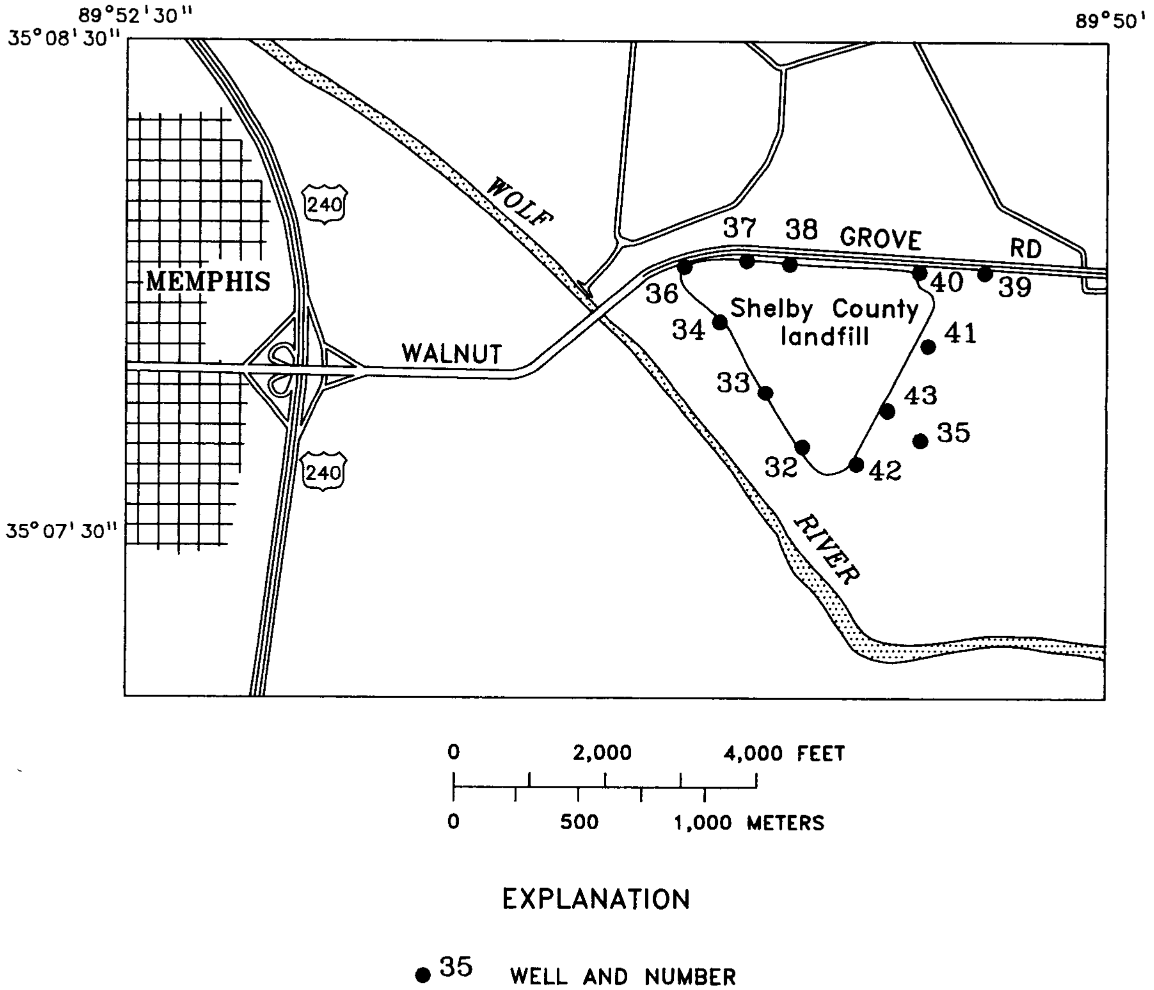


Figure 2.—Twelve wells installed in the alluvial aquifer or upper part of the confining unit at the Shelby County landfill during this investigation.

alluvium from the main body of the Memphis Sand is mostly a discontinuous facies in the upper part of the Memphis Sand. Therefore, this sequence of strata is referred to herein informally as the "confining unit" for the purposes of description and discussion.

At the Shelby County landfill, the confining unit consists of lenses of very fine to fine sand, sandy silt, and silty clay ranging from 0 to at least 75 feet in thickness (fig. 6; *Appendix C*; Bradley, 1988). These lenses interfinger with each other over relatively short distances. In the test hole for well MS-8 (abandoned) north of Walnut Grove Road about 600 feet north of the landfill, the confining unit was absent and the alluvium directly overlies the main body of the Memphis Sand (fig. 6). In the test hole for well MS-11 on the south side of Walnut Grove Road near the northeast corner of the landfill, the confining unit consisted of only 8 feet of silty clay (fig. 6; *Appendix C*). These two test holes indicate that the confining unit is thin or absent in the area just north and northeast of the landfill.

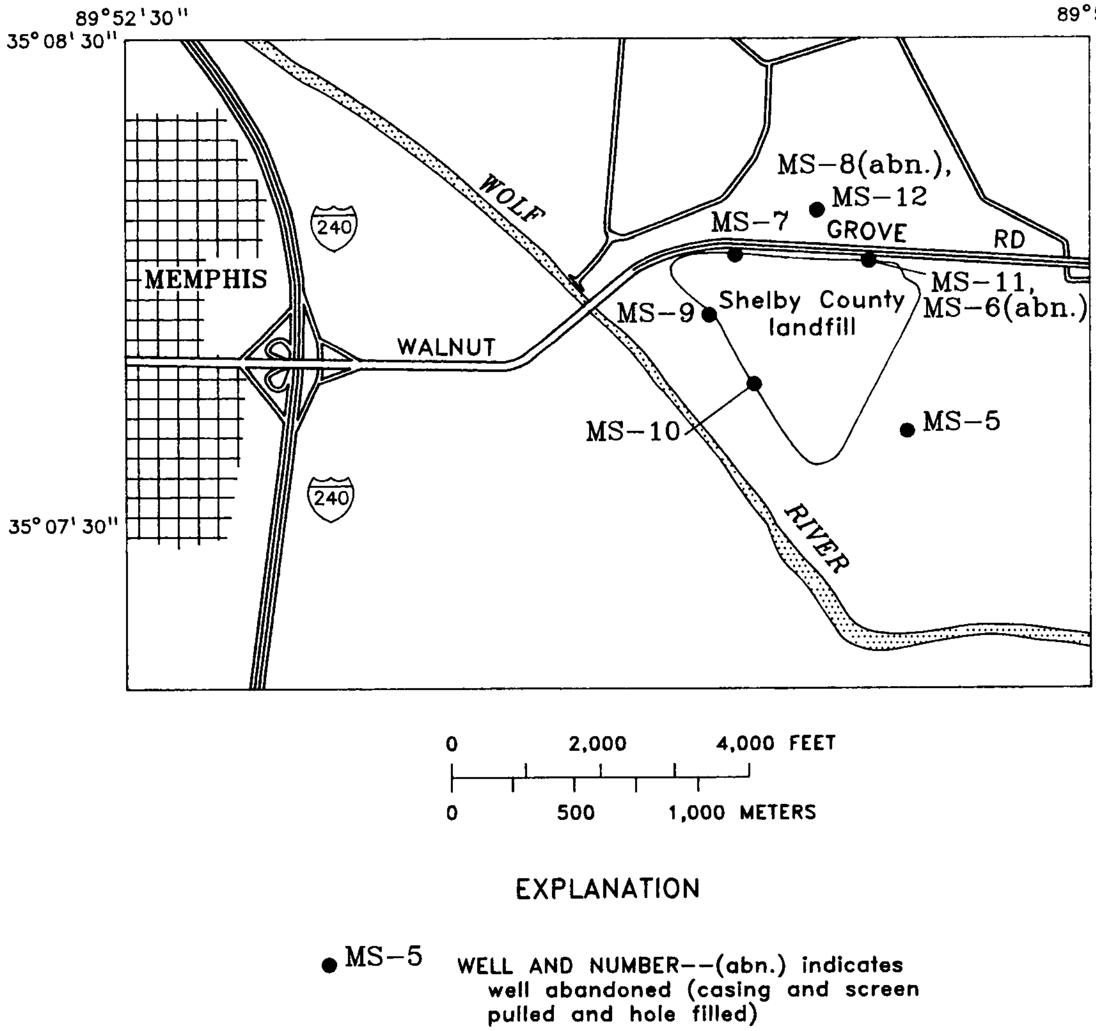


Figure 3. – Eight wells installed in the Memphis aquifer at the Shelby County landfill during this investigation.

On the south side of Walnut Grove Road near the northwest corner of the landfill, the test hole for well MS-7 penetrated the confining unit, consisting of 35 feet of silty clay directly underlying the alluvium at a depth of 47 to 82 feet (fig. 6; *Appendix C*). This depth is 36 to 71 feet below the original land surface when adjusted by subtracting 11 feet of fill for Walnut Grove Road penetrated at the top of the test hole.

On the west side of the landfill near the Wolf River, the confining unit ranged from 50 to 75 feet in thickness in the test holes for wells MS-1 (Bradley, 1988), MS-9, and MS-10 (fig. 6; Appendix C). However, the confining unit in these test holes consisted mostly of very fine to fine sand and sandy silt. The only prominent clay bed penetrated was 24-feet thick in the test hole for well MS-9, at a depth of 67 to 91 feet below land surface. Only about 4 feet of silty clay were penetrated in the test hole for well MS-1 at a depth of 54 to 58 feet.

On the east side of the landfill, the test hole for well MS-5 penetrated a 64-foot thick confining unit consisting mostly of sandy silt and silty clay (fig. 6; Appendix C). This confining unit included a 40-foot thick silty clay at a depth of 60 to 100 feet below land surface.

The most persistent clay bed in the area of the Shelby County landfill, based on available test hole information, is at a nearest distance of about 1,200 feet north of the landfill at well MS-3 in which about 30 feet of silty clay was penetrated (fig. 6). As much as 48 feet of silty clay were penetrated in the auger hole for well 11 and about 35 feet in

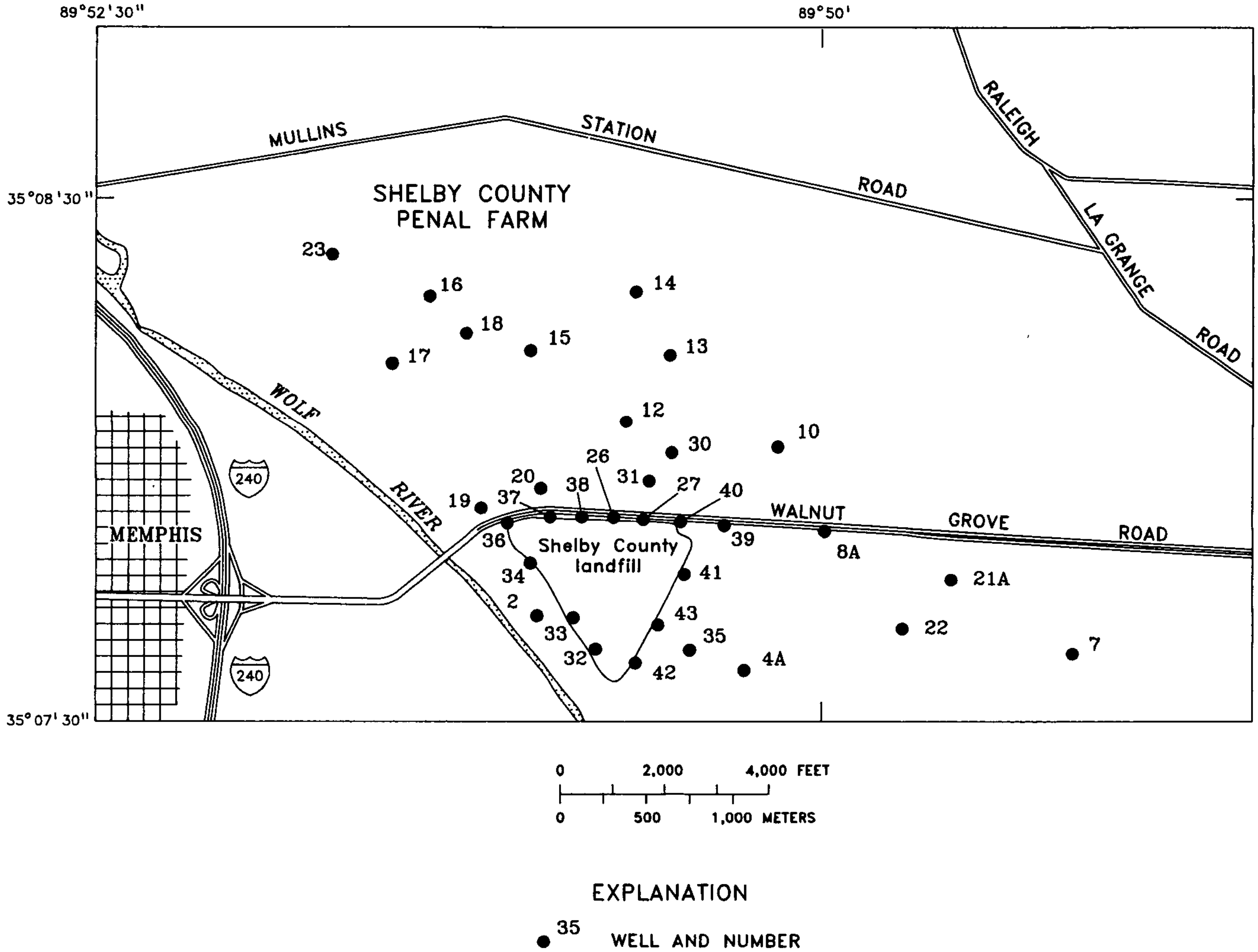


Figure 4.—Wells in the alluvial aquifer or upper part of the confining unit in which water levels were measured during October 1989.

Table 3.- — *Water-level data from wells screened in the alluvial aquifer or upper part of the confining unit and in the Memphis aquifer near the Shelby County landfill*

[Less than (<) indicates that in wells that were dry the altitude of the water level was below the bottom of the well]

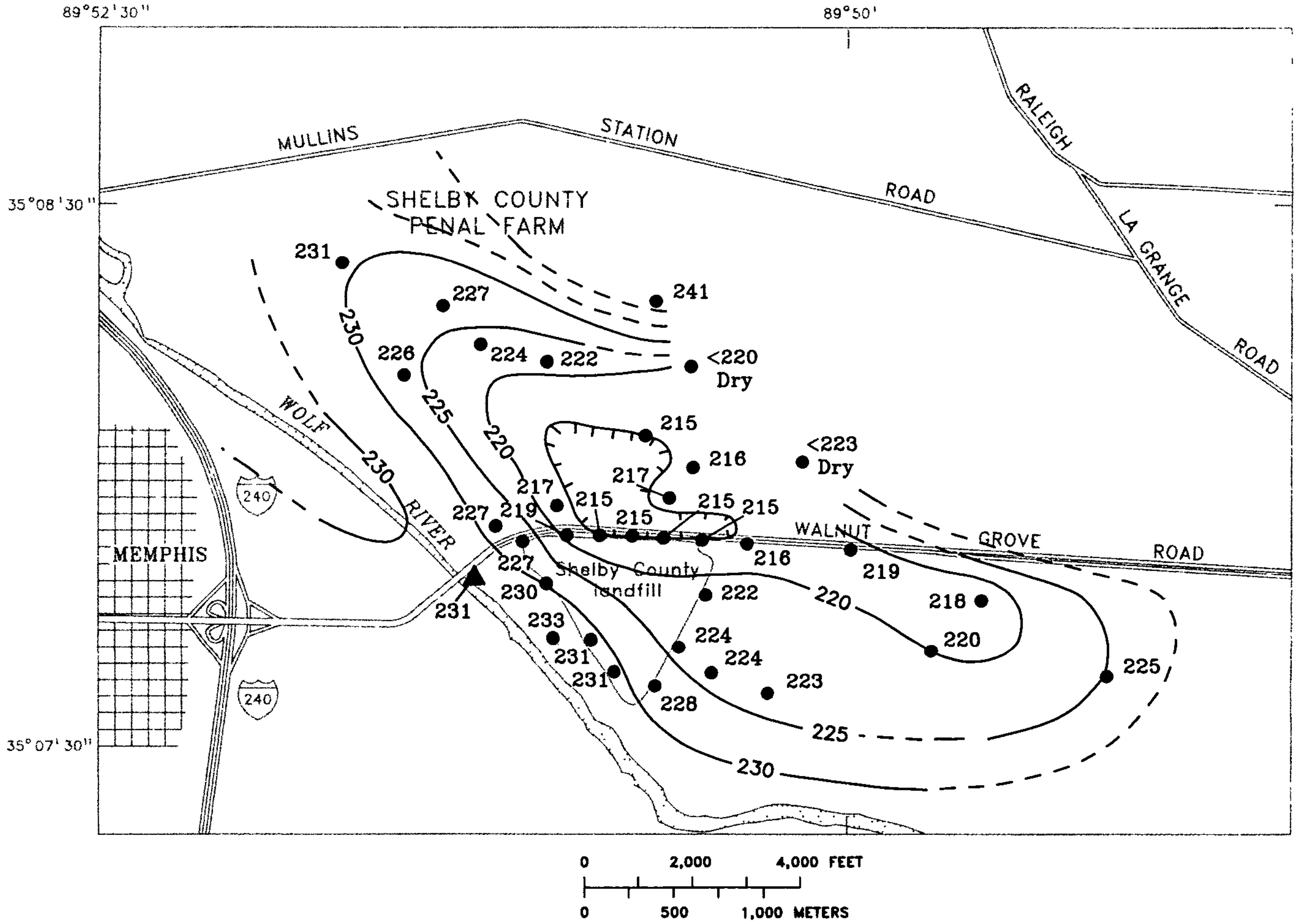
Well numbers: Project and map	Well numbers: USGS local for Tennessee	Latitude	Longitude	Altitude of land-surface datum, in feet above sea level	Hydrogeologic unit screened	Screened interval, in feet below land surface	Water-level below land-surface: Depth, in feet	Water-level below land-surface: Date of measurement	Water-level altitude, in feet above sea level
2	Sh:Q-96	350749	0895058	247	Alluvial aquifer	43.3 - 48.3	14.47	10-10-89	233
4A	Sh:Q-98	350739	0895017	254	Alluvial aquifer	47.5 - 52.5	31.10	10-09-89	223
7	Sh:Q-101	350741	0894909	258	Alluvial aquifer	32.7 - 37.7	33.28	10-12-89	225
8A	Sh:Q-102	350803	0894959	262	Alluvial aquifer	48.7 - 53.7	42.78	10-12-89	219
10	Sh:Q-104	350816	0895009	267	Alluvial aquifer	39 - 44	dry	10-12-89	<223
12	Sh:Q-105	350822	0895040	252	Alluvial aquifer	38.7 - 43.7	36.60	10-11-89	215
13	Sh:Q-106	350833	0895030	264	Alluvial aquifer	38.8 - 43.8	dry	10-11-89	<220
14	Sh:Q-107	350844	0895032	264	Alluvial aquifer	39.5 - 44.5	22.64	10-12-89	241
15	Sh:Q-108	350836	0895032	260	Alluvial aquifer	38.3 - 43.8	38.38	10-11-89	222
16	Sh:Q-109	350845	0895121	257	Alluvial aquifer	39.7 - 44.7	29.72	10-11-89	227
17	Sh:Q-110	350833	0895121	255	Alluvial aquifer	39.2 - 44.2	29.21	10-11-89	226
18	Sh:Q-111	350838	0895113	258	Alluvial aquifer	38.3 - 43.3	34.36	10-11-89	224
19	Sh:Q-112	350807	0895111	247	Alluvial aquifer	39.4 - 44.4	20.08	10-11-89	227
20	Sh:Q-113	350812	0895059	248	Alluvial aquifer	38.2 - 43.2	30.89	10-11-89	217
21A	Sh:Q-114	350753	0894933	260	Alluvial aquifer	40 - 45	42.38	10-12-89	218
22	Sh:Q-115	350745	0894945	255	Alluvial aquifer	49.2 - 54.2	35.31	10-12-89	220
23	Sh:Q-116	350853	0895140	246	Alluvial aquifer	23.3 - 28.3	15.30	10-11-89	231
26	Sh:Q-119	350804	0895041	260	Confining unit	60.1 - 65.1	45.03	10-09-89	215
27	Sh:Q-120	350804	0895035	262	Confining unit	60.2 - 65.2	47.07	10-09-89	215
30	Sh:Q-128	350817	0895035	250	Alluvial aquifer	33.7 - 38.7	33.58	10-12-89	216
31	Sh:Q-129	350810	0895035	249	Alluvial aquifer	34 - 39	32.12	10-12-89	217
32	Sh:Q-132	350743	0895048	259	Alluvial aquifer	43.5 - 48.5	28.09	10-09-89	231
33	Sh:Q-133	350749	0895053	264	Alluvial aquifer	42.0 - 47.0	32.99	10-09-89	231
34	Sh:Q-134	350758	0895101	252	Alluvial aquifer	33.5 - 38.5	22.48	10-09-89	230
35	Sh:Q-135	350742	0895029	249	Confining unit	35.9 - 40.9	24.80	10-09-89	224
36	Sh:Q-136	350805	0895106	257	Alluvial aquifer	43.4 - 48.4	29.88	10-09-89	227
37	Sh:Q-137	350806	0895056	259	Confining unit	58.8 - 63.8	39.64	10-09-89	219
38	Sh:Q-138	350805	0895049	260	Confining unit	58.8 - 63.8	44.87	10-09-89	215
39	Sh:Q-139	350804	0895021	260	Confining unit	62.3 - 67.3	43.85	10-09-89	216
40	Sh:Q-140	350804	0895030	259	Confining unit	60.1 - 65.1	44.49	10-09-89	215
41	Sh:Q-141	350755	0895029	260	Confining unit	61.9 - 6.9	38.13	10-09-89	222
42	Sh:Q-142	350738	0895040	261	Alluvial aquifer	36.7 - 41.7	32.57	10-09-89	228
43	Sh:Q-143	350746	0895035	262	Alluvial aquifer	51.5 - 56.5	38.40	10-09-89	224
None	Sh:Q-1	350900	0894823	330	Memphis aquifer	375 - 384	106.88	10-10-89	223
MS-2	Sh:Q-92	350749	0895058	247	Memphis aquifer	150 - 180	34.66	10-10-89	212
MS-4	Sh:Q-126	350817	0895035	250	Memphis aquifer	68.7 - 97.7	39.64	10-10-89	210
MS-5	Sh:Q-144	350742	0895029	249	Memphis aquifer	110 - 130	33.64	10-09-89	215
MS-7	Sh:Q-146	350806	0895056	260	Memphis aquifer	88.5 - 108.5	45.80	10-12-89	214
MS-9	Sh:Q-148	350758	0895101	252	Memphis aquifer	97.5 - 117.5	40.30	10-09-89	212
MS-10	Sh:Q-149	350749	0895053	264	Memphis aquifer	127.5 - 147.5	50.57	10-09-89	213
MS-11	Sh:Q-150	350804	0895037	261	Memphis aquifer	107.5 - 127.5	49.75	10-09-89	211
MS-12	Sh:Q-151	350811	0895047	248	Memphis aquifer	67.5 - 87.5	32.52	10-12-89	215

the stratigraphic test hole Sh:Q-124 (fig. 6; Bradley, 1988, p. 31). These clay beds occur directly below the base of the alluvium or fluvial deposits and overlie the Memphis Sand.

Clay beds underlying the alluvium or fluvial deposits in wells MS-3, MS-7, MS-11, 11 and Sh:Q-124 (fig. 6) may be the Cook Mountain Formation. If so, because of their position as related to sands in wells MS-8 and MS-11 and the sea-level datum, the structural geology of the area may be complicated by faults. Insufficient test-hole and other information is available to conclusively determine the location of any faults.

Memphis Sand

The upper part of the Memphis Sand locally consists of interbedded and interlensed fine sand, silt, and clay, as



EXPLANATION

——230 — — WATER-TABLE CONTOUR--Shows altitude of water table. Dashed where approximately located. Hachures indicate depression. Contour interval 5 feet. Datum is sea level

● 223 WELL IN WHICH WATER LEVEL WAS MEASURED--Dry wells contained no water

▲ 231 STREAMFLOW-GAGING STATION--Average stage at low flow during October 1989

Figure 5.—Altitude of the water table in the alluvial aquifer or upper part of the confining unit in the area of the Shelby County landfill, October 1989.

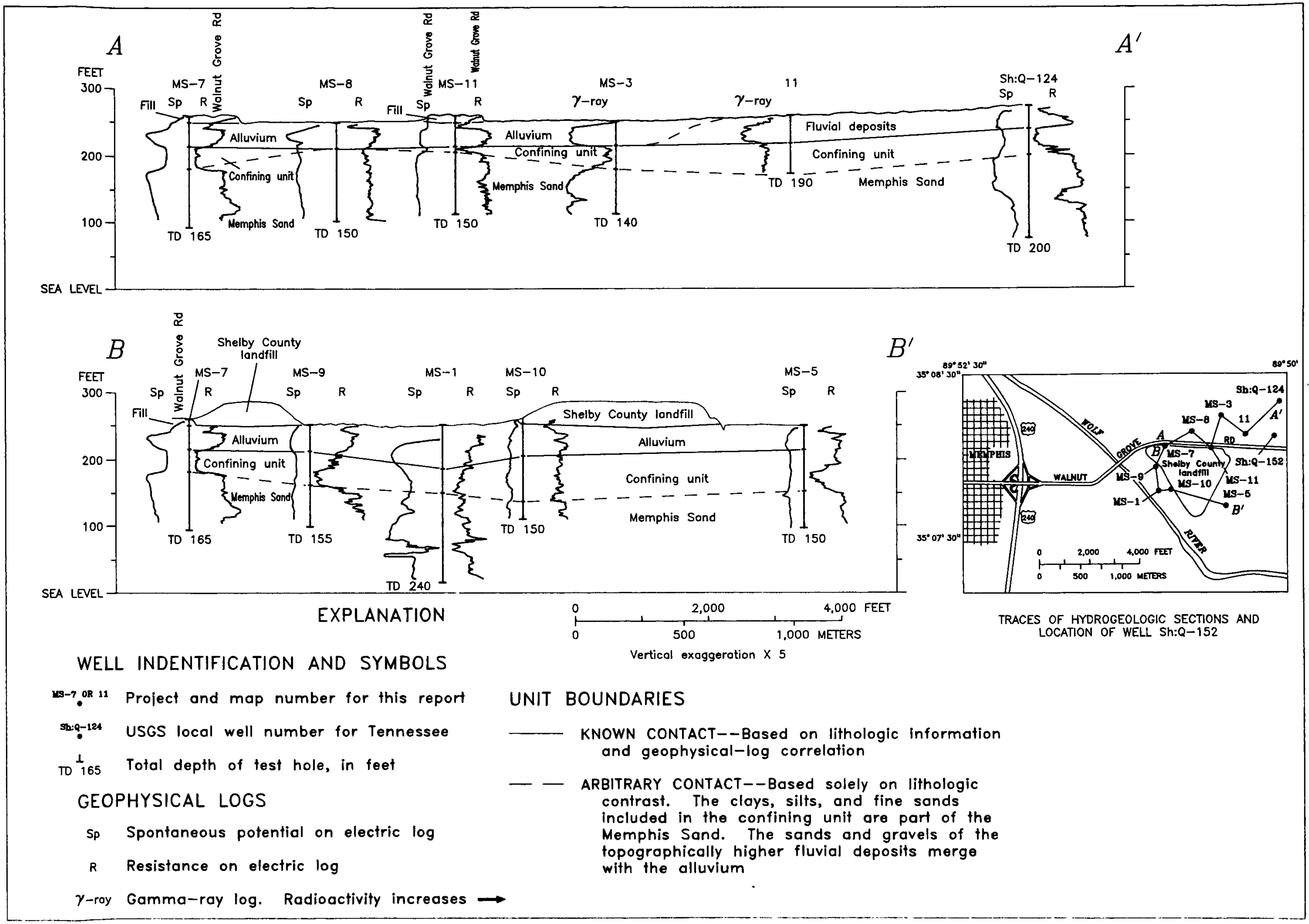


Figure 6.—Hydrogeologic sections through the area of the Shelby County landfill.

discussed previously. The main body of the Memphis Sand consists chiefly of a thick section of sand that includes subordinate lenses or beds of clay and silt at various horizons. Sands in the main body range from very fine to very coarse and also are interbedded and interlensed. Locally, the coarser sands in the main body of the Memphis Sand interfinger with finer sediments in the upper part and locally extend upward to the top of the Memphis Sand. The Memphis Sand at the Shelby County landfill is estimated to be about 725 feet thick, based on a map of the generalized thickness of the Memphis Sand in western Tennessee (Parks and Carmichael, 1990).

The geophysical log made in the test hole for well Sh:Q-152, located about 2,000 feet east-northeast of the landfill (fig. 6), indicated that the top of the main body of the Memphis Sand is at a depth of 80 feet below land surface or about 180 feet above sea level. This test hole was drilled to a depth of about 375 feet below land surface. Well Sh:Q-152, screened from 290 to 350 feet below land surface, was installed to supply water for a recreational lake formed as a result of the excavation of material to cap the landfill.

Based on the map for western Tennessee (Parks and Carmichael, 1990), the base of the Memphis Sand would be at an altitude of about 550 feet below sea level near the landfill. If so, the Memphis Sand would be about 730 feet thick at well Sh:Q-152, which is in agreement with the 725-foot thickness estimated from the map of Parks and Carmichael (1990). Thus, this information about thickness of the Memphis Sand, although generalized and open to verification, supports the idea that the clay beds underlying the alluvium north of the landfill may be the Cook Mountain Formation. In well Sh:Q-152, the Cook Mountain would be about 34 feet thick (46 to 80 feet in depth below land surface).

Water-level measurements were made in nine wells (fig. 7) in the Memphis aquifer in the area of the Shelby County landfill during October 1989 (table 3). From these measurements and estimates utilizing an earlier potentiometric map (Parks, 1990), a map was prepared that shows the altitude of the potentiometric surface of the Memphis aquifer in October 1989 (fig. 8).

The direction of ground-water flow in the area of the landfill is generally westward, based on an interpretation of this map (fig. 8). A comparison of the map showing the altitude of the alluvial aquifer water table (fig. 5) with the altitude of the potentiometric surface in the Memphis aquifer (fig. 8) indicates a head difference favoring downward leakage from the alluvial aquifer or upper part of the confining unit to the Memphis aquifer. The altitude of the potentiometric surface of the Memphis aquifer (fig. 8) in the area of the Shelby County landfill also suggests that downward leakage from the alluvial aquifer to the Memphis aquifer has caused a "mounding" effect at the landfill, particularly at wells MS-7 and MS-12 (fig. 7). Water-levels in these wells seem to be anomalously high.

GROUND-WATER QUALITY

Water-quality samples were collected from 31 wells near the Shelby County landfill during October 1989 (*Appendix A*). Twenty-two of these wells (fig. 9; table 4) are screened in the alluvial aquifer or upper part of the confining unit, and 9 wells (fig. 10; table 4) are screened in the Memphis aquifer. These water samples were analyzed for major and trace inorganic constituents, nutrients, and synthetic organic compounds (volatiles and extractables). Analyses of the water from 14 wells in the alluvial aquifer or upper part of the confining unit, and 8 wells in the Memphis aquifer indicated that the ground water contained synthetic organic compounds or relatively high concentrations of trace inorganic constituents. These 22 wells were resampled during June and July 1990 (table 4) to verify the results of the first round of sampling and to obtain additional water-quality data for major inorganic constituents and nutrients.

In the discussion that follows (and in tables 9 and 10), reference is made to maximum contaminant level (MCL) in drinking water. The TDEC is the regulatory agency that determines these levels for the State of Tennessee (Tennessee Department of Health and Environment, 1988). The TDEC follows many of the MCL's established by the USEPA (U.S. Environmental Protection Agency, 1986). Therefore, for the discussion of trace inorganic constituents and synthetic organic compounds, reference is made to MCL's of both the Tennessee Department of Health and Environment (TDHE) and the USEPA.

Major Inorganic Constituents and Nutrients

Water-quality properties and concentrations of major inorganic constituents and nutrients were determined for samples from wells screened in the alluvial aquifer and upper part of the confining unit (table 5). A comparison of these water-quality data between the two sampling periods (October 1989, and June and July 1990) shows some variability. Concentrations of major inorganic constituents and nutrients typically vary by 5 to 20 percent between sampling periods.

Spatial differences in ground-water quality in the alluvial aquifer or upper part of the confining unit near the Shelby County landfill can be attributed to different sources of ground-water flowing through the landfill. Contributions to ground-water flow in this aquifer include recharge from precipitation and (to a lesser degree) inflow to the alluvial aquifer from the Wolf River.

For analysis of the ground-water quality in the alluvial aquifer or upper part of the confining unit, wells 4A and 7 (fig. 9) serve as background stations that are located in areas where ground-water flow (fig. 5) is toward the Shelby County landfill. The water-quality data for these wells do not indicate contamination from the landfill. Wells 2, 32, 33, and 34 (fig. 9) serve as upgradient stations prior to passage of ground water beneath the landfill. Wells 26, 27, 31, 38, 39, and 40 (fig. 9) serve as downgradient sampling stations for determination of ground-water quality after passage of ground water beneath the landfill. Other alluvial aquifer wells sampled during this investigation serve as wells to detect contamination emanating from the landfill. Bar graphs provide comparisons of major inorganic constituents and nutrients among background, upgradient, and downgradient wells (fig. 11).

The most significant effect on ground-water quality in the alluvial aquifer or upper part of the confining unit is shown by the water-quality data from wells 26 and 27 and (to a lesser degree) from wells 31, 38, 39, and 40 (fig. 9; table 5). Water from downgradient wells 26, 27, 31, 38, 39, and 40 has concentrations of total organic carbon, chloride, dissolved solids, iron, ammonia nitrogen, calcium, sodium, potassium, and iodide commonly 2 to 10 times higher than concentrations detected in water from background and upgradient wells (fig. 11). Samples having maximum concentrations of

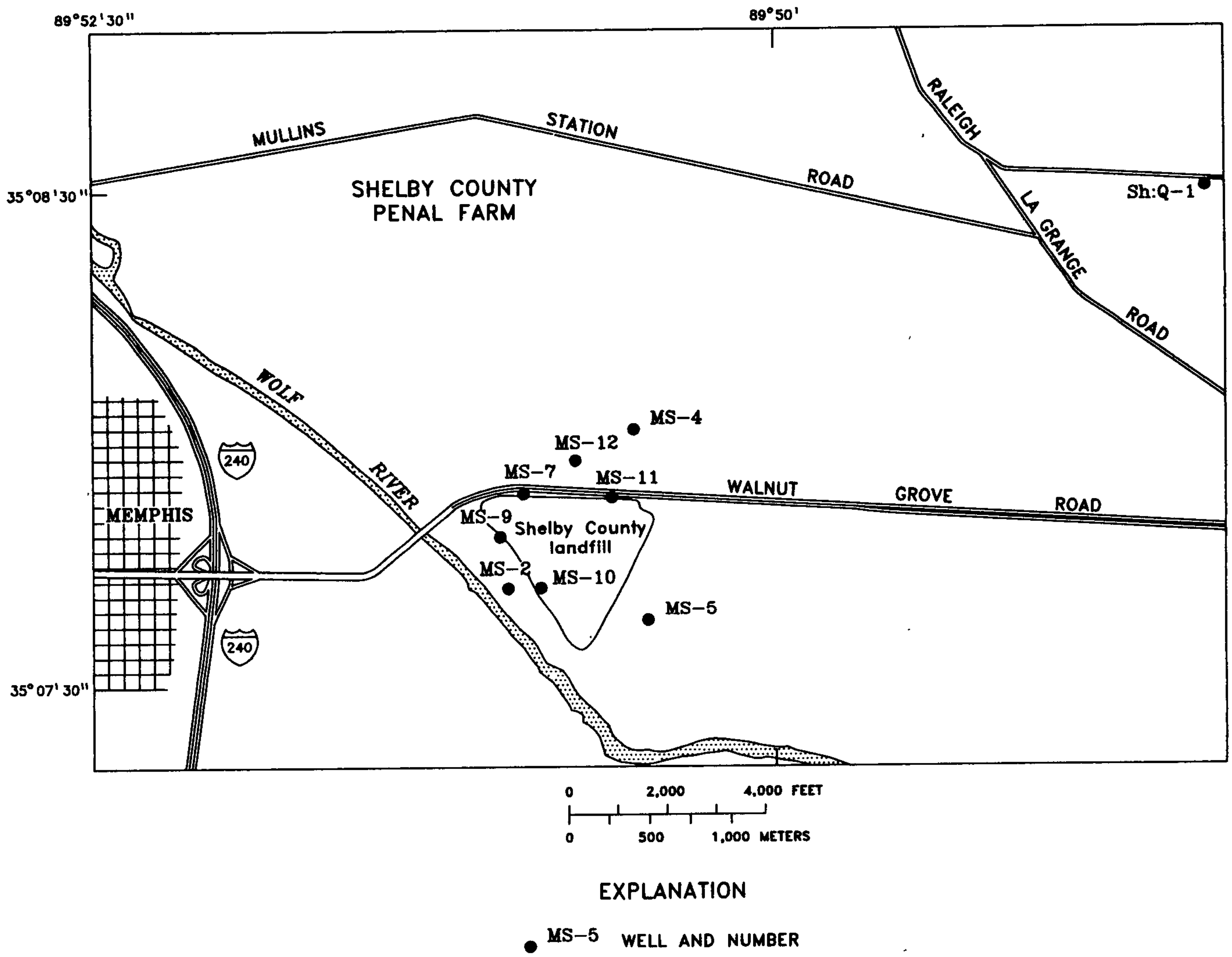
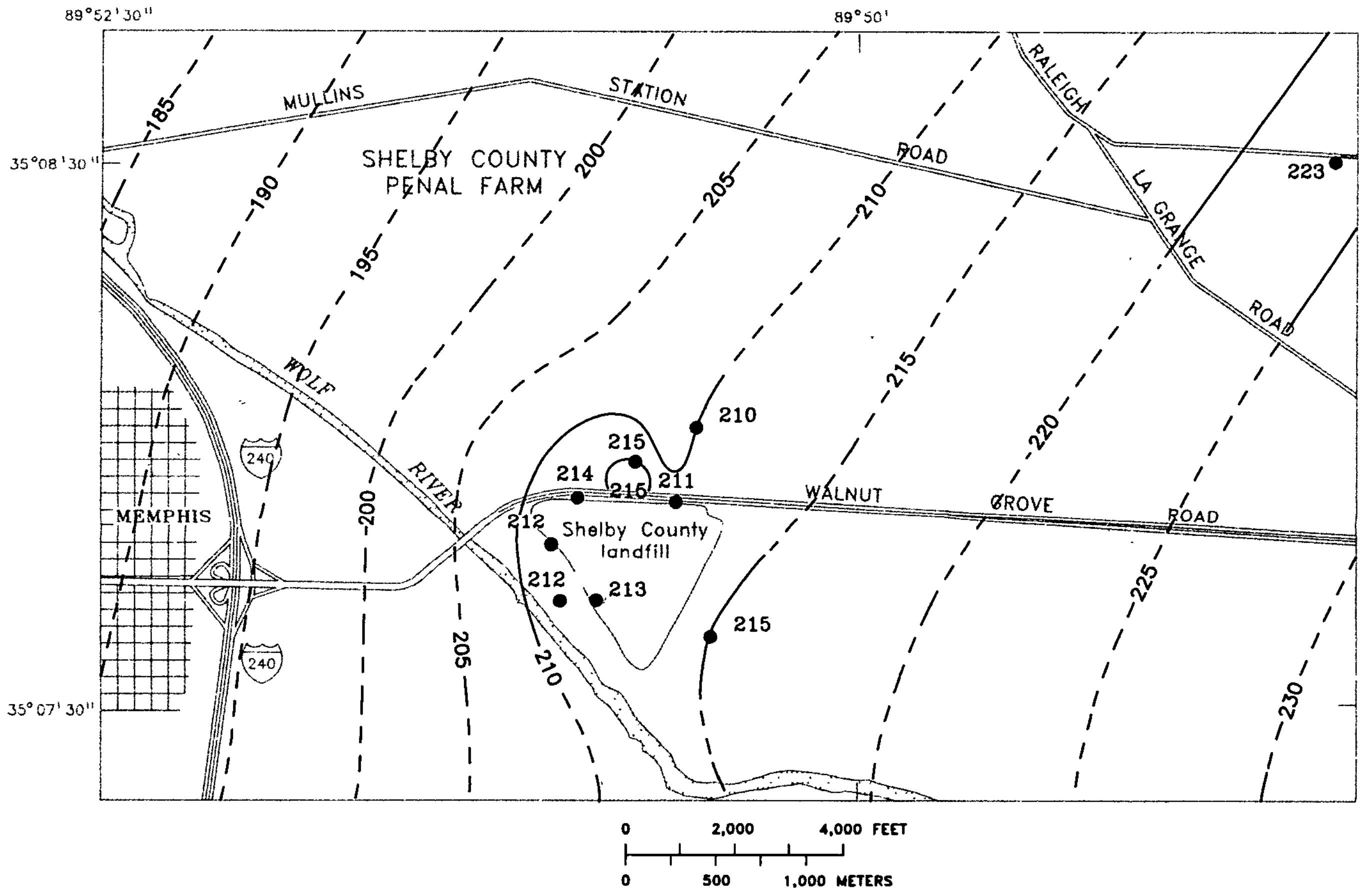


Figure 7.—Wells screened in the Memphis aquifer in which water levels were measured during October 1989.

these constituents at the Shelby County landfill (table 5) were all obtained from downgradient wells. These downgradient maxima exceed previously published maximum concentrations for chloride [12 milligrams per liter (mg/L)], total dissolved solids (652 mg/L), and iron [24,000 micrograms per liter (μg/L)] in samples from 11 wells screened in the alluvial aquifer in the Memphis area (Brahana and others, 1987, table 2).

The geochemical composition of leachate plumes from sanitary landfills have been characterized elsewhere. Borden and Yanoschak (1990) observed elevated total organic carbon and dissolved solids concentrations (among other constituents) in leachate from sanitary landfills in North Carolina. Increased iron, potassium, magnesium, sodium, chloride, and ammonia nitrogen concentrations were observed in sanitary landfill leachate flowing through sandy sediments (Nicholson and others, 1983; Domenico and Schwartz, 1990). Elevated concentrations of total organic carbon, total dissolved solids, and ammonia nitrogen can result from subsurface microbial oxidation of organic matter. High dissolved iron concentrations can result from reduction of ferric iron and subsequent dissolution of ferrous iron.

Total organic carbon, chloride, dissolved solids, iron, ammonia nitrogen, calcium, sodium, and iodide are the most likely tracers for the leachate plume emanating from the



EXPLANATION

——210— — POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Contour interval 5 feet. Datum is sea level. Dashed contours are modified from the map of the potentiometric surface of the Memphis aquifer, late summer-fall 1988, by Parks (1990)

● 210 WELL AND NUMBER IN WHICH WATER LEVEL WAS MEASURED

Figure 8.—Altitude of potentiometric surface of the Memphis aquifer in the area of the Shelby County landfill, October 1989.

Shelby County landfill. Other major inorganic constituents such as manganese, silica, fluoride, and bromide were examined to determine their suitability as geochemical tracers, but these constituents in samples from the alluvial aquifer or upper part of the confining unit showed no systematic variation between the wells within the plume and unaffected areas (fig. 11). In addition, maximum concentrations of silica (37 mg/L) and fluoride (0.7 mg/L) reported for samples from 11 wells screened in the alluvial aquifer in the Memphis area (Brahana and others, 1987, table 2) are greater than those values detected in samples from downgradient plume wells (table 5).

Nutrient (nitrite plus nitrate, phosphorous, phosphate, and sulfate) concentrations typically show variability of 20 percent between sampling periods (October 1989, and June and July 1990). No systematic variation was observed in concentrations of any nutrient among samples from background, upgradient, and downgradient plume wells screened in the alluvial aquifer or upper part of the confining unit (fig. 11). The highest concentration of nitrite plus nitrate observed in the alluvial aquifer or upper part of the confining unit (1.6 mg/L) is well below the nitrite plus nitrate concentration (44 mg/L) cited as a health risk (Hem, 1985). In addition, nitrite plus nitrate concentrations are well below

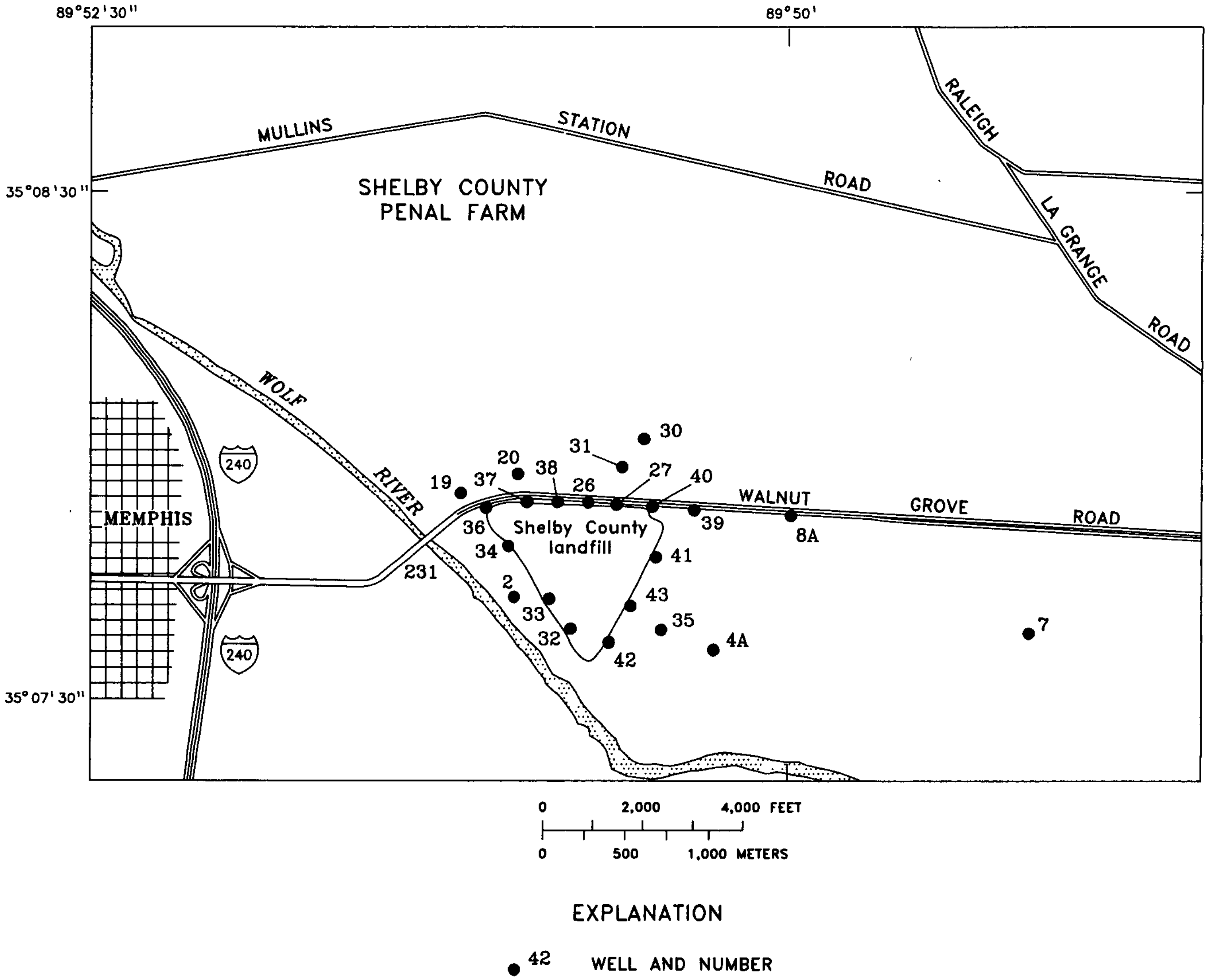


Figure 9.—Wells screened in the alluvial aquifer or upper part of the confining unit sampled for water quality during this investigation.

Table 4.— *Wells sampled for water-quality analysis near the Shelby County landfill*

[-- indicates that the well was not sampled in the summer 1990]

Well numbers		USGS	Hydrogeologic	Screened interval, in	Dates sampled	
Project and map	USGS local for Tennessee	site identification number	unit screened	feet below land surface	Fall 1989	Summer 1990
2	Sh:Q-96	350749089505806	Alluvial aquifer	43.3 - 48.3	10-14-89	--
4A	Sh:Q-98	350739089501701	Alluvial aquifer	47.5 - 52.5	10-16-89	--
7	Sh:Q-101	350741089490901	Alluvial aquifer	32.7 - 37.7	10-26-89	7-10-90
8A	Sh:Q-102	350803089495901	Alluvial aquifer	48.7 - 53.7	10-15-89	--
19	Sh:Q-112	350807089511101	Alluvial aquifer	39.4 - 44.4	10-17-89	--
20	Sh:Q-113	350812089505901	Alluvial aquifer	38.2 - 43.2	10-20-89	7-06-90
26	Sh:Q-119	350804089504101	Alluvial aquifer	60.1 - 65.1	10-20-89	7-13-90
27	Sh:Q-120	350804089503801	Alluvial aquifer	60.2 - 65.2	10-11-89	7-02-90
30	Sh:Q-128	350817089503504	Alluvial aquifer	33.7 - 38.7	10-27-89	6-26-90
31	Sh:Q-129	350810089503501	Alluvial aquifer	34 - 39	10-30-89	6-25-90
32	Sh:Q-132	350743089504801	Alluvial aquifer	43.5 - 48.5	10-12-89	--
33	Sh:Q-133	350749089505301	Alluvial aquifer	42.0 - 47.0	10-13-89	6-27-90
34	Sh:Q-134	350758089510101	Alluvial aquifer	33.5 - 38.5	10-13-89	6-28-90
35	Sh:Q-135	350742089502901	Confining unit	35.9 - 40.9	10-15-89	--
36	Sh:Q-136	350805089510601	Alluvial aquifer	43.4 - 48.4	10-19-89	--
37	Sh:Q-137	350806089505601	Confining unit	58.8 - 63.8	10-30-89	7-13-90
38	Sh:Q-138	350805089504901	Confining unit	58.8 - 63.8	10-19-89	7-03-90
39	Sh:Q-139	350804089502101	Confining unit	62.3 - 67.3	10-11-89	7-11-90
40	Sh:Q-140	350804089503001	Confining unit	60.1 - 65.1	10-19-89	7-11-90
41	Sh:Q-141	350755089502901	Confining unit	61.9 - 66.9	10-10-89	--
42	Sh:Q-142	350738089504001	Alluvial aquifer	36.7 - 41.7	10-14-89	6-29-90
43	Sh:Q-143	350746089503501	Alluvial aquifer	51.5 - 56.5	10-12-89	7-05-90
None	Sh:Q-88	350733089482501	Memphis aquifer	215 - 295	10-26-89	7-10-90
MS-2	Sh:Q-92	350749089505802	Memphis aquifer	150 - 180	10-14-89	7-09-90
MS-4	Sh:Q-126	350817089503502	Memphis aquifer	68.7 - 97.7	10-16-89	--
MS-5	Sh:Q-144	350742089502902	Memphis aquifer	110 - 130	10-15-89	6-29-90
MS-7	Sh:Q-146	350806089505602	Memphis aquifer	88.5 - 99.5	10-18-89	7-06-90
MS-9	Sh:Q-148	350758089510102	Memphis aquifer	97.5 - 117.5	10-13-89	6-28-90
MS-10	Sh:Q-149	350749089505302	Memphis aquifer	127.5 - 147.5	10-13-89	6-27-90
MS-11	Sh:Q-150	350804089503701	Memphis aquifer	107.5 - 127.5	10-11-89	7-02-90
MS-12	Sh:Q-151	350810489504702	Memphis aquifer	67.5 - 87.5	10-27-89	6-26-90

the drinking water MCL for nitrate of 10.0 mg/L (Tennessee Department of Health and Environment, 1988; U.S. Environmental Protection Agency, 1986).

Sulfate concentrations in the alluvial aquifer or upper part of the confining unit near the Shelby County landfill commonly exceed the maximum concentration of 33 mg/L reported previously for samples from 11 wells screened in the alluvial aquifer in the Memphis area (Brahana and others, 1987, table 2). However, maximum sulfate concentrations (ranging from 60 to 170 mg/L) in wells 7, 8A, 20, 30, and 35 near the landfill are not associated with the leachate plume; instead, these wells with high sulfate concentrations are located in open fields in agricultural areas away from the landfill. Elevated sulfate concentrations are typically associated with surface and ground water in regions receiving acidic precipitation, or water affected by biological activity (Hem, 1985; Drever, 1988). High sulfate concentrations near Shelby County landfill cannot be attributed solely to leachate contamination.

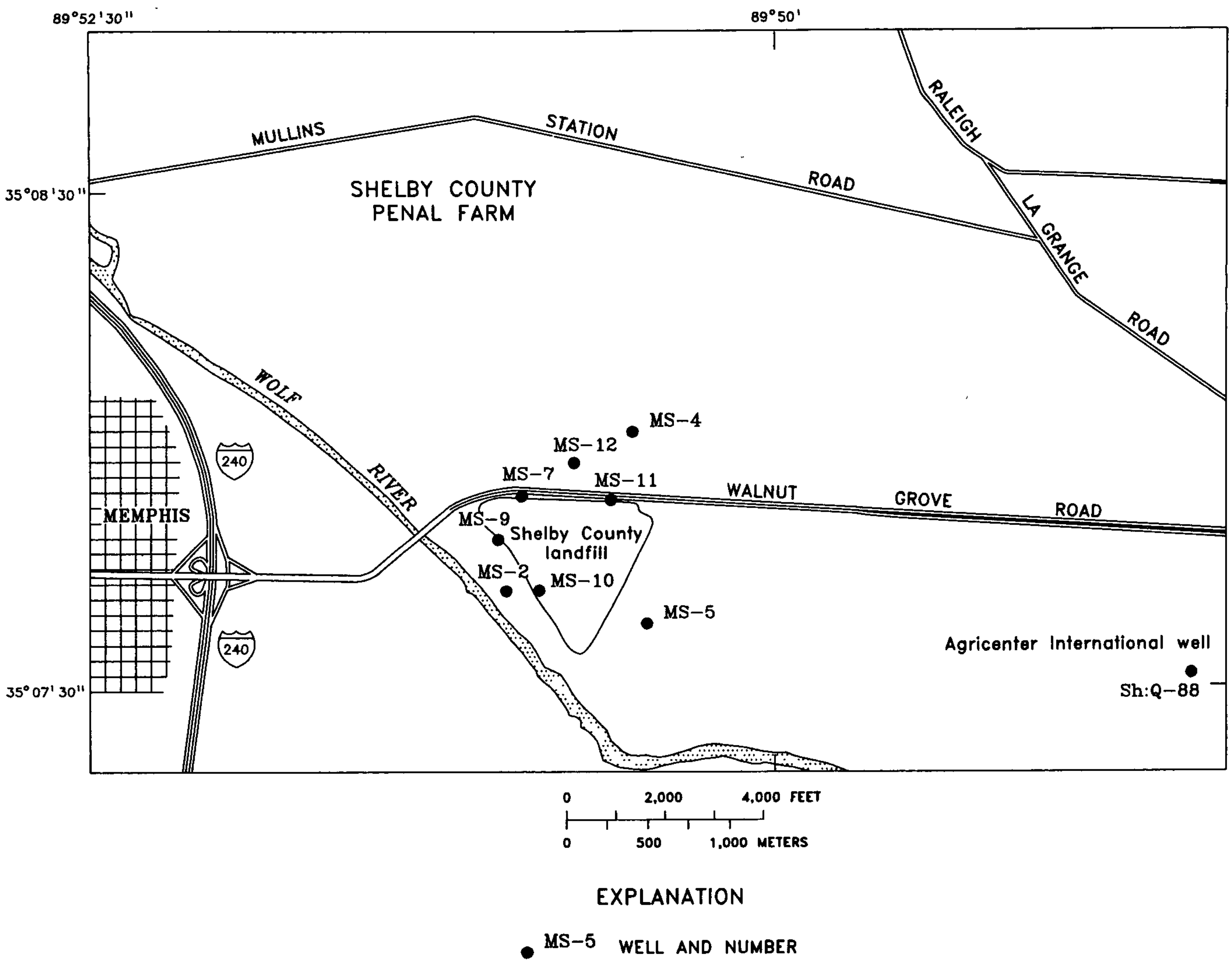


Figure 10.—Wells screened in the Memphis aquifer sampled for water quality during this investigation.

Water-quality properties and concentrations of major inorganic constituents and nutrients were determined for samples from wells screened in the Memphis aquifer (table 6). A comparison of these water-quality data between the two sampling periods (October 1989, and June and July 1990) shows that the variability was commonly less than 10 percent for all constituents except for concentrations of total organic carbon, ammonia nitrogen, iron, and manganese, which vary 25 percent or more (table 6). Variations in water quality for samples from wells screened in the Memphis aquifer can result from downward leakage of ground water from the overlying alluvial aquifer to the Memphis aquifer where the confining unit is thin or absent.

For analysis of the ground-water quality data for the Memphis aquifer, wells Sh:Q-88, MS-4, and MS-5 (fig. 10) serve as background stations that are located in areas where ground water in the Memphis aquifer flows toward or past the Shelby County landfill (fig. 8). Wells MS-2, MS-9, and MS-10 serve as downgradient stations that are on the west side of the landfill in the direction of ground-water flow in the Memphis aquifer (fig. 5). Wells MS-7, MS-11, and MS-12 serve as leachate plume stations that are located in the general area where contaminants have been detected in the alluvial aquifer or upper part of the confining unit. Bar graphs provide comparisons of major inorganic constituents and nutrients in background, downgradient, and leachate plume wells (fig. 12).

Dissolved solids, calcium, sodium, and possibly ammonia nitrogen and chloride concentrations are elevated significantly in samples from Memphis aquifer plume wells MS-7, MS-11, MS-12 when compared to background and downgradient wells (fig. 12). Maximum concentrations of

Table 5.--*Water-quality properties and concentrations of nutrients, major inorganic constituents, and trace inorganic constituents in samples from wells screened in the alluvial aquifer or upper part of the confining unit near the Shelby County landfill*

[MG/L, milligrams per liter; UG/L, micrograms per liter; DEG C, degrees Celsius; US/CM, microsiemens per centimeter. Values given as < (less than) indicate that the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, indicate no data]

WELL NUMBERS: PROJECT AND MAP	WELL NUMBERS: USGS LOCAL FOR TENNESSEE	DATE	TEMPERATURE WATER (DEG C)	COLOR (PLATINUM COBALT UNITS)	PH (STANDARD UNITS)	SPECIFIC CONDUCTANCE (US/CM)	SOLIDS RESIDUE AT 180 DEG C DISSOLVED (MG/L)	CARBON, TOTAL ORGANIC (MG/L AS C)	NITROGEN, ORGANIC TOTAL (MG/L AS N)	NITROGEN, AMMONIA TOTAL (MG/L AS N)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N)
02	Sh:Q-096	10-14-89	17.0	1	6.5	90	43	1.5	0.08	0.32	< 0.010	< 0.100
4A	Sh:Q-098	10-16-89	16.0	8	5.9	245	132	2.2	0.07	0.23	0.010	< 0.100
07	Sh:Q-101	10-26-89	18.0	< 1	5.3	446	308	1.0	--	0.06	< 0.010	1.00
		07-10-90	17.5	< 1	5.2	339	224	1.2	0.15	0.15	< 0.010	0.300
8A	Sh:Q-102	10-15-89	19.0	2	6.1	564	362	0.5	--	< 0.01	< 0.010	1.60
19	Sh:Q-112	10-17-89	15.5	2	6.3	120	65	1.1	--	0.07	0.020	< 0.100
20	Sh:Q-113	10-20-89	17.0	5	5.4	222	147	1.2	0.31	0.09	0.010	< 0.100
		07-06-90	17.5	< 1	5.4	235	149	1.1	0.11	0.09	< 0.010	< 0.100
26	Sh:Q-119	10-20-89	19.0	28	6.3	957	485	13	5.0	25	0.040	< 0.100
		07-13-90	20.0	7	6.3	1,020	488	11	18.7	2.3	< 0.010	< 0.100
27	Sh:Q-120	10-11-89	19.5	17	6.5	1,030	663	15	7.0	32	0.030	< 0.100
		07-02-90	20.0	25	6.4	1,380	652	15	27.0	3.0	< 0.010	< 0.100
30	Sh:Q-128	10-27-89	19.0	10	6.7	435	274	3.8	0.64	0.36	0.020	1.20
		06-26-90	26.0	3	6.1	610	376	0.5	0.28	0.12	< 0.010	1.30
31	Sh:Q-129	10-30-89	19.5	7	6.8	740	485	2.3	0.47	0.23	< 0.010	< 0.100
		06-25-90	27.0	3	6.0	685	400	1.2	0.42	0.18	< 0.010	< 0.100
32	Sh:Q-132	10-12-89	17.0	30	6.3	91	41	1.3	0.19	0.41	< 0.010	< 0.100
33	Sh:Q-133	10-13-89	16.0	20	5.8	117	83	3.0	0.08	0.52	< 0.010	< 0.100
		06-27-90	16.5	75	5.8	93	230	2.7	0.06	0.44	0.030	< 0.100
34	Sh:Q-134	10-13-89	16.5	50	5.8	188	112	2.3	0.06	0.64	< 0.010	< 0.100
		06-28-90	16.0	130	5.8	102	73	2.9	0.00	0.51	0.010	< 0.100
35	Sh:Q-135	10-15-89	17.0	3	5.7	226	145	1.1	0.11	0.09	< 0.010	< 0.100
36	Sh:Q-136	10-19-89	15.5	20	6.1	145	52	1.4	0.00	0.21	0.030	< 0.100
37	Sh:Q-137	10-30-89	20.5	250	8.2	176	110	20	1.0	0.76	0.480	< 0.100
		07-13-90	22.0	110	6.8	132	84	4.7	0.32	0.08	0.060	< 0.100
38	Sh:Q-138	10-19-89	18.0	15	6.1	530	295	4.4	1.2	7.3	0.020	< 0.100
		07-03-90	20.5	7	6.1	574	247	5.0	5.9	0.09	< 0.010	< 0.100
39	Sh:Q-139	10-11-89	18.5	50	6.2	480	222	2.2	0.00	1.4	0.010	< 0.100
		07-11-90	19.0	5	6.4	880	400	3.6	0.10	1.2	< 0.010	< 0.100
40	Sh:Q-140	10-19-89	16.0	15	6.4	783	507	7.0	6.1	7.9	0.040	< 0.100
		07-11-90	23.5	5	6.4	925	473	6.4	1.0	11	< 0.010	0.100
41	Sh:Q-141	10-10-89	19.0	2	6.5	192	105	0.7	--	0.03	0.010	< 0.100
42	Sh:Q-142	10-14-89	16.0	35	5.7	169	89	3.7	0.25	0.75	0.030	< 0.100
		06-29-90	16.0	13	5.8	175	103	5.3	0.30	0.90	0.030	< 0.100
43	Sh:Q-143	10-12-89	17.5	18	5.8	336	157	2.7	0.18	0.52	0.020	< 0.100
		07-05-90	17.5	2	5.8	346	161	2.0	0.15	0.45	< 0.010	< 0.100

Table 5.--*Water-quality properties and concentrations of nutrients, major inorganic constituents, and trace inorganic constituents in samples from wells screened in the alluvial aquifer or upper part of the confining unit near the Shelby County landfill*--Continued

[MG/L, milligrams per liter; UG/L, micrograms per liter; DEG C, degrees Celsius; US/CM, microsiemens per centimeter. Values given as < (less than) indicate that the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, indicate no data]

WELL NUMBERS: PROJECT AND MAP	WELL NUMBERS: USGS LOCAL FOR TENNESSEE	DATE	PHOSPHORUS TOTAL (MG/L AS P)	PHOSPHATE TOTAL (MG/L AS PO4)	SULFATE, DISSOLVED (MG/L AS SO4)	ALUMINUM, DISSOLVED (UG/L AS AL)	LITHIUM, DISSOLVED (UG/L AS LI)	SELENIUM, DISSOLVED (UG/L AS SE)	FLUORIDE, DISSOLVED (MG/L AS F)	IODIDE, DISSOLVED (MG/L AS I)	BROMIDE, DISSOLVED (MG/L AS BR)
02	Sh:Q-096	10-14-89	0.020	--	3.0	< 10	< 4	< 1	0.10	0.013	0.010
4A	Sh:Q-098	10-16-89	0.080	0.21	72	40	9	< 1	< 0.10	0.005	0.030
07	Sh:Q-101	10-26-89	0.010	--	170	< 10	7	< 1	< 0.10	0.014	0.090
		07-10-90	0.010	--	110	< 10	9	< 1	0.40	0.014	0.080
8A	Sh:Q-102	10-15-89	0.020	0.03	63	< 10	5	6	0.10	0.004	0.830
19	Sh:Q-112	10-17-89	0.070	0.25	3.0	< 10	< 4	< 1	0.10	0.008	< 0.010
20	Sh:Q-113	10-20-89	0.020	0.06	51	10	< 4	< 1	< 0.10	0.016	< 0.010
		07-06-90	< 0.010	--	60	20	< 4	< 1	< 0.10	0.017	0.020
26	Sh:Q-119	10-20-89	0.050	0.15	< 1	10	< 4	< 1	0.20	0.220	0.250
		07-13-90	0.040	--	< 1	< 10	4	< 1	< 0.10	0.200	0.250
27	Sh:Q-120	10-11-89	< 0.010	0.09	4.0	< 10	9	< 1	0.20	0.240	0.260
		07-02-90	< 0.010	--	2.0	< 10	< 4	< 1	< 0.10	0.077	0.600
30	Sh:Q-128	10-27-89	0.110	0.18	88	< 10	< 4	17	0.20	0.012	0.060
		06-26-90	0.050	--	170	< 10	< 4	20	0.20	0.006	0.040
31	Sh:Q-129	10-30-89	0.040	0.03	54	< 10	5	< 1	0.10	0.100	0.060
		06-25-90	< 0.010	--	40	< 10	5	< 1	0.20	0.120	0.050
32	Sh:Q-132	10-12-89	0.030	0.15	2.0	< 10	< 4	< 1	0.20	0.011	0.010
33	Sh:Q-133	10-13-89	0.210	0.43	9.0	< 10	< 4	< 1	0.10	0.013	0.020
		06-27-90	0.200	0.61	4.2	50	5	< 1	< 0.10	< 0.001	0.100
34	Sh:Q-134	10-13-89	0.160	0.12	2.0	< 10	< 4	< 1	0.10	0.030	< 0.010
		06-28-90	0.160	0.25	3.8	40	5	< 1	< 0.10	0.004	0.030
35	Sh:Q-135	10-15-89	0.020	0.06	60	10	4	< 1	0.10	0.004	0.030
36	Sh:Q-136	10-19-89	0.110	0.43	< 1	20	< 4	< 1	0.10	0.023	0.020
37	Sh:Q-137	10-30-89	0.370	3.37	6.0	470	< 4	< 1	0.70	0.005	0.160
		07-13-90	0.050	--	3.4	20	5	< 1	0.20	0.012	0.040
38	Sh:Q-138	10-19-89	0.040	0.06	< 1	20	< 4	< 1	0.10	0.064	0.160
		07-03-90	0.030	--	1.1	140	< 4	< 1	0.30	0.029	0.170
39	Sh:Q-139	10-11-89	< 0.010	--	22	< 10	< 4	< 1	0.20	0.070	< 0.010
		07-11-90	< 0.010	--	35	< 10	< 4	< 3	0.20	0.075	0.080
40	Sh:Q-140	10-19-89	0.050	0.18	19	10	< 4	< 1	0.20	0.320	0.300
		07-11-90	0.040	--	19	< 10	< 4	< 1	< 0.10	0.270	0.210
41	Sh:Q-141	10-10-89	< 0.010	0.12	36	< 10	< 4	< 1	0.10	0.007	0.010
42	Sh:Q-142	10-14-89	0.290	0.98	16	30	< 4	< 1	0.10	0.012	0.020
		06-29-90	0.290	--	9.7	30	< 4	< 1	0.20	0.013	0.050
43	Sh:Q-143	10-12-89	0.010	0.09	31	< 10	< 4	< 1	0.20	0.063	0.020
		07-05-90	0.010	--	47	< 10	< 4	< 1	< 0.10	0.021	0.040

Table 5.--*Water-quality properties and concentrations of nutrients, major inorganic constituents, and trace inorganic constituents in samples from wells screened in the alluvial aquifer or upper part of the confining unit near the Shelby County landfill*--Continued

[MG/L, milligrams per liter; UG/L, micrograms per liter; DEG C, degrees Celsius; US/CM, microsiemens per centimeter. Values given as < (less than) indicate that the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, indicate no data]

WELL NUMBERS: PROJECT AND MAP	WELL NUMBERS: USGS LOCAL FOR TENNESSEE	DATE	ARSENIC, DISSOLVED (UG/L AS AS)	BERYLLIUM, DISSOLVED (UG/L AS BE)	SILICA, DISSOLVED (MG/L AS SIO2)	HARDNESS, TOTAL (MG/L AS CACO3)	ALKALINITY, LAB (MG/L AS CACO3)	CALCIUM, DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)
2	Sh:Q-096	10-14-89	15	< 0.5	9.8	22	28	6.3	1.4	3.5	2.6
4A	Sh:Q-098	10-16-89	< 1	< 0.5	20	74	19	19	6.4	4.6	1.9
07	Sh:Q-101	10-26-89	< 1	< 0.5	22	170	23	41	16	23	2.0
		07-10-90	< 1	< 0.5	21	110	20	27	10	18	1.8
8A	Sh:Q-102	10-15-89	< 1	< 0.5	20	140	82	33	15	67	2.0
19	Sh:Q-112	10-17-89	< 1	< 0.5	12	40	46	9.2	4.2	5.3	1.4
20	Sh:Q-113	10-20-89	< 1	< 0.5	18	76	42	19	6.8	11	1.3
		07-06-90	< 1	< 0.5	19	67	38	15	7.2	12	1.4
26	Sh:Q-119	10-20-89	< 1	< 0.5	14	280	436	75	23	54	27
		07-13-90	< 1	< 0.5	14	250	271	67	20	45	23
27	Sh:Q-120	10-11-89	< 1	< 2.0	16	380	563	110	25	72	39
		07-02-90	< 1	0.5	14	320	341	88	23	67	36
30	Sh:Q-128	10-27-89	7	< 0.5	22	130	136	31	13	48	1.5
		06-26-90	3	< 0.5	21	180	92	43	18	41	1.4
31	Sh:Q-129	10-30-89	1	< 0.5	22	210	385	56	16	110	3.6
		06-25-90	1	< 0.5	21	190	301	49	16	74	2.8
32	Sh:Q-132	10-12-89	< 1	< 0.5	12	26	32	6.4	2.3	3.6	1.5
33	Sh:Q-133	10-13-89	< 1	< 0.5	18	31	31	7.6	2.8	4.6	1.4
		06-27-90	< 1	< 0.5	17	22	24	5.4	2.1	4.5	1.0
34	Sh:Q-134	10-13-89	< 1	< 0.5	15	57	70	14	5.4	7.4	1.9
		06-28-90	< 1	< 0.5	15	28	31	6.8	2.6	3.9	1.1
35	Sh:Q-135	10-15-89	< 1	< 0.5	19	86	43	21	8.1	7.2	5.0
36	Sh:Q-136	10-19-89	1	< 0.5	14	42	48	9.8	4.2	5.1	1.6
37	Sh:Q-137	10-30-89	< 1	< 0.5	14	57	87	17	3.4	18	2.5
		07-13-90	< 1	< 0.5	14	33	54	9.1	2.5	10	5.1
38	Sh:Q-138	10-19-89	< 1	< 0.5	15	130	188	34	12	30	6.8
		07-03-90	< 1	< 0.5	14	130	172	34	12	26	6.5
39	Sh:Q-139	10-11-89	< 1	< 0.5	18	140	163	35	13	21	5.1
		07-11-90	1	< 0.5	16	160	177	42	13	24	4.3
40	Sh:Q-140	10-19-89	6	< 0.5	14	280	259	66	27	54	10
		07-11-90	10	< 0.5	14	270	350	65	26	51	10
41	Sh:Q-141	10-10-89	< 1	< 0.5	10	83	51	21	7.4	4.3	0.6
42	Sh:Q-142	10-14-89	1	< 0.5	19	36	32	9.2	3.1	4.4	2.6
		06-29-90	1	< 0.5	18	37	44	9.3	3.3	5.2	2.3
43	Sh:Q-143	10-12-89	< 1	< 0.5	17	120	100	30	11	7.0	2.1
		07-05-90	< 1	< 0.5	18	110	72	29	8.8	6.8	1.9

Table 5-*Water-quality properties and concentrations of nutrients, major inorganic constituents, and trace inorganic constituents in samples from wells screened in the alluvial aquifer or upper part of the confining unit near the Shelby County landfill*--Continued

[MG/L, milligrams per liter; UG/L, micrograms per liter; DEG C, degrees Celsius; US/CM, microsiemens per centimeter. Values given as < (less than) indicate that the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, indicate no data]

WELL NUMBERS: PROJECT AND MAP	WELL NUMBERS: USGS LOCAL FOR TENNESSEE	DATE	CHLORIDE, DISSOLVED (MG/L AS CL)	BARIUM, DISSOLVED (UG/L AS BA)	STRONTIUM, DISSOLVED (UG/L AS SR)	BORON, DISSOLVED (UG/L AS B)	VANADIUM, DISSOLVED (UG/L AS V)	ZINC, DISSOLVED (UG/L AS ZN)	CADMIUM, DISSOLVED (UG/L AS CD)	CHROMIUM, DISSOLVED (UG/L AS CR)	COPPER, DISSOLVED (UG/L AS CU)
02	Sh:Q-096	10-14-89	3.4	130	46	20	< 6	< 3	< 1.0	< 1	5
4A	Sh:Q-098	10-16-89	2.1	60	89	< 10	< 6	16	3.0	1	3
07	Sh:Q-101	10-26-89	11	40	110	< 10	< 6	5	< 1.0	< 1	2
		07-10-90	8.5	150	69	< 10	< 6	9	< 1.0	< 1	< 1
8A	Sh:Q-102	10-15-89	100	140	110	< 10	< 6	7	< 1.0	2	1
19	Sh:Q-112	10-17-89	3.5	77	87	< 10	< 6	7	< 1.0	< 1	1
20	Sh:Q-113	10-20-89	4.4	87	53	< 10	< 6	14	< 1.0	< 1	1
		07-06-90	6.2	330	59	< 10	< 6	26	2.0	2	1
26	Sh:Q-119	10-20-89	59	290	380	530	6	7	3.0	< 1	< 1
		07-13-90	52	1,400	330	430	13	< 3	11	< 1	< 1
27	Sh:Q-120	10-11-89	80	1,300	800	920	< 12	15	4.0	< 1	< 1
		07-02-90	74	340	740	880	< 6	< 3	4.0	< 1	1
30	Sh:Q-128	10-27-89	7.7	210	250	10	< 6	7	< 1.0	< 1	< 1
		06-26-90	9.8	170	220	10	< 6	22	< 1.0	< 1	< 1
31	Sh:Q-129	10-30-89	11	150	490	30	< 6	15	< 1.0	< 1	< 1
		06-25-90	< 0.10	30	430	20	< 6	28	< 1.0	< 1	< 1
32	Sh:Q-132	10-12-89	2.6	59	26	10	< 6	< 3	< 1.0	< 1	< 1
33	Sh:Q-133	10-13-89	3.4	47	46	< 10	< 6	9	< 1.0	< 1	< 1
		06-27-90	110	140	32	20	< 6	3	2.0	1	1
34	Sh:Q-134	10-13-89	4.5	66	96	20	< 6	< 3	< 1.0	1	2
			0.50	83	43	20	< 6	4	2.0	1	1
35	Sh:Q-135	10-15-89	3.2	180	75	< 10	< 6	13	< 1.0	2	6
36	Sh:Q-136	10-19-89	4.1	310	97	< 10	< 6	11	< 1.0	< 1	1
37	Sh:Q-137	10-30-89	3.8	48	100	60	< 6	11	< 1.0	2	2
		07-13-90	6.6	210	54	20	< 6	4	< 1.0	< 1	1
38	Sh:Q-138	10-19-89	29	200	120	440	9	< 3	4.0	< 1	< 1
		07-03-90	30	230	120	440	< 6	4	4.0	< 1	< 1
39	Sh:Q-139	10-11-89	12	280	180	20	< 6	6	4.0	< 1	1
		07-11-90	14	270	250	30	45	< 3	32	< 1	< 1
40	Sh:Q-140	10-19-89	60	240	260	310	< 6	6	1.0	< 1	< 1
		07-11-90	54	23	250	320	10	11	9.0	< 1	< 1
41	Sh:Q-141	10-10-89	2.1	100	44	10	< 6	14	1.0	< 1	< 1
42	Sh:Q-142	10-14-89	3.7	100	56	20	< 6	9	1.0	1	2
		06-29-90	6.2	94	57	20	< 6	7	4.0	< 1	< 1
43	Sh:Q-143	10-12-89	6.2	87	100	20	< 6	< 3	< 1.0	< 1	< 1
		07-05-90	7.9		95	20	7	7	6.0	1	1

Table 5-*Water-quality properties and concentrations of nutrients, major inorganic constituents, and trace inorganic constituents in samples from wells screened in the alluvial aquifer or upper part of the confining unit near the Shelby County landfill*--Continued

[MG/L, milligrams per liter; UG/L, micrograms per liter; DEG C, degrees Celsius; US/CM, microsiemens per centimeter. Values given as < (less than) indicate that the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, indicate no data]

WELL NUMBERS: PROJECT AND MAP	WELL NUMBERS: USGS LOCAL FOR TENNESSEE	DATE	IRON, DISSOLVED (UG/L AS FE)	MANGANESE, DISSOLVED (UG/L AS MN)	LEAD, DISSOLVED (UG/L AS PB)	MERCURY, DISSOLVED (UG/L AS HG)	MOLYBDENUM, DISSOLVED (UG/L AS MO)	NICKEL, DISSOLVED (UG/L AS NI)	SILVER, DISSOLVED (UG/L AS AG)
02	Sh:Q-096	10-14-89	5,100	520	< 1	< 0.1	< 10	6	< 1.0
4A	Sh:Q-098	10-16-89	20,000	2,800	1	0.4	< 10	23	< 1.0
07	Sh:Q-101	10-26-89	33	59	< 1	< 0.1	< 10	5	< 1.0
		07-10-90	22	310	1	0.1	< 10	2	< 1.0
8A	Sh:Q-102	10-15-89	10	1	< 1	< 0.1	< 10	2	< 1.0
19	Sh:Q-112	10-17-89	5,400	220	< 1	< 0.1	10	1	< 1.0
20	Sh:Q-113	10-20-89	2,100	130	< 1	< 0.1	< 10	13	< 1.0
		07-06-90	2,400	190	< 1	< 0.1	< 10	16	< 1.0
26	Sh:Q-119	10-20-89	52,000	1,000	< 1	< 0.1	< 10	6	< 1.0
		07-13-90	50,000	1,300	< 1	< 0.1	< 10	8	< 1.0
27	Sh:Q-120	10-11-89	61,000	1,900	< 1	< 0.1	< 20	17	< 1.0
		07-02-90	56,000	1,600	< 1	0.4	< 10	15	< 1.0
30	Sh:Q-128	10-27-89	5,600	7,900	< 1	< 0.1	< 10	15	< 1.0
		06-26-90	3,600	5,800	< 1	< 0.1	< 10	12	< 1.0
31	Sh:Q-129	10-30-89	1,000	1,600	< 1	< 0.1	< 10	16	< 1.0
		06-25-90	780	1,500	< 1	< 0.1	< 10	5	< 1.0
32	Sh:Q-132	10-12-89	3,800	730	< 1	< 0.1	< 10	1	< 1.0
33	Sh:Q-133	10-13-89	8,200	1,100	< 1	< 0.1	< 10	< 1	< 1.0
		06-27-90	5,400	750	< 1	< 0.1	< 10	< 1	< 1.0
34	Sh:Q-134	10-13-89	16,000	2,200	< 1	< 0.1	< 10	13	< 1.0
			5,900	1,000	< 1	< 0.1	< 10	1	< 1.0
35	Sh:Q-135	10-15-89	1,400	590	1	< 0.1	10	3	< 1.0
36	Sh:Q-136	10-19-89	7,800	260	< 1	< 0.1	< 10	1	< 1.0
37	Sh:Q-137	10-30-89	360	65	1	< 0.1	< 10	4	< 1.0
		07-13-90	34	40	< 1	< 0.1	< 10	2	< 1.0
38	Sh:Q-138	10-19-89	48,000	1,300	< 1	< 0.1	< 10	5	< 1.0
		07-03-90	46,000	1,300	< 1	< 0.1	< 10	3	< 1.0
39	Sh:Q-139	10-11-89	50,000	3,900	< 1	< 0.1	< 10	9	< 1.0
		07-11-90	160,000	9,000	< 1	< 0.1	< 10	15	< 1.0
40	Sh:Q-140	10-19-89	41,000	940	< 1	< 0.1	< 10	19	< 1.0
		07-11-90	37,000	830	< 1	< 0.1	< 10	7	< 1.0
41	Sh:Q-141	10-10-89	370	620	< 1	< 0.1	20	1	< 1.0
42	Sh:Q-142	10-14-89	16,000	1,500	1	< 0.1	< 10	5	< 1.0
		06-29-90	20,000	1,900	< 1	< 0.1	< 10	3	< 1.0
43	Sh:Q-143	10-12-89	26,000	2,200	< 1	< 0.1	< 10	11	< 1.0
		07-05-90	31,000	2,100	< 1	< 0.1	< 10	11	< 1.0

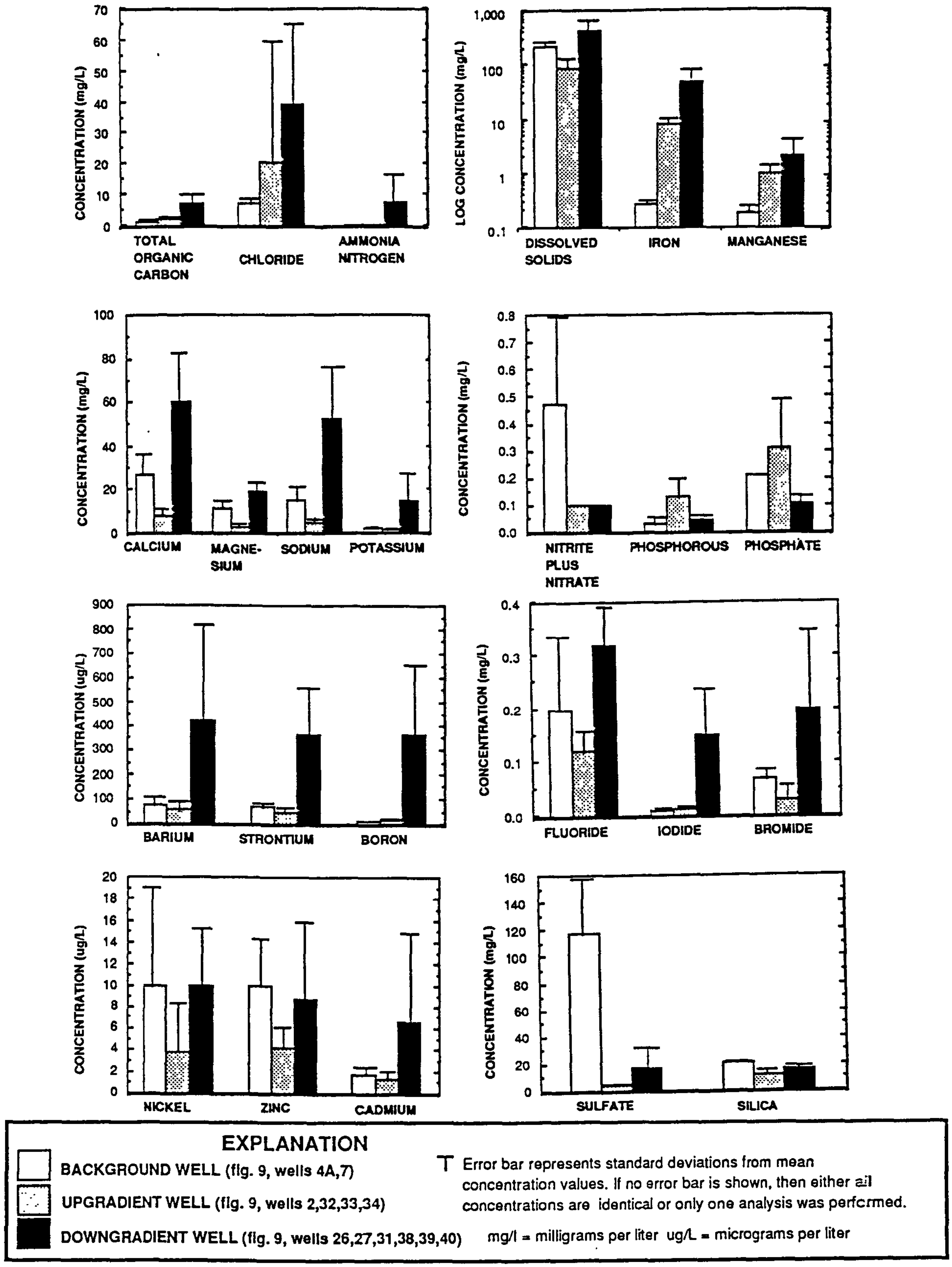


Figure 11.—Mean values of concentrations of selected major and trace inorganic constituents and nutrients in samples from background, upgradient, and downgradient wells screened in the alluvial aquifer or upper part of the confining unit near the Shelby County landfill.

Table 6.--*Water-quality properties and concentrations of nutrients, major inorganic constituents, and trace inorganic constituents in samples from wells screened in the Memphis aquifer near the Shelby County landfill*

[MG/L, milligrams per liter; UG/L, micrograms per liter; DEG C, degrees Celsius; US/CM, microsiemens per centimeter. Values given as < (less than) indicate that the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, indicate no data]

WELL NUMBERS: PROJECT AND MAP	WELL NUMBERS: USGS LOCAL FOR TENNESSEE	DATE	TEMPERATURE WATER (DEG C)	COLOR (PLATINUM COBALT UNITS)	PH (STANDARD UNITS)	SPECIFIC CONDUCTANCE (US/CM)	SOLIDS RESIDUE AT 180 DEG C DISSOLVED (MG/L)	CARBON, ORGANIC TOTAL (MG/L AS C)	NITROGEN, ORGANIC TOTAL (MG/L AS N)	NITROGEN, AMMONIA TOTAL (MG/L AS N)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N)	PHOSPHORUS TOTAL (MG/L AS P)
NONE	Sh:Q-088	10-26-89	17.5	3	6.0	188	107	< 0.1	--	0.020	< 0.010	< 0.100	< 0.010
		07-10-90	17.0	2	6.0	161	90	0.3	0.18	0.120	< 0.010	< 0.100	< 0.010
MS-2	Sh:Q-092	10-14-89	16.5	2	6.7	120	73	70.0	--	0.080	< 0.010	< 0.100	0.040
		07-09-90	17.0	7	6.5	111	75	1.5	0.21	0.090	< 0.010	< 0.100	0.030
MS-4	Sh:Q-126	10-16-89	18.0	3	6.9	253	116	2.4	0.28	0.020	< 0.010	< 0.100	0.060
MS-5	Sh:Q-144	10-15-89	17.0	4	6.1	212	131	21.0	--	0.020	< 0.010	< 0.100	0.020
		06-29-90	16.5	2	6.2	200	115	0.9	0.29	0.010	< 0.010	< 0.100	0.020
MS-7	Sh:Q-146	10-18-89	18.5	3	6.2	220	150	1.0	--	0.040	< 0.010	< 0.100	0.010
		07-06-90	19.0	2	6.3	291	163	1.6	0.07	0.130	< 0.010	< 0.100	0.030
MS-9	Sh:Q-148	10-13-89	17.0	12	6.3	130	73	90.0	0.26	0.040	< 0.010	< 0.100	< 0.010
		06-28-90	16.5	5	6.5	119	70	1.5	0.25	0.050	< 0.010	< 0.100	0.040
MS-10	Sh:Q-149	10-13-89	17.5	30	6.6	137	90	33.0	--	0.050	< 0.010	< 0.100	0.010
		06-27-90	17.0	7	6.8	144	111	2.6	0.26	0.040	< 0.010	< 0.100	0.010
MS-11	Sh:Q-150	10-11-89	19.0	18	6.1	541	337	4.8	0.30	2.40	< 0.010	< 0.100	< 0.010
		07-02-90	18.5	17	6.1	714	362	7.8	0.70	3.00	< 0.010	< 0.100	0.020
MS-12	Sh:Q-151	10-27-89	18.0	2	6.3	492	325	1.3	--	0.070	0.040	1.20	0.050
		06-26-90	18.0	3	5.9	371	239	2.4	0.47	0.030	0.020	0.600	0.020

WELL NUMBERS: PROJECT AND MAP	WELL NUMBERS: USGS LOCAL FOR TENNESSEE	DATE	PHOSPHATE (MG/L AS PO4)	SULFATE, DISSOLVED (MG/L AS SO4)	ALUMINUM, DISSOLVED (UG/L AS AL)	LITHIUM, DISSOLVED (UG/L AS LI)	SELENIUM, DISSOLVED (UG/L AS SE)	FLUORIDE, DISSOLVED (MG/L AS F)	IODIDE, DISSOLVED (MG/L AS I)	BROMIDE, DISSOLVED (MG/L AS BR)	ARSENIC, DISSOLVED (UG/L AS AS)	BERYLLIUM, DISSOLVED (UG/L AS BE)	SILICA, DISSOLVED (MG/L AS SIO2)
NONE	Sh:Q-088	10-26-89	--	6.0	< 10	< 4	< 1	< 0.10	0.003	0.310	< 1	< 0.5	15
		07-10-90	--	5.1	< 10	< 4	< 1	< 0.10	0.005	0.220	< 1	< 0.5	15
MS-2	Sh:Q-092	10-14-89	0.06	4.0	< 10	< 4	< 1	0.10	0.017	0.020	1	< 0.5	9.7
		07-09-90	--	3.1	130	5	< 1	0.20	0.016	0.020	1	< 0.5	9.7
MS-4	Sh:Q-126	10-16-89	0.09	3.0	< 10	< 4	< 1	0.20	0.020	0.040	< 1	< 0.5	12
MS-5	Sh:Q-144	10-15-89	0.03	37	< 10	< 4	< 1	0.10	0.016	0.020	< 1	< 0.5	16
		06-29-90	--	14	< 10	< 4	< 1	0.20	0.005	0.030	< 1	< 0.5	17
MS-7	Sh:Q-146	10-18-89	0.09	22	10	< 4	< 1	0.10	0.024	0.060	2	< 0.5	12
		07-06-90	--	22	10	< 4	< 1	0.30	0.022	0.080	2	< 0.5	13
MS-9	Sh:Q-148	10-13-89	--	3.0	< 10	< 4	< 1	0.10	0.060	0.040	< 1	< 0.5	10
		06-28-90	--	1.9	< 10	7	< 1	0.10	0.008	0.020	< 1	< 0.5	11
MS-10	Sh:Q-149	10-13-89	--	4.0	< 10	< 4	< 1	0.10	0.031	< 0.010	< 1	< 0.5	9.9
		06-27-90	0.03	1.5	< 10	5	< 1	< 0.10	< 0.001	0.070	1	< 0.5	9.8
MS-11	Sh:Q-150	10-11-89	--	26	< 10	5	< 1	0.10	0.190	0.300	< 1	< 0.5	10
		07-02-90	--	25	< 10	< 4	< 1	< 0.10	0.050	1.100	< 1	< 0.5	9.6
MS-12	Sh:Q-151	10-27-89	0.12	64	< 10	5	5	0.20	0.024	0.030	2	< 0.5	33
		06-26-90	--	62	< 10	< 4	3	0.20	0.026	0.040	< 1	< 0.5	24

Table 6.--*Water-quality properties and concentrations of nutrients, major inorganic constituents, and trace inorganic constituents in samples from wells screened in the Memphis aquifer near the Shelby County landfill* --*Continued*

[MG/L, milligrams per liter; UG/L, micrograms per liter; DEG C, degrees Celsius; US/CM, microsiemens per centimeter. Values given as < (less than) indicate that the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, indicate no data]

WELL NUMBERS FIELD NO.	WELL NO.	DATE	HARDNESS TOTAL (MG/L AS CAC03)	ALKALINITY LAB (MG/L AS CACO3)	CALCIUM, DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOVLED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	CHLORIDE, DISSOLVED (MG/L AS CL)	BARIUM, DISSOLVED (UG/L AS BA)	STRONTIUM, DISSOLVED (UG/L AS SR)	BORON, DISSOLVED (UG/L AS B)	VANADIUM, DISSOLVED (UG/L AS V)
NONE	Sh:Q-088	10-26-89	49	36	12	4.6	18	0.8	31	38	34	< 10	< 6
		07-10-90	38	33	9.1	3.7	15	0.7	30	27	27	< 10	< 6
MS-2	Sh:Q-092	10-14-89	54	61	16	3.3	3.7	1.0	2.7	77	91	10	< 6
		07-09-90	42	52	11	3.5	3.6	1.0	3.4	86	65	< 10	< 6
MS-4	Sh:Q-126	10-16-89	99	110	31	5.1	8.7	1.1	3.0	82	57	< 10	< 6
MS-5	Sh:Q-144	10-15-89	87	62	22	7.7	7.2	0.9	3.7	64	80	< 10	< 6
		06-29-90	71	56	16	7.5	6.9	0.9	4.3	51	49	20	< 6
MS-7	Sh:Q-146	10-18-89	93	79	26	6.8	11	1.0	9.6	69	65	< 10	< 6
		07-06-90	120	112	34	7.3	16	1.4	11	93	100	40	< 6
MS-9	Sh:Q-148	10-13-89	54	59	14	4.7	4.5	1.0	3.0	61	60	30	< 6
		06-28-90	47	62	11	4.8	4.0	1.5	0.5	150	110	20	< 6
MS-10	Sh:Q-149	10-13-89	60	65	15	5.4	4.9	0.9	2.1	43	47	20	< 6
		06-27-90	59	72	15	5.1	5.6	0.9	1.5	38	51	30	< 6
MS-11	Sh:Q-150	10-11-89	210	207	54	18	43	3.1	58	87	120	50	< 6
		07-02-90	220	237	57	20	48	5.2	64	86	140	80	< 6
MS-12	Sh:Q-151	10-27-89	190	197	61	10	41	2.9	6.8	86	250	20	< 6
		06-26-90	120	127	31	11	39	1.6	9.9	68	91	30	< 6

WELL NUMBERS FIELD NO.	WELL NO.	DATE	ZINC, DISSOLVED (UG/L AS ZN)	CADMIUM, DISSOLVED (UG/L AS CD)	CHROMIUM, DISSOLVED (UG/L AS CR)	COPPER, DISSOLVED (UG/L AS CU)	IRON, DISSOLVED (UG/L AS FE)	MANGANESE, DISSOLVED (UG/L AS MN)	LEAD, DISSOLVED (UG/L AS PB)	MERCURY, DISSOLVED (UG/L AS HG)	MOLYBDENUM, DISSOLVED (UG/L AS MO)	NICKEL, DISSOLVED (UG/L AS NI)	SILVER, DISSOLVED (UG/L AS AG)
NONE	Sh:Q-088	10-26-89	13	< 1.0	< 1	1	330	15	< 1	< 0.1	< 10	2	< 1.0
		07-10-90	7	< 1.0	< 1	< 1	300	8.0	< 1	< 0.1	< 10	1	< 1.0
MS-2	Sh:Q-092	10-14-89	< 3	< 1.0	< 1	2	330	120	< 1	< 0.1	< 10	2	< 1.0
		07-09-90	26	< 1.0	< 1	1	660	200	1	0.2	< 10	4	< 1.0
MS-4	Sh:Q-126	10-16-89	27	< 1.0	< 1	1	160	69	< 1	< 0.1	< 10	1	< 1.0
MS-5	Sh:Q-144	10-15-89	44	< 1.0	< 1	1	24	190	1	< 0.1	< 10	3	< 1.0
		06-29-90	31	< 1.0	< 1	1	69	84	< 1	0.2	< 10	2	< 1.0
MS-7	Sh:Q-146	10-18-89	9	1.0	< 1	1	720	52	< 1	< 0.1	< 10	3	< 1.0
		07-06-90	32	< 1.0	< 1	1	2,200	310	< 1	< 0.1	< 10	2	< 1.0
MS-9	Sh:Q-148	10-13-89	17	< 1.0	< 1	1	290	160	< 1	< 0.1	< 10	1	< 1.0
		06-28-90	22	< 1.0	< 1	5	9.0	310	1	< 0.1	< 10	5	< 1.0
MS-10	Sh:Q-149	10-13-89	27	< 1.0	< 1	< 1	220	130	< 1	< 0.1	10	< 1	< 1.0
		06-27-90	79	< 1.0	< 1	1	590	250	2	< 0.1	< 10	1	< 1.0
MS-11	Sh:Q-150	10-11-89	56	< 1.0	< 1	3	2,000	190	< 1	< 0.1	10	8	< 1.0
		07-02-90	110	< 1.0	1	< 1	3,400	240	1	< 0.1	< 10	7	< 1.0
MS-12	Sh:Q-151	10-27-89	38	< 1.0	2	3	9.0	270	< 1	< 0.1	< 10	3	< 1.0
		06-26-90	50	< 1.0	< 1	< 1	58	150	2	< 0.1	< 10	2	< 1.0

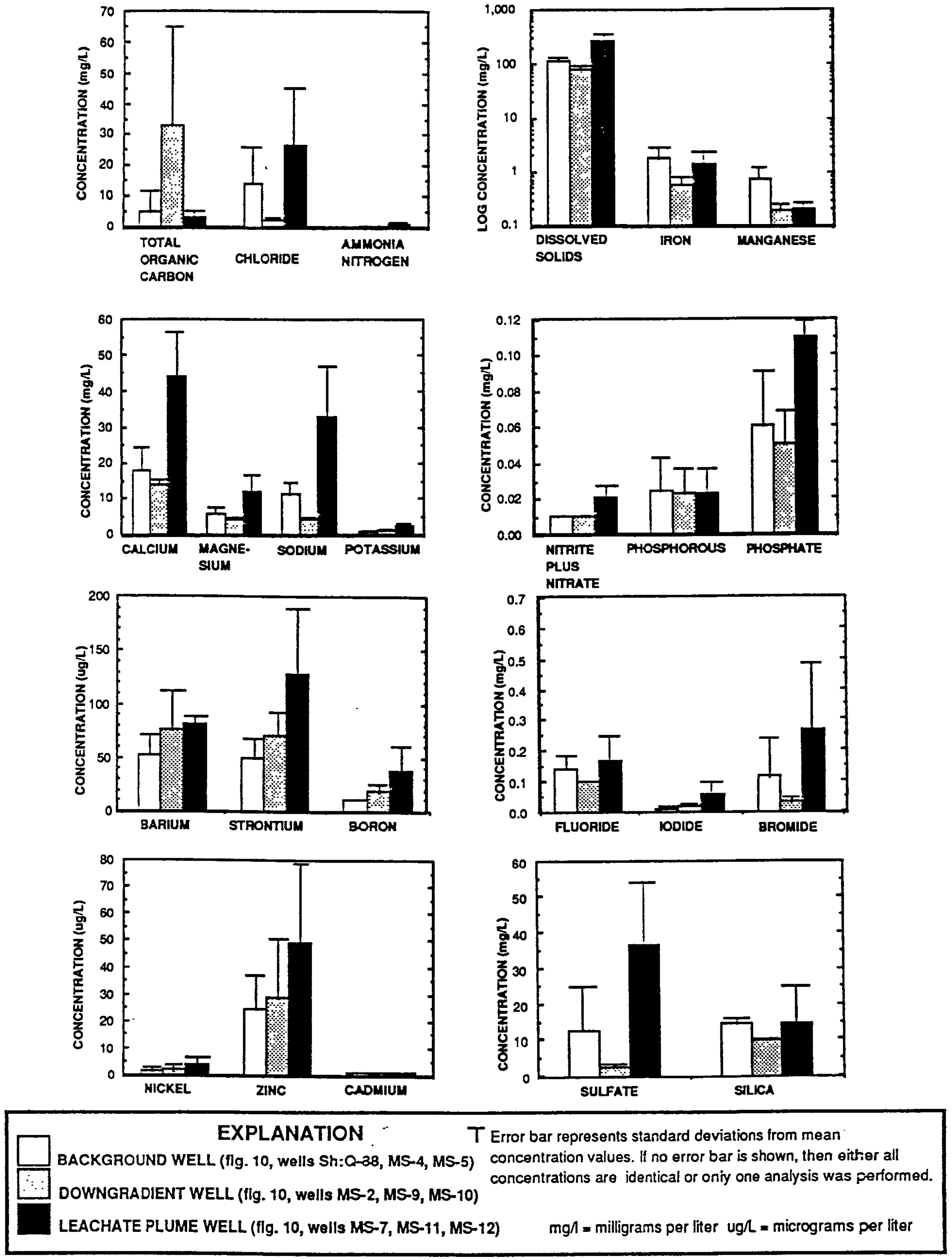


Figure 12.—Mean values of concentrations of selected major and trace inorganic constitutents and nutrients in samples from background, downgradient, and leachate plume wells screened in the Memphis aquifer near the Shelby County landfill.

dissolved solids (362 mg/L), ammonia nitrogen (3.00 mg/L), chloride (64 mg/L), sodium (48 mg/L), and iron (3.4 mg/L) were detected in samples from Memphis aquifer well MS-11 (table 6). These values exceed maximum concentrations for dissolved solids (333 mg/L, mean value from 99 wells), sodium (22 mg/L from 101 wells), and chloride (10 mg/L from 98 wells) previously published for the Memphis aquifer in western Tennessee (Parks and Carmichael, 1990, table 2) and in the Memphis area (Brahana and others, 1987, table 2). In addition, dissolved solids concentrations in samples from Memphis aquifer wells MS-7, MS-11, and MS-12 are significantly higher than dissolved solids concentrations detected in samples from other nearby Memphis aquifer wells, which range from 35 to 61 mg/L (Brahana and others, 1987, fig. 6).

Total organic carbon concentrations were relatively high in samples from wells within the plume in the alluvial aquifer, but maximum total organic carbon values were not detected in samples from Memphis aquifer leachate plume wells MS-7, MS-11, and MS-12. Maximum total organic carbon concentrations (ranging from 70 to 90 mg/L) were detected in samples from Memphis aquifer wells MS-2 and MS-9, respectively (table 6). The lithologic log for MS-1, which is near MS-2, indicated some lignite associated with a clay bed just above the screened interval (Bradley, 1988, p. 28), and well MS-9 includes a thin lignite bed at the bottom of the screened interval (*Appendix C*). These lignite beds could be a source of organic carbon that contributed to the high total organic carbon concentrations in samples from these wells.

Water-quality data from wells MS-7, MS-11, and MS-12 are particularly significant for indicating transport of chemical constituents between the alluvial and Memphis aquifers. Eight major inorganic constituents characterize the leachate plume in samples from wells 26, 27, 31, 38, 39, and 40 screened in the alluvial aquifer or upper part of the confining unit. Of these eight, three constituents (dissolved solids, chloride, and sodium) show concentrations in samples from Memphis aquifer wells MS-7, MS-11, and MS-12 that exceed maxima previously published (Parks and Carmichael, 1990, table 2; Brahana and others, 1987, table 2) and are higher than background concentrations reported for samples from wells Sh:Q-88 and MS-4. Memphis aquifer wells MS-7, MS-11, and MS-12 are separated from the overlying alluvium by a confining unit that ranges from 0 foot (MS-12, Appendix C) to 35 feet (MS-7, Appendix C) in thickness. Apparently, certain constituents (specifically dissolved solids, sodium, chloride, and possibly ammonia nitrogen) from the alluvial aquifer have migrated into the Memphis aquifer by downward leakage where the confining unit is thin or absent.

Nutrient (nitrite plus nitrate, phosphorous, phosphate, sulfate) concentrations in samples from the Memphis aquifer do not clearly indicate downward migration from the alluvial aquifer. Nitrite plus nitrate concentrations in samples from the Memphis aquifer near the Shelby County landfill are low (maximum value of 1.2 mg/L) and well below the drinking water MCL for nitrate of 10.0 mg/L (Tennessee Department of Health and Environment, 1988; U. S. Environmental Protection Agency, 1986). Phosphorous and phosphate concentrations in samples from the Memphis aquifer do not exceed 0.12 mg/L. These concentrations generally are 50 percent lower than phosphorous and phosphate concentrations in samples from the alluvial aquifer and upper part of the confining unit.

Sulfate concentrations (1.5 to 37 mg/L) in most samples from Memphis aquifer wells near the Shelby County landfill (table 6) are consistent with the range in concentrations (0.2 to 30 mg/L) in samples from 105 wells in the Memphis aquifer in the Memphis area (Brahana and others, 1987, table 2) and the range in concentrations (0.2 to 27 mg/L) in samples from 192 wells in western Tennessee (Parks and Carmichael, 1990, table 2). Elevated sulfate concentrations (62 and 64 mg/L) are observed only in samples from Memphis aquifer well MS-12, but this anomaly cannot be interpreted as a leachate effect because sulfate concentrations are significantly lower in the overlying alluvial aquifer.

Trace Inorganic Constituents

Concentrations of trace inorganic constituents were determined for samples from wells screened in the alluvial aquifer or upper part of the confining unit (table 5) and in the Memphis aquifer (table 6). Trace inorganic constituent data were interpreted in the same manner as the major inorganic constituents and nutrients data. Therefore, the same wells were used as background, upgradient, and downgradient wells for the alluvial aquifer or upper part of the confining unit (fig. 11) and as background, downgradient, and leachate plume wells for the Memphis aquifer (fig. 12).

Barium, strontium, boron, and cadmium concentrations are significantly higher in samples from wells associated with the leachate plume in the alluvial aquifer or upper part of the confining unit. On average, barium and strontium concentrations (fig. 11) are 5 times higher in samples from downgradient wells 26, 27, 31, 38, 39, and 40 than in samples from background wells (4A, 7) and upgradient wells (2, 32, 33, 34). Barium concentrations in samples from these downgradient alluvial aquifer wells range from 23 to 1,400 μg/L, with the maximum concentrations reported in samples from wells 26 and 27 (table 5). These maxima exceed the MCL of 1,000 μg/L in drinking water (Tennessee

Department of Health and Environment, 1988; U.S. Environmental Protection Agency, 1986). Strontium concentrations in samples from alluvial aquifer wells 26, 27, 31, 38, 39, and 40 range from 120 to 800 μg/L; maximum concentrations of strontium were measured in samples from well 27 (table 5).

Barium and strontium concentrations measured in samples from wells screened in the alluvial aquifer or upper part of the confining unit near Shelby County landfill are within the ranges reported previously for eight wells screened in the alluvial aquifer in the Memphis area (McMaster and Parks, 1988, table 2). However, the ranges of barium concentrations (41 to 1,400 μg/L) and strontium concentrations (28 to 1,100 μg/L) reported by McMaster and Parks (1988, p. 13) may include data from a contaminated well. A map showing the distribution of natural barium concentrations in the alluvial aquifer in the Memphis area suggests that natural barium concentrations should be less than 50 μg/L near the Shelby County landfill (McMaster and Parks, 1988, fig. 4). Barium concentrations near the Shelby County landfill exceed 50 μg/L in samples from 17 of 22 wells screened in alluvial aquifer or upper part of the confining unit (table 5).

Elevated boron concentrations in downgradient plume wells 26, 27, 31, 38, 39, and 40 in the alluvial aquifer or upper part of the confining unit also are apparently characteristic of leachate. On average, boron concentrations are 20 times higher in samples from downgradient wells 26, 27, 31, 38, 39, and 40 than in background or upgradient wells (fig. 11). Boron concentrations in samples from these wells range from 20 to 920 μg/L, with the maximum concentrations reported from well 27 (table 5). High boron concentrations are characteristic of hydrothermal systems and evaporite deposits (Hem, 1985), neither of which affect ground water composition near the Shelby County landfill.

Cadmium concentrations are approximately 4 times higher in samples from downgradient wells 26, 27, 31, 38, 39, and 40 when compared to data from upgradient and background wells (fig. 11). Cadmium concentrations in samples from these wells range from less than 1.0 to 32 μg/L, with maximum concentrations of 11 and 32 μg/L detected in samples from wells 26 and 39, respectively (table 5). These maxima exceed the MCL of 10 μg/L for drinking water (Tennessee Department of Health and Environment, 1988; U.S. Environmental Protection Agency, 1986). Cadmium is used in the manufacture of pigments and plastics, and is often found associated with buried waste (Hem, 1985).

Elevated selenium concentrations (17 and 20 μg/L) were detected in samples from well 30 (table 5). These concentrations exceed the MCL of 10 μg/L for selenium in drinking water (Tennessee Department of Health and Environment, 1988; U.S. Environmental Protection Agency, 1986). Selenium is a relatively rare element. Of many analyses of surface and ground water from widely distributed sources in the United States, selenium concentrations rarely exceeded 1 μg/L (Hem, 1985).

Concentrations of trace inorganic constituents were determined for water samples from wells screened in the Memphis aquifer (table 6). Concentrations of barium, strontium, boron, and cadmium are lower in samples from the Memphis aquifer than in the overlying alluvial aquifer. On average, concentrations of boron and cadmium in the Memphis aquifer are equal to background concentrations in the alluvial aquifer.

Barium concentrations in all samples from Memphis aquifer wells ranged between 27 and 150 μg/L (table 6), which is within the range of concentrations (0 to 644 μg/L) for samples from 46 wells screened in the Memphis aquifer in Shelby County (Parks and Carmichael, 1990, table 3). Average barium concentrations are higher in samples from downgradient and leachate plume wells than from background wells in the Memphis aquifer (fig. 12) although the difference among data from background, downgradient, and leachate plume wells is not statistically significant.

Strontium concentrations in samples from all Memphis aquifer wells range between 27 and 250 μg/L (table 6), which is within the range of concentrations (13 to 270 μg/L) for samples from seven wells screened in the Memphis aquifer in Shelby County (Parks and Carmichael, 1990, table 3). As with barium, average strontium concentrations are higher in samples from downgradient and leachate plume wells than background wells in the Memphis aquifer (fig. 12), although the difference among data from background, downgradient, and leachate plume wells is not statistically significant.

The maximum barium concentration (150 μg/L) was detected in a sample from well MS-9. The greatest strontium concentrations (ranging from 100 to 250 μg/L) are associated with Memphis aquifer wells MS-7, MS-9, MS-11, and MS-12. However, these strontium concentrations in Memphis aquifer samples are not uncommonly high when compared to the median value of 110 μg/L reported for larger U.S. public water supplies (Hem, 1985).

Concentrations of barium and strontium are at least 50 percent lower in samples from the Memphis aquifer than in the overlying alluvial aquifer. However, it is unclear if these trace inorganic constituents serve as a tracer for the leachate plume emanating from the landfill. Alluvial aquifer samples showing maximum barium and strontium concentrations are not always adjacent to Memphis aquifer samples showing maximum barium and strontium concentrations, even in the absence of the confining unit.

Boron concentrations in all samples from Memphis aquifer wells range from less than 10 to 80 μg/L (table 6), which is approximately an order of magnitude lower than concentrations found in the overlying alluvial aquifer. Cadmium concentrations are all 1.0 μg/L or lower in samples from the Memphis aquifer (table 6), indicating that cadmium contamination in the overlying alluvial aquifer has not reached the Memphis aquifer.

Synthetic Organic Compounds

Concentrations of synthetic organic compounds were detected in samples from wells screened in the alluvial aquifer or upper part of the confining unit (table 7) and in samples from wells screened in the Memphis aquifer (table 8). Twenty-two synthetic organic compounds were measured in samples from 14 wells screened in the alluvial aquifer or upper part of the confining unit (table 9), and 18 synthetic organic compounds were measured or detected in samples from 8 wells screened in the Memphis aquifer (table 10). Sixteen of the same compounds detected in the alluvial aquifer or upper part of the confining unit were detected in the Memphis aquifer. All of these compounds are volatile organic compounds except for bis(2-ethylhexyl)phthalate, which is a base-neutral extractable compound detected in two samples from wells in the Memphis aquifer. Samples from some wells indicate that a compound was measured in the first or second sample, but not in both samples (tables 9 and 10). The measurement limit for the gas-chromatography/mass spectrometry method used for analysis of the volatile organic compounds was 0.20 or 0.2 μg/L; that for the base-neutral and acid extractable organic compounds varied among compounds from less than 5 to 30 μg/L.

Interpretation of the data for synthetic organic compounds was conducted in a different manner than interpretation of the data for the major and trace inorganic constituents and nutrients. Synthetic organic compounds are not distributed widely in either the alluvial aquifer or upper part of the confining unit, or the Memphis aquifer. Consequently, it is not possible to clearly characterize upgradient, downgradient, or leachate plume wells using synthetic organic compounds, because samples from the majority of wells show concentrations below the detection level. Instead, the degree of contamination by synthetic organic compounds near the Shelby County landfill is interpreted by using sums of synthetic organic compounds at specific wells. The distribution of these synthetic organic compounds is considered in the context of trends observed in major and trace inorganic constituents and nutrients data.

Data for volatile organic compounds are tabulated (tables 9 and 10), and their distributions are plotted (fig. 13 and 14). For these illustrations, the volatile organic compound data have been grouped into three sets based on similar chemical structure: (1) substituted ring compounds, consisting of benzene molecules with chlorine, methyl or ethyl groups; (2) halogenated alkanes, consisting of simple chain hydrocarbon molecules substituted with chlorine or fluorine; and (3) halogenated alkenes, consisting of more complex, double-bonded hydrocarbon chains substituted with chlorine or ether groups.

Relatively high concentrations of volatile organic compounds were detected in samples from the alluvial aquifer or upper part of the confining unit collected from wells 20, 26, 27, 31, 37, 38, 39, and 40 on the north margin or north of the landfill (fig. 13). These wells are downgradient in the direction of ground-water flow from the landfill northward toward the center of the depression in the water table (fig. 5).

Substituted ring compounds [specifically benzene, chlorobenzene, and dichlorobenzenes (1,2-dichlorobenzene plus 1,4-dichlorobenzene)] were detected in high concentrations in samples from downgradient wells 26, 27, 31, 38, 39, and 40 screened in the alluvial aquifer or upper part of the confining unit (fig. 13). One analysis from well 38 showed a benzene concentration (5.8 μg/L, table 9) that exceeds the Federal and State MCL of 5.0 μg/L (Tennessee Department of Health and Environment, 1988; U.S. Environmental Protection Agency, 1986). Analyses of samples from wells 26 and 27 showed the highest sums of substituted ring compound concentrations, both exceeding 8.0 μg/L (fig. 13). Substituted ring compounds are used commonly as industrial solvents (Smith and others, 1988).

Halogenated alkanes were detected in highest concentrations in samples from alluvial aquifer or upper part of the confining unit wells 20, 27, 31, 38, 39, and 40 (fig. 13). Fluorine-substituted alkane (trichlorofluoromethane and dichlorodifluoromethane) concentrations were particularly high in samples from wells 20 and 27 (table 9). These two compounds are used as refrigerants, or propellants in aerosol sprays (Smith and others, 1988). Considering other halogenated alkane compounds, maximum concentrations of 1,2-dichloropropane (14 μg/L and 6.4 μg/L, table 9) were detected in samples from well 31. Analyses of samples from wells 31 and 39 also showed maximum concentrations of dichloroethanes (1,1-dichloroethane plus 1,2-dichloroethane, table 9, fig. 13). However, no concentration of any halogenated alkane exceeded Federal or State MCLs (table 9). Dichloromethane is used commonly as an industrial solvent (Smith and others, 1988).