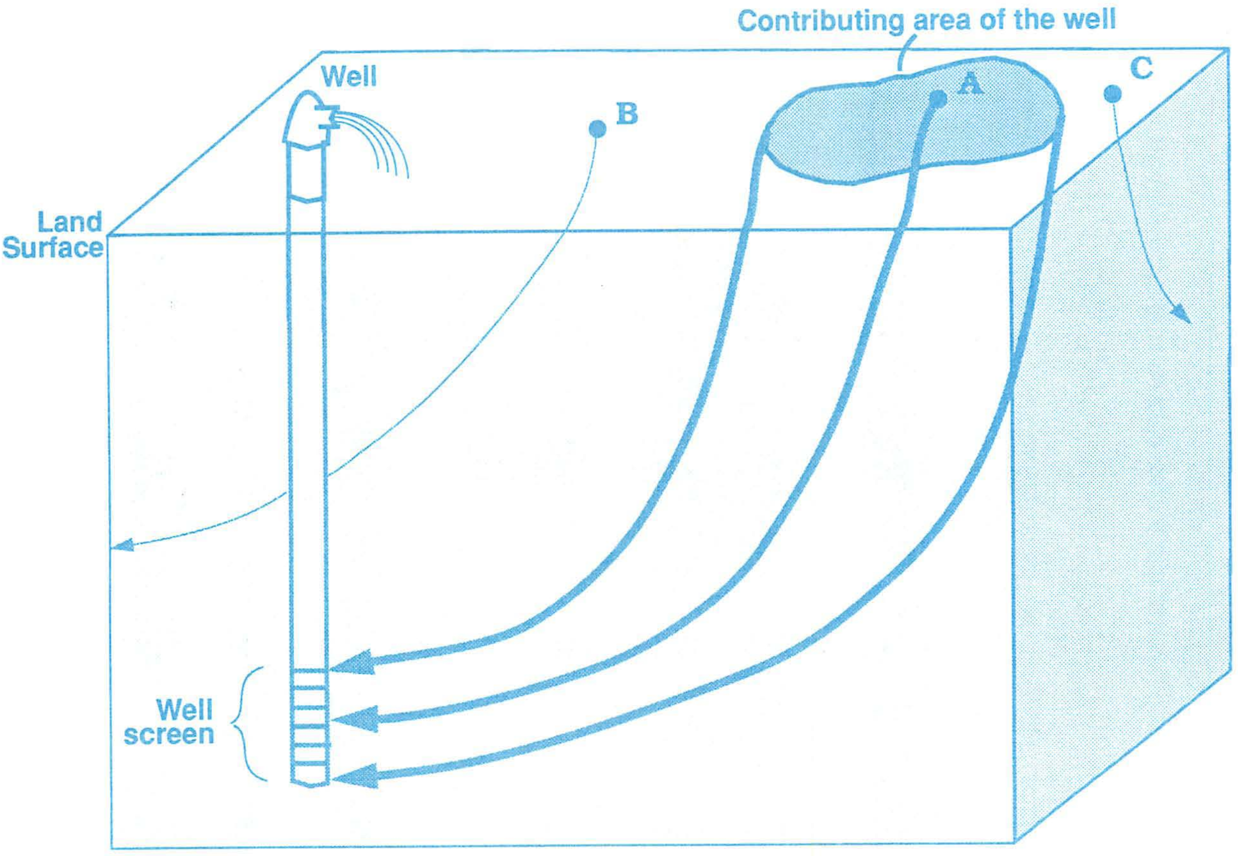
REPORT OF INVESTIGATIONS NO. 63
1997

HYDROGEOLOGY AND ESTIMATION OF GROUND-WATER CONTRIBUTING AREAS OF THE PERRYMAN WELL FIELD, HARFORD COUNTY, MARYLAND

by
David D. Drummond and Richard P.B. Johnston



Prepared in cooperation with the
Maryland Department of Environment
and
The Harford County Department of Public Works

Department of Natural Resources
Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

CONVERSION FACTORS, VERTICAL DATUM, AND WATER-QUALITY UNITS

Multiply inch-pound units	By	To obtain metric units
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
gallon (gal)	3.785	liter (L)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	3.785	liter per day (L/d)
million gallons per day (Mgal/d)	3,785	cubic meters per day (m^3/d)
inch per year (in./yr)	0.02540	meter per year (m/yr)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

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

In this report, chemical concentration is expressed in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (μg/L). Milligrams per liter and micrograms per liter are units expressing the concentration of chemical constituents in solution as weight of solute per unit volume of water.

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HYDROGEOLOGY AND ESTIMATION OF GROUND-WATER CONTRIBUTING AREAS OF THE PERRYMAN WELL FIELD, HARFORD COUNTY, MARYLAND

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ABSTRACT

The protection of public ground-water supplies from chemical contamination is a major priority of federal, state, and county governments. As part of a wellhead protection program, the hydrogeology of the Perryman area in Harford County, Maryland was studied in order to estimate the extent of contributing areas of the wells in the Perryman well field. The Perryman well field consists of eight production wells screened between 45 and 192 ft below land surface, which pumped an average of 2.2 million gallons per day of ground water in 1994. Water from several of these wells has had nitrate concentrations exceeding the U.S. Environmental Protection Agency maximum contaminant level (MCL) for drinking water (10 mg/L as N), and beginning in 1992, analyses of water from two of the wells showed concentrations of TCE (trichloroethene) that exceeded the MCL (5 μg/L). Agricultural application of fertilizer and discharges from on-site septic systems are possible sources of nitrate; and military, commercial, and industrial activities are possible sources of TCE. TCE-contaminated soil at the Army Fire Training Area (AFTA) on Aberdeen Proving Ground, is a possible source of TCE.

The Perryman area is underlain by fluvial clay, silt, sand, and gravel sediments of Lower Cretaceous and Quaternary ages. The sediments create a system of irregularly shaped aquifers and confining units which produce complex ground-water flow paths. These sediments were divided into three aquifers (designated aquifers 1, 2, and 3) and two intervening confining units (designated confining units 1 and 2). Aquifer 1 is a water-table aquifer, and ranges in thickness from 0 to 85 ft. Aquifers 2 and 3 are semiconfined to confined aquifers, and range in thickness from 0 to 105 ft, and 0 to 100 ft respectively. These aquifers are underlain by relatively low-permeability bedrock of Paleozoic age. The natural flow gradient is from the central part of the study area outward toward the tidal estuaries (Chesapeake Bay, Swan Creek, and Bush River).

A ground-water flow model was developed to simulate hydraulic heads and flow for present (1994) conditions, and for projected-pumpage scenarios. A particle-tracking program was used to estimate: 1) the contributing areas of wells in the well field, 2) traveltime of water entering the wells, 3) migration of the TCE plume, and 4) TCE concentrations in water from wells in the Perryman well field. Simulations indicate that contributing areas for the wells in the Perryman well field extend about one-half mile to the southwest and about two miles northeast of the well field. Traveltime for water entering the wells ranges from a few years to more than 500 years, but most of the contributing areas are within the 0-20 year traveltime zone.

Simulations indicate that if 1994 pumpage were continued for 20 years, heads would not change appreciably from 1994 heads, and that TCE concentrations at the contaminated wells would decrease due to a decline in pumpage prior to 1994 and the removal of TCE-contaminated soil from the AFTA. Under these conditions, the main part of the TCE plume would migrate to the southeast toward the Chesapeake Bay. Simulations in which pumpage is increased for 20 years show a concomitant increase in TCE concentrations at the contaminated wells, and simulations in which pumpage is decreased for 20 years show a decrease in TCE concentrations. A simulation in which the contaminated wells are shut off for 20 years indicates that the TCE plume would migrate westward toward a previously uncontaminated well.

INTRODUCTION

The Perryman well field is the largest supplier of ground water in Harford County. It produced about 2.2 Mgal/d as a yearly average in 1994, and it has a capacity of 4.3 Mgal/d during peak usage periods of the summer. Until recently, it supplied good quality water that required minimal treatment before being distributed to the public.

In 1992, however, low levels of VOC's (volatile organic compounds) were discovered in raw water from two of the supply wells, and subsequent monitoring of the wells showed increasing TCE levels. Studies conducted by the Army (Woodward-Clyde Federal Services, 1994) indicated that a probable source of the TCE was the Army Fire Training Area (AFTA), located on Aberdeen Proving Ground, about a mile northeast of the contaminated wells. An activated carbon treatment system was constructed with Army funding in 1993 to remove TCE from water coming from the contaminated wells.

These events prompted state and county officials to initiate a wellhead protection program for the Perryman well field. The purpose of the program is to assess the quantity and quality aspects of the well field, and to protect the water supply, to the extent possible, from further contamination. The current study is part of the wellhead protection program, and is based largely on a regional hydrogeologic study of Harford County (Drummond and Blomquist, 1993).

A major task in developing the wellhead protection program is the identification of contributing areas of the production wells in the Perryman well field (U.S. Environmental Protection Agency, 1993). The contributing area of a well is the land-surface area on which water that falls as precipitation will eventually flow to the well, and contribute to the production of that well (fig. 1). The contributing area of a well field is the combined contributing areas of the wells that make up the well field. This concept is of critical importance because any contaminants released within the contributing area of a well might migrate with the water flowing toward the well, and eventually contaminate it. The time it takes the water (or contaminant) to flow from the land surface to the well is referred to as the traveltime.

PURPOSE AND SCOPE

The purpose of this report is to describe a refined hydrogeologic framework of the Perryman well-field area, and to estimate the areas contributing ground water to the well field. It is intended to be a planning tool that will be used to assist state and county planning officials in the management of pumping rates in existing wells, and to provide a basis for siting new wells. The analysis is part of Harford County's Wellhead Protection Plan, the purpose of which is to protect the drinking-water supply from contamination. This report also provides an estimate of migration paths and water travel times from AFTA.

LOCATION OF STUDY AREA

The Perryman well field is located in Harford County, about two miles southwest of the town of Aberdeen, and about 20 miles northeast of Baltimore City (fig. 2). It borders

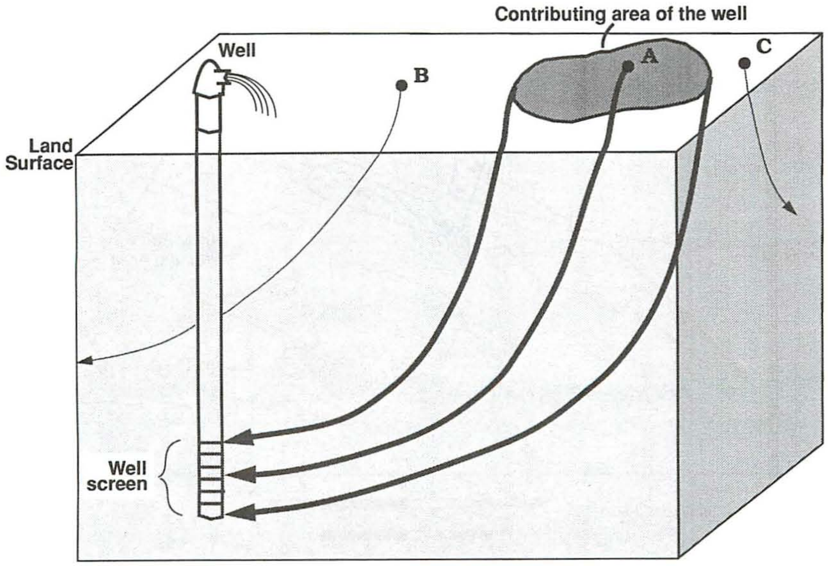

Figure 1.—Schematic diagram showing the contributing area of well. Water entering the flow system in the contributing area (e.g., point A) will discharge to the well. Water entering the flow system outside the contributing area (e.g., points B and C) will discharge elsewhere.

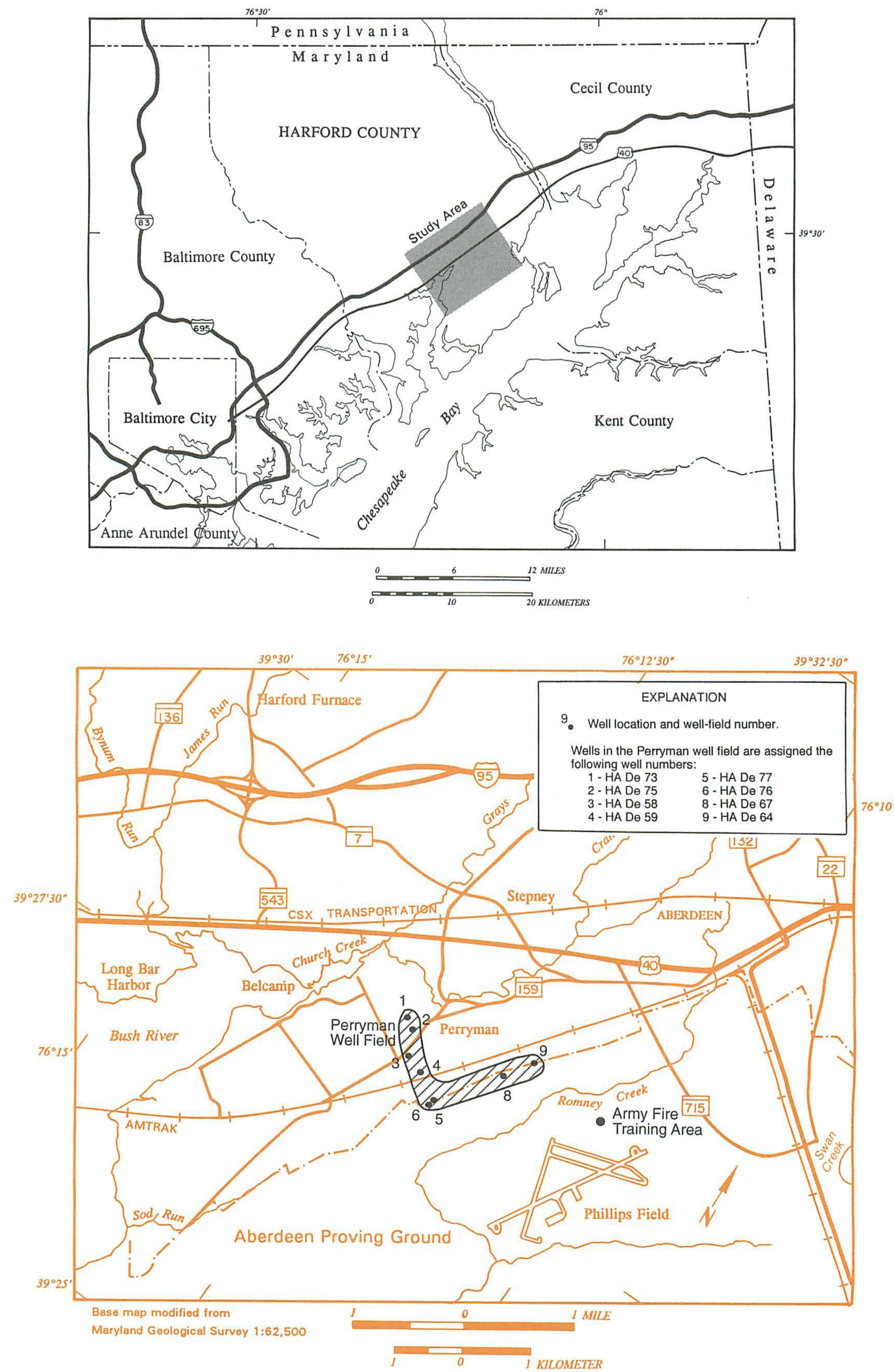

Figure 2.—Location of study area, Perryman Well Field, and Army Fire Training Area.

on the U.S. Army Aberdeen Proving Ground (APG), and wells 5 (De 77), 6 (De 76), 8 (De 67), and 9 (De 64) are actually on Proving Ground property. The well field lies at the neck of a broad peninsula which borders on the Bush River to the southwest, the Susquehanna River to the northeast, and the Chesapeake Bay to the southeast. The vicinity is drained by numerous streams including Cranberry Run, Romney Creek, Bynum Run, James Run, and Grays Run.

The study area boundaries were chosen to coincide with the largest possible contributing area of the well field, as shown in Drummond and Blomquist (1993, p. 96). The boundaries align with the regional flow model so that simulated conditions from the regional model could easily be used for boundary conditions in the local model. The local model boundaries are identical to the study area boundaries.

METHODS OF INVESTIGATION

A literature search was conducted in which published reports concerning the hydrogeology of the Perryman area were collected. The data base was updated by inventorying wells that had been drilled since the regional study was conducted, and by field checking previously inventoried wells in the current study area. Water levels and water-quality analyses that had been collected by other agencies were also entered into the data base. To refine the hydrogeologic framework, about 140 lithologic logs and about 50 geophysical logs were examined and incorporated into 5 cross sections which display the subsurface distribution of the sediments. Structure-contour maps showing the altitude of the tops and bottoms for each of the three major aquifers in the study area were prepared. Continuous water-level recorders were installed on 8 wells to record water-level fluctuations at key sites, and hydrographs which display water fluctuations with time were produced.

A quasi-three dimensional ground-water flow model (MODFLOW) was used to simulate ground-water levels and flow rates in response to historical conditions, and to estimate the effects of future pumpage scenarios on the hydrogeologic system. Many of the data sets required by the flow model were generated by entering spatially distributed data into a GIS (geographic information system), and programming the GIS to output the data in the proper format.

A particle-tracking program (MODPATH) was used to estimate water-migration paths from contaminant sources, to delineate contributing areas of the production wells in the Perryman well field, and to estimate travel times for water moving toward the well field. The particle-tracking program was run in forward-tracking mode to simulate water migration, and in backward-tracking mode to estimate contributing areas. Simulations with these two programs were used to estimate the effects of constructing new production wells at several sites.

PREVIOUS INVESTIGATIONS

The Coastal Plain aquifers were first described by Darton (1896, p. 152), who provided sparse information on the hydrogeology of Harford County. Clark, Mathews, and Berry (1918) further described the aquifers of Harford County, and tabulated data such as well depths, yields, and water levels. Bennett and Meyer (1952) extensively described the geology and hydrogeology of the Baltimore area, which included the Harford County Coastal Plain. Glaser (1969) described the petrology of the Potomac Group sediments in Maryland and Virginia. Owens (1969) described the geology of the Coastal Plain of Harford County. Nutter and Smigaj (1975) compiled ground-water information for Harford County, including well records, chemical data, and pumpage.

A test-well program was conducted for the Perryman well field by Whitman, Requardt and Associates (1976). In that program, recommendations were made for increasing the capacity of the well field. Nutter (1977) reported on the ground-water resources of Harford County, and described water chemistry. Edwards and Hansen (1979) provide stratigraphic data from a deep hole drilled to bedrock in southeastern Harford County at Spesutie Island. Geraghty and Miller, Inc. (1985) investigated the ground-water conditions for a potential nuclear power-plant site southwest of Perryman, near the Bush River.

Numerous disposal sites on APG were investigated by U.S. Army Environmental Hygiene Agency (1988), Miller, Derryberry, and Breland (1990) and Derryberry, Miller, and Breland (1990). Whitten and others (1992) provide a hydrologic assessment of the AFTA, and include a history of the facility, a description of the hydrogeology of the area, and chemical analyses of ground water near the site. Drummond and Blomquist (1993) investigated the hydrogeology of the Coastal Plain aquifers in Harford County, and developed the hydrogeologic framework used in this study. Woodward-Clyde Federal Services (1994) describe the results of a ground-water quality investigation on APG near the Perryman well field, using Hydropunch™ samples.

ACKNOWLEDGMENTS

The authors would like to thank the Army Corps of Engineers, Waterways Experiment Station for providing lithologic, water-chemistry, and water-level data from APG; and the Baltimore Gas and Electric Company for allowing installation of water-level recorders on their property. We would also like to thank the many businesses and homeowners for allowing water-level measurements in their wells. Funding for the project was provided by the Harford County Department of Public Works, and the Maryland Department of the Environment, using a grant from the U.S. Environmental Protection Agency provided under Section 106 of the Clean Water Act.

HYDROGEOLOGY

The Perryman area is underlain by unconsolidated sediments (clays, silts, sands, and gravels) of Cretaceous and Quaternary ages.These unconsolidated sediments form a series of aquifers and confining units which overlie Paleozoic crystalline bedrock and associated saprolite. The bedrock surface generally slopes to the southeast at about 100 ft per mile, and there is at least 150 ft of relief on the bedrock surface in the study area (Drummond and Blomquist, 1993).

The hydrogeology of the area was described in detail by Drummond and Blomquist (1993). Since that report was published, additional test wells and borings have been drilled, which provide more detailed information on the aquifer system, especially in the APG area. This report retains the general framework used in Drummond and Blomquist (1993), but incorporates the new data, and presents it at a smaller scale. Some changes were made to the framework, such as revising aquifer top and bottom maps, refining aquifer transmissivity and confining-unit leakance arrays, and modifying aquifer boundaries. Revisions to aquifer top and bottom maps resulted in the reassignment of some wells to different designated aquifers. In addition, aquifer 4 of Drummond and Blomquist was not included in this study because it is not an important unit in the study area. Confining unit 3 of Drummond and Blomquist was also excluded from this study.

HYDROGEOLOGIC FRAMEWORK

The unconsolidated sediments of the Perryman area were divided into a framework comprising three aquifers and two intervening confining units. The structure of these units is shown in a series of cross sections, the locations of which are shown in figure 3. It should be noted that these aquifer boundaries are somewhat arbitrary and generalized. Thus some fine-grained sediments may be present in the aquifers and some coarse-grained sediments may be present in the confining units. Emphasis was placed on ensuring that aquifer properties and flow paths in the conceptual model reflect those in the real aquifer system as closely as possible.

The hydrogeologic sections are shown in figures 4 through 8. Sections A-A′, A′-A″, A″-A‴, and B-B′ generally trend along strike, and sections C-C′, D-D′, and E-E′ generally trend down dip.

AQUIFER DESCRIPTIONS

Aquifer 1

Aquifer 1 is a shallow water-table aquifer that extends throughout most of the Coastal Plain portion of the study area (fig. 9). Some shallow sediments near the Fall Line are predominantly clay, and were excluded from aquifer 1. It consists mostly of silty sands, but also contains areas of sand and gravel with fewer fine-grained materials, and areas that are predominantly clay. Aquifer 1 receives recharge from precipitation, and discharges through evapotranspiration, base flow to streams, and estuarine discharge. Water also flows to and from the deeper aquifers as leakage through the underlying

(Text continued on p. 16.)

Table 1.—Generalized stratigraphy and hydrogeology of the Perryman area

SYSTEM	SERIES	STRATI-GRAPHIC UNIT	HYDRO-GEOLOGIC UNIT	THICKNESS (FEET)	LITHOLOGIC CHARACTER	WATER-BEARING PROPERTIES
QUATERNARY	PLEISTOCENE	Talbot Formation	Aquifer 1	0-85	Highly variable; clay, silt, sand, and gravel.	Functions as an unconfined or semi-confined aquifer where coarse-grained, and a confining unit where fine-grained.
CRETACEOUS	LOWER CRETACEOUS	Potomac Group	Aquifer 2	0-105	Highly variable; interbedded light-colored sand, variegated silty clay, and very gravelly sand.	Functions as major confined and semi-confined aquifers where coarse-grained, and confining units where fine-grained.
			Aquifer 3	0-100		
PALEOZOIC		Crystalline rocks			Various types of crystalline rock and saprolite.	Yields small amounts of water in the Piedmont and where the overlying Coastal Plain sediments are thin or impermeable.

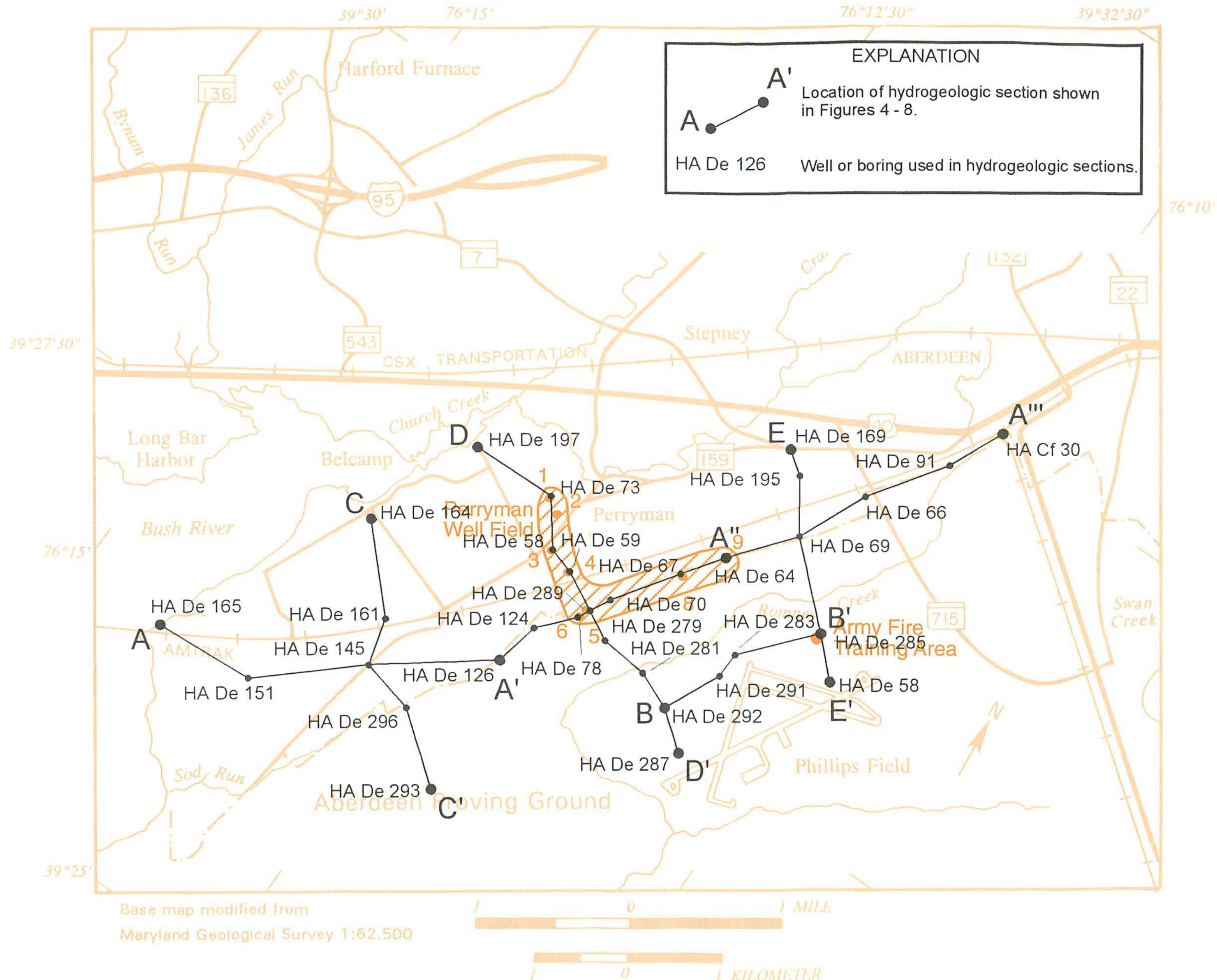

Figure 3.—Locations of hydrogeologic sections.

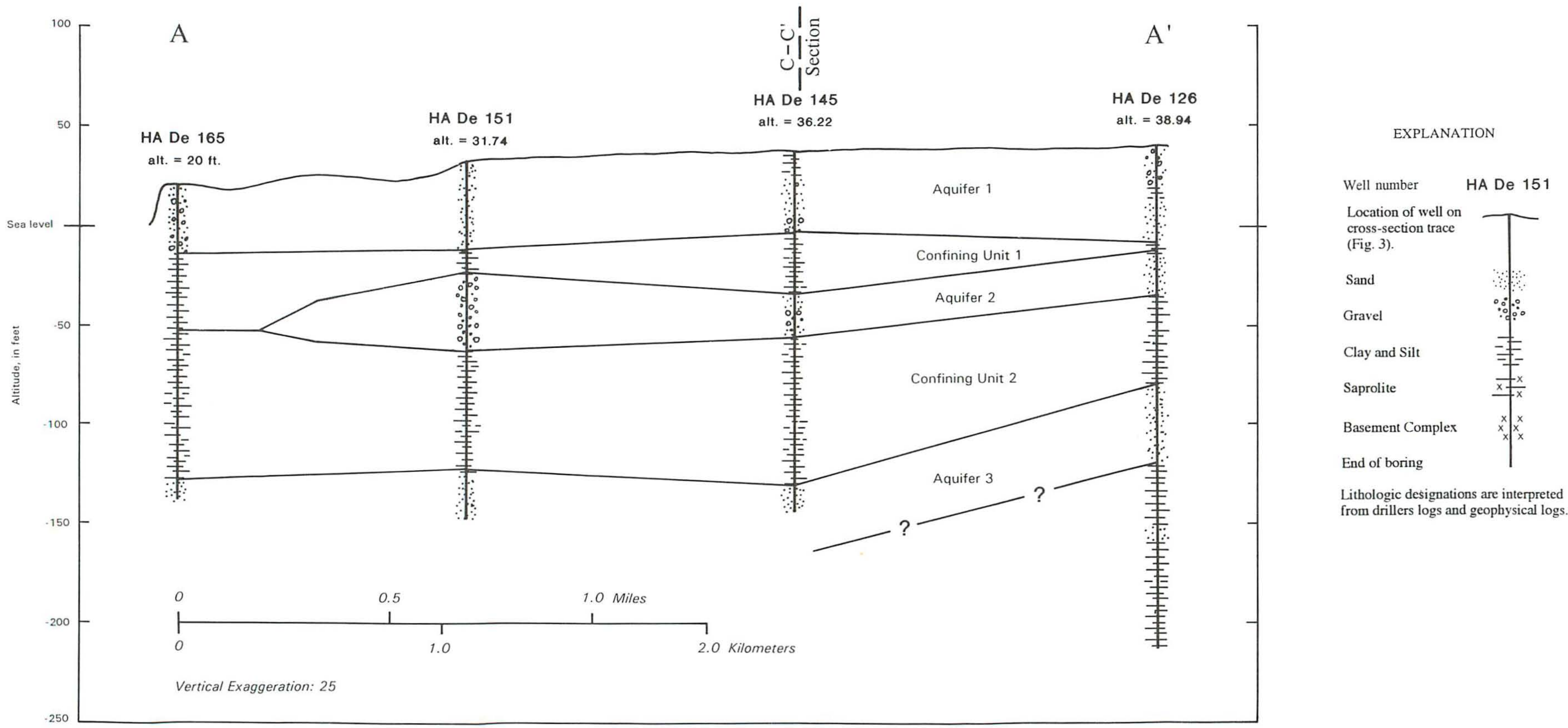

Figure 4a.—Hydrogeologic section A-A$'$.

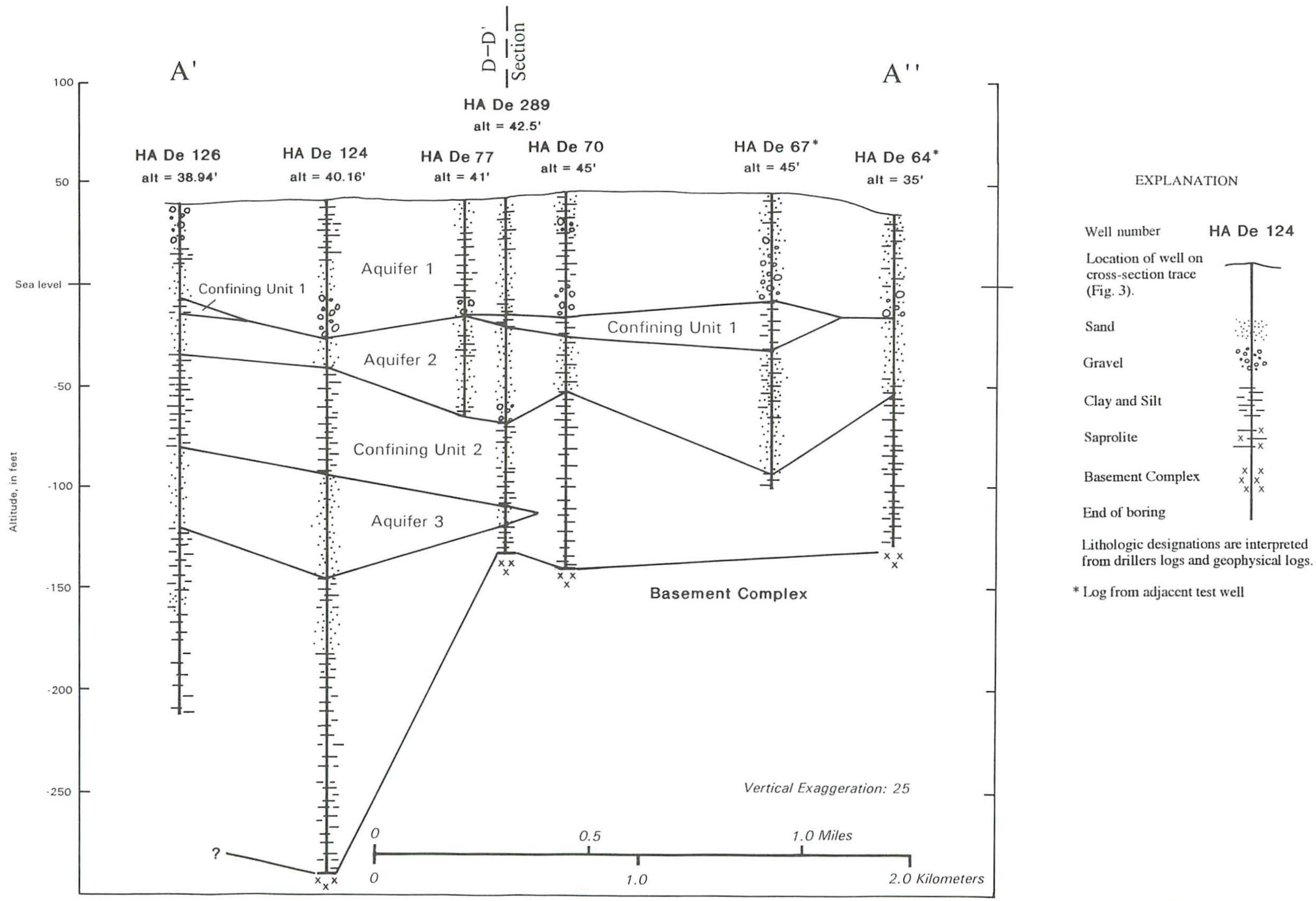

Figure 4b.—Hydrogeologic section A′-A″.

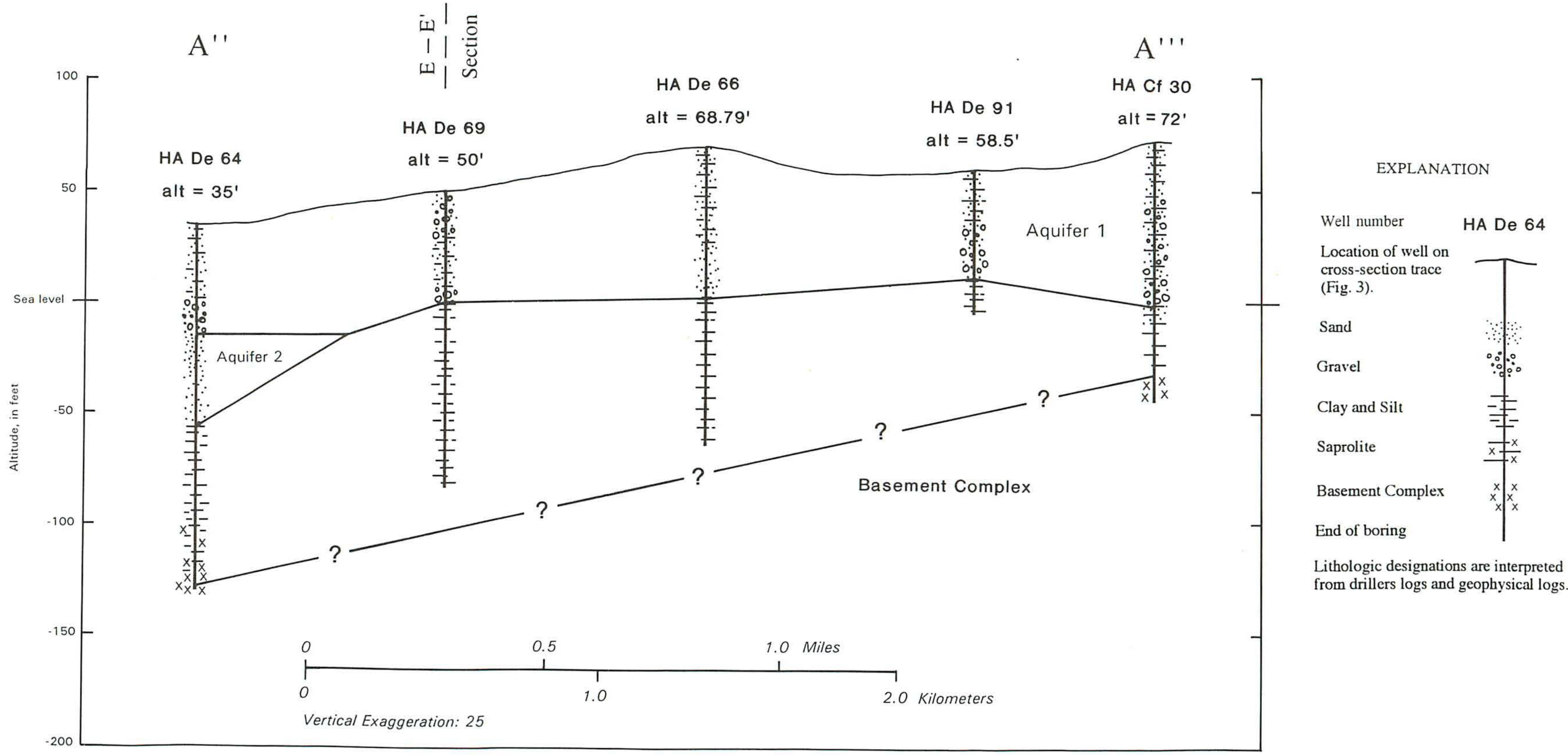

Figure 4c.—Hydrogeologic section A''-A'''.

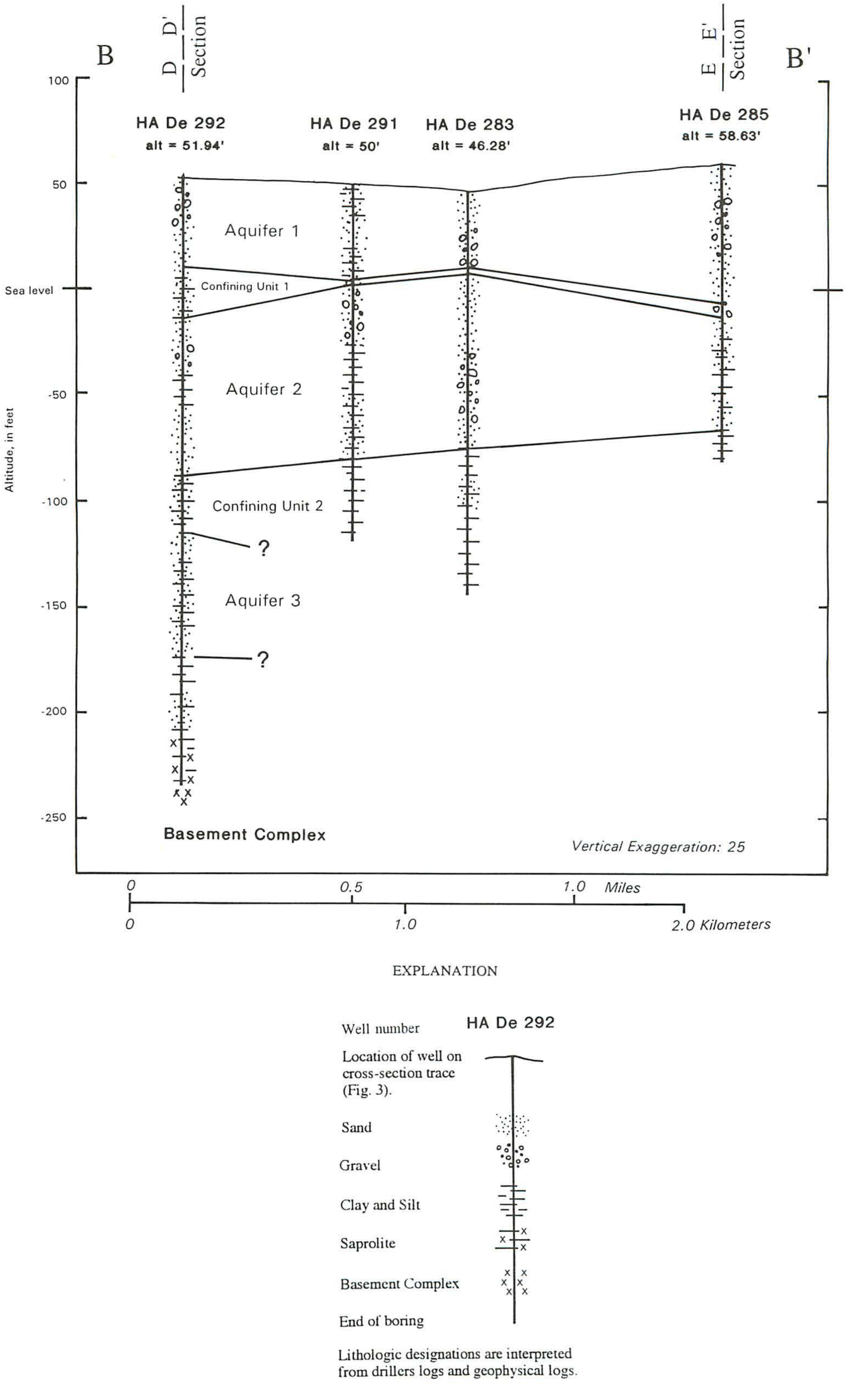

Figure 5.—Hydrogeologic section B-B'.

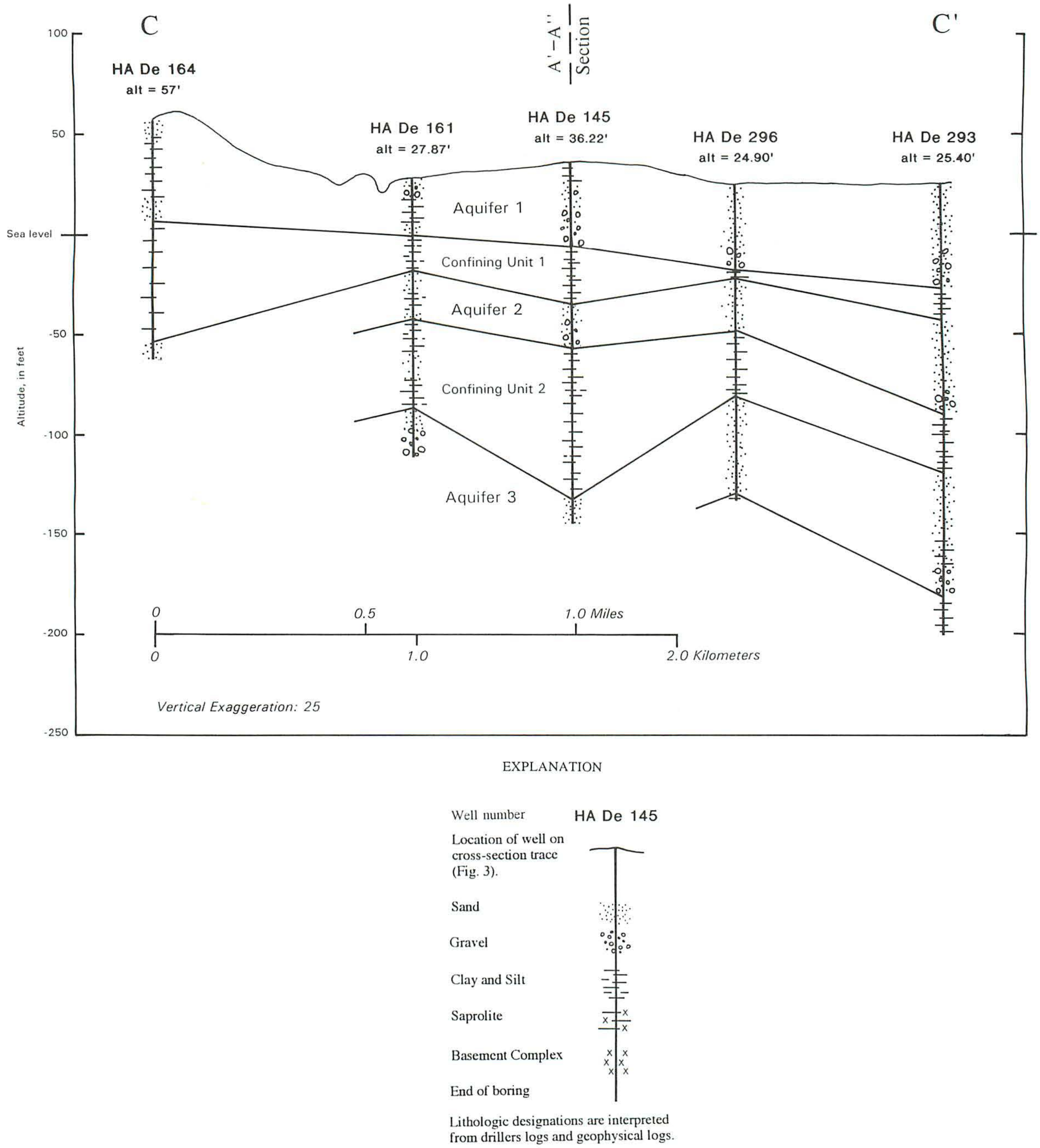

Figure 6.—Hydrogeologic section C-C'.

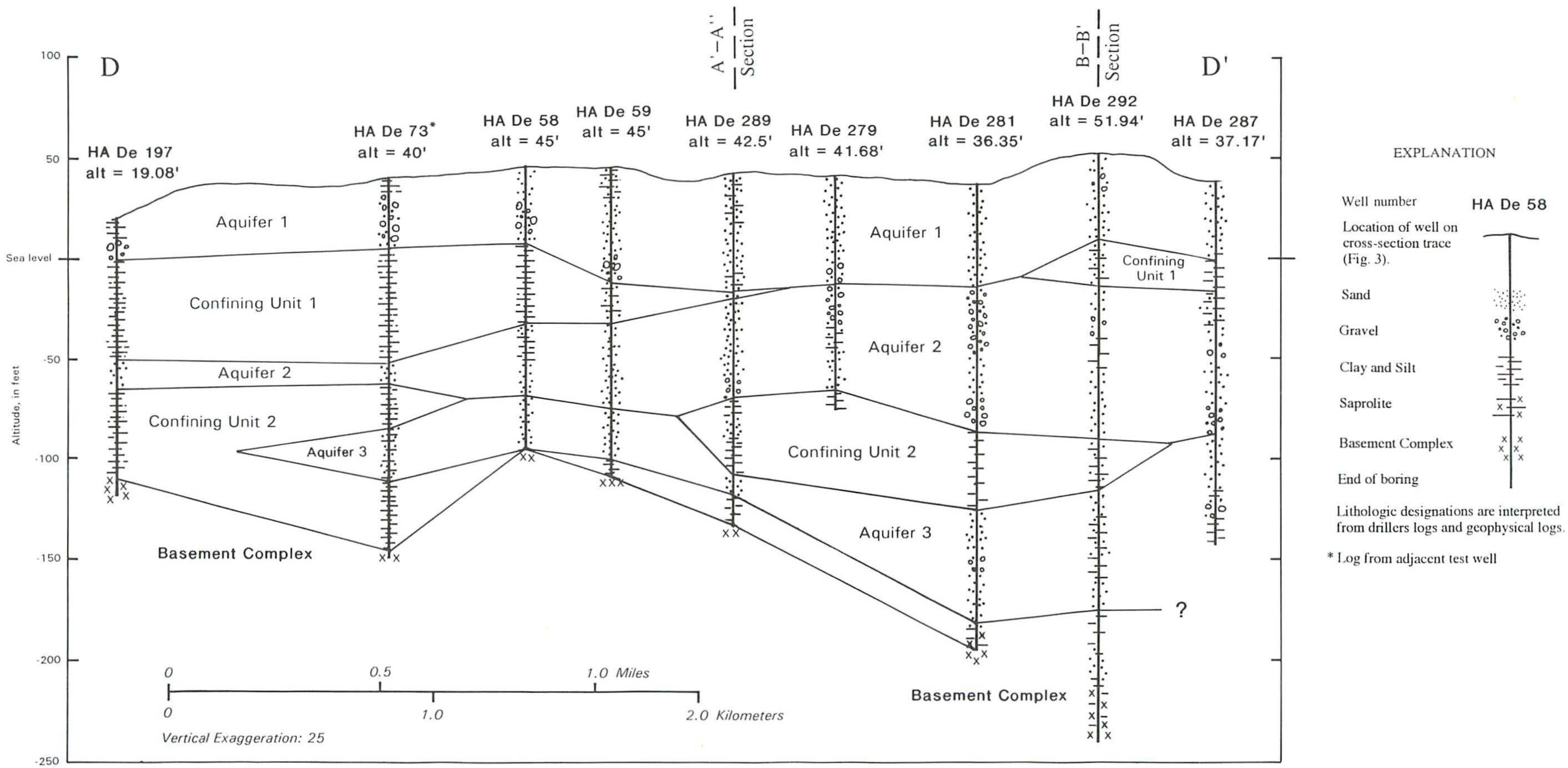

Figure 7.—Hydrogeologic section D-D′.

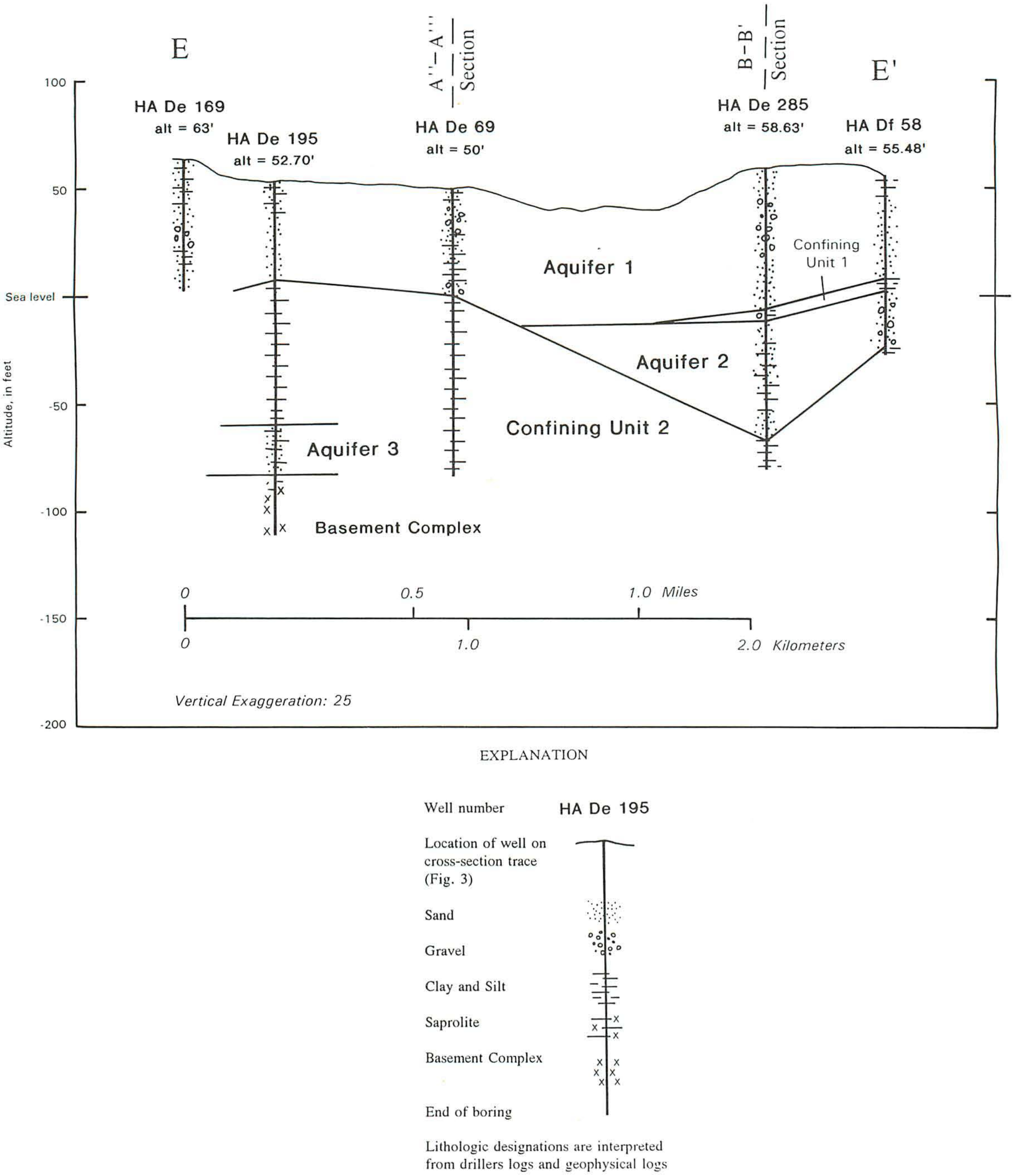

Figure 8.—Hydrogeologic section E-E′.

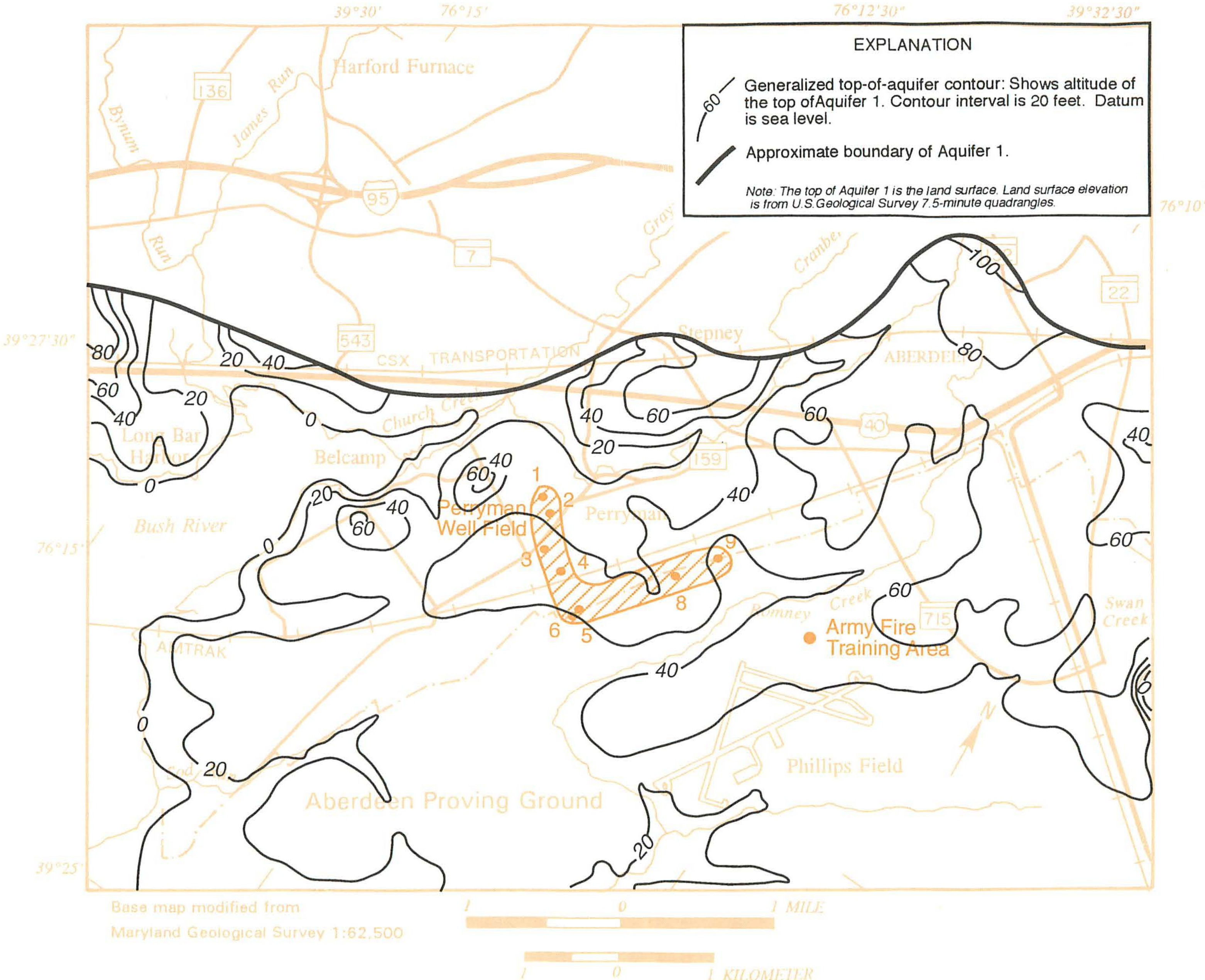

Figure 9.—Altitude of the top of aquifer 1.

confining unit 1. It supplies water to the Aberdeen well fields and numerous domestic wells.

The top of aquifer 1 is the water table, which varies with time. The maximum top of the aquifer is land surface, which is shown in figure 9. This surface ranges in altitude from sea level at the shores of Bush River and Swan Creek to about 100 ft above sea level northwest of Aberdeen. The bottom of aquifer 1 is coincident with the top of confining unit 1, and is shown in figure 10. The altitude of this surface ranges from 50 ft above sea level northwest of Aberdeen to 60 ft below sea level in the southern corner of the study area. The thickness of aquifer 1 ranges from 0 ft at its updip truncation line to about 85 ft near Long Bar Harbor.

The altitude of the water table in aquifer 1 ranges from sea level at the shores of Bush River and Swan Creek to 45 ft above sea level in the area between Aberdeen, Perryman, and AFTA (fig. 11). The pattern of water-table contours indicates that the area of high water table is a recharge zone, and water in aquifer 1 flows away from this area toward Bush River, Swan Creek, and the Chesapeake Bay. Bimonthly water-level measurements indicate the water-table altitude generally varies about 2-4 ft during the year, with highest water levels in the spring, and lowest water levels in the late fall and early winter.

The hydraulic properties of aquifer 1 are quite variable, owing to the variable nature of the sediments which it comprises. Contoured horizontal hydraulic conductivities for aquifer 1 are shown in figure 12, along with values calculated from aquifer tests and locations of well borings used to estimate hydraulic conductivity. The contoured values are final values from flow-model calibration and do not conform precisely to measured values. Modeled conductivities range from below 50 ft/d near the Fall Line to more than 250 ft/d just south of Perryman. Areas of high conductivity (over 250 ft/d) also occur east of Perryman near Phillips Field, east of Aberdeen, and near Sod Run. The specific yield is probably about 0.01 to 0.3 (Drummond and Blomquist, 1993).

Confining unit 1 underlies aquifer 1 throughout most of the study area. It consists mainly of silt and clay, but also contains some sand lenses. It ranges in thickness from less than 10 ft to over 50 ft just southwest of Perryman. The leakance of confining unit 1 was estimated from thickness and lithologic character shown in drillers' logs, and from model calibration. Areas of equal leakance from final model calibration are shown in figure 13. Leakance in most of the study area is 0.0001 d^{-1}, and ranges up to 1.0 d^{-1} in several areas in the central part of the study area where the confining unit is either very thin or sandy. Confining unit 1 is very thin or absent at wells 5, 6, and 9 (De 77, 76, and 64) (fig. 4b). In these areas aquifers 1 and 2 are hydraulically connected. Unlike the hydraulic conductivity data and interpretation, the poorer quality leakance data prevent interpolation of leakance across the study area.

Aquifer 2

Aquifer 2 is a semi-confined to confined aquifer which underlies aquifer 1. Where confining unit 1 is very thin or absent, aquifer 2 is semi-confined or possibly even unconfined. It extends throughout most of the southern part of the study area, and consists predominantly of sand and gravel, with some areas of low-permeability silt and clay. It receives recharge mostly as leakage from aquifer 1, but also receives some recharge as leakage from aquifer 3 and from overlying estuaries. It supplies water to wells 1, 5, 6, 8, and 9 (De 73, De 77, De 76, De 67, and De 64) in the Perryman well field, and a portion of the water for the well supplying Price Brothers (De 28). It also supplies water for many domestic and small commercial wells.

The top of aquifer 2 coincides with the bottom of confining unit 1, and ranges in altitude from about 80 ft below sea level in the southern corner of the study area to sea level at the Army Fire Training Area (fig. 14). The bottom of aquifer 2 coincides with the top of confining unit 2, and ranges in altitude from 120 ft below sea level at the southeastern boundary of the study to 20 ft below sea level near the Army Fire Training Area (fig. 15). The thickness of aquifer 2 ranges from 0 ft at its updip truncation line to about 105 ft near Phillips Field.

The altitude of the potentiometric surface in aquifer 2 ranges from about sea level near Sod Run to about 33 ft above sea level near AFTA (fig. 16). The pattern of potentiometric contours indicates that the area near AFTA is a recharge zone, and water flows away from this area toward Bush River, Swan Creek, the Chesapeake Bay, and the Perryman well field. The potentiometric mound near the AFTA is caused primarily by the topographic high and resultant high water-table elevation in that area.

The transmissivity of aquifer 2 ranges from less than 500 ft^2/d near Long Bar Harbor, where it is a silty sand, to more than 32,000 ft^2/d near Phillips Field and southeast of Perryman, where it is a clean, coarse sand and gravel (fig. 17). Drummond and Blomquist (1993), cited values of 0.0002 and 0.30 for storativity and porosity respectively, for aquifer 2, which are typical for confined aquifers.

Confining unit 2 underlies aquifer 2. It ranges in thickness from virtually 0 ft near the Bush River to more than 100 ft north of Phillips Field.The leakance of confining unit 2 was estimated from thickness and lithologic character shown in drillers' logs, and from model calibration. Areas of equal leakance from final model calibration are shown in figure 18. Leakance in most of the study area is 0.00001 d^{-1}, and ranges up to 0.1 d^{-1} in the central part of the study area where the confining unit pinches out or is moderately sandy.

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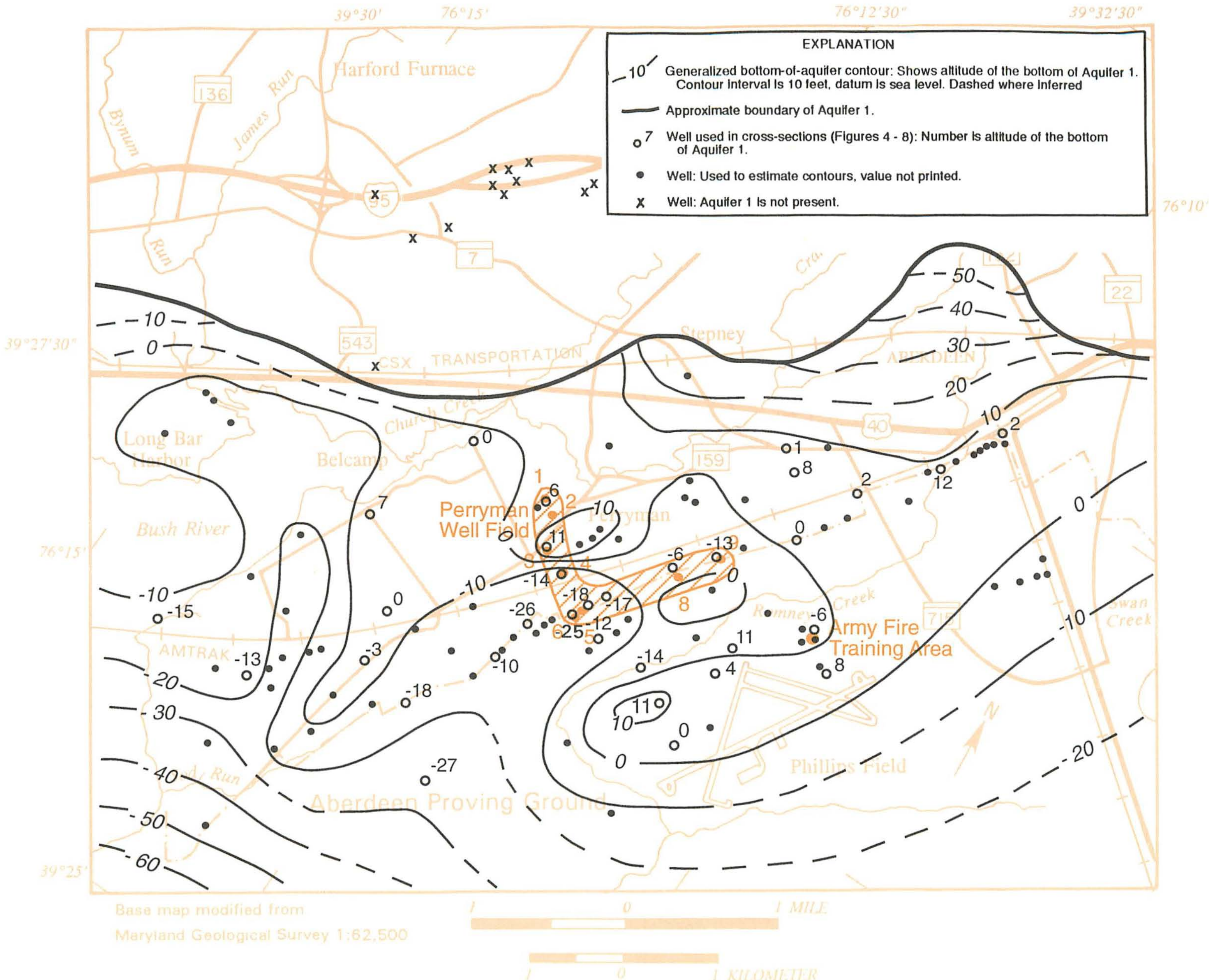


Figure 10.—Altitude of the bottom of aquifer 1.

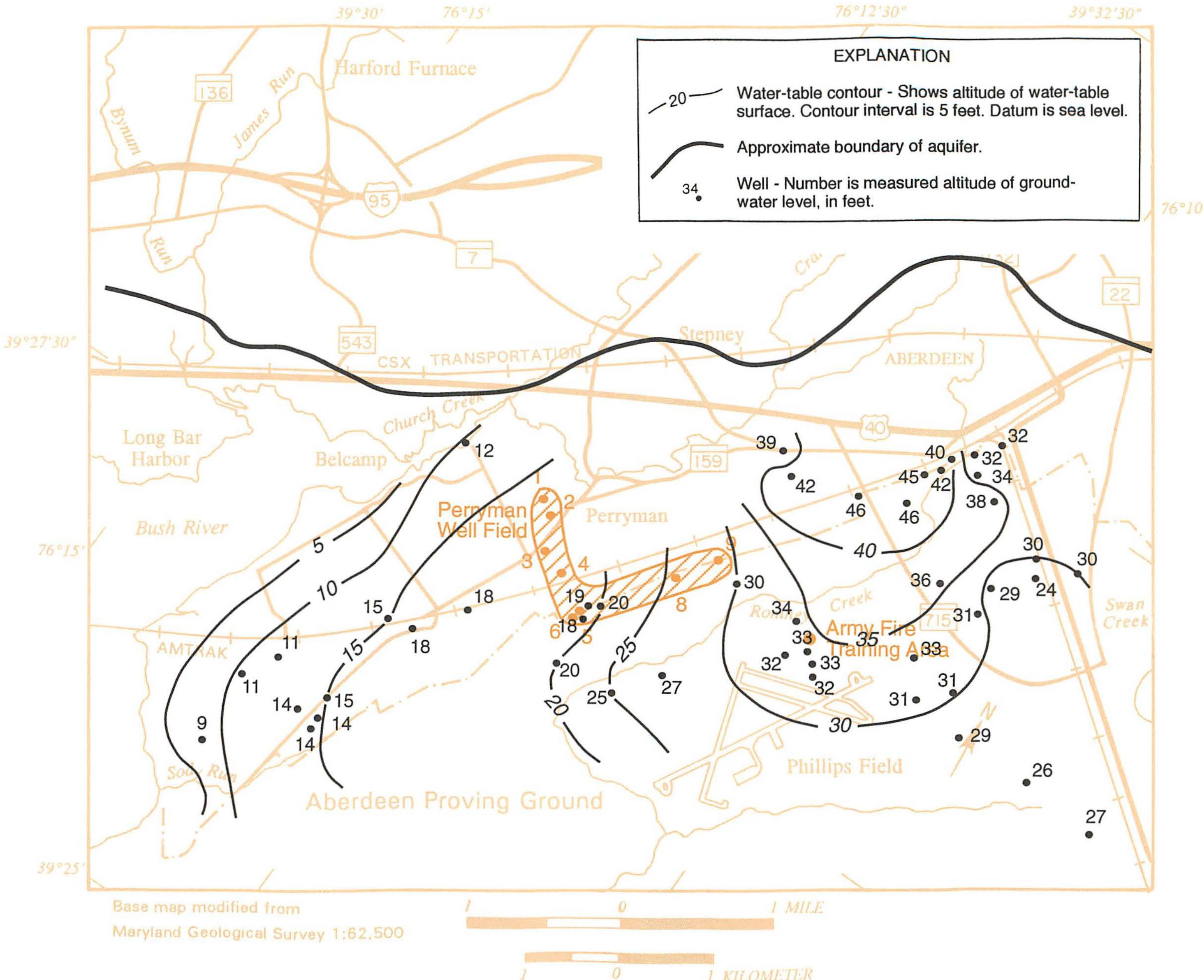


Figure 11.—Altitude of the water table in aquifer 1, June 1994.

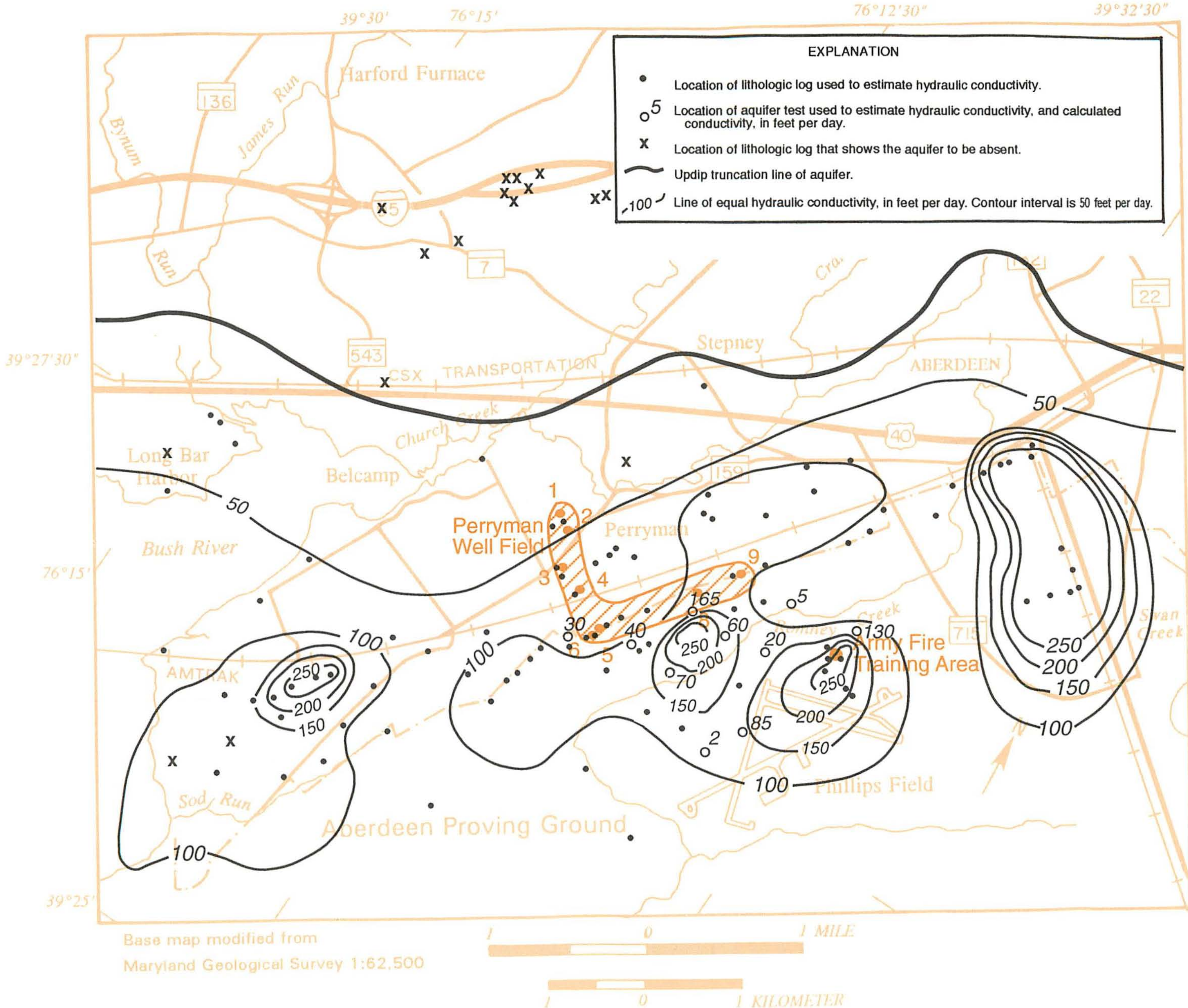


Figure 12.—Hydraulic conductivity of aquifer 1.

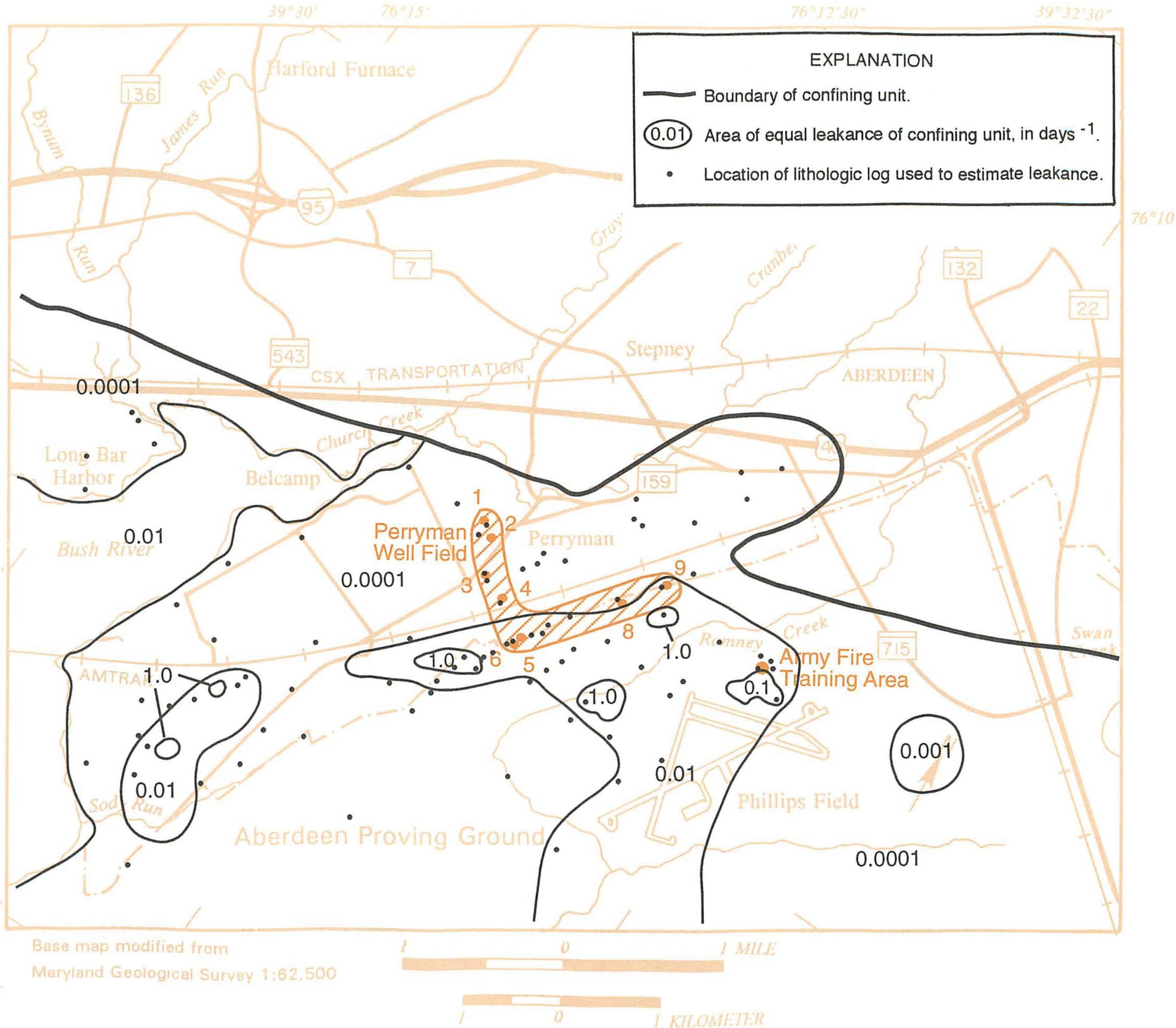


Figure 13.—Leakance of confining unit 1, based on lithologic logs and model calibration.

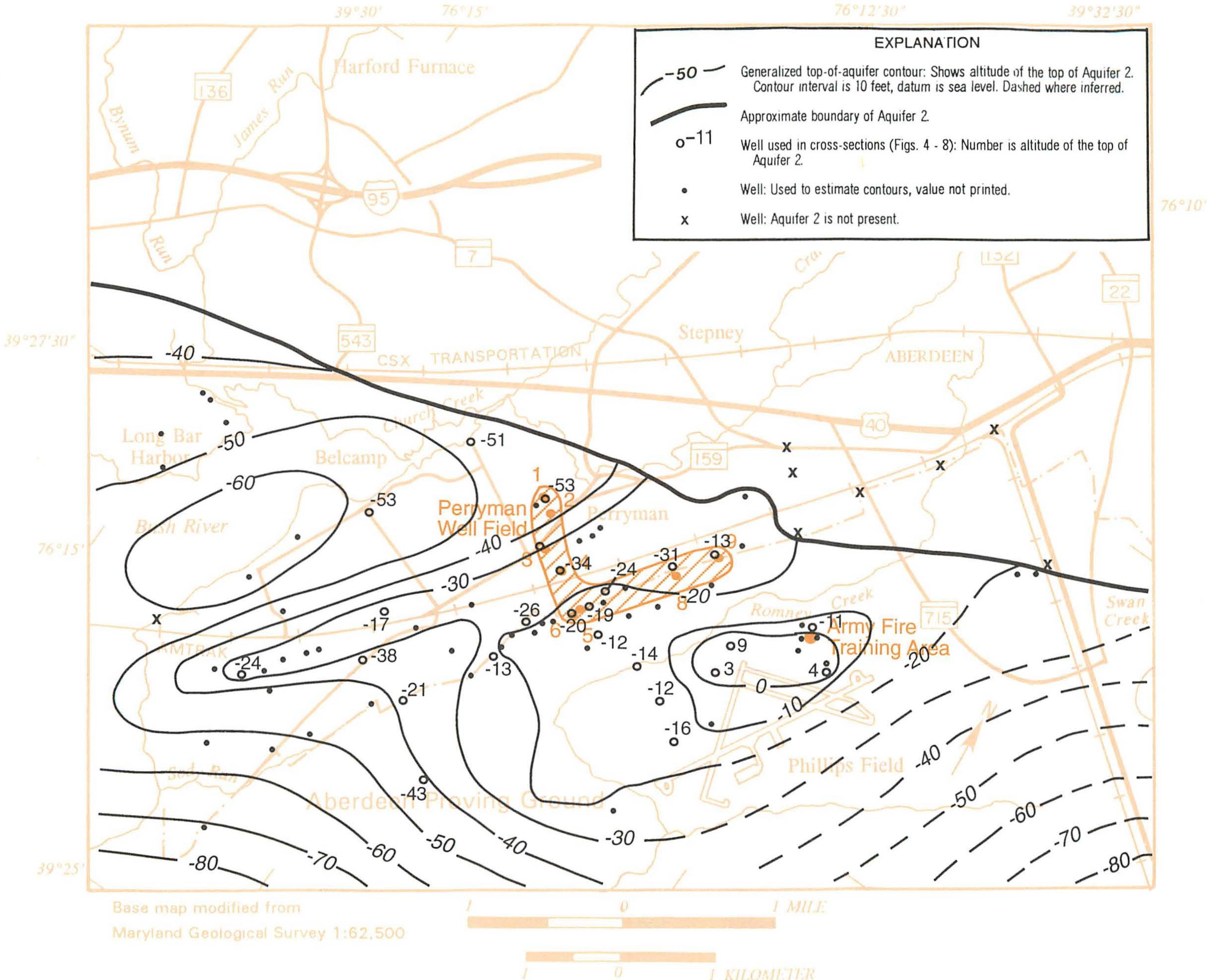


Figure 14.—Altitude of the top of aquifer 2.

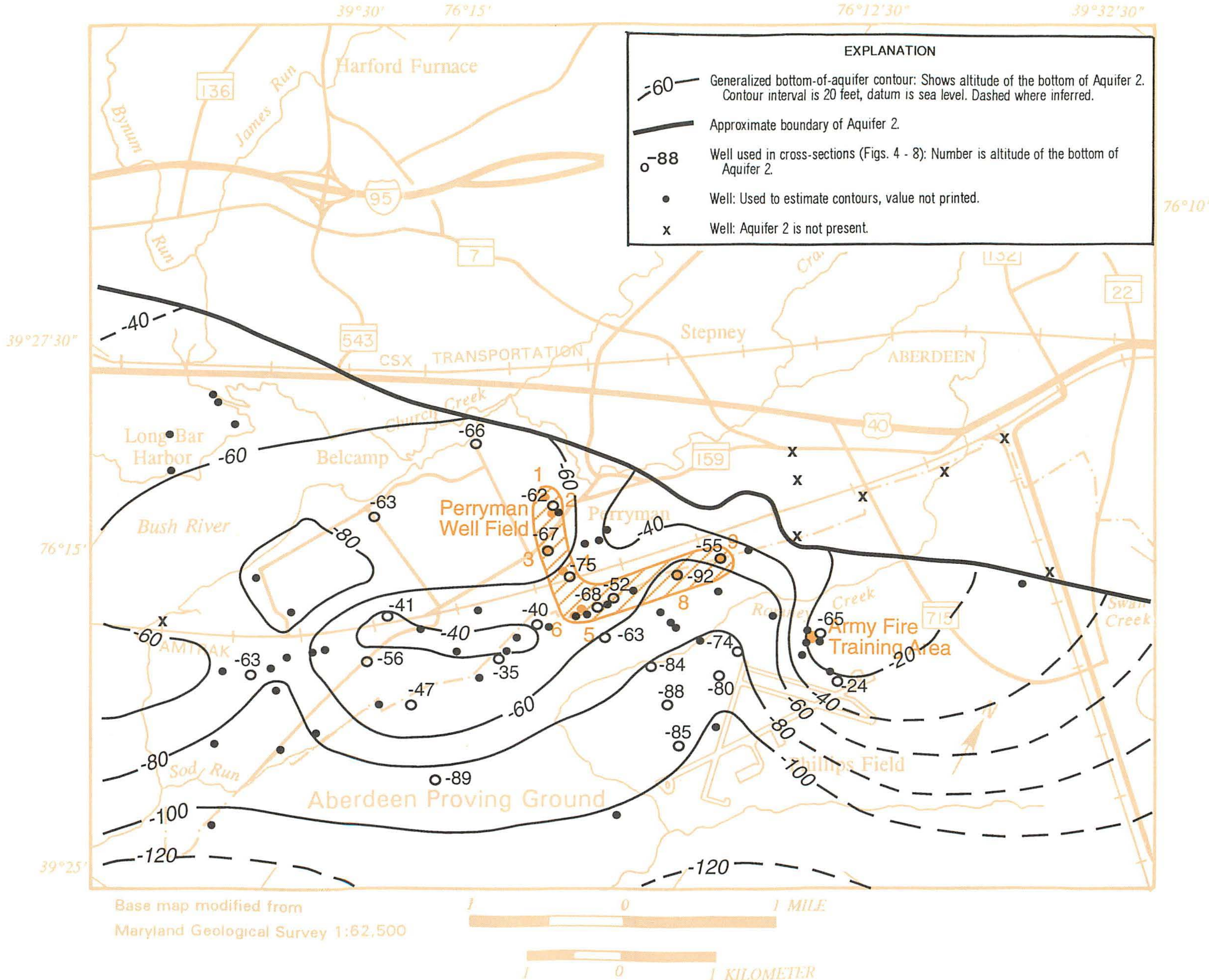


Figure 15.—Altitude of the bottom of aquifer 2.

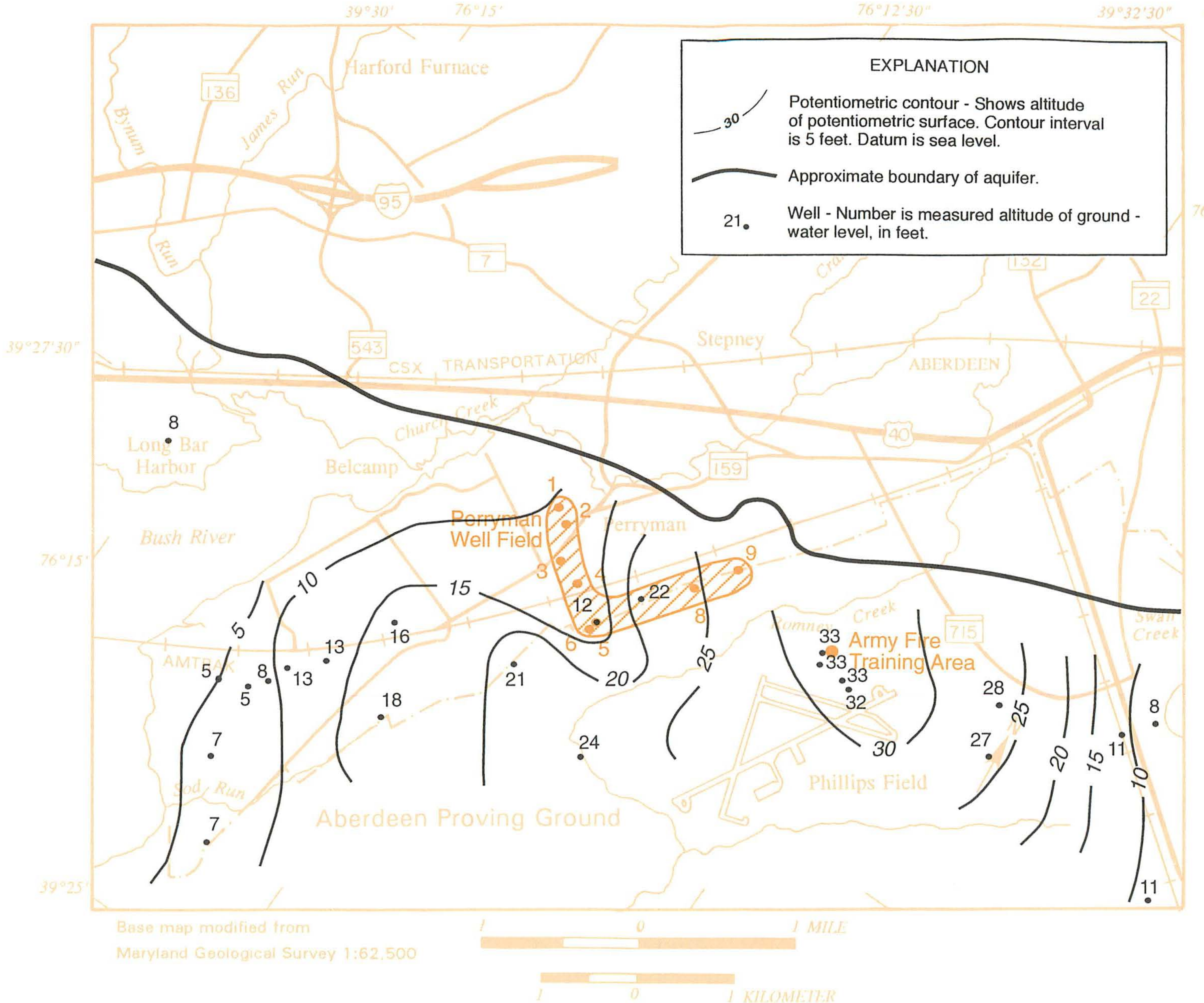


Figure 16.—Altitude of the potentiometric surface in aquifer 2, June 1994.

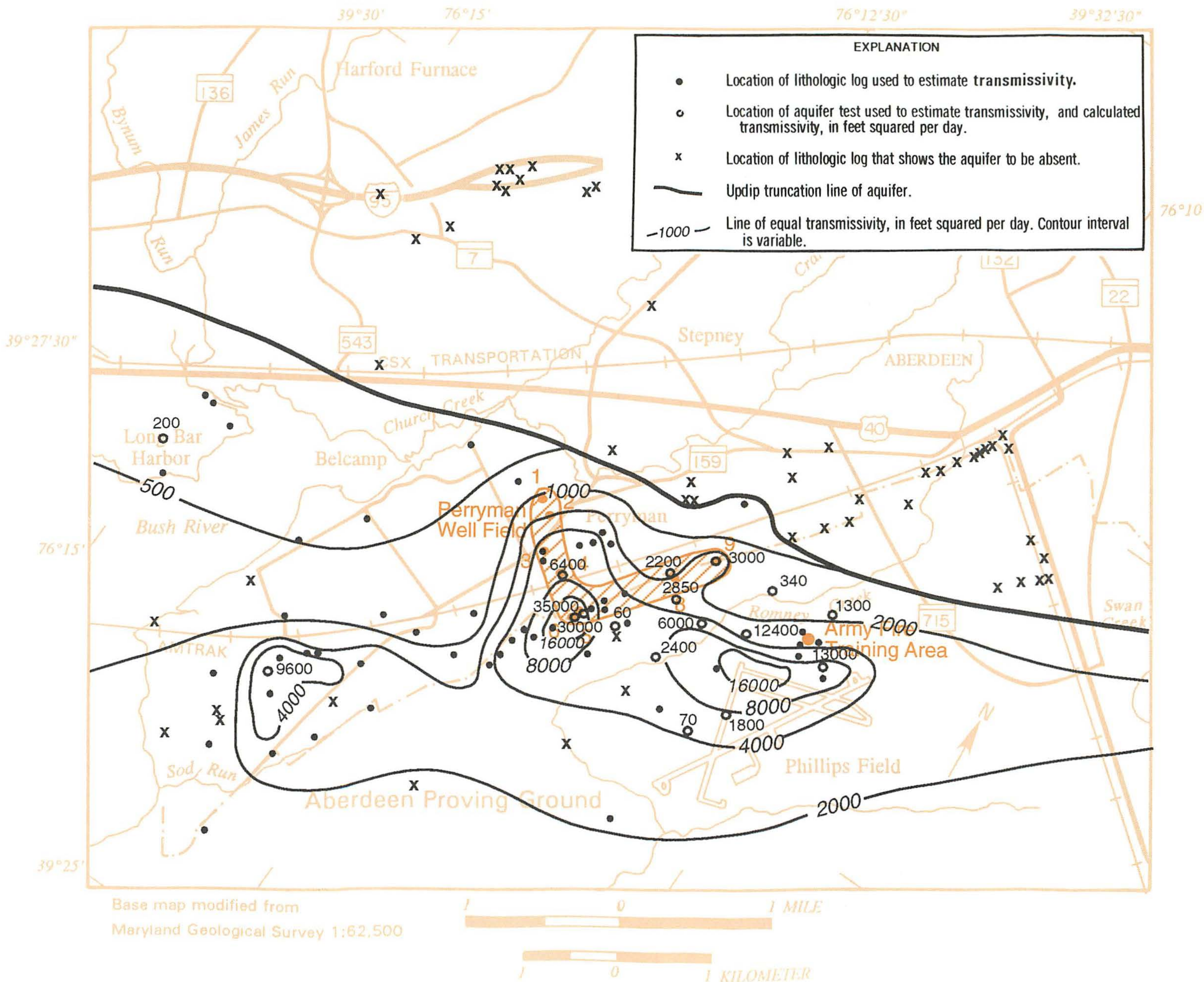


Figure 17.—Transmissivity of aquifer 2.

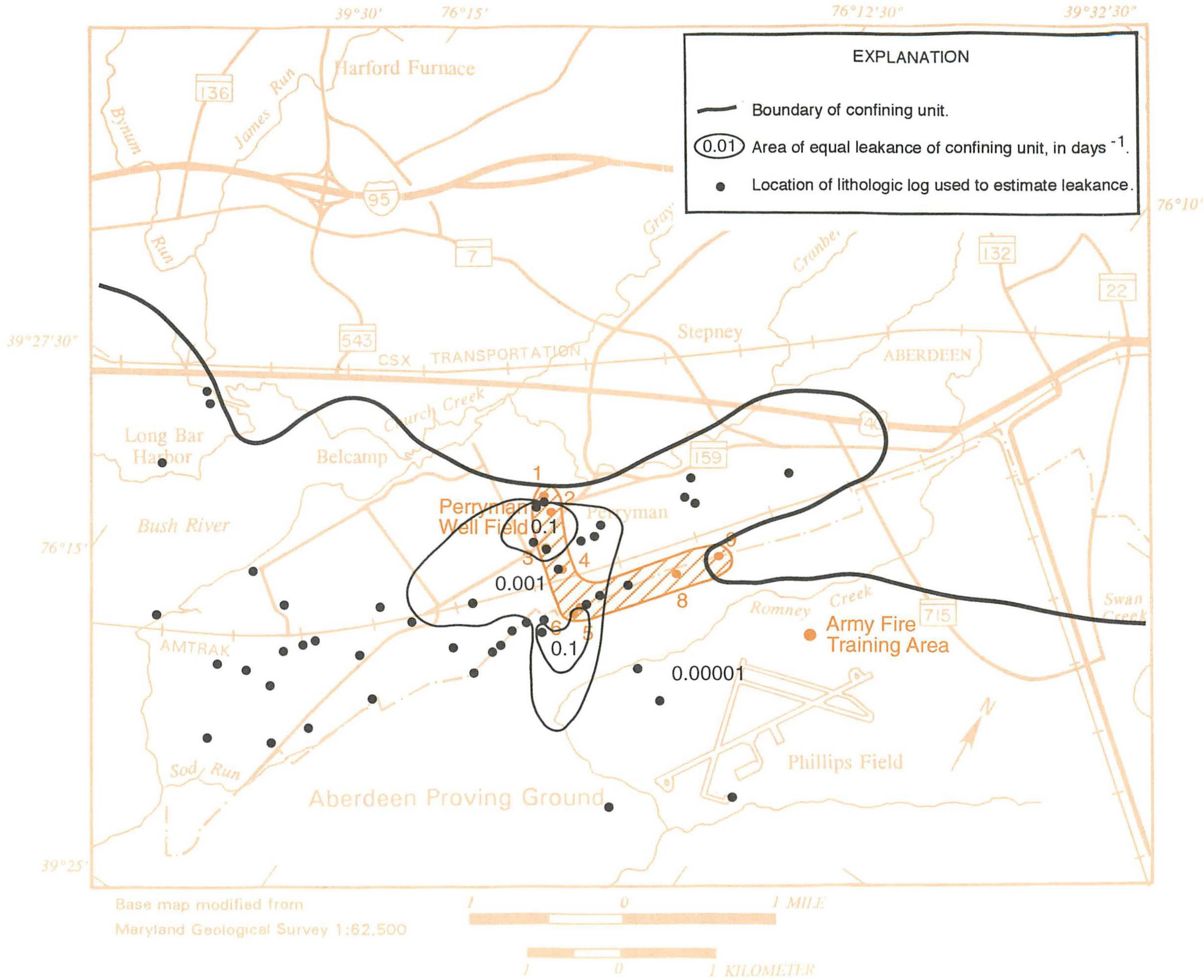


Figure 18.—Leakance of confining unit 2, based on lithologic logs and model calibration.

Aquifer 3

Aquifer 3 is a confined aquifer that underlies aquifer 2. It generally consists of coarse sand and gravel, but also contains some areas of fine sand, silt, and clay. Most of the water in aquifer 3 enters as leakage from aquifer 2, but some water also enters directly from aquifer 1 (where aquifer 2 is absent). Some water may also enter aquifer 3 from underlying sediments and bedrock, but the amount is probably insignificant due to the low permeability of those materials. Aquifer 3 supplies water to wells 2, 3, and 4 (De 75, De 58, and De 59) in the Perryman well field, and a portion of the well supplying water for Price Brothers (De 28). It also supplies water for some domestic and small commercial wells.

The top of aquifer 3 coincides with the bottom of confining unit 2, and ranges in altitude from about 200 ft below sea level in the southern corner of the study area to about 60 ft below sea level north of Perryman (fig. 19). The bottom of aquifer 3 ranges in altitude from 240 ft below sea level in the southern corner of the study area to 80 ft below sea level near Perryman (fig. 20). Its thickness ranges from 0 ft at its updip truncation line to about 100 ft near Perryman.

The potentiometric surface in aquifer 3 ranges from about 7 ft above sea level near the Bush River to about 25 ft above sea level just north of Perryman (fig. 21). The potentiometric surface indicates that the aquifer is primarily recharged in the northeastern part of the study area, water flows toward the southwest, and discharges up into aquifer 2 near the Bush River and to wells.

The transmissivity of aquifer 3 ranges from less than 50 ft^2/d near the updip truncation line to over 3,700 ft^2/d south of Perryman (fig. 22). Drummond and Blomquist (1993), cited values of 0.0002 and 0.30 for storativity and porosity respectively, for aquifer 3, which are typical for confined aquifers.

RECHARGE AND DISCHARGE

Recharge, discharge, and ground-water flow components for the Harford County Coastal Plain were calculated by Drummond and Blomquist (1993). Some of these values will be different for the Perryman study area because of different boundary conditions and differing proportions of estuaries and streams in the two areas. Drummond and Blomquist (1993) calculated values of 18 to 23 in./yr for recharge, 11 in./yr for evapotranspiration, 6 in./yr for base flow, and 3 in./yr for pumpage in 1989.

PUMPAGE

Total ground-water pumpage in the Coastal Plain part of the Perryman study area was about 3.6 Mgal/d in 1994, and included domestic, commercial, industrial, and public-supply usage. Ground-water users pumping more than 10,000 gal/d are required to submit pumpage amounts to the Maryland Water Resources Administration (Department of Natural Resources)[1]. These figures are shown in figure 23 for the period 1989 through 1994. Pumpage decreased about 23 percent during this period, due primarily to a decrease in pumpage from the Perryman well field. An increasing percentage of Harford County's water supply has been obtained from the Susquehanna Aqueduct in recent years. Locations of major production wells are shown in figure 24. Pumpage prior to 1989 was described by Drummond and Blomquist (1993). Pumpage amounts are shown in the flow-modeling section of this report.

Most of the ground-water usage in the Perryman area is for public supply. The Perryman well field produced about 3.7 Mgal/d in 1991, the year of maximum pumpage, and 2.2 Mgal/d in 1994. The wells in the Perryman well field are screened in aquifers 2 and 3, and screened intervals of the wells range from 45 to 192 ft below land surface (fig. 25). Two well fields for the town of Aberdeen produced about 1.3 Mgal/d in 1994. Several hundred homes in the Perryman area obtain their water supply from individual domestic wells. This pumpage probably amounts to less than 0.1 Mgal/d, or about 2 percent of total pumpage at most, and is dispersed throughout the area between APG and Route 40. Commercial and industrial pumpage amounted to about 0.2 Mgal/d.

GROUND-WATER CONTAMINATION

Ground water in the Perryman area has been contaminated with low levels of nitrate and VOC's (volatile organic compounds), particularly TCE (trichloroethene). Nitrate concentrations in water from wells in the Perryman well field have been as high as 24 mg/L as nitrogen at well 4 (De 59) (fig. 26), and generally range between 1 and 15 mg/L. The U.S. EPA MCL (maximum contaminant level) is 10 mg/L as nitrogen. Nitrate concentrations are generally higher in water from wells 1, 2, 3, 4, and 9 (De 73, 75, 58, 59, and 64) than in water from wells 5, 6, and 8 (De 77, 76, and 67) (fig. 26). Nitrate concentrations in water from all 8 wells in the well field show a slight downward trend in the three years of available data. By mixing water from wells with lower and higher nitrate concentrations, county water-supply operators are able to provide finished water below the MCL.

The dissolved nitrate probably comes from fertilizer applied to corn fields in the general vicinity of Perryman. Much of the area between the Bush River and APG has been cultivated in the past, primarily in corn and soy beans. As shown

(Text continued on p. 33.)

[1]This agency was renamed the Water Rights Division and transferred to the Maryland Department of Environment in 1995.

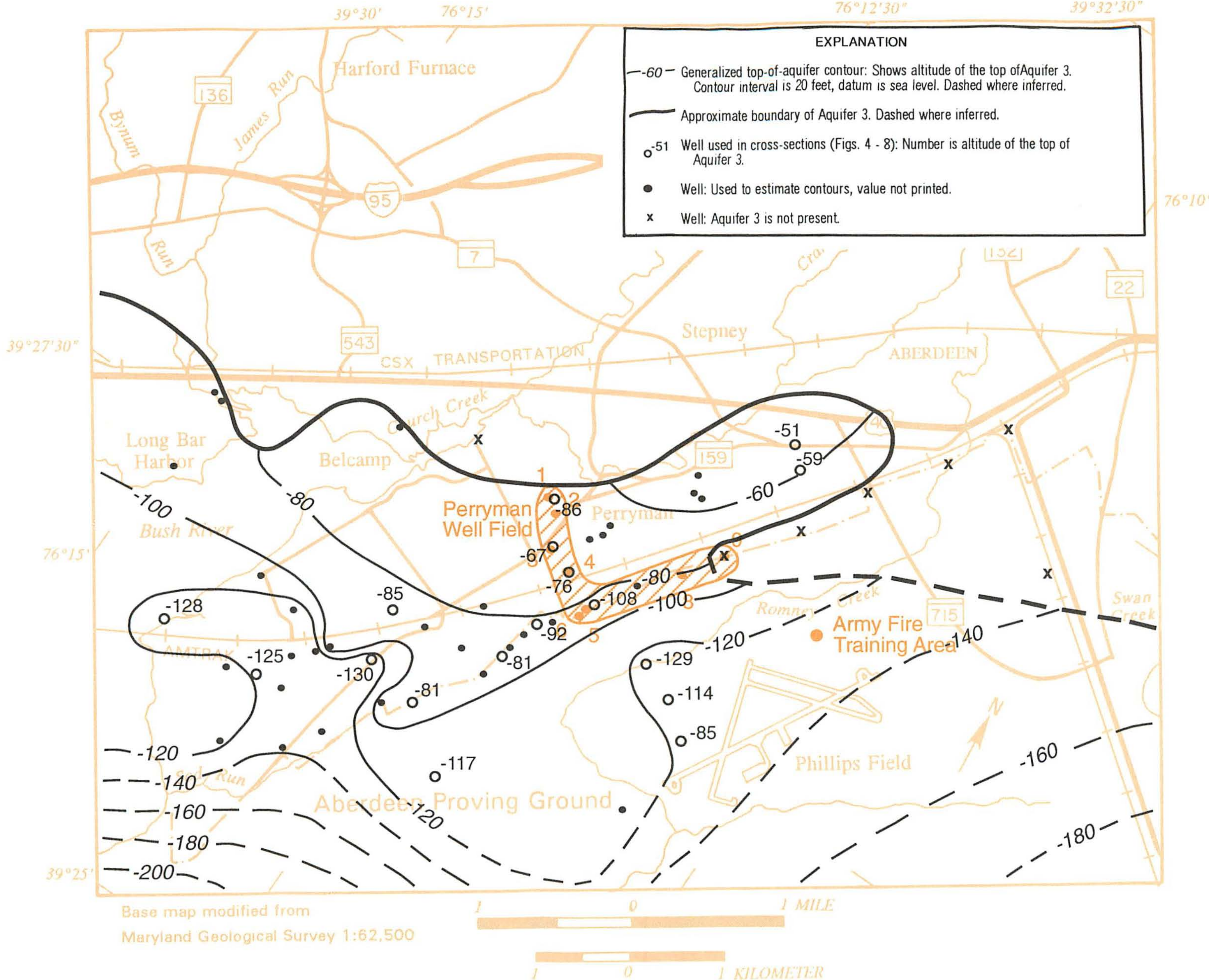


Figure 19.—Altitude of the top of aquifer 3.

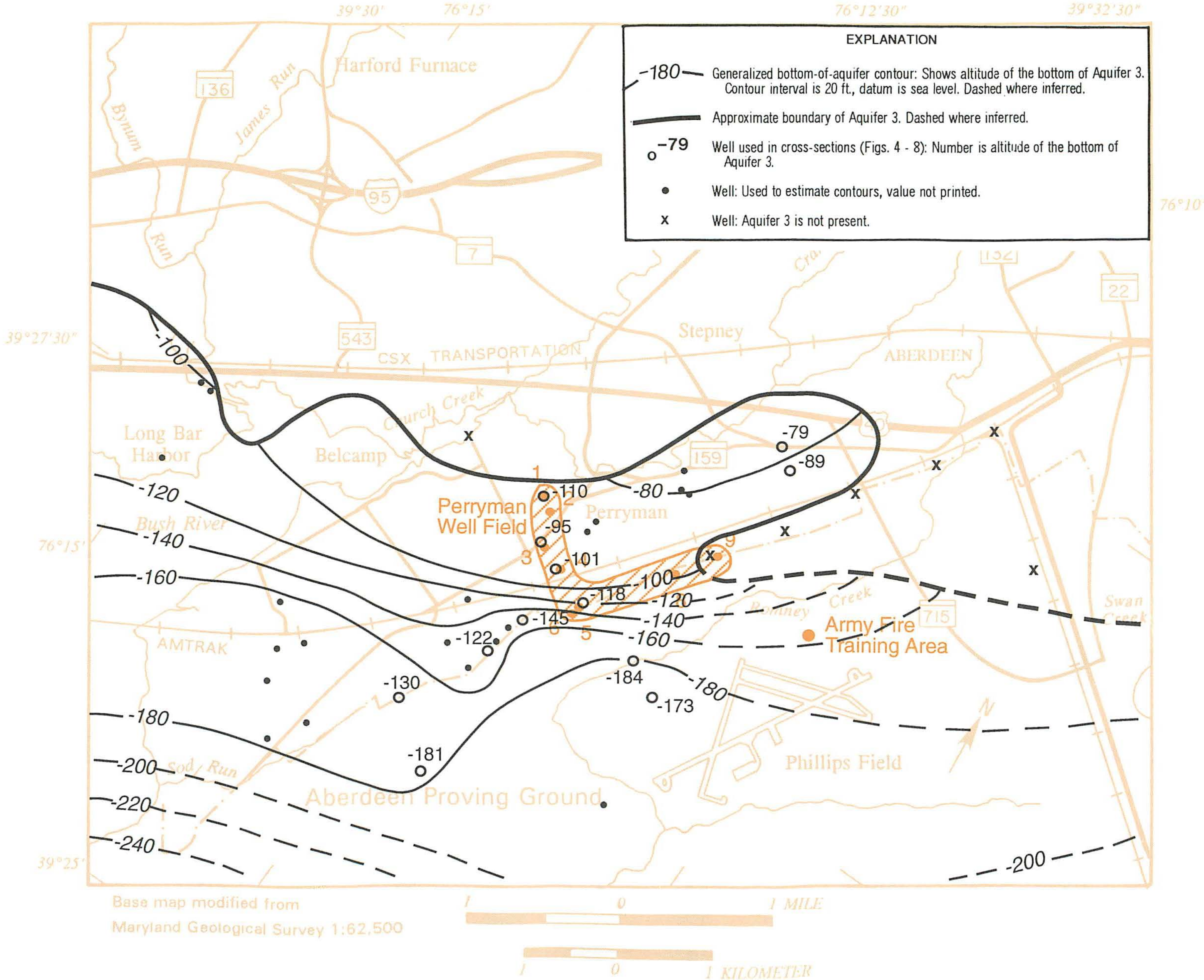


Figure 20.—Altitude of the bottom of aquifer 3.

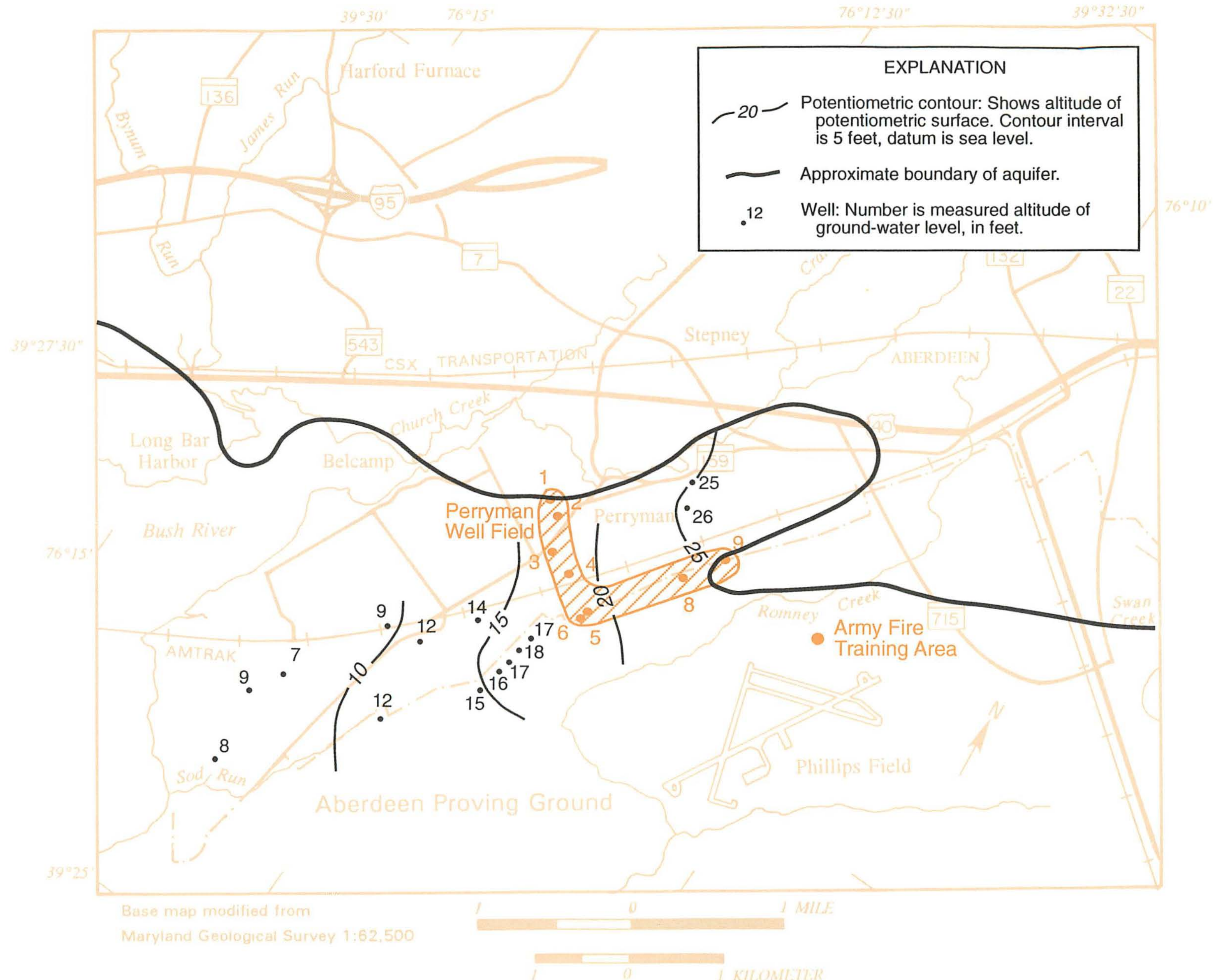


Figure 21.—Altitude of the potentiometric surface in aquifer 3, June 1994.

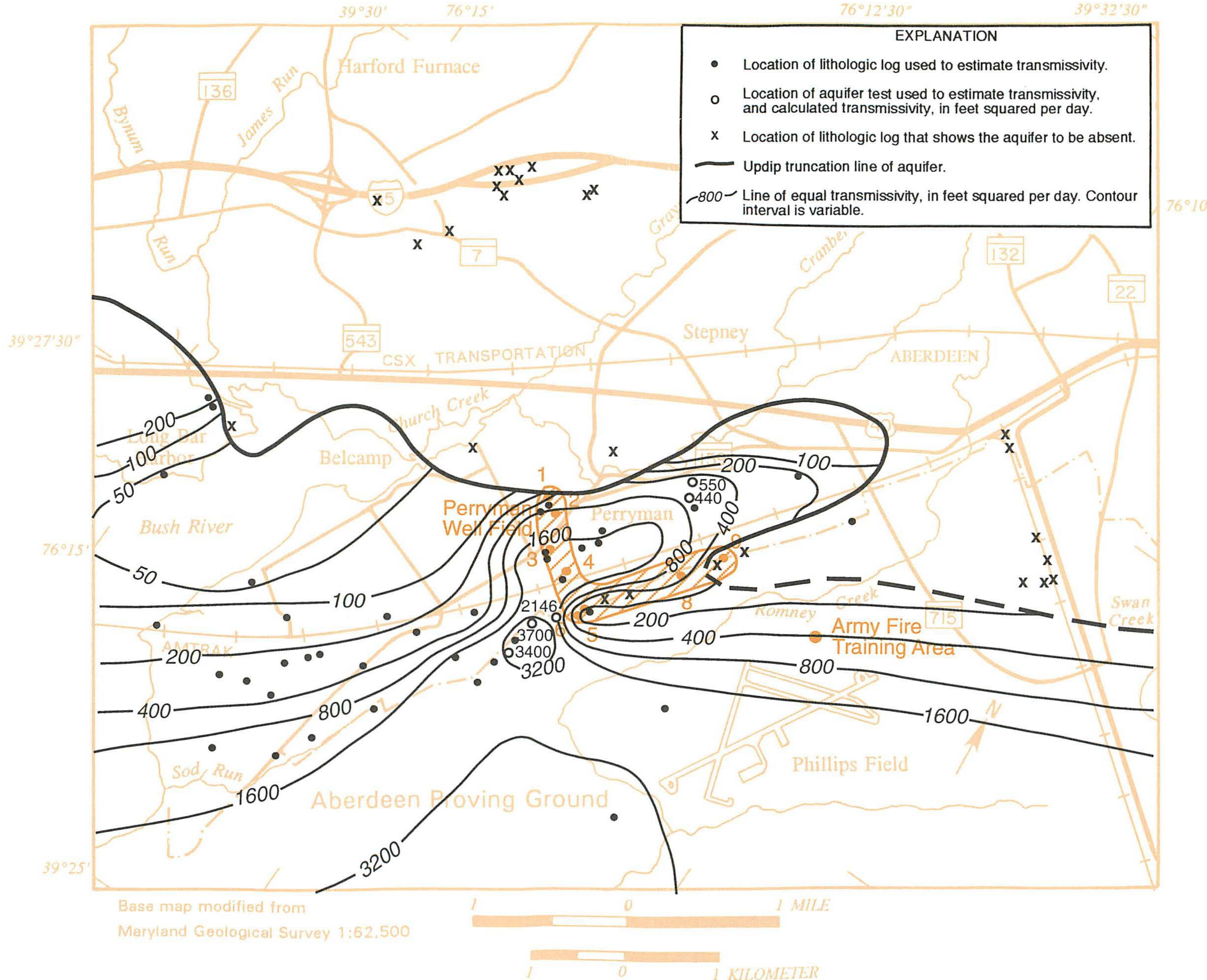
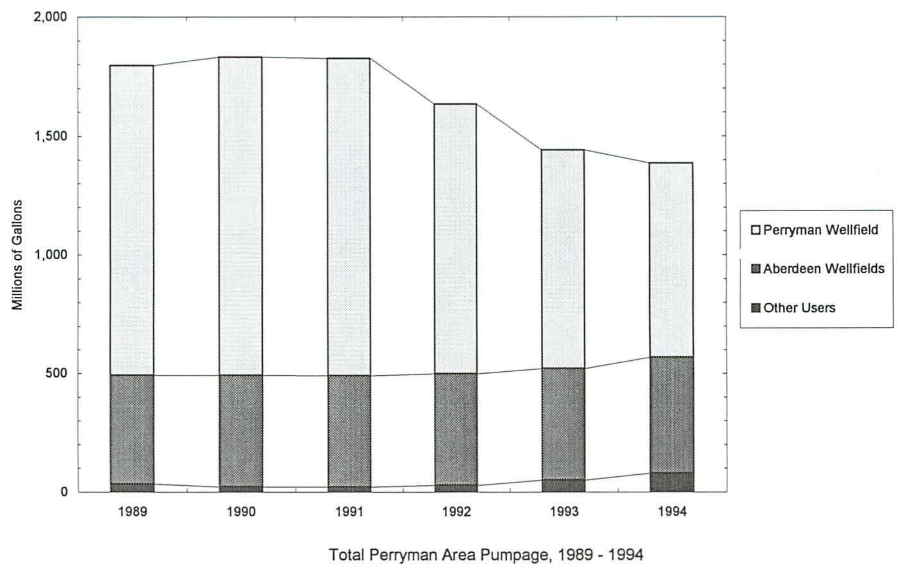


Figure 22.—Transmissivity of aquifer 3.



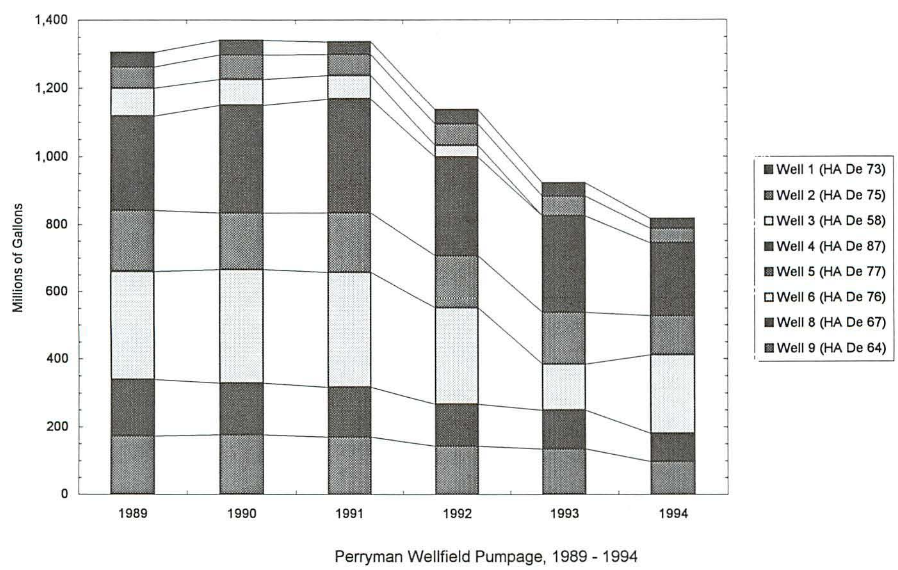


Figure 23.—Ground-water pumpage in the Perryman area, 1989 to 1994.

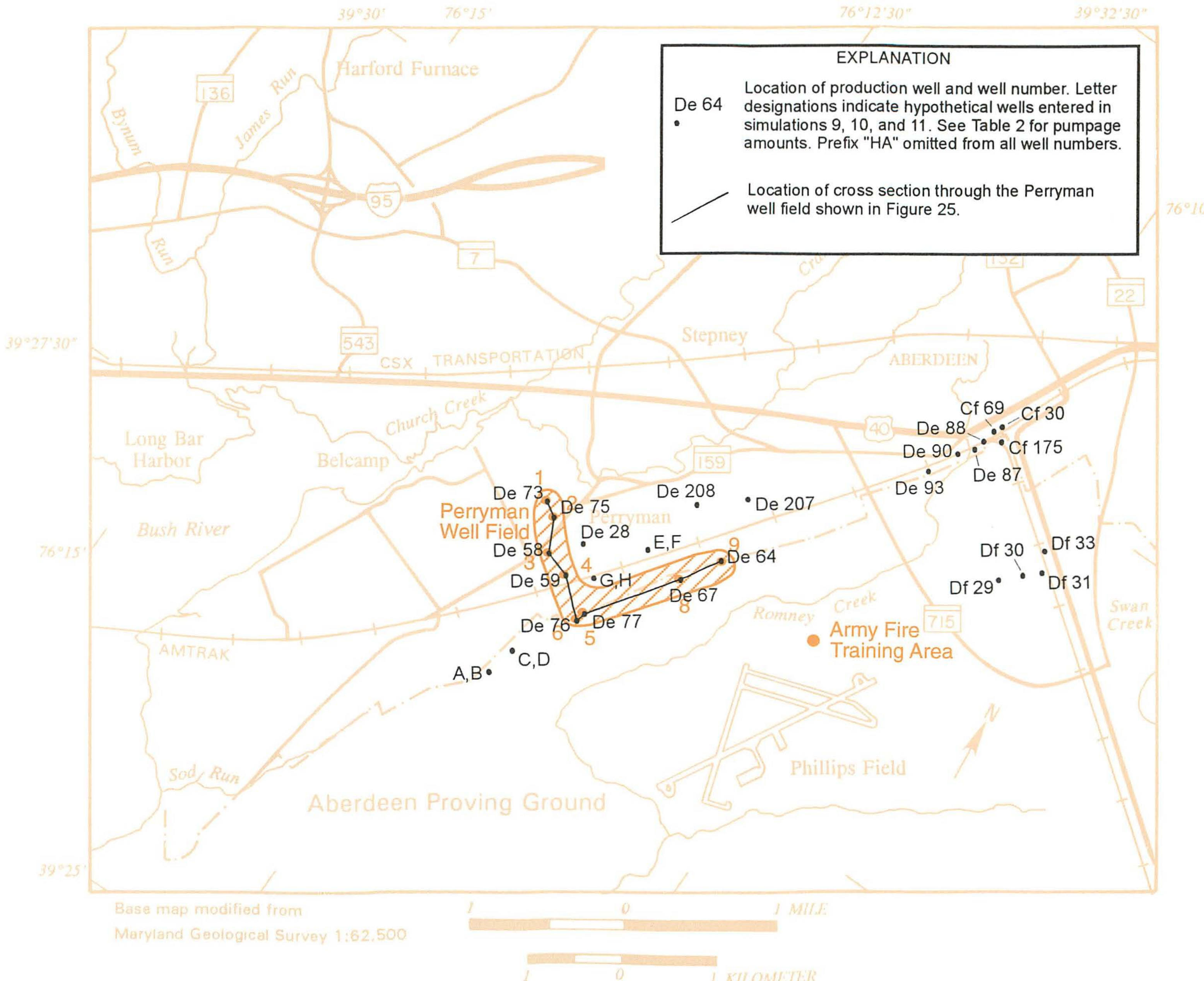


Figure 24.—Locations of production wells simulated in the flow model, and location of cross section through the Perryman well field.

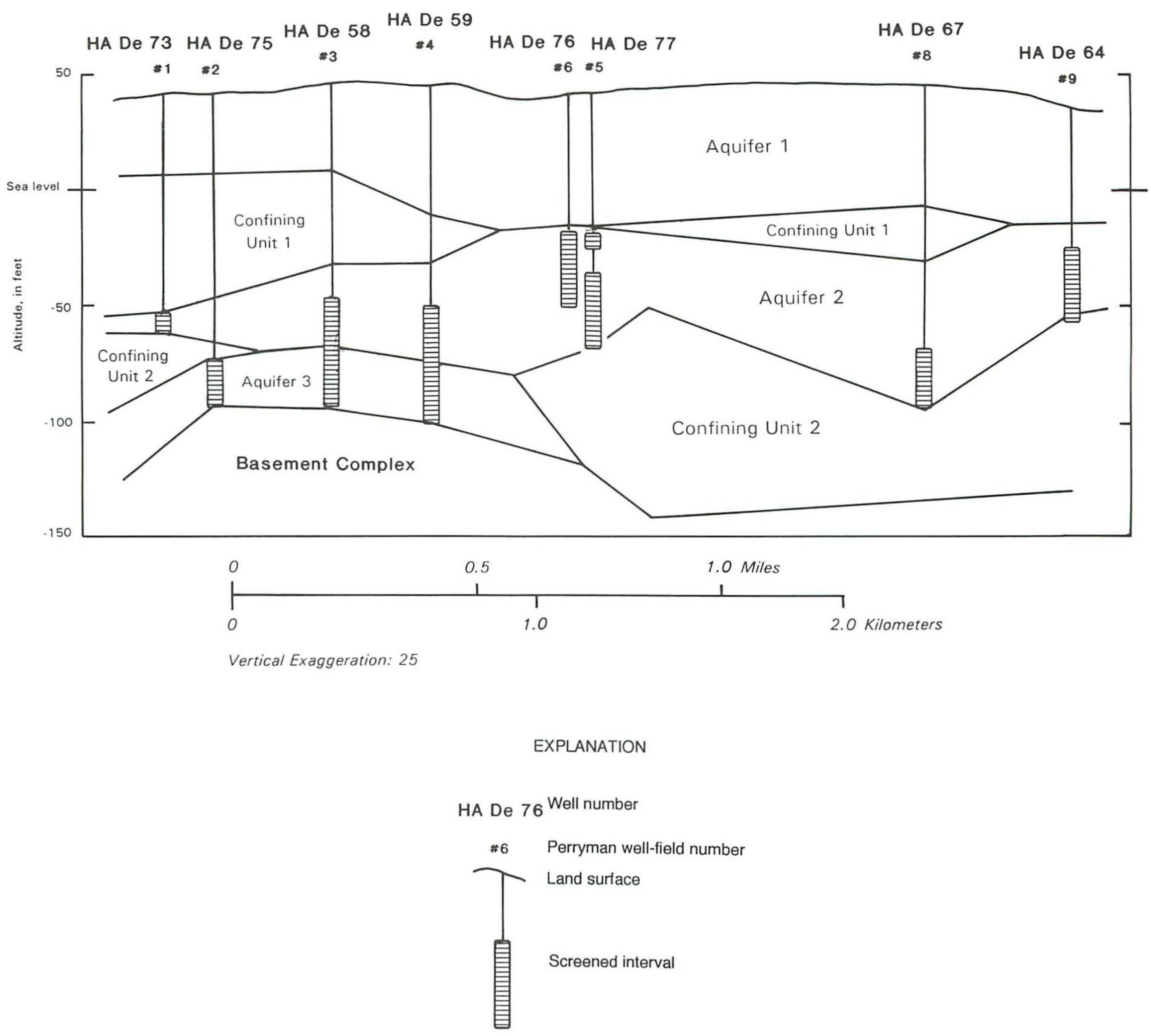


Figure 25.—Cross section through the Perryman well field.

in later sections of this report, much of this agricultural area coincides with the contributing area of the Perryman well field. Nitrate may also come from septic systems.

TCE has been detected in water from wells 5 (De 77) and 6 (De 76) in concentrations as high as 18 μg/L in well 6 in December 1993. Initial sampling in February 1992 showed TCE concentrations of 2 and 6 μg/L for water from wells 5 and 6 respectively (the U.S. EPA maximum contaminant level for TCE is 5 μg/L). Concentrations in both wells increased slightly through the end of 1992 when pumpage from well 6 was temporarily discontinued. At that point TCE concentrations increased rapidly in well 5 to 13 μg/L in May 1993. When pumpage from well 6 was resumed in June 1993, TCE concentrations in well 5 decreased to previous levels by January 1994, whereas concentrations in well 6 generally increased to 12 μg/L in December 1994.

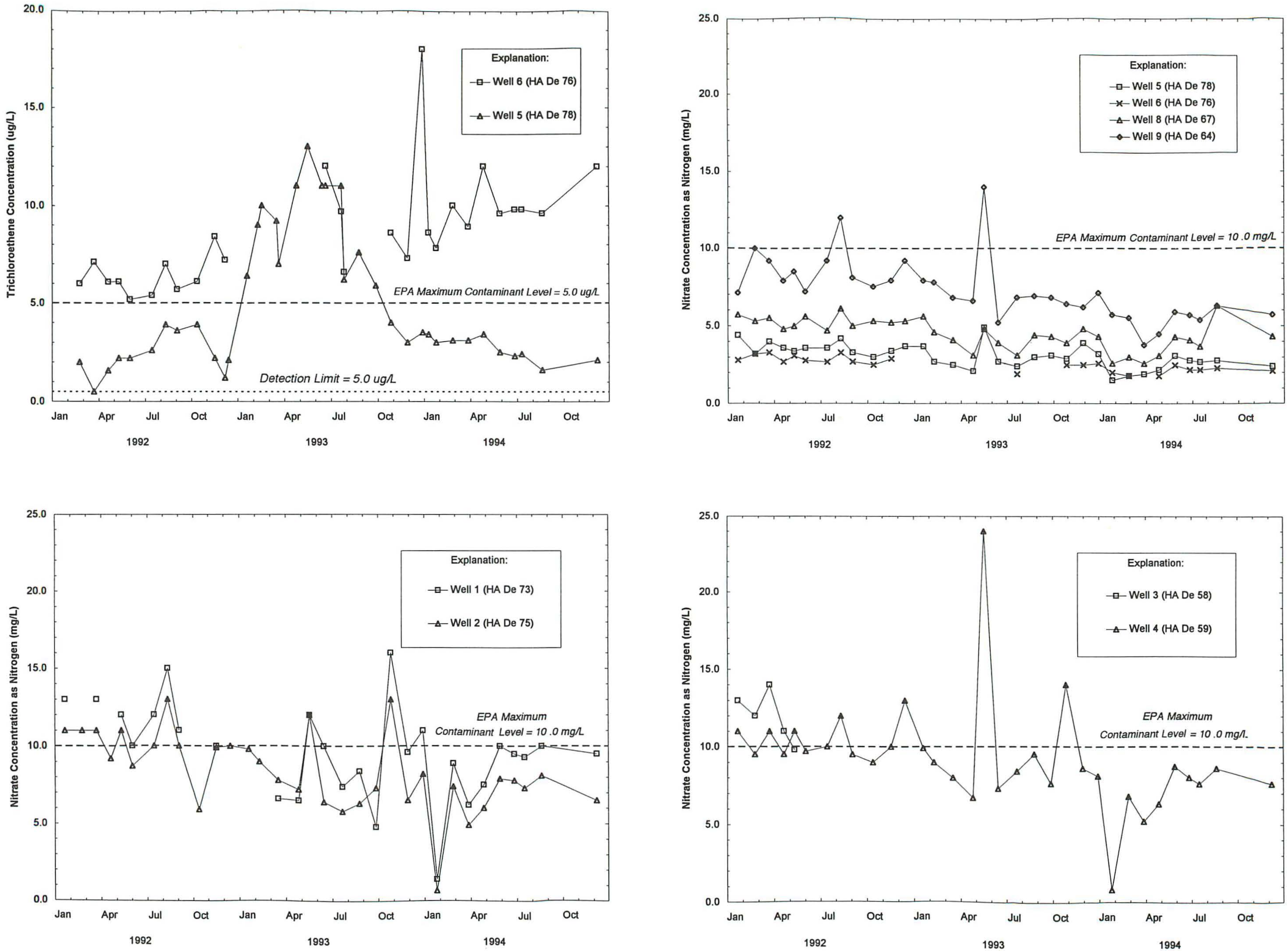


Figure 26.—Nitrate and TCE concentrations of water from wells in the Perryman well field, January 1992 to December 1994.

ESTIMATION OF CONTRIBUTING AREAS FOR THE PERRYMAN WELL FIELD

The land-surface area that provides recharge to a well is of great importance to resource managers, because any contaminants that are spilled or released in that area might eventually migrate to the well. These contributing areas must be protected from contamination in order to minimize the potential for contamination of the drinking-water supply. The contributing areas of the wells in the Perryman well field were estimated using a particle-tracking program which estimates the subsurface paths of water particles or conservative contaminant particles as they flow through the ground-water system. The particle-tracking program used output from a ground-water flow model, so the development of the flow model was a preliminary step.

The flow model was first set up and calibrated to historical and present (1994) conditions, then run to simulate any desired future conditions, such as projected pumpage amounts or drought conditions. Heads and flux values were calculated by the model, and written to output files. The particle-tracking program then read the output from the flow model, and calculated the paths of a specified set of particles. The particle-tracking program was run in forward-tracking mode to estimate the movement of water from AFTA, and in backward-tracking mode to estimate contributing areas of wells in the Perryman well field.

GROUND-WATER FLOW MODEL

A ground-water flow model was developed to estimate the response of ground-water levels to future pumpage scenarios, and to provide input for the particle-tracking program. The U.S. Geological Survey's MODFLOW program was used for all simulations. MODFLOW is a quasi-three-dimensional finite-difference flow model, and was run on a Data General UNIX workstation.

The three aquifers in the Perryman area were simulated as active model layers (fig. 27) and the two intervening confining units were simulated as vertical leakage between the aquifer layers. Aquifer 1 was simulated as an unconfined model layer, and receives water as recharge, and discharges water as evapotranspiration, and can gain or lose water as baseflow to streams. Aquifer 1 also represents the Bush River and Swan Creek as specified-head boundaries with heads at

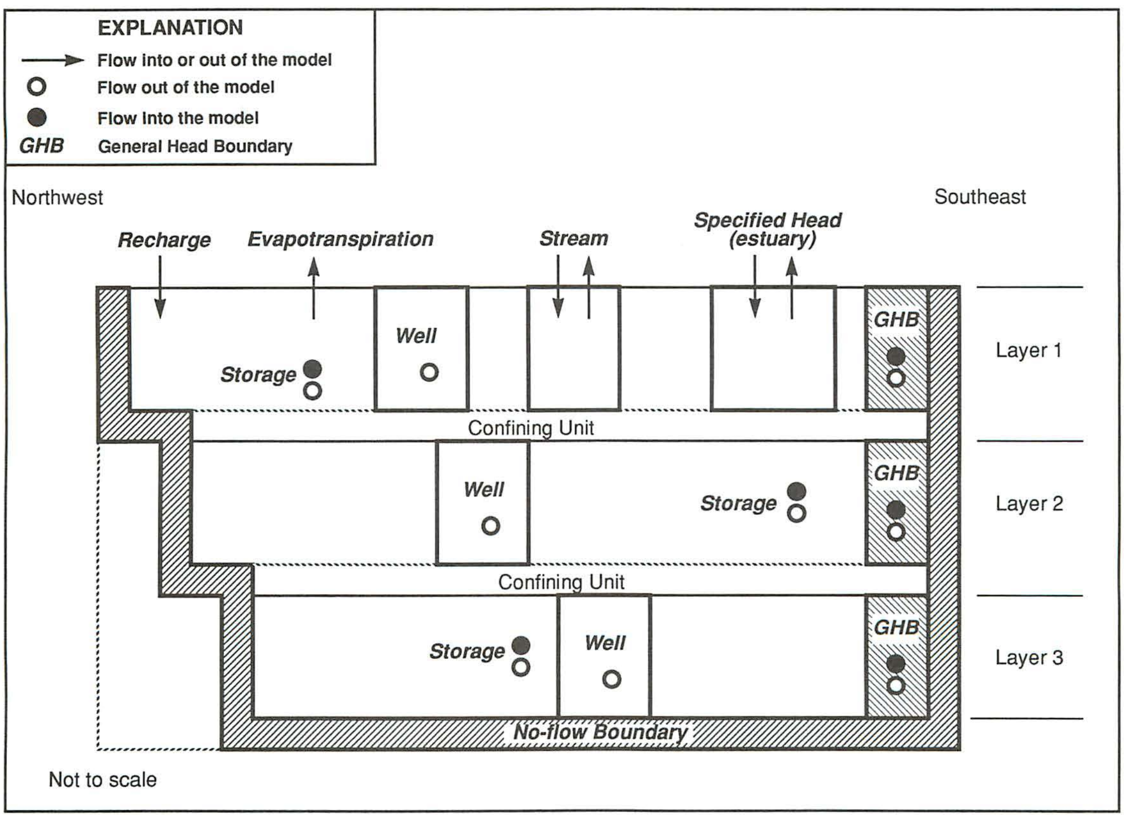


Figure 27.—Schematic diagram showing the ground-water flow model setup.

sea level. Aquifers 2 and 3 were simulated as confined model layers which receive recharge and discharge as leakage through confining layers and from lateral (general-head) boundaries. All model layers discharge water as pumpage to wells, and can gain or lose water to storage.

Grid Design

The finite-difference grid used in the flow-model simulations is 5.7 mi by 7.0 mi, with 58 rows, 99 columns, and 3 layers (fig. 28). Cell dimensions range in size from 200 ft square to 2,025 ft by 4,556 ft. Finer grid spacing was used in the Perryman area to provide better control in the area of critical importance. The long axis of the model grid was oriented about 34.5 degrees north of east to match the angle of the regional flow model. The model area coincides with the maximum possible contributing area to the Perryman well field, as delineated by Drummond and Blomquist (1993, p. 94-96).

Time Discretization

Model simulations were divided into stress periods, which are time periods during which pumpage and all other hydraulic stresses were kept constant. The first stress period was 1,000 years long (966 through 1965), and simulated hydrologic conditions before there was significant pumpage in the area. This unusually long prepumping stress period was required to backtrack some particles that had rather long travel times. Stress period 2 was 10 years long (1966 to 1975) and represents the period in which the Perryman well field was constructed, and pumped at about 40 percent of its present capacity. The third stress period was 12 years long (1976 to 1987) and simulates the Perryman well field pumping at 85 percent of its present capacity. Stress periods 4 through 10 represent one year each, and simulate pumpage estimated from files on record at the Maryland Water Resources Administration[2], and from records maintained by well operators.

Boundary Conditions

Boundary conditions were applied to the edges of the model to simulate flow or heads at those boundaries (figs. 29, 30, and 31). The top boundary of the modeled ground-water system is the water table which receives water as recharge, discharges water as evapotranspiration, and may gain or lose water to streams and estuaries. Recharge is a specified flux component, and was simulated with the Recharge package of MODFLOW. Evapotranspiration is a head-dependent flux component, and was simulated with the ET package. Base flow to and from streams is also a head-dependent flux component, and was simulated with the River package. Flow to and from estuaries is a head-dependent-flux component and was simulated by setting model cells in estuaries as constant-head cells (with a head at sea level) and allowing flow through confining unit 1.

The bottom of the model was simulated as a no-flow boundary. This boundary represents either bedrock or tight clays in the Potomac Group, both of which are impermeable relative to the aquifers in the study area (Drummond and Blomquist, 1993).

The sides of the model were simulated as head-dependent flux boundaries with the General Head Boundary package. Head and conductance values for each boundary cell were calculated from the regional flow model (Drummond and Blomquist, 1993) for points 1,000 ft outside the model boundary. The up-dip truncation line for each aquifer was simulated as a no-flow boundary.

Input Data

Recharge and evapotranspiration data from the regional flow model (Drummond and Blomquist, 1993) were used in this model. Recharge was specified as 0.0041 ft/d (18 in./yr). A maximum ET rate was specified as 0.0041 ft/d (18 in./yr) when the water level in a cell was within 3 ft of the land surface, and the ET extinction depth was specified as 8 ft below land surface. A linear relation was used by the model to calculate ET rate when the water level in a cell was between 3 ft and 8 ft below land surface. Hydraulic conductivity for aquifer 1, transmissivity for aquifers 2 and 3, and leakance for confining units 1 and 2 are shown in the Hydrogeology section of this report. Historical pumpage data were taken from Drummond and Blomquist (1993) and updated for current conditions with records from the former Maryland Water Resources Administration and operators' records.

Stream stages were estimated from topographic maps. Stream conductances were calculated for each stream cell with the equation (McDonald and Harbaugh, 1988)

$$C = KLW/M, \tag{1}$$

where

C = conductance (ft^2/d),
K = hydraulic conductivity of the streambed material (ft/d),
L = sum of lengths of stream reaches (ft),
W = average width of stream reaches (ft),
M = average thickness of stream bed (ft).

Stream lengths in each cell were calculated using a GIS, widths were estimated from a topographic map, and all streambed thicknesses were estimated to be 2 ft. Hydraulic conductivity of the stream bed material was estimated to be

[2]Records currently on file at the Maryland Department of Environment (Water Rights Division).

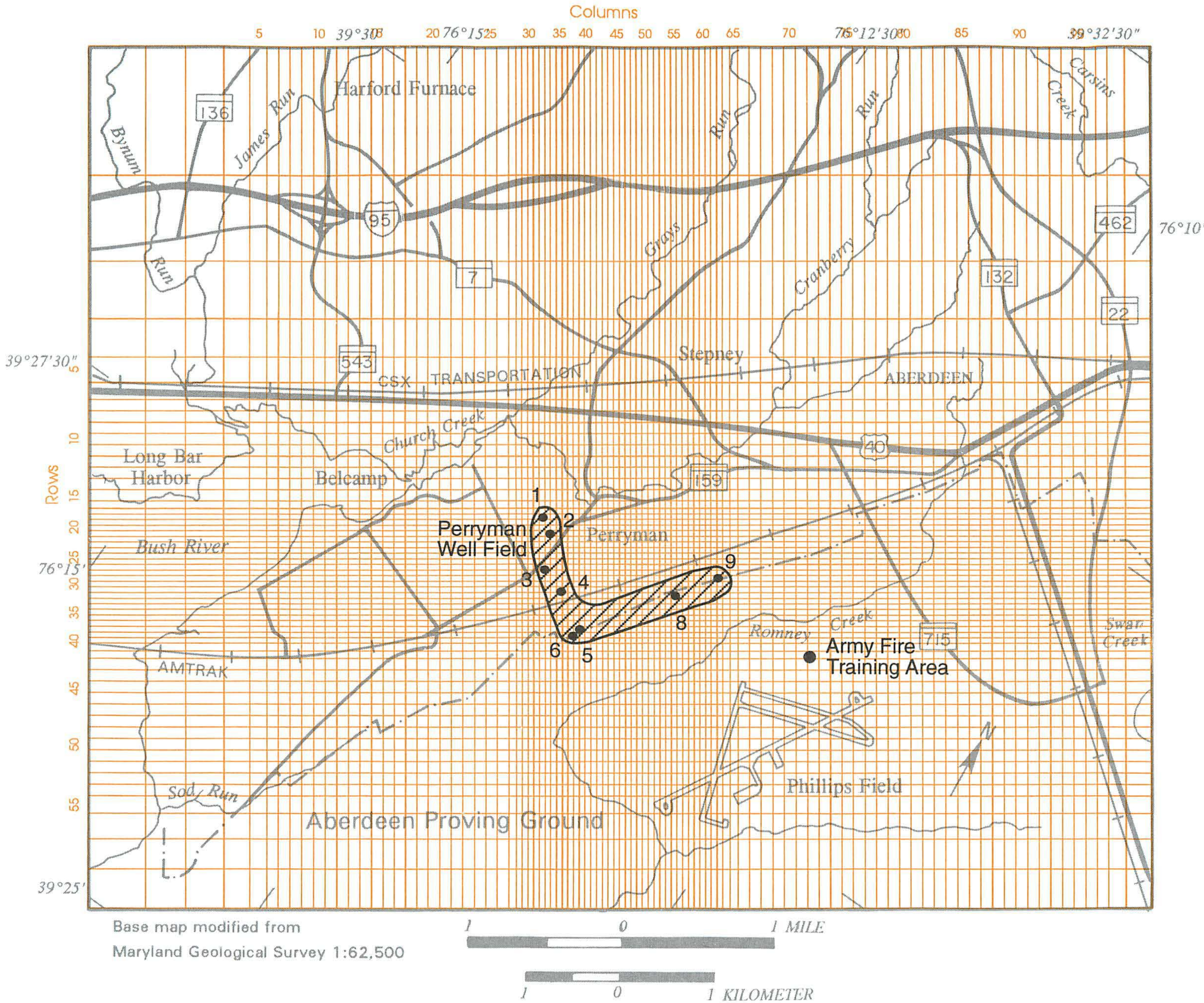


Figure 28.—Finite-difference grid used in the flow model.

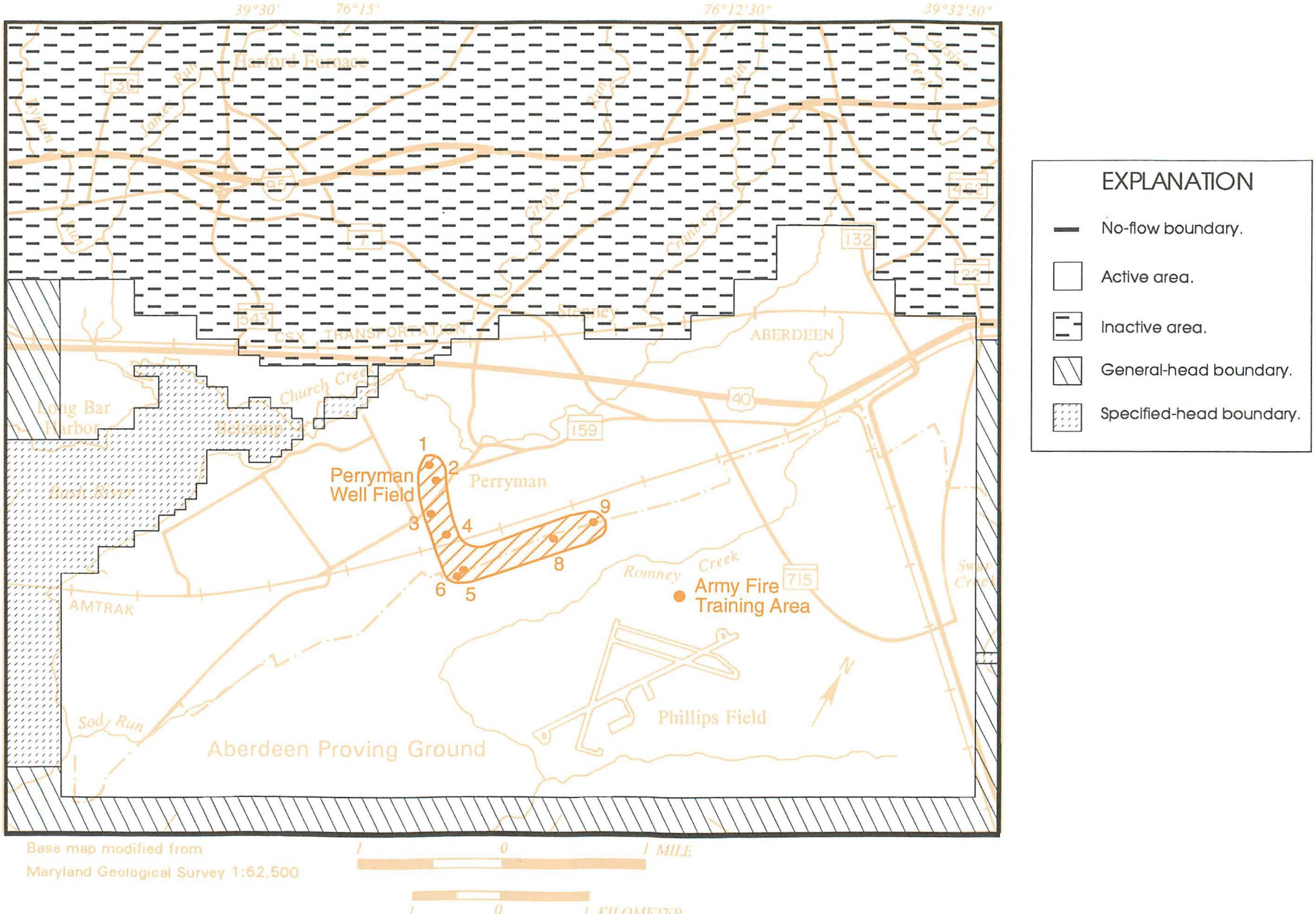


Figure 29.—Simulated boundaries for aquifer 1.

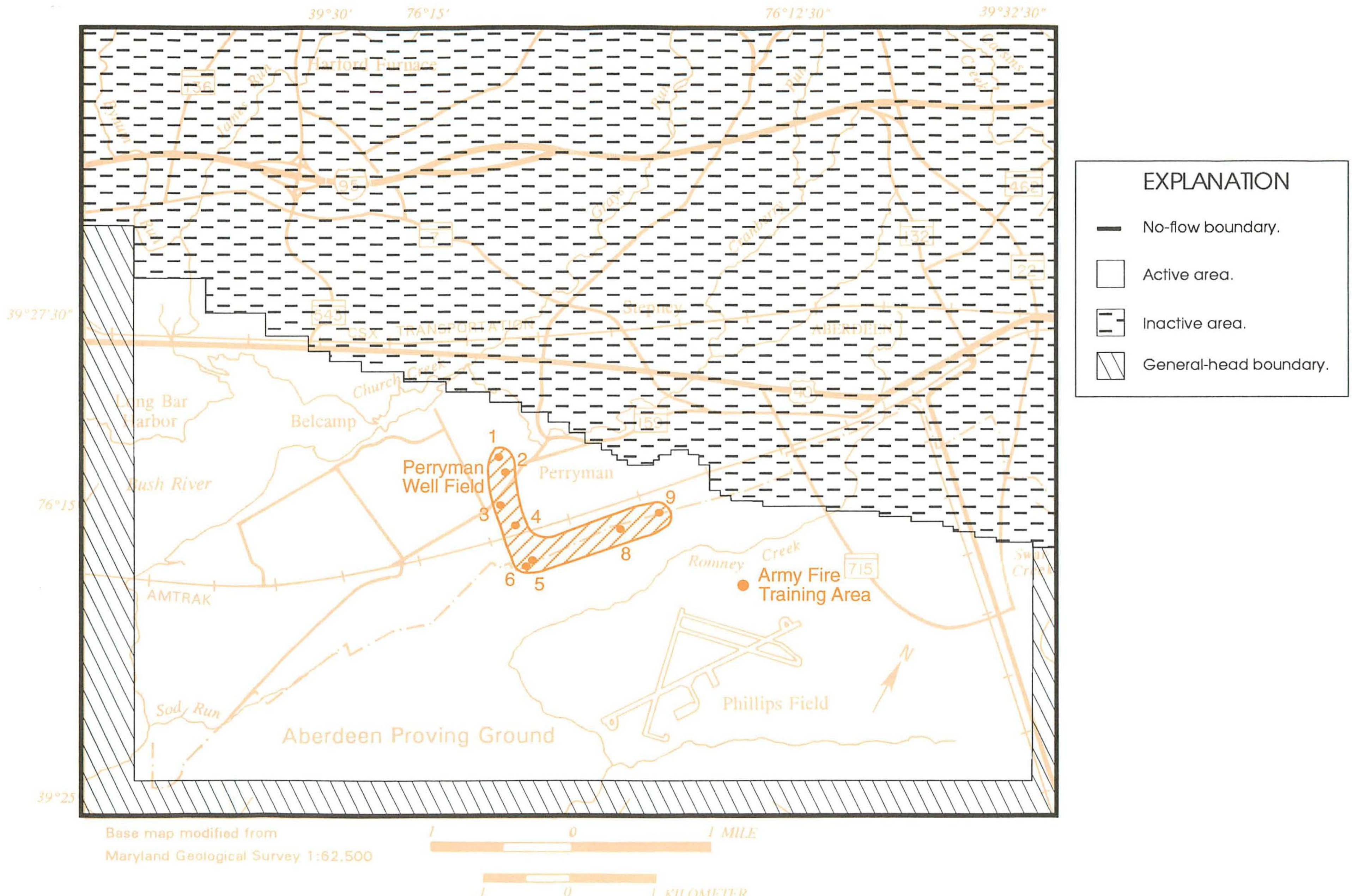


Figure 30.—Simulated boundaries for aquifer 2.

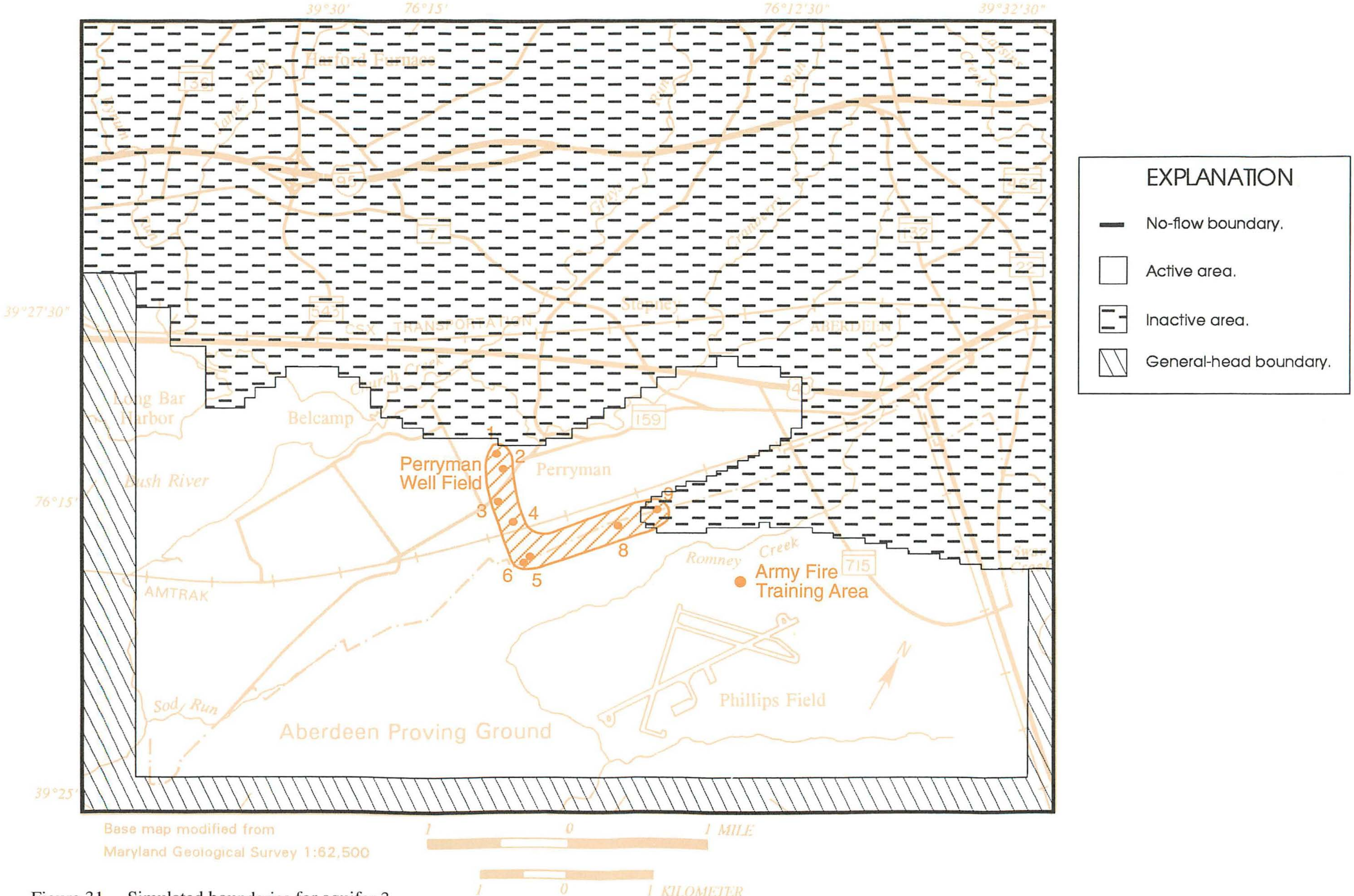


Figure 31.—Simulated boundaries for aquifer 3.

0.44 ft/d, as in the regional model (Drummond and Blomquist, 1993), except for cells in Romney Creek where the conductivity was decreased to 0.044 ft/d. Romney Creek is rather swampy, and based on water-table measurements (Woodward-Clyde Federal Services, 1994), does not show a strong hydraulic connection with aquifer 1.

Historical ground-water pumpage was compiled from Drummond and Blomquist (1993), Wheeler and Wilde (1989), and from records kept by well-field operators. Pumpage amounts entered in the flow model are shown in table 2. Total pumpage for the Perryman well field in 1994 was 2.2 Mgal/d.

Initial Conditions

A steady-state simulation with no pumpage was used to generate initial conditions for transient simulations. The steady-state simulation created a set of stable head arrays and flow fields from which to begin the transient runs.

Calibration

The flow model was calibrated by changing selected input data, within reasonable limits, until model output matched measured (or estimated) data. The model was first calibrated to match measured water levels and to produce reasonable flow components (such as base flow and ET), and then calibrated so that the particle-tracking analysis simulated the known distribution of TCE in the subsurface (see section on Particle Tracking). The model was considered calibrated with respect to head distribution when the root-mean-square error for the entire model was below 2.5 ft.

Simulated water levels matched measured water levels in all three aquifers (figs. 32, 33, and 34) very well with several exceptions. Maximum residuals were 9.2, 13.1, and −18.5 ft for aquifers 1, 2, and 3 respectively. In all three cases, the measured water levels were from wells in or near pumping centers. Static water levels were difficult to obtain in these wells because of pumping cycles and rapidly changing water levels.

Simulated flow components are shown in table 3 for pre-pumping, 1989, 1994, drought conditions, and maximum GAP (Ground-water Appropriation Permit) conditions. Recharge is the major inflow component for all simulated conditions. Stream leakage (along losing reaches) is a minor inflow component for all simulated conditions. Storage is a minor inflow component during drought conditions due to regional water-level declines, and general-head boundary flux becomes a minor inflow component in the maximum GAP simulation.

Evapotranspiration, constant-head-boundary flux, stream leakage (along gaining reaches), general-head-boundary flux, and pumpage are all major outflow components under most simulated conditions. General-head-boundary flux is the predominant outflow component under all simulated conditions except for the maximum-GAP simulation, in which pumpage is the predominant outflow component.

Sensitivity Analysis

A sensitivity analysis was performed on the calibrated flow model. The purpose of this analysis was to determine the sensitivity of model results to changes in model input, and to provide an indication of the amount of error in model results that could result from errors in model input.

The sensitivity analysis was performed by individually changing each model input parameter while keeping all others at their calibration values, and recording resultant changes in simulated heads. Sensitivity runs simulated transient conditions for 1994. Error parameters that were recorded included maximum head change, range of head changes, mean error, absolute mean error, and root mean square (RMS) error. Each input parameter was changed plus and minus 10, 20, and 50 percent, for a total of six runs per parameter. The model is considered most sensitive to input parameters that, when changed by 50 percent, caused changes in RMS error greater than 1.0 ft. The model is considered moderately sensitive to input parameters that caused changes in RMS error between 0.1 and 1.0 ft, and least sensitive to input parameters that caused changes in RMS error less than 0.1 ft.

The results of the sensitivity analysis are summarized in table 4. The model is most sensitive to the altitude of the evapotranspiration surface, the recharge rate, the altitude of the river-stage, and the altitude of the river-bottom. The model is moderately sensitive to evapotranspiration rate, hydraulic conductivity of aquifer 1, leakance of confining unit 1, altitude of the bottom of aquifer 1, transmissivities of aquifers 2 and 3, and head specified at general-head-boundary nodes. The model is least sensitive to evapotranspiration extinction depth, river-bed conductance, conductance specified at general-head-boundary nodes, storage of all aquifers, and leakance of confining unit 2.

PARTICLE-TRACKING METHODOLOGY

The particle-tracking program used for these simulations was MODPATH, version 3 (Pollack, 1994), which was developed by the U.S. Geological Survey. This program uses head and flow data produced by the flow model as a basis for simulation of particle movement through the subsurface. MODPATH was used to refine calibration of the flow model, to estimate the contributing areas of wells in the Perryman well field, and to simulate the movement of TCE from the AFTA to the Perryman well field.

(Text continued on p. 48.)

Table 2.—Pumpage data simulated in the Perryman flow model

[* = pumpage equal to 1994 pumpage]

Local name	Well number	Aquifer	Pumpage, in thousand gallons per day									
			Calibration									
			966-1965	1966-1975	1976-1987	1988	1989	1990	1991	1992	1993	1994
Clorox	HA De 207, 208	3	0	4	8	8	10	0	0	3	59	132
Price Brothers	HA De 28	2&3	0	32	68	68	80	56	56	55	55	54
Sod Run	HA De 211	2	0	0	1	1	1	1	1	19	17	25
Perryman #1	HA De 73	2	0	46	99	99	116	116	103	114	106	80
Perryman #2	HA De 75	3	0	68	145	145	170	196	165	171	158	120
Perryman #3	HA De 58	3	0	90	190	190	224	208	192	95	0	0
Perryman #4	HA De 59	3	0	303	644	644	757	866	913	797	79	591
Perryman #5	HA De 77	2	0	199	424	424	498	460	486	427	420	320
Perryman #6	HA De 76	2	0	352	747	747	879	923	933	778	371	634
Perryman #8	HA De 67	2	0	0	388	388	457	416	400	339	313	225
Perryman #9	HA De 64	2	0	0	402	402	473	486	467	393	369	269
Perryman A	(Hypothetical)	2	0	0	0	0	0	0	0	0	0	0
Perryman B	(Hypothetical)	3	0	0	0	0	0	0	0	0	0	0
Perryman C	(Hypothetical)	2	0	0	0	0	0	0	0	0	0	0
Perryman D	(Hypothetical)	3	0	0	0	0	0	0	0	0	0	0
Perryman E	(Hypothetical)	2	0	0	0	0	0	0	0	0	0	0
Perryman F	(Hypothetical)	3	0	0	0	0	0	0	0	0	0	0
Perryman G	(Hypothetical)	2	0	0	0	0	0	0	0	0	0	0
Perryman H	(Hypothetical)	3	0	0	0	0	0	0	0	0	0	0
Aberdeen #1	HA Cf 30	1	0	74	156	156	184	189	188	188	189	196
Aberdeen #2	HA De 86	1	0	49	105	105	124	127	126	126	127	132
Aberdeen #3	HA Cf 69	1	0	45	96	96	113	116	115	115	116	120
Aberdeen #4	HA De 87	1	0	43	91	91	107	110	109	109	110	114
Aberdeen #5	HA De 90	1	0	38	82	82	96	98	98	98	99	102
Aberdeen #6	HA De 93	1	0	19	40	40	47	49	49	49	49	51
Aberdeen #7	HA Df 29	1	0	63	135	135	158	162	162	162	163	169
Aberdeen #8	HA Df 30	1	0	72	152	152	179	184	183	183	184	191
Aberdeen #9	HA Df 31	1	0	38	81	81	95	97	97	97	98	101
Aberdeen #10	HA Df 33	1	0	31	66	66	77	79	79	79	79	82
Aberdeen #11	HA Cf 175	1	0	31	66	66	77	79	79	79	79	82
Total			0	1,597	4,184	4,184	4,922	5,019	5,002	4,477	3,238	3,791

Future simulations												
1	2	3	4	5	6	7	8	9	10	11	12	13
1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995	1995-1997
132	158	106	197	258	0	*	*	*	*	*	*	*
54	65	43	140	290	0	*	*	*	*	*	*	*
25	30	20	21	32	0	*	*	*	*	*	*	*
80	96	64	152	187	0	*	*	*	*	*	*	*
120	144	96	227	281	0	*	*	*	*	*	*	*
0	*	*	*	*	*	*	*	*	*	*	*	*
591	709	473	1,122	1,386	0	*	*	*	*	*	*	*
320	384	256	607	750	0	0	639	*	*	*	*	*
634	761	507	1,204	1,487	0	0	793	*	*	*	*	*
225	270	180	428	528	0	*	*	*	*	*	*	*
269	323	215	511	631	0	*	*	*	*	*	*	*
0	*	*	*	*	*	*	*	158	*	*	*	*
0	*	*	*	*	*	*	*	238	*	*	*	*
0	*	*	*	*	*	*	*	158	*	*	*	*
0	*	*	*	*	*	*	*	238	*	*	*	*
0	*	*	*	*	*	*	*	*	434	*	*	*
0	*	*	*	*	*	*	*	*	569	*	*	*
0	*	*	*	*	*	*	*	*	*	726	*	*
0	*	*	*	*	*	*	*	*	*	277	*	*
196	236	157	293	366	0	*	*	*	*	*	*	*
132	158	106	197	246	0	*	*	*	*	*	*	*
120	144	96	179	224	0	*	*	*	*	*	*	*
114	137	91	170	212	0	*	*	*	*	*	*	*
102	123	82	153	191	0	*	*	*	*	*	*	*
51	61	41	76	94	0	*	*	*	*	*	*	*
169	203	135	252	315	0	*	*	*	*	*	*	*
191	229	153	285	356	0	*	*	*	*	*	*	*
101	122	81	158	189	0	*	*	*	*	*	*	*
82	99	66	123	153	0	*	*	*	*	*	*	*
82	99	66	123	153	0	*	*	*	*	*	*	*
3,791	4,549	3,033	6,616	8,331	0	2,837	4,269	4,583	4,793	4,793	*	*

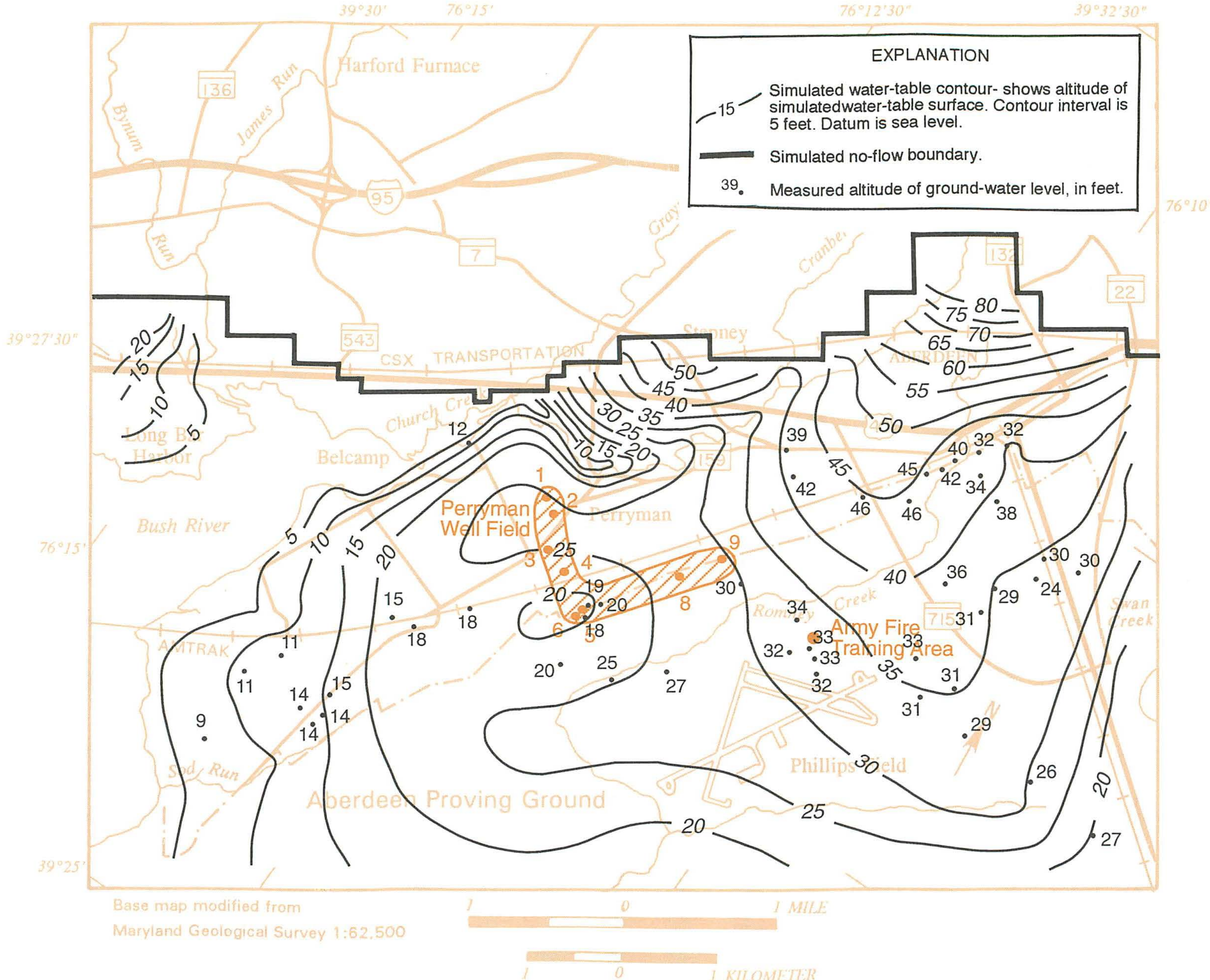


Figure 32.—Simulated and measured water-table altitudes in aquifer 1, 1994.

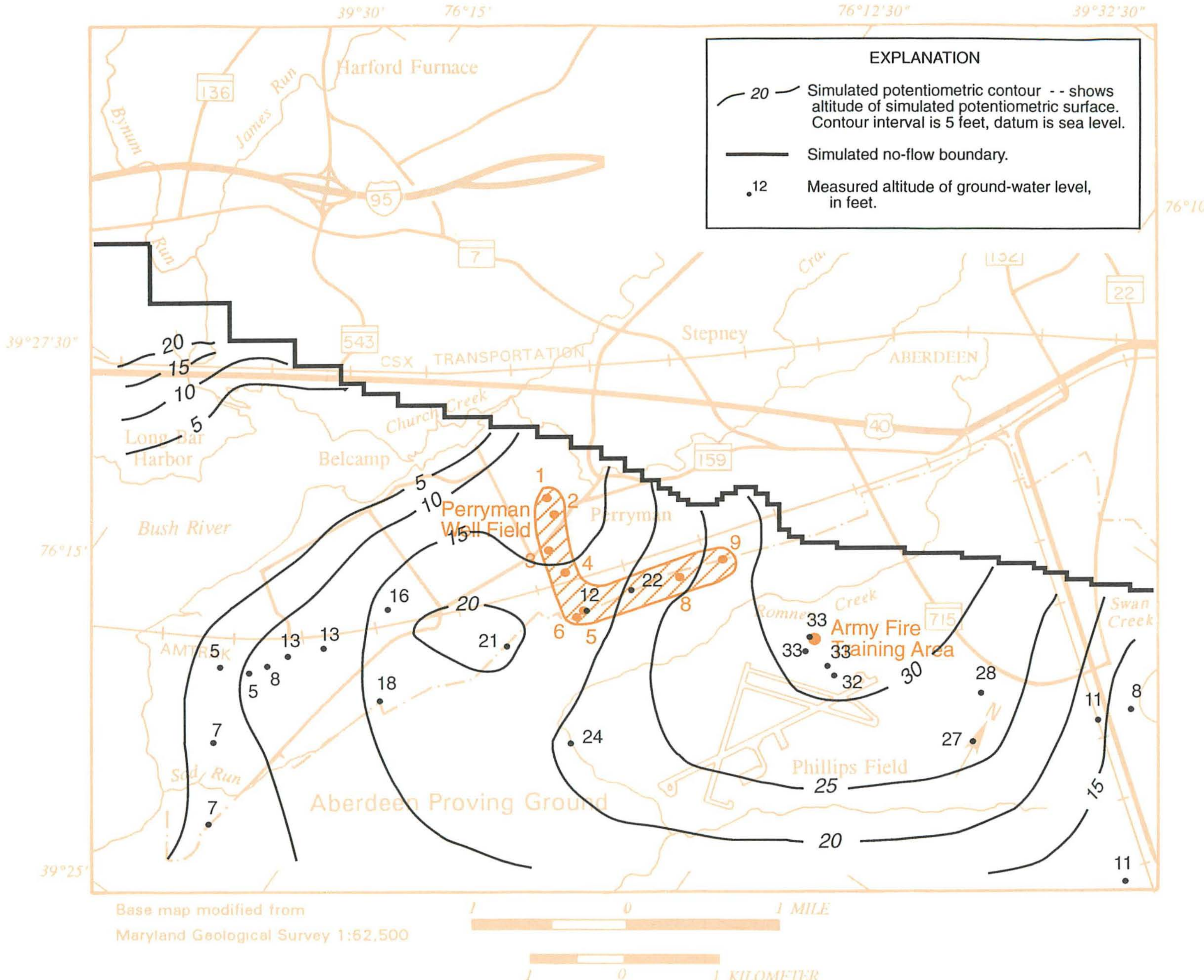


Figure 33.—Simulated potentiometric surface and measured heads in aquifer 2, 1994.

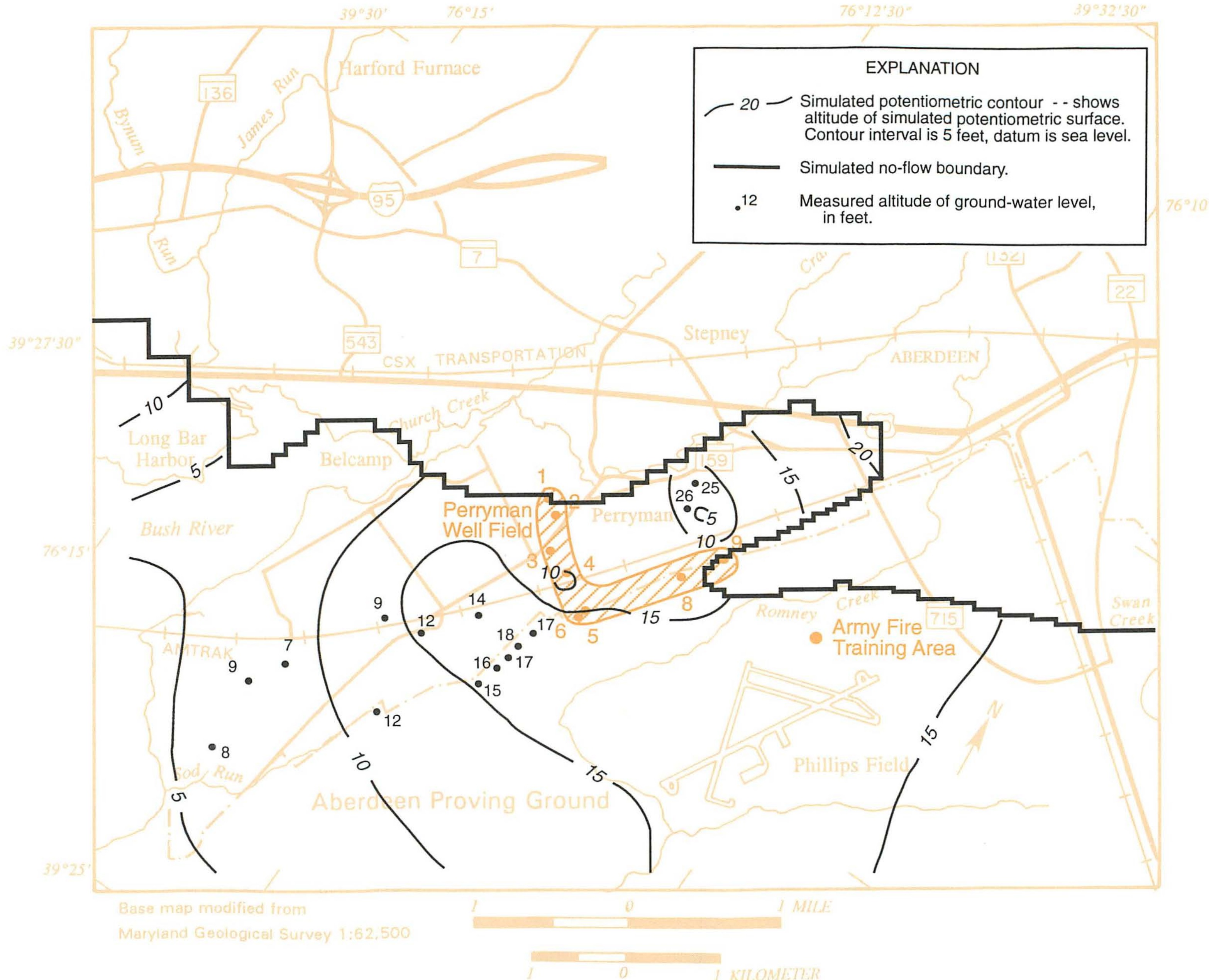


Figure 34.—Simulated potentiometric surface and measured heads in aquifer 3, 1994.

Table 3.—Flow components of prepumping, 1989, 1994, 1-year drought, and maximum-GAP model simulations

[GAP = Ground-water Appropriation Permit]

	Flow rate, in thousand cubic feet per day (inches per year)				
Components	Prepumping	1989	1994	Drought	Maximum GAP
Inflow					
Recharge	2,639	2,639	2,639	1,583	2,639
	(18)	(18)	(18)	(11)	(18)
Constant-head boundary	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Stream leakage	162	204	200	283	254
	(1.1)	(1.4)	(1.4)	(1.9)	(1.7)
General-head boundary	34	54	49	82	103
	(0.23)	(0.37)	(0.33)	(0.56)	(0.70)
Storage	1	61	7	269	0
	(0.007)	(0.41)	(0.05)	(1.8)	(0)
Totals[1]	2,836	2,958	2,895	2,217	2,996
	(19.3)	(20.2)	(19.8)	(15.3)	(20.4)
Outflow					
Evapotranspiration	788	612	628	485	519
	(5.4)	(4.2)	(4.3)	(3.3)	(3.5)
Constant-head boundary	471	439	443	343	406
	(3.2)	(3.0)	(3.0)	(2.3)	(2.8)
Stream leakage	569	437	456	278	351
	(3.9)	(3.0)	(3.1)	(1.9)	(2.4)
General-head boundary	1,015	833	845	604	652
	(6.9)	(5.7)	(5.8)	(4.1)	(4.4)
Storage	0	0	14	0	0
	(0)	(0)	(0.1)	(0.0)	(0.0)
Pumpage	0	658	507	507	1,114
	(0.0)	(4.5)	(3.5)	(3.5)	(7.6)
Totals[1]	2,843	2,979	2,893	2,217	3,042
	(19.4)	(20.4)	(19.8)	(15.1)	(20.7)

[1]Discrepancies between inflow and outflow totals are due to rounding.

Table 4.—Summary of results of the sensitivity analysis

Model parameter changed	Greatest change in head for all active cells, in feet	Greatest change in root-mean-square error for measured heads, in feet
Recharge rate	-31.	1.4
Evapotranspiration rate	3.9	0.096
Altitude of evapotranspiration surface	-11.	2.5
Evapotranspiration extinction depth	1.0	0.041
Altitude of river stage	*	2.7
Altitude of river bottom	*	2.4
Conductance of river bed	3.3	0.067
Altitude of general-head-boundary heads	-12.	0.64
Conductance of general-head boundaries	5.4	0.092
Hydraulic conductivity of aquifer 1	5.3	0.37
Specific yield of aquifer 1	0.098	-0.0037
Leakance of confining unit 1	-4.5	0.13
Altitude of bottom of aquifer 1	*	0.16
Transmissivity of aquifer 2	50	0.18
Storage coefficient of aquifer 2	-0.0020	-0.0001
Leakance of confining unit 2	-6.3	0.021
Transmissivity of aquifer 3	-11.	0.090
Storage coefficient of aquifer 3	-0.032	-0.0002

* These simulations caused some cells to go dry.

Several assumptions are inherent in MODPATH particle-tracking simulations. MODPATH assumes that particle movement is controlled only by advective flow, and does not take into account the effects of dispersion, density-dependent flow, multi-phase flow, chemical, or biological reactions. Dispersion will cause contaminant-plume dilution by spreading and mixing as it moves through the subsurface, and particle-tracking simulations will indicate a more compact plume than in reality. This is probably a minor consideration. Free-product plumes of contaminants that are denser than water will tend to sink as they move through the subsurface. With the low concentrations of dissolved TCE indicated in this study, however, (no greater than 140 µg/L) density-dependent flow is not a factor.

Chemical reactions, such as biological degradation and adsorption/desorption are important considerations. Chemical degradation will decrease concentrations with time as the solute is chemically converted to other substances. Adsorption/desorption will tend to retard the movement of a contaminant plume, as the solute is adsorbed onto sediments (primarily clays) on the leading edge of the plume, and desorbed from sediments into the dissolved state on the trailing edge of the plume. Thus simulated movement of the contaminant plume may be faster than actual movement. Because of these assumptions, simulated contaminant-migration velocities and arrival times at wells should be viewed in a general sense, and should not be interpreted in absolute terms.

Input Data

In addition to data required by MODFLOW, MODPATH requires data sets for the altitudes of top and bottom of each aquifer, and porosity values for each aquifer and confining unit. Aquifer top and bottom maps are shown in the Hydrogeology section of this report. Porosity was set to 0.27 for all aquifers, and 0.35 for both confining units. Porosity values of 0.30 and 0.35 for aquifers and confining units, respectively, are given in Drummond and Blomquist (1993). These values were originally used in this study, but porosity for aquifers was reduced to 0.27 during model calibration. Starting locations of particles are also required for particle-tracking input; starting locations are described for each simulation.

Calibration

Particle-tracking simulation was used to aid in flow-model calibration by simulating the distribution of dissolved TCE in the subsurface. Dissolved TCE distribution in ground water is shown in Woodward-Clyde Federal Services (1994, figs. 5-1 and 5-2, and table 5-2), as determined by Hydropunch sampling. This simulation was run in forward-tracking mode.

Particles were released at one-year intervals, from 1964 to 1994. For each release, 100 particles were started in a 10 by 10 array at the top face of cell (43,71), which is the location of AFTA. Information on the release of contaminants to the environment is incomplete, but Derryberry, Miller and Breland (1990) indicate that fire-training activities that led to the contamination began in the early 1960's and ended in 1989. Preliminary simulations that ended particle release in 1989, however, showed a large gap between AFTA and the simulated plume that is not evident in the measured TCE distribution. This indicates that TCE was probably adsorbed onto soil particles when dissolved concentrations were high, then desorbed after contaminant application ended and dissolved concentrations decreased. Soil samples collected from AFTA in 1994 showed contamination of TCE and other VOC's (Woodward-Clyde Federal Services, 1994), and contaminated soil was removed from the site in 1994. Simulated TCE release was therefore continued until 1994 to account for the desorption of TCE.

The simulated TCE plume is shown in figure 35a in map view, along with the estimated TCE distribution as documented by Woodward-Clyde Federal Services (1994, fig. 5-1). Simulated particles in all three aquifers are projected into the map view. Both plumes extend about 1.5 miles from AFTA to Perryman wells 5 (De 77) and 6 (De 76). A secondary arm of the simulated plume also extends about 1 mi due south of AFTA. Particle-tracking simulation shows that this secondary arm comprises contaminants released in the 1960's and early 1970's before the Perryman well field was pumping at its current capacity. The contaminants migrated south before the Perryman capture zone extended to AFTA.

The simulated TCE distribution is shown in cross sections in figure 35b. Simulated particles in the entire model area are projected into these sections. Figure 35b shows a section along model row 38, which is generally along strike. The two arms of the plume are visible, the younger one emanating down from the source area to the well field, and the other, older arm in the deeper part of aquifer 2. Figure 35b shows a cross section along model column 38, which is generally down dip. The two arms of the plume are again visible, with the deeper arm heading southeast toward the model boundary.

Particles that discharge into wells represent TCE contamination in those wells. Histograms showing particle arrivals by year in wells 5 (De 77) and 6 (De 76) are shown in figure 36, and represent, in a general way, simulated TCE concentration through time of water from those wells. No direct correlation between number of particles per year and TCE concentration can be inferred because the rate, frequency, and exact location of TCE release to the ground-water system is unknown.

Particles first arrived at well 5 (De 77) in 1989. The number of particles reached a maximum of 55 in 1991, and declined to zero in 1994. Particles first arrived at well 6 (De 76) in 1990, and the number of particles generally increased to 84 in 1994. Particles may have reached well 5 first because it is closer to the AFTA, but later migrated primarily to well 6 because of its higher pumping rate. This general pattern is similar to TCE concentrations observed in wells 5 and 6 (fig. 26).

Estimation of Contributing Areas

Contributing areas of wells in the Perryman well field were estimated by running MODPATH in backward-tracking mode. Particles were started in the cells that represent each well in arrays of 10 by 10 by 10 (1,000 particles for each well), and their paths were tracked backward to the land surface where the particles entered the ground-water system. The composite area where all particles for a particular well entered the ground-water system is the contributing area for that well. Particles were released in 1994, so the contributing areas represent water that discharged from the wells in 1994. Contributing areas are dependent on the historical pumpage in the area, and might change with time.

Contributing areas for wells in the Perryman well field are shown in figures 37 - 44. Each contributing area is divided into traveltime zones determined by the amount of time required for the particles to travel from the land surface to the well. For example, precipitation that falls in the 20 to 50-year traveltime zone of well 5 (De 77) will require between 20 and 50 years to reach well 5. In some cases, traveltime zones of a contributing area overlap; in these cases the younger traveltime zone is shown.

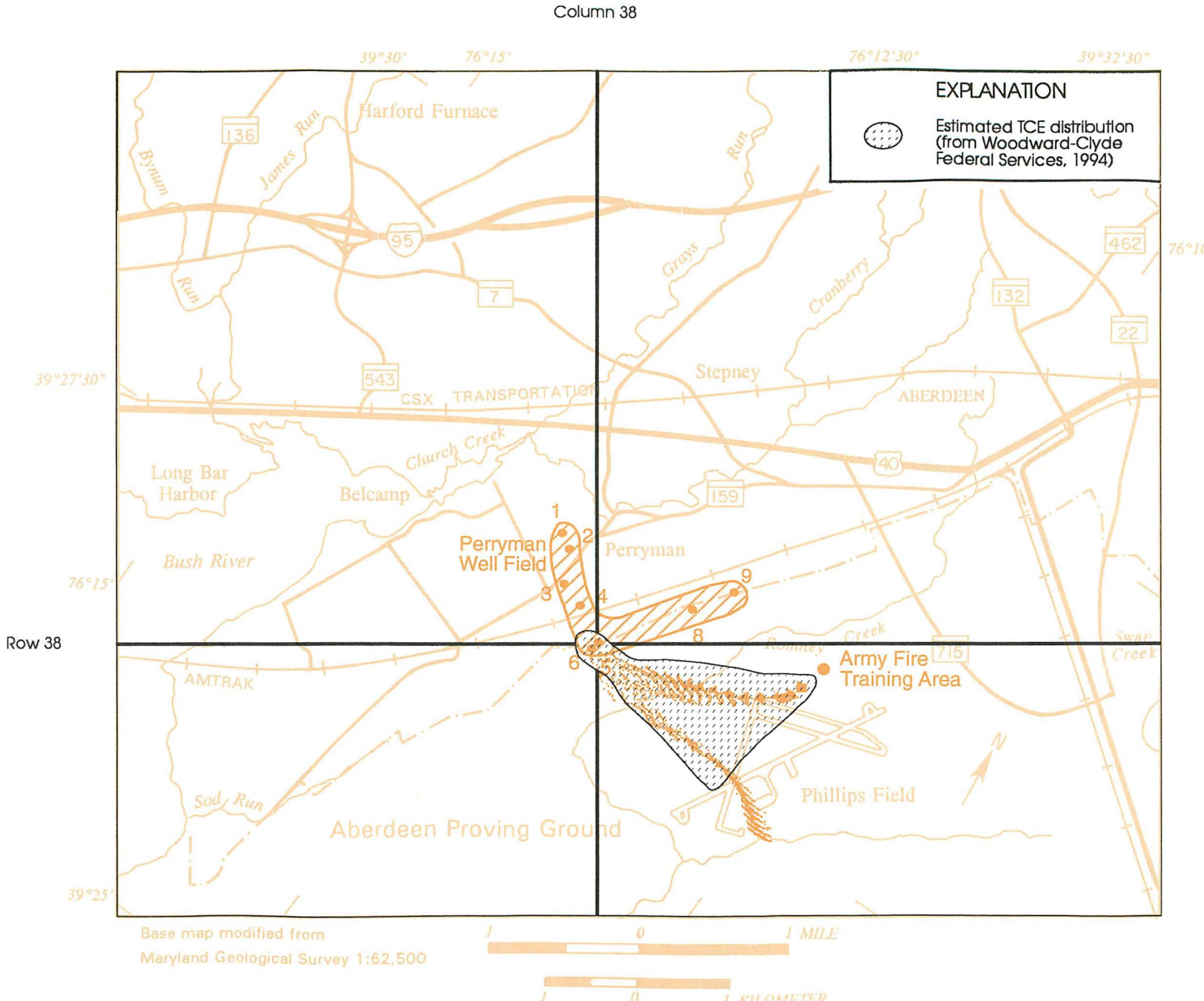


Figure 35a.—Simulated TCE distribution and estimated TCE distribution near Perryman, 1994 (map view).

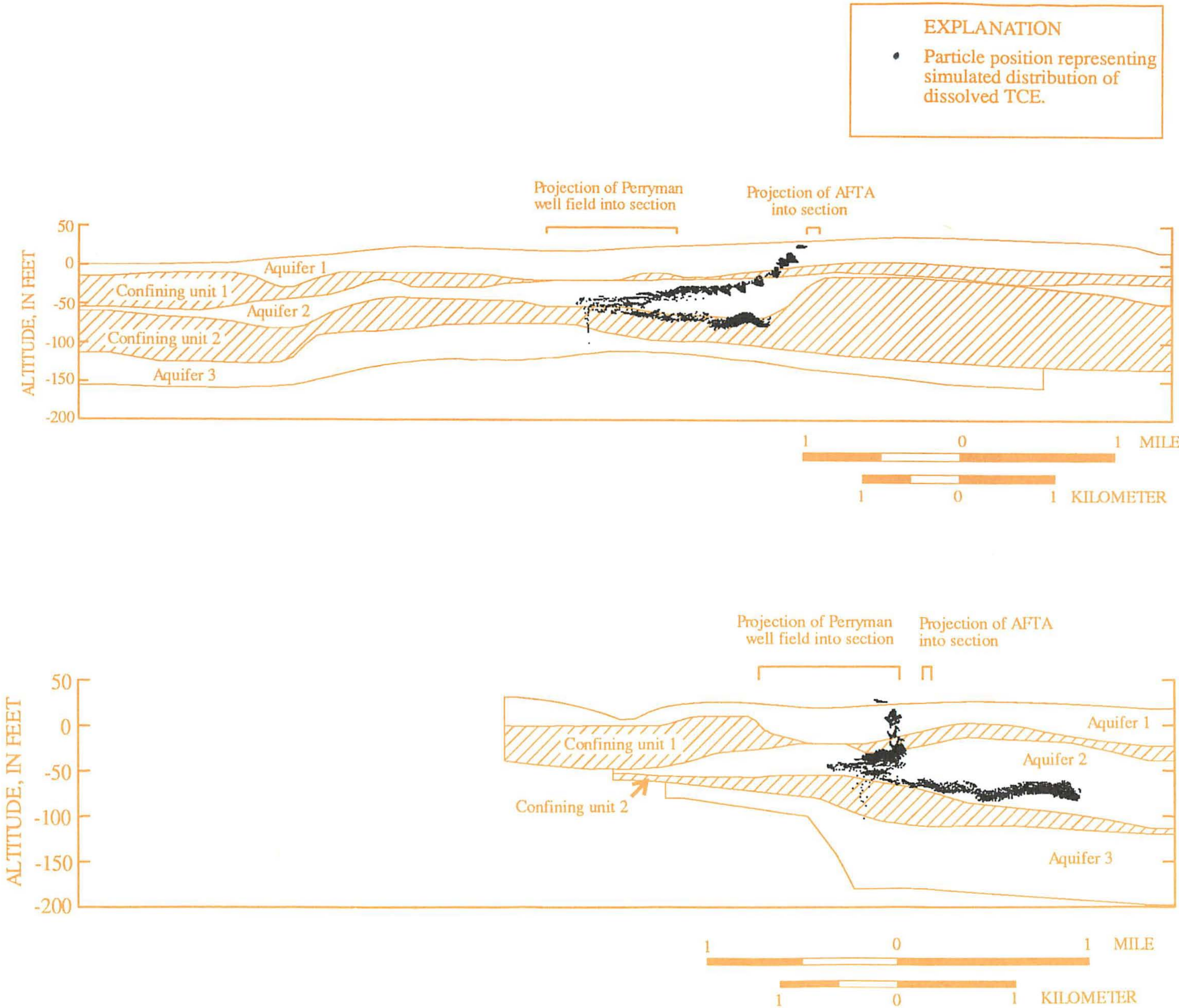


Figure 35b.—Simulated TCE distribution near Perryman, 1994 (cross section along model row 38 [top] and cross section along model column 38 [bottom]).

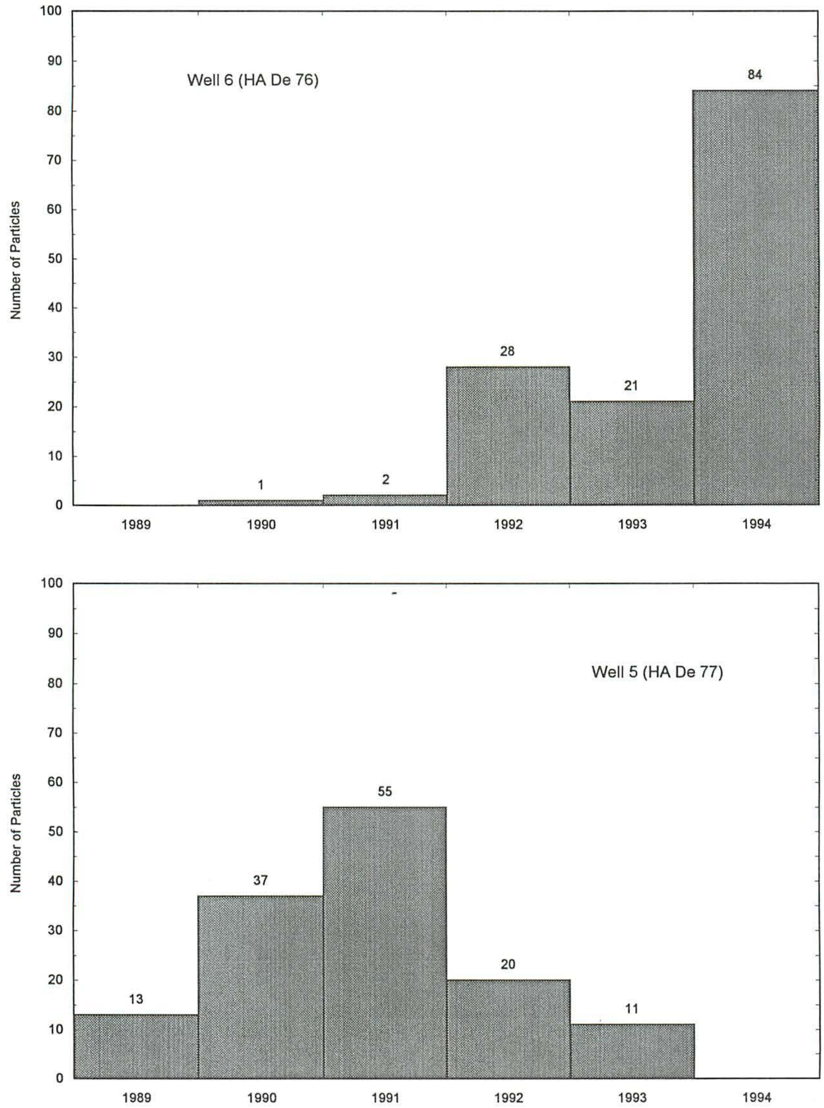


Figure 36.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1989-1994.

The contributing area for well 1 (De 73), which is screened in aquifer 2, comprises two long narrow areas, one of which is in the vicinity of the well field, and is about 1 mile long and a few hundred feet wide (fig. 37). This area contains time zones of 20 to 50, 50 to 100, and 100 to 200 years, but is mostly in the 50 to 200-year range. The other area is about two miles northeast of the well field, and extends northeast to Aberdeen. It is about one-and-a-half miles long by a few hundred feet wide. It contains time zones of 100 to 200, and 200 to 500 years.

The contributing area for well 2 (De 75), which is screened in aquifer 3, forms a long narrow area, about four miles long, and a few hundred feet wide (fig. 38). It extends from about one-half mile southwest of the well field, northeast to Aberdeen. It is composed of numerous time zones, ranging from zero to 500 years. Most of the contributing area is in the zero to 100-year range.

The contributing area for well 3 (De 58), which is screened in aquifers 2 and 3, was calculated in a different way than the other wells. Because well 3 was not pumping in 1994, its contributing area was simulated using 1991 pumpage, when it was pumping at its full capacity. This contributing area extends about a mile southwest of the well field, and contains time zones of zero to 20, 20 to 50, and 50 to 100 years (fig. 39). Most of the area is in the zero to 100-year range.

The contributing area for well 4 (De 59), which is screened in aquifers 2 and 3, comprises several areas extending from about one-half mile south of the well field in APG, north to Aberdeen (fig. 40). It contains traveltime zones of

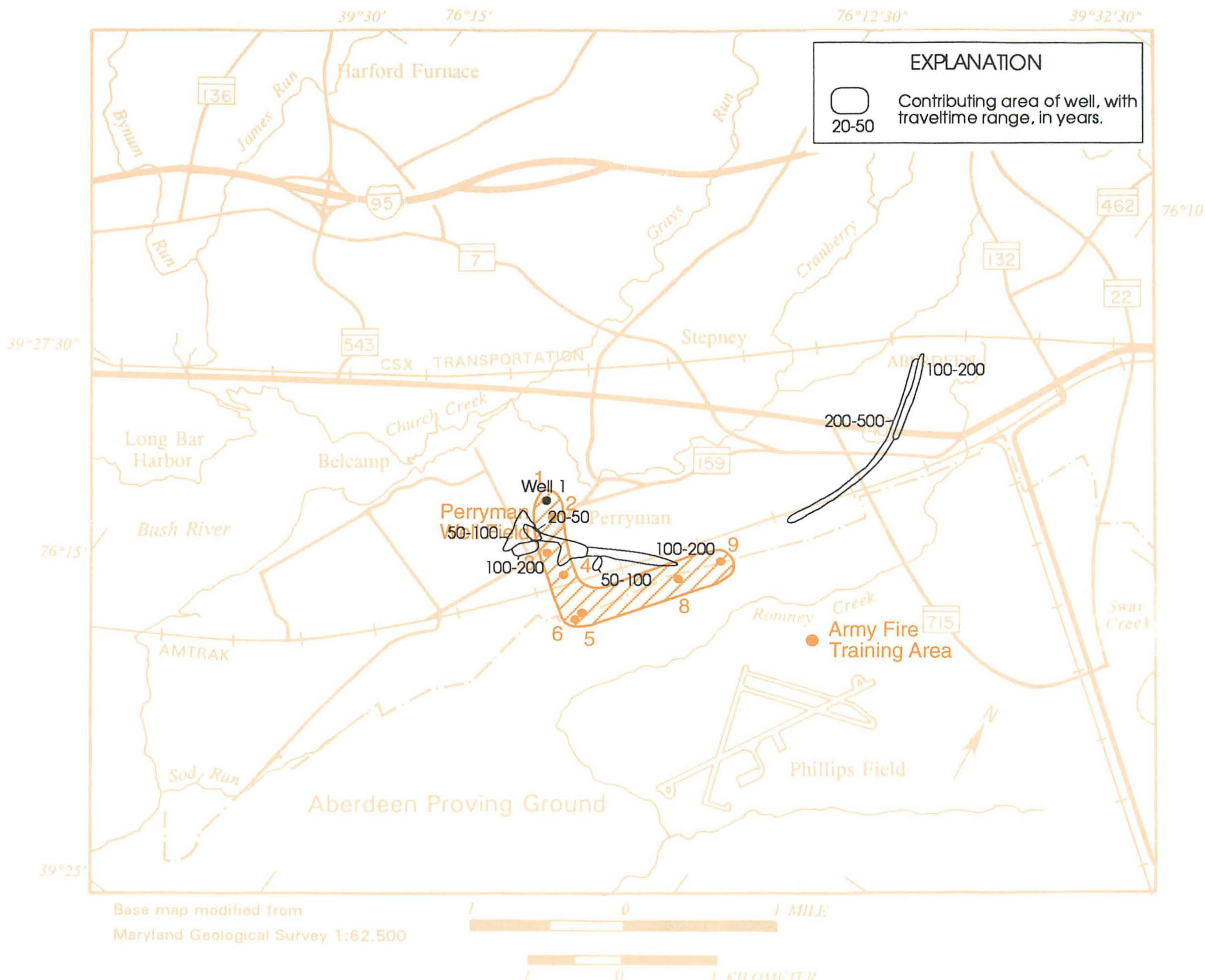


Figure 37.—Contributing area and traveltime zones for Perryman well 1.

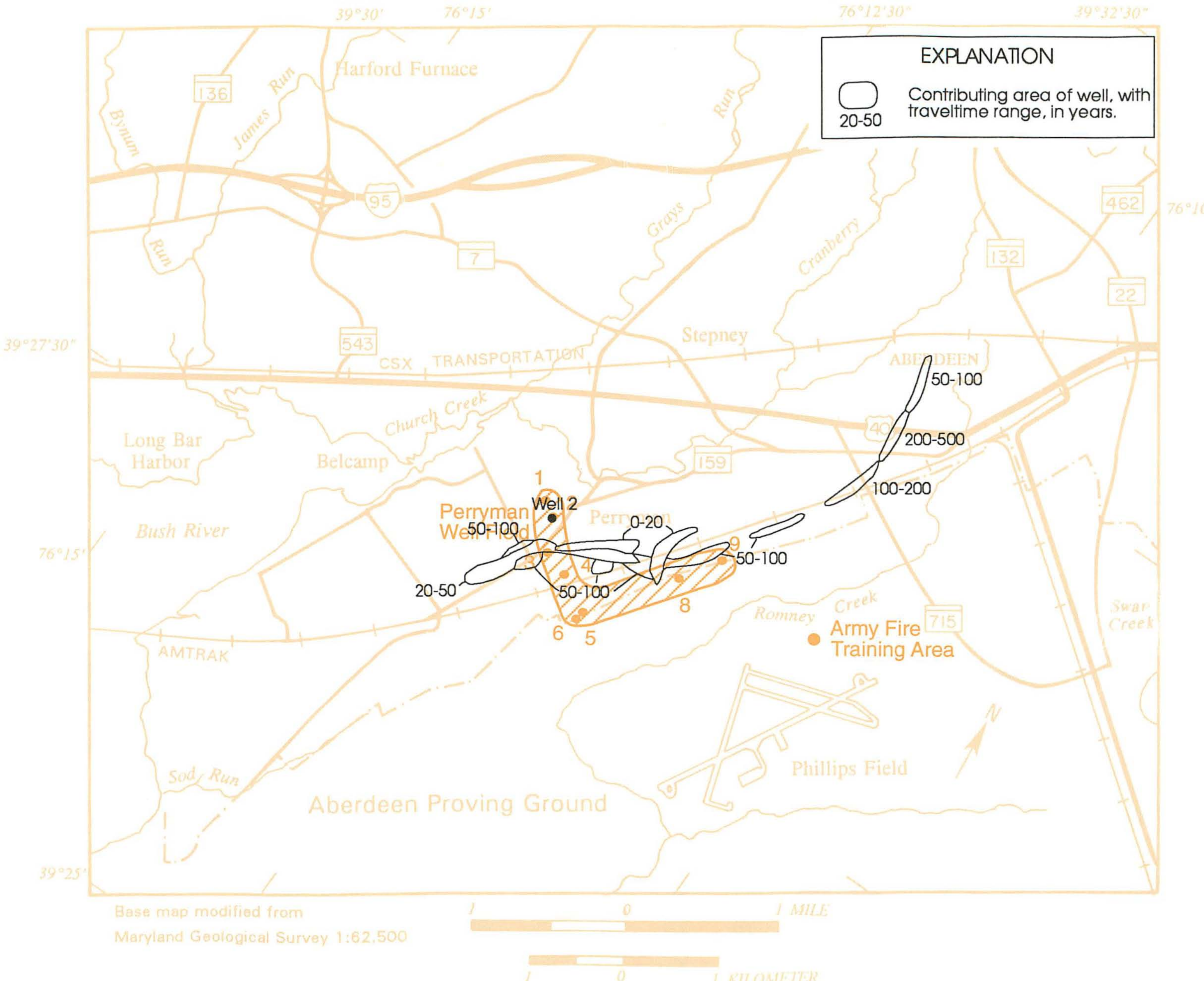


Figure 38.—Contributing area and traveltime zones for Perryman well 2.

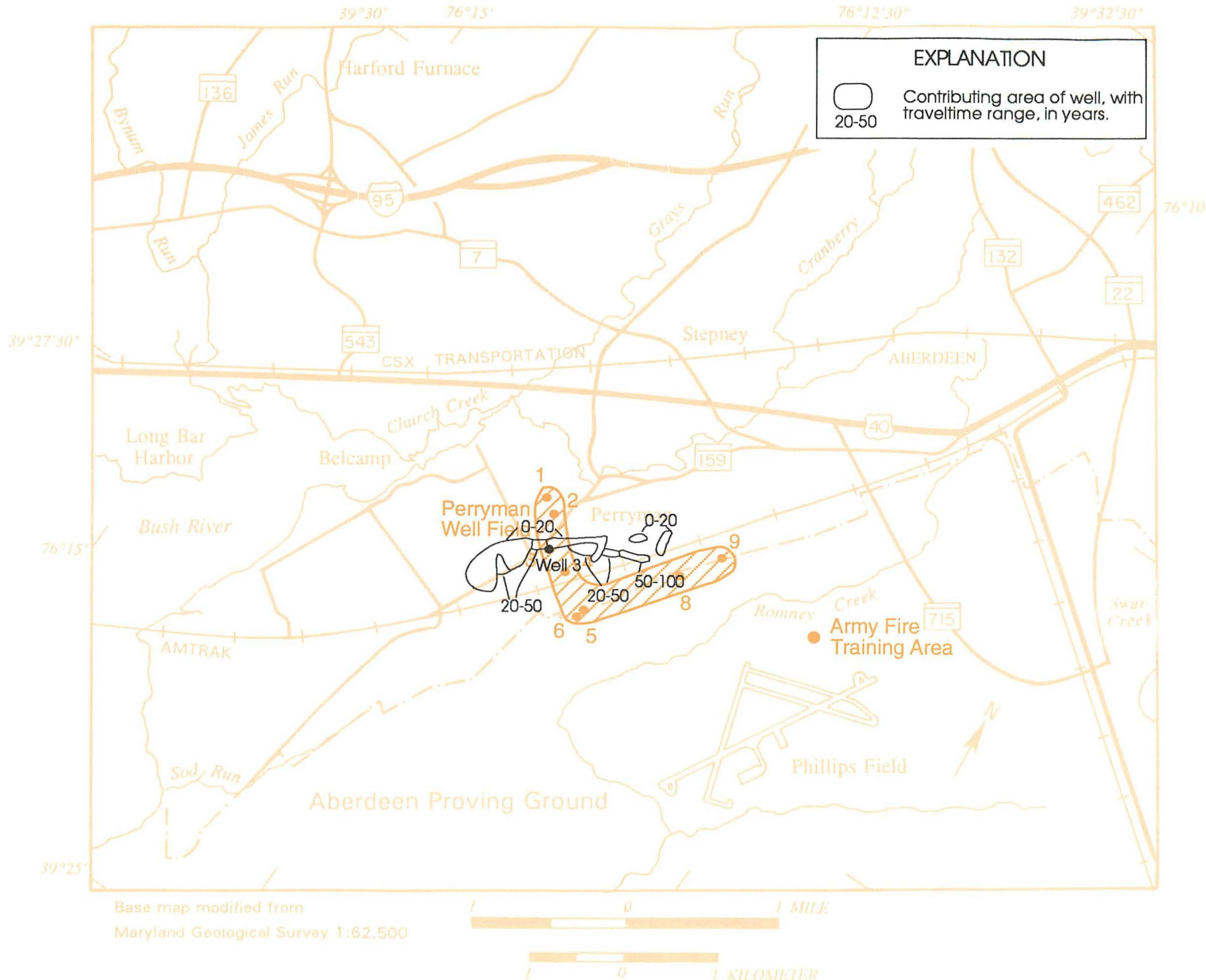


Figure 39.—Contributing area and traveltime zones for Perryman well 3.

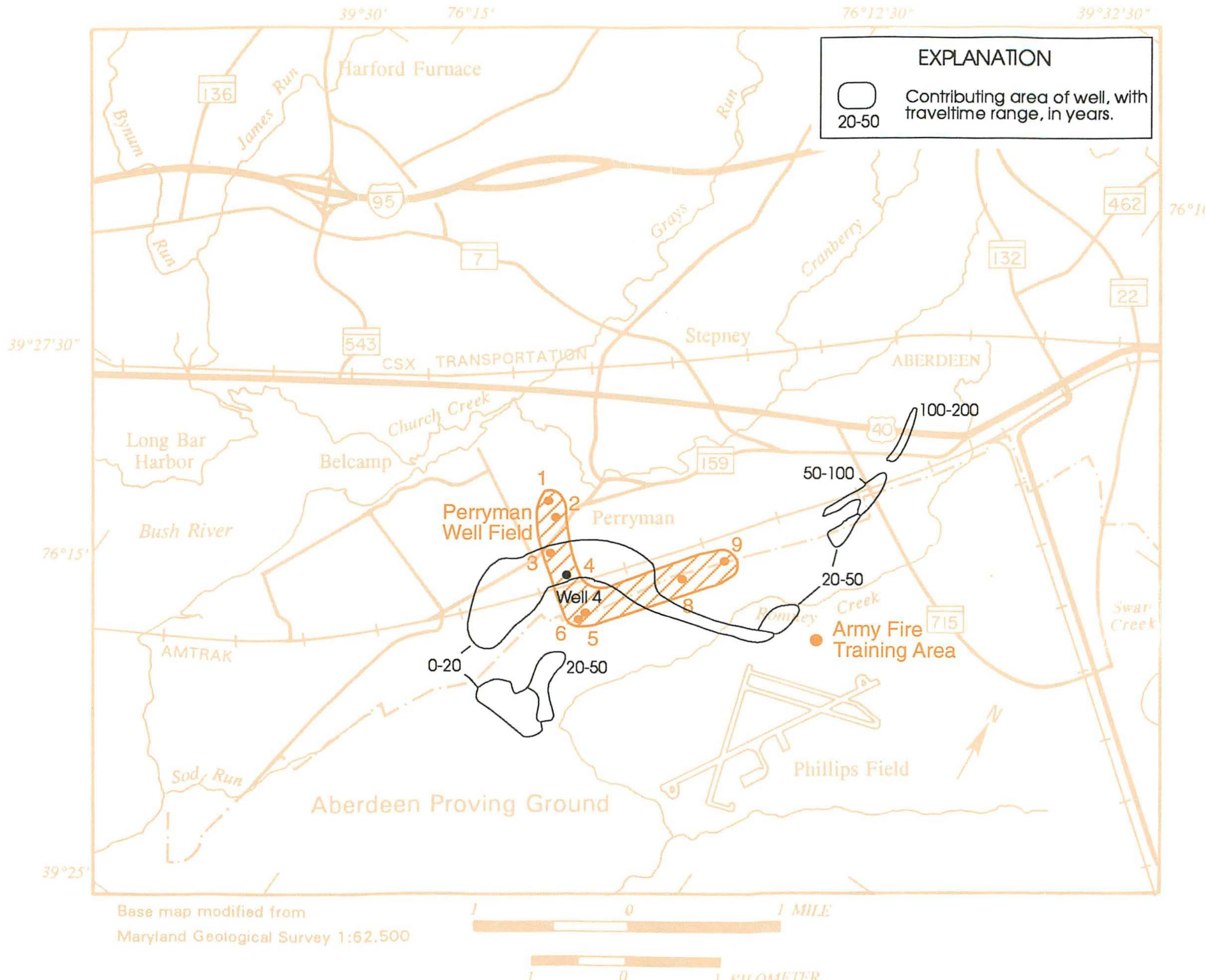


Figure 40.—Contributing area and traveltime zones for Perryman well 4.

zero to 20, 20 to 50, 50 to 100, and 100 to 200 years. The largest area is in the vicinity of the well field, is about two miles long by one-half mile wide, and contains traveltime zones of zero to 20, and 20 to 50 years.

The contributing area for well 5 (De 77), which is screened in aquifer 2, comprises two areas, which contain traveltime zones of zero to 20 and 20 to 50 years (fig. 41). The larger area extends from the well field eastward into APG near the AFTA, and is about two miles long by a quarter mile wide. It contains one traveltime zone of zero to 20 years.

The contributing area for well 6 (De 76), which is screened in aquifer 2, is one large area east of the well field, extending to the AFTA (fig. 42). It is composed primarily of one zero to 20-year traveltime zone, with two small 20 to 50-year zones.

The contributing area for well 8 (De 67), which is screened in aquifer 2, is a crescent-shaped area northeast of the well field. It is composed primarily of a zero to 20-year traveltime zone, and a smaller 20 to 50-year zone (fig. 43). The area within this crescent is part of the contributing area for well 9 (De 64).

The contributing area for well 9 (De 64), which is screened in aquifer 2, is an elongate area northeast of the well field that extends to Aberdeen (fig. 44). It is about one-half mile wide at its widest, two miles long, and comprises traveltime zones of zero to 20, 20 to 50, and 50 to 100 years. The zero to 20-year zone is the largest.

The 20-year contributing area for the entire Perryman well field is shown in figure 45. Contributing areas of individual wells overlap in some places. This area represents the land-surface area that contributes recharge to the well field within 20 years of entering the ground-water system. The 20-year contributing area is about 3 miles long and 1 mile wide, and straddles the APG boundary. It extends to the AFTA in the southeast, and nearly to Aberdeen in the northeast.

The sensitivity of the simulated contributing area to changes in model input values was tested by calculating the 20-year contributing area from sensitivity-analysis model runs that were determined to have the greatest sensitivity on simulated heads. These inputs are altitude of ET surface, recharge rate, altitude of river stage, and altitude of river bottom. Variations in the possible range of error for each input caused changes in the extent of the contributing area of as much as 300 ft. This analysis indicates that the boundary of the estimated contributing area could be off by as much as 300 ft as a result of errors in input data.

PUMPAGE SIMULATIONS

Projected pumpage was simulated by entering future pumpage scenarios into the calibrated flow model and running the model for 20 years to the year 2014. Simulations were also made in which pumpage was discontinued, and recharge was reduced to demonstrate the effects of pumpage and drought conditions. All other model inputs were kept the same as in the calibration run. The results of the projected-pumpage simulations are shown in figures 46 through 93 as contoured drawdowns, simulated TCE distribution, and particle-arrival histograms. Drawdown maps show the difference between simulated water levels in 1994 and 2014, based on individual pumpage scenarios. Simulations that resulted in drawdowns of less than 5 ft are generally not shown. Positive drawdowns indicate declining water levels.

TCE distribution maps show the simulated locations of particles which represent TCE from the AFTA, as of 2014. The 1994 simulated distribution of particles was used for starting locations in these simulations. New particles were not released after 1994; contaminated soil at AFTA was removed by that time. Particle-arrival histograms show the number of simulated particles arriving each year at wells in the Perryman well field. The relative number of particles arriving at each well generally represents TCE concentrations, but a direct correlation between number of particles and concentration can not be made.

Simulation 1

Simulation 1 demonstrates the effects of continuing 1994 pumpage through 2014 (table 2). Water levels in all three aquifers are within 1 ft of 1994 water levels, and drawdowns are less than 1 ft. This simulation indicates that the aquifer system reached equilibrium after 1 year of pumpage in 1994, and 20 additional years produced no further water-level changes. The simulated 20-year contributing area for the Perryman well field for 2014 is nearly identical to the area calculated for 1994 (fig. 45).

The simulated TCE distribution in figure 46a shows a plume to the southeast of the Perryman well field that reaches well 6 (De 76). A long thin secondary plume extends eastward to the southeastern model boundary. This secondary plume is composed of particles that were released from AFTA before the Perryman well field began pumping, and so were not captured by the well field. Figure 46b shows that the plume has partially migrated into aquifer 3, caused by a simulated downward head gradient. Histograms of particle arrivals (fig. 47) show that TCE concentrations in well 5 (De 77) are low until 2000 when they decline to zero; concentrations are much higher in well 6, but decline to near zero by 2008. The decline in concentrations in both wells is caused by a reduction in pumpage from the well field between 1991 and 1994 (fig. 23), and by the removal of TCE-contaminated soil at the AFTA.

(Text continued on p. 65.)

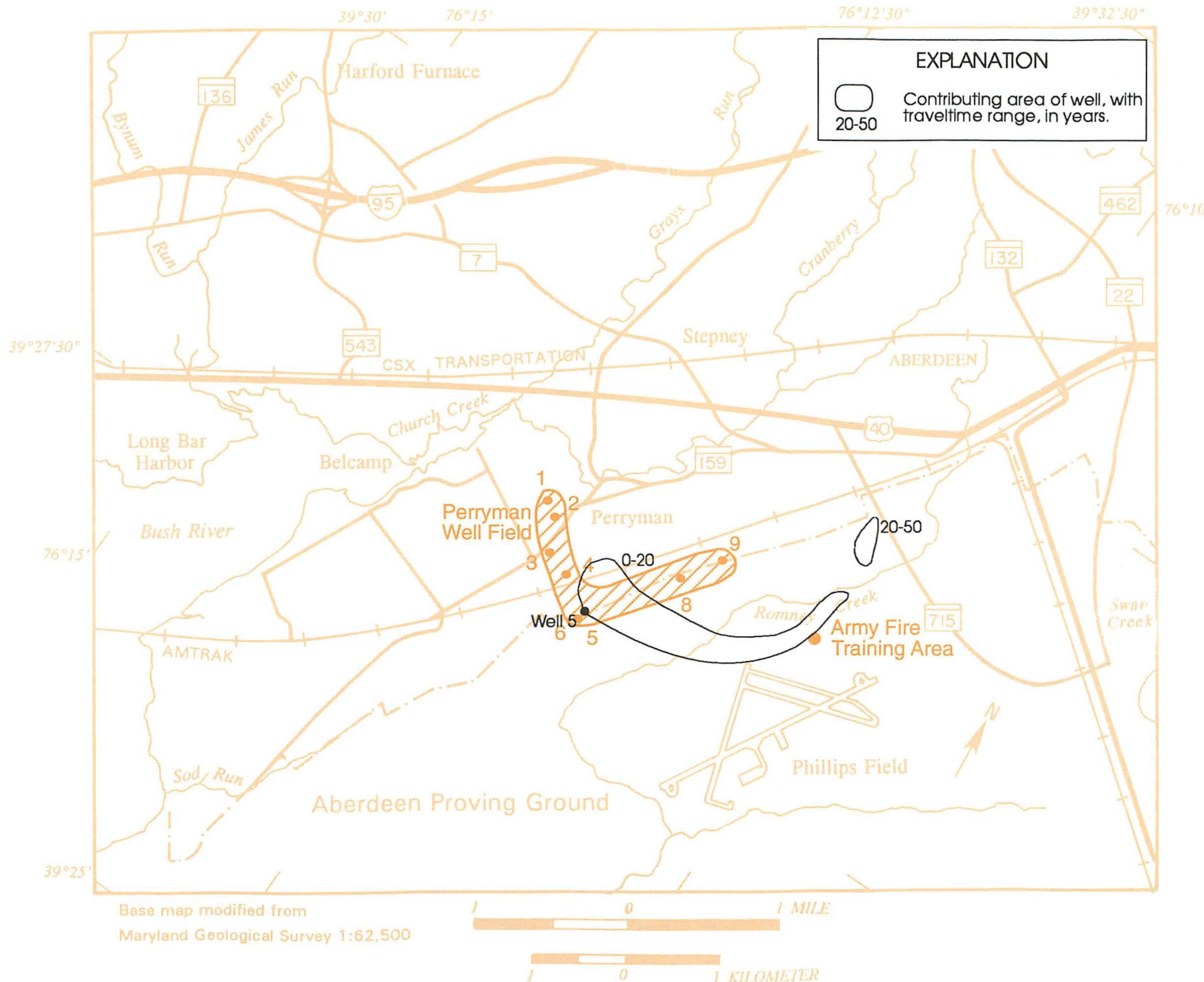


Figure 41.—Contributing area and traveltime zones for Perryman well 5.

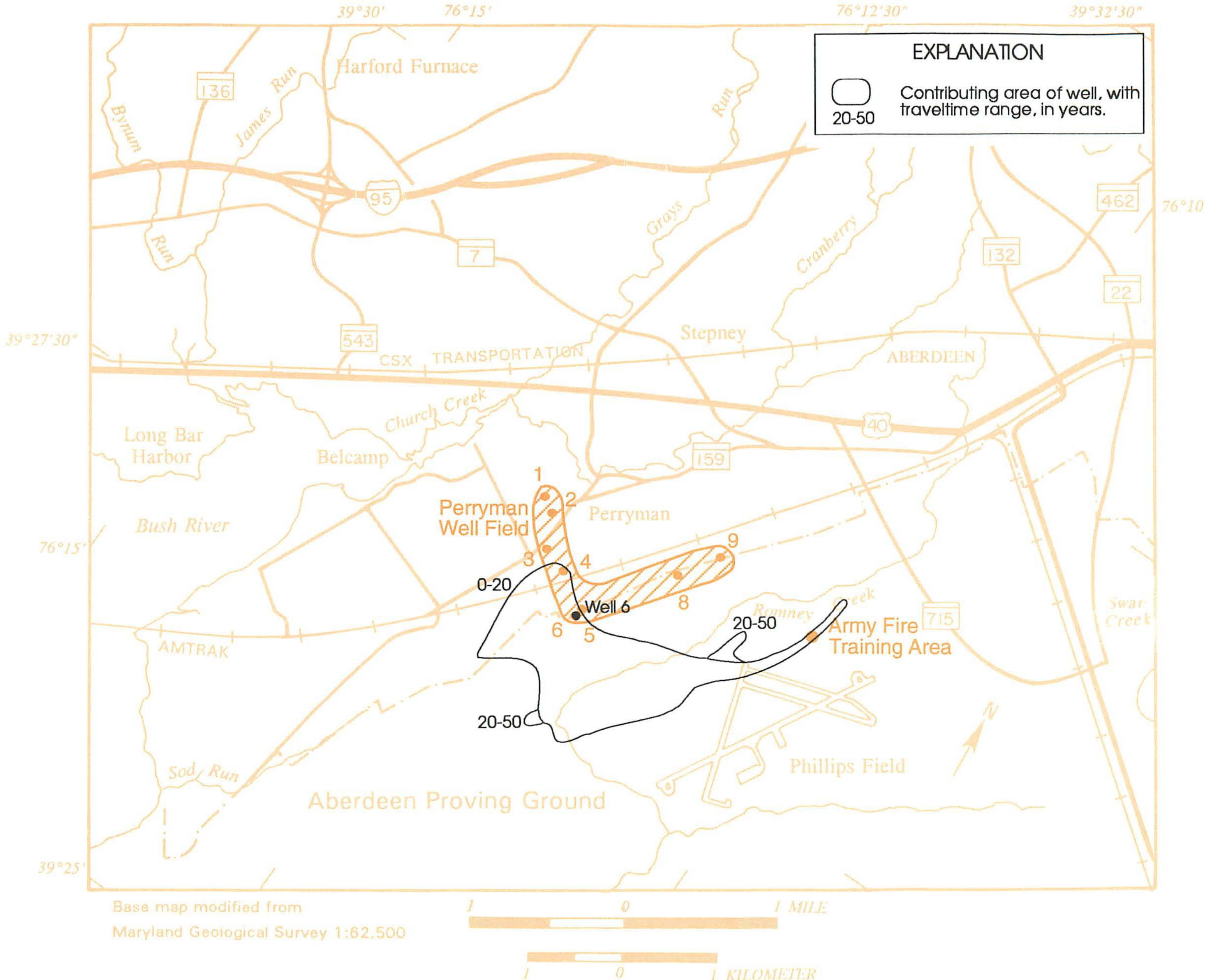


Figure 42.—Contributing area and traveltime zones for Perryman well 6.

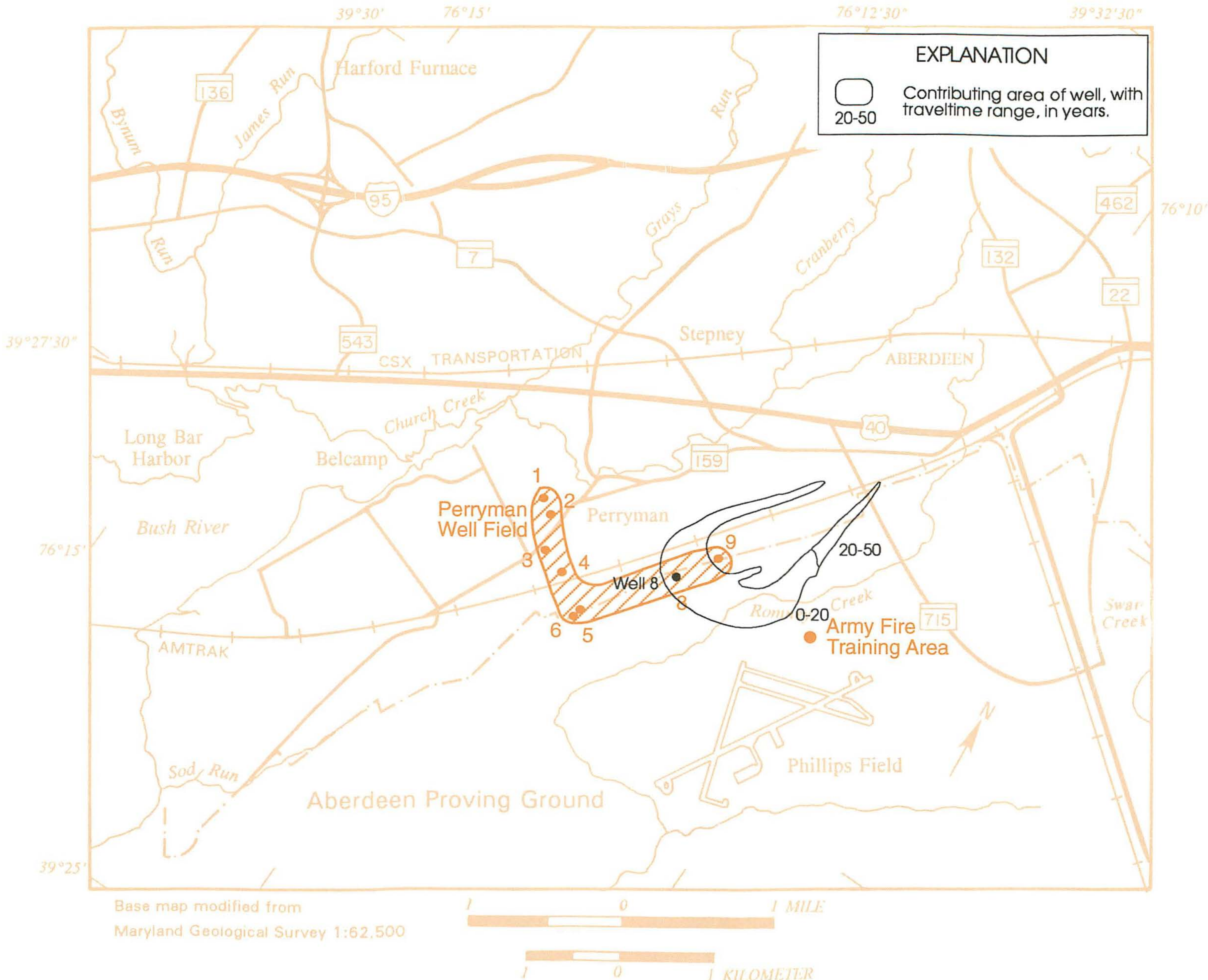


Figure 43.—Contributing area and traveltime zones for Perryman well 8.

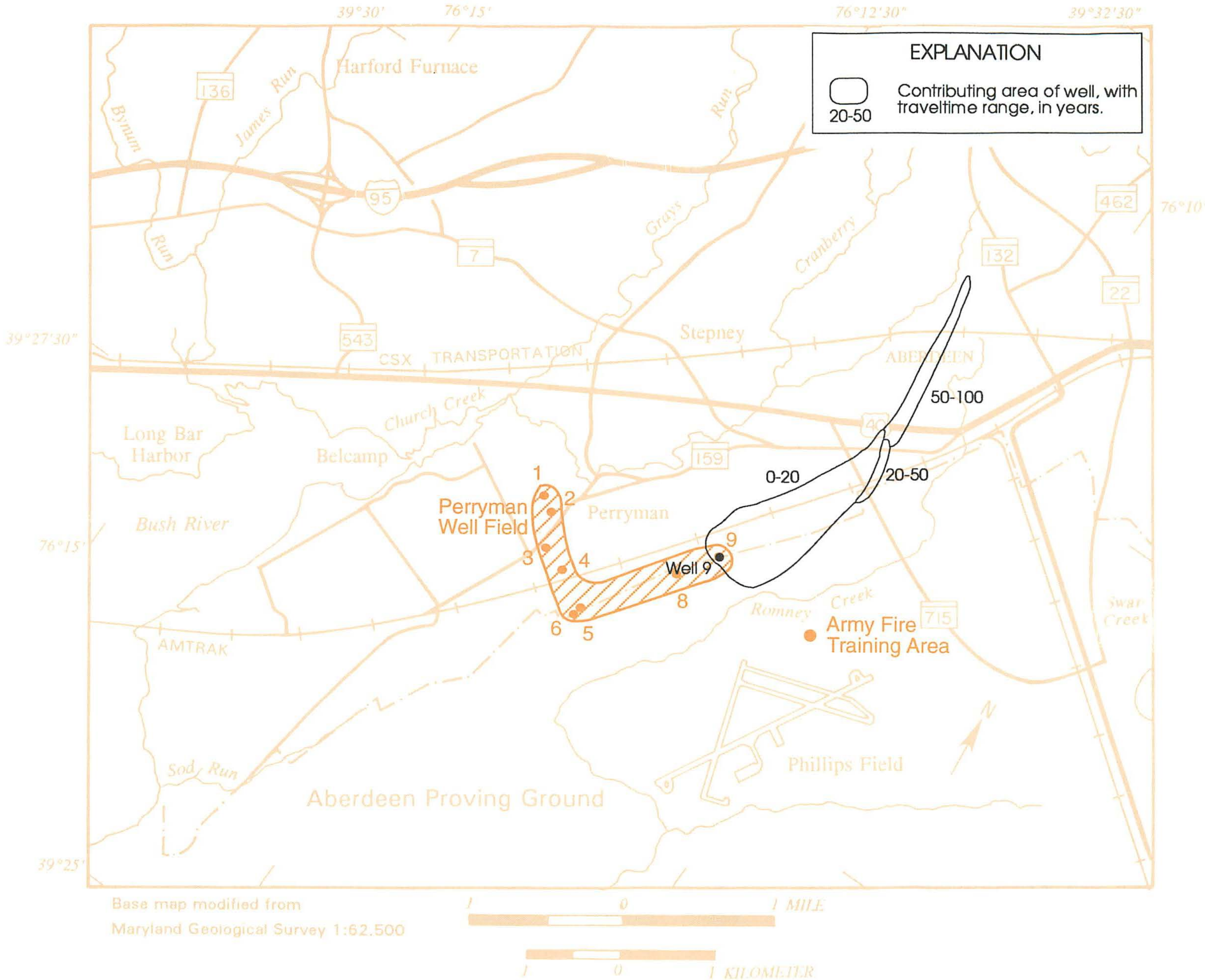


Figure 44.—Contributing area and traveltime zones for Perryman well 9.

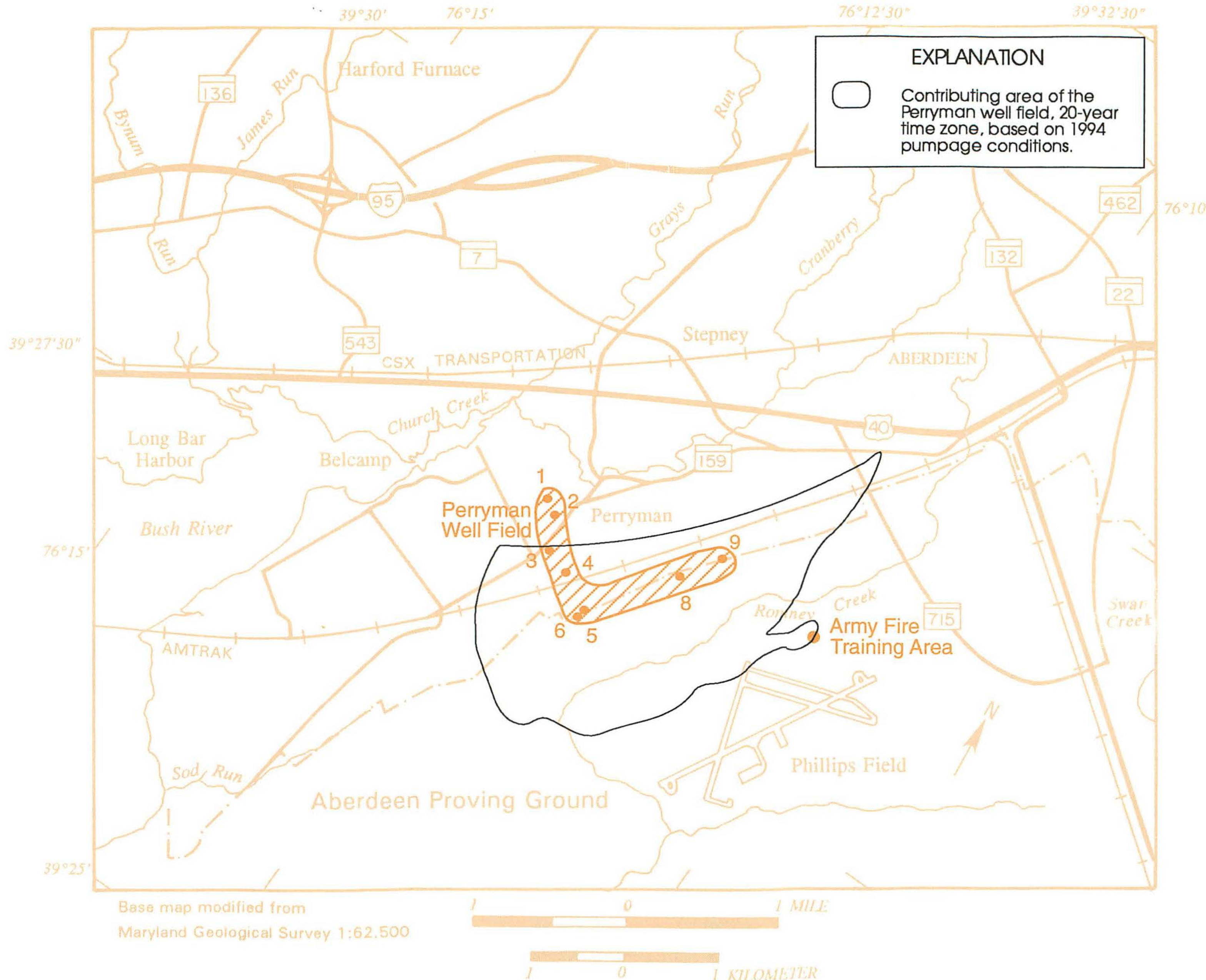


Figure 45.—Twenty-year contributing area for the Perryman well field, based on 1994 pumpage.

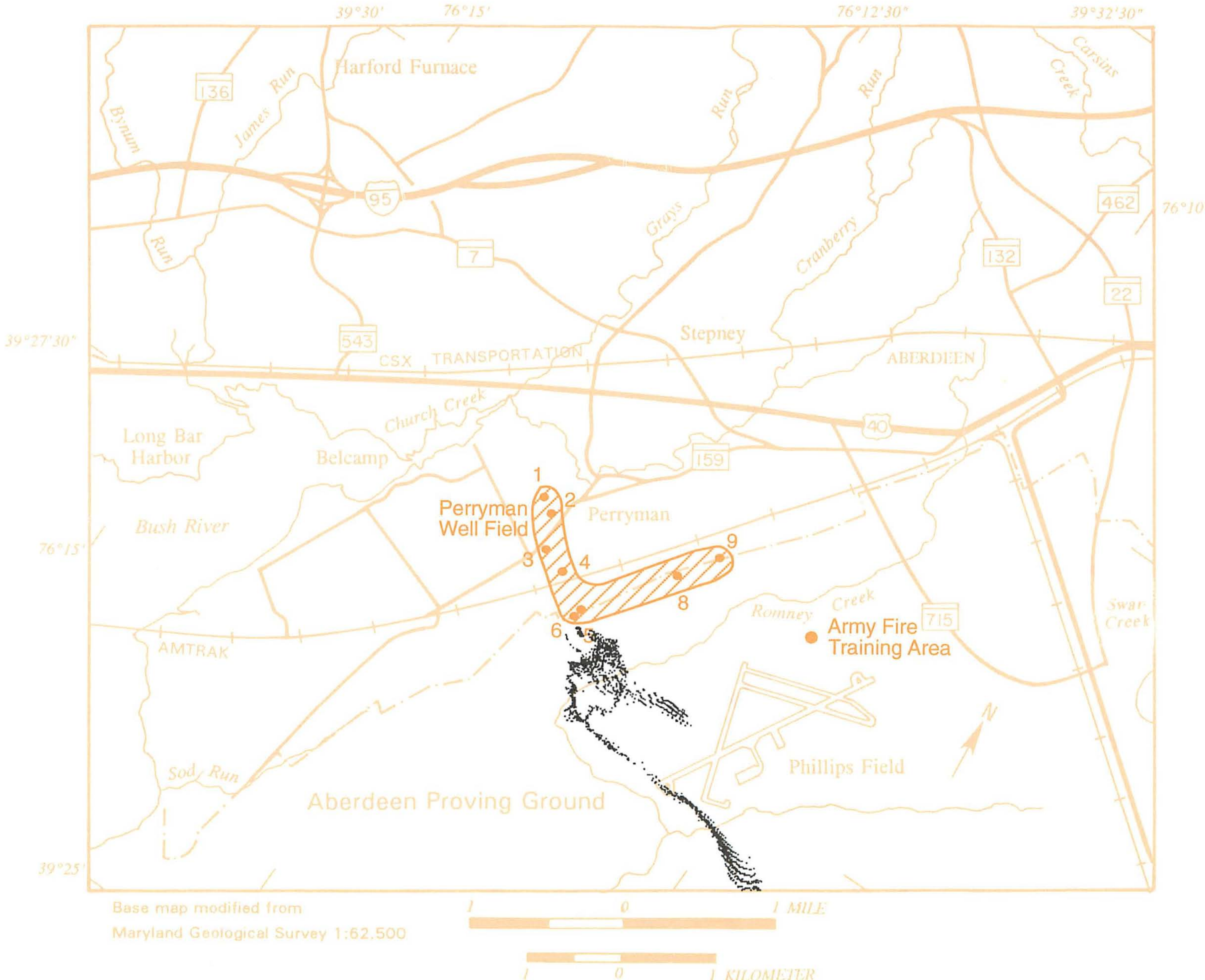


Figure 46a.—Simulated TCE distribution near Perryman, 2014, based on simulation 1 (map view).

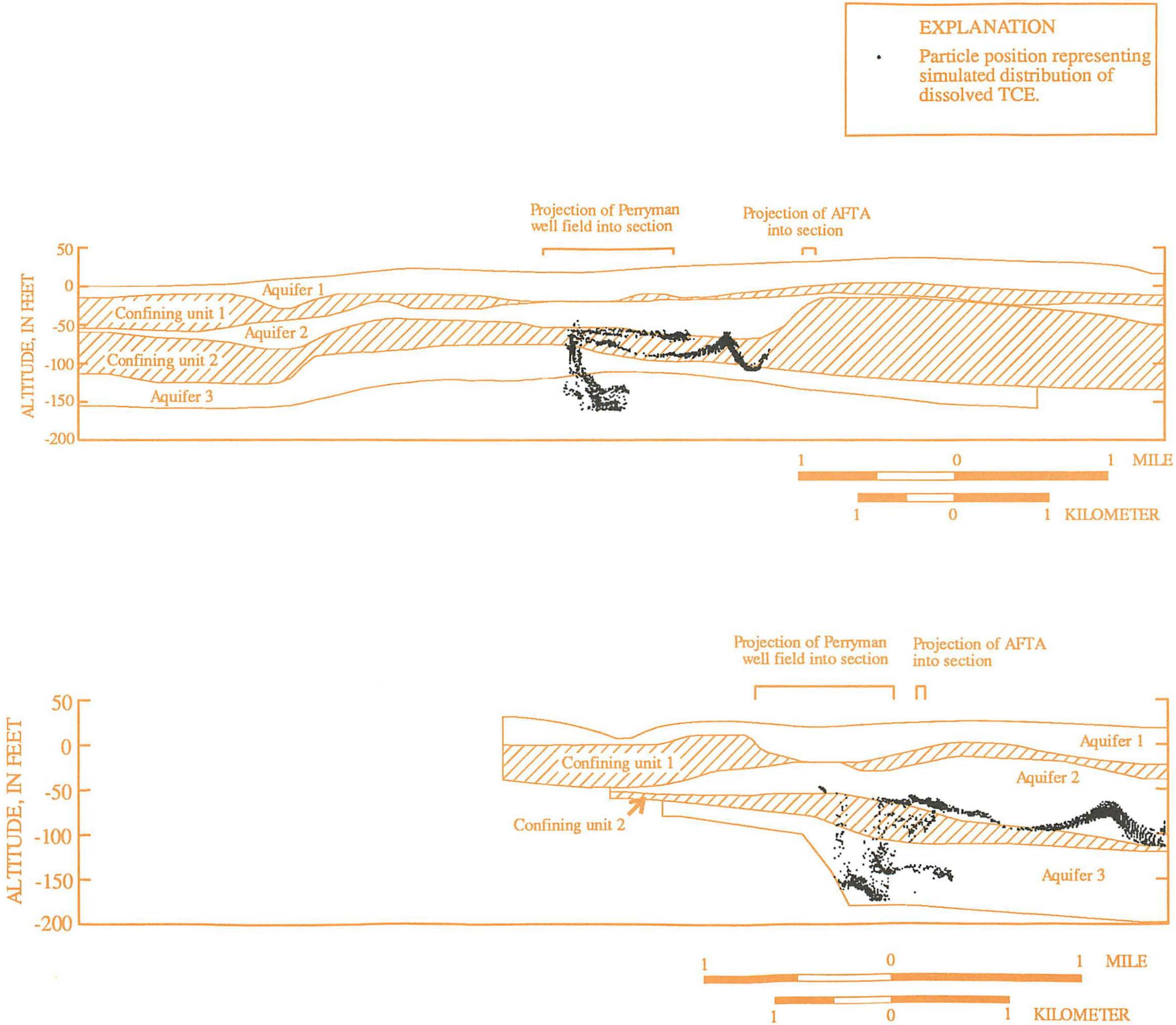
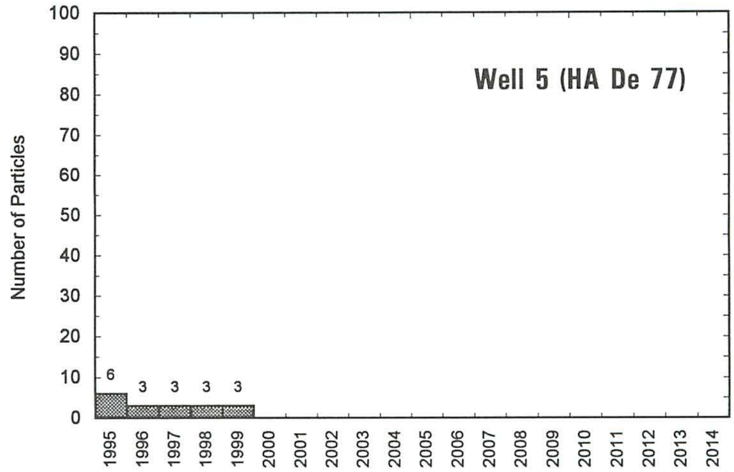


Figure 46b.—Simulated TCE distribution near Perryman, 2014, based on simulation 1 (cross section along model row 38 [top] and cross section along model column 38 [bottom]).



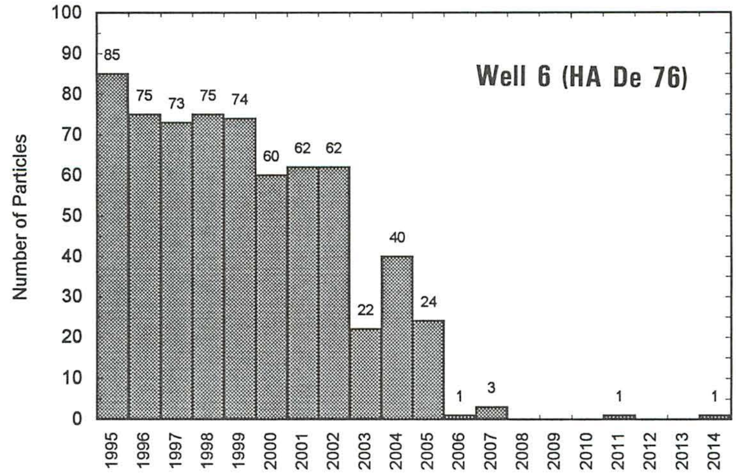


Figure 47.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 1.

Simulation 2

In simulation 2, all pumpage in the study area was increased by 20 percent from 1994 pumpage (table 2). Simulated water levels were lower than 1994 levels, but changes were less than 5 ft everywhere in the study area. Figure 48 shows that the simulated TCE distribution is similar to that based on simulation 1, but the plume is less dense, probably because more TCE was withdrawn from wells 5 (De 77) and 6 (De 76) in simulation 2. Histograms of particle arrivals (fig. 49) show that more TCE is withdrawn by wells 5 and 6 than in simulation 1, but concentrations decline to near zero by 2001 in well 5 and by 2013 in well 6.

Simulation 3

In simulation 3, all pumpage in the study area was decreased by 20 percent from 1994 pumpage (table 2). Simulated water levels were higher than 1994 levels, but changes were less than 5 ft everywhere in the study area. Figure 50 shows that the simulated TCE distribution is similar to that based on simulation 1, but the plume is slightly farther to the east. Histograms of particle arrivals (fig. 51) show that TCE concentrations are essentially zero in well 5 (De 77), and concentrations in well 6 (De 76) are lower than in simulation 1, and decline to zero by 2005.

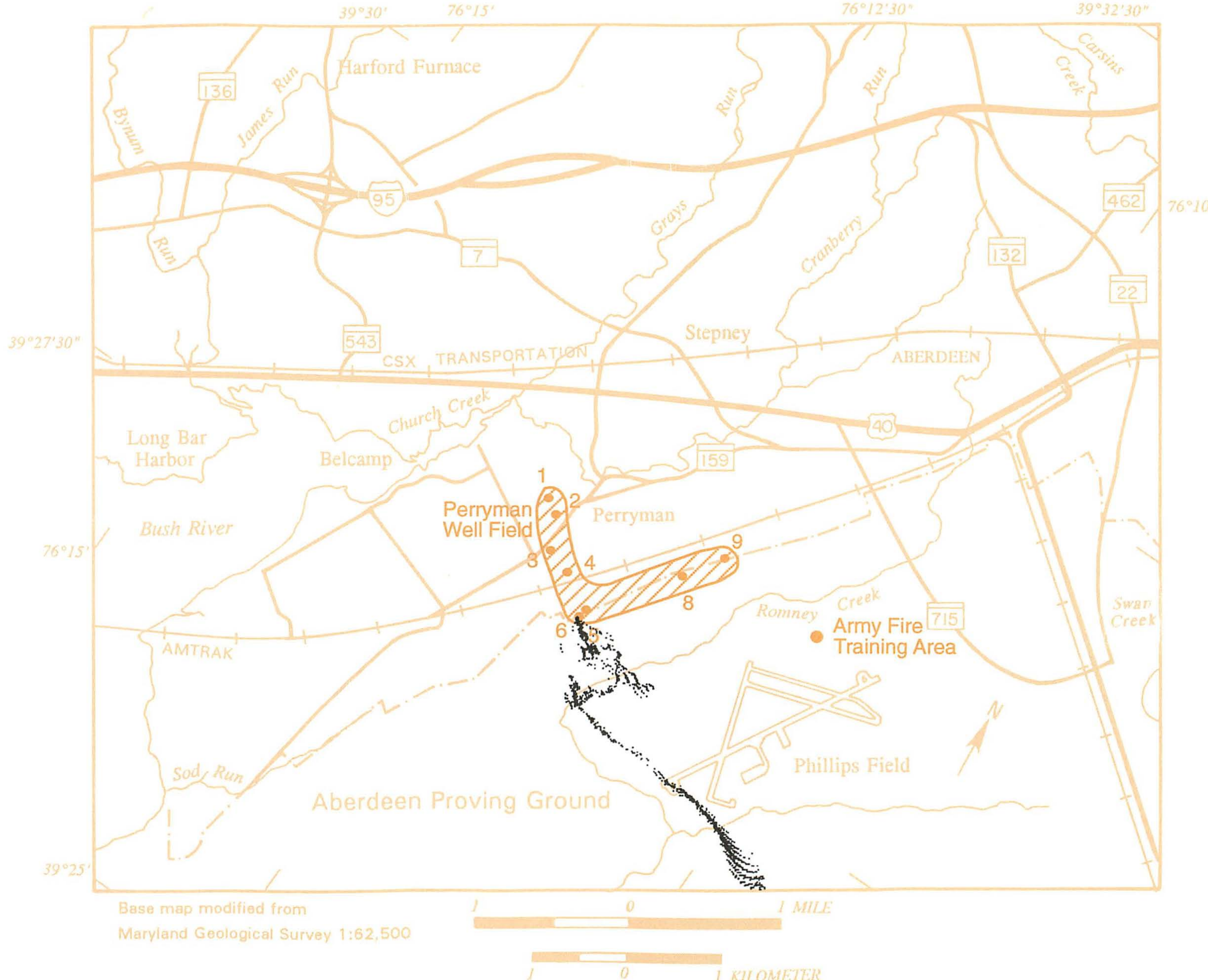


Figure 48.—Simulated TCE distribution near Perryman, 2014, based on simulation 2 (map view).

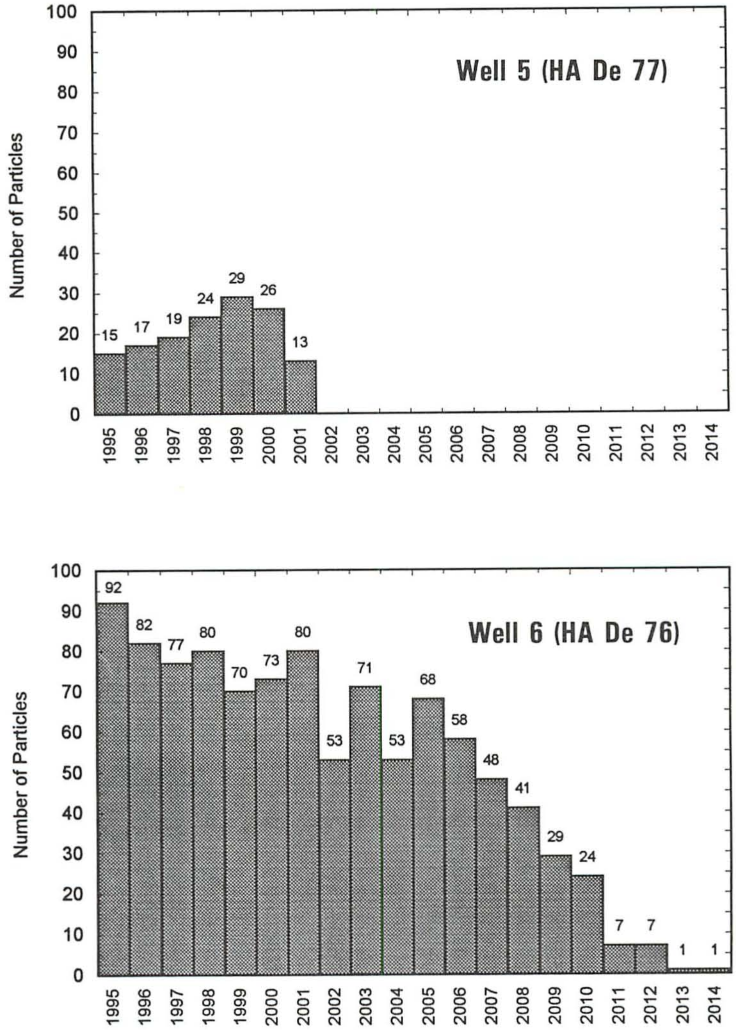


Figure 49.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 2.

Simulation 4

Simulation 4 simulates the average Ground-water Appropriation Permit (GAP) allocations for all large pumpage centers in the study area (table 2). Total pumpage for the Perryman well field in this simulation is 4.2 Mgal/d (table 2). Drawdown in layer 1 is 11 ft at the Perryman well field and 7 ft at the Aberdeen well field (fig. 52). Drawdown in layer 2 is 15 ft at the Perryman well field (fig. 53), and drawdown in layer 3 is 18 ft at the Perryman well field (fig. 54). Average allocations at the Perryman and Aberdeen well fields were 90 percent and 50 percent greater than 1994 pumpage amounts, which resulted in the lowered water levels in this simulation.

The 20-year contributing area for the Perryman well field, based on simulation 4, is shown in figure 55, along with the contributing area based on 1994 pumpage shown for comparison. The contributing area for this simulation extends about 0.4 miles farther to the southwest and to the east than the area based on 1994 pumpage. The larger contributing area for this simulation provides more recharge to accommodate the increased pumping rates.

Figure 56 shows the simulated TCE distribution for 2014 based on simulation 4. The large plume to the southeast of the Perryman well field that was present in simulation 1 is absent in this simulation. That contaminated water has been drawn into wells 5 (De 77) and 6 (De 76), due to increased with-

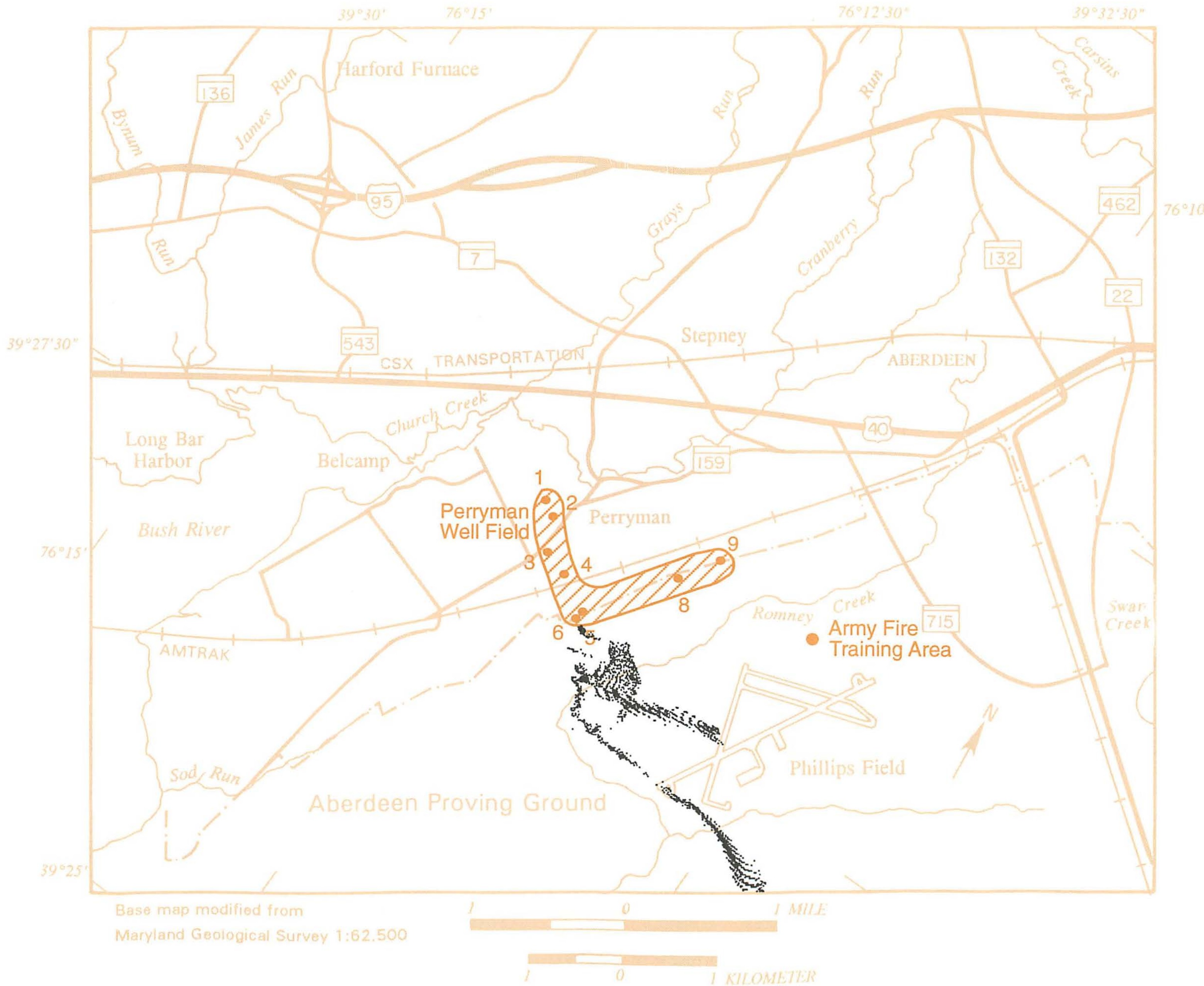


Figure 50.—Simulated TCE distribution near Perryman, 2014, based on simulation 3 (map view).

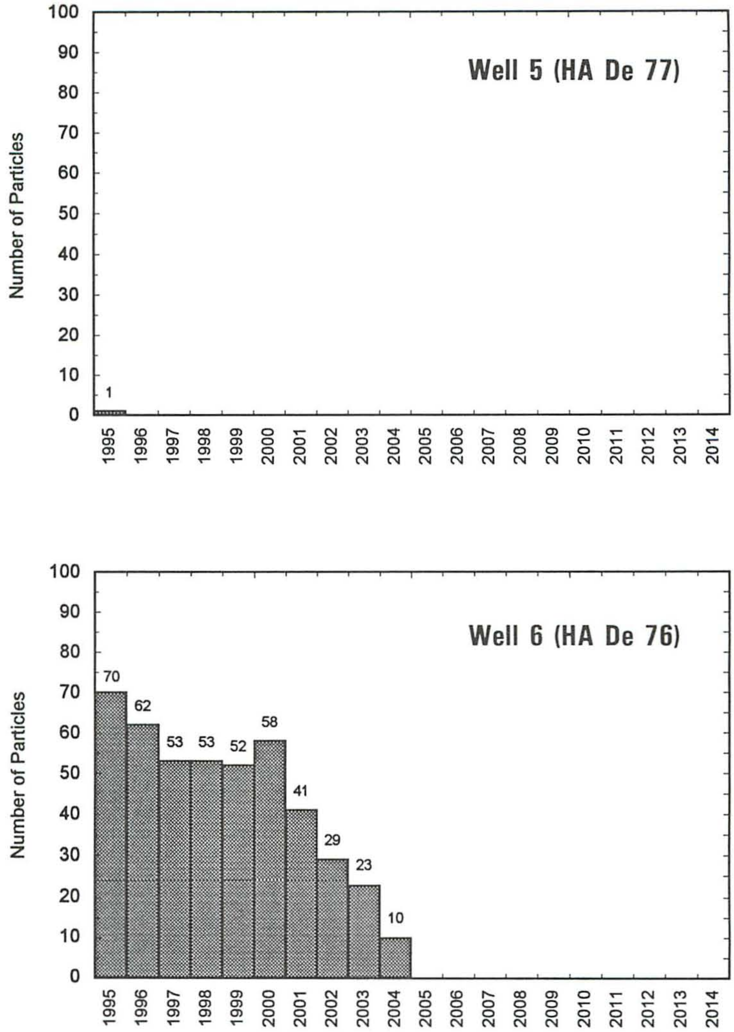


Figure 51.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 3.

drawal rates, and higher hydraulic gradients. The thin section of the TCE plume farther to the south of Perryman is present in this simulation, but has not yet reached the southeastern model boundary by 2014. The histogram showing particle arrivals at well 5 (fig. 57) indicates TCE concentrations much higher than in the previous simulation through 2005 when concentrations fall to near zero. The histogram showing particle arrivals at well 6 indicates TCE concentrations slightly higher than in the previous simulations which decrease somewhat but continue to the end of the simulation.

Simulation 5

Simulation 5 simulates the maximum Ground-water Appropriation Permit allocations for all large pumpage centers in the study area (table 2). Ground-water users would not be allowed to pump at these rates for more than one month in each year; this simulation is used to demonstrate the effects on water levels and contaminant migration of very high withdrawal rates. Total pumpage for the Perryman well field in this simulation is 5.3 Mgal/d (table 2). Drawdown in layer 1 is 20 ft at the Perryman well field and 16 ft at the Aberdeen well field (fig. 58). Drawdown in layer 2 is 27 ft at the Perryman well field (fig. 59). Drawdown in layer 3 is 33 ft at the Perryman well field and 34 ft at the Clorox wells (fig. 60). Maximum allocations at the Perryman and Aberdeen well fields were 133 percent and 87 percent greater than 1994 pumpage amounts, which resulted in the lowered water levels in this simulation.

Figure 61 shows the simulated TCE distribution. The large plume to the southeast of the Perryman well field that was

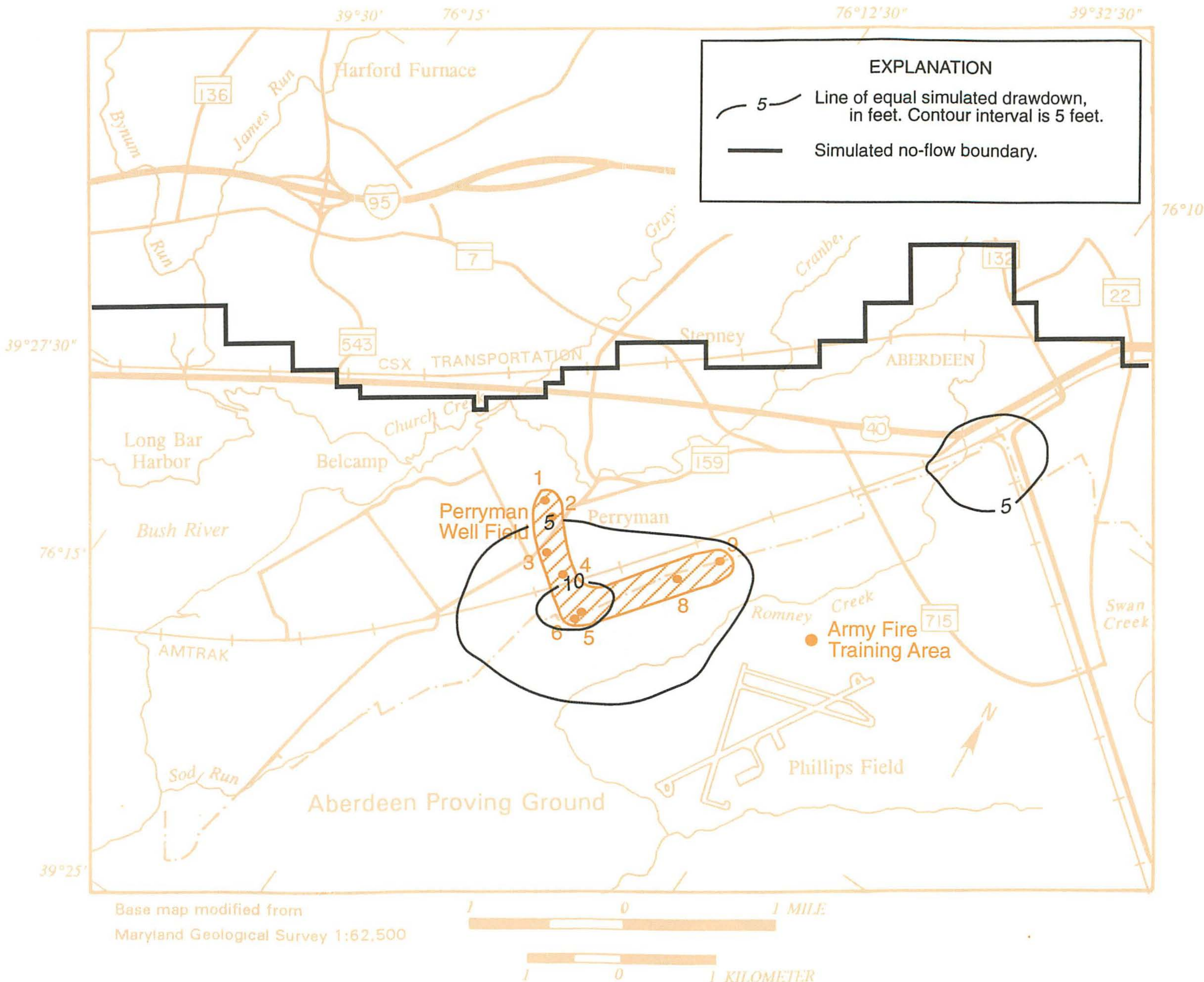


Figure 52.—Simulated drawdown in aquifer 1 for 1994-2014, based on simulation 4.

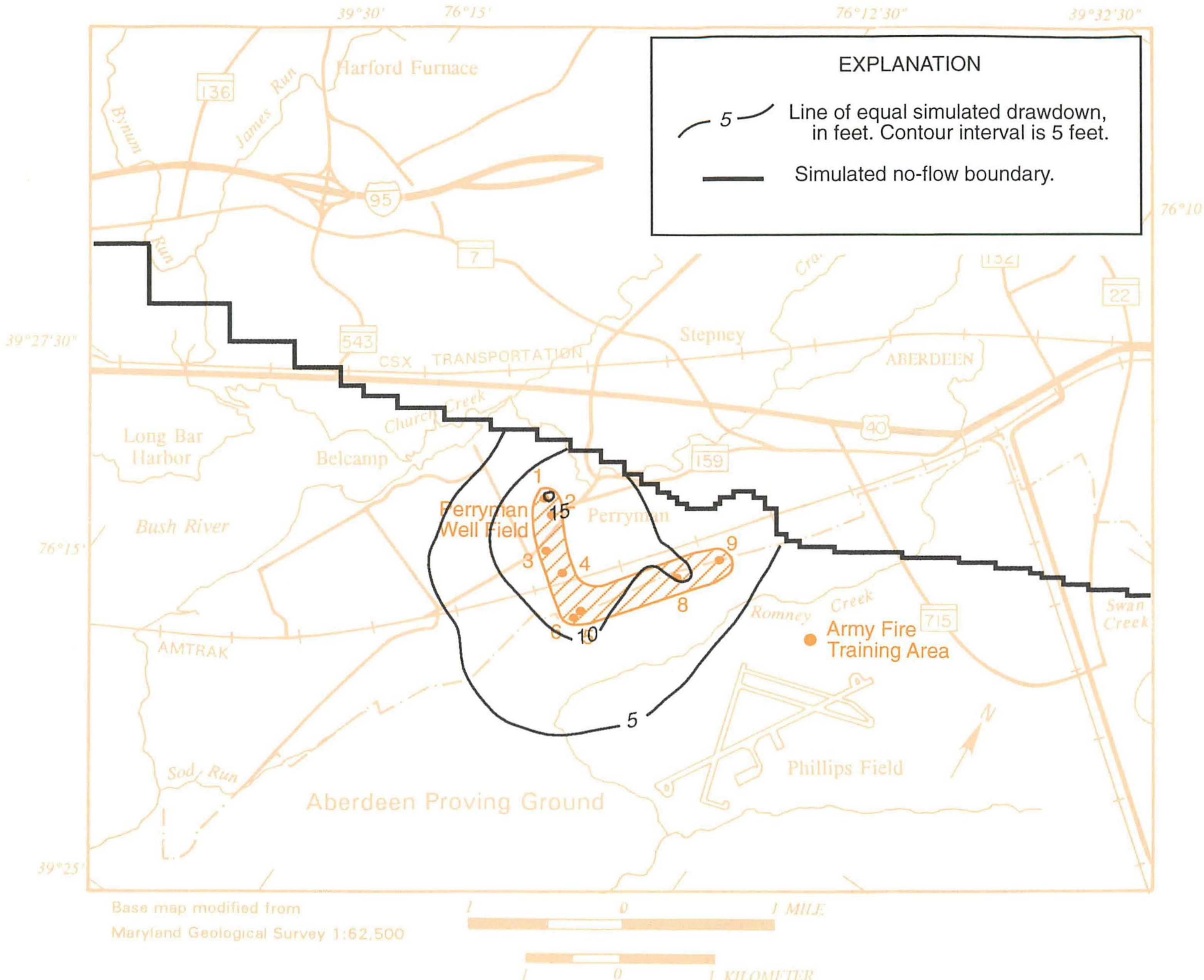


Figure 53.—Simulated drawdown in aquifer 2 for 1994-2014, based on simulation 4.

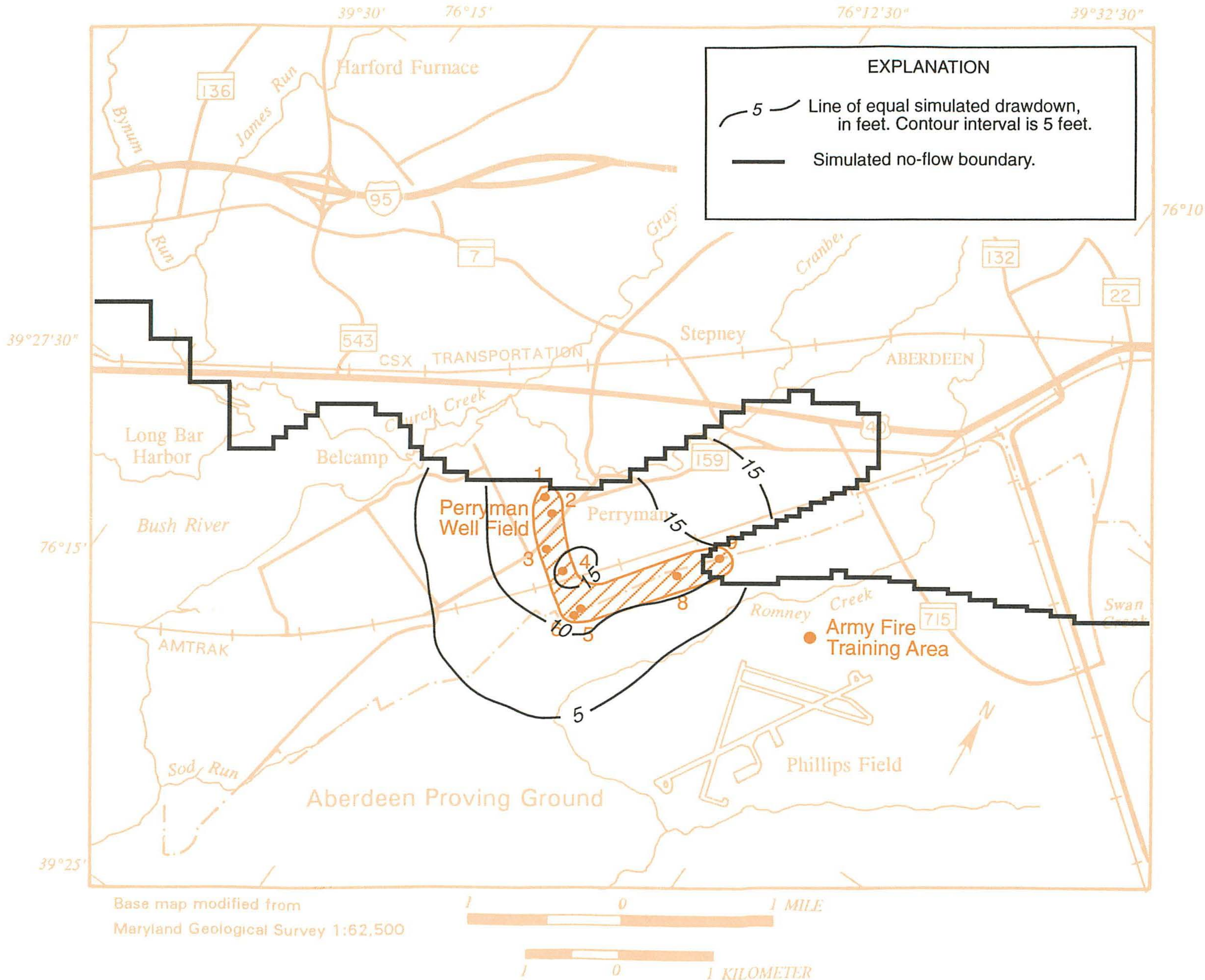


Figure 54.—Simulated drawdown in aquifer 3 for 1994-2014, based on simulation 4.

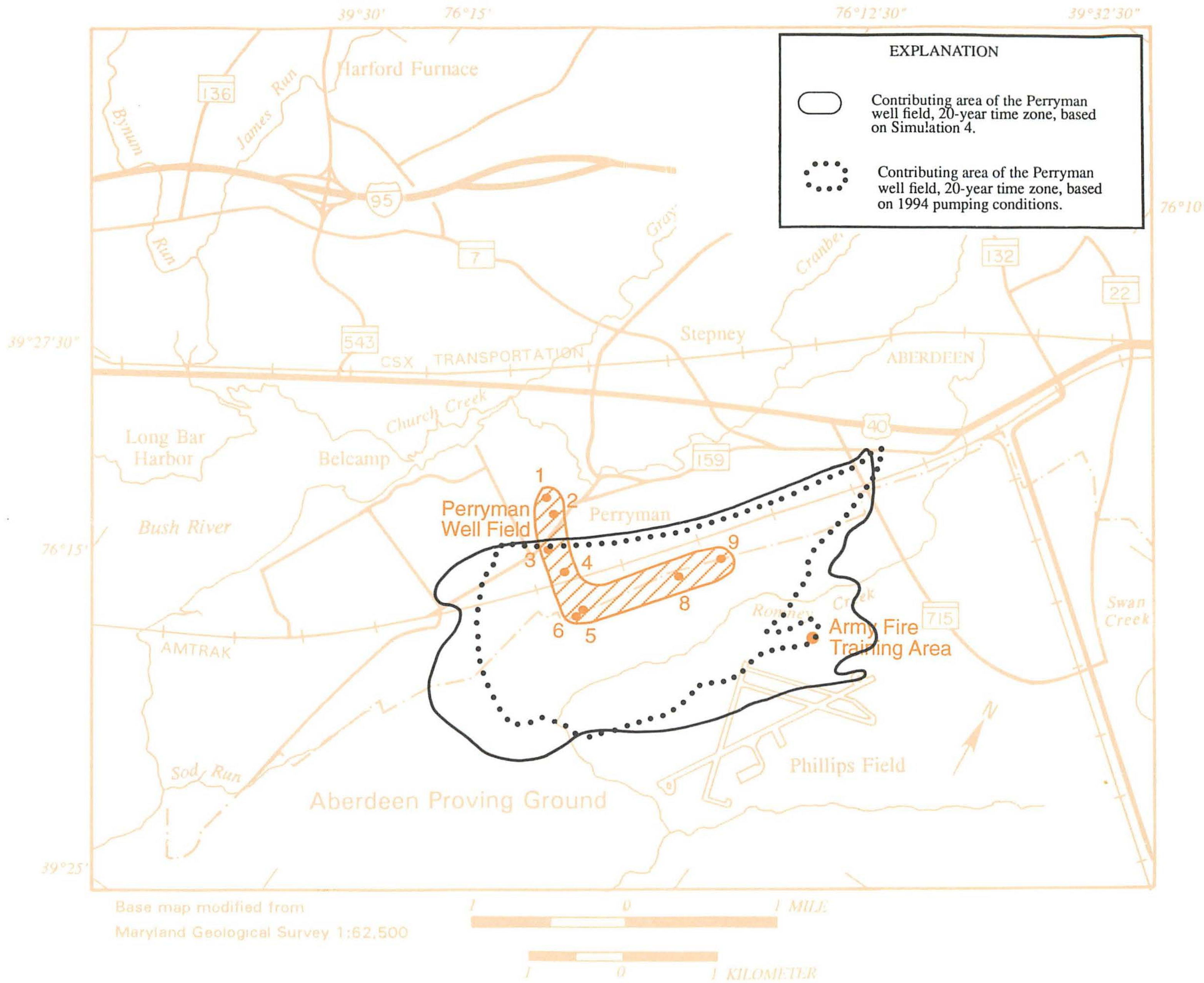


Figure 55.—Twenty-year contributing area of the Perryman well field, based on simulation 4.

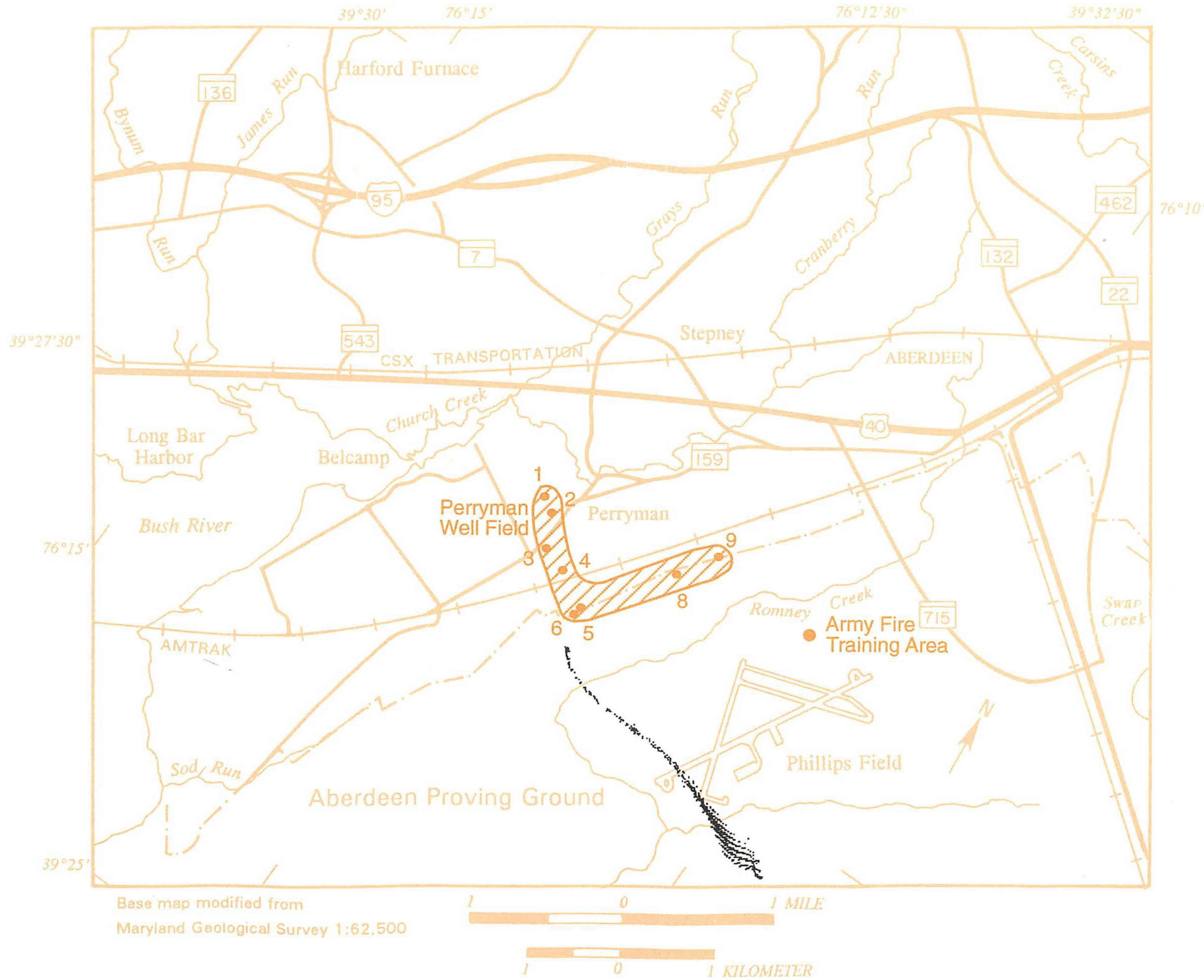
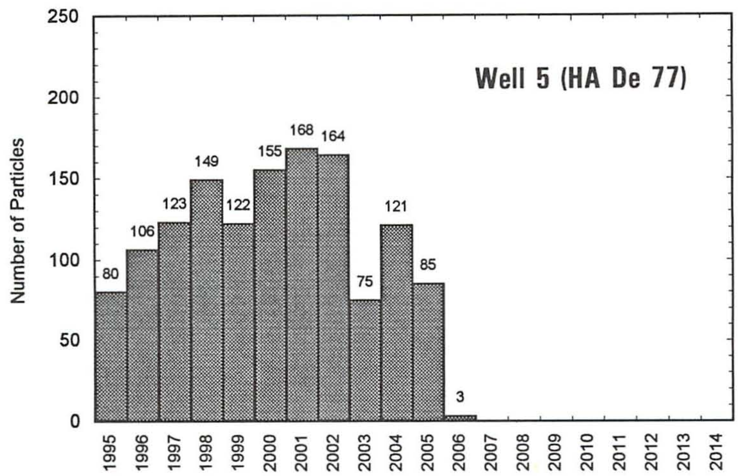


Figure 56.—Simulated TCE distribution near Perryman, 2014, based on simulation 4 (map view).



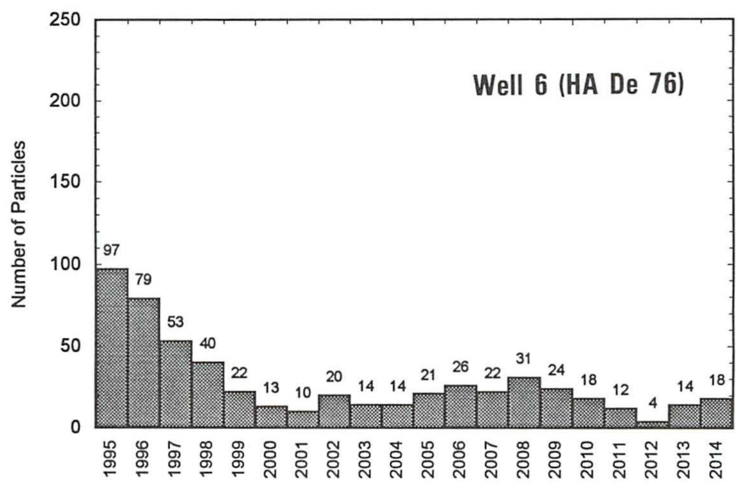


Figure 57.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 4.

present in simulation 1 is absent in this simulation. That contaminated water has been drawn into wells 5 (De 77) and 6 (De 76), due to increased withdrawal rates and higher hydraulic gradients. The thin section of the TCE plume farther to the south of Perryman is present in this simulation, but has not yet reached the southeastern model boundary by 2014. The histogram showing particle arrivals at well 5 (fig. 62) indicates TCE concentrations much higher than in previous simulations through 2004 when concentrations fall to zero. The histogram showing particle arrivals at well 6 indicates TCE concentrations higher than in the previous simulations which decrease to near zero at the end of the simulation.

Simulation 6

This simulation demonstrates the role of pumpage in the movement of the TCE plume. All simulated pumpage in the study area was discontinued for 20 years, and resultant water levels and the position of the TCE plume were compared to those from simulation 1. Well-field operators for the Perryman well field (and other wells in the study area) do not plan to shut off their wells; this simulation was included to demonstrate the effects of pumpage in the study area. Water levels in all three aquifers return to their prepumping levels, which result in negative drawdowns (or recoveries). Draw-

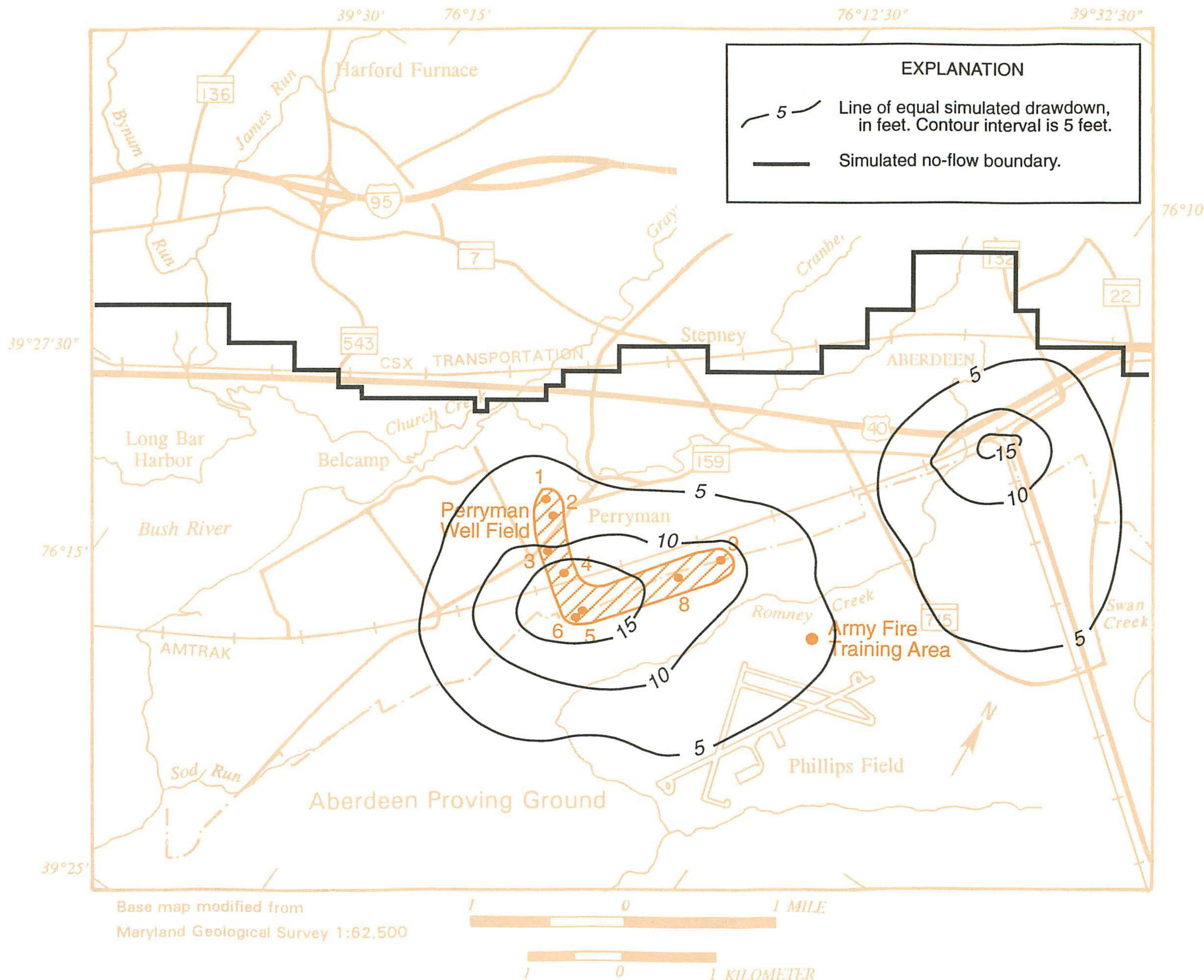


Figure 58.— Simulated drawdown in aquifer 1 for 1994-2014, based on simulation 5.

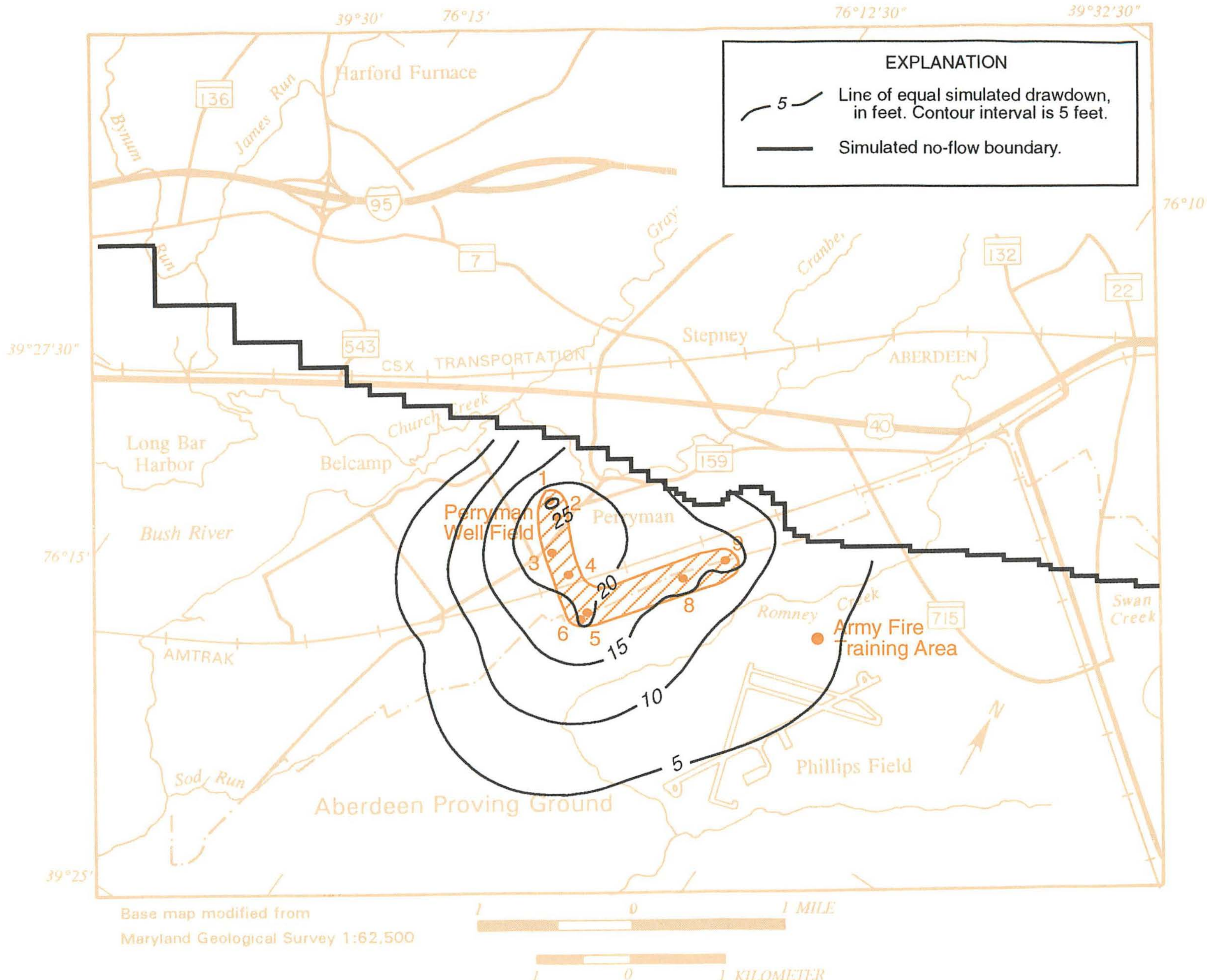


Figure 59.— Simulated drawdown in aquifer 2 for 1994-2014, based on simulation 5.

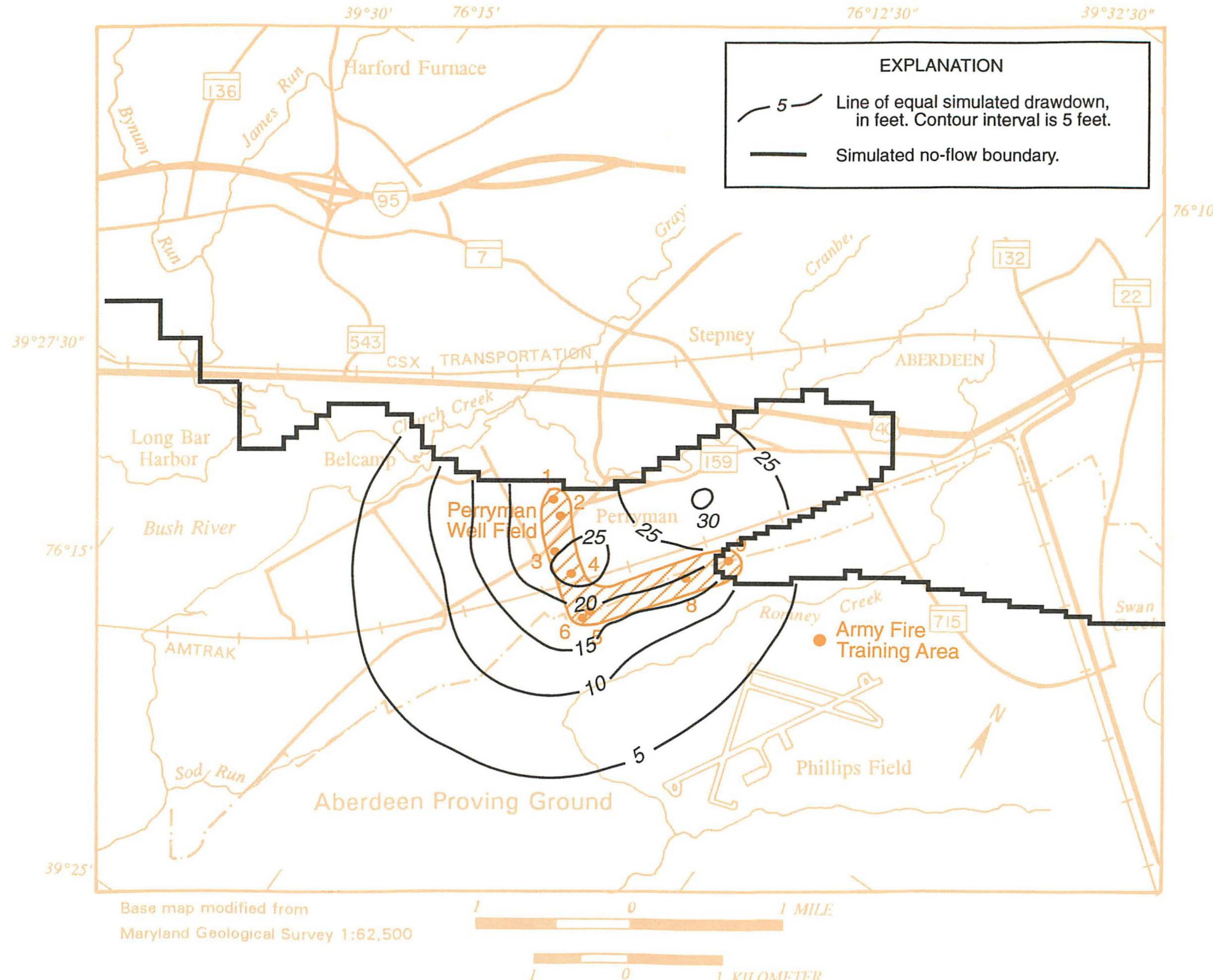


Figure 60.—Simulated drawdown in aquifer 3 for 1994-2014, based on simulation 5.

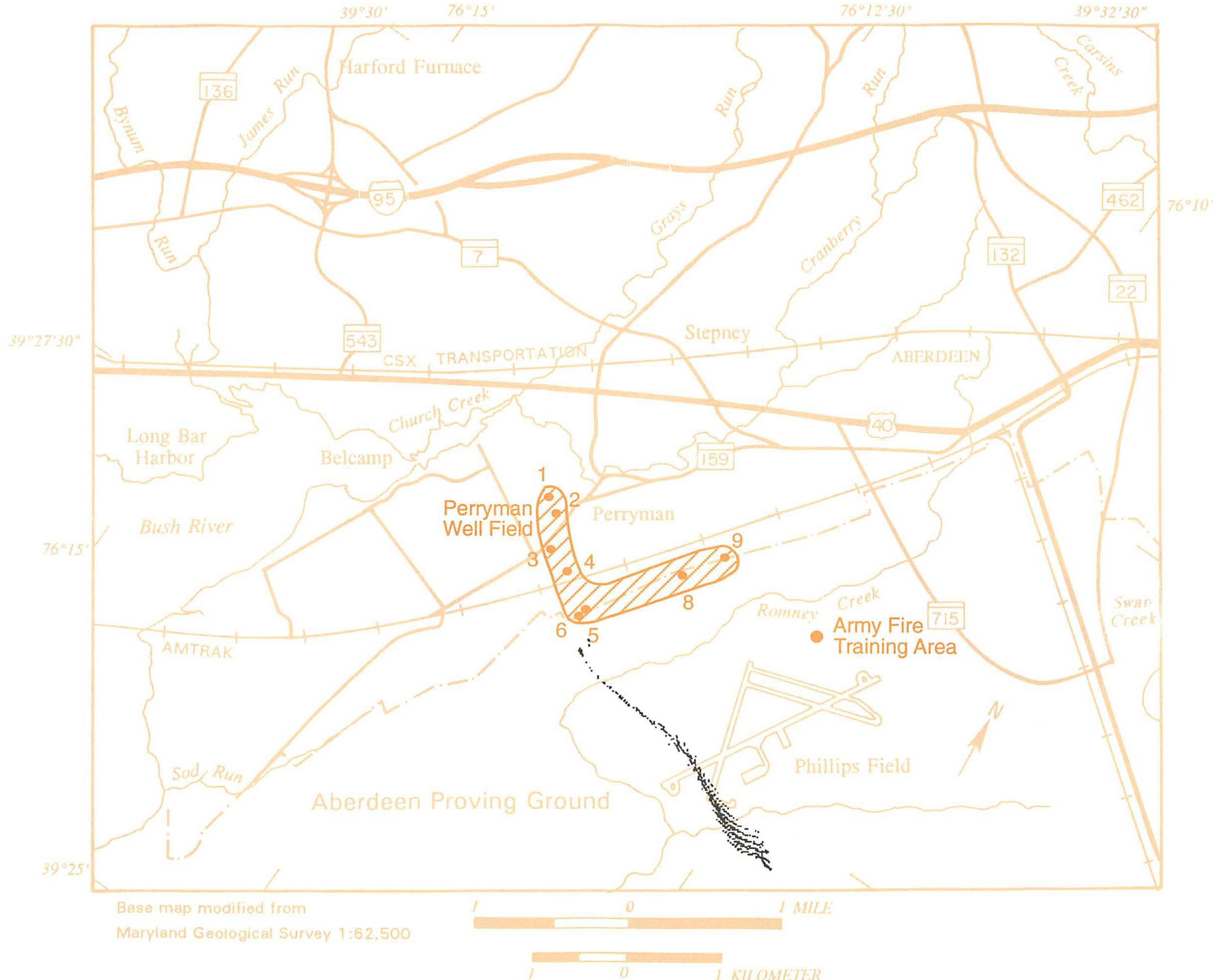


Figure 61.—Simulated TCE distribution near Perryman, 2014, based on simulation 5 (map view).

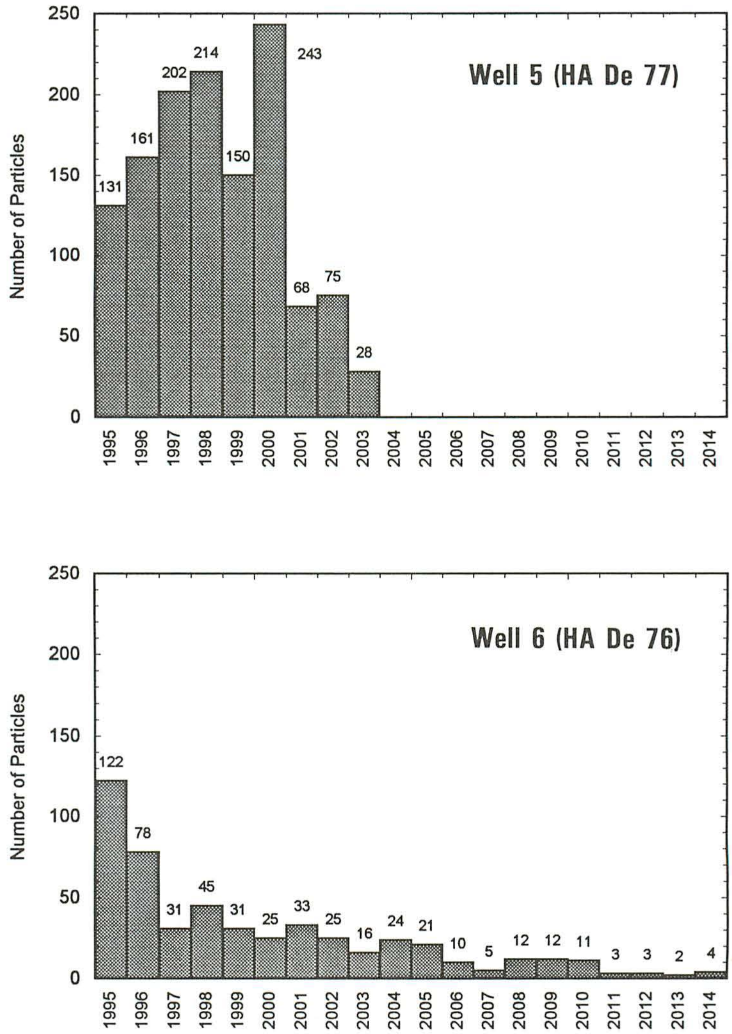


Figure 62.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 5.

downs are −10 ft in aquifer 1 at both the Perryman and Aberdeen well fields (fig. 63). Maximum simulated drawdown in aquifer 2 is −16 ft at the Perryman well field (fig. 64), and in aquifer 3 is −23 ft at the Clorox plant (fig. 65).

The simulated TCE distribution (fig. 66) shows that the main part of the plume has migrated about one-half mile farther to the southeast than in simulation 1. The narrow section of the plume is also slightly farther to the southeast than in simulation 1. A few stray particles linger near the APG boundary, heading for the Bush River. Because the wells are not pumping in this simulation, particles do not discharge to those wells, and particle-arrival histograms are not shown.

Simulation 7

Simulation 7 demonstrates the effects of discontinuing pumpage at Perryman wells 5 (De 77) and 6 (De 76). Although county well operators have no intention of turning these wells off, the simulation is useful in showing the fate of the TCE plume if the contaminated wells were to be shut down. Simulated water levels rise, resulting in maximum drawdowns, centered at wells 5 and 6, of −5, −6, and −5 ft in aquifers 1, 2, and 3, respectively (figs. 67, 68, and 69).

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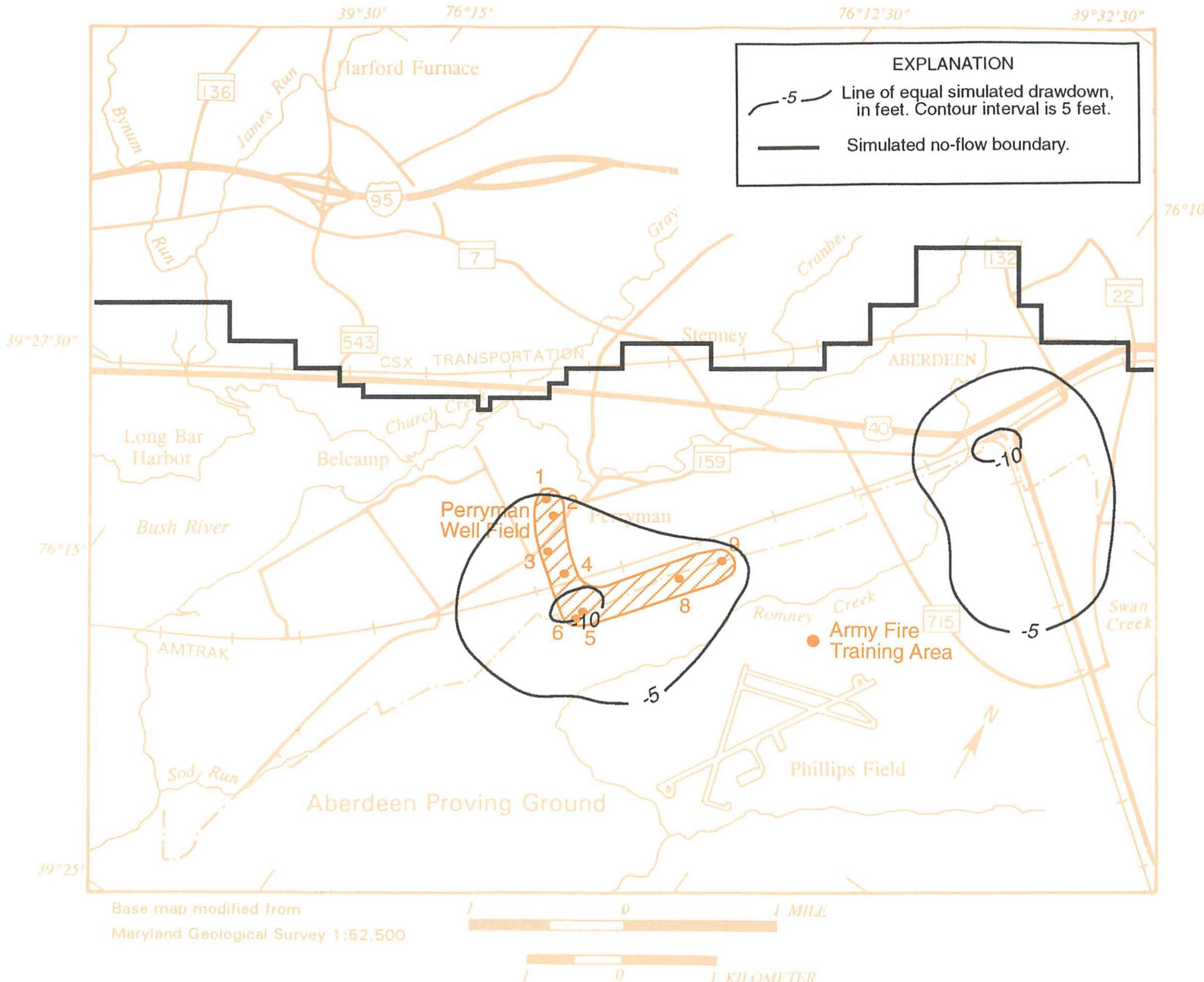

Figure 63.—Simulated drawdown in aquifer 1 for 1994-2014, based on simulation 6.

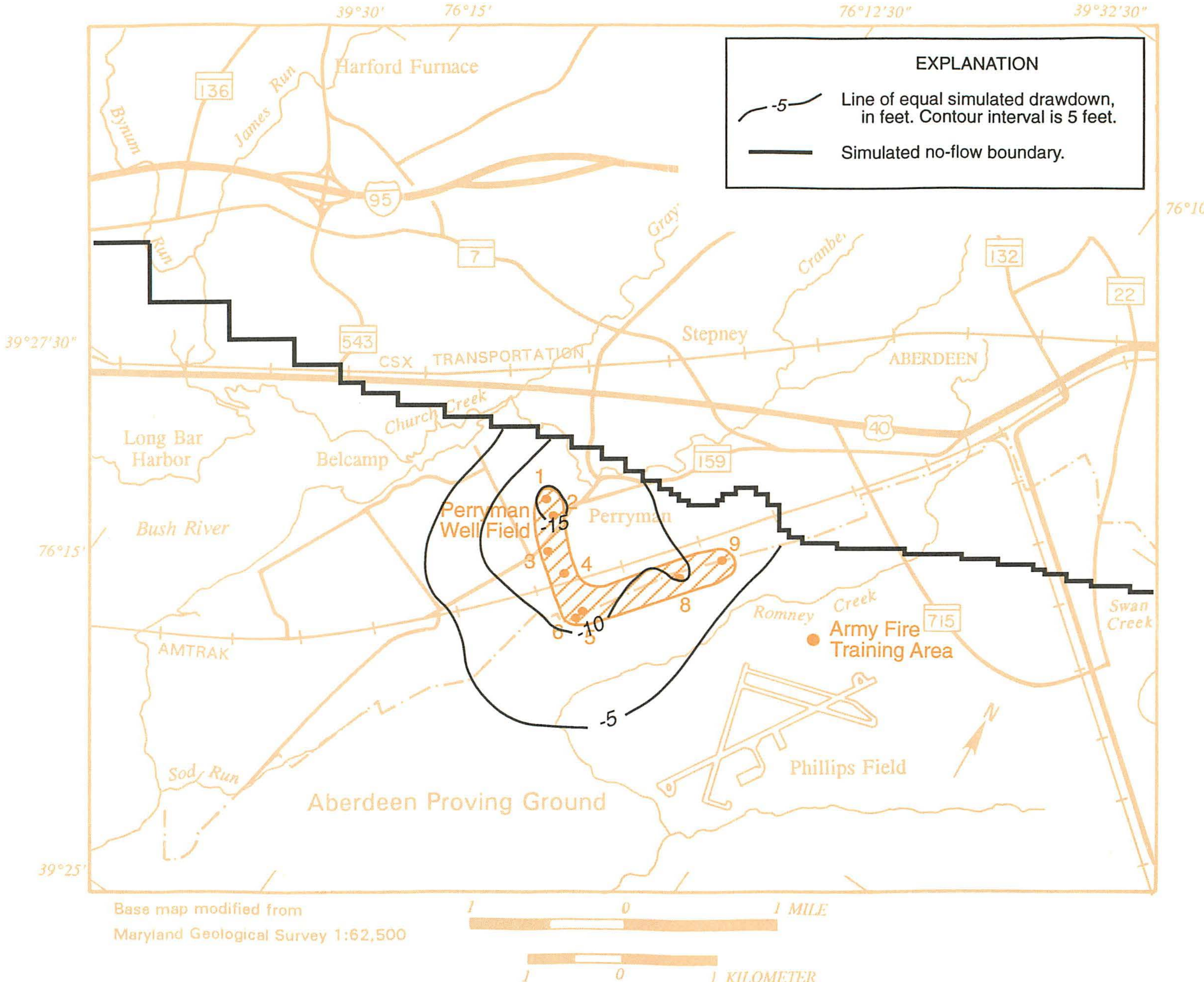

Figure 64.—Simulated drawdown in aquifer 2 for 1994-2014, based on simulation 6.

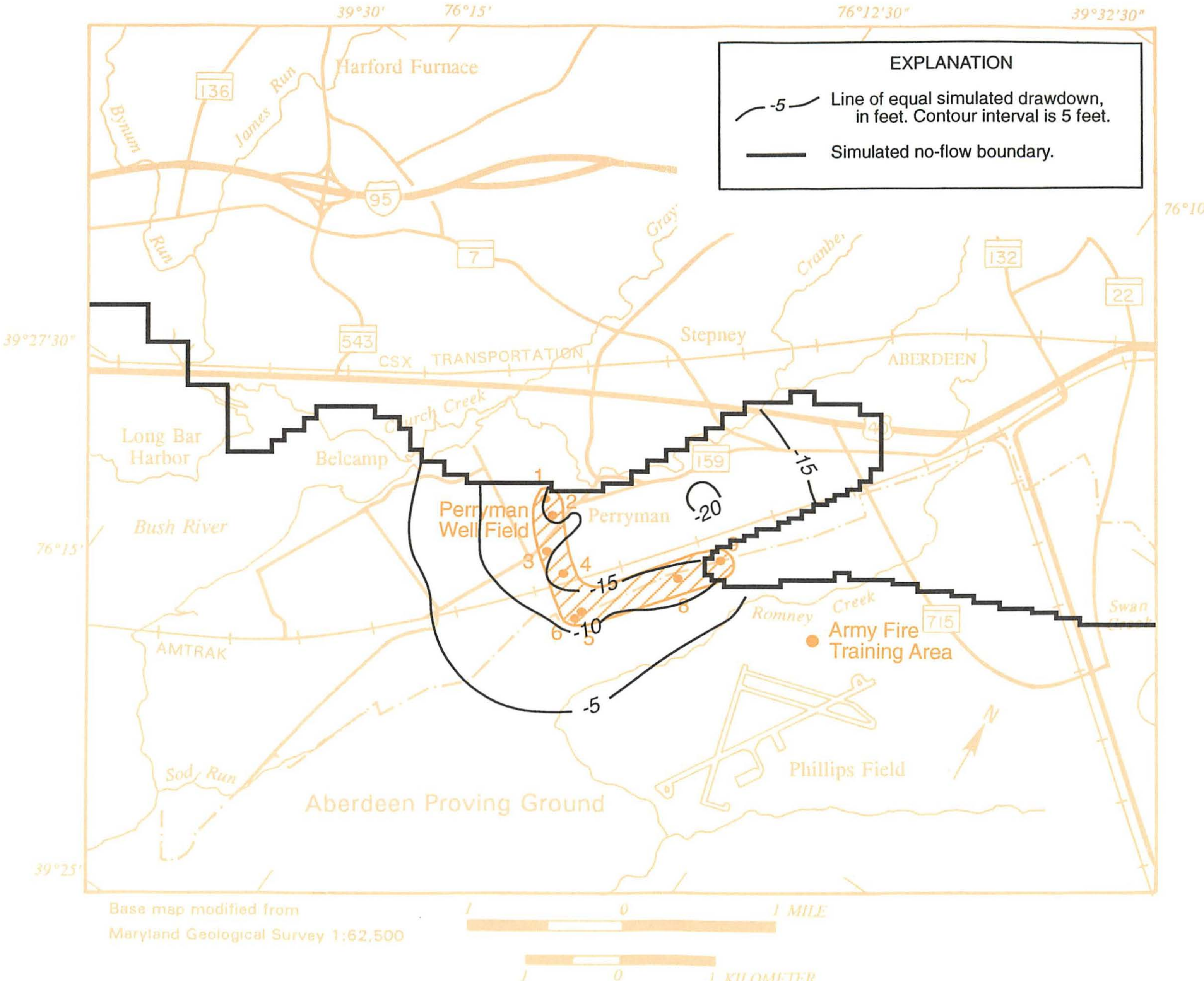

Figure 65.—Simulated drawdown in aquifer 3 for 1994-2014, based on simulation 6.

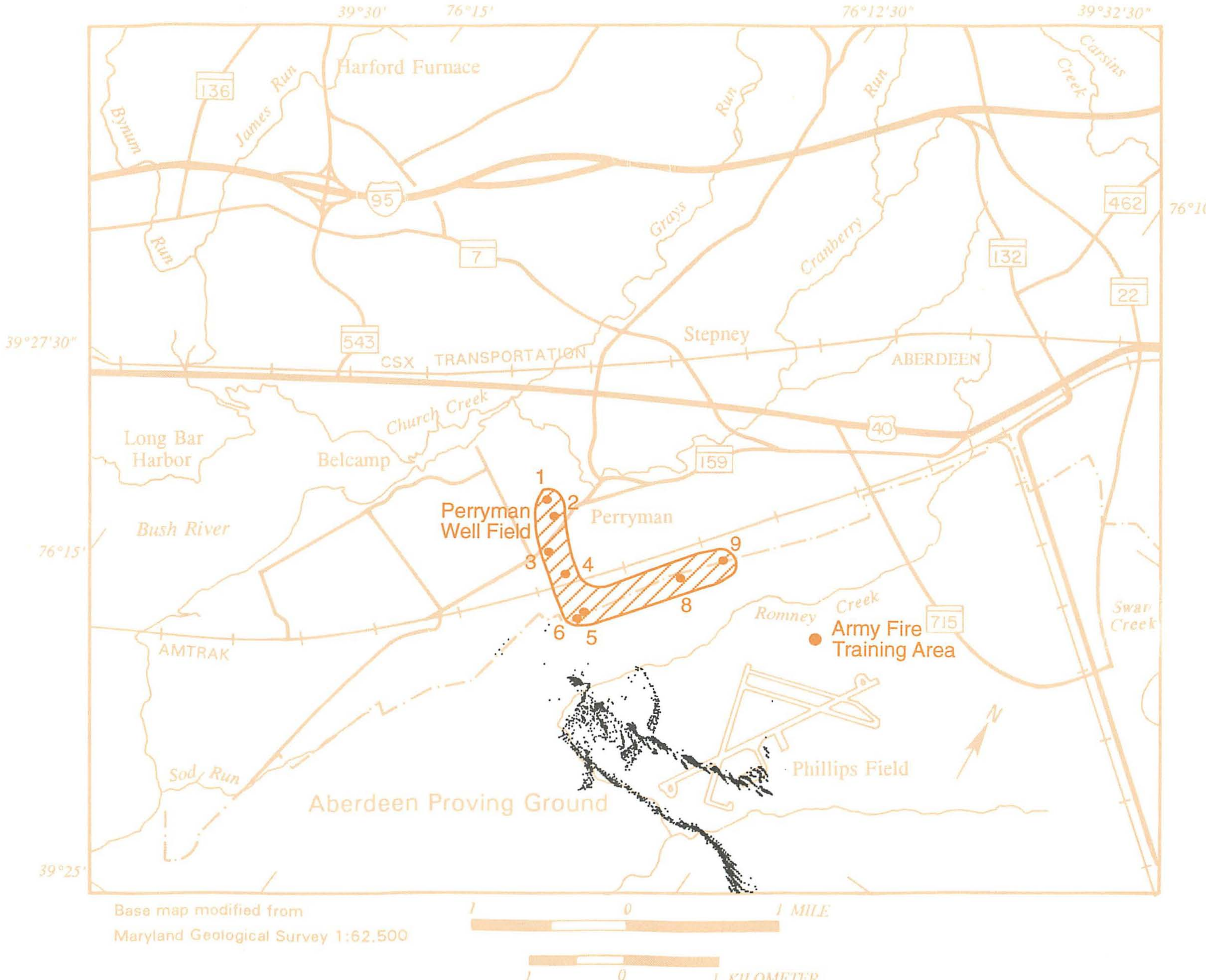

Figure 66.—Simulated TCE distribution near Perryman, 2014, based on simulation 6 (map view).

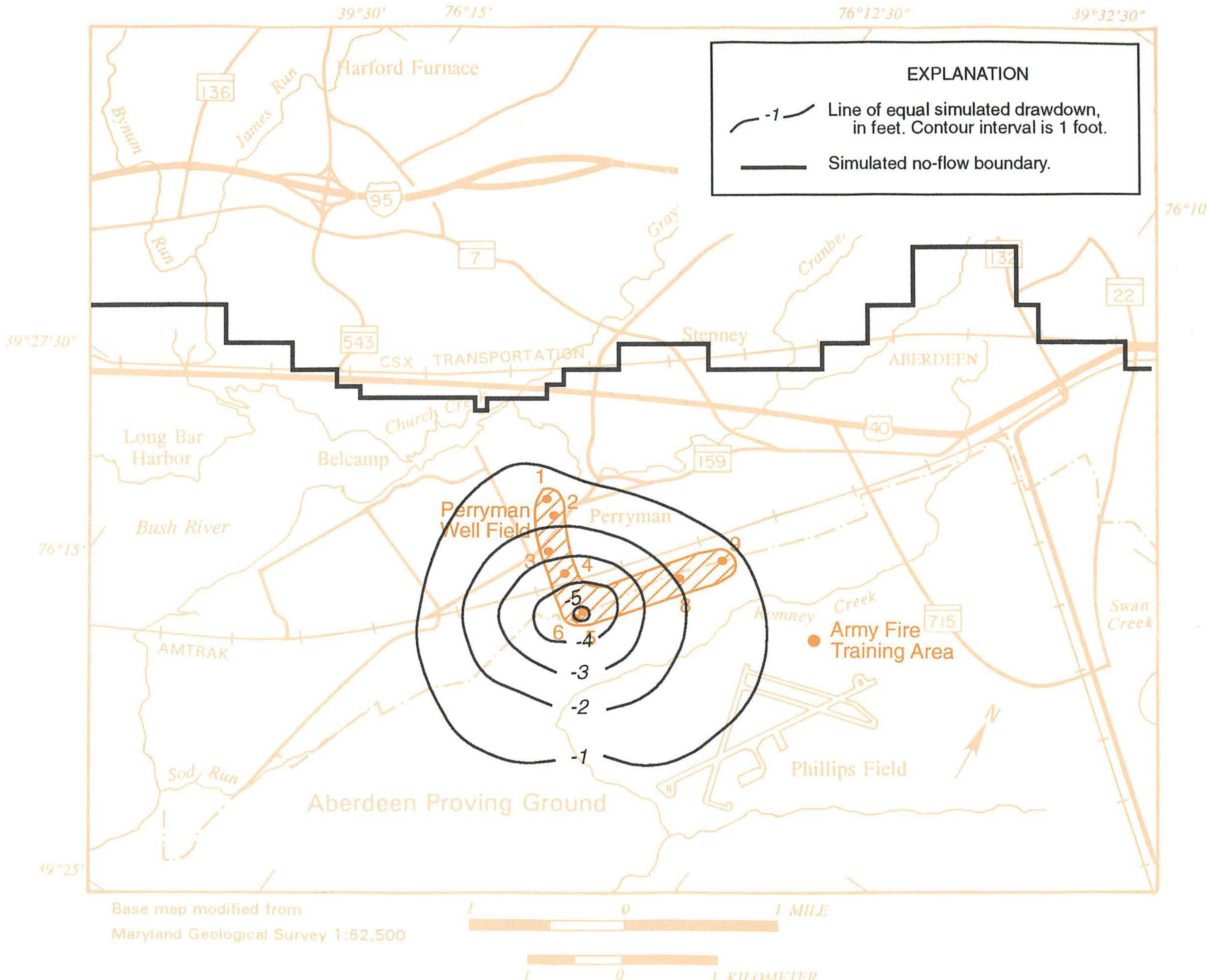

Figure 67.—Simulated drawdown in aquifer 1 for 1994-2014, based on simulation 7.

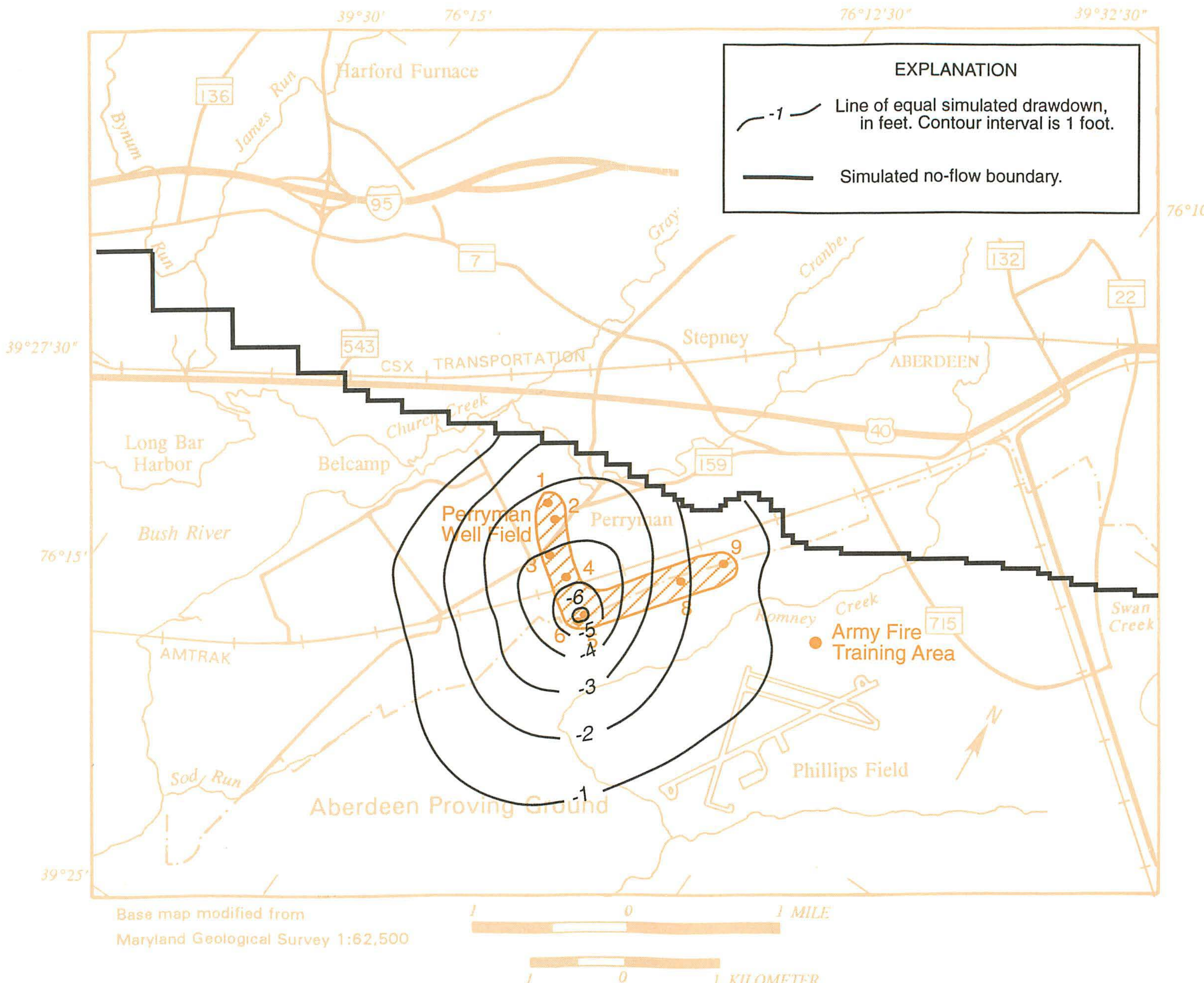

Figure 68.—Simulated drawdown in aquifer 2 for 1994-2014, based on simulation 7.

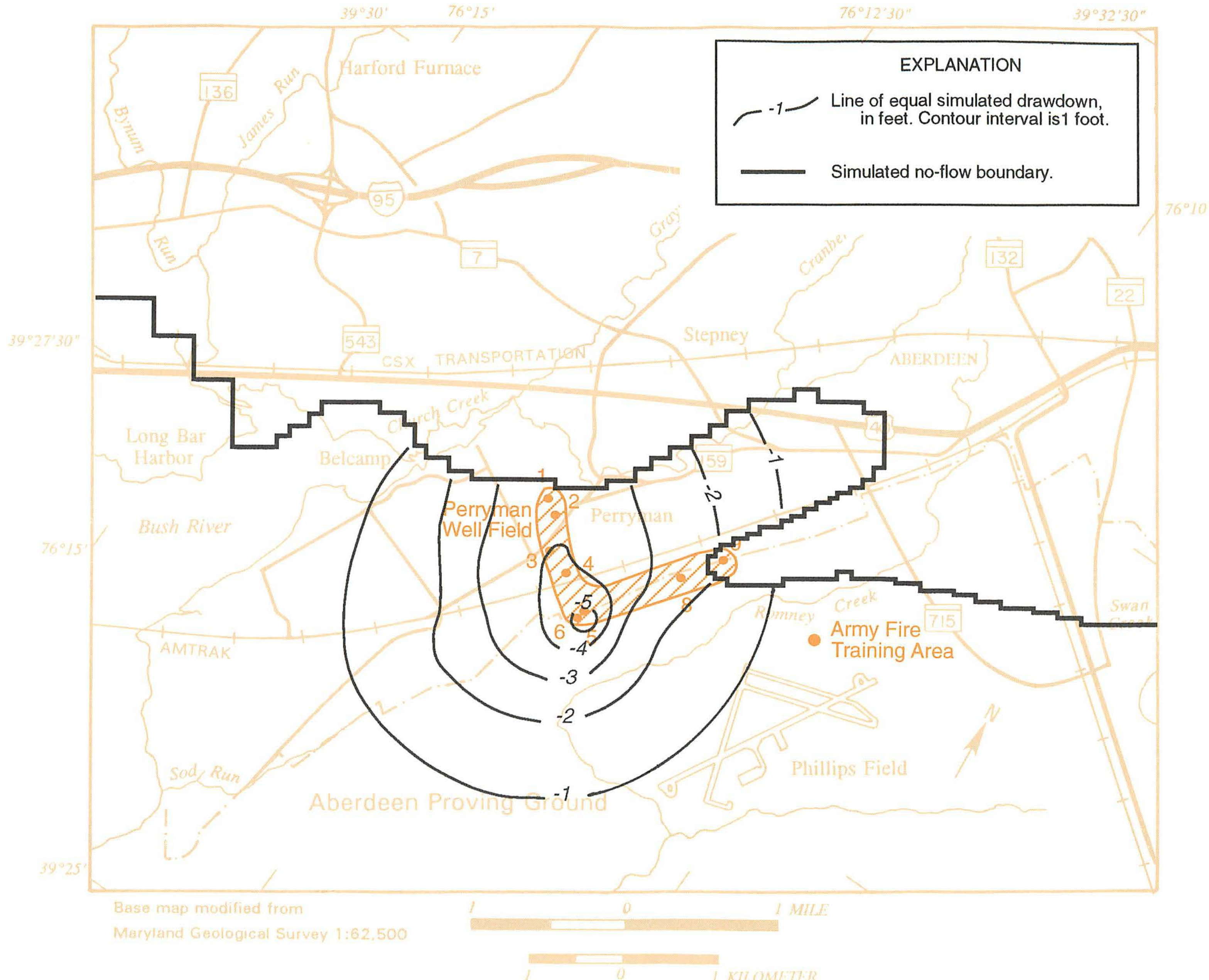

Figure 69.—Simulated drawdown in aquifer 3 for 1994-2014, based on simulation 7.

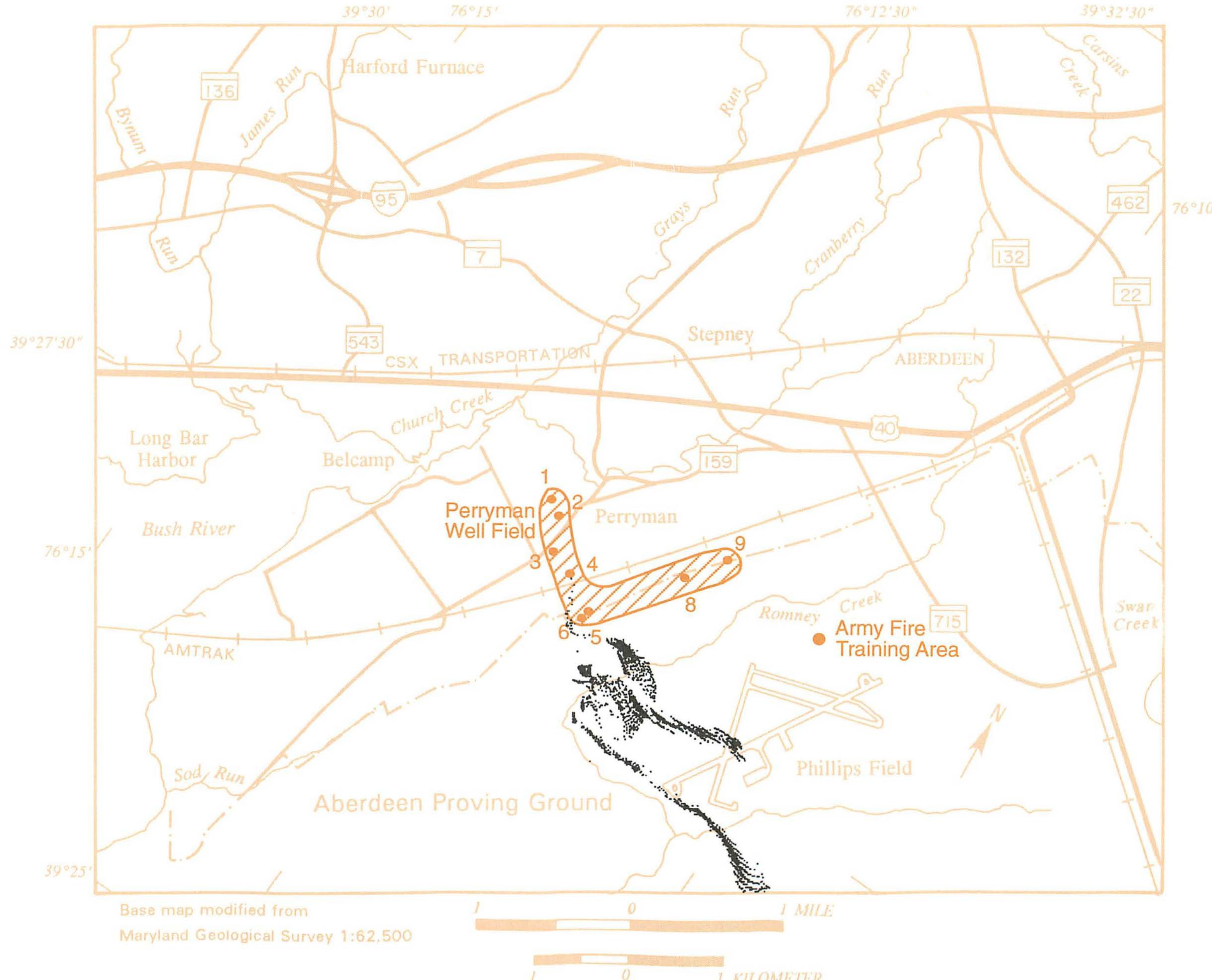

Figure 70.—Simulated TCE distribution near Perryman, 2014, based on simulation 7 (map view).

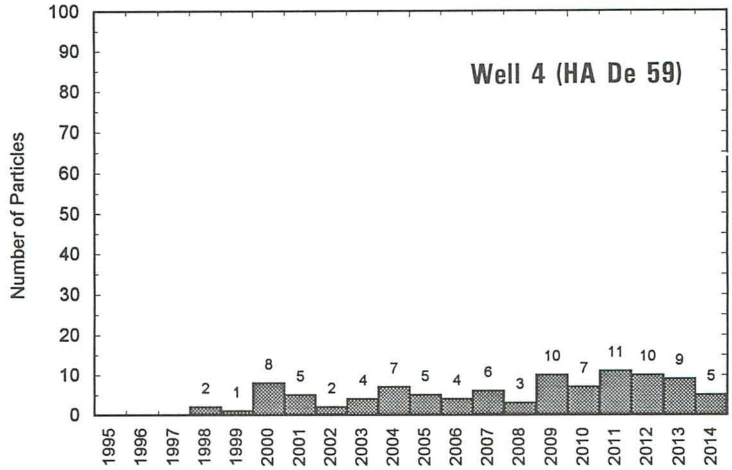

Figure 71.—Histogram showing simulated particle arrivals at Perryman well 4, 1995-2014, based on simulation 7.

The main part of the simulated TCE plume is slightly farther to the east than in simulation 1, due to the reduced pumpage at the Perryman well field (fig. 70). Some of the particles, however, have migrated northwestward toward Perryman well 4 (De 59) the narrow part of the plume to the southeast is in approximately the same position as in simulation 1. Wells 5 (De 77) and 6 (De 76) are not pumping in this simulation; however, particles have migrated to well 4 by 1998, and continue to discharge from that well, at low levels, through the end of the simulation (fig. 71). This simulation indicates that if wells 5 and 6 were turned off to avoid introducing TCE to the water system, well 4 could soon become contaminated.

Simulation 8

Simulation 8 demonstrates the effects of increasing the pumping rates at Perryman well 5 (De 77) from 400 to 800 gal/min, and well 6 (De 76) from 800 to 1,000 gal/min. These pumping rates were recommended as a means of increasing the production of the Perryman well field (Whitman, Requardt and Associates, 1976). The increased well capacities were multiplied by the fraction of time pumps in the well field typically operate (0.55) to calculate an increase in well field production of about 500,000 gal/d (table 2). Maximum simulated drawdowns in aquifers 1, 2, and 3 were 2, 3, and 2 ft, respectively.

The main part of the simulated TCE plume is closer to the well field and not as dense as in simulation 1 (fig. 72). The secondary plume is in approximately the same position as in simulation 1. Particle-arrival histograms indicate that the TCE concentration in well 5 (De 77) is significantly higher than in simulation 1, but drops to zero by 2005; and the TCE concentration in well 6 (De 76) is somewhat lower than in simulation 1, but remains above zero through 2014 (fig. 73).

Simulation 9

Simulation 9 demonstrates the effects of adding four hypothetical production wells (designated wells A, B, C, and D) to the southwest of the current well field (fig. 24). Two wells were placed in each of two locations, with one well in aquifer 2 and one well in aquifer 3 at each location. The wells in aquifer 2 (A and C) were assigned capacities of 200 gal/min, and the wells in aquifer 3 (B and D) were assigned capacities of 300 gal/min. This configuration was recommended by Whitman, Requardt and Associates (1976) as a means of supplying additional water during droughts. These hypothetical well capacities were multiplied by the fraction of time pumps in the well field typically operate (0.55) to calculate an increase in well-field production of about 800,000 gal/d (table 2). Maximum simulated drawdowns in aquifers 1, 2, and 3 were 3 ft, 5 ft and 6 ft, respectively (figs. 74 and 75).

The 20-year contributing area for the Perryman well field, based on simulation 9, is shown in figure 76, along with the contributing area based on 1994 pumpage, shown for comparison. The contributing area for this simulation extends

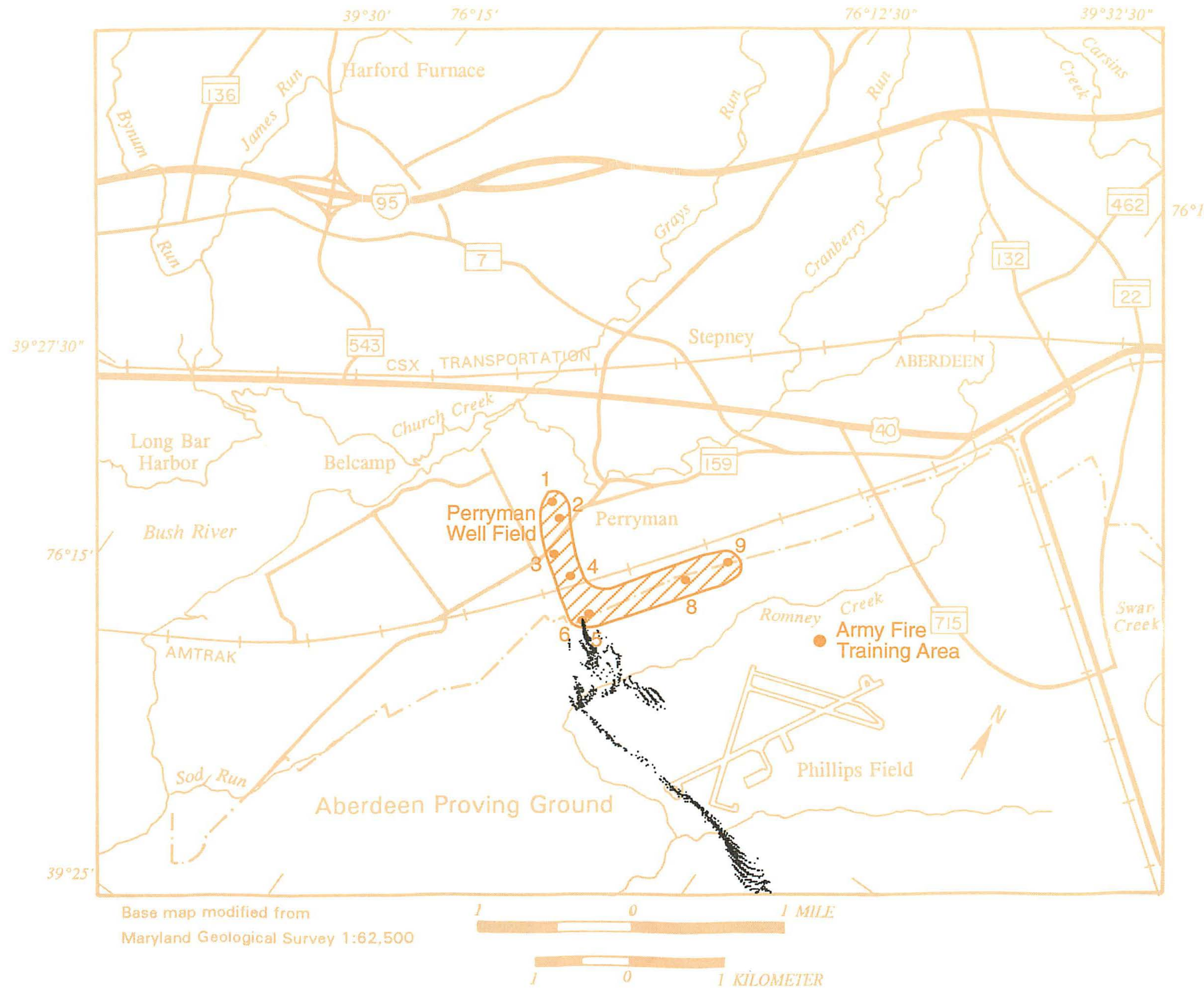

Figure 72.—Simulated TCE distribution near Perryman, 2014, based on simulation 8 (map view).

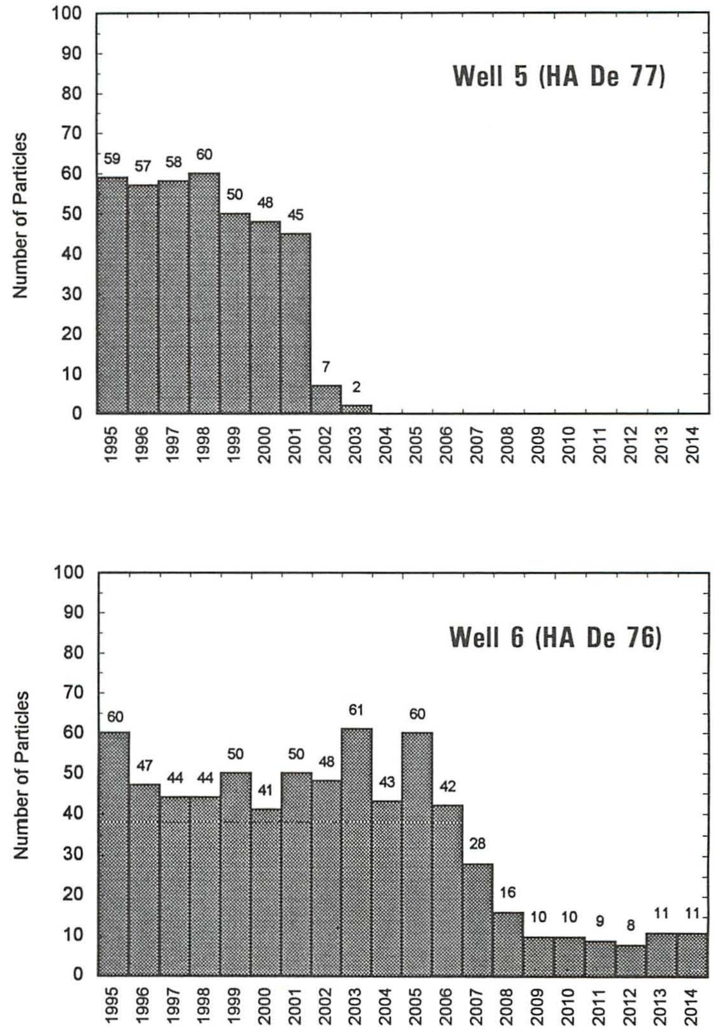

Figure 73.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 8.

about 0.4 mile farther to the southwest than the area based on 1994 pumpage. The contributing area for this simulation provides more recharge to accommodate the increased pumping rates, and extends in the direction of the hypothetical production wells.

The main part of the simulated TCE plume has been split, with a section migrating toward the hypothetical wells (fig. 77). This part of the plume does not quite reach the hypothetical wells by the end of the simulation (2014), but probably would reach them soon thereafter. A section of the plume has also migrated past wells 5 (De 77) and 6 (De 76) toward well 4 (De 59), but does not reach well 4 by 2014. Particle-arrival histograms show that simulated TCE concentrations in well 5 are zero and TCE concentrations in well 6 are slightly higher than in simulation 1, but otherwise similar (fig. 78).

Simulation 10

Simulation 10 demonstrates the effects of adding two hypothetical production wells (designated wells E and F) northeast of the Perryman well field (fig. 24) that produce an additional 1 Mgal/d. Pumpage was adjusted in the two wells to produce the same amount of drawdown in each aquifer (table

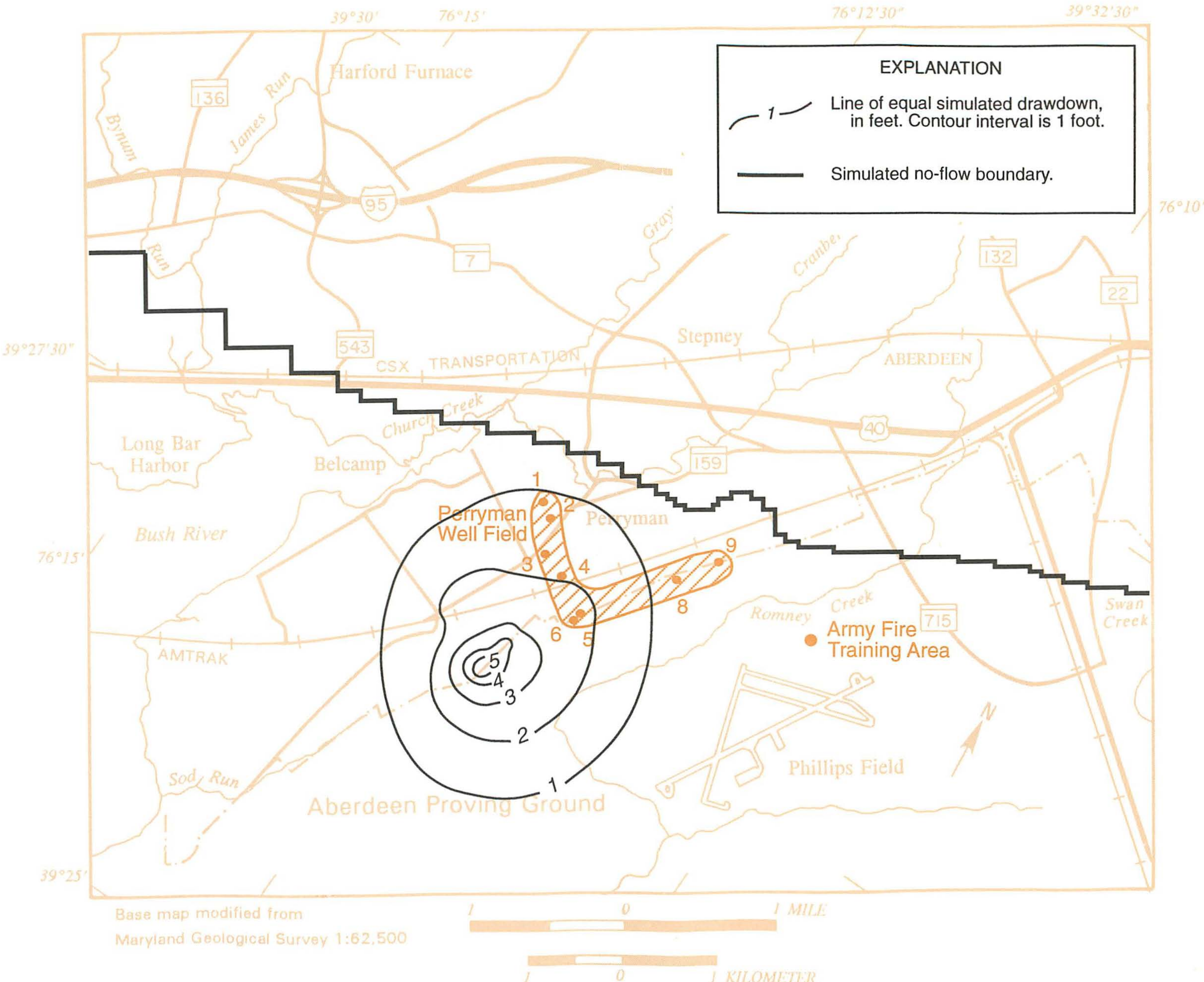

Figure 74.—Simulated drawdown in aquifer 2 for 1994-2014, based on simulation 9.

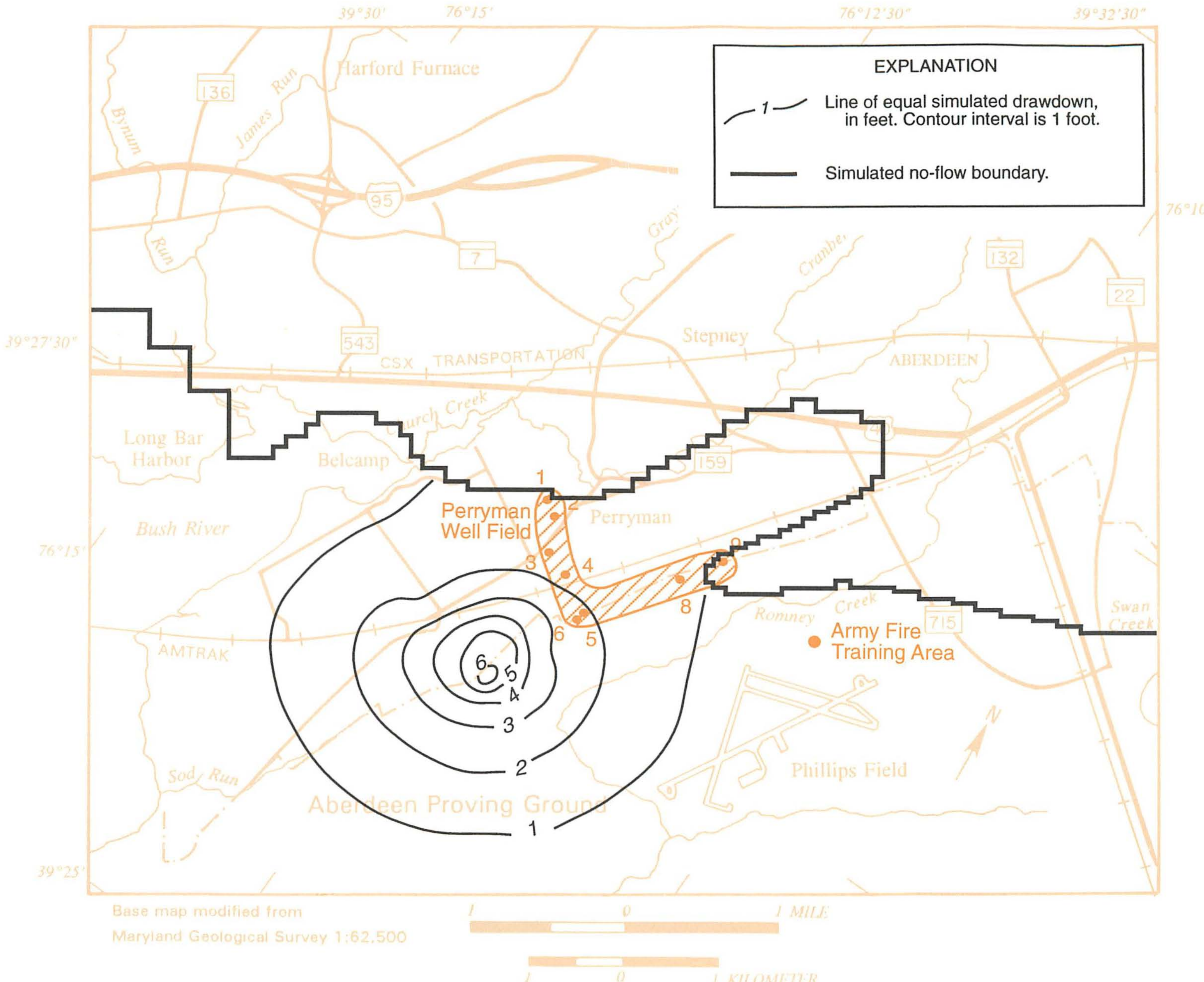

Figure 75.—Simulated drawdown in aquifer 3 for 1994-2014, based on simulation 9.

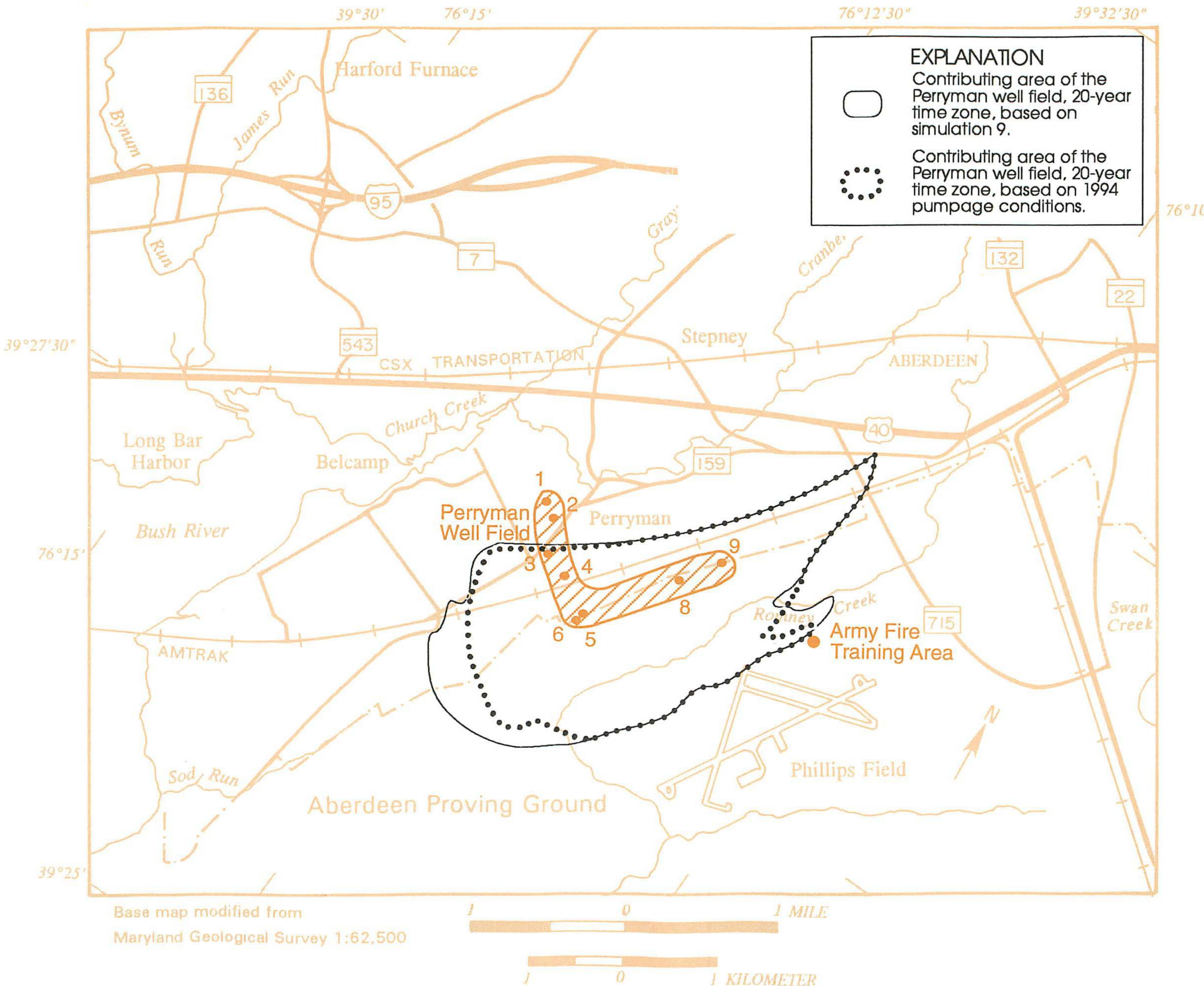

Figure 76.—Twenty-year contributing area for the Perryman well field, based on simulation 9.

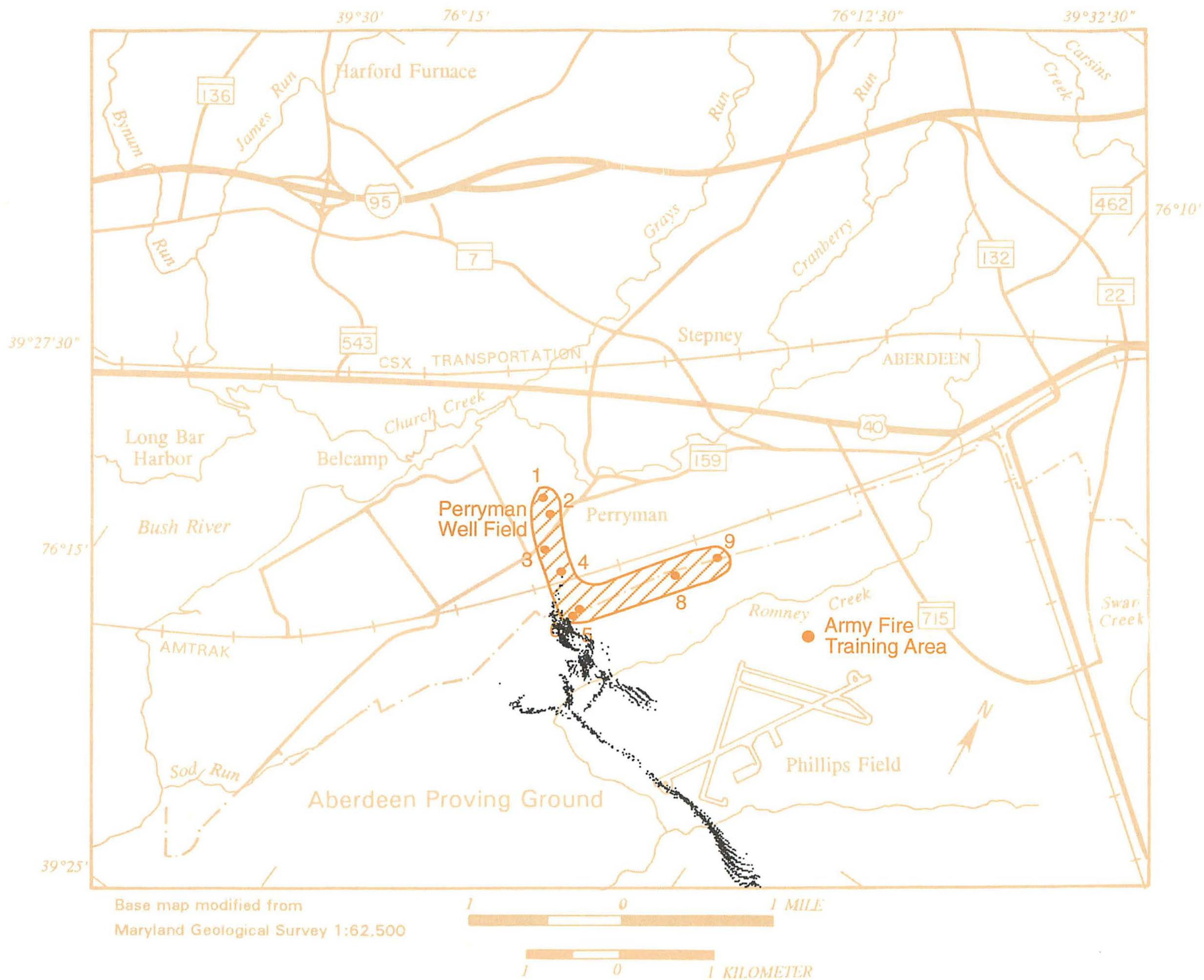

Figure 77.—Simulated TCE distribution near Perryman, 2014, based on simulation 9 (map view).

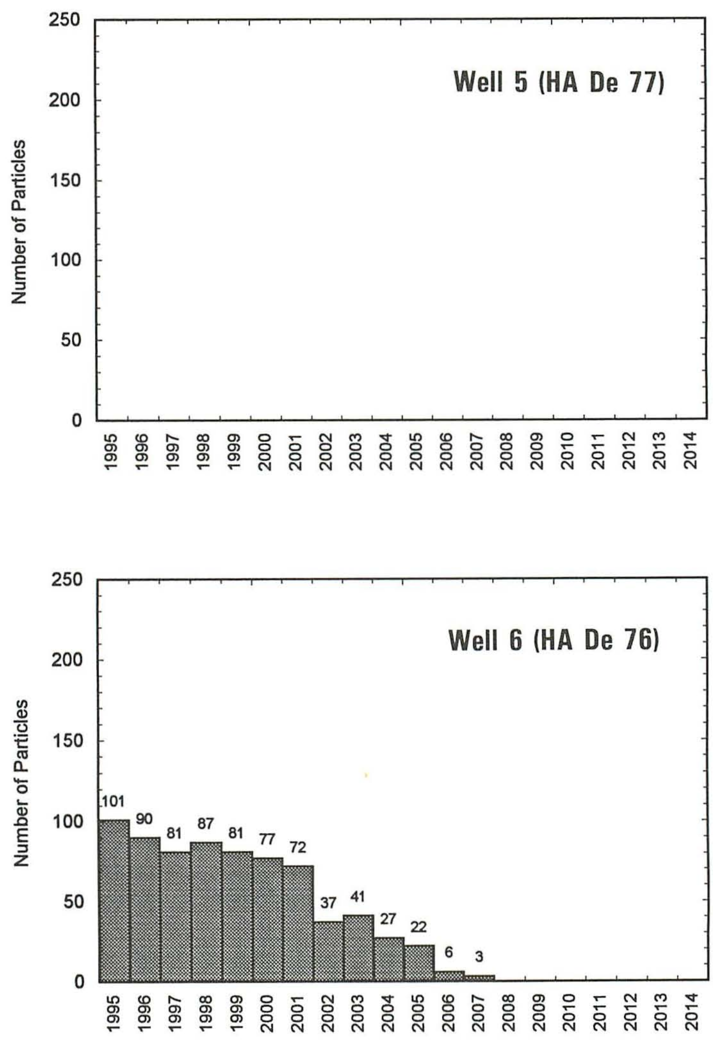

Figure 78.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 9.

2). Maximum simulated drawdowns were 4 ft in aquifer 1, and 27 ft in aquifers 2 and 3 (figs. 79 and 80).

The simulated TCE distribution shows that the main part of the plume is less dense and slightly farther north than in simulation 1 (fig. 81). Particle-arrival histograms (fig. 82) indicate that concentrations of TCE are much higher in well 5 (De 77) in this simulation than in simulation 1, but decrease to zero by 2011. Concentrations of TCE in well 6 (De 76) are lower than in simulation 1, but remain above zero until 2014. Although the TCE plume is not drawn to the hypothetical wells, the additional pumpage causes more TCE to be drawn into wells 5 and 6.

Simulation 11

Simulation 11 demonstrates the effects of adding two hypothetical production wells (designated wells G and H) north of the Perryman well field near well 4 (De 59) (fig. 24) that produce an additional 1 Mgal/d. Pumpage was adjusted in the two wells to produce the same amount of drawdown in each aquifer (table 2). Maximum simulated drawdowns were 5 ft in aquifer 1, and 14 ft in aquifers 2 and 3 (figs. 83, 84, and 85).

The simulated TCE distribution shows that the main part of the plume is less dense and slightly farther north than in

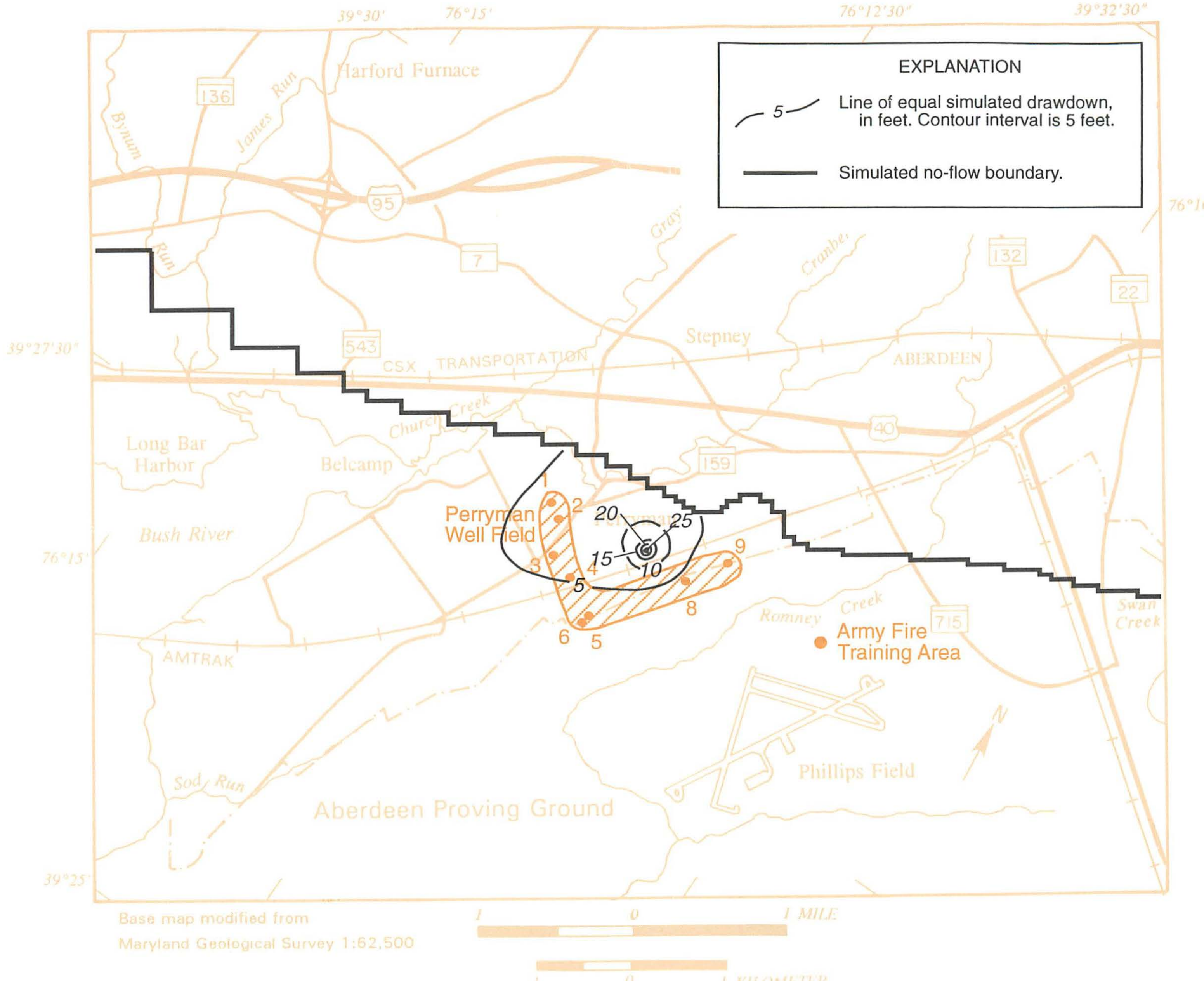

Figure 79.—Simulated drawdown in aquifer 2 for 1994-2014, based on simulation 10.

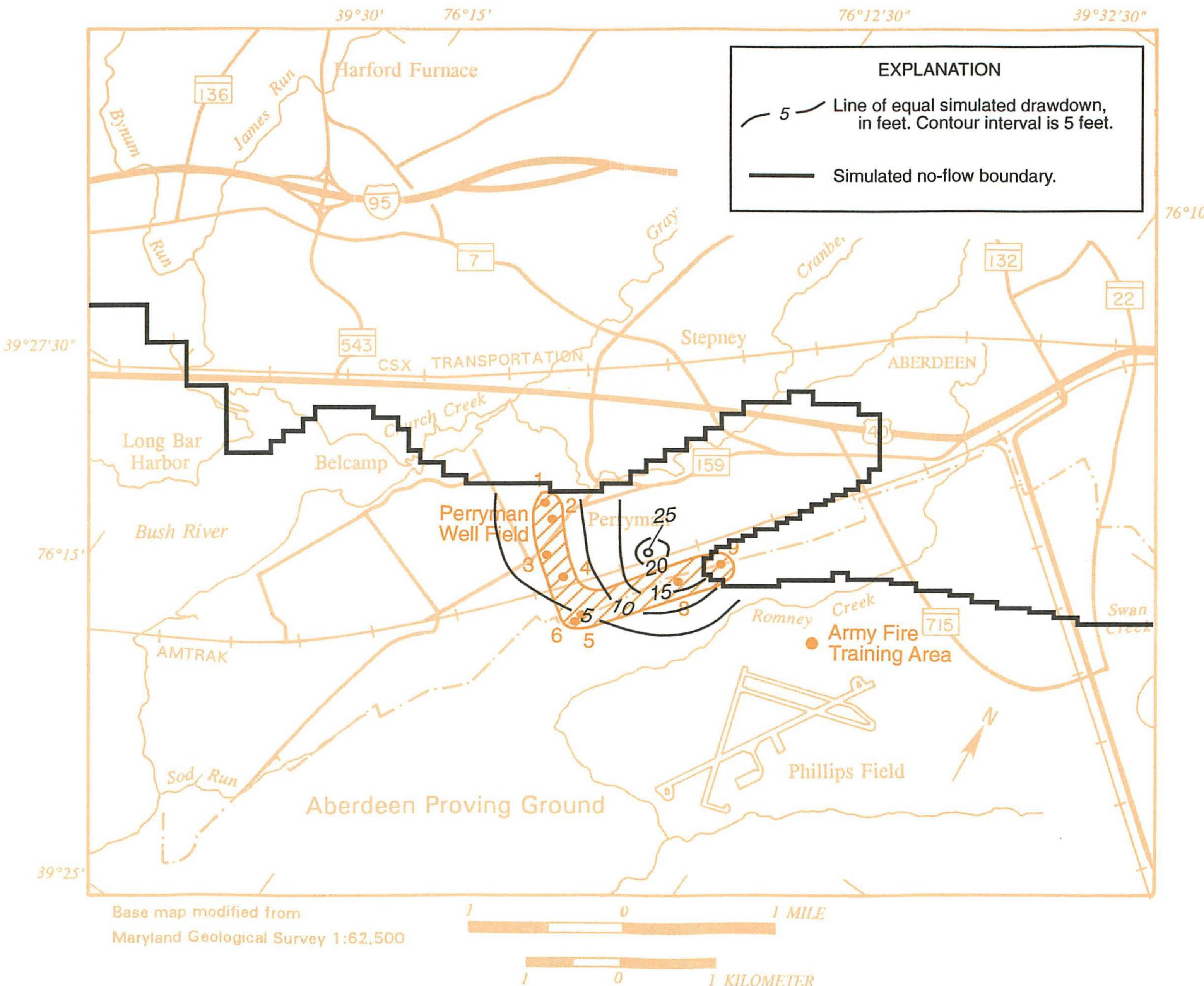

Figure 80.—Simulated drawdown in aquifer 3 for 1994-2014, based on simulation 10.

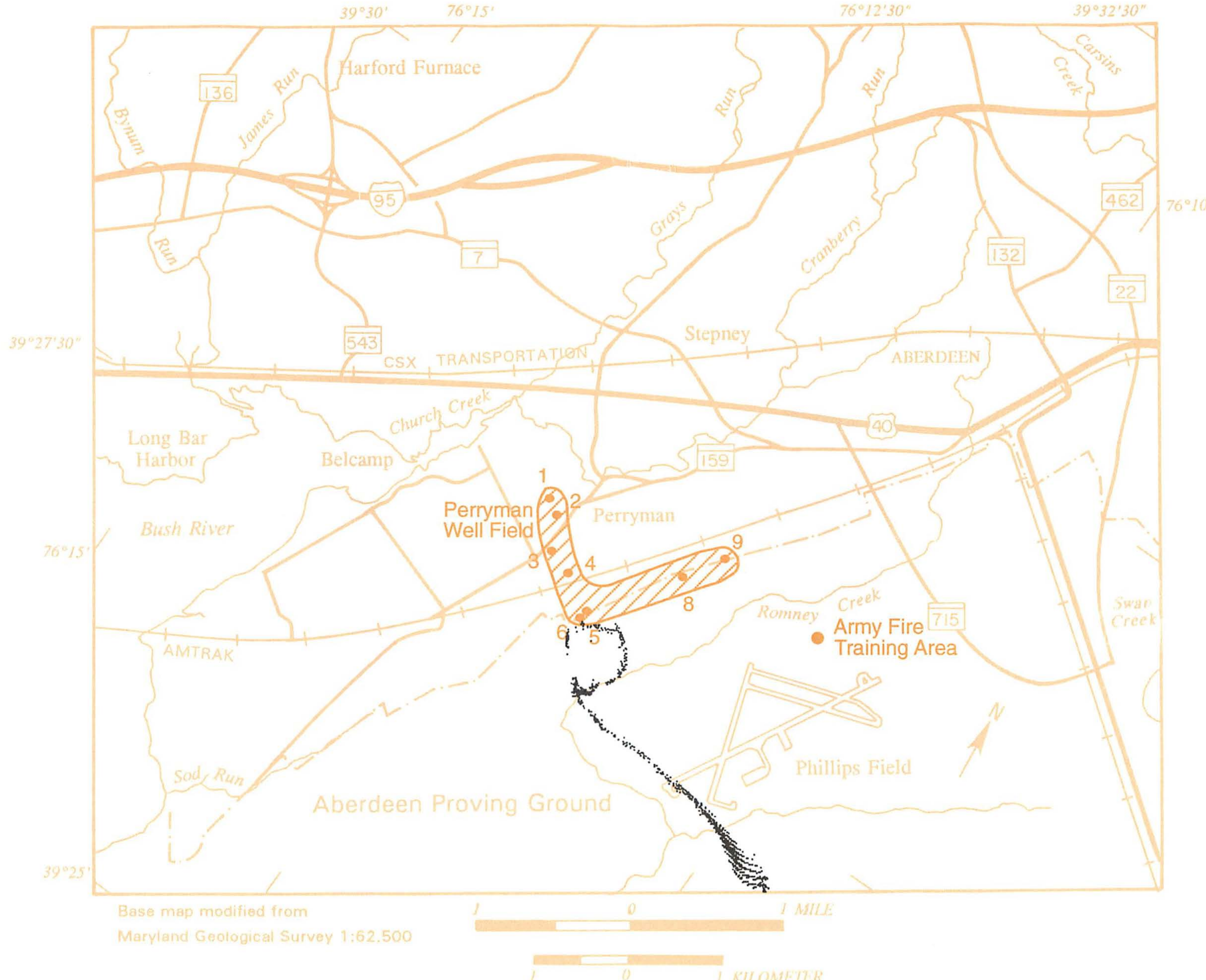

Figure 81.—Simulated TCE distribution near Perryman, 2014, based on simulation 10 (map view).

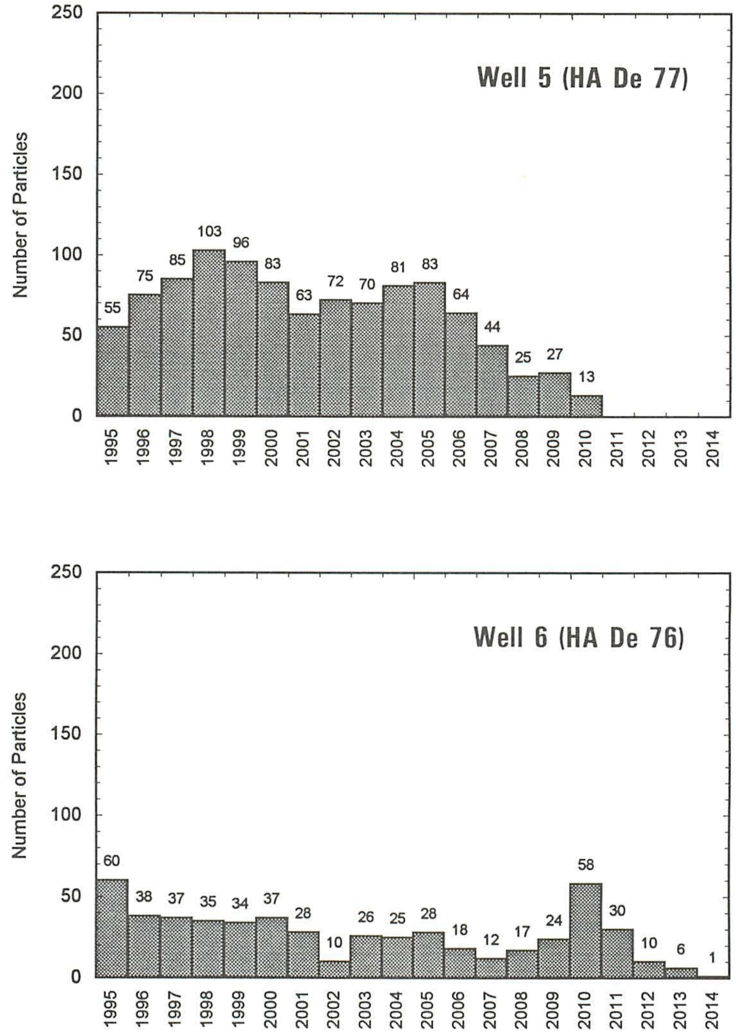

Figure 82.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 10.

simulation 1 (fig. 86). Particle-arrival histograms (fig. 87) indicate that concentrations of TCE are much higher in well 5 (De 77) in this simulation than in simulation 1, but decrease to zero by 2011. Concentrations of TCE in well 6 (De 76) are lower than in simulation 1, but remain above zero until 2014. As in simulation 10, the TCE plume is not drawn to the hypothetical wells, but the additional pumpage causes more TCE to be drawn into wells 5 and 6.

Simulation 12

Simulation 12 demonstrates the effects of a one-year drought, in which recharge was reduced 40 percent throughout the study area for 1995. The choice of the year for this simulation was arbitrary, and does not simulate real 1995 conditions. Pumpage amounts from 1994 were continued for this one-year simulation. Maximum simulated drawdown in

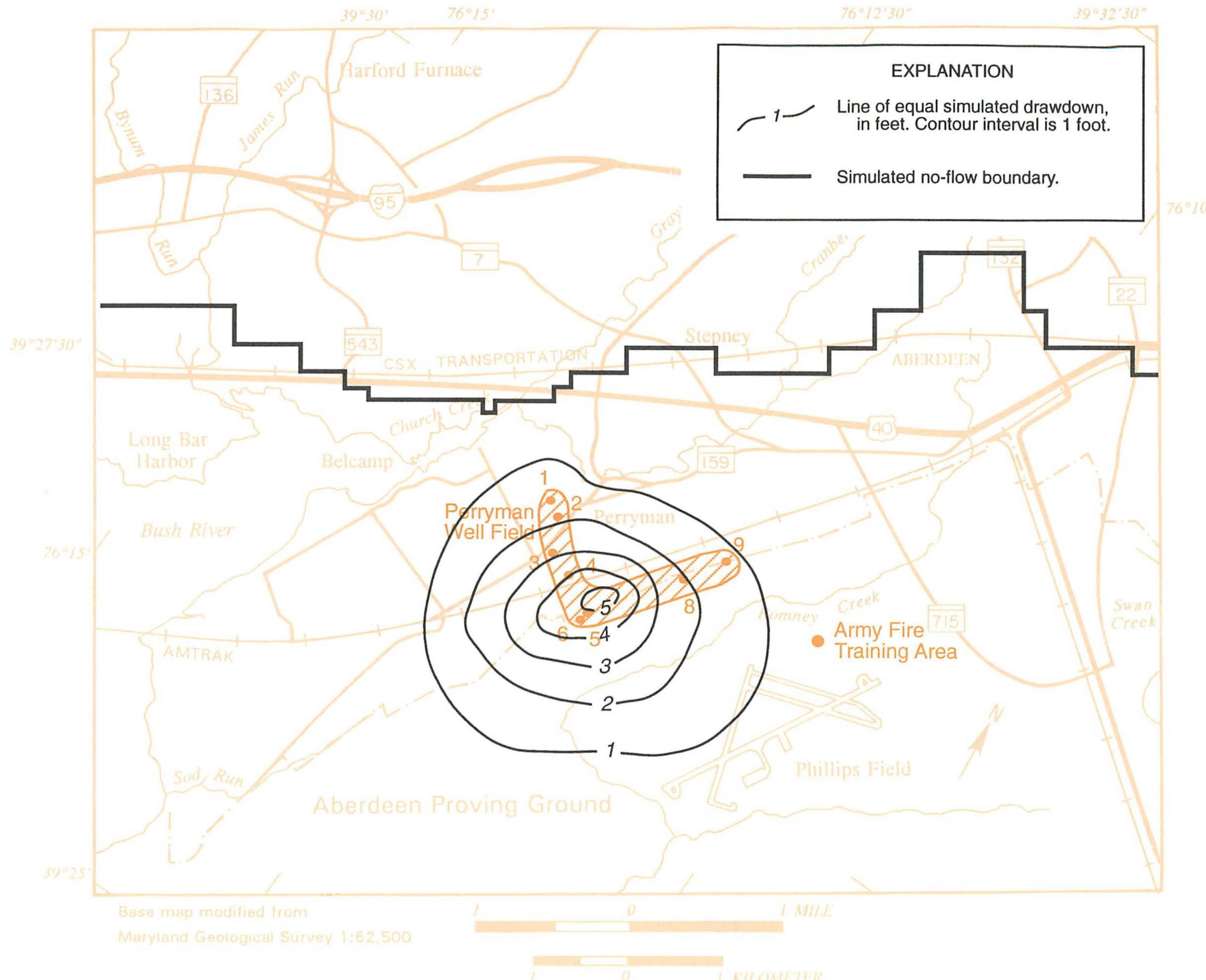

Figure 83.—Simulated drawdown in aquifer 1 for 1994-2014, based on simulation 11.

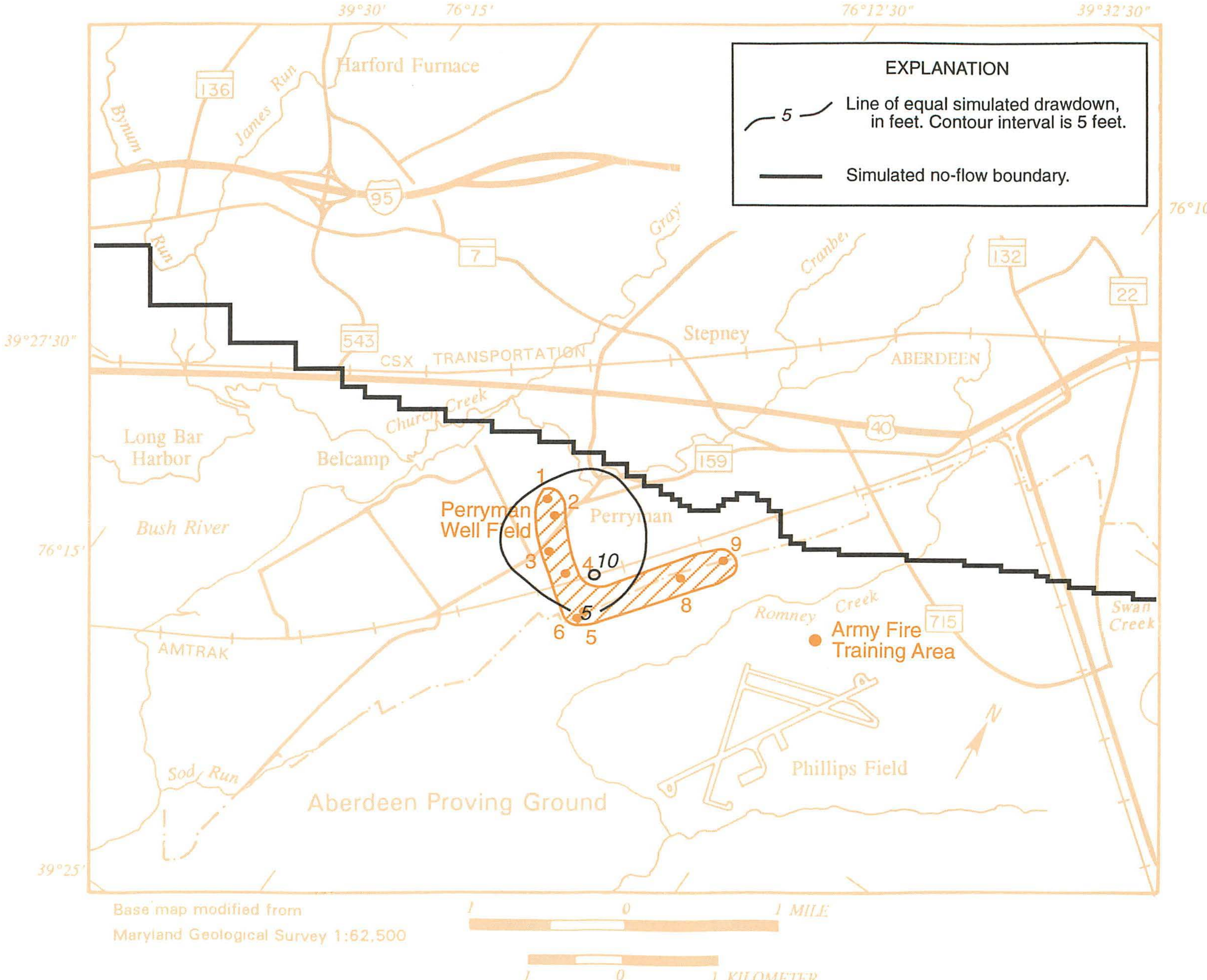

Figure 84.—Simulated drawdown in aquifer 2 for 1994-2014, based on simulation 11.

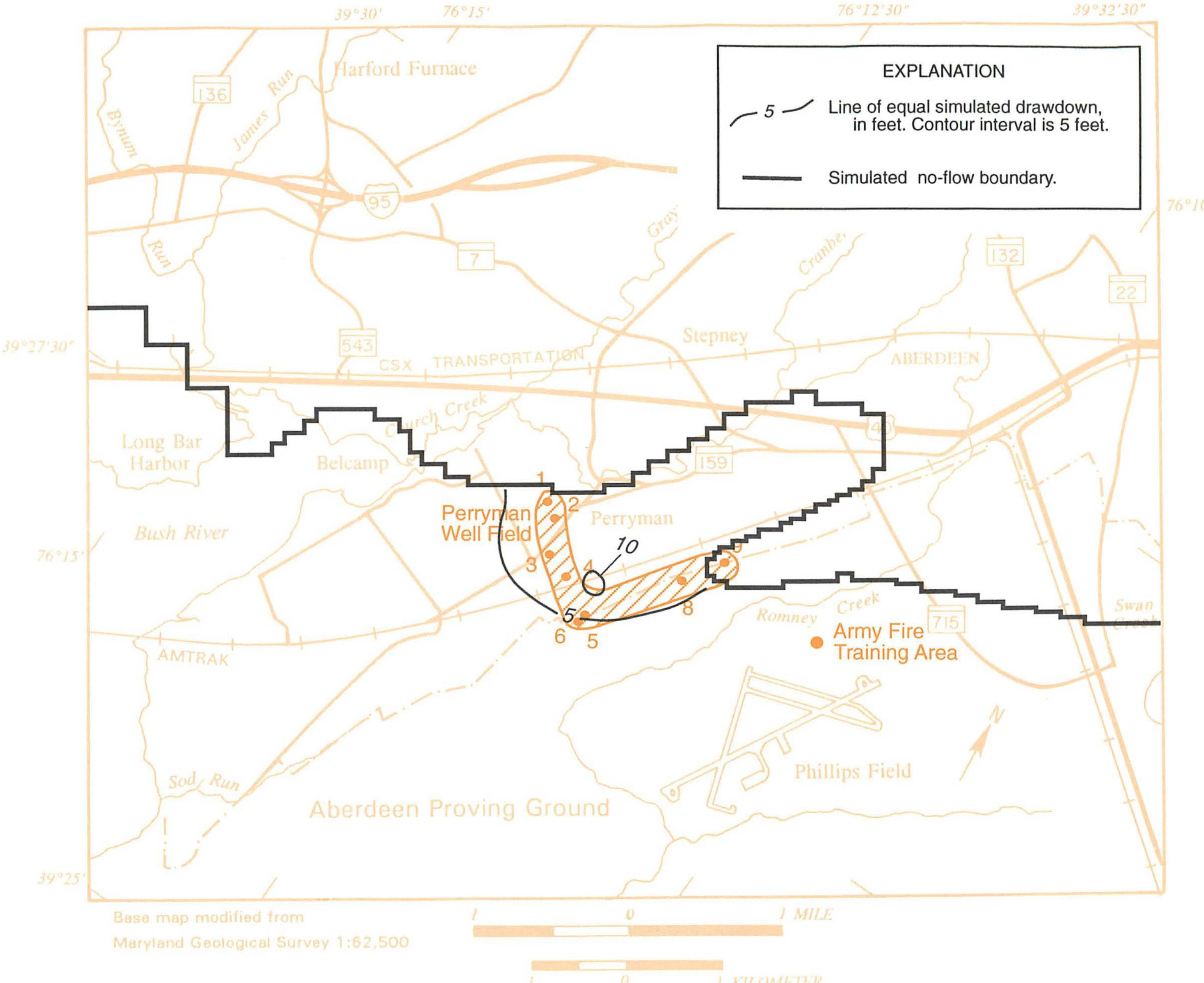

Figure 85.—Simulated drawdown in aquifer 3 for 1994-2014, based on simulation 11.

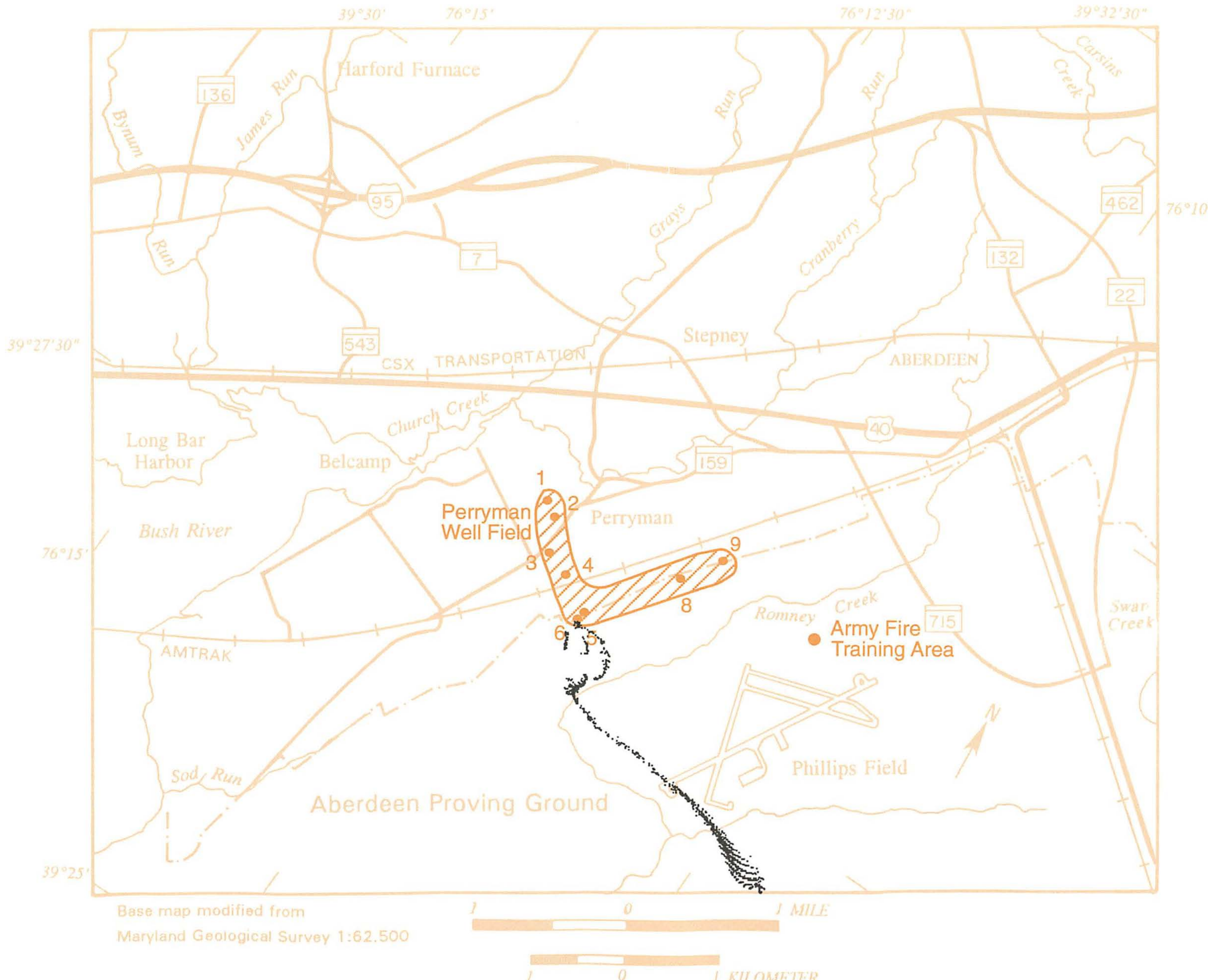

Figure 86.—Simulated TCE distribution near Perryman, 2014, based on simulation 11 (map view).

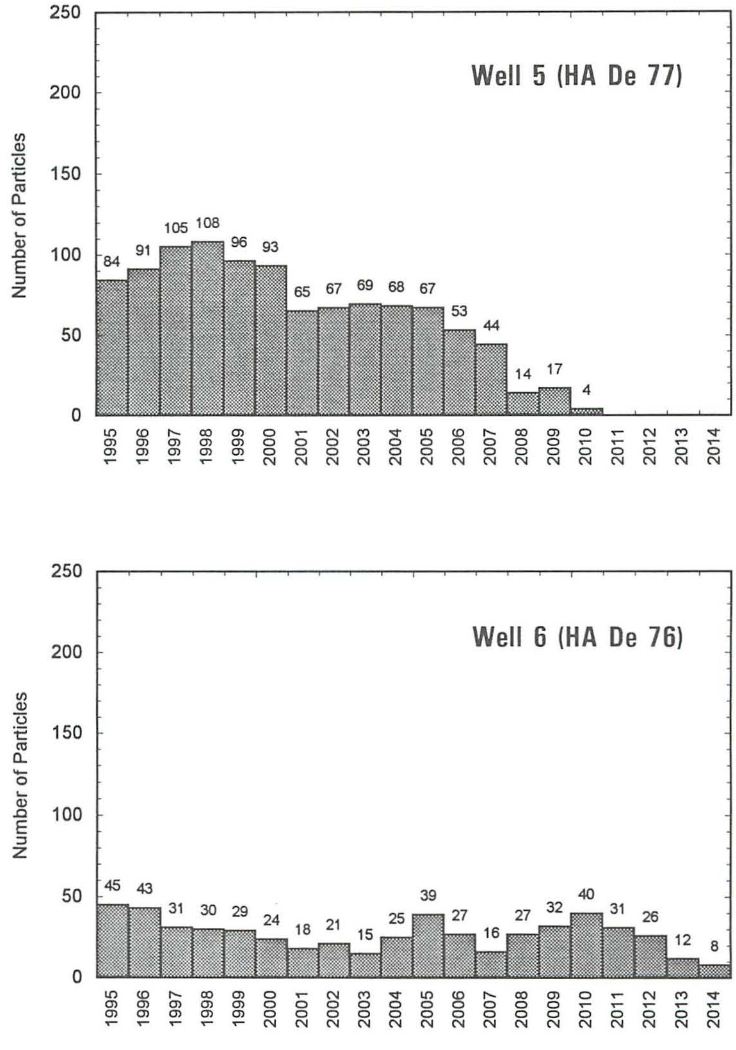

Figure 87.—Histograms showing simulated particle arrivals at Perryman wells 5 and 6, 1995-2014, based on simulation 11.

aquifer 1 was 4 ft at the Perryman well field, and 5 ft at the Aberdeen well field (fig. 88). Maximum simulated drawdown was about 3 ft in aquifers 2 and 3 (figs. 89 and 90). Particle-tracking simulations were not run for this simulation because of its short duration.

Simulation 13

Simulation 13 demonstrates the effects of a three-year drought, in which recharge was reduced 40 percent throughout the study area for 1995-1997. The choice of years for this simulation was arbitrary, and does not reflect real conditions. Pumpage amounts from 1994 were continued for this three-year simulation. Maximum simulated drawdowns in aquifer 1 were 6 ft at the Perryman well field, and 9 ft at the Aberdeen well field (fig. 91). Maximum simulated drawdown was about 5 ft in aquifers 2 and 3 (figs. 92 and 93). The greater drawdown in this simulation than in the one-year drought of simulation 12 indicates that water levels had not equilibrated after one year of reduced recharge. Particle-tracking simulations were not run for this simulation because of its short duration.

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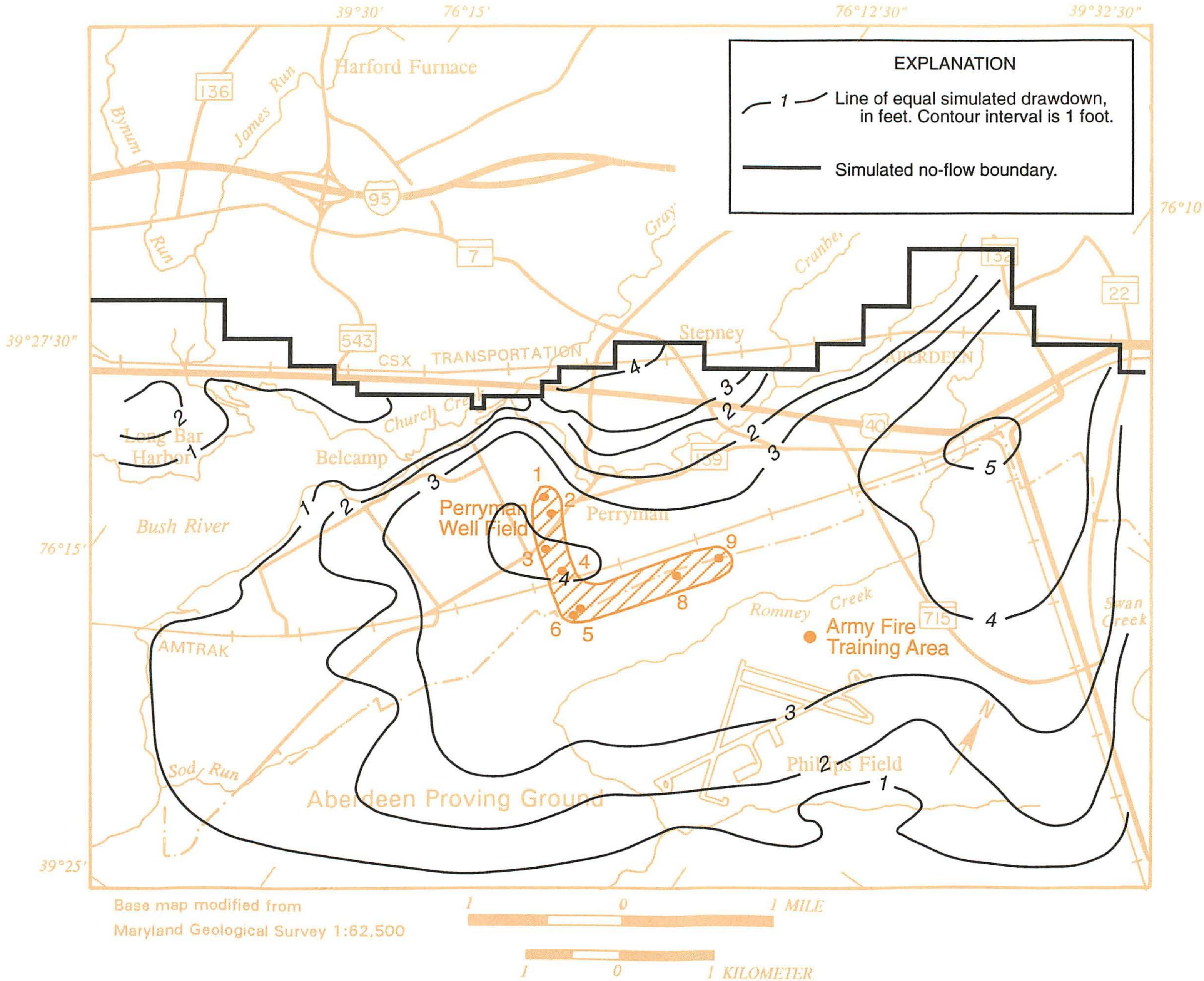

Figure 88.—Simulated drawdown in aquifer 1 for 1994-1995, based on simulation 12.

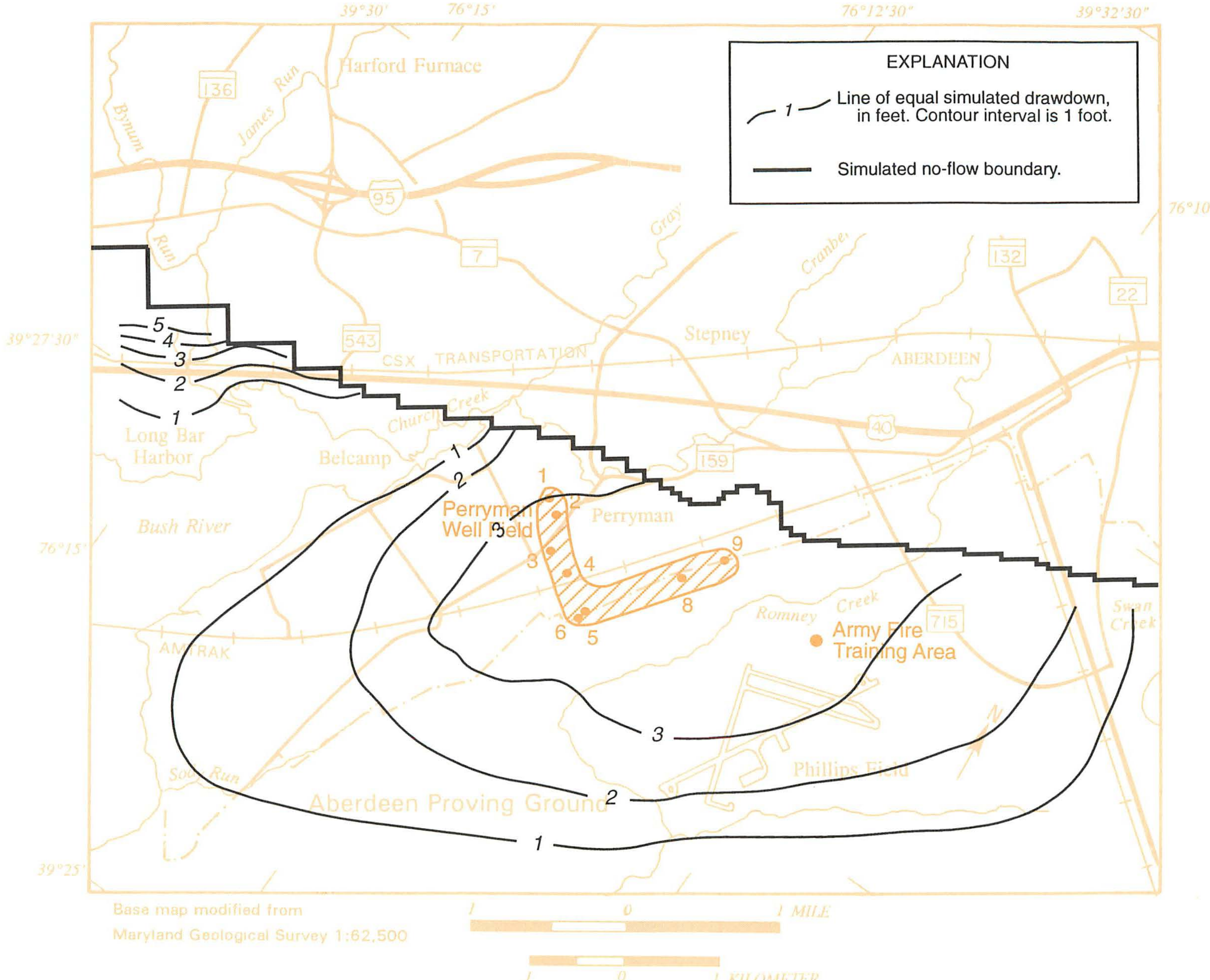

Figure 89.—Simulated drawdown in aquifer 2 for 1994-1995, based on simulation 12.

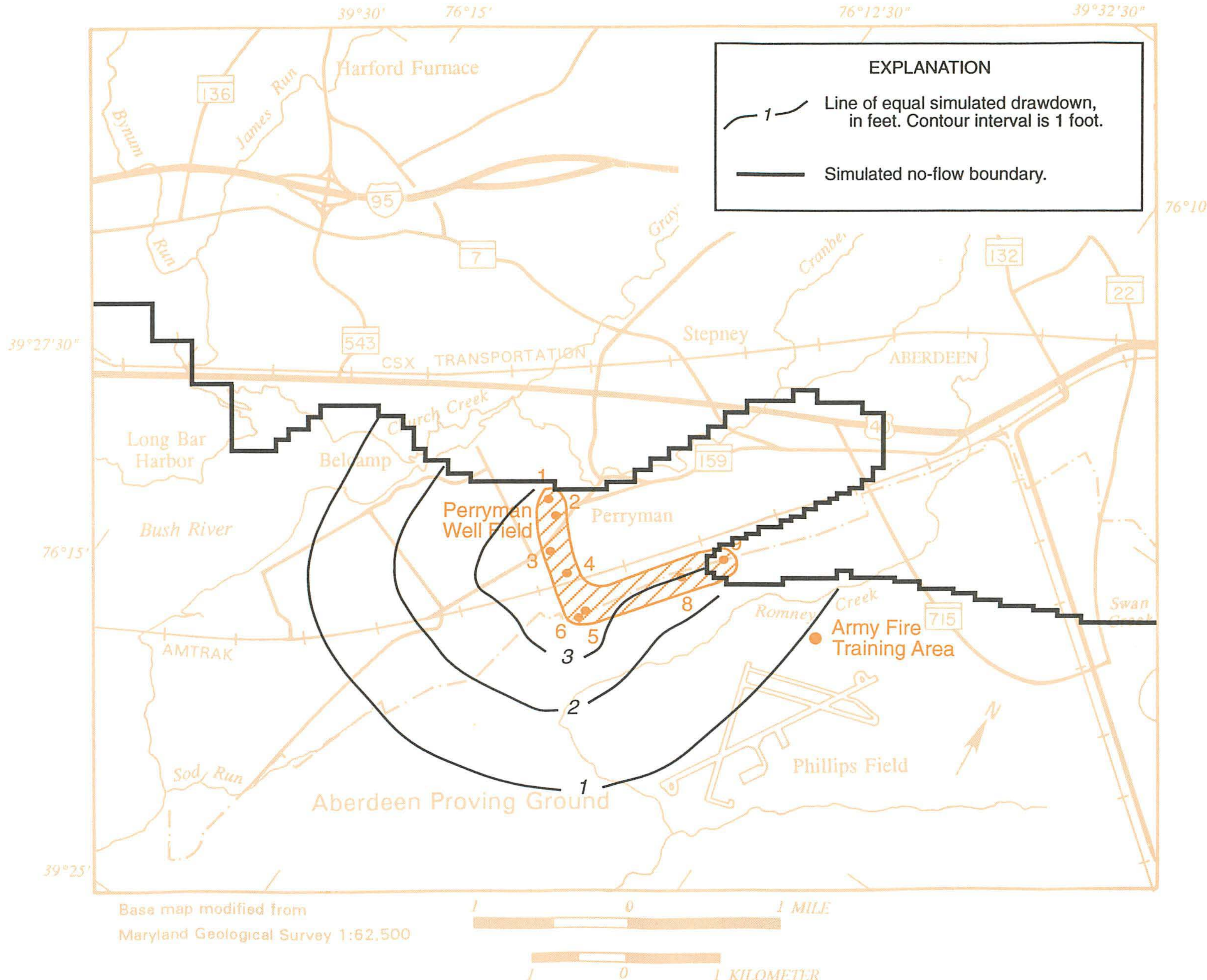

Figure 90.—Simulated drawdown in aquifer 3 for 1994-1995, based on simulation 12.

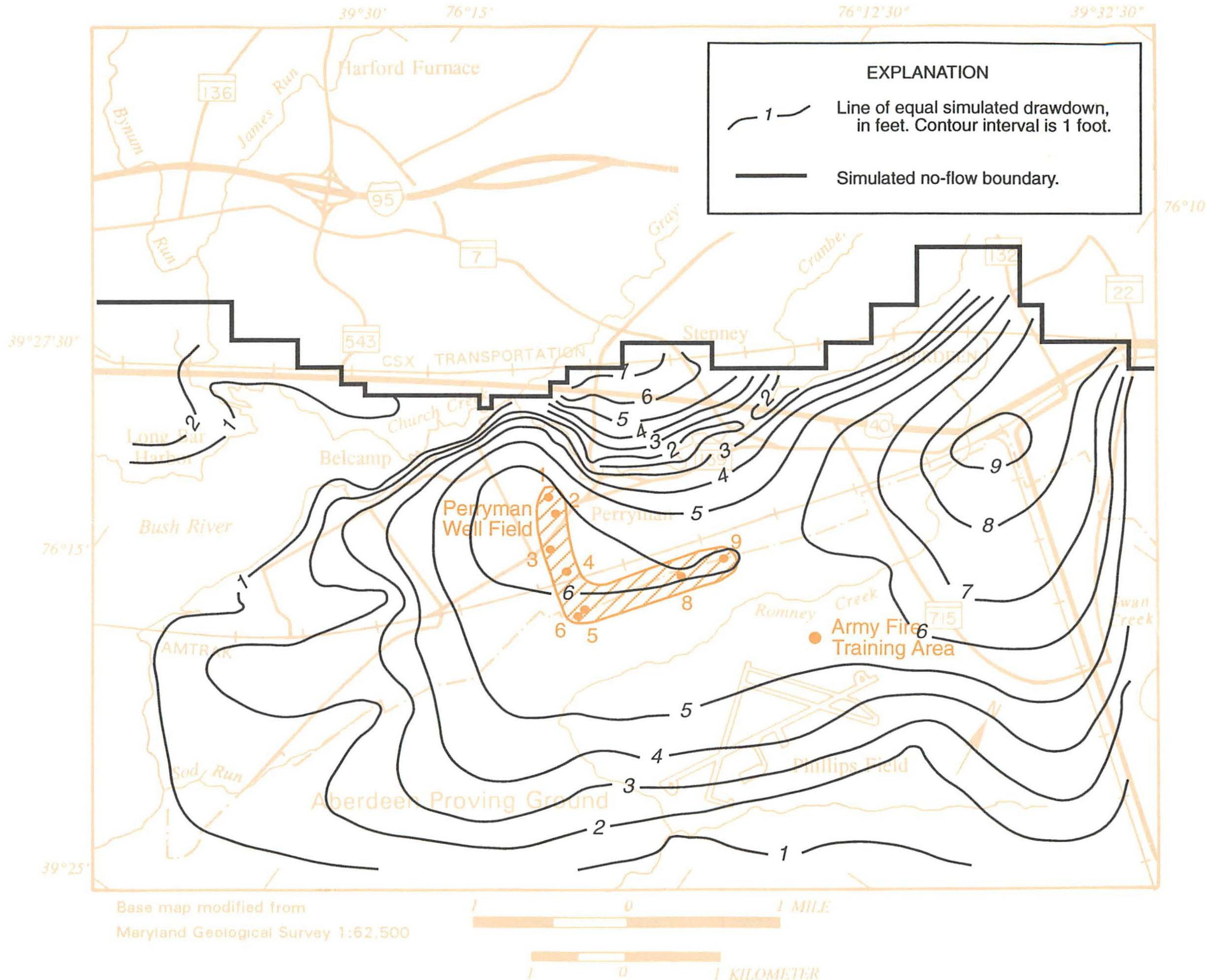

Figure 91.—Simulated drawdown in aquifer 1 for 1994-1997, based on simulation 13.

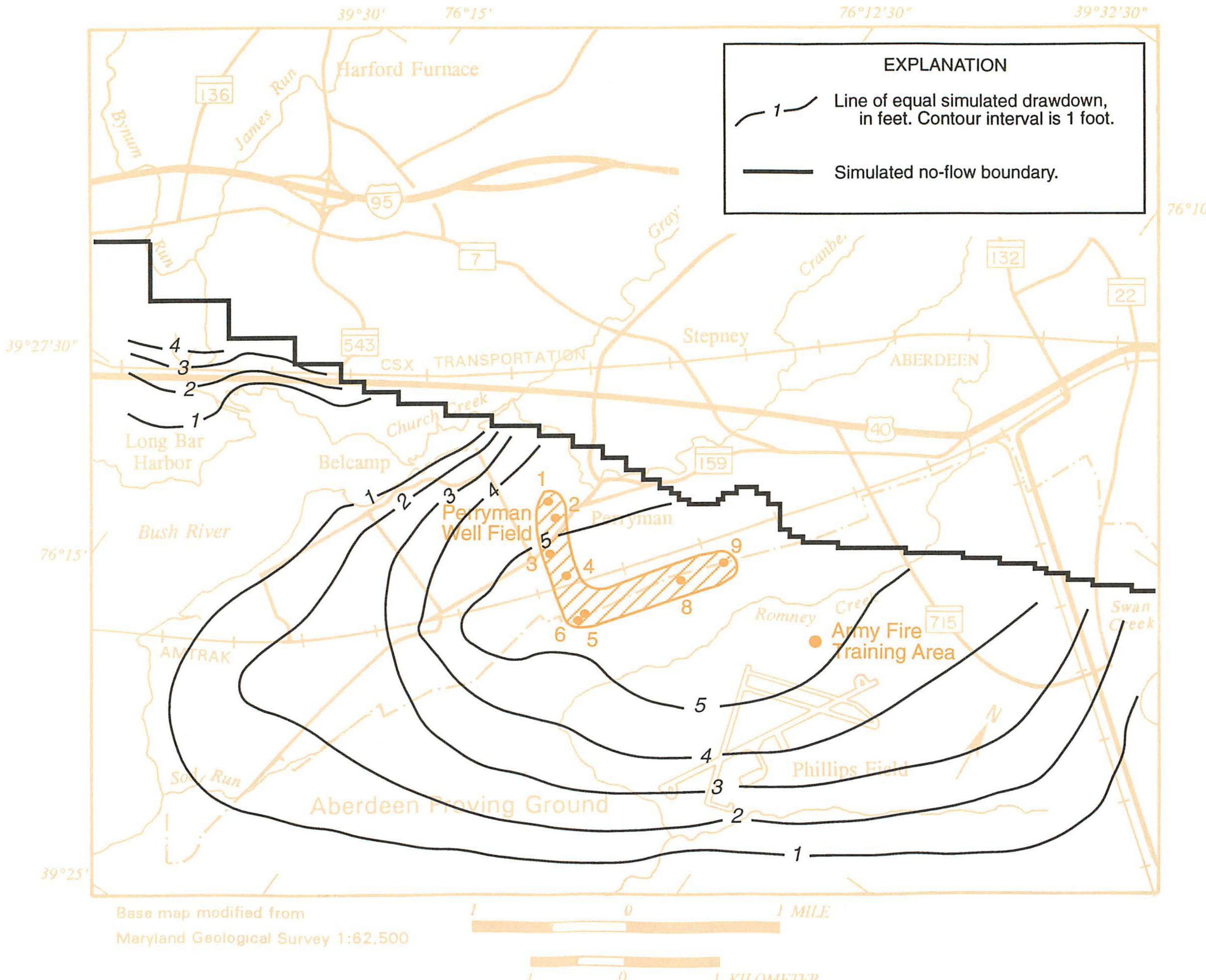

Figure 92.—Simulated drawdown in aquifer 2 for 1994-1997, based on simulation 13.

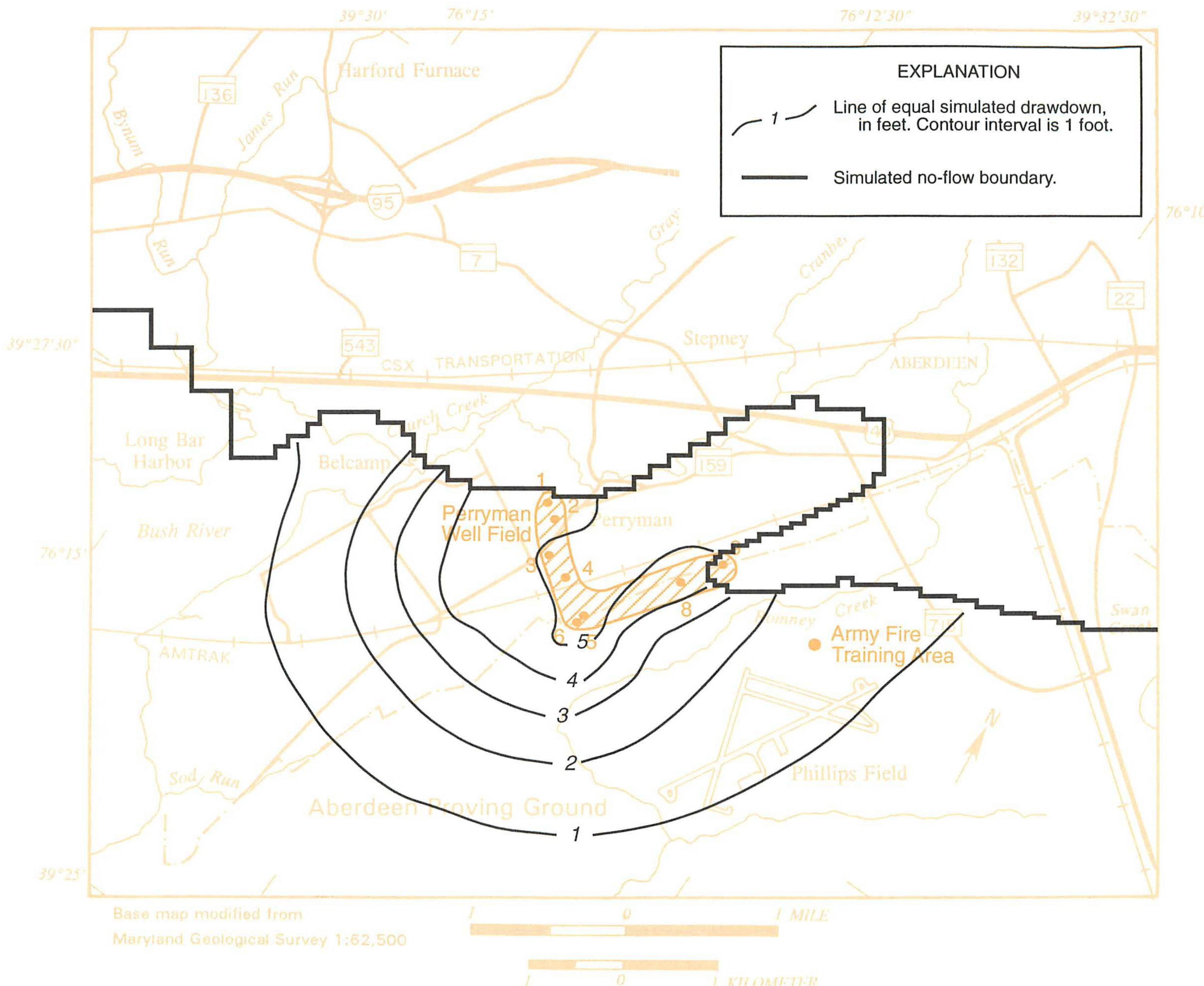

Figure 93.—Simulated drawdown in aquifer 3 for 1994-1997, based on simulation 13.

SUMMARY AND CONCLUSIONS

The protection of public ground-water supplies from chemical contamination is a major priority of federal, state, and county governments. A wellhead protection program has been initiated for the Perryman well field with funding from federal, state, and county sources. The hydrogeology of the Perryman area in Harford County, Maryland was studied in order to estimate the extent of contributing areas of the wells in the Perryman well field, as part of the wellhead protection program. The Perryman well field consists of eight production wells (designated wells 1, 2, 3, 4, 5, 6, 8, and 9; De 73, De 75, De 58, De 59, De 77, De 76, De 67, De 64) screened between 45 and 192 ft below land surface.

The well field pumped ground water at an average rate of 2.2 Mgal/d in 1994. Water from several of these wells has had nitrate concentrations exceeding the U.S. Environmental Protection Agency maximum contaminant level (MCL) for drinking water, and beginning in 1992, analyses of water from two of the wells showed concentrations of TCE (trichloroethene) that exceeded the MCL. Agricultural application of fertilizer and septic systems are possible sources of nitrate, and the Army Fire Training Area (AFTA), located on Aberdeen Proving Ground, is a possible source of TCE.

The Perryman area is underlain by fluvial sediments of the Potomac Group (of Lower Cretaceous age) and the Talbot Formation (of Quaternary age), which consist of clay, silt, sand, and gravel. The sediments form a system of irregularly shaped aquifers and confining units which produce complex ground-water flow paths. These sediments were divided into three aquifers (designated aquifers 1, 2, and 3) and two intervening confining units (designated confining units 1 and 2).

Aquifer 1 is a water-table aquifer, and ranges in thickness from 0 to 85 ft. The top of aquifer 1 ranges in altitude from about sea level to 100 ft above sea level, and the bottom ranges in altitude from 60 ft below sea level to 50 ft above sea level. The water table in aquifer 1 ranges in altitude from about sea level to about 45 ft above sea level. Hydraulic conductivities of aquifer 1, derived from aquifer tests and model calibration, range from 50 ft/d to 300 ft/d, and the specific yield is probably about 0.01 to 0.3. Confining unit 1, which directly underlies aquifer 1 in most places, is mostly silty clay, and ranges in leakance from 0.0001 to 1.0 d^{-1}.

Aquifer 2 is a semiconfined to confined aquifer, and ranges in thickness from 0 to 105 ft. The top of aquifer 2 ranges in altitude from about 80 ft below sea level to sea level, and the bottom ranges in altitude from about 120 ft below sea level to 20 ft below sea level. The potentiometric surface in aquifer 2 ranges in altitude from about 5 ft above sea level to 33 ft above sea level. Transmissivity of aquifer 2, derived from aquifer tests and model calibration, ranges from 500 to 32,000 ft^2/d, and the storage coefficient is probably about 0.0002. Confining unit 2, which directly underlies aquifer 2 in most places, is mostly silty clay, and ranges in leakance from 0.00001 to 0.1 d^{-1}.

Aquifer 3 is a confined aquifer, and ranges in thickness from 0 to 100 ft. The top of aquifer 3 ranges in altitude from about 200 ft below sea level to 60 ft below sea level, and the bottom ranges in altitude from about 240 to 80 ft below sea level. The potentiometric surface in aquifer 3 ranges in altitude from about 7 to 25 ft above sea level. Transmissivity of aquifer 3, derived from aquifer tests and model calibration, ranges from less than 50 to 3,700 ft^2/d, and the storage coefficient is probably about 0.0002. Aquifer 3 is underlain mostly by relatively impermeable clay and bedrock.

Ground water in the Perryman area has been contaminated with nitrate and TCE. Concentrations of nitrate in water from wells in the Perryman well field generally range between 1 and 15 mg/L (as nitrogen), but have been as high as 24 mg/L. TCE has been detected in water from two of the wells in the Perryman well field in concentrations as high as 18 μg/L. Possible sources of nitrate include fertilizer application and septic systems. The Army Fire Training Area, on Aberdeen Proving Ground has been identified as a possible source of TCE in ground water, but other sources may also be present. A plume of dissolved TCE has been delineated which extends from the AFTA to the Perryman well field.

A ground-water flow model was developed to simulate hydraulic heads and flow for present (1994) conditions, and for projected-pumpage scenarios. The finite-difference grid used in the flow-model simulations was 5.7 miles by 7.0 miles, with 58 rows, 99 columns, and 3 layers, and cell dimensions range in size from 200 ft square to 2,025 ft by 4,556 ft. Simulated flow components of the model include recharge, evapotranspiration, stream base flow, estuarine discharge, and storage.

A particle-tracking program was used to estimate the contributing areas of wells in the well field, to estimate travel-time of water entering the wells, to simulate migration of the TCE plume, and to estimate TCE concentrations in water from wells in the Perryman well field. The particle-tracking program only simulates advective flow, and does not simulate dispersion, density-dependent flow, or chemical reactions.

The contributing area for well 1 (De 73) comprises two long narrow areas, one of which is in the vicinity of the well field, and is about 1 mile long and a few hundred feet wide. This area contains time zones of 20 to 50, 50 to 100, and 100 to 200 years, but is mostly in the 50 to 200-year range. The other area is about two miles northeast of the well field, and extends northeast to Aberdeen. It is about one-and-a-half miles long by a few hundred feet wide. It contains time zones of 100 to 200, and 200 to 500 years. The contributing area for well 2 (De 75) forms a long narrow area, about four miles long, and a few hundred feet wide. It extends from about one-half mile southwest of the well field, northeast to Aberdeen. It is composed of numerous time zones, ranging from zero to 500 years. Most of the contributing area is in the zero to 100-year range. This contributing area extends about a mile southwest of the well field, and contains time zones of zero to 20, 20 to 50, and 50 to 100 years. Most of the area is in the zero to 100-year range. The contributing area for well 3 (calculated using 1993 pumpage) extends about a mile to the southwest of the well field and contains time zones from 0 to 100 years.

The contributing area for well 4 (De 59) comprises several areas extending from about one-half mile south of the well field in APG, north to Aberdeen. It contains traveltime zones of zero to 20, 20 to 50, 50 to 100, and 100 to 200 years. The largest area is in the vicinity of the well field, is about two miles long by one-half mile wide, and contains traveltime zones of zero to 20, and 20 to 50 years. The contributing area for well 5 (De 77) comprises two areas, which contain traveltime zones of zero to 20 and 20 to 50 years. The larger area extends from the well field eastward into APG near the AFTA, and is about two miles long by a quarter mile wide. It contains one traveltime zone of zero to 20 years. The contributing area for well 6 (De 76) is one large area east of the well field, extending to the AFTA. It is composed primarily of one zero to 20-year traveltime zone, with two small 20 to 50-year zones.

The contributing area for well 8 (De 67) is a crescent-shaped area northeast of the well field. It is composed primarily of a zero to 20-year traveltime zone, and a smaller 20 to 50-year zone. The area within this crescent is part of the contributing area for well 9. The contributing area for well 9 (De 64) is an elongate area northeast of the well field that extends to Aberdeen. It is about one-half mile wide at its widest, two miles long, and comprises traveltime zones of zero to 20, 20 to 50, and 50 to 100 years. The zero to 20-year zone is the largest.

Simulations indicate that if 1994 pumpage were continued for 20 years, heads would not change appreciably from 1994 heads, and that TCE concentrations at the contaminated wells would decrease due to the decline in pumpage prior to 1994 and to the removal of TCE-contaminated soil at the AFTA. Under these conditions, the main part of the TCE plume would migrate to the southeast toward the Chesapeake Bay. Simulations in which pumpage is increased 20 percent for 20 years show an increase in TCE concentrations at the contaminated wells, and simulations in which pumpage is decreased 20 percent for 20 years show a decrease in TCE concentrations.

A simulation in which average Ground-water Appropriation Permit allocations were entered indicate maximum drawdowns from 1994 levels in aquifers 1, 2, and 3 of 11, 15, and 18 ft respectively. In this simulation, the main part of the TCE plume has been drawn into wells in the Perryman well field by 2014. A simulation in which maximum Ground-water Appropriation Permit allocations were entered indicate maximum drawdowns from 1994 levels in aquifers 1, 2, and 3 of 20, 27, and 34 ft respectively. In this simulation, the main part of the TCE plume has been drawn into wells in the Perryman well field by 2014.

A simulation in which all pumpage in the study area is discontinued for 20 years shows that water levels quickly recover to their prepumping levels, and the TCE plume migrates farther to the southern model boundary. A simulation in which pumpage from the contaminated wells (5 and 6 (De 77 and 76)) is discontinued (but other wells are pumped at 1994 rates) for 20 years indicates that water levels in all three aquifers recover by about 5 feet at wells 5 and 6, and the TCE plume would migrate toward previously uncontaminated well 4 (De 59). A simulation in which pumpage at wells 5 and 6 was increased to the estimated maximum capacity of those wells (800 and 1,000 gal/min respectively) shows that the main part of the TCE plume is closer to the well field, and that TCE concentrations in well 5 increase significantly, and in well 6, decrease slightly.

A simulation in which four hypothetical production wells were added southwest of the Perryman well field with an additional 1,000 gal/min capacity indicate a maximum drawdown of 6 ft in aquifer 3. Part of the TCE plume migrates toward the hypothetical wells but does not quite reach them by 2014. A simulation in which two hypothetical production wells were added northeast of the Perryman well field that pump an additional 1 Mgal/d indicates a maximum drawdown of 27 ft in aquifers 2 and 3. The TCE plume migrates slightly farther north in this simulation, and TCE concentrations are much higher in well 5 (De 77). A simulation in which two hypothetical production wells were added north of the Perryman well field near well 4 (De 59) that pump an additional 1 Mgal/d indicates a maximum drawdown of 14 ft in aquifers 2 and 3. The TCE plume migrates slightly farther north in this simulation, and TCE concentrations are higher in well 5.

A simulation in which recharge was reduced 40 percent (drought conditions) for one year indicates maximum drawdowns of 5 ft in aquifer 1 and 3 ft in aquifers 2 and 3. A simulation in which recharge was reduced 40 percent for three years indicates maximum drawdowns of 9 ft in aquifer 1 and 5 ft in aquifers 2 and 3.

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SUPPLEMENTAL DATA

Table 5.—Records of selected wells and borings in the Perryman area

[FT = feet; LS = land surface; GAL/MIN = gallons per minute; [(GAL/MIN)/FT] = gallons per minute per foot; other abbreviations are found at the end of the table]

WELL NUMBER	LOCAL NAME	STATE PERMIT NUMBER	OWNER	CONTRACTOR	DATE WELL CONSTRUCTED	ALTITUDE (FT)	WELL DEPTH (FT)	WELL DIAMETER (INCHES) CASING	SCREEN
HA Cf 30	ABERDEEN #1	HA-01-0405	TOWN OF ABERDEEN	SHANNAHAN CO	06/26/52	72	69	16-10	--
HA Cf 32	ABERDEEN #3	HA-01-5239	TOWN OF ABERDEEN	SHANNAHAN CO	06/18/54	65	65	16-10	10
HA Cf 174	TW-1	HA-81-1139	TOWN OF ABERDEEN	SHANNAHAN CO	02/08/84	71.82	71	2	2
HA Cf 175	ABERDEEN #11	HA-81-1140	TOWN OF ABERDEEN	SHANNAHAN CO	02/09/84	68	65	4	4
HA Dd 91	--	HA-81-4136	MD. GEOL. SURVEY	W C SERVICES	01/28/88	19.73	78	4	4
HA Dd 92	--	HA-81-4137	MD. GEOL. SURVEY	W C SERVICES	02/05/88	20.06	38	4	4
HA De 7	BLDG 1041	--	U. S. ARMY	LAYNE-ATL CO	1942	58.89	81	10	--
HA De 26	--	HA-02-2483	INTERPACE CORP	SHANNAHAN CO	03/29/56	40	207	4	--
HA De 27	--	HA-02-2484	INTERPACE CORP	SHANNAHAN CO	1956	40	167	4	--
HA De 28	--	HA-02-4175	INTERPACE CORP	SHANNAHAN CO	08/23/56	40	127	10-8	8
HA De 33	MANSION	HA-00-3395	BATA SHOE CO	W E REIBOLD	01/1949	60	167	6	--
HA De 34	SRV. AREA #1	HA-05-0364	MD HWY ADMIN	L WALTON	11/03/62	194.3	130	6	--
HA De 35	MNT. AREA #1	HA-05-0355	MD HWY ADMIN	L WALTON	11/10/62	160	141	6	--
HA De 36	SRV. AREA #2	HA-05-0365	MD HWY ADMIN	L WALTON	11/20/62	189.8	141	6	--
HA De 37	SRV. AREA #3	HA-05-0366	MD HWY ADMIN	L WALTON	12/04/62	181.2	134	6	--
HA De 38	SRV. AREA #4	HA-05-0367	MD HWY ADMIN	L WALTON	01/03/63	210.6	160	6	--
HA De 39	SRV. AREA #5	HA-05-0368	MD HWY ADMIN	L WALTON	01/10/63	186.3	148	6	--
HA De 47	--	HA-04-5127	ROBERT SCHLOER	LEONARD DRLG	12/20/61	160	78	6.25	--
HA De 51	SRV. AREA #6	HA-05-1497	MD HWY ADMIN	L WALTON	02/27/63	173	245	6	--
HA De 52	SRV. AREA	HA-05-1761	CARY JACKSON	G EDGAR HARR	03/18/63	250	101	6.25	--
HA De 53	SRV. AREA #1A	HA-05-1495	MD HWY ADMIN	L WALTON	03/18/63	115	158	6	--
HA De 55	SRV. AREA #3A	HA-05-1496	MD HWY ADMIN	L WALTON	04/03/63	100	123	6	--
HA De 56	TW-A	HA-67-0088	HARFORD CO DPW	SHANNAHAN CO	11/29/66	10	105	4	4
HA De 57	TW	HA-67-0604	HARFORD CO DPW	SHANNAHAN CO	07/07/67	10	126	4	4
HA De 58	PERRYMAN #3	HA-68-0657	HARFORD CO DPW	LAYNE ATL CO	07/17/68	45	138.5	8	8
HA De 59	PERRYMAN #4	HA-70-0086	HARFORD CO DPW	LAYNE ATL CO	12/11/69	45	144	10	--
HA De 60	--	HA-70-0377	BALT GAS & ELEC	SHANNAHAN CO	08/01/70	28	207	10	10 10 10
HA De 64	PERRYMAN #9	HA-71-0164	HARFORD CO DPW	SHANNAHAN CO	11/20/70	35	91	8	--
HA De 66	2-69	HA-69-0394	HARFORD CO DPW	SHANNAHAN CO	01/14/69	68.79	66	4	4
HA De 67	PERRYMAN #8	HA-71-0165	HARFORD CO DPW	SHANNAHAN CO	11/16/70	45	137	16-8	--

TOP OF SCREEN BELOW LS (FT)	BOTTOM OF SCREEN BELOW LS (FT)	WATER-BEARING FORMATION[1]	WATER LEVEL BELOW LS (FT)	DATE MEASURED	PUMPING TEST DATA: WATER LEVELS BELOW LS (FT) STATIC	PUMPING	DATE REPORTED	YIELD (GAL/MIN)	HOURS PUMPED	SPECIFIC CAPACITY [(GAL/MIN)/FT]	USE OF WATER[2]	WELL NUMBER
47	69	112TLBT	17	06/26/52	17	23.5	06/26/52	150	8	23.1	P	HA Cf 30
45	65	112TLBT	20.5	06/18/54	20.5	32	06/18/54	250	8	21.7	P	HA Cf 32
60	71	112TLBT	41	02/08/84	41	45	02/08/84	12	1	3	U	HA Cf 174
50	65	112TLBT	42.8	07/13/94	38	43	02/09/84	32	2	6.4	P	HA Cf 175
58	68	112TLBT	--	--	--	--	04/15/88	25	--	--	U	HA Dd 91
18	28	112TLBT	11.5	10/03/88	13.7	26.6	02/05/88	7.5	4	0.58	U	HA Dd 92
71	81	112TLBT	28.35	05/03/89	27	69	09/1942	252.6	--	6.0	U	HA De 7
--	--	--	15	03/29/56	14.5	--	03/29/56	--	4	--	U	HA De 26
--	--	--	4	05/01/56	--	--	--	--	--	--	U	HA De 27
81 116	92 127	--	15	08/23/56	15	29	08/23/56	96	24	6.86	N	HA De 28
--	--	300MBAB	65	01/1949	65	145	01/1949	5	5	0.06	H	HA De 33
--	--	300MBAB	5	11/02/62	5	27	11/03/62	25	24	1.14	U	HA De 34
--	--	300MBAB	20	11/10/62	20	80	11/10/62	12	10	0.2	U	HA De 35
--	--	300MBAB	2	11/20/62	2	105	11/20/62	5	4	0.05	U	HA De 36
--	--	300MBAB	2.33	01/11/63	6.5	130	12/1962	25	--	0.2	U	HA De 37
--	--	300MBAB	24.28	01/11/63	60	160	01/03/63	1	4	0.01	U	HA De 38
--	--	300MBAB	1.79	01/15/63	7	148	01/10/63	5	5	0.04	U	HA De 39
--	--	300MBAB	45	12/20/61	45	68	12/20/61	15	1	0.65	H	HA De 47
--	--	300MBAB	6.08	02/26/63	7	72	02/27/63	7	24	0.11	U	HA De 51
--	--	300MBAB	26	03/18/63	26	70	03/18/63	3	3	0.07	U	HA De 52
--	--	300MBAB	3	03/18/63	3	158	03/18/63	4	6	0.03	U	HA De 53
--	--	300MBAB	4	04/03/63	4	123	04/03/63	1	4	0.01	U	HA De 55
94	104	112TLBT	25.7	07/07/67	24.5	60	11/29/66	5	6	0.14	U	HA De 56
104	115	112TLBT	32	--	32	53	07/07/67	7.5	6	0.36	U	HA De 57
93.5	138.5	217PTMC	29.96	07/24/86	19	83	07/17/68	201	24	3.14	P	HA De 58
96	144	217PTMC	21	12/11/69	21	44	12/11/69	450	24	19.6	P	HA De 59
96 160 194	100 180 207	217PTMC	20	08/01/70	20	60	08/01/70	336	48	8.4	F	HA De 60
60	91	217PTMC	10	11/20/70	10	43	11/20/70	350	24	10.6	U	HA De 64
45	66	112TLBT	28.5	01/14/69	28.5	31.4	01/14/69	15	4	5.2	U	HA De 66
112	137	217PTMC	17	11/16/70	17	72	11/16/70	350	24	6.4	U	HA De 67

Table 5.—Records of selected wells and borings in the Perryman area—Continued

WELL NUMBER	LOCAL NAME	STATE PERMIT NUMBER	OWNER	CONTRACTOR	DATE WELL CONSTRUCTED	ALTITUDE (FT)	WELL DEPTH (FT)	WELL DIAMETER (INCHES)	
								CASING	SCREEN
HA De 68	1-69	HA-69-0393	HARFORD CO DPW	SHANNAHAN CO	01/09/69	55	43	4	4
HA De 69	3-69	HA-69-0395	HARFORD CO DPW	SHANNAHAN CO	01/20/69	50	50	4	4
HA De 70	2-68	HA-69-0284	HARFORD CO DPW	SHANNAHAN CO	12/17/68	45	185	--	--
HA De 73	PERRYMAN #1	HA-66-0814	HARFORD CO DPW	SHANNAHAN CO	07/28/66	40	103	8	8
HA De 75	PERRYMAN #2	HA-66-0813	HARFORD CO DPW	SHANNAHAN CO	08/15/66	40	133	8	8
HA De 76	PERRYMAN #6	HA-71-0613	HARFORD CO DPW	SHANNAHAN CO	02/09/70	41	89	16-10	10
HA De 77	PERRYMAN #5	HA-71-0619	HARFORD CO DPW	SHANNAHAN CO	03/15/70	41	107	16-10	10
HA De 78	--	--	HARFORD CO DPW	SHANNAHAN CO	09/14/70	41.84	97	8	--
HA De 79	--	HA-69-0392	HARFORD CO DPW	SHANNAHAN CO	02/05/69	40	135	4	--
HA De 80	--	HA-05-6658	HARFORD CO DPW	SHANNAHAN CO	03/23/64	20	134	4	--
HA De 81	--	HA-05-6657	HARFORD CO DPW	SHANNAHAN CO	03/18/64	20	117	4	4
HA De 82	--	HA-05-6659	HARFORD CO DPW	SHANNAHAN CO	03/19/64	15	120	--	--
HA De 83	5-69	HA-69-0397	HARFORD CO DPW	SHANNAHAN CO	01/31/69	50	135	4	--
HA De 84	4-69	HA-69-0396	HARFORD CO DPW	SHANNAHAN CO	01/28/69	43.43	135	4	4
HA De 85	SOD RUN	HA-68-0131	HARFORD CO DPW	SHANNAHAN CO	07/20/67	15	118	6	4
HA De 86	ABERDEEN #2	HA-01-0406	TOWN OF ABERDEEN	SHANNAHAN CO	1952	60	61	16-10	--
HA De 87	ABERDEEN #4	HA-02-8021	TOWN OF ABERDEEN	SHANNAHAN CO	10/15/57	55	54.5	10	10
HA De 88	TW-2	HA-65-0540	TOWN OF ABERDEEN	SHANNAHAN CO	03/26/65	55.15	42	2	2
HA De 89	TW-3	HA-65-0540	TOWN OF ABERDEEN	SHANNAHAN CO	03/27/65	60.4	54	2	2
HA De 90	ABERDEEN #5	HA-02-8020	TOWN OF ABERDEEN	SHANNAHAN CO	09/04/57	60	54	10	10
HA De 91	TW-4	HA-65-0540	TOWN OF ABERDEEN	SHANNAHAN CO	03/29/65	58.5	47	2	2
HA De 92	TW-5	HA-65-0540	TOWN OF ABERDEEN	SHANNAHAN CO	03/24/65	55.6	45	2	2
HA De 93	ABERDEEN #6	HA-67-0381	TOWN OF ABERDEEN	SHANNAHAN CO	04/02/67	60	47	10	10
HA De 94	--	HA-67-0604	HARFORD CO DPW	SHANNAHAN CO	07/28/67	50	109	2	2
HA De 95	--	HA-72-0433	U. S. ARMY - APG	FRANK'S DRLG	12/20/71	50	70	6	4
HA De 101	TW101	--	BALT GAS & ELEC	W GEORGE INC	03/21/72	25	346	5	--
HA De 104	TW104	--	BALT GAS & ELEC	W GEORGE INC	03/29/72	42	397	5	--
HA De 107	TW107	--	BALT GAS & ELEC	W GEORGE INC	04/06/72	34	365	5	--
HA De 111	--	--	BALT GAS & ELEC	MD FOUNDATION	1972	23	80	9	--
HA De 113	--	--	BALT GAS & ELEC	MD FOUNDATION	1972	28	80	9	--

TOP OF SCREEN BELOW LS (FT)	BOTTOM OF SCREEN BELOW LS (FT)	WATER-BEARING FORMATION[1]	WATER LEVEL BELOW LS (FT)	DATE MEASURED	PUMPING TEST DATA: WATER LEVELS BELOW LS (FT): STATIC	PUMPING	DATE REPORTED	YIELD (GAL/MIN)	HOURS PUMPED	SPECIFIC CAPACITY [(GAL/MIN)/FT]	USE OF WATER[2]	WELL NUMBER
33	43	112TLBT	18	01/09/69	18	20	01/09/69	15	4	7.5	U	HA De 68
44	50	112TLBT	12	01/20/69	12	28	01/20/69	7.5	4	0.5	U	HA De 69
..	..	..	..	..	..	..	..	..	..	..	U	HA De 70
94	103	217PTMC	7	07/28/66	7	32	07/28/66	130	24	5.2	P	HA De 73
112	132	217PTMC	20	08/15/66	20	66	08/15/66	164	24	3.6	P	HA De 75
60	67	112TLBT	17	02/09/70	17	35	02/09/70	1000	24	55.5	P	HA De 76
74	89											
60	66	112TLBT	20	03/15/70	20	44	03/15/70	915	24	38.1	P	HA De 77
77	107	217PTMC										
72	..	112TLBT	14.4	09/14/70	..	..	..	350	24	..	U	HA De 78
..	..	..	..	..	..	..	..	..	..	..	U	HA De 79
..	..	..	..	..	..	..	..	..	..	..	U	HA De 80
66	81	112TLBT	20	03/01/64	20	32	03/18/64	23	4	1.92	U	HA De 81
..	..	..	..	..	..	..	..	..	..	..	U	HA De 82
34	50	112TLBT	25	01/31/69	25	27	01/31/69	10	4	5	U	HA De 83
44	65	112TLBT	20	01/28/69	20	23	01/28/69	25	24	8.33	U	HA De 84
103	118	217PTMC	27.9	08/14/86	25	3.0	07/20/67	42	6	8.4	N	HA De 85
39	..	112TLBT	5	08/01/52	5	16	08/1952	160	8	14.5	P	HA De 86
28	54.5	112TLBT	15	10/15/57	14.8	16.5	10/15/57	30	4	17.6	P	HA De 87
37	42	112TLBT	23	03/26/65	23	26	03/26/65	2	2	0.67	U	HA De 88
49	54	112TLBT	25	03/27/65	25	29	03/27/65	3	2	0.75	U	HA De 89
27	54	112TLBT	13	09/04/57	13	17.8	09/04/57	60	4	12.5	P	HA De 90
42	47	112TLBT	17	03/29/65	17	21	03/29/65	10	2	2.5	U	HA De 91
40	45	112TLBT	13.1	03/24/65	13.1	17	03/24/65	10	2	2.56	U	HA De 92
29.1	47.3	112TLBT	19.3	04/02/67	19.3	23.4	04/02/67	29	8	7.07	P	HA De 93
99	109	217PTMC	24.84	07/24/86	17	30	07/28/67	25	4	1.92	U	HA De 94
65	70	112TLBT	22	12/20/71	22	31	12/20/71	70	6	7.78	H	HA De 95
..	..	112TLBT	12	03/21/72	..	..	..	..	..	..	U	HA De 101
..	..	112TLBT	30	03/29/72	..	..	..	..	..	..	U	HA De 104
..	..	112TLBT	24	04/06/72	..	..	..	..	..	..	U	HA De 107
40	80	112TLBT	13	08/01/72	13	35	..	360	23	16.4	U	HA De 111
30	80	112TLBT	21.32	08/02/72	21	33.8	08/1972	82	23	6.4	U	HA De 113

Table 5.—Records of selected wells and borings in the Perryman area—Continued

WELL NUMBER	LOCAL NAME	STATE PERMIT NUMBER	OWNER	CONTRACTOR	DATE WELL CONSTRUCTED	ALTITUDE (FT)	WELL DEPTH (FT)	WELL DIAMETER (INCHES)	
								CASING	SCREEN
HA De 117	--	HA-65-0039	HARFORD CO DPW	SHANNAHAN CO	06/25/64	45	115	2	--
HA De 118	--	HA-04-9570	YORK BLDG PROD	ENNIS BROS	11/09/62	60	80	6	--
HA De 124	2-76-A	HA-73-2531	HARFORD CO DPW	SHANNAHAN CO	01/30/76	40.16	218	4	4
								4	4
HA De 125	3-76-A	HA-73-2533	HARFORD CO DPW	SHANNAHAN CO	02/04/76	39.85	228	2	2
								2	2
HA De 126	5-76	HA-73-2530	HARFORD CO DPW	SHANNAHAN CO	02/10/76	38.94	143	2	2
HA De 127	6-76-A	HA-73-2532	HARFORD CO DPW	SHANNAHAN CO	02/12/76	34.0	161	2-1	1
HA De 128	4-76-B	HA-73-2534	HARFORD CO DPW	SHANNAHAN CO	02/18/76	38.77	66	4	4
								4	4
HA De 129	4-76-A	HA-73-2535	HARFORD CO DPW	SHANNAHAN CO	02/19/76	38.8	165	4	4
								4	4
HA De 136	GM-13	HA-81-0953	BALT GAS & ELEC	HARDIN-HUBER	01/10/84	33.90	125	4	4
HA De 137	GM-14	HA-81-0957	BALT GAS & ELEC	HARDIN-HUBER	01/16/84	34.07	45	2	2
HA De 138	GM-1	HA-81-0950	BALT GAS & ELEC	HARDIN-HUBER	01/10/84	29.87	152	4	4
HA De 139	GM-2	HA-81-0946	BALT GAS & ELEC	HARDIN-HUBER	02/08/84	29.71	65	2	2
HA De 140	GM-4	HA-81-0949	BALT GAS & ELEC	HARDIN-HUBER	01/05/84	29.5	75	2	2
HA De 141	GM-3	HA-81-0951	BALT GAS & ELEC	HARDIN-HUBER	01/05/84	28.65	212	4	4
HA De 142	PM-5D	HA-81-1242	MD DEPT NAT RSRC	ENGNR DRILL	04/29/84	14	260	2	2
HA De 145	PM-2D	HA-81-1246	MD DEPT NAT RSRC	ENGNR DRILL	04/16/84	36.22	180	2	2
HA De 149	--	HA-73-6303	FUTTY, CHARLES	FRANK'S DRLG	10/28/80	32	45	4	2
HA De 150	--	HA-73-5780	CLINE , HOWARD	FRANK'S DRLG	08/07/79	23	100	4	2
HA De 151	GM-5	HA-81-0952	BALT GAS & ELEC	HARDIN-HUBER	01/11/84	31.74	180	4	4
HA De 152	GM-6	HA-81-0948	BALT GAS & ELEC	HARDIN-HUBER	01/11/84	32.55	95	2	2
HA De 153	GM-7	HA-81-0955	BALT GAS & ELEC	HARDIN-HUBER	01/16/84	14.74	138	4	4
HA De 154	GM-8	HA-81-0956	BALT GAS & ELEC	HARDIN-HUBER	10/05/83	14.41	70	2	2
HA De 155	GM-15	HA-81-0954	BALT GAS & ELEC	HARDIN-HUBER	01/16/84	38.84	120	4	4
HA De 156	GM-16	HA-81-0947	BALT GAS & ELEC	HARDIN-HUBER	01/09/84	38.66	50	2	2
HA De 157	GM-9	HA-81-0960	BALT GAS & ELEC	HARDIN-HUBER	01/09/84	33.83	40	2	2
HA De 158	PM-3D	HA-81-1251	MD DEPT NAT RSRC	ENGNR DRILL	04/29/84	23.76	105	2	2
HA De 159	PM-3S	HA-81-1250	MD DEPT NAT RSRC	ENGNR DRILL	04/25/84	22.92	190	2	2
HA De 160	PM-1S	HA-81-1245	MD DEPT NAT RSRC	ENGNR DRILL	04/10/84	28.19	47	2	2
HA De 161	PM-1D	HA-81-1244	MD DEPT NAT RSRC	ENGNR DRILL	04/06/84	27.87	140	2	2
HA De 162	PM-4S	HA-81-1249	MD DEPT NAT RSRC	ENGNR DRILL	04/24/84	30.69	79	2	2

TOP OF SCREEN BELOW LS (FT)	BOTTOM OF SCREEN BELOW LS (FT)	WATER-BEARING FORMATION[1]	WATER LEVEL BELOW LS (FT)	DATE MEASURED	PUMPING TEST DATA: WATER LEVELS BELOW LS (FT): STATIC	PUMPING	DATE REPORTED	YIELD (GAL/MIN)	HOURS PUMPED	SPECIFIC CAPACITY [(GAL/MIN)/FT]	USE OF WATER[2]	WELL NUMBER
--	--	112TLBT	--	--	--	--	--	--	--	--	U	HA De 117
33	43	112TLBT	11	11/09/62	--	--	--	35	25	--	N	HA De 118
147	167	217PTMC	24.31	04/22/87	21.1	28.4	01/30/76	56	4	7.7	U	HA De 124
208	218											
150	155	217PTMC	23.07	04/22/87	19	30	02/04/76	20	2	1.82	U	HA De 125
223	228											
134	143	217PTMC	23.09	04/22/87	18.7	30	02/10/76	17	2	1.5	U	HA De 126
151	161	217PTMC	19.20	04/22/87	13.2	20	02/12/76	10	2	1.47	U	HA De 127
40	50	112TLBT	19.91	04/22/87	16.01	18.19	02/18/76	38	3	17.4	U	HA De 128
55	66											
125	140	217PTMC	23.29	04/22/87	19.91	26.27	02/19/76	56	3	8.80	U	HA De 129
155	165											
115	125	217PTMC	23.10	11/03/86	--	--	01/10/84	1	1	--	U	HA De 136
35	45	112TLBT	19.50	11/03/86	--	--	01/16/84	2	1	--	U	HA De 137
140	150	217PTMC	20.94	11/03/86	--	--	01/10/84	20	1	--	U	HA De 138
55	65	112TLBT	18.92	11/03/86	--	--	02/08/84	1	1	--	U	HA De 139
65	75	112TLBT	--	--	--	--	01/05/84	2	1	--	U	HA De 140
200	210	217PTMC	22.12	11/03/86	--	--	01/05/84	20	1	--	U	HA De 141
250	260	217PTMC	11.69	12/12/86	7	--	04/29/84	25	1	--	U	HA De 142
170	180	217PTMC	25.20	04/22/87	--	--	--	20	1	--	U	HA De 145
38	45	112TLBT	19.27	08/26/86	17	27	10/28/80	25	2	2.5	H	HA De 149
95	100	217PTMC	19.29	08/27/86	17	29	08/07/79	25	2	2.08	H	HA De 150
168	178	217PTMC	25.00	08/13/86	--	--	01/11/84	20	1	--	U	HA De 151
85	95	112TLBT	26.18	04/21/87	--	--	01/11/84	2	1	--	U	HA De 152
126	136	217PTMC	8.98	11/03/86	--	--	01/16/84	5	2	--	U	HA De 153
60	70	112TLBT	10.97	11/03/86	--	--	10/05/83	2	1	--	U	HA De 154
110	120	217PTMC	26.86	11/03/86	--	--	01/16/84	3	1	--	U	HA De 155
40	50	112TLBT	23.71	11/03/86	--	--	01/09/84	2	1	--	U	HA De 156
30	40	112TLBT	22.12	11/03/86	--	--	01/09/84	1	1	--	U	HA De 157
95	105	112TLBT	16.83	04/21/87	--	--	04/29/84	30	1	--	U	HA De 158
180	190	217PTMC	15.44	04/21/87	--	--	04/25/84	35	1	--	U	HA De 159
40	47	112TLBT	15.38	12/12/86	--	--	04/10/84	20	1	--	U	HA De 160
130	140	217PTMC	20.43	12/12/86	--	--	04/06/84	20	1	--	U	HA De 161
69	79	112TLBT	16.26	12/12/86	--	--	04/24/84	20	1	--	U	HA De 162

Table 5.—Records of selected wells and borings in the Perryman area—Continued

WELL NUMBER	LOCAL NAME	STATE PERMIT NUMBER	OWNER	CONTRACTOR	DATE WELL CONSTRUCTED	ALTITUDE (FT)	WELL DEPTH (FT)	WELL DIAMETER (INCHES)	
								CASING	SCREEN
HA De 163	PM-4D	HA-81-1248	MD DEPT NAT RSRC	ENGNR DRILL	04/20/86	29.96	165	2	2
HA De 164	--	HA-73-3141	DOANE, DAVE	LEONARD DRLG	07/28/76	57	120	4	2
HA De 165	--	HA-73-6437	ROSCHEL, SYLVIA	KIRK DRLG	04/10/81	20	158	6	6
HA De 166	--	HA-81-2322	WELSH, MILES W.	FRANK'S DRLG	11/12/85	17	140	4	2
HA De 169	--	HA-81-1729	TOOL & DIE SPECIALTIES	FRANK'S DRLG	12/11/84	63	60	4	2
HA De 172	--	HA-81-0381	REEVES, HARRIS	BARBER DRLG	11/27/82	33	149	6	--
HA De 173	--	HA-73-6439	N MD SFTAORC	FRANK'S DRLG	02/11/81	105	275	6	--
HA De 178	--	HA-73-6436	COLLIER, TEDDY	KIRK DRLG	03/09/81	62	65	6	6
HA De 183	--	HA-81-4577	MD. GEOL. SURVEY	WC SERVICES	12/19/87	12.53	165	4	4
HA De 184	--	HA-81-0978	F. O. MITCHELL	SHANNAHAN CO	03/22/84	39	189	12-8	12 8 8
HA De 187	--	--	MD. GEOL. SURVEY	U.S. GEOL. SURVEY	1987	5.08	10	--	--
HA De 195	--	HA-81-4142	MD. GEOL. SURVEY	WC SERVICES	01/20/88	52.70	45	4	4
HA De 197	--	HA-81-4140	MD. GEOL. SURVEY	WC SERVICES	01/19/88	19.08	85	4	4
HA De 198	--	HA-81-4141	MD. GEOL. SURVEY	WC SERVICES	02/11/88	18.92	19	4	4
HA De 200	AA-4	HA-81-1463	U. S. ARMY - APG	NAT FND ENGR	11/30/84	51.37	44	4	4
HA De 202	PM-3WT	HA-81-3518	BALT GAS & ELEC	HARDIN-HUBER	01/20/87	24.4	35	2	2
HA De 203	PM-9WT	HA-81-3514	BALT GAS & ELEC	HARDIN-HUBER	02/02/87	27.75	40	2	2
HA De 204	PM-8WT	HA-81-3515	BALT GAS & ELEC	HARDIN-HUBER	01/27/87	32.47	27	2	2
HA De 207	SW-2	HA-88-2042	CLOROX COMPANY	A C SCHULTES	01/29/92	40	84	8	8
HA De 208	SW-1	HA-88-0887	CLOROX COMPANY	DELMARVA	03/28/90	33.5	132	10	10
HA De 209	OW-3	HA-92-0161	CLOROX COMPANY	A C SCHULTES	05/14/92	35.11	113	4	4
HA De 210	OW-4	HA-92-0162	CLOROX COMPANY	A C SCHULTES	05/14/92	37.17	110	4	4
HA De 211	SOD RUN	HA-81-4574	HARFORD CO DPW	CZ ENTERPRISES	05/26/88	32	135	8	8
HA De 218	MW-7	HA-92-0343	BALT GAS & ELEC	G W TECH	08/03/92	33.49	29	4	4
HA De 219	MW-8	HA-92-0344	BALT GAS & ELEC	G W TECH	08/03/92	32.77	20	4	4
HA De 220	MW-9	HA-92-0345	BALT GAS & ELEC	G W TECH	08/04/92	29.93	30	4	4
HA De 221	MW-10	HA-92-0346	BALT GAS & ELEC	G W TECH	08/04/92	30.09	25	4	4
HA De 222	MW-11	HA-92-0442	BALT GAS & ELEC	G W TECH	09/17/92	29.62	25	4	4
HA De 223	MW-12	HA-92-0443	BALT GAS & ELEC	G W TECH	09/17/92	26.67	25	4	4
HA De 224	--	HA-93-0162	BALT GAS & ELEC	MILLER, GEORGE	11/12/93	30.98	99	2	2

TOP OF SCREEN BELOW LS (FT)	BOTTOM OF SCREEN BELOW LS (FT)	WATER-BEARING FORMATION[1]	WATER LEVEL BELOW LS (FT)	DATE MEASURED	PUMPING TEST DATA: WATER LEVELS BELOW LS (FT) STATIC	PUMPING	DATE REPORTED	YIELD (GAL/MIN)	HOURS PUMPED	SPECIFIC CAPACITY [(GAL/MIN)/FT]	USE OF WATER[2]	WELL NUMBER
155	165	217PTMC	18.91	12/12/86	--	--	04/20/84	25	1	--	U	HA De 163
115	120	217PTMC	58.88	12/04/86	60	70	07/28/76	19	2	1.9	H	HA De 164
153	158	217PTMC	17.88	12/04/86	17	60	04/10/81	16	4	0.4	H	HA De 165
131	140	217PTMC	11.22	12/04/86	17	27	11/12/85	30	3	3.0	H	HA De 166
50	60	112TLBT	28.98	11/21/86	24	33	12/11/84	15	3	1.67	N	HA De 169
--	--	300MBAB	17.53	04/23/87	20	124	11/27/82	4	6	0.04	H	HA De 172
--	--	300MBAB	--	--	--	170	02/11/81	20	2	--	T	HA De 173
60	65	217PTMC	15.64	12/23/86	20	30	03/09/81	12	3	1.2	H	HA De 178
155	165	217PTMC	--	--	--	--	--	--	--	--	U	HA De 183
87	100	217PTMC	--	--	22	27	03/22/84	94	4	18.8	J	HA De 184
147	157											
170	189											
--	--	112TLBT	2.81	05/04/89	--	--	--	--	--	--	U	HA De 187
35	45	112TLBT	12.85	05/16/88	--	--	--	--	--	--	U	HA De 195
75	85	217PTMC	--	--	15.7	33.9	01/19/88	7.5	4	0.4	U	HA De 197
9	19	112TLBT	6.91	05/13/88	--	--	--	--	--	--	U	HA De 198
7	44	112TLBT	12.52	11/13/87	10	10	11/30/84	10	2	--	U	HA De 200
25	35	112TLBT	15.72	04/21/87	--	--	--	--	--	--	U	HA De 202
30	40	112TLBT	16.94	04/21/87	--	--	--	--	--	--	U	HA De 203
17	27	112TLBT	23.88	04/21/87	--	--	--	--	--	--	U	HA De 204
64	84	217PTMC	17	01/29/92	17	56	01/29/92	80	48	2.05	J	HA De 207
76	132	217PTMC	13	03/28/90	13	64	03/28/90	310	72	6.1	J	HA De 208
83	113	217PTMC	13	05/14/92	13	45	05/14/92	40	2	1.2	U	HA De 209
80	110	217PTMC	15	05/14/92	15	45	05/14/92	60	2	2.0	U	HA De 210
120	135	217PTMC	27	05/26/88	27	100	05/26/88	151	4	2.1	J	HA De 211
4	29	112TLBT	19.69	03/22/94	--	--	--	--	--	--	U	HA De 218
5	20	112TLBT	19.41	03/31/94	--	--	--	--	--	--	U	HA De 219
10	30	112TLBT	15.48	03/22/94	--	--	--	--	--	--	U	HA De 220
5	25	112TLBT	15.44	03/22/94	--	--	--	--	--	--	U	HA De 221
5	25	112TLBT	15.38	03/22/94	--	--	--	--	--	--	U	HA De 222
5	25	112TLBT	14.5	03/22/94	--	--	--	--	--	--	U	HA De 223
79	99	112TLBT	18.05	03/31/94	22	--	11/12/93	15	3	--	U	HA De 224

Table 5.—Records of selected wells and borings in the Perryman area—Continued

WELL NUMBER	LOCAL NAME	STATE PERMIT NUMBER	OWNER	CONTRACTOR	DATE WELL CONSTRUCTED	ALTITUDE (FT)	WELL DEPTH (FT)	WELL DIAMETER (INCHES) CASING	SCREEN
HA De 225	--	HA-93-0167	BALT GAS & ELEC	MILLER, GEORGE	11/17/93	25	104	6	6
HA De 226	MW 4 UST	HA-88-1831	U. S. ARMY - APG	J. E. FRITTS	07/09/91	53.97	30	4	4
HA De 227	FTA M5	HA-88-0701	U. S. ARMY - APG	USCE	10/27/89	61.71	34.9	4	4
HA De 228	FTA M9	HA-88-0758	U. S. ARMY - APG	USCE	11/30/89	59.96	32.5	4	4
HA De 229	FTA M10	HA-88-0703	U. S. ARMY - APG	--	10/14/89	63.70	37	4	4
HA De 230	FTA M12	HA-88-0705	U. S. ARMY - APG	KONECNY	11/24/89	55.56	26.5	4	4
HA De 231	WB MW 1A	HA-92-0497	U. S. ARMY - APG	LAYNE ENV S	10/16/92	45.03	42.5	4	4
HA De 232	WB MW 3A	HA-92-0469	U. S. ARMY - APG	LAYNE ENV S	10/12/92	41.68	42	4	4
HA De 233	WB P3	HA-92-0492	U. S. ARMY - APG	LAYNE ENV S	10/13/92	40.88	63	2	2
HA De 234	WB P7	HA-92-0471	U. S. ARMY - APG	LAYNE ENV S	10/19/92	47.35	80	2	2
HA De 235	WB P9	HA-92-0498	U. S. ARMY - APG	LAYNE ENV S	10/08/92	40.25	80	2	2
HA De 236	PZ FTA P3	HA-92-0349	U. S. ARMY - APG	LAYNE ENV S	08/05/92	50.35	28	2	2
HA De 237	PZ FTA P12	HA-92-0358	U. S. ARMY - APG	LAYNE ENV S	08/01/92	42.23	31.2	2	2
HA De 238	PZ FTA P14	HA-92-0317	U. S. ARMY - APG	LAYNE ENV S	08/01/92	33.48	31.5	2	2
HA De 239	PZ FTA P15	HA-92-0318	U. S. ARMY - APG	LAYNE ENV S	07/31/92	33.25	26.2	2	2
HA De 240	CSTA TRAK	HA-88-0012	U. S. ARMY - APG	WHITEFORD C	10/28/88	34.55	65	4	2
HA De 241	FTA MD 7	HA-92-0386	U. S. ARMY - APG	LAYNE ENV S	09/12/92	59.96	76.3	4	4
HA De 242	FTA MD 13	HA-92-0385	U. S. ARMY - APG	LAYNE ENV S	09/11/92	60.94	72.5	4	4
HA De 243	MW-1	HA-93-0175	HARFORD CO DPW	STEVENS DRLG	10/25/93	18.43	24	2	2
HA De 244	MW-2	HA-93-0174	HARFORD CO DPW	STEVENS DRLG	10/27/93	20	24	2	2
HA De 245	MW-3	HA-93-0176	HARFORD CO DPW	STEVENS DRLG	10/26/93	8.63	20	2	2
HA De 246	MW-4	HA-93-0177	HARFORD CO DPW	STEVENS DRLG	10/26/93	7.22	15	2	2
HA De 247	MW-5	HA-93-0178	HARFORD CO DPW	STEVENS DRLG	10/27/93	6.89	14	2	2
HA De 248	WB-MW-5A	HA-93-0368	U. S. ARMY - APG	J. E. FRITTS	04/26/94	40	31	4	4
HA De 249	WB-MW-5B	HA-93-0369	U. S. ARMY - APG	J. E. FRITTS	1994	40	87	--	--
HA De 250	WB-MW-5C	HA-93-0370	U. S. ARMY - APG	J. E. FRITTS	04/26/94	40	147	4	4
HA De 251	WB-MW-6A	HA-93-0273	U. S. ARMY - APG	J. E. FRITTS	04/26/94	40.83	35	4	4
HA De 252	WB-MW-6B	HA-93-0274	U. S. ARMY - APG	J. E. FRITTS	04/26/94	41.09	65	4	4
HA De 253	WB-MW-6C	HA-93-0275	U. S. ARMY - APG	J. E. FRITTS	04/26/94	41.41	107	4	4
HA De 254	WB-MW-7A	HA-93-0278	U. S. ARMY - APG	J. E. FRITTS	04/26/94	41.68	30	4	4

TOP OF SCREEN BELOW LS (FT)	BOTTOM OF SCREEN BELOW LS (FT)	WATER-BEARING FORMATION[1]	WATER LEVEL BELOW LS (FT)	DATE MEASURED	PUMPING TEST DATA: WATER LEVELS BELOW LS (FT) STATIC	PUMPING	DATE REPORTED	YIELD (GAL/MIN)	HOURS PUMPED	SPECIFIC CAPACITY [(GAL/MIN)/FT]	USE OF WATER[2]	WELL NUMBER
82	104	217PTMC	19.96	03/31/94	22	47	11/17/93	265	12	10.6	--	HA De 225
15	30	112TLBT	22.51	04/18/94	22	--	07/09/91	2	1	--	U	HA De 226
24.9	34.9	112TLBT	29.31	04/18/94	--	--	--	--	--	--	U	HA De 227
22.5	33.5	112TLBT	28.21	04/18/94	--	--	--	--	--	--	U	HA De 228
27	37	112TLBT	31.65	04/18/94	--	--	--	--	--	--	U	HA De 229
16.5	26.5	112TLBT	21.43	04/18/94	--	--	--	--	--	--	U	HA De 230
27.5	42.5	112TLBT	26.36	04/18/94	--	--	--	--	--	--	U	HA De 231
27	42	112TLBT	23.63	04/18/94	--	--	--	--	--	--	U	HA De 232
58	63	112TLBT	19.31	04/18/94	--	--	--	--	--	--	U	HA De 233
75	80	217PTMC	25.76	04/18/94	--	--	--	--	--	--	U	HA De 234
75	80	217PTMC	21.19	04/18/94	--	--	--	--	--	--	U	HA De 235
23	28	112TLBT	20.10	06/17/94	--	--	--	--	--	--	U	HA De 236
26.2	31.2	112TLBT	15.12	04/18/94	--	--	--	--	--	--	U	HA De 237
26.5	31.5	112TLBT	13.12	04/18/94	--	--	--	--	--	--	U	HA De 238
21.2	26.2	112TLBT	8.27	04/18/94	--	--	--	--	--	--	U	HA De 239
57	65	217PTMC	10.26	04/18/94	15	35	10/28/88	60	3	3.0	U	HA De 240
66.3	76.3	112TLBT	27.90	04/18/94	--	--	--	--	--	--	U	HA De 241
62.5	72.5	112TLBT	28.27	04/18/94	--	--	--	--	--	--	U	HA De 242
9	24	112TLBT	11.07	08/03/94	--	--	--	--	--	--	U	HA De 243
9	24	112TLBT	12.84	08/03/94	--	--	--	--	--	--	U	HA De 244
10	20	112TLBT	2.78	08/03/94	--	--	--	--	--	--	U	HA De 245
5	15	112TLBT	1.81	08/03/94	--	--	--	--	--	--	U	HA De 246
4	14	112TLBT	1.53	08/03/94	--	--	--	--	--	--	U	HA De 247
16	31	112TLBT	22	04/26/94	22	24	04/26/94	--	1	--	U	HA De 248
--	--	112TLBT	23.40	02/14/95	--	--	--	--	--	--	U	HA De 249
137	147	217PTMC	24.29	02/14/95	23	26	04/26/94	13	2	4.3	U	HA De 250
20	35	112TLBT	24	04/26/94	24	27	04/26/94	11	1	--	U	HA De 251
55	65	--	24	04/26/94	24	--	04/26/94	4	1	--	U	HA De 252
97	--	--	26	04/26/94	26	--	04/26/94	10	2	--	U	HA De 253
15	30	112TLBT	20	04/26/94	20	21	04/26/94	11	1	11.0	U	HA De 254

Table 5.—Records of selected wells and borings in the Perryman area—Continued

WELL NUMBER	LOCAL NAME	STATE PERMIT NUMBER	OWNER	CONTRACTOR	DATE WELL CONSTRUCTED	ALTITUDE (FT)	WELL DEPTH (FT)	WELL DIAMETER (INCHES) CASING	SCREEN
HA De 255	WB-MW-7B	HA-93-0277	U. S. ARMY - APG	J. E. FRITTS	04/26/94	40.31	65	4	4
HA De 256	WB-MW-7C	HA-93-0276	U. S. ARMY - APG	J. E. FRITTS	04/26/94	41.93	110	4	4
HA De 257	WB-MW-9A	HA-93-0371	U. S. ARMY - APG	J. E. FRITTS	04/26/94	38.62	27	4	4
HA De 258	WB-MW-9B	HA-93-0372	U. S. ARMY - APG	J. E. FRITTS	04/26/94	39.87	90	4	4
HA De 259	WB-MW-9C	HA-93-0373	U. S. ARMY - APG	J. E. FRITTS	04/26/94	38.74	120	4	4
HA De 260	WB-MW-10A	HA-93-0281	U. S. ARMY - APG	J. E. FRITTS	04/26/94	38.80	25	4	4
HA De 261	WB-MW-10B	HA-93-0280	U. S. ARMY - APG	J. E. FRITTS	04/26/94	39.27	87	4	4
HA De 262	WB-MW-10C	HA-93-0279	U. S. ARMY - APG	J. E. FRITTS	04/26/94	39.00	120	4	4
HA De 263	WB-MW-11A	HA-93-0284	U. S. ARMY - APG	J. E. FRITTS	04/26/94	45.43	30	4	4
HA De 264	WB-MW-11B	HA-93-0283	U. S. ARMY - APG	J. E. FRITTS	04/26/94	46.04	80	4	4
HA De 265	WB-MW-11C	HA-93-0282	U. S. ARMY - APG	J. E. FRITTS	04/26/94	45.69	117	4	4
HA De 266	WB-MW-12A	HA-93-0271	U. S. ARMY - APG	J. E. FRITTS	04/26/94	41.04	23	4	4
HA De 267	WB-MW-12B	HA-93-0270	U. S. ARMY - APG	J. E. FRITTS	04/26/94	40.88	45	4	4
HA De 268	WB-MW-12C	HA-93-0272	U. S. ARMY - APG	J. E. FRITTS	04/26/94	39.98	105	4	4
HA De 269	WB-MW-13A	HA-93-0374	U. S. ARMY - APG	J. E. FRITTS	04/26/94	62.10	40	4	4
HA De 270	WB-MW-13B	HA-93-0375	U. S. ARMY - APG	J. E. FRITTS	04/26/94	62.27	80	4	4
HA De 271	WB-MW-13C	HA-93-0376	U. S. ARMY - APG	J. E. FRITTS	04/26/94	60.42	126	4	4
HA De 272	WB-MW-14A	HA-93-0287	U. S. ARMY - APG	J. E. FRITTS	04/26/94	43.61	28	4	4
HA De 273	WB-MW-14B	HA-93-0286	U. S. ARMY - APG	J. E. FRITTS	04/26/94	44.10	85	4	4
HA De 274	WB-MW-14C	HA-93-0285	U. S. ARMY - APG	J. E. FRITTS	04/26/94	44.15	165	4	4
HA De 275	WB-MW-15A	HA-93-0377	U. S. ARMY - APG	J. E. FRITTS	04/26/94	37.81	25	4	4
HA De 276	WB-MW-15B	HA-93-0379	U. S. ARMY - APG	J. E. FRITTS	04/26/94	37.65	121	4	4
HA De 277	WB-MW-15C	HA-93-0378	U. S. ARMY - APG	J. E. FRITTS	04/26/94	37.57	172	4	4
HA De 278	WB-PB-05	--	U. S. ARMY - APG	H. P. DRILLING	12/13/93	37.91	151	--	--
HA De 279	WB-PB-06	--	U. S. ARMY - APG	H. P. DRILLING	12/01/93	41.69	123	--	--
HA De 280	WB-PB-07	--	U. S. ARMY - APG	H. P. DRILLING	11/22/93	41.44	157	--	--
HA De 281	WB-PB-09	--	U. S. ARMY - APG	H. P. DRILLING	12/06/93	36.35	231	--	--
HA De 282	WB-PB-10	--	U. S. ARMY - APG	H. P. DRILLING	11/29/93	37.74	150	--	--
HA De 283	WB-PB-11	--	U. S. ARMY - APG	H. P. DRILLING	12/01/93	46.28	187	--	--
HA De 284	WB-PB-12	--	U. S. ARMY - APG	H. P. DRILLING	11/24/93	32.69	152	--	--

TOP OF SCREEN BELOW LS (FT)	BOTTOM OF SCREEN BELOW LS (FT)	WATER-BEARING FORMATION[1]	WATER LEVEL BELOW LS (FT)	DATE MEASURED	PUMPING TEST DATA: WATER LEVELS BELOW LS (FT) STATIC	PUMPING	DATE REPORTED	YIELD (GAL/MIN)	HOURS PUMPED	SPECIFIC CAPACITY [(GAL/MIN)/FT]	USE OF WATER[2]	WELL NUMBER
55	65	112TLBT	18	04/26/94	18	19	04/26/94	11	1	11.0	U	HA De 255
100	110	217PTMC	21	04/26/94	21	27	04/26/94	10	2	1.7	U	HA De 256
12	27	112TLBT	16	04/26/94	16	18	04/26/94	12	1	6.0	U	HA De 257
80	90	112TLBT	17	04/26/94	17	33	04/26/94	11	1	0.7	U	HA De 258
110	120	217PTMC	16	04/26/94	16	19	04/26/94	12	2	4.0	U	HA De 259
10	25	112TLBT	13	04/26/94	13	15	04/26/94	12	1	6.0	U	HA De 260
77	87	112TLBT	18	04/26/94	18	44	04/26/94	12	1	0.5	U	HA De 261
109	120	217PTMC	16	04/26/94	16	17	04/26/94	14	2	--	U	HA De 262
15	30	112TLBT	18	04/26/94	18	21	04/26/94	10	1	--	U	HA De 263
70	80	112TLBT	19	04/26/94	19	20	04/26/94	12	1	--	U	HA De 264
107	117	112TLBT	25	04/26/94	--	--	04/26/94	60	2	--	U	HA De 265
8	23	112TLBT	8	04/26/94	8	--	04/26/94	13	1	--	U	HA De 266
35	45	112TLBT	9	04/26/94	9	45	04/26/94	2	1	--	U	HA De 267
95	105	112TLBT	14	04/26/94	14	15	04/26/94	50	2	--	U	HA De 268
25	40	112TLBT	32	04/26/94	32	33	04/26/94	12	1	--	U	HA De 269
70	80	112TLBT	32	04/26/94	32	58	04/26/94	10	1	--	U	HA De 270
116	126	217PTMC	30	04/26/94	30	33	04/26/94	10	2	--	U	HA De 271
13	28	112TLBT	19	04/26/94	19	20	04/26/94	12	1	--	U	HA De 272
75	85	112TLBT	19	04/26/94	19	28	04/26/94	12	1	--	U	HA De 273
155	165	217PTMC	19	04/26/94	19	25	04/26/94	11	2	--	U	HA De 274
10	25	112TLBT	4	04/26/94	4	20	04/26/94	4	1	--	U	HA De 275
111	121	217PTMC	15	04/26/94	15	59	04/26/94	10	2	--	U	HA De 276
162	172	217PTMC	12	04/26/94	12	28	04/26/94	10	2	--	U	HA De 277
--	--	--	--	--	--	--	--	--	--	--	--	HA De 278
--	--	--	--	--	--	--	--	--	--	--	--	HA De 279
--	--	--	--	--	--	--	--	--	--	--	--	HA De 280
--	--	--	--	--	--	--	--	--	--	--	--	HA De 281
--	--	--	--	--	--	--	--	--	--	--	--	HA De 282
--	--	--	--	--	--	--	--	--	--	--	--	HA De 283
--	--	--	--	--	--	--	--	--	--	--	--	HA De 284

Table 5.—Records of selected wells and borings in the Perryman area—Continued

WELL NUMBER	LOCAL NAME	STATE PERMIT NUMBER	OWNER	CONTRACTOR	DATE WELL CONSTRUCTED	ALTITUDE (FT)	WELL DEPTH (FT)	WELL DIAMETER (INCHES) CASING	SCREEN
HA De 285	WB-PB-13	--	U. S. ARMY - APG	H. P. DRILLING	12/20/93	58.63	140	--	--
HA De 286	WB-PB-14	--	U. S. ARMY - APG	H. P. DRILLING	11/23/93	43.92	180	--	--
HA De 287	WB-PB-15	--	U. S. ARMY - APG	H. P. DRILLING	02/01/94	37.17	182	--	--
HA De 288	WB-SB-01	--	U. S. ARMY - APG	LAYNE ENV S	08/16/92	31.7	130	--	--
HA De 289	WB-SB-02	--	U. S. ARMY - APG	LAYNE ENV S	08/30/92	42.5	175	--	--
HA De 290	WB-SB-03	--	U. S. ARMY - APG	LAYNE ENV S	09/02/92	41.2	94	--	--
HA De 291	WB-SB-04	--	U. S. ARMY - APG	LAYNE ENV S	11/01/92	50.0	170	--	--
HA De 292	WB-SB-12	--	U. S. ARMY - APG	H. P. DRILLING	12/10/93	51.94	286	--	--
HA De 293	WB-SB-13	--	U. S. ARMY - APG	H. P. DRILLING	12/20/93	25.40	226	--	--
HA De 294	WB-PB-18	--	U. S. ARMY - APG	A. C. SCHULTES	08/09/94	20	125	--	--
HA De 295	WB-SB-15	--	U. S. ARMY - APG	H. P. DRILLING	08/04/94	41.50	376	--	--
HA De 296	WB-PB-17	--	U. S. ARMY - APG	A. C. SCHULTES	08/01/94	25	--	--	--
HA Df 3	O-3	--	U. S. ARMY	--	1918	9.2	135	10-8	8
HA Df 4	O-4	--	U. S. ARMY	--	--	14.6	147	--	--
HA Df 27	--	HA-65-0540	TOWN OF ABERDEEN	SHANNAHAN CO	12/06/66	58.4	45	2	2
HA Df 29	ABERDEEN #7	HA-73-2481	TOWN OF ABERDEEN	SHANNAHAN CO	01/20/76	66.8	64	4	4
HA Df 30	ABERDEEN #8	HA-73-2482	TOWN OF ABERDEEN	SHANNAHAN CO	12/17/75	65	80	4	4
HA Df 31	ABERDEEN #9	HA-73-2483	TOWN OF ABERDEEN	SHANNAHAN CO	12/15/75	73.42	72	4	4
HA Df 32	--	HA-73-2484	TOWN OF ABERDEEN	SHANNAHAN CO	12/11/75	55	64	4	4
HA Df 33	ABERDEEN #10	HA-73-2485	TOWN OF ABERDEEN	SHANNAHAN CO	12/10/75	67.8	75	4	4
HA Df 34	--	HA-73-2486	TOWN OF ABERDEEN	SHANNAHAN CO	12/03/75	55	42	4	4
HA Df 40	--	HA-81-1641	U. S. ARMY - APG	A. C. SCHULTES	04/01/85	30.18	431	2	2
HA Df 41	--	HA-81-1640	U. S. ARMY	A. C. SCHULTES	05/14/85	30.10	439	6	6
HA Df 44	AA-1	HA-81-1460	U. S. ARMY - APG	NAT FND ENGR	11/30/84	60.20	71	4	4
HA Df 45	AA-2	HA-81-1461	U. S. ARMY - APG	NAT FND ENGR	11/30/84	56.0	41	4	4
HA Df 46	AA-3	HA-81-1459	U. S. ARMY - APG	NAT FND ENGR	11/30/84	74.30	61	4	4
HA Df 47	AA-5	HA-81-1462	U. S. ARMY - APG	NAT FND ENGR	11/30/84	70.5	49	4	4
HA Df 48	PW 9	--	U. S. ARMY - APG	NAT FND ENGR	--	36.62	22	4	4
HA Df 49	PW 13	--	U. S. ARMY - APG	NAT FND ENGR	--	37.96	25	4	4
HA Df 50	PW 17	--	U. S. ARMY - APG	USCE	--	37.32	31	4	4

TOP OF SCREEN BELOW LS (FT)	BOTTOM OF SCREEN BELOW LS (FT)	WATER-BEARING FORMATION[1]	WATER LEVEL BELOW LS (FT)	DATE MEASURED	PUMPING TEST DATA: WATER LEVELS BELOW LS (FT) STATIC	PUMPING	DATE REPORTED	YIELD (GAL/MIN)	HOURS PUMPED	SPECIFIC CAPACITY [(GAL/MIN)/FT]	USE OF WATER[2]	WELL NUMBER
--	--	--	--	--	--	--	--	--	--	--	--	HA De 285
--	--	--	--	--	--	--	--	--	--	--	--	HA De 286
--	--	--	--	--	--	--	--	--	--	--	--	HA De 287
--	--	--	--	--	--	--	--	--	--	--	--	HA De 288
--	--	--	--	--	--	--	--	--	--	--	--	HA De 289
	--	--	--	--	--	--	--	--	--	--	--	HA De 290
--	--	--	--	--	--	--	--	--	--	--	--	HA De 291
--	--	--	--	--	--	--	--	--	--	--	--	HA De 292
--	--	--	--	--	--	--	--	--	--	--	--	HA De 293
--	--	--	--	--	--	--	--	--	--	--	--	HA De 294
--	--	--	--	--	--	--	--	--	--	--	--	HA De 295
--	--	--	--	--	--	--	--	--	--	--	--	HA De 296
125	135	217PTMC	1.03	05/03/89	23	--	--	--	--	--	U	HA Df 3
--	--	217PTMC	4.74	05/03/89	28	--	--	--	--	--	U	HA Df 4
39	45	112TLBT	31	12/06/66	31	34	12/06/66	2	1	0.67	U	HA Df 27
54	64	112TLBT	31	01/20/76	31	32.3	01/20/76	20	10	15.4	U	HA Df 29
50	80	112TLBT	33	12/17/75	33.2	34.1	12/17/75	30	2	33.3	U	HA Df 30
57	72	112TLBT	35.84	03/01/76	38.7	39.9	12/15/75	15	2	12.5	U	HA Df 31
49	64	112TLBT	34	12/11/75	34.3	38.3	12/11/75	10	2	2.5	U	HA Df 32
55	75	112TLBT	30.5	12/10/75	30.5	32.5	12/10/75	14	2	7	U	HA Df 33
32	42	112TLBT	32	12/03/75	32	33	12/03/75	0.5	1	0.5	U	HA Df 34
421	431	217PTMC	24.77	05/03/89	28	30	04/01/85	1	2	0.5	U	HA Df 40
399	439	217PTMC	25.00	05/14/85	--	--	--	--	--	--	--	HA Df 41
24	71	112TLBT	31.22	11/13/87	25	39	11/30/84	10	2	0.7	U	HA Df 44
17	41	112TLBT	24.51	11/13/87	23	24	11/30/84	8	2	8	U	HA Df 45
30	61	112TLBT	40.19	11/13/87	35	35	11/30/84	5	2	--	U	HA Df 46
34	49	112TLBT	41.72	11/13/87	37	39	11/30/84	10	2	5	U	HA Df 47
12	22	112TLBT	5.49	04/18/94	--	--	--	--	--	--	U	HA Df 48
20	25	112TLBT	8.70	04/18/94	--	--	--	--	--	--	U	HA Df 49
21	31	112TLBT	7.27	04/18/94	--	--	--	--	--	--	U	HA Df 50

Table 5.—Records of selected wells and borings in the Perryman area—Continued

WELL NUMBER	LOCAL NAME	STATE PERMIT NUMBER	OWNER	CONTRACTOR	DATE WELL CONSTRUCTED	ALTITUDE (FT)	WELL DEPTH (FT)	WELL DIAMETER (INCHES) CASING	SCREEN
HA Df 51	PW 18	--	U. S. ARMY - APG	USCE	--	37.61	68	4	4
HA Df 52	PW 21	--	U. S. ARMY - APG	USCE	--	31.41	73	4	4
HA Df 53	BLDG 2378A	HA-88-1480	U. S. ARMY - APG	HARDIN-HUBER	12/27/90	58.95	59	4	4
HA Df 54	BLDG 3329	HA-88-1649	U. S. ARMY - APG	HARDIN-HUBER	04/04/91	56.80	57	4	4
HA Df 55	BLDG 5222	HA-88-1650	U. S. ARMY - APG	HARDIN-HUBER	04/03/91	32.61	20	4	4
HA Df 56	BLDG 4027	HA-88-1892	U. S. ARMY - APG	J.E. FRITTS	08/05/91	33.43	23	4	4
HA Df 57	BLDG 4726	HA-88-1483	U. S. ARMY - APG	HARDIN-HUBER	12/28/90	64.47	49	4	4
HA Df 58	BLDG 1040	--	U. S. ARMY - APG	LAYNE ATL CO	1942	55.48	83	10	--

[1]WATER-BEARING FORMATION

112TLBT = Talbot Formation
217PTMC = Potomac Group
300MBAB = Metagabbro and Amphibolite

[2]USE OF WATER

F = Fire
H = Domestic
J = Industrial (cooling)
N = Industrial
P = Public Supply
T = Institutional
U = Unused

OWNER ABBREVIATIONS

BALT GAS & ELEC=Baltimore Gas & Electric Company
BUSH RIVER PLNT=Bush River Wastewater Treatment Plant
HARFORD CO DPW=Harford County Department of Public Works
MD DEPT NAT RSRC=Maryland Department of Natural Resources
MD. GEOL SURVEY=Maryland Geological Survey
MD HWY ADMIN=Maryland Highway Administration
N MD SFTAORC=Northern Maryland Society for the Aid of Retarded Children
U.S. ARMY APG=United States Army, Aberdeen Proving Ground
YORK BLDG PROD=York Building Products Company

CONTRACTOR ABBREVIATIONS

ENGNR DRLG=Engineering Drilling Company
G W TECH=Groundwater Technology, Inc.
LAYNE ATL CO=Layne Atlantic Company
LAYNE ENV S=Layne Environmental Services
MD FOUNDATION=Maryland Foundation Testing Company
NAT FND ENGR=National Foundation Engineering, Inc.
STEVENS DRLG=Stevens Drilling, Inc.
USCE=U.S. Army Corps of Engineers

TOP OF SCREEN BELOW LS (FT)	BOTTOM OF SCREEN BELOW LS (FT)	WATER-BEARING FORMATION[1]	WATER LEVEL BELOW LS (FT)	DATE MEASURED	PUMPING TEST DATA: WATER LEVELS BELOW LS (FT) STATIC	PUMPING	DATE REPORTED	YIELD (GAL/MIN)	HOURS PUMPED	SPECIFIC CAPACITY [(GAL/MIN)/FT]	USE OF WATER[2]	WELL NUMBER
53	68	112TLBT	10.02	04/18/94	--	--	--	--	--	--	U	HA Df 51
43	71	112TLBT	3.89	04/18/94	--	--	--	--	--	--	U	HA Df 52
44	59	112TLBT	51.24	04/14/94	--	--	--	--	--	--	U	HA Df 53
42	57	112TLBT	46.05	04/14/94	--	--	--	--	--	--	U	HA Df 54
5	20	112TLBT	6.30	04/14/94	--	--	--	--	--	--	U	HA Df 55
8	23	112TLBT	5.88	04/14/94	--	--	--	--	--	--	U	HA Df 56
34	49	112TLBT	34.22	04/14/94	--	--	--	--	--	--	U	HA Df 57
73	83	112TLBT	24.9	05/03/89	29	67.5	1942	260	--	6.8	U	HA Df 58

Table 6.—Synoptic water-level measurements from wells in the Perryman area

[-- = data not collected]

Well number	Aquifer	Water level, in feet above (+) or below (-) sea level							
		Feb. 94	Apr. 94	Jun. 94	Aug. 94	Oct. 94	Jan. 95	Feb. 95	Apr. 95
HA Cf 174	1	--	31.06	31.72	48.77	30.09	29.64	29.72	29.44
HA Dd 91	2	6.80	8.35	8.12	7.65	7.71	7.17	7.00	7.12
HA Dd 92	1	9.19	11.21	10.63	10.53	9.78	9.49	9.49	9.43
HA De 7	2	--	31.91	32.57	31.87	31.50	30.67	30.63	30.74
HA De 66	1	43.14	45.74	45.84	44.62	43.85	42.49	42.67	42.81
HA De 76	2	--	14.38	14.23	12.06	16.24	13.10	17.66	17.10
HA De 78	2	--	12.31	12.38	16.98	19.32	10.19	17.89	19.25
HA De 84	1	--	19.59	19.69	20.98	21.27	18.73	18.08	18.59
HA De 85	2	6.55	7.27	5.87	3.93	5.15	5.89	6.32	6.72
HA De 88	1	--	46.05	31.91	30.49	29.57	29.23	29.29	29.09
HA De 89	1	--	38.85	39.33	37.96	36.90	--	34.36	33.83
HA De 91	1	--	42.95	42.42	40.89	39.30	37.86	37.19	36.78
HA De 92	1	--	44.30	44.50	41.37	40.85	37.15	37.41	37.07
HA De 124	3	--	17.13	16.90	18.33	18.28	14.88	16.28	16.74
HA De 125	3	--	17.87	17.55	18.92	18.78	16.85	17.10	17.38
HA De 126	3	--	17.51	16.26	18.21	18.14	16.64	16.65	16.77
HA De 127	3	--	15.57	14.58	16.22	15.94	14.74	14.89	15.16
HA De 128	2	17.89	21.06	21.02	20.78	20.50	19.35	19.52	19.57
HA De 129	3	15.00	17.65	16.74	18.24	18.15	16.55	16.87	16.95
HA De 136	3	11.29	13.19	11.89	13.30	13.55	12.23	10.19	--
HA De 137	1	16.31	18.74	18.38	18.49	17.93	16.72	17.13	--
HA De 139	2	--	13.36	12.96	12.62	12.21	11.74	11.98	12.01
HA De 140	2	11.41	13.07	11.62	12.13	11.73	11.23	11.38	11.52
HA De 141	3	--	7.30	7.08	7.30	7.39	6.87	7.18	7.00
HA De 149	1	13.74	16.15	15.50	15.81	15.24	14.15	14.52	14.57
HA De 150	2	--	--	--	--	--	--	3.36	3.84
HA De 151	3	8.27	9.14	8.83	8.78	9.00	8.43	8.52	8.40
HA De 152	2	6.46	7.42	5.22	6.67	6.92	6.29	6.42	6.67
HA De 154	2	--	--	4.90	4.22	--	4.16	4.28	4.49
HA De 155	3	--	14.16	13.78	15.14	15.06	13.29	13.77	--
HA De 156	1	15.49	18.40	18.19	18.56	18.24	16.68	16.98	--
HA De 157	1	12.95	14.81	14.68	14.11	13.61	12.95	13.28	13.33
HA De 158	2	6.51	7.27	7.08	7.31	7.08	6.73	6.69	6.57
HA De 159	3	7.01	8.35	7.61	7.01	7.26	6.92	7.11	7.29
HA De 160	2	14.55	16.38	15.88	15.90	15.33	14.63	14.98	14.94
HA De 161	3	8.87	10.24	9.09	10.79	10.71	9.45	9.56	9.76

Table 6.—Synoptic water-level measurements from wells in the Perryman area—Continued

[-- = data not collected]

Well number	Aquifer	Water level, in feet above (+) or below (-) sea level							
		Feb. 94	Apr. 94	Jun. 94	Aug. 94	Oct. 94	Jan. 95	Feb. 95	Apr. 95
HA De 162	2	16.06	18.44	17.84	17.30	16.60	16.01	16.44	16.50
HA De 163	3	11.74	13.48	12.46	13.88	13.66	12.53	12.75	12.69
HA De 164	2	--	--	--	-1.31	-0.44	-1.73	-1.62	-1.17
HA De 165	3	--	--	--	1.42	2.96	2.36	2.44	2.47
HA De 166	3	--	--	--	6.25	7.03	--	6.01	--
HA De 169	1	37.03	39.27	38.58	37.83	36.64	36.26	36.58	36.58
HA De 187	1	--	--	--	2.30	0.23	2.08	2.16	2.02
HA De 195	1	40.02	42.58	42.18	41.69	40.24	39.76	39.78	39.78
HA De 197	2	7.56	7.73	7.78	7.92	8.17	7.36	7.30	7.43
HA De 198	1	11.20	12.44	11.53	11.77	10.61	11.08	11.16	11.24
HA De 200	1	--	47.12	45.93	44.68	42.72	42.18	42.66	42.73
HA De 202	1	7.89	9.37	8.92	8.39	8.04	7.75	7.94	8.04
HA De 203	1	10.13	11.80	11.46	10.86	10.46	9.97	10.11	10.26
HA De 204	1	9.19	10.95	10.51	9.85	9.47	9.01	9.22	9.36
HA De 209	3	25.10	-8.13	25.57	24.16	-10.87	19.95	6.17	10.34
HA De 210	3	23.82	3.56	23.58	22.23	0.38	18.45	6.67	-2.18
HA De 211	2	7.06	8.87	-6.93	-5.43	-4.63	6.88	7.26	7.91
HA De 218	1	--	14.69	13.76	13.55	13.00	12.53	12.66	12.76
HA De 219	1	--	14.85	13.35	13.33	12.61	12.16	12.31	12.39
HA De 220	1	--	15.05	14.52	14.37	13.91	13.72	13.84	13.90
HA De 221	1	--	15.36	14.93	15.89	15.44	--	14.04	14.09
HA De 222	1	--	15.06	14.62	14.99	14.49	13.53	13.67	13.75
HA De 223	1	--	15.25	9.34	13.45	12.95	12.60	12.72	12.79
HA De 224	2	--	13.76	12.90	11.79	11.42	10.92	10.98	1.24
HA De 225	2	--	5.44	5.04	--	--	--	--	--
HA De 226	1	--	31.47	32.15	--	--	31.11	31.08	31.20
HA De 227	1	--	32.40	32.94	32.48	32.09	31.21	31.24	31.28
HA De 228	1	--	31.75	32.14	31.84	31.40	30.57	30.59	30.74
HA De 229	1	--	32.05	32.67	32.46	38.11	31.21	31.15	31.31
HA De 230	1	--	34.13	33.96	32.80	30.78	31.53	31.60	31.86
HA De 231	1	--	18.67	19.09	19.91	20.68	17.50	18.19	19.00
HA De 232	1	--	18.05	18.37	19.14	20.62	16.25	17.99	18.51
HA De 233	1	--	21.57	--	21.94	21.85	20.10	20.23	20.52
HA De 234	2	--	21.59	21.93	22.49	22.65	20.65	20.66	20.99
HA De 235	2	--	19.06	19.27	19.57	19.65	17.89	18.94	18.27
HA De 236	1	--	--	30.25	38.31	37.22	38.46	36.74	37.03

Table 6.—Synoptic water-level measurements from wells in the Perryman area—Continued

[-- = data not collected]

Well number	Aquifer	Water level, in feet above (+) or below (-) sea level							
		Feb. 94	Apr. 94	Jun. 94	Aug. 94	Oct. 94	Jan. 95	Feb. 95	Apr. 95
HA De 237	1	--	27.11	27.16	26.49	25.95	25.13	25.10	25.19
HA De 238	1	--	20.36	20.32	19.80	19.63	18.73	18.55	18.78
HA De 239	1	--	24.98	24.88	24.32	23.75	22.82	22.85	22.93
HA De 240	2	--	24.29	23.83	23.48	22.83	22.55	22.66	--
HA De 241	2	--	32.06	32.53	31.87	30.45	30.61	30.59	30.71
HA De 242	2	--	32.67	33.07	32.19	31.77	30.92	30.94	31.12
HA De 243	1	--	--	--	7.59	7.02	6.61	6.80	6.86
HA De 244	1	--	--	--	7.16	6.78	6.36	6.55	6.68
HA De 245	1	--	--	--	6.18	5.60	5.44	5.54	5.60
HA De 246	1	--	--	--	5.71	5.15	4.97	5.05	5.08
HA De 247	1	--	--	--	5.61	5.11	4.79	4.93	4.97
HA De 248	1	--	--	--	--	--	--	--	--
HA De 249	2	--	--	--	--	--	--	18.69	18.92
HA De 250	2	--	--	--	--	--	--	18.82	19.18
HA Df 3	2	--	10.53	11.00	10.86	10.34	10.13	10.10	10.22
HA Df 4	3	--	10.28	10.38	9.86	9.66	9.45	9.36	9.76
HA Df 27	1	--	33.90	34.32	33.45	32.78	32.04	31.92	31.64
HA Df 29	1	--	28.44	28.70	28.72	27.80	27.58	27.25	28.03
HA Df 31	1	--	24.12	24.41	23.60	23.35	22.68	22.76	--
HA Df 33	1	--	28.87	29.83	30.14	29.37	28.61	28.91	29.52
HA Df 44	1	--	32.04	32.75	--	--	--	--	--
HA Df 45	1	--	35.14	35.55	34.71	34.27	33.27	33.20	33.50
HA Df 46	1	--	37.00	38.20	37.37	36.68	35.40	35.07	35.05
HA Df 47	1	--	29.17	29.83	29.48	29.39	28.79	28.57	28.45
HA Df 48	1	--	31.13	31.48	31.07	30.72	30.14	30.09	30.09
HA Df 49	1	--	29.26	28.57	26.94	26.12	26.59	27.53	28.31
HA Df 50	1	--	30.05	30.63	30.11	29.80	28.96	28.92	28.95
HA Df 51	2	--	27.59	27.23	25.66	24.96	25.21	25.96	26.71
HA Df 52	2	--	27.52	27.85	27.45	30.03	26.43	26.37	26.31
HA Df 53	2	--	7.71	7.74	7.81	7.66	7.37	7.39	7.54
HA Df 54	2	--	10.75	10.95	11.13	11.07	10.66	10.62	10.59
HA Df 55	2	--	26.31	25.71	24.22	23.41	23.40	24.49	24.55
HA Df 56	1	--	27.55	27.41	--	--	--	--	--
HA Df 57	1	--	30.25	30.91	30.56	30.20	29.15	29.08	29.31
HA Df 58	2	--	31.77	32.43	31.76	31.40	30.59	30.53	30.63

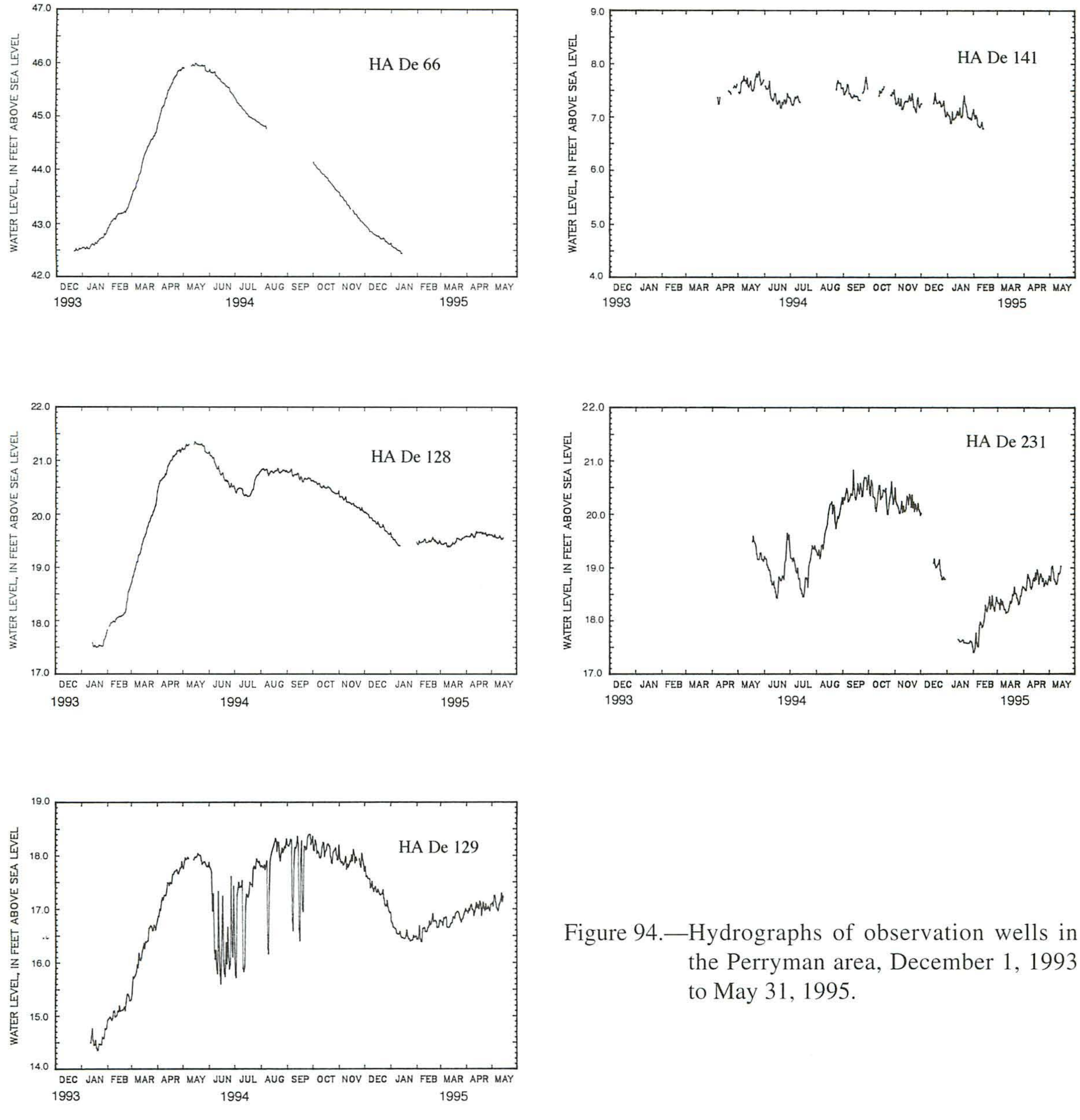


Figure 94.—Hydrographs of observation wells in the Perryman area, December 1, 1993 to May 31, 1995.

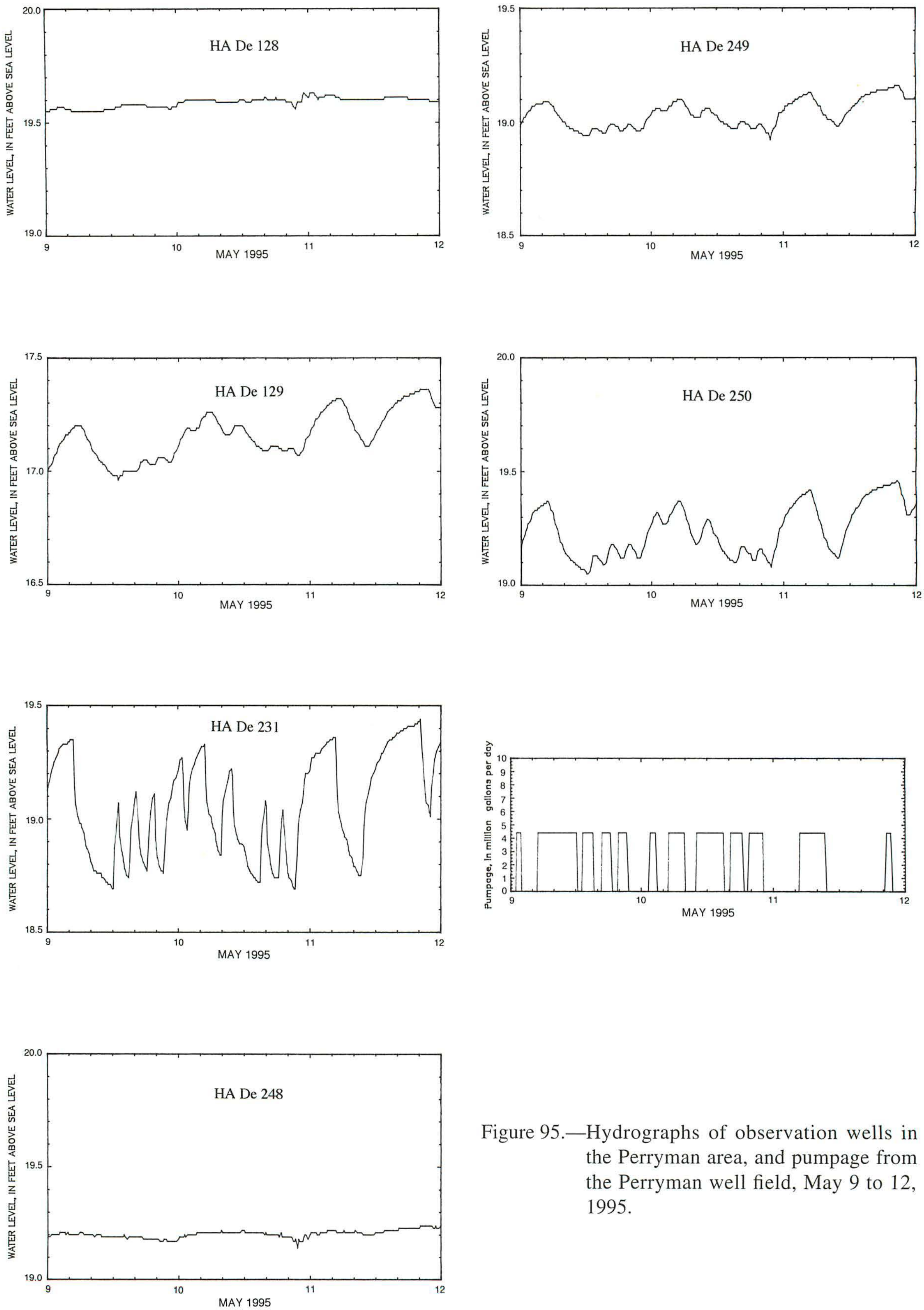


Figure 95.—Hydrographs of observation wells in the Perryman area, and pumpage from the Perryman well field, May 9 to 12, 1995.

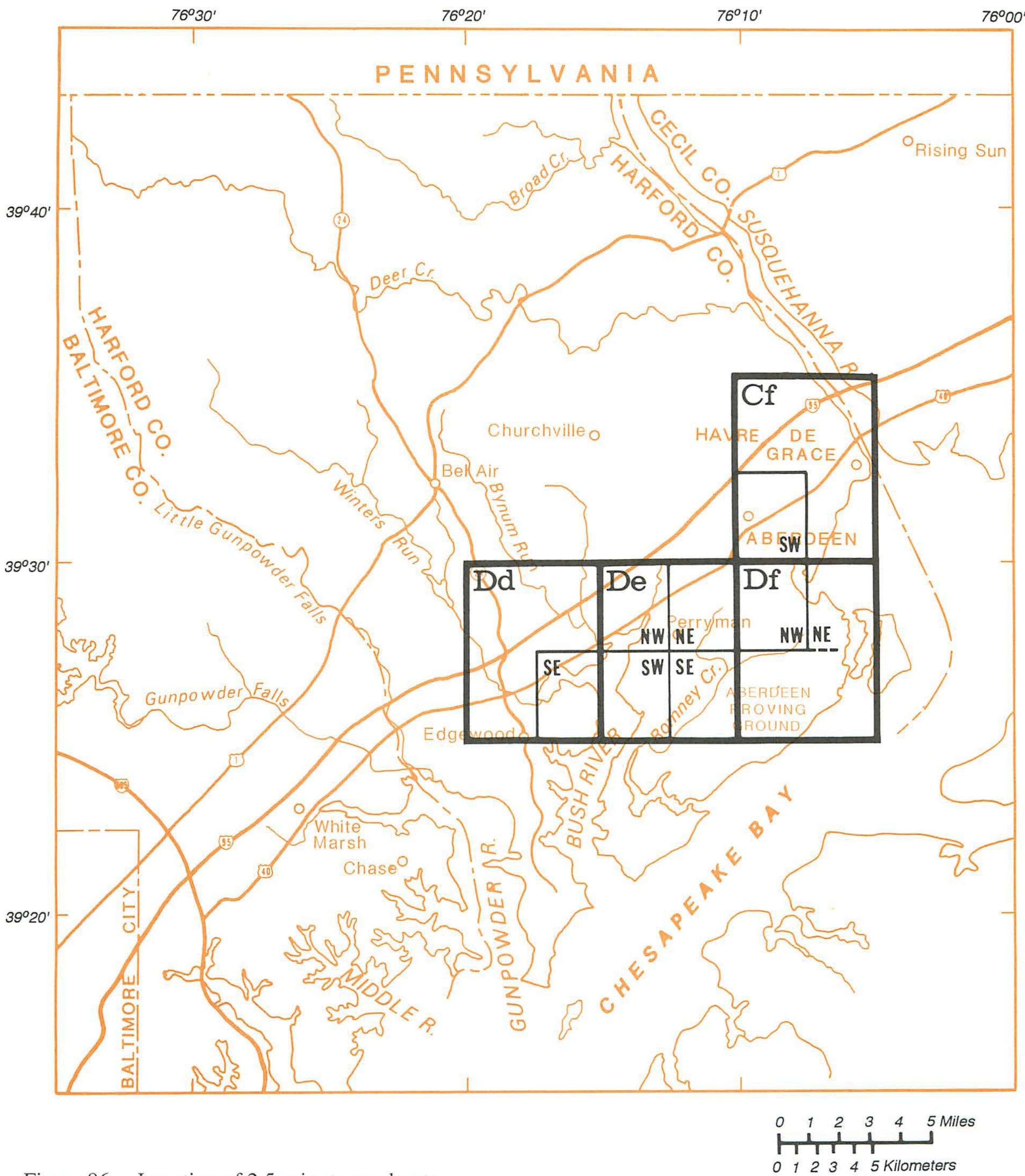
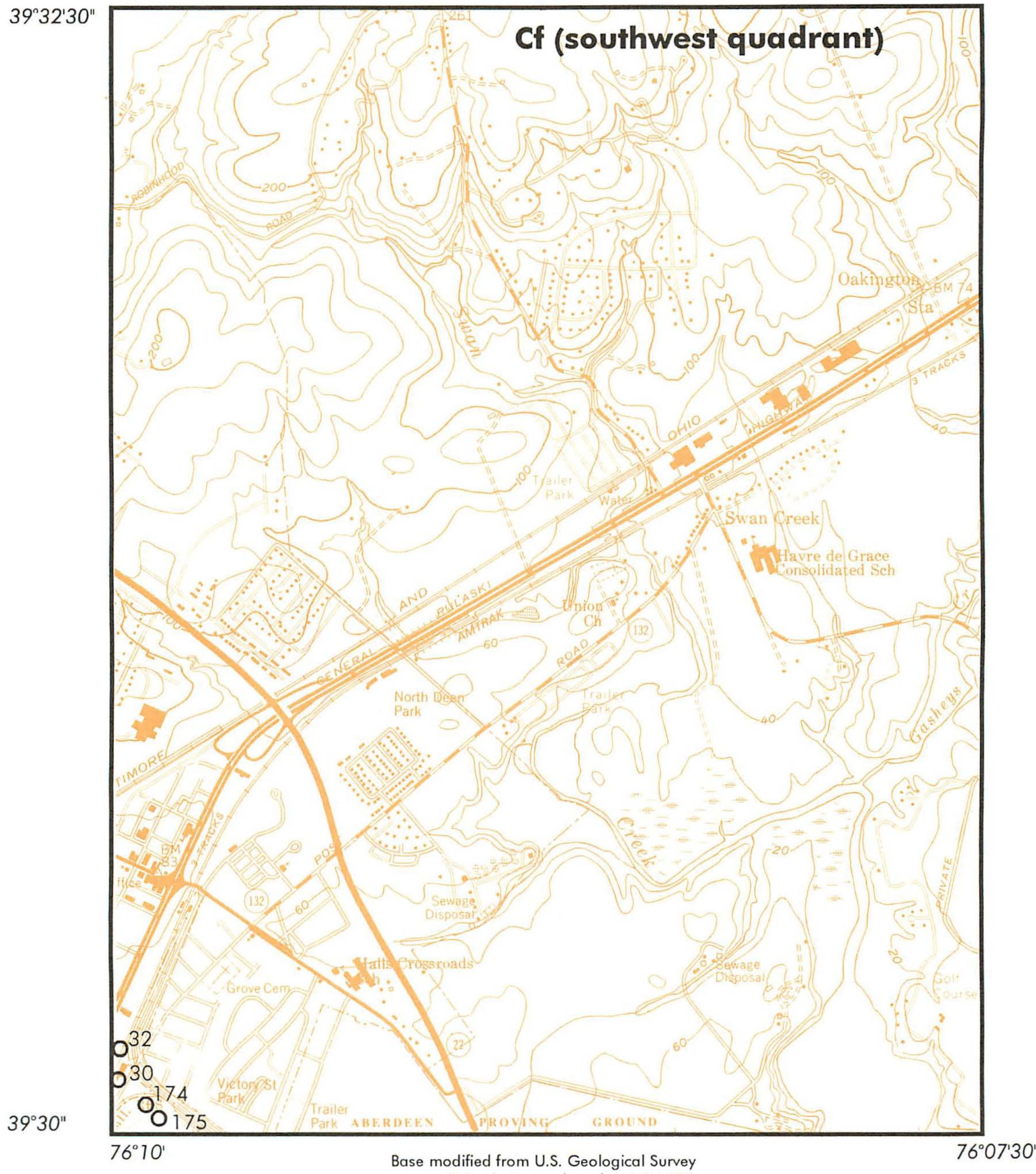


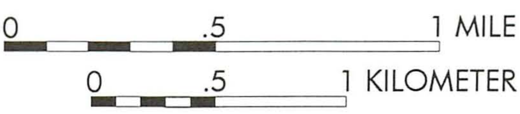
Figure 96.—Location of 2.5-minute quadrants.



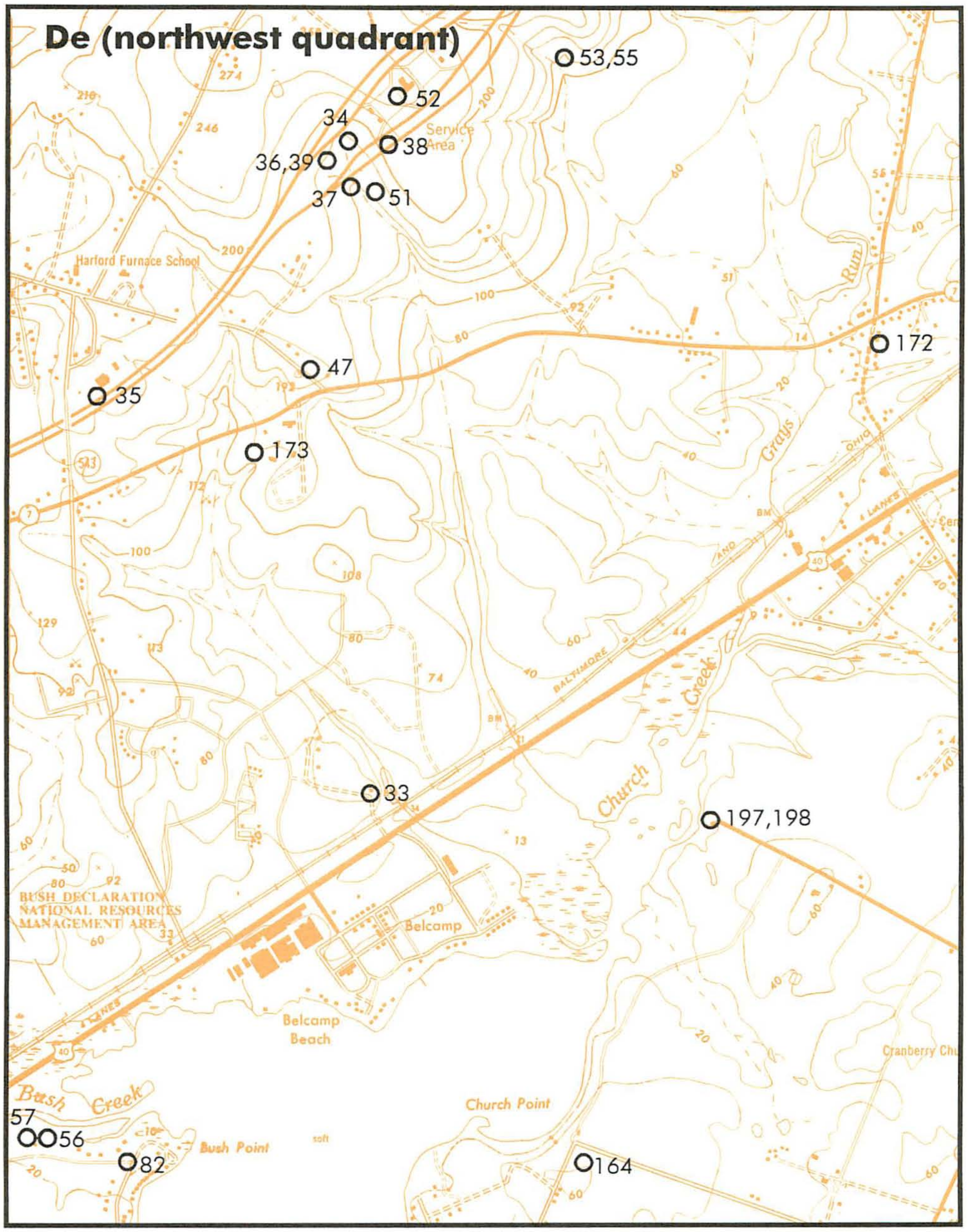
Base modified from U.S. Geological Survey
7.5 minute quadrangles 1:24,000

EXPLANATION

O 174 Well location and number



39°30'



39°27'30"

76°15'

Base modified from U.S. Geological Survey
7.5 minute quadrangles 1:24,000

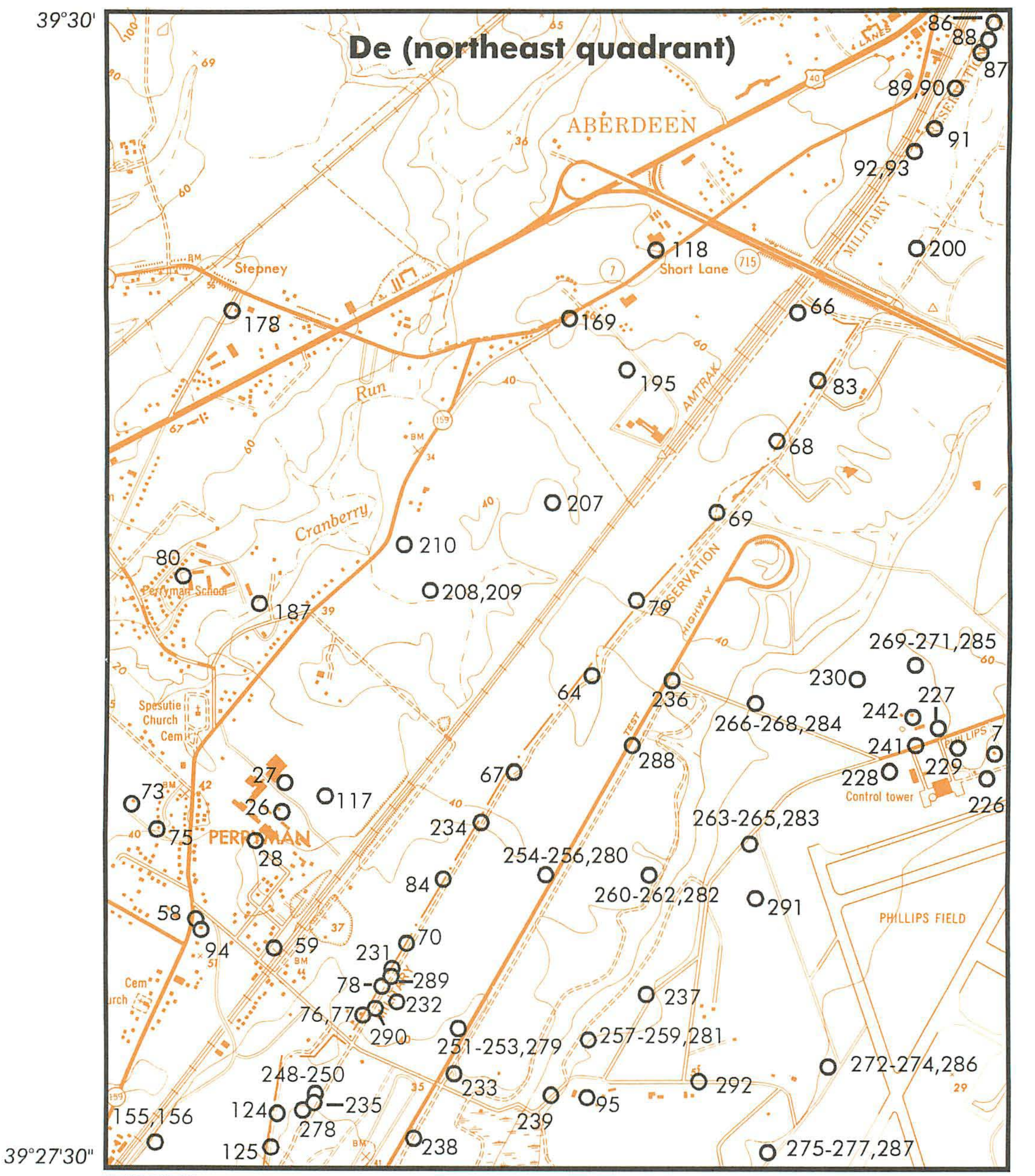
76°17'30"

EXPLANATION

O 173 Well location and number

0 .5 1 MILE

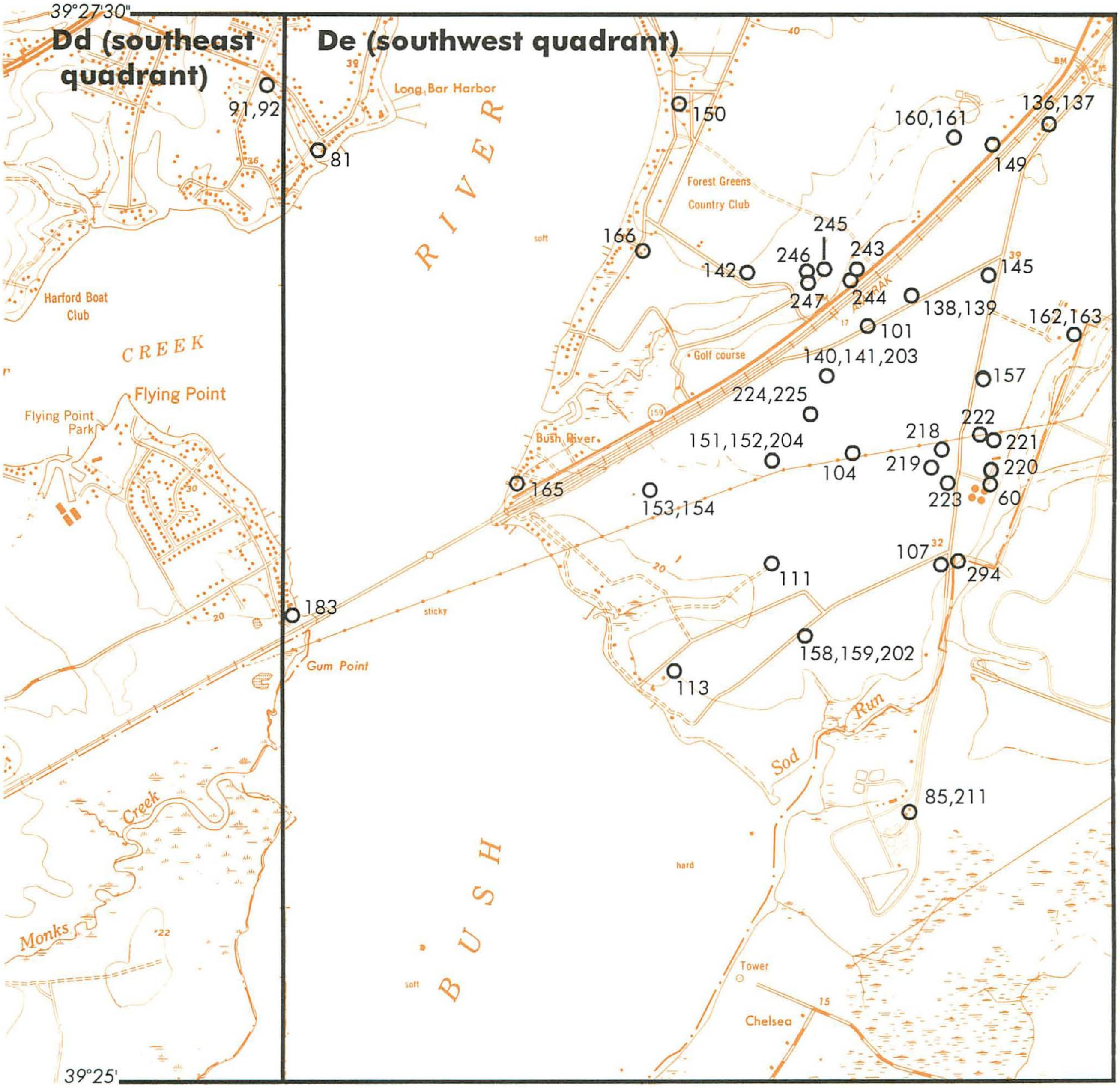
0 .5 1 KILOMETER



Base modified from U.S. Geological Survey
7.5 minute quadrangles 1:24,000

EXPLANATION
O 291 Well location and number

0 .5 1 MILE
0 .5 1 KILOMETER



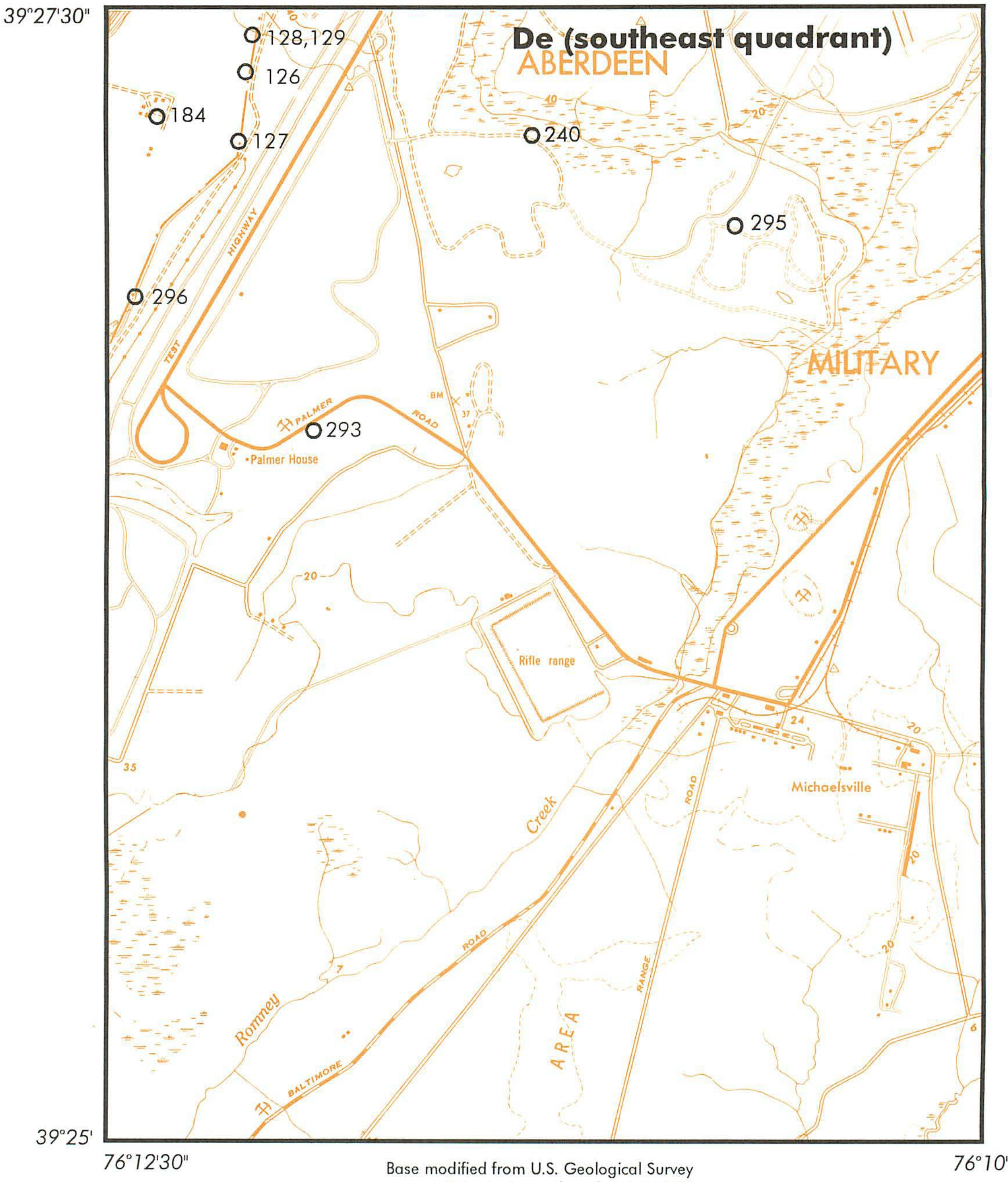
Base modified from U.S. Geological Survey
7.5 minute quadrangles 1:24,000

EXPLANATION

O 113 Well location and number

0 .5 1 MILE

0 .5 1 KILOMETER



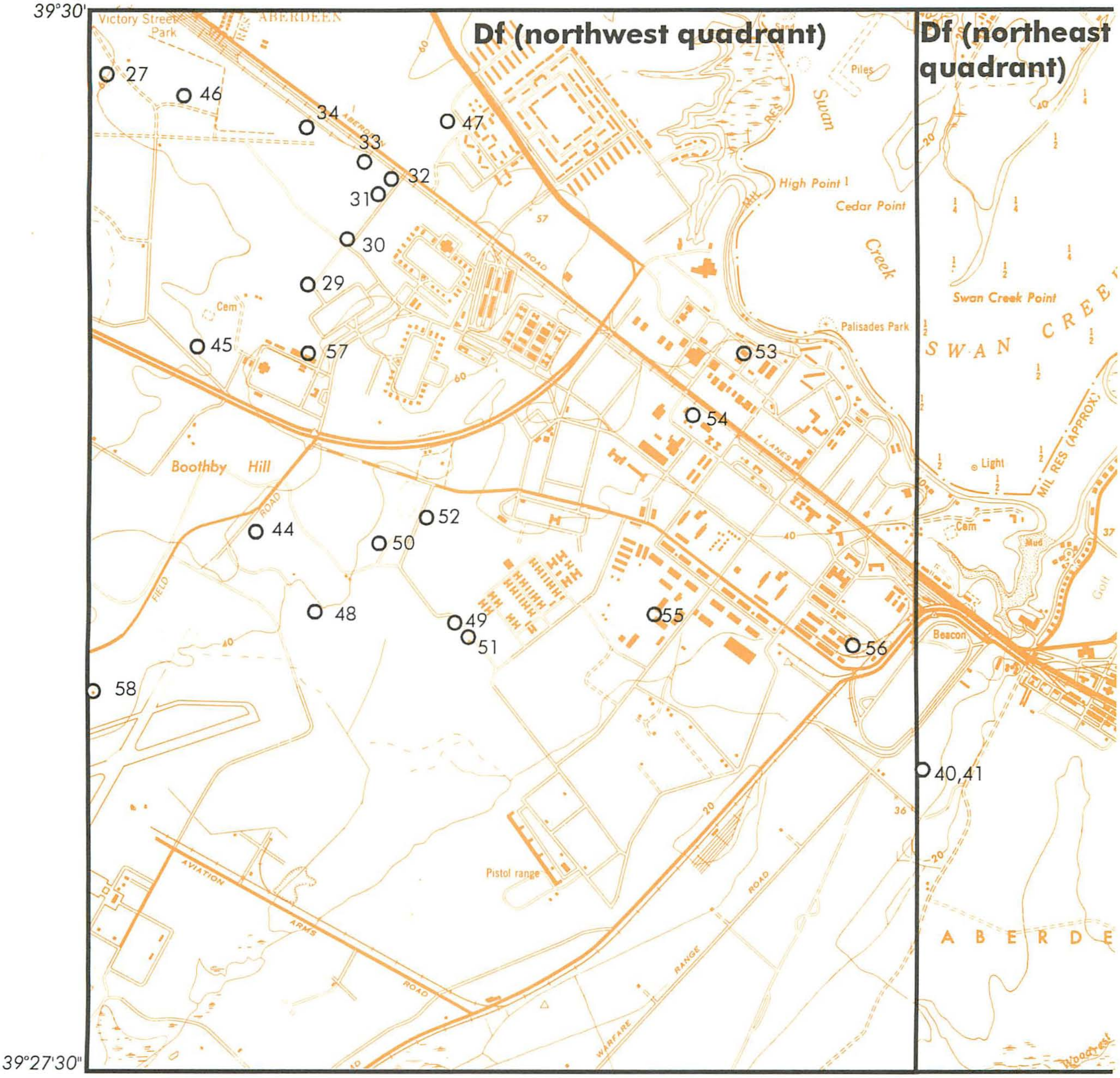
Base modified from U.S. Geological Survey
7.5 minute quadrangles 1:24,000

EXPLANATION

O 293 Well location and number

0 .5 1 MILE

0 .5 1 KILOMETER



Base modified from U.S. Geological Survey
7.5 minute quadrangles 1:24,000

EXPLANATION

O 31 Well location and number

0 .5 1 MILE

0 .5 1 KILOMETER