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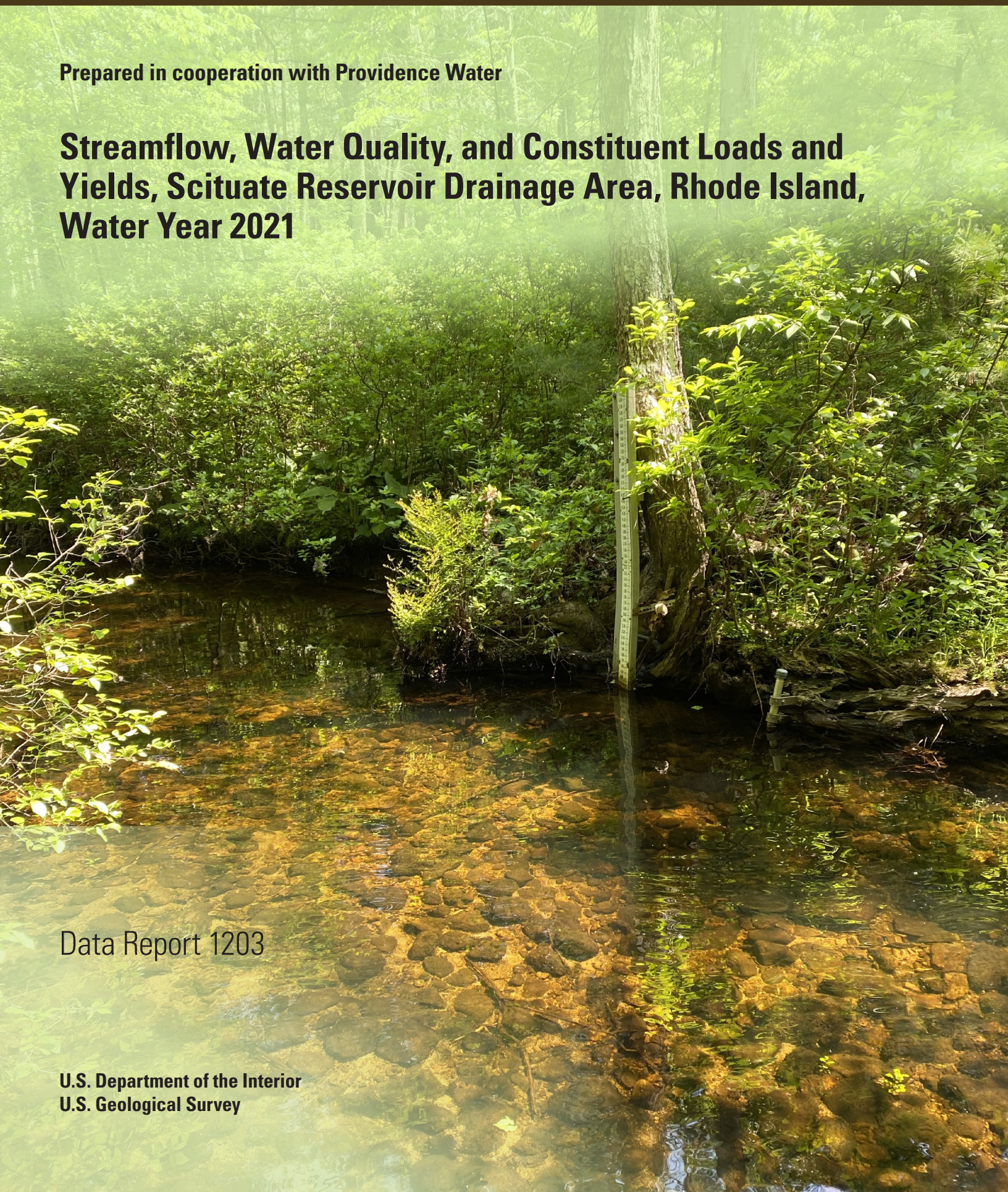
Streamflow, Water Quality, and Constituent Loads and Yields, Scituate Reservoir Drainage Area, Rhode Island, Water Year 2021



Data Report 1203

U.S. Department of the Interior
U.S. Geological Survey

Cover. Streamgage staff in Huntinghouse Brook makes up the U.S. Geological Survey Huntinghouse Brook at Elmdale Road at North Scituate, Rhode Island (station 01115110) streamgage; photograph by Phillip Woodford, U.S. Geological Survey.

Streamflow, Water Quality, and Constituent Loads and Yields, Scituate Reservoir Drainage Area, Rhode Island, Water Year 2021

By Kirk P. Smith and Alana B. Spaetzel

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Contents

Figures

Tables

Conversion Factors

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
liter (L)	0.03531	cubic foot (ft^3)
	Discharge	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
liter per day (L/d)	0.03531	cubic foot per day (ft3/d)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton (t)	1.102	ton, short [2,000 lb]
	Load	
gram per day (g/d)	0.0022	pound per day (lb/d)
kilogram per day (kg/d)	2.205	pound per day (lb/d)
metric ton per year (t/yr)	2205	pound per year (lb/yr)
	Yield	
kilogram per day per square mile ([kg/d]/mi^2)	2.590	kilogram per day per square kilometer ([kg/d]/km^2)
kilogram per day per square mile ([kg/d]/mi^2)	2.205	pound per day per square mile ([lb/d]/mi^2)
metric ton per year per square mile ([t/yr]/mi^2)	2.590	metric ton per year per square kilometer ([t/yr]/mi^2)
metric ton per year per square mile ([t/yr]/mi^2)	2205	pound per year per square mile ([lb/yr]/mi^2)

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Supplemental Information

Concentrations of constituents in water are given in either milligrams per liter (mg/L) or colony forming units per 100 milliliters (CFU/100 mL).

Loads of bacteria in water are given in million colony forming units per day).

Yields of bacteria are given in million colony forming units per day per square mile ($[(CFU \times 10^6)/d]/mi^2$).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Color is given in platinum-cobalt units (PCU).

A water year is the period from October 1 to September 30 and is designated by the year in which it ends; for example, water year 2020 was from October 1, 2019, to September 30, 2020.

Abbreviations

MOVE.1	Maintenance of Variance Extension type 1
NWIS	National Water Information System
PW	Providence Water (formerly Providence Water Supply Board)
USGS	U.S. Geological Survey
WY	water year

Streamflow, Water Quality, and Constituent Loads and Yields, Scituate Reservoir Drainage Area, Rhode Island, Water Year 2021

By Kirk P. Smith and Alana B. Spaetzel

Abstract

As part of a long-term cooperative program to monitor water quality within the Scituate Reservoir drainage area, the U.S. Geological Survey in cooperation with Providence Water (formerly Providence Water Supply Board) collected streamflow and water-quality data in tributaries to the Scituate Reservoir, Rhode Island. Streamflow and concentrations of chloride and sodium estimated from records of specific conductance for 16 tributaries were used to calculate loads of chloride and sodium during water year 2021 (October 1, 2020, through September 30, 2021). Water-quality samples were collected by Providence Water at 36 sampling stations on tributaries to the Scituate Reservoir during water year 2021. These water-quality data are summarized by using values of central tendency and are used, in combination with measured (or estimated) streamflows, to calculate loads and yields of selected water-quality constituents for water year 2021.

Annual mean streamflows for monitoring stations in this study ranged from 0.37 to 32.4 cubic feet per second during water year 2021. At the 16 continuous-record streamgages, tributaries transported about 2,900 metric tons (t) of chloride and 1,800 t of sodium to the Scituate Reservoir; annual chloride yields for the tributaries ranged from 15 to 110 metric tons per square mile (t/mi^2), and annual sodium yields ranged from 10 to 68 t/mi^2. At the stations where water-quality samples were collected by Providence Water, the medians of the median daily loads were 180 kilograms per day for chloride, 12 grams per day as nitrogen for nitrite, less than 700 grams per day as nitrogen for nitrate, 410 grams per day as orthophosphate for phosphate, 71,000 million colony forming units per day for coliform bacteria, and less than 2,000 million colony forming units per day for *Escherichia coli*. The medians of the median yields were 67 kilograms per day per square mile for chloride, 4.2 grams per day per square mile as nitrogen for nitrite, 400 grams per day per square mile as nitrogen for nitrate, 180 grams per day per square mile as orthophosphate as phosphate, 46,000 million colony forming units per day per square mile for coliform bacteria, and 1,000 million colony forming units per day per square mile for *Escherichia coli*.

Introduction

The Scituate Reservoir is the primary source of drinking water for more than 60 percent of the population of Rhode Island. The Scituate Reservoir drainage area consists of six subbasins and covers an area of about 94 square miles (mi^2) in parts of the towns of Cranston, Foster, Glocester, Johnston, and Scituate, R.I. (fig. 1). The six subbasins are referred to in this report as the Barden Reservoir, "Direct Runoff,", Moswansicut Pond reservoir, Ponaganset Reservoir, "Regulating reservoir,", and Westconnaug Reservoir subbasins ["informal" names are used for subbasins that do not have official names]. Information about the water quality of the reservoir and its tributaries is important for management of the water supply and for the protection of human health. Providence Water (PW; formerly the Providence Water Supply Board) is the agency responsible for the management and distribution of the Scituate Reservoir water supply and has been monitoring and assessing water quality in the reservoir and reservoir drainage area for more than 60 years.

Since 1993, the U.S. Geological Survey (USGS) has been cooperating with PW and the Rhode Island Department of Environmental Management to measure streamflow in tributaries to the Scituate Reservoir. Streamflow has been continuously measured at 10 streamgages in the drainage area (table 1) since 2009 by the USGS. Streamflow also was continuously measured at four streamgages from 2009 to 2014 and periodically measured at nine additional streamgages on tributaries in the drainage area. In October 2020, three streamgages began or resumed collection of continuous streamflow data (table 1). At 11 streamgages, daily mean streamflow was estimated for the period between October 1, 2020, and September 30, 2021, by using methods developed by the USGS (table 1; Hirsch, 1982). The USGS also has been continuously measuring specific conductance at 14 monitoring stations since 2009 and at 2 additional monitoring stations since 2020 (table 1). Equations that relate specific conductance to concentrations of chloride and sodium in stream water were developed as part of previous cooperative studies of the USGS and PW (Nimiroski and Waldron, 2002; Smith, 2015b, 2018a, 2022a, 2024; Spaetzel and Smith, 2022b). These equations, used

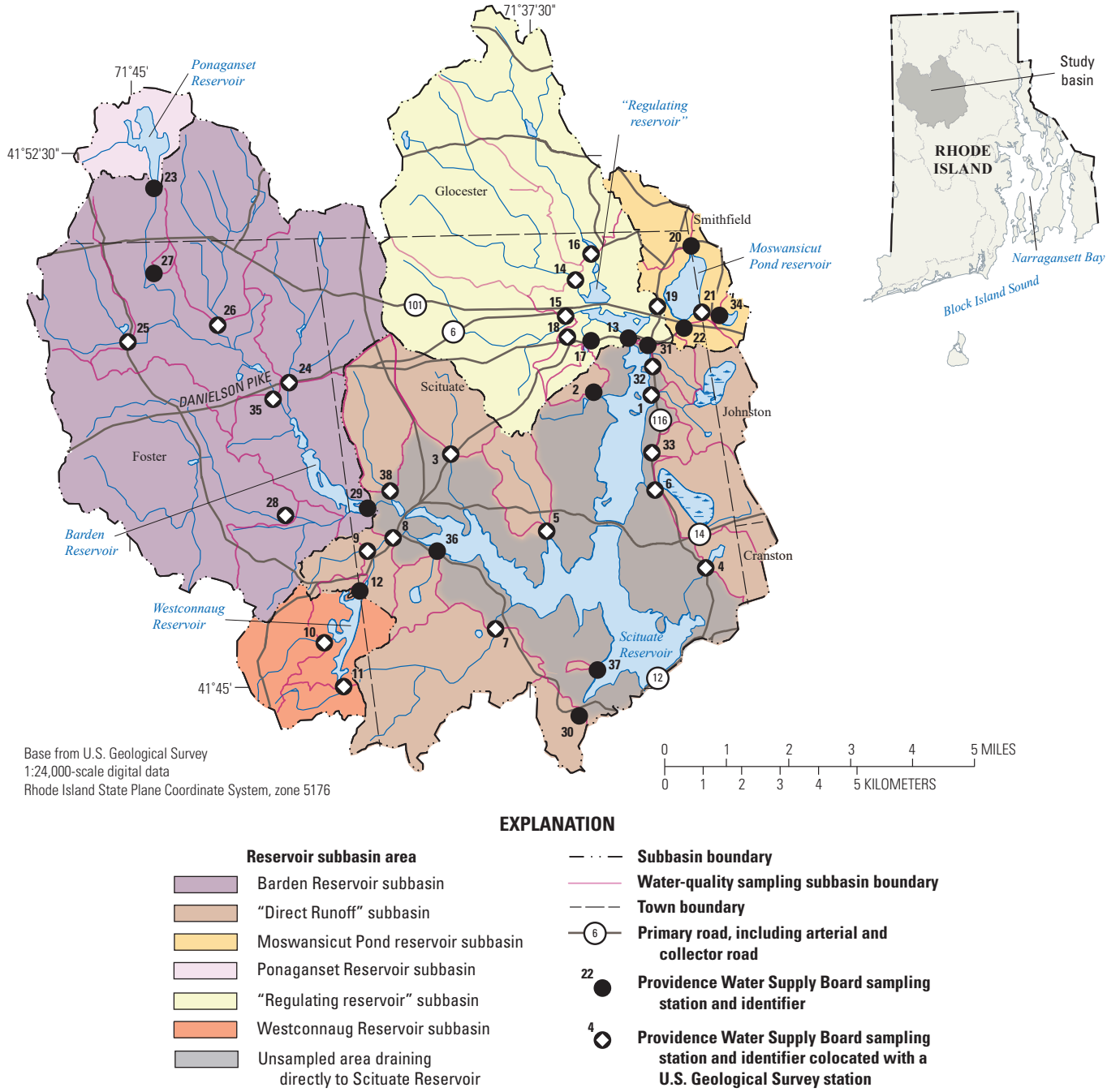

Figure 1. Map showing locations of tributary-reservoir subbasins and stations in the Scituate Reservoir drainage area, Rhode Island, in water year 2021 (October 1, 2020, through September 30, 2021). Modified from Breault (2009). Data are from Smith and Spaetzel (2021).

Table 1. Providence Water water-quality sampling stations and corresponding U.S. Geological Survey streamgages, in the Scituate Reservoir drainage area, Rhode Island, and data collection and monitoring statistics from October 1, 2020, to September 30, 2021.

[Data are from U.S. Geological Survey (2023). Alternate station names given in parenthesis for stations where different historical names were used for the same sampling location by Providence Water (PW). Locations of stations are shown on figure 1. USGS, U.S. Geological Survey; mi², square mile; WQ, water quality; Cl, chloride; Na, sodium; M, monthly; Q, quarterly; Y, yes; N, no; --, not applicable]

PW station number	USGS station number	USGS station short name	Alternate name	Drainage area (mi²)	Frequency of WQ sample collection by PW	Number of samples collected by PW[1]	Daily estimated Na and Cl loads	Streamflow data availability	Specific conductance data availability
Barden Reservoir subbasin									
24	01115190	Dolly Cole Brook	—	4.9	M	11	Y	Continuous	Continuous
25	01115200	Shippee Brook	—	2.37	Q	4	N	Estimated	None
26	01115185	Winsor Brook	—	4.33	Q	4	Y	Continuous[2]	Continuous[2]
27	011151845	Unnamed tributary to Ponaganset River	Unnamed brook B; unnamed brook west of Winsor Brook	0.10	Q	3	N	None	None
28	01115265	Barden Reservoir	Hemlock Brook	8.72	M	12	Y	Continuous	Continuous
29	01115271	Ponaganset River	Barden Stream	33.0	M	11	N	None	None
35	01115187	Ponaganset River	—	14.0	M	11	Y	Continuous	Continuous
Direct runoff subbasin									
1	01115180	Brandy Brook	—	1.57	M	11	N	Estimated	None
2	01115181	Unnamed tributary 2 to Scituate Reservoir	Unnamed brook north of Bullhead Brook	0.22	Q	2	N	None	None
3	01115280	Cork Brook	—	1.87	M	10	Y	Continuous	Continuous
4	01115400	Kent Brook	Betty Pond Stream	0.85	M	11	N	Estimated	None
5	01115184	Spruce Brook	—	1.26	Q	3	Y	Continuous[2]	Continuous
6	01115183	Quonopaug Brook	—	1.96	M	10	Y	Continuous	Continuous
7	01115297	Wilbur Hollow Brook	—	4.33	M	12	Y	Estimated	Continuous
8	01115276	Westconnaug Brook	Westconnaug Reservoir	5.18	M	11	Y	Continuous	Continuous
9	01115275	Bear Tree Brook	—	0.62	Q	4	Y	Estimated	Continuous
30	01115350	Unnamed tributary 4 to Scituate Reservoir	Coventry Brook, Knight Brook	0.79	Q	3	N	None	None
31	01115177	Toad Pond	—	0.03	Q	0	N	None	None
32	01115178	Unnamed tributary 1 to Scituate Reservoir	Pine Swamp Brook	0.45	Q	4	N	Estimated	None
33	01115182	Unnamed tributary 3 to Scituate Reservoir	Halls Estate Brook	0.28	Q	4	N	Estimated	None
36	—	Outflow from King Pond	—	0.76	Q	4	N	None	None
37	—	Fire tower stream	—	0.03	Q	3	N	None	None
38	01115278	Swamp Brook	—	1.92	—	0	Y	Continuous[2]	Continuous[2]

Table 1. Providence Water water-quality sampling stations and corresponding U.S. Geological Survey streamgages, in the Scituate Reservoir drainage area, Rhode Island, and data collection and monitoring statistics from October 1, 2020, to September 30, 2021.—Continued

[Data are from U.S. Geological Survey (2023). Alternate station names given in parenthesis for stations where different historical names were used for the same sampling location by Providence Water (PW). Locations of stations are shown on figure 1. USGS, U.S. Geological Survey; mi², square mile; WQ, water quality; Cl, chloride; Na, sodium; M, monthly; Q, quarterly; Y, yes; N, no; --, not applicable]

PW station number	USGS station number	USGS station short name	Alternate name	Drainage area (mi²)	Frequency of WQ sample collection by PW	Number of samples collected by PW[1]	Daily estimated Na and Cl loads	Streamflow data availability	Specific conductance data availability
Moswansicut Pond reservoir subbasin									
19	01115170	Moswansicut Stream	—	3.25	M	10	Y	Continuous	Continuous
20	01115160	Unnamed tributary 1 to Moswansicut Pond reservoir	Blanchard Brook	1.18	M	10	N	None	None
21	01115165	Unnamed tributary 2 to Moswansicut Pond reservoir	Brook from Kimball Reservoir	0.30	Q	3	N	Estimated	None
22	01115167	Unnamed tributary 3 to Moswansicut Reservoir	—	0.10	M	8	N	None	None
34	01115164	Unnamed tributary from Kimball Reservoir	Kimball Stream	0.27	Q	4	N	None	None
Ponaganset Reservoir subbasin									
23	011151843	Ponaganset Reservoir	—	1.92	M	10	N	None	None
Regulating reservoir subbasin									
13	01115176	Unnamed waterbody at Horseshoe Dam	Regulating reservoir	22.1	M	10	N	None	None
14	01115110	Huntinghouse Brook	—	6.29	M	11	Y	Continuous	Continuous
15	01115114	Rush Brook	—	4.70	M	11	Y	Continuous	Continuous
16	01115098	Peeptoad Brook	Harrisdale Brook	4.97	M	11	Y	Continuous	Continuous
17	01115119	Dexter Pond	Paine Pond	0.22	Q	2	N	None	None
18	01115120	Unnamed tributary to Regulating reservoir	Unnamed brook A	0.28	Q	3	Y	Estimated	Continuous
Westconnaug Reservoir subbasin									
10	01115274	Westconnaug Brook	—	1.48	M	11	N	Estimated	None
11	01115273	Unnamed tributary to Westconnaug Reservoir	Unnamed brook south of Westconnaug Reservoir	0.72	Q	4	N	Estimated	None
12	011152745	Unnamed tributary to Westconnaug Brook	Unnamed brook north of Westconnaug Reservoir	0.16	Q	2	N	None	None

[1]Not all samples were analyzed for all water-quality properties or constituents.

[2]Continuous monitoring began or resumed in October 2020.

together with measured (or estimated) streamflows, allow for nearly continuous estimation of chloride and sodium loads to the reservoir.

In 2021, PW regularly, either monthly or quarterly, visited fixed sites on 37 tributaries within the Scituate Reservoir drainage area and collected water-quality samples; however, no samples were collected at the Toad Pond (USGS station 01115177; PW station 31) site because it was routinely dry. Although the Swamp Brook (USGS station 01115278; PW station 38) site began being monitored by USGS in October 2020 and is the 38th site to be monitored by PW, samples were first collected after September 30, 2021 (table 1). Therefore, a total of 36 sites were sampled by PW between October 1, 2020, and September 30, 2021, of which, three were sampled fewer than three times. Compiled and tabulated streamflow (measured or estimated by the USGS) and water-quality data (collected by PW) have been published in Breault and others (2000), Nimiroski and others (2008), Breault (2009), Breault and Campbell (2010a-d), Breault and Smith (2010), Smith and Breault (2011), Smith (2013, 2014, 2015a, b, 2016, 2018a-d, 2019a, b, 2021, 2022a, b, 2024), Smith and Spaetzel (2021), and Spaetzel and Smith (2022a, b).

This report presents data on streamflow, water quality, and loads and yields of selected constituents for water year (WY) 2021 in the Scituate Reservoir drainage area. Data were collected in past studies by the USGS in cooperation with PW and the Rhode Island Department of Environmental Management and continuous measurements provided by PW (Smith and Spaetzel, 2021). This report summarizes measured and estimated streamflows presented for the 13 continuous-record and 11 partial-record streamgages (called "estimated" in table 1) in the drainage area. Estimated monthly and annual loads and yields of chloride and sodium are presented for the 16 streamgages at which specific conductance is continuously monitored by the USGS (table 1). Summary statistics for water-quality data collected by PW for 36 sampling stations during WY 2021 also are presented, and these data were used to calculate loads and yields of selected water-quality constituents where flow data were available. Water-quality data related to the Scituate Reservoir drainage area have been published serially by the USGS since 2000 (Breault and others, 2000). The presentation and content of this report has been replicated from Breault (2009), with annually updated methods, data, and interpretations (Breault and Campbell, 2010a–d; Breault and Smith, 2010; Smith and Breault, 2011; Smith 2013, 2014, 2015a, 2016, 2018a, b, 2019a, 2022a).

Streamflow Data Collection and Estimation

Streamflow was measured or estimated by the USGS at 24 streamgages (table 1). Measured and estimated streamflows are necessary to estimate water volume and water-quality constituent loads and yields from tributary basins. Stream gage height was measured at 10- or 15-minute intervals at the continuous-record streamgages. Streamflow was computed with a gage height to discharge relation (known as a rating), which was developed on the basis of periodic manual measurements of streamflow. Daily mean streamflow at a streamgage was calculated by dividing the total volume of water that passed the streamgage each day by 86,400 (the number of seconds in a day). Periodic manual streamflow measurements at partial-record streamgages were used concurrently with continuous-record measurements from streamgages in nearby hydrologically similar drainage areas to estimate a continuous daily record at the partial-record streamgages. Specifically, daily streamflow records for the 11 partial-record sites in the Scituate Reservoir drainage area (table 1) were estimated by using the maintenance of variance extension type 1 (MOVE.1) method, as described by Ries and Friesz (2000), Smith (2015b), and Spaetzel and Smith (2022b); data needed to estimate streamflows at partial-record sites were retrieved from the USGS National Water Information System (NWIS; U.S. Geological Survey, 2023). The upper and lower 90-percent confidence limits for the estimated mean annual streamflows, as described by Tasker and Driver (1988), are listed in table 2. These USGS data indicate that there is a 90-percent chance that the estimated mean annual streamflow is between the upper and lower 90-percent confidence limits.

Continuous-record streamgages were operated and maintained by the USGS during WY 2021 (fig. 1; table 1). Streamflow data for these streamgages were collected at 10- or 15-minute intervals (near-real-time streamflow data) and were updated at 1-hour intervals through NWIS (U.S. Geological Survey, 2023). Error associated with measured streamflows was generally within about 15 percent as noted in the annual water year summary for each USGS streamgage (U.S. Geological Survey, 2023).

Table 2. Measured or estimated annual mean streamflow for tributary streams in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.

[Data were collected by the U.S. Geological Survey (U.S. Geological Survey, 2023). Stations are shown on figure 1. PW, Providence Water; USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $(ft^3/s)/mi^2$, cubic foot per second per square mile]

PW station number	USGS station number	Annual mean streamflow (ft^3/s)			Annual mean streamflow yield ($[ft^3/s]/mi^2$)
		Streamflow	Upper 90-percent confidence limit	Lower 90-percent confidence limit	
Barden Reservoir subbasin					
24	01115190	10.0	11.3	8.71	2.04
25	01115200	9.62	31.3	2.96	4.06
26	01115185	9.98	11.2	8.74	2.31
28	01115265	14.9	17.2	12.7	1.71
35	01115187	32.4	36.3	28.5	2.32
Direct Runoff subbasin					
1	01115180	3.28	6.95	1.55	2.09
3	01115280	3.32	3.87	2.77	1.78
4	01115400	1.86	8.38	0.41	2.19
5	01115184	2.05	2.30	1.81	1.63
6	01115183	4.00	4.42	3.58	2.04
7	01115297	8.32	17.1	4.04	1.92
8	01115276	9.19	9.78	8.59	1.77
9	01115275	1.62	2.78	0.95	2.61
32	01115178	0.69	1.29	0.37	1.53
33	01115182	0.37	0.86	0.16	1.33
38	01115278	3.84	4.50	3.18	2.00
Moswansicut Pond reservoir subbasin					
19	01115170	6.27	6.75	5.79	1.93
21	01115165	0.63	1.34	0.29	2.09
Regulating reservoir subbasin					
14	01115110	12.5	14.3	10.7	1.98
15	01115114	9.58	11.1	8.01	2.04
16	01115098	12.7	15.0	10.4	2.56
18	01115120	0.72	3.13	0.16	2.56
Westconnaug Reservoir subbasin					
10	01115274	4.09	9.80	1.71	2.77
11	01115273	2.33	6.16	0.88	3.23

Water-Quality Data Collection and Analysis

Water-quality data were collected by the USGS and PW. Concentrations of sodium and chloride were estimated by the USGS from continuous records of specific conductance from 16 of the 24 streamgages. Water-quality samples were collected monthly or quarterly at 36 sampling stations in the Scituate Reservoir drainage area by PW during WY 2021 as part of a long-term sampling program (table 1).

Data Collected by the U.S. Geological Survey

Three or more water-quality samples were collected by the USGS at each of the 16 streamgages equipped with continuous specific conductance monitors in the Scituate Reservoir drainage area during WY 2021 (table 1), except from unnamed brook A (USGS station 01115120; PW station 18) and Peeptoad Brook (USGS station 01115098; PW station 16) sites where samples were not collected during the summer because the streambeds were dry. Samples were collected in the centroid of the streams during fall,

winter, and summer. Water samples were processed in the USGS New England Water Science Center laboratory in Northborough, Massachusetts, at the conclusion of scheduled sampling. After the processing, the samples were packed in ice and shipped overnight to the USGS National Water Quality Laboratory in Lakewood, Colorado. Analytical results for the USGS water-quality samples are available through the NWIS web interface (U.S. Geological Survey, 2023); these include specific conductance and dissolved concentrations of calcium, chloride, magnesium, potassium, sodium, and sulfate.

The USGS collected and analyzed continuous-record specific conductance data at 16 streamgages (fig. 1; table 1). Measurements of specific conductance were recorded automatically at 10- or 15-minute intervals at each streamgage. Measurements were made by using an instream probe and standard USGS methods for continuous water-quality monitoring at streams (Wagner and others, 2006). The specific conductance measurement data are available through the NWIS web interface (U.S. Geological Survey, 2023). Concentrations of chloride and sodium were estimated from continuous measurements of specific conductance by using equations that were developed by the USGS to relate specific conductance to concentrations of chloride and sodium, as follows:

$$C_{Cl}=SPC^{m}\times b \text{ and} \quad (1)$$

$$C_{Na}=SPC^{m}\times b, \quad (2)$$

where

C_{Cl} is the chloride concentration, in milligrams per liter;

C_{Na} is the sodium concentration, in milligrams per liter;

SPC is the specific conductance, in microsiemens per centimeter;

m is the slope from the MOVE.1 analysis (table 3); and

b is the intercept from the MOVE.1 analysis (table 3).

These regression equations were developed by using the MOVE.1 method (also known as the line of organic correlation; Helsel and Hirsch, 2002) on the basis of concurrent measurements of specific conductance (USGS parameter code 90095, corresponding to the observed property "Specific conductance, water, unfiltered, normalized to 25 degrees Celsius, laboratory" with units of µS/cm) along with chloride (USGS parameter code 00940, corresponding to the observed property "Chloride, water filtered" with units of mg/L) and sodium (USGS parameter code 00930, corresponding to the observed property "Sodium, water filtered" with units of mg/L) concentrations measured in water-quality samples collected by the USGS from tributaries in the Scituate Reservoir drainage area during WY 2000, WY 2005, and WYs 2009–23 (table 3; U.S. Geological Survey, 2023).

MOVE.1 was chosen for regression analysis to maintain variance (Hirsch and Gilroy, 1984). Under some circumstances, specific conductance records were unavailable, possibly because of the following reasons: a sensor malfunctioned, was affected by debris, fouling, or ice, or was not submerged during low flow. In these cases, values of specific conductance were estimated by proportional distribution between recorded values. In general, the period of specific conductance record when streamflow occurred that was unavailable for each USGS station represents a small fraction of the record period for WY 2021 (table 3).

Data Collected by Providence Water

Water-quality samples were collected by PW at 36 fixed stations on tributaries draining to the Scituate Reservoir during WY 2021. Samples were scheduled to be collected monthly at 19 stations and quarterly at another 17 stations (table 1). A periodic water-quality sampling schedule was followed so that water-quality samples would be representative of various streamflow conditions. However, sometimes samples could not be collected because tributaries at the sampling stations were dry or frozen or because of inclement weather conditions. When possible, water-quality samples were collected by dipping the sample bottle into the tributary at the center of flow (Richard Blodgett, PW, written commun., 2005). Samples were transported on ice to PW water-quality laboratory at the P.J. Holton Water Purification Plant in Scituate. Water-quality properties and constituent concentrations were measured by using unfiltered water samples. These water-quality properties included pH, alkalinity, color, turbidity, and concentrations of chloride, nitrite, nitrate, orthophosphate, and *Escherichia coli* (*E. coli*) and total coliform bacteria; these data collected by PW are published in Smith and Spaetzel (2021). In this report, orthophosphate is the name for compounds with only one phosphate molecule, whereas phosphate is used to name any compound having one or more phosphate molecules. Analytical methods used for the determination of values or concentrations of pH, color, turbidity, alkalinity, and chloride are documented by Baird and others (2018). Concentrations of nitrite were determined by U.S. Environmental Protection Agency method 353.2 (U.S. Environmental Protection Agency, 1993). Concentrations of nitrate were determined by Standard Method 4500–NO_3^- (Holm and others, 2018). Concentrations of orthophosphate were determined by the Hach PhosVer Method (Hach Method 8048; Hach Company, 2000). Standard Method 9223 was used for the determination of concentrations of bacteria (Best and others, 2018).

Table 3. Regression equation coefficients used to estimate concentrations of chloride and sodium from values of specific conductance for U.S. Geological Survey streamgage stations in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.

[Data were collected by the U.S. Geological Survey (U.S. Geological Survey, 2023). Constituent concentrations, continuous specific conductance, and parameter codes are available in National Water Information System (U.S. Geological Survey, 2023). Locations of stations are shown in figure 1. Chloride is "Chloride, water filtered" (U.S. Geological Survey [USGS] parameter code 00940); sodium is "Sodium, water filtered" (USGS parameter code 00930); specific conductance is "Specific conductance, water, unfiltered, normalized to 25 degrees Celsius, laboratory" (USGS parameter code 90095) measured in microsiemens per centimeter at 25 degrees Celsius. PW, Providence Water; mg/L, milligram per liter; ft^3/s, cubic foot per second; ≥, greater than or equal to]

PW station number	USGS station number	Samples used in analyses		Chloride (mg/L)			Sodium (mg/L)			Percentage of specific conductance record unavailable where streamflow is ≥0.01 ft^3/s
		Date range of samples	Number of samples	Slope	Intercept	Standard error of regressions (percent)	Slope	Intercept	Standard error of regressions (percent)	
24	01115190	03/08/2000; 03/29/2005; 01/22/2009 to 08/22/2023	44	1.1657	0.10659	3.2	1.1018	0.08995	5.0	6.1
26	01115185	01/22/2020 to 08/22/2023	12	1.1063	0.14054	6.3	0.9185	0.21066	2.9	4.6
28	01115265	03/28/2001; 03/30/2005; 01/22/2009 to 08/22/2023	45	1.1437	0.11781	3.8	1.0533	0.11041	5.3	4.9
35	01115187	03/28/2001; 03/29/2005; 01/22/2009 to 08/21/2023	44	1.1723	0.10101	4.0	1.0951	0.08976	5.2	0.35
3	01115280	03/08/2000; 03/30/2005; 01/22/2009 to 08/21/2023	42	1.2008	0.08650	3.1	1.0875	0.09106	4.8	5.2
5	01115184	03/05/2009 to 08/22/2023	41	1.2314	0.07031	3.8	1.0848	0.08551	4.8	0.038
6	01115183	03/08/2000; 03/30/2005; 01/22/2009 to 08/22/2023	55	1.1793	0.08437	4.6	1.1894	0.04825	6.2	2.0
7	01115297	03/28/2001; 03/30/2005; 01/22/2009 to 08/21/2023	44	1.0316	0.14569	4.4	0.8601	0.20013	5.3	5.1
8	01115276	01/22/2009 to 08/22/2023	41	1.0871	0.14598	2.6	1.0286	0.12185	3.5	0.53
9	01115275	03/08/2000; 03/30/2005; 01/22/2009 to 08/22/2023	43	1.0548	0.18169	2.2	1.0818	0.09317	3.0	0.22
38	01115278	01/22/2020 to 08/23/2023	12	1.4687	0.02243	11.2	1.2124	0.04999	7.6	0.14
19	01115170	03/08/2000; 03/29/2005; 01/22/2009 to 08/21/2023	50	1.2118	0.07599	2.3	1.2127	0.04507	2.6	4.0
14	01115110	01/22/2009 to 08/22/2023	50	0.9935	0.18278	7.2	0.9335	0.14700	7.6	1.4
15	01115114	01/22/2009 to 08/22/2023	56	1.1367	0.11580	3.7	1.0674	0.10164	5.3	18
16	01115098	03/28/2001; 03/29/2005; 01/22/2009 to 08/22/2023	44	1.2439	0.06412	4.0	1.06100	0.09808	6.0	0.31
18	01115120	01/22/2009 to 08/21/2023	34	1.1610	0.09934	2.6	1.1454	0.06242	3.2	6.7

Water-quality samples were collected by PW during a wide range of flow conditions. The WY 2021 measured or estimated daily mean flow-duration curves for the USGS streamgages at Westconnaug Brook (USGS station 01115276; PW station 8) and Shippee Brook (USGS station 01115200; PW station 25) are shown in figure 2. The curves represent the percentage of time that each flow was equaled or exceeded at the respective stations; the flows at each station on days when water-quality samples were collected are represented by the plotted points superimposed on the curves. At Westconnaug Brook, 11 samples were collected at flow rates that are exceeded between 16 and 95 percent of the time; this range indicates that the water-quality samples collected in WY 2021 represent a large range of the flow conditions but do not represent flows less than 1.7 ft^3/s and greater than 14 ft^3/s. At Shippee Brook, samples were collected only on a quarterly schedule at flow rates that are exceeded between 13 and 80 percent of the time; this range of flow rates excludes the flow conditions for both the lower (less than 0.74 ft^3/s) and upper (greater than 15 ft^3/s) flow range at Shippee Brook during WY 2021 (fig. 2).

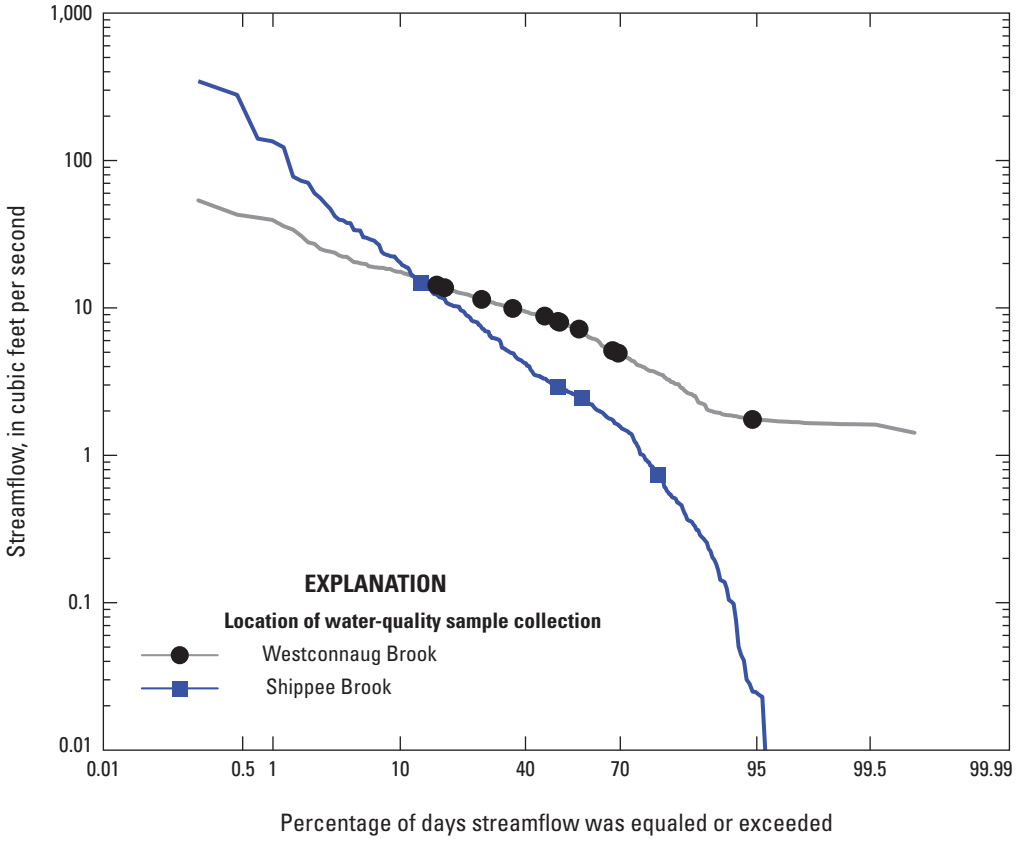

Figure 2. Graph showing flow-duration curves and streamflow on the dates (represented by points) when water-quality samples were collected by Providence Water at the Westconnaug Brook (station 01115276) and Shippee Brook (station 01115200) U.S. Geological Survey streamgages in Foster, Rhode Island, for water year 2021 (October 1, 2020, through September 30, 2021). Locations of stations are shown on figure 1. Modified from Breault (2009). Data are from Smith and Spaetzel (2021).

Estimating Daily, Monthly, and Annual Loads and Yields

Daily, monthly, and annual chloride and sodium loads (in kilograms) were estimated for all streamgages for which continuous-streamflow and specific-conductance data were available for WY 2021. Daily flow-weighted concentrations of chloride and sodium were calculated by multiplying instantaneous flows by concurrent concentrations of chloride and sodium (estimated from measurements of specific conductance) for each day and dividing the sum by the total flow for that day. At the three instrumented monitoring stations, where continuous flow was unavailable (table 1), daily mean concentrations of chloride and sodium were calculated from the daily mean value of specific conductance for each day. The latter method may result in less accurate concentrations because instantaneous measurements of specific conductance may change (decrease or increase) with surface-water runoff; however, the variability of instantaneous measurements of specific conductance at these streamgages was generally small and daily mean values did not differ substantially from daily flow-weighted values estimated during prior water years when instantaneous flow data were available. Daily loads of chloride and sodium were estimated by multiplying daily flow-weighted concentrations of chloride and sodium (in milligrams per liter) by daily discharge (in liters per day). Daily data were summed to estimate monthly or annual loads (converted to metric tons).

Daily loads of water-quality constituents (in samples collected by PW) were calculated for all sampling dates during WY 2021 (table 4) for which periodic- or continuous-streamflow data were available (table 1). These loads were calculated by multiplying constituent concentrations (in milligrams or colony forming units per liter) in single samples by the daily discharge (in liters per day) for the day on which each sample was collected. The flows, which in some cases were estimates, were assumed to be representative of the flow at the time of the sample collection. Loads (in million colony forming units per day, kilograms per day, or grams per day) and yields (in million colony forming units per day per square mile, kilograms per day per square mile, or grams per day per square mile) were calculated for bacteria, chloride, nitrite, nitrate, and orthophosphate. Censored data (concentrations reported as less than method detection limits) were replaced with concentrations equal to one half the method detection limit.

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.

[Data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d, gram per day as N, gram per day as nitrogen; g/d as P, gram per day as phosphate; <, less than; >, greater than]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ([$CFU \times 10^6$]/d)	E. coli ([$CFU \times 10^6$]/d)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as P)
Barden Reservoir subbasin									
24	01115190	11/19/20	1.08	18,000	1,400	90	2.6	<130	160
		12/21/20	7.68	55,000	<1,900	410	19	1,600	190
		01/29/21	5.57	57,000	2,700	310	14	900	270
		02/18/21	9.57	40,000	<2,300	580	23	3,000	700
		03/15/21	5.38	26,000	<1,300	310	13	1,100	530
		04/15/21	5.29	400,000	2,600	350	13	<650	780
		05/25/21	2.15	130,000	2,700	140	11	<260	370
		06/22/21	4.04	230,000	11,000	250	20	680	590
		07/14/21	17.1	1,300,000	13,000	870	84	4,600	2,100
		08/20/21	2.25	180,000	17,000	150	11	350	280
		09/21/21	2.77	69,000	<680	130	14	520	540
25	01115200	11/24/20	14.7	5,100,000	540,000	530	72	3,800	3,600
		03/25/21	2.95	25,000	<720	89	7.2	460	290
		06/25/21	0.73	25,000	1,800	17	3.6	<89	71
		07/26/21	2.42	150,000	3,000	66	12	<300	240
26	01115185	11/24/20	14.5	6,100,000	220,000	1,200	71	5,300	2,100
		03/25/21	6.67	48,000	<1,600	440	16	1,300	820
		06/25/21	1.63	330,000	1,600	130	8	<200	240
		07/26/21	2.49	74,000	<610	150	6.1	450	300
28	01115265	10/14/20	0.20	7,700	470	20	0.49	<24	20
		11/16/20	5.28	530,000	47,000	580	26	<650	390
		12/16/20	9.15	140,000	9,200	470	22	<1,100	1,300
		01/14/21	7.82	76,000	23,000	570	19	1,400	570
		02/11/21	7.84	41,000	5,900	770	19	2,600	3,100
		03/10/21	9.89	34,000	<2,400	640	24	1,400	1,500
		04/23/21	27.1	550,000	13,000	1,500	130	<3,300	2,700
		05/11/21	46.3	2,100,000	35,000	2,100	230	<5,700	3,400
		06/09/21	4.70	210,000	13,000	300	46	<570	1,100
		07/12/21	54.3	9,100,000	290,000	210	530	7,000	4,000
		08/10/21	2.50	46,000	3,900	210	18	410	550
		09/08/21	13.0	480,000	9,900	750	95	2,100	1,300

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.—Continued

[Data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d, gram per day as N, gram per day as nitrogen; g/d as P, gram per day as phosphate; <, less than; >, greater than]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($[CFU \times 10^6]/d$)	E. coli ($[CFU \times 10^6]/d$)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as P)
Barden Reservoir subbasin—Continued									
35	01115187	11/19/20	6.17	170,000	3,000	460	30	<750	1,500
		12/21/20	18.0	150,000	4,400	870	220	5,500	1,800
		01/29/21	18.4	210,000	4,500	970	45	6,900	1,400
		02/18/21	35.7	220,000	8,700	1,800	87	13,000	1,700
		03/15/21	16.2	130,000	<4,000	910	40	4,600	2,000
		04/15/21	17.5	1,600,000	8,600	1,000	43	<2,100	1,300
		05/25/21	4.38	370,000	4,400	250	21	<540	540
		06/22/21	8.39	890,000	30,000	440	41	1,300	1,000
		07/14/21	69.5	5,500,000	17,000	2,700	340	12,000	6,800
		08/20/21	13.5	1,800,000	89,000	720	66	<1,700	2,000
		09/21/21	7.69	340,000	24,000	370	38	1,700	940
Direct Runoff subbasin									
1	01115180	10/06/20	0.04	1,200	<9.8	2	0.098	22	4.9
		11/10/20	0.60	31,000	440	22	2.9	520	120
		12/08/20	4.73	530,000	72,000	170	46	1,300	1,000
		01/04/21	4.49	38,000	<1,100	140	22	2,000	330
		03/02/21	6.85	130,000	99,000	230	50	3,800	670
		04/01/21	8.32	280,000	<2,000	260	41	1,800	200
		05/04/21	7.77	1,100,000	73,000	230	76	2,100	2,100
		06/01/21	6.61	380,000	12,000	230	65	1,500	1,300
		07/01/21	2.16	120,000	<530	68	21	1,300	480
		08/11/21	1.00	33,000	240	30	4.9	440	370
		09/02/21	24.9	>15,000,000	350,000	780	300	4,200	4,900
3	01115280	11/12/20	0.19	9,000	230	30	0.46	<23	28
		12/10/20	2.20	26,000	540	200	5.4	960	220
		01/12/21	1.92	14,000	470	170	4.7	1,600	280
		03/04/21	3.96	25,000	3,000	430	9.7	2,600	290
		04/02/21	7.70	82,000	18,000	730	19	1,200	570
		05/06/21	5.52	130,000	5,500	540	14	<680	540
		06/03/21	2.72	130,000	1,300	230	6.7	710	270
		07/06/21	1.57	75,000	1,500	160	3.8	460	270
		08/06/21	1.65	75,000	13,000	150	8.1	400	200
		09/13/21	1.72	33,000	840	150	4.2	650	460

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.—Continued

[Data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d, gram per day as N, gram per day as nitrogen; g/d as P, gram per day as phosphate; <, less than; >, greater than]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($[CFU \times 10^6]/d$)	E. coli ($[CFU \times 10^6]/d$)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as P)
Direct Runoff subbasin—Continued									
4	01115400	11/10/20	0.07	1,800	<17	1.4	0.17	<8.6	10
		12/08/20	2.42	62,000	3,700	32	5.9	<300	120
		01/04/21	2.12	8,900	<520	41	5.2	680	160
		02/02/21	0.74	5,100	<180	18	1.8	<91	91
		03/02/21	4.61	51,000	<1,100	73	11	<560	230
		04/01/21	6.47	220,000	1,600	110	16	1,500	<160
		05/04/21	5.75	87,000	<1,400	110	14	<700	280
		06/01/21	4.33	290,000	2,100	77	11	<530	320
		07/01/21	0.62	160,000	150	14	1.5	<76	61
		08/11/21	0.16	17,000	<39	6.5	0.39	<20	20
		09/02/21	43.8	3,700,000	32,000	880	110	7,300	3,200
5	01115184	02/25/21	3.26	52,000	800	150	8	3,000	400
		06/24/21	0.84	41,000	840	44	4.1	470	82
		08/30/21	0.34	26,000	83	27	1.7	190	100
6	01115183	11/10/20	0.66	27,000	1,800	91	1.6	310	210
		12/08/20	7.57	220,000	7,600	450	37	4,200	370
		01/04/21	5.33	53,000	6,800	350	13	3,700	390
		03/02/21	7.37	37,000	3,600	610	36	6,900	720
		04/01/21	14.5	790,000	43,000	1,200	110	4,000	350
		05/04/21	9.66	1,700,000	170,000	730	95	<1,200	1,200
		06/01/21	6.24	400,000	15,000	460	61	1,400	610
		07/01/21	1.24	130,000	2,400	120	27	<150	270
		08/11/21	1.35	96,000	3,200	130	20	<170	430
		09/02/21	33.7	>20,000,000	680,000	2,000	490	5,100	4,900
7	01115297	10/01/20	<0.01	950	4.9	0.36	0.049	4.9	0.73
		11/12/20	2.15	100,000	5,300	82	11	<260	420
		12/10/20	10.2	160,000	7,700	230	50	1,800	1,200
		01/12/21	6.02	93,000	<1,500	210	15	1,900	880
		02/04/21	9.60	80,000	4,700	310	23	4,600	1,200
		03/04/21	10.8	110,000	5,300	290	26	3,500	1,600
		04/02/21	19.6	730,000	30,000	420	96	3,300	960
		05/06/21	11.4	690,000	18,000	300	56	<1,400	2,200
		06/03/21	9.69	340,000	17,000	210	47	<1,200	1,200
		07/06/21	6.61	560,000	24,000	210	49	<810	810
		08/06/21	10.9	4,100,000	550,000	330	53	<1,300	1,100
		09/13/21	4.45	140,000	5,400	110	22	680	760

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.—Continued

[Data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d, gram per day as N, gram per day as nitrogen; g/d as P, gram per day as phosphate; <, less than; >, greater than]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($[CFU \times 10^6]/d$)	E. coli ($[CFU \times 10^6]/d$)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as P)
Direct Runoff subbasin—Continued									
8	01115276	10/15/20	1.74	83,000	<430	66	4.3	<210	85
		12/15/20	13.7	28,000	<3,400	380	34	2,700	2,700
		01/13/21	8.78	8,600	<2,100	280	21	<1,100	640
		02/05/21	7.98	5,900	<2,000	270	20	<980	590
		03/09/21	9.90	2,400	<2,400	300	24	<1,200	2,900
		04/08/21	11.4	17,000	<2,800	350	28	<1,400	1,400
		05/07/21	14.2	56,000	<3,500	450	35	<1,700	2,100
		06/08/21	7.12	130,000	3,500	240	17	<870	2,100
		07/20/21	8.03	180,000	<2,000	260	20	<980	980
		08/12/21	5.10	130,000	1,200	170	12	<620	1,100
		09/24/21	4.97	110,000	1,200	180	12	<610	240
9	01115275	12/22/20	1.62	99,000	<400	230	4	2,100	280
		02/25/21	2.19	36,000	<540	250	11	2,400	54
		06/24/21	0.75	42,000	370	110	3.7	980	73
		08/30/21	0.62	27,000	150	97	1.5	910	76
32	01115178	10/30/20	0.82	400,000	52,000	27	6	<100	160
		03/18/21	0.59	8,100	<140	20	1.4	830	120
		06/28/21	0.31	29,000	530	9.7	3.8	230	99
		07/23/21	0.44	26,000	750	15	3.2	260	75
33	01115182	12/30/20	0.87	7,400	<210	21	2.1	460	130
		03/26/21	0.34	4,500	<83	11	0.83	190	33
		06/29/21	0.07	5,000	17	4.7	0.17	21	15
		08/27/21	0.01	1,500	4.9	0.58	0.049	3	2
Moswansicut Pond reservoir subbasin									
19	01115170	11/23/20	2.02	1,200,000	2,600	220	9.9	270	1,700
		12/11/20	7.29	20,000	<1,800	980	18	1,500	180
		01/19/21	14.7	65,000	18,000	1,200	36	3,700	1,100
		03/05/21	7.91	1,900	<1,900	980	19	2,500	1,200
		04/20/21	10.0	21,000	<2,400	1,200	24	3,100	730
		05/12/21	13.1	19,000	<3,200	1,700	64	3,400	2,200
		06/10/21	3.57	130,000	870	500	17	<440	700
		07/19/21	10.9	140,000	<2,700	1,400	27	<1,300	530
		08/17/21	0.24	19,000	59	30	0.59	<29	53
		09/20/21	1.25	89,000	<310	150	3.1	210	180
21	01115165	03/23/21	0.57	13,000	570	54	2.8	790	84
		06/25/21	0.32	38,000	860	33	3.9	310	63
		07/22/21	0.51	130,000	2,000	48	5	430	62

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.—Continued

[Data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d, gram per day as N, gram per day as nitrogen; g/d as P, gram per day as phosphate; <, less than; >, greater than]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($[CFU \times 10^6]/d$)	E. coli ($[CFU \times 10^6]/d$)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as P)
Regulating reservoir subbasin									
14	01115110	11/25/20	7.50	1,800,000	110,000	280	18	<920	1,500
		12/09/20	13.7	170,000	10,000	1,300	34	3,500	2,000
		01/21/21	11.3	80,000	<2,800	410	28	3,400	1,700
		02/10/21	5.71	24,000	<1,400	240	42	2,700	1,300
		03/11/21	10.0	15,000	2,400	370	24	2,500	1,700
		04/27/21	11.8	210,000	2,900	410	29	<1,400	1,700
		05/20/21	4.01	320,000	4,900	140	9.8	<490	98
		06/15/21	12.2	3,100,000	130,000	460	60	2,100	1,500
		07/08/21	15.5	>9,200,000	3,100,000	690	110	3,800	1,500
		08/23/21	13.5	2,700,000	130,000	560	66	1,900	3,600
		09/10/21	17.2	10,000,000	210,000	590	84	3,600	2,100
15	01115114	11/25/20	5.42	1,000,000	41,000	560	13	940	530
		12/09/20	8.34	150,000	11,000	260	20	2,900	1,000
		01/21/21	7.19	19,000	<1,800	570	18	3,300	700
		02/10/21	3.92	14,000	<960	470	9.6	2,400	860
		03/11/21	7.24	7,100	1,800	750	18	2,800	2,100
		04/27/21	7.99	240,000	5,900	760	20	<980	590
		05/20/21	2.07	94,000	<510	260	10	<250	100
		06/15/21	9.12	3,900,000	270,000	880	67	1,400	670
		07/08/21	10.6	>6,300,000	640,000	830	100	2,200	1,800
		08/23/21	8.13	1,800,000	68,000	780	60	2,300	1,200
		09/10/21	12.3	>7,200,000	140,000	910	60	2,000	1,500
16	01115098	11/25/20	15.1	1,200,000	79,000	1,500	37	3,200	1,500
		12/09/20	11.3	150,000	2,800	870	28	4,100	1,900
		01/21/21	8.65	55,000	4,200	730	21	5,600	850
		02/10/21	7.69	11,000	<1,900	730	110	6,500	1,500
		03/11/21	8.36	240,000	<2,000	730	20	4,900	2,000
		04/27/21	11.1	170,000	5,400	1,100	27	2,300	810
		05/20/21	8.88	270,000	<2,200	890	43	<1,100	<220
		06/15/21	10.8	1,800,000	67,000	970	79	2,200	530
		07/08/21	10.5	940,000	5,100	1,100	51	1,900	1,500
		08/23/21	6.75	600,000	9,900	560	50	1,000	1,200
		09/10/21	12.9	1,100,000	6,300	1,000	63	3,300	1,600
18	01115120	12/23/20	0.18	8,500	180	30	0.44	130	8.8
		03/23/21	0.20	1,500	98	32	0.49	160	29
		07/22/21	0.19	72,000	1,100	30	1.4	93	56

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.—Continued

[Data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d, gram per day as N, gram per day as nitrogen; g/d as P, gram per day as phosphate; <, less than; >, greater than]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($[CFU \times 10^6]/d$)	E. coli ($[CFU \times 10^6]/d$)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as P)
Westconnaug Reservoir subbasin									
10	01115274	11/16/20	1.29	87,000	8,200	75	6.3	<160	95
		12/16/20	2.62	27,000	<640	140	6.4	<320	130
		01/14/21	1.69	29,000	<410	110	4.1	260	120
		02/11/21	1.22	13,000	<300	81	<3	190	120
		03/10/21	2.18	17,000	<530	130	5.3	<270	590
		04/23/21	4.30	71,000	<1,100	260	11	<530	530
		05/11/21	8.27	440,000	<2,000	490	20	<1,000	2,400
		06/09/21	0.92	110,000	450	52	2.3	<110	290
		07/12/21	15.7	1,300,000	33,000	830	38	<2,200	1,500
		08/10/21	0.45	12,000	220	30	1.1	<55	110
		09/08/21	1.91	87,000	2,900	120	4.7	<230	190
11	01115273	10/27/20	0.04	2,200	<9.8	0.69	0.2	<4.9	2.9
		03/22/21	1.33	30,000	<330	26	6.5	440	200
		04/30/21	2.62	310,000	6,200	46	13	<320	320
		08/24/21	6.51	870,000	8,300	89	64	<800	1,100

Streamflow

Monitoring streamflow is a necessary step to measure the volume of water and estimate constituent loads to the Scituate Reservoir. The Ponaganset River is the largest monitored tributary to the Scituate Reservoir. Mean annual streamflow at the streamgage on the Ponaganset River (USGS station 01115187, PW station 35) for the entire period of its operation (mean of the annual mean streamflows for the period of record, WYs 1995–2020) before WY 2021 was 28.9 cubic feet per second (ft^3/s; U.S. Geological Survey, 2023). During WY 2021, the annual mean streamflow of 32.4 ft^3/s was just below the 75th percentile (33.2 ft^3/s) for the period of record (fig. 3). Daily mean streamflows were commonly within the 10th and 90th percentile of all mean daily streamflows for WYs 1995–2020 and were similar to the median daily streamflows from December through June. Daily mean streamflows in WY 2021 were lower than the median long-term streamflows and 10th percentile values in October and November and were higher than the median daily streamflows and 90th percentile values from July through September (fig. 3). The other long-term continuous-record streamgage in the Scituate Reservoir drainage area is the Peeptoad Brook streamgage (USGS station 01115098; PW station 16). The mean annual streamflow at the Peeptoad Brook streamgage for the period of record (WYs 1995–2020) before WY 2021 was 10.4 ft^3/s (U.S. Geological Survey, 2023). The annual mean streamflow at the Peeptoad Brook streamgage during WY 2021 also was higher than the mean annual streamflow for its period of record at 12.7 ft^3/s. The annual mean measured or estimated streamflows for the other monitoring stations in this study ranged from 0.37 to 14.9 ft^3/s (table 2).

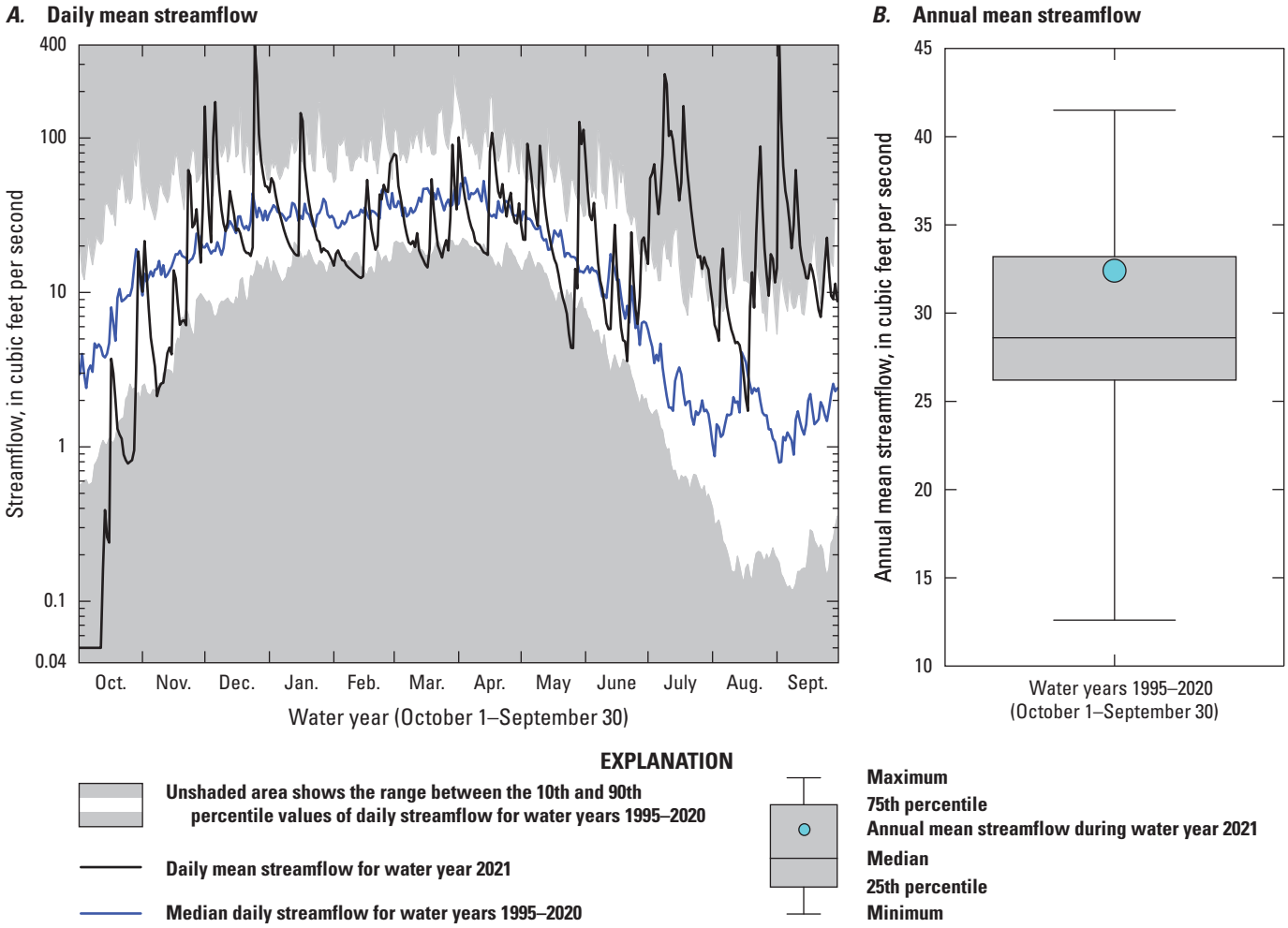

Figure 3. Hydrologic data taken at the U.S. Geological Survey streamgage on the Ponaganset River in Foster, Rhode Island (station 01115187). *A*, Graph showing measured daily mean streamflow for water year 2021 (October 1, 2020, through September 30, 2021) and the 10th percentile, median, and 90th percentile values of daily streamflow for water years 1995–2020 (October 1, 1994, through September 30, 2020). *B*, Boxplot showing annual mean streamflow during water year 2021 and the distribution of mean annual streamflows for water years 1995–2020. Location of station is shown on figure 1. Modified from Breault (2009). Data are from Smith and Spaetzel (2021).

Water Quality and Constituent Loads and Yields

Water-quality conditions in the Scituate Reservoir drainage area are described by summary statistics for water-quality properties, constituent concentrations, and estimated constituent loads and yields. Loads and yields measure the rates at which masses of constituents are transferred to the reservoir by tributaries. Tributaries with high flows tend to have high loads because the greater volume of water can carry more of the constituent to the reservoir per unit time than tributaries with low flows. Yield represents the constituent load per unit of drainage area and is calculated by dividing the load estimated for a streamgage by the drainage area for the monitoring station. Yields are useful for comparison among streamgages that have different drainage areas because each basin size and therefore total streamflow volume is normalized. Yields also are useful for examining potential differences among basin properties that may contribute to water quality in the reservoir.

Summary statistics include means and medians. For some purposes, median values are more appropriate because they are less likely to be affected by high or low concentrations (or outliers). Medians are especially important to use for summarizing a relatively limited number of values. In contrast, datasets that include a large number of values, such as continuously monitored streamflow and loads of chloride and sodium (estimated from measurements of specific conductance), are better summarized in terms of means because large datasets are more resistant to the effects of outliers than small datasets. Mean values also are particularly appropriate for measuring loads because outlier values, which typically represent large flows, are important to include in estimates of constituent masses delivered to receiving waters.

Uncertainties associated with measuring streamflow and specific conductance and with chloride and sodium sample collection, preservation, and analysis produce uncertainties in load and yield estimates. The load and yield estimates presented in the text and tables are the most likely values for chloride and sodium inputs from tributaries or their drainage basins, based on the available data and analysis methods. It may be best to discuss loads and yields in terms of a range within which the true values lie; however, the most likely values of loads and yields are presented for ease of discussion and presentation. The range within which the true values lie depends on the uncertainties in individual measurements of streamflow and concentration, which are difficult to quantify with the available information. The uncertainties associated with streamflow are commonly assumed to affect load and yield calculations more than the errors associated with measuring specific conductance or chemical analysis, and the uncertainties associated with estimated streamflow are greater than those associated with measured streamflow. The most likely values of loads and yields presented in the tables and text are sufficient for planning-level analysis of water quality in tributaries and their drainage basins.

Chloride and Sodium Loads and Yields Estimated From Specific-Conductance Monitoring Data

Chloride and sodium are constituents of special concern in the Scituate Reservoir drainage area. Chloride is difficult to remove from finished drinking water and can affect the taste and sodium is a constituent of potential concern for human health because some people on restricted diets might need to limit their sodium intake. Chloride and sodium are major constituents of road salt used for deicing, and several major roadways cross the Scituate Reservoir drainage area. State Routes 12 and 14 cut across the main body of the reservoir, and Route 116 parallels the eastern limb of the reservoir (fig. 1). Nimiroski and Waldron (2002) indicated that tributaries in basins with State-maintained roads had substantially higher concentrations of chloride and sodium than tributaries in basins with low road density, presumably because of deicing activities. Smith (2015b) indicated relations between concentrations of chloride collected from the tributaries to the Scituate Reservoir and total impervious area of the respective subbasins were significant; and Spaetzel and Smith (2022b) found 32 significant upward trends in tributary chloride concentrations at the 37 stations during WYs 1983–2019.

Monthly mean concentrations were calculated by dividing the total monthly load by the total discharge for the month. Estimated monthly mean chloride concentrations in tributaries of the Scituate Reservoir drainage area ranged from 7.9 to 100 milligrams per liter (mg/L) and estimated monthly mean sodium concentrations ranged from 5.6 to 58 mg/L (table 5). The highest monthly mean concentrations of chloride and sodium were estimated to be 100 and 58 mg/L, respectively, in the Rush Brook tributary to Regulating reservoir (USGS station 01115114; PW station 15) in October 2020. The estimated monthly mean concentrations for 13 of the 16 stations were highest or tied for highest during October 2020 compared with the estimated mean concentrations during the winter months. Monthly estimated mean concentrations were highest in November 2020 for Ponaganset River (USGS station 01115187; PW station 35), and highest in February 2021 for the unnamed tributary to Regulating reservoir (USGS station 01115120; PW station 18) and Swamp Brook (USGS station 01115187; PW station 38). The estimated monthly mean concentrations of chloride and sodium in Moswansicut stream (USGS station 01115170; PW station 19) remained consistent throughout the water year, ranging only by a maximum of 3 mg/L.

Annual mean concentrations were calculated by dividing the total annual load by the total discharge for the year. The highest annual mean concentrations of chloride and sodium were estimated to be 51 and 30 mg/L, respectively, in Moswansicut stream (USGS station 01115170; PW station 19; table 6). The stations on the Moswansicut Pond reservoir and the unnamed tributary to Regulating reservoir are in the more developed, northeastern part of the Scituate Reservoir drainage area (fig. 1.) The similarly high annual mean concentrations of 49 mg/L of chloride and 29 mg/L of sodium in Bear Tree Brook (USGS station 01115275; PW station 9) are the result of residual chloride and sodium leaching to groundwater from a formerly uncovered salt storage pile (Nimiroski and Waldron, 2002).

During WY 2021, the Scituate Reservoir received about 2,900 t of chloride and 1,800 t of sodium from tributaries that are equipped with instrumentation capable of continuously monitoring specific conductance (table 6). The highest annual chloride and sodium loads in the Scituate Reservoir drainage area during WY 2021 were estimated to be 500 and 320 t, respectively, at the Ponaganset River station (USGS station 01115187; PW station 35; table 6). Monthly estimated chloride and sodium loads tended to be lowest in October at each station (fig. 4). Monthly estimated chloride and sodium loads were both highest or tied for highest in December for 13 of the 16 stations. Monthly estimated chloride loads for Rush Brook (USGS station 01115114; PW station 15) were highest in March and April (31 t) but were similar to the December load of 30 t; monthly estimated sodium loads for Rush Brook were tied in December, March, and April (19 t). Hemlock Brook (USGS station 01115265; PW station 28) had the highest loads for chloride (37 t) and sodium (23 t) in April, and Swamp Brook (USGS station 01115278; PW station 38) had the highest loads for chloride (20 t) and sodium (12 t) in March (fig. 4). Monthly estimated chloride and sodium loads for Winsor Brook (USGS station 01115185; PW station 26) were highest in September (28 and 19 t, respectively) but similar to July (26 and 17 t, respectively; fig. 4).

During WY 2021, estimated annual loads of chloride and sodium at the continuous streamgage stations were greater than the median estimated annual loads for WYs 2009–20 for 8 of the 16 USGS stations (fig. 5; note that two stations do not

have estimates for WYs 2009–20). From December through April, the sum of the monthly estimated loads of chloride and sodium for the respective drainage areas upstream of each streamgage accounted for about 50 to 70 percent of the annual load of chloride and sodium (fig. 4). The Ponaganset River (USGS station 01115187; PW station 35), which accounts for 20 percent of the combined drainage area upstream from the 16 USGS streamgage stations, accounted for 17 percent of the combined annual load of chloride and sodium for the 16 USGS streamgage stations. Peeptoad Brook (USGS station 01115098; PW station 16) drains an area that is 7 percent of the combined drainage area upstream from the 16 USGS streamgage stations and had the second highest percentage (13 percent) of the combined annual load of chloride and sodium (table 6).

The sum of annual loads during WY 2021 for 14 stations with continuous monitoring in WYs 2009–20 was 17 percent greater than the sum of annual loads estimated during the previous water year and approximately equal to the average of WYs 2009–20 (fig. 6). The two additional stations (Swamp Brook [USGS station 01115187; PW station 38] and Winsor Brook [USGS station 01115185; PW station 26]) represent about 11 percent of the sum of annual loads of chloride and sodium (fig. 6). The annual mean discharge yield in cubic feet per second per square mile for WY 2021 was marginally greater (by 0.13 cubic foot per second per square mile) than the WY 2009–20 average.

The highest annual chloride and sodium yields were 110 and 68 metric tons per year per square mile ([t/yr]/mi^2; table 6), respectively, measured at Bear Tree Brook (USGS station 01115275; PW station 9) in a small subbasin (0.62 mi^2). These high yields were the result, in part, from chloride and sodium groundwater contamination (Nimiroski and others, 2008). Chloride and sodium yields for Ponaganset River (USGS station 01115187; PW station 35), the largest subbasin in the Scituate Reservoir watershed, were approximately three times lower at 36 and 23 (t/yr)/mi^2, respectively, than the yields for Bear Tree Brook (USGS station 01115275; PW station 9). The estimated annual mean yields of chloride and sodium for the drainage area upstream from the 16 USGS streamgage stations were 52 and 32 (t/yr)/mi^2 (table 6), respectively. These estimated annual mean yields of chloride and sodium for WY 2021 were greater than the estimated annual mean yields of chloride and sodium in the prior water year by about 49 and 45 percent, respectively (Smith, 2024).

Physical and Chemical Properties and Daily Loads and Yields Estimated From Data Collected by Providence Water

PW routinely measured four water-quality properties (pH, color, turbidity, and alkalinity), and concentrations of chloride, nitrite, nitrate, orthophosphate, total coliform bacteria, and *E. coli* bacteria in monthly or quarterly samples of tributary water. These data are general indicators of water-quality conditions in the Scituate Reservoir drainage area.

Physical and Chemical Properties

Physical and chemical properties including pH, turbidity, alkalinity, and color were routinely measured to determine water quality in each of the six subbasins in the Scituate Reservoir drainage area (table 7) by PW. Specifically, pH is a measure of the effective hydrogen-ion concentration (U.S. Geological Survey, 2021) representing the negative base-10 logarithm of hydrogen-ion activity of a solution, in moles per liter; color can be an indirect measure of the amount of organic carbon dissolved in the water column; turbidity is an indirect measure of suspended particles; and alkalinity is a measure of the buffer capacity of water.

The median pH in tributaries in the Scituate Reservoir drainage area ranged from 5.7 to 7.0; the median of the medians for all stations with more than two samples was 6.3. Median values of color ranged from 17 to 250 platinum-cobalt units; the median for all stations was 42 platinum-cobalt units. Median values of turbidity ranged from 0.17 to 1.5 nephelometric turbidity units; the median for all stations was 0.57 nephelometric turbidity unit. Median alkalinity values in tributaries were low, ranging from 3.8 to 20 mg/L as calcium carbonate; the median for all stations was 7.6 mg/L alkalinity as calcium carbonate (table 7).

Constituent Concentrations and Daily Loads and Yields

Fecal indicator bacteria, chloride, and nutrients such as nitrogen and phosphorus are commonly detected in natural water; at elevated concentrations, these constituents can cause or contribute to water-quality impairments. Fecal indicator bacteria, which are found in the intestines of warm-blooded animals, may indicate impairment from sewage contamination or from livestock or wildlife that defecate in or near the stream margin. Chloride originates in tributary stream water from precipitation, weathering, or human activities such as waste disposal, use of septic systems, and road deicing. Sources of nutrients in tributary stream water include atmospheric deposition, leaching of naturally occurring organic material, discharge of groundwater that is enriched with nutrients from septic-system leachate, and runoff contaminated with fertilizer or animal waste. The ultimate intended use of water in the tributaries is drinking water, which must meet specific water-quality standards. For this reason, PW closely monitors concentrations of these constituents in tributaries. Median concentrations, loads, and yields of water-quality constituents are listed in tables 7, 8, and 9.

Table 5. Monthly mean concentrations of chloride and sodium estimated from continuous measurements of specific conductance in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.

[Data were collected by the U.S. Geological Survey (2023). Locations of stations are shown on figure 1. Monthly mean concentrations were calculated by dividing the monthly load by the total discharge for the month. PW, Providence Water; USGS, U.S. Geological Survey; Cl, chloride; Na, sodium; mg/L, milligram per liter; —, not applicable]

PW station number	USGS station number	October 2020		November 2020		December 2020		January 2021		February 2021	
		Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)
Barden Reservoir subbasin											
24	01115190	46	28	31	19	19	12	20	13	24	15
26	01115185	45	25	34	20	19	12	21	13	25	16
28	01115265	52	30	46	27	19	12	22	14	26	16
35	01115187	27	16	28	17	16	10	17	11	20	12
Direct Runoff subbasin											
3	01115280	69	39	46	27	27	16	25	15	38	22
5	01115184	48	27	25	15	20	12	17	11	27	16
6	01115183	94	57	55	33	25	15	26	15	34	21
7	01115297	17	10	12	8.1	7.9	5.6	8.6	6.0	9.1	6.3
8	01115276	27	17	27	17	17	11	18	12	20	13
9	01115275	69	41	55	33	43	25	47	28	48	29
38	01115278	18	12	35	22	23	15	21	14	60	33
Moswansicut Pond reservoir subbasin											
19	01115170	52	31	52	31	51	31	50	30	52	31
Regulating reservoir subbasin											
14	01115110	23	14	18	11	10	6.5	11	7.0	14	8.7
15	01115114	100	58	60	35	17	11	27	17	42	26
16	01115098	41	24	40	24	34	21	34	21	38	23
18	01115120	33	19	54	31	39	22	47	27	63	36
Mean for Scituate Reservoir drainage area											
Mean	—	47	28	39	23	24	15	26	16	34	20

Bacteria

Median concentrations of total coliform bacteria were above the detection limit (1 colony forming unit per 100 milliliters [CFU/100 mL]) at all sites (table 7). Median concentrations of *E. coli* were censored below detection limits of either 10, 25, or 31 CFU/100 mL at 11 of the 33 stations that had more than 2 samples collected in WY 2021. Median concentrations of *E. coli* were uncensored for 22 stations, and these concentrations ranged from 10 to 110 CFU/100 mL. For three stations, medians were not determined because fewer than three samples were collected, and these concentrations ranged from less than 10 to 63 CFU/100 mL. Total coliform bacteria concentrations were greater than *E. coli* concentrations (as expected because total coliform is a more inclusive measure than *E. coli*); the medians of median concentrations for all sites in the drainage area were 1,500 CFU/100 mL for total coliform bacteria and 30 CFU/100 mL for *E. coli* (table 7). The highest median concentration of total coliform bacteria, 4,900 CFU/100 mL, was at unnamed tributary 2 to Moswansicut Reservoir (USGS station 01115165; PW station 21) which drains a 0.30 mi^2 area in the Moswansicut Pond reservoir subbasin (table 1). Median concentrations of total coliform bacteria exceeded 2,000 CFU/100 mL at eight other stations including Winsor Brook (USGS station 01115185; PW station 26), Brandy Brook (USGS station 01115180; PW station 1), Quonopaug Brook (USGS station 01115183; PW station 6), unnamed tributary 1 to Scituate Reservoir (USGS station 01115178; PW station 32), unnamed tributary 1 to Moswansicut Pond reservoir (USGS station 01115160; PW station 20), unnamed tributary from Kimball Reservoir (USGS station 01115164; PW station 34), Huntinghouse Brook (USGS station 01115110; PW station 14), and unnamed tributary to Westconnaug Reservoir (USGS station 01115273; PW station 11). Median concentrations of total coliform bacteria were lowest at Westconnaug Brook

Table 5. Monthly mean concentrations of chloride and sodium estimated from continuous measurements of specific conductance in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.—Continued

[Data were collected by the U.S. Geological Survey (2023). Locations of stations are shown on figure 1. Monthly mean concentrations were calculated by dividing the monthly load by the total discharge for the month. PW, Providence Water; USGS, U.S. Geological Survey; Cl, chloride; Na, sodium; mg/L, milligram per liter; —, not applicable]

March 2021		April 2021		May 2021		June 2021		July 2021		August 2021		September 2021	
Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)	Cl (mg/L)	Na (mg/L)
Barden Reservoir subbasin													
25	16	25	16	23	15	23	15	18	11	23	14	17	11
25	15	23	15	22	14	28	17	23	14	25	15	18	12
22	14	20	13	19	12	22	13	16	10	26	16	15	9.4
20	12	19	12	18	11	18	12	15	9.3	19	12	14	8.7
Direct Runoff subbasin													
40	24	33	20	28	17	30	18	26	16	35	21	18	12
17	11	16	9.9	16	10	17	11	17	11	23	14	14	8.7
32	19	30	18	28	17	30	18	26	15	36	21	26	16
8.8	6.1	8.4	5.9	8.7	6.1	9.0	6.2	8.2	5.8	11	7.3	7.9	5.6
20	13	18	12	19	12	22	14	19	12	24	15	18	12
49	29	48	28	49	29	57	34	49	29	62	37	49	29
47	28	35	22	27	18	25	16	21	14	28	18	15	11
Moswansicut Pond reservoir subbasin													
51	30	52	31	51	31	52	31	50	30	50	30	49	29
Regulating reservoir subbasin													
13	8.0	12	7.4	11	7.1	12	7.8	10	6.4	14	8.7	9.1	5.8
37	23	32	20	25	16	24	15	19	12	16	10	21	13
37	22	37	22	36	22	38	23	30	19	34	21	30	19
58	34	49	28	45	26	62	36	40	23	61	35	26	15
Mean for Scituate Reservoir drainage area													
31	19	29	17	27	16	29	18	24	15	30	18	22	13

(USGS station 01115276; PW station 8). The highest median concentration of *E. coli*, 110 CFU/100 mL (table 7), also was at unnamed tributary 2 to Moswansicut Reservoir.

Median daily loads and yields of total coliform bacteria and *E. coli* varied by two orders of magnitude or more (tables 8 and 9). The median daily loads of total coliform bacteria for all subbasins in the Scituate Reservoir drainage area ranged from 4,800 to 340,000 million colony forming units per day ([CFU×10^6]/d), and yields ranged from 11,000 to 240,000 million colony forming units per day per square mile ([(CFU×10^6)/d]/mi^2); *E. coli* loads ranged from less than 180 to 11,000 (CFU×10^6)/d, and yields ranged from 530 to 3,700 ([CFU×10^6]/d)/mi^2 (table 8 and 9). The highest median daily yield of total coliform bacteria at 240,000 ([CFU×10^6]/d)/mi^2 was at unnamed tributary to Westconnaug Reservoir (USGS station 01115273; PW station 11), and the *E. coli* median yield at this station may have been up to 4,600 ([CFU×10^6]/d)/mi^2. The highest (uncensored) median daily yield of *E. coli* of 3,700 ([CFU×10^6]/d)/mi^2 occurred at Quonopaug Brook (USGS station 01115183; PW station 6; table 9). Although relatively high for sampling stations in the Scituate Reservoir subbasin, median daily bacteria yields at these stations were low to moderate for yields of indicator bacteria in sewage-contaminated stream water or stream water affected by stormwater runoff in an urban environment (Breault and others, 2002).

Chloride

Median chloride concentrations among PW stations ranged from 7.1 to 71.4 mg/L. The highest median concentration was collected at unnamed tributary 1 to Moswansicut Pond reservoir (USGS station 01115160; PW station 20; table 7). The median of median concentrations for all sites in the drainage area was 23.7 mg/L (table 7), which is very similar to the median of median concentrations

Table 6. Estimated annual mean chloride and sodium concentrations, loads, and yields for streamgage stations in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.

[Data were collected by the U.S. Geological Survey (2023). Locations of stations are shown on figure 1. Annual mean concentrations were calculated by dividing the annual load by the total discharge for the year; annual mean yields were calculated by dividing the sum of individual loads by the sum of the drainage area. PW, Providence Water; USGS, U.S. Geological Survey; Cl, chloride; mg/L, milligram per liter; Na, sodium; t/yr, metric ton per year; (t/yr)/mi^2, metric ton per year per square mile; —, not applicable]

PW station number	USGS station number	Concentration		Load		Yield	
		Cl mg/L)	Na (mg/L)	Cl (t/yr)	Na (t/yr)	Cl ([t/yr]/mi^2)	Na ([t/yr]/mi^2)
Barden Reservoir subbasin							
24	01115190	22	14	190	120	39	25
26	01115185	22	14	200	120	46	29
28	01115265	20	13	270	170	31	19
35	01115187	17	11	500	320	36	23
Direct Runoff subbasin							
3	01115280	30	18	88	53	47	28
5	01115184	18	11	33	21	26	16
6	01115183	30	18	110	65	55	33
7	01115297	8.8	6.1	66	45	15	10
8	01115276	19	12	160	100	30	20
9	01115275	49	29	71	42	110	68
38	01115278	30	19	100	65	54	34
Moswansicut Pond reservoir subbasin							
19	01115170	51	30	290	170	88	52
Regulating reservoir subbasin							
14	01115110	12	7.2	130	80	20	13
15	01115114	28	17	240	150	50	31
16	01115098	34	21	390	240	79	48
18	01115120	43	25	27	16	98	57
Scituate Reservoir drainage area							
Mean	—	27	17	—	—	52	32
Total	—	—	—	2,900	1,800	—	—

in WY 2020 (24.8 mg/L; Smith, 2024). Median daily chloride loads and yields estimated from samples collected by PW varied among monitoring stations in the drainage area (tables 8 and 9). Moswansicut Stream (USGS station 01115170; PW station 19) had the largest median daily chloride load at 980 kilograms per day, followed by Peeptoad Brook (USGS station 01115098; PW station 16) and Ponaganset River (USGS station 01115187; PW station 35) at 890 and 870 kilograms per day, respectively (table 8). The median daily chloride yield at Moswansicut stream was about five times greater than the median yield at Ponaganset River and was the maximum among all stations at 300 kilograms per day per square mile (table 9). The median daily chloride yield for monitored areas within the drainage area was 67 kilograms per day per square mile.

Nutrients

Median concentrations of nitrite and nitrate (table 7) were 0.002 and 0.08 mg/L as nitrogen, respectively. The highest median concentrations of nitrite (0.014 mg/L as nitrogen) and nitrate (1.10 mg/L as nitrogen) were at unnamed tributary 3 to Moswansicut Reservoir (USGS station 01115167; PW station 22). The median concentration of orthophosphate for the entire study area (table 7) was 0.05 mg/L as phosphate. The maximum median concentration of orthophosphate was 0.13 mg/L as phosphate measured in a sample collected at Fire Tower Stream (PW station 37). Median daily loads of nitrite were largest at Ponaganset River (USGS station 01115187; PW station 35) and Peeptoad Brook (USGS station 01115098; PW station 16) at 43 grams per day as nitrogen (g/d; table 8). Median daily loads of nitrate were largest at Peeptoad Brook

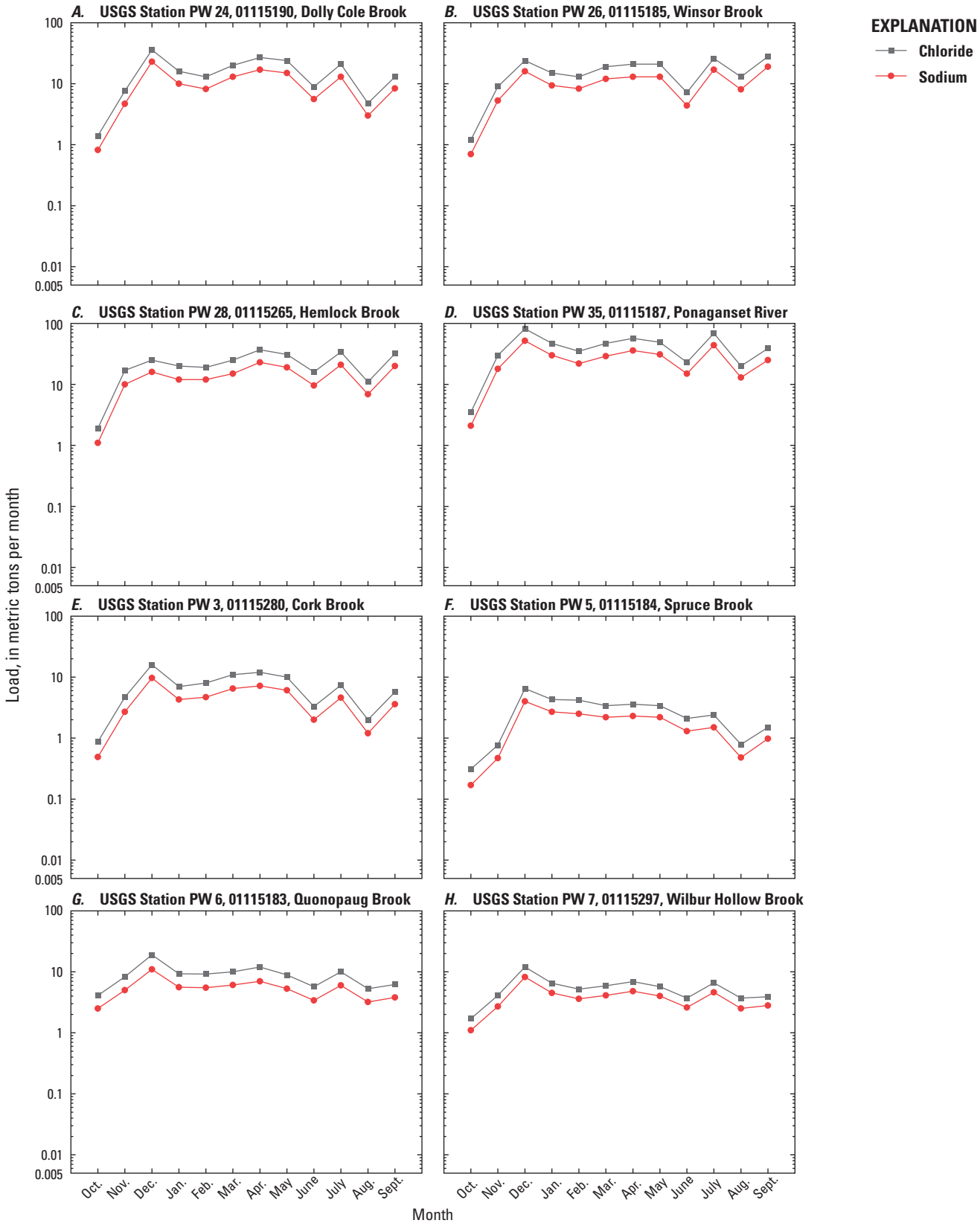

Figure 4. Graphs showing monthly loads of chloride and sodium estimated from streamflow and specific conductance data for water year 2021 (October 1, 2020, through September 30, 2021) at 16 Providence Water sampling stations with continuous-record U.S. Geological Survey (USGS) water-quality data in the Scituate Reservoir drainage area, Rhode Island. Locations of stations are shown on figure 1; station information is listed in table 1. Data are from Smith and Spaetzel (2021).

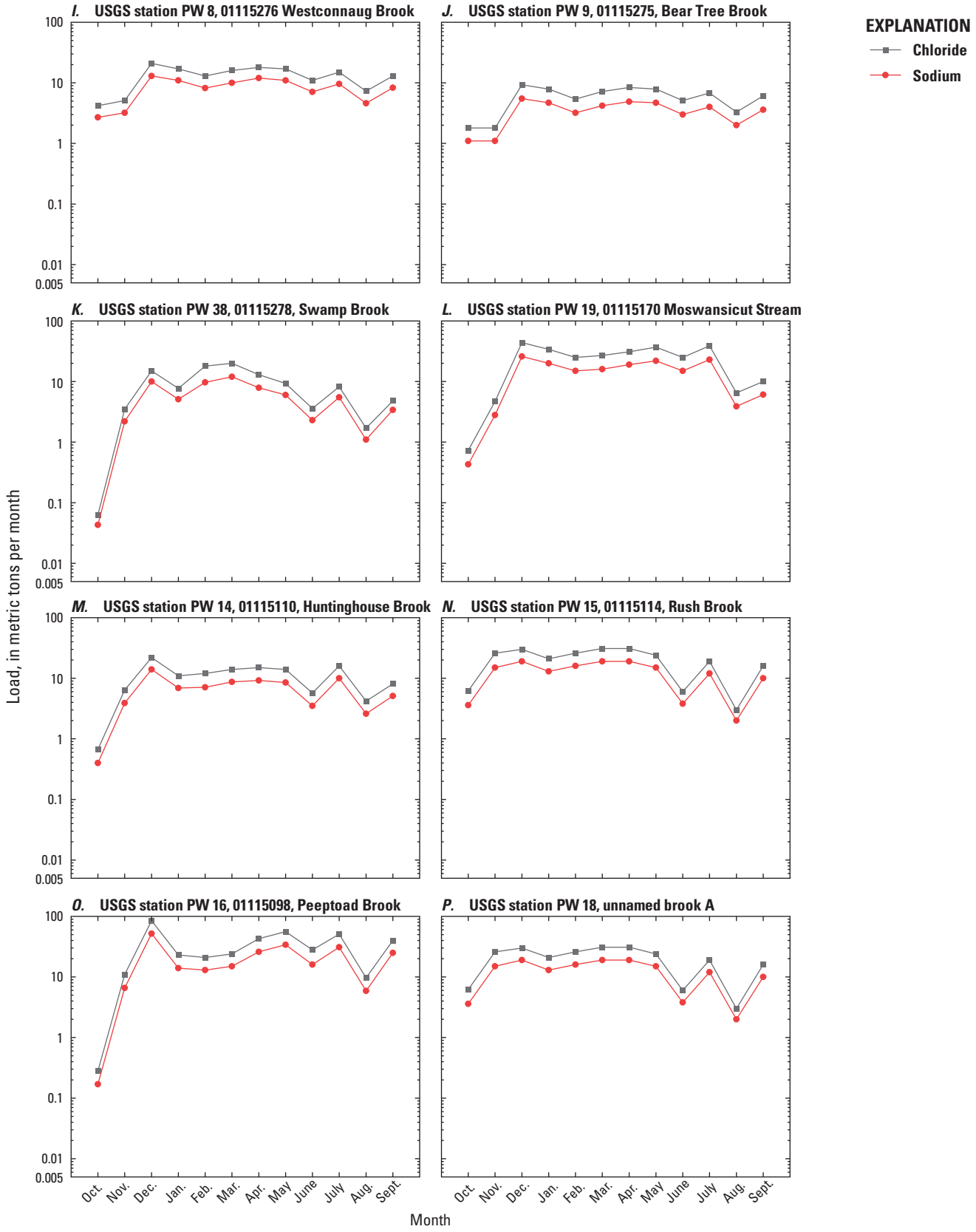

Figure 4.—Continued

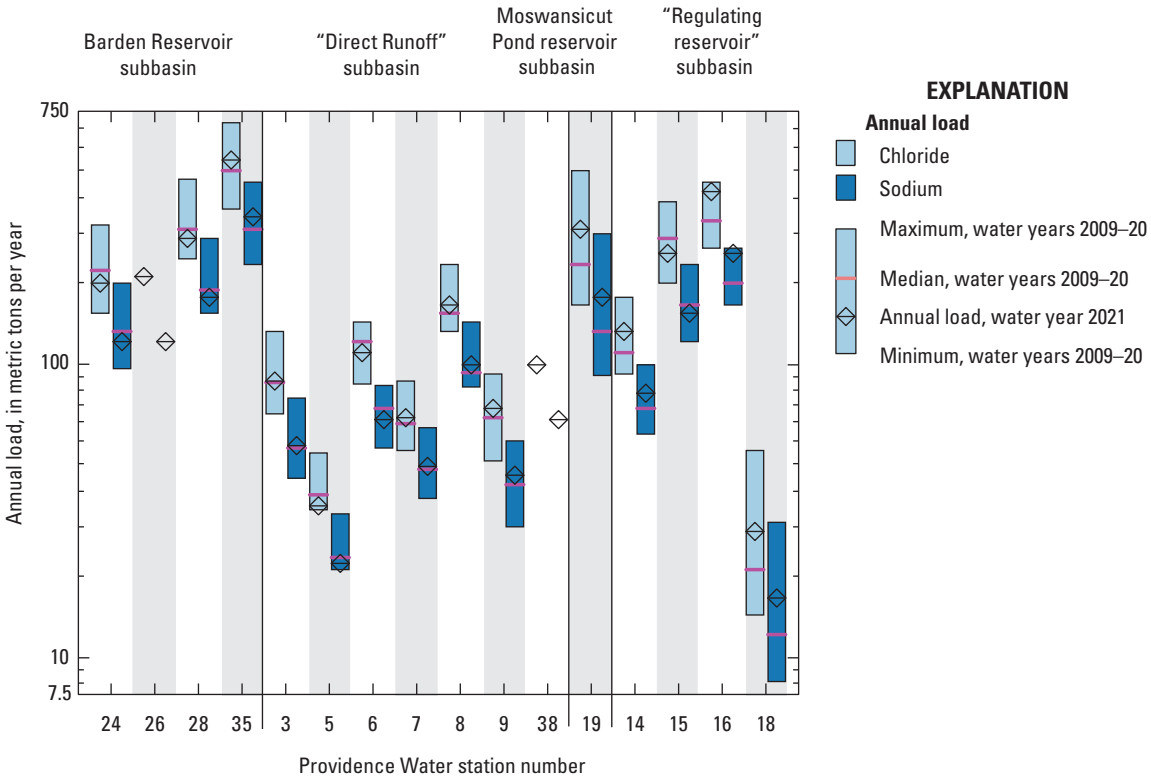

Figure 5. Graph showing annual loads of chloride and sodium estimated from streamflow and specific conductance data for water year 2021 (October 1, 2020, through September 30, 2021) and associated minimum, maximum, and median annual loads for water years 2009–20 (October 1, 2008, through September 30, 2020) at 16 Providence Water sampling stations with continuous-record U.S. Geological Survey water quality data in the Scituate Reservoir drainage area, Rhode Island. Locations of stations are shown on figure 1; station information is shown in table 1. Modified from Smith (2016). Data are from Smith and Spaetzel (2021).

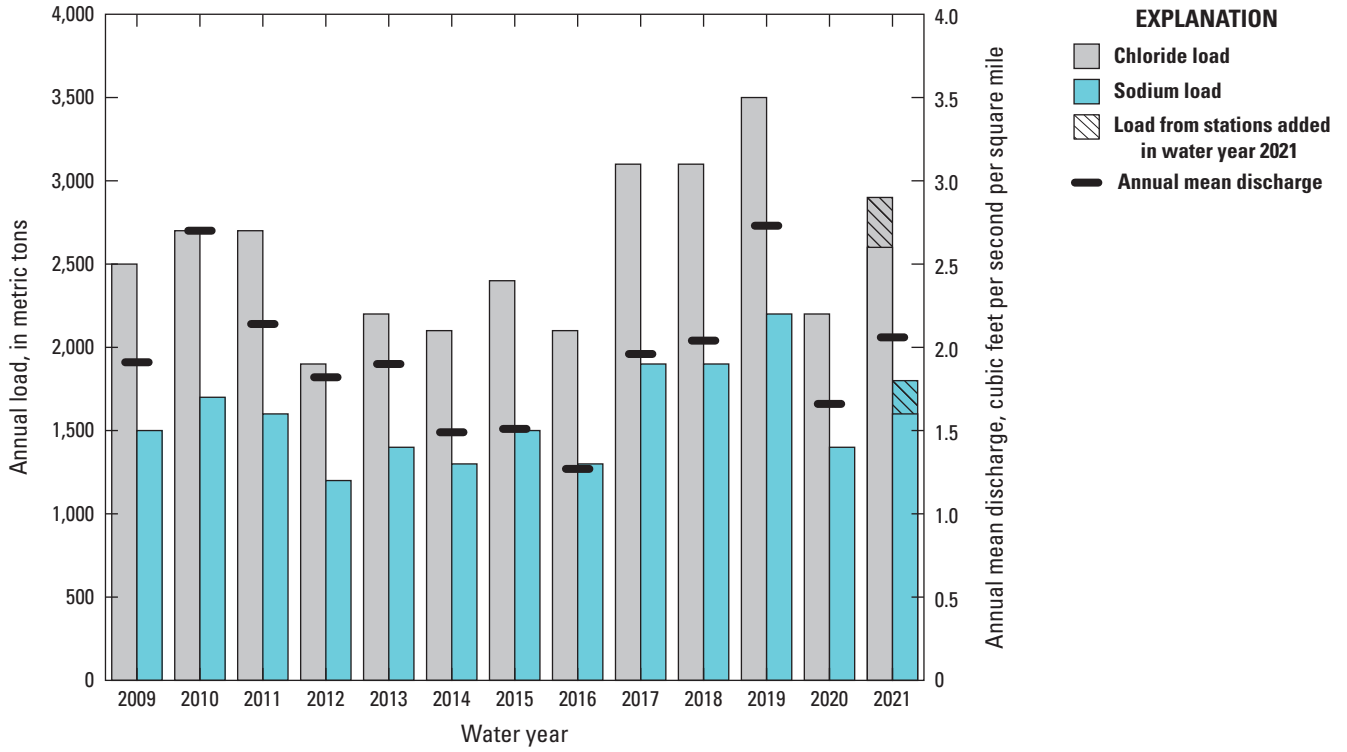

Figure 6. Bar chart showing estimated annual loads of chloride and sodium estimated from continuous measurements of streamflow and specific conductance and the annual mean discharge for water years 2009–21 (October 1, 2009, through September 30, 2021) for the area upstream from 16 Providence Water sampling stations in the Scituate Reservoir drainage area, Rhode Island. Locations of stations are shown on figure 1; station information is listed in table 1. Modified from Smith (2019a). Data are from Smith and Spaetzel (2021).

(USGS station 01115098; PW station 16) at 3,200 g/d as nitrogen. Median daily orthophosphate loads were largest (1,700 g/d as phosphate) at Huntinghouse Brook (USGS station 01115110; PW station 14; table 8). The maximum median daily yield for nitrite was 26 grams per day per square mile ([g/d]/mi^2) as nitrogen at Brandy Brook (USGS station 01115180; PW station 1), and the maximum median daily yield for nitrate was 2,400 (g/d)/mi^2 as nitrogen at Bear Tree Brook (USGS station 01115275; PW station 9). The maximum yields for nitrite and nitrate were six times greater than the median yields among all stations which were equal to 4.2 and 400 [g/d]/mi^2 as nitrogen, respectively.

For orthophosphate, the maximum median daily yield was 360 (g/d)/mi^2 as phosphate at unnamed tributary to Westconnaug Reservoir (USGS station 01115273; PW station 11), which also had the highest total coliform bacteria median yield. The maximum median daily yield of orthophosphate was two times greater than the median among all station medians (180 [g/d]/mi^2 as phosphate). The medians of median daily loads were 12 g/d for nitrite as nitrogen, less than 700 g/d for nitrate as nitrogen, and 410 g/d for orthophosphate as phosphate (table 8), respectively.

Table 7. Median values for water-quality data collected at Providence Water stations in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.

[Data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations are shown on figure 1. If fewer than three samples were collected, the sample values are reported instead of a median. Minimum, median, and maximum values of all stations are based on station with more than two samples. USGS, U.S. Geological Survey; PCU, platinum-cobalt unit; NTU, nephelometric turbidity unit; CFU/100 mL, colony forming unit per 100 milliliters; *E.coli*., *Escherichia coli*; mg/L, milligram per liter; $CaCO_3$, calcium carbonate; N, nitrogen; PO_4, phosphate; <, less than; —, no data]

PW station number	USGS station number	Properties			Constituents						
		pH	Color (PCU)	Turbidity (NTU)	Total coliform bacteria (CFU/100 mL)	*E. coli* (CFU/100 mL)	Alkalinity (mg/L as $CaCO_3$)	Chloride (mg/L)	Nitrite (mg/L as N)	Nitrate (mg/L as N)	Orthophosphate (mg/L as PO_4)
Barden Reservoir subbasin											
24	01115190	6.4	33	0.47	1,000	20	6.5	24.9	0.001	0.07	0.05
25	01115200	6.1	58	0.57	2,000	75	5.4	11.8	0.002	<0.06	0.04
26	01115185	6.3	42	0.70	4,700	<25	6.4	29.3	0.002	0.08	0.055
27	011151845	5.7	17	0.32	340	41	3.8	12.9	<0.001	0.24	0.03
28	01115265	5.9	70	0.52	1,200	52	5.1	26.4	0.002	<0.05	0.04
29	01115271	6.3	40	0.61	290	<10	5.7	21.2	0.002	<0.05	0.04
35	01115187	6.4	40	0.57	1,800	20	6.4	21.6	0.002	0.07	0.05
Direct Runoff subbasin											
1	01115180	6.8	100	1.4	2,100	30	11	12.9	0.003	0.18	0.08
2	01115181	6.2; 6.0	15; 10	0.18; 0.22	370; 75	<10; 10	6.7; 5.4	54.1, 63.9	0.001; 0.001	0.88; 0.69	0.11; 0.05
3	01115280	6.5	35	0.31	870	36	6.3	37.8	0.001	0.11	0.045
4	01115400	6.2	30	0.54	1,100	<10	8.1	8.0	0.001	<0.05	0.03
5	01115184	6.3	50	0.35	2,000	10	6	21.3	0.002	0.23	0.05
6	01115183	6.2	190	1.1	2,400	97	10	32.1	0.004	0.10	0.045
7	01115297	6.2	80	0.66	1,500	56	7.6	11.6	0.002	0.06	0.05
8	01115276	6.3	25	0.41	160	<10	5.5	13.2	0.001	<0.05	0.05
9	01115275	6.6	45	0.42	2,000	<10	8.8	58.6	0.002	0.53	0.045
30	01115350	5.9	55	0.35	880	10	5.8	23.7	0.001	0.14	0.04
31	01115177	—	—	—	—	—	—	—	—	—	—
32	01115178	6.5	210	1.2	3,100	70	13.8	14.0	0.003	0.28	0.08
33	01115182	6.2	26	0.5	1,700	<10	18.5	18.0	0.001	0.17	0.07
36	—	6.6	25	0.38	1,100	25	7.4	7.4	0.001	<0.06	0.095
37	—	5.7	23	0.22	910	<10	7.1	7.1	0.001	0.05	0.13

Table 7. Median values for water-quality data collected at Providence Water stations in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.—Continued

[Data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations are shown on figure 1. If fewer than three samples were collected, the sample values are reported instead of a median. Minimum, median, and maximum values of all stations are based on station with more than two samples. USGS, U.S. Geological Survey; PCU, platinum-cobalt unit; NTU, nephelometric turbidity unit; CFU/100 mL, colony forming unit per 100 milliliters; *E.coli*., *Escherichia coli*; mg/L, milligram per liter; $CaCO_3$, calcium carbonate; N, nitrogen; PO_4, phosphate; <, less than; —, no data]

PW station number	USGS station number	Properties			Constituents						
		pH	Color (PCU)	Turbidity (NTU)	Total coliform bacteria (CFU/100 mL)	*E. coli* (CFU/100 mL)	Alkalinity (mg/L as $CaCO_3$)	Chloride (mg/L)	Nitrite (mg/L as N)	Nitrate (mg/L as N)	Orthophosphate (mg/L as PO_4)
Moswansicut Pond reservoir subbasin											
19	01115170	7.0	22	0.57	360	<10	12	51.1	0.001	0.08	0.06
20	01115160	6.3	250	0.86	2,300	52	13	71.4	0.006	0.07	0.11
21	01115165	6.7	37	1.5	4,900	110	18	38.7	0.004	0.40	0.06
22	01115167	6.7	32	1.1	1,200	42	20	49.8	0.014	1.10	0.05
34	01115164	6.2	55	1.1	2,200	60	15	29.6	0.002	<0.09	0.07
Ponaganset Reservoir subbasin											
23	011151843	6.2	22	0.56	650	<10	5.4	19.4	0.001	0.06	0.03
Regulating reservoir subbasin											
13	01115176	6.7	38	0.62	830	30	9.6	33.0	0.001	<0.05	0.05
14	01115110	6.5	65	0.59	3,300	50	8.1	15.1	0.001	0.08	0.06
15	01115114	6.7	70	0.75	1,900	52	10	39.1	0.001	0.08	0.05
16	01115098	6.5	45	0.95	1,200	20	11	36.7	0.002	0.09	0.05
17	01115119	5.6; 6.2	40; 45	0.28; 0.38	1,100; 470	20; <10	8.5; 7.6	32.7; 37.4	0.001; 0.001	<0.05; 0.09	0.03; 0.02
18	01115120	6.4	55	0.37	1,900	40	9.3	65.6	0.001	0.30	0.06
Westconnaug Reservoir subbasin											
10	01115274	5.8	25	0.17	1,100	<10	4.8	24.9	0.001	<0.05	0.04
11	01115273	5.7	170	0.63	3,600	<31	7.6	7.2	0.002	<0.05	0.055
12	011152745	6.2; 6.1	25; 30	0.72; 0.67	320; 560	<10; 63	5.6; 5.4	13.1; 13.1	0.001; 0.001	0.14; <0.05	0.07; 0.03
Scituate Reservoir drainage area											
Minimum		5.7	17	0.17	160	<10	3.8	7.1	<0.001	<0.05	0.03
Median		6.3	42	0.57	1,500	30	7.6	23.7	0.002	0.08	0.05
Maximum		7.0	250	1.5	4,900	110	20	71.4	0.014	1.10	0.13

Table 8. Median daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.

[Concentration data from Spaetzel and Smith (2021)]. Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations are shown on figure 1. USGS, U.S. Geological Survey; (CFU×10^6)/d; million colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d, gram per day; N, nitrogen; PO_4, phosphate; <, less than; —, not applicable]

PW station number	USGS station number	Total coliform bacteria ([CFU×10^6]/d)	*E. coli* ([CFU×10^6]/d)	Chloride (kg/d)	Nitrite (as N; g/d)	Nitrate (as N; g/d)	Orthophosphate (as PO_4; g/d)
Barden Reservoir subbasin							
24	01115190	69,000	2,600	310	14	680	530
25	01115200	88,000	2,400	78	10	<380	260
26	01115185	200,000	<1,600	300	12	880	560
28	01115265	180,000	11,000	580	25	1,400	1,300
35	01115187	340,000	8,600	870	43	<2,100	1,500
Direct Runoff subbasin							
1	01115180	130,000	<2,000	170	41	1,500	480
3	01115280	54,000	1,400	180	6.0	<700	280
4	01115400	62,000	<1,100	41	5.9	<530	<160
5	01115184	41,000	800	44	4.1	470	100
6	01115183	180,000	7,200	460	36	2,600	410
7	01115297	150,000	6,600	220	36	<1,400	1,000
8	01115276	56,000	<2,100	270	20	<980	1,100
9	01115275	39,000	<380	170	3.8	1500	74
32	01115178	28,000	640	18	3.5	240	110
33	01115182	4,800	<50	7.8	0.48	110	24
Moswansicut Pond reservoir subbasin							
19	01115170	43,000	<1,600	980	18	<1,400	710
21	01115165	38,000	860	48	3.9	430	63
Regulating reservoir subbasin							
14	01115110	320,000	10,000	410	34	2,500	1,700
15	01115114	240,000	11,000	750	20	2,200	860
16	01115098	270,000	5,100	890	43	3,200	1,500
18	01115120	8,500	180	30	0.49	130	29
Westconnaug Reservoir subbasin							
10	01115274	71,000	<640	120	5.3	260	190
11	01115273	170,000	<3,300	36	9.8	<380	260
Scituate Reservoir drainage area							
Minimum	—	4,800	180	7.8	0.48	110	24
Median	—	71,000	<2,000	180	12	<700	410
Maximum	—	340,000	11,000	980	43	3,200	1,700

Table 9. Median daily yields of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2020, through September 30, 2021.

[Concentration data from Spaetzel and Smith (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ([CFU×10^6]/d)/mi^2; millions of colony forming units per day per square mile; *E. coli*, *Escherichia coli*; N, nitrogen; PO_4, phosphate; (kg/d)/mi^2, kilogram per day per square mile; (g/d)/mi^2, gram per day per square mile; <, less than; —, not applicable]

PW station number	USGS station number	Total coliform bacteria ([CFU×10^6]/mi^2)	*E. coli* ([CFU×10^6]/mi^2)	Chloride ([kg/d]/mi^2)	Nitrite (as N; [g/d]/mi^2)	Nitrate (as N; [g/d]/mi^2)	Orthophosphate (as PO_4; [g/d]/mi^2)
Barden Reservoir subbasin							
24	01115190	14,000	530	63	2.9	140	110
25	01115200	37,000	1,000	33	4.2	<160	110
26	01115185	46,000	<370	69	2.8	200	130
28	01115265	21,000	1,300	67	2.9	160	150
35	01115187	24,000	610	62	3.1	<150	110
Direct Runoff subbasin							
1	01115180	83,000	<1,300	110	26	960	310
3	01115280	29,000	750	96	3.2	<370	150
4	01115400	73,000	<1,300	48	6.9	<620	<190
5	01115184	33,000	630	35	3.3	370	79
6	01115183	92,000	3,700	230	18	1,300	210
7	01115297	35,000	1,500	51	8.3	<320	230
8	01115276	11,000	<410	52	3.9	<190	210
9	01115275	63,000	<610	270	6.1	2,400	120
32	01115178	62,000	1,400	40	7.8	530	240
33	01115182	17,000	<180	28	1.8	390	86
Moswansicut Pond reservoir subbasin							
19	01115170	13,000	<490	300	5.5	<430	220
21	01115165	130,000	2,900	160	13	1,400	210
Regulating reservoir subbasin							
14	01115110	51,000	1,600	65	5.4	400	270
15	01115114	51,000	2,300	160	4.2	470	180
16	01115098	54,000	1,000	180	8.7	640	300
18	01115120	30,000	640	110	1.8	460	100
Westconnaug Reservoir subbasin							
10	01115274	48,000	<430	81	3.6	180	130
11	01115273	240,000	<4,600	50	14	<530	360
Scituate Reservoir drainage area							
Minimum	—	11,000	530	28	1.8	140	79
Median	—	46,000	1,000	67	4.2	400	180
Maximum	—	240,000	3,700*	300	26	2,400	360

*The maximum uncensored yield was 3,700 [CFU×10^6]/mi^2, but the maximum value may have been up to 4,600 [CFU×10^6]/mi^2.

Summary

Since 1993, the U.S. Geological Survey (USGS), in cooperation with Providence Water (PW), has maintained a long-term cooperative water-quality monitoring program within the Scituate Reservoir drainage area. PW also has been independently monitoring and assessing water quality in the reservoir and reservoir drainage area for more than 60 years. Together, the data collected by the USGS and PW are used to calculate concentrations, loads, and yields of chloride, sodium, nutrients, and bacteria for tributaries within Scituate Reservoir drainage area on an annual basis.

During water year (WY) 2021, the U.S. Geological Survey measured or estimated streamflow at 24 streamgages; 16 of these streamgages are equipped with instrumentation capable of continuously monitoring water level, specific conductance, and water temperature. Before WY 2021, 14 streamgages were equipped with continuous-monitoring instrumentation; therefore, for annual comparisons of total chloride and sodium loads measured in the drainage area over the WY 2009–20 period, loads from the two streamgages added in WY 2021 are omitted. Water-quality samples, that are analyzed for dissolved concentrations of major ions (including chloride and sodium), were periodically collected by the USGS at each of the 16 streamgages. Concentrations of chloride and sodium, collected during WY 2021 and in previous water years, were used to support and refine relations between each ion and specific conductance. Using equations to relate specific conductance to concentrations of chloride and sodium, and combined with measured or estimated streamflow data, monthly and annual concentrations, loads, and yields were estimated for the 16 streamgages.

At 16 of the 24 USGS streamgages, where both streamflow and continuous specific conductance data were available, estimated monthly mean chloride concentrations ranged from 7.9 to 100 milligrams per liter (mg/L) and estimated monthly mean sodium concentrations ranged from 5.6 to 58 mg/L in tributaries of the Scituate Reservoir drainage area. The highest annual mean concentrations of chloride and sodium were estimated to be 51 and 30 mg/L, respectively, in Moswansicut stream (USGS station 01115170; PW station 19) in the more developed, northeastern part of the Scituate Reservoir drainage area. An estimated 2,900 metric tons (t) of chloride and 1,800 t of sodium were transported to the Scituate Reservoir during WY 2021 from tributaries equipped with instrumentation; annual chloride yields for tributaries in the drainage area ranged from 15 to 110 metric tons per square mile (t/mi^2), and annual sodium yields ranged from 10 to 68 t/mi^2. The sum of annual loads during WY 2021 for 14 stations with continuous monitoring in WYs 2009–20 was 17 percent greater than the sum of annual loads estimated during the previous water year and approximately equal to the average of WYs 2009–20.

PW collected at least one water-quality sample at 36 of 38 sampling stations in WY 2021, including at 15 of the 16 USGS continuous-record streamgages, as part of their long-term sampling program in the Scituate Reservoir drainage area. In WY 2021, Toad Pond (USGS station 01115177; PW station 31) and Swamp Brook (USGS station 01115278; PW station 38) were not sampled. Water-quality samples are analyzed by PW for pH, color, turbidity, alkalinity, and concentrations of chloride, nutrients, and bacteria. Water-quality data collected by PW are summarized by using values of central tendency and are used in combination with periodic- or continuous-streamflow data available at 23 of the 36 stations sampled in WY 2021 to calculate loads and yields of chloride, nutrients, and bacteria.

For water samples collected by PW, the median of the median pH values for samples from all stations on tributaries in the Scituate Reservoir drainage area was 6.3; the median value for color was 42 platinum-cobalt units; the median value for turbidity was 0.57 nephelometric turbidity unit; and the median concentration for alkalinity was 7.6 mg/L as calcium carbonate. The medians of the median concentrations for water samples from all stations were 23.7 milligrams per liter for chloride, 0.002 milligram per liter as nitrogen for nitrite, 0.08 milligram per liter as nitrogen for nitrate, 0.05 milligram per liter as phosphate for orthophosphate, 1,500 colony forming units per 100 milliliters for total coliform bacteria and 30 colony forming units per 100 milliliters for *Escherichia coli*. The medians of the median daily loads were 180 kilograms per day for chloride, 12 grams per day as nitrogen for nitrite, less than 700 grams per day as nitrogen for nitrate, 410 grams per day as orthophosphate for phosphate, 71,000 million colony forming units per day for coliform bacteria, and less than 2,000 million colony forming units per day for *Escherichia coli*. The medians of the median yields were 67 kilograms per day per square mile for chloride, 4.2 grams as nitrogen per day per square mile for nitrite, 400 grams as nitrogen per day per square mile for nitrate, 180 grams as orthophosphate per day per square mile for phosphate, 46,000 million colony forming units per day per square mile for coliform bacteria, and 1,000 million colony forming units per day per square mile for *Escherichia coli*.

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For more information, contact
Director, New England Water Science Center
U.S. Geological Survey
10 Bearfoot Road
Northborough, MA 01532
dc_nweng@usgs.gov
or visit our website at
https://www.usgs.gov/centers/new-england-water

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