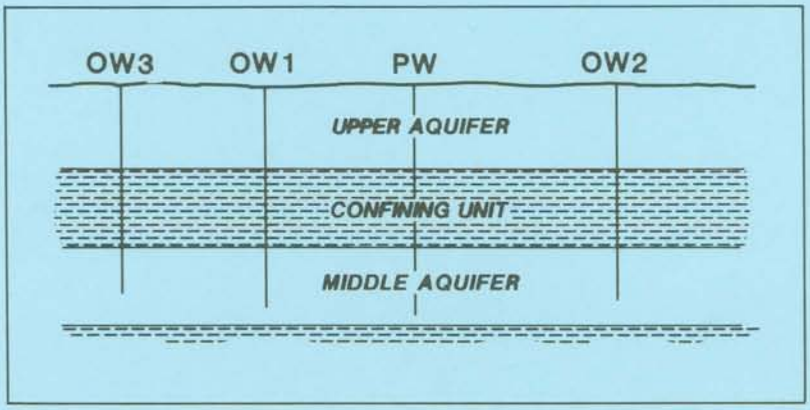
NEW JERSEY GEOLOGICAL SURVEY

GEOLOGICAL SURVEY REPORT 18

Hydraulic Properties of the Middle and Upper Aquifers of the Potomac-Raritan-Magothy Aquifer System in the Northern Coastal Plain of New Jersey



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New Jersey Geological Survey
Geological Survey Report 18

Hydraulic Properties of the Middle and Upper Aquifers of the Potomac-Raritan-Magothy Aquifer System in the Northern Coastal Plain of New Jersey

by

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Prepared by the
United States Geological Survey
in cooperation with the
New Jersey Department of Environmental Protection
Division of Water Resources

New Jersey Department of Environmental Protection
Division of Water Resources
Geological Survey
CN-029
Trenton, New Jersey 08625

1989

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CONVERSION FACTORS AND ABBREVIATIONS

For use of readers who prefer to use metric units (International System) conversion factors for the inch-pound terms used in this report are listed below:

Multiply Inch-Pound Unit	By	To obtain Metric Unit
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Area	
square mile (mi^2)	2.59	square kilometer (km^2)
	Volume	
gallon (gal)	.003785	cubic meter (m^3)
	Flow	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot squared per day (ft^2/d)	0.09294	meter squared per day (m^2/d)
gallon per minute (gal/min)	0.000063	cubic meter per second (m^3/s)
gallon per minute per foot ((gal/min)/ft)	0.0000192	cubic meter per second per meter ($(m^3/s)/m$)

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."

HYDRAULIC PROPERTIES OF THE MIDDLE AND UPPER AQUIFERS OF THE POTOMAC-RARITAN-MAGOTHY AQUIFER SYSTEM IN THE NORTHERN COASTAL PLAIN OF NEW JERSEY

By Amleto A. Pucci, Jr., Jo Ann M. Gronberg, and Daryll A. Pope

ABSTRACT

Data from 27 aquifer tests were analyzed to determine the transmissivities, hydraulic conductivities, and storage coefficients of the middle and upper aquifers, and the leakances of the intervening confining units of the Potomac-Raritan-Magothy aquifer system in the northern Coastal Plain of New Jersey. Hydraulic conductivities also were estimated from 147 well-acceptance tests for these aquifers.

The transmissivity ranges, determined from the aquifer tests, are 2,140 to 13,800 feet squared per day in the middle aquifer, and 1,760 to 19,400 feet squared per day in the upper aquifer. Storage coefficients range from 2.6×10^{-5} to 3.4×10^{-3} for the confined middle aquifer, and from 1.0×10^{-5} to 1.8×10^{-3} in the confined upper aquifer. Storage coefficients for the unconfined parts of the upper aquifer range from 3.7×10^{-3} to 5.7×10^{-1}. The ranges of lateral hydraulic conductivities, from aquifer tests and well-acceptance tests, are from 17 to 385 feet per day in the middle aquifer, and from 4 to 483 feet per day in the upper aquifer. Variability in hydraulic conductivity was found to be higher in or near the outcrops. The largest hydraulic conductivity values were concentrated in or near the outcrop areas of both aquifers. Greater leakage between the middle and upper aquifers is likely to occur in the southwest of the study area where the confining unit between the middle and upper aquifers is thin or is sandy.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the New Jersey Department of Environmental Protection (NJDEP), is investigating the water-bearing properties of the middle and upper aquifers of the Potomac-Raritan-Magothy aquifer system of the northern Coastal Plain of New Jersey (fig.1). This investigation is part of a 5-year evaluation of the ground-water resources of the region (Leahy and others, 1987).

The middle and upper aquifers of the Potomac-Raritan-Magothy aquifer system in central New Jersey are the main focus of the investigation for three reasons:

1. The Potomac-Raritan-Magothy aquifer system is the most productive ground-water resource in the region, accounting for 100 percent of ground-water withdrawals from Coastal Plain resources in Middlesex County and 72 percent in Monmouth County (Vowinkel, 1984).
2. Extensive ground-water withdrawals from the Potomac-Raritan-Magothy aquifer system have resulted in deep cones of depression in the potentiometric surface of both the middle and upper aquifers. In 1983, in the middle aquifer, ground-water levels in the center of

the cone of depression in northern Monmouth County were 91 feet below sea level (Eckel and Walker, 1986, table 3). In 1983, water levels in the upper aquifer were 59 feet below sea level in areas of Monmouth County (Eckel and Walker, 1986, table 4).

3. Saltwater intrusion has been induced in both aquifers due to these cones of depression (Schaefer, 1983).

Purpose and Scope

The purpose of this study is to determine the hydraulic properties--transmissivity, hydraulic conductivity and, where possible, storage coefficients--for the middle and upper aquifers of the Potomac-Raritan-Magothy aquifer system in the northern New Jersey Coastal Plain. These values will be used in a computer simulation of the regional ground-water flow system.

This report summarizes the hydraulic properties of the middle and upper aquifers determined from aquifer tests at 27 sites and from well-acceptance tests at 147 locations. The aquifer-test data were solicited from consultants and water-supply companies. Analytic and finite-element numerical methods (Reilly, 1984) were used to evaluate the aquifer tests. Well-acceptance-test data were derived from existing computer files in the U.S. Geological Survey Ground Water Site Inventory data base. The methods of interpretation and test data are summarized.

Location of the Study Area

The study area, which covers approximately 400 square miles in the northern New Jersey Coastal Plain, is located in Middlesex, Monmouth, and eastern Mercer Counties. The western boundary of the study area is the Fall Line--the physiographic boundary between the Triassic and Jurassic rocks of the Appalachian Highlands and the unconsolidated sediments of the Atlantic Coastal Plain. The study area is bounded to the north by the Raritan Bay and to the east by the Atlantic Ocean. The southern boundary is an arbitrary southeast trending line running from the vicinity of Hightstown to the Atlantic Ocean (fig.1).

Previous Investigations

Several studies have addressed the ground-water resources of the Potomac-Raritan-Magothy aquifer system in the northern part of the New Jersey Coastal Plain. Vermeule (1884) first described the water supplies of the area. Barksdale (1937) discussed the geology and hydrology of the Farrington Sand near Parlin in Middlesex County. Barksdale and others (1943) extended the investigation, within Middlesex County, to all the major aquifers of the county. Appel (1962) reported on saltwater intrusion into the Farrington (middle) and Old Bridge (upper) aquifers in the northwest part of the study area. Parker and others (1964) included a description of the ground-water resources of the study area in a report on the Delaware River Basin. Jablonski (1968) discussed the major aquifers in Monmouth County. Hasan and others (1969) discussed the Old Bridge aquifer in the Sayreville area of Middlesex County. The Potomac-Raritan-Magothy aquifer system in the New Jersey Coastal Plain was described by Gill and Farlekas

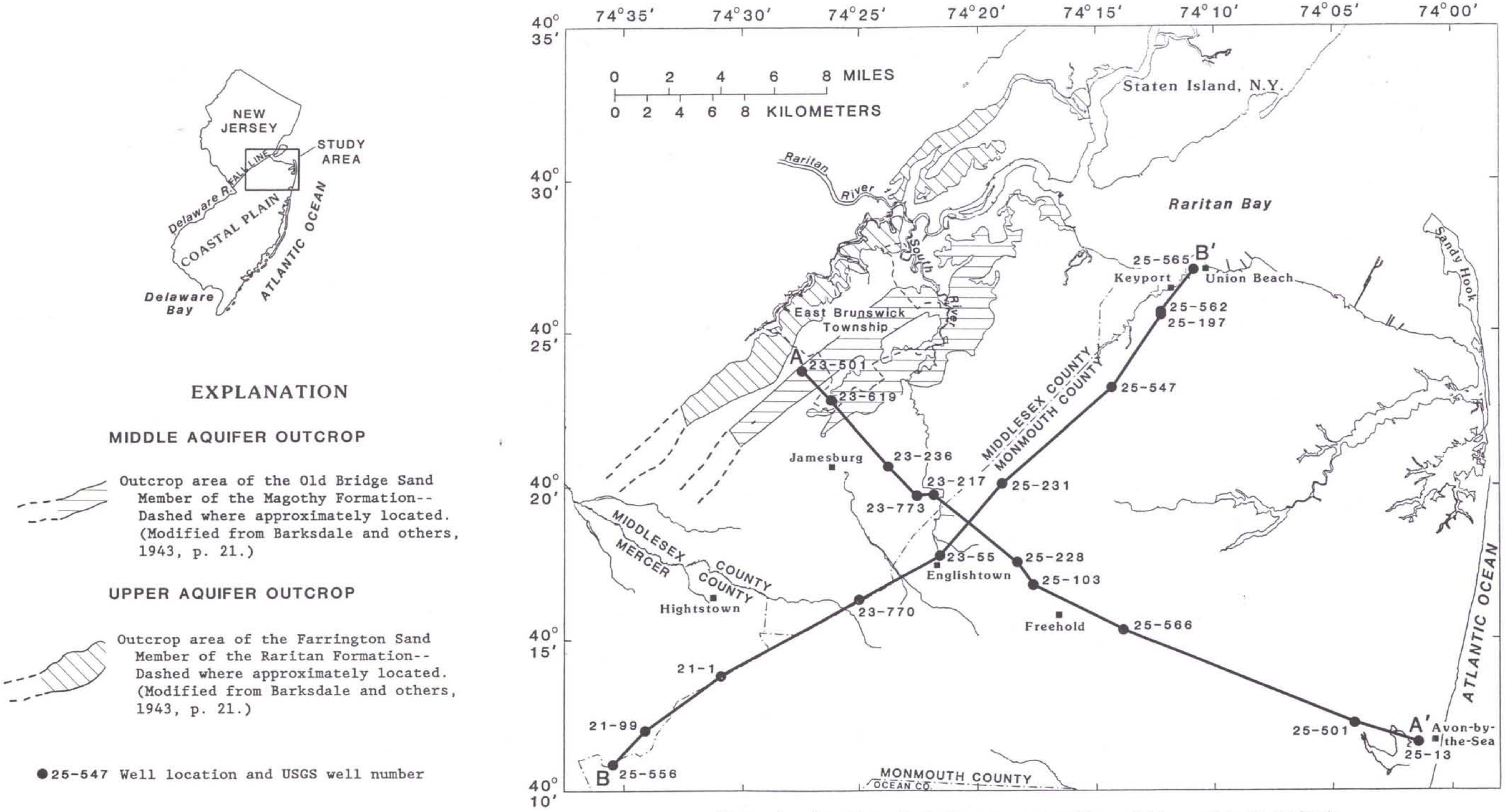


Figure 1.--Location of study area, and wells and lines of hydrogeologic sections (A-A', B-B') of the Potomac-Raritan-Magothy aquifer system.

(1976). Farlekas (1979) presented the geohydrology and a simulation of the Farrington (middle) aquifer in Middlesex and Monmouth Counties. Zapecza (1984) included the area in his report on the hydrogeologic framework of the New Jersey Coastal Plain. Pucci (1986) presented a summary of published and unpublished reports and data on the hydrogeology of the northern part of this study area.

Hydrogeology

The sediments of the Potomac Group, and the Raritan and Magothy Formations make up the Potomac-Raritan-Magothy aquifer system (table 1). Generally, this aquifer system is divided into lower, middle, and upper aquifers separated from each other by confining units (Zapecza, 1984, p. 14). However, in the study area this aquifer system consists only of the middle and upper aquifers (fig. 2); the lower aquifer is not present. In the northern part of the study area, the sediments of the Raritan and Magothy Formations have been subdivided into nine distinct units on the basis of economic importance (Ries and others, 1904, p. 166; Barksdale and others, 1943, p. 18). The lithologic subdivision of the Raritan and Magothy Formations and hydrogeologic units in and near the outcrop area are shown in table 2. Locally, the middle aquifer is known as the Farrington aquifer, and the upper aquifer is known as the Old Bridge aquifer (Farlekas, 1979).

Locally in updip parts of the study area the confining unit underlying the middle aquifer can consist of the Raritan fire clay, pre-Cretaceous bedrock, and saprolitic clay. Where present, the fire clay is a massive, multicolored clay that grades transitionally into the saprolitic clay that rests on bedrock (Ries and others, 1904, p. 192). In downdip areas the confining unit underlying the middle aquifer is composed primarily of fine grained sediments of the Potomac Group.

The middle aquifer is composed of the Farrington Sand Member of the Raritan Formation. In most of the study area, this sand member is characterized by sand, gravel, and lenses of clay. Locally in Monmouth County, the middle aquifer also includes the uppermost sand deposits of the Potomac Group (Farlekas, 1979, p. 9). According to Zapecza (1984, p. 17), the aquifer ranges in thickness from less than 50 feet in the outcrop area to more than 150 feet near the junction of Mercer, Middlesex, and Monmouth Counties.

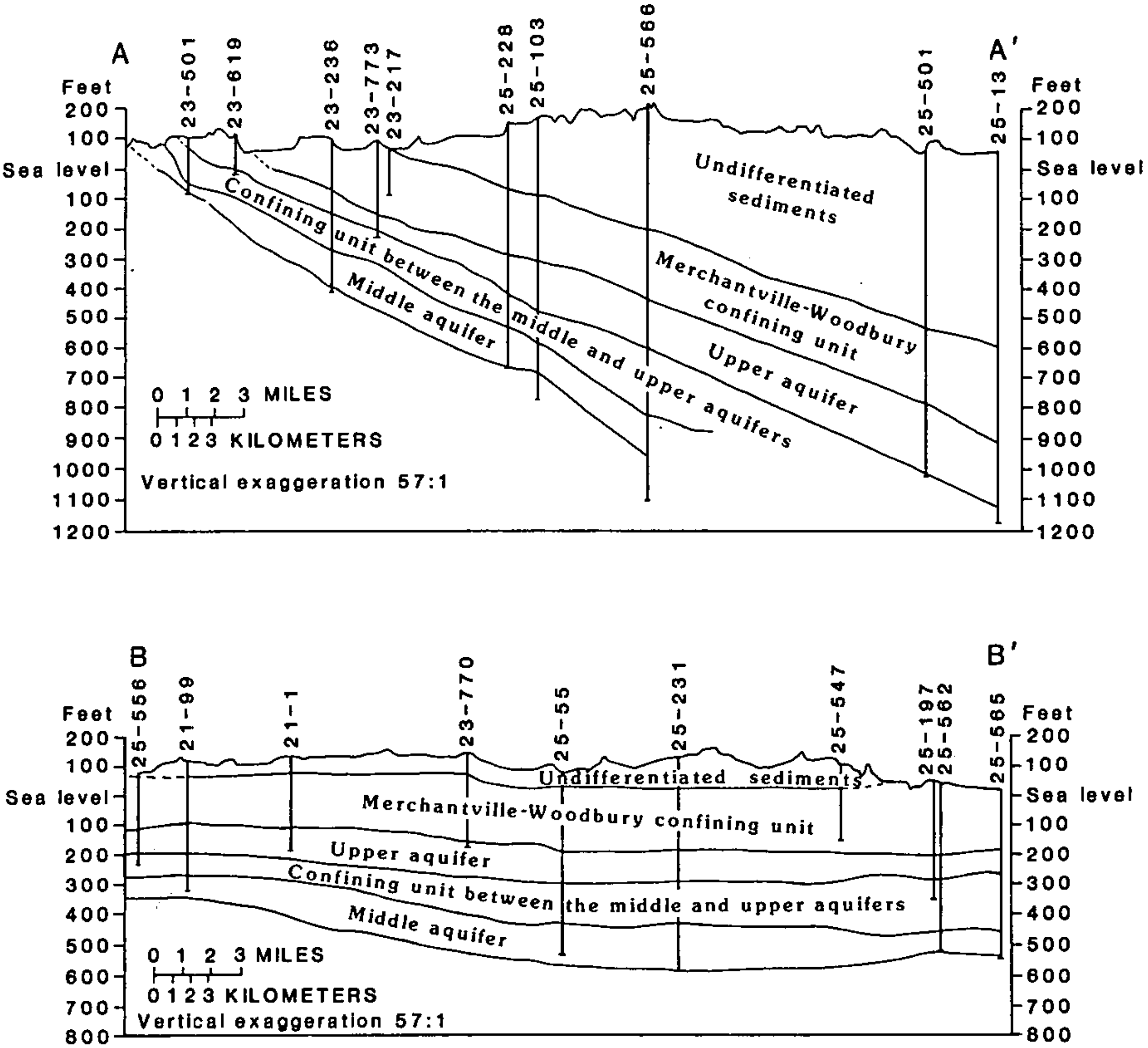
The confining unit between the middle and upper aquifers is formed chiefly by the Woodbridge Clay Member of the Raritan Formation. The Woodbridge Clay Member is made up of micaceous silt and clay (Owens and Sohl, 1969, p. 239). Locally, it also includes the clayey lithofacies of the Sayreville Sand Member and the South Amboy Clay Member of the Raritan Formation (Farlekas, 1979, p. 16). This unit thickens from less than 50 feet in the outcrop area to more than 150 feet downdip (Zapecza, 1984, p. 18).

Locally, the upper aquifer includes the Old Bridge Sand Member and the Sayreville Sand Member where the South Amboy Fire Clay Member is thin or missing (Farlekas, 1979, p. 22). It consists chiefly of coarse-grained sand and gravel. Further downdip the upper aquifer coincides closely with the entire Magothy Formation. The thickness of this unit ranges from

Table 1.--Geologic and hydrogeologic units in the Coastal Plain of New Jersey

SYSTEM	SERIES	GEOLOGIC UNIT	LITHOLOGY	HYDROGEOLOGIC UNIT		HYDROLOGIC CHARACTERISTICS
Quaternary	Holocene	Alluvial deposits	Sand, silt, and black mud.	Undifferentiated		Surficial material, commonly hydraulically connected to underlying aquifers. Locally some units may act as confining units. Thicker sands are capable of yielding large quantities of water.
		Beach sand and gravel	Sand, quartz, light-colored, medium-to coarse-grained, pebbly.			
	Pleistocene	Cape May Formation	Sand, quartz, light-colored, heterogeneous clayey, pebbly.			
Tertiary	Miocene	Pensauken Formation				
		Bridgeton Formation		Kirkwood-Cohansey aquifer system		A major aquifer system. Ground water occurs generally under water-table conditions. In Cape May County the Cohansey Sand is under artesian conditions.
		Beacon Hill Gravel	Gravel, quartz, light colored, sandy.			
		Cohansey Sand	Sand, quartz, light-colored, medium to coarse-grained, pebbly; local clay beds.			
		Kirkwood Formation	Sand, quartz, gray and tan, very fine-to, medium-grained, micaceous, and dark-colored diatomaceous clay.	Confining unit		Thick diatomaceous clay bed occurs along coast and for a short distance inland. A thin water-bearing sand is present in the middle of this unit.
				Rio Grande water bearing zone		
				Confining unit		
				Atlantic City 800-foot sand		A major aquifer along the coast.
				Composite confining unit		Poorly permeable sediments.
	Oligocene	Piney Point Formation	Sand, quartz and glauconite, fine-to coarse-grained.		Piney Point aquifer	Yields moderate quantities of water.
	Eocene	Shark River Formation				
		Manasquan Formation	Clay, silty and sandy, glauconitic, green, gray and brown, fine-grained quartz sand.			Poorly permeable sediments.
	Paleocene	Vincentown Formation	Sand, quartz, gray and green, fine-to coarse-grained, glauconitic, and brown clayey, very fossiliferous, glauconite and quartz calcarenite.		Vincentown aquifer	Yields small to moderate quantities of water in and near its outcrop area.
		Hornerstown Sand	Sand, clayey, glauconitic, dark green, fine to coarse-grained.			Poorly permeable sediments.
Cretaceous	Upper Cretaceous	Tinton Sand	Sand, quartz, and glauconite, brown and gray, fine-to coarse-grained, clayey, micaceous.			
		Red Bank Sand			Red Bank sand	Yields small quantities of water in and near its outcrop area.
		Navesink Formation	Sand, clayey, silty, glauconitic, green and black, medium-to coarse-grained.			Poorly permeable sediments.
		Mount Laurel Sand	Sand, quartz, brown and gray, fine-to coarse-grained, slightly glauconitic.	Wenonah-Mount Laurel aquifer		A major aquifer.
		Wenonah Formation	Sand, very fine-to fine-grained, gray and brown, silty, slightly glauconitic.	Marshalltown-Wenonah confining unit		A leaky confining unit.
		Marshalltown Formation	Clay, silty, dark greenish gray, glauconitic quartz sand.			
		Englishtown Formation	Sand, quartz, tan and gray, fine-to medium-grained; local clay beds.	Englishtown aquifer system		A major aquifer. Two sand units in Monmouth and Ocean Counties.
		Woodbury Clay	Clay, gray and black, micaceous silt.	Merchantville-Woodbury confining unit		A major confining unit. Locally the Merchantville Formation may contain a thin water-bearing sand.
		Merchantville Formation	Clay, glauconitic, micaceous, gray and black; locally very fine-grained quartz and glauconitic sand.			
		Magothy Formation	Sand, quartz, light-gray, fine-to coarse-grained. Local beds of dark-gray lignitic clay.	Potomac-Raritan-Magothy aquifer system	Upper aquifer	A major aquifer system. In the northern Coastal Plain, the upper aquifer is equivalent to the Old Bridge aquifer and the middle aquifer is equivalent to the Farrington aquifer. In the Delaware River Valley three aquifers are recognized. In the deeper subsurface, units below the upper aquifer are undifferentiated.
		Raritan Formation	Sand, quartz, light-gray, fine-to coarse-grained, pebbly, arkosic, red, white, and variegated clay.		Confining unit	
					Middle aquifer	
	Lower Cretaceous	Potomac Group	Alternating clay, silt, sand, and gravel.		Confining unit	
					Lower aquifer	
Pre-Cretaceous		Bedrock	Precambrian and lower Paleozic crystalline rocks, metamorphic schist and gneiss; locally Triassic sandstone, shale and Jurassic basalt.	Bedrock confining unit		No wells obtain water from these consolidated rocks, except along Fall Line.

Modified from Zapecza, 1984, table 1



EXPLANATION

25-566 U.S. Geological Survey well number

Datum is sea level

Hydrogeologic data from **Gronberg** and others (in press)

Figure 2.--Hydrogeologic sections of the northern Coastal Plain of New Jersey, A-A' and B-B'.

Table 2.--Lithologic subdivisions of the Raritan and Magothy Formations and hydrogeologic units in and near the outcrop

System	Geologic unit		Lithology	Hydrogeologic unit	
Cretaceous	Magothy Formation	Cliffwood beds	Sand, quartz, light-gray, fine- to coarse-grained; local beds of dark-gray lignitic clay.	Potomac-Raritan-Magothy aquifer system[1]	Confining unit
		Morgan beds			
		Amboy Stoneware Clay Member			
		Old Bridge Sand Member			Upper aquifer[2]
	Raritan Formation	South Amboy Fire Clay Member	Sand, quartz, light-gray, fine to coarse-grained, pebbly, arkosic, red white and variegated clay, and saprolitic clay developed on bedrock.		Confining unit
		Sayreville Sand Member			
		Woodbridge Clay Member			
		Farrington Sand Member			Middle aquifer
		Raritan fire clay			Confining unit
Pre-Cretaceous	Bedrock		Precambrian and lower Paleozoic crystalline rocks, metamorphic shist and gneiss; locally Triassic, sandstone, shale and Jurassic basalt.	Bedrock confining unit	

Modified from Christopher, 1979, figure 2 and Zapecza, 1984, table 2.

[1] To maintain consistent terminology, the aquifer-system name commonly used throughout New Jersey is used in this report. The lower aquifer is not mappable within the study area.

[2] Locally the upper aquifer can include the Sayreville Sand Member where the South Amboy Fire Clay Member is thin or missing

approximately 50 feet in the outcrop area to more than 200 feet in southeastern Monmouth County (Zapecza, 1984, p. 18, and plate 11).

The confining unit which overlies the upper aquifer of the Potomac-Raritan-Magothy aquifer system is the Merchantville-Woodbury confining unit. It is composed mainly of the Merchantville Formation and the Woodbury Clay. The Merchantville Formation is made up of glauconite beds, and beds of micaceous clays and clayey silts (Zapecza, 1984, p. 19), while the Woodbury Clay is made up of massive clayey silt (Owens and Sohl, 1969, p. 242). This confining unit also locally includes the discontinuous Amboy Stoneware Clay Member and the Cliffwood and Morgan beds of the Magothy Formation. The thickness of this confining unit ranges from less than 200 feet near its outcrop to more than 300 feet in the Sandy Hook area (Zapecza, 1984, plate 12).

Well-Numbering System

The well-numbering system used in this report was developed by the New Jersey District of the U.S. Geological Survey. The first part of the number is a two-digit county code: 21 for Mercer, 23 for Middlesex, and 25 for Monmouth. The second part is a sequence number assigned to the well within the county. A representative well number is 23-236 for the 236th well inventoried in Middlesex County.

Acknowledgments

The authors would like to thank the following people for providing and permitting the publication of the aquifer test information: Gregory C. Fehrenbach, Administrator, Township of East Brunswick; Robert O. Harris, Health Officer, South Brunswick; William Iafe, Project Engineer, O & Y Old Bridge Development Corp.; Frederick E. Jahn, Township Administrator, Township of Freehold; Paul Kamber, Senior Vice President, Nestles Food Corporation; Martin E. Langenohl, Director, City of Perth Amboy, Department of Municipal Utilities; Harvey E. Lohr, Superintendent of Public Works, Borough of Spotswood; Raymond Martinelli, Water Commissioner, Borough of Hightstown; Donald J. Murphy, P.E., Managing Principal, Dames and Moore; Charles E. Robinson, Sr., P.E., Adtek Engineering Inc.; Michael A. Rogers, Executive Director, Monroe Township Municipal Utility Authority; August C. Schultes, P.E., President, A.C. Schultes and Sons; Russel G. Slayback, President, Leggette, Brashears, and Graham; Fred Trois, Director, Water Information Center, Geraghty and Miller; Peter S. Wersinger III, Esq., Attorney, Marlboro Township Municipal Utilities Authority; Hyman Bzura, President, Madison Industries; and Joseph M. DeSalvo, P.E., Senior Vice President, Converse Consultants, Inc.

METHODS OF INVESTIGATION

Hydraulic properties of the middle and upper aquifers were determined by two methods: (1) analysis of data from aquifer tests, and (2) analysis of data from well-acceptance tests. The transmissivity, hydraulic conductivity, and storage coefficient are hydraulic properties of an aquifer that can be determined from aquifer tests. Well-acceptance tests are used to test the productivity of a well and usually include specific-capacity data. Specific-capacity data can be used to estimate hydraulic conductivity

(McClymonds and Franke, 1972, p. 10). In general, the hydraulic-conductivity values estimated from the aquifer and well-acceptance tests fell within the range of values for sand and gravel published in several references (table 3).

Table 3.--Summary of average hydraulic conductivity and storage coefficient values

[ft/d=feet per day; a double dash (--) indicates data not available]

Reference	Lithologic description	Hydraulic conductivity	Storage coefficient (confined aquifer)
Davis, S.N., and De Wiest, R.J.M. (1966, p. 164)	Clean sands (good aquifers)	1 - 1,337 ft/d	--
Freeze, R.A. and Cherry, John A. (1979, p29, p60)	Clean sands	1 - 1,337 ft/d	$5\text{x}10^{-5}$ to $5\text{x}10^{-3}$
Todd, D.K. (1976, p.71)	Gravel, fine to sand, fine	8 - 1,476 ft/d	$5\text{x}10^{-5}$ to $5\text{x}10^{-3}$
Lohman, S.W. (1972, p.53)	Gravel, coarse to sand, very fine	3 - 1,000 ft/d	--

Lithologic descriptions also can be used to estimate values of hydraulic conductivity. Well logs from the aquifer and well-acceptance tests for the middle and upper aquifers showed that these aquifers are composed of fine-to-coarse sands. The lithologic descriptions at each aquifer-test site are included in the summary tables 4 and 5 of the following sections.

Aquifer Tests

Data

Data from each aquifer test were evaluated for reasonableness and correctness. Factors that were considered in this evaluation included: (1) local hydrogeologic conditions, (2) duration of the test, (3) length of the well screen, (4) distance of the observation wells from the pumping well, and (5) the influence of other pumping wells in the vicinity of the test. This evaluation was followed by a field inspection of each aquifer-test site. Records of long-term water-level trends were not available for the aquifer tests, so static-water level measurements made just prior to the tests were assumed to represent prepumping conditions. Drawdown, recovery, or water-level data for the aquifer tests are included in figures 5-32, and figures 35-39 of this report. These figures are in two appendixes at the end of this report.

Identifying data, design characteristics, the method of analysis, and estimated hydraulic properties are presented for each aquifer test in tables 4 and 5. Each aquifer test is numbered and can be referenced to a location on a plate; numbers 1 through 12 are shown on plate 1 for aquifer tests in the middle aquifer, numbers 13 through 27 are shown on plate 2 for aquifer tests in the upper aquifer. Identifying data for each aquifer test include a test identifier or name, the test date, the municipality where the test

Table 4.--Summary of aquifer tests and estimated hydraulic properties for the middle aquifer of the Potomac-Raritan-Magothy aquifer system

[1] Lithologic Descriptors: (f,m,c)=(fine,medium,coarse)
[2] PW=pumped well
[3] R=Recovery Data
[4] Methods of Analysis: J=Jacob, T=Theis, FEM=radial finite element method
[5] T=Transmissivity in square feet per day
K=Lateral hydraulic conductivity in feet per day
S=Storage coefficient (dimensionless)
L=Leakance in feet per day per foot

[6] Combined leakance of the overlying and underlying confining units of the middle aquifer
* Combined observation well data used in the analysis
** Analysis contributed by source of data
*** Analysis published by Hardt and Jablonski (1959)
† Leakance for the overlying confining unit.

[gal/min, gallons per minute; hr, hour; ft, feet; a double dash indicates data is not applicable or not available]

Test No.	Test Identifier Test date Municipality Source of data	Discharge Test Duration Lithology[1] Mean unit thickness Drawdown of pumped well Type of confinement	USGS well number (distance from PW[2] (ft))	Screened interval (ft)	Method of analysis[3], [4]	Hydraulic properties[5]			
						T	K	S	L[6]
1.	Dupont 6/16/44 Sayreville Boro USGS	610 gal/min 2 hr sand 85 ft -- confined	23-393(PW)	246-284	--	--	--	--	--
			23-392(1,050)	237-291	T	7,750	91	4.8×10^{-5}	--
2.	East Brunswick #4 7/8-10/75 E. Brunswick Twp A.C. Schultes	500 gal/min 24 hr sand, clayey 70 ft 23.7 ft confined	23- 42(PW)	161-171 195-215	J**	9,800	140	--	--
			23- 43(50)	161-166 195-200	T	10,400	148	1.4×10^{-4}	--
3.	East Brunswick #5 7/7-9/75 E. Brunswick Twp A.C. Schultes	310 gal/min 24 hr sand 92 ft 20.5 ft confined	23- 40(PW)	162-172 201-221	J**	13,180	143	--	--
			23- 41(50)	161-166 197-202	J(R)**	10,200	111	3.4×10^{-3}	--
4.	East Brunswick #6 9/29-30/75 E. Brunswick Twp A.C. Schultes	540 gal/min 24 hr sand(f-c),clayey 83 ft 16.5 ft confined	23- 44(PW)	217-237 271-281	J**	9,630	116	--	--
			23-789(50)	212-217 271-276	T	10,600	128	8.0×10^{-5}	--
5.	East Brunswick #7 10/16-17/75 E. Brunswick Twp A.C. Schultes	325 gal/min 24 hr sand(m-c),clayey 55 ft 12.25 ft confined	23- 47(PW)	119-144	--	--	--	--	--
			23-788(50)	127-133	T	9,400	171	4.2×10^{-5}	--
6.	Hercules 6/16/44 Sayreville Boro USGS	590 gal/min 3 hr sand 65 ft -- confined	23-380(PW)	184-237	--	--	--	--	--
			23-384(350)	170-225	T	7,420	114	1.6×10^{-3}	--
7.	Hightstown 3/10-23/77 Hightstown Boro A.C. Schultes	800 gal/min 8 hr sand(f-c),clayey 115 ft -- confined	21- 85(PW)	316-336	--	--	--	--	--
			21- 86(75)*	294-304 324-334					
			21-144(250)*	294-304 319-340	T	11,500	100	5.0×10^{-5}	--
8.	Marlboro MUA 4/3/72 Marlboro Twp A.C. Schultes	1,236 gal/min 24 hr sand(f-m),clayey 98 ft 48 ft leaky confined	25-268(PW)	632-679 688-698	--	--	--	--	--
			25-269(600)	647-687 696-716	FEM	9,800	100	1.0×10^{-4}	†7.0×10^{-4}

Table 4.--Summary of aquifer tests and estimated hydraulic properties for the middle aquifer of the Potomac-Raritan-Magothy aquifer system --Cont.

[gal/min, gallons per minute; hr, hour; ft, feet; a double dash indicates data is not applicable or not available]

Test No.	Test Identifier Test date Municipality Source of data	Discharge Test Duration Lithology[1] Mean unit thickness Drawdown of pumped well Type of confinement	USGS well number (distance from PW[2] (ft))	Screened interval (ft)	Method of analysis[3,4]	Hydraulic properties[5] T	K	S	L[6]
9.	Runyon, Old Deep 8/41 Old Bridge Twp	1,500 gal/min 2 hr sand	23-194(PW)	201-231 251-281	--	--	--	--	--
	USGS	82 ft -- confined	23-197(298)	205-260	T	6,250	76	3.0×10^{-4}	--
10.	South Brunswick 5/21-29/56 S. Brunswick Twp	1,000 gal/min 168 hr	23-288(PW)	190-200	--	--	--	--	--
		sand,clayey	*23-287(500)	218-228					
	Leggette, Brashears, and Graham	59 ft 27.6 ft leaky confined	*23-290(1,000)	218-228	FEM	11,800	200	3.5×10^{-4}	†1.1×10^{-3}
11.	Spotswood 1976 4/21-27/76	703 gal/min 168 hr sand,clayey	23-499(PW)	198-282	--	--	--	--	--
	Spotswood	90 ft	*23-127(1,600)	236-296					
	Leggette, Brashears, and Graham	25.6 ft confined	*23-171(7,000)	240-300	T	13,800	153	2.2×10^{-4}	--
12.	Woodbridge 3/25-28/57	140 gal/min 72 hr	23-473(PW)	39-59	--	--	--	--	--
	Woodbridge Twp USGS	sand 60 ft	23-474(480)	41-61	T	2,145	--	2.6×10^{-5}	2.3×10^{-3}
		-- confined	23-482(2,030)	44-54 64-76	T***	2,140	36	2.3×10^{-4}	--

Table 5.--Summary of aquifer tests and estimated hydraulic properties for the upper aquifer of the Potomac-Raritan-Magothy aquifer system

[1] Lithologic Descriptors: (f,m,c)=(fine,medium,coarse)
[2] PW=pumped well
[3] R=Recovery Data
[4] Methods of Analysis: J=Jacob, DD=Distance Drawdown, HJ=Hantush Jacob, HM=Hantush Modified, T=Theis, Tm=Thiem, FEM=Radial Finite Element Mode
[5] T=Transmissivity in square feet per day
K=Lateral hydraulic conductivity in feet per day
S=Storage coefficient (dimensionless)
L=Leakance in feet per day per foot

[6] Specific yield is reported for unconfined aquifer tests
* Combined observation well data used in the analysis
** Analysis contributed by data source
*** Analysis published by Barksdale, and others (1943)
† leakance for confining bed above upper aquifer
†† leakance for confining bed below upper aquifer

[gal/min, gallons per minute; hr, hour; ft, feet; a double dash indicates data is not applicable or not available]

Test No.	Test Identifier Test date Municipality Source of data	Discharge Test Duration Lithology[1] Mean unit thickness Drawdown of pumped well Type of confinement	USGS well number (distance from PW[2] (ft))	Screened interval (ft)	Method of analysis[3],[4]	Hydraulic properties[5] T	K	S[6]	L
13.	E. Brunswick WD Phase I 9/12-15/78 E.Brunswick Twp Leggette, Brashears, and Graham	101 gal/min 9.5 hr sand(f-c) 20 ft 10.4 ft unconfined	23-614(PW)	28-38	--	--	--	--	--
			23-615(100)	30-35	FEM	5,000	250	1.0×10^{-2}	--
14.	E. Brunswick WD Phase II Test Well 6 10/30-11/6/78 E.Brunswick Twp Leggette, Brashears, and Graham	300 gal/min 164 hr sand(f-m) 52 ft 17.5 ft semi-confined	23-621(PW)	88-118	--	--	--	--	--
			*23-620(245) *23-619(490)	114-119 112-117	DD**	5,600	108	1.4×10^{-1}	--
15.	East Brunswick Phase II Test Well 8 1/24-2/1/79 E.Brunswick Twp Leggette, Brashears and Graham	239 gal/min 70 hr sand(f-c) 49 ft 18.4 ft semi-confined	23-626(PW)	35-55	--	--	--	--	--
			*23-624(250) *23-625(122)	47-52 50-55	DD**	4,010	82	1.8×10^{-3}	--
16.	Freehold Twp 5/14-17/84 Freehold Twp A.C. Schultes	1,218 gal/min 72 hr sand 150 ft 21.45 ft confined	25-551(PW)	621-680	J**	8,420	56	--	--
			25-550(100)	636-651	T	7,500	50	3.3×10^{-4}	--
17.	Hightstown WD 3/10-23/77 Hightstown Boro A.C. Schultes	900 gal/min 8 hr sand(f-m),clayey 90 ft -- leaky confined	21- 84(PW)	169-183	--	--	--	--	--
			21- 81(70) *21- 86(245)	181-205 144-264	HM	6,900	77	1.2×10^{-4}	3.0×10^{-4}
18.	Madison Industries 3/4/82 Old Bridge Twp Converse	150 gal/min 24 hr sand 60 ft 21.45 ft unconfined	23-690(PW)	29-39	J(R)	5,130	86	--	--
			23-684(170)	17-37	J(R)	5,820	97	5.7×10^{-2}	--
19.	Matawan/ Levitt and Sons 1/23-20/62 Aberdeen Twp Legette, Brashears, and Graham	1,100 gal/min 168 hr sand,clayey 84 ft 159.4 ft leaky confined	25-292(PW)	341-414	--	--	--	--	--
			*25-289(590) *25-290(1,000) *25-291(2,020)	372-377 348-353 330-335	HM	5,600	67	2.6×10^{-4}	1.5×10^{-5} 1.5×10^{-5} 1.6×10^{-5}

Table 5.--Summary of aquifer tests and estimated hydraulic properties for the upper aquifer of the Potomac-Raritan-Magothy aquifer system--Cont.

[gal/min, gallons per minute; hr, hour; ft, feet; a double dash indicates data is not applicable or not available]

Test No.	Test Identifier Test date Municipality Source of data	Discharge Test Duration Lithology[1] Mean unit thickness Drawdown of pumped well Type of confinement	USGS well number (distance from PW[2] (ft))	Screened interval (ft)	Method of analysis[3],[4]	Hydraulic properties[5]			
						T	K	S[6]	L
20.	Monroe MUA 8/21-24/80 Monroe Twp Dames and Moore	985 gal/min 72 hr sand 103 ft 24.2 ft leaky confined	23-555(PW)	168-200	--	--	--	--	--
			23-228(1,100)	127-138	FEM	15,450	150	1.0 x 10^{-5}	†2.5 x 10^{-2} ††2.5 x 10^{-2}
21.	Nestles 6/22-25/70 Freehold Boro Leggette, Brashears, and Graham	1,000 gal/min 72 hr sand,clayey 93 ft 35.9 ft confined	25-70(PW)	576-640					
			*25-68(870)	557-607					
			*25-69(1,300)	564-614	T	8,060	87	3.1 x 10^{-4}	--
22.	Olympia and York 7/8-10/81 Old Bridge Twp Geraghty and Miller	844 gal/min 48 hr sand,clayey 64 ft 69.9 ft confined	23-594(PW)	275-315	--	--	--	--	--
			*23-595(725)	285-290					
			*23-596(1100)	289-294	T	5,400	84	1.9 x 10^{-4}	--
23.	Perth Amboy WD 3/73 Old Bridge Twp Adtek	200 gal/min 2 hr sand 69 ft -- unconfined	23-602(PW)	45-53	J**	1,760	26	--	--
			23-600(80)	68-79	J**	2,850	41	4.0 x 10^{-5}	--
24.	Parlin 5/31-6/1/39 Old Bridge Twp USGS	512 gal/min 24 hr sand 59 ft -- unconfined	23-172(PW)	55-75	--	--	--	--	--
			23-119(25)	65-85	Tm**	11,500	195	1.4 x 10^{-4}	--
			23-121(85)	75-85	Tm**	19,400	329	3.7 x 10^{-3}	--
25.	Perth Amboy WD 6/20-22/85 Runyon Hydro Group	570 gal/min 48 hr sand 65 ft 28.6 ft unconfined	23-743(PW)	50-65	--	--	--	--	--
			*23-745(50)	57-67	DD	--	--	--	--
			*23-746(91)	57-67	DD	--	--	--	--
			*23-744(207)	60-75	DD**	9,500	146	--	--
26.	Spotswood WD 03/18/58 Spotswood Boro USGS	560 gal/min 4 hr -- -- -- semi-confined	23-447(PW)	64-85	--	--	--	--	--
			23-448(245)	62-83	T	9,750	--	7.0 x 10^{-4}	--
27.	Union Beach 04/21-28/86 Union Beach Boro USGS	1,375 gal/min 144 hr sand 70 ft -- leaky confined	25-419(PW)	250-300	--	--	--	--	--
			25-420(PW)	235-285	--	--	--	--	--
			*25-207(4340)	247-277					
			*25-206(4320)	225-285	HJ	8,400	120	4.2 x 10^{-4}	6.5 x 10^{-5}

occurred, supplier of the test data, and the U.S. Geological Survey well number. The design characteristics include the rate of discharge, duration of the test, lithologic descriptions of the aquifer material, the mean thickness of the aquifer, final drawdown in the pumped well, type of confinement, the designation of pumped well or the distance of the observation wells from the pumped well (next to the well number), and the screen intervals. The method of analysis of water-level data for the aquifer tests is included in the row of data for each well. In some cases, data from more than one observation well were used to analyze an aquifer test. The estimated hydraulic properties include the transmissivity, lateral hydraulic conductivity, storage coefficient for the aquifer, and leakance of the confining unit(s).

Methods of Interpretation

Transmissivity, lateral hydraulic conductivity, storage coefficient, confining-unit leakance(s), and specific capacity were calculated from drawdown and recovery data from 12 multiple-well aquifer tests in the middle aquifer, and 15 multiple-well aquifer tests in the upper aquifer. These data were analyzed by one or more of the following methods: (1) Theis (Wenzel, 1942, p. 88-89), (2) Jacob (Cooper and Jacob, 1946), (3) Thiem or Distance Drawndown (Lohman, 1972, p. 11-13), (4) Hantush-Jacob (Hantush and Jacob, 1955), (5) Hantush (Modified) (Hantush, 1960), (6) Boulton (1954), and (7) finite-element method (FEM) (Reilly, 1984).

The Theis, Jacob, and Thiem methods were developed to analyze tests in confined aquifers assuming constant discharge of a well in a nonleaky aquifer. The Hantush-Jacob method was developed using the assumption that the confining units leak. The Hantush (modified) method assumes the aquifer is confined and that leakage to the aquifer is from storage within the confining units. The analytic assumptions, procedures, and numerical criteria for all interpretations except the finite-element method are found in Reed (1980), Kruseman and De Ridder (1970), and Lohman (1972). The graphical analysis for those aquifer tests, which were evaluated using methods 1-6, are included in figures 5-32 of appendix 1 to this report. Results of analysis using method 7 are presented in figures 33-39 of appendix 2 to this report.

Most of the tests were conducted in the confined parts of the middle and upper aquifers. The data from the tests were analyzed using one or more of the methods for confined aquifers: Theis, Jacob, or Thiem. However, six of these tests were found to have characteristics of a leaky confined aquifer, and were analyzed with the Hantush-Jacob, Hantush (Modified), or finite-element methods. Six tests in the upper aquifer were located over the unconfined part of the aquifer. Tests in the unconfined region did not appear to be greatly affected by delayed yield, or they did not satisfy the Boulton criteria. Therefore, these tests were analyzed using methods designated for confined aquifers (Kruseman and De Ridder, 1970, p.107; and Lohman, 1972, p.22) or the finite-element method.

The graphical methods of analysis (methods 1-6) result from analytic solutions to ground-water-flow equations. For method 2, the field values for drawdown in a well over time are plotted on semilogarithmic paper

(Lohman, 1972, p. 23). In method 3, a plot of the relation of drawdown to the distance from the pumped well is made (Lohman, 1972, p. 11).

Graphical analysis for methods 1 and 4-6 are based on type-curve matching. Lohman (1972) explains the procedures for using each of these methods. In graphical analysis, field values for drawdown versus time (or time divided by the squared distance of the observation well to pumping well) are plotted on log-log paper. Both aquifer transmissivity and storage coefficient can be calculated using these methods. Methods 4 and 5 also are used to determine the leakance of confining units.

Numerical simulation, using the finite-element model RADFLOW (Reilly, 1984), was used to analyze data from aquifer tests 8, 10, 13, and 20. This model is applicable to analysis of radial flow in confined and unconfined aquifer flow systems. All four aquifer tests were simulated using a variation of the same 273-node, 480-element grid (figure 33 in appendix 2). The simulated area was 30,000 feet in radius and extended from either the surface of the overlying confining unit for confined aquifers, or from the water table to the underlying confining unit for unconfined aquifers to the bottom confining unit. Aquifers and confining units are represented as horizontal, homogeneous layers of uniform thickness.

The thicknesses of the hydrogeologic units, the location of geologic contacts, and the hydraulic properties for final calibrated simulation of each site are presented in figure 34 in appendix 2. Initial estimates of the hydraulic properties were made from simple analytic solutions. A series of simulations was done for each site in which the hydraulic properties of the confining units and the aquifers were varied until a match with the field data was obtained. Although a formal sensitivity analysis was not made, several simulations were done in which one value was changed while others were held constant, and the effect on the system was noted. Comparing the simulated values to other known hydraulic-property values in the area suggest that the values of the aquifer properties obtained in this way are reasonable. The graphical representations of field data and the matched numerical simulations for those aquifer tests are included in appendix 2. A match was defined when the shape and magnitude of the simulated drawdown curve was similar to the field data. The assumptions of numerical modeling and restrictions for the numerical code are beyond the scope of this report and are presented by Reilly (1984).

Middle aquifer of the Potomac-Raritan-Magothy aquifer system

Hydraulic properties for the middle aquifer were calculated by the graphical methods of either Theis or Jacob for confined, radially isotropic aquifers for 10 of the aquifer tests; finite-element analysis was used for 2 aquifer tests. The method used for analysis of each test is indicated in table 4.

Upper aquifer of the Potomac-Raritan-Magothy aquifer system

Hydraulic properties from five aquifer tests in the confined and semi-confined areas of the upper aquifer were determined by the type-curve matching graphical methods of Theis; by the distance-drawdown analysis of Thiem; and by the straight-line method of Jacob. Four aquifer tests indicated the confinement of the upper aquifer was leaky. Data from these tests were analyzed using Hantush-Jacob, Hantush (Modified) or the finite-element method. Tests in the unconfined region did not appear to be greatly affected by delayed yield nor did they satisfy the criteria for the Boulton (1954) method of analysis for unconfined aquifers. Therefore, these tests were analyzed using methods designated for confined aquifers (Kruseman and De Ridder, 1970, p. 107; and Lohman, 1972, p.22). The six unconfined aquifer tests were analyzed using the type-curve methods of Theis, the straight-line methods of Jacob and Thiem, and the finite-element method. The method of analysis for each test is indicated in table 5.

Well-Acceptance Tests

Data

The four criteria used in selecting well-acceptance tests in both aquifers were: (1) outside diameter of screen at least 6 inches, (2) screen length at least 20 feet, (3) test duration at least equal to 8 hours, and (4) constant pumping rate. The first two criteria insured that only well-acceptance tests for major production wells would be selected. These high-volume wells affect larger areas of the aquifer, and thereby, minimize the effects of small-scale heterogeneities in the aquifer in the vicinity of the well. The third and fourth criteria, test duration and constant pumping, were imposed so that a maximum drawdown for a constant rate of withdrawal would be approached, and the conditions of steady flow would be approximated.

Summaries of well-acceptance-test data, which were selected using the above criteria, are presented in tables 6 and 7 for the middle and upper aquifers, respectively. The well number, latitude and longitude, screen diameter and length, and test date are included in each table. Test data include the duration of the test, the pump discharge rate, drawdown in the discharging well at the end of the test, the specific capacity, and the estimated lateral hydraulic conductivity computed from these data. The location of each test site is shown on plate 1 or 2.

Method of Interpretation

Various formulas for estimating hydraulic conductivity from well-acceptance-test data have been reported (Bedinger and Emmett, 1963; McClymonds and Franke, 1972). Bennett (1976) derived the following linear interpolating formula used in this report to estimate lateral hydraulic conductivity from data that include specific-capacity measurements:

$$K=1.1\ Q/(s \times l) \qquad (1)$$

where K is the lateral hydraulic conductivity, in feet per day (ft/d);
Q is the discharge, in cubic feet per day (ft^3/day);
s is the water-level drawdown, in feet (ft); and
l is the length of well screen, in feet (ft).

Table 6.--Summary of well-acceptance tests and estimated hydraulic conductivity for the middle aquifer of the Potomac-Raritan-Magothy aquifer system.

[in., inches; ft, feet; hr, hour; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; ft/d, feet per day]

USGS well number	Location		Screen		Well-acceptance-test data					Estimated hydraulic conductivity (ft/d)
	Latitude	Longitude	Diameter (in.)	Length (ft)	Date	Duration (hr)	Discharge (gal/min)	Drawdown (ft)	Specific capacity ((gal/min)/ft)	
23- 7	401755	743118	10	30	05/19/1964	8	590	209	3	20
23- 9	401800	743206	12	30	06/10/1950	55	1,200	22	55	385
23- 11	401818	742932	10	30	12/10/1956	8	644	147	4	31
23- 13	401841	743355	10	30	11/27/1954	8	400	92	4	31
23- 16	401842	743055	10	30	02/12/1973	24	473	52	9	64
23- 17	401843	743055	10	30	03/26/1963	28	560	228	3	17
23- 25	401902	742912	12	30	07/23/1964	8	785	47	17	118
23- 45	402426	742515	10	30	03/26/1969	8	60	5	12	85
23- 46	402427	742507	10	30	12/02/1968	8	60	5	12	85
23- 48	402431	742214	10	37	04/01/1931	8	620	50	12	71
23- 50	402432	742212	10	50	10/11/1963	8	1,012	27	37	159
23- 57	402441	742448	10	25	05/06/1954	16	600	35	17	145
23- 58	402448	742700	8	20	05/07/1975	24	302	13	23	245
23- 59	402456	742442	12	40	04/07/1955	8	1,067	36	30	157
23- 60	402459	742643	6	20	05/10/1952	24	70	20	4	37
23- 63	402501	742440	12	40	08/16/1951	8	1,000	21	48	253
23- 66	402516	742408	10	25	03/14/1954	15	600	30	20	169
23-146	402350	741834	10	45	05/07/1966	8	1,254	35	36	169
23-147	402350	741840	10	50	06/30/1966	8	1,265	44	29	122
23-176	402407	741924	6	42	05/23/1972	8	285	43	7	33
23-179	402436	742041	6	42	06/07/1972	8	363	6	61	305
23-196	402537	742020	12	60	02/12/1968	8	1,534	28	55	193
23-201	402614	741744	12	40	10/10/1956	24	1,227	22	56	295
23-202	402625	741611	8	21	02/01/1957	8	360	40	9	91
23-232	402023	742858	12	42	06/15/1961	8	708	30	24	119
23-236	402038	742345	8	30	05/13/1963	8	740	78	9	67
23-240	402051	742746	12	48	03/15/1961	8	708	46	15	68
23-289	402056	742937	20	30	05/21/1956	167	1,000	28	36	252
23-298	402129	742901	10	20	06/03/1965	8	614	43	14	151
23-300	402124	742824	12	40	09/24/1966	8	726	65	11	59
23-302	402138	742940	10	30	04/14/1955	9	465	79	6	42
23-303	402139	742820	10	30	06/12/1957	19	1,050	45	23	165
23-304	402143	742821	12	30	01/05/1962	8	785	60	13	92
23-305	402143	742821	8	20	03/14/1957	9	698	20	35	370
23-315	402204	743024	12	35	08/03/1971	12	1,200	64	19	113
23-320	402223	742824	10	20	11/25/1952	8	515	39	13	140
23-332	402319	742708	10	30	06/27/1958	9	650	52	13	88
23-352	402605	741958	18	55	07/12/1967	8	1,236	22	56	216
23-386	402701	741917	12	61	04/04/1930	8	1,071	23	47	162
23-401	402744	741628	18	34	06/09/1967	16	1,218	82	15	93
23-411	402822	741630	10	25	05/28/1947	8	800	40	20	169
23-430	402923	741651	12	30	10/13/1972	38	305	50	6	43
23-432	402557	742138	8	31	06/27/1975	8	542	20	27	185
23-434	402556	742141	17	25	10/01/1951	8	960	41	23	198
23-436	402557	742138	6	29	02/01/1968	8	250	18	14	101
23-437	402559	742142	17	36	05/02/1967	48	1,130	90	13	74
23-452	402401	742243	10	50	05/22/1947	24	1,400	32	44	185
23-453	402404	742235	12	20	01/21/1929	8	1,040	82	13	134
23-502	402432	742215	12	50	03/21/1978	10	1,001	50	20	85
23-551	402548	742155	12	53	03/01/1980	24	825	19	43	174
23-552	402018	743021	16	50	05/01/1979	8	1,536	18	85	361
23-554	402745	741645	12	73	04/21/1980	24	1,455	76	19	56
23-568	402410	742231	12	70	02/17/1983	8	1,413	36	39	119
25- 55	401744	742135	10	20	11/01/1963	24	400	70	6	61
25-153	402444	741010	12	55	04/20/1970	8	1,000	70	14	55
25-230	402004	741853	12	90	02/18/1972	8	1,200	30	40	94
25-231	402004	741855	12	80	06/01/1974	8	1,001	22	46	120
25-247	401902	741811	8	70	07/09/1964	8	805	56	14	43
25-249	401859	741809	8	69	06/17/1968	8	700	38	18	57
25-262	402102	741353	8	80	06/01/1966	8	450	34	13	35
25-283	402514	741450	12	46	12/29/1956	8	703	28	25	116
25-299	402604	741417	10	35	06/22/1965	8	1,007	68	15	90
25-320	402705	735959	10	40	09/01/1970	8	638	39	16	87
25-452	401857	741811	12	60	12/23/1980	8	1,200	33	36	128
25-466	402610	741351	12	50	07/29/1977	8	1,263	216	6	25
25-467	402436	741013	12	50	02/06/1979	8	1,002	66	15	64
25-503	401640	741722	12	108	06/12/1981	16	1,205	23	52	103

Table 7.--Summary of well-acceptance tests and estimated hydraulic conductivity for the upper aquifer of the Potomac-Raritan-Magothy aquifer system.

[in., inches; ft, feet; hr, hour; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; ft/d, feet per day]

USGS well number	Location		Screen		Well-acceptance-test data					Estimated hydraulic conductivity (ft/d)
	Latitude	Longitude	Diameter (in.)	Length (ft)	Date	Duration (hr)	Discharge (gal/min)	Drawdown (ft)	Specific capacity ((gal/min)/ft)	
23-5	401706	743033	8	20	06/01/1965	8	550	78	7	75
23-6	401727	743042	8	40	12/01/1973	60	403	23	18	93
23-18	401841	742905	12	40	10/24/1957	9	1,002	73	14	73
23-20	401848	742902	12	40	02/20/1968	8	950	31	31	162
23-21	401850	742901	12	40	09/29/1958	8	930	20	47	246
23-27	401906	742855	12	30	09/01/1964	8	771	47	16	116
23-34	401924	743015	10	24	09/24/1963	16	200	5	40	353
23-35	402010	742838	10	30	04/27/1956	144	524	36	15	103
23-108	402253	742247	18	20	11/01/1947	8	1,018	67	15	161
23-110	402308	742252	18	20	07/01/1942	12	1,215	55	22	234
23-135	402345	741838	12	58	12/02/1966	8	754	24	31	115
23-145	402348	742050	16	40	10/03/1972	8	602	58	10	55
23-148	402350	742232	17	20	05/11/1939	25	570	22	26	274
23-156	402356	742056	16	30	09/25/1972	8	907	59	15	109
23-192	402535	742014	16	20	01/02/1951	8	700	43	16	172
23-195	402537	742002	16	30	09/14/1965	24	550	25	22	155
23-227	402013	742834	12	30	10/09/1967	8	650	83	8	55
23-231	402019	742708	10	20	07/24/1965	8	401	57	7	74
23-237	402038	742755	10	44	11/15/1954	36	455	39	12	56
23-245	402202	742305	12	30	07/01/1963	8	500	13	38	272
23-345	402604	742003	12	20	10/11/1965	16	200	36	6	59
23-356	402614	741955	12	21	02/21/1959	48	662	44	15	152
23-361	402619	741958	12	23	10/01/1957	48	400	30	13	123
23-367	402624	741944	12	31	03/23/1960	48	402	31	13	89
23-403	402745	741631	18	58	01/26/1973	16	400	19	21	77
23-413	402824	741631	12	22	07/01/1965	8	380	36	11	102
23-443	402318	742333	6	20	07/28/1970	24	50	36	1	15
23-447	402329	742319	16	21	11/26/1956	8	421	29	15	146
23-451	402401	742243	18	20	08/26/1941	8	1,050	23	46	483
23-454	402404	742235	26	25	03/21/1929	8	845	45	19	159
23-490	401925	742620	12	38	10/24/1974	8	1,002	41	24	136
23-549	402745	741645	10	41	05/00/1980	24	430	44	10	50
23-567	401950	742750	16	81	07/07/1983	24	1,177	56	21	55
23-569	402738	741700	10	30	03/25/1982	24	503	27	19	132
23-570	402538	741950	16	20	11/08/1982	8	704	21	34	355
25-37	401607	741209	12	20	09/10/1963	168	660	199	3	35
25-56	401744	742135	10	21	05/07/1965	8	524	47	11	112
25-82	401412	741606	8	51	08/26/1957	8	510	28	18	76
25-91	401516	741530	8	53	08/21/1969	8	554	37	15	60
25-97	401625	741501	6	60	07/15/1966	24	200	168	1	4
25-98	401633	741726	12	54	04/17/1969	48	1,007	44	23	90
25-100	401635	741721	8	26	10/10/1948	8	625	35	18	145
25-101	401635	741721	12	99	06/01/1970	48	1,000	26	38	82
25-103	401646	741737	12	97	06/01/1974	48	1,001	30	33	73
25-111	402532	740932	10	40	04/05/1958	8	1,000	52	19	102
25-112	402537	740933	10	40	04/27/1960	8	1,000	40	25	132
25-113	402542	740850	6	32	08/01/1970	8	200	107	2	12
25-116	402400	735912	10	60	10/06/1961	8	700	154	5	16
25-121	402023	741100	10	30	01/11/1960	27	430	34	13	89
25-146	402327	741114	8	30	02/20/1962	24	157	56	3	20
25-154	402445	741019	10	30	02/27/1964	8	1,007	95	11	75
25-175	401246	741516	8	81	10/06/1969	8	564	70	8	21
25-177	401255	741147	8	20	08/31/1969	8	190	65	3	31
25-190	402621	740739	10	60	06/01/1945	8	1,023	56	18	64
25-191	402620	740741	12	60	05/27/1968	8	1,034	66	16	55
25-199	402542	741220	10	30	04/08/1964	18	430	128	3	24
25-202	402624	741145	10	63	12/01/1955	8	1,060	78	14	46
25-207	402626	741144	12	30	04/01/1970	8	1,254	47	27	188
25-210	401639	735936	12	50	05/01/1956	8	726	66	11	47
25-212	401232	742107	6	31	04/21/1956	8	403	26	16	106

Table 7.--Summary of well-acceptance tests and estimated hydraulic conductivity for the upper aquifer of the Potomac-Raritan-Magothy aquifer system. (cont.)

[in., inches; ft, feet; hr, hour; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; ft/d, feet per day]

USGS well number	Location		Screen		Well-acceptance-test data					Estimated hydraulic conductivity (ft/d)
	Latitude	Longitude	Diameter (in.)	Length (ft)	Date	Duration (hr)	Discharge (gal/min)	Drawdown (ft)	Specific capacity ((gal/min)/ft)	
25-244	401850	741459	12	70	05/01/1969	8	1,500	39	39	116
25-288	402349	741232	12	80	06/15/1967	10	1,300	89	15	39
25-293	402403	741245	12	38	06/12/1962	8	1,158	76	15	85
25-294	402428	741345	8	30	08/29/1944	10	580	35	17	117
25-295	402427	741348	8	30	05/25/1943	28	510	30	17	120
25-322	401157	742418	8	30	06/11/1956	72	350	110	3	22
25-332	401930	735841	8	33	05/04/1971	8	350	20	18	112
25-333	401214	740355	8	72	06/19/1956	8	1,001	32	31	92
25-345	401233	740100	8	40	06/28/1958	8	1,000	68	15	78
25-349	401322	740202	8	112	03/15/1956	8	1,000	77	13	25
25-358	402047	740420	8	50	05/25/1950	8	1,012	29	35	148
25-360	402054	740320	10	91	09/11/1975	24	1,100	77	14	33
25-362	401312	742802	8	30	12/14/1956	8	524	30	17	123
25-456	402640	740904	10	39	07/01/1976	8	608	62	10	53
25-462	402717	740816	8	50	06/04/1969	8	230	14	16	70
25-499	402353	741239	16	50	03/04/1981	24	1,200	128	9	40
25-501	401212	740358	12	75	08/04/1981	24	1,404	29	48	137
25-502	401420	741619	12	55	06/01/1981	36	1,205	68	18	68
25-513	402442	740242	10	42	10/07/1981	8	876	69	13	64
25-514	402641	740911	10	46	05/28/1983	8	524	19	28	127

This equation may be rewritten using discharge, Q, in gallons per minute (gal/min) and all other variables the same, as:

$$K=211.8\ Q/(s \times l). \qquad (2)$$

Estimates of lateral hydraulic conductivity from specific-capacity data are shown in tables 6 and 7.

RESULTS OF HYDRAULIC PROPERTIES FROM PREVIOUS INVESTIGATIONS

Barksdale and others (1943, p. 42, 68, 106) summarized hydraulic-conductivity values determined from permeability-test data from 7 cores from the upper aquifer collected in or near the outcrop of the Farrington Sand Member of the Raritan Formation, and from 12 cores from the upper aquifer taken in or near the outcrop of the Old Bridge Sand Member of the Magothy Formation. Laboratory analysis showed that the vertical hydraulic conductivities range from 28 to 468 ft/d (feet per day) for the middle aquifer, and 31 to 340 ft/d for the upper aquifer; specific yields for the middle and upper aquifer were about 0.32 and 0.40, respectively.

Barksdale and others (1943) reported that lateral hydraulic-conductivity values, calculated from aquifer tests in the middle aquifer at the Perth Amboy Water Department well field in Old Bridge Township, ranged from 161 to 201 ft/d. They also reported three aquifer tests in the upper aquifer that produced lateral hydraulic-conductivity values ranging from 134 to 201 ft/d. The methods of analysis for these tests are not described nor are the exact locations given in their report. Results of aquifer test 24, in this report, was originally published by Barksdale and others (1943).

Hardt and Jablonski (1959) reported a transmissivity value of 2,140 ft^2/d (feet squared per day), and a storage coefficient value of 2.3×10^{-4} for the middle aquifer at Woodbridge. Results from their report are included in this report (aquifer test 12). Additional unpublished data from their aquifer test were analyzed and are included in this report. Geraghty and Miller, Inc. (1976) reported a mean specific capacity of the middle aquifer of 29 (gal/min)/ft (gallons per minute per foot), and 20 (gal/min)/ft for the upper aquifer.

Farlekas (1979, p.12) analyzed data from an aquifer test of the middle aquifer performed by Leggette, Brashears, and Graham (1961) near Jamesburg in Middlesex County. At this site, Farlekas (1979) determined the transmissivity for the middle aquifer to be 13,400 ft^2/d , the storage coefficient to be 1.6×10^{-4}, and the lateral hydraulic conductivity to be 216 ft/d. Farlekas (1979, p.30-32) also published a transmissivity map, calculated from specific-capacity data, for the middle aquifer. The resultant transmissivity values range from 42 ft^2/d near the Raritan River to 16,800 ft^2/d in the vicinity of Marlboro Township.

RESULTS OF AQUIFER AND WELL-ACCEPTANCE TESTS

Hydraulic Properties of the Middle Aquifer of the Potomac-Raritan-Magothy Aquifer System

All of the aquifer tests occurred in the confined part of the aquifer; most of the tests occurred in Middlesex County, where depth to the aquifer is shallower. Results of the analyses indicate that the middle aquifer is a highly transmissive unit throughout most of the study area.

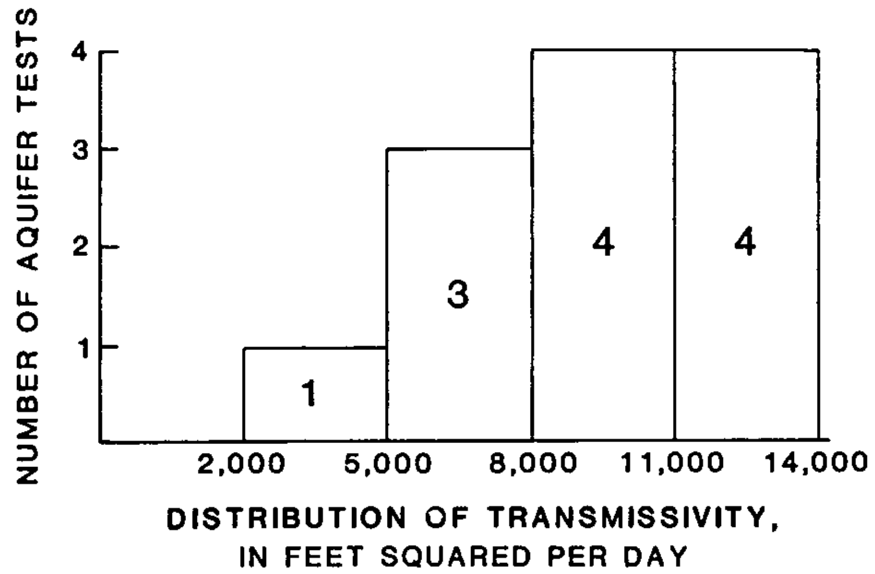
The transmissivities, determined from the 12 aquifer tests in the middle aquifer, range from 2,140 to 13,800 ft^2/d (table 4). Lower transmissivity values tend to prevail in the northern half of the study area, in Sayreville Borough (test 1 and 6), Old Bridge Township (test 9) and Woodbridge Township (test 12), probably because the aquifer is thinner in these areas. If these four northernmost aquifer tests are not considered, the range in transmissivity is from 9,400 to 13,800 ft^2/d. Figure 3(a) includes a histogram of the mean transmissivity values from each aquifer test in the middle aquifer.

Lateral hydraulic conductivities of the middle aquifer determined from aquifer tests range from 36 to 200 ft/d (table 4); whereas the range of hydraulic conductivities from well-acceptance tests is slightly larger but of the same orders of magnitude--17 to 385 ft/d (table 6). These values of hydraulic conductivity are consistent with aquifers composed of clean sands, and are consistent with the lithologic description of the aquifer material at each aquifer-test site. Figure 4(a) is a histogram of lateral hydraulic conductivities determined from the well-acceptance-test data for the middle aquifer.

Some of the variation in the hydraulic conductivities is due to the randomness of this aquifer property in the region and to the accuracy of the well-acceptance-test method of calculating hydraulic conductivity. Hydraulic-conductivity values from both aquifer tests and well-acceptance tests were divided into two categories; low (less than or equal to 100 ft/d) and high (greater than 100 ft/d). Low hydraulic-conductivity values were scattered throughout the study area; however, high values of hydraulic conductivity were concentrated near the outcrop of the Farrington Sand Member of the Raritan Formation of the middle aquifer. The range of hydraulic-conductivity values for the middle aquifer, within approximately 4 miles of the outcrop of the Farrington Sand Member, is from 20 to 385 ft/d; the range downdip from this area is from 15 to 169 ft/d.

Storage coefficients were derived only from the aquifer-test analyses. The storage coefficients for the middle aquifer range from 2.6×10^{-5} to 3.4×10^{-3}. Errors in the estimated storage coefficient may be introduced if the screened intervals for the pumped well are small in comparison to the aquifer thickness and if the aquifer contains semipermeable units that retard the vertical movement of water. If data from wells that are screened across a large part of an aquifer are considered, the effects of semipermeable units on this determination are minimized (Bentley, 1977). For these reasons, the best estimates of storage coefficient were from results for six of seven aquifer tests (aquifer tests 1, 2, 5, 8, 9, 11) where the well screen in the pumping well spans more than 40 percent of the

(a) Middle aquifer



(b) Upper aquifer

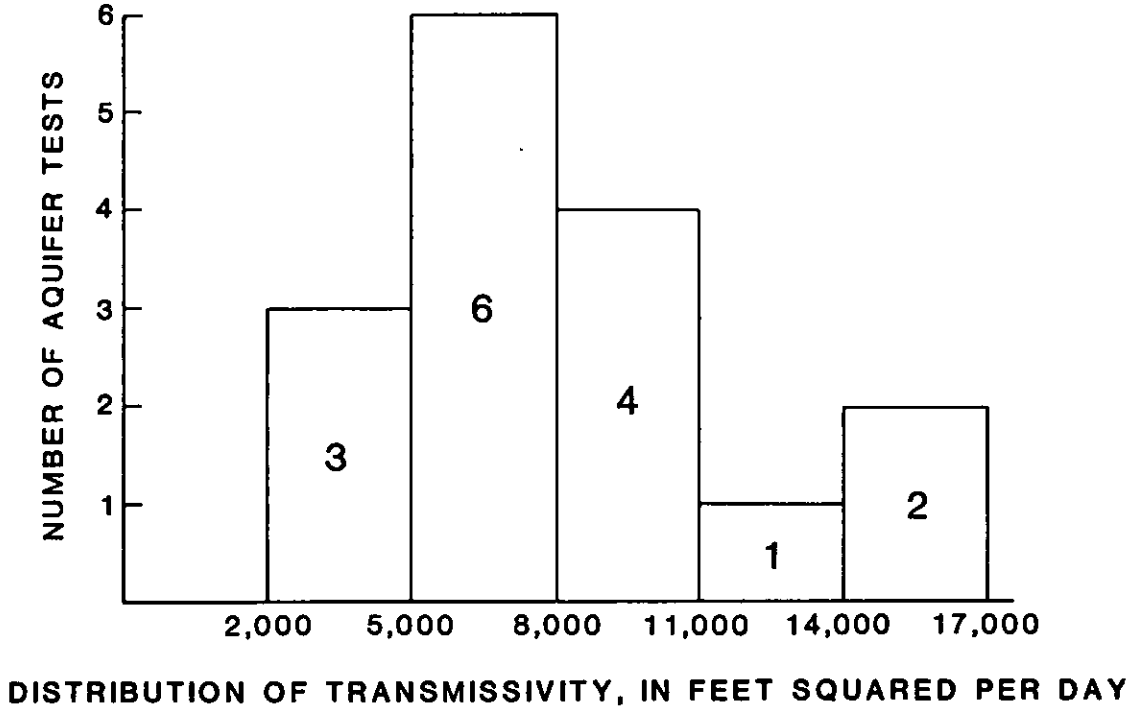
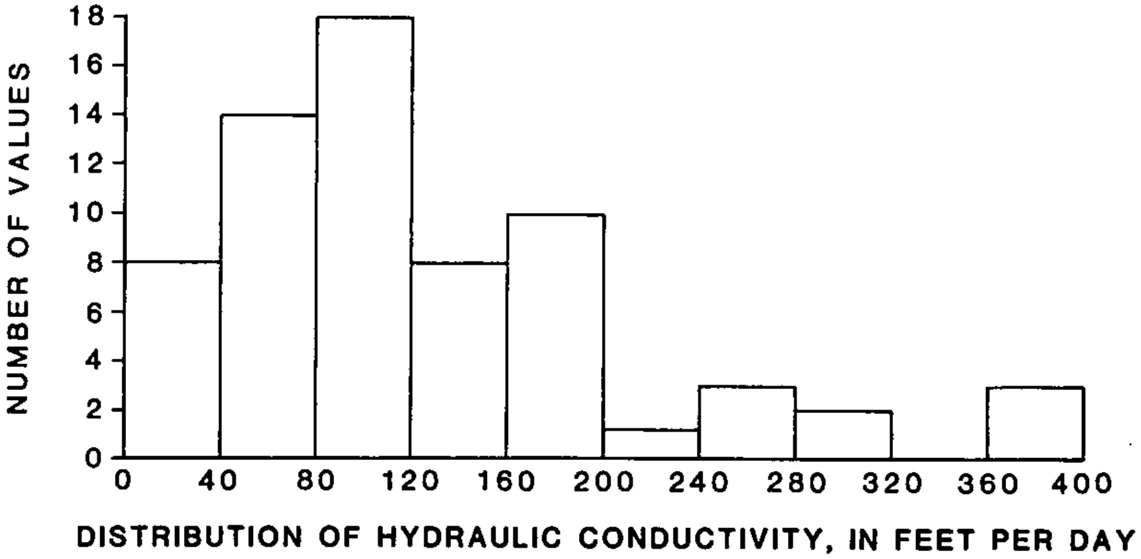


Figure 3.--Histograms of mean transmissivities for aquifer tests in the middle and upper aquifers of the Potomac-Raritan-Magothy aquifer system.

(a) Middle aquifer



(b) Upper aquifer

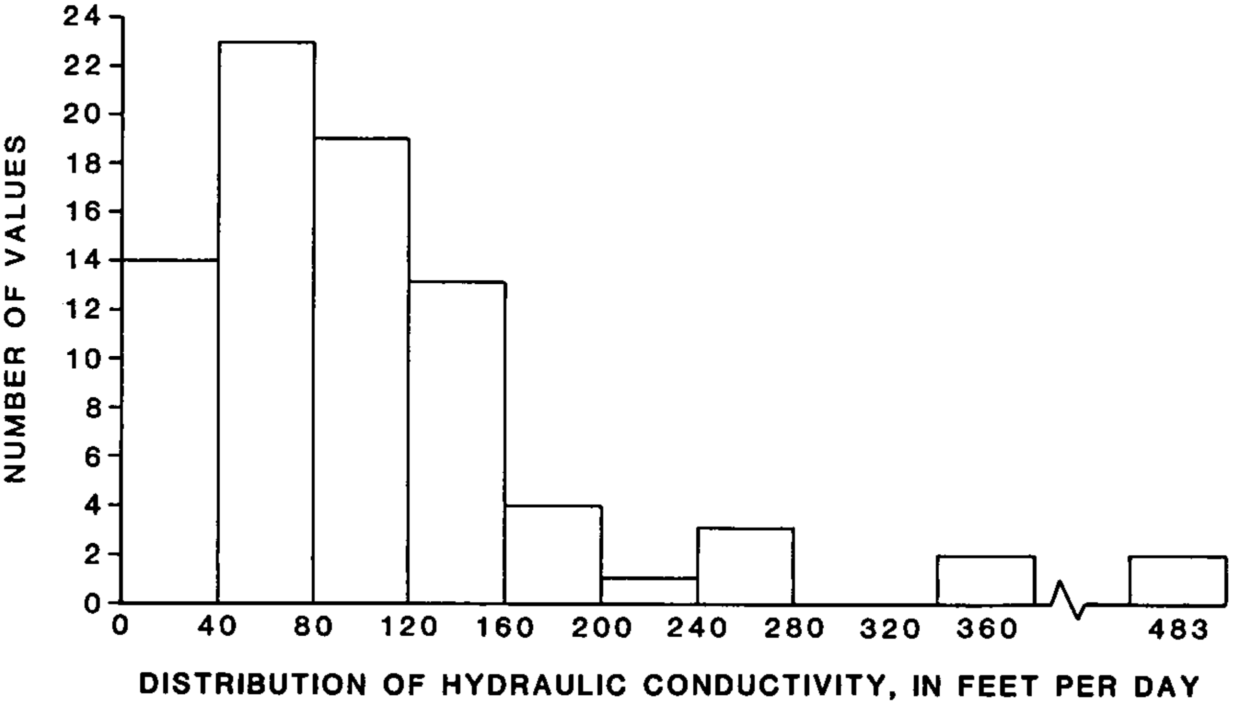


Figure 4.--Histograms of lateral hydraulic conductivities determined from well-acceptance tests for the middle and upper aquifers of the Potomac-Raritan-Magothy aquifer system.

aquifer thickness. The range of storage coefficients for these tests is from 4.2×10^{-5} to 3.0×10^{-4}.

The analyses of the aquifer tests in the middle aquifer indicate that the confining units are relatively impermeable; however, leakage from the confining units was observed to affect drawdowns at three test locations (tests 8, 10, and 12). It is assumed in this analysis that leakage from the basal fire clay member (table 1) and bedrock is negligible. If so, leakage into the middle aquifer is from the overlying confining unit. The results of tests 8, 10, and 12, indicate a range of leakance from 7.0×10^{-4} 1/d (leakance in feet per day per foot) to 2.3×10^{-3} 1/d for this confining unit.

Hydraulic Properties of the Upper Aquifer of the Potomac-Raritan-Magothy Aquifer System

Aquifer tests in the upper aquifer were located in both confined and unconfined areas, and they were more broadly distributed throughout Monmouth County than the aquifer tests for the middle aquifer. This reflects the greater use of the water resources of the upper aquifer in the downdip part of the aquifer system (Vowinkel, 1984).

The transmissivity values for the upper aquifer range from 1,760 to 19,400 ft^2/d. A histogram of the mean transmissivities for aquifer tests is presented in figure 3(b). Transmissivities for the confined, semiconfined, and leaky-confined areas of the aquifer range from 4,010 to 15,450 ft^2/d. Of these, the six aquifer tests of the deepest part of the system (aquifer tests 16, 17, 19, 21, 22, 27) range in transmissivity values from 5,400 to 8,420 ft^2/d.

Transmissivities in the unconfined part of the upper aquifer range from 1,760 to 19,400 ft^2/d. Transmissivities for the three northernmost tests in the unconfined aquifer (aquifer tests 13, 18, and 23) range from 1,760 to 5,820 ft^2/d. The lower transmissivity values for these tests are likely due to the thinness of the aquifer in the northern part of the study area. The remaining transmissivities in the unconfined area range from 9,500 to 19,400 ft^2/d. Based on the interpretation of well logs, the upper aquifer is believed to be semiconfined at the site of aquifer tests 14 and 15, although the test sites are in the outcrop area.

The hydraulic conductivity from aquifer tests of the upper aquifer ranges from 26 to 329 ft/d; for well-acceptance tests, the values range from 4 to 483 ft/d (table 7). A histogram of hydraulic-conductivities determined from well-acceptance tests is shown in figure 4(b). The same distribution pattern of hydraulic conductivities observed in the middle aquifer is indicated in the upper aquifer. Low values (less than or equal to 100 ft/d) were scattered throughout the study area, whereas high values (greater than 100 ft/d) were concentrated in or near the outcrop of the Old Bridge Sand Member of the Magothy Formation.

The estimated range of storage coefficients in the confined, semiconfined, and leaky-confined areas of the upper aquifer range from 1.0×10^{-5} to 1.8×10^{-3}. This result derives from eight of the nine aquifer tests (tests 15, 16, 17, 19, 20, 21, 22, and 27). Test 14 had a value above this range (1.4×10^{-1}), which is closer to properties of an unconfined system. Lithologic interpretation of logs at this site, and proximity to the general outcrop region for the aquifer, suggest that the system is semiconfined at the site of test 14.

Analysis of drawdown data from three of five aquifer tests in the unconfined part of the aquifer (tests 13, 18, and 24) gave storage coefficients representative of unconfined aquifers, ranging from 3.7×10^{-3} to 5.7×10^{-2}. A storage-coefficient value below this range was calculated for test 23 (4.0×10^{-5}) in which the well screen penetrated only 11 percent of the saturated aquifer thickness. As discussed in the section on the results of analysis for the middle aquifer, where the screen length is such a small fraction of the aquifer thickness, clay layers within the aquifer can limit the migration of water to the screen causing a low value for storage coefficient (Bentley, 1977). Test 26, which was located near the edge of the unconfined area of the upper aquifer in the outcrop of the Old Bridge Sand Member, had a low storage coefficient (7.0×10^{-4}), which may indicate some effects of confining units at the site.

Leakage across the confining units was observed from the stresses caused by the test pumping at four locations. Because of the position of the upper aquifer between two confining units, leakage can occur through both the overlying and underlying confining units. Of the five tests in the deepest part of the system (aquifer tests 16, 19, 21, 22, and 27) leakage was observed at two, tests 19 and 27. Leakage at test 20, in the shallower part of the aquifer, was interpreted to come from both the overlying confining unit and the underlying confining unit. Test 10, in proximity to test 20, also indicates that the confining unit between the middle and upper aquifers is leaky in this part of the study area. The areal lithology as interpreted from lithologic logs indicates that this confining unit is thin or sandy in part of the aquifer system in the vicinity of Jamesburg Borough, South Brunswick Township, and the northwestern part of the Hightstown Borough area. The leakage observed during test 17 was likely to be predominantly through the overlying confining unit. Lithologic and geophysical logs at the site of test 17 show that the underlying confining unit between the middle and upper aquifer is intact. Test 7, which was a test of the middle aquifer near test 17, showed that the confining unit between the middle and upper aquifers was relatively impermeable to the imposed stresses during the aquifer test. Leakage to the upper aquifer is represented in table 5, either as combined leakance for the intervening confining units, where analytic methods of analysis were used, or as separate leakances from the overlying or underlying confining units where numerical methods of analysis were used.

SUMMARY

Transmissivities, lateral hydraulic conductivities, storage coefficients, and leakances were determined from 27 aquifer tests, and lateral hydraulic conductivities were determined from 147 well-acceptance tests for the middle and upper aquifers of the Potomac-Raritan-Magothy aquifer system in the northern Coastal Plain of New Jersey. Both aquifers are more uniform in hydraulic properties in the deeper confined system to the south and southeast. More variation in hydraulic properties was found in and near the unconfined parts of both aquifers.

Both the middle and upper aquifers are unconfined in the outcrop areas in the northwest part of the study area. Southeast of the outcrop areas, the aquifers become semiconfined and then confined. The confining unit between the middle and upper aquifers is thin or sandy in the southwestern part of the study area, and vertical leakage may occur between the aquifers in that area. Both aquifers are highly transmissive on the regional scale, and have hydraulic conductivities representative of clean sands.

Based on 12 aquifer tests in the confined area of the middle aquifer, the transmissivity ranges from 2,140 to 13,800 ft^2/d. The lowest transmissivities generally are in the thinner part of the aquifer to the north. Lateral hydraulic conductivities of the middle aquifer calculated from aquifer tests and well-acceptance tests, range from 17 to 385 ft/d. Greater variation in lateral hydraulic conductivity for the middle aquifer appears in or near the unconfined part of the aquifer. The range of storage coefficient values for the middle aquifer is 2.6×10^{-5} to 3.4×10^{-3}. The confining units are relatively impermeable; however, leakance was observed to occur in three aquifer tests.

Fifteen aquifer tests are reported for the unconfined and confined parts of the upper aquifer. Transmissivities for the upper aquifer range from 1,760 to 19,400 ft^2/d. Lateral hydraulic conductivities from aquifer and well-acceptance tests for the upper aquifer range from 4 to 483 ft/d. Storage coefficients from three aquifer tests in the unconfined region range from 3.7×10^{-3} to 5.7×10^{-2}, which approaches estimated storage coefficients of unconfined aquifers. The effects of partial confinement on two other tests in the unconfined region produced storage coefficients below this range. Transmissivities of the confined part of the aquifer range from 4,010 to 15,450 ft^2/d. The range of storage coefficients is estimated to be from 1.0×10^{-5} to 1.8×10^{-3}. The confining units are relatively impermeable, although leakance values were determined at two of five sites in the deeper confined system. Greater leakage between the middle and upper aquifers is likely to occur in the southwestern part of the study area near its outcrop, where the confining unit between the middle and upper aquifers is thin or sandy.

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GLOSSARY

ANISOTROPY: That condition in which significant properties vary with direction.

AQUIFER: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs.

AQUIFER TEST: A controlled field experiment wherein the effect of pumping a well is measured in the pumped well and in observation wells for the purpose of determining hydraulic properties of an aquifer.

BEDROCK: The solid rock, commonly called "ledge", that underlies gravel, soil, or other superficial material.

CONFINED AQUIFER: An aquifer in which ground water is under greater than atmospheric pressure. The static-water level in a well in a confined aquifer will rise above the top of the aquifer.

DRAWDOWN: The decline of the water level in a well after pumping starts. It is the difference between the water level in a well after pumping starts and the static water level.

HETEROGENEITY: Synonomous with nonuniformity. A material is heterogeneous if its hydrologic properties vary with position within it.

HYDRAULIC CONDUCTIVITY: The volume of water at the existing kinematic viscosity that will move in unit time under unit hydraulic gradient through a unit area measured at right angles to the direction of flow, expressed herein in units of feet per day.

ISOTROPY: That condition in which significant properties are independent of direction.

LEAKANCE: The ratio of the vertical conductivity and thickness of a confining unit. Units of 1 over day.

LITHOLOGIC LOG: Description of the geologic material collected during the sampling of test wells.

RECOVERY: The rise of the water level in a well after pumping has stopped. It is the difference between the water level in a well after pumping stops and the water level as it would have been if pumping had continued at the same rate.

SATURATED THICKNESS: The thickness of an aquifer below the water table. As measured for the sedimentary aquifers in this report, it is the vertical distance between the water table and the lower confining unit in the unconfined areas of the aquifers; in the confined areas, it is the vertical distance between the confining units of an aquifer.

SPECIFIC CAPACITY: The rate of discharge of water from the well divided by the drawdown of water level in the pumped well, expressed herein in units of gallons per minute per foot per unit of time.

SPECIFIC DISCHARGE (FOR GROUND WATER): The rate of discharge of ground water per unit area measured at right angles to the direction of flow, expressed in units of feet per day.

SPECIFIC YIELD: Ratio of the volume of water a fully saturated rock or unconsolidated material will yield by gravity drainage, given sufficient time, to the total volume of rock or unconsolidated material. Expressed as a dimensionless unit.

STEADY FLOW: The flow that occurs if at every point of a flow system the specific discharge has the same magnitude and direction over time.

STORAGE COEFFICIENT: Volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer the storage coefficient is approximately equal to the specific yield. Expressed as a dimensionless unit.

TRANSMISSIVITY: Rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of aquifer under unit hydraulic gradient. It is equal to the product of hydraulic conductivity and saturated thickness of the aquifer, expressed herein in units of square feet per day.

UNCONFINED AQUIFER (WATER-TABLE): One in which the upper surface of the saturated zone, the water table, is at atmospheric pressure and is free to rise and fall.

WATER TABLE: The upper surface of the saturated zone.

WELL-ACCEPTANCE TEST: A controlled test by an installed pump to determine the productivity of a well expressed as its specific capacity.

APPENDIX I

GRAPHS SHOWING WATER-LEVEL DATA FROM AQUIFER TESTS

Data are included in figures 5-32 for documentation purposes and for reference by the reader. The methods for interpreting these data are summarized in the text. Descriptors and type curves, which are used in the graphical analyses, also are included in each figure. Descriptors and interpretation procedures are as documented in the cited references, and are compiled in Lohman (1972).

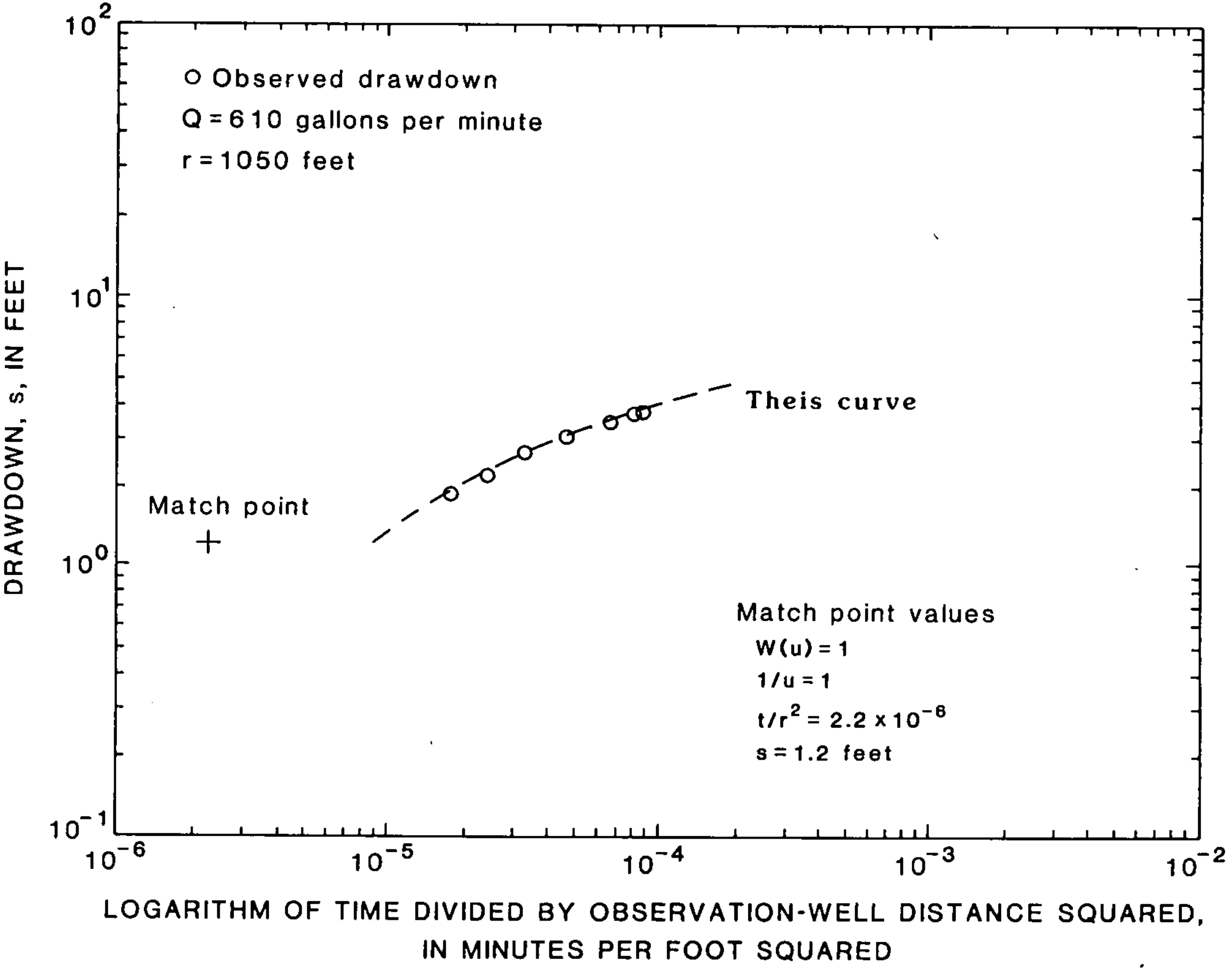


Figure 5.--Drawdown in observation well 23-392 for aquifer test 1.

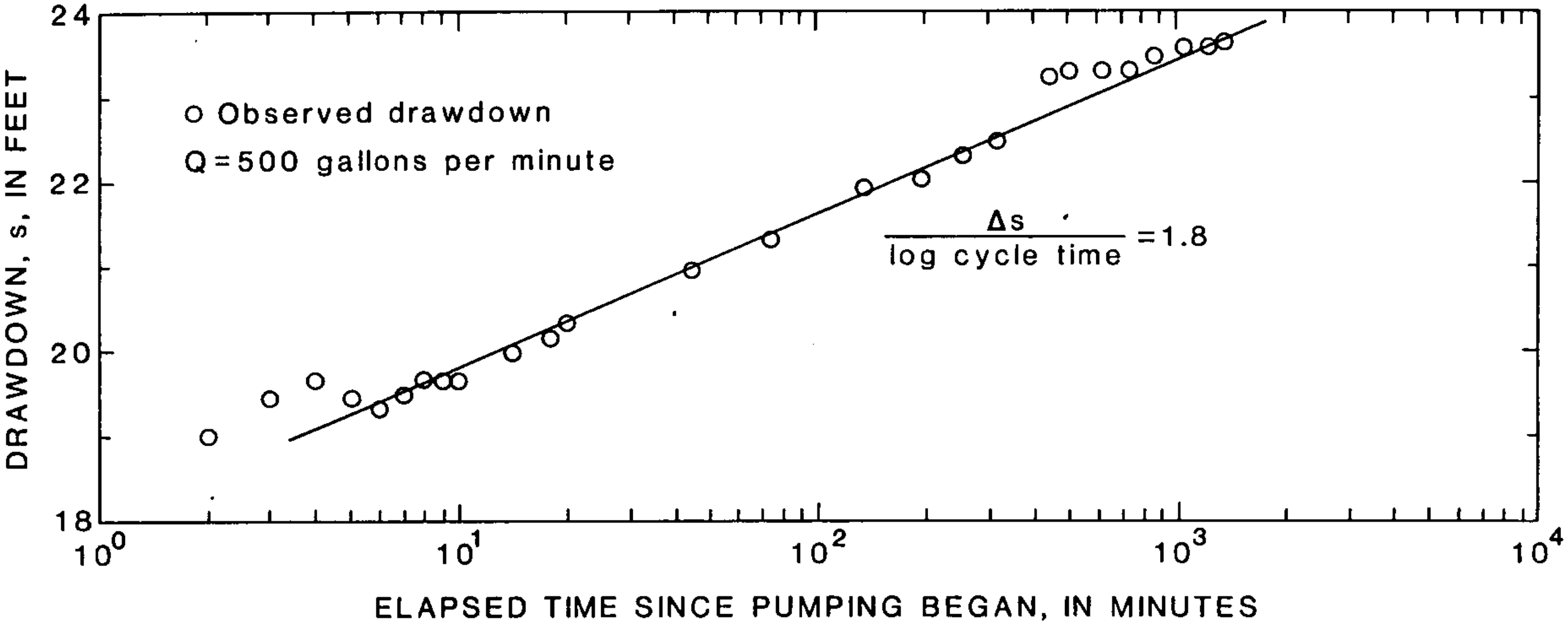


Figure 6.--Drawdown in pumping well 23-42 for aquifer test 2.

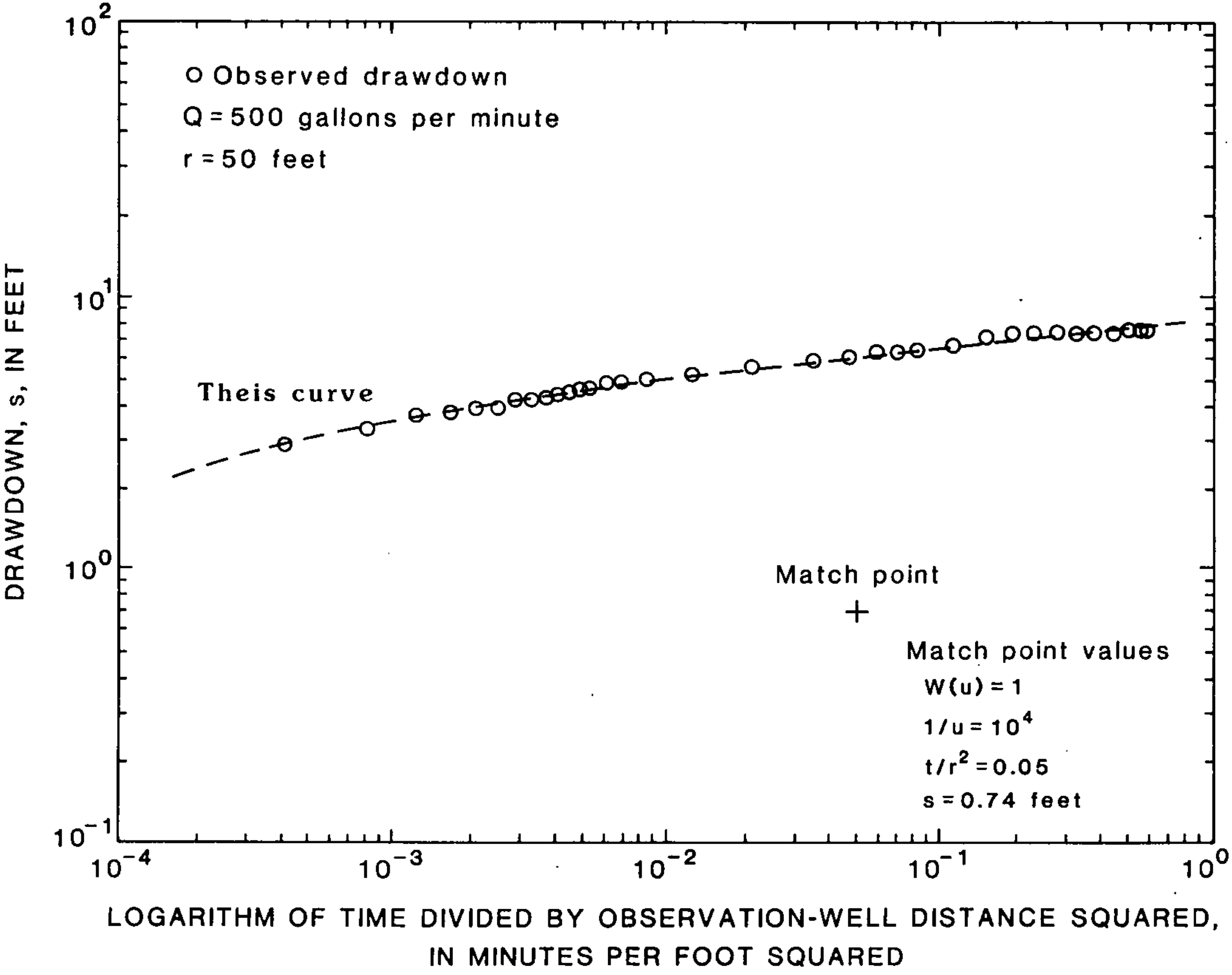


Figure 7.--Drawdown in observation well 23-43 for aquifer test 2.

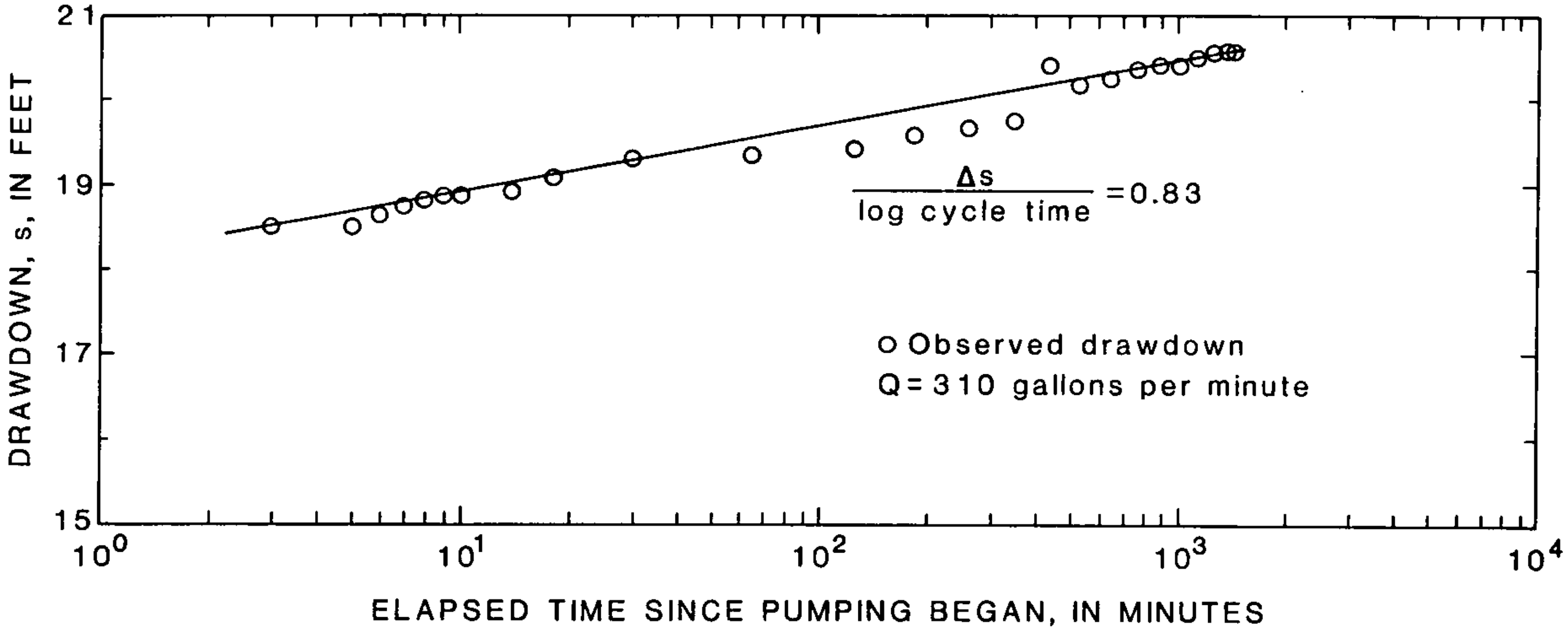


Figure 8.--Drawdown in pumping well 23-40 for aquifer test 3.

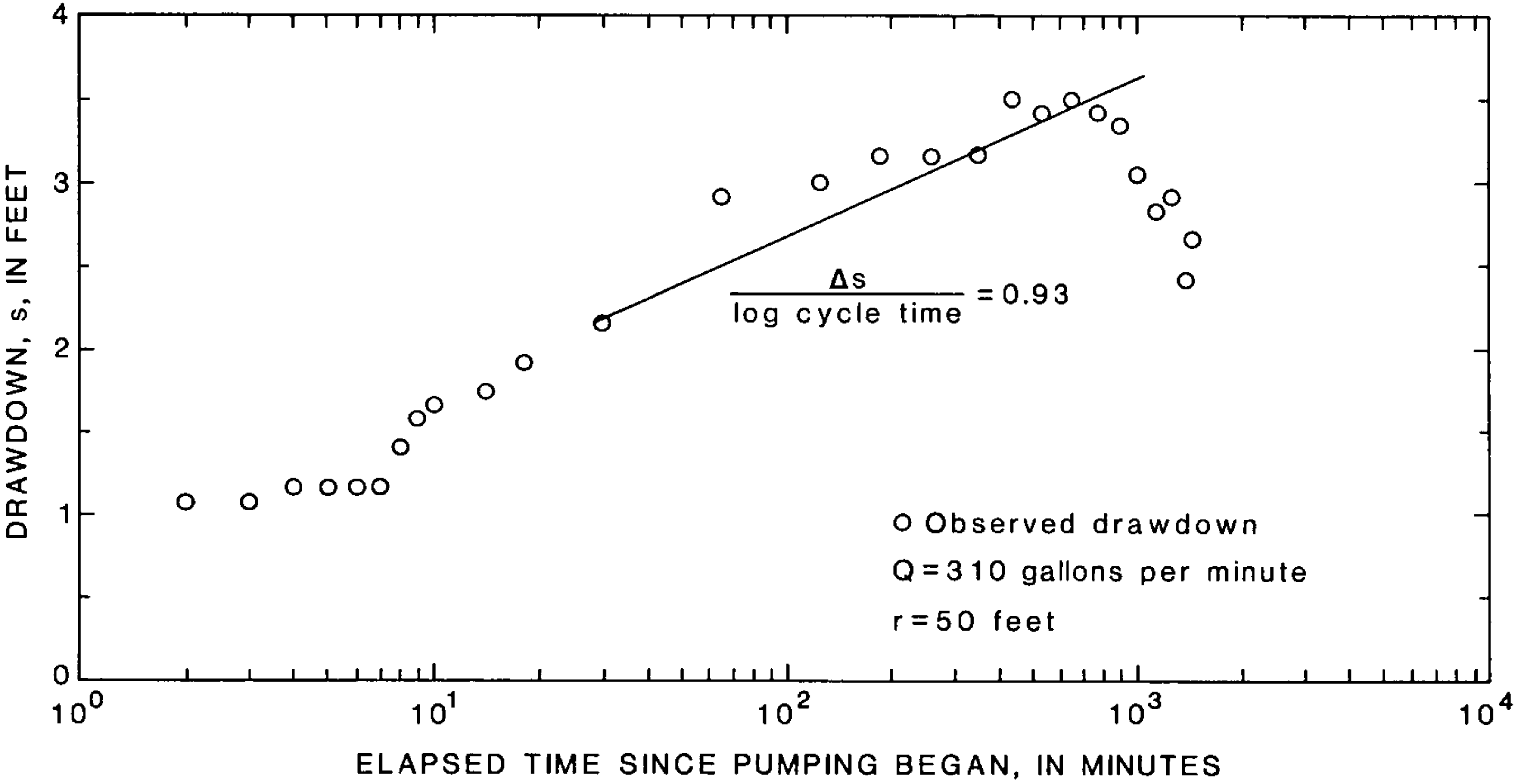


Figure 9.--Recovery in observation well 23-41 for aquifer test 3.

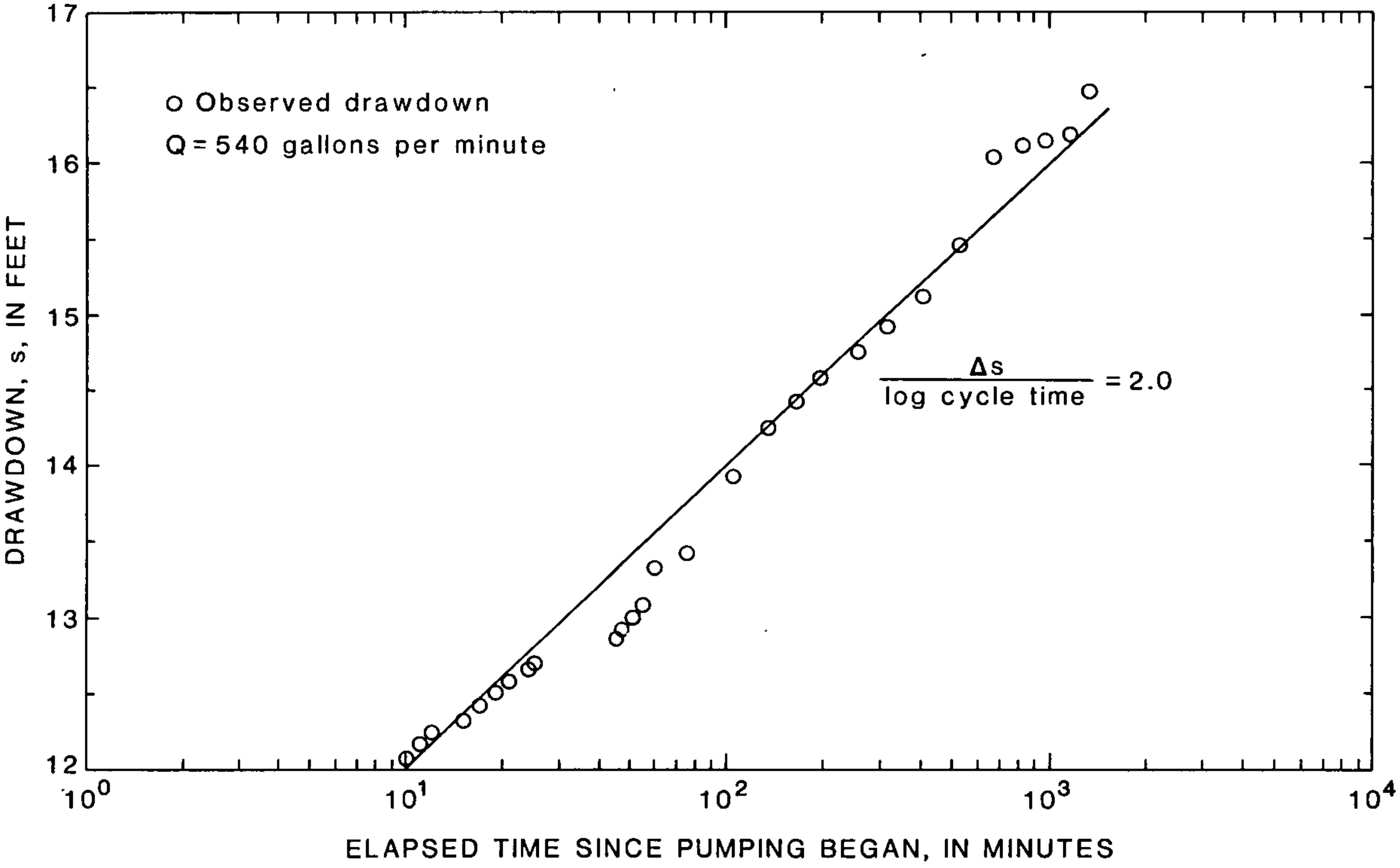


Figure 10.--Drawdown in pumping well 23-44 for aquifer test 4.

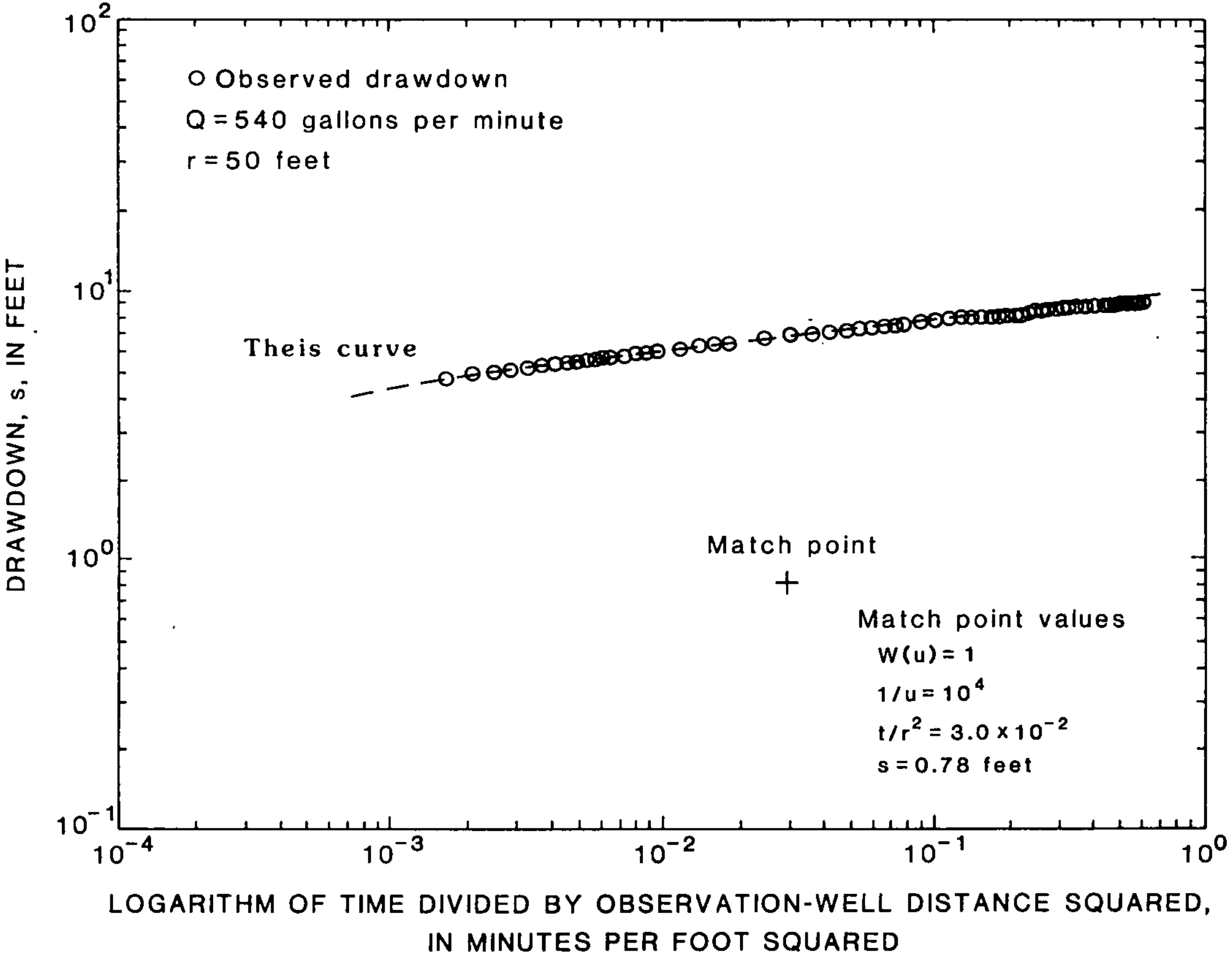


Figure 11.--Drawdown in observation well 23-789 for aquifer test 4.

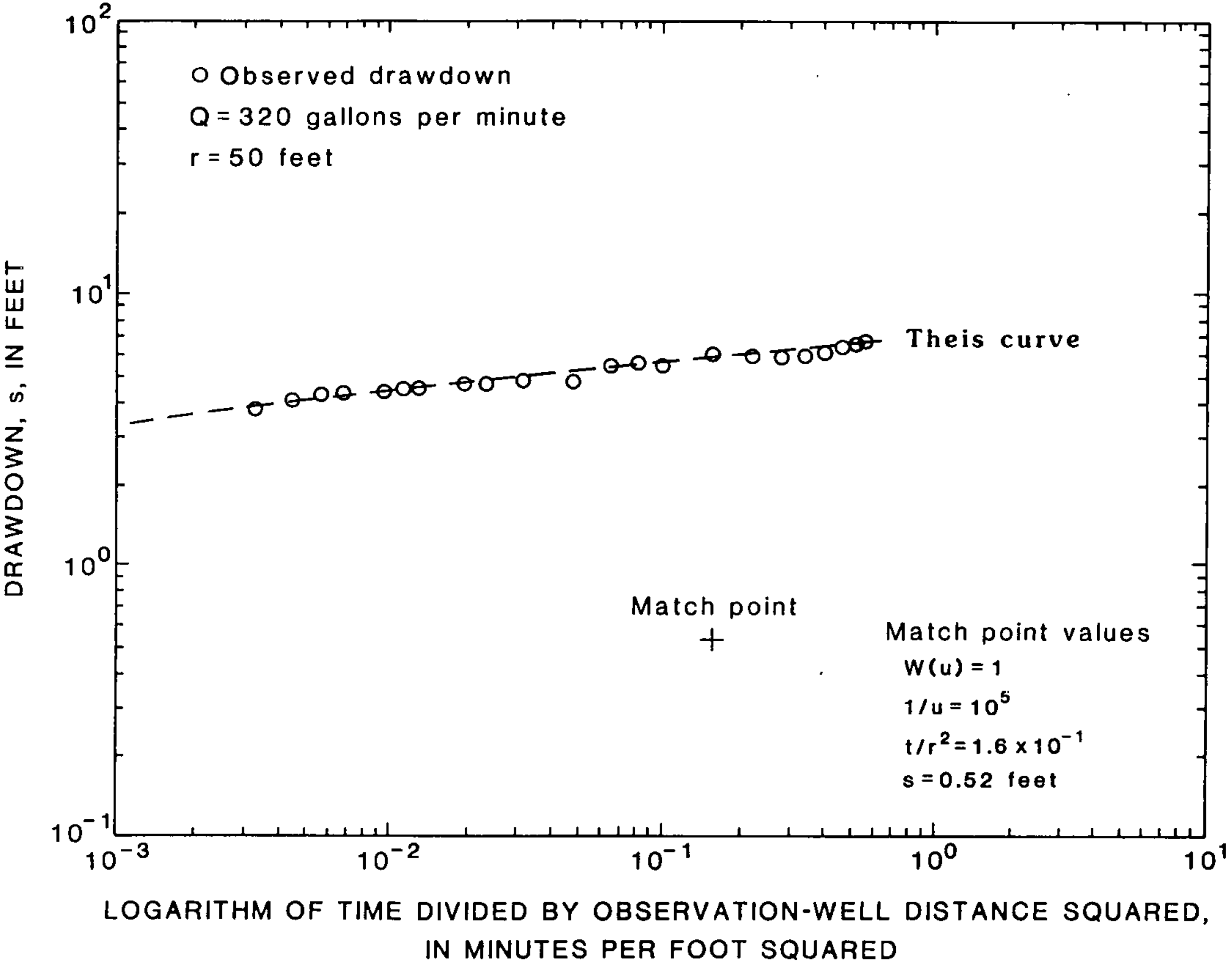


Figure 12.--Drawdown in observation well 23-788 for aquifer test 5.

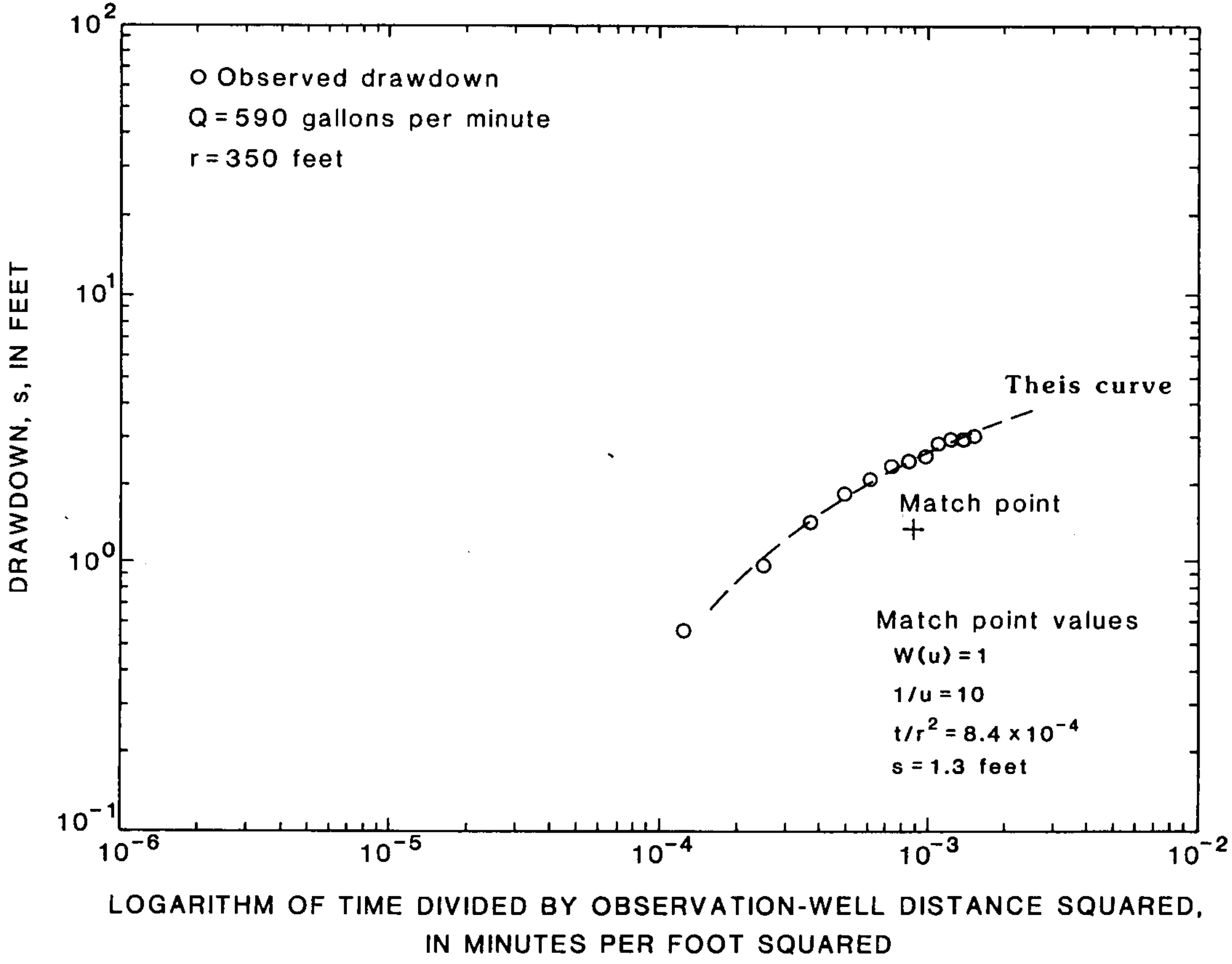


Figure 13.--Drawdown in observation well 23-384 for aquifer test 6.

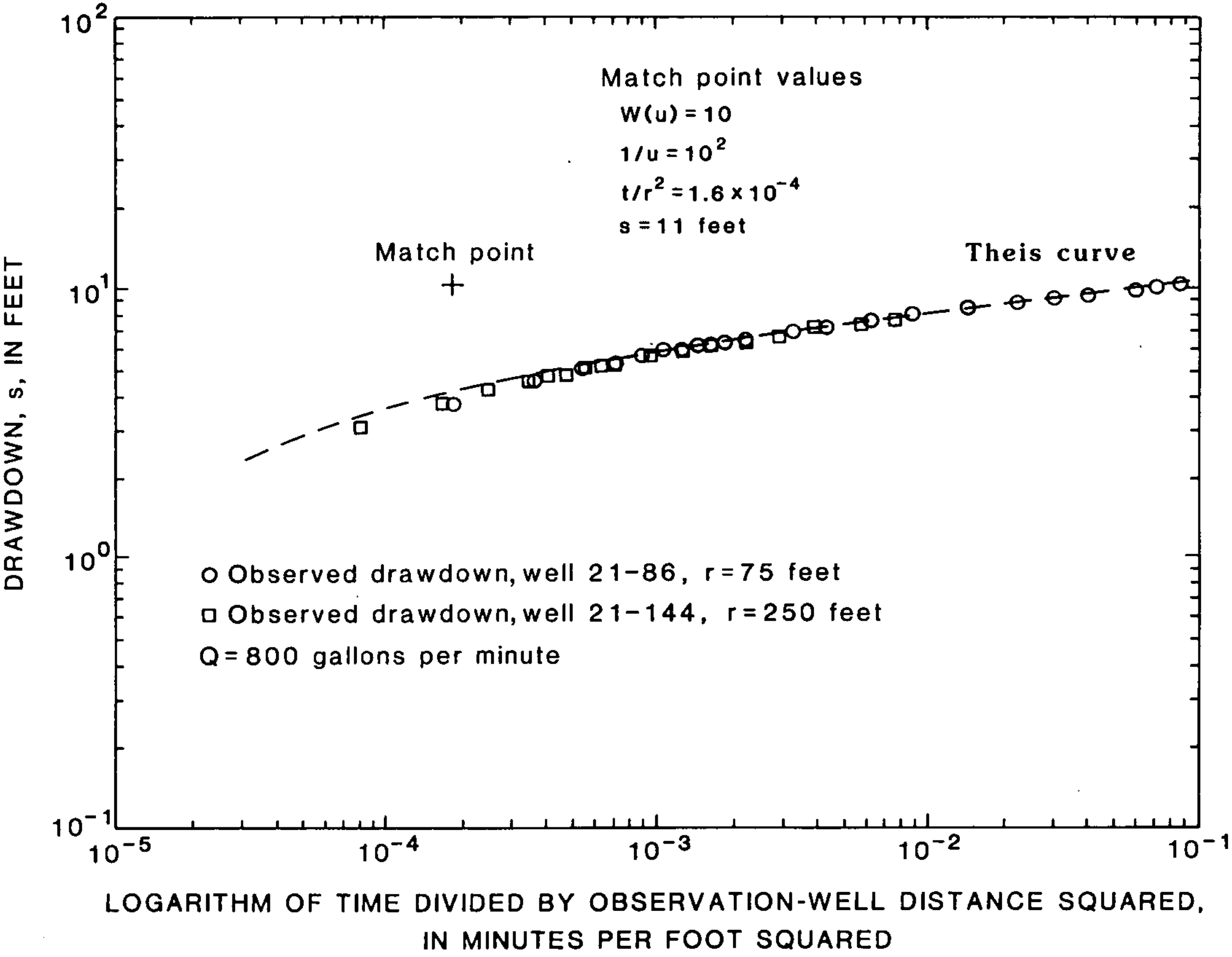


Figure 14.--Drawdown in observation wells 21-86 and 21-144 for aquifer test 7.

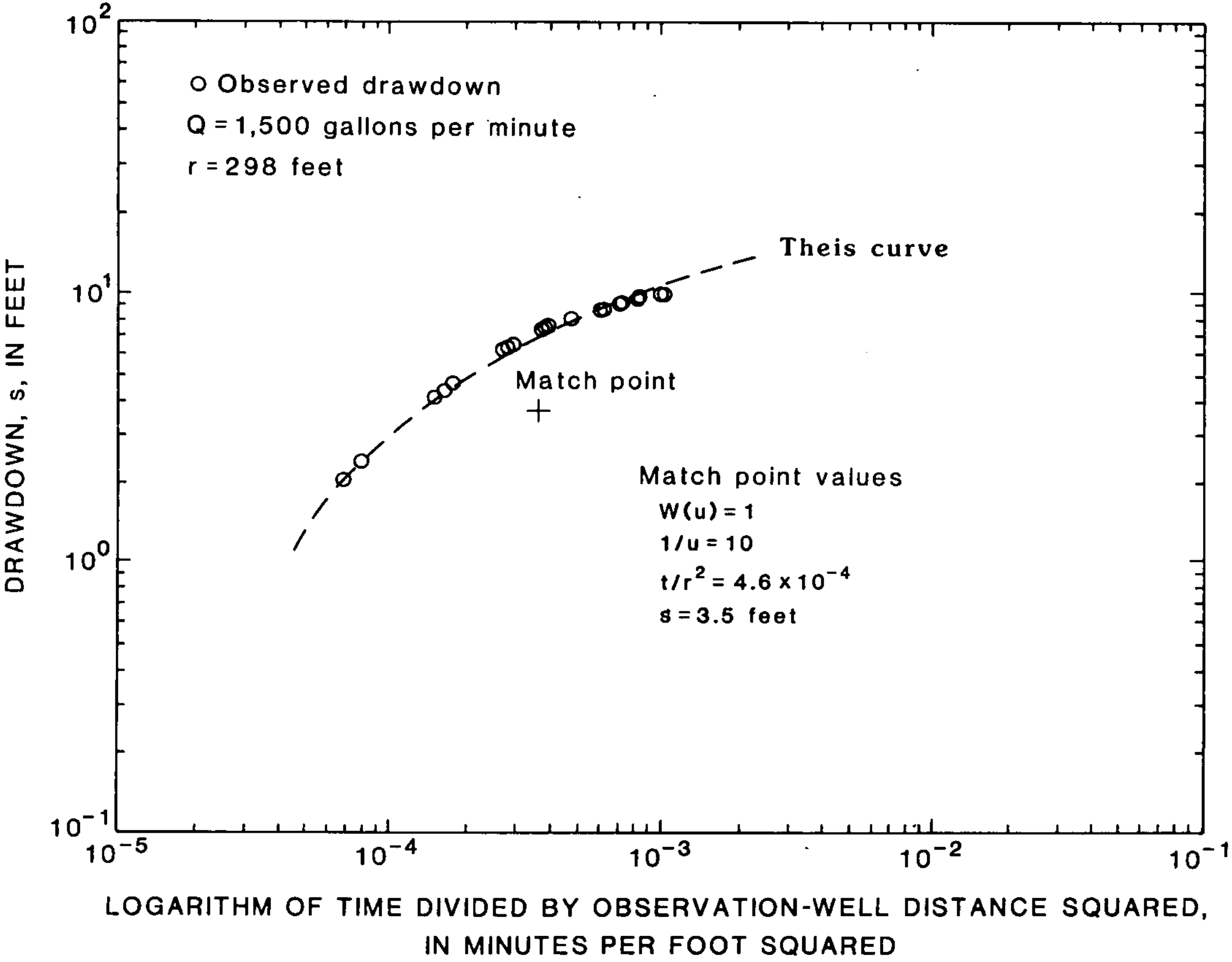


Figure 15.--Drawdown in observation well 23-197 for aquifer test 9.

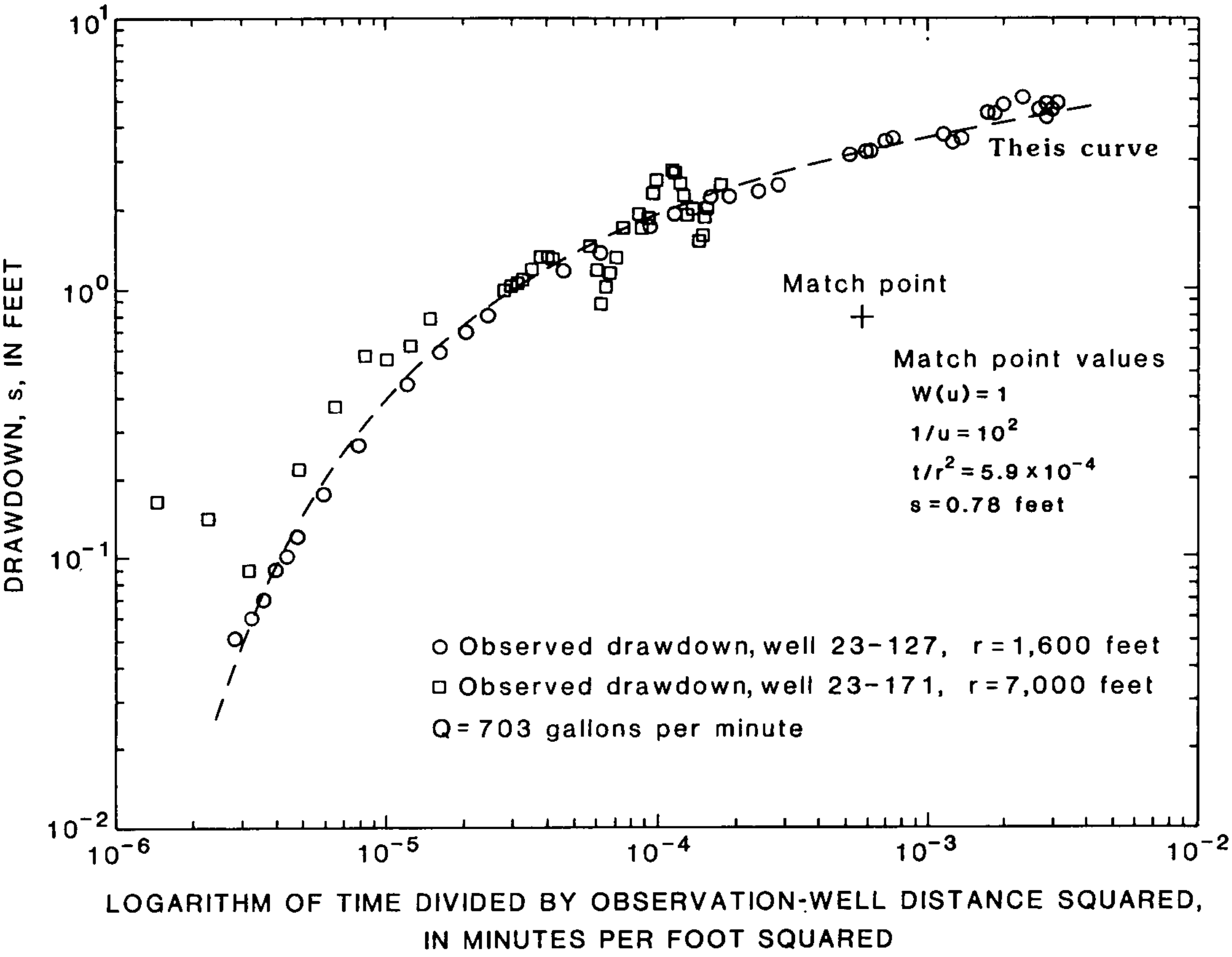


Figure 16.--Drawdown in observation wells 23-127 and 23-171 for aquifer test 11.

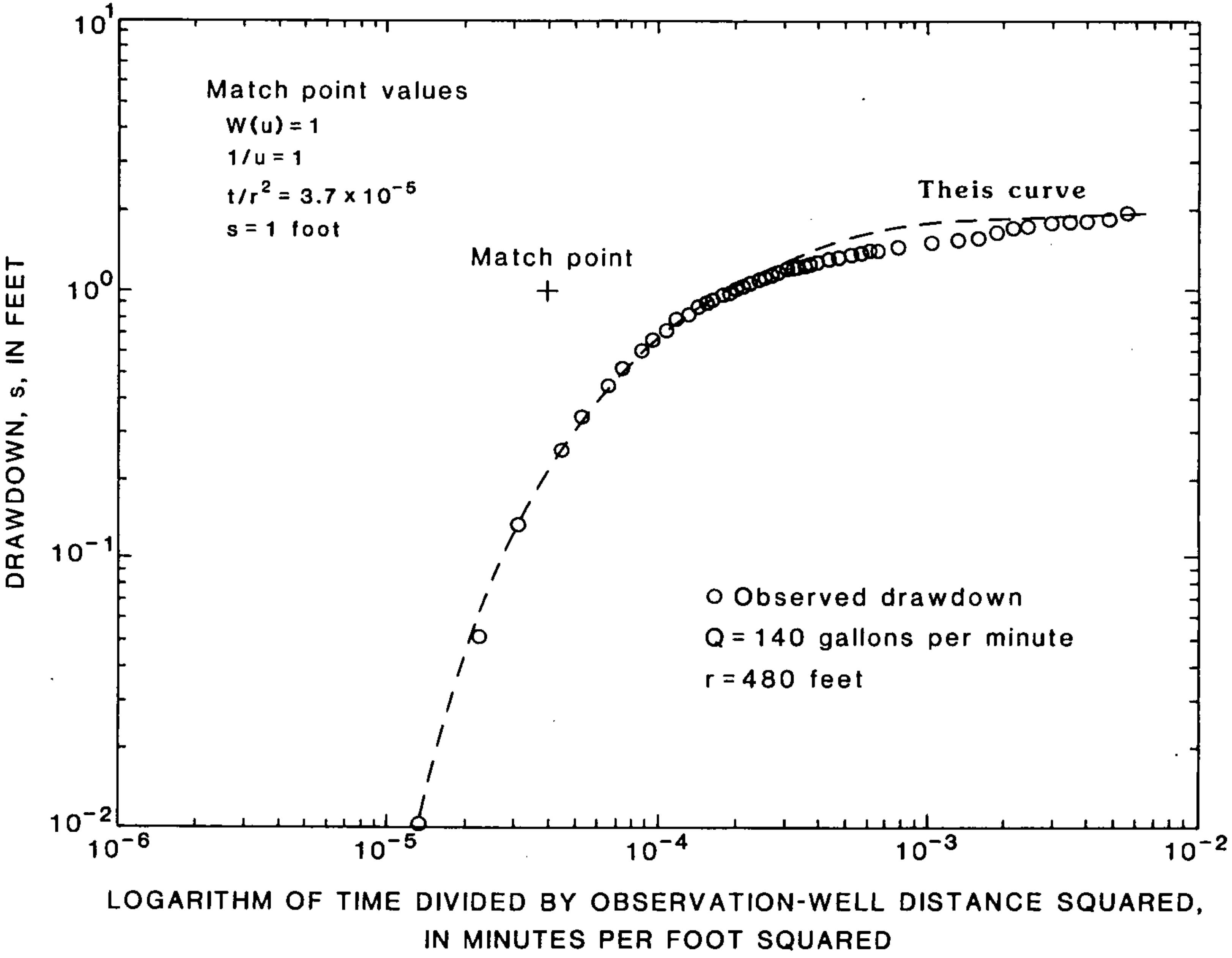


Figure 17.--Drawdown in observation well 23-474 for aquifer test 12.

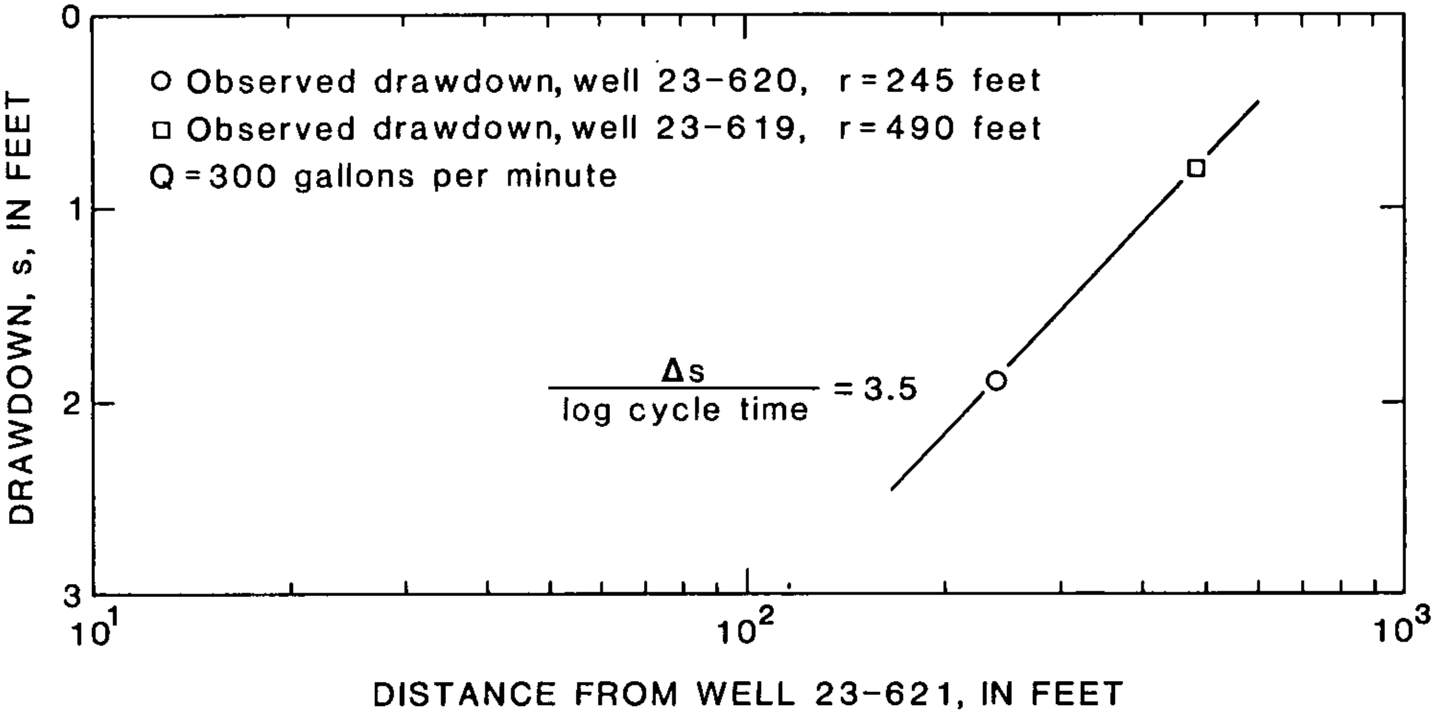


Figure 18.--Distance-drawdown relation when well 23-621 was pumped for 164 hours in aquifer test 14.

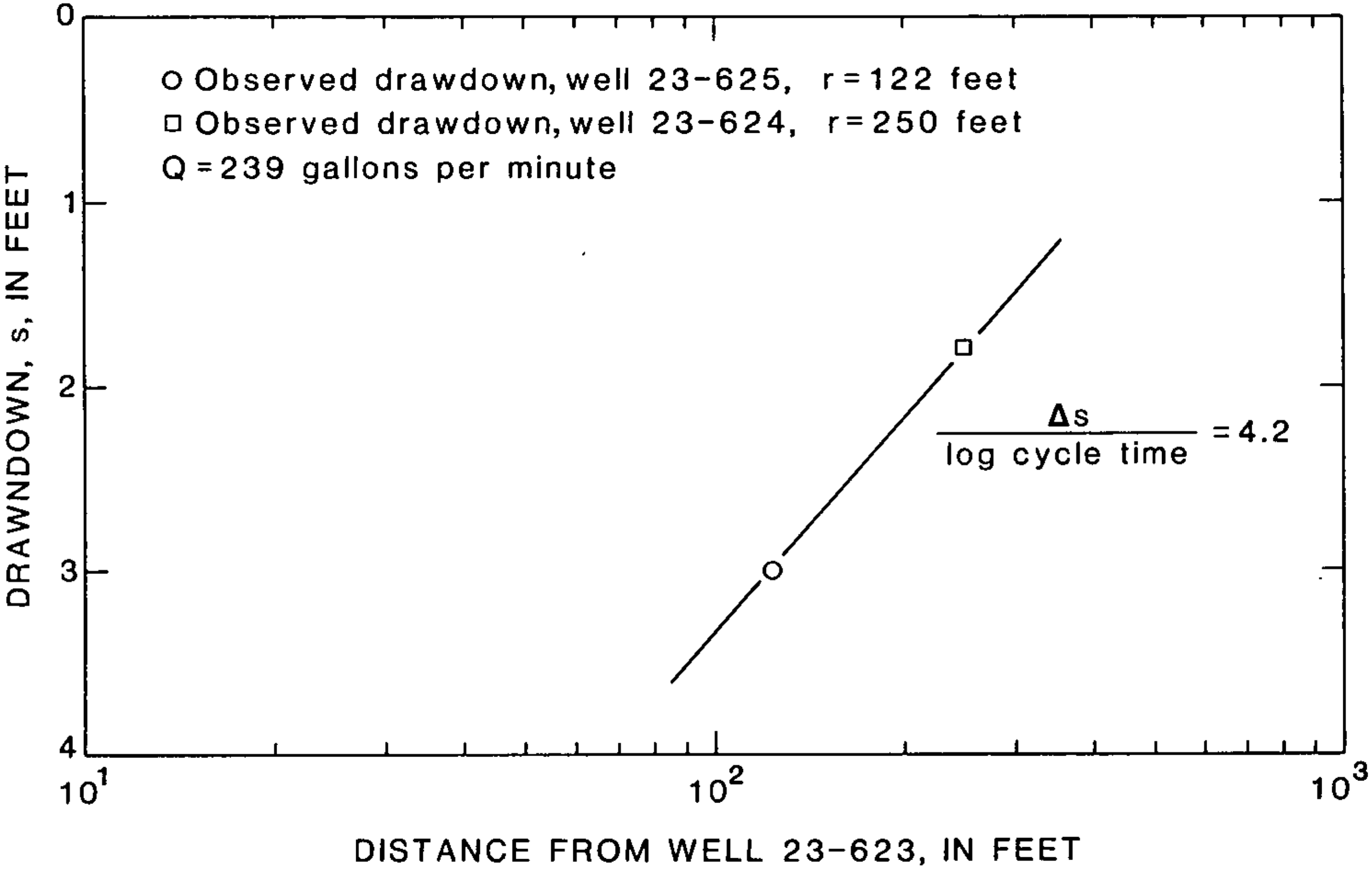


Figure 19.--Distance-drawdown relation when well 23-626 was pumped for 70 hours in aquifer test 15.

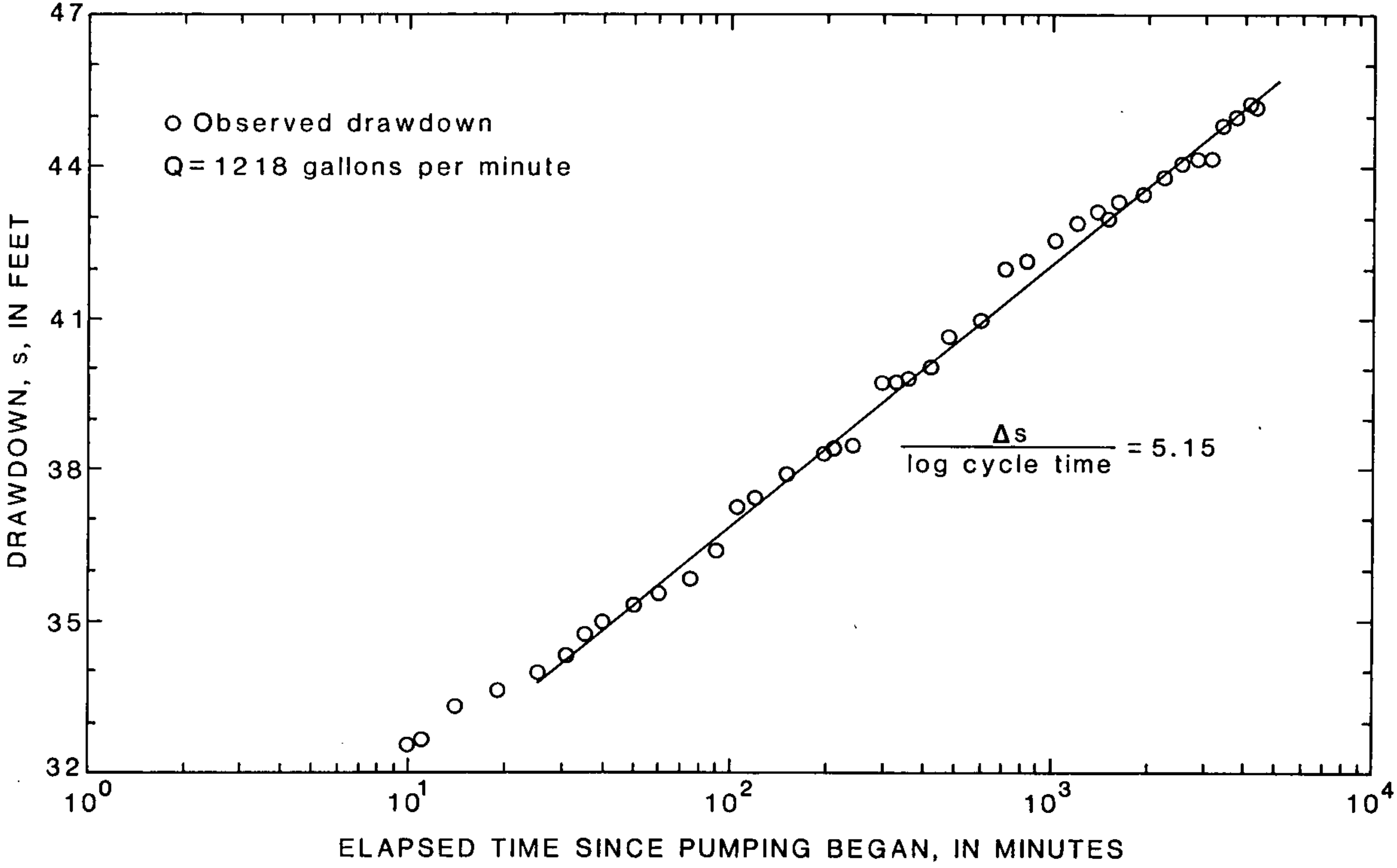


Figure 20.--Drawdown in test well 25-551 for aquifer test 16.

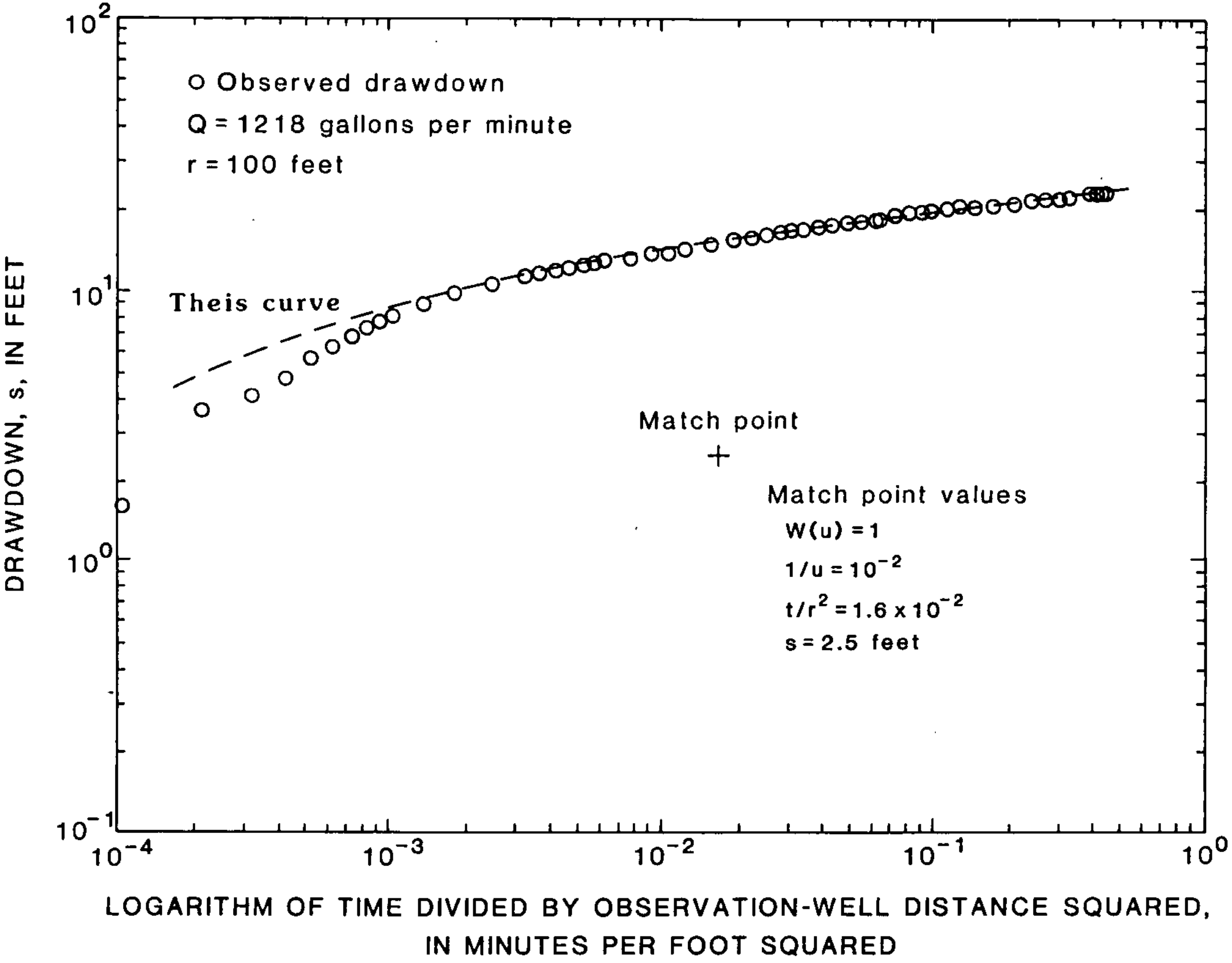


Figure 21.--Drawdown in observation well 25-550 for aquifer test 16.

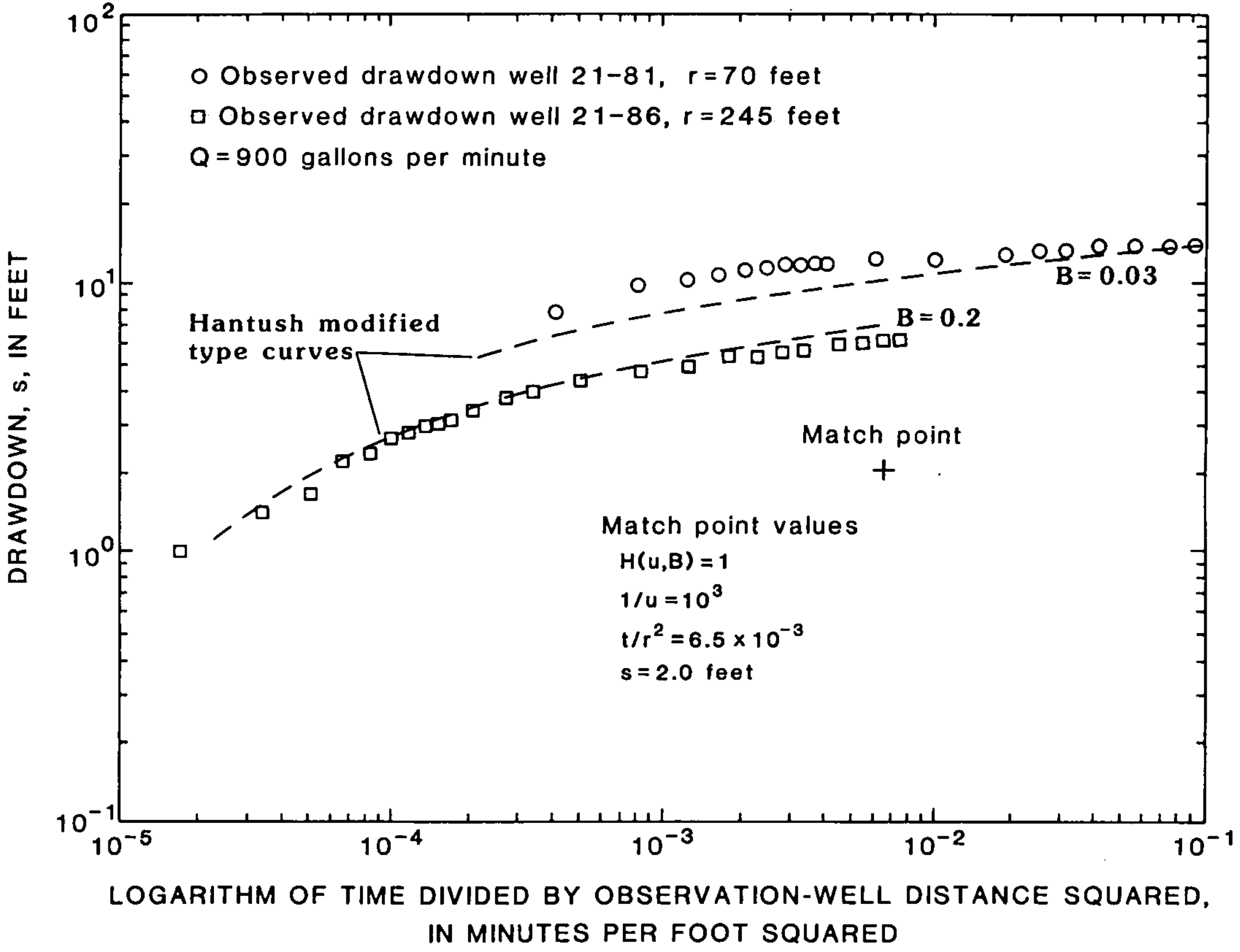


Figure 22.--Drawdown in observation wells 21-81 and 21-86 for aquifer test 17.

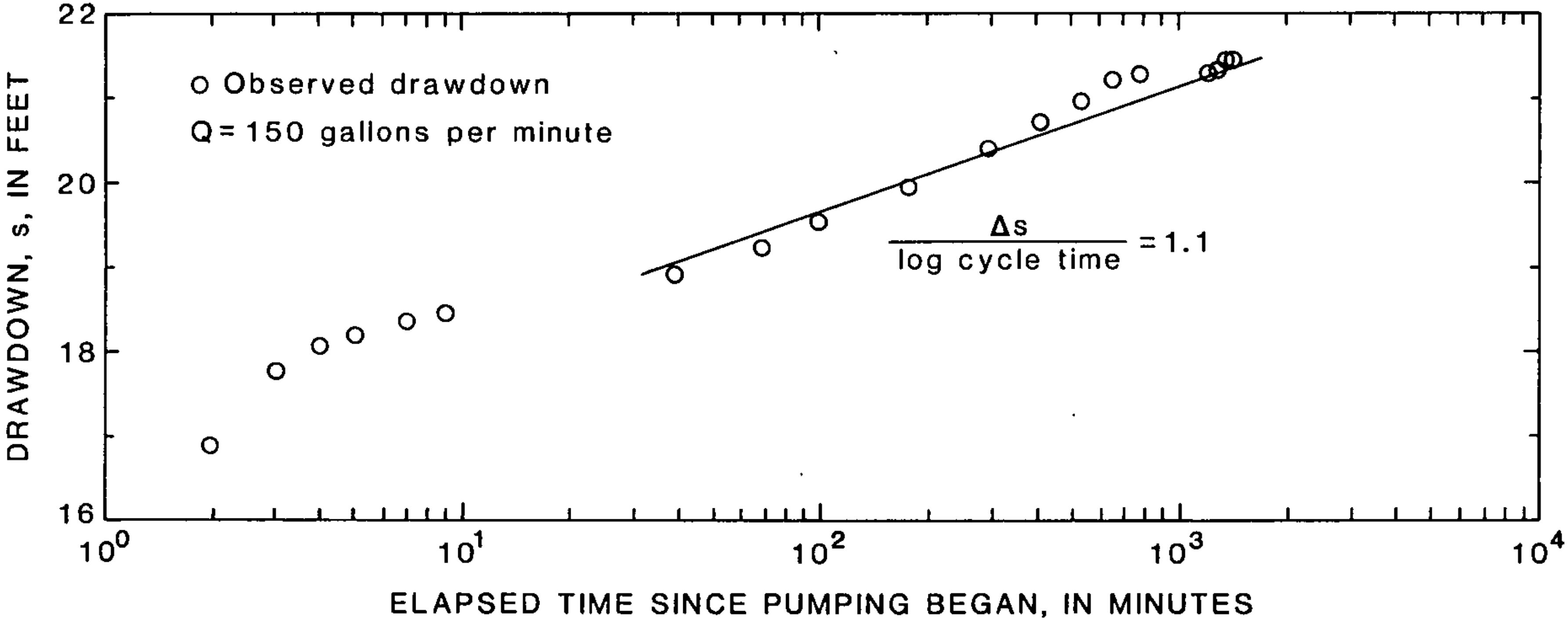


Figure 23.--Drawdown in test well 23-690 for aquifer test 18.

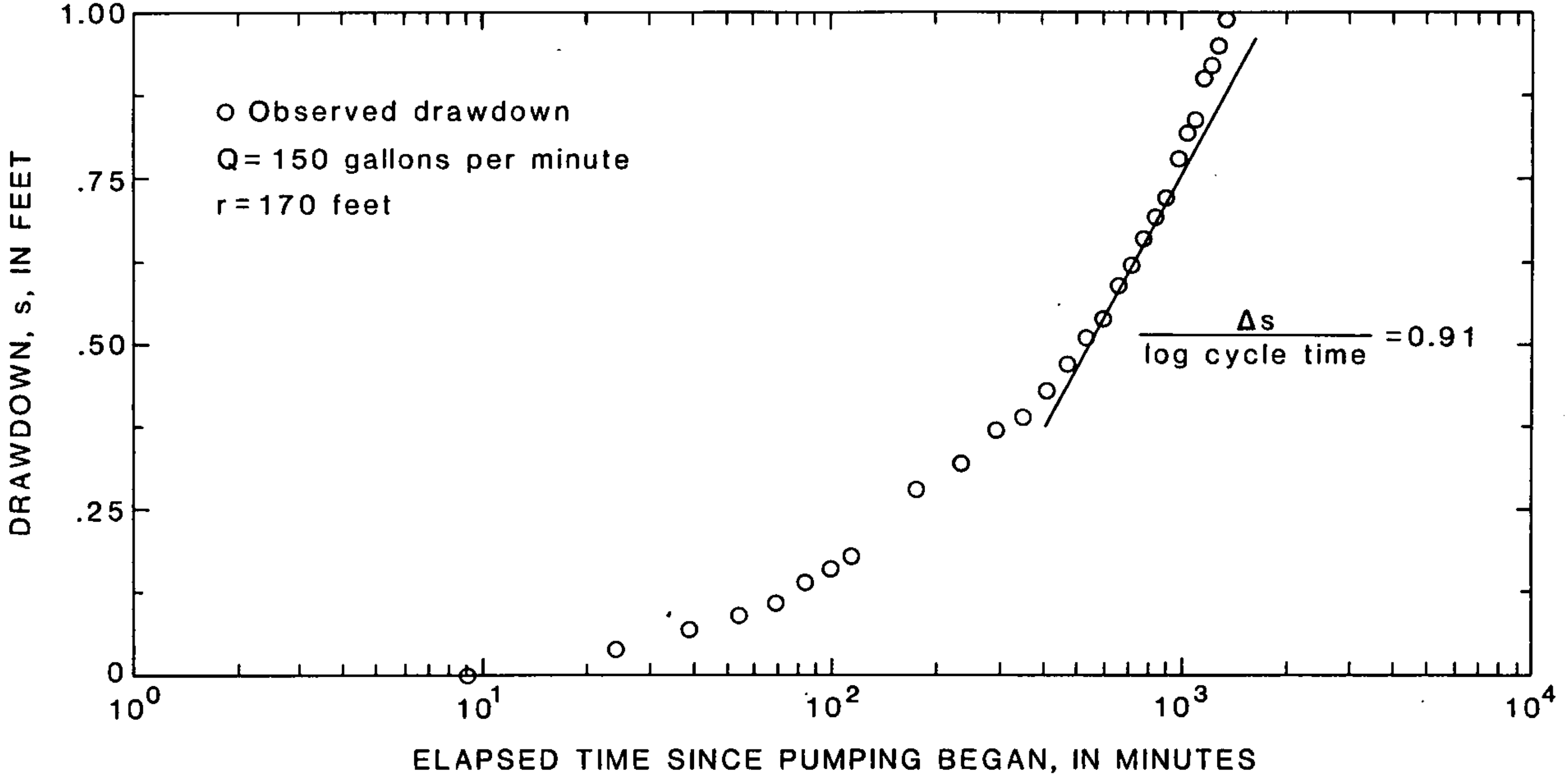


Figure 24.--Drawdown in observation well 23-684 for aquifer test 18.

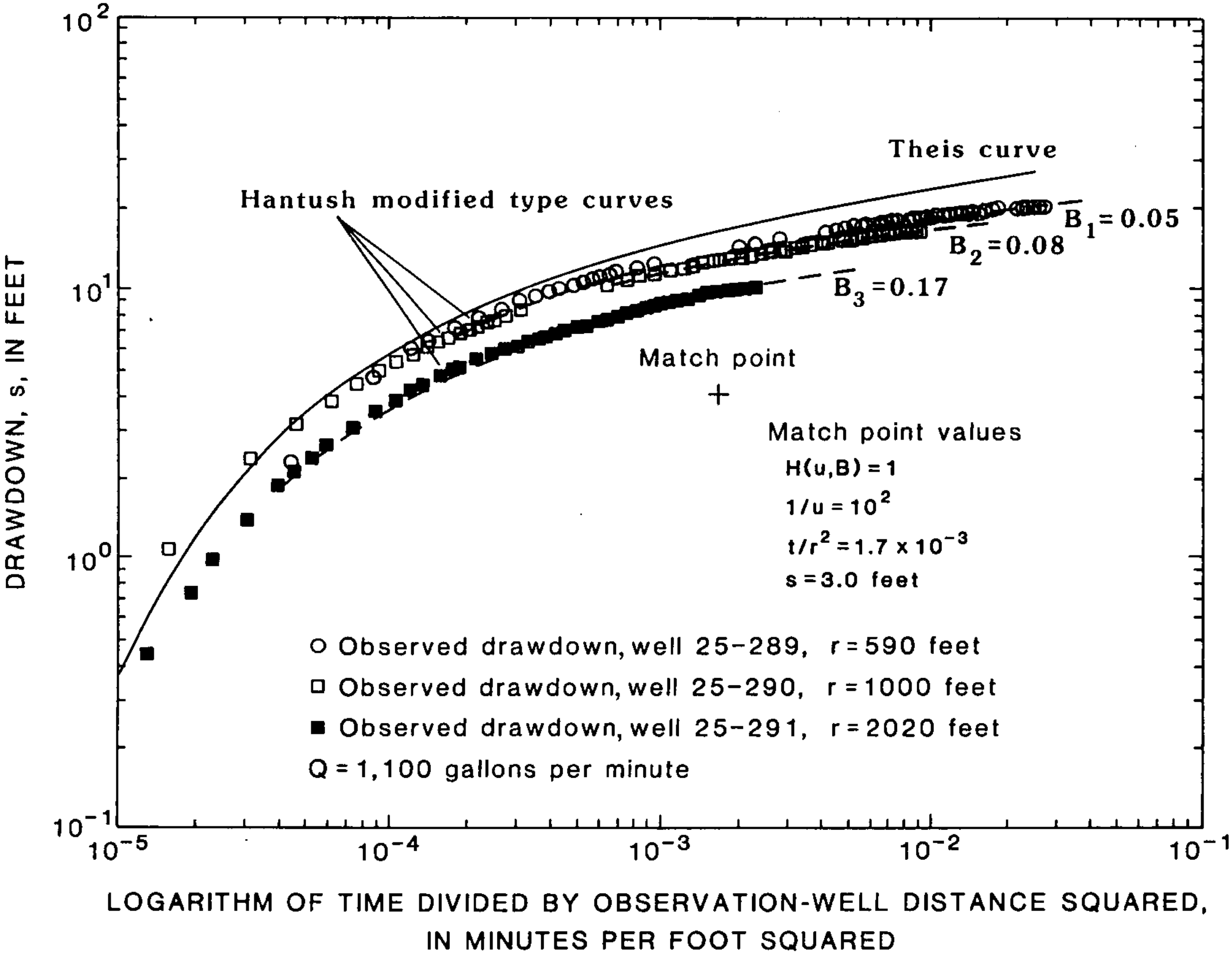


Figure 25.--Drawdown in observation wells 25-289, 25-290, and 25-291 for aquifer test 19.

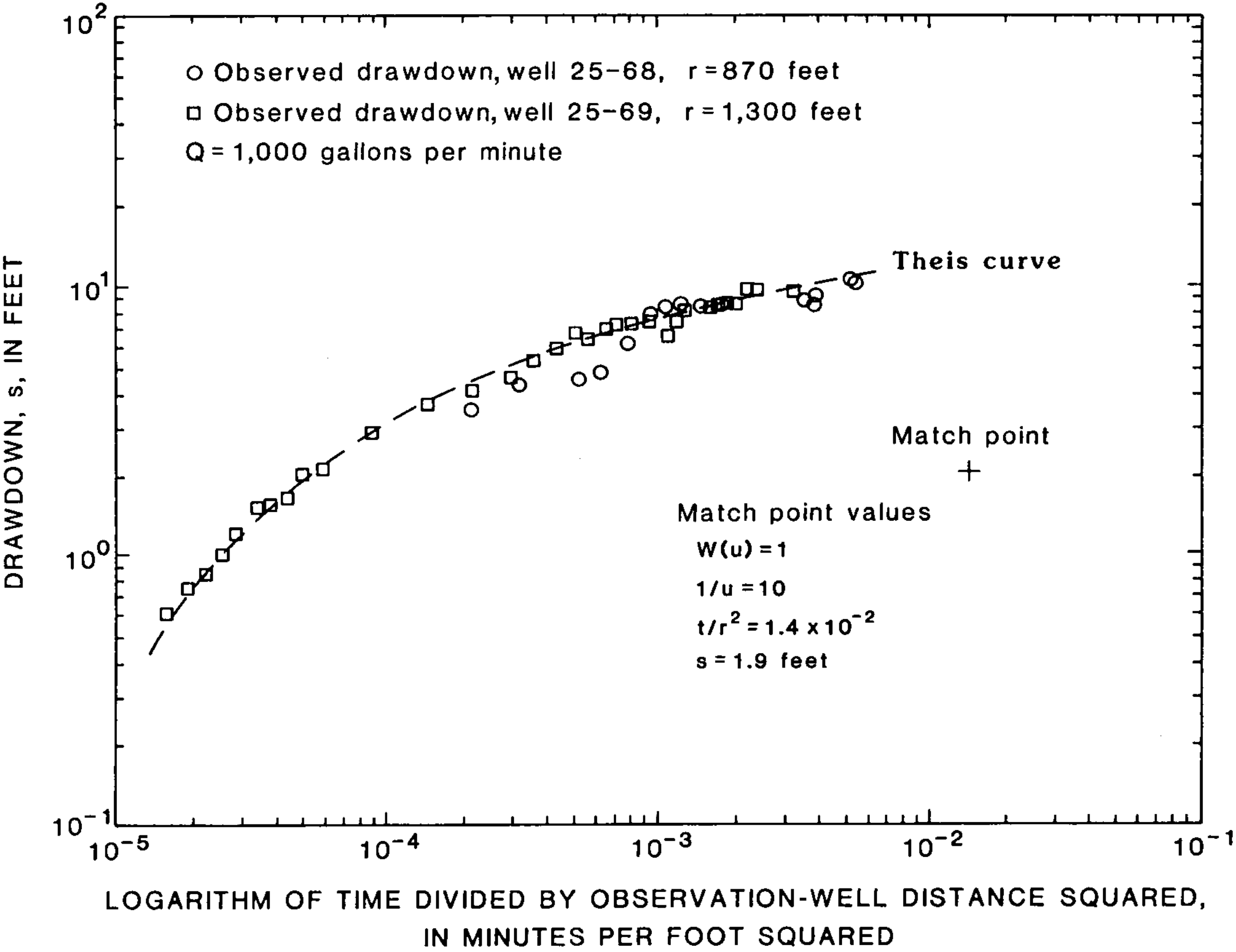


Figure 26.--Drawdown in observation wells 25-68 and 25-69 for aquifer test 21.

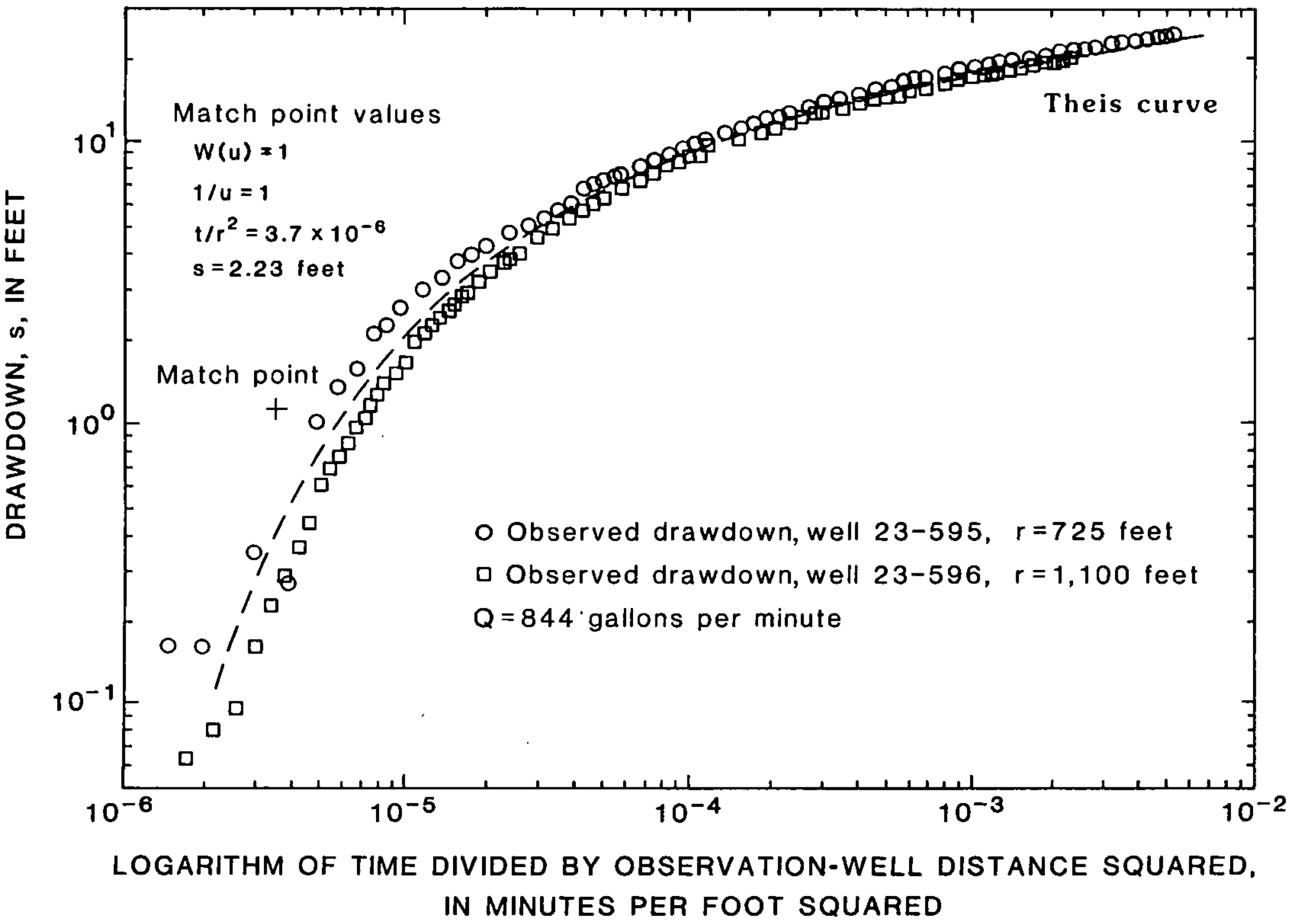


Figure 27.--Drawdown in observation wells 23-595 and 23-596 for aquifer test 22.

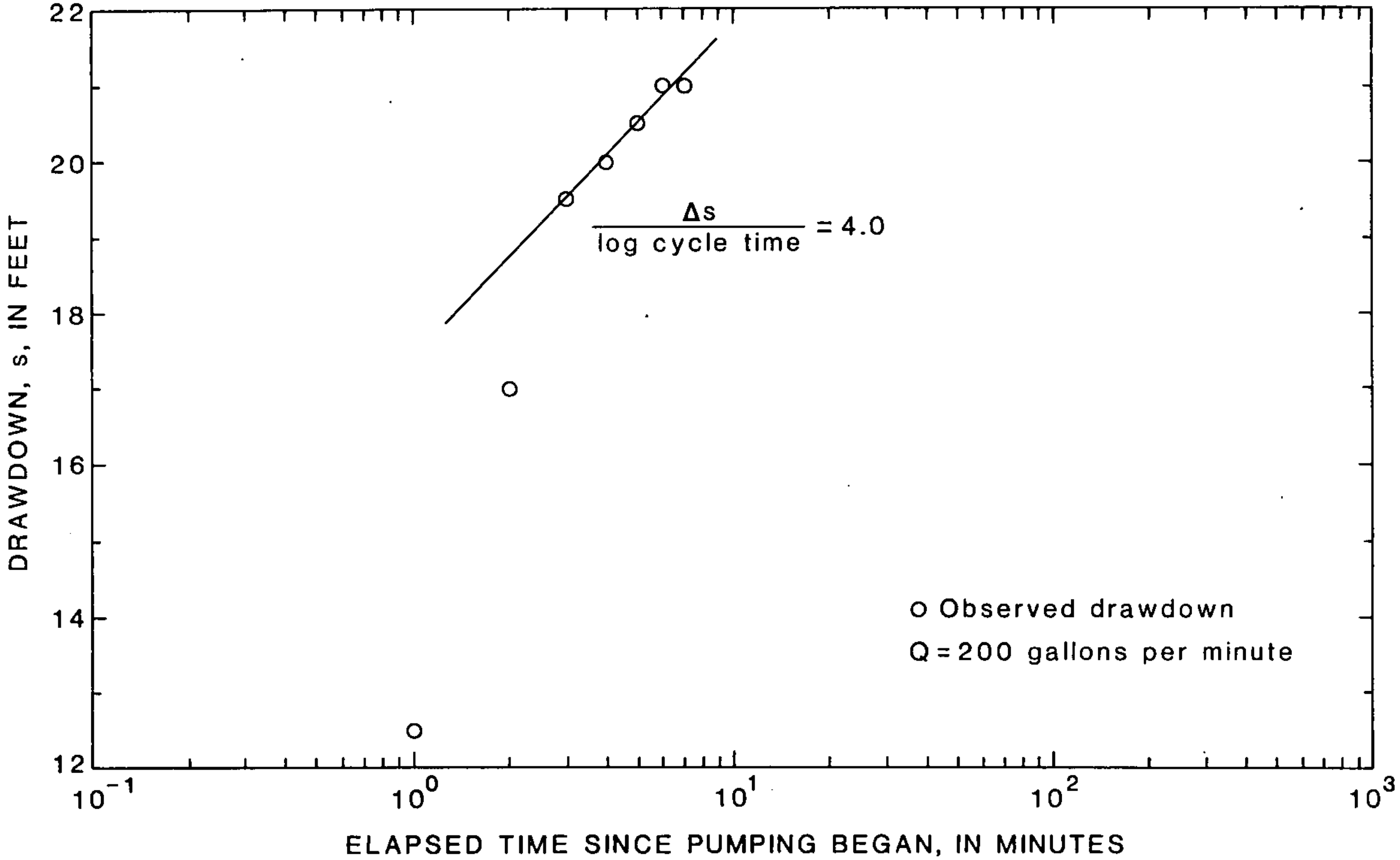


Figure 28.--Drawdown in test well 23-602 for aquifer test 23.

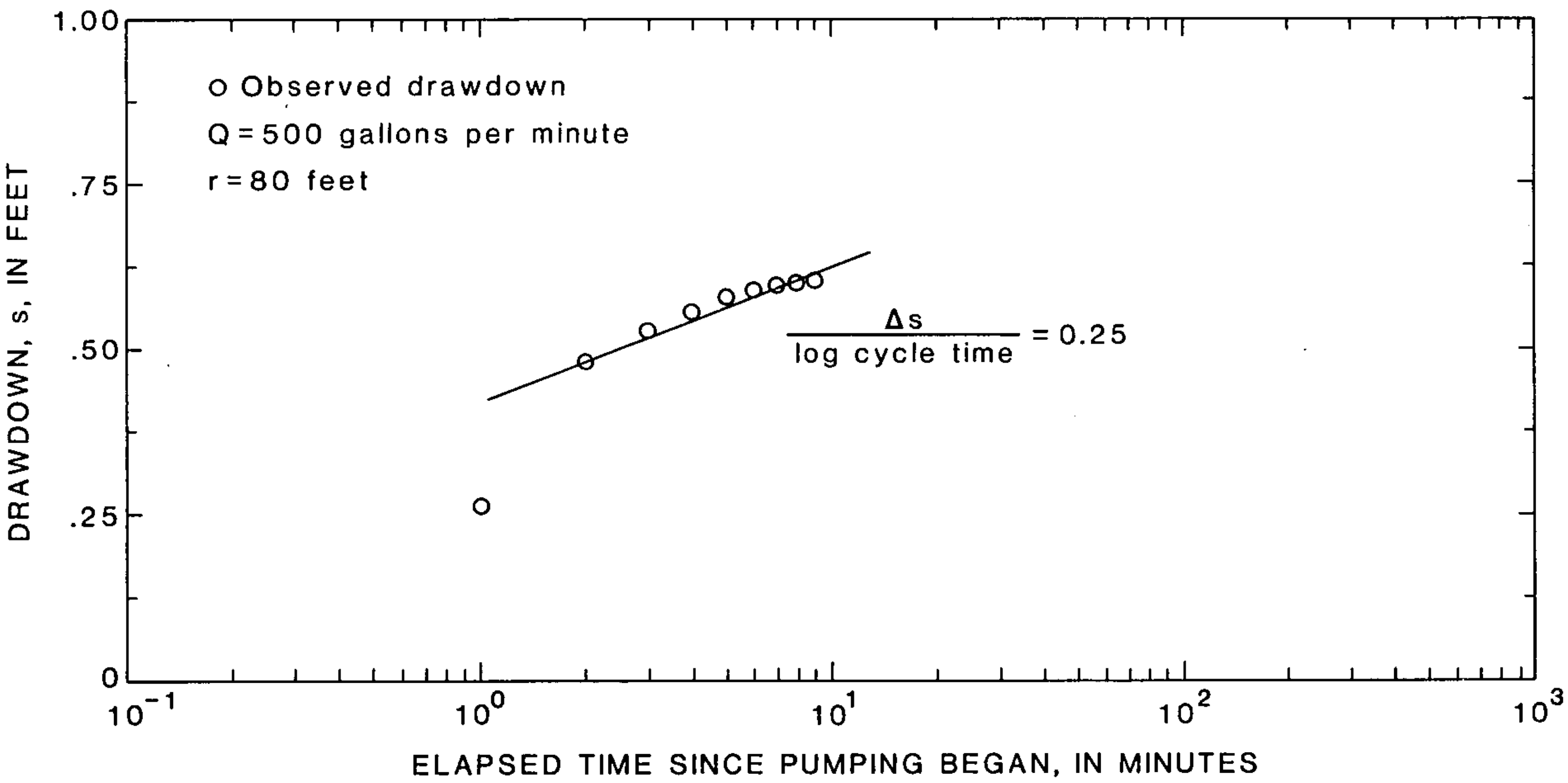


Figure 29.--Drawdown in observation well 23-121 for aquifer test 24.

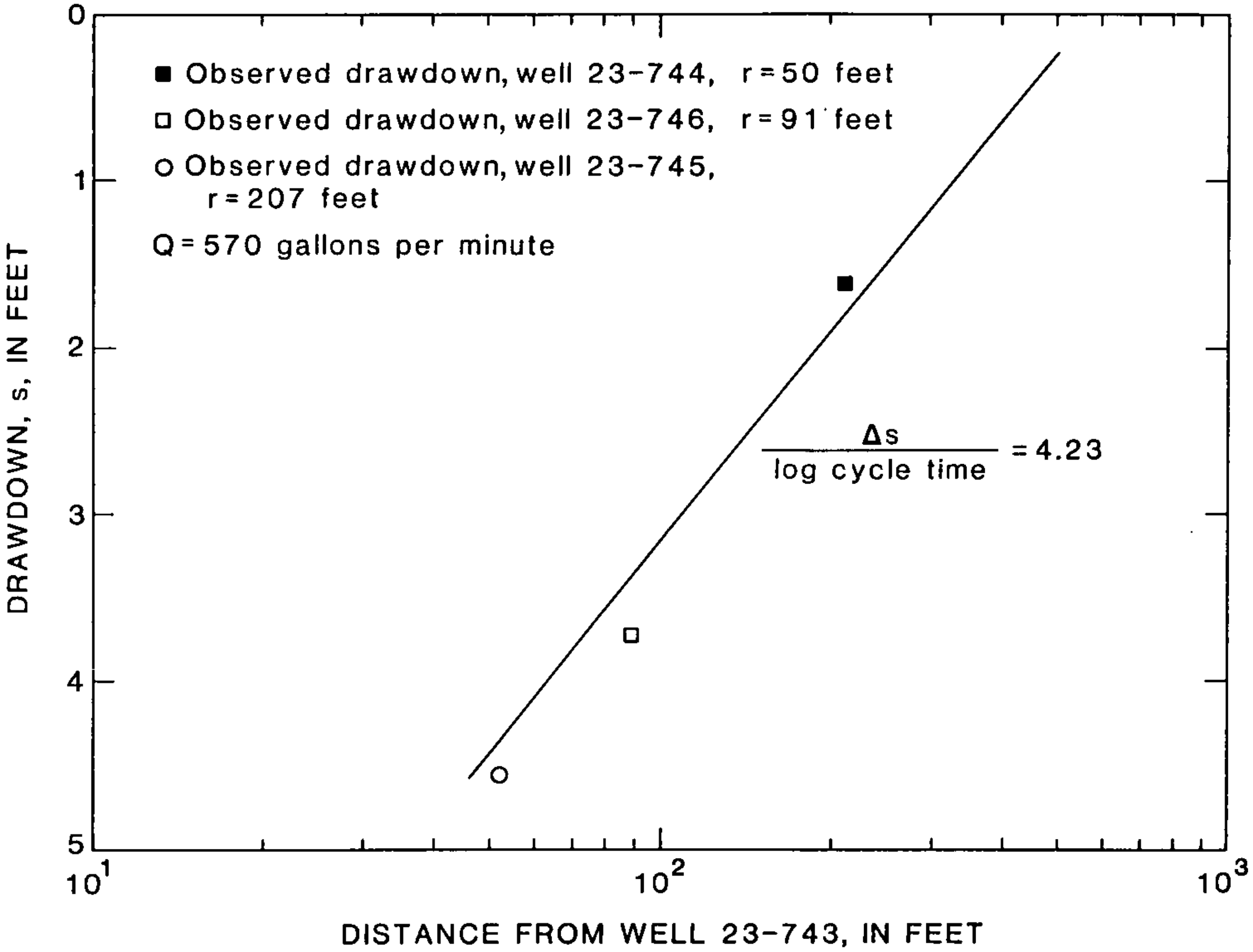


Figure 30.--Distance-drawdown relations when well 23-743 was pumped for 48 hours in aquifer test 25.

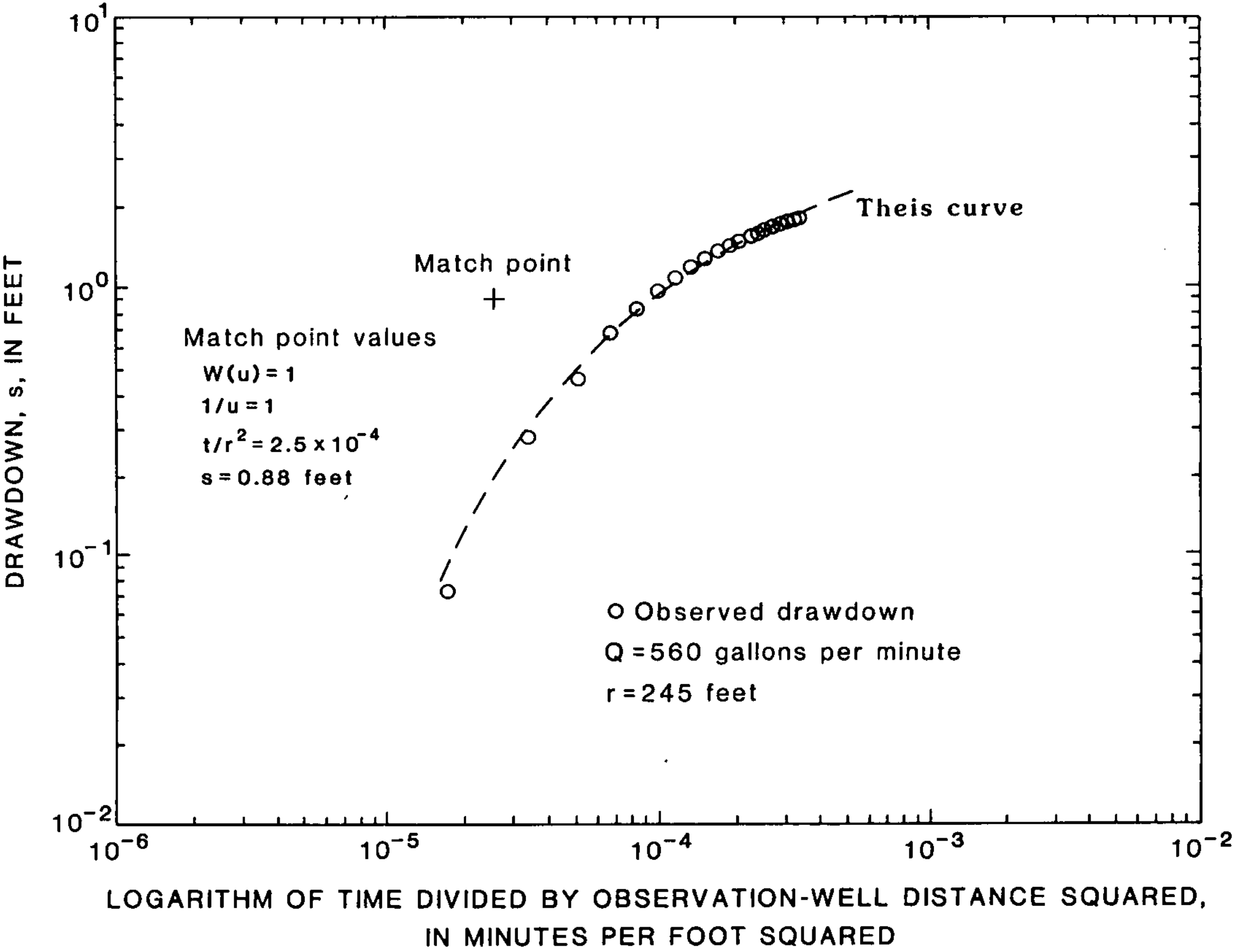


Figure 31.--Drawdown in observation well 23-448 for aquifer test 26.

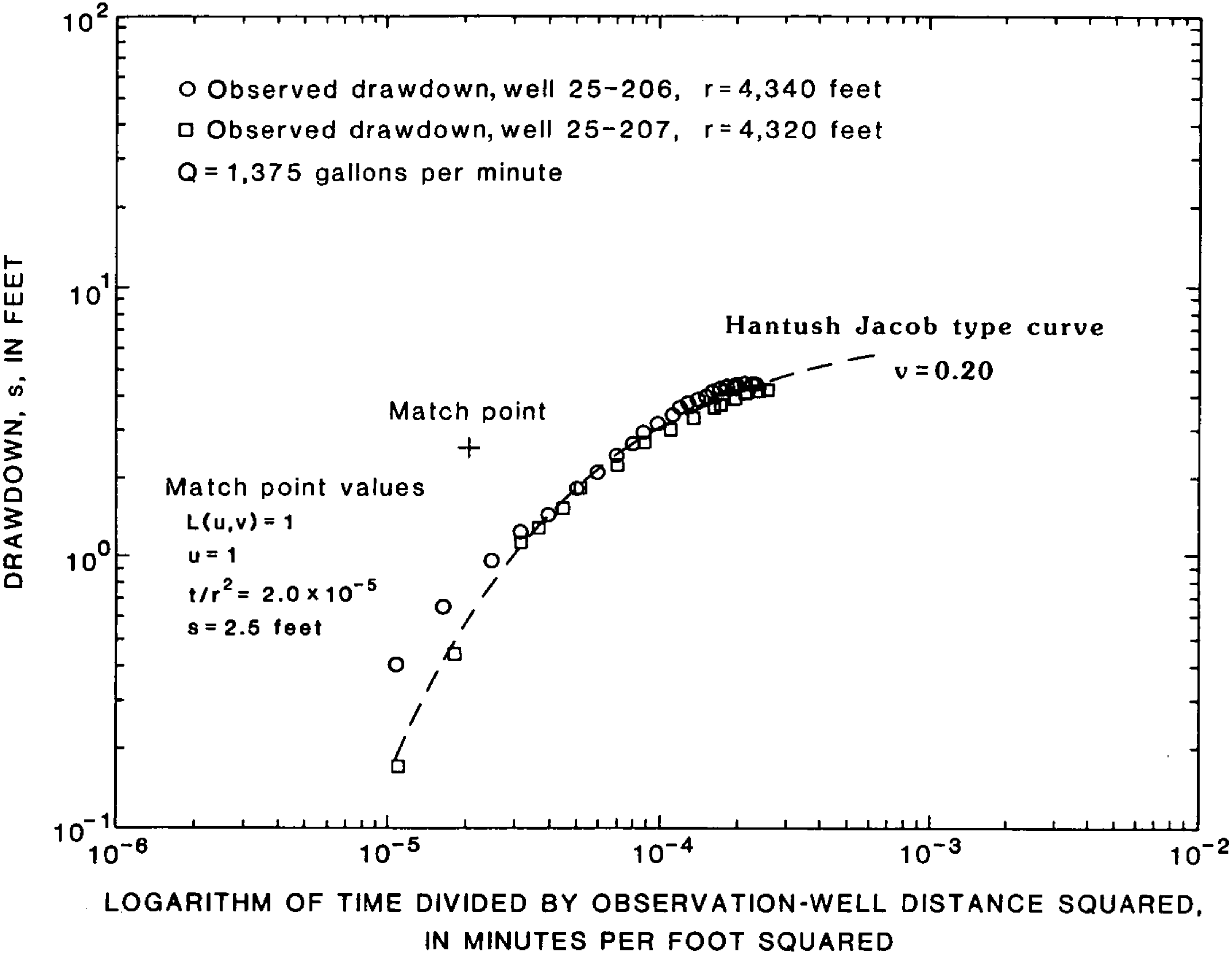


Figure 32.--Drawdown in observation wells 25-206 and 25-207 for aquifer test 27.

APPENDIX 2

GRAPHS SHOWING WATER-LEVEL DATA FROM AQUIFER TESTS AND FINITE-ELEMENT SIMULATIONS

Data included in figures 33-39 are for documentation purposes and for reference by the reader. The method of finite-element analysis, which is used to interpret the data, is summarized in the text, and in Reilly (1984).

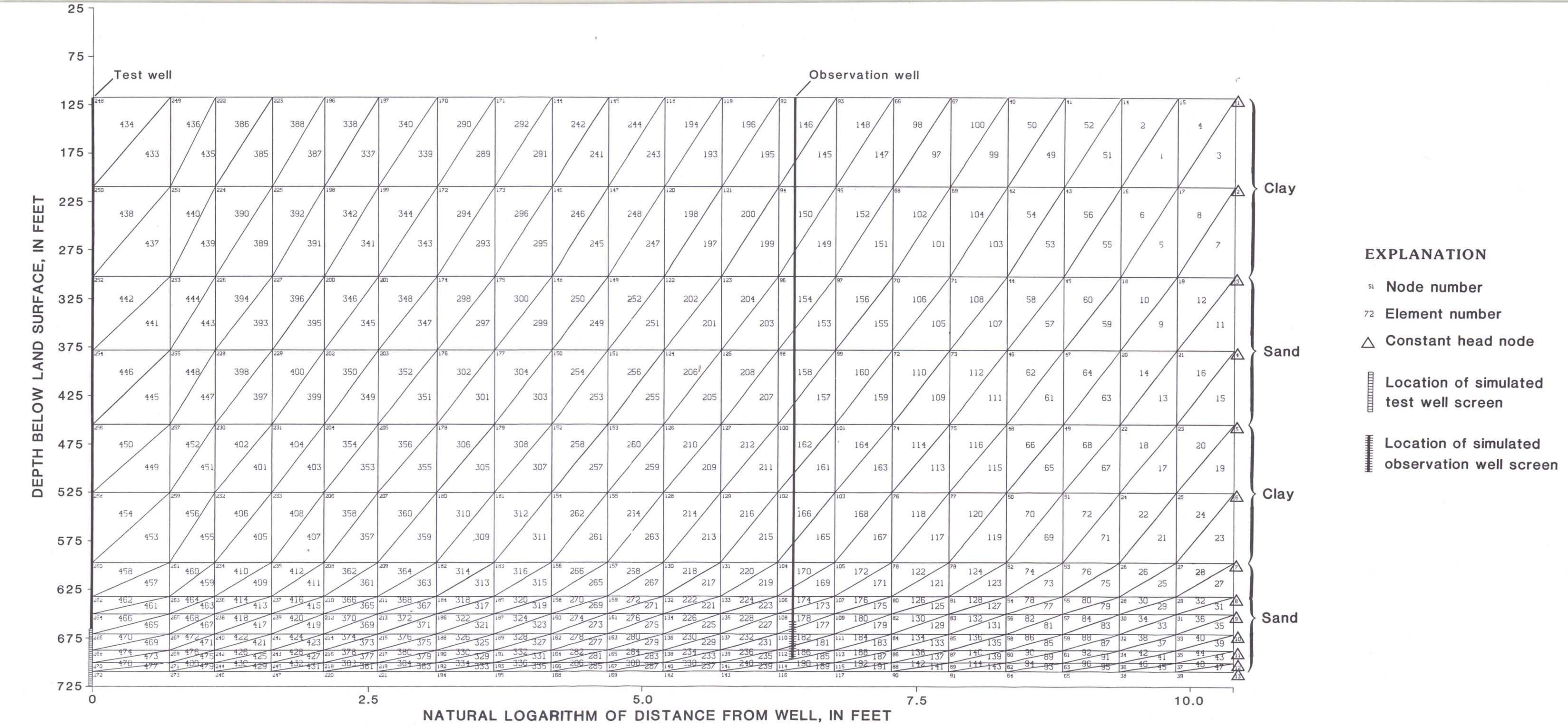
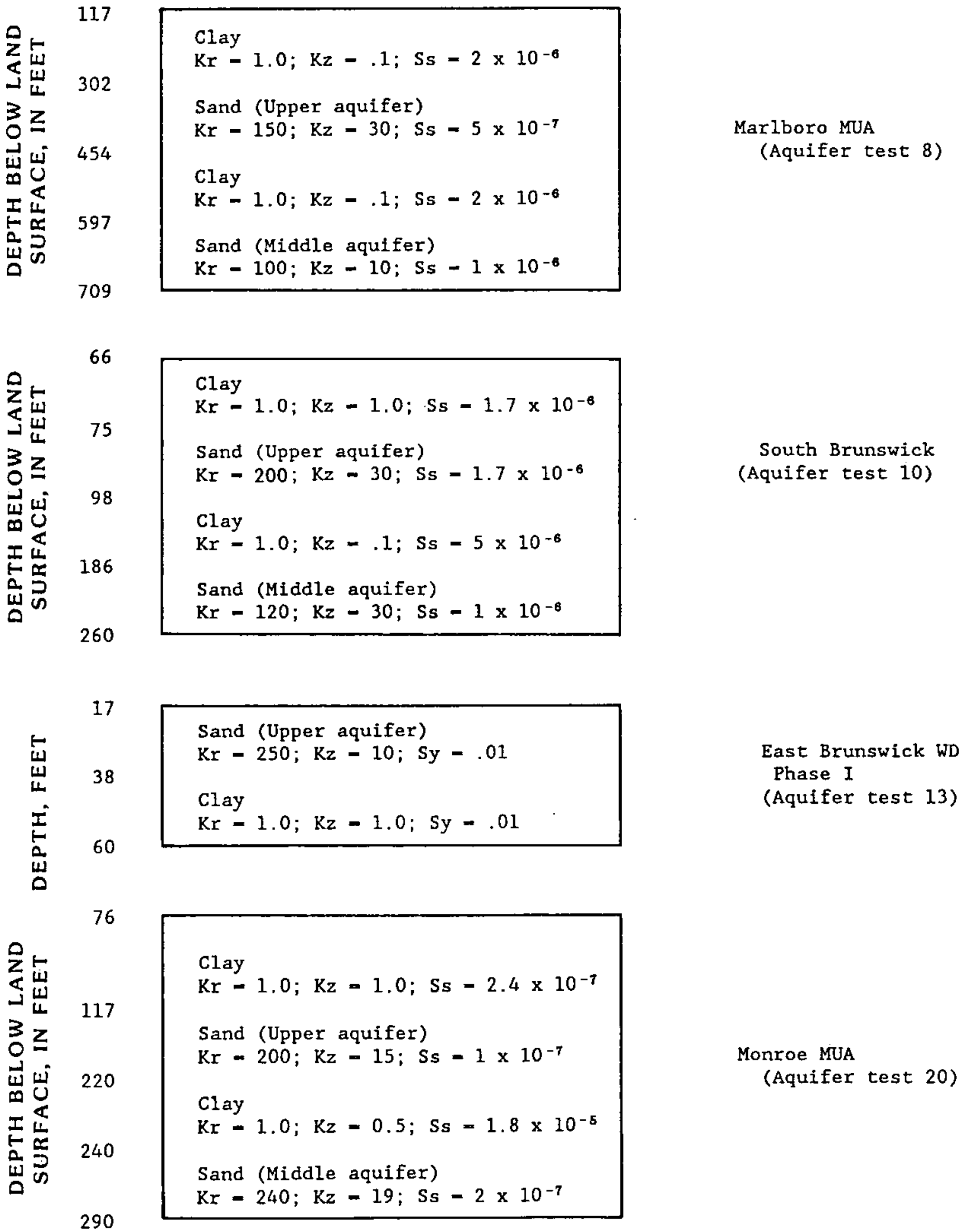


Figure 33.--Model grid representing aquifer section for aquifer test 8.



Kr = lateral hydraulic conductivity, in feet per day;
Kz = vertical hydraulic conductivity, in feet per day;
Ss = specific storage (dimensionless)
Sy = specific yield (dimensionless)

Figure 34.--Simplified hydrogeologic sections of aquifer-test sites 8, 10, 13, and 20 showing lateral and vertical hydraulic-conductivity values used in final model.

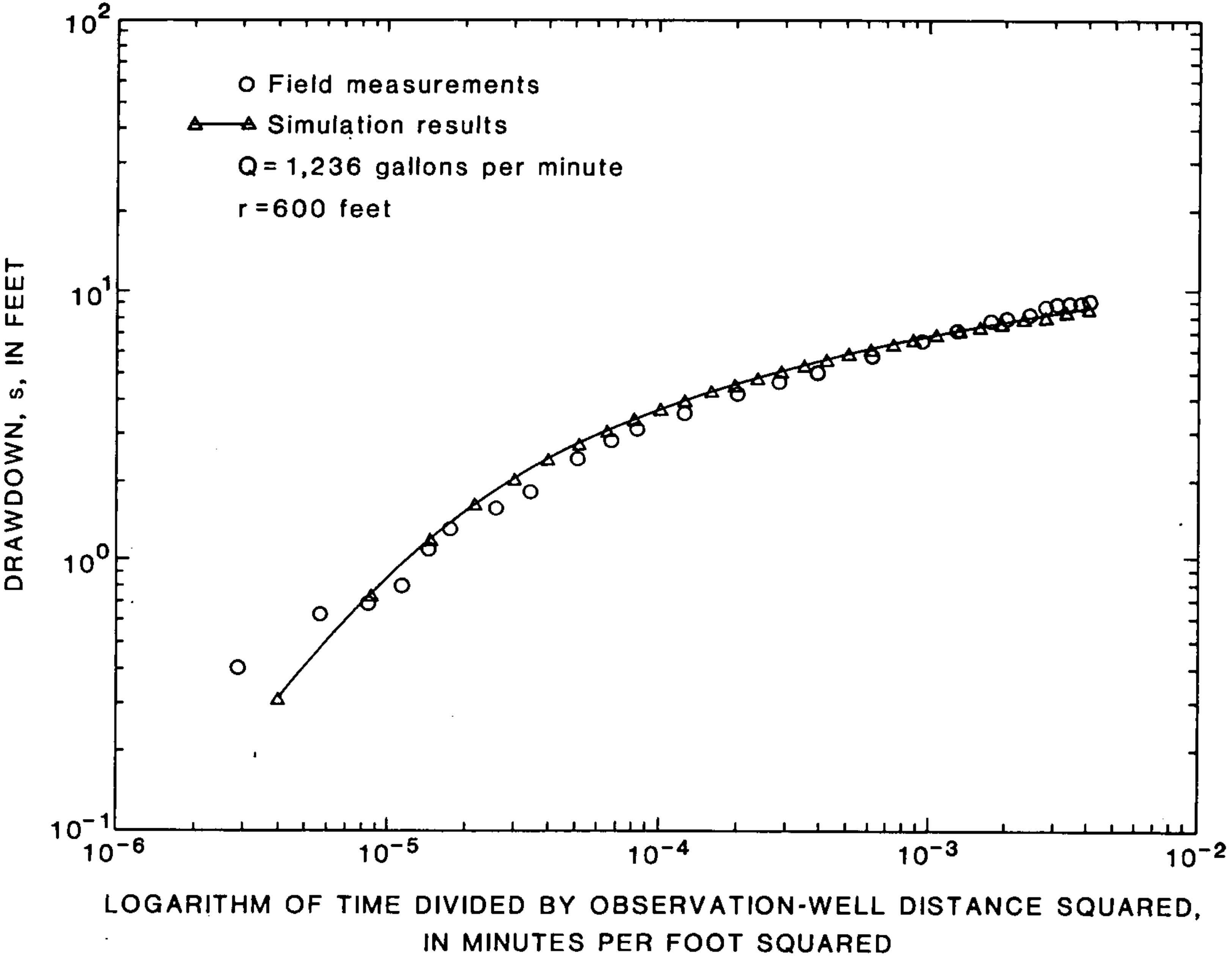


Figure 35.--Drawdown from field measurements and simulations results for observation well 25-269 for aquifer test 8.

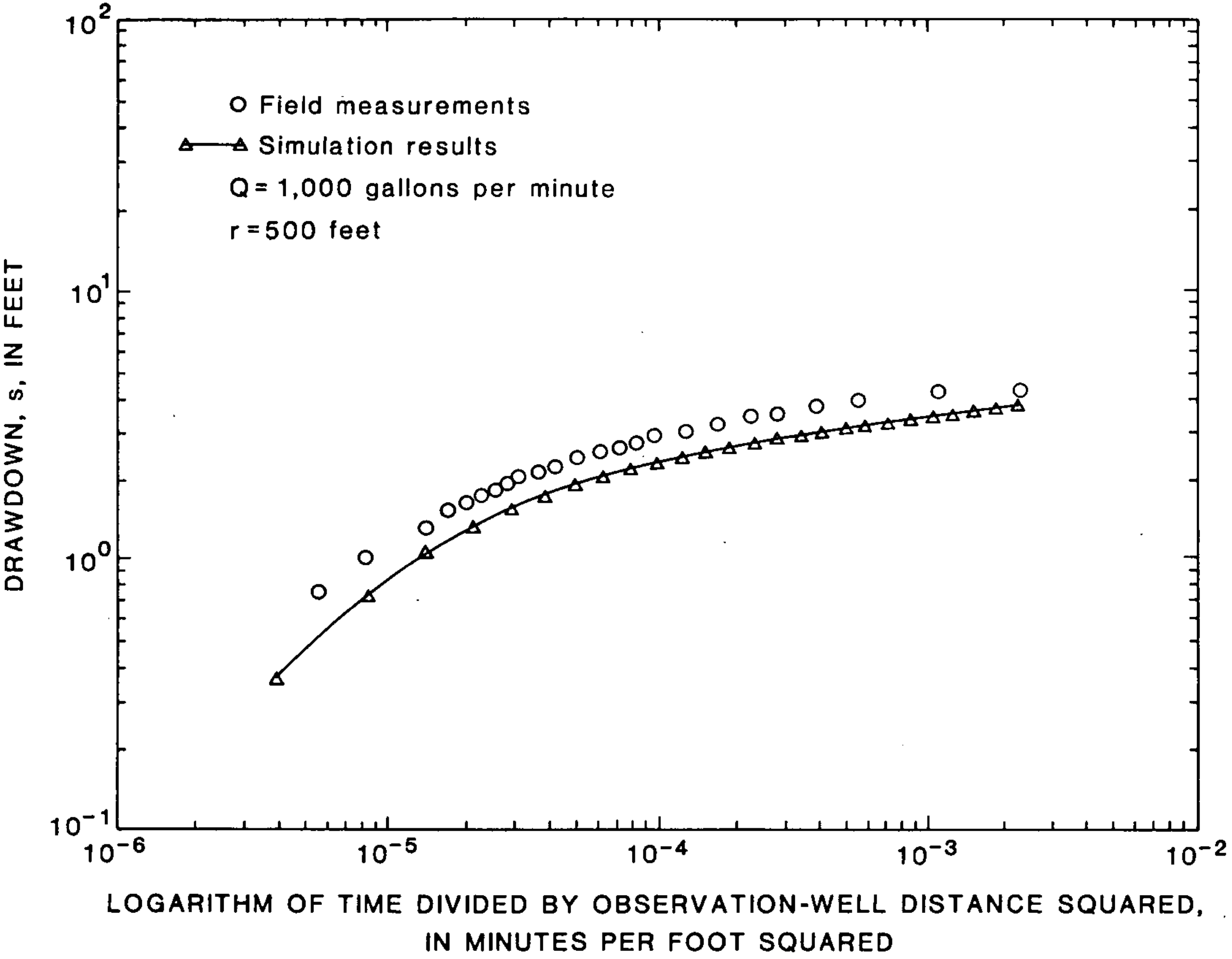


Figure 36.--Drawdown from field measurements and simulations results for observation well 23-287 for aquifer test 10.

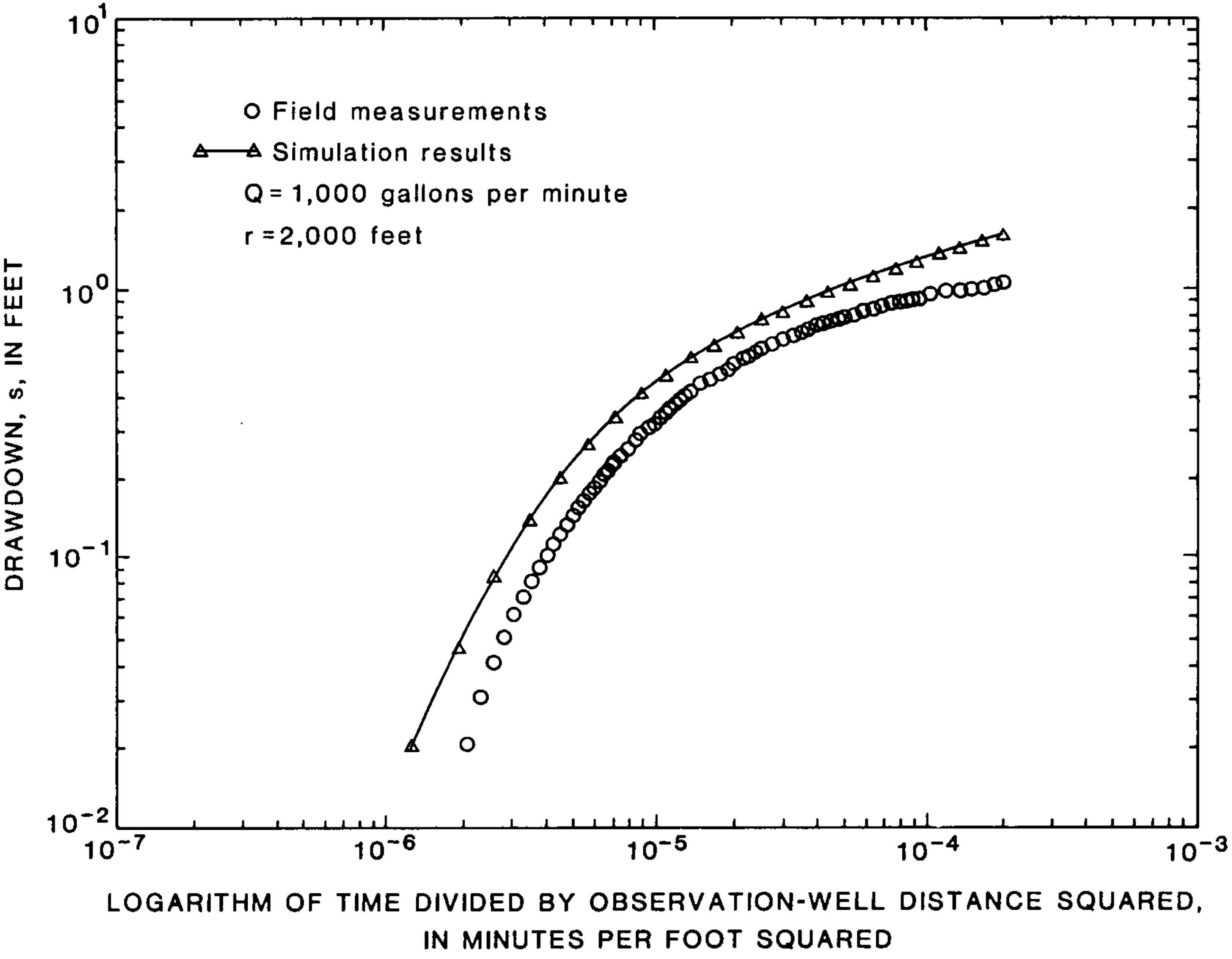


Figure 37.--Drawdown from field measurements and simulations results for observation well 23-290 for aquifer test 10.

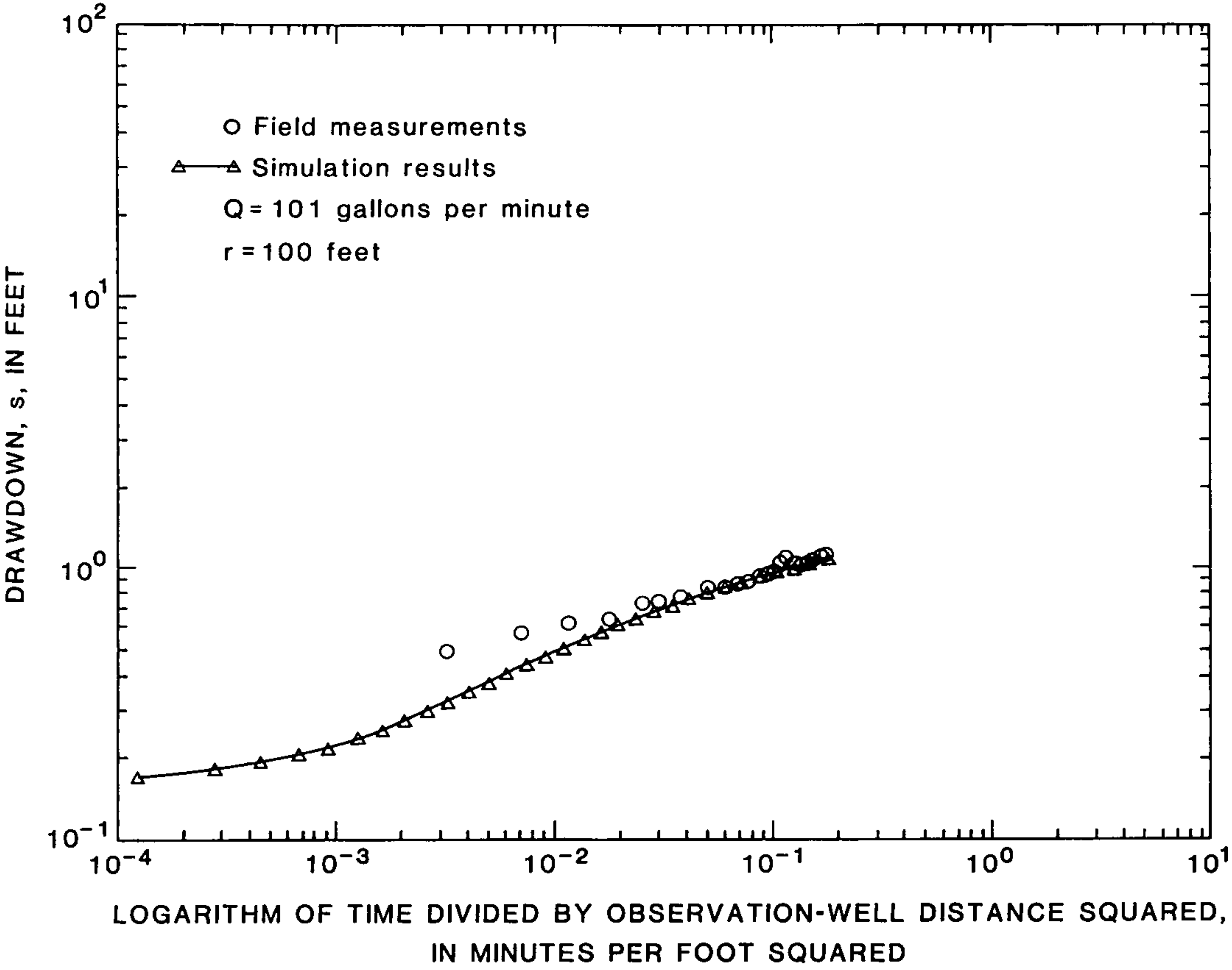


Figure 38.--Drawdown from field measurements and simulations results for observation well 23-615 for aquifer test 13.

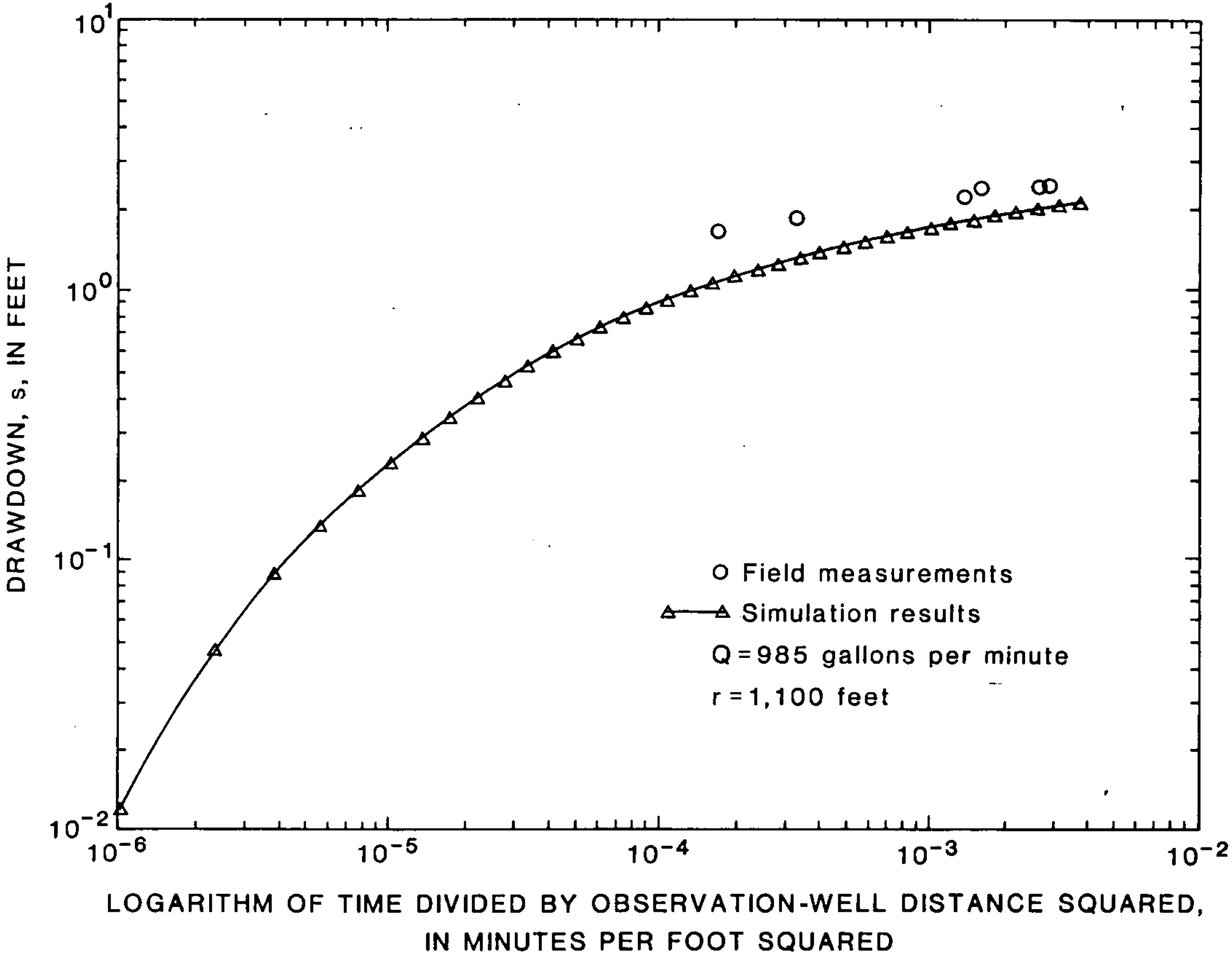
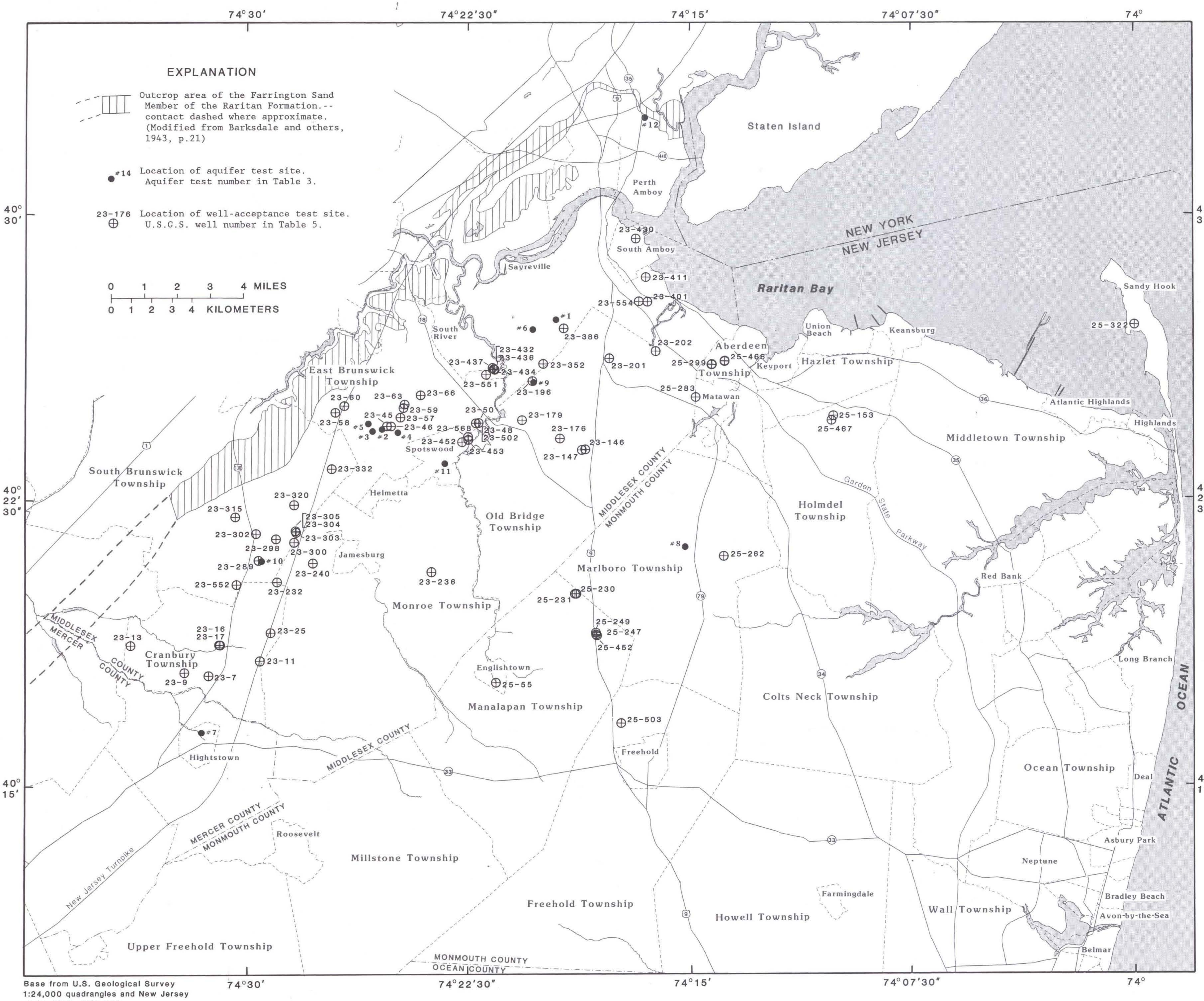


Figure 39.--Drawdown from field measurements and simulations results for observation well 23-228 for aquifer test 20.

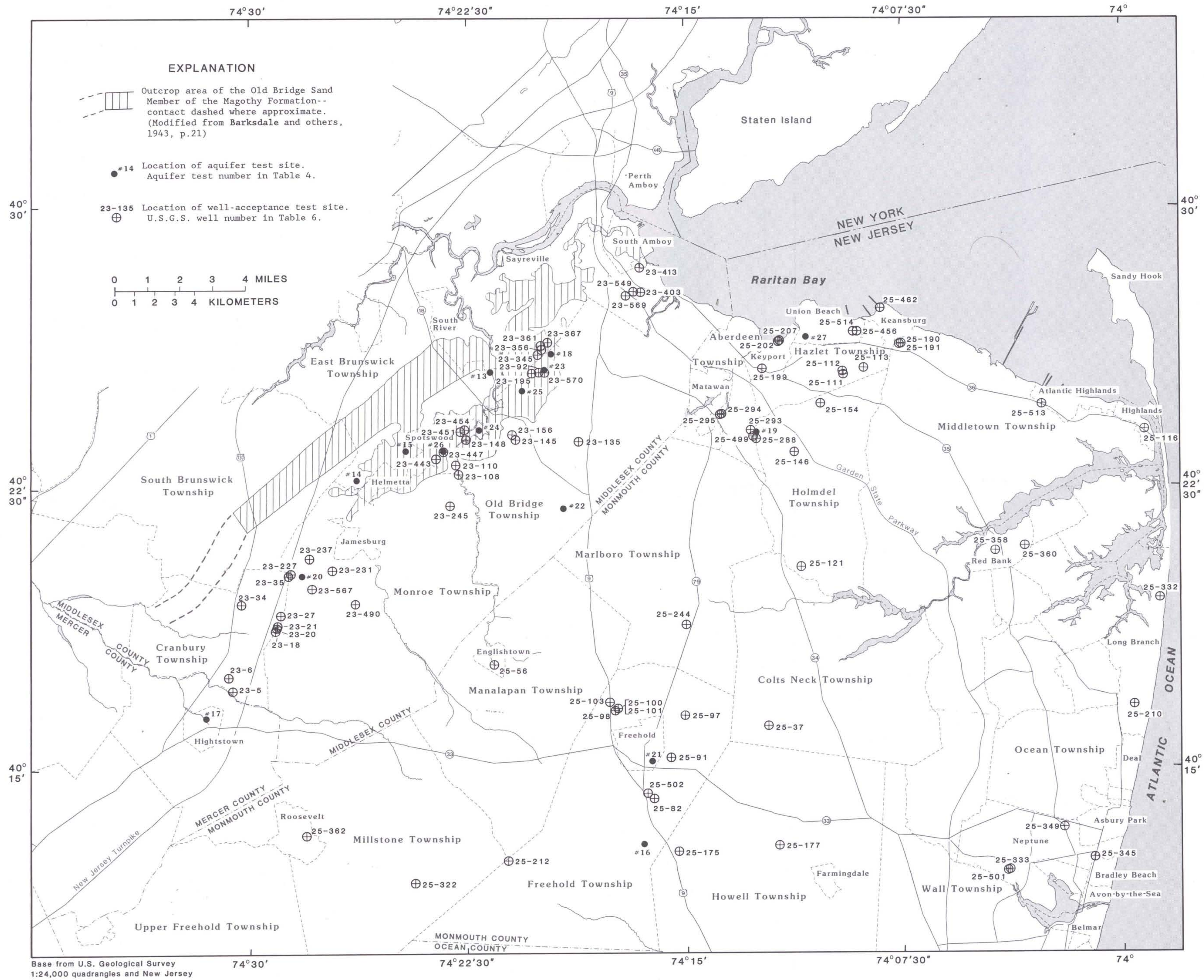
Hydraulic Properties of the Middle and Upper Aquifers of the Potomac-Raritan-Magothy Aquifer System in the Northern Coastal Plain of New Jersey
(Geological Survey Report 18, New Jersey Geological Survey)

ISSN: 0741-7357



Base from U.S. Geological Survey
1:24,000 quadrangles and New Jersey
state atlas, 1:63,360

Aquifer-test and well-acceptance-test site locations for the middle aquifer, Potomac-Raritan-Magothy aquifer system



Base from U.S. Geological Survey
1:24,000 quadrangles and New Jersey
state atlas, 1:63,360

Aquifer-test and well-acceptance-test site locations for the upper aquifer, Potomac-Raritan-Magothy aquifer system