Estimated Water Use and Availability in the South Coastal Drainage Basin, Southern Rhode Island, 1995–99

By Emily C. Wild and Mark T. Nimiroski

In cooperation with the
Rhode Island Water Resources Board

Scientific Investigations Report 2004-5288

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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)
foot squared (ft^2)	0.3048	meter squared (m^2)
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
gallon 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 meters per day per square kilometer (m^3/d/km^2)
square mile (mi^2)	12.590	square kilometer (km^2)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

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

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

7Q10	7-day, 10-year flow
ABF	Aquatic Base Flow
GIS	Geographic Information System
HUC	Hydrologic Unit Code
IWR-MAIN	Institute of Water Resources, Municipal and Industrial Needs System
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
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 Agency
USGS	U.S. Geological Survey
UWRI	United Water of Rhode Island
WSO	Weather Station Observatory
WWTF	Wastewater-Treatment Facility

Estimated Water Use and Availability in the South Coastal Drainage Basin, Southern Rhode Island, 1995–99

By Emily C. Wild and Mark T. Nimiroski

Abstract

The South Coastal Drainage Basin includes approximately 59.14 square miles in southern Rhode Island. The basin was divided into three subbasins to assess the water use and availability: the Saugatucket, Point Judith Pond, and the Southwestern Coastal Drainage subbasins. Because there is limited information on the ground-water system in this basin, the water use and availability evaluations for these subbasins were derived from delineated surface-water drainage areas. An assessment was completed to estimate water withdrawals, use, and return flow over a 5-year study period from 1995 through 1999 in the basin. During the study period, one major water supplier in the basin withdrew an average of 0.389 million gallons per day from the sand and gravel deposits. Most of the potable water is imported (about 2.152 million gallons per day) from the adjacent Pawcatuck Basin to the northwest. The estimated water withdrawals from the minor water suppliers, which are all in Charlestown, during the study period were 0.064 million gallons per day. The self-supplied domestic, industrial, commercial, and agricultural withdrawals from the basin were 0.574 million gallons per day. Water use in the basin was 2.874 million gallons per day. The average return flow in the basin was 1.190 million gallons per day, which was entirely from self-disposed water users. In this basin, wastewater from service collection areas was exported (about 1.139 million gallons per day) to the Narragansett Bay Drainage Basin for treatment and discharge.

During times of little to no recharge, in the form of precipitation, the surface- and ground-water system flows are from storage primarily in the stratified sand and gravel deposits, although there is flow moving through the till deposits at a slower rate. The ground water discharging to the streams, during times of little to no precipitation, is referred to as base flow. The PART program, a computerized hydrograph-separation application, was used at the selected index stream-gaging station to determine water availability based on the 75th, 50th, and 25th percentiles of the total base flow, the base flow minus the 7-day, 10-year flow criteria, and the base flow minus the Aquatic Base Flow criteria at the index station. The base flow calculated at the selected index station was subdivided into two rates on the basis of the percent contributions from sand-and-gravel and till deposits. There has been no long-term collection of surface-water data in this study area and therefore an index stream-gaging station in the Pawcatuck Basin was used for the South Coastal Drainage Basin.

The Pawcatuck River at Wood River Junction was chosen as the index station for the South Coastal Drainage Basin because the station is representative of the basin on the basis of the percentage of sand and gravel deposits and the average extent of thickness of the sand and gravel deposits. The base-flow contributions from sand and gravel deposits at the index station were computed for June, July, August, and September, and applied to the percentage of surficial deposits at the index station. The base-flow contributions were converted to a per unit area at the station for the till, and for the sand and gravel deposits and applied to the South Coastal Drainage Basin to determine the water availability. The results from the index station, the Pawcatuck River at Wood River Junction stream-gaging station, were lowest for the summer in September.

To determine water availability in the South Coastal Drainage Basin, the per unit area of the estimated base flows from sand and gravel deposits and till deposits at the index station was applied to the subbasin areas, and the resultant flows were lowest in September. The base flow at the 75th percentile in the basin was 56.95 million gallons per day in June; 32.78 million gallons per day in July; 30.22 million gallons per day in August; and 23.94 million gallons per day in September. The base flow at the 50th percentile in the basin was 44.59 million gallons per day in June; 25.31 million gallons per day in July; 20.75 million gallons per day in August; and 17.01 million gallons per day in September. The base flow at the 25th percentile in the basin was 35.52 million gallons per day in June; 20.40 million gallons per day in July; 14.94 million gallons per day in August; and 12.00 million gallons per day in September. There are some limitations in

the application of this method along the coast, because saltwater intrusion can change the amount of fresh ground-water discharge to the coastal saltwater ecosystem. A ground-water system analysis evaluating these variances would provide additional information to assess the water availability along the coast.

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 assessed and compared to water withdrawals in the basin. The ratios were calculated by dividing the water withdrawals by the water-availability flow scenarios at the 75th, 50th, and 25th percentiles for the basin, which are based on total water available from base-flow contributions from till and sand and gravel deposits in the basin. The closer the ratio is to one, the closer the withdrawals are to the estimated water available, and the net water available decreases. For the study period, the withdrawals in July were higher than the other summer months. The ratios in the basin for the base-flow scenario, with no low-flow criteria removed, ranged from 0.029 to 0.046 in June; 0.059 to 0.094 in July; 0.050 to 0.100 in August; and 0.040 to 0.079 in September.

A long-term hydrologic budget (60 years) was calculated for the South Coastal Drainage Basin to identify and assess the basin and subbasin inflow and outflows. This coastal basin is different than other study areas because all three of the subbasins drain into salt water, Point Judith Point, Long Island Sound, and Rhode Island Sound towards the Atlantic Ocean, or internally within the subbasin to the salt ponds. The hydrologic budgets, therefore, were compiled by subbasin. The basin hydrologic budget is the sum of the three subbasin budgets. Unlike a river subbasin drainage system, however, the estimated streamflows out of the subbasins were also considered outflows from the basin. The water withdrawals and return flows used in the budget were from 1995 through 1999. For the hydrologic budget, it was assumed that inflow equals outflow, where the estimated inflows were from precipitation and wastewater-return flow, and the estimated outflows were from evapotranspiration, streamflow, and water withdrawals.

Introduction

The South Coastal Drainage Basin in southern Rhode Island (fig. 1) was one of the predominant areas of concern to the State in the assessment of the water-use components (1995–99) and long-term availability (1941–2000) because ground water is the principal water source for public suppliers and domestic users in the basin (about 44 and 39 percent of the average annual water withdrawals, respectively, during the 1995 through 1999 study period). According to the U.S. Census Bureau, southern Rhode Island had the highest population growth in the State, ranging from a 6.3-percent increase in Westerly to a 21-percent increase in Charlestown, from the 1990 Population Census to the 2000 Population Census (Rhode Island Statewide Planning, 2001), for the towns in this study. Likewise, from 1995 through 1999 in the study area, the estimated population growth was higher in the southern region in the State, ranging from a 3-percent increase in Narragansett and Westerly to a 6-percent increase in Exeter and South Kingstown (Rhode Island Economic Development Corporation, 2001). During the 1995 through 1999 study period, there was an increase in the Rhode Island town populations in the basin, and an increase in withdrawals from the ground-water system (stratified sand and gravel deposits and till deposits). During the summer of 1999, the average precipitation at the Kingston, Rhode Island, climatological station for June was only about 0.05 in., compared to the 30-year long-term average precipitation for June that was 3.936 in. (1971–2000). Because precipitation is a key component of ground-water infiltration (fig. 2), the rain deficiency, or period of little to no recharge, resulted in ground-water levels and streamflows to drop below the long-term averages throughout Rhode Island. Consequently, water availability became a concern to the State during the 1999 drought, and further investigation was needed to assess water use and availability.

The U.S. Geological Survey (USGS), in cooperation with the Rhode Island Water Resources Board (RIWRB), began a series of water-use and availability projects to better understand 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. The mission of the Rhode Island Water Resources Board (RIWRB) is to serve 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). This project and the additional basin study areas in the statewide assessment will be used by the State to accomplish this mission by looking at the water demands during the study period in comparison to the water availability during times of little to no recharge in June, July, August, and September.

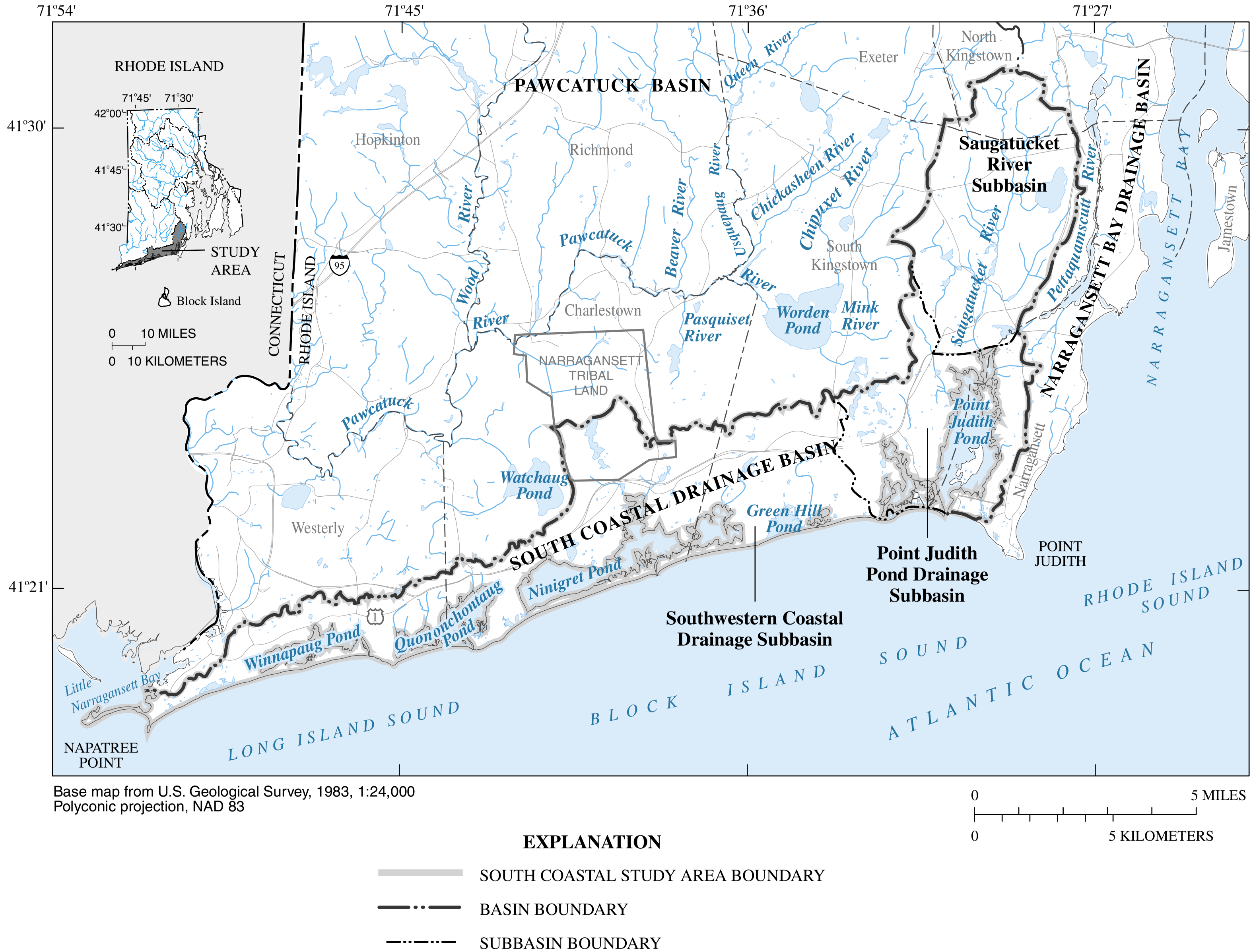

Figure 1. The South Coastal Drainage Basin and subbasins, southern Rhode Island.

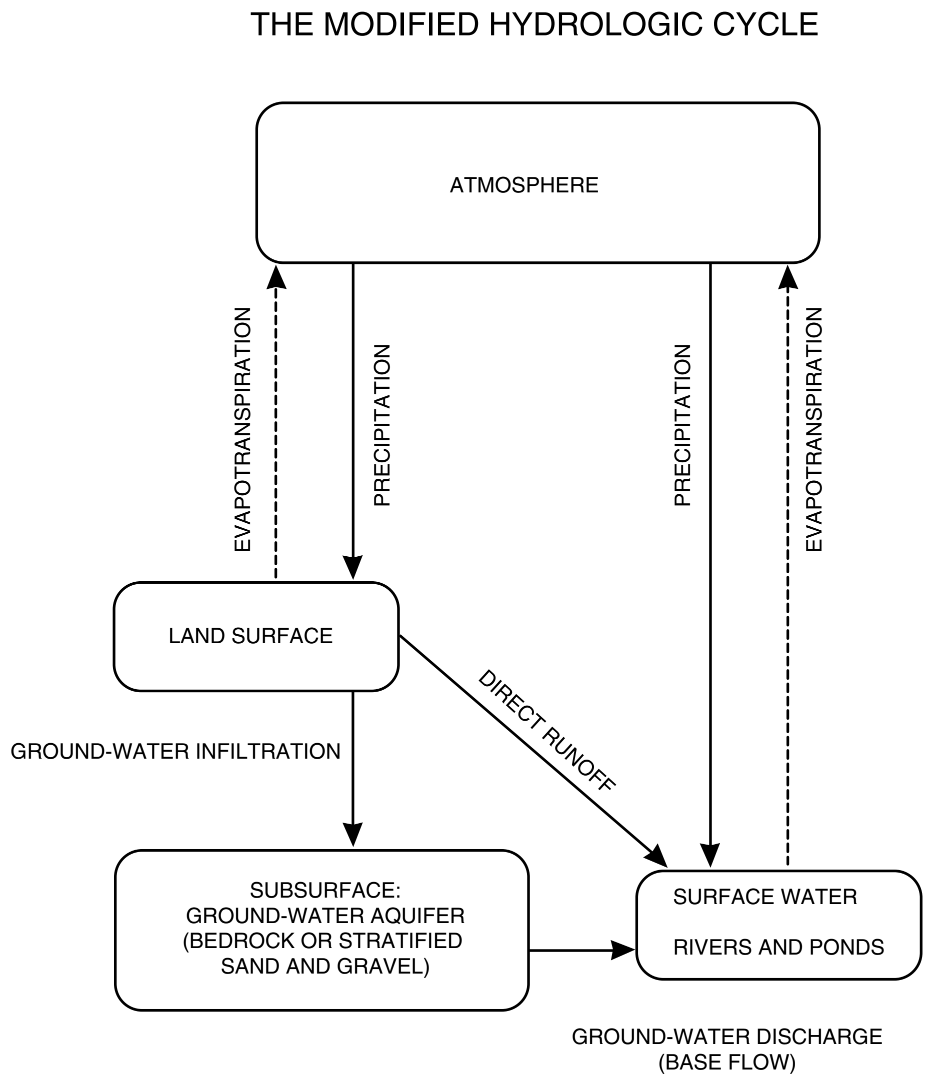

Figure 2. The modified hydrologic cycle.

Purpose and Scope

This report identifies the water-use components (for example, withdrawals, categorical use, and return flow) and assesses water withdrawals and availability in the South Coastal Drainage Basin and its three subbasins for periods of little to no recharge for the summer months, which are June, July, August, and September for this assessment.
To estimate water use, data were collected for the components of water use by the Natural Resources Conservation Service (NRCS) Watershed Boundary Dataset (WBD) delineated subbasins for the towns and systems (supply and disposal) in the South Coastal Drainage Basin. The water withdrawals, users, and dischargers were organized and retrieved for the study period by using the New England Water-Use Data System (NEWUDS) for calendar years 1995–99. The information and data for the water-use components were grouped by town in the three subbasins. The report presents the results of the calculated water availability for the basin and subbasins with a method of determining ground-water discharge during streamflow-recession periods in the summer. A basin water budget is presented in this report. The water budget summarizes the interaction between selected water-use components for the 5-year study period and the components of the hydrologic cycle based on the long-term period of record (60 years).

Previous Investigations

The U.S. Geological Survey has been monitoring ground-water levels for more than 55 years in the South Coastal Drainage Basin. The study area is within the Carolina, Kingston, Narragansett Pier, Quonochontaug, Watch Hill, and Wickford USGS quadrangles. The USGS has published these

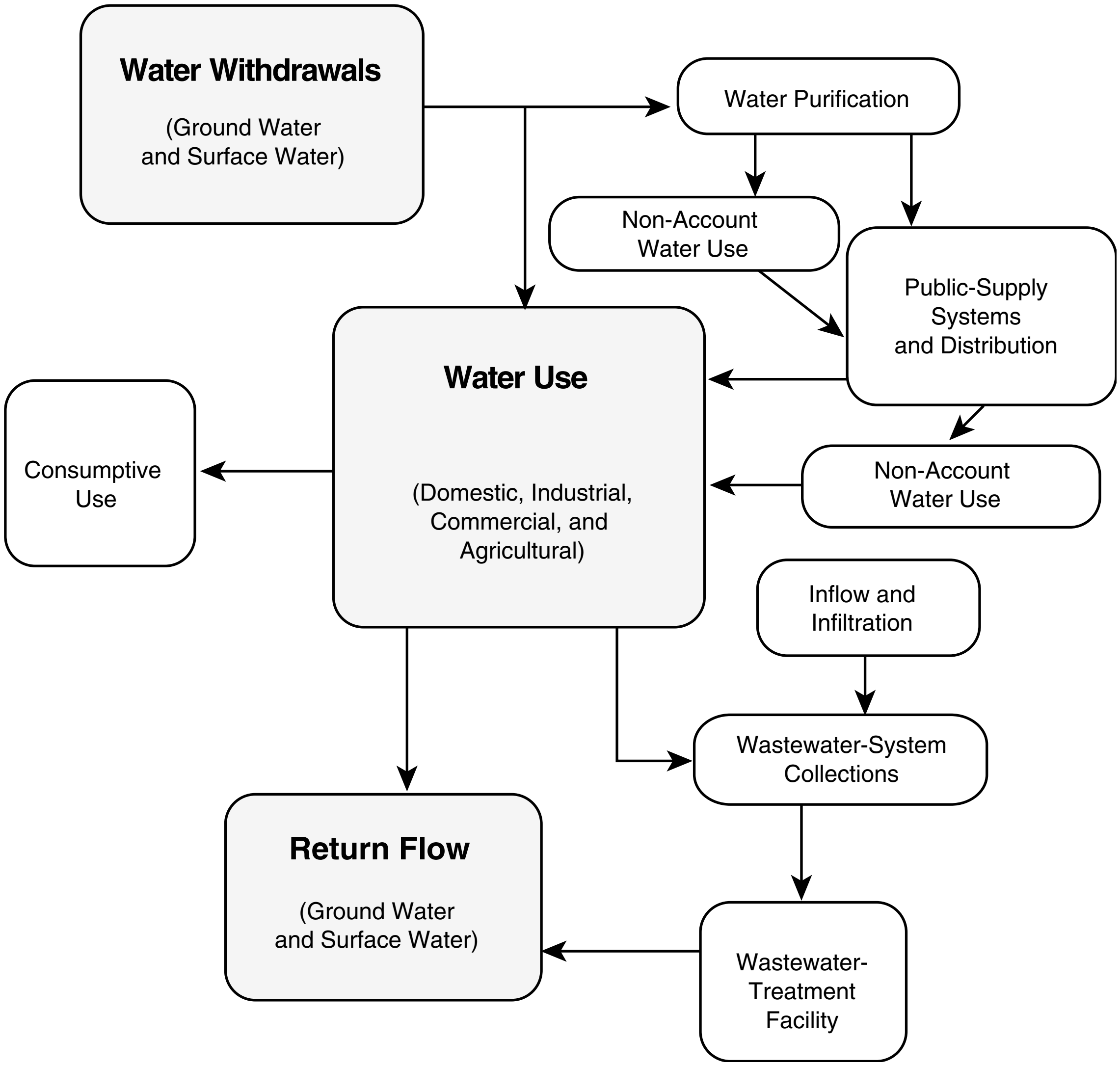

Figure 3. The components of water use.

quadrangles in detailed thematic maps describing the surficial and bedrock geology (Kaye, 1961; Moore, 1959, 1964, 1967; Schafer, 1961a, 1961b, 1965; Williams, 1964). In addition, the USGS has published basin studies that provide information on hydrologic characteristics of the surficial deposits (stratified sand and gravel deposits and till deposits), computer ground-water models, precipitation, and streamflows in the Open-File Report, Professional Paper, Water-Resources Investigations Report, and Water-Supply Paper series (Allen and others, 1966; Cervione and others, 1993; Crosby, 1904, 1905; DeSimone and Ostiguy, 1999; Dickerman, 1984; Dickerman and Ozbilgin, 1985; Dickerman and others 1990; Dickerman and others, 1997; Gonthier and others, 1974; Johnston and Dickerman, 1985; Morrissey, 1989).

Although there has been limited data collection in the South Coastal Drainage Basin, surface-water and ground-water data have been collected for over 60 and 50 years, respectively, in the Pawcatuck Basin, to the north of the study area. Because there has been extensive data collection and research in the Pawcatuck Basin, enough information was available to estimate water available based on the similar basin characteristics for the selected index stream-gaging station in the Pawcatuck Basin with the surficial deposits in the South Coastal Drainage Basin.

Previous investigations have been completed in cooperation with the Rhode Island Water Resources Board, the Geological Bulletin, Ground-Water Map, Hydrologic Bulletin, and Scientific Contribution Report series. The Geologic Bulletins provide well records, lithologic logs, water-quality assessments, hydrologic characteristics of the surficial deposits (stratified sand and gravel deposits and till deposits), and water-table information, and the information is provided by USGS quadrangle (Allen and Kinnison, 1953; Bierschenk, 1956; Lang, 1961). Ground-Water Maps provide bedrock contours, water-table altitudes, well locations, and stratified sand and gravel deposits and till deposits, and the information is provided by USGS quadrangle (Hahn, 1959; Johnson, 1961; Johnson and Marks, 1959; LaSala and Hahn, 1960; LaSala and Johnson, 1960). Hydrologic Bulletins describe lithologic logs and historical aquifer tests (Lang and others, 1960). The Scientific Contribution series reports well records, and information on bedrock and surficial deposits (Allen and Jeffords, 1948).

In addition to studies pertaining to surficial deposits in the basin and subbasins, information has been collected and compiled for the water use in the South Coastal Drainage Basin and statewide assessments (Barlow, 2003; Craft and others, 1995; Horn, 2000; Horn and Craft, 1991; Medalie, 1996; Wild and Nimiroski, 2004). Information on major public-water suppliers has been collected through written and oral communication from the Rhode Island Water Resources Board and major public-water suppliers. The suppliers also prepare water-supply management plans that are submitted to the Rhode Island Water Resources Board, 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.

South Coastal Drainage Basin

The South Coastal Drainage Basin is in southern Rhode Island (fig. 1). Land area in the basin totals approximately 59.14 mi^2, of which about 3.31 percent is freshwater ponds and streams, and about 14.7 percent is wetlands (Rhode Island Geographic Information System, 1995a). The basin includes six Rhode Island towns that are partially within the study area: Charlestown, Exeter, Narragansett, North Kingstown, South Kingstown, and Westerly. In 1990, the basin population was approximately 23,577, and the estimated population during the study period was 25,263 (table 1). The South Coastal Drainage Basin has little relief because all of the towns, with the exception of Exeter, are along the Atlantic Ocean, and has higher altitudes along the north and northwestern part of the basin-divide border with the Pawcatuck Basin, and along the eastern basin divide with the Pettaquanscutt River drainage to Narragansett Bay. The highest altitudes for towns in the South Coastal Drainage Basin are as follows: Westerly is 120 ft, Charlestown is 130 ft, South Kingstown is 261 ft, North Kingstown is 230 ft, Exeter is 290 ft, and Narragansett is 62 ft. Although there are no defined principal ground-water reservoirs, or aquifers, in the basin, the thickness of the sand and gravel deposits ranges from about 10 to 60 ft, and about 36 percent of the area of the deposits in the South Coastal Drainage Basin are sand and gravel (Rhode Island Geographic Information System, 1988). The area of surficial deposits does not include some of the smaller islands in Point Judith Pond and other saline areas because the surficial geology coverage was not completed for the land; therefore, the total land area used for the water availability section of this report was 54.93 mi^2.

For this study, the South Coastal Drainage Basin has been divided into three subbasins to assess the water use and availability: the Saugatucket River, Point Judith Pond, and the Southwestern Coastal Drainage subbasins (fig. 4). Because the three subbasins in this study drain to more than one saline water body (salt ponds and the Atlantic Ocean), the study area will be referred to as the South Coastal Drainage Basin. Although there are no stream-gaging stations in the subbasins, for about 57 years, the USGS has collected ground-water information from an observation well in Charlestown (CHW-18) in the Southwestern Coastal Drainage subbasin (fig. 5).

Precipitation and temperature data for the climatological station at Kingston, Rhode Island, on the University of Rhode Island (URI) campus and the Providence Weather Station Observatory (WSO) climatological station at the airport in Warwick, Rhode Island, were compiled by using the monthly and annual summaries published in the series Climatological Data New England from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). The total annual precipitation at the Kingston climatological station from 1971 through 2000 was 51.79 in., and the average precipitation ranged from 3.308 in. (July) to 4.400 in. (August) for the summer, which is defined as June, July, August, and September for this report. The total annual precipitation at the Kingston climatological station for the study period was 53.11 in., and the average monthly precipitation ranged from 2.728 in. (July) to 4.474 in. (September) for the summer. At the Providence WSO climatological station in Warwick, Rhode Island, the average annual precipitation for the 30-year period, 1971–2000, was 46.46 in., and the 30-year average monthly precipitation ranged from 3.169 in. (July) to 3.904 in. (August) for the summer. The average annual precipitation at Providence WSO for the study period was 43.91 in., and the average monthly precipitation ranged from 1.978 in. (July) to 4.014 in. (September) for the summer. The average annual temperature at the Kingston climatological station from 1971 through 2000 was 49.94°F, and the average temperature ranged from 62.72°F (September) to 71.06°F (July) for the summer. The average annual temperature at the Kingston climatological station for the study period was 50.91°F, and the average monthly temperatures ranged from 63.74°F (September) to 71.88°F (July) for the summer. At the Providence WSO climatological station, the average annual temperature for the 30-year period, 1971 through 2000, was 51.13°F, and the 30-year average monthly temperatures ranged from 63.99°F (September) to 73.37°F (July) for the summer. The average annual temperature at Providence WSO for the study period was 51.84°F, and the average monthly temperatures ranged from 64.74°F (September) to 74.14°F (July) for the summer. Precipitation and temperature data for the climatological stations are summarized in table 2.

Table 1. Total town populations by subbasin for 1990, estimated 1995–99 populations, and estimated populations of public- and self-supply use and disposal in the South Coastal Drainage Basin, southern Rhode Island.

[Total populations in Rhode Island 1990, from Rhode Island Geographic Information System (1991). Estimated 1995–99 population from the Rhode Island Economic Development Corporation (2000). --, not applicable]

Town	Population		Estimated 1995–99 population			
	1990	Estimated 1995–99	Supply		Disposal	
			Public	Self	Public	Self
Saugatucket River Subbasin						
Exeter	7	8	1	7	--	8
Narragansett	35	37	36	1	22	15
North Kingstown	492	536	398	138	--	536
South Kingstown	9,300	9,968	8,718	1,250	6,761	3,207
Subbasin total	9,834	10,549	9,153	1,396	6,783	3,766
Point Judith Pond Drainage Subbasin						
Narragansett	3,758	3,957	3,866	91	1,482	2,475
South Kingstown	1,836	1,967	1,242	725	228	1,738
Subbasin total	5,594	5,924	5,108	816	1,710	4,214
Southwestern Coastal Drainage Subbasin						
Charlestown[1]	2,570	2,844	225	2,619	77	2,767
South Kingstown	2,867	3,072	2,373	699	249	2,823
Westerly	2,712	2,874	2,695	179	361	2,513
Subbasin total	8,149	8,790	5,293	3,497	687	8,103
South Coastal Drainage Basin						
Basin total	23,577	25,263	19,554	5,709	9,180	16,083

[1]The estimated data for this table were obtained with a geographic information system. Analysis of populations of site-specific data (minor public suppliers in table 9), and seasonal variations in the extent of the water-supply districts presented in other sections of this report may differ to account for the estimated imported and exported water distributions for a town that is supplied by multiple water districts.

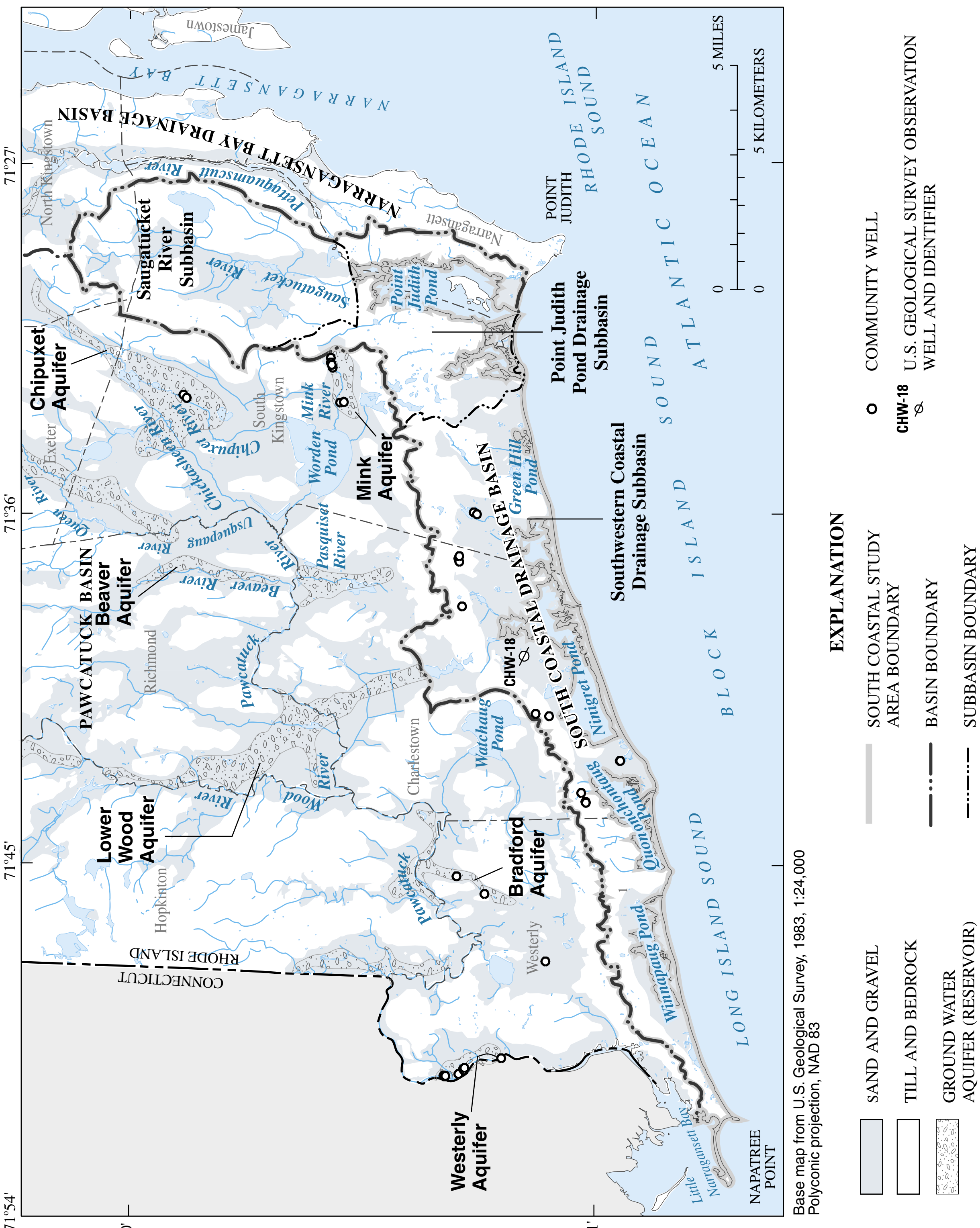

Figure 4. Sand and gravel deposits and selected withdrawal wells for the subbasins in the South Coastal Drainage Basin, southern Rhode Island.

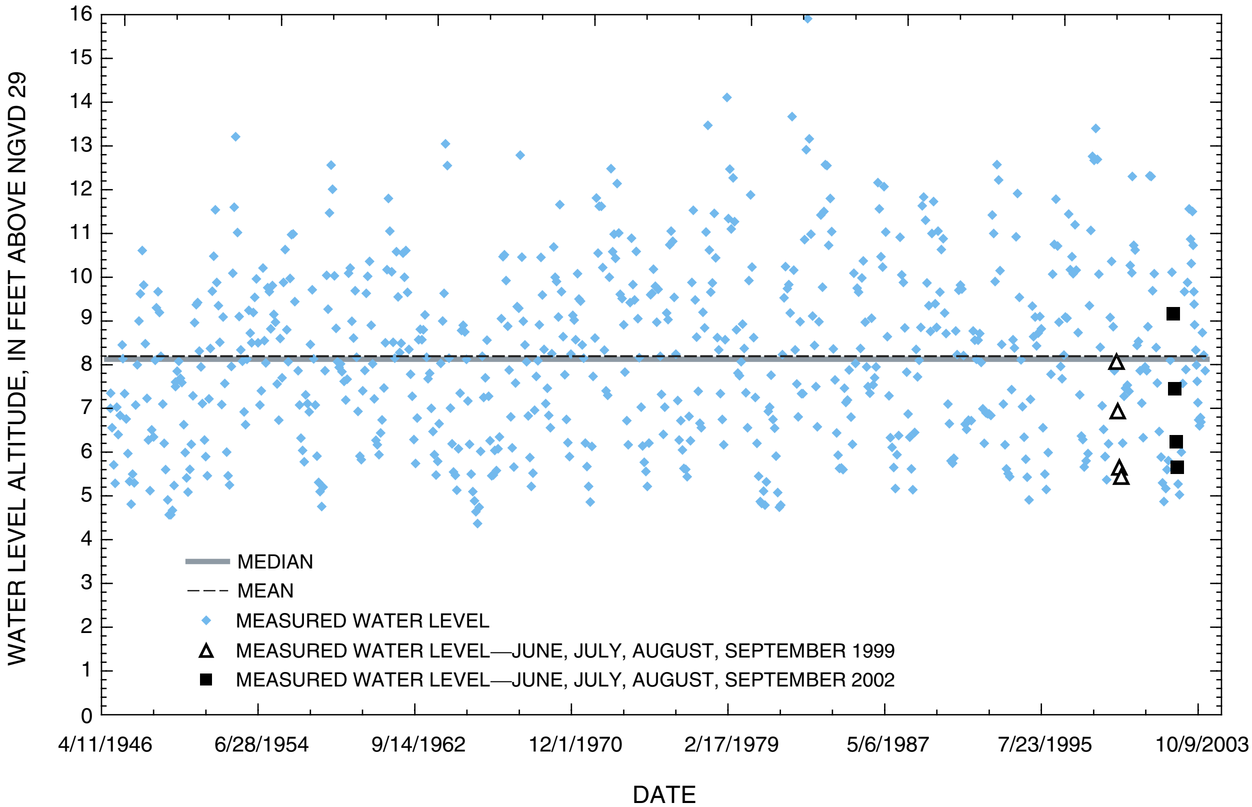

Figure 5. Long-term water levels for U.S. Geological Survey observation well Charlestown 18 (CHW-18), 1946–2004.

Table 2. Summary of climatological data pertinent to the South Coastal Drainage Basin, southern Rhode Island.

[Climatological data from monthly and annual summaries from the National Climate Data Center of the National Oceanic and Atmospheric Administration, 1971–2000. WSO, weather station observatory; in., inch; °F, degrees Fahrenheit]

Climatological station	Period of record	Average Temperature (°F)				
		June	July	August	September	Annual
Kingston	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	1971–2000	67.65	73.37	71.88	63.99	51.13
	1995–99	68.20	74.14	72.08	64.74	51.84

Climatological station	Period of record	Average Precipitation (in.)				Annual total precipitation (in.)
		June	July	August	September	
Kingston	1971–2000	3.936	3.308	4.400	4.163	51.79
	1995–99	4.106	2.728	4.356	4.474	53.11
Providence WSO Airport, Warwick	1971–2000	3.382	3.169	3.904	3.704	46.46
	1995–99	3.414	1.978	3.190	4.014	43.91

Land use was calculated by merging the Rhode Island Geographic Information Systems (RIGIS) land-use coverages with the basin and subbasin coverages. Land-use area was used as a tool to aggregate commercial, industrial, and agricultural water-use estimates into the applicable towns, subbasins, and basin (table 3). For the South Coastal Drainage Basin, the total land-use area for commercial, industrial, and agricultural was 1.040 mi^2, 0.054 mi^2, and 4.917 mi^2, respectively. The commercial land-use area ranged from 0.296 mi^2 in the Point Judith Pond Drainage subbasin to 0.418 mi^2 in the Southwestern Coastal Drainage subbasin. The industrial land-use area was 0.001 mi^2 in the Point Judith Pond Drainage subbasin, 0.053 mi^2 in the Saugatucket River Drainage subbasin, and there was no industrial land use in the Southwestern Coastal Drainage subbasin. The agricultural land-use area ranged from 1.297 mi^2 in the Saugatucket River Drainage subbasin to 2.240 mi^2 in the Southwestern Coastal Drainage subbasin. For the towns in the water-supply districts, land-use area was used to aggregate the water-use categories by basin and subbasin (table 4). When categorical data were available by the water-supply districts, water use was disaggregated by basin (table 5), as well as by subbasin, and then by town, by using the land-use area category on public supply. The total land-use area by public-supply district for commercial, industrial, and agricultural was 0.794 mi^2, 0.080 mi^2, and 2.580 mi^2, respectively, within the South Coastal Drainage Basin.

Table 3. Town land and land-use area by category in the subbasins of the South Coastal Drainage Basin, southern Rhode Island.

[Land-use areas were estimated by using the coverage from the Rhode Island Geographic Information System, 1995a. mi^2, square mile; --, not applicable]

Towns	Land area (mi^2)	Land-use area by category (mi^2)		
		Commercial	Industrial	Agricultural
Saugatucket River Subbasin				
Exeter	0.062	--	--	--
Narragansett	.062	--	--	--
North Kingstown	2.663	--	--	0.065
South Kingstown	14.30	0.326	0.053	1.232
Subbasin total	17.09	0.326	0.053	1.297
Point Judith Pond Drainage Subbasin				
Narragansett	7.057	0.255	0.001	0.194
South Kingstown	7.523	.041	--	1.186
Subbasin total	14.58	0.296	0.001	1.380
Southwestern Coastal Drainage Subbasin				
Charlestown	12.10	0.227	--	0.412
South Kingstown	8.774	.037	--	1.604
Westerly	6.593	.154	--	.224
Subbasin total	27.47	0.418	--	2.240
South Coastal Drainage Basin				
Total	59.14	1.040	0.054	4.917

Table 4. Land-use area and percentage of land-use area by town and water-supply district in the South Coastal Drainage Basin and areas outside of the basin, southern 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]

Town	Water-supply districts	Total land in South Coastal Basin (mi^2)	Land-use area by category in the South Coastal Drainage Basin (mi^2)			Total land outside of South Coastal Basin (mi^2)	Land-use area by category outside of the South Coastal Drainage Basin (mi^2)		
			Commercial	Industrial	Agricultural		Commercial	Industrial	Agricultural
Narragansett	Narragansett Water District[1]	4.674	0.147	0.001	0.100	2.316	0.074	0.026	0.047
	United Water of Rhode Island[2]	2.404	.108	--	.093	4.224	.048	.005	.181
Narragansett total		7.078	0.255	0.001	0.193	6.540	0.122	0.031	0.228
South Kingstown	Kingston Water District[3]	.947	.031	.031	.082	1.739	.024	.024	.126
	South Kingstown Water Department[4]	5.713	.069	--	1.436	.426	--	--	.009
	United Water of Rhode Island	8.927	.285	.048	.645	3.287	.006	.014	.509
South Kingstown total		15.59	0.385	0.079	2.163	5.452	0.030	0.038	0.644
Westerly total	Westerly Water Department[5]	6.036	0.154	--	0.224	13.39	0.536	0.097	0.841

[1]Water ver subbasin of the Narragansett Bay Drainage Basin.

[2]Water-supply district is in the Saugatucket River subbasin of the South Coastal Drainage Basin, the Pawcatuck Basin, and the Narragansett Bay Drainage Basin.

[3]Water-supply district is in the Saugatucket River subbasin of the South Coastal Drainage Basin and in the Pawcatuck Basin.

[4]Water-supply district is i

[5]Water-supply district is in the Southwestern Coastal Drainage subbasin of the South Coastal Drainage Basin and in the Pawcatuck Basin.

Table 5. Land-use area and percentage of land-use area by water-supply district in the South Coastal Drainage Basin study area and areas outside of the basin, southern 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]

Water supplier	Basin (subbasin) of well withdrawal	Total land in South Coastal Basin (mi^2)	Land-use area by category in the South Coastal Drainage Basin (mi^2)			Total land outside of South Coastal Basin (mi^2)	Land-use area by category outside of the South Coastal Drainage Basin (mi^2)		
			Commercial	Industrial	Agricultural		Commercial	Industrial	Agricultural
Kingston Water District	Chipuxet	0.947	0.031	0.031	0.082	1.739	0.024	0.024	0.126
Narragansett Water District	--	4.674	.147	.001	.100	2.316	.074	.026	.047
South Kingstown Water Department	South Coastal Drainage	5.713	.069	--	1.436	.426	--	--	.009
United Water of Rhode Island	Pawcatuck (Chipuxet)	11.33	.393	.048	.738	7.511	.054	.019	.689
Westerly Water Department	Pawcatuck (Lower Pawcatuck)	6.036	.154	--	.224	13.39	.536	.097	.841

Water supplier	Basin (subbasin) of well withdrawal	Percent land use in the South Coastal Drainage Basin				Percent land use outside of the South Coastal Drainage Basin			
		Total	Commercial	Industrial	Agricultural	Total	Commercial	Industrial	Agricultural
Kingston Water District	Chipuxet	35	56	56	39	65	44	44	61
Narragansett Water District	--	6	67	4	68	33	33	96	32
South Kingstown Water Department	South Coastal Drainage	93	100	100	99	7	--	--	1
United Water of Rhode Island	Pawcatuck (Chipuxet)	60	88	72	52	40	12	28	48
Westerly Water Department	Pawcatuck (Lower Pawcatuck)	31	22	--	21	69	78	100	79

South Coastal Drainage Subbasins

The USGS subbasin boundaries delineated for this study area are similar to the cataloging units defined by the Watershed Boundary Dataset (WBD) delineated by the Natural Resources Conservation Service (NRCS). The WBD used the Federal standards for delineations of the boundaries established by the Federal Geographic Data Committee (FGDC) in 2002. There are slight differences in the drainage areas between the study and the WBD (table 6). The South Coastal Drainage Basin is part of the Pawcatuck River Basin USGS 8-digit Hydrologic Unit Code (HUC). For the WBD 8-digit, 10-digit, and 12-digit cataloging units, the NRCS included the Pettaquamscutt River Drainage subbasin originally delineated as a part of the Narragansett Bay Basin (Natural Resources Conservation Service, 2003), which for this series of water use and availability studies will be included in the West Narragansett Bay Drainage Basin. Block Island is also part of the Pawcatuck River Basin USGS 8-digit and part of the NRCS-delineated 8-digit, 10-digit, and 12-digit cataloging units. The Block Island water use and availability assessment was completed by the Rhode Island Geological Survey in 2003 at the University of Rhode Island. In addition, naming conventions differ in the comparison between the South Coastal Drainage Basin study and the WBD 10-digit and WBD 12-digit cataloging units. Land area and naming convention comparisons are presented in table 6. The WBD spatial data are primarily defining the land by using surface-water features, and these delineations have been specified using the criteria listed in the FGDC guidelines (2002).

The salt-pond land areas in the subbasins were not included in the WBD surface-water drainage divides. The areas were, however, included in the delineated areas defined for the Rhode Island South Shore Sea Grant project, in association with the University of Rhode Island, (2002). Salt pond drainage areas in the South Coastal Drainage Basin are presented in table 7.

The Saugatucket River subbasin (17.09-mi^2 drainage area) is in the northeastern section of the South Coastal Drainage Basin in Rhode Island. Towns in the subbasin include Exeter, Narragansett, North Kingstown, and South Kingstown (fig. 1). Land areas and land-use areas by category are summarized in tables 3 and 4. The Saugatucket River flows southward into Point Judith Pond, a salt pond that drains into the Block Island Sound and then to the Atlantic Ocean. Areas of sand and gravel deposits (5.326 mi^2, 31 percent of the 17.08-mi^2 surficial deposits) extend along the Saugatucket River (Rhode Island Geographic Information Systems, 1988).

The Point Judith Pond subbasin (14.58-mi^2 drainage area) is in the central section of the South Coastal Drainage Basin in Rhode Island. Towns in the subbasin include Narragansett and South Kingstown (fig. 1). Land areas and land-use areas by category are summarized in tables 3 and 4. Because the coastal setting has little relief or change in altitude, there are several freshwater ponds (White Pond, Long Pond, Spectacle Ponds, Hot House Pond, Lily Pond, Wash Pond, Little Wash Pond, Cedar Swamp Pond,) and salt water ponds (Potter Pond) that are fed by direct runoff and (or) ground-water discharge, and limited inflow from rivers and brooks. Areas of sand and gravel deposits (1.704 mi^2, 16 percent of the 10.54-mi^2 surficial deposits) extend along the topographic depressions in the subbasin (Rhode Island Geographic Information Systems, 1988).

The Southwestern Coastal Drainage subbasin (27.47-mi^2 drainage area) is in the western section of the South Coastal Drainage Basin in Rhode Island. The towns in the subbasin include Charlestown, South Kingstown, and Westerly (fig. 1). Land areas and land-use areas by category are summarized in tables 3 and 4. Areas of the sand and gravel deposits (12.98 mi^2, 47 percent of the 27.29-mi^2 surficial deposits) extend along the topographic depressions in the subbasin.

There has been no continuous stream-gaging data collection in the South Coastal Drainage Basin. Therefore, the Pawcatuck River at Wood River Junction station (01117500), was used as the index stream-gaging station for the basin (fig. 6). The drainage area for the stream-gaging station is 100 mi^2, and about 47 percent of the drainage area at the stream-gaging station is sand and gravel deposits, the period of record for the station is more than 60 years long. The index station has more than 60 years of surface-water data. Approximately 47 percent of the drainage area at the stream-gaging station is sand and gravel deposits.

Table 6. Defined subbasins in the Pawcatuck Basin, South Coastal Drainage Basin, and Block Island study areas in Rhode Island compared to the 10-digit and 12-digit Watershed Boundary Dataset in Rhode Island.

[The total land area in Rhode Island, 309.1 square miles, for the Watershed Boundary Dataset for the Pawcatuck Basin 8-digit Hydrologic Unit Code (01090005) includes Block Island (0109000505), 7.752 square miles, which is outside of the study area. mi^2, square mile]

Study Area in Rhode Island		National Hydrography Dataset for Pawcatuck Basin in Rhode Island					
		10-digit			12-digit		
Subbasins	Drainage areas (mi^2)	Name	Number	Drainage area (mi^2)	Name	Number	Drainage area (mi^2)
Pawcatuck Basin							
Chipuxet Subbasin	36.93	Wood River	0109000501	79.70	Upper Wood River	010900050101	52.61
Usquepaug–Queen Subbasin	36.10				Lower Wood River	010900050102	27.09
Beaver–Pasquiset Subbasin	22.47	Upper Pawcatuck River	0109000502	153.3	Chipuxet River	010900050201	25.79
Upper Wood Subbasin	63.80				Queen River	010900050202	36.63
Lower Wood Subbasin	36.40				Beaver River	010900050203	12.50
Lower Pawcatuck Subbasin	49.50				Upper Pawcatuck River	010900050204	21.61
					Pawcatuck mainstem	010900050205	56.82
		Lower Pawcatuck River	0109000503	12.52	Ashaway River	010900050301	4.729
					Lower Pawcatuck River	010900050303	7.792
South Coastal Drainage Basin							
Saugatucket River Subbasin	17.09	Southwestern Coastal Waters	0109000504	55.08	Saugatucket River	010900050402	17.08
Point Judith Pond Drainage Subbasin	14.58				Point Judith Pond	010900050403	10.54
Southwestern Coastal Drainage Subbasin	27.47				Southwestern Coastal Waters	010900050404	27.46
Total South Coastal Drainage Basin study area in Rhode Island	59.14	Total 10-digit area of the South Coastal Drainage Basin in Rhode Island (excluding Block Island)		55.08	Total 12-digit area of the South Coastal Drainage Basin in Rhode Island (excluding Block Island)		55.08

Table 7. The Sea Grant Drainage Areas in Rhode Island.

[mi^2, square mile]

Sea Grant Drainage Area name (listed from east to west)	Total area (mi^2)	Land area (mi^2)	Fresh-water area (mi^2)	Salt-water area (mi^2)
Point Judith Pond	28.76	25.65	0.74	2.42
Potter Pond	5.69	4.89	.23	.57
Cards Pond	3.09	3.00	.03	.06
Trustom Pond	1.31	1.02	.01	.28
Green Hill Pond	5.35	4.61	.08	.66
Ninigret Pond	11.95	9.09	.38	2.47
Quonochontaug Pond	4.61	3.42	.03	1.16
Winnapaug Pond	4.28	3.52	.02	.74
Maschaug Pond	.61	.53	.01	.07
Little Narragansett Bay[1]	--	--	--	--
Napatree Point[2]	--	--	--	--
Sea Grant Drainage Area total[1,2]	65.65	55.74	1.53	8.43

[1]Data were available only for the entire Pawcatuck and Wetquetequock watersheds and estuary areas (Rhode Island South Shore Sea Grant Project, 2002).

[2]Data not available for the Napatree Point area.

Minor Civil Divisions

The U.S. Census Bureau classifies towns and cities into minor civil divisions (MCDs). The six MCDs in the study area include Charlestown, Exeter, Narragansett, North Kingstown, South Kingstown, and Westerly in Rhode Island. The study area also includes part of the Narragansett Tribal Land in the southeastern section of Charlestown. Polygons within the towns were assigned population densities in the GIS coverages by using Census Bureau TIGER data available through the Rhode Island Geographic Information System (RIGIS). These 1990 population coverages were merged with the USGS basin and subbasin coverage to determine the population in the South Coastal Drainage Basin, and in the subbasins (table 1). Also, the town land area by basin and subbasin was determined by overlaying town boundaries and basin-boundary coverages from the WBD defining the 12-digit NRCS HUCs. The ratio of the 1990 to 1995 through 1999 populations for towns by subbasins is the increase (or decrease) of the town population. To estimate the 1995 through 1999 town populations on public- and self-supplied water and public- and self-wastewater disposals, the population ratios were multiplied by the 1990 population on private wells and by the 1990 population on public-wastewater collection (table 1) that were available through RIGIS. 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 [Code of Federal Regulations (CFR), title 40, part 141, section 2, 1996]. For this report, public suppliers were categorized into major public suppliers that have distribution systems, and into minor suppliers with closed systems.

Charlestown is in south-central Rhode Island (fig. 1). The total land area is 37.63 mi^2, of which 12.10 mi^2 is in the South Coastal Drainage Basin (table 8). The estimated total town population for the study period was 7,062, and the estimated town population in the basin for the study period was 2,844 (table 8). Charlestown also includes the Narragansett Tribal Land, which comprises 1,400 acres in the southeastern section of the town (Narragansett Indian Tribe, 2002). Charlestown has no major public-water supply or wastewater-collection facilities, and six minor water suppliers serve small populations in the basin. Population data, however, were available only for five of these minor suppliers.

Exeter is in south-central Rhode Island (fig. 1). The total land area is 58.39 mi^2, of which 0.062 mi^2 is in the South Coastal Drainage Basin (table 8). The estimated total town population for the study period was 5,932, and the estimated town population in the basin for the study period was 8 (table 8). There are no major public-water suppliers that withdraw water or provide water to users in the South Coastal Drainage Basin part of Exeter.

Narragansett is in south-central Rhode Island (fig. 1). The total land area is 13.68 mi^2, of which 7.119 mi^2 is in the South Coastal Drainage Basin (table 8). The estimated total town population for the study period was 15,777, and the estimated town population in the basin for the study period was 3,994 (table 8). The Narragansett Water Department supplies the town through wholesale and retail water purchases from United Water of Rhode Island (UWRI), which withdraws its water from the Pawcatuck Basin. Wastewater is collected from the town in the locality of Scarborough and southern parts of Narragansett by the Narragansett Wastewater-Treatment Facility (WWTF), and in the northern parts of Narragansett, from Narragansett Pier to the north part of town, by the South Kingstown Regional WWTF.

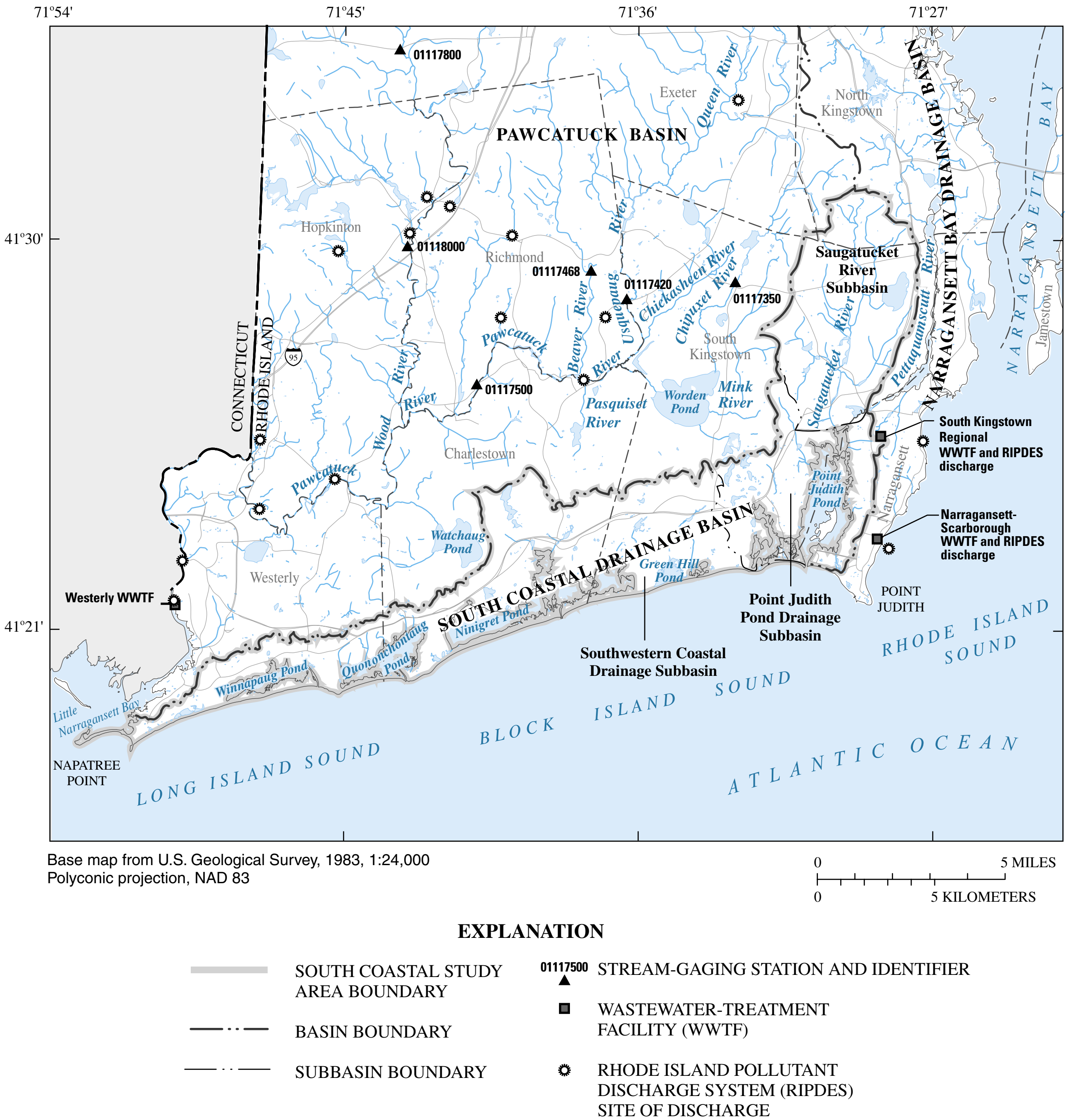

Figure 6. Stream-gaging stations, wastewater-treatment plants, and RIPDES dischargers associated with the South Coastal Drainage Basin, southern Rhode Island.

Table 8. Summary of total land area, land area in the South Coastal Drainage Basin, total 1990 populations, total estimated 1995–99, estimated 1995–99 populations in the South Coastal Drainage Basin, and land-use area by category in the South Coastal Drainage Basin, southern Rhode Island.

[All towns are in Rhode Island unless otherwise noted. Total populations in Rhode Island 1990 from Rhode Island Geographic Information System (1991). Estimated 1995–99 population from the Rhode Island Economic Development Corporation (2000). Land-use areas in Rhode Island were estimated by using the coverage from the Rhode Island Geographic Information System (1995a). mi^2, square mile]

Towns	Total land area (mi^2)	Land area in the South Coastal Drainage Basin (mi^2)	Total populations		Estimated 1995–99 population in the South Coastal Drainage Basin	Total land-use area by category (mi^2)		
			1990	Estimated 1995–99		Commercial	Industrial	Agricultural
Charlestown	37.63	12.10	6,381	7,062	2,844	0.302	0.066	1.439
Exeter	58.39	.062	5,472	5,932	8	.140	.042	4.451
Narragansett	13.68	7.119	14,983	15,777	3,994	.377	.032	.421
North Kingstown	43.42	2.663	23,774	25,906	536	.788	1.676	3.133
South Kingstown	60.85	30.59	24,632	26,401	15,007	.490	.155	7.666
Westerly	29.51	6.593	21,603	22,896	2,874	.696	.114	1.584

North Kingstown is in central Rhode Island (fig. 1). The total land area is 43.42 mi^2, of which 2.663 mi^2 is in the South Coastal Drainage Basin (table 8). The estimated total town population for the study period was 25,906, and the estimated town population in the basin for the study period was 536 (table 8). The North Kingstown Water District serves approximately 94 percent of the town. There is no public wastewater collection in North Kingstown. A private wastewater-treatment facility serves the Quonset Point establishment, formerly a U.S. Navy Air Station, which is currently (2003) owned and operated by the Rhode Island Economic Development Corporation (RIEDC).

South Kingstown is in south-central Rhode Island (fig. 1). The total land area is 60.85 mi^2, of which 30.59 mi^2 is in the South Coastal Drainage Basin (table 8). The estimated total town population for the study period was 26,401, and the estimated town population in the basin for the study period was 15,007 (table 8).

Four major water suppliers serve the town of South Kingstown in the South Coastal Drainage Basin: the Kingston Water District, UWRI, South Kingstown Water Department, and Narragansett Water Department. The Kingston Water District supplies the rest of the locality in the South Coastal Drainage Basin, as well as areas outside of the basin. Northeastern sections of South Kingstown (Wakefield and Peace Dale) also are supplied by a private water utility, UWRI, which withdraws water from the Pawcatuck Basin, and imports the water to the South Coastal Drainage Basin. In addition, UWRI distributes retail water to the town and sells water wholesale to the South Kingstown Water Department and to the Narragansett Water Department. The total average population of the towns served by UWRI during the study period was 18,000. Along the coast, in the southern part of the town, the South Kingstown Water Department withdraws and distributes water within the South Coastal Drainage Basin. The Narragansett Water Department purchases from UWRI are included as imports to the basin from the Pawcatuck Basin. The South Kingstown Regional WWTF serves the town and some sections of Narragansett located outside of the study area. Wastewater collected within the Kingston Water District and the UWRI service areas is exported to the South Kingstown Regional WWTF located outside of the study area in the Narragansett Bay Drainage Basin. During this study period, there were no minor water suppliers in the basin for the town of South Kingstown.

Westerly is in southwestern Rhode Island (fig. 1). The total land area is 29.51 mi^2, of which 6.593 mi^2 is in the South Coastal Drainage Basin (table 8). The estimated total town population for the study period was 22,896, and the estimated town population in the basin for the study period was 2,874 (table 8). The Westerly Water Department serves the town and the village of Pawcatuck in Stonington, CT. The Westerly wastewater facility serves the town, but the wastewater collection is only in the Pawcatuck Basin.

Water Use

Components of water use include water withdrawals, public-supply systems and distributions, non-account use, water use by category, consumptive water use, wastewater-system collections, and return flow (fig. 3). During the study period, data were categorized as either self- or public-supplied withdrawals from ground water. Conveyance losses are an example of non-account water use (which is unmetered) in public-supply systems, and include leaks, system flushing, and fire-hydrant uses within the systems. The non-account water use for a public-supply system is the total distribution minus the public-supply distributions for the water-use categories in the system. Water-use categories used in this report are domestic, commercial, industrial, and agricultural for public- and self-supplied users. Consumptive water use is water removed from the environment through uses by humans, livestock, production, or evapotranspiration. Wastewater from local and regional public wastewater systems is returned to a surface-water body. Return flow to ground water or surface water includes site-specific discharges from permitted dischargers and aggregate discharges from self-disposed septic systems within the town, basin, and subbasins. Water withdrawals, water use, consumptive use, and return flow were calculated for each subbasin by town for the calendar years during the study period.

New England Water-Use Data System

Water use in the South Coastal Drainage Basin and subbasins were organized by using the New England Water-Use Data System (NEWUDS). The data entered into NEWUDS consist of site-specific and aggregate water withdrawals, uses, and discharges in the South Coastal Drainage Basin and its subbasins. When available, monthly, quarterly, and yearly metered (or reported) data were entered from the original source and converted to common units (million gallons per day) for data comparison. Unmetered water withdrawals, uses, and discharges were calculated by methods used to estimate water use by category (domestic, industrial, commercial, and agricultural). The database was used as a tool to track the water withdrawn from the South Coastal Drainage Basin and subbasins. 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. For quality-assurance purposes, NEWUDS allows the data compiler to indicate the original data source, rate units, and method of rate determined within the database. Documentation describing database development and how to use the database are presented in reports by Tessler (2002) and Horn (2003), respectively.

Public-Water Supply and Interbasin Transfers

Public-water suppliers are defined as suppliers serving more than 25 people or having 15 service connections year-round [Code of Federal Regulations (CFR), title 40, part 141, section 2, 1996]. For this report, public suppliers were categorized into major public-water suppliers that have a system of distribution, and minor public-water suppliers with closed systems. Five major public-water suppliers serve the South Coastal Drainage Basin: Kingston Water District, Narragansett Water Department, South Kingstown Water Department, UWRI, and the Westerly Water Department (fig. 7), which supply the domestic, commercial, industrial, and agricultural sectors. Six minor water suppliers serve small public populations, such as nursing homes, condominium associations, and mobile home parks (table 9). Total water withdrawals from public supplies by town and subbasin are summarized in figure 8 and table 10.

Potable interbasin transfers are water that is conveyed from public-water suppliers across hydrologic divides, basins and subbasins. The water is an import, or a gain to the basin, if the withdrawal occurs in another basin or subbasin and used in the study area. An export, or a loss to the basin, occurs when the water withdrawal is in the basin, but the potable water is used elsewhere in another basin or subbasin.

The Kingston Water District supplies the domestic, industrial, commercial, and agricultural water users in the locality of Kingston. Average withdrawals for the study period were 0.444 Mgal/d from the Chipuxet ground-water aquifer in the Pawcatuck Basin. The interbasin transfers imported to the South Coastal Drainage Basin were approximately 0.082 Mgal/d for use. The Kingston Water District accounts for 11 percent of the total water use in the Saugatucket River subbasin and 3 percent of the total water use in the South Coastal Drainage Basin. The water withdrawals and distributions for the Kingston Water District are summarized in figure 9.

The Narragansett Water District supplies the domestic, industrial, and commercial water users in the southern part of the town. The average purchases from UWRI for the study period were 0.633 Mgal/d, which are imported to the South Coastal Drainage Basin from the Pawcatuck Basin. The Narragansett Water District accounts for 27 percent of the total water use in the Point Judith Pond Drainage subbasin and 7 percent of the total water use in the South Coastal Drainage Basin. Water distributions for the Narragansett Water District are summarized in figure 10.

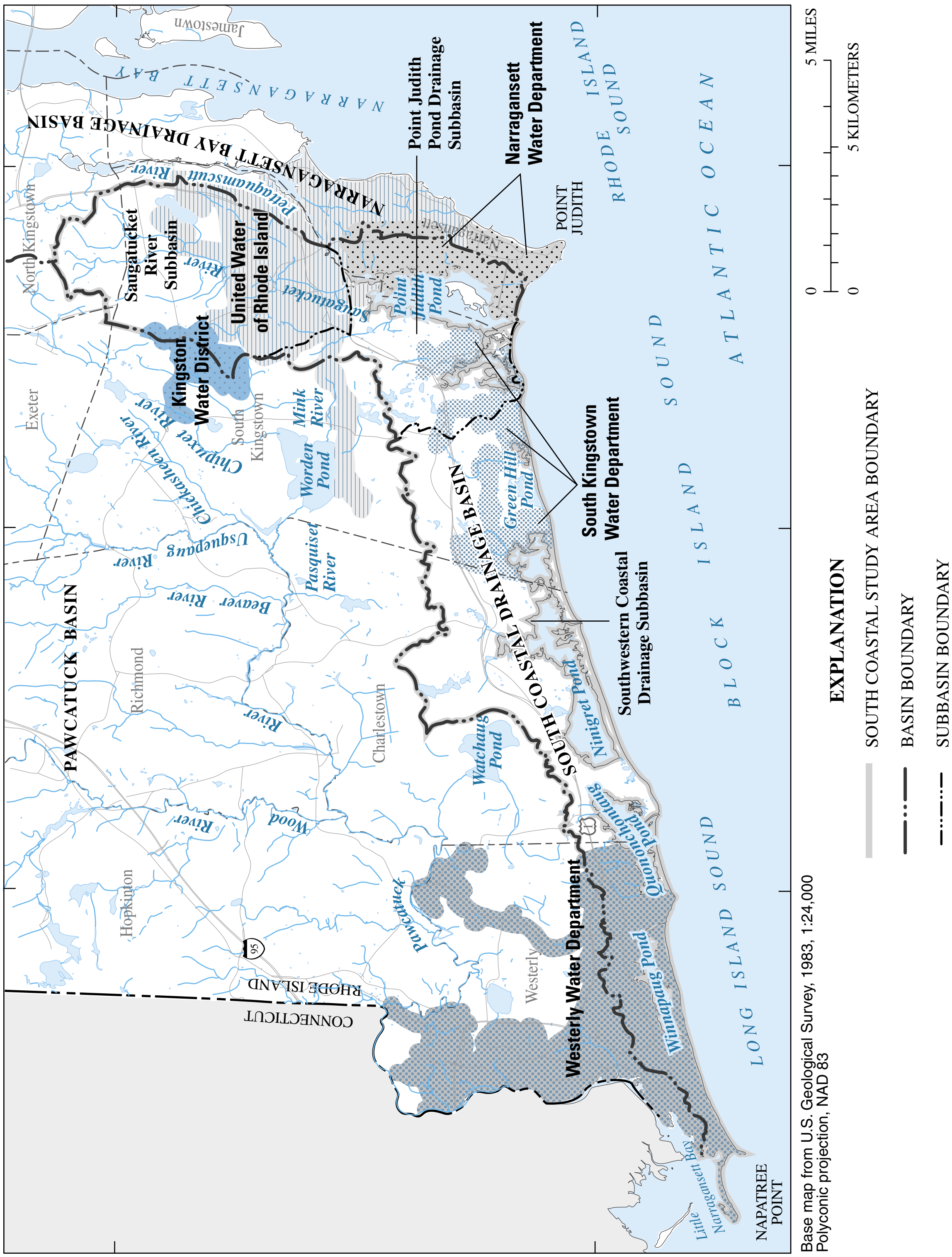

Figure 7. Major public-water suppliers associated with the South Coastal Drainage Basin, Southern Rhode Island, 1995–99.

Table 9. Minor suppliers in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

[Population and estimated water withdrawals and use in the summer are assumed to be during June, July, and August. Coefficient used for minor public-supplier population is 67 gallons per day per person. BD, bedrock well; DG, dug well; SG, sand and gravel well; Mgal/d, million gallons per day; --, not applicable]

Minor supplier	Town	Aquifer or type of well(s)	Estimated 1995–99 populations: Fall, winter, and spring — Estimated population	Fall, winter, and spring — Estimated water withdrawals and use (Mgal/d)	Summer — Estimated population	Summer — Water withdrawals and use (Mgal/d)	Total estimated water withdrawals and use (Mgal/d)
Border Hill Mobile Home Park	Charlestown	SG	60	0.004	100	0.007	0.005
Castle Rock Condominiums	Charlestown	BD	292	.020	292	.020	.020
Central Beach Fire District	Charlestown	SG	120	.008	1,000	.067	.023
Crescent Club[1]	Charlestown	BD	--	--	--	--	--
Ninigret Realty Company (Land Harbor)	Charlestown	BD	25	.002	225	.015	.005
Shady Harbor Fire District	Charlestown	SG and BD	162	.011	162	.011	.011
South Coastal Basin total			659	0.045	1,779	0.120	0.064

[1]Population data not available.

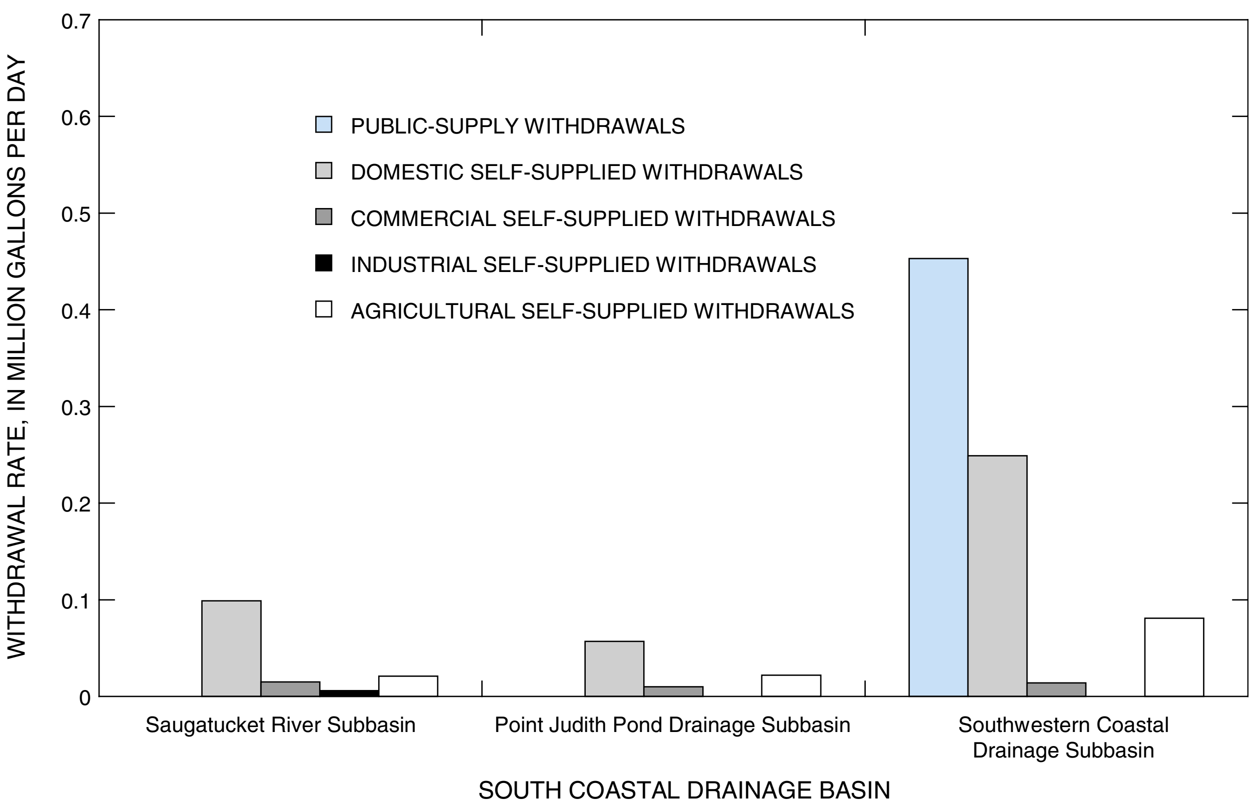

Figure 8. Public-supply withdrawals and self-supplied domestic, commercial, industrial, and agricultural withdrawals for the subbasins in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

Table 10. Ground- and surface-water withdrawals by town and subbasin in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

[Public-supply, domestic, commercial, and industrial water withdrawals are from ground water (wells). For agricultural withdrawals, 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 estimated to be public-supply withdrawals. Mgal/d, million gallons per day; <0.001, value not included in totals; <, actual value is less than value shown; --, not applicable]

Towns	Public-supply withdrawals (Mgal/d)	Self supply withdrawals (Mgal/d)				Total (Mgal/d)
		Domestic	Commercial	Industrial	Agricultural	
Saugatucket River Subbasin						
Exeter	--	<0.001	--	--	--	<0.001
Narragansett	--	<.001	--	--	--	<.001
North Kingstown	--	.010	--	--	0.001	.011
South Kingstown	--	.089	0.015	0.006	.020	.130
Subbasin total	--	0.099	0.015	0.006	0.021	0.141
Point Judith Pond Drainage Subbasin						
Narragansett	--	0.006	--	--	0.003	0.009
South Kingstown	--	.051	0.010	--	.019	.080
Subbasin total	--	0.057	0.010	--	0.022	0.089
Southwestern Coastal Drainage Subbasin						
Charlestown	0.064	0.186	0.012	--	0.007	0.269
South Kingstown	.389	.050	.002	--	.025	.466
Westerly	--	.013	--	--	.049	.062
Subbasin total	0.453	0.249	0.014	--	0.081	0.797
South Coastal Drainage Basin						
Basin total	0.453	0.405	0.039	0.006	0.124	1.027

The South Kingstown Water Department supplies the domestic, industrial, and commercial water users in the southern part of the town, along the coast, with water from withdrawal wells, about 0.389 Mgal/d from 1995 through 1999. Wholesale purchases from UWRI were about 0.040 Mgal/d, but solely serve the Middlebridge area in the Pettaquamscutt subbasin of the Narragansett Bay Drainage Basin. The South Kingstown Water Department accounts for 13 percent of the public-supply use in the basin and 11 percent of the total water use in the South Coastal Drainage Basin. Water distributions for the South Kingstown Water Department are summarized in figure 11.

The UWRI system includes the Tuckertown (four wells) and Howland (two wells) wellfields that are in the Pawcatuck Basin, and this water-supply system withdrew an average of 2.603 Mgal/d during the study period from the Mink aquifer. For the retail distributions, about 1.292 Mgal/d of the UWRI water-supply system is imported to the South Coastal Drainage Basin for use from the Pawcatuck Basin and about 0.399 Mgal/d of the water used in the Narragansett Bay Drainage Basin is exported for use from the Pawcatuck Basin. The UWRI retail distribution was 73 percent of the total use in the Saugatucket subbasin, 51 percent of the total use in the Point Judith Pond subbasin, and 45 percent of the total use in the basin. The withdrawals, estimated imports, and estimated distributions for use are summarized in figure 12 for the UWRI water-supply system.

The Westerly Water Department withdrew an average of 3.236 Mgal/d during the study period from the aquifers in the Pawcatuck Basin. The Westerly Water Department imported about 10 percent of the total water used in the South Coastal Drainage Basin. The water withdrawals, estimated imports, and estimated distributions for use are summarized in figure 13 for the Westerly Water Department.

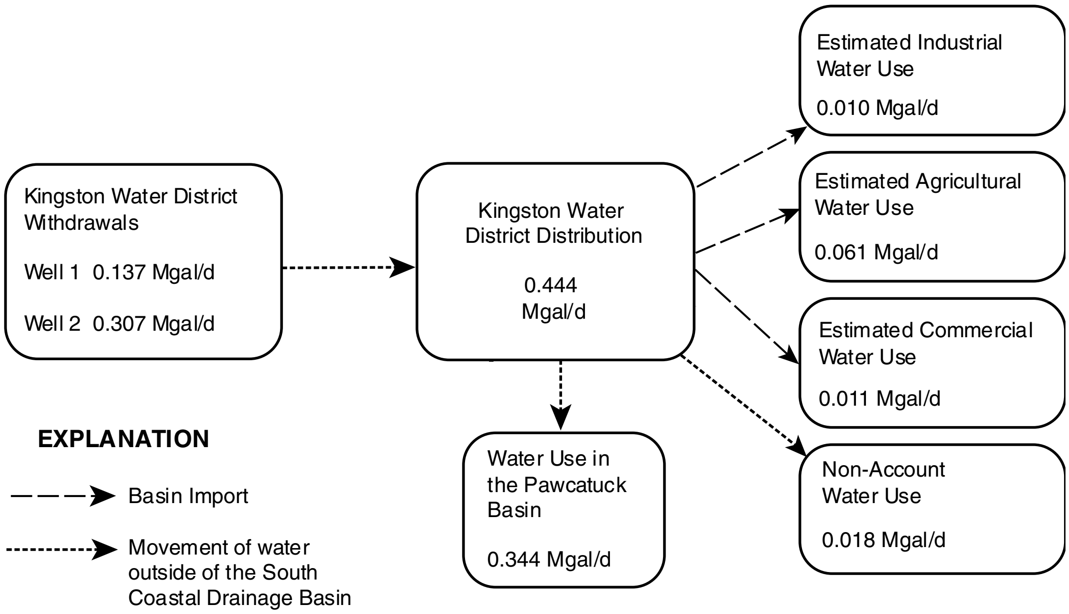

Figure 9. Kingston Water District withdrawals, distribution, and estimated water uses in the South Coastal Drainage Basin and basin exports, 1995–99 (Mgal/d, million gallons per day).

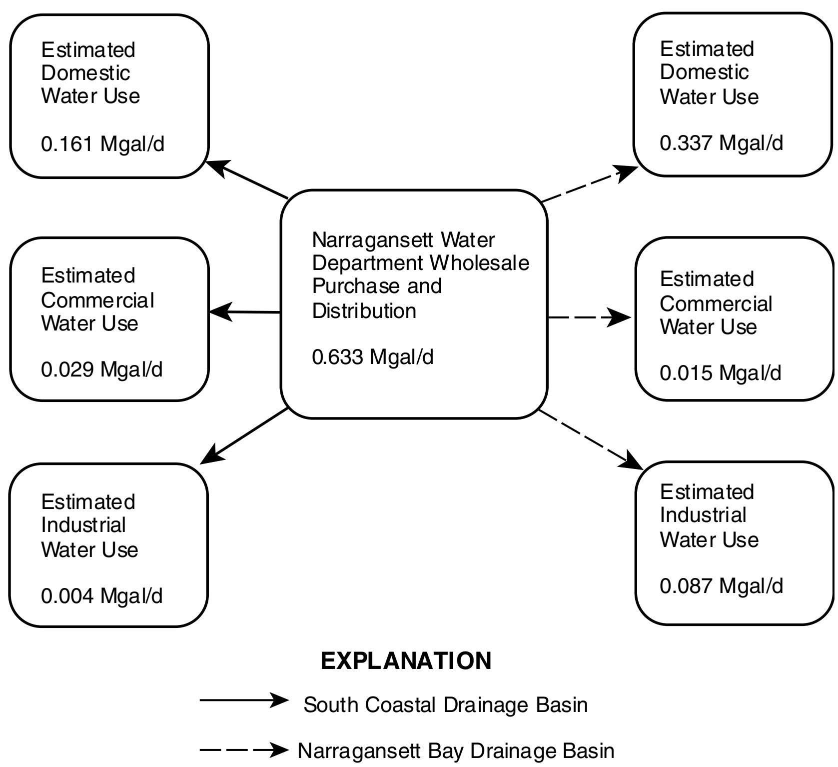

Figure 10. Narragansett Water Department wholesale purchases and estimated water uses in the South Coastal Drainage Basin and Narragansett Bay Drainage Basin, 1995–99 (Mgal/d, million gallons per day).

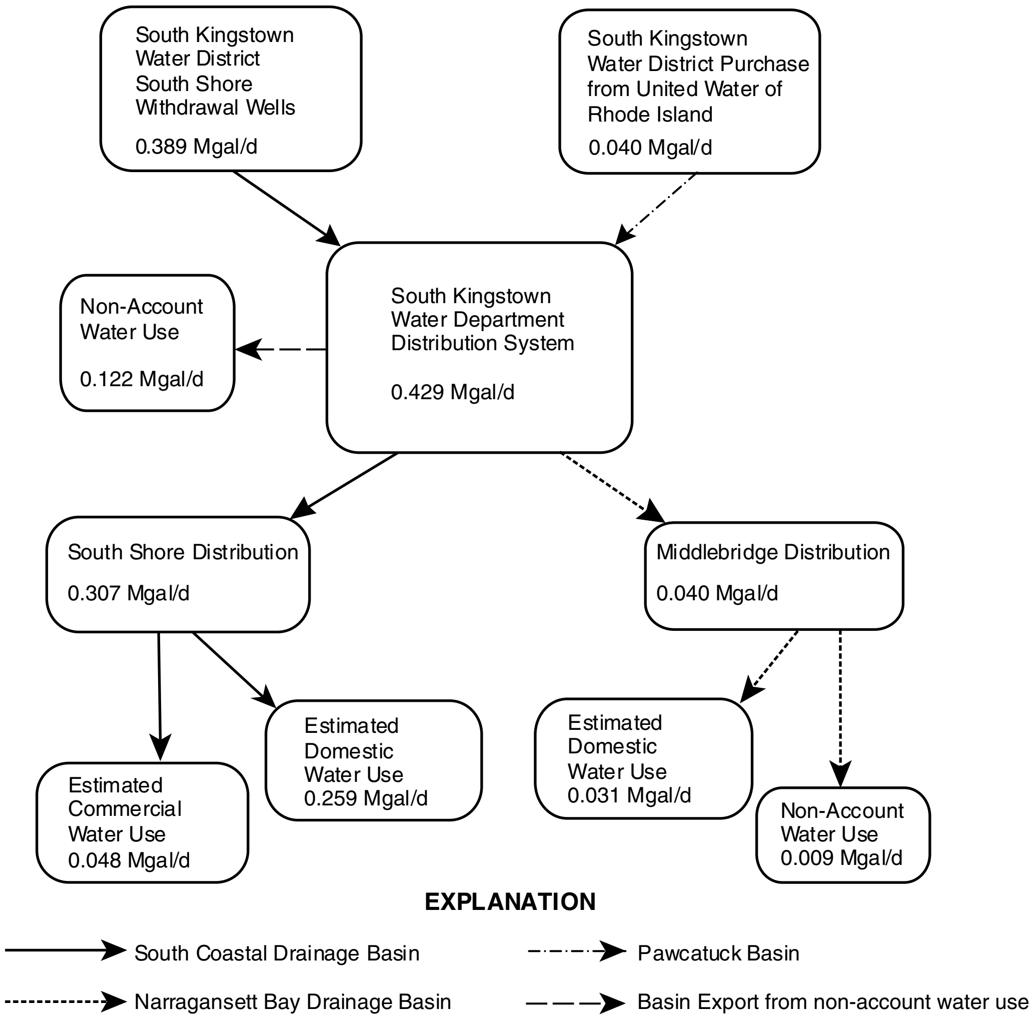

Figure 11. South Kingstown Water Department withdrawals, distributions, and estimated water uses in the South Coastal Drainage Basin and Narragansett Bay Drainage Basin, 1995–99 (Mgal/d, million gallons per day).

Six minor water suppliers serve the South Coastal Drainage Basin in Charlestown (table 9). Limited data are available on these water withdrawals from the minor public-water suppliers; therefore, water withdrawals and use were estimated by applying the water-use coefficient (67 gal/d/person in Rhode Island) for public-water supply (Korzendorfer and Horn, 1995). Because populations were available only for five of the minor suppliers, estimated water withdrawals and use were calculated for these minor public-water suppliers. In addition, three minor suppliers have a considerable increase of population during the summer months, and therefore, water withdrawals were estimated for the average fall-winter-spring population (0.045 Mgal/d, for September through May) and for the summer population (0.120 Mgal/d, for June through August). The total estimated annual water withdrawals in the basin for minor suppliers was 0.064 Mgal/d. Estimated water withdrawals for the individual minor suppliers ranged from 0.002 Mgal/d to 0.020 Mgal/d in the fall-winter-spring months (September through May); from 0.007 Mgal/d to 0.067 Mgal/d, in the summer months (June through August); and from 0.005 Mgal/d to 0.023 Mgal/d, annually.

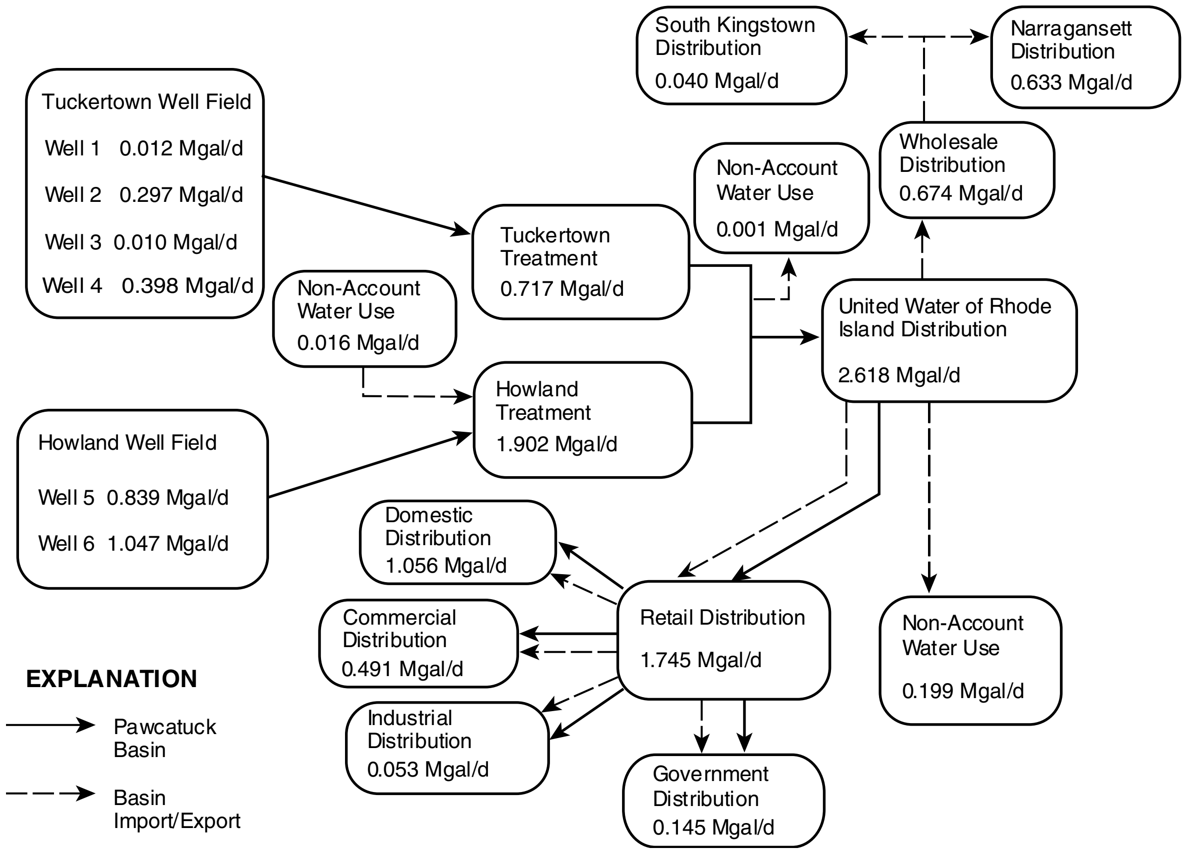

Figure 12. United Water of Rhode Island withdrawals, treatment, distributions, and non-account water use in the South Coastal Drainage Basin and basin exports, 1995–99 (Mgal/d, million gallons per day).

Three systems transfer public-supply water into the South Coastal Drainage Basin. The Kingston Water District imports about 0.082 Mgal/d to the South Coastal Drainage Basin from the Pawcatuck Basin. The UWRI system distributes water to retail users within the South Coastal Drainage Basin, as well as to areas outside the study area, in the West Narragansett Bay Drainage Basin and the Pawcatuck Basin. The 1995 through 1999 average amount of wholesale water purchased by South Kingstown from UWRI was 0.040 Mgal/d. The 1995 through 1999 average amount of wholesale water purchased by the Narragansett Water Department from UWRI was 0.633 Mgal/d, which was exported from the Pawcatuck Basin to the West Narragansett Bay Drainage Basin. Parts of the Westerly Water Department retail service area are in the South Coastal Drainage Basin, and approximately 0.288 Mgal/d was imported from the Pawcatuck Basin to this area in the South Coastal Drainage Basin.

Domestic Water Use

Domestic water use is the amount of water used by residential populations either served by public-water supplies or self-supplied users on private wells. The domestic water-use category includes the public-water supply deliveries to users within the political or hydrologic boundaries in the study area. Domestic withdrawals were estimated from the 1990 census coverages available through RIGIS. The coverage has the 1990 self-supply populations on private wells. The coverages then were separated by subbasin. To obtain the populations on public-water supplies, the self-supplied populations were subtracted from the total population in the subbasins. 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-supplied domestic water use, and 67 gal/d/person for public-supply domestic water use, which were from the 1990 national water-use compilation (Korzendorfer and Horn, 1995).

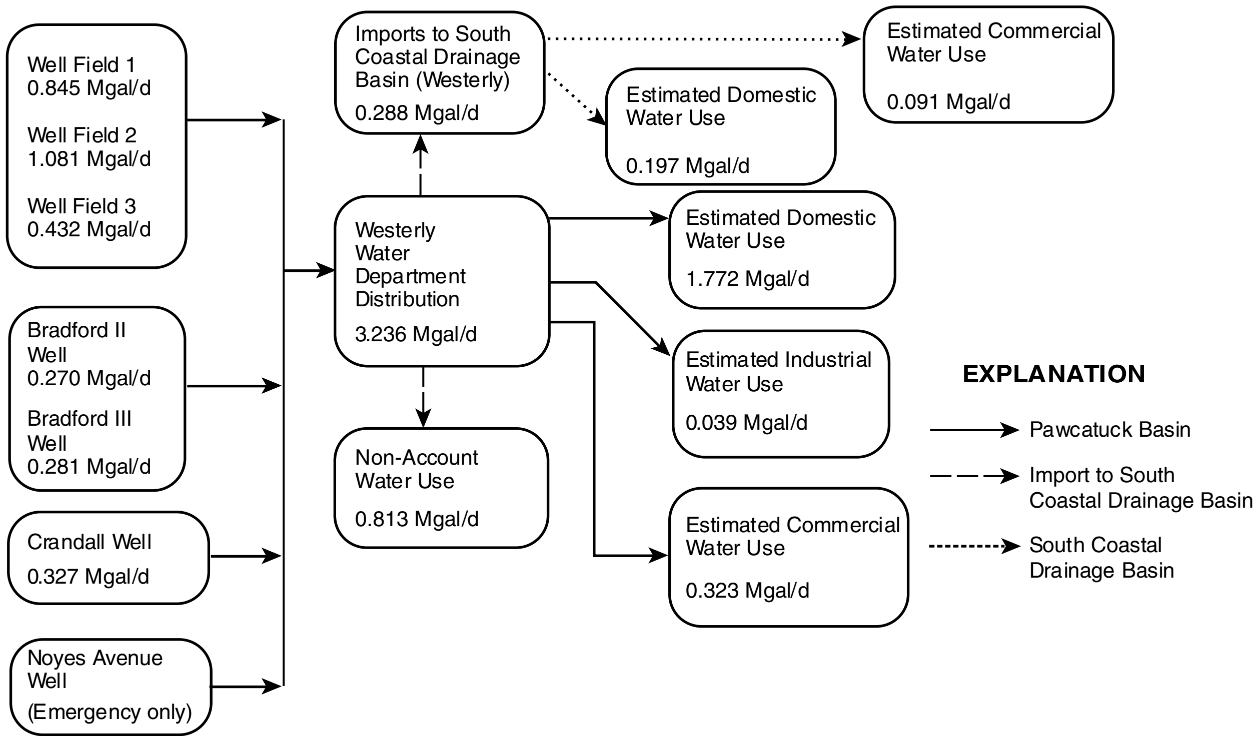

Figure 13. Westerly Water Department withdrawals, distributions, and estimated water uses in the South Coastal Drainage Basin and basin exports, southern Rhode Island and southeastern Connecticut, 1995–99 (Mgal/d, million gallons per day).

Public-Supply Use

Because the water suppliers provide information on populations served within towns rather than subbasins, GIS was used to estimate subbasin populations on public supply by merging the 1990 census blocks that have the domestic populations on private wells with the subbasin coverage. The 1990 population that supplies its own water was subtracted from the total population for each subbasin. The ratio of the 1990 to 1995 through 1999 populations was applied in each subbasin to obtain the populations on public-supply and self-supplied water by subbasin for each town (table 1). Because limited withdrawal data are available for the six minor public suppliers in the basin, the water-use coefficient was applied to populations served for each entity (Korzendorfer and Horn, 1995).

Public-supply water uses in the subbasins from the minimum to the maximum in the basin were 0.415 Mgal/d in the Point Judith Pond Drainage subbasin, 0.420 Mgal/d in the Southwestern Drainage subbasin, and 0.615 Mgal/d in the Saugatucket River subbasin for domestic users. The estimated domestic uses of publicly supplied water by town are listed in table 11 and illustrated in figure 14.

Self-Supplied Use

Domestic use of self-supplied water was calculated by merging the basin coverages with the U.S. Census 1990 population coverages obtained through RIGIS. The 1990 census blocks have the population using private wells. The 1995 through 1999 population using self-supplied water for each subbasin was estimated from the 1990 population and from the 1995 through 1999 ratio of growth within each subbasin (table 1). Domestic water withdrawals and uses in the subbasins were 0.057 Mgal/d in the Point Judith Pond Drainage subbasin, 0.099 Mgal/d in the Saugatucket River subbasin, and 0.249 Mgal/d in the Southwestern Coastal Drainage subbasin for self-supplied users (figs. 8 and 14, tables 10 and 11).

Table 11. Estimated water use by town and subbasin in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

[All towns are in Rhode Island unless otherwise noted. All water use is in million gallons per day. <0.001, value not included in totals; <, actual value is less than value shown; --, not applicable]

Town	Domestic supply		Commercial supply		Industrial supply		Agricultural supply		Total
	Public	Self	Public	Self	Public	Self	Public	Self	
Saugatucket River Subbasin									
Exeter	--	<0.001	--	--	--	--	--	--	<0.001
Narragansett	0.004	<.001	--	--	--	--	--	--	.004
North Kingstown	.027	.010	--	--	--	--	--	0.001	.038
South Kingstown	.584	.089	0.403	0.015	0.048	0.006	0.061	.020	1.226
Subbasin total	0.615	0.099	0.403	0.015	0.048	0.006	0.061	0.021	1.268
Point Judith Pond Drainage Subbasin									
Narragansett	0.332	0.006	0.183	--	0.004	--	--	0.003	0.528
South Kingstown	.083	.051	.035	0.010	--	--	--	.019	.198
Subbasin total	0.415	0.057	0.218	0.010	0.004	--	--	0.022	0.726
Southwestern Coastal Drainage Subbasin									
Charlestown	[1]0.064	0.186	--	0.012	--	--	--	0.007	0.269
South Kingstown	.159	.050	0.025	.002	--	--	--	.025	.261
Westerly	[2].197	.013	[2].091	--	--	--	--	.049	.350
Subbasin total	0.420	0.249	0.116	0.014	--	--	--	0.081	0.880
South Coastal Drainage Basin									
Basin total	1.450	0.405	0.737	0.039	0.052	0.006	0.061	0.124	2.874

[1]All minor public-supply use.

[2]Westerly public-supply use is seasonal; therefore, the average annual distributions for 1995–99 were used instead of the public-water-supply coefficient for domestic use.

Commercial and Industrial Water Use

Limited data are available on commercial and industrial water use from public-water supply and self-supplied systems, because withdrawals and use for these water-use categories (figs. 8 and 14) are not regulated in Rhode Island. Commercial and industrial water-use estimates, therefore, were derived from the total water calculated and divided by basin and subbasin for each town based on the land-use type. Commercial and industrial consumptive water use (table 12) is assumed to be 10 percent of the total water use (Solley and others, 1998).

Public-Supply Use

Information on commercial and industrial use of public-supply water included metered (or reported) and unmetered water-use data. When the data were available, the public suppliers provided the delivery volume and the number of service connections for commercial and industrial water users. In some cases, the suppliers have reported the commercial and industrial users together; and in other cases, the information was not available. Governmental water use is accounted for within the commercial water-use category, according to the Standard Industrial Classification (SIC) codes. For this study, government water use was entered as a separate distribution into NEWUDS, if the supplier collected the data to this level of detail. Because some water-supply district service areas are within one or more basins and subbasins, the public-supplied commercial and industrial water use were apportioned on the basis of land-use area percentages (tables 4 and 5). Land-use coverages from RIGIS were merged with the water supply, town, and basin coverages to obtain the percentage of commercial and industrial land use within the supply districts for towns served in the South Coastal Drainage Basin. Commercial uses of public-supply water were 0.116 Mgal/d in the Southwestern Coastal Drainage subbasin, 0.218 Mgal/d in the Point Judith Pond Drainage subbasin, and 0.403 Mgal/d in the Saugatucket River subbasin. Industrial uses of public-supply water were 0.004 in the Point Judith Pond Drainage subbasin, 0.048 Mgal/d in the Saugatucket River subbasin, and there was no industrial use on public supply in the Southwestern Coastal Drainage subbasin.

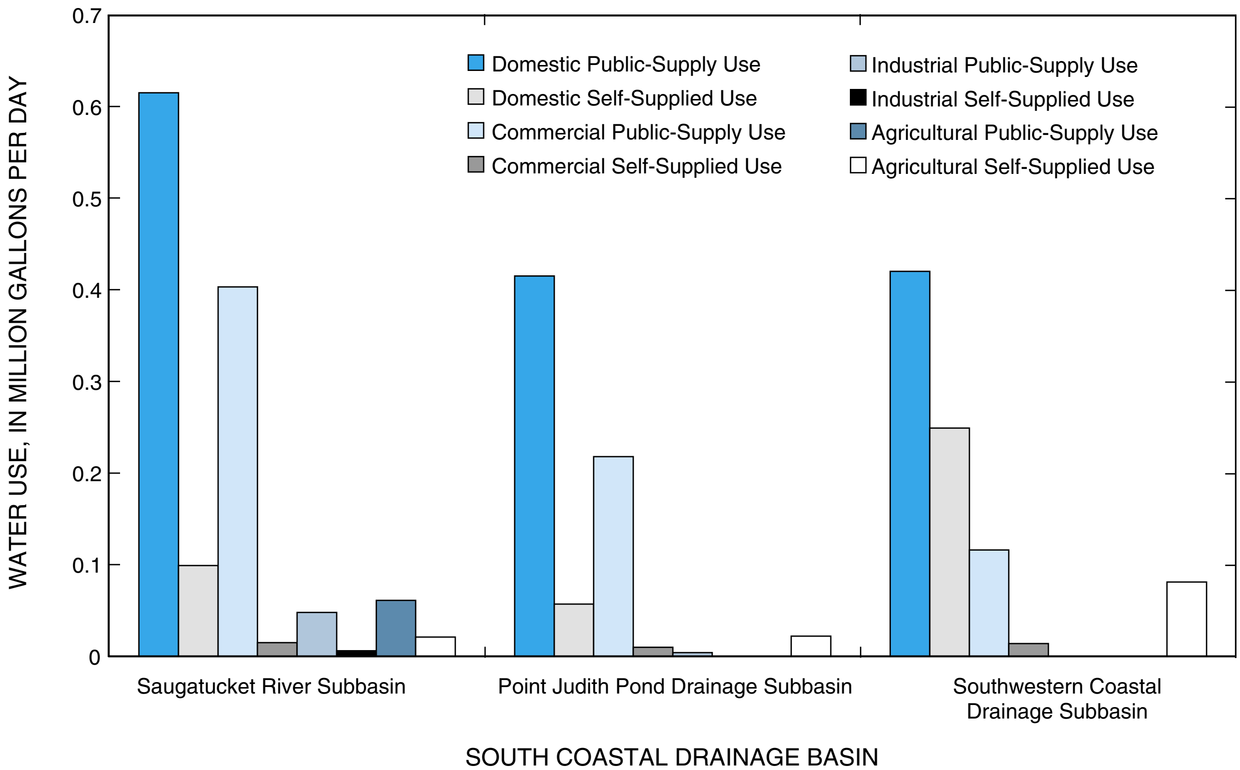

Figure 14. Public-supply and self-supplied domestic, commercial, industrial, and agricultural water use for the subbasins in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

Self-Supplied Use

Commercial and industrial use of self-supplied water was calculated from industrial and commercial directories available from the RIEDC (Export/Import Directory, High Tech Industries in Rhode Island, and Major Employers in Rhode Island). Commercial and industrial water use was estimated for each town by identifying the number of employees for the industrial and commercial sectors for each SIC code and applying the U.S. Army Corp of Engineers' Institute for Water Resources Municipal and Industrial Needs (IWR-MAIN) water-use coefficient (in gallons/day/person) for each town (table 13) as described in Horn (2000). The estimated commercial and industrial land-use areas within the public-supply districts were subtracted from the total aggregate land-use areas to obtain the estimated total self-supplied use for these categories. The results for commercial and industrial withdrawals and use are listed in tables 10 and 11. The total commercial and industrial water use estimated for a town was disaggregated by basin (table 8), and then by subbasin based on the industrial and commercial land-use area by town as listed in table 3. Commercial uses of self-supplied water were 0.010 Mgal/d in the Point Judith Pond Drainage subbasin, 0.014 Mgal/d in the Southwestern Coastal Drainage subbasin, and 0.015 Mgal/d in the Saugatucket River subbasin (figs. 8 and 14). The only self-supplied industrial water use in the South Coastal Drainage Basin was 0.006 Mgal/d in the Saugatucket River subbasin. Commercial and industrial water use by subbasin and town are listed in table 11.

Agricultural Water Use

Estimated agricultural water use (livestock, crop irrigation, and golf-course irrigation) was obtained from information provided from the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), and the RIDEM Division of Agriculture. An estimated value was calculated for each town and then disaggregated into the State basins and subbasins. Livestock withdrawals and use were assumed to be 9 percent from surface water (streams and ponds) and 82 percent from ground water (wells) on the basis of previously estimated statewide livestock water use from the former SCS (1993). Withdrawals and use for irrigation (golf courses and crops) were assumed to be 81 percent from surface water and 13 percent from ground water, on the basis of previously estimated statewide irrigation water use (Soil Conservation Service, 1993). The remaining 9 percent of livestock use and 6 percent of irrigation use were assumed to be from public-supply distributions.

Table 12. Consumptive water use by town and subbasin in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

[All towns are in Rhode Island unless otherwise noted. All water use is in million gallons per day. <0.001, value not included in totals; <, actual value is less than value shown; --, not applicable]

Town	Domestic		Commercial		Industrial		Agricultural		Total
	Public	Self	Public	Self	Public	Self	Public	Self	
Saugatucket River Subbasin									
Exeter	--	<0.001	--	--	--	--	--	--	<0.001
Narragansett	0.001	<.001	--	--	--	--	--	--	.001
North Kingstown	--	.006	--	--	--	--	--	0.001	.007
South Kingstown	.069	.032	0.040	0.001	0.005	0.001	0.061	.020	.229
Subbasin total	0.070	0.038	0.040	0.001	0.005	0.001	0.061	0.021	0.237
Point Judith Pond Drainage Subbasin									
Narragansett	0.019	0.032	0.018	--	<0.001	--	--	0.003	0.072
South Kingstown	.002	.018	.003	0.001	--	--	--	.019	.043
Subbasin total	0.021	0.050	0.021	0.001	<0.001	--	--	0.022	0.115
Southwestern Coastal Drainage Subbasin									
Charlestown	--	0.037	--	0.001	--	--	--	0.007	0.045
South Kingstown	--	.031	--	.003	--	--	--	.025	.059
Westerly	--	.031	--	.009	--	--	--	.049	.089
Subbasin total	--	0.099	--	0.013	--	--	--	0.081	0.193
South Coastal Drainage Basin									
Basin total	0.091	0.187	0.061	0.015	0.005	0.001	0.061	0.124	0.545

Livestock water requirements also are included in agricultural water use and include water-use estimates for each type of livestock (Laura Medalie, U.S. Geological Survey, written commun., 1995) multiplied by the number of livestock. 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 by town and then basin on the basis of the number of farms in the town and the percentage of agricultural land use by town and by basin. The livestock water-use estimates represent a year-round usage. For this study, agricultural water use is assumed to be 100-percent consumed on the basis of previous investigations (Horn and others, 1994). Although it is estimated that 60 percent of livestock water use is consumptive, and 40 percent is returned to the ground water (Horn and others, 1994), this distinction was negligible for the subbasins in the South Coastal Drainage Basin. Livestock water use is minor in the basin, accounting for about 1.7 percent of the agricultural water use during the summer and about 5.6 percent of the agricultural water use during the study period.

Crop and golf-course irrigation were estimated with a method derived by the USGS water-use specialists in Vermont and New Hampshire during previous water-use compilations (Laura Medalie, U.S. Geological Survey, written commun., 2000). The percentage of agricultural land-use area for each town was estimated by using the percentage of total land-use area in the county. The town acreage determined was subdivided by basin and subbasin. For the resulting acreage of crop irrigation for the portions of the towns in the South Coastal Drainage Basin, it was assumed that 1 in/week/acre of water was needed to irrigate crop land, an average of 0.143 in/day/acre. The monthly deficiency of water 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 using the Web sites from 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 courses for the towns in the South Coastal Drainage Basin. The coefficient used for this study was comparable to the metered (or reported) withdrawal data summarized for the 2000 water-use compilation for Massachusetts, where the average withdrawals were approximately 0.0117 Mgal/d per 1,000 yards (Wild and Nimiroski, 2004). According to the Soil Conservation Service (1993), most of the irrigation occurred during June, July, and August; therefore, it was assumed that crop- and golf-course-irrigation water was used during these months. A concurrent USGS study is presently (2003)

Table 13. Estimated water use per 2-digit Standard Industrial Classification code by town in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

[IWR-MAIN, Institute for Water Resources Municipal and Industrial Needs; Mgal/d, Million gallons per day; <0.001, value not included in totals; <, actual value is less than value shown; --, not applicable]

2-digit Standard Industrial Classification category and code	IWR-MAIN coefficient	Estimated water use (Mgal/d)				
		Charlestown	Exeter	Narragansett	South Kingstown	Westerly
Industrial [20-39]						
Food [20]	469	--	--	0.103	0.052	0.006
Textile Mills [22]	315	--	--	--	.008	.111
Finished apparel [23]	13	--	--	--	--	--
Wood, lumber [24]	78	--	--	--	--	--
Furniture [25]	30	--	--	--	--	--
Paper Products [26]	863	--	--	--	--	--
Printing, Publishing [27]	42	--	--	--	--	--
Chemical Products [28]	289	--	--	--	.003	--
Petroleum Refining [29]	104	--	--	--	--	--
Rubber [30]	119	--	0.024	--	--	--
Leather [31]	148	--	--	--	--	--
Stone, clay, glass, and concrete [32]	202	--	--	--	--	--
Primary metals [33]	178	--	--	--	--	.001
Fabricated metal [34]	95	0.004	--	--	--	--
Machinery [35]	58	<.001	--	<.001	--	.012
Electrical equipment [36]	71	--	--	--	.110	.005
Transportation equipment [37]	63	--	--	--	.001	--
Instruments [38]	66	--	--	--	.007	--
Jewelry, precious metals [39]	36	--	--	--	--	.004
Total industrial [20-39]	--	0.004	0.024	0.103	0.181	0.139
Commercial [40-97]						
Transportation, communication, utilities [40-49]	51	--	--	--	--	0.001
Wholesale trade [50-51]	58	--	--	0.001	--	--
Retail trade [52-59]	58	--	--	.025	0.014	.076
Finance, insurance, real estate [60-67]	71	--	--	--	--	.028
Services [70-89]	106	0.016	0.017	.035	.365	.091
Public administration [91-97]	71	--	--	.011	--	--
Total commercial [40-97]	--	0.016	0.017	0.072	0.379	0.196

collecting data on crop and golf-course irrigation in the adjacent Pawcatuck Basin; however, the data were unavailable at the time of the data-collection process for this study.

In the South Coastal Drainage Basin, some agricultural water use was from public-supply water. In the Kingston Water District, agricultural water use was one of the largest uses, consuming an average of 66 percent of the water distributions, and 0.061 Mgal/d in the basin during the study period (table 11).

Self-supplied agricultural water use was estimated to obtain the self-supplied water use by town and was then disaggregated by basin and by subbasin. Self-supplied water withdrawals and uses for agriculture were 0.021 Mgal/d in the Saugatucket River subbasin, 0.022 Mgal/d in the Point Judith Pond Drainage subbasin, and 0.081 Mgal/d in the Southwestern Coastal Drainage subbasin (figs. 8 and 14, tables 10 and 11).

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 into surface water (usually to rivers) and ground water. When reported data from dischargers are not available, the return flow is estimated. Examples of estimated data are domestic, commercial, and industrial entities on septic systems, which are assumed to return water to the environment in the ground. The estimated ground-water return flow in the South Coastal Drainage Basin was 1.190 Mgal/d (table 14). Interbasin transfers are wastewater, or potable water as previously discussed in other sections of this report, imports and exports, to and from the basin or subbasin, respectively. Wastewater interbasin transfers are conveyed across hydrologic divides, basins, and subbasins. The wastewater is an import, or a gain to the basin, if it is collected from another basin or subbasin and returned to the study area. An export, or a loss to the basin, occurs when the wastewater in the basin is collected, processed, and returned to the environment outside of the study area.

Site-Specific Return Flow

Small return-flow systems in Rhode Island that release water back to the environment are identified through the RIDEM Rhode Island Pollutant Discharge Elimination System (RIPDES), and some are required to report their discharges. Discharge pipes dispose of water used during industrial and commercial processes (operations). Part of that water includes water condensation from air-conditioning systems, which discharge to the environment. There were no reported RIPDES discharges in the South Coastal Drainage Basin during the 1995 through 1999 study period, although there were unmetered discharges to the study area, by way of RIDPES return flow discharged to salt water.

Table 14. Estimated public- and self-disposed domestic, commercial, and industrial disposal, and metered return flow by subbasin in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

[All towns are in Rhode Island unless otherwise noted. All values in million gallons per day. Public disposal is wastewater collection to treatment plant; Self-disposal is inflow to ground water; RIPDES, Rhode Island Pollution Discharge Elimination System; RIPDES and wastewater-treatment facilities, inflow to surface water; <0.001, value not included in totals; <, actual value is less than value shown; --, not applicable]

Town	Estimated domestic disposal		Estimated commercial disposal		Estimated industrial disposal		Metered return flow		Total self disposal and return flow
	Public	Self	Public	Self	Public	Self	RIPDES	Wastewater-treatment facilities	
Saugatucket River Subbasin									
Exeter	--	<0.001	--	--	--	--	--	--	<0.001
Narragansett	0.002	.001	--	--	--	--	--	--	.001
North Kingstown	--	.031	--	--	--	--	--	--	.031
South Kingstown	.389	.183	0.363	0.014	0.043	0.005	--	--	.202
Subbasin total	0.391	0.215	0.363	0.014	0.043	0.005	--	--	0.234
Point Judith Pond Drainage Subbasin									
Narragansett	0.124	0.163	0.165	--	0.004	--	--	--	0.163
South Kingstown	.014	.100	.032	0.009	--	--	--	--	.109
Subbasin total	0.138	0.263	0.197	0.009	0.004	--	--	--	0.272
Southwestern Coastal Drainage Subbasin									
Charlestown	--	0.212	--	0.011	--	--	--	--	0.223
South Kingstown	--	.177	--	.024	--	--	--	--	.201
Westerly	--	.178	--	.082	--	--	--	--	.260
Subbasin total	--	0.567	--	0.117	--	--	--	--	0.684
South Coastal Drainage Basin									
Basin total	0.529	1.045	0.560	0.140	0.047	0.005	--	--	1.190

Aggregate Return flow

Aggregate return flow was estimated for domestic, industrial, and commercial water use. Populations on public wastewater collection were used to determine the populations on septic systems (self-disposed water) (table 1). It was assessed that 85 percent of the water used by domestic populations on septic systems was returned to ground water, on the basis of the estimate that 15 percent of the water used was consumed (Solley and others, 1998). To estimate the amount of domestic self-disposed wastewater, the population was multiplied by the water-use coefficient for self-supplied water use (71 gal/d/person), converted to million gallons per day, and then multiplied by the 85 percent. Self-disposed wastewater totals from domestic users were 0.215 Mgal/d in the Saugatucket River subbasin, 0.263 Mgal/d in the Point Judith Pond Drainage subbasin, and 0.567 Mgal/d in the Southwestern Coastal Drainage subbasin (table 14 and fig. 15). Self-disposed water totals from commercial users were 0.014 Mgal/d in the Saugatucket River subbasin, 0.009 Mgal/d in the Point Judith Pond Drainage subbasin, and 0.117 Mgal/d in the Southwestern Coastal Drainage subbasin. The only wastewater returned to the environment from aggregate industrial users was in the South Kingstown part of the Saugatucket River subbasin and the return flow was 0.005 Mgal/d. The other 15 percent of the water was assumed to be consumed (table 12). It is estimated that 90 percent of industrial and commercial return flow is disposed to ground water, where 10 percent is consumptive water use (Horn, 2000). A summary of the consumptive water use for domestic, commercial, industrial, and agricultural water users by subbasin is in table 12, and a summary of the return flow is in table 14.

Interbasin Transfers

Monthly data were collected for public disposal wastewater-treatment facilities in or serving the towns in the South Coastal Drainage Basin. The wastewater-treatment facilities serving populations in the basin include the South Kingstown Wastewater-Treatment Facility and the Narragansett Wastewater-Treatment Facility. The average discharge for the study period to Narragansett Bay from the South Kingstown system was 2.639 Mgal/d and from the Narragansett system was 0.665 Mgal/d. The estimated wastewater export from the South Coastal Drainage Basin in South Kingstown and Narragansett to the South Kingstown facility was 0.843 Mgal/d, and the estimated wastewater export from the South Coastal Drainage Basin in Narragansett to the Narragansett facility, commonly referred to as Scarborough, was 0.293 Mgal/d. The sum of the wastewater exports from

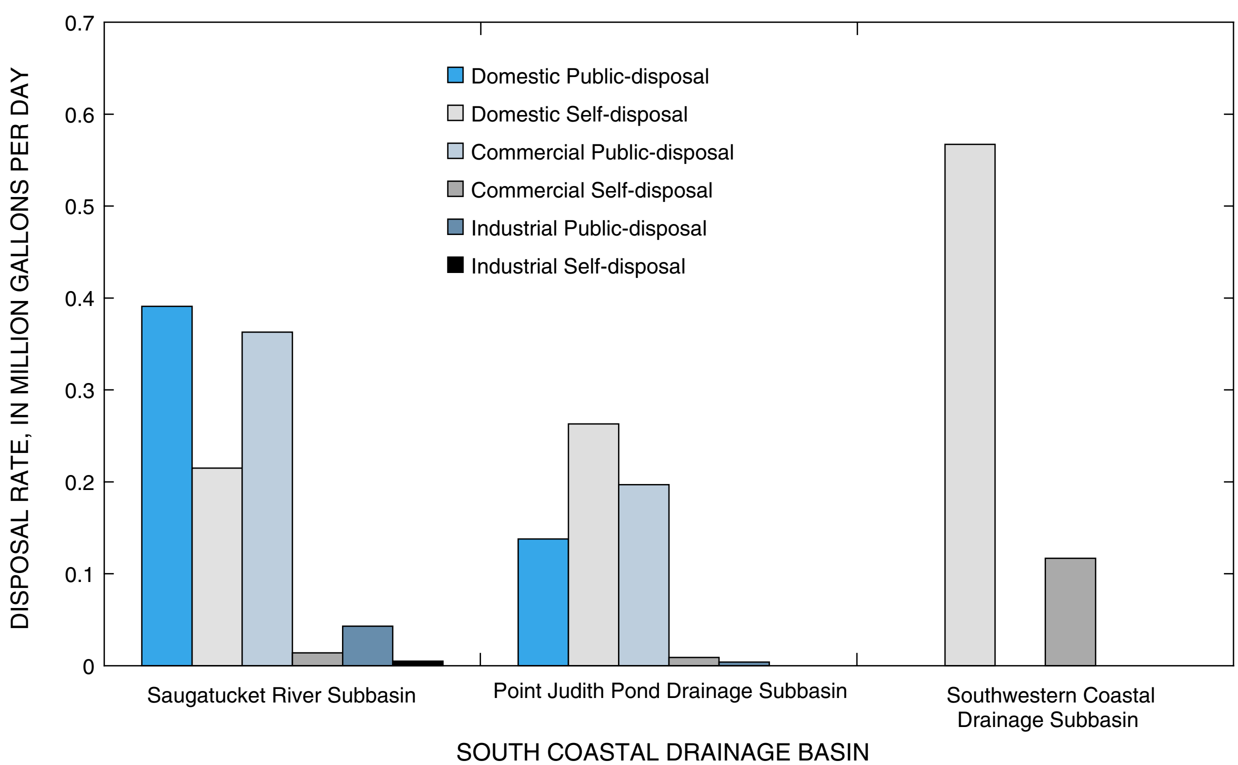

Figure 15. Public- and self-disposed wastewater for domestic, commercial, industrial, and agricultural users for the subbasins in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

Table 15. Summary of estimated water withdrawals, imports, exports, use, non-account use, consumptive use, and return flow in the South Coastal Drainage Basin, southern Rhode Island, 1995–99.

[Non-account use is a loss of water through the system. Consumptive use is a basin export. Net import and exports are the sum of the potable water and wastewater imports and exports and do not include non-account and consumptive water uses. AG, agricultural; COM, commercial; DOM, domestic; IND, industrial; Mgal/d, million gallons per day; +, potable distribution and wastewater collection imported to subbasin and basin; -, potable distribution and wastewater collection exported from subbasin and basin; <0.001, values not included in town and subbasin totals; <, actual value is less than value shown; --, water use 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)	Non-account (public use)		Surface water	Ground water		
Saugatucket	0.141	+1.214	1.268	0.087	0.237	--	0.234	-0.797	+0.417
Point Judith	.089	+.736	.726	.099	.115	--	.272	-.339	+.397
Southwestern	.797	+.202	.880	.119	.193	--	.684	-.003	+.199
South Coastal Drainage Basin total	1.027	+2.152	2.874	0.305	0.545	--	1.190	-1.139	+1.013

the basin was 1.139 Mgal/d, and potable water imports to the basin were 2.152 Mgal/d, which resulted in a net import to the basin of 1.013 Mgal/d. The total non-account water use for the basin was 0.305 Mgal/d, and the total consumptive use was 1.190 Mgal/d, which are considered losses not returned to the basin. The summary of estimated water withdrawals, imports, exports, use, non-account water use, consumptive use, and return flow in the South Coastal Drainage Basin and subbasins are summarized in table 15.

Water Availability

During periods of little or no precipitation, when direct runoff is assumed to be negligible, the flow in the stream is primarily from ground-water discharge. This type of streamflow is known as base flow. The computerized PART method (Rutledge, 1993, 1998) was used to obtain ground-water discharge to the streams during periods of little or no precipitation in the summer. Because water withdrawals can be higher during the summer, while the precipitation and ground-water discharge may be lower than average for the year, the ratio of the water withdrawals to water availability was assessed to determine the net availability of the water withdrawals to the hydrologic system during June, July, August, and September for the South Coastal Drainage Basin.

Water availability during periods of little or no precipitation was determined with streamflow data collected at the selected index stream-gaging station. In the South Coastal Drainage Basin, there has been no long-term stream-gaging data collection. The index stream-gaging station, Pawcatuck River at Wood River Junction (01117500), in the adjacent Pawcatuck Basin was used for the water availability in the South Coastal Drainage Basin. The Wood River Junction station is in close proximity to the South Coastal Drainage Basin and shares similar basin characteristics: percentage of sand and gravel deposits and the thickness of the sand and gravel deposits. The Westerly and Bradford ground-water aquifers in the Pawcatuck Basin share similar characteristics to the Lower Wood ground-water aquifer where average thicknesses of sand and gravel deposits were about 70 ft. As a result of these similarities, the water availability in the Lower Pawcatuck subbasin of the Pawcatuck Basin, which includes the Westerly and Bradford aquifers, was estimated by using the Pawcatuck River at Wood River Junction stream-gaging station in the Lower Wood subbasin of the Pawcatuck Basin (Wild and Nimiroski, 2004). Likewise in the South Coastal Drainage Basin, the average thickness of the sand and gravel deposits is similar to that in the Lower Wood subbasin of the Pawcatuck Basin. Because the estimated water availability is affected mainly by the average per unit area of sand and gravel deposits, the Wood River Junction station was a more representative index station for estimating the water availability in the South Coastal Drainage Basin. Other stream-gaging stations, Chipuxet, Usquepaug, Beaver, and Arcadia (table 16), were assessed because of their proximity to the South Coastal Drainage Basin. These four stations, however, were not used for this study because the characteristics upstream of the stations include higher ranges and average thicknesses of sand and gravel deposits, thus yielding higher flow rates, which is one of the aspects affecting the flow rates in the water-availability estimations at the stations. Water-availability estimates made from base-flow calculations

Table 16. U.S. Geological Survey stream-gaging stations and minimum streamflows in the Pawcatuck Basin, southern Rhode Island and southeastern Connecticut.

[Station drainage areas are from Socolow and others (2001). Water years are from October 1 to September 30, are designated by the calendar year in which they end, and may vary from the period of record. 7Q10, 7-day, 10-year flow (G.W. Parker, U.S. Geological Survey, written commun., 2002); ABF, Aquatic Base Flow, based on the median of the monthly means; USGS, U.S. Geological Survey; Mgal/d, million gallons per day; mi², square mile]

USGS stream-gaging station number (fig. 6)	Station name	Drainage area (mi²)	Percentage of sand and gravel	Annual mean flow (Mgal/d) [water years]	Minimum flows (Mgal/d)	
					7Q10 [water years]	ABF [water years]
01117350	Chipuxet River at West Kingston, RI	9.99	43	13.71 [1974–2000]	0.957 [1959–2001]	5.994 [1974–2000]
01117420	Usquepaug River near Usquepaug, RI	36.1	34	49.59 [1975–2000]	3.608 [1959–2002]	18.30 [1975–2000]
01117468	Beaver River near Usquepaug, RI	8.87	26	13.77 [1975–2000]	1.093 [1976–2002]	4.746 [1975–2000]
01117500	Pawcatuck River at Wood River Junction, RI	100	47	126.7 [1941–2000]	17.07 [1942–2002]	45.45 [1941–2000]
01117800	Wood River near Arcadia, RI	35.2	28	49.53 [1964–1981; 1983–2000]	4.209 [1964–1981; 1983–2000]	13.84 [1964–1981; 1983–2000]

are conservative estimates. Consequently, actual streamflows generally are greater than base flow except for periods of little or no recharge from precipitation.

The PART program, a hydrograph-separation application, was used at the selected index station, Wood River Junction, to determine water availability based on the 75th, 50th, and 25th percentiles of the total base flow, the base flow minus the 7-day, 10-year flow (7Q10) at the index station, and the base flow minus the Aquatic Base Flow (ABF) at the index station (table 16).

Contributions of base flow from surficial deposits, till and stratified sand and gravel, for the index station are based on previous work by the U.S. Geological Survey. The base-flow contributions from sand and gravel deposits at the index stations were 71 percent at the Wood River Junction stream-gaging station (Dickerman and others, 1997), and the base-flow contributions from till deposits at the index station were 29 percent at the stream-gaging station. The two contributions for June, July, August, and September were applied to the percentage of surficial deposits at the index station, and converted into a per unit area rate for the till areas and stratified sand and gravel areas in the basin. For the area upstream of the index station, about 47 percent of the surficial deposits are sand and gravel, and about 57 percent of the surficial deposits are till. The scenarios used to estimate the gross yield of base flow, as well as subtracting out the two low-flow criteria, resulted in various water-availability values at each index station, which were present in the basin after applying the per unit area rates from the index station (table 17).

Summer Water Availability

Because there is limited information to delineate the ground-water subbasins on the basis of contribution areas from sand and gravel deposits, the water availability assessed for the subbasin areas was based on the surface-water drainage divides. In the area near Blackberry Hill in South Kingstown, for example, the surface-water drainage area divide extends through sand and gravels deposits. The direction of the ground-water movement, however, is not known, and based on previous investigations, therefore, it can be assumed that this movement of water between the subbasins is negligible for this study. Similar situations are present within other basin water use and availability assessments in Rhode Island. For the Pawcatuck Basin, adjacent to the South Coastal Drainage Basin to the north, there were many previous investigations, including ground-water models, that determined ground-water drainage areas that were different from the surface-water drainage areas delineated for the WBD. In the Pawtuxet River Basin, the Providence-Warwick aquifer crosses the basin near the confluence along the Narragansett Bay shoreline, and

Table 17. Summer water availability for selected stream-gaging stations in the Pawcatuck Basin that were used in the South Coastal Basin, southern Rhode Island.

[7Q10, 7-day, 10-year 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]

Summer base flow for selected index stations	Estimated gross yield (Mgal/d)			Estimated gross yield for 7Q10 (Mgal/d)			Estimated gross yield for ABF (Mgal/d)		
	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Chipuxet Stream-Gaging Station									
June	14.01	9.273	6.653	13.04	8.303	5.683	8.020	3.279	0.660
July	8.822	4.918	3.676	7.852	3.948	2.706	2.828	--	--
August	7.123	5.070	3.296	6.153	4.100	2.326	1.130	--	--
September	5.134	4.191	3.012	4.164	3.221	2.043	--	--	--
Beaver Stream-Gaging Station									
June	14.94	8.865	7.158	13.84	7.772	6.065	10.19	4.119	2.412
July	6.505	5.121	3.718	5.412	4.028	2.625	1.759	.375	--
August	5.334	3.653	2.399	4.242	2.560	1.306	.588	--	--
September	4.358	3.188	2.160	3.265	2.065	1.067	--	--	--
Wood River Junction Stream-Gaging Station									
June	115.5	90.40	72.00	98.40	73.33	54.93	70.02	44.95	26.55
July	66.45	51.32	41.36	49.39	34.25	24.29	21.00	5.862	--
August	61.27	42.06	30.29	44.20	24.99	13.22	15.82	--	--
September	48.53	34.48	24.34	31.46	17.41	7.268	3.081	--	--

ground-water movement along the surface-water delineation is considered negligible. Additional analysis assessing the ground-water drainage areas would be needed in the State to resolve the differences in the basin and subbasin delineations in areas where the ground-water aquifers differ from surface-water drainage areas. In addition to further investigation for the subbasins in the South Coastal Drainage Basin, further investigation could be done to assess the gains and (or) losses to (from) the Pawcatuck Basin, which is separated from the South Coastal Drainage Basin by moraine deposits.

Water-availability estimates from the contributions of sand and gravel deposits and till deposits for all the scenarios at the 75th, 50th, and 25th percentiles in the South Coastal Drainage Basin are presented in table 18. In the basin the estimated water availability for the total gross yield at the 50th percentile ranged from 10.42 Mgal/d in September to 27.33 Mgal/d in June for the contributions from sand and gravel deposits, and ranged from 6.584 Mgal/d in September to 17.26 Mgal/d in June for the contributions from till deposits (table 18). Water availability in the basin at the 50th percentile for the gross yield ranged from 17.01 Mgal/d in September to 44.59 Mgal/d in June, and using the 7Q10 scenario ranged from 8.588 Mgal/d in September to 36.17 Mgal/d in June (table 18). The water-availability estimates in July from sand and gravel deposits at the 50th percentile for the total gross yield were 15.51 Mgal/d and were 9.799 Mgal/d from the till deposits in the South Coastal Drainage Basin. For the 7-day, 10-year low-flow scenario, the water-availability estimates in July from sand and gravel deposits at the 50th percentile for the gross yield were 10.35 Mgal/d, and were 6.540 from the till deposits in the South Coastal Drainage Basin. The total gross yields from surficial deposits for the South Coastal Drainage Basin are presented in table 18, and figure 16 illustrates the water availability from sand and gravel deposits and till deposits for June, July, August, and September at the 50th percentile for the gross yield, 7-day, 10-year low-flow scenario, and Aquatic Base Flow scenario by subbasin. There are some limitations in the application of this method along the coast, because saltwater intrusion can change the amount of fresh ground-water discharge to the coastal saltwater ecosystem. A ground-water system analysis evaluating these variances would provide additional information to assess the water availability along the coast.

The water withdrawals-to-availability ratios were calculated for June, July, August, and September as an indicator of basin and subbasin net water availability. The closer the ratio is to one, the closer the withdrawals are to the estimated water

Table 18. Estimated gross yield, gross yield for the 7-day, 10-year flow scenario, and gross yield for the Aquatic Base Flow scenario of water availability for June, July, August, and September in the South Coastal Drainage Basin, southern Rhode Island.

[Water availability was calculated by using the index stream-gaging station, the Pawcatuck River at Wood River Junction (01118000), in the Pawcatuck Basin. 7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow; Mgal/d, million gallons per day; --, values at 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
				Estimated Yields from Sand and Gravel Deposits					
Saugatucket	9.290	7.274	5.793	7.917	5.900	4.420	5.633	3.617	2.136
Point Judith	2.972	2.327	1.853	2.533	1.888	1.414	1.802	1.157	.683
Southwestern	22.64	17.73	14.12	19.29	14.38	10.77	13.73	8.814	5.206
Basin total	34.90	27.33	21.77	29.74	22.17	16.60	21.17	13.59	8.025
				Estimated Yields from Till Deposits					
Saugatucket	7.428	5.816	4.632	6.330	4.718	3.534	4.504	2.892	1.708
Point Judith	5.582	4.370	3.481	4.757	3.545	2.656	3.385	2.173	1.284
Southwestern	9.039	7.077	5.636	7.703	5.741	4.300	5.481	3.519	2.078
Basin total	22.05	17.26	13.75	18.79	14.00	10.49	13.37	8.584	5.070
				Total Estimated Yields					
Saugatucket	16.72	13.09	10.43	14.25	10.62	7.954	10.14	6.509	3.844
Point Judith	8.554	6.697	5.334	7.290	5.433	4.070	5.187	3.330	1.967
Southwestern	31.68	24.81	19.76	26.99	20.12	15.07	19.21	12.33	7.284
Basin total	56.95	44.59	35.52	48.53	36.17	27.09	34.54	22.17	13.10

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
				Estimated Yields from Sand and Gravel Deposits					
Saugatucket	5.349	4.129	3.328	3.973	2.756	1.954	1.690	0.472	--
Point Judith	1.711	1.321	1.065	1.271	.882	.625	.541	.151	--
Southwestern	13.03	10.06	8.110	9.684	6.716	4.763	4.118	1.149	--
Basin total	20.09	15.51	12.50	14.93	10.35	7.342	6.349	1.772	--
				Estimated Yields from Till Deposits					
Saugatucket	4.275	3.301	2.661	3.177	2.203	1.563	1.351	0.377	--
Point Judith	3.213	2.481	2.000	2.387	1.656	1.174	1.015	.283	--
Southwestern	5.202	4.017	3.238	3.866	2.681	1.902	1.644	.459	--
Basin total	12.69	9.799	7.899	9.430	6.540	4.639	4.010	1.119	--
				Total Estimated Yields					
Saugatucket	9.624	7.430	5.989	7.150	4.959	3.517	3.041	0.849	--
Point Judith	4.924	3.802	3.065	3.658	2.538	1.799	1.556	.434	--
Southwestern	18.23	14.08	11.35	13.55	9.397	6.665	5.762	1.608	--
Basin total	32.78	25.31	20.40	24.36	16.89	11.98	10.36	2.891	--

Table 18. Estimated gross yield, gross yield for the 7-day, 10-year flow scenario, and gross yield for the Aquatic Base Flow scenario of water availability for June, July, August, and September in the South Coastal Drainage Basin, southern Rhode Island.—Continued

[Water availability was calculated by using the index stream-gaging station, the Pawcatuck River at Wood River Junction (01118000), in the Pawcatuck Basin. 7Q10, 7-day, 10-year flow; ABF, Aquatic Base Flow; Mgal/d, million gallons per day; --, values at 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
Estimated Yields from Sand and Gravel Deposits									
Saugatucket	4.930	3.384	2.437	3.556	2.011	1.063	1.273	--	--
Point Judith	1.577	1.083	.780	1.138	.643	.340	.407	--	--
Southwestern	12.01	8.247	5.938	8.667	4.900	2.591	3.101	--	--
Basin total	18.52	12.71	9.155	13.36	7.554	3.994	4.781	--	--
Estimated Yields from Till Deposits									
Saugatucket	3.942	2.706	1.948	2.843	1.608	0.850	1.017	--	--
Point Judith	2.962	2.033	1.464	2.137	1.208	.639	.765	--	--
Southwestern	4.796	3.292	2.371	3.460	1.956	1.035	1.238	--	--
Basin total	11.70	8.031	5.783	8.440	4.772	2.524	3.020	--	--
Total Estimated Yields									
Saugatucket	8.872	6.090	4.385	6.399	3.619	1.913	2.290	--	--
Point Judith	4.539	3.116	2.244	3.275	1.851	.979	1.172	--	--
Southwestern	16.81	11.54	8.309	12.13	6.856	3.626	4.339	--	--
Basin total	30.22	20.75	14.94	21.80	12.33	6.518	7.801	--	--

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
Estimated Yields from Sand and Gravel Deposits									
Saugatucket	3.905	2.774	1.958	2.531	1.401	0.585	0.248	--	--
Point Judith	1.249	.888	.626	.810	.448	.187	.079	--	--
Southwestern	9.516	6.761	4.772	6.169	3.414	1.425	.604	--	--
Basin total	14.67	10.42	7.356	9.510	5.263	2.197	0.931	--	--
Estimated Yields from Till Deposits									
Saugatucket	3.122	2.218	1.566	2.024	1.120	0.468	0.198	--	--
Point Judith	2.346	1.667	1.177	1.521	.842	.351	.149	--	--
Southwestern	3.799	2.699	1.905	2.463	1.363	.569	.241	--	--
Basin total	9.267	6.584	4.648	6.008	3.325	1.388	0.588	--	--
Total Estimated Yields									
Saugatucket	7.027	4.992	3.524	4.555	2.521	1.053	0.446	--	--
Point Judith	3.595	2.555	1.803	2.331	1.290	.538	.228	--	--
Southwestern	13.32	9.460	6.677	8.632	4.777	1.994	.845	--	--
Basin total	23.94	17.01	12.00	15.52	8.588	3.585	1.519	--	--

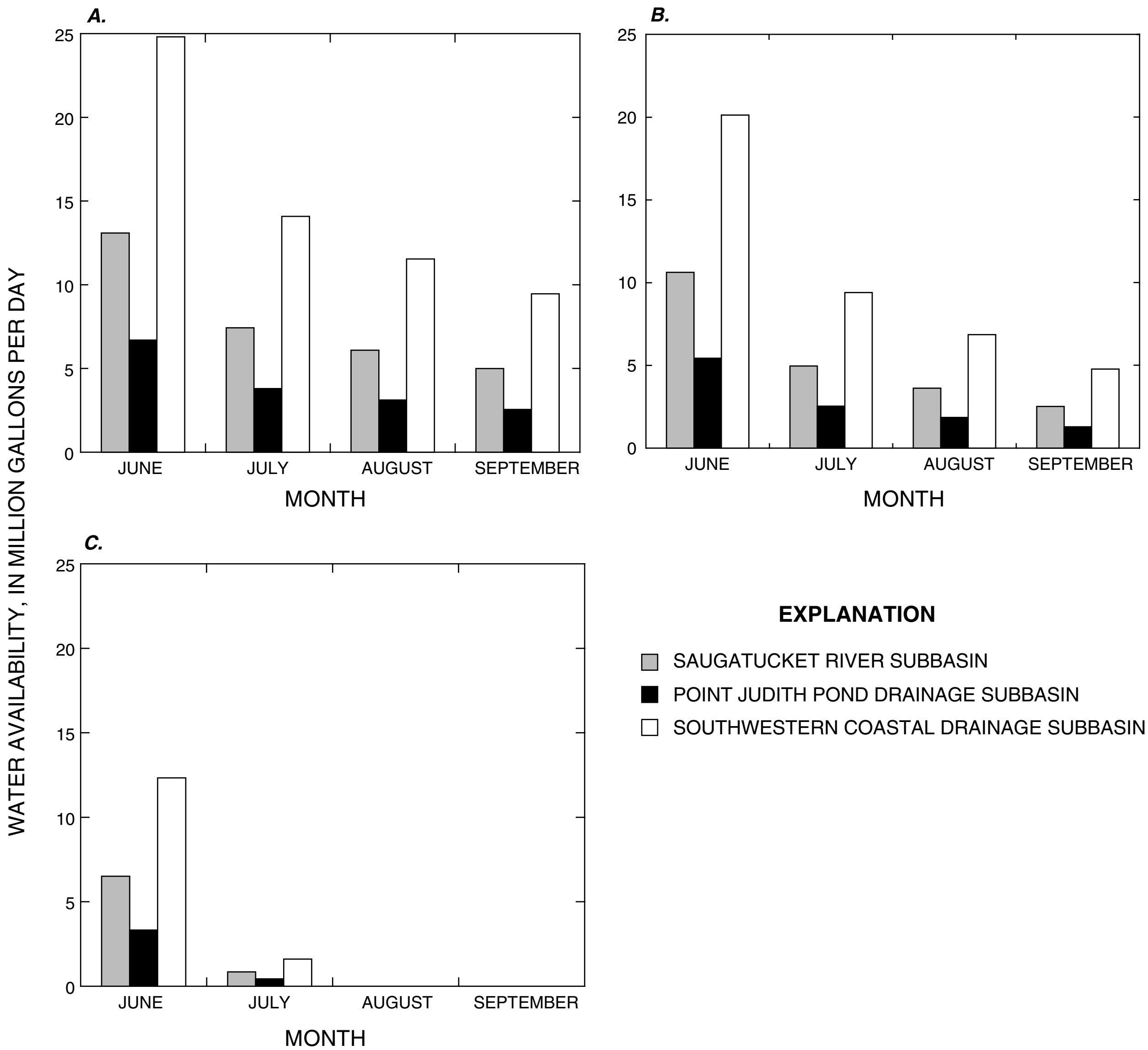

Figure 16. Estimated water availability for June, July, August, and September for the subbasins in the South Coastal Drainage Basin based on the *A*, 50th-percentile scenario; *B*, 50th percentile for the 7-day, 10-year flow scenario; and *C*, 50th percentile for the Aquatic Base Flow scenario.

available. The ratios were calculated by using the water-availability flow scenarios at the 75th, 50th, and 25th percentiles for the subbasins. These flow scenarios were based on total water available from base-flow contributions from till and sand and gravel deposits in the subbasins.

Water withdrawals in the summer ranged from 0.951 Mgal/d in September to 1.926 Mgal/d in July (table 19) in the South Coastal Drainage Basin. Although the water availabilities were lower in September at the 50th percentile for the gross yield, there were more withdrawals in July than in September in the basin (table 19). The analysis of the water withdrawals-to-availabilities resulted in higher ratios in July for the estimated gross yield and for the Aquatic Base Flow scenario. Other water-availability scenarios that resulted in higher ratios in July include the estimated gross yield at the 75th percentile and at the 75th percentile for the 7-day, 10-year low flow scenario. The results for the ratios for the gross-yield scenario at the 50th percentile ranged from 0.037 in June to 0.076 in July, and for the 7Q10 scenario the ratios ranged from 0.046 in June to 0.121 in August. The results for the ratios for the gross-yield scenario at the 75th percentile ranged from 0.029 in June to 0.059 in July, and for the 7Q10

Table 19. Monthly water withdrawals for June, July, August, and September and summary of water withdrawals-to-availability ratios for these months in the South Coastal Drainage Basin, southern Rhode Island.

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

Month	Withdrawals from the South Coastal Drainage Basin (Mgal/d)	Water withdrawals-to-availability ratios in the South Coastal Drainage Basin: Estimated gross yield			Estimated gross yield for 7Q10 scenario			Estimated gross yield for ABF scenario		
		75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile	75th percentile	50th percentile	25th percentile
Saugatucket River Subbasin										
June	0.216	0.013	0.017	0.021	0.015	0.020	0.027	0.021	0.033	0.056
July	.239	.025	.032	.040	.033	.048	.068	.079	.282	--
August	.135	.015	.022	.031	.021	.037	.071	.059	--	--
September	.122	.017	.024	.035	.027	.048	.116	.273	--	--
Point Judith Pond Drainage Subbasin										
June	0.169	0.020	0.025	0.032	0.023	0.031	0.042	0.033	0.051	0.086
July	.194	.039	.051	.063	.053	.076	.108	.125	.447	--
August	.083	.018	.027	.037	.025	.045	.085	.071	--	--
September	.069	.019	.027	.038	.030	.053	.128	.302	--	--
Southwestern Coastal Drainage Subbasin										
June	1.265	0.040	0.051	0.064	0.047	0.063	0.084	0.066	0.103	0.174
July	1.493	.082	.106	.132	.110	.159	.224	.259	.928	--
August	1.280	.076	.111	.154	.106	.187	.353	.295	--	--
September	.760	.057	.080	.114	.088	.159	.381	.899	--	--
South Coastal Drainage Basin										
June	1.650	0.029	0.037	0.046	0.034	0.046	0.061	0.048	0.074	0.126
July	1.926	.059	.076	.094	.079	.114	.161	.186	.666	--
August	1.498	.050	.072	.100	.069	.121	.230	.192	--	--
September	.951	.040	.056	.079	.061	.111	.265	.626	--	--

scenario the ratios ranged from 0.034 in June to 0.079 in July. The ratios of water withdrawals-to-availabilities for June, July, August, and September for the basin for the three scenarios at the 75th, 50th, and 25th percentiles are presented in table 19.

In the Saugatucket River subbasin, estimated water availability for the gross yield at the 50th percentile ranged from 2.774 Mgal/d in September to 7.274 Mgal/d in June for the contributions from the sand and gravel deposits, and ranged from 2.218 Mgal/d in September to 5.816 Mgal/d in June for the contributions from the till deposits (table 18). The total water availability in the subbasin at the 50th percentile for gross yield ranged from 4.992 Mgal/d in September to 13.09 Mgal/d in June, and for the 7Q10 scenario ranged from 2.521 Mgal/d in September to 10.62 Mgal/d in June. The average water withdrawals in the subbasin ranged from 0.122 Mgal/d in September to 0.239 Mgal/d in July for the study period (table 19). The results for the ratios for the total gross-yield scenario at the 50th percentile ranged from 0.017 in June to 0.032 in July, and for the 7Q10 scenario ranged from 0.020 in June to 0.048 in July and September (table 19). The variation of the water withdrawal-to-availability ratios in the subbasin for July, August, and September at the 50th percentile for the gross yield, for the 7-day, 10-year low-flow scenario, are illustrated in figure 17.

In the Point Judith Pond Drainage subbasin, estimated water availability for the gross yield at the 50th percentile ranged from 0.888 Mgal/d in September to 2.327 Mgal/d in June for the contributions from the sand and gravel deposits, and ranged from 1.667 Mgal/d in September to 4.370 Mgal/d in June for the contributions from the till deposits (table 18). The total water availability in the subbasin at the 50th percentile for gross yield ranged from 2.555 Mgal/d in September to 6.697 Mgal/d in June, and for the 7Q10 scenario ranged from 1.290 Mgal/d in September to 5.433 Mgal/d in June. The average water withdrawals in the subbasin ranged from 0.069 Mgal/d in September to 0.194 Mgal/d in July for the study period (table 19). The results for the ratios for the total gross-yield scenario at the 50th percentile ranged from

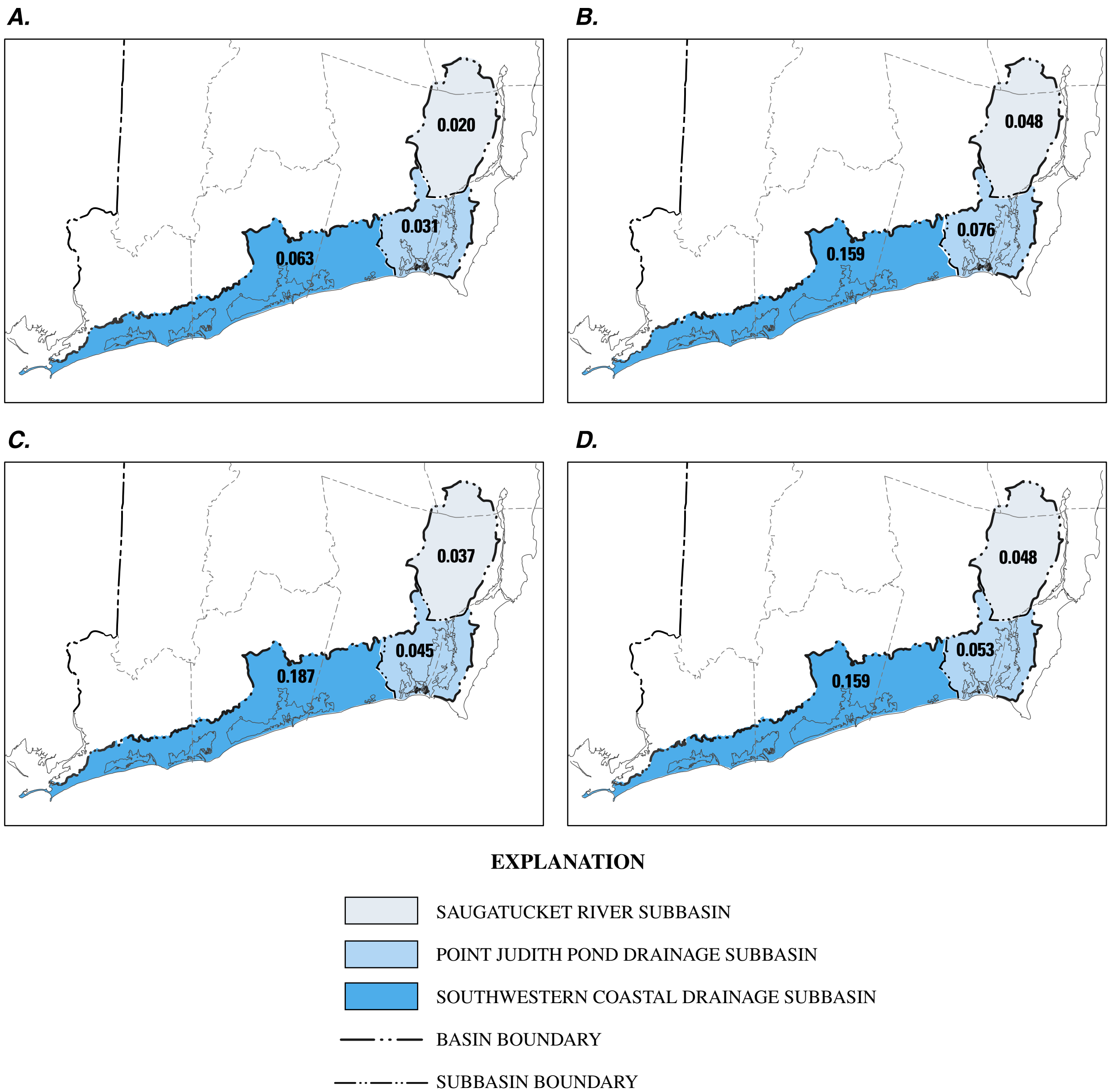

Figure 17. The water withdrawal-to-availability ratio in *A*, June; *B*, July; *C*, August; and *D*, September for the South Coastal Drainage Basin at the 50th percentile for the 7-day, 10-year flow scenario.

0.025 in June to 0.051 in September, and for the 7Q10 scenario ranged from 0.031 in June to 0.076 in July (table 19). The variation of the water withdrawal-to-availability ratios in the subbasin for July, August, and September at the 50th percentile for the gross yield, for the 7-day, 10-year low-flow scenario, are illustrated in figure 17.

In the South Coastal Drainage subbasin, estimated water availability for the gross yield at the 50th percentile ranged from 6.761 Mgal/d in September to 17.73 Mgal/d in June for the contributions from the sand and gravel deposits, and ranged from 2.699 Mgal/d in September to 7.077 Mgal/d in June for the contributions from the till deposits (table 18). The total water availability in the subbasin at the 50th percentile for gross yield ranged from 9.460 Mgal/d in September to 24.81 Mgal/d in June, and for the 7Q10 scenario ranged from 4.777 Mgal/d in September to 20.12 Mgal/d in June. The average water withdrawals in the subbasin ranged from 0.760 Mgal/d in September to 1.493 Mgal/d in July for the study period (table 19). The results for the ratios for the total gross-yield scenario at the 50th percentile ranged from 0.051 in June to 0.111 in August, and for the 7Q10 scenario ranged from 0.063 in June to 0.187 in August (table 19). The variation of the water withdrawal-to-availability ratios in the subbasin for July, August, and September at the 50th percentile for the gross yield, for the 7-day, 10-year low flow scenario, are illustrated in figure 17.

Water Budget

The South Coastal Drainage Basin water budget encompasses the hydrologic cycle and the water-use components, inflow and outflow to and from the basin. For a water budget, inflow minus outflow equals the change in storage in the basin. For this report, a long-term water budget was calculated where inflow equals outflow in the system. The change in water storage from surface-water bodies and ground-water aquifers is considered to be negligible in this water budget. Inflows to the basin include precipitation, streamflow from upstream subbasins, ground-water inflow, and return flow (septic systems, RIPDES, and wastewater-treatment facilities). Outflows from the basin include evapotranspiration, streamflow out of the subbasins, water withdrawals (public supplies and self-supplied domestic, commercial, industrial, and agricultural withdrawals), and ground-water underflow. The precipitation and evapotranspiration were calculated during a long-term period from 1941 through 2000. The return flow and withdrawals were calculated for the 1995 through 1999 study period. The water-budget components are summarized in table 20.

The South Coastal Drainage Basin is a hydrologically unique basin in Rhode Island because all of the subbasins drain into saltwater, and do not follow typical hydrological characteristics found inland. The water budget, or hydrologic budget, is an average annual assessment using long-term information pertinent to the hydrologic components and the short-term selected water-use components, and therefore was completed using each of the three defined subbasins as separate water budgets. The average precipitation at Kingston, RI, was calculated for the period of record reported in the water budget at the index station. For the South Coastal Drainage Basin, an average precipitation of 48.02 in/yr, from 1941 through 2000, was applied to the subbasins as

Table 20. Average water budget by subbasin for the South Coastal Drainage Basin, southern Rhode Island.

[in/yr, inch 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	Saugatucket subbasin	Point Judith Pond subbasin	Southwestern Coastal subbasin	South Coastal Drainage Basin
Estimated inflow (Mgal/d)				
Precipitation[1]	39.08	33.34	62.82	135.2
Streamflow from upstream subbasins	--	--	--	--
Ground-water inflow	--	--	--	--
Return flow[2]	.234	.272	.684	1.190
Total inflow	39.31	33.61	63.50	136.4
Estimated outflow (Mgal/d)				
Evapotranspiration[3]	17.50	14.93	28.13	60.56
Streamflow or coastal discharge[4, 5]	21.67	18.59	34.57	74.81
Water withdrawals[6]	.141	.089	.797	1.027
Ground-water underflow	--	--	--	--
Total outflow	39.31	33.61	63.50	136.4
Streamflow or coastal discharge per square mile (Mgal/d/mi^2)	1.268	1.275	1.258	1.265
Total drainage area at outlet (mi^2)	17.09	14.58	27.47	59.14

[1]Based on average precipitation (48.02 in/yr) at Kingston, RI, 1941–2000.

[2]Return flow based on the total return flow from septic systems in the subbasins of the South Coastal Drainage Basin, 1995–99.

[3]Evapotranspiration based on the difference between the average precipitation at Kingston, RI, and average monthly flow of the index stream-gaging station for the subbasin.

[4]Based on average monthly flow per unit area (1.263 Mgal/d/mi^2) at the stream-gaging station Pawcatuck River at Wood River Junction, RI, 1941–2000.

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

[6]Water-withdrawal types include domestic, commercial, industrial, and agricultural served by public- and self-supplied water in the subbasins of the South Coastal Drainage Basin, 1995–99.

2.287 Mgal/d/mi^2. Usually in a hydrologic budget, the outflow of surface water from upstream subbasins to a subbasin downstream is accounted for in the inflows. Because the surface-water outflow from Saugatucket River discharges to Point Judith Pond, a coastal salt pond in the Point Judith Pond Drainage subbasin, the inflow of surface water was not assessed as part of the Point Judith Pond Drainage subbasin hydrologic budget. In fact, all of three subbasins were assessed independently and summed for the South Coastal Drainage Basin. Estimating ground-water inflow was considered negligible for this study because of data availability. Return flow included the average 1995 through 1999 disposal of water from septic systems in the South Coastal Drainage Basin. Evapotranspiration was estimated on the basis of the difference between the precipitation and outflow at the confluence, which was based on the mean annual flow at the index stream-gaging station. The outflow of streamflow from each subbasin was estimated by using the sum of the inflows minus the withdrawals minus evapotranspiration. Finally, estimating ground-water underflow was considered negligible for this study because of data availability.

For the water budget, it was assumed that inflow equals outflow for the subbasins. The subbasins in the South Coastal Drainage Basin discharge into a salt pond (Saugatucket River subbasin) or to Rhode Island Sound along the Atlantic Coast (Point Judith Pond Drainage and Southwestern Drainage subbasins); therefore, the hydrologic budgets were calculated as individual hydrologic areas and then totalled for the study area. The total for the Saugatucket River subbasin was 39.31 Mgal/d. The estimated inflows from precipitation and water return flow were 99 and 1 percent, and the estimated outflows from evapotranspiration, streamflow, and water withdrawals were 45, 55, and less than 1 percent in the Saugatucket River subbasin, respectively. The total for the Point Judith Pond Drainage subbasin was 33.61 Mgal/d. The estimated inflows from precipitation and water return flow were 99 and 1 percent, and the estimated outflows from evapotranspiration, streamflow, and water withdrawals were 44, 55, and 1 percent in the Point Judith Pond Drainage subbasin, respectively. The total for the Southwestern Coastal Drainage subbasin was 63.50 Mgal/d. The estimated inflows from precipitation and water return flow were 99 and 1 percent, and the estimated outflows from evapotranspiration, streamflow, and water withdrawals were 44, 55, and 1 percent in the Southwestern Coastal Drainage subbasin, respectively (table 20).

Summary

The U.S. Geological Survey (USGS), in cooperation with the Rhode Island Water Resources Board (RIWRB), began a series of water-use and availability projects to better understand the relations between the water-use components and the components of the hydrologic cycle (surface and ground water) during periods of little to no recharge. The South Coastal Drainage Basin (59.14 mi^2), in southern Rhode Island, is one of the nine water-use and availability study areas in the State. The three subbasins in the South Coastal Drainage Basin were delineated on the basis of the surface-water drainage areas. The one major water supplier in the basin withdrew an average of 0.389 Mgal/d from the sand and gravel deposits in the subbasins during the 1995 through 1999 study period. The estimated water withdrawal total from minor suppliers during the study period was 0.064 Mgal/d. Self-supplied domestic, industrial, commercial, and agricultural withdrawals from the basin were 0.574 Mgal/d. Public-supply and self-supplied domestic, commercial, and industrial withdrawals in the basin were from ground water. Agricultural withdrawals for irrigation were assumed to be from surface water and ground water on the basis of previously published studies. Water use in the basin averaged 2.874 Mgal/d from 1995 through 1999. The average return flow in the basin was 1.190 Mgal/d, which was effluent from self-disposed wastewater.

The computerized PART program, a hydrograph-separation application, was used for data at the selected index stream-gaging station to determine water availability based on the 75th, 50th, and 25th percentiles of the total base flow, the base flow minus the 7-day, 10-year low-flow (7Q10) criteria at the index station, and the base flow minus the Aquatic Base Flow (ABF) criteria at the index station. The Pawcatuck River at Wood River Junction stream-gaging station (01117500) was used as the index station for the basin.

The surficial deposits are stratified sand and gravel deposits and till deposits. Contributions of base flow from surficial deposits for the index station are based on previous work by the U.S. Geological Survey. The base-flow contributions from sand and gravel deposits at the index station were 71 percent at the Wood River Junction stream-gaging station, and the base-flow contributions from till deposits at the index stations were 29 percent at the Wood River Junction stream-gaging station. The two contributions for June, July, August, and September were applied to the percentage of surficial deposits at the index station and converted into a per unit area rate for the till and sand and gravel areas in the subbasins. The scenarios used to estimate the gross yield of base flow, as well as subtracting out the two low-flow criterias resulted in various water-availability scenarios at the index station, which then were present in the basin after applying the per unit area rates from the index station. The results at the index stream-gaging station were lowest for the summer in September.

Water withdrawals and use are greater during the summer than other times in the year, and therefore, water availability in June, July, August, and September was assessed during these months in the South Coastal Drainage Basin. The average water withdrawals in the basin and subbasins were compiled by using metered withdrawals available from the major water supplier in the basin, the South Kingstown Water Department, and estimated for the minor suppliers, and for the self-supplied domestic, commercial, industrial, and agricultural entities. The average water withdrawals for the South Coastal Drainage Basin ranged from 0.951 Mgal/d in September to 1.926 Mgal/d in July for the study period. Water availability in the basin at the 50th percentile for the gross yield ranged from 17.01 Mgal/d in September to 44.59 Mgal/d in June, and for the 7Q10 scenario water availability in the basin ranged from 8.588 Mgal/d in September to 36.17 Mgal/d in June. There are some limitations in the application of this method along the coast, because saltwater intrusion can change the amount of fresh ground-water discharge to the coastal saltwater ecosystem. An analysis evaluating these variances in the ground-water system would provide additional information to assess water availability along the coast.

The water withdrawals-to-availability ratios were calculated for June, July, August, and September as an indicator of basin net availability. The closer the ratio is to one, the closer the withdrawals are to the estimated water available. The ratios were calculated by using the water-availability flow scenarios at the 75th, 50th, and 25th percentiles for the basin, based on total water available from base-flow contributions from till deposits and stratified sand and gravel deposits in the South Coastal Drainage Basin.

The withdrawals in July for the study period were higher than in the other summer months, and the water withdrawal-to-availability ratio was closer to one in the South Coastal Drainage Basin. The ratio at the 75th percentile for the basin was 0.059 for the gross-yield scenario, and 0.079 for the base flow minus the 7Q10 scenario at the index station for July. The results in the basin for the ratios in July at the 50th percentile were 0.076 for the gross-yield scenario and 0.114 for the base flow minus the 7Q10 scenario at the index station.

A long-term hydrologic budget (60 years) was calculated for the South Coastal Drainage Basin to identify and assess the basin and subbasin inflow and outflows. The water withdrawals and return flows used in the budget were from the period of study, 1995–99. For the hydrologic budget, it was assumed that inflow equals outflow, which resulted in 136.4 Mgal/d in the basin. Because the subbasins in the South Coastal Drainage Basin discharge into a salt pond (Saugatucket River subbasin) or to Rhode Island Sound (Point Judith Pond Drainage and Southwestern Drainage subbasins), the hydrologic budgets were calculated as individual hydrologic areas and then totalled for the study area. The estimated inflows from precipitation and water return flow were 99 and 1 percent in the basin, respectively. The estimated outflows from evapotranspiration, streamflow, and water withdrawals were 44, 55, and 1 percent in the basin, 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) Median flow during August established by the U.S. Fish and Wildlife Service and considered adequate flow to protect indigenous aquatic fauna throughout the year. It can be calculated as long as there is: "USGS 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 Service, 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 2-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 for household purposes, such as drinking, food preparation, bathing, washing, clothes and dishes, flushing toilets, and watering lawns and gardens. Households include single and multi-family 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 (the 2-digit Standard Industrial Classification codes 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 water-supply districts to convey water. These connections can be for wholesale distributions or used as water-supply backups.

Irrigation water use The artificial application of water on lands to assist in the growth of crops or pasture including in greenhouses. Irrigation water use may also include application of water to maintain vegetative growth in recreational lands such as parks and golf courses, including water used for 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, it is defined as 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, general equivalent to a city or town.

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

Non-account 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 Refers to 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 Water 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 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-supplied 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 Institute for Water Resources Municipal and Industrial Needs (IWR-MAIN) coefficients for industrial and commercial water use are based on the first two digits.

Surface-water return flow Effluent 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 hydrologic system for use, including public-water supply, industry, and commerce, domestic, irrigation, livestock, and thermoelectric power generation water uses.