Prepared in cooperation with the
TOWN OF NORTH KINGSTOWN WATER DEPARTMENT;
RHODE ISLAND DEPARTMENT OF ENVIRONMENTAL MANAGEMENT, OFFICE OF WATER RESOURCES; AND
RHODE ISLAND ECONOMIC DEVELOPMENT CORPORATION

WATER-RESOURCES INVESTIGATIONS REPORT 97-4167
Dickerman, D.C., and Barlow, P.M., 1997, Map showing water-table conditions and stream-aquifer interaction in the Hunt-Annaquatucket-Pettaquamscutt aquifer, central Rhode Island, October 7-9, 1996

INTRODUCTION

The Hunt-Annaquatucket-Pettaquamscutt sole-source aquifer underlies parts of five river basins in central Rhode Island (fig. 1) and is the source of water for North Kingstown and parts of Warwick, East Greenwich, and Narragansett. Pumping from water-supply wells completed in this unconfined, stratified sand and gravel aquifer are placing stresses on ground- and surface-water resources, particularly during summer months when water demands are often greatest, and water levels and streamflow generally are lowest. There is concern that proposed additional ground-water development may further exacerbate these stresses on the water resources of the aquifer.

A cooperative study between the U.S. Geological Survey and the town of North Kingstown, Rhode Island Department of Environmental Management (Office of Water Resources), and Rhode Island Economic Development Corporation was begun during the summer of 1995 to evaluate the effects of current and future ground-water pumping on streamflow and on water levels in the Hunt-Annaquatucket-Pettaquamscutt aquifer. As part of this study, ground-water levels and streamflow were measured on October 7-9, 1996, to determine the altitude and configuration of the water table throughout the aquifer and the interaction of the aquifer with hydraulically connected streams. These data are used to infer the effects of pumping water-supply wells on streamflow depletion, areas of ground-water discharge to streams, and ground-water flow directions. This report describes the methods of water-level and streamflow-data collection, water-table conditions, and stream-aquifer interaction in the Hunt-Annaquatucket-Pettaquamscutt aquifer during October 7-9, 1996. The configuration and altitude of the water table in the Hunt-Annaquatucket-Pettaquamscutt aquifer was last determined in 1963 (Rosenshein and others, 1968), although small areas of the aquifer have been mapped more recently (Heath, 1991; GZA GeoEnvironmental, Inc., 1992).

DATA COLLECTION

The altitude of the water table was mapped using measurements of water levels in 65 observation wells, 18 ponds, and 16 streambed piezometers on October 7-9, 1996; most of the measurements were made on October 8. Stream-surface altitudes also were measured at the 16 streambed-piezometer sites. Water-level altitudes were measured to an accuracy of 0.01 foot relative to the measuring point; the altitudes of the measuring points were surveyed to sea level datum. Water levels were measured in observation wells screened at or near the water table, which is the uppermost limit of the saturated zone of the aquifer. Total precipitation for the 7 days preceding the 2-day measurement period was 0.02 inch. Precipitation of 2.06 inches occurred on October 8 after all but three of the water-level measurements had been made. These remaining three ground-water-level measurements were made on October 9 and are assumed to have been unaffected by the precipitation on October 8 because depth to water at the three wells was greater than 53 feet below land surface. Discharge was measured at 22 stream sites on October 8.

Water-level and streamflow data reported here were collected by the U.S. Geological Survey, Rhode Island Department of Environmental Management, and U.S. Environmental Protection Agency. Pumping rates at the 17 water-supply wells in the Hunt-Annaquatucket-Pettaquamscutt aquifer for October 7 and 8 were provided by local water suppliers. The authors thank Galen McGovern and Ernest Panciera of the Rhode Island Department of Environmental Management and Douglas Heath of the U.S. Environmental Protection Agency for their assistance in the collection of water-level data.

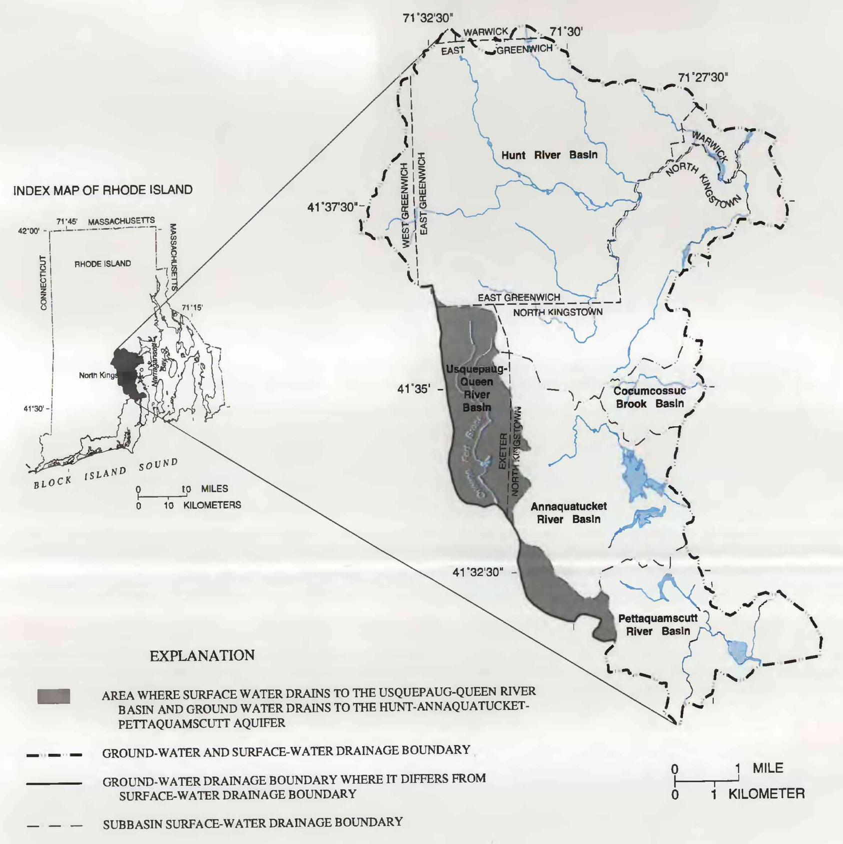

Figure 1. Location and drainage boundaries of the Hunt-Annaquatucket-Pettaquamscutt aquifer, central Rhode Island.

WATER-TABLE CONDITIONS

Water-table contours were drawn for areas of the aquifer consisting of stratified sand and gravel, which in a few locations is interbedded with till. Water-table contours were not drawn in areas consisting solely of till or bedrock. Areas of till and bedrock are differentiated from areas of stratified sand and gravel in figure 2. All supply wells in the study area derive water from stratified sand and gravel and, with the exception of the lower reach of Cocumcussoc Brook, all streams measured for this study flow across stratified sand and gravel deposits. The surface-water drainage area (35.6 square miles) to the aquifer is smaller than the ground-water drainage area (39.6 square miles) to the aquifer because surface water in the Usquepaug-Queen River Basin drains to the Queen River (west of the Hunt-Annaquatucket-Pettaquamscutt aquifer, fig. 1), whereas some of the ground water recharged in the Usquepaug-Queen River Basin flows to the Hunt-Annaquatucket-Pettaquamscutt aquifer.

The position of water-table contours near streams where ground-water data were not available were estimated using U.S. Geological Survey topographic maps. Pond water-level altitudes also were used to delineate water-table contours. The ponds and streams are hydraulically connected to the aquifer and in most places represent the position of the water table.

The altitude of the water table in stratified sand and gravel ranged from 1.4 feet above sea level near the Hunt River at Forge Road in the northeast part of the study area to a maximum altitude of about 220 feet above sea level in the southwest part of the study area. Ground water moves continually through the Hunt-Annaquatucket-Pettaquamscutt aquifer in the direction of declining water-table altitudes. The altitude and configuration of the water-table contours indicate that the direction of ground-water flow is from the western contact of the aquifer with till-bedrock uplands to the east and northeast toward Narragansett Bay and to the southeast toward Carr Pond. The Hunt-Annaquatucket-Pettaquamscutt aquifer is recharged by precipitation, stream leakage, and ground-water inflow from adjacent till-bedrock uplands. The aquifer also is recharged locally by septic-system return flow. Under natural conditions, ground water discharges to streams, ponds, and wetlands, and by evapotranspiration and underflow to adjacent flow systems. Water-supply wells intercept ground water that would have flowed to natural discharge areas. Only 13 of the 17 water-supply wells in the Hunt-Annaquatucket-Pettaquamscutt aquifer were in operation during each of the 2 days of measurement (table 1). Although pumping lowers ground-water levels around the wells, the scale of figure 2 is too small and the distances between observation wells are too large to show individual cones of depression. A substantial part of the water withdrawn from the water-supply wells is exported from the drainage area of the Hunt-Annaquatucket-Pettaquamscutt aquifer, treated, used for various purposes, and then discharged into Narragansett Bay.

Water levels have been measured monthly at North Kingstown well (NKW) 255 in the southern part of the study area (fig. 2) since August 1954, with the exception of the 2-year period January 1964 through December 1965. The mean water-table altitude at observation well NKW 255 for January 1966 through December 1996 was 36.82 feet above sea level. The water-table altitude measured October 8, 1996, at NKW 255 was 36.31 feet above sea level, indicating that water levels in figure 2 are representative of near-mean water-table conditions for the aquifer. Historical water-level fluctuations at NKW 255 for a representative 10-year period (January 1987 through December 1996) are shown in figure 3. These fluctuations are caused by seasonal and long-term variations in recharge to the ground-water system.

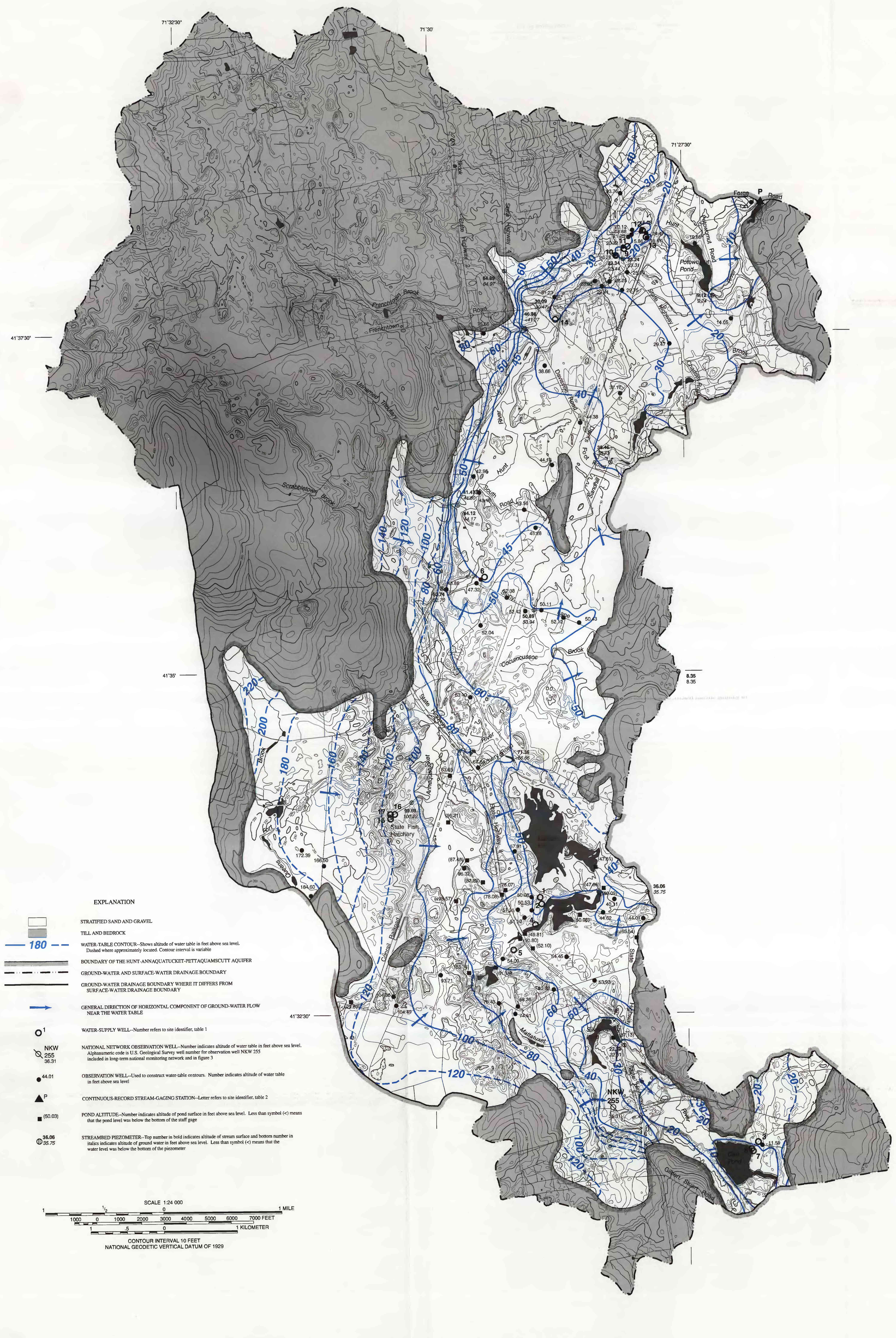

Figure 2. Altitude and configuration of the water table in the Hunt-Annaquatucket-Pettaquamscutt aquifer, central Rhode Island, October 7-9, 1996.

Table 1. Pumping rates for water-supply wells in the Hunt-Annaquatucket-Pettaquamscutt aquifer, central Rhode Island, October 7-8, 1996

Site identifier (See figure 2)	Local name	Pumping rate, in million gallons per day	
		October 7	October 8
NORTH KINGSTOWN WATER DEPARTMENT (NKWD)			
1	NKWD 1	0.29	0.49
2	NKWD 2	.20	.04
3	NKWD 3	.20	.19
4	NKWD 4	.31	0
5	NKWD 5	.29	.52
6	NKWD 6	.58	.34
7	NKWD 7	0	.11
8	NKWD 8	0	.08
9	NKWD 9	.60	.77
10	NKWD 10	0	0
Total		2.47	2.54
KENT COUNTY WATER AUTHORITY (KCWA)			
11	KCWA 1	0	0
Total		0	0
RHODE ISLAND ECONOMIC DEVELOPMENT CORPORATION (RIEDC)			
12	RIEDC 9A	0.16	0.50
13	RIEDC 14A	.51	0
14	RIEDC 3A	.12	.37
Total		0.79	0.87
RHODE ISLAND STATE FISH HATCHERY (RISFH)			
15	RISFH 1	0.43	0.43
16	RISFH 2	.64	.64
17	RISFH 3 (Dug well)	.16	.16
Total		1.23	1.23
TOTALS FOR AQUIFER			
Totals		4.49	4.64

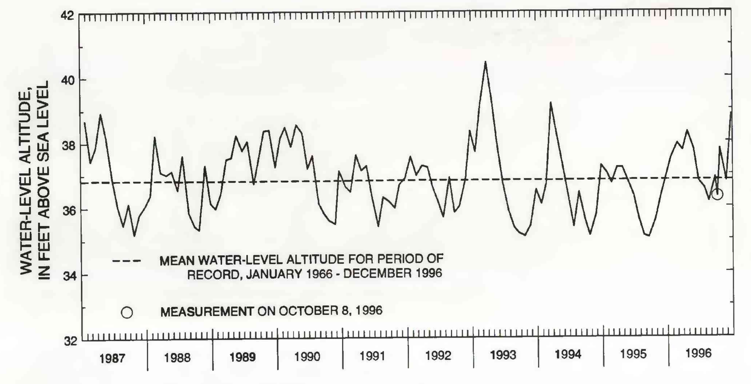

Figure 3. Historical water-level fluctuations at North Kingstown well (NKW) 255, central Rhode Island, 1987-96. (Location of well on figure 2.)

STREAM-AQUIFER INTERACTION

The interaction of ground water with adjacent streams is inferred from water-table contours near the streams and by downstream changes in discharge at successive streamflow-measurement sites. Discharges measured on October 8, 1996, are shown in table 2. Upstream inflections of water-table contours at a stream indicate ground-water discharge to the stream (a gaining stream reach); downstream inflections indicate stream leakage to the underlying aquifer (a losing stream reach). Gaining stream reaches also are defined by increases in discharge between two measurement sites; losing stream reaches are defined by decreases in discharge between two measurement sites.

Increases in discharge (gaining reaches) were measured between all measurement sites in the Hunt-Annaquatucket-Pettaquamscutt aquifer on October 8, 1996, with the exception of reaches G-I on the Hunt River and R-S on the Annaquatucket River, wherein discharge decreased (losing reaches) (fig. 4). The decrease in discharge (-2.81 million gallons per day) on the Hunt River (reach G-I) was caused by pumping from water-supply wells near the river. Stream leakage caused by ground-water pumping is referred to as induced infiltration. The amount of induced infiltration along a particular reach depends on the (1) area of stream affected by pumping, (2) vertical hydraulic conductivity of the streambed and underlying aquifer, (3) viscosity of stream water, and (4) vertical hydraulic gradient across the streambed (Rosenshein and others, 1968). The areal extent and distribution of losing reaches on the Hunt River changes as the number, location, and pumping rates of water-supply wells near the river vary.

Pumping from wells along the Hunt River also reduces discharge at the continuous-recording gaging station on the Hunt River at Forge Road. Discharge has been measured continuously on the Hunt River at Forge Road since August 1940 (site P in figure 2 and table 2). The mean discharge at site P for October 1940 through September 1996 was 30.0 million gallons per day. Discharge at the site on October 8, 1996, was 9.50 million gallons per day. This low discharge is typical of streamflow conditions during early autumn; discharge on other streams in the study area on October 8, 1996, also was likely to be lower than average. Fluctuations of mean daily discharge for the Hunt River at Forge Road for January 1987 through December 1996 are shown in figure 5. Fluctuations in discharge of the Hunt River are caused by daily, seasonal, and long-term variations in ground-water discharge to the river, pumping from water-supply wells along the river, and precipitation and evapotranspiration in the basin.

The losing reach (-0.38 million gallons per day) on the Annaquatucket River (reach R-S) probably reflects a deepening of the bedrock surface and thickening of the saturated thickness of the sand and gravel aquifer in that area. Streamflow in the Annaquatucket River in reach R-S is supported by discharges directly to headwater areas of the river at the State Fish Hatchery near site R. The large increase in discharge in reach S-T on the Annaquatucket River (6.68 million gallons per day) is the result of the large ground-water drainage area west of Belleville Pond and upgradient of site T.

Queens Fort Brook in the Usquepaug-Queen River Basin also is a naturally losing stream that is dry over most of its length during most of the year (Kliever, 1995). At the time of measurement on October 8, 1996, the brook was dry near its intersection with the boundary of the Hunt-Annaquatucket-Pettaquamscutt aquifer.

REFERENCES CITED

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Heath, D.L., 1991, The North Kingstown, Rhode Island wellhead protection area pilot project: Ground Water Management Section, U.S. Environmental Protection Agency Region 1, Boston, Massachusetts, various pagination.

Kliever, J.D., 1995, Hydrologic data for the Usquepaug-Queen River Basin, Rhode Island: U.S. Geological Survey Open-File Report 95-305, 68 p.

Rosenshein, J.S., Gonthier, J.B., and Allen, W.B., 1968, Hydrologic characteristics and sustained yield of principal ground-water units Potowomut-Wickford area, Rhode Island: U.S. Geological Survey Water-Supply Paper 1775, 38 p., 5 pls.

CONVERSION FACTORS AND VERTICAL DATUM

CONVERSION FACTORS

Multiply	By	To obtain
foot	0.3048	meter
inch	25.4	millimeter
mile	1.609	kilometer
million gallons per day	0.04381	cubic meter per second
square mile	2.590	square kilometer

VERTICAL DATUM

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 the United States and Canada, formerly called Sea Level Datum of 1929.

Table 2. Instantaneous discharge of streams in the Hunt-Annaquatucket-Pettaquamscutt aquifer, central Rhode Island, October 8, 1996

Site identifier (See figure 4)	Site name	Instantaneous discharge in million gallons per day
HUNT RIVER BASIN		
A	Scrabbletown Brook at State Highway 2	0.35
B	Unnamed Tributary at State Highway 2	.63
C	Hunt River near South Road	1.98
D	Hunt River at Davisville Road	3.11
E	Frenchtown Brook at State Highway 2	1.80
F	Frenchtown Brook at Davisville Road	1.91
G	Hunt River at Frenchtown Road	6.59
H	Fry Brook at State Highway 4	.83
I	Hunt River at State Highway 1	4.61
J	Hunt River at Conrail railroad	4.98
K	Hunt River at Potowomut Road	6.85
L	Sandhill Brook at Stony Lane	.12
M	Sandhill Brook at Devil's Foot Road	.58
N	Sandhill Brook at Chadsey Road	1.18
O	Sandhill Brook at North Quidnesset Road	1.39
P	Hunt River at Forge Road	9.50
COCUMCUSSOC BROOK BASIN		
Q	Cocumcossuc Brook at State Highway 1	0.74
ANNAQUATUCKET RIVER BASIN		
R	Annaquatucket River at State Fish Hatchery	1.26
S	Annaquatucket River at Hatchery Road	.88
T	Annaquatucket River at State Highway 1	7.56
PETTAQUAMSCUTT RIVER BASIN		
U	Mattatuxet River at State Highway 1	1.54
V	Mattatuxet River at Gilbert Stuart Road	2.59

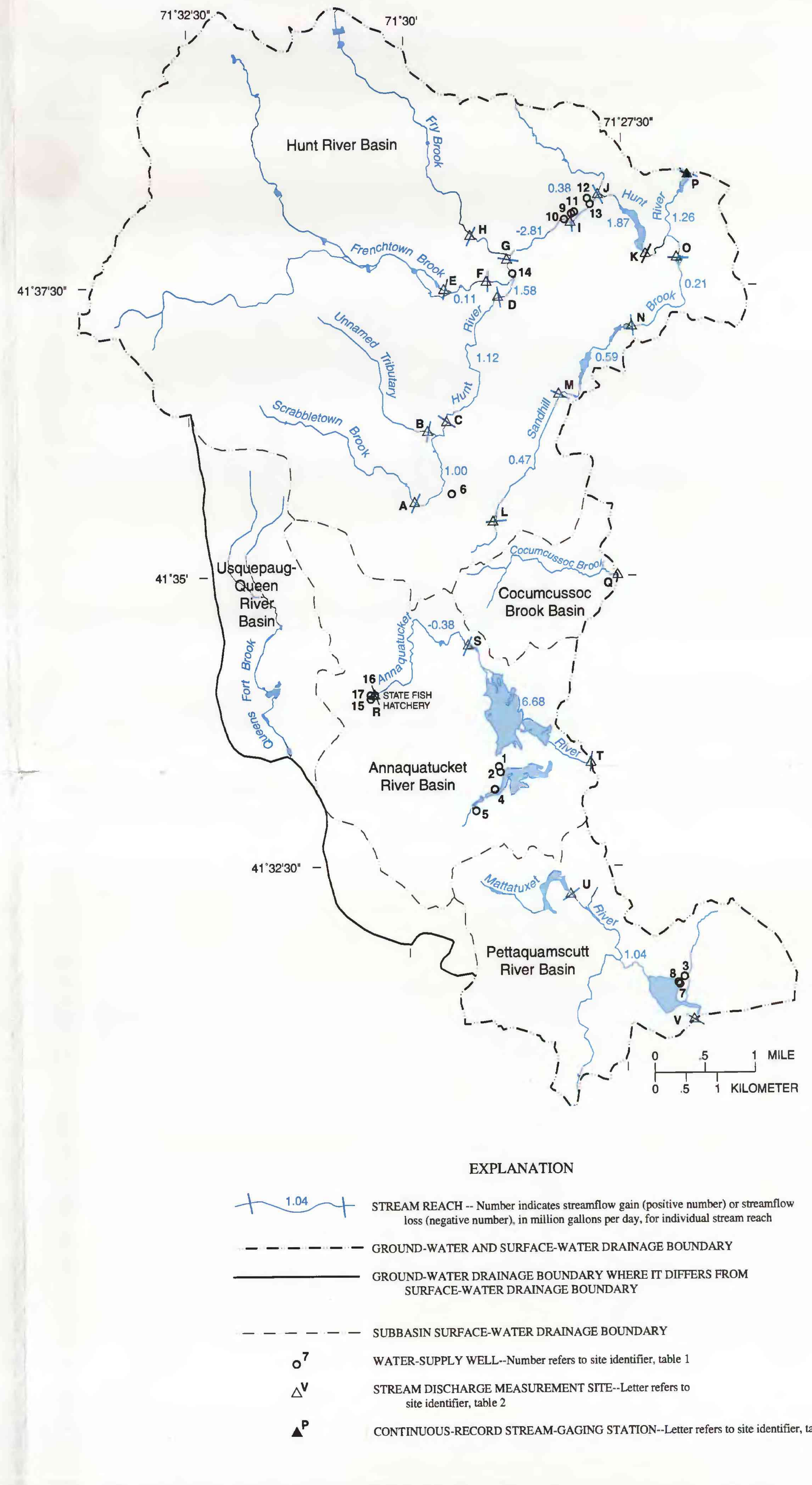

Figure 4. Stream discharge measurement sites and distribution of gaining and losing stream reaches in the Hunt-Annaquatucket-Pettaquamscutt aquifer, central Rhode Island, October 8, 1996.

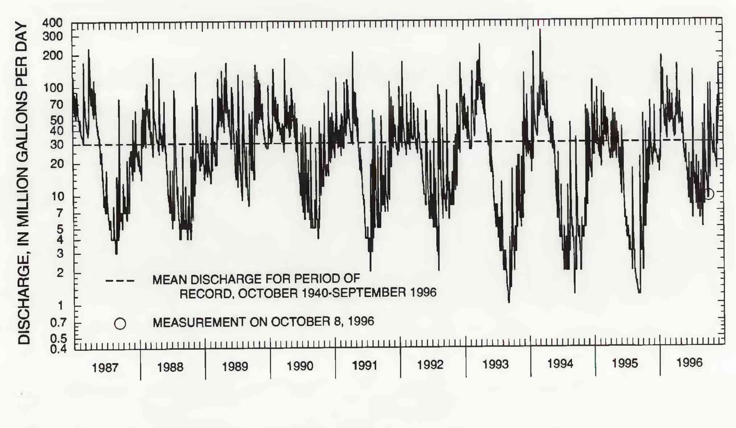

Figure 5. Historical fluctuations in discharge for Hunt River at Forge Road, central Rhode Island, 1987-96. (Location of discharge site on figure 2.)

Base map and coverage information from Rhode Island Geographic Information System digital data, 1:24,000, 1988-1994, Rhode Island State plane Projection, Zone 19

MAP SHOWING WATER-TABLE CONDITIONS AND STREAM-AQUIFER INTERACTION IN THE HUNT-ANNAQUATUCKET-PETTAQUAMSCUTT AQUIFER, CENTRAL RHODE ISLAND, OCTOBER 7-9, 1996

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