Estimated Water Use and Availability in the Pawtuxet and Quinebaug River Basins, Rhode Island, 1995–99

By Emily C. Wild and Mark T. Nimiroski

Prepared in cooperation with the Rhode Island Water Resources Board

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Conversion Factors, Vertical Datum, Abbreviations, and Acronyms

Multiply	By	To obtain
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
foot (ft)	0.3048	meter (m)
square foot (ft^2)	0.09290	square meter (m^2)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
gallons per day (gal/d)	0.003785	cubic meter per day (m^3/d)
mile (mi)	1.609	kilometer (km)
million gallons per day (Mgal/d)	3,785	cubic meters per day (m^3/d)
million gallons per day per square mile (Mgal/d/mi^2)	1,462.1	cubic meter per day per square kilometer (m^3/d/km^2)
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:
°C=(°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD83).

To convert water use and availability data to cubic feet per second, multiply million gallons per day by 1.5466.

Abbreviations and Acronyms

7Q10	7-day, 10-year low flow
ABF	Aquatic Base Flow
GIS	Geographic Information Systems
HUC	Hydrologic Unit Code
IWR-MAIN	Institute of Water Resources, Municipal and Industrial Needs System
KCWA	Kent County Water Authority
MCD	Minor Civil Division
NCDC	National Climatic Data Center
NEWUDS	New England Water-Use Data System
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
ProvWater	Providence Water Supply Board
RIDEM	Rhode Island Department of Environmental Management
RIEDC	Rhode Island Economic Development Corporation
RIGIS	Rhode Island Geographic Information System
RIPDES	Rhode Island Pollutant Discharge Elimination System
SCS	Soil Conservation Service
SIC	Standard Industrial Classification
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Administration
USGS	U.S. Geological Survey
WSO	Weather Station Observatory
WWTF	Wastewater-Treatment Facility

Estimated Water Use and Availability in the Pawtuxet and Quinebaug River Basins, Rhode Island, 1995–99

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Abstract

Water availability became a concern in Rhode Island during a drought in 1999, and an investigation was needed to assess demands on the hydrologic system from withdrawals during periods of little to no precipitation. The low water levels during the drought prompted the U.S. Geological Survey and the Rhode Island Water Resources Board to begin a series of studies on water use and availability in each drainage area in Rhode Island for 1995–99. The study area for this report, which includes the Pawtuxet River Basin in central Rhode Island (231.6 square miles) and the Quinebaug River Basin in western Rhode Island (60.97 square miles), was delineated as the surface-water drainage areas of these basins.

During the study period from 1995 through 1999, two major water suppliers withdrew an average of 71.86 million gallons per day (Mgal/d) from the Pawtuxet River Basin; of this amount, about 35.98 Mgal/d of potable water were exported to other basins in Rhode Island. The estimated water withdrawals from minor water suppliers were 0.026 Mgal/d in the Pawtuxet River Basin and 0.003 Mgal/d in the Quinebaug River Basin. Total self-supply withdrawals were 2.173 Mgal/d in the Pawtuxet River Basin and 0.360 Mgal/d in the Quinebaug River Basin, which has no public water supply. Total water use averaged 18.07 Mgal/d in the Pawtuxet River Basin and 0.363 Mgal/d in the Quinebaug River Basin. Total return flow in the Pawtuxet River Basin was 30.64 Mgal/d, which included about 12.28 Mgal/d that were imported from other basins in Rhode Island. Total return flow was 0.283 Mgal/d in the Quinebaug River Basin.

During times of little to no recharge in the form of precipitation, the surface- and ground-water flows are from storage primarily in the stratified sand and gravel deposits; water also flows through the till deposits, but at a slower rate. The ground water discharging to the streams during times of little to no recharge from precipitation is referred to as base flow. The PART program, a computerized hydrograph-separation application, was used to analyze the data collected at two selected index stream-gaging stations to determine water availability on the basis of the 75th, 50th, and 25th percentiles of the total base flow; the base flow for the 7-day, 10-year low-flow scenario; and the base flow for the Aquatic Base Flow scenario for both stations. The index stream-gaging stations used in the analysis were the Branch River at Forestdale, Rhode Island (period of record 1957–1999) and the Nooseneck River at Nooseneck, Rhode Island (period of record 1964–1980). A regression equation was used to estimate unknown base-flow contributions from sand and gravel deposits at the two stations. The base-flow contributions from sand and gravel deposits and till deposits at the index stations were computed for June, July, August, and September within the periods of record, and divided by the area of each type of surficial deposit at each index station. These months were selected because they define a period when there is usually an increased demand for water and little to no precipitation. The base flows at the stream-gaging station Branch River at Forestdale, Rhode Island were lowest in August at the 75th, 50th, and 25th percentiles (29.67, 21.48, and 13.30 Mgal/d, respectively). The base flows at the stream-gaging station Nooseneck River at Nooseneck, Rhode Island were lowest in September at the 75th percentile (3.551 Mgal/d) and lowest in August at the 50th and 25th percentiles (2.554 and 1.811 Mgal/d).

The base flows per unit area for the index stations were multiplied by the areas of sand and gravel and till in the study-area subbasins to determine the amount of available water for each scenario. The water availability in the Pawtuxet River Basin at the 50th percentile ranged from 126.5 Mgal/d in August to 204.7 Mgal/d in June, and the total gross water availability for the 7-day, 10-year low-flow scenario at the 50th percentile ranged from 112.2 Mgal/d in August to 190.4 Mgal/d in June. The Scituate Reservoir safe yield was 83 Mgal/d in all scenarios. Water availability in the Quinebaug River Basin ranged from 13.94 Mgal/d in August to 30.53 Mgal/d in June at the 50th percentile. The total gross water availability for the 7-day, 10-year low-flow scenario at the 50th percentile ranged from 14.26 Mgal/d in August to 42.69 Mgal/d in June.

Because water withdrawals and use are greater during the summer than other times of the year, water availability in June, July, August, and September was compared to water withdrawals in the basin and subbasins. The ratios of water withdrawn to water available were calculated for the 75th, 50th, and 25th percentiles for the subbasins; the closer the ratio is to 1, the closer the withdrawals are to the estimated water available, and the less net water is available. Withdrawals in July were higher than in the other summer months in both basins. In the Pawtuxet River Basin, the ratios were close to 1 in July for the estimated gross yield (from sand and gravel and from till and from the Scituate Reservoir safe yield), 7-day, 10-year low-flow scenario, and Aquatic Base Flow scenario at the 75th percentile and in

August for all three scenarios at the 50th and 25th percentiles. In the Quinebaug River Basin, the ratios were close to 1 in August for the estimated gross yield; 7-day, 10-year low-flow scenario; and Aquatic Base Flow scenario.

A long-term water budget was calculated for 1941 through 1999 to identify and assess the basin and subbasin inflow and outflows for the Pawtuxet and Quinebaug River Basins. The water withdrawals and return flows used in the budget were from 1995 through 1999. Inflow was assumed to be equal to outflow; total inflows and outflows were 574.9 Mgal/d in the Pawtuxet River Basin and 148.4 Mgal/d in the Quinebaug River Basin. Precipitation and return flow were 95 and 5 percent of the estimated inflows to the Pawtuxet River Basin, respectively. Precipitation was 100 percent of the estimated inflow to the Quinebaug River Basin; return flow was less than 1 percent of the inflow. Evapotranspiration, streamflow, and water withdrawals were 46, 41, and 13 percent, respectively, of the estimated outflows in the Pawtuxet River Basin. Evapotranspiration and streamflow were 49 and 51 percent, respectively, of the estimated outflows in the Quinebaug River Basin. Water withdrawals were less than 1 percent of outflows in the Quinebaug River Basin.

Introduction

Water availability became a concern to the State of Rhode Island during a drought in 1999, and an investigation was needed to assess water use and availability in the state, including the Pawtuxet and Quinebaug River Basins (fig. 1). During the summer of 1999, the average precipitation at the Kingston, RI, climatological station for June was only about 0.05 in., compared to the 30-year (1971-2000) long-term average precipitation of 3.936 in. for June. Because precipitation is a key component of surface-water runoff and ground-water infiltration (fig. 2), the rain deficiency caused a period of little to no recharge. As a result, ground-water levels and streamflows dropped below their long-term averages throughout Rhode Island.

To address water use and availability concerns in Rhode Island, the U.S. Geological Survey (USGS) began a series of nine water use and availability investigations in different basins for 1995–99 in cooperation with the Rhode Island Water Resources Board (RIWRB), which serves as a water-sourcing agency to ensure future water availability for residential growth and economic development for all Rhode Islanders (Rhode Island Water Resources Board, 2003). The purpose of the nine studies was to determine the relations between the water-use components (fig. 3) and the components of the hydrologic cycle (surface and ground water) during periods of little to no recharge. This particular study focused on the Pawtuxet and Quinebaug River Basins in central and western Rhode Island, respectively. Results of the Pawtuxet and Quinebaug River Basins studies and additional studies of other basins in or adjacent to Rhode Island will be used to compare water demands to water availability for times of little to no recharge, particularly during June, July, August, and September.

Purpose and Scope

This report identifies the water-use components and estimates water use and availability in the Pawtuxet and Quinebaug River Basins for calendar years 1995–99. To estimate water use, data for the components of water use were collected by basin and subbasin for the towns in the Pawtuxet and Quinebaug River Basins. The information and data on water withdrawals, use, and discharges were organized and retrieved by using the New England Water-Use Data System (NEWUDS) for the study period. The report presents the results of the calculated water availability for the Pawtuxet and Quinebaug River Basins for periods of little to no recharge by determining ground-water discharge during streamflow-recession periods and by using the previously published safe yield for the Scituate Reservoir (Weston, 1990). Because there are no major public water suppliers, wastewater collections, or interbasin transfers in the Quinebaug River Basin, discussion of these topics pertains only to the Pawtuxet River Basin. Water budgets, however, are presented for both basins. These budgets summarize the components of the hydrologic cycle on the basis of the long-term period of record for both basins (59 years) and selected water-use components for the study period.

Previous Investigations

The USGS has been collecting streamflow data from partial and continuous stream-gaging stations in the Pawtuxet River Basin for more than 63 years, and has been monitoring ground-water levels for more than 59 years. The data collected in the basin and its subbasins have been used for numerous hydrologic studies. Many studies have focused on the ground-water and surface-water resources and the water quality in the Pawtuxet River Basin and its subbasins. The Pawtuxet River Basin occupies areas within the Chepachet, Clayville, Coventry Center, Crompton, East Greenwich, East Killingly, Georgiaville, Hope Valley, North Scituate, Providence, Slocum, and Thompson USGS quadrangles. These quadrangles are published in the form of detailed thematic maps in reports describing the surficial geology (Feininger, 1962; Power, 1957; Richmond, 1953; Robinson, 1961; Smith, 1955; Smith, 1956a; and Smith, 1956b) and bedrock geology (Barosh, 1976; Dixon, 1974; Moore, 1958; Moore, 1963; Power, 1959; Quinn, 1951; Quinn, 1952; Quinn, 1959; Richmond, 1952). The Quinebaug River Basin occupies areas within the East Killingly, Oneco, Oxford, Thompson, and Voluntown USGS quadrangles. The surficial geology of the basin is described in quadrangle-map reports by Feininger (1965b) and Harwood and Goldsmith (1971b), and the bedrock geology in similar reports by Dixon (1974), Feininger (1965a), Harwood and Goldsmith (1971a), and Moore (1963).

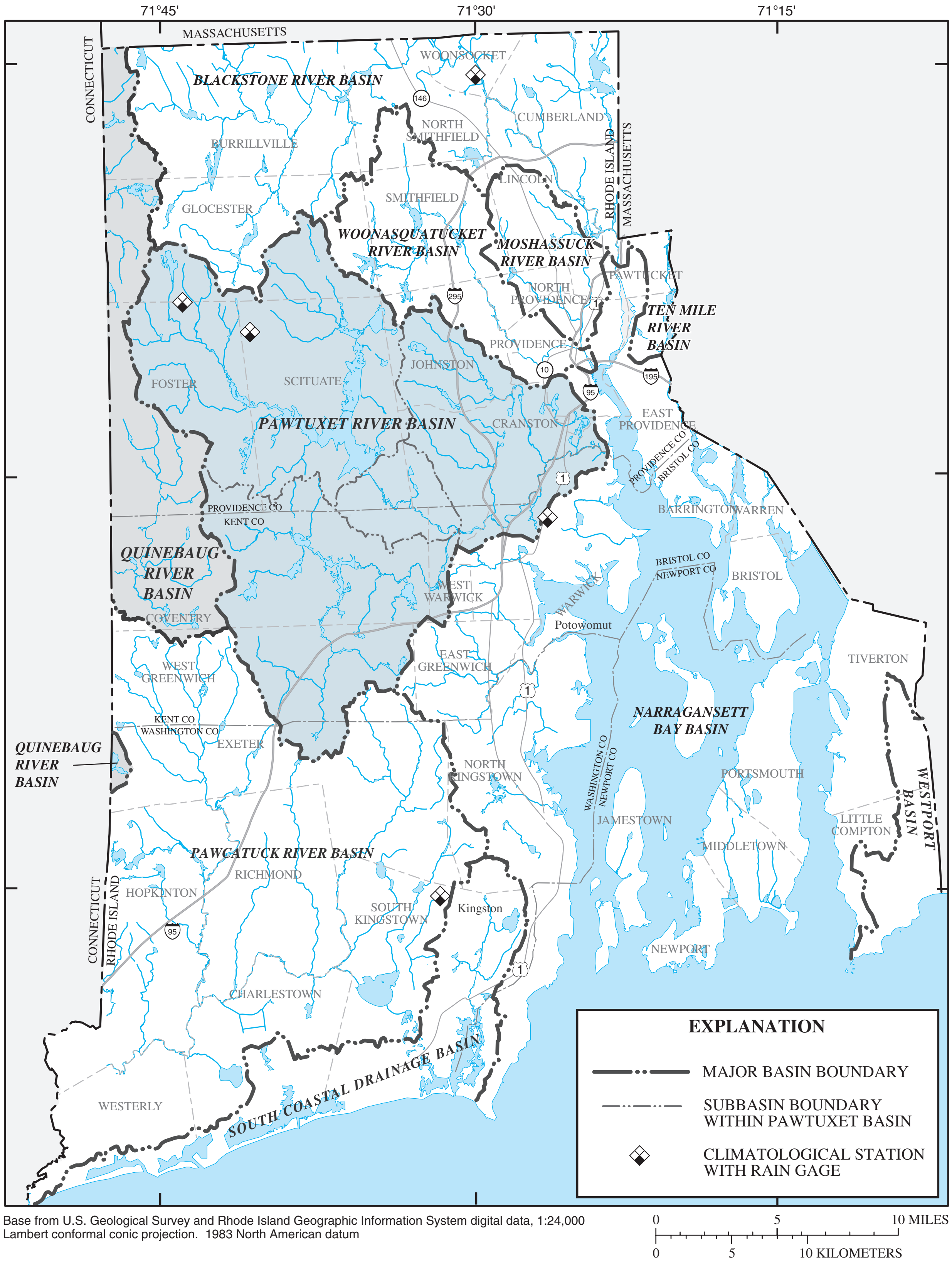


Figure 1. Towns and climatological stations in the Pawtuxet River Basin, central Rhode Island, and Quinebaug River Basin, western Rhode Island.

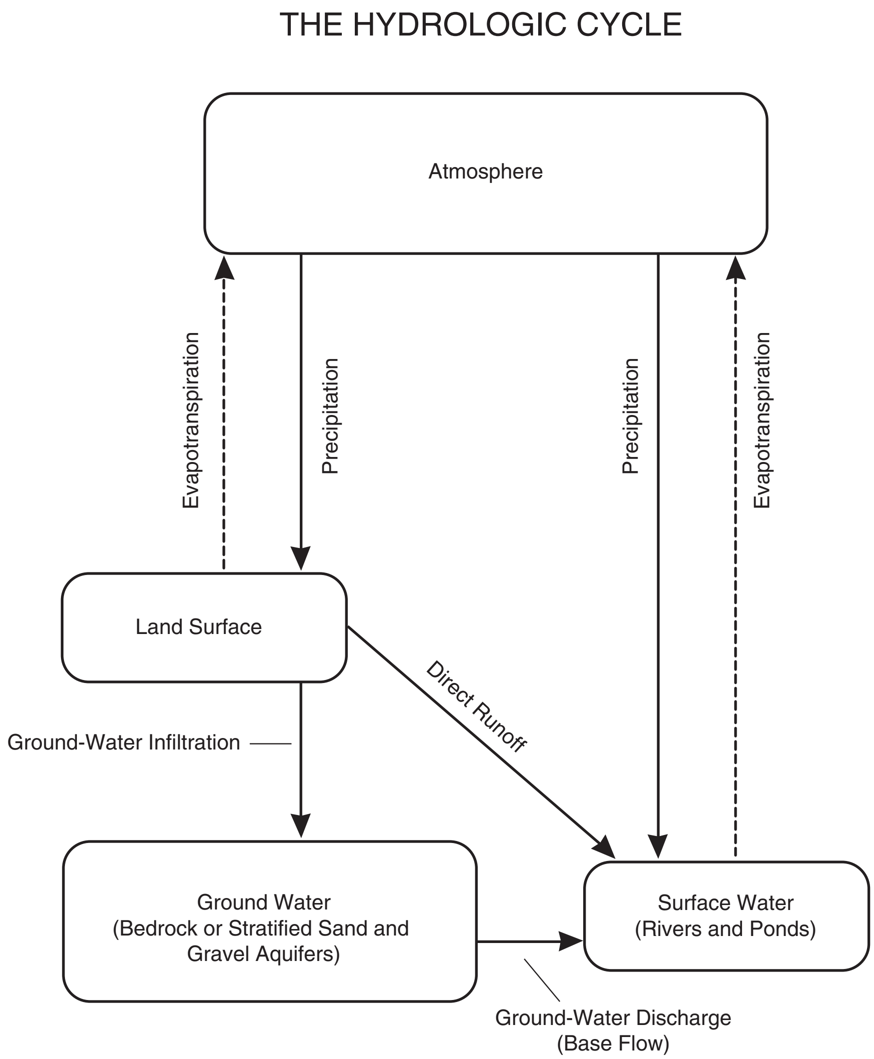


Figure 2. The hydrologic cycle. (Modified from U.S. Geological Survey, 2004).

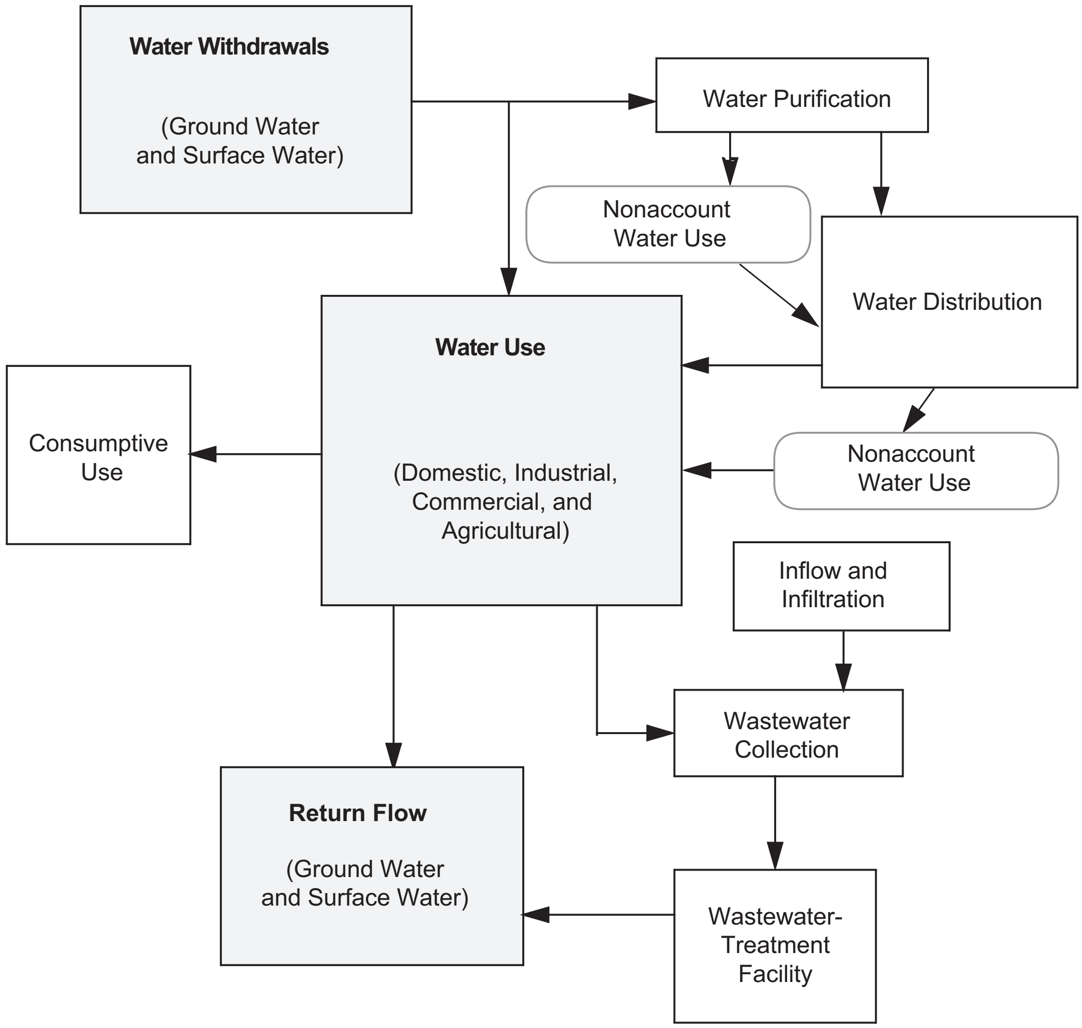


Figure 3. The components of water use.

The Rhode Island Water Resources Geologic Bulletin report series provides information about well records, lithologic logs, water-quality assessments, hydrologic characteristics of the surficial deposits (till and stratified sand and gravel deposits), and water-table altitudes. The Geologic Bulletin reports used in this assessment include Allen (1956), Bierschenk (1959), Hahn (1961), Richmond and Allen (1951), Roberts and Brashears (1945), and Roberts and Halberg (1945). The Rhode Island Water Resources Ground-Water Map report series provides information about bedrock contours, water-table altitudes, well locations, and till and stratified sand and gravel deposits. Ground-water maps used in this assessment include Allen and others (1959), Bierschenk and Hahn (1959), Hahn (1959), Hahn and Hansen (1961), Hansen (1962a, 1962b), Johnson (1962), Mason and Hahn (1960), and Pollock (1960). Details about partial-record stations can be found in the USGS annual data report series (Socolow and others, 2001), in studies of the Scituate Basin (Breault and others, 2000; and Nimiroski and Waldron, 2002), and in a recent summary of stream-gaging stations and ground-water monitoring wells (Zarriello and Socolow, 2003). Limited data about ground water (Allen, 1953; Allen and Lang, 1957; Kliever, 1995; Lang, 1961) and surface water (Allen, 1953) are available for the Quinebaug River Basin in Rhode Island.

In addition to studies pertaining to surficial deposits in the basin and subbasins, water-use data for the Pawtuxet and Quinebaug River Basins have been published in statewide assessments (Craft and others, 1995; Horn, 2000; Horn and Craft, 1991; and Medalie, 1996). Previous investigations in this series of USGS water use and availability studies (Barlow, 2003; and Nimiroski and Wild, 2005) contain additional information on wholesale purchases for districts within the Blackstone, Woonasquatucket, and Moshassuck River Basins from the Pawtuxet River Basin. The public water suppliers submit individual water-supply management plans to the RIWRB as a part of the state's Water Supply Systems Management Plan. Information on public disposal was collected (oral and written communication) from wastewater assessments that have been completed and submitted to the Rhode Island Department of Environmental Management (RIDEM), Office of Water Resources.

Climatological Setting

The National Oceanic and Atmospheric Administration has been publishing precipitation and temperature data from the climatological stations in Rhode Island for more than 100 years (fig. 1). Data have been collected continuously at some of the climatological stations, whereas other stations have had months-long breaks in operation. The breaks in the record make it difficult to assess accurately the annual precipitation and trends in the average monthly precipitation and temperature through the period of record.

Precipitation data for the climatological stations at Kingston, Rhode Island, on the University of Rhode Island (URI) campus; the Providence Weather Station Observatory (WSO) at the airport in Warwick, Rhode Island; at North Foster, Rhode Island; and at North Scituate, Rhode Island, were compiled by using the monthly and annual summaries published in the series "Climatological Data New England" (National Oceanic and Atmospheric Administration, 2000), and are presented in table 1. These data were used to calculate components of water use and the hydrologic cycle. Statewide, total annual precipitation is about 47.98 in., the average annual temperature is about 50.08°F (National Oceanic and Atmospheric Administration, 2000 and 2002), and the climate is humid and temperate. For June, July, August, and September, long-term (1971–2000) trends in average precipitation differ substantially from trends during the study period (table 1). During the study period, the total annual precipitation was about 48.92 in., and the average annual temperature was about 50.96°F. The Kingston climatological station has the longest precipitation record (1889–2005) of all of the Rhode Island climatological stations. The total annual precipitation at the Kingston climatological station for the study period was 53.11 in., and the average monthly precipitation for the summer ranged from 2.728 in. (July) to 4.474 in. (September). In addition to precipitation data from the stations operated by the National Oceanic and Atmospheric Administration, data from a network of precipitation stations operated by the Providence Water Supply Board (ProvWater) were used in calculating water budgets for 1941–99 (Providence Water Supply Board, written commun., 2000).

The Pawtuxet River Basin

The Pawtuxet River Basin in central Rhode Island (fig. 4) has a land area of about 231.6 mi^2. Thirteen Rhode Island towns are partially within the study area. In 1990, the basin population was about 196,121, and the estimated population during the study period was 194,963 (table 2). The Pawtuxet River Basin is mostly hilly, with higher altitudes in the northwest. For this study, the basin was divided into four subbasins—the Scituate Reservoir Complex, North Branch Pawtuxet, South Branch Pawtuxet, and Northeastern Pawtuxet subbasins (fig. 4)—which are based on the surface-water drainage areas. Aquifers for this study were defined as areas of stratified sand and gravel deposits with more than 40 ft of saturated thickness. One principal aquifer, the Mishnock aquifer, referred to as a ground-water reservoir in Rhode Island, is completely within the basin (fig. 5). The Providence-Warwick aquifer extends north to south along the coast of Narragansett Bay; the aquifer crosses the basin near the confluence of the Pawtuxet River with Narragansett Bay (fig. 5). Because limited data are available pertaining to the ground-water flow in this aquifer, the basin's surface-water divides were used for water-use and availability calculations. Losses from ground-water underflow within the defined surface-water drainage areas were considered negligible for this study.

Table 1. Summary of National Oceanic and Atmospheric Administration climatological stations and data pertinent to the Pawtuxet River Basin, central Rhode Island, and to the Quinebaug River Basin, western Rhode Island, 1995–99.

[Locations of climatological stations are shown on fig. 1. Climatological data are from monthly and annual summaries from the National Climate Data Center of the National Oceanic and Atmospheric Administration, 1971–2000 (National Oceanic and Atmospheric Administration, 2000a and b). WSO, weather station observatory; °F, degrees Fahrenheit; in., inches]

Climatological station	Period of record [study period]	June	July	August	September	Annual
		Average total precipitation (in.)				
Kingston, RI	1971–2000	3.936	3.308	4.400	4.163	51.79
	[1995–99]	4.106	2.728	4.356	4.474	53.11
North Foster, RI[1]	1975–2000	3.921	3.690	4.723	3.899	51.74
	[1995–99]	4.256	2.904	3.002	4.976	52.59
North Scituate, RI[2]	1970–74	4.126	2.908	3.488	5.104	53.75
Providence WSO Airport, Warwick, RI	1971–2000	3.382	3.169	3.904	3.704	46.46
	[1995–99]	3.414	1.978	3.190	4.014	43.91
Woonsocket, RI	1971–2000	3.653	3.666	4.279	4.093	50.05
	[1995–99]	3.506	3.932	3.126	4.290	51.58
		Average temperature (°F)				
Kingston, RI	1971–2000	65.63	71.06	69.91	62.72	49.94
	[1995–99]	66.50	71.88	70.32	63.74	50.91
Providence WSO Airport, Warwick, RI	1971–2000	67.65	73.37	71.88	63.99	51.13
	[1995–99]	68.20	74.14	72.08	64.74	51.84

[1]North Foster station is missing precipitation data (September 1981, March 1982, July 1982, February 1983, March 1983, and January 1985), and therefore these data were not included in the monthly averages. No total annual precipitation data were available for the years 1981, 1982, 1983, and 1985.

[2]North Scituate station was offline from October through December 1974, and therefore these data were not included in the monthly averages. No average total annual precipitation was calculated for 1974.

Land Use

Land-use areas were calculated by merging the Rhode Island Geographic Information Systems (RIGIS) land-use coverages with the subbasin-boundary coverages. Land-use area was used as a tool to aggregate commercial, industrial, and agricultural water-use estimates by town, subbasin, and basin (table 3). If categorical data were available from the public-supply district, water use was disaggregated by subbasin on the basis of land-use area in the public-supply district (table 4). Land-use areas not within public-supply districts were assumed to be self-supplied.

Pawtuxet River Subbasins

The surface-water-flow boundaries were used for assessing water use and determining water availability for the summer in the basin (fig. 4) because data on ground-water movement along the currently defined surface-water delineations are limited. Based on the surface-water-drainage boundaries, about 29.5 percent of the surficial geology in the Pawtuxet River Basin is stratified sand and gravel deposits. The thickness of the sand and gravel deposits is greater at the confluence of the Pawtuxet River Basin with Narragansett Bay, mainly because of the Providence-Warwick aquifer.

The USGS subbasin boundaries delineated for the study area are similar to the cataloging units defined in the Watershed Boundary Dataset (WBD) delineated by the Natural Resources Conservation Service (NRCS) in 2003 (table 5). The WBD used the standards for delineations of the boundaries that were established by the Federal Geographic Data Committee in 2002. The WBD cataloging units are compared visually to the areas used for this study in figure 6. The main spatial difference between them is that the smaller drainage areas determined by the WBD are grouped together by segments for this study. Naming conventions are another difference between the study subbasins and the WBD 10-digit and WBD 12-digit cataloging units (table 5, fig. 6). The Pawtuxet River Basin is one of the WBD 10-digit cataloging areas within the USGS 8-digit Hydrologic Unit Code (HUC) area for the Narragansett Bay Basin.

Table 2. Total town populations by subbasin for 1990, estimated populations for 1995–99, and estimated populations on public and self-supply and on public and self-disposal in the Pawtuxet River Basin, central Rhode Island, and in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Shaded areas are basin totals. Total populations in Rhode Island, 1990, from Rhode Island Geographic Information System (1991). Estimated 1995–99 population from the Rhode Island Economic Development Corporation (2001). --, not applicable]

Towns	Population		Estimated 1995–99 population			
	1990	Estimated 1995–99	Supply		Disposal	
			Public	Self	Public	Self
Pawtuxet River Basin						
Scituate Reservoir Complex Subbasin						
Cranston	144	142	97	45	16	126
Foster	2,455	2,509	100	2,409	--	2,509
Glocester	2,799	2,815	--	2,815	--	2,815
Johnston	978	971	432	539	41	930
Scituate	7,832	8,006	431	7,575	238	7,768
Smithfield	91	90	--	90	--	90
Subbasin total	14,832	14,533	1,301	13,232	540	13,993
North Branch Pawtuxet Subbasin						
Coventry	3,822	3,999	3,500	499	309	3,691
Cranston	1,047	1,031	701	330	114	916
Scituate	1,676	1,713	901	812	135	1,578
West Warwick	6,036	5,986	5,952	34	5,526	460
Subbasin total	12,581	12,729	11,054	1,675	6,084	6,645
South Branch Pawtuxet Subbasin						
Coventry	25,627	26,816	20,753	6,063	3,307	23,509
East Greenwich	49	50	31	19	3	47
Exeter	367	398	4	394	--	398
Foster	213	218	--	218	--	218
Scituate	281	287	--	287	--	287
Warwick	20	20	20	--	8	12
West Greenwich	2,062	2,330	742	1,588	19	2,311
West Warwick	12,866	12,759	12,684	75	12,177	582
Subbasin total	41,485	42,878	34,234	8,644	15,514	27,364
Northeastern Pawtuxet Subbasin						
Cranston	68,683	67,611	66,627	984	60,603	7,008
Johnston	13,100	13,014	10,913	2,101	7,110	5,904
Providence	25,417	23,957	23,957	--	23,957	--
Warwick	17,349	17,061	17,054	7	11,560	5,501
West Warwick	3,207	3,180	3,039	141	3,024	156
Subbasin total	127,756	124,823	121,590	3,233	106,254	18,569
Basin total	196,121	194,963	168,179	26,784	128,392	66,571
Quinebaug River Basin						
Burrillville	524	514	--	514	--	514
Coventry	1,552	1,569	40	1,529	--	1,569
Exeter	75	81	--	81	--	81
Foster	1,648	1,684	--	1,684	--	1,684
Glocester	643	647	--	647	--	647
West Greenwich	41	46	--	46	--	46
Basin total	4,483	4,541	40	4,501	--	4,541

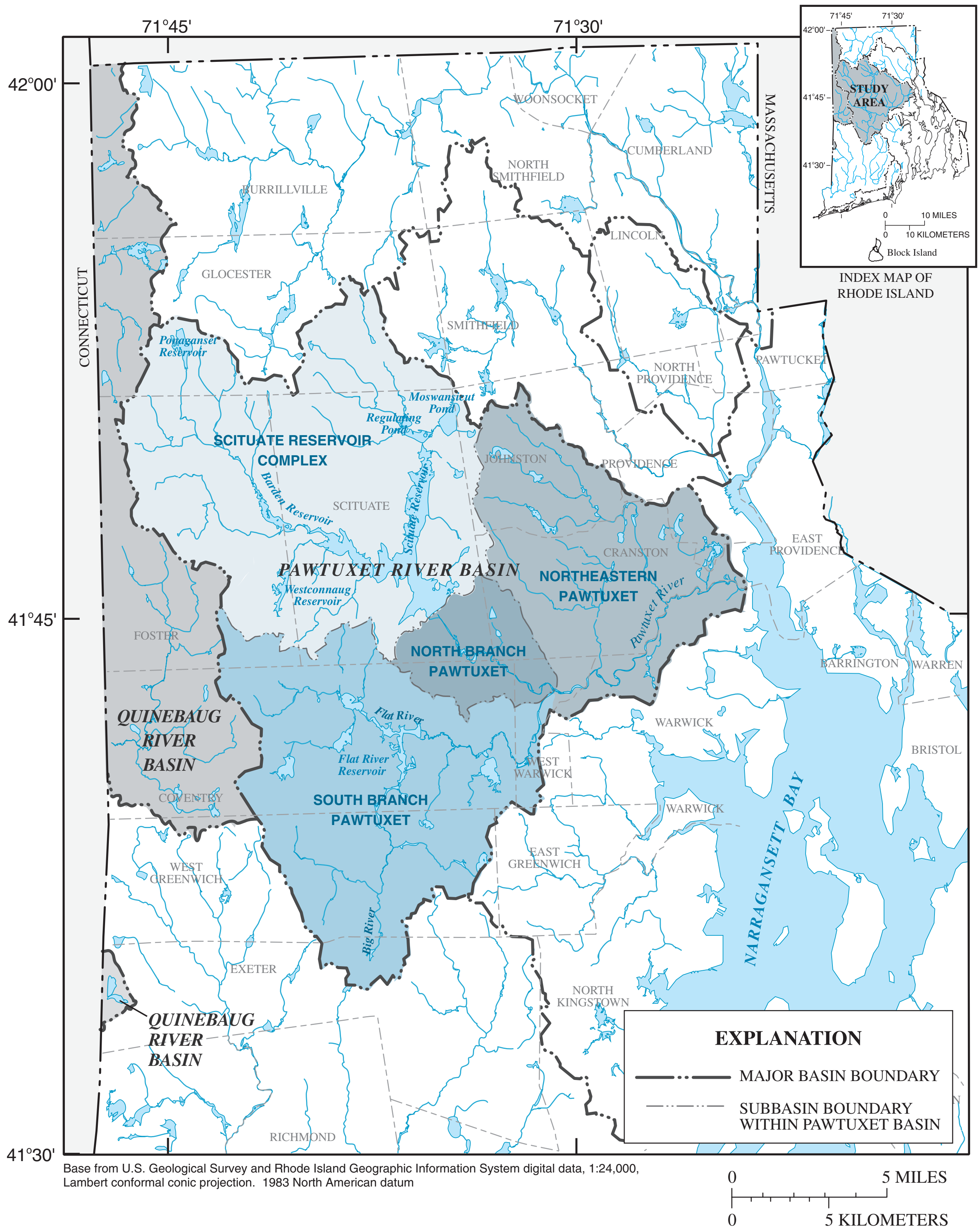
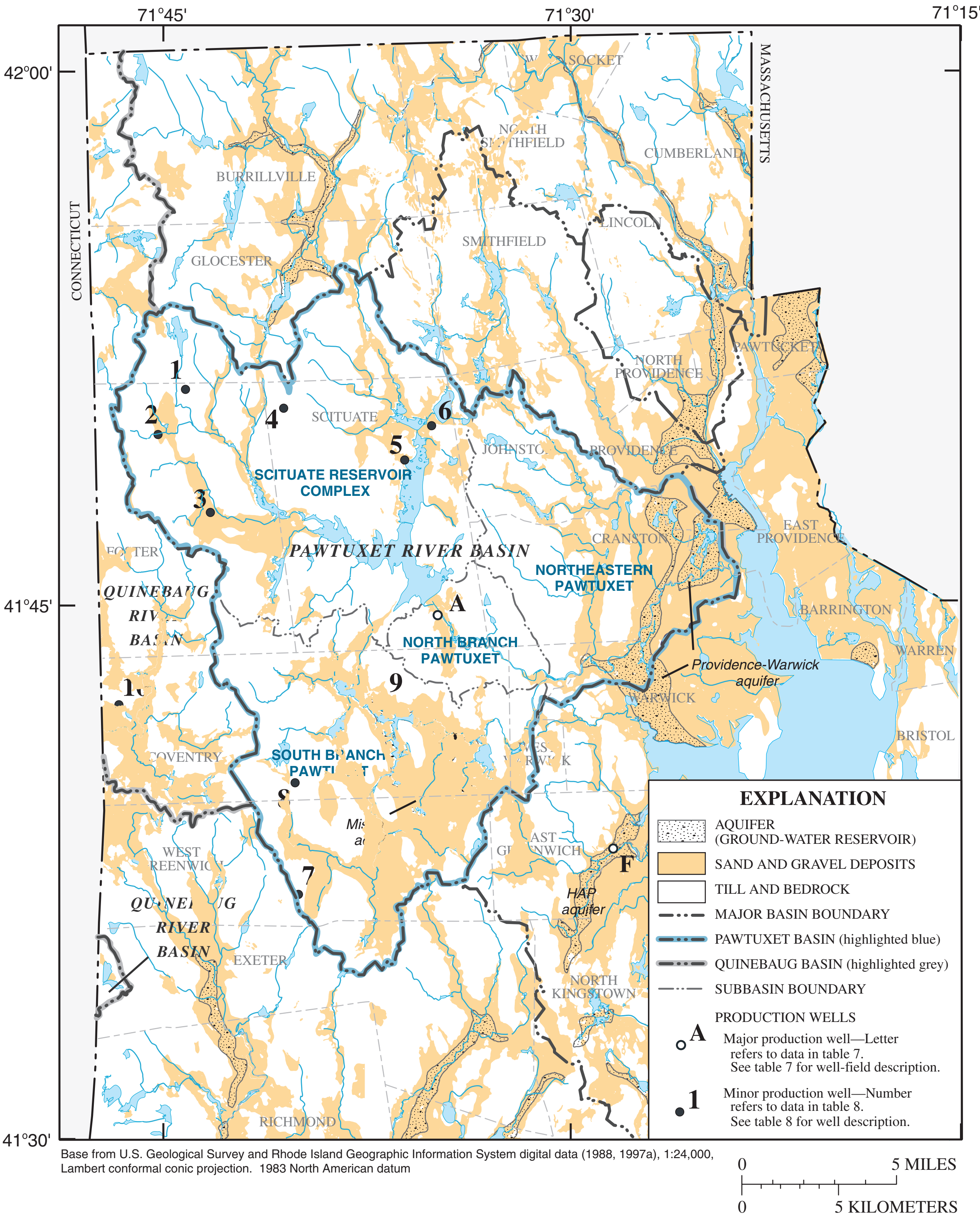


Figure 4. Subbasins in the Pawtuxet River Basin, central Rhode Island, and the Quinebaug River Basin, western Rhode Island.



Base from U.S. Geological Survey and Rhode Island Geographic Information System digital data (1988, 1997a), 1:24,000, Lambert conformal conic projection. 1983 North American datum

Figure 5. Aquifers and selected production wells for the subbasins in the Pawtuxet and Quinebaug River Basins, central and western Rhode Island. [HAP, Hunt-Annaquatucket-Pettaquamscutt]

Table 3. Town land area and land-use area by category in the subbasins of the Pawtuxet River Basin, central Rhode Island, and in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Shaded areas are basin totals. Land-use areas were estimated by using the coverage from the Rhode Island Geographic Information System (1995a). mi^2, square mile; <0.001, value not included in totals; --, not applicable]

Town	Land area (mi^2)	Land-use area by category (mi^2) Commercial	Industrial	Agricultural
Pawtuxet River Basin				
Scituate Reservoir Complex Subbasin				
Cranston	0.461	--	--	0.095
Foster	28.95	0.170	0.042	.950
Glocester	16.39	.066	--	1.023
Johnston	1.941	.033	.002	.175
Scituate	46.33	.174	.009	1.604
Smithfield	.032	--	--	.003
Subbasin total	94.11	0.443	0.053	3.850
North Branch Pawtuxet Subbasin				
Coventry	3.917	0.029	0.062	0.123
Cranston	3.159	.001	.005	.892
Scituate	5.493	.014	.019	.538
West Warwick	1.525	.093	.080	.035
Subbasin total	14.09	0.137	0.166	1.588
South Branch Pawtuxet Subbasin				
Coventry	37.32	0.575	0.284	0.985
East Greenwich	.140	--	--	--
Exeter	3.247	.008	--	.133
Foster	2.902	--	--	.083
Scituate	2.967	--	--	.172
Warwick	.043	.001	--	.002
West Greenwich	23.10	.187	.038	.775
West Warwick	2.958	.247	.144	.017
Subbasin total	72.68	1.018	0.466	2.167
Northeastern Pawtuxet Subbasin				
Cranston	24.56	1.141	1.155	1.622
Johnston	14.60	.508	.269	.971
Providence	2.952	.279	.395	--
Warwick	7.140	1.014	.874	.058
West Warwick	1.460	.054	.020	.031
Subbasin total	50.71	2.996	2.713	2.682
Basin total	231.6	4.594	3.398	2.682
Quinebaug River Basin				
Burrillville	8.595	--	--	0.047
Coventry	20.30	0.023	0.009	1.284
Exeter	1.432	--	--	--
Foster	20.09	.077	--	1.746
Glocester	9.703	.027	.037	.278
West Greenwich	.853	--	--	.006
Basin total	60.97	0.127	0.046	3.361

The Scituate Reservoir Complex subbasin (94.11 mi^2 drainage area) is in the western section of the Pawtuxet River Basin. The towns in the subbasin include Cranston, Foster, Glocester, Johnston, Scituate, and Smithfield (fig. 4). The Scituate Reservoir Complex subbasin is a headwater subbasin defined by the Gainer Dam embankment at the confluence with the North Branch Pawtuxet River. The complex includes the drainage areas for five reservoirs — the Ponaganset, Barden, Westconnaug, Regulating, and Moswansicut Reservoirs — which drain into the drainage area of the Scituate Reservoir (fig. 7), and comprises three 12-digit cataloging units defined by the WBD (fig. 6 and table 5). The Ponaganset River flows southeast from the Ponaganset Reservoir dam and into the Barden Reservoir. Hemlock Brook flows east into Barden Reservoir, which drains to the Scituate Reservoir at the confluence of Swamp Brook. Just south of the Barden Reservoir confluence, the Westconnaug Brook flows from the Westconnaug Reservoir into the Scituate Reservoir. In the northern part of the Scituate Reservoir Complex subbasin, Peeptoad, Huntinghouse, and Rush Brooks flow into the Regulating Reservoir. In the northeastern corner of the Scituate Reservoir Complex subbasin, drainage from the Moswansicut Reservoir flows west into the Regulating Reservoir. Other tributaries to the Scituate Reservoir include Brandy Brook from the east, Cork Brook from the north, Kent Brook from the east, Spruce Brook from the north, Quonapaug Brook from the east, and Wilbur Hollow Brook from the southwest. Although no defined aquifers are in the Scituate Reservoir Complex subbasin, about 17.4 percent of the glacial deposits are stratified sand and gravel deposits (figs. 5 and 7). One continuous stream-gaging station (fig. 8), the Ponaganset River at South Foster, Rhode Island (01115187), has a period of record of more than 8 years, and the surficial deposits in the area upstream of the stream-gaging station are about 15 percent sand and gravel. The USGS has been collecting surface-water data from partial-record stations within the Scituate Reservoir Complex subbasin in cooperation with ProvWater for about 10 years (fig. 7).

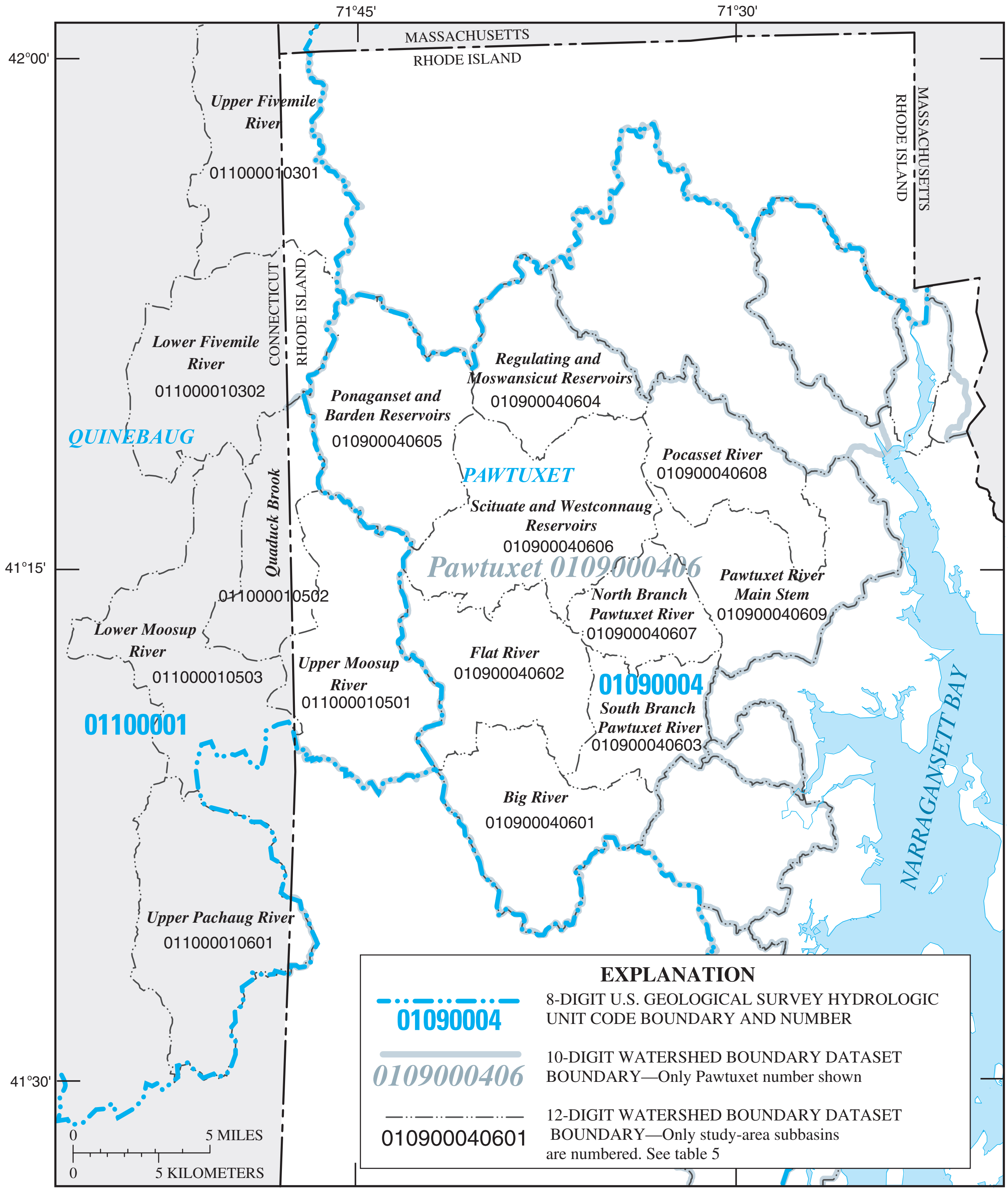
The North Branch Pawtuxet subbasin (14.09 mi^2 drainage area) is the central section of the Pawtuxet River Basin. The towns in the subbasin include Coventry, Cranston, Scituate, and West Warwick (fig. 4). Land areas and land-use areas by category for towns and major public water suppliers are summarized in tables 3 and 4, respectively. The North Branch Pawtuxet River flows southeast from Gainer Dam. Although the North Branch Pawtuxet subbasin has no defined aquifer, the area of the subbasin is about 12 percent sand and gravel (fig. 5); these deposits are the source of water for some self-supply users. One discontinued stream-gaging station in the subbasin (fig. 8), Pawtuxet River at Fiskeville, Rhode Island (01115500), has a period of record of more than 20 years. The surficial deposits in the area upstream of the Fiskeville station are about 12 percent sand and gravel, which is about the same as the percentage of sand and gravel deposits for the North Branch Pawtuxet subbasin.

Table 4. Land-use area and percentage of land-use area by major public water-supply district for the subbasins in the Pawtuxet River Basin study area and areas outside of the Pawtuxet River Basin, central Rhode Island, 1995–99.

[Land-use areas for the water-supply districts were estimated by using the coverages from the Rhode Island Geographic Information System (1995a, b). mi^2, square mile; --, not applicable]

Major public water supplier	Basin (and subbasin) where water is withdrawn or major supplier from which water is purchased wholesale	Total land area in Pawtuxet River Basin (mi^2)	Land-use area by category in the Pawtuxet River Basin (mi^2)			Total land area outside Pawtuxet River Basin (mi^2)	Land-use area by category outside of the Pawtuxet River Basin (mi^2)		
			Commercial	Industrial	Agricultural		Commercial	Industrial	Agricultural
Cranston Water District	Providence Water Supply Board	7.712	0.104	0.224	0.691	--	--	--	--
Johnston Water District	Providence Water Supply Board	8.241	.133	.208	.598	0.031	--	--	--
Kent County Water Authority	Pawtuxet (South Branch Pawtuxet) and West Narragansett Bay (Hunt)	24.33	1.274	.577	.514	21.04	1.202	0.541	0.819
Providence Water Supply Board	Pawtuxet (Scituate Reservoir Complex)	19.34	1.642	1.369	.386	24.99	2.635	1.527	.114
Warwick Water Department	Providence Water Supply Board; Kent County Water Authority	6.035	.815	.852	--	19.36	.895	.137	.802
Basin totals		65.66	3.968	3.230	2.189	65.42	4.732	2.205	1.735

Major public water supplier	Basin (and subbasin) where water is withdrawn or major supplier from which water is purchased wholesale	Total percentage of land use in Pawtuxet River Basin	Percentage of land use in the Pawtuxet River Basin			Total percentage of land use outside Pawtuxet River Basin	Percentage of land use outside of the Pawtuxet River Basin		
			Commercial	Industrial	Agricultural		Commercial	Industrial	Agricultural
Cranston Water District	Providence Water Supply Board	100.0	100.0	100.0	100.0	--	--	--	--
Johnston Water District	Providence Water Supply Board	99.63	100.0	100.0	100.0	0.370	--	--	--
Kent County Water Authority	Pawtuxet (South Branch Pawtuxet) and West Narragansett Bay (Hunt)	53.63	51.45	51.61	45.97	46.37	48.55	48.39	54.03
Providence Water Supply Board	Pawtuxet (Scituate Reservoir Complex)	43.63	38.39	47.27	77.20	56.37	61.61	52.73	22.80
Warwick Water Department	Providence Water Supply Board; Kent County Water Authority	23.77	47.66	86.15	--	76.23	52.34	13.85	100.0



Base from U.S. Geological Survey, Connecticut Map and Geographic Information Center, and Rhode Island Geographic Information System data sets
Rhode Island state plane, 5176 fipzone
1983 North American datum

Watershed Boundary Dataset from Natural Resources Conservation Service

Figure 6. The 8-, 10-, and 12-digit Watershed Boundary Dataset delineations for the Pawtuxet and Quinebaug River Basins, central and western Rhode Island.

Table 5. Defined subbasins in the Pawtuxet and Quinebaug River Basin study areas in Rhode Island compared to the 10-digit and 12-digit Natural Resources Conservation Service Watershed Boundary Dataset (2003) for Rhode Island

[Total land area for the Natural Resources Conservation Service Watershed Boundary Dataset for the Quinebaug River Basin 8-digit Hydrologic Unit Code (01100001) in Rhode Island is 60.97 mi^2; outside of the study area, the areas of the Quinebaug River Basin in Connecticut and Massachusetts are about 433 and 249 mi^2, respectively. Numbers may not add to totals because of rounding; mi^2, square mile]

Pawtuxet River Basin study area in Rhode Island		Watershed Boundary Dataset for Pawtuxet River Basin					
		10-digit			12-digit		
Subbasin	Drainage area (mi^2)	Name	Number	Drainage area (mi^2)	Name	Number	Drainage area (mi^2)
Scituate Reservoir Complex[1]	94.11	Pawtuxet River	0109000406	231.6	Regulating and Moswansicut Reservoirs	010900040604	[1]22.10
North Branch Pawtuxet[2]	14.09				Ponaganset and Barden Reservoirs	010900040605	[1]32.99
South Branch Pawtuxet[3]	72.68				Scituate and Westconnaug Reservoirs	010900040606	[1]39.01
Northeastern Pawtuxet[4]	50.71				North Branch Pawtuxet River	010900040607	[2]14.09
					Big River	010900040601	[3]28.41
					Flat River	010900040602	[3]27.75
					South Branch Pawtuxet River	010900040603	[3]16.52
					Pocasset River	010900040608	[4]20.61
					Pawtuxet River mainstem	010900040609	[4]30.11
Total Pawtuxet River Basin study area	231.6	Total Pawtuxet River Basin		231.6	Total Pawtuxet River Basin		231.6

Quinebaug River Basin study area in Rhode Island		Watershed Boundary Dataset for Quinebaug River Basin in Rhode Island					
		10-digit			12-digit		
Basin	Drainage area (mi^2)	Name	Number	Drainage area (mi^2)	Name	Number	Drainage area (mi^2)
Quinebaug[5]	60.97	Fivemile River	0110000103	19.26	Upper Fivemile River	011000010301	11.67
					Lower Fivemile River	011000010302	7.588
		Moosup River	0110000105	40.31	Upper Moosup River	011000010501	33.81
					Quaduck Brook	011000010502	6.350
					Lower Moosup River	011000010503	.155
		Pachaug River	0110000106	1.435	Upper Pachaug River	011000010601	1.435
Total Quinebaug River Basin study area in Rhode Island	60.97	Total Quinebaug River Basin in Rhode Island		61.01	Total Quinebaug River Basin in Rhode Island		61.01

[1]Scituate Reservoir Complex subbasin includes the Watershed Boundary Dataset 12-digit number 010900040604, 010900040605, and 010900040606.

[2]North Branch Pawtuxet subbasin includes the Watershed Boundary Dataset 12-digit number 010900040607.

[3]South Branch Pawtuxet subbasin includes the Watershed Boundary Dataset 12-digit numbers 010900040601, 010900040602, and 010900040603.

[4]Northeastern Pawtuxet subbasin includes the Watershed Boundary Dataset 12-digit numbers 010900040608 and 010900040609.

[5]Areas of the Quinebaug River Basin 10-digit and 12-digit datasets extend into Massachusetts and Connecticut (fig. 9), but were not used in this assessment.

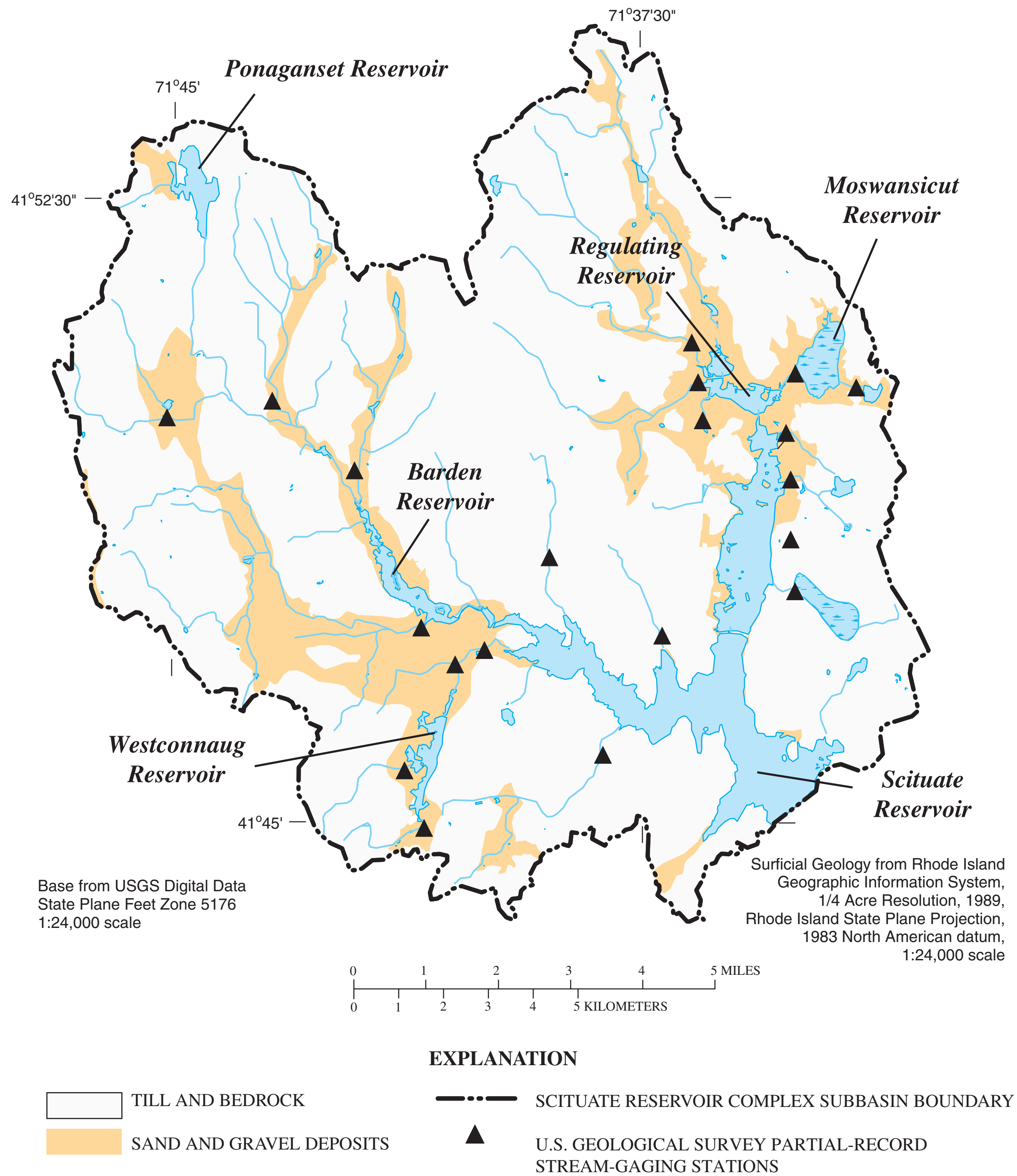


Figure 7. Scituate Reservoir Complex subbasin with selected partial-record stream-gaging stations and surficial deposits, Pawtuxet River Basin, central Rhode Island.

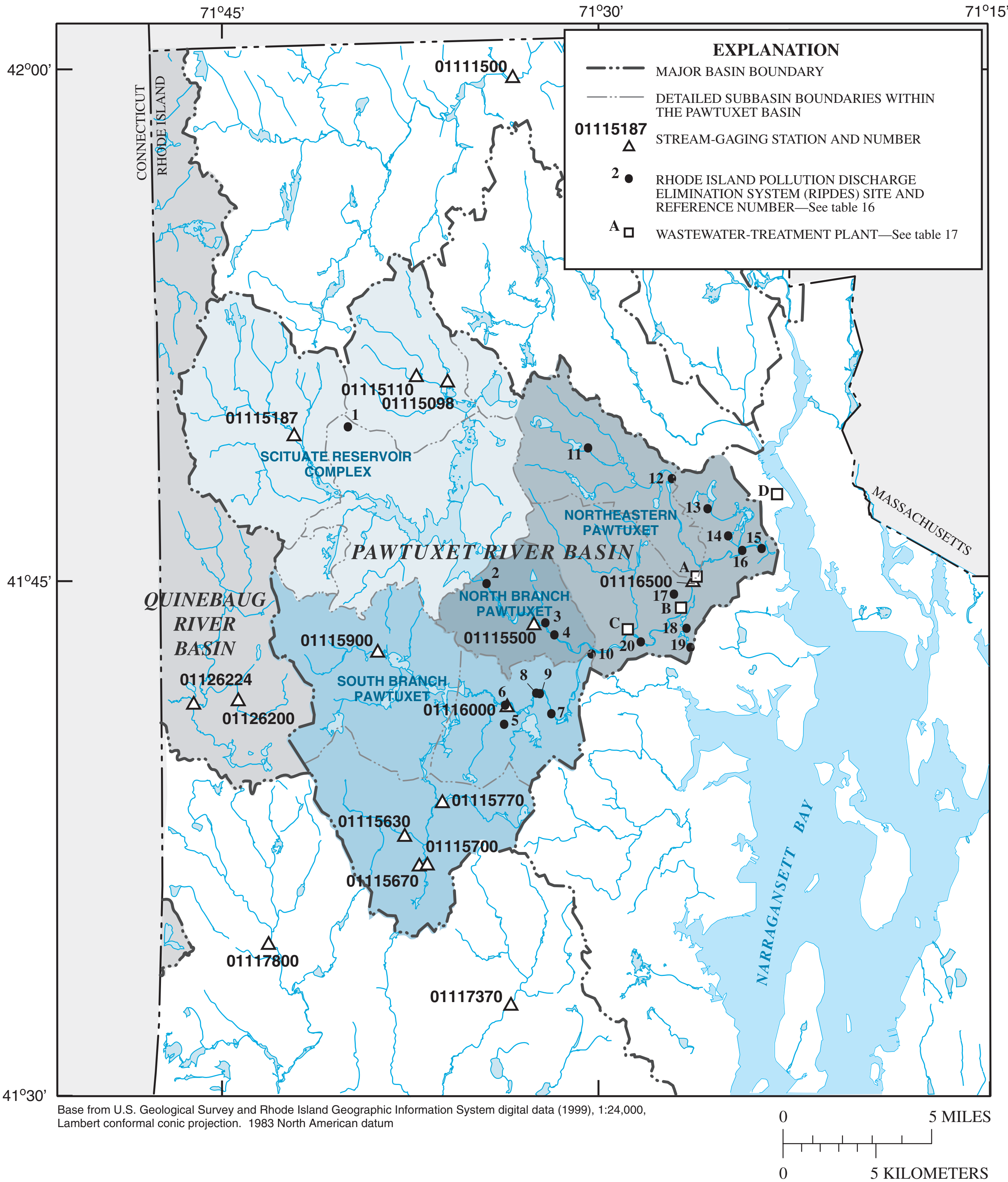


Figure 8. Stream-gaging stations, Rhode Island Pollutant Discharge Elimination System sites, and wastewater-treatment plants associated with the Pawtuxet and Quinebaug River Basins, central and western Rhode Island.

The South Branch Pawtuxet subbasin (72.68 mi^2 drainage area) is in the southern section of the Pawtuxet River Basin. The towns in the subbasin are Coventry, East Greenwich, Exeter, Foster, Scituate, Warwick, West Greenwich, and West Warwick (fig. 4). In the southern part of the subbasin, the Nooseneck River flows into the Big River from the west, and the Carr River flows into the Big River from the east. The Big River flows north to the Flat River Reservoir in the western part of the subbasin. The reservoir is used for recreation, and the flow out of the reservoir is regulated by three flashboards, although no discharge data are collected. The outflow eastward from the reservoir is called the South Branch Pawtuxet River. The Mishnock River flows north from Lake Mishnock to its confluence with the South Branch Pawtuxet River. The main stem of the Pawtuxet River forms at the confluence of the South Branch Pawtuxet River and the North Branch Pawtuxet River.

The Mishnock aquifer is entirely within the South Branch Pawtuxet subbasin. The major public-supply withdrawals in the South Branch Pawtuxet subbasin are by the Kent County Water Authority, which withdraws water from the Mishnock aquifer (fig. 5). Self-suppliers withdraw water from the sand and gravel deposits, till deposits, and bedrock. Because the three major river and ground-water systems are hydrologically linked through the sand and gravel deposits in the subbasin, they were grouped together for estimations of water withdrawal, use, and availability in the subbasin. The area of the surficial deposits in the subbasin is 41 percent sand and gravel (fig. 5). The only continuous stream-gaging station in the subbasin is the South Branch Pawtuxet River at Washington (01116000) with a drainage area of 62.8 mi^2 (fig. 8). About 40 percent of the drainage area to this station is sand and gravel deposits. The USGS has been collecting surface-water data at this station for more than 63 years. Two discontinued stream-gaging stations, Nooseneck River at Nooseneck (01115630) and Carr River near Nooseneck (01115770) (fig. 8), have 17 and 16 years of record, respectively. The drainage areas for the Nooseneck River station and the Carr River station are 8.28 mi^2 and 7.33 mi^2, respectively. The percentages of sand and gravel deposits for the areas upstream of the stations are about 35 percent for the Nooseneck River station and 63 percent for the Carr River station.

The Northeastern Pawtuxet subbasin (50.71 mi^2 drainage area) is in the northeastern section of the Pawtuxet River Basin. The subbasin includes the towns of Cranston, Johnston, Providence, Warwick, and West Warwick (fig. 4). The subbasin includes the Pocasset River and the main stem of the Pawtuxet River. The Pocasset River flows southeast into the main stem of the Pawtuxet River in Cranston. The Pawtuxet River confluence with Narragansett Bay is in the easternmost part of the basin in the village of Pawtuxet. The surficial deposits in the subbasin are about 47 percent sand and gravel deposits. The USGS has been collecting surface-water data for more than 64 years at the one continuous stream-gaging station is in the subbasin (fig. 8), the Pawtuxet River at Cranston (01116500). Twenty-eight percent of the surficial deposits upstream of the station are sand and gravel.

The Providence-Warwick aquifer (fig. 5) is a defined ground-water source that extends along Narragansett Bay and crosses the Moshassuck, Woonasquatucket, Pawtuxet, and Narragansett Bay Basins in a north-south direction. Because data on this particular aquifer are limited, ground-water drainage divides were not used in the calculations of water use and availability. In addition, losses from lateral ground-water movement out of the basin were considered negligible for this study.

Minor Civil Divisions

The U.S. Census Bureau classifies towns and cities into minor civil divisions (MCDs). The 13 MCDs in the study area include Coventry, Cranston, East Greenwich, Exeter, Foster, Glocester, Johnston, Providence, Scituate, Smithfield, Warwick, West Greenwich, and West Warwick. Polygons within the towns were assigned population densities by using Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) system data available through RIGIS coverages. These 1990 population coverages were merged with the USGS basin and subbasin coverages to determine the population in the Pawtuxet River Basin and its subbasins (table 2). Also, town land area apportioned by basin and subbasin was determined by overlaying town boundaries and basin-boundary coverages (table 3). The population for a city or town was calculated by averaging the 1995, 1996, 1997, 1998, and 1999 populations estimated by the Rhode Island Economic Development Corporation (2001). The percentage of the total 1990 population for each town in each subbasins was applied to the estimated 1995–99 population for that town.

Public water suppliers are defined by the U.S. Environmental Protection Agency (USEPA) as suppliers serving more than 25 people or having 15 service connections year-round (U. S. Government Printing Office, 1996). Public suppliers were categorized into major public suppliers that have a system of distribution and minor public suppliers that have closed systems. The 1990 population on self-supply for the part of a town within a given subbasin was divided by the 1990 population for that part of the town. This procedure was repeated for the 1990 populations on public-wastewater collection. The resulting percentages of the 1990 populations on self-supply and wastewater collection in the subbasins for each town were applied to the 1995–99 populations to provide estimates of the 1995–99 populations on self-supply and public disposal (table 2). The 1995–99 populations on public supply and self-disposal were determined by subtracting the 1995–99 populations on self-supply and public disposal from the total 1995–99 populations in the subbasins for each town (table 2).

The town of Coventry is in central Rhode Island (fig. 1). The total land area is 62.45 mi^2, of which 41.24 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period (1995–99) was 30,815 out of a total town population of 32,523 (table 6). One major public water supplier, the Kent County Water Authority, supplies water to the eastern

Table 6. Summary of total town land area, land area in the Pawtuxet and Quinebaug River Basins, total 1990 town populations and estimated 1995–99 populations, and land-use area by category in the Pawtuxet and Quinebaug River Basins, central and western Rhode Island.

[All towns are in Rhode Island unless otherwise noted. Total 1990 populations in Rhode Island were obtained from Rhode Island Geographic Information System (1991). Populations for 1995–99 were estimated from Rhode Island Economic Development Corporation (2001). Land-use areas in Rhode Island were estimated by using the coverage from the Rhode Island Geographic Information System (1995a). mi^2, square mile; --, not applicable]

Towns	Total land area (mi^2)	Land area in the Pawtuxet River Basin (mi^2)	Land area in the Quinebaug River Basin (mi^2)	Total populations		Estimated 1995–99 population in the Pawtuxet River Basin	Estimated 1995–99 population in the Quinebaug River Basin	Total land-use area by category (mi^2)		
				1990	Estimated 1995–99			Commercial	Industrial	Agricultural
Burrillville	56.96	--	8.595	16,229	15,910	--	514	0.209	0.183	2.182
Coventry	62.45	41.24	20.30	31,081	32,523	30,815	1,569	.627	.355	2.392
Cranston	28.90	28.18	--	76,077	74,890	68,784	--	1.177	1.174	2.609
East Greenwich	16.25	.140	--	11,807	12,120	50	--	.349	.195	.924
Exeter	58.39	3.247	1.432	5,472	5,932	398	81	.140	.042	4.451
Foster	51.94	31.85	20.09	4,316	4,410	2,727	1,684	.247	.042	2.779
Glocester	56.83	16.39	9.703	9,227	9,280	2,815	647	.279	.055	3.039
Johnston	24.33	16.54	--	26,606	26,433	13,985	--	.779	.398	1.412
Providence	18.78	2.952	--	160,262	151,151	23,957	--	2.180	1.701	.008
Scituate	54.81	54.79	--	9,793	10,012	10,006	--	.188	.028	2.314
Smithfield	27.61	.032	--	19,163	18,906	90	--	.699	.388	1.459
Warwick	35.02	7.183	--	85,457	84,038	17,081	--	2.598	1.138	1.217
West Greenwich	51.22	23.10	.853	3,501	3,956	2,330	46	.227	.064	1.865
West Warwick	8.091	5.943	--	29,278	29,034	21,925	--	.557	.464	.108

section of Coventry. Two minor public water suppliers serve small populations in the eastern part of the town in the Pawtuxet River Basin. The wastewater-collection area for the eastern section of Coventry is maintained by the West Warwick Regional Wastewater-Treatment Facility (WWTF).

The city of Cranston is in central Rhode Island (fig. 1). The total land area is 28.90 mi^2, of which 28.18 mi^2 is in the Pawtuxet River Basin. The total city population in the basin for the study period was 68,784 out of a total town population of 74,890 (table 6). The city purchases water from ProvWater. The interconnections with ProvWater that serve the part of the city west of Interstate 295 were maintained by the Cranston Water District until 1997. ProvWater also supplies Cranston's retail sales of water in the area east of Interstate 295; this area is part of ProvWater's retail-service area. The US Filter Cranston Water Pollution Control Facility and the West Warwick Regional WWTF collect and process wastewater for certain areas in Cranston.

The town of East Greenwich is in central Rhode Island (fig. 1). The total land area is 16.25 mi^2, of which 0.140 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 50 out of a total town population of 12,120 (table 6). The Kent County Water Authority supplies water to all of East Greenwich, and the East Greenwich WWTF collects wastewater for the community.

The town of Exeter is in south central Rhode Island (fig. 1). The total land area is 58.39 mi^2, of which 3.247 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 398 out of a total town population of 5,932 (table 6). No public water suppliers are in the part of Exeter in the basin. Outside the basin, the Ladd School operated as a minor public water supplier and small facility that treated their wastewater for 5 months (from January through May of 1995). The facility is currently (2004) owned by the Rhode Island Economic Development Corporation (RIEDC) and is undeveloped.

The town of Foster is in western Rhode Island (fig. 1). The total land area is 51.94 mi^2, of which 31.85 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 2,727 out of a total town population of 4,410 (table 6). Foster has no major public water suppliers; likewise, the town has no local wastewater collection. Three minor public water suppliers, however, serve small populations in the town.

The town of Glocester is in western Rhode Island (fig. 1). The total land area is 56.83 mi^2, of which 16.39 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 2,815 out of a total town population of 9,280 (table 6). Glocester has no public water supply in the basin; likewise, the town has no local wastewater collection.

The town of Johnston is in central Rhode Island (fig. 1). The total land area is 24.33 mi^2, of which 16.54 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 13,985 out of a total town population of 26,433 (table 6). During the study period, the Cranston Water District served the area of the town area west of Interstate 295 until 1997. From 1997 to the present (2004), the area has been served by the Johnston Water District. ProvWater serves the area in Johnston east of Interstate 295; this area is part of ProvWater's retail service area. No minor public water suppliers are in the part of Johnston that is in the basin. Johnston has no local wastewater collection; however, the town wastewater is collected and processed by a regional facility, the Narragansett Bay Commission facility at Fields Point in Providence. This WWTF is along Narragansett Bay and discharges to the bay.

The city of Providence is in central Rhode Island (fig. 1). The total land area is 18.78 mi^2, of which 2.952 mi^2 is in the Pawtuxet River Basin. The total city population in the basin for the study period was 23,957 out of a total city of 151,151 (table 6). ProvWater serves the city. No minor public water suppliers are in the part of Providence that is in the basin. City wastewater is collected and processed by the NBC facility at Fields Point in Providence.

The town of Scituate is in central Rhode Island (fig. 1). The total land area is 54.81 mi^2, of which 54.79 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 10,006 out of a total town population of 10,012 (table 6). The Kent County Water Authority serves the southeastern corner of the town, and the Johnston Water District serves the northeastern part of the town. Three minor public water suppliers serve small populations in the town. The West Warwick Regional WWTF collects and processes wastewater for the southeast corner of Scituate.

The town of Smithfield is in north central Rhode Island (fig. 1). The total land area is 27.61 mi^2, of which 0.032 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 90 out of a total town population of 18,906 (table 6). The part of Smithfield that is in the basin has no public water supply or wastewater collection.

The city of Warwick is in central Rhode Island (fig. 1). The total land area is 35.02 mi^2, of which 7.183 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 17,081 out of a total town population of 84,038 (table 6). The major public water supplies for the city are operated and maintained by the Warwick Water Department and the Kent County Water Authority. Warwick purchases water from ProvWater. The Kent County Water Authority, in addition to obtaining water from its own withdrawal wells, purchases water wholesale from ProvWater and the Warwick Water Department. No minor public water suppliers are in the part of Warwick that is in the Pawtuxet River Basin. The Warwick WWTF and the West Warwick Regional WWTF collect and process wastewater for the city.

The town of West Greenwich is in central Rhode Island (fig. 1). The total land area is 51.22 mi^2, of which 23.10 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 2,330 out of a total town population of 3,956 (table 6). The Kent County Water Authority serves the part of West Greenwich that is in the basin. One minor water supplier serves a small population in the basin. A small area of West Greenwich in the basin is served by the West Warwick Regional WWTF.

The city of West Warwick is in central Rhode Island (fig. 1). The total land area is 8.091 mi^2, of which 5.943 mi^2 is in the Pawtuxet River Basin. The total town population in the basin for the study period was 21,925 out of a total town population of 29,034 (table 6). The Kent County Water Authority serves West Warwick. City wastewater is collected and processed by the West Warwick Regional WWTF.

The Quinebaug River Basin

The Quinebaug River Basin is in western Rhode Island, eastern Connecticut, and south central Massachusetts (fig. 9). The total land area in the basin is about 743 mi^2 (Thomas and others, 1966), which includes about 60.97 mi^2 in Rhode Island, about 433 mi^2 in Connecticut, and about 249 mi^2 in Massachusetts (Simcox, 1992). Four major tributaries enter the Quinebaug River in Connecticut, including the French River from the north, the Fivemile River from the northeast, the Moosup River from the east, and the Pachaug River from the southeast (fig. 9). Only the part of the basin in Rhode Island, however, was included in this analysis.

Six Rhode Island towns are partially within the basin. In 1990, the basin population was about 4,483, and the estimated population during the study period was 4,541 (table 2). The Quinebaug River Basin is mostly hilly, with higher altitudes in the northwest. No defined principal aquifers are in the study area; however, it does include areas of stratified sand and gravel deposits (fig. 5). On the basis of the surface-water-drainage boundaries, about 27.1 percent of the area of the surficial deposits in the Quinebaug River Basin is stratified sand and gravel deposits.

The USGS subbasin boundaries delineated for this study area differ from the cataloging units defined by the WBD (fig. 6). Naming conventions also differ between the Quinebaug River Basin study and the 10-digit and 12-digit cataloging units. The study area was defined by the USGS 8-digit HUC because use of the 10-digit cataloging units resulted in withdrawals and water use less than 0.001 Mgal/d when estimated by town, and because there are no defined ground-water aquifers in the basin. Comparisons of land-area and naming conventions between the Quinebaug River Basin and the WBD cataloging units are presented in table 5.

The town of Burrillville is in northwestern Rhode Island (fig. 1). The total land area is 56.96 mi^2, of which 8.595 mi^2 is in the Quinebaug River Basin. The total town population in the basin for the study period was 514 out of a total town population of 15,910. For the town of Coventry, the land area in the basin is 20.30 mi^2, and the estimated town population in the basin was 1,569 (table 6). One minor public water supplier serves a small population in the part of the town in the basin. The land area in Exeter in the basin is 1.432 mi^2, and the estimated town population in the basin was 81. The land area in Foster in the basin is 20.09 mi^2, and the estimated town population in the basin was 1,684. The land area in Glocester in the basin is 9.703 mi^2, and the estimated town population in the basin was 647. The land area in West Greenwich in the basin is 0.853 mi^2, and the estimated town population in the basin was 46 (table 6). The Quinebaug River Basin had no local or regional wastewater-collection service areas during the study period.

Estimated Water Use

Water-use data for the study period for the Pawtuxet and Quinebaug River Basins were organized by using NEWUDS. Components of water use include water withdrawals, public-supply distributions, nonaccount use, water use by category, consumptive water use, wastewater-system collections, and return flow (fig. 3). Withdrawal data were categorized as either self- or public supply from surface and ground water. Conveyance losses are an example of nonaccount water use (which is unmetered) in public-supply systems, and include leaks, system flushing, and fire-hydrant uses. The nonaccount water use for a public-supply system is calculated as the difference between the total distribution and the distributions received for all of the water-use categories in the system. Water-use categories in this report are domestic, commercial, industrial, and agricultural for public-supply and self-supply users. The public-supply withdrawals were from surface and ground water, whereas minor public-supply and self-supply domestic, industrial, and commercial withdrawals were only from ground water. Consumptive water use is water removed from the environment through uses by humans, livestock, production, or evapotranspiration. Wastewater from a local or a regional public wastewater system is returned to a surface-water body. Return flow to ground water or surface water includes wastewater disposed from site-specific discharges, permitted discharges, and aggregate discharges. Water withdrawals, water use, consumptive use, and return flow were calculated for each subbasin by town for the calendar years during the study period. Because the Quinebaug River Basin has no major public water suppliers, wastewater collection, and interbasin transfers, the sections of the report on these topics pertain only to the Pawtuxet River Basin.

New England Water-Use Data System

The NEWUDS database was used as a tool to track the water withdrawn in the Pawtuxet and Quinebaug River Basins. The database was queried to obtain the average water use for the study period, and the results are presented in the tables of this report. The data entered into NEWUDS consist of site-specific and aggregate water withdrawals, uses, and discharges in the two basins. When available, monthly, quarterly, and (or) yearly metered (or reported) data were entered as reported from the original source, and were converted to common units (Mgal/d) for comparison into NEWUDS. Unmetered water withdrawals, uses, and discharges were calculated by methods used to estimate water use by category. For quality-assurance purposes, NEWUDS allows the data compiler to indicate the original data

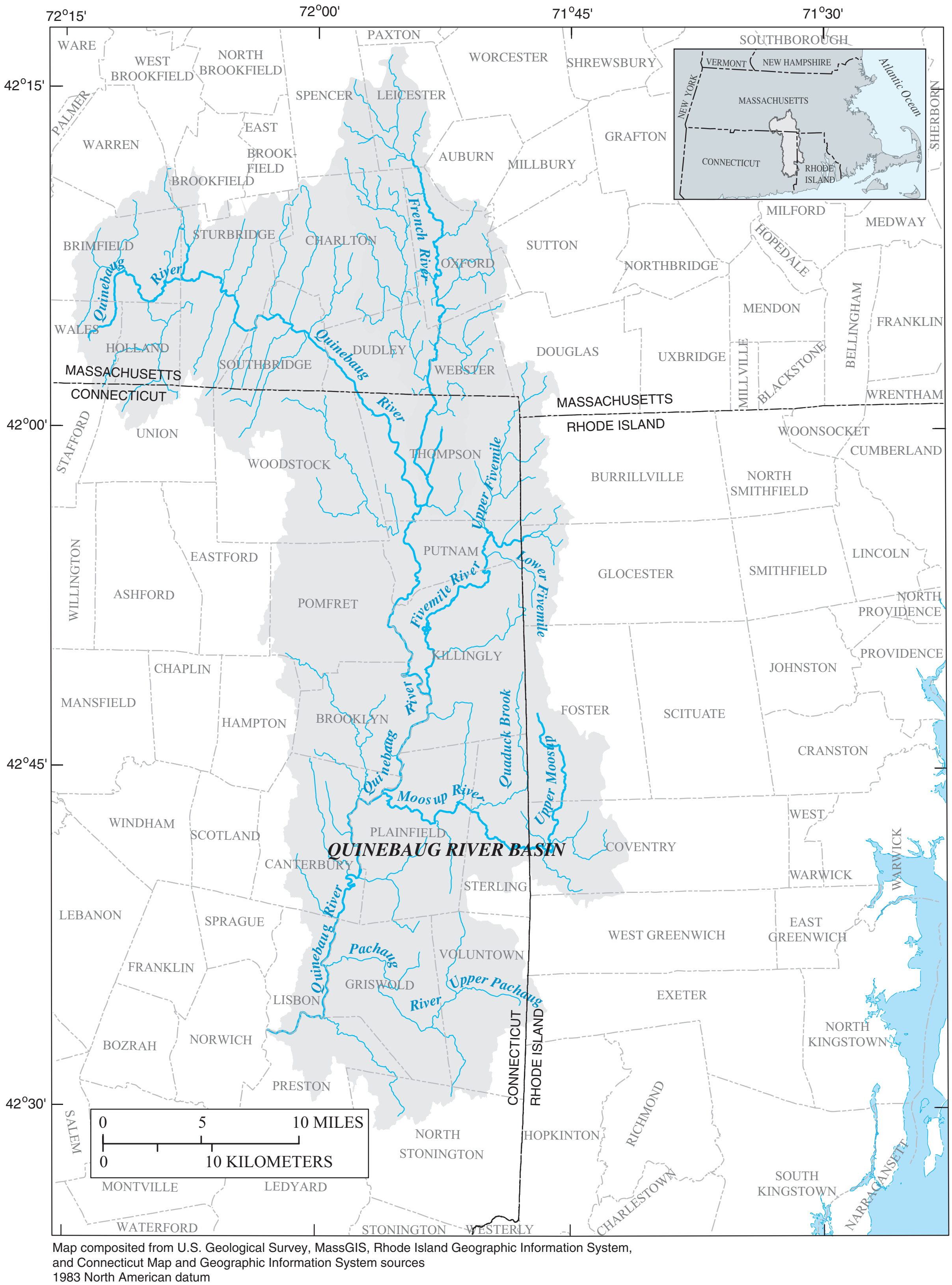


Figure 9. The Quinebaug River Basin in western Rhode Island, northeastern Connecticut, and south-central Massachusetts.

source, rate units, and the method of reporting the water-use rate. Documentation describing database development and how to use the database are presented in Tessler (2002) and Horn (2003), respectively.

Public Water Supply and Interbasin Transfers

Five major public suppliers served the domestic, commercial, industrial, and agricultural sectors in the Pawtuxet River Basin during the study period (table 7, fig. 10): Cranston Water District, Johnston Water District, Kent County Water Authority, Providence Water Supply Board, and Warwick Water Department. Ten minor water suppliers, such as nursing homes, condominium associations, and mobile home parks, served small public populations; nine minor suppliers were in the Pawtuxet River Basin and one was in the Quinebaug River Basin (table 8). The total public-supply withdrawals by subbasin and town are summarized in table 9.

Potable interbasin transfers are water that is conveyed from public water suppliers across hydrologic divides between basins and subbasins. The water is an import, or a gain to the Pawtuxet River Basin, if the water is withdrawn in another basin or subbasin and used in the Pawtuxet River Basin. The water is an export, or a loss to the basin, if the water is withdrawn in the basin but used elsewhere in another basin or subbasin.

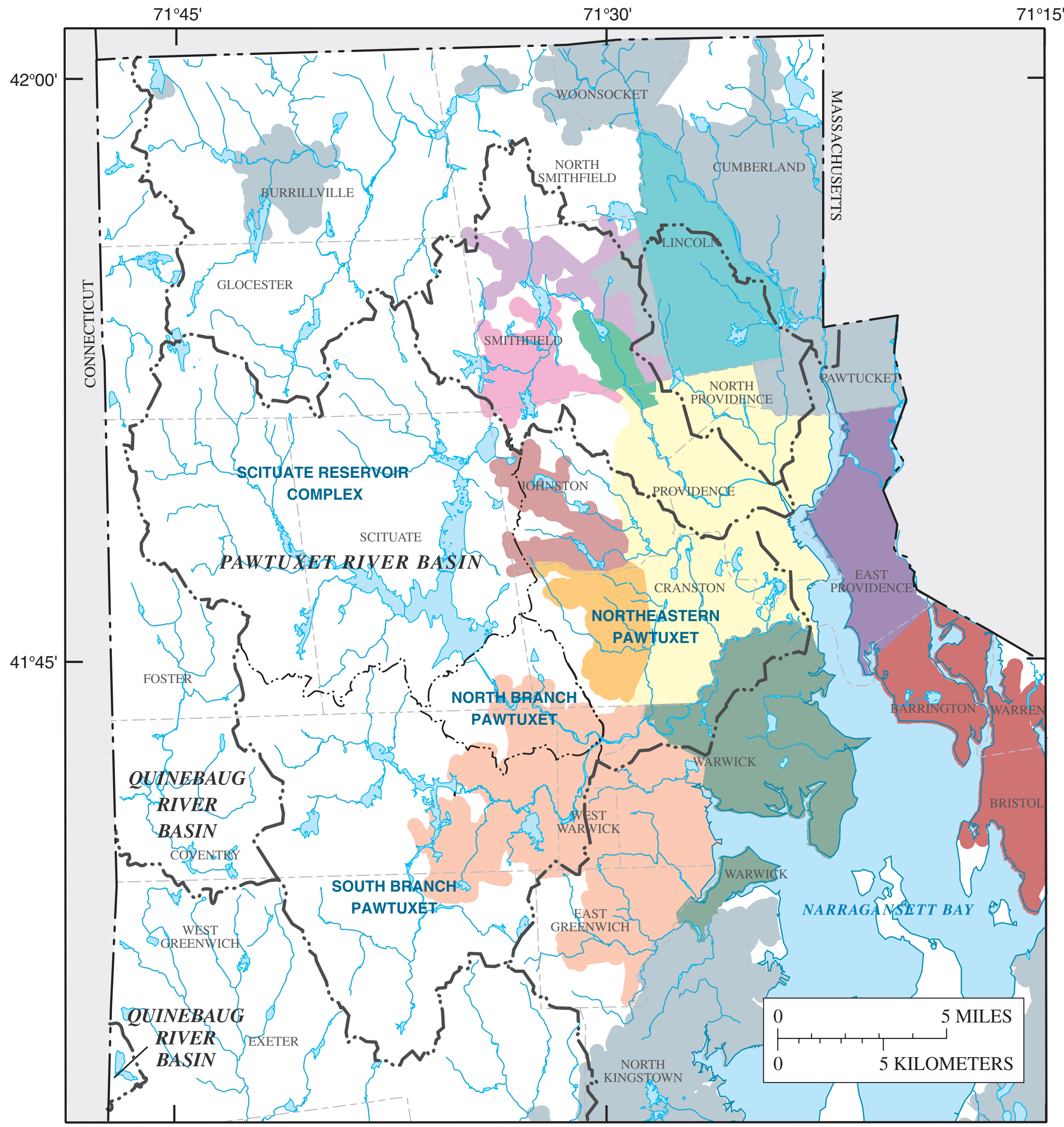
Table 7. Withdrawals by major public water-supply districts in and outside the subbasins of the Pawtuxet River Basin, central Rhode Island, 1995–99.

[The Cranston and Johnston Water Districts and the Warwick Water Department do not withdraw water; they only purchase water. **Reference number:** Identifier used in figure 5. **Aquifer type:** SG, sand and gravel. HAP, Hunt-Annaquatucket-Pettaquamscutt; Mgal/d, million gallons per day; --, not applicable]

Major public water-supply district	Reference number	Location of surface-water intake	Well field and well description (Mgal/d)	Aquifer		Water withdrawals 1995–99 (Mgal/d)
				Type	Name	
Pawtuxet River Basin						
Scituate Reservoir Complex Subbasin						
Providence Water Supply Board	A	Scituate Reservoir	--	--	--	70.85
Subbasin total						70.85
North Branch Pawtuxet Subbasin						
--	--	--	--	--	--	--
South Branch Pawtuxet Subbasin						
Kent County Water Authority	B	--	Mishnock Well 1	SG	Mishnock	0.338
	C	--	[1]Mishnock Well 2	SG	Mishnock	.363
	D	--	[2]Mishnock Well 3	SG	Mishnock	--
	E	--	Spring Lake Well	SG	Mishnock	.305
Subbasin total						1.006
Northeastern Pawtuxet Subbasin						
--	--	--	--	--	--	--
Basin total						71.86
Withdrawals outside the Pawtuxet River Basin						
Kent County Water Authority	F	--	East Greenwich Well	SG	HAP	0.586

[1]Mishnock well 2 was discontinued after October 1999.

[2]Mishnock well 3 was drilled near the site of discontinued Mishnock well 2. Withdrawals started in March 2000 and continue to the present (2004).



Base from U.S. Geological Survey and Rhode Island Geographic Information System digital data (1995b), 1:24,000, Lambert conformal conic projection. 1983 North American datum

EXPLANATION

MAJOR PUBLIC WATER-SUPPLY DISTRICTS—Districts in Pawtuxet study area are in **bold** type. See figures 11-14 for schematic diagrams of water distribution

- **Providence Water Supply Board**
- **Johnston Water District**
- **Cranston Water District**
- **Warwick Water Department**
- **Kent County Water Authority**
- East Providence Water Department
- Bristol County Water Authority
- Greenville Water District
- Smithfield Water Supply Board
- East Smithfield Water District
- Lincoln Water Commission
- Other service areas

MAJOR BASIN BOUNDARY

STUDY SUBBASIN BOUNDARY

Figure 10. Public water-supply districts associated with the Pawtuxet River Basin and in the northern Narragansett Bay area, Rhode Island.

Table 8. Minor public water suppliers by subbasin in the Pawtuxet River Basin, central Rhode Island, and in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Shaded areas are basin totals. **Minor public water supplier:** Coefficient used for minor supplier population is 67 gal/d/person. **Reference number:** Identifier used in figure 5. **Aquifer type:** BD, bedrock; SG, sand and gravel. gal/d/person, gallons per day per person; Mgal/d, million gallons per day; --, not applicable]

Minor public water supplier	Reference number	Town	Aquifer type	Estimated 1995–99	
				Population	Water withdrawals and use (Mgal/d)
Pawtuxet River Basin					
Scituate Reservoir Complex Subbasin					
Abbey Lane Community Association	1	Foster	BD	46	0.003
Nancy Ann Nursing Home, Inc.	2	Foster	BD	20	.001
Hemlock Village	3	Foster	BD	34	.002
Oak Crest Manor, Inc.	4	Scituate	BD	46	.003
Scituate Housing for the Elderly/Rockland Oaks	5	Scituate	BD	26	.002
Scituate Commons	6	Scituate	BD	35	.002
Subbasin total				207	0.013
North Branch Pawtuxet Subbasin					
--	--	--	--	--	--
South Branch Pawtuxet Subbasin					
Blueberry Heights Mobile Park	7	West Greenwich	BD	50	.003
Alpine Nursing Home	8	Coventry	BD	29	.002
Woodland Homeowners Association	9	Coventry	SG	120	.008
Subbasin total				199	0.013
Northeastern Pawtuxet Subbasin					
--	--	--	--	--	--
Basin total				406	0.026
Quinebaug River Basin					
Woodpecker Hill Nursing Home	10	Coventry	BD	40	0.003
Basin total				40	0.003

Table 9. Ground-water and surface-water withdrawals by town and subbasin in the Pawtuxet River Basin, central Rhode Island, and in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Shaded areas are basin totals. Withdrawals are from ground-water wells and surface-water reservoirs. For agricultural use, irrigation water withdrawals are assumed to be 81 percent from surface water (ponds and rivers) and 13 percent from ground water (wells). Livestock water withdrawals are assumed to be 9 percent from surface water and 82 percent from ground water. The remaining 6 percent for irrigation and 9 percent for livestock are assumed to be from public supply. All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; <0.001, value not included in totals; --, not applicable]

Towns	Public-supply withdrawals (Mgal/d)	Self-supply withdrawals (Mgal/d)				Total (Mgal/d)
		Domestic	Commercial	Industrial	Agricultural	
Pawtuxet River Basin						
Scituate Reservoir Complex Subbasin						
Cranston	--	0.003	--	--	0.002	0.005
Foster	0.006	.171	0.001	0.002	.002	.182
Glocester	--	.200	.007	--	.003	.210
Johnston	--	.038	--	--	.001	.039
Scituate	70.86	.538	.008	.012	.007	71.43
Smithfield	--	.006	--	--	<.001	.006
Subbasin total	70.87	0.956	0.016	0.014	0.015	71.87
North Branch Pawtuxet Subbasin						
Coventry	--	0.035	--	0.009	0.003	0.047
Cranston	--	.023	<0.001	--	.005	.028
Scituate	--	.058	--	--	.003	.061
West Warwick	--	.002	--	--	--	.002
Subbasin total	--	0.118	<0.001	0.009	0.011	0.138
South Branch Pawtuxet Subbasin						
Coventry	1.016	0.430	0.004	0.017	0.022	1.489
East Greenwich	--	.001	--	--	--	.001
Exeter	--	.028	.001	--	.002	.031
Foster	--	.015	--	--	.003	.018
Scituate	--	.020	--	--	.001	.021
Warwick	--	--	--	--	--	--
West Greenwich	.003	.113	.001	.065	<.001	.182
West Warwick	--	.005	--	--	--	.005
Subbasin total	1.019	0.612	0.006	0.082	0.028	1.747
Northeastern Pawtuxet Subbasin						
Cranston	--	0.070	0.015	0.011	0.019	0.115
Johnston	--	.149	.027	.004	.001	.181
Providence	--	--	--	--	--	--
Warwick	--	<.001	--	--	--	<.001
West Warwick	--	.010	--	--	--	.010
Subbasin total	--	0.229	0.042	0.015	0.020	0.306
Basin total	71.89	1.915	0.064	0.120	0.074	74.06
Quinebaug River Basin						
Burrillville	--	0.036	--	--	<0.001	0.036
Coventry	0.003	.109	0.002	0.004	.007	.125
Exeter	--	.006	--	--	--	.006
Foster	--	.120	<.001	--	.024	.144
Glocester	--	.045	.003	<.001	.001	.049
West Greenwich	--	.003	--	--	--	.003
Basin total	0.003	0.319	0.005	0.004	0.032	0.363

The Cranston Water District purchased water from ProvWater and maintained the six Johnston Water District interconnections until 1997. At this time, Johnston started to maintain the interconnections with ProvWater, and the Cranston Water District became part of ProvWater's retail-service area. During the transition, records of the historical purchases that the Cranston Water District maintained were destroyed by fire, so they were unavailable for this study.

The Johnston Water District purchases water through six interconnections with ProvWater (fig. 11). Monthly data for each of the six interconnections were available from January 1998 through December 1999. The total of the Johnston wholesale purchases for each month was available from ProvWater for calendar year 1997, but the monthly data were not available for each individual interconnection. Johnston's monthly wholesale purchases for 1995 and 1996 were not available and were estimated on the basis of the 1998 and 1999 data (Peter LePage, Providence Water Supply Board, written commun., 2002).

The Kent County Water Authority system includes Mishnock wells 1, 2, and 3, and Spring Lake well, all of which withdraw from the Mishnock aquifer in the South Branch Pawtuxet subbasin (fig. 12). Mishnock well 3 was not in operation during the study period. An average of 1.006 Mgal/d was withdrawn during the study period from the Mishnock aquifer. The Kent County Water Authority withdrawal well in East Greenwich withdrew 0.586 Mgal/d from the Hunt-Annaquatucket-Pettaquamscutt aquifer (fig. 5) in the West Narragansett Bay Basin (fig. 12). To supplement the system, the Kent County Water Authority purchased 6.752 Mgal/d from ProvWater and 1.537 Mgal/d from the Warwick Water Department (fig. 12). The Kent County Water Authority sold 0.221 Mgal/d to the Warwick Water Department to supply Potowomut, a small section in Warwick that is east of East Greenwich.

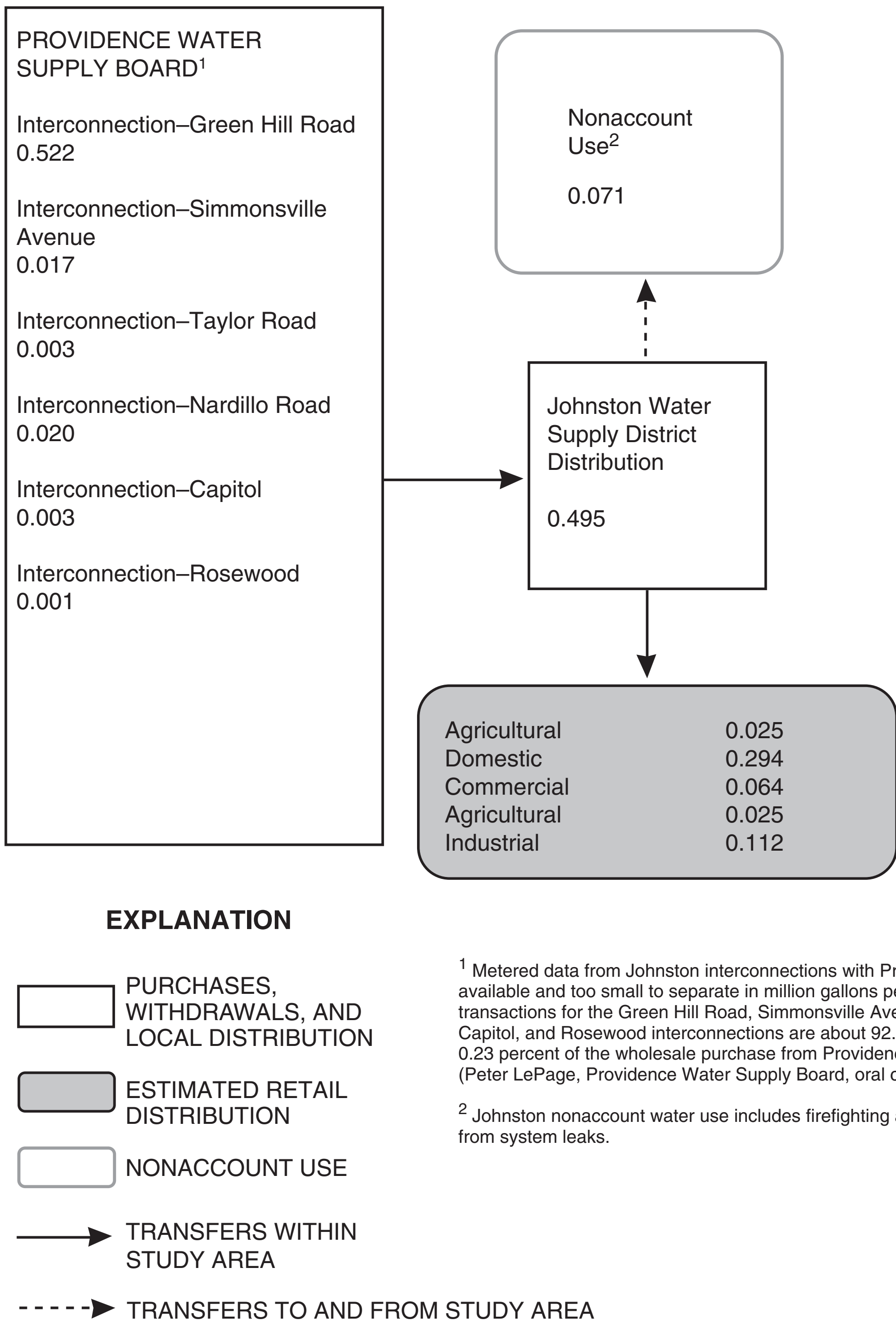
Water sources for withdrawals and purchases by the Kent County Water Authority differed during the study period. To determine what percentage of withdrawals and purchases occurred during each month of the summer, the well withdrawals for June, July, August, and September were compared to the total of the withdrawals and purchases for June, July, August, and September, respectively (table 10). Likewise, the percentages of wholesale purchases from each of the interconnections for each month were compared to the total water withdrawn and purchased June, July, August, and September, respectively (table 10). The Kent County Water Authority withdrawals ranged from 16 percent in June and July to 18 percent in September of the total water withdrawn and purchased for the system. From the total water withdrawn and purchased for the Kent County Water Authority system, withdrawals from the Mishnock aquifer in the Pawtuxet River Basin ranged from 8.6 percent in July to 11 percent in September; withdrawals from the East Greenwich well ranged from 6.7 percent in September to 8.2 percent in August; wholesale water purchases from the Clinton interconnection ranged from 54 percent in July to 61 percent in September; wholesale water purchases from the Oaklawn interconnection ranged from 1.8 percent in September to 2.8 percent in July; and wholesale water purchases from the Bald Hill interconnection ranged from 19 percent in September to 26 percent in July.

In 2000, ProvWater supplied 70.39 percent of the public-supply surface-water withdrawals and 60.40 percent of all public-supply water withdrawals in Rhode Island. The average rate of water withdrawal from the Scituate Reservoir to the J.P. Holton Water Purification Plant for the study period was 70.85 Mgal/d in the Scituate Reservoir Complex subbasin. ProvWater collects data on the rate of water movement within the subbasin; 35.25 Mgal/d flowed over the spillway and 11.92 Mgal/d flowed through the gatehouse during the study period (fig. 13a). ProvWater withdrawals conveyed to the purification plant accounted for 98.58 percent of the total withdrawals in the Scituate Reservoir Complex subbasin and 95.67 percent of the total withdrawals in the Pawtuxet River Basin during the study period. Retail distribution was more than 58 percent of the total regional distribution from the purification plant to cities inside and outside the study area; further analysis and estimation was completed to assess the movement of this water within and out of the Pawtuxet River Basin (fig. 13b). It was estimated that most of the retail sales, about 46 percent, were for domestic water users, and about 36 percent of this water was used in the Pawtuxet River Basin.

During the summer when precipitation is limited, water use tends to increase. For this reason and because ProvWater supplies over 60 percent of the Rhode Island population, average water withdrawal and distribution rates for the system for June, July, August, and September were calculated (table 11). The regional distribution for the system ranged from 71.81 Mgal/d in September to 91.52 Mgal/d in July. Retail distribution ranged from 40.45 Mgal/d in September to 49.23 Mgal/d in July. Wholesale purchases by other public-supply districts varied from year to year because of water restrictions were different each year and because the sizes of the public-supply districts changed. Also, wholesale purchases made by some public-supply districts from ProvWater varied from one year to the next. These districts included the Lincoln Water Commission, Kent Count Water Authority, and the Bristol County Water Authority. Purchases from ProvWater generally were less in September and more in July. The three highest wholesale purchases each accounted for more than 8 percent of the regional distribution.

The Warwick Water Department had no withdrawals during the study period; instead, it purchased 9.649 Mgal/d from ProvWater and 0.221 Mgal/d from the Kent County Water Authority (fig. 14). The Warwick Water Department also sold 1.537 Mgal/d to the Kent County Water Authority; of this amount, about 0.054 Mgal/d was nonaccount water use.

Nine minor public suppliers served the Pawtuxet River Basin (table 8). Limited data were available on minor public-supply withdrawals from these users; therefore, water withdrawals and use were estimated by applying the water-use coefficient for domestic users (67 gal/d/person) on public supply (Korzendorfer and Horn, 1995). The total of the estimated water withdrawn by minor suppliers was 0.026 Mgal/d. There were no



[1] Metered data from Johnston interconnections with Providence Water were not available and too small to separate in million gallons per day (Mgal/d). The estimated transactions for the Green Hill Road, Simmonsville Avenue,Taylor Road, Nardillo Road, Capitol, and Rosewood interconnections are about 92.17, 2.93, 0.51, 3.55, 0.62, and 0.23 percent of the wholesale purchase from Providence Water. (Peter LePage, Providence Water Supply Board, oral commun., 2002)

[2] Johnston nonaccount water use includes firefighting and losses from system leaks.

Figure 11. Johnston Water District interconnections, purchases, distribution, exports, and estimated water uses in the Pawtuxet River Basin, central Rhode Island, 1995–99. All rates in Mgal/d, million gallons per day.

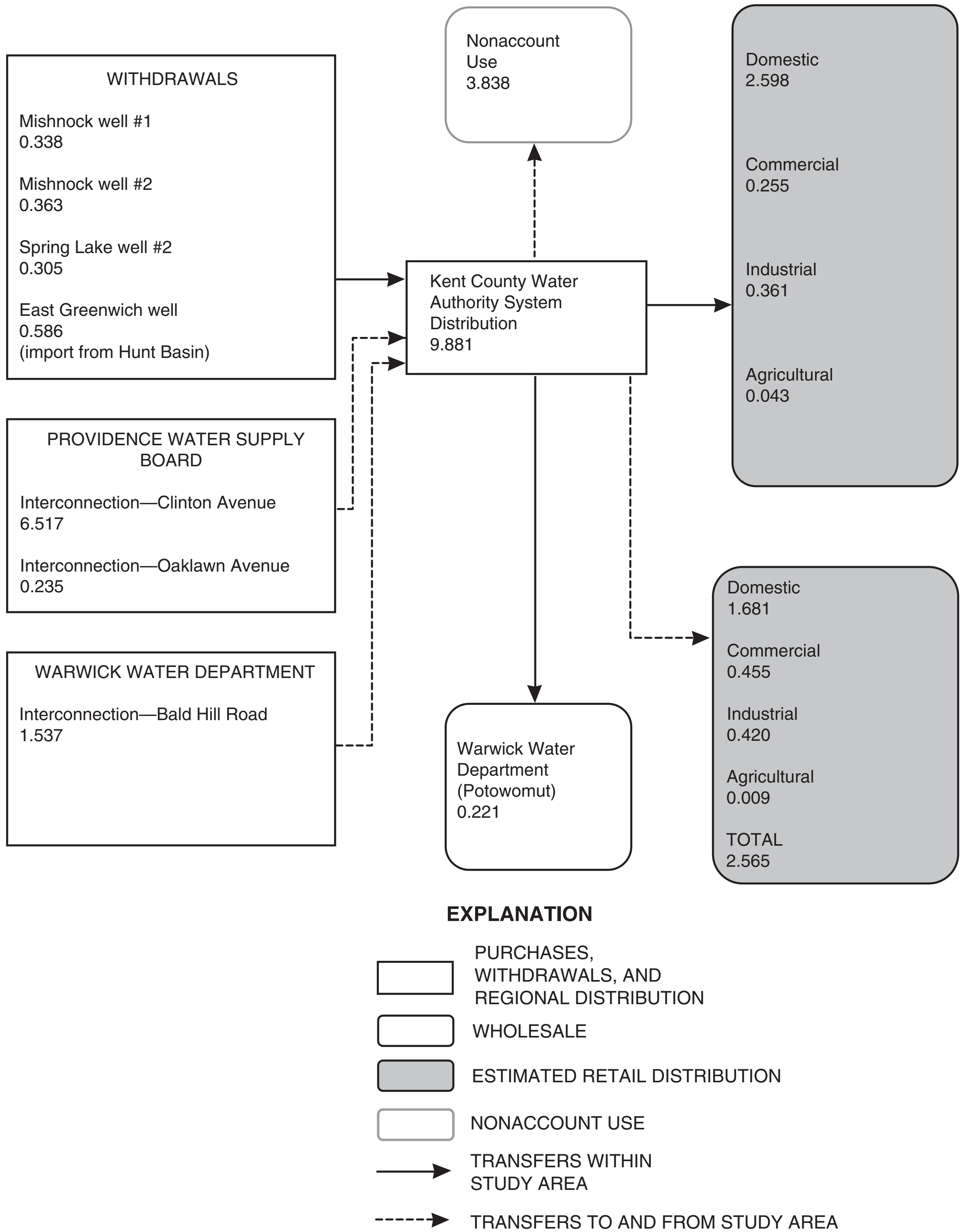


Figure 12. Kent County Water Authority withdrawals, interconnections, purchases, distribution, exports, and estimated water uses, central Rhode Island, 1995–99. All rates in Mgal/d, million gallons per day; KCWA, Kent County Water Authority.

Table 10. Average withdrawals and purchases for the Kent County Water Authority for June, July, August, and September, 1995–99.

[ProvWater, Providence Water Supply Board; Mgal/d, million gallons per day; --, not applicable]

Kent County Water Authority withdrawals and purchases					
Transaction, resource name, site type	Conveyance action	Transaction rate (Mgal/d)			
		June	July	August	September
Withdrawal from Mishnock well 1, Mishnock aquifer, withdrawal well	From withdrawal well to regional distribution	0.234	0.268	0.370	0.274
Withdrawal from Mishnock well 2, Mishnock aquifer, withdrawal well	From withdrawal well to regional distribution	.528	.546	.436	.524
Withdrawal from Spring Lake well, Mishnock aquifer, withdrawal well	From withdrawal well to regional distribution	.412	.424	.376	.352
Withdrawal from East Greenwich well, Hunt aquifer, regional distribution system	From withdrawal well to regional distribution	.877	1.135	1.045	.701
Wholesale purchase from ProvWater at Clinton, --, regional distribution system	From regional distribution to regional distribution	7.479	7.846	7.215	6.453
Wholesale purchase from ProvWater at Oaklawn, --, regional distribution system	From regional distribution to regional distribution	.301	.403	.297	.184
Wholesale purchase from Warwick Water Department at Bald Hill, --, local distribution system	From local distribution to regional distribution	3.000	3.777	3.034	2.016
Kent County Water Authority totals		12.83	14.40	12.77	10.50

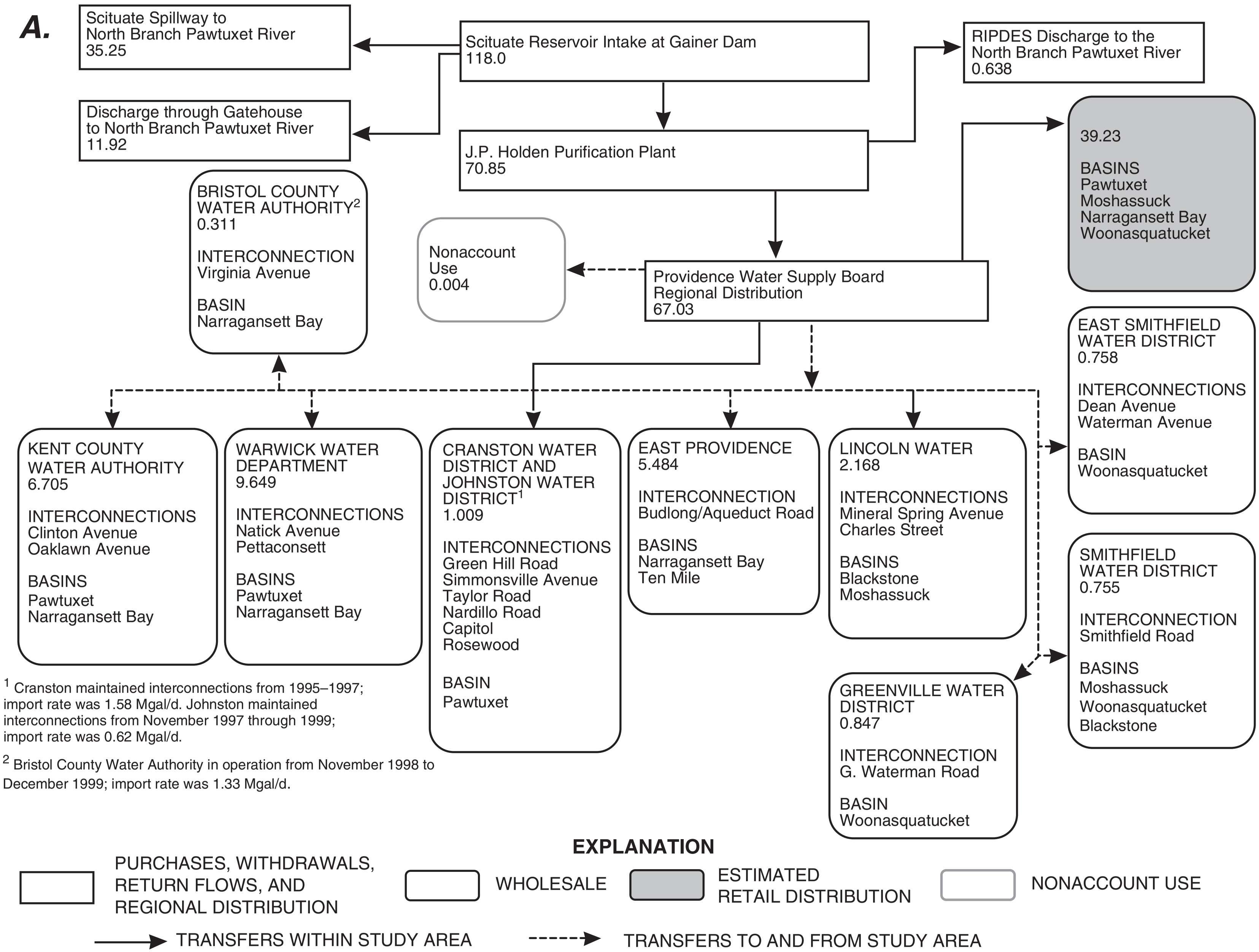
minor public-supply withdrawals in the North Branch Pawtuxet and Northeastern Pawtuxet subbasins, and the minor public-supply withdrawals in the Scituate Reservoir Complex and South Branch Pawtuxet subbasins were each 0.013 Mgal/d. Estimated water withdrawals for the individual minor suppliers ranged from 0.001 Mgal/d to 0.008 Mgal/d. One minor public supplier in the Quinebaug River Basin withdrew an estimated 0.003 Mgal/d.

Domestic Water Use

Domestic water use is water used by residential populations served by public supplies or by private wells. To calculate the water use for this category, population estimates in Rhode Island were multiplied by the water-use coefficients 71 gal/d/person for self-supply domestic water use and 67 gal/d/person for public-supply domestic water use. These coefficients were based on the 1990 national water-use compilation (Korzendorfer and Horn, 1995).

Public-Supply Use in the Pawtuxet and Quinebaug River Basins

Because water suppliers provide information on populations served within towns rather than within subbasins, census coverages available through RIGIS were used to estimate subbasin populations on public supply. The 1990 census blocks, which include the domestic populations on private wells, were merged with the subbasin coverages. The 1990 self-supply population was subtracted from the total population to obtain the public-supply population for the part of each town in each subbasin. The 1990 populations on public and self-supply were divided by the total population for the part of each town within each subbasin to determine the percentages of public- and self-supply populations within each subbasin. This method was repeated for the 1990 populations on public-wastewater collection and wastewater return flow for domestic users, also known as septic systems. The 1995–99 population on self-supply for each subbasin was estimated by multiplying the 1990 population by the ratio of growth or decline within each subbasin from 1995 through 1999 (table 2). The percentages of public- and self-supply populations, assumed to be the same for the 1995–99 study period as for 1990, were applied to the 1995–99 populations to determine the 1995–99 populations on self-disposal and on public-wastewater collection (table 2). The 1995–99 populations on public-wastewater collection and self-disposal of wastewater were then calculated by the same subtraction procedure as above. Because limited withdrawal data were available for the 13 minor public suppliers in the basin, the water-use coefficient was applied to the populations served by each supplier (Korzendorfer and Horn, 1995).



[1] Cranston maintained interconnections from 1995–1997; import rate was 1.58 Mgal/d. Johnston maintained interconnections from November 1997 through 1999; import rate was 0.62 Mgal/d.

[2] Bristol County Water Authority in operation from November 1998 to December 1999; import rate was 1.33 Mgal/d.

Figure 13. Providence Water Supply Board *A,* withdrawals, interconnections, distribution, and estimated water uses, central Rhode Island; and *B,* retail distribution, exports, and estimated water uses, 1995–99. All rates in Mgal/d, million gallons per day.

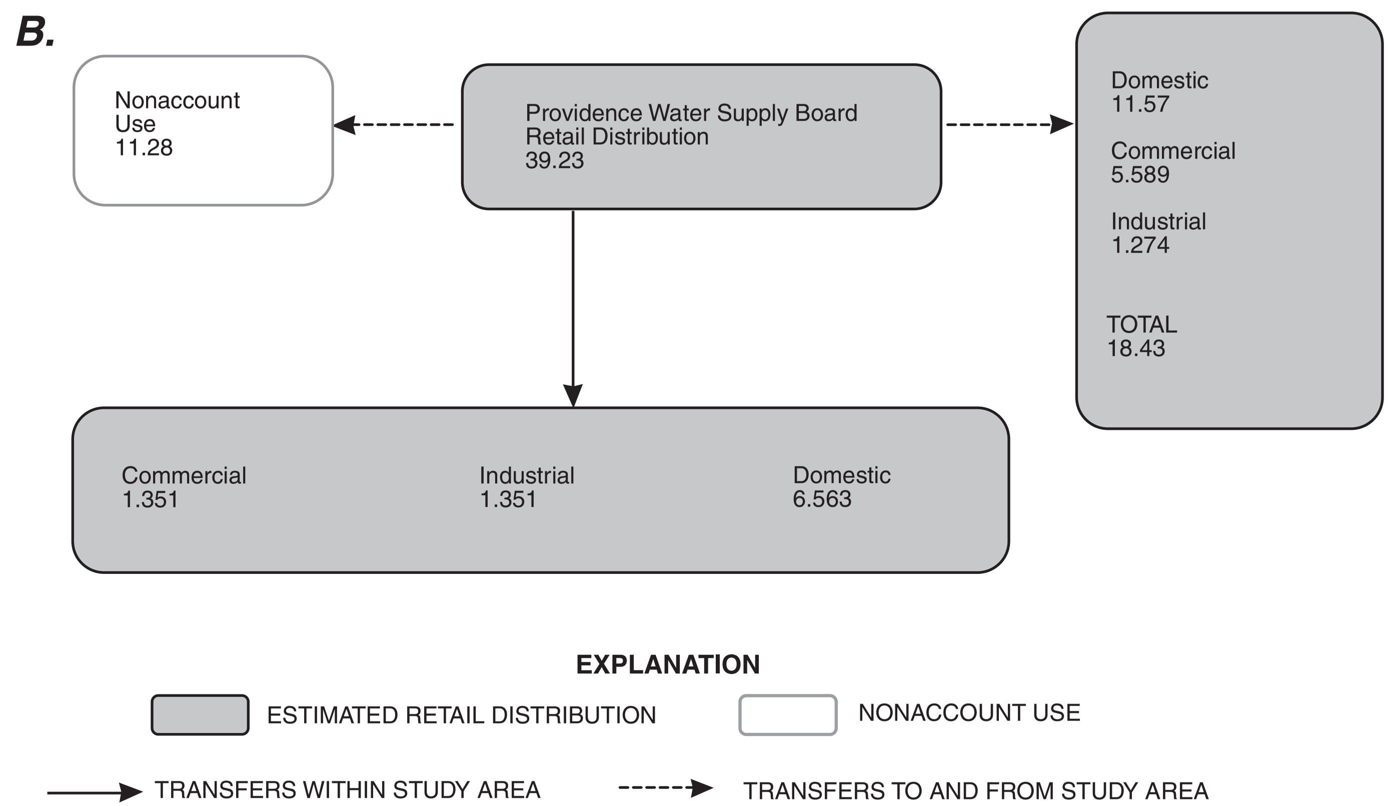


Figure 13. Providence Water Supply Board *A,* withdrawals, interconnections, distribution, and estimated water uses, central Rhode Island; and *B,* retail distribution, exports, and estimated water uses, 1995–99. All rates in Mgal/d, million gallons per day.—Continued

Table 11. Withdrawals, discharges, retail sales, and wholesale purchases for the Providence Water Supply Board system in June, July, August, and September, 1995–99.

[The Providence Water Supply Board withdraws from the Scituate Reservoir. ProvWater, Providence Water Supply Board; RIPDES, Rhode Island Pollutant Discharge Elimination System; Mgal/d, million gallons per day; --, not applicable]

Transaction, resource name, site type	Conveyance action	Transaction rate (Mgal/d)			
		June	July	August	September
Intake from Scituate Reservoir, Scituate Reservoir, intake pipe and surface-water withdrawal	From intake pipe and surface-water withdrawal	139.9	116.5	99.22	86.53
Spillover to North Branch Pawtuxet River, North Branch Pawtuxet Basin, surface-water return flow	From surface-water withdrawal to surface water	41.49	9.195	--	--
Discharge through gatehouse to North Branch Pawtuxet River, North Branch Pawtuxet Basin, surface-water return flow	From surface-water withdrawal to surface water	10.38	11.21	11.78	10.88
Intake at J.P. Holton Purification Plant, --, potable treatment plant	From intake pipe to potable treatment	88.05	96.11	87.44	75.65
RIPDES discharge to North Branch Pawtuxet River, North Branch Pawtuxet Basin, discharge pipe	From potable treatment to surface water	.782	.728	.685	.549
Regional distribution from ProvWater, --, regional distribution system	From potable treatment to regional distribution	83.68	91.52	83.31	71.81
Retail sales from ProvWater, --, local distribution system	From regional distribution to local distribution	47.86	49.23	46.18	40.45
Wholesale purchases by East Smithfield Water District, --, local distribution system	From regional distribution to local distribution	.935	1.077	.914	.783
Wholesale purchases by Smithfield Water Supply Board, --, local distribution system	From regional distribution to local distribution	.972	1.156	1.016	.862
Wholesale purchases by Greenville Water District, --,local distribution system	From regional distribution to local distribution	1.208	1.493	1.199	.826
Wholesale purchases by Lincoln Water Commission, --, local distribution system	From regional distribution to local distribution	2.952	2.853	2.495	2.307
Wholesale purchases by East Providence Water Department, --, local distribution system	From regional distribution to local distribution	6.740	7.860	6.891	6.320
Wholesale purchases by Cranston/Johnston Water District, --, local distribution system	From regional distribution to local distribution	1.479	1.964	1.778	1.485
Wholesale purchases by Warwick Water Department, --, local distribution system	From regional distribution to local distribution	13.25	16.98	14.80	11.72
Wholesale purchases by Kent County Water Authority, --, regional distribution system	From regional distribution to regional distribution	7.852	8.418	7.533	6.620
Wholesale purchases by Bristol County Water Authority, --, regional distribution system	From regional distribution to regional distribution	.436	.484	.505	.439

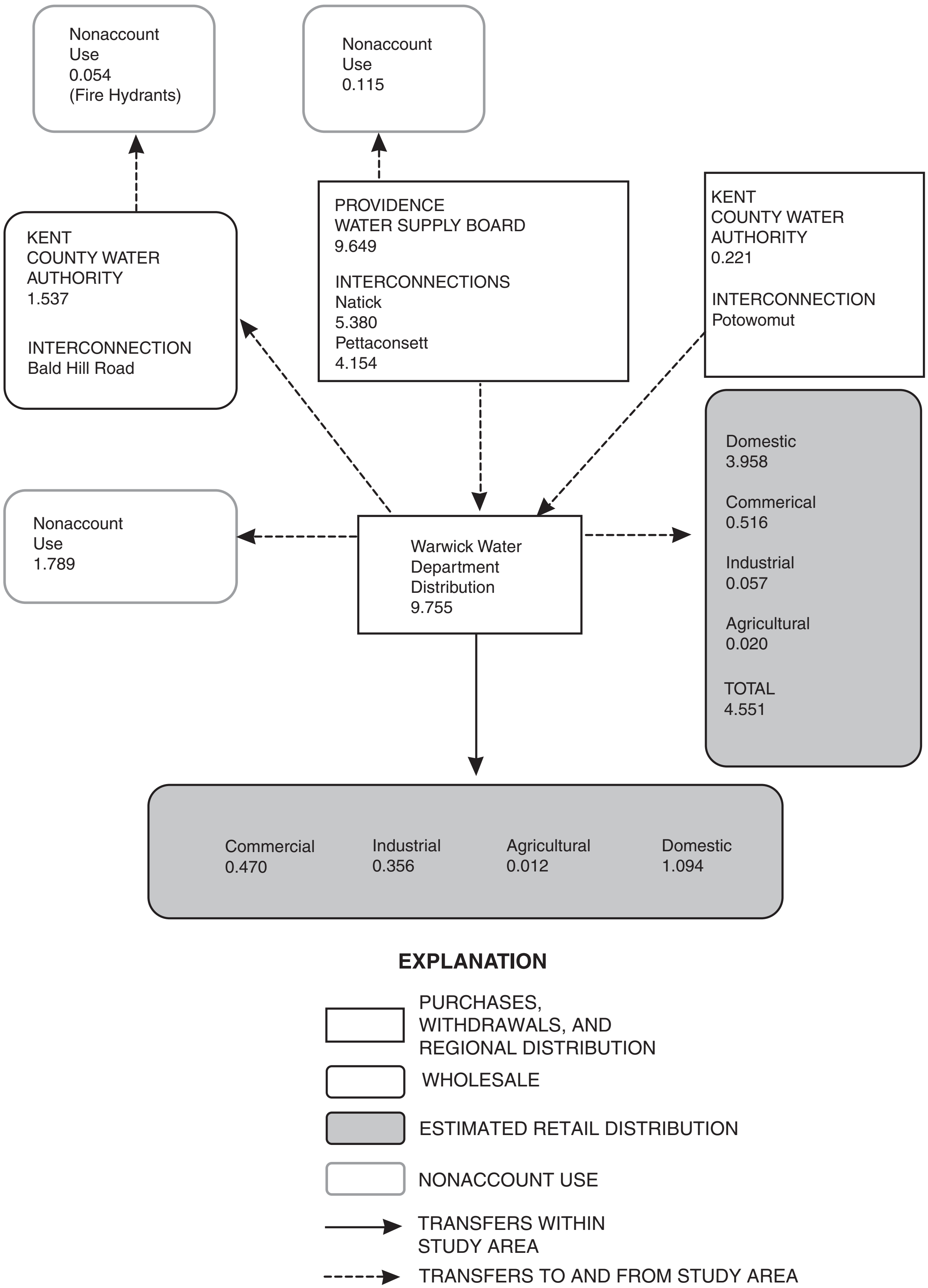


Figure 14. Warwick Water Department interconnections, purchases, distribution, exports, and estimated water uses, central Rhode Island, 1995–99. All rates in Mgal/d, million gallons per day.

Public-supply domestic water use in the Pawtuxet River subbasins ranged from 0.072 Mgal/d in the Scituate Reservoir Complex subbasin to 8.147 Mgal/d in the Northeastern Pawtuxet subbasin. One minor public water supplier in the Quinebaug River Basin used an estimated 0.003 Mgal/d for domestic purposes (table 12).

Self-Supply Use in the Pawtuxet and Quinebaug River Basins

Domestic self-supply water withdrawals and use in the Pawtuxet subbasins ranged from 0.118 Mgal/d in the North Branch Pawtuxet subbasin to 0.956 Mgal/d in the Scituate Reservoir Complex subbasin (tables 9 and 12). Domestic self-supply water withdrawals and use in the Quinebaug were 0.319 Mgal/d (tables 9 and 12).

Commercial and Industrial Water Use

Limited data are available on commercial and industrial water use from public- and self-supply systems, because withdrawals and use for these categories are not regulated in Rhode Island unless the withdrawal point is adjacent to a wetland (Rhode Island Department of Environmental Management, 2001). Commercial and industrial water-use estimates, therefore, were calculated for each town by apportioning the total commercial and industrial water uses by the percentage of the commercial and industrial land-use areas in each subbasin. Consumptive commercial and industrial water use (table 13) is assumed to be 10 percent of the total water use (Solley and others, 1998).

Public-Supply Use in the Pawtuxet River Basin

Information on commercial and industrial use of public-supply water included metered (or reported) and unmetered (or estimated) water-use data. If the data were available, public suppliers provided the delivery volume and the number of service connections for commercial and industrial water users. In some cases, suppliers combined the water amounts supplied to commercial and industrial users, but in other cases, the information was not available. Government water use is accounted for within the commercial water-use category according to the Standard Industrial Classification (SIC) codes; however, government water use was entered as a separate distribution into NEWUDS. Because some public-supply district service areas are within one or more basins and subbasins, the public-supply commercial and industrial water uses were apportioned according to percentages of land-use areas (table 4). Land-use coverages from RIGIS were merged with the water-supply district, town, and basin coverages to obtain the percentages of commercial and industrial land use within the supply districts for towns served in the Pawtuxet River Basin. Commercial use of public-supply water ranged from 0.015 Mgal/d in the Scituate Reservoir Complex subbasin to 2.253 Mgal/d in the Northeastern Pawtuxet subbasin. Industrial use of public-supply water ranged from 0.001 Mgal/d in the Scituate Reservoir Complex subbasin to 1.843 Mgal/d in the Northeastern Pawtuxet subbasin (table 12).

Self-Supply Use in the Pawtuxet and Quinebaug River Basins

Self-supply commercial and industrial-use estimates were calculated from the employee counts published in the RIEDC's "Export/Import Directory" (2000a), "High Tech Industries in Rhode Island" (1999), and "Major Employers in Rhode Island" (2000b). The numbers of employees in the industrial and commercial sectors for each SIC code were multiplied by the U.S. Army Corp of Engineers' Institute for Water Resources Municipal and Industrial Needs (IWR-MAIN) water-use coefficient (in gal/d/person) for each town (table 14) as described in Horn (2000). The estimated public-supply commercial and industrial water-use rates were subtracted from the total aggregate water-use rates to obtain the estimated total self-supply use for these categories. The total commercial and industrial water-use estimates for towns were disaggregated by basin (table 6) and then by subbasin on the basis of the land-use area by town as listed in table 3. Self-supply commercial use ranged from less than 0.001 Mgal/d in the North Branch Pawtuxet subbasin to 0.042 Mgal/d in the Northeastern Pawtuxet subbasin. Self-supply industrial use ranged from 0.009 Mgal/d in the North Branch Pawtuxet subbasin to 0.082 Mgal/d in the South Branch Pawtuxet subbasin (tables 9 and 12).

Agricultural Water Use

The estimated agricultural water use (livestock, crop irrigation, and golf-course irrigation) was obtained from information provided by the Department of Agriculture (USDA) NRCS, formerly known as the USDA Soil Conservation Service (SCS). The estimate was calculated for each town and then disaggregated by state basin and subbasin. Nine percent of withdrawals and use for livestock were assumed to be from surface water (streams and ponds) and 82 percent from ground water (wells); these livestock water-use rates were previously estimated in a study completed by the SCS (1993). Likewise, eighty-one percent of withdrawals and use for irrigation (golf courses and crops) were assumed to be from surface water and 13 percent from ground water (SCS, 1993). The remaining 9 percent of livestock use and 6 percent of irrigation use were assumed to be from public-supply distributions.

The water-use coefficients for each type of livestock (Laura Medalie, U.S. Geological Survey, written commun., 1995) were multiplied by the number of livestock of each type. Because the livestock and crop-irrigation data are reported in the 1997 Census of Agriculture at the county level (U.S. Department of Agriculture, 1997a,b), the estimates were disaggregated on the basis of the number of farms in the towns in each

Table 12. Estimated water supply by town and subbasin in the Pawtuxet River Basin, central Rhode Island, and in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Shaded areas are basin totals. All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; --, not applicable; <0.001, value not included in totals]

Town	Domestic (Mgal/d)		Commercial (Mgal/d)		Industrial (Mgal/d)		Agricultural (Mgal/d)		Total (Mgal/d)
	Public	Self	Public	Self	Public	Self	Public	Self	
Pawtuxet River Basin									
Scituate Reservoir Complex Subbasin									
Cranston	0.007	0.003	--	--	--	--	0.001	0.002	0.013
Foster	.007	.171	--	0.001	--	0.002	--	.002	.183
Glocester	--	.200	--	.007	--	--	--	.003	.210
Johnston	.029	.038	0.015	--	0.001	--	<.001	.001	.084
Scituate	.029	.538	--	.008	--	.012	--	.007	.594
Smithfield	--	.006	--	--	--	--	--	<.001	.006
Subbasin total	0.072	0.956	0.015	0.016	0.001	0.014	0.001	0.015	1.090
North Branch Pawtuxet Subbasin									
Coventry	0.235	0.035	0.003	--	0.015	0.009	0.003	0.003	0.303
Cranston	.047	.023	<.001	<0.001	.004	--	<.001	.005	.079
Scituate	.060	.058	.001	--	.026	--	<.001	.003	.148
West Warwick	.399	.002	.018	--	.064	--	.009	--	.492
Subbasin total	0.741	0.118	0.022	<0.001	0.109	0.009	0.012	0.011	1.022
South Branch Pawtuxet Subbasin									
Coventry	1.390	0.430	0.058	0.004	0.096	0.017	0.004	0.022	2.021
East Greenwich	.002	.001	--	--	--	--	--	--	.003
Exeter	<.001	.028	--	.001	--	--	--	.002	.031
Foster	--	.015	--	--	--	--	--	.003	.018
Scituate	--	.020	--	--	--	--	--	.001	.021
Warwick	.001	--	.001	--	--	--	<.001	--	.002
West Greenwich	.050	.113	--	.001	.017	.065	<.001	<.001	.246
West Warwick	.850	.005	.047	--	.114	--	<.001	--	1.016
Subbasin total	2.293	0.612	0.106	0.006	0.227	0.082	0.004	0.028	3.358
Northeastern Pawtuxet Subbasin									
Cranston	4.464	0.070	0.689	0.015	0.977	0.011	0.021	0.019	6.266
Johnston	.731	.149	.199	.027	.131	.004	.003	.001	1.245
Providence	1.605	--	.767	--	.354	--	--	--	2.726
Warwick	1.143	<.001	.588	--	.365	--	.019	--	2.115
West Warwick	.204	.010	.010	--	.016	--	.008	--	.248
Subbasin total	8.147	0.229	2.253	0.042	1.843	0.015	0.051	0.020	12.60
Basin total	11.25	1.915	2.396	0.064	2.180	0.120	0.068	0.074	18.07
Quinebaug River Basin									
Burrillville	--	0.036	--	--	--	--	--	<0.001	0.036
Coventry	0.003	.109	--	0.002	--	0.004	--	.007	.125
Exeter	--	.006	--	--	--	--	--	--	.006
Foster	--	.120	--	<.001	--	--	--	.024	.144
Glocester	--	.045	--	.003	--	<.001	--	.001	.049
West Greenwich	--	.003	--	--	--	--	--	--	.003
Basin total	0.003	0.319	--	0.005	--	0.004	--	0.032	0.363

Table 13. Estimated consumptive water use by town and subbasin in the Pawtuxet River Basin, central Rhode Island, and in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Shaded areas are basin totals. All towns are in Rhode Island unless otherwise noted. Mgal/d, million gallons per day; <0.001, value not included in totals; --, not applicable]

Town	Domestic (Mgal/d)		Commercial (Mgal/d)		Industrial (Mgal/d)		Agricultural (Mgal/d)		Total (Mgal/d)
	Public	Self	Public	Self	Public	Self	Public	Self	
Pawtuxet River Basin									
Scituate Reservoir Complex Subbasin									
Cranston	<0.001	0.001	--	--	--	--	0.001	0.002	0.004
Foster	--	.027	--	<0.001	--	<0.001	--	.002	.047
Glocester	--	.030	--	.001	--	--	--	.003	.034
Johnston	<.001	.010	0.001	--	<0.001	--	<.001	.001	.012
Scituate	.002	.083	--	.001	--	.001	--	.007	.094
Smithfield	--	.001	--	--	--	--	--	<.001	.001
Subbasin total	0.002	0.152	0.001	0.002	<0.001	0.001	0.001	0.015	0.174
North Branch Pawtuxet Subbasin									
Coventry	0.003	0.039	<0.001	--	0.001	0.001	0.003	0.003	0.050
Cranston	.001	.010	<.001	<0.001	<.001	--	<.001	.005	.016
Scituate	.001	.017	<.001	--	.003	--	<.001	.003	.024
West Warwick	.055	.005	.002	--	.006	--	.009	--	.077
Subbasin total	0.060	0.071	0.002	<0.001	0.010	0.001	0.012	0.011	0.167
South Branch Pawtuxet Subbasin									
Coventry	0.033	0.250	0.006	<0.001	0.010	0.002	0.004	0.022	0.327
East Greenwich	<.001	.001	--	--	--	--	--	--	.001
Exeter	--	.004	--	<.001	--	--	--	.002	.006
Foster	--	.002	--	--	--	--	--	.003	.005
Scituate	--	.003	--	--	--	--	--	.001	.004
Warwick	<.001	<.001	<.001	--	--	--	<.001	--	<.001
West Greenwich	<.001	.025	--	<.001	.002	.006	<.001	<.001	.033
West Warwick	.122	.006	.005	--	.011	--	<.001	--	.144
Subbasin total	0.155	0.291	0.011	<0.001	0.023	0.008	0.004	0.028	0.520
Northeastern Pawtuxet Subbasin									
Cranston	0.609	0.075	0.069	0.001	0.098	0.001	0.021	0.019	0.893
Johnston	.072	.063	.020	.003	.013	<.001	.003	.001	.175
Providence	.241	--	.077	--	.035	--	--	--	.353
Warwick	.116	.059	.059	--	.037	--	.019	--	.290
West Warwick	.030	.002	.001	--	.002	--	.008	--	.043
Subbasin total	1.068	0.199	0.226	0.004	0.185	0.001	0.051	0.020	1.754
Basin total	1.285	0.713	0.240	0.006	0.218	0.011	0.068	0.074	2.615
Quinebaug River Basin									
Burrillville	--	0.006	--	--	--	--	--	<0.001	0.006
Coventry	--	.017	--	<0.001	--	<0.001	--	.007	.024
Exeter	--	.001	--	--	--	--	--	--	.001
Foster	--	.018	--	<.001	--	--	--	.024	.042
Glocester	--	.007	--	<.001	--	<.001	--	.001	.008
West Greenwich	--	.001	--	--	--	--	--	--	.001
Basin total	--	0.050	--	<0.001	--	<0.001	--	0.032	0.082

Table 14. Estimated water use for each 2-digit Standard Industrial Classification code by town in the Pawtuxet and Quinebaug River Basins, 1995–99.

[**IWR-MAIN coefficient**, Institute for Water Resources Municipal and Industrial Needs coefficient in millions of gallons per day per person; Mgal/d, million gallons per day; --, not applicable; <0.001, value not used in totals]

2-digit Standard Industrial Classification category and [code]	IWR-MAIN coefficient	Estimated water use in Rhode Island towns (Mgal/d)				
		Burrillville	Coventry	Cranston	East Greenwich	Exeter
Industrial [20-39]						
Food [20]	469	0.033	--	0.162	0.003	--
Textile mills [22]	315	.016	0.022	.008	--	--
Finished apparel [23]	13	--	--	--	--	--
Wood, lumber [24]	78	--	--	--	--	--
Furniture [25]	3	--	--	--	--	--
Paper products [26]	863	--	--	.237	--	--
Printing, publishing [27]	42	--	--	<.001	<.001	--
Chemical products [28]	289	--	.102	.069	--	--
Petroleum refining [29]	1,045	--	--	--	--	--
Rubber [30]	119	.008	--	.150	--	0.024
Leather [31]	148	--	--	.007	--	--
Stone, clay, glass, and concrete [32]	202	--	--	.141	--	--
Primary metals [33]	178	--	--	.012	.026	--
Fabricated metal [34]	95	.011	--	.066	.002	--
Machinery [35]	58	--	.009	.029	.085	--
Electrical equipment [36]	71	--	--	.035	.072	--
Transportation equipment [37]	63	--	--	--	--	--
Instruments [38]	66	--	.001	.039	.003	--
Jewelry, precious metals [39]	36	--	.008	.040	.003	--
Total industrial [20-39]	--	0.067	0.142	0.995	0.194	0.024
Commercial [40-97]						
Transportation, communication, utilities [40-49]	51	--	--	0.019	0.013	--
Wholesale trade [50-51]	58	0.007	--	.034	--	--
Retail trade [52-59]	58	.007	0.034	.290	.006	--
Finance, insurance, real estate [60-67]	71	--	--	.008	--	--
Services [70-89]	106	.038	.034	.375	.004	0.017
Public administration [91-97]	71	--	--	--	--	--
Total commercial [40-97]	--	0.051	0.068	0.726	0.023	0.017

Table 14. Estimated water use for each 2-digit Standard Industrial Classification code by town in the Pawtuxet and Quinebaug River Basins, 1995–99.—Continued

[**IWR-MAIN coefficient**, Institute for Water Resources Municipal and Industrial Needs coefficient in millions of gallons per day per person; Mgal/d, million gallons per day; --, not applicable; <0.001, value not used in totals]

2-digit Standard Industrial Classification category and [code]	IWR-MAIN coefficient	Estimated water use in Rhode Island towns (Mgal/d)				
		Foster	Glocester	Johnston	Providence	Scituate
Industrial [20-39]						
Food [20]	469	--	--	0.002	0.176	--
Textile mills [22]	315	--	--	--	.058	--
Finished apparel [23]	13	--	--	--	.001	--
Wood, lumber [24]	78	0.001	--	--	--	--
Furniture [25]	30	--	--	--	.003	--
Paper products [26]	863	--	--	--	.582	--
Printing, publishing [27]	42	--	--	.001	.069	--
Chemical products [28]	289	--	--	--	.019	--
Petroleum refining [29]	1,045	--	--	--	--	--
Rubber [30]	119	--	--	.025	.044	0.036
Leather [31]	148	--	--	--	.001	.001
Stone, clay, glass, and concrete [32]	202	--	--	.101	--	--
Primary metals [33]	178	--	--	.026	.055	--
Fabricated metal [34]	95	--	--	.006	.125	--
Machinery [35]	58	--	<0.001	<.001	.026	.002
Electrical equipment [36]	71	--	--	.002	.048	--
Transportation equipment [37]	63	--	--	--	.026	--
Instruments [38]	66	--	--	.005	.075	--
Jewelry, precious metals [39]	36	<.001	--	.032	.215	--
Total industrial [20-39]	--	0.001	<0.001	0.200	1.523	0.039
Commercial [40-97]						
Transportation, communication, utilities [40-49]	51	--	--	0.006	0.435	--
Wholesale trade [50-51]	58	<0.001	--	--	.038	--
Retail trade [52-59]	58	--	--	.041	.122	0.008
Finance, insurance, real estate [60-67]	71	--	--	.052	.676	--
Services [70-89]	106	.001	0.031	.247	4.716	.001
Public administration [91-97]	71	--	--	--	.008	--
Total commercial [40-97]	--	0.001	0.031	0.346	5.995	0.009

Table 14. Estimated water use for each 2-digit Standard Industrial Classification code by town in the Pawtuxet and Quinebaug River Basins, 1995–99.—Continued

[**IWR-MAIN coefficient**, Institute for Water Resources Municipal and Industrial Needs coefficient in millions of gallons per day per person; Mgal/d, million gallons per day; --, not applicable; <0.001, value not used in totals]

2-digit Standard Industrial Classification category and [code]	IWR-MAIN coefficient	Estimated water use in Rhode Island towns (Mgal/d)			
		Smithfield	Warwick	West Greenwich	West Warwick
Industrial [20-39]					
Food [20]	469	0.077	0.009	--	--
Textile mills [22]	315	--	.031	0.009	0.090
Finished apparel [23]	13	--	--	--	--
Wood, lumber [24]	78	--	--	--	--
Furniture [25]	30	.003	.017	--	--
Paper products [26]	863	--	.022	--	--
Printing, publishing [27]	42	--	.007	--	--
Chemical products [28]	289	--	.010	.068	.147
Petroleum refining [29]	1045	--	--	--	--
Rubber [30]	119	--	.004	.003	.015
Leather [31]	148	--	--	--	--
Stone, clay, glass, and concrete [32]	202	.006	--	--	.015
Primary metals [33]	178	.011	.039	--	--
Fabricated metal [34]	95	.001	.050	--	.060
Machinery [35]	58	.005	.026	.058	.008
Electrical equipment [36]	71	.003	.146	--	.031
Transportation equipment [37]	63	.002	--	--	--
Instruments [38]	66	.032	.038	--	--
Jewelry, precious metals [39]	36	.019	.054	--	.001
Total industrial [20-39]	--	0.159	0.453	0.138	0.367
Commercial [40-97]					
Transportation, communication, utilities [40-49]	51	--	0.075	0.001	0.020
Wholesale trade [50-51]	58	--	.008	--	--
Retail trade [52-59]	58	0.030	.363	--	.006
Finance, insurance, real estate [60-67]	71	.076	.166	--	.066
Services [70-89]	106	.143	.892	--	.014
Public administration [91-97]	71	--	--	--	--
Total commercial [40-97]	--	0.249	1.504	0.001	0.106

county and the percentage of agricultural land use in each town and subbasin. The livestock water-use estimates represent a year-round usage. Although it is estimated that 60 percent of livestock water use is consumed and 40 percent is returned to ground water (Horn and others, 1994), this distinction was negligible for the Pawtuxet and Quinebaug River Basins. Thus, agricultural water use was assumed to be 100 percent consumed (table 13) (Horn and others, 1994). Livestock water use accounted for about 13 percent of the agricultural water withdrawals and about 0.01 percent of the total water withdrawals during the study period, and thus was a minor component of water use in the Pawtuxet River Basin. In the Quinebaug River Basin, livestock water withdrawals accounted for 6.3 percent of the agricultural withdrawals and about 0.5 percent of the total water withdrawals.

Crop and golf-course irrigation were estimated on the basis of the assumption that the percentage of agricultural land-use area for each town is equal to the percentage of the total town agricultural land-use area in the county. The irrigated town acreage determined from the estimation was then subdivided by basin and subbasin. For irrigated acreage in the Pawtuxet River Basin, it was assumed that 1 in/week/acre of water (an average of 0.143 in/day/acre) was needed to irrigate crop land (Laura Medalie, U.S. Geological Survey, written commun., 2000). The monthly water deficit was determined by subtracting the average monthly rainfall from the 0.143 in/day/acre needed for crop irrigation. Yardages for the golf courses were collected from the websites WorldGolf.com (2002) and GolfCourse.com (2002). The coefficient of 0.0116 Mgal/d per 1,000 yards (Laura Medalie, U.S. Geological Survey, written commun., 2000) was applied to the golf-course areas in the towns in the Pawcatuck Basin (Wild and Nimiroski, 2004) and was used in this study. The coefficient used for the 2000 water-use compilation for Massachusetts was comparable at 0.0117 Mgal/d per 1,000 yards (Wild and Nimiroski, 2004). According to the SCS (1993), most of the irrigation occurred during June, July, and August. There was no crop and golf-course irrigation in the Quinebaug River Basin during the study period.

Self-supply agricultural water use was estimated by town and disaggregated by basin and subbasin. In the Pawtuxet River Basin, self-supply water withdrawals and use for agriculture ranged from 0.011 Mgal/d in the North Branch Pawtuxet subbasin to 0.028 Mgal/d in the South Branch Pawtuxet subbasin (tables 9 and 12). In the Quinebaug River Basin, self-supply water withdrawals and use for agriculture ranged from less than 0.001 Mgal/d in Burrillville to 0.024 Mgal/d in Foster (tables 9 and 12). Agricultural water withdrawals and use in the Quinebaug River Basin were 0.032 Mgal/d (tables 9 and 12).

Return Flow and Interbasin Transfers

In Rhode Island, commercial and industrial dischargers are required to report to the RIDEM Office of Water Resources the rates of water returned to the environment. These dischargers, referred to as Rhode Island Pollutant Discharge Elimination Systems (RIPDES), return wastewater to surface water (usually to rivers), or in some cases, to the ground-water system. In addition, local and regional facilities that treat wastewater are required to report wastewater discharges into rivers in Rhode Island. Domestic, commercial, and industrial disposers who use septic systems, which create inflow to the ground-water system, are not required to report discharges. For the Pawtuxet River Basin, the total metered RIPDES return flow was 5.903 Mgal/d, and the total metered wastewater from treatment facilities was 20.54 Mgal/d (table 15). The return flow from RIPDES sites and WWTFs totaled 26.28 Mgal/d to surface water, and 0.163 Mgal/d to ground water. The estimated return flow from septic systems was 4.031 Mgal/d for domestic disposers, 0.058 Mgal/d for commercial disposers, and 0.109 Mgal/d for industrial disposers (table 15). Therefore, the Pawtuxet River Basin total estimated ground-water return flow was 4.361 Mgal/d for the study period. The estimated return flow from septic systems, the only return flow in the Quinebaug River Basin, was 0.274 Mgal/d for domestic disposers, 0.005 Mgal/d for commercial disposers, and 0.004 Mgal/d for industrial disposers (table 15).

Interbasin transfers include imports and exports of wastewater and potable water to and from a basin or subbasin. Wastewater is an import, or a gain to the Pawtuxet River Basin, if it is collected in another basin or subbasin and conveyed to the Pawtuxet River Basin for discharge. Wastewater is an export, or a loss to the basin, when it is collected and processed in the basin but is returned to the environment outside the basin.

Site-Specific Return Flow in the Pawtuxet River Basin

Some RIPDES systems are required to report their discharges to RIDEM. Return-flow data were collected from RIDEM for these small systems — for example, wastewater-treatment plants (Horn and Craft, 1991) — in the Pawtuxet River Basin (table 16). Return flows are conveyed by discharge pipes that dispose water used during industrial and commercial processes. Total RIPDES discharges in the Pawtuxet River Basin were 5.903 Mgal/d, and ranged from 0.001 Mgal/d in the Scituate Reservoir Complex subbasin to 4.479 Mgal/d in the South Branch Pawtuxet subbasin (tables 15 and 16).

Monthly data were collected for wastewater-treatment facilities in or serving the town populations in the Pawtuxet River Basin (table 17), including the Cranston Water Pollution Control Facility, the Warwick WWTF, the West Warwick Regional WWTF, and the Narragansett Bay Commission Fields Point Facility. Cranston, Warwick, and West Warwick wastewater is collected in the Pawtuxet River Basin and in the adjacent West Narragansett Bay Basin, and the treated return flow is discharged to the Pawtuxet River in the Northeastern Pawtuxet subbasin. Average discharges to the Pawtuxet River were 11.69 Mgal/d from the Cranston system, 3.642 Mgal/d from the Warwick system, and 5.204 Mgal/d from the West Warwick system. These totals include wastewater collected in the Pawtuxet River Basin and imported from outside of the basin. An estimated 3.092 Mgal/d of wastewater is collected from the parts of Johnston and Providence in the Pawtuxet River Basin and exported to the adjacent West Narragansett Bay Basin (table 17).

Table 15. Estimated public- and self-disposed domestic, commercial, industrial, and metered return flow by subbasin in the Pawtuxet River Basin, central Rhode Island, and in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Shaded areas are basin totals. Public disposal, wastewater collection to treatment plant; Self-disposal, inflow to ground water; RIPDES and WWTFs, inflow to surface water; **RIPDES**, Rhode Island Pollutant Discharge Elimination System; **WWTF**, wastewater-treatment facilities; Mgal/d, million gallons per day; <0.001, value not included in totals; --, not applicable]

Town	Domestic disposal (Mgal/d)		Commercial disposal (Mgal/d)		Industrial disposal (Mgal/d)		Metered return flow (Mgal/d)		Total self-disposal and return flow (Mgal/d)
	Public	Self	Public	Self	Public	Self	RIPDES	WWTF	
Pawtuxet River Basin									
Scituate Reservoir Complex Subbasin									
Cranston	0.001	0.008	--	--	--	--	--	--	0.008
Foster	--	.151	--	0.001	--	0.002	--	--	.154
Glocester	--	.170	--	.006	--	--	--	--	.176
Johnston	.002	.056	0.014	--	0.001	--	--	--	.056
Scituate	.013	.469	--	.007	--	.011	0.001	--	.488
Smithfield	--	.005	--	--	--	--	--	--	.005
Subbasin total	0.016	0.859	0.014	0.014	0.001	0.013	0.001	--	0.887
North Branch Pawtuxet Subbasin									
Coventry	0.018	0.223	0.003	--	0.014	0.008	0.020	--	0.251
Cranston	.006	.055	--	--	.004	--	--	--	.055
Scituate	.008	.095	.001	--	.023	--	.637	--	.732
West Warwick	.315	.028	.016	--	.058	--	.028	--	.056
Subbasin total	0.347	0.401	0.020	--	0.099	0.008	0.685	--	1.094
South Branch Pawtuxet Subbasin									
Coventry	0.188	1.419	0.052	0.004	0.086	0.015	4.449	--	5.887
East Greenwich	<.001	.003	--	--	--	--	--	--	.003
Exeter	--	.024	--	.001	--	--	--	--	.025
Foster	--	.013	--	--	--	--	--	--	.013
Scituate	--	.017	--	--	--	--	--	--	.017
Warwick	<.001	.001	.001	--	--	--	--	--	.001
West Greenwich	.001	.139	--	.001	.015	.059	--	--	.199
West Warwick	.693	.035	.042	--	.103	--	.030	--	.065
Subbasin total	0.882	1.651	0.095	0.006	0.204	0.074	4.479	--	6.210
Northeastern Pawtuxet Subbasin									
Cranston	3.513	0.423	0.620	0.014	0.879	0.010	0.018	11.69	12.16
Johnston	.405	.356	.179	.024	.118	.004	.018	--	.402
Providence	1.364	--	.690	--	.319	--	--	--	--
Warwick	.658	.332	.529	--	.329	--	.702	3.642	4.676
West Warwick	.172	.009	.009	--	.014	--	--	5.204	5.213
Subbasin total	6.112	1.120	2.027	0.038	1.659	0.014	0.738	20.54	22.45
Basin total	7.357	4.031	2.156	0.058	1.963	0.109	5.903	20.54	30.64
Quinebaug River Basin									
Burrillville	--	0.031	--	--	--	--	--	--	0.031
Coventry	--	.095	--	0.002	--	0.004	--	--	.101
Exeter	--	.005	--	--	--	--	--	--	.005
Foster	--	.101	--	<.001	--	--	--	--	.101
Glocester	--	.039	--	.003	--	<.001	--	--	.042
West Greenwich	--	.003	--	--	--	--	--	--	.003
Basin total	--	0.274	--	0.005	--	0.004	--	--	0.283

Table 16. Return flows by subbasin for the Rhode Island Pollutant Discharge Elimination System sites in the Pawtuxet River Basin, central Rhode Island, 1995–99.

[Shaded area represents basin total. **Reference Number:** The identifier for sites shown on figure 8. **SIC**, Standard Identification Code; Mgal/d, million gallons per day; MHRH, Mental Health, Retardation and Hospitals; RI, Rhode Island; --, unknown]

Return-flow site	Reference number	Town	Discharge permit number	Receiving water body	SIC code	Return flow 1995–99 (Mgal/d)
Pawtuxet River Basin						
Scituate Reservoir Complex Subbasin						
Kenyon Oil Company	1	Scituate	RI0023191	--[1]	5541	0.001
Subbasin total						0.001
North Branch Pawtuxet Subbasin						
Providence Water Supply Board	2	Scituate	RI0021601	North Branch Pawtuxet River	4941	0.637
Arkwright, Inc.	3	Coventry	RI0000035	North Branch Pawtuxet River	3081	.020
Victor Electric Wire	4	West Warwick	RI0001473	North Branch Pawtuxet River	3357	.028
Subbasin total						0.685
South Branch Pawtuxet Subbasin						
Shell Service Station	5	Coventry	RI0021822	--[1]	5541	<0.001
Garland Industries	6	Coventry	RI0021075	South Branch Pawtuxet River	3951	--[2]
Clarient Corporation	7	Coventry	RI0000132	South Branch Pawtuxet River	2865	4.449
Concordia Manufacturing	8	Coventry	RI0000981	South Branch Pawtuxet River	2282	<.001
Coventry Narrow Fabrics	9	Coventry	RI0021580	South Branch Pawtuxet River	2241	<.001
Original Bradford Soap Works	10	West Warwick	RI0000248	South Branch Pawtuxet River	2841	.030
Subbasin total						4.479
Northeastern Pawtuxet Subbasin						
Medical Homes of Rhode Island	11	Johnston	RI0020168	Dry Brook	8051	0.018
Coastal Food Service	12	Cranston	RI0021687	Print Works Pond	3589	.001
Merit Oil of Rhode Island, Inc.	13	Cranston	RI0022110	--[1]	5541	<.001
Leonard Valve Company, Inc.	14	Cranston	RI0021563	--[1]	3491	.008
EG&G Sealol	15	Cranston	RI0000396	Pawtuxet River	3491	.007
Chem Pak Corp	16	Cranston	RI0021156	Pawtuxet River	2812	.001
RI Department of MHRH	17	Cranston	RI0020176	Pawtuxet River	8063	.001
Leviton Manufacturing	18	Warwick	RI0021377	Three Ponds Brook	3643	.547
Kenney Manufacturing	19	Warwick	RI0023027	--[1]	2591	.155
Rhode Island Mall	20	Warwick	RI0001546	Pawtuxet River	7389	<.001
Subbasin total						0.738
Basin total						5.903

[1] The receiving water body is not specified in the NEWUDS database. In this report, return flows were assumed to be discharged directly to the local aquifer and were treated as such in the calculation of water budgets.

[2] No data for period of study (1995–99).

Table 17. Return flow from wastewater-treatment facilities within and outside of the Pawtuxet River Basin, central Rhode Island, 1995–99.

[Reference letter: Identifier used on fig. 8. Mgal/d, million gallons per day]

Wastewater-treatment facility	Reference letter	Discharge permit number	Receiving water body (subbasin or basin)	Average discharge 1995–99 (Mgal/d)
Return flow to the Pawtuxet River Basin				
Cranston Water Pollution-Control Facility	A	RI0100013	Pawtuxet River (Northeastern Pawtuxet Subbasin)	11.69
Warwick Wastewater-Treatment Facility	B	RI0023141	Pawtuxet River (Northeastern Pawtuxet Subbasin)	3.642
West Warwick Regional Wastewater-Treatment Facility	C	RI0100153	Pawtuxet River (Northeastern Pawtuxet Subbasin)	5.204
Total				[1]20.54
Return flow outside of the Pawtuxet River Basin				
Narragansett Bay Commission-Fields Point Regional Wastewater-Treatment Facility[2]	D	RI0100315	Narragansett Bay (West Narragansett Bay Drainage Basin)	55.44
Total				55.44

[1]Wastewater imported from outside the Pawtuxet River Basin, 12.283 Mgal/d.

[2]Wastewater exported from the Pawtuxet River Basin to the Narragansett Bay Drainage Basin, 3.092 Mgal/d.

Aggregate Return Flow in the Pawtuxet and Quinebaug River Basins

Aggregate return flow was estimated for domestic, industrial, and commercial water use. Domestic populations on septic systems were assumed to return 85 percent of their wastewater to ground water and to consume 15 percent of the water withdrawn (Solley and others, 1998). To estimate the rate of domestic self-disposal of wastewater, the population was multiplied by the water-use coefficient for self-supply water use (71 gal/d/person), converted to Mgal/d, and multiplied by 85 percent. Domestic rates of self-disposal of wastewater in the Pawtuxet River Basin ranged from 0.401 Mgal/d in the North Branch Pawtuxet subbasin to 1.651 Mgal/d in the South Branch Pawtuxet subbasin; in the Quinebaug River Basin, the rate was 0.274 Mgal/d (table 15). It is estimated that 90 percent of industrial and commercial return flow is disposed to ground water and 10 percent is consumed (Horn, 2000). Commercial rates of self-disposal of wastewater in the Pawtuxet River Basin ranged from none in the North Branch Pawtuxet subbasin to 0.038 Mgal/d in the Northeastern Pawtuxet subbasin; in the Quinebaug River Basin, the rate was 0.005 Mgal/d. Industrial rates of self-disposal of wastewater in the Pawtuxet River Basin ranged from 0.008 Mgal/d in the North Branch Pawtuxet subbasin to 0.074 Mgal/d in the South Branch Pawtuxet subbasin; in the Quinebaug River Basin, the rate was 0.004 Mgal/d (table 15). Total consumptive water-use rates in the Pawtuxet River Basin ranged from 0.167 Mgal/d in the North Branch Pawtuxet subbasin to 1.754 Mgal/d in the Northeastern Pawtuxet subbasin, and the rate for the Quinebaug River Basin was 0.082 Mgal/d (table 13).

Interbasin Transfers in the Pawtuxet River Basin

The public water supply withdrawn from the Scituate Reservoir Complex subbasin by ProvWater supplied almost all of the other basins in Rhode Island, including the Blackstone, the Moshassuck, the Woonasquatucket, the Narragansett Bay, and the Westport Basins; only the Quinebaug, the Pawcatuck, and the South Coastal Basins were not supplied by the Scituate Reservoir. In addition, withdrawals from the Kent County Water Authority supplied areas outside of the Pawtuxet River Basin. Of the major public-supply withdrawals from the Pawtuxet River Basin, about 22 percent were used (domestic, commercial, industrial, and agricultural uses) in the Pawtuxet River Basin, and about 51 percent were exported to other basins in Rhode Island (fig. 15). The remaining water use was classified as nonaccount. Some of the water exported from the basin was returned to the basin as wastewater. A comparison of the total water withdrawals from the basin to the total use and nonaccount water losses resulted in a net export of 48.48 Mgal/d of potable water from the Pawtuxet River Basin (table 18).

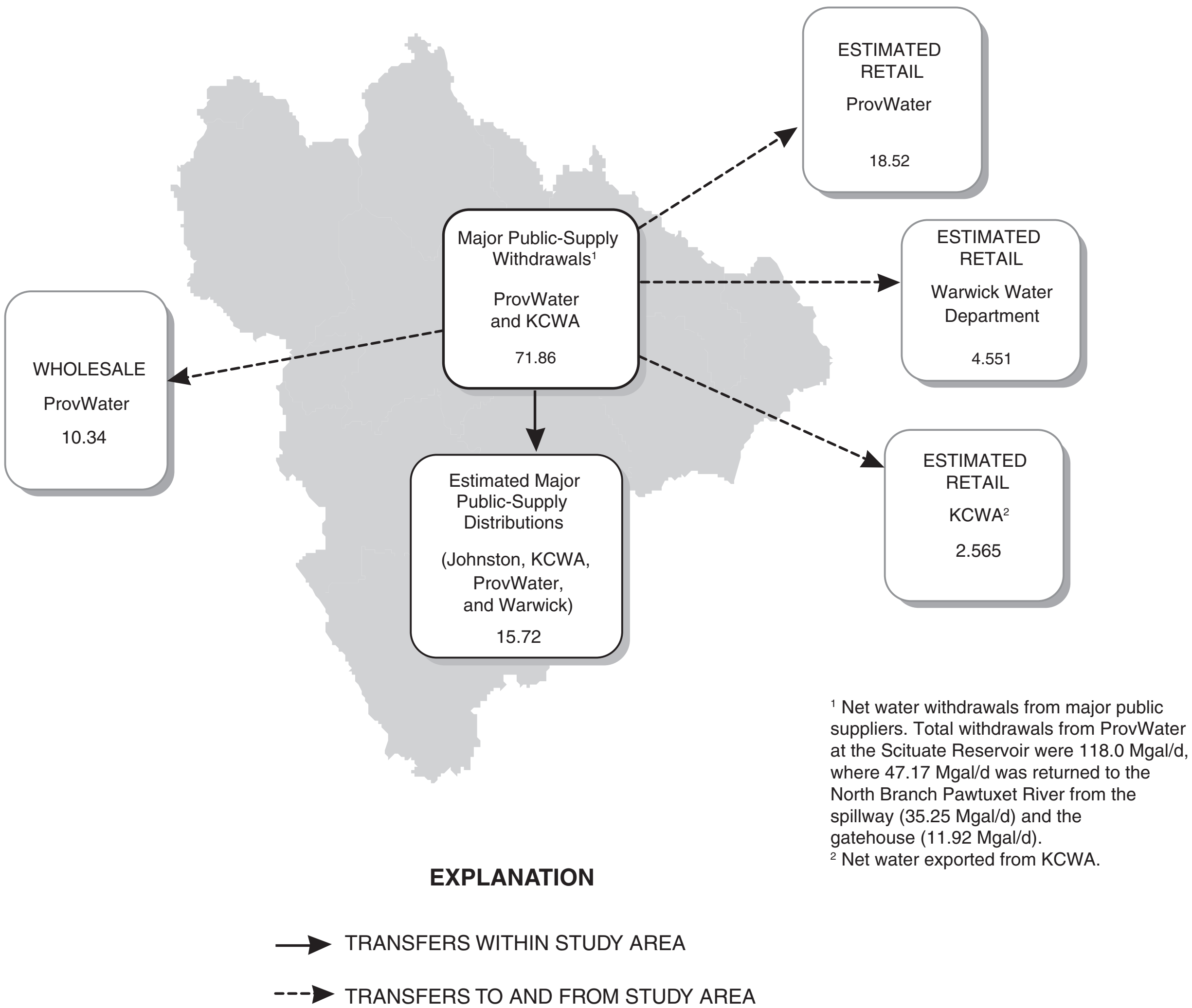


Figure 15. Public-supply withdrawals and estimated exports from the Pawtuxet River Basin, central Rhode Island, 1995–99. All rates in Mgal/d, million gallons per day. [ProvWater, Providence Water Supply Board; KCWA, Kent County Water Authority]

Within the water balance of withdrawals, use by category, nonaccount use, consumptive use, and return flows, a percent error can be attributed to the addition of metered (or reported) and estimated water-use components for each category. Public-supply withdrawals are metered (or reported), for example, but water use by subbasin is estimated, and then the return flow is metered (or reported) and estimated. Similarly, RIPDES data are metered (or reported), but the rates of withdrawal and use are estimated.

Wastewater is collected from the Pawtuxet River Basin and outside the basin, and then it is processed and returned to the Pawtuxet River from the towns of Cranston, Warwick, and West Warwick. Wastewater from the Pawtuxet River Basin is also exported in Johnston and Providence to the Narragansett Bay Basin, where the wastewater is processed and returned to Narragansett Bay (fig. 16). Estimated rates of publicly disposed industrial and commercial water were used to determine wastewater imports and exports. In the Pawtuxet River Basin, the net import of wastewater was 15.19 Mgal/d (table 18). The only exports from the Quinebaug River Basin are losses from consumptive water use, and were 0.136 Mgal/d (table 19).

Table 18. Summary of estimated water withdrawals, imports, exports, use, consumptive use, and return flow in the Pawtuxet River Basin, central Rhode Island, 1995–99.

[**Nonaccount:** A loss of water through the system. **Consumptive use:** A basin export. **Net import and exports:** The sum of the potable water and wastewater imports and exports; does not include nonaccount and consumptive water uses. **AG**, agricultural; **COM**, commercial; **DOM**, domestic; **IND**, industrial; Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; +, potable distribution and wastewater imported to subbasin and basin; -, potable distribution and wastewater exported from subbasin and basin; --, not applicable]

Subbasin	Water withdrawals (Mgal/d)	Potable water imports (+) and exports (-) (Mgal/d)	Total water use, public and self (Mgal/d)		Consumptive use (Mgal/d)	Return flow (Mgal/d)		Wastewater imports (+) and exports (-) (Mgal/d)	Net imports (+) and exports (-) (Mgal/d)
	Public and self		Use (DOM, COM, IND, AG)	Nonaccount (public use)		Surface water	Ground water		
Scituate Reservoir Complex	71.87	-70.77	1.090	0.011	0.174	--	0.887	-0.029	-70.80
North Branch Pawtuxet	.138	+1.358	1.022	.474	.167	0.685	.409	+.240	+1.598
South Branch Pawtuxet	1.747	+3.072	3.358	1.461	.520	4.479	1.731	+3.372	+6.444
Northeastern Pawtuxet	.306	+17.86	12.60	5.563	1.754	21.12	1.335	+11.61	+29.47
Pawtuxet River Basin total	74.06	-48.48	18.07	7.509	2.615	26.28	4.362	+15.19	-33.29

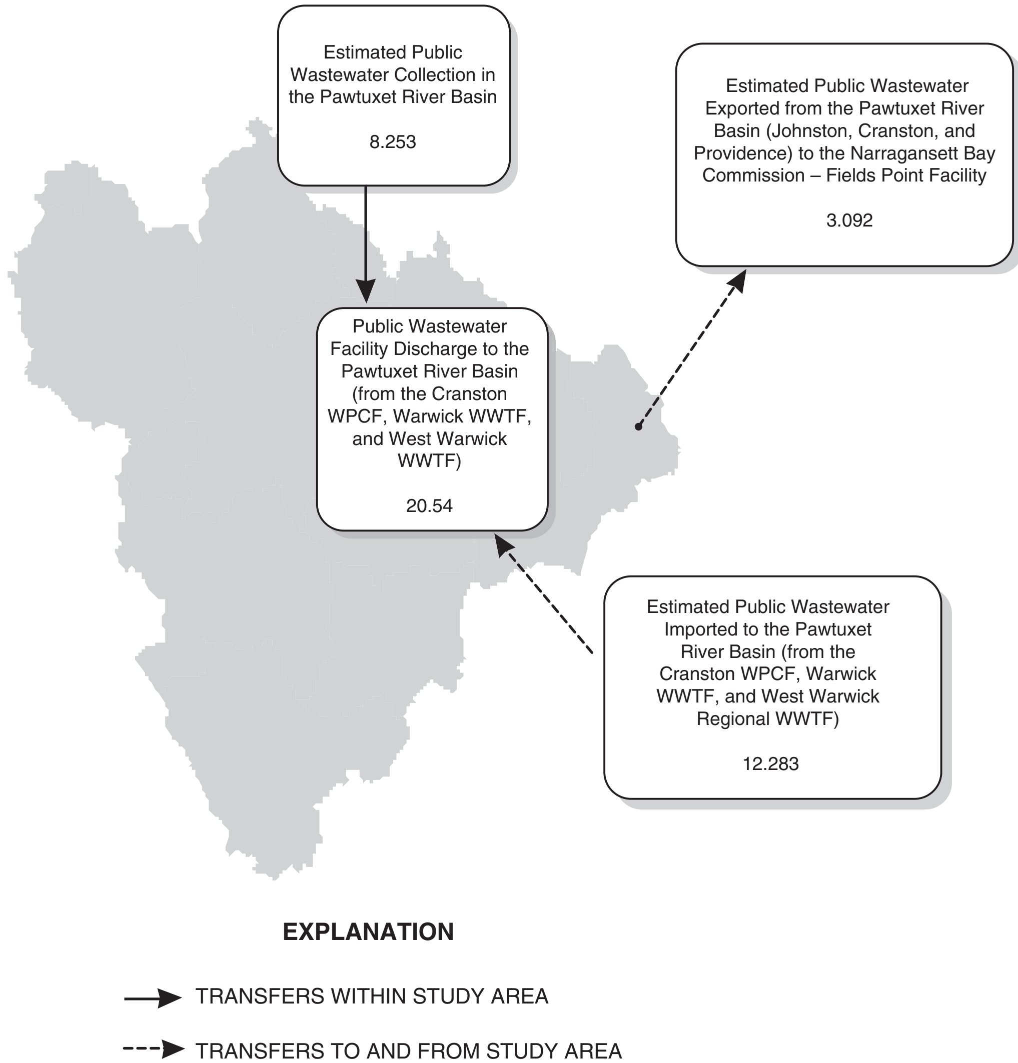


Figure 16. Estimated public wastewater collection, discharge, and estimated exports from the Pawtuxet River Basin, central Rhode Island, 1995–99. All rates in Mgal/d, million gallons per day. [WPCF, Water Pollution Control Facility; WWTF, Wastewater Treatment Facility]

Table 19. Summary of estimated water withdrawals, imports, exports, use, consumptive use, and return flow in the Quinebaug River Basin, western Rhode Island, 1995–99.

[**Consumptive use:** A basin export. **AG**, agricultural; **COM**, commercial; **DOM**, domestic; **IND**, industrial; Mgal/d, million gallons per day; <0.001, values not included in town and subbasin totals; +, potable distribution and wastewater imported to subbasin and basin; -, potable distribution and wastewater exported from subbasin and basin; --, not applicable]

Subbasin	Water withdrawals (Mgal/d)	Potable water imports (+) and exports (-) (Mgal/d)	Total water use (Mgal/d)	Consumptive use (Mgal/d)	Return flow (Mgal/d)		Wastewater imports (+) and exports (-) (Mgal/d)	Net imports (+) and exports (-) (Mgal/d)
	Self-supply		Self-supply (DOM, COM, IND, AG)		Surface water	Ground water		
Burrillville[1]	0.036	--	0.036	0.006	--	0.031	--	--
Coventry	.125	--	.125	.024	--	.101	--	--
Exeter	.006	--	.006	.001	--	.005	--	--
Foster[1]	.198	--	.198	.096	--	.101	--	--
Glocester[1]	.049	--	.049	.008	--	.042	--	--
West Greenwich[1]	.003	--	.003	.001	--	.003	--	--
Basin total	0.417	--	0.417	0.136	--	0.283	--	--

[1]Differences between the total water use and the sum of the consumptive use and the wastewater return flow are a result of rounding.

Estimated Water Availability in the Summer

During periods of little or no precipitation, streamflow is primarily sustained from surface-water storage (lakes and reservoirs) and from ground-water discharge; direct runoff is assumed to be negligible. Water withdrawals are often higher during the summer, and precipitation and ground-water discharge may be lower in the summer than the annual average. Therefore, it was important to estimate the amount of available water and to compare it to the withdrawals in the study area. Water-availability estimates that are made from base-flow calculations are conservative because actual streamflows generally are greater than base flow except during periods of no recharge from precipitation.

Because most of the study area is ungaged and records from stations in the study area are affected by ground-water withdrawals, estimates of available water had to be based on streamflows measured at stream-gaging stations in nearby basins. First, index stations were chosen whose upstream areal percentages of sand and gravel deposits and till deposits are similar to those in the study area. The Branch River at Forestdale stream-gaging station (01111500) was the index station used to determine water availability in the Scituate Reservoir Complex and North Branch Pawtuxet subbasins in the Pawtuxet River Basin and in the Quinebaug River Basin (fig. 8). The Nooseneck River at Nooseneck stream-gaging station (01115630) was the index station used to determine water availability in the South Branch Pawtuxet and Northeastern Pawtuxet subbasins of the Pawtuxet River Basin (table 20). Second, the hydrograph-separation application PART (Rutledge, 1993, 1998) was applied to the records for the two index stations to determine the 75th, 50th, and 25th percentiles of base flow for June, July, August, and September. The 75th, 50th, and 25th percentiles of base flow and these base flows minus the 7Q10 and ABF low flows (called the 7Q10 and ABF scenarios) were calculated (table 21). Third, these base flows were apportioned according to the contributions of base flow from sand and gravel deposits and of till deposits upstream of the two index stations to give base flows per unit area in Mgal/d/mi^2. Contributions of base flow from stratified sand and gravel deposits and till deposits for the index stations used in this assessment were based on previous USGS work for five index stations in the Pawcatuck Basin (Wild and Nimiroski, 2004). The regression equation

$$y = (0.4)\, e^{(x)(1.38)}, \qquad (1)$$

where

y = percentage of base-flow contribution from sand and gravel deposits at the index station, and

x = sand and gravel area divided by the total drainage area at the index station,

was used to estimate base-flow contributions from sand and gravel deposits for the index stations, for which the flow contributions by deposit were unknown. The percentages of base-flow contributions from sand and gravel deposits were estimated to be 60 percent for the Branch River at Forestdale and 63 percent for the Nooseneck River at Nooseneck stations. The base flow for each deposit was divided by the area of each deposit upstream of each index station. The resulting values are estimates of the base flows per unit area in Mgal/d/mi^2 for the sand and gravel and for the till areas upstream of the stations (table 22). Finally, the flow per unit area for each type of deposit at each index station was multiplied by the area of the same type of deposit in the study-area subbasins assigned to each index station. The gross yield from ground water for each subbasin was defined as the sum of the base-flow contributions from the two types of surficial deposits. The available water was defined for the same three scenarios as for the index stations. Ratios of water withdrawn to water available were calculated for each subbasin.

Table 20. U.S. Geological Survey stream-gaging stations and minimum streamflows used in the analysis of water availability in the Pawtuxet River Basin, central Rhode Island, and in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Stations are shown on fig. 8. Water years are from October to September and may differ from the period of record in the 2000 Water Data Report for Massachusetts and Rhode Island (Socolow and others, 2001). **7Q10**, 7-day, 10-year low flow; **ABF**, Aquatic Base Flow, based on the median of the August monthly means; USGS, U.S. Geological Survey; Mgal/d, million gallons per day]

USGS stream-gaging station number	Station name	Drainage area (mi^2)	Annual mean flow (Mgal/d) [calendar years]	Minimum flows (Mgal/d)	
				7Q10 [water years]	ABF [calendar years]
01111500	Branch River at Forestdale, RI	91.2	116.4 [1957–99]	7.694 [1957–99]	25.09 [1957–99]
01115630	Nooseneck River at Nooseneck, RI	8.28	12.28 [1964–80]	.821 [1964–80]	2.910 [1964–80]

Table 21. Summer gross yields for the index stream-gaging stations used in the water-availability analysis in the Pawtuxet River Basin, central Rhode Island, and Quinebaug River Basin, western Rhode Island.

[**7Q10,** 7-day, 10-year low flow; **ABF,** Aquatic Base Flow, based on the median of the August monthly means; Mgal/d, million gallons per day; --, values less than zero and not used]

Month	Estimated gross yield (Mgal/d)			Estimated gross yield minus 7Q10 (Mgal/d)			Estimated gross yield minus ABF (Mgal/d)		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Branch River at Forestdale stream-gaging station									
June	73.47	47.04	35.15	65.77	39.35	27.45	48.38	21.95	10.06
July	34.78	26.60	17.39	27.09	18.90	9.696	9.693	1.510	--
August	29.67	21.48	13.30	21.97	13.79	5.604	4.578	--	--
September	35.15	23.78	16.12	27.45	16.09	8.426	10.06	--	--
Nooseneck River at Nooseneck stream-gaging station									
June	10.03	7.246	6.046	9.196	6.412	5.213	7.152	4.368	3.169
July	4.737	3.622	2.694	3.903	2.789	1.860	1.860	.745	--
August	4.551	2.554	1.811	3.717	1.721	.978	1.673	--	--
September	3.551	3.071	2.255	2.718	2.238	1.422	.674	--	--

Table 22. Estimated gross yields; gross yields minus the 7-day, 10-year low flow; and gross yields minus the Aquatic Base Flow per unit area for the two index stations used to determine water availability for June, July, August, and September in the Pawtuxet River Basin, central Rhode Island, and the Quinebaug River Basin, western Rhode Island.

[Estimated gross yields based on base flow from the Branch River at Forestdale, RI, stream-gaging station for the period 1957–99. Estimated gross yields based on base flow from the Nooseneck River at Nooseneck, RI, stream-gaging station for the period 1964–80. **7Q10,** 7-day, 10-year low flow; **ABF,** Aquatic Base Flow; Mgal/d, million gallons per day; --, values at station less than zero and not used]

Month	Estimated gross yield per unit area (Mgal/d/mi^2)			Estimated gross yield minus 7Q10 per unit area (Mgal/d/mi^2)			Estimated gross yield minus ABF per unit area (Mgal/d/mi^2)		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Branch River at Forestdale stream-gaging station									
Yields from sand and gravel deposits estimated from base flow									
June	1.666	1.067	0.797	1.492	0.892	0.623	1.097	0.498	0.228
July	.789	.603	.541	.614	.429	.220	.220	.034	--
August	.673	.487	.302	.498	.313	.127	.104	--	--
September	.797	.539	.366	.623	.365	.191	.228	--	--
Yields from till deposits estimated from base flow									
June	0.454	0.291	0.217	0.406	0.243	0.170	0.299	0.136	0.062
July	.215	.164	.147	.167	.117	.060	.060	.009	--
August	.183	.133	.082	.136	.085	.035	.028	--	--
September	.217	.147	.100	.170	.099	.052	.062	--	--
Nooseneck River at Nooseneck stream-gaging station									
Yields from sand and gravel deposits estimated from base flow									
June	2.180	1.575	1.314	1.999	1.394	1.133	1.555	0.950	0.689
July	1.030	.787	.586	.849	.606	.404	.404	.162	--
August	.989	.555	.394	.808	.374	.213	.364	--	--
September	.772	.668	.490	.591	.486	.309	.146	--	--
Yields from till deposits estimated from base flow									
June	0.689	0.460	0.384	0.632	0.407	0.331	0.492	0.277	0.201
July	.326	.230	.171	.268	.177	.118	.128	.047	--
August	.313	.162	.115	.256	.109	.062	.115	--	--
September	.244	.195	.143	.187	.142	.090	.046	--	--

Pawtuxet River Basin

In the Pawtuxet River Basin, water availability was calculated at the 75th, 50th, and 25th percentiles for the gross-yield scenario, the 7Q10 scenario, and the ABF scenario (table 23). The gross-yield value is equal to the estimated ground water available in the North Branch Pawtuxet, South Branch Pawtuxet, and Northeastern Pawtuxet subbasins. Estimated gross yields and gross yields for the 7Q10 scenarios were lower for August at the 50th and 25th percentiles. The water-availability rates by subbasin from sand and gravel deposits and till deposits are illustrated in figures 17 and 18, respectively. Although water availability was greater statewide in July than in August, more water was withdrawn in July than in August (table 24).

Basin withdrawal-to-availability ratios at the 75th percentiles were highest in July for all three scenarios (table 25). Although the ratios were higher in July for the Scituate Reservoir Complex subbasin and in August for the North Branch Pawtuxet, South Branch Pawtuxet, and Northeastern Pawtuxet subbasins, the basinwide ratios for the gross yield and the 7Q10 scenarios at the 50th and 25th percentiles were higher in August. The ratios for June, July, August, and September at the 50th percentile for the 7Q10 scenario are illustrated for the subbasins in figure 19.

In the Scituate Reservoir Complex subbasin, the estimated ground-water availability for the four summer months illustrates the probable pattern of ground-water fluctuations within the subbasin (table 23). The outlet of the Scituate Reservoir at the Gainer Dam is also the surface-water outlet for the subbasin. The regulated outflow of 83 Mgal/d from the reservoir was assumed to include the ground-water component of base flow (table 23) within the subbasins tributary to the reservoir. Because no additional water is discharged into the North Branch Pawtuxet River within the subbasin below the dam, there is no variation in the available water caused by flows downstream of the dam. Thus, the total available water is equal to the regulated outflow from the dam. (In addition, 9 Mgal/d are required to be released to the North Branch Pawtuxet River (Weston, 1990); thus, the gross yield for the Scituate Reservoir Complex subbasin was 92 Mgal/d.) Use that exceeds the safe yield during the summer months is offset by storage in the reservoir (table 25). This is the reason why the water used is most nearly equal to the available water (indicated by withdrawal-to-availability ratios closest to 1) in this subbasin. Because the total water available for each month was the same and the summer withdrawals (table 24) were lowest in September and highest in July (table 24), the ratios also were lowest in September and highest in July (table 25).

For the gross yield scenario at the 50th percentile, the water availability for the North Branch Pawtuxet subbasin was lowest in August and highest in June; because summer water withdrawals were lowest in September and highest in August (table 24), however, the withdrawal-to-availability ratio was lowest in June and highest in August (table 25). For the gross yield scenario at the 50th percentile, the water-availability results for the South Branch Pawtuxet subbasin and Northeastern Pawtuxet subbasin were lowest in August and highest in June; however, summer water withdrawals were lowest in September and highest in July (table 24), and the ratios were lowest in June and highest in August (table 25). For the ABF scenario at the 50th and 25th percentiles, the North Branch, South Branch, and Northeastern Pawtuxet subbasins have no water available in August and September (table 23).

Quinebaug River Basin

In the Quinebaug River Basin, water availability in the subbasin for the gross yield at the 50th percentile was lowest in August and highest in June (table 26); however, summer water withdrawals were lowest in September and highest in July (table 27), and the withdrawal-to-availability ratios were lowest in June and highest in August (table 28). For the ABF scenario, the basin has no water available at the 50th percentile in August and September, and at the 25th percentile in July, August, and September (table 26).

Water Budget

The water budget encompasses the hydrologic cycle and the water-use components, both of which produce inflows and outflows to the basin. In a basin water budget, inflow minus outflow equals the change in storage. For this investigation, calculation of the long-term water budget was based on the assumption that inflow equals outflow; the change in water storage from surface-water bodies and aquifers is considered to be negligible. Inflows to the basin include precipitation, streamflow from upstream subbasins, ground-water inflow, and return flow (from septic systems, RIPDES, and WWTFs). Outflows from the basin include evapotranspiration, streamflow out of the subbasins, water withdrawals (for public supply and self-supply domestic, commercial, industrial, and agricultural uses), and ground-water underflow. The water budget components are summarized in table 29 for the Pawtuxet River Basin and in table 30 for the Quinebaug River Basin.

Pawtuxet River Basin

Since 1917, ProvWater has collected precipitation data at a network of stations within the Scituate Reservoir Complex subbasin for management purposes, and these data were used to calculate the water budget for 1941 through 1999. The average precipitation for the Scituate Reservoir Complex subbasin (Providence Water Supply Board, written commun., 2000) (estimated to be 2.429 Mgal/d/mi^2) was used for the Scituate Reservoir Complex and North Branch Pawtuxet subbasin water budgets. The average precipitation at the Kingston climatological station (National Oceanic and Atmospheric Administration, 2000) (estimated to be 2.280 Mgal/d/mi^2) was used for the South Branch Pawtuxet and the Northeastern Pawtuxet subbasin water budgets. The North Branch Pawtuxet and the Northeastern Pawtuxet subbasins have surface-water inflow from upstream subbasins. Data on ground-water inflow were not available for this study. Return flow includes the average rate of disposal from 1995 through 1999 from septic systems, RIPDES, and wastewater-treatment facilities. Evapotranspiration estimates were calculated as the difference between the mean annual precipitation per unit area and the mean annual flow per unit area at each subbasin's assigned index station (table 29). The outflow of streamflow from each subbasin was estimated as sum of the inflows minus withdrawals minus evapotranspiration.

The total water budget for the Pawtuxet River Basin was 574.7 Mgal/d. The estimated inflows from precipitation and return flow were 94.7 and 5.3 percent of the total budget, and the estimated outflows from evapotranspiration, streamflow, and water withdrawals were 46.3, 40.8, and 12.9 percent, respectively. Forty percent of this water is accounted for in the Scituate Reservoir Complex subbasin.

Quinebaug River Basin

The average precipitation for the Scituate Reservoir Complex (2.429 $Mgal/d/mi^2$) (Providence Water Supply Board, written commun., 2000) was used to calculate the water budget for the Quinebaug River Basin for 1941 through 1999. Data for ground-water inflow were unavailable for this study. Return flow is the average rate of disposal from 1995 through 1999 from septic systems. Evapotranspiration estimates were calculated as the difference between the mean annual precipitation per unit area and the mean annual flow per unit area at each subbasin's assigned index station (table 30). The outflow from the basin was estimated as the sum of the inflows minus the withdrawals minus evapotranspiration.

The total water budget for the Quinebaug River Basin study area was 148.4 Mgal/d. The estimated inflows from precipitation and return flow were 99.8 and 0.2 percent of the total budget, respectively; and the estimated outflows from evapotranspiration, streamflow, and water withdrawals were 48.6, 51.2, and 0.2 percent, respectively.

Table 23. Estimated ground-water availability and total availability for June, July, August, and September in the Pawtuxet River Basin, central Rhode Island, 1995–99.

[**7Q10,** 7-day, 10-year low flow; **ABF,** Aquatic Base Flow; Mgal/d, million gallons per day; --, values at index station less than zero and not used]

Subbasin	Estimated gross yield for June (Mgal/d)			Estimated gross yield for 7Q10 scenario for June (Mgal/d)			Estimated gross yield for ABF scenario for June (Mgal/d)		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Scituate Reservoir Complex subbasin[1]	58.79	37.65	28.13	52.64	31.49	21.97	38.72	17.57	8.052
North Branch Pawtuxet subbasin[1]	8.521	5.456	4.077	7.629	4.564	3.185	5.611	2.546	1.167
South Branch Pawtuxet subbasin[2]	94.23	66.43	55.43	86.40	58.79	47.79	67.20	40.05	29.05
Northeastern Pawtuxet subbasin[2]	70.40	49.83	41.59	64.56	44.10	35.85	50.21	30.04	21.79
Total estimated gross yield	231.9	159.4	129.2	211.2	138.9	108.8	161.7	90.21	60.06
Total estimated available water[3]	256.1	204.7	184.1	241.5	190.4	169.8	206.0	155.6	135.0

Subbasin	Estimated gross yield for July (Mgal/d)			Estimated gross yield for 7Q10 scenario for July (Mgal/d)			Estimated gross yield for ABF scenario for July (Mgal/d)		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Scituate Reservoir Complex subbasin[1]	27.84	21.28	19.09	21.68	15.13	7.762	7.758	1.208	--
North Branch Pawtuxet subbasin[1]	4.034	3.085	2.767	3.141	2.192	1.125	1.125	.175	--
South Branch Pawtuxet subbasin[2]	44.51	33.21	24.70	36.68	25.57	17.06	17.47	6.828	--
Northeastern Pawtuxet subbasin[2]	33.25	24.91	18.53	27.40	19.18	12.79	13.05	5.123	--
Total estimated gross yield	109.6	82.48	65.09	88.91	62.07	38.74	39.40	13.33	--
Total estimated available water[3]	164.8	144.2	129.0	150.2	129.9	114.0	114.6	95.13	83.00

Table 23. Estimated ground-water availability and total availability for June, July, August, and September in the Pawtuxet River Basin, central Rhode Island, 1995–99.—Continued

[**7Q10,** 7-day, 10-year low flow; **ABF,** Aquatic Base Flow; Mgal/d, million gallons per day; --, values at index station less than zero and not used]

Subbasin	Estimated gross yield for August (Mgal/d)			Estimated gross yield for 7Q10 scenario for August (Mgal/d)			Estimated gross yield for ABF scenario for August (Mgal/d)		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Scituate Reservoir Complex subbasin[1]	23.74	17.19	10.64	17.58	11.03	4.485	3.664	--	--
North Branch Pawtuxet subbasin[1]	3.441	2.492	1.543	2.548	1.599	.650	.531	--	--
South Branch Pawtuxet subbasin[2]	42.76	23.41	16.60	34.93	15.78	8.963	15.72	--	--
Northeastern Pawtuxet subbasin[2]	31.95	17.56	12.46	26.10	11.83	6.724	11.75	--	--
Total estimated gross yield	101.9	60.67	41.24	81.17	40.24	20.82	31.66	--	--
Total estimated available water[3]	161.1	126.5	113.6	146.6	112.2	99.34	111.0	83.00	83.00

Subbasin	Estimated gross yield for September (Mgal/d)			Estimated gross yield for 7Q10 scenario for September (Mgal/d)			Estimated gross yield for ABF scenario for September (Mgal/d)		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Scituate Reservoir Complex subbasin[1]	28.13	19.03	12.90	21.97	12.87	6.743	8.052	--	--
North Branch Pawtuxet subbasin[1]	4.077	2.758	1.870	3.185	1.866	.977	1.167	--	--
South Branch Pawtuxet subbasin[2]	33.36	28.16	20.68	25.53	20.52	13.04	6.331	--	--
Northeastern Pawtuxet subbasin[2]	24.93	21.12	15.51	19.08	15.39	9.778	4.730	--	--
Total estimated gross yield	90.50	71.08	50.96	69.77	50.65	30.54	20.28	--	--
Total estimated available water[3]	145.4	135.0	121.1	130.8	120.8	106.8	95.23	83.00	83.00

[1]Estimated gross yield from ground water based on base flow from the Branch River at Forestdale, RI, stream-gaging station for the period 1957–99.

[2]Estimated gross yield from ground water based on base flow from the Nooseneck River at Nooseneck, RI, stream-gaging station for the period 1964–80.

[3]Total water-availability estimate for the Scituate Reservoir Complex subbasin is defined as the net safe yield of 83 Mgal/d instead of the estimated gross yield.

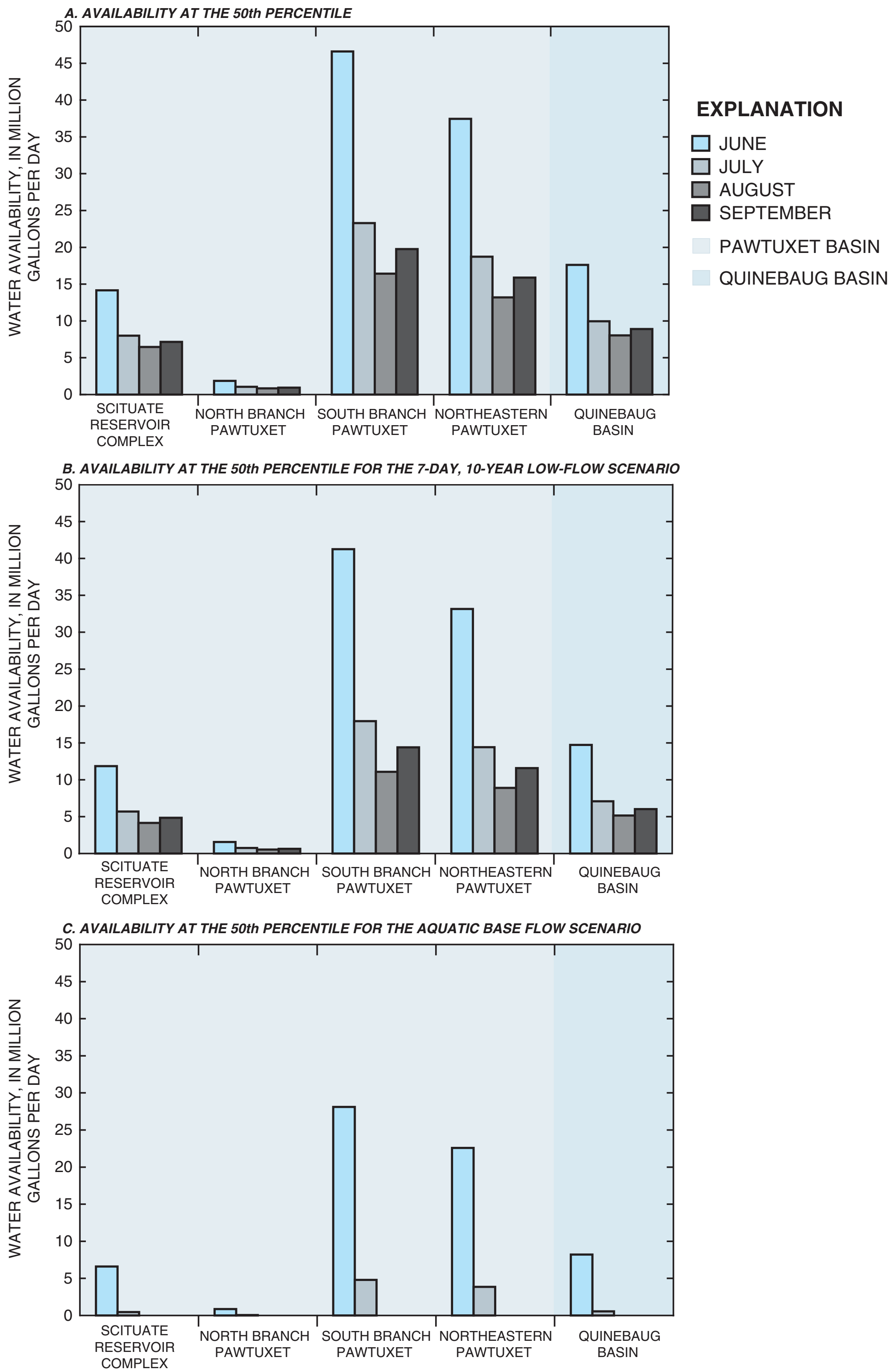


Figure 17. Estimated water availability for June, July, August, and September from sand and gravel deposits for the subbasins in the Pawtuxet and Quinebaug River Basins, central and western Rhode Island, for the *A,* 50th percentile; *B,* 50th percentile for the 7-day, 10-year low-flow scenario; and *C,* 50th percentile for the Aquatic Base Flow scenario.

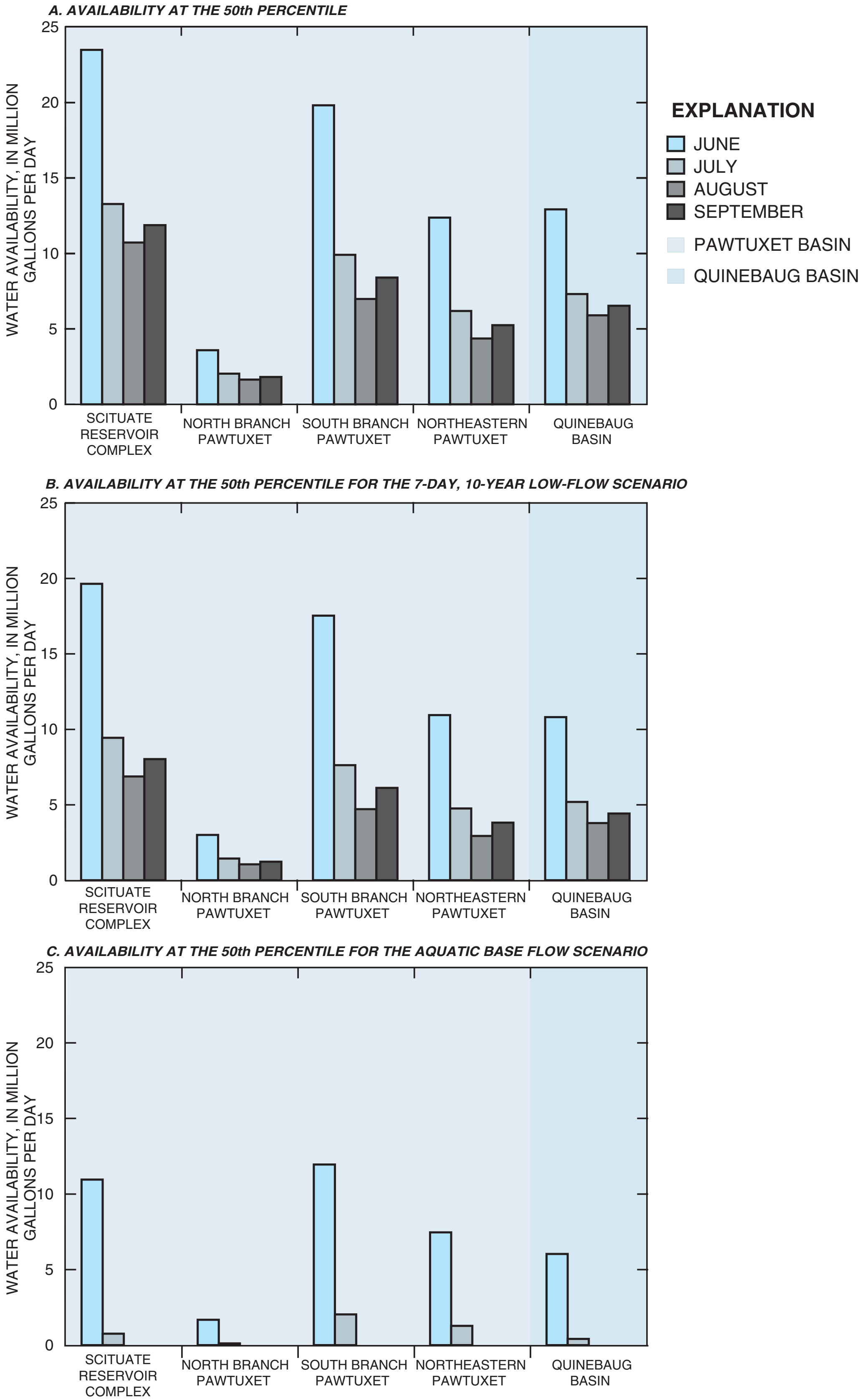


Figure 18. Estimated water availability for June, July, August, and September from till deposits for the subbasins in the Pawtuxet and Quinebaug River Basins, central and western Rhode Island, for the *A,* 50th percentile; *B,* 50th percentile for the 7-day, 10-year low-flow scenario; and *C,* 50th percentile for the Aquatic Base Flow scenario.

Table 24. Average water withdrawals for June, July, August, and September in the subbasins of the Pawtuxet River Basin, central Rhode Island, 1995–99.

[Mgal/d, million gallons per day; --, not applicable]

Subbasin	Average water withdrawals 1995–99 (Mgal/d)								Total average water withdrawals 1995–99 (Mgal/d)			
	June		July		August		September		June	July	August	September
	Public	Self	Public	Self	Public	Self	Public	Self				
Scituate Reservoir Complex subbasin	88.06	1.010	96.12	1.055	87.45	1.022	75.66	0.990	89.07	97.18	88.47	76.65
North Branch Pawtuxet subbasin	--	.215	--	.227	--	.250	--	.130	.25	.227	.250	.130
South Branch Pawtuxet subbasin	1.187	.829	1.251	.835	1.195	.811	1.163	.700	2.016	2.086	2.006	1.863
Northeastern Pawtuxet subbasin	--	.698	--	.703	--	.691	--	.415	.698	.703	.691	.415
Basin total	89.25	2.752	97.37	2.820	88.65	2.774	76.82	2.235	92.00	100.20	91.42	79.06

Table 25. Summary of water withdrawal-to-availability ratios for June, July, August, and September in the Pawtuxet River Basin, central Rhode Island, 1995–99.

[**7Q10,** 7-day, 10-year low flow; **ABF,** Aquatic Base Flow; Mgal/d, million gallons per day; --, values at index station less than zero and not used]

Subbasin	Ratio for June, estimated gross yield			Ratio for June, estimated gross yield for 7Q10 scenario			Ratio for June, estimated gross yield for ABF scenario		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Scituate Reservoir Complex subbasin[1]	1.073	1.073	1.073	1.073	1.073	1.073	1.073	1.073	1.073
North Branch Pawtuxet subbasin[2]	.025	.039	.053	.028	.047	.068	.038	.084	.184
South Branch Pawtuxet subbasin[3]	.021	.030	.036	.023	.034	.042	.030	.050	.069
Northeastern Pawtuxet subbasin[3]	.010	.014	.017	.011	.016	.019	.014	.023	.032
Basin ratio	0.359	0.449	0.500	0.381	0.483	0.542	0.447	0.591	0.681

Subbasin	Ratio for July, estimated gross yield scenario			Ratio for July, estimated gross yield for 7Q10 scenario			Ratio for July, estimated gross yield for ABF scenario		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Scituate Reservoir Complex subbasin[1]	1.171	1.171	1.171	1.171	1.171	1.171	1.171	1.171	1.171
North Branch Pawtuxet subbasin[2]	.056	.074	.082	.072	.104	.202	.202	1.297	--
South Branch Pawtuxet subbasin[3]	.047	.063	.084	.057	.082	.122	.122	.306	--
Northeastern Pawtuxet subbasin[3]	.021	.028	.038	.026	.037	.055	.055	.137	--
Basin ratio	0.608	0.695	0.777	0.667	0.771	0.879	0.874	1.053	1.207

Table 25. Summary of water withdrawal-to-availability ratios for June, July, August, and September in the Pawtuxet River Basin, central Rhode Island, 1995–99.—Continued

[**7Q10,** 7-day, 10-year low flow; **ABF,** Aquatic Base Flow; Mgal/d, million gallons per day; --, values at index station less than zero and not used]

Subbasin	Ratio for August, estimated gross yield			Ratio for August, estimated gross yield for 7Q10 scenario			Ratio for August, estimated gross yield for ABF scenario		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Scituate Reservoir Complex subbasin[1]	1.066	1.066	1.066	1.066	1.066	1.066	1.066	1.066	1.066
North Branch Pawtuxet subbasin[2]	.073	.100	.162	.098	.156	.385	.471	--	--
South Branch Pawtuxet subbasin[3]	.047	.086	.121	.057	.127	.224	.128	--	--
Northeastern Pawtuxet subbasin[3]	.022	.039	.055	.026	.058	.103	.059	--	--
Basin ratio	0.567	0.723	0.805	0.624	0.815	0.920	0.824	1.101	1.101

Subbasin	Ratio for September, estimated gross yield			Ratio for September, estimated gross yield for 7Q10 scenario			Ratio for September, estimated gross yield for ABF scenario		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Scituate Reservoir Complex subbasin[1]	0.923	0.923	0.923	0.923	0.923	0.923	0.923	0.923	0.923
North Branch Pawtuxet subbasin[2]	.032	.047	.070	.041	.070	.133	.111	--	--
South Branch Pawtuxet subbasin[3]	.056	.066	.090	.073	.091	.143	.294	--	--
Northeastern Pawtuxet subbasin[3]	.017	.020	.027	.022	.027	.042	.088	--	--
Basin ratio	0.544	0.585	0.653	0.604	0.655	0.740	0.830	0.953	0.953

[1]Water-availability estimate is based on the Scituate Reservoir net safe yield of 83 Mgal/d (Weston, 1990).

[2]Estimated gross yield based on base flow from the Branch River at Forestdale, RI, stream-gaging station for the period 1957–99.

[3]Estimated gross yield based on base flow from the Nooseneck River at Nooseneck, RI, stream-gaging station for the period 1964–80.

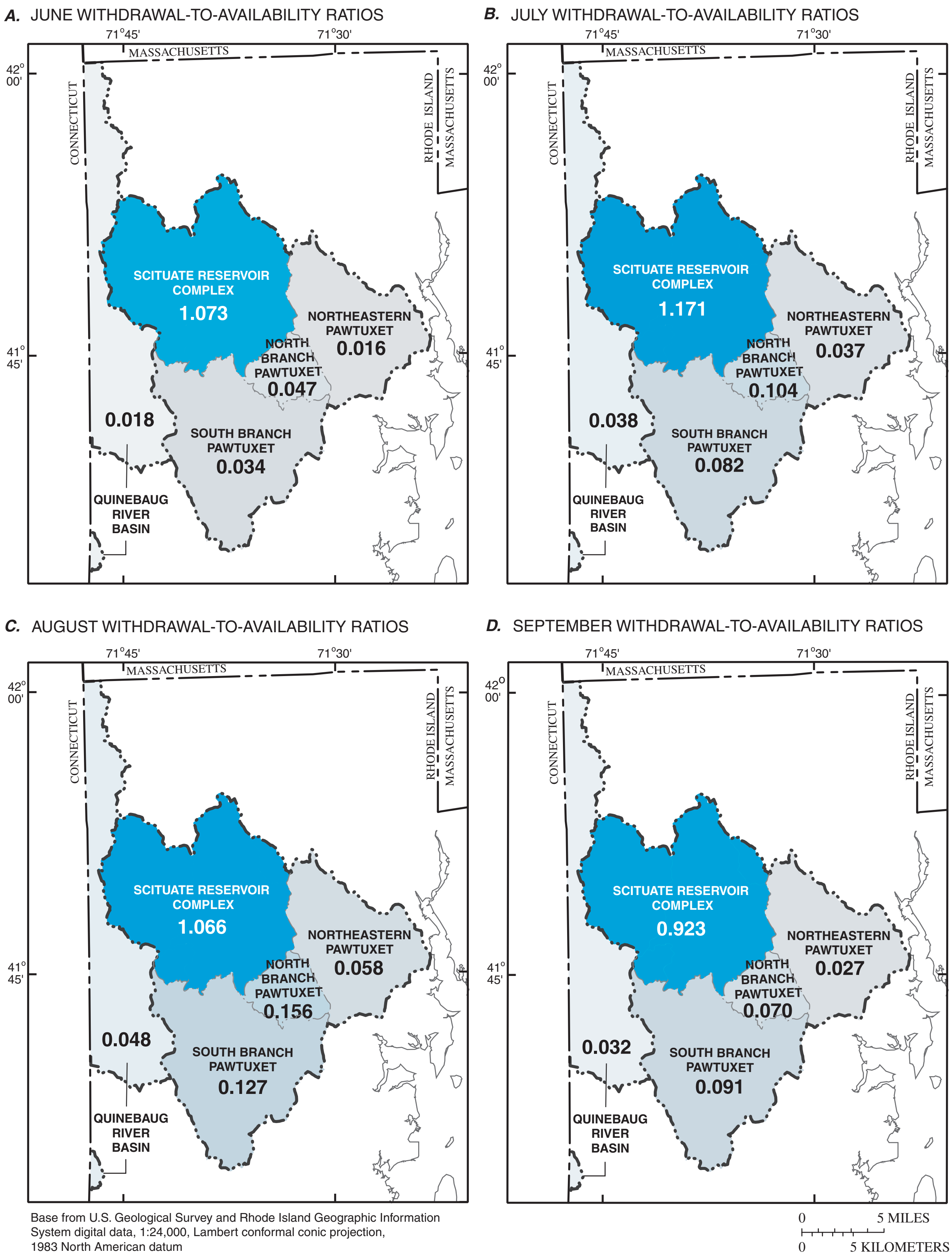


Figure 19. The water withdrawal-to-availability ratios in *A,* June; *B,* July; *C,* August; and *D,* September for the subbasins in the Pawtuxet and Quinebaug River Basins, central and western Rhode Island, at the 50th percentile for the 7-day, 10-year low-flow scenario.

Table 26. Estimated gross yield; gross yield for the 7-day, 10-year low-flow scenario; and gross yield for the Aquatic Base Flow scenario for June, July, August, and September in the Quinebaug River Basin, western Rhode Island.

[Estimated gross yields calculated from base flow at the Branch River at Forestdale, RI, stream-gaging station, 1957–99. **7Q10,** 7-day, 10-year low flow; **ABF,** Aquatic Base Flow; Mgal/d, million gallons per day; --, values at index station less than zero and not used]

Month	Estimated gross yield (Mgal/d)			Estimated gross yield for the 7Q10 scenario (Mgal/d)			Estimated gross yield for the ABF scenario (Mgal/d)		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Estimated yields from sand and gravel deposits									
June	27.50	17.61	13.16	24.62	14.73	10.28	18.11	8.216	3.765
July	13.02	9.954	8.930	10.14	7.074	3.630	3.628	.565	--
August	11.10	8.040	4.978	8.223	5.160	2.097	1.714	--	--
September	13.156	8.901	6.033	10.28	6.021	3.153	3.765	--	--
Estimated yields from till deposits									
June	20.18	12.92	9.656	18.07	10.81	7.542	13.29	6.031	2.764
July	9.555	7.306	6.554	7.441	5.192	2.664	2.663	.415	--
August	8.150	5.901	3.654	6.036	3.787	1.539	1.258	--	--
September	9.656	6.533	4.428	7.542	4.419	2.314	2.764	--	--
Total estimated yields									
June	47.68	30.53	22.81	42.69	25.54	17.82	31.40	14.25	6.529
July	22.57	17.26	15.49	17.58	12.27	6.295	6.291	.980	--
August	19.25	13.94	8.632	14.26	8.947	3.637	2.971	--	--
September	22.81	15.43	10.46	17.82	10.44	5.468	6.529	--	--

Table 27. Average water withdrawals for June, July, August, and September in the towns in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Mgal/d, million gallons per day]

Town	Average water withdrawals 1995–99 (Mgal/d)			
	June	July	August	September
Burrillville	0.037	0.037	0.037	0.036
Coventry	.147	.153	.124	.120
Exeter	.006	.006	.006	.006
Foster	.216	.216	.211	.120
Glocester	.052	.048	.051	.048
West Greenwich	.003	.003	.003	.003
Basin total	0.461	0.463	0.432	0.333

Table 28. Summary of water withdrawal-to-availability ratios for June, July, August, and September in the Quinebaug River Basin, western Rhode Island, 1995–99.

[Estimated gross yields calculated from base flow at the Branch River at Forestdale, RI, stream-gaging station for 1957–99. **7Q10,** 7-day, 10-year low flow; **ABF,** Aquatic Base Flow; Mgal/d, million gallons per day; --, values at index station less than zero and not used]

Month	Ratio for the estimated gross yield			Ratio for the estimated gross yield for the 7Q10 scenario			Ratio for the estimated gross yield for the ABF scenario		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
June	0.010	0.015	0.020	0.011	0.018	0.026	0.015	0.032	0.071
July	.021	.027	.030	.026	.038	.074	.074	.472	--
August	.022	.031	.050	.030	.048	.145	.145	--	--
September	.015	.022	.032	.019	.032	.051	.051	--	--

Table 29. Average water budget by subbasin for the Pawtuxet River Basin, central Rhode Island.

[Shaded areas are basin totals. RIPDES, Rhode Island Pollutant Discharge Elimination System; in/yr, inches per year; Mgal/d, million gallons per day; Mgal/d/mi^2, million gallons per day per square mile; mi^2, square mile; --, not applicable]

Water-budget component	Scituate Reservoir Complex subbasin	North Branch Pawtuxet subbasin	South Branch Pawtuxet subbasin	Northeastern Pawtuxet subbasin	Pawtuxet River Basin total
Estimated inflow (Mgal/d)					
Precipitation	[1]228.6	[1]34.22	[2]165.7	[2]115.6	544.1
Streamflow from upstream subbasins	--	36.33	--	154.6	--
Ground-water inflow	--	--	--	--	--
Return flow[3]	.887	1.094	6.210	22.45	30.64
Total inflow	229.5	71.64	171.9	292.6	574.7
Estimated outflow (Mgal/d)					
Evapotranspiration[4]	[5]121.3	[5]18.16	[6]68.83	[7]57.81	266.1
Streamflow[8]	36.33	53.34	101.3	234.5	234.5
Water withdrawals[9]	71.87	.138	1.747	.306	74.06
Ground-water underflow	--	--	--	--	--
Total outflow	229.5	71.64	171.9	292.6	574.7
Streamflow at confluence per square mile (Mgal/d/mi^2)	0.386	0.493	1.394	1.012	1.012
Total drainage area at outlet (mi^2)[10]	94.11	108.2	72.68	231.6	231.6

[1]Based on average precipitation (51.00 in/yr (equal to 2.429 Mgal/d/mi^2)) in the Scituate Reservoir Complex subbasin for the period 1941–99 (data from precipitation network, Providence Water Supply Board, written commun., 2000).

[2]Based on average precipitation (47.87 in/yr (equal to 2.280 Mgal/d/mi^2)) at Kingston, RI for the period 1941–99 (data from National Oceanic and Atmospheric Administration, 2000).

[3]Based on the total return flow from septic, RIPDES, and wastewater-treatment facilities in the subbasins of the Pawtuxet River Basin, 1995–99.

[4]Evapotranspiration based on the difference between the average precipitation and average monthly flow at the index stream-gaging station for the subbasin.

[5]Based on the difference between the average annual precipitation per unit area (2.429 Mgal/d/mi^2; data from Providence Water Supply Board, written commun., 2000) and average annual flow per unit area (1.140 Mgal/d/mi^2) at the stream-gaging station Pawtuxet River at Cranston, RI for the period 1941–99.

[6]Based on the difference between the average annual precipitation per unit area measured at the Kingston climatological station (2.280 Mgal/d/mi^2; data from National Oceanic and Atmospheric Administration, 2000) and average annual flow per unit area (1.333 Mgal/d/mi^2) at the stream-gaging station South Branch Pawtuxet River at Washington, RI for the period 1941–99.

[7]Based on the difference between the average annual precipitation per unit area measured at the Kingston climatological station (2.280 Mgal/d/mi^2; data from National Oceanic and Atmospheric Administration, 2000) and average annual flow per unit area (1.140 Mgal/d/mi^2) at the stream-gaging station Pawtuxet River at Cranston, RI for the period 1941–99.

[8]Based on the sum of the inflows minus the sum of the withdrawals minus evapotranspiration.

[9]Water-withdrawal types include domestic, commercial, industrial, and agricultural from public and self-supply in the subbasins of the Pawtuxet River Basin, 1995–99.

[10]Based on the sum of the subbasin drainage area and drainage areas upstream of the subbasin.

Table 30. Average water budget for the Quinebaug River Basin, western Rhode Island.

[Shaded areas are basin totals. in/yr, inches per year; Mgal/d, million gallons per day; Mgal/d/mi^2, million gallons per day per square mile; mi^2, square miles; --, not applicable]

Water-budget component	
Estimated inflow (Mgal/d)	
Precipitation[1]	
Streamflow from upstream subbasins	
Ground-water inflow	
Return flow[2]	
Total inflow	
Estimated outflow (Mgal/d)	
Evapotranspiration[3]	
Streamflow[4]	
Water withdrawals[5]	
Ground-water underflow	
Total outflow	
Streamflow per square mile (Mgal/d/mi^2)	
Total drainage area at outlet (mi^2)[6]	

[1]Based on average precipitation (51.00 in/yr) in the Scituate Reservoir Complex subbasin for the period 1941–99 (data from precipitation network, Providence Water Supply Board, written commun., 2000).

[2]Based on the total return flow from septic in the Quinebaug River Basin, 1995–99.

[3]Evapotranspiration is based on the difference between the average annual precipitation per unit area (2.429 Mgal/d/mi^2; data from precipitation network, Providence Water Supply Board, written commun., 2000) and average annual flow per unit area (1.247 Mgal/d/mi^2) at the stream-gaging station Branch River at Forestdale, RI, for the period 1941–99.

[4]Based on the sum of the inflows minus the sum of the withdrawals minus evapotranspiration.

[5]Water-withdrawal types include domestic, commercial, industrial, and agricultural from public and self-supply in the Quinebaug River Basin, 1995–99.

[6]Basin outlet is defined as the political boundary with Connecticut for this study.

Summary

During a drought in 1999, ground-water levels and streamflows dropped below long-term averages throughout Rhode Island. Consequently, the State of Rhode Island became concerned about water availability, and further investigation was needed to assess water use and availability throughout the state. The U.S. Geological Survey (USGS), in cooperation with the Rhode Island Water Resources Board (RIWRB), began a series of water-use and availability investigations for 1995–99 to describe the relations between water-use and hydrologic-cycle components for both surface and ground water during periods of little to no recharge. The investigations for the Pawtuxet (area 231.6 mi^2) and Quinebaug (area 60.97 mi^2) River Basins are two of a planned series of nine being completed for basins in Rhode Island.

In addition to water use and availability, basin water budgets were calculated to summarize the components of the hydrologic cycle and selected water-use components for 1941 through 1999. Data were collected for the subbasins in this study by using the spatial delineation derived from the surface-water-system drainage areas. The New England Water-Use Data System was used to organize and retrieve data for water withdrawals, users by category, and return flows for the study period.

In the Pawtuxet River Basin, the Scituate Reservoir was the primary source of water withdrawn by public suppliers (about 95 percent of the average annual water withdrawals during the study period). The only major public water supplier in the Scituate Reservoir Complex subbasin is Providence Water Supply Board, which supplies almost all of the other basins in Rhode Island, including the Blackstone, the Moshassuck, the Woonasquatucket, the Narragansett Bay, and the Westport Basins. Only the Quinebaug, the Pawcatuck, and the South Coastal Basins are not supplied by the Scituate Reservoir. In the Quinebaug River Basin, ground water is the sole source for the one minor public supplier and all the domestic users, which together accounted for about 89 percent of the average annual water withdrawals during the study period.

In the Pawtuxet River Basin, two major water suppliers withdrew a total of 71.86 Mgal/d from ground and surface water (which includes the Scituate Reservoir). Estimated water withdrawals from minor water suppliers were 0.026 Mgal/d in the Pawtuxet River Basin and 0.003 Mgal/d in the Quinebaug River Basin. About 35.98 Mgal/d of potable water from major public-supply withdrawals was exported from the Pawtuxet River Basin to other basins in Rhode Island. Self-supply domestic, industrial, commercial, and agricultural withdrawals from the basin totaled 2.173 Mgal/d in the Pawtuxet River Basin and 0.360 Mgal/d in the Quinebaug River Basin. Total water use was 18.07 Mgal/d in the Pawtuxet River Basin and was 0.363 Mgal/d in the Quinebaug River Basin. The total return flow was 30.64 Mgal/d in the Pawtuxet River Basin, which included effluent from permitted facilities and water users on self-disposal; of the total, about 12.28 Mgal/d of wastewater was imported to the Pawtuxet River Basin from other basins in Rhode Island. Return flow in the Quinebaug River Basin was 0.283 Mgal/d.

Ground-water availability was estimated from output from the PART program, a computerized hydrograph-separation application. To determine water availability at the 75th, 50th, and 25th percentiles, two index stream-gaging stations in nearby basins were used for three scenarios: the total base-flow scenario; the base flow for the 7-day, 10-year (7Q10) low-flow scenario; and the base flow for the Aquatic Base Flow (ABF) scenario. A regression equation was used to estimate unknown base-flow contributions from sand and gravel deposits at the two stations. The water available at the Branch River at Forestdale, Rhode Island, stream-gaging station was lowest in August at the 75th, 50th, and 25th percentiles (29.67, 21.48, and 13.30 Mgal/d, respectively). The water available at the Nooseneck River at Nooseneck, Rhode Island, stream-gaging station was lowest in September at the 75th percentile (3.551 Mgal/d) and in August at the 50th and 25th percentiles (2.554 and 1.811 Mgal/d).

Base-flow contributions at the stations estimated from sand and gravel deposits and from till deposits (surficial deposits) were divided by the respective drainage areas for the two types of deposits to give ratios of flow per unit area. The ratios were multiplied by the areas of the sand and gravel deposits and till deposits in the subbasins. Finally, the total flows from the sand and gravel deposits and till deposits in the subbasin were added to obtain the gross yield. In the Pawtuxet River Basin, the gross yield from ground water was assumed to be part of the net safe yield of 83 Mgal/d from the Scituate Reservoir. This amount was defined as the total water available for the Scituate Reservoir Complex subbasin.

Because water withdrawals and use are greater during the summer than other times of the year, water availability at the 75th, 50th, and 25th percentiles in June, July, August, and September was calculated and compared to water withdrawals in the basin and subbasins. The closer the withdrawals are to the estimated water available because the net water available decreases, the closer the resulting ratio is to one. For the study period, withdrawals in July were higher than withdrawals in the other summer months in both basins. For the Pawtuxet River Basin, the ratios were higher in August than in the other three summer months for all three scenarios at the 50th percentile. The ratios were close to 1 for the Scituate Reservoir Complex subbasin for all scenarios in all of the summer months because of the fixed safe yield from the Scituate Reservoir. For the Quinebaug River Basin, the ratios were also higher in August for all three scenarios, but because of reduced water availability, were generally lower than the total basin ratios for the Pawtuxet River Basin.

For estimating the water budget, it was assumed that inflow equals outflow. The water budgets of the Pawtuxet River Basin and the Rhode Island part of the Quinebaug River Basin were 574.9 Mgal/d and 148.4 Mgal/d, respectively. The estimated inflows from precipitation and return flow were 94.7 and 5.3 percent, respectively, of the total budget for the Pawtuxet River Basin. The estimated inflow from precipitation was 99.8 percent of the total budget for the Quinebaug River Basin. The estimated outflows in the Pawtuxet River Basin from evapotranspiration, streamflow, and water withdrawals were 46.3, 40.8, and 12.9 percent of the budget, respectively. The estimated outflows in the Quinebaug River Basin from evapotranspiration and streamflow were 48.6 and 51.2 percent of the budget, respectively.

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Glossary

7-day, 10-year low flow (7Q10) The discharge at the 10-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for 7 consecutive days (the 7-day low flow).

Aquatic Base Flow (ABF) As established by the U.S. Fish and Wildlife Service, median flow during the month of August considered adequate to protect indigenous aquatic fauna throughout the year. It can be calculated as long as there are USGS stream-gaging data for at least 25 years of unregulated flow, and the drainage area at the stream-gaging station is at least 50 square miles (U.S. Fish and Wildlife, 1981).

Base flow Streamflow from ground-water discharge.

Commercial water use Water used for transportation; wholesale trade; retail trade; finance, insurance, and real estate; services; and public administration (the two-digit Standard Industrial Classification codes are in the range 40-97). The water can be from public or self-supply.

Consumptive use Water that is removed from the environment through evaporation, transpiration, production, or consumed by humans or livestock.

Conveyance Movement of water from one point to another, for example, water withdrawals, water distributions, and wastewater collection.

Distribution The conveyance of water from a point of withdrawal or purification system to a user or other water customer.

Domestic water use Water used for household purposes, such as drinking, food preparation, bathing, washing, clothes and dishes, flushing toilets, and watering lawns and gardens. Households include single and multifamily dwellings. Also called residential water use. The water may be obtained from a public water supply or may be self-supplied.

Industrial water use Water used for food; tobacco; textile mill products; apparel; lumber and wood; furniture; paper; printing; chemicals; petroleum; rubber; leather; stone, clay, glass, and concrete; primary metal; fabricated metal; machinery; electrical equipment; transportation equipment; instruments; and jewelry, precious metals; for which the two-digit Standard Industrial Classification code range is 20-39. The water may be obtained from a public water supply or may be self-supplied.

Interbasin transfers Conveyance of water across a drainage or river-basin divide.

Interconnections Links between public-supply districts to convey water. These connections can be for wholesale distributions or water-supply backups.

Irrigation water use The application of water to lands to assist in the growth of crops or pasture, including plants in greenhouses. Irrigation water use may also include application of water to maintain vegetative growth on recreational lands such as parks and golf courses and to provide frost and freeze protection of crops.

Major water supplier A public or private system that withdraws and distributes water to customers or other suppliers for use.

Major user In Rhode Island, a customer that uses more than three million gallons of water per year.

Minor Civil Division (MCD) A term used by the U.S. Census Bureau, generally equivalent to a city or town.

Minor public water suppliers Water withdrawn to supply a site-specific public population, for example nursing homes, condominium complexes, and mobile home parks.

Nonaccount water use The difference between the metered (or reported) supply and the metered (or reported) use for a specific period of time, which includes water used for fire fighting. It comprises authorized and unauthorized water uses.

Outfall The outlet or structure through which effluent is finally discharged into the environment.

Per capita water use The average volume of water used per person during a standard time period, generally per day.

PART A computer program developed by A.T. Rutledge (1993 and 1998) to determine the mean rate of ground-water discharge.

Public wastewater system Wastewater collected from users or groups of users, conveyed to a wastewater-treatment plant, and then released as return flow into the hydrologic environment or sent back to users as reclaimed wastewater.

Public water system Water withdrawn by public and private water systems, and then delivered to users or groups of users. Public water systems provide water for a variety of uses, such as domestic, commercial, industrial, agricultural, and public water use.

Public water use Water supplied from a public water system and used for fire fighting, street washing, and municipal parks and swimming pools.

Public-disposed water Wastewater return flow from public and private wastewater-collection systems.

Public-supply water Water distributed to domestic, industrial, commercial, agricultural or other customers by a public or private water-supply system.

Return flow Water that is returned to surface or ground water after use or wastewater treatment, and thus becomes available for reuse. Return flow can go directly to surface water, directly to ground water through an injection well or infiltration bed, or indirectly to ground water through a septic system.

Self-disposed water Water returned to the ground (septic systems) by a user or group of users that are not on a wastewater-collection system.

Self-supply water Water withdrawn from a ground- or surface-water source by a user and not obtained from a public or private water-supply system.

Standard Industrial Classification (SIC) code Four-digit codes established by the U.S. Office of Management and Budget and used in the classification of establishments by type of activity in which they are engaged. The IWR-MAIN coefficients for industrial and commercial water use are based on the first two digits.

Surface-water return flow Effluent that flows from a discharge pipe to a river or lake.

Wastewater Water that carries wastes from domestic, industrial, and commercial consumers; a mixture of water and dissolved or suspended solids.

Wastewater treatment The processing of wastewater for the removal or reduction of contained solids or other undesirable constituents.

Wastewater-treatment return flow Water returned to the hydrologic system by wastewater-treatment facilities. Also referred to as effluent water.

Water purification The processes that withdrawn water may undergo prior to use, including chlorination, fluoridation, and filtration.

Water supply All of the processes that are involved in obtaining water for the user before use. Includes withdrawal, water treatment, and other distribution.

Water use (1) In a restrictive sense, the term refers to water that is actually used for a specific purpose, such as for domestic use, irrigation, or industrial processing. (2) More broadly, water use pertains to human interaction with and impact on the hydrologic cycle, and includes elements such as water withdrawal, distribution, consumptive use, wastewater collection, and return flow.

Withdrawal The removal of surface water or ground water from the natural hydrologic system for uses such as public water supply, industry, commerce, domestic use, irrigation, livestock, and thermoelectric power generation.