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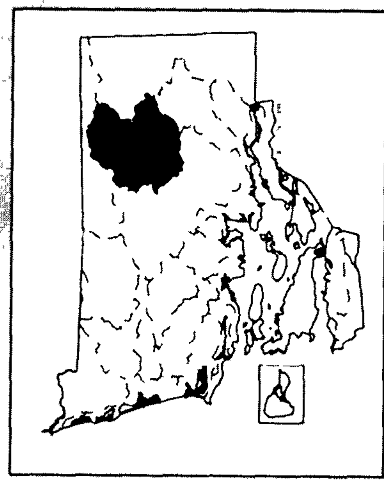
Water-Quality Conditions and Relation to Drainage-Basin Characteristics in the Scituate Reservoir Basin, Rhode Island, 1982–95



Water-Resources Investigations Report 00-4086

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

The median instantaneous loads and yields of many of the selected water-quality constituents sampled from the Westconnaug Reservoir subbasin were among the smallest compared to the other subbasins, except for manganese yield (0.15 kg/d/mi^2) that was among the largest. These results may be due partly to the smaller size of the subbasin and partly to the dominance of forestland cover (99.7 percent). These results indicate that generally the Westconnaug Reservoir subbasin is contributing a small amount of total coliform bacteria, chloride, nitrate, iron, and manganese in terms of both loads and yields to Westconnaug Reservoir, and perhaps ultimately to the Scituate Reservoir, compared to the other tributary subbasins.

TRENDS IN SELECTED WATER-QUALITY CONSTITUENT CONCENTRATIONS

It is important to note that changes in sampling or analytical methods, trends in streamwater discharge, and human uses of land and water resources may have affected the detected trends in water-quality constituents in the Scituate Reservoir Basin. Determining the magnitudes of these factors for specific drainage basins and water-quality constituents is an area for further investigation.

Basinwide trends in concentrations of selected constituents are shown in fig. 10. On each map, a trend is indicated at a sampling station only if a significant trend was found ($p < 0.05$). The following trends in water-quality constituents were detected for water years 1982–95: (1) increasing concentrations of pH, color, turbidity, and alkalinity at most stations, (2) increasing concentrations of chloride at one-third of the stations where a trend was detected, and (3) decreasing concentrations of sodium at all stations where a trend was detected.

pH

Upward trends in pH during 1982 through 1995 indicate less acidic conditions in streams and rivers in the Scituate Basin. Increases in pH may be related to reduced acid deposition (acid rain). Federally mandated improvements (Title VI of the Clean Air Act Amendments of 1990) to reduce acidic deposition in the United States, including phased reductions in sulfur dioxide and nitrogen oxide emissions, have decreased hydrogen-ion concentrations in precipitation in the eastern United States (Lynch and others, 1995). A study of trends in Connecticut (Trench, 1996) also detected geographically widespread increases in pH during a similar time period.

Color

Absorbance of light by naturally occurring dissolved organic carbon (DOC), referred to here as color, is often used as an indicator of DOC, a complex mixture consisting largely of humified plant material that is not easily characterized (Thurman, 1985). A possible reason for the upward trend in color values may be related to increased pH, which would indicate that the surface waters in the Scituate Reservoir Basin are becoming less acidic with time. Less acidic water has a greater capacity to solubilize and dissolve organic carbon than more acidic water (McKnight and Bencala, 1990; Donahue and others, 1998).

Turbidity

Natural or anthropogenic suspended matter is the primary cause of turbidity in surface-waters; components include clay, silt, fine organic and inorganic matter, DOC, and synthetic inorganic and organic contaminants. Increasing volumes of storm runoff from impervious surfaces in expanding residential areas may contribute to the upward trend in turbidity.

Total Coliform Bacteria

Total coliform bacteria is used as an indicator of fecal contamination from humans and other warm-blooded animals, because fecal contamination can introduce disease-causing viruses and bacteria into a stream, river, or reservoir. Total coliform concentrations showed no statistically significant trend at the 32 sampling stations.

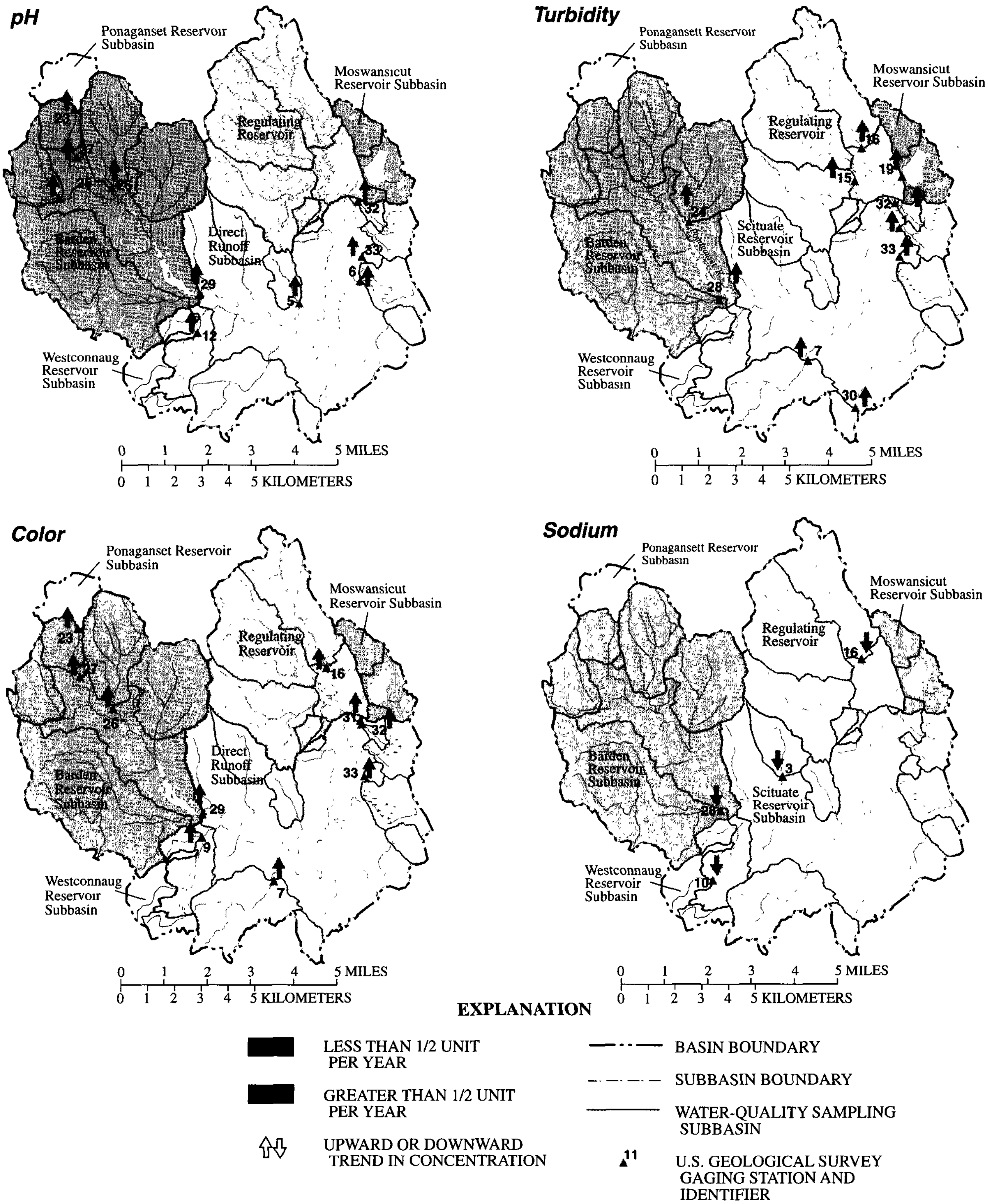


Figure10. Trends of water-quality constituents, October 1982–September 1995, Scituate Reservoir Basin, Rhode Island.

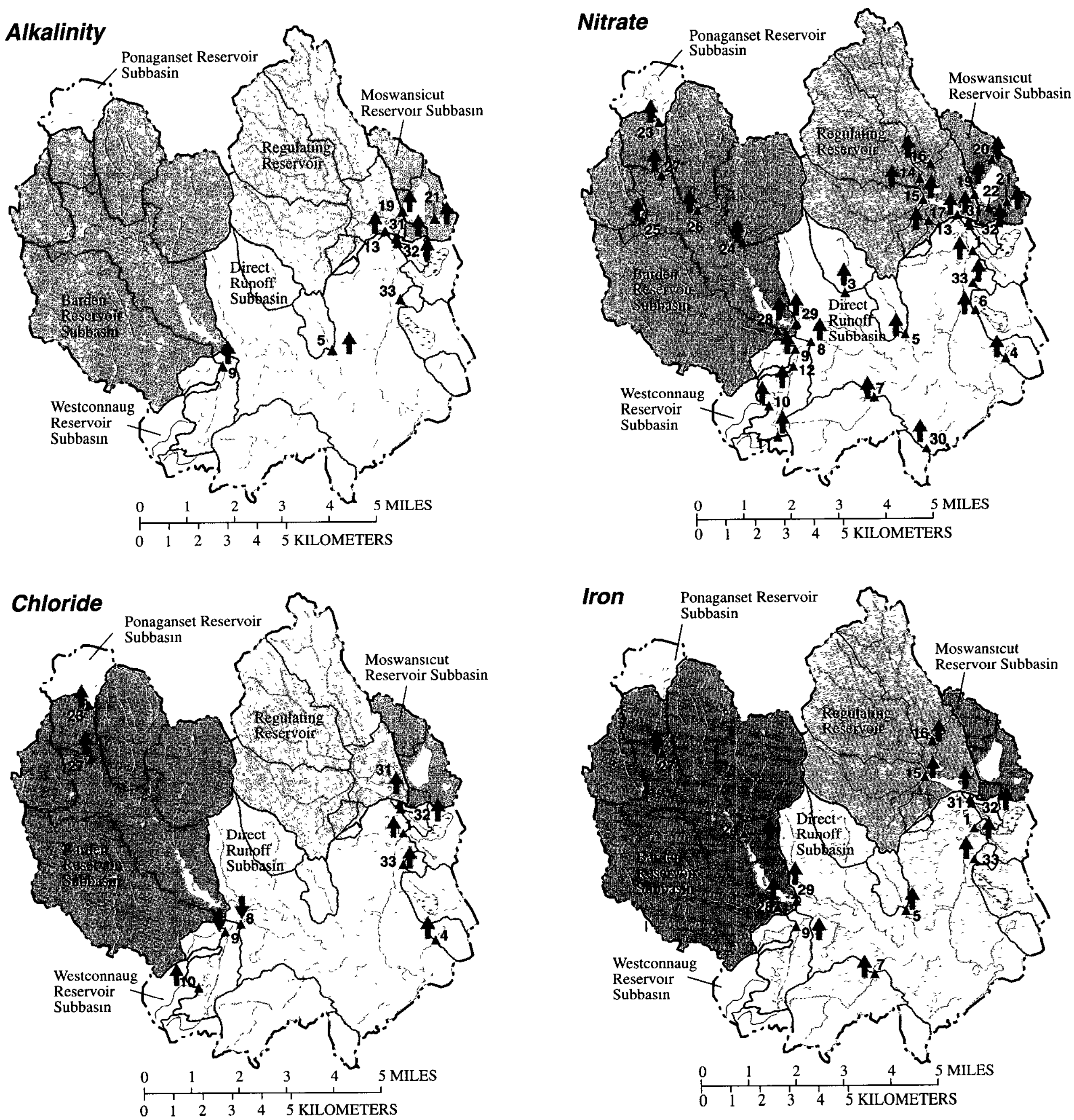


Figure10. Trends of water-quality constituents, October 1982–September 1995, Scituate Reservoir Basin, Rhode Island—*Continued.*

Sodium

The downward trend in sodium concentration at all stations where a trend was detected could have been the result of policy changes in road-deicing practices in the Scituate Reservoir Basin. In the late 1980s, Runge and others (1988) determined that road salt was the largest source of sodium and chloride to the reservoir's drainage basin. Consequently, in 1990, the PWSB and the Rhode Island Department of Transportation (RIDOT) adopted the use of a calcium chloride/sodium chloride premix in place of sodium chloride alone on State roads in the basin. The premix is a 60/40 mixture of $CaCl_2/NaCl$, which is about 12 percent calcium, 26 percent sodium, and 60 percent chloride by weight (Granato and others, 1995).

Alkalinity

Urban and industrial development has increased as a result of population growth in the Scituate Reservoir Basin during 1982 through 1995. Larger quantities of urban runoff and industrial discharge resulting from this development are probable causes of increasing alkalinity. For example, Smith and Lord (1990) showed that highway systems have the capacity to buffer the runoff of acid precipitation by increasing the alkalinity of streams receiving highway runoff.

Chloride

Natural sources of chloride in freshwater streams of the Scituate Reservoir Basin area are limited, and upward trends in chloride are likely caused by a variety of human activities, including nonpoint runoff containing road-deicing salts. Chloride-containing salts are used for many domestic and industrial applications, such as roads, parking areas, and sidewalks, and may be associated with septic system discharge; as the population increases, the quantity of salt increases proportionally. During the winter, salt dissolves and is carried to nearby streams by surface runoff and ground-water discharge. The downward trend in chloride concentrations at sampling stations 9 and 8 may be the result of the 1988 enclosure of the Clayville RIDOT salt-storage facility in the Bear Tree Brook subbasin.

Nitrate

Sources of nitrate in streamwater include the atmosphere, biological activity, and human activities, such as agriculture and onsite sewage disposal (Weiskel and Howes, 1991). For example, many homeowners in the basin have livestock such as horses, cows, pigs, and sheep. Waste from these animals may be a source of nitrate.

Iron

An increase in urban and industrial development has contributed to larger quantities of residential runoff and commercial discharge partly resulting in increased iron concentrations in the Scituate Reservoir Basin. Another possible cause is related to the increased concentrations of dissolved organic carbon or color. Iron in solution can be bound by DOC and stabilized as a dissolved iron-organic carbon complex, allowing for a greater transport of iron (Hem, 1985).

FREQUENCY OF EXCEEDENCE OF WATER-QUALITY CRITERIA AND GUIDELINES

The RIDEM has developed water-quality guidelines that set concentration limits for water-quality constituents, depending on the intended use of the water body. The RIDEM publishes water-quality criteria that are intended to "restore, preserve and enhance the physical, chemical, and biological integrity of the waters and to maintain existing water. These regulations provide for the protection of the surface-waters from pollutants so that the waters shall, where attainable, be fishable and swimmable, be available for all designated uses, taking into consideration their uses and value for public water supplies, propagation of fish and wildlife, and recreational purposes" (State of Rhode Island and Providence Plantations Department of Environmental Protection, 1997). Surface waters in the State are assigned to one of four classes: A, B, B1, and C. The class a surface-water body is assigned to (A, B, B1 or C) is determined by the most sensitive of its intended uses. For example, the water resources in the Scituate Reservoir Basin are assigned to class A, because they are used as a source of public drinking-water supply, although they also are used for primary and secondary contact-recreational activities and for fish and wildlife habitat.

At present, many water-quality constituents monitored by the PWSB are not regulated by the State. The U.S. Environmental Protection Agency (USEPA) publishes water-quality criteria and guidelines for drinking water, not untreated water supply (raw water). These criteria and guidelines include maximum contaminant levels (MCLs), secondary maximum contaminant levels (SMCLs), and water contaminant candidates lists (CCLs) and are shown here to represent the degree of treatment and purification needed to meet USEPA criteria for drinking water (table 4). This criteria may be important because some of these constituents are often difficult to remove through present treatment and purification processes.

The following evaluation of the extent and frequency of exceedence of Rhode Island and USEPA water-quality guidelines and standards should be considered an informal screening to distinguish the water-quality constituents and locations that may fail to meet the minimum water-quality necessary to support the designated surface-water use classification (table 4) or require significant treatment and purification to meet USEPA guidelines and standards for drinking water. The frequency of exceedence of water-quality criteria and guidelines is shown in figure 11.

pH

The RIDEM has set water-quality standards for untreated water pH of 6.5 to 9.0 (Rhode Island Department of Environmental Management, 1997). At least 80 percent of the samples collected between 1982 and 1995 at 21 of the 33 water-quality sampling stations were less than the RIDEM standard pH of 6.5. This result represents the most geographically widespread failure to meet the minimum water-quality standards necessary to support the applicable drinking-water use classification; however, drinking-water supplies with naturally occurring pH values outside of the RIDEM criteria are presently exempted from this standard.

Table 4. Water-quality guidelines and standards for Rhode Island

[RIDEM, Rhode Island Department of Environmental Management (1997); USEPA, U.S. Environmental Protection Agency (1996). MCL, maximum contamination level; SMCL, secondary maximum contamination level; CCL, contaminant candidate list; CFU, colony-forming units; NTU, nephelometry turbidity units; mg/L, milligrams per liter; --, not applicable]

Constituent	RIDEM	USEPA (MCL)	USEPA (SMCL)	USEPA (CCL)
pH	6.5–9.0	--	6.5–8.5	--
Color		--	15	--
Turbidity, in NTU	5 NTU over back-ground	--	--	--
Bacteria, in CFU/100 mL	[1]100	1	--	--
Sodium, in mg/L		--	--	20
Chloride, in mg/L		--	250	--
Nitrate, in mg/L		10	--	--
Nitrite, in mg/L		1	--	--
Iron, in mg/L		--	0.3	--
Manganese, in mg/L		--	0.05	--

[1]Written as a mean for a given site.

Color

Color in natural water is usually produced from leaching of organic debris and is used as an indicator of DOC. DOC is important in stream and reservoir chemistry because it complexes many metals and nutrients (Koenings and Hooper, 1976; Jackson and Hecky, 1980), often controls transparency, affects pH and alkalinity (Oliver and others, 1983), and acts as substrate for microbial production (Hessen, 1992). Recently, concern has arisen over the transformation of DOC to various types of chlorinated organic compounds, such as trihalomethanes and haloacetic acids, during the chlorination process (Miller, 1993).

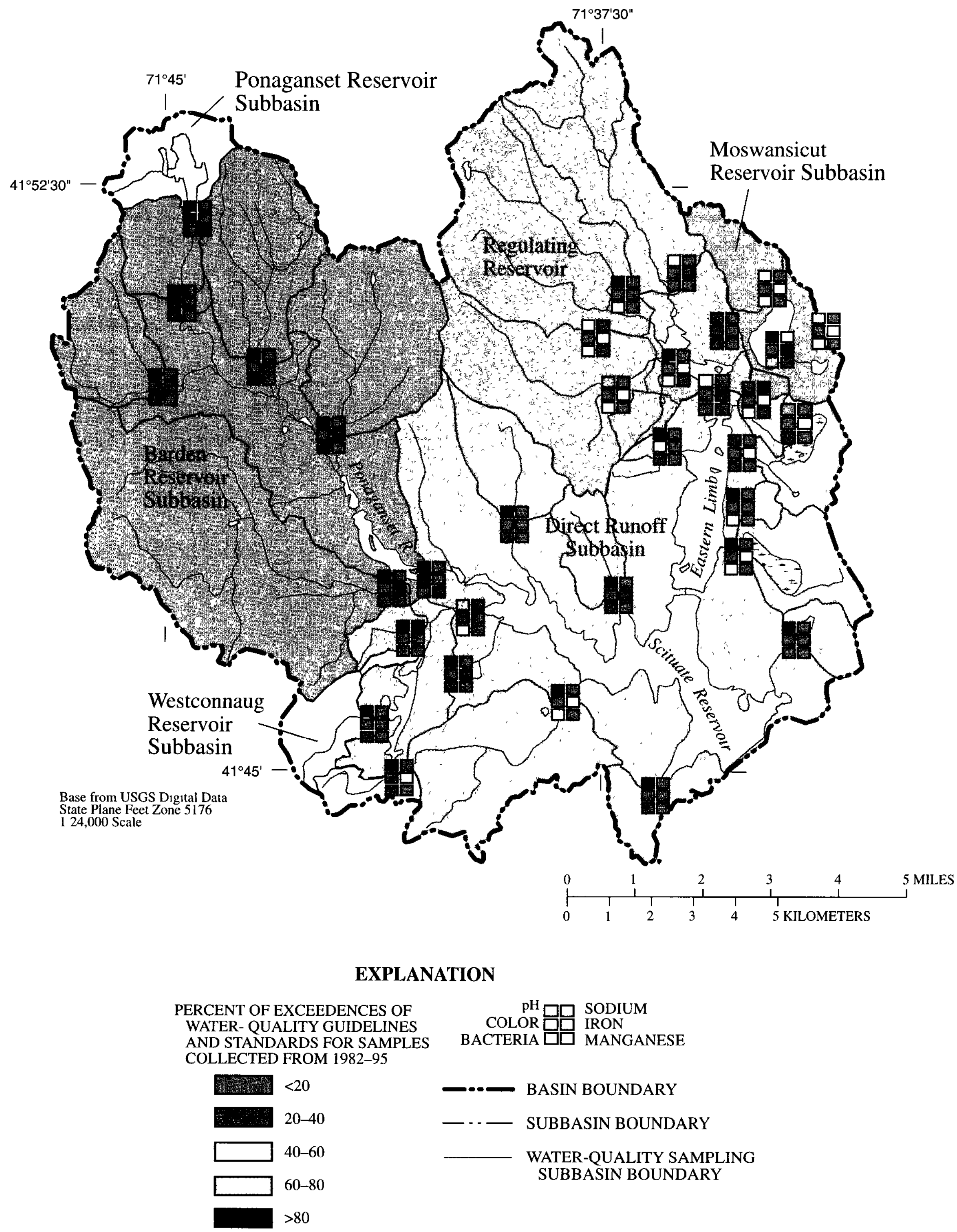


Figure 11. Frequency of exceedences of water-quality standards and guidelines in the Scituate Reservoir Basin, Rhode Island.

Such compounds, known collectively as disinfection by-products, have been identified as possible carcinogens, and the USEPA is presently establishing new limits for by-products in drinking water.

The USEPA has set a SMCL of 15 for color. Generally, color values were less than the SMCL of 15; however, 20 to 60 percent of the samples exceeded the SMCL at four sampling stations. More than 80 percent of the samples collected from station 23 (Ponaganset Reservoir) exceeded the SMCL for color.

Turbidity

The suspended and colloidal material comprising turbidity is important for both aesthetic and health reasons. One heath-related characteristic of turbidity is the association of microorganisms with particulate matter. This association can limit disinfection efficiency and increase production of disinfection by-products. Additionally, suspended solids can be associated with synthetic inorganic and organic contaminants (tire and street surface-wear particles) and also can have negative ecological effects on aquatic life (U.S. Environmental Protection Agency, 1983). The RIDEM has set a maximum water-quality standard of 5 NTU over background for class A waters. Based on the mean-median turbidity value for all water-quality sampling stations as background (5.6 NTU), all of the samples collected for turbidity in the study area had concentrations less than the allowed 5 NTU above background, or 10.6 NTU.

Total Coliform Bacteria

Water in streams and reservoirs commonly contains a wide variety of microorganisms, some of which cause diseases in humans. Many microorganisms occur naturally, and some are introduced into water supplies by human activities, such as sewage disposal. Water suppliers disinfect water from reservoirs to eliminate microbial contamination before drinking water is distributed to consumers. A useful indicator of microbial contamination in water is total coliform bacteria concentrations. Although the total-coliform group does not generally include disease-causing organisms, coliforms indicate the potential presence of other human pathogens including bacteria, protozoans (*Cryptosporidium* and *Giardia*), and enteric viruses.

The RIDEM has established a drinking-water supply standard (Class A waters) for total coliform bacteria of 100 CFU/100 mL (Rhode Island Department of Environmental Management, 1997). The USEPA has established a MCL of 1 CFU/100 mL for treated drinking water (US Environmental Protection Agency, 1996). Untreated water must have total coliform concentrations no greater than 5,000 CFU/100 mL to allow filtration and chlorination to produce treated water with concentrations less than the MCL (James M. Montgomery, Consulting Engineers, 1985).

From 20 to 60 percent of the samples had coliform concentrations greater than the RIDEM standard at 24 of the 33 stations. Total coliform concentrations at sampling station 22, (Moswansicut Reservoir) were greater than the RIDEM standard for at least 60 percent of the samples collected there. Total coliform concentrations for all the Moswansicut Reservoir sampling stations were greater than the RIDEM standard for more than 40 percent of the samples collected in this subbasin; this is the largest percentage of total coliform exceedences observed in the Scituate Basin.

Sodium

Sodium is a common, naturally occurring element found in soil and water. Although necessary for the normal functioning of the human body, sodium can cause problems for some people who have difficulty regulating fluids as a result of various diseases, such as hypertension. Although sodium from drinking water is generally a small part of a person's total sodium intake, monitoring sodium intake in these individuals is important. Additionally, many State and Federal agencies are requiring public water suppliers to report all results that show a detection of sodium to their local board of health. This notification is required so that individuals who are on sodium-restricted diets or who wish to monitor their sodium intake for other reasons will be able to take the amount of sodium in their water into account. The USEPA has set a sodium guideline (defined as a contaminant candidate) of 20 mg/L for drinking water. Generally, sodium concentrations were below the USEPA guideline with the exception of the samples collected at stations 9 and 31 (Bear Tree Brook and Toad Pond); more than 80 percent of the samples collected from these stations exceeded the USEPA sodium guideline.

Chloride

Chloride is present in all natural waters but concentrations are usually low in streams and reservoirs of New England. Although chloride is not considered to be a health hazard, high concentrations can produce corrosion and give water a salty taste. The USEPA has established a SMCL of 250 mg/L for chloride (U.S. Environmental Protection Agency, 1996). Chloride concentrations for all samples analyzed at all stations in the Scituate Reservoir Basin were less than the USEPA SMCL.

Nitrate and Nitrite

Nitrogen can be present in water as nitrite, nitrate, ammonium, and as part of organic solutes (Hem, 1985) Excessive concentrations of nitrate in drinking water can cause methemoglobinemia in small children. As a result, the USEPA has set an MCL of 10 mg/L for nitrate (as nitrogen) in finished drinking-water. Nitrate concentrations for all samples analyzed at all sampling stations in the Scituate Reservoir Basin were less than the USEPA MCL. Nitrite usually occurs in natural waters at much lower concentrations than does nitrate. Currently, the USEPA MCL for nitrite in drinking water is 1 mg/L. The PWSB collects data for nitrite at 33 water-quality sampling stations, but concentrations are generally quite low, commonly less than or near the detection limit, because nitrite is readily oxidized to nitrate under most surface-water conditions.

Iron and Manganese

Iron is a necessary nutrient for human life, but in excess can give an unpleasant taste and odor to water. The USEPA has established a SMCL of 0.3 mg/L for iron (U.S. Environmental Protection Agency, 1996). From 20 to 60 percent of the samples analyzed for iron exceeded the SMCL at 19 sampling stations (56 percent of the stations). More than 80 percent of the samples analyzed for iron from station 22 (Moswansicut Reservoir) exceeded the SMCL for iron. Manganese also is a necessary nutrient for human life, but can give an unpleasant taste to water, cause staining, and foster the growth of microorganisms in water-distribution systems. The USEPA has established a SMCL of 0.05 mg/L for manganese (U.S. Environmental Protection Agency, 1996). More than 85 percent of the samples analyzed for manganese were below the SMCL.

RELATION OF WATER-QUALITY CONDITIONS TO DRAINAGE-BASIN CHARACTERISTICS

The quality of natural waters is affected by a variety of different drainage-basin characteristics; however, the number of water-quality variables, the interspersed nature of drainage-basin characteristics in the Scituate Reservoir Basin, and the fact that water-quality constituents can be affected by more than one drainage-basin characteristic make it difficult to determine the key characteristic(s) responsible for controlling water quality. By clustering water-quality data by tributary subbasin and looking at the effect of drainage-basin characteristics on water-quality at a smaller scale, the likelihood of gaining insights into relations between water-quality variables and drainage-basin characteristics is increased. Subbasin-wide relations between water-quality constituent concentrations and drainage basin characteristics are shown in table 5. In the table, a relation is indicated between each water-quality constituent and drainage-basin characteristic by tributary subbasin only if a significant relation was found ($r > 0.71$).

Table 5. Selected correlation-analysis results (Pearsons *r*-values > 0.71) of median values for water-quality data and selected drainage-basin characteristics by tributary subbasin, Scituate Reservoir Basin, Rhode Island

[No relation between water-quality constituents and commercial, industrial, and institutional land use were found. B; Barden Reservoir subbasin; D, Direct Runoff subbasin; M, Moswansicut Reservoir; R, Regulating Reservoir subbasin; S, Scituate, W, Westconnaug Reservoir subbasin]

Drainage-basin characteristics	pH	Color	Turbidity	Total coliform bacteria	Sodium	Alkalinity	Chloride	Nitrate	Orthophosphate	Iron	Manganese
Land use—Urban											
Urban	M, R	W	D, S	B	B	D, R, S	B				
Residential	M, R				B	R	B				
Land use—Rural											
Agricultural		M		B		S		R			
Mixed Forest		R	M	M, R	M, W	M	M, R, W	M	M	M	M
Water	D, W		D, W			D, M, R, W	B	R			D
Wetlands		M									
Barren Land		M									
Geology—Bedrock											
Felsic	M		R		R	M	R		R	R	R
Igneous				B	B		B				
Non-calcareous		M	D	D		D					
Geology—Surficial											
Outwash	B, M	B, R, W	B	R	D		D			B	
Till	R				W		W	B, R			
Wetlands											
Forested wetlands	W	M	R, W	R		W				R	R
Non-forested wetlands	B	B, R, W	D	W	B	D	B			B, D, W	D
Slope											
Slope 0–5	B		B							B	W
Slope 5–10	W	W	M, W	M, W	M	M, W	M	B, M		M, W	M
Slope 10–15	W	W	W	W	M	W	M			W	
Slope 15–20	W	W	M, W	B, M, W	B, M	M, W	B, M	M	M	M, W	M
Slope 20–25	M	W	D	B, W	B	D	B			W	
Slope >25		R, W	D	B, W	B	D	B			W	
Soil Drainablility											
Excessively drained		W, R	B, M	M, R	D, M	M	D, M	M	M	M	M
Moderately well drained	B	M			W	B					W
Well drained	M, R, W	W	M, W	M, W		R,W		M, R	M	M, W	M
Variable	D, W		D, R, W	B		W,D			R	R, W	
Poorly drained		B, M			R, W		R, W			B	W
Very poorly drained		D,M,R, S,W	B	R, W						B, W	
Roads											
Primary road miles	R	B, D, M	B		B, R		B, R			B	W
Primary road density	R	B	D	B	R	D	B, R			B	
Secondary road miles	R	B, M, D	B		W		W	R		B	W
Secondary road density		M,RW	D	R		D		B			D

Land Use

The significant correlation (Pearsons *r* greater than 0.71) between pH, total coliform, sodium, and chloride and urban land use in some of the tributary reservoir subbasins indicates that these constituents may be partly due to human effects. For example, Weiskel and others (1996) determined that the major sources of total coliform bacteria to stormwater in a largely residential area were most likely the feces of domestic animals. They hypothesized that fecal material accumulates on paved surfaces during dry periods, with surviving bacteria becoming entrained during storm events. Additionally, significant relations among alkalinity, manganese, nitrate, total coliform bacteria, and drainability of soils may indicate a substantial contribution of constituents from onsite septic-tank systems. Because the entire population of the Scituate Reservoir Basin uses septic-tank soil-absorption systems for wastewater disposal, the potential of constituent loads to the Scituate Reservoir Basin is great (Rich Blogget, Providence Water Supply Board, oral commun., 1998).

Geology

The significant correlation (Pearsons *r* greater than 0.71) in some of the subbasins between geology and pH, color, turbidity, total coliform bacteria, chloride, iron, and manganese is likely because sources of some of these water-quality constituents are correlated, such as wetlands and melt water deposits. However, potential sources of manganese and iron may include the weathering of mafic minerals (Robinson, 1997), and mechanical erosion of coatings of manganese and iron oxides that are widely distributed in stream sediments and soils (Hem, 1985).

Wetlands and Soil Drainability

The significant correlation (Pearsons *r* greater than 0.71) between wetlands or soil drainability (table 6) (poorly drained soils may be a more accurate index for wetlands than the available wetland coverages) and pH, color, turbidity, total coliform bacteria, alkalinity, and iron in most of the tributary subbasins indicates that these water-quality constituents are partly controlled by biogeochemical processes in wetlands. Wetland research in recent years has demonstrated that wetlands can act either as a net importer or net exporter of these constituents (Elder, 1987). For example, "when an organic wetland soil is flooded, the oxygen available in the soil and in the water is rapidly depleted through microbial metabolism. Generally, the rate of diffusion of molecular oxygen through water is limited and cannot supply the metabolic demand. When the demand exceeds the supply, dissolved oxygen is depleted, the redox potential in the soil drops rapidly, and ions such as nitrate, manganese, iron, sulfate, and carbon dioxide, are reduced and mobilized" (Mitsch and Gosselink, 1986). Hemond and Benoit (1988) showed the DOC was larger and hydrogen-ion concentrations (pH) were smaller in watersheds that had the greatest percentage of wetland area. Weiskel and others (1996) found that animal bacteria from saturated wetland surfaces is a likely source of total coliform bacteria to streams and has been observed in a wetland-dominated watershed free of residential land-use-related bacterial sources.

Roads and Slope

The significant correlation (Pearsons *r* values greater than 0.71) between roads or slope and pH, color, turbidity, sodium, alkalinity, chloride, and iron in most of the tributary subbasins indicates that these water-quality constituents are partly controlled by stormwater runoff from primary and secondary roads. Increased sodium and chloride concentrations in rivers (Peters and Turk, 1981), ponds (Hutchinson, 1970), and ground water (Hutchinson, 1970), have been attributed to deicing practices. Of particular interest are the results of an investigation done by Runge and others (1988) who reviewed sodium and chloride data in the Scituate Reservoir Basin and concluded that road salting was the primary source of sodium and chloride concentrations in the reservoir and its tributaries. Granato and others (1995) found that concentrations of iron and manganese were larger in ground water down-gradient from a highway, in some cases an order of magnitude larger. Iron and manganese concentrations were highly correlated with chloride concentrations, indicating that mobilization is probably caused by deicing chemical migration. Iron in stormwater also can be derived from the corrosion of cars and other steel (for example, guardrails or stabilizing slag for grade material) and is associated with suspended sediment. Anthropogenic sources of manganese in stormwater include fertilizers and engine parts (Makepeace and others, 1995).

Turbidity can be caused by solids transported in road runoff during rain events. Runoff from paved surfaces transports dissolved, colloidal, and solid constituents in a heterogeneous mixture of metals, organic compounds, and inorganic compounds (Sansalone and Burchberger, 1997). The generation and accumulation of these constituents on highways result from traffic activities, vehicular wear, pavement degradation, maintenance activities, littering, and atmospheric deposition. For example, tire and pavement interaction abrades both materials, generating solids that can be a significant source of turbidity (Muschack, 1990). Pavement has been shown to account for 40 to 50 percent and tires for 20 to 30 percent of solids generated by road runoff (Kobriger and Geinopolos, 1984).

SUMMARY AND CONCLUSIONS

This report discusses the results of a study by the U.S. Geological Survey, in cooperation with the Providence Water Supply Board to provide detailed information about water-quality conditions and relations with drainage-basin characteristics in the Scituate Reservoir Drainage Basin, Rhode Island, between 1982 and 1995. The results of the study reported here indicate that concentrations, loads, and trends of pH, color, turbidity, total coliform bacteria, sodium, alkalinity, chloride, nitrate, orthophosphate, iron, and manganese in streams tributary to the Scituate Reservoir appear to be primarily controlled by the size of the drainage basin and the geographic distribution of drainage-basin characteristics, such as point and nonpoint contaminant sources, wetlands, and external forces such as atmospheric deposition. Median concentrations and yields of these water-quality constituents were larger in residential areas where point and non-point sources are likely, and in areas of poorly drained soils (or wetlands). Median instantaneous loads of the water-quality constituents reflect drainage basin size; that is, loads generally were larger for larger subbasins compared to smaller subbasins. Results of this study indicate that, in general, the Barden and Direct Reservoir subbasins are exporting large loads of most water-quality constituents. In contrast, the Moswansicut and Westconnaug Reservoir subbasins are likely discharging smaller loads of these constituents compared to the other subbasins. The results also indicate that the Direct and Moswansicut Reservoir subbasins are exporting disproportionately large amounts of the water-quality constituents related to other subbasins such as the Barden Regulating, and Westconnaug Reservoir subbasins.

Significant trends in water-quality constituents from 1982 to 1995 in the Scituate Reservoir Basin indicate that the quality of the water resources in the basin may be slowly changing. Scituate Reservoir subbasins with large amounts of residential land use showed increasing trends in alkalinity and chloride. In contrast, subbasins distributed throughout the drainage basin showed increasing trends in pH, color, nitrate, and iron concentrations, indicating that these characteristics and constituents may be controlled more by atmospheric deposition.

Some water-quality constituent concentrations measured between 1982 and 1995 in the Scituate Reservoir Basin occasionally exceeded Rhode Island and USEPA water-quality guidelines and standards for source water. However, at present, most of the selected water-quality constituents monitored by the PWSB are not regulated by the State of Rhode Island or the U.S. Environmental Protection Agency (USEPA) in source water. More accurate assessment of the effects of the presence of elevated concentrations of the selected water-quality constituents would require analysis to be made between intake and finished water.

The percentage of wetlands, roads, and slope appear to have the greatest effect on water-quality in the Scituate Reservoir Basin. The percentage of urban, residential, and commercial land uses also are important, but to a lesser degree than wetlands, roads, and slope. Finally, geology appears to have the least effect on water quality compared to other drainage-basin characteristics investigated.

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Table 6. Drainage-basin characteristics by subbasin in the Scituate Reservoir Basin, Rhode Island

[Values are given as percentages. **Wetlands:** Includes nonforested (marsh/wet meadow, emergent fen or bog, shrub fen or bog) and forested (coniferous forested wetland, deciduous forested wetland and wetlands with standing dead trees). **Barren land:** Includes open-pit mines, quarries, and gravel pits. **Felsic:** Includes granitoid plutonic rocks and their metamorphic equivalents. **Igneous:** Includes mafic and ultramafic igneous rocks and their metamorphic equivalents. **Noncalcareous:** Includes metamorphosed clastic sedimentary rocks. **Meltwater deposits:** Includes noncompacted poor-to-well-sorted sand and gravel. **Till:** Includes nonsorted sand, silt, clay, and boulders. PWSB, Providence Water Supply Board; USGS, U.S. Geological Survey; Bolded values are the maximum values of the water-quality sampling stations; italics are maximum values of the tributary reservoir subbasins. No., number; mi, mile, mi/mi^2, mile per square mile; mi^2, square mile; >, actual value is greater than value shown]

USGS station No.	PWSB station No.	Area (mi^2)	Land use									Geology				
			Urban				Rural					Bedrock			Surficial	
			Residential	Commercial	Industrial	Institutional	Agricultural	Mixed forest	Water	Wetlands	Barren land	Felsic	Igneous	Noncalcareous	Meltwater deposits	Till
Barden Reservoir Subbasin																
01115190	24	5.01	2.0	0.0	0.0	0.0	0.3	95.8	2.0	0.0	0.0	62.7	**37.3**	0.0	13.8	84.6
01115200	25	2.39	.0	.0	.0	.0	.0	95.4	.0	.0	.0	98.1	.0	.0	13.8	85.6
01115185	26	4.22	.0	2.0	.0	.0	1.4	96.6	.0	.0	.0	91.2	8.8	.0	11.6	88.1
011151845	27	.10	.0	.0	.0	.0	.0	100.0	.0	.0	.0	**100.0**	.0	.0	.0	100.0
01115270	28	10.62	.3	.4	.0	.0	.0	96.7	.0	.0	.0	97.3	1.9	.0	30.5	66.5
01115271	29	**33.02**	.7	.4	.0	.0	.3	94.8	2.5	.0	.0	85.3	14.3	.0	20.6	75.4
01115187	A	3.69	1.8	.0	.0	.0	.3	97.3	.6	.0	.0	81.1	18.9	.0	27.3	71.7
	B	1.57	.3	.0	**.9**	.0	.0	98.0	.4	.0	.0	100.0	.0	.0	**.0**	99.2
Subbasin total...........		31.16	0.7	0.4	0.0	0.0	0.3	95.8	1.5	0.0	0.0	84.4	*15.1*	0.0	21.0	75.9
Direct Runoff Subbasin(s)																
01115180	1	1.57	4.8	0.0	0.0	0.0	5.7	72.8	2.5	**13.2**	1.0	100.0	0.0	0.0	51.3	44.3
01115181	2	.15	.0	.0	.0	.0	.0	**100.0**	.0	.0	.0	100.0	.0	.0	19.4	80.6
01115280	3	1.90	.0	.0	.0	.0	.9	95.2	.0	.0	.0	100.0	.0	.0	.0	99.5
01115400	4	.86	2.9	.0	.0	.0	7.2	78.0	4.4	.0	.0	100.0	.0	.0	.0	95.1
01115184	5	1.23	2.5	.0	.0	.0	2.4	95.0	.0	.0	.0	100.0	.0	.0	.0	95.6
01115183	6	1.99	.0	.0	.0	.0	3.2	88.1	.0	4.0	.0	99.3	.7	.0	26.1	73.9
01115297	7	4.42	.0	.0	.0	.0	1.1	97.0	.0	.0	.2	100.0	.0	.0	10.7	86.6
01115276	8	5.10	.0	.0	.0	.0	.0	95.5	3.6	.0	.0	100.0	.0	.0	34.5	57.2
01115275	9	.64	.0	.0	.0	.0	.0	99.2	.0	.0	.0	100.0	.0	.0	**97.1**	2.8
01115350	30	.74	.1	.0	.0	.0	.1	99.9	.0	.0	.0	100.0	.0	.0	20.0	80.0
01115177	31	.04	.0	.0	.0	**57.4**	.0	17.9	24.7	.0	.0	32.3	.0	**67.7**	93.2	.0
01115178	32	.40	.0	.0	.0	.0	.0	99.8	.2	.0	.0	100.0	.0	.0	36.2	63.8
01115182	33	.27	.0	.0	.0	.0	.0	**100.0**	.0	.0	.0	100.0	.0	.0	4.8	95.0
	C	20.23	1.1	.0	.0	.0	1.1	71.2	**26.3**	.0	.3	99.8	.0	.2	6.8	65.1
Subbasin total...........		*36.97*	1.0	0.0	0.0	*0.5*	1.4	80.3	15.3	0.8	0.2	99.8	0.0	0.2	13.6	69.0

Table 6. Drainage-basin characteristics by subbasin in the Scituate Reservoir Basin, Rhode Island—*Continued*

USGS station No.	PWSB station No.	Area (mi^2)	Land use: Urban: Resi-dential	Land use: Urban: Com-mercial	Land use: Urban: Indus-trial	Land use: Urban: Institu-tional	Land use: Rural: Agri-cultural	Land use: Rural: Mixed forest	Land use: Rural: Water	Land use: Rural: Wet-lands	Land use: Rural: Barren land	Geology: Bedrock: Felsic	Geology: Bedrock: Igneous	Geology: Bedrock: Noncal-careous	Geology: Surficial: Melt-water deposits	Geology: Surficial: Till
Moswansicut Reservoir Subbasin																
01115170	19	3.20	20.0	0.0	0.0	0.0	5.3	54.5	15.7	3.5	1.1	60.4	0.0	21.3	19.7	65.2
01115160	20	1.21	26.7	.0	.0	.0	**8.8**	52.3	.0	9.2	3.0	53.3	.0	46.7	4.2	95.7
01115165	21	.32	**32.5**	.0	.0	.0	.0	49.8	17.8	.0	.0	**100.0**	.0	.0	37.4	49.0
				.0	.0	.0				.0	.0		.0			
01115167	22	.22	29.1	.0	.0	.0	.0	70.9	.0	.0	.0	95.4	.0	4.6	17.0	82.9
01115164	34	.27	30.4	.0	.0	.0	.0	48.6	21.0	.0	.0	**100.0**	.0	.0	6.8	48.7
Subbasin total..........		3.20	*27.6*	0.0	0.0	0.0	*7.2*	54.5	15.7	*3.5*	*1.1*	60.4	0.0	*21.3*	19.7	65.2
Ponaganset Reservoir Subbasin																
011151843	23	1.86	0.7	0.0	0.0	0.0	0.0	78.0	18.1	0.0	0.0	99.3	0.0	0.0	13.8	67.5
Subbasin total..........		1.86	0.7	0.0	0.0	0.0	0.0	78.0		0.0	0.0	99.3	0.0	0.0	13.8	67.5
Regulating Reservoir Subbasin																
01115176	13	22.17	4.5	0.0	0.0	0.3	2.5	87.6	4.1	0.5	0.2	90.0	0.2	7.1	21.3	74.1
01115110	14	6.24	.3	.0	.0	.0	2.7	96.4	.6	.0	.0	99.2	.8	.0	9.8	88.6
01115115	15	4.98	1.4	.0	.0	.4	.0	98.2	.0	.0	.0	**100.0**	.0	.0	17.6	81.8
01115098	16	4.92	2.2	.0	.0	.4	4.3	92.0	1.1	.0	.0	**100.0**	.0	.0	23.7	75.2
01115119	17	.13	.0	.0	.0	.0	.0	**100.0**	.0	.0	.0	**100.0**	.0	.0	62.2	33.6
01115120	18	.54	.3	**4.9**	.0	.0	.0	94.8	.0	.0	.0	**100.0**	.0	.0	43.8	55.2
Subbasin total..........		18.97	1.9	*0.4*	0.0	0.3	2.0	93.2	2.2	0.0	0.0	95.0	0.3	4.7	*21.1*	75.6
Westconnaug Reservoir Subbasin																
01115274	10	1.37	0.0	0.0	0.0	0.0	0.0	**100.0**	0.0	0.0	0.0	**100.0**	0.0	0.0	3.1	94.6
01115273	11	.69	.0	.0	.0	.0	.0	**100.0**	.0	.0	.0	**100.0**	.0	.0	21.7	77.6
011152745	12	.15	.0	.0	.0	.0	.0	95.2	.0	.0	.0	**100.0**	.0	.0	72.3	26.4
Subbasin total..........		2.20	0.0	0.0	0.0	0.0	0.0	99.7	0.0	0.0	0.0	100.0	0.0	0.0	13.6	*84.7*
Scituate Reservoir Basin																
Basin total		94.10	1.7	0.2	0.0	0.3	1.2	87.6	7.8	0.4	0.1	92.4	5.1	1.8	17.9	72.8

Table 6. Drainage-basin characteristics by subbasin in the Scituate Reservoir Basin, Rhode Island—*Continued*

USGS station No.	PWSB station No.	Wetlands: Forested	Wetlands: Non-forested	Slope: 0–5	Slope: 5–10	Slope: 10–15	Slope: 15–20	Slope: 20–25	Slope: > 25	Soil Drainability: Excessively drained	Soil Drainability: Moderately well drained	Soil Drainability: Well drained	Soil Drainability: Variable	Soil Drainability: Poorly drained	Soil Drainability: Very poorly drained	Roads: Primary miles (mi)	Roads: Primary road density (mi/mi²)	Roads: Secondary miles (mi)	Roads: Secondary road density (mi/mi²)
Barden Reservoir Subbasin																			
01115190	24	7.5	3.9	44.3	36.2	13.7	4.3	1.2	0.3	0.3	37.2	39.7	0.8	18.2	1.4	13.55	2.71	37.77	7.54
01115200	25	12.1	2.3	41.1	48.4	10.0	.5	.0	.0	.1	52.5	28.2	.6	15.4	2.6	3.68	1.54	14.20	5.94
01115185	26	9.7	3.1	52.8	32.4	9.5	3.8	1.2	.4	3.7	**54.2**	25.6	2.0	12.4	1.8	8.15	1.93	38.41	9.10
011151845	27	11.3	.0	35.4	**54.6**	10.0	.0	.0	.0	.0	20.3	69.0	.0	10.7	.0	.11	1.02	1.21	11.60
01115270	28	11.1	2.7	57.4	33.8	6.9	1.3	.3	.2	8.6	39.5	26.4	.6	19.1	5.7	18.64	1.76	66.11	6.22
01115271	29	8.9	4.8	48.9	35.9	10.8	3.1	.9	.5	5.1	40.2	32.2	.7	16.1	2.7	58.61	1.76	**244.37**	7.40
01115187	A	7.5	2.3	43.5	41.4	11.5	2.3	.7	.5	7.6	30.5	45.1	.4	14.7	1.0	5.55	1.50	35.31	9.56
	B	11.7	1.5	44.8	26.8	15.6	7.7	2.8	2.3	.0	28.8	50.0	.0	20.5	.5	5.79	3.68	8.0	5.06
Subbasin total..........		9.1	3.8	*49.5*	36.1	10.4	2.8	0.8	0.4	5.2	*40.4*	*32.5*	0.7	16.4	2.8	58.01	1.86	*226.43*	7.27
Direct Runoff Subbasin(s)																			
01115180	1	15.9	7.2	20.8	34.4	26.0	12.5	4.4	1.9	12.4	9.0	53.1	2.3	7.3	11.4	0.031	0.02	19.45	12.36
01115181	2	14.3	.7	13.8	30.9	30.8	17.3	5.6	1.6	7.3	34.3	32.6	.0	23.2	2.6	.0	.0	2.23	14.47
01115280	3	13.7	1.3	**75.8**	23.6	.6	.0	.0	.0	.0	38.7	31.7	.2	**28.7**	.7	6.73	3.54	12.61	6.63
01115400	4	12.5	5.7	22.0	32.2	25.4	15.2	4.4	.9	1.2	33.2	47.0	2.2	11.5	.0	.38	.45	2.69	3.11
01115184	5	9.4	1.7	34.7	40.7	17.2	4.8	1.4	1.2	2.2	8.9	67.9	.1	19.1	1.8	2.08	1.69	3.04	2.47
01115183	6	19.2	1.7	18.4	35.7	26.9	13.0	4.2	1.8	1.0	19.4	58.4	.7	7.4	13.0	7.38	3.72	16.94	8.54
01115297	7	13.9	2.7	42.7	38.8	13.4	3.8	1.0	.4	7.1	15.4	55.3	.4	18.1	3.7	2.93	.66	22.66	5.13
01115276	8	7.2	6.1	42.5	38.4	12.9	4.3	1.4	.5	7.3	17.1	45.5	.5	11.0	2.8	11.69	2.29	33.13	6.5
01115275	9	11.1	1.4	36.2	38.1	16.7	6.5	1.8	.6	**42.7**	7.8	32.6	1.9	9.0	6.0	1.37	2.14	2.22	3.5
01115350	30	7.4	.9	33.6	38.4	18.5	7.6	1.3	.6	.0	3.7	**83.7**	.0	12.2	.4	1.49	2.01	2.43	3.3
01115177	31	.0	9.8	14.2	29.3	21.7	12.8	**8.4**	**3.8**	31.6	.0	.0	6.3	.0	.0	.64	**15.4**	.9	**21.63**
01115178	32	14.3	2.4	13.5	29.4	**31.1**	**18.1**	6.7	1.1	8.2	12.5	62.2	.0	9.1	8.0	.0	.0	2.79	6.91
01115182	33	15.1	1.0	21.5	41.6	27.3	7.7	1.5	.4	.6	8.5	78.7	.0	12.0	.0	.19	.73	2.13	8.05
	C	5.6	**25.9**	46.0	43.7	8.2	.8	.4	.8	4.3	12.6	47.7	.6	8.4	.9	5.03	2.47	92.3	4.56
Subbasin total..........		8.7	16.1	42.4	39.9	12.1	3.6	1.2	0.8	5.9	14.6	50.0	0.6	11.1	2.5	77.61	2.06	201.4	5.49

Table 6. Drainage-basin characteristics by subbasin in the Scituate Reservoir Basin, Rhode Island—*Continued*

		Wetlands		Slope						Soil Drainability						Roads			
USGS station No.	PWSB station No.	For-ested	Non-for-ested	0–5	5–10	10–15	15–20	20–25	> 25	Exces-sively drained	Moder-ately well drained	Well drained	Vari-able	Poorly drained	Very poorly drained	Pri-mary miles (mi)	Pri-mary road density (mi/mi^2)	Sec-ond-ary miles (mi)	Sec-ond-ary road density (mi/mi^2)
Moswansicut Reservoir Subbasin																			
01115170	19	11.2	16.8	28.3	29.2	23.7	12.3	4.3	2.2	6.0	16.0	48.3	1.4	6.3	6.8	19.16	5.99	27.6	8.62
01115160	20	**19.9**	2.5	18.1	36.0	28.4	13.2	3.6	.7	.3	30.7	47.6	.2	8.8	12.4	8.6	7.12	14.49	12.02
01115165	21	11.0	15.1	27.0	26.1	20.3	13.8	7.5	5.4	1.1	1.6	57.5	10.0	6.1	10.1	1.17	3.62	2.59	7.99
01115167	22	7.5	1.8	15.1	34.2	29.0	16.7	4.7	.3	20.5	7.8	62.4	.0	4.9	4.4	1.23	5.62	1.74	7.96
01115164	34	11.0	17.3	28.5	23.6	20.0	13.6	8.1	6.3	1.3	.0	54.9	**11.8**	4.1	11.9	1.72	4.28	2.59	9.44
Subbasin total..........		*11.2*	16.8	28.3	29.2	*23.7*	*12.3*	*4.3*	*2.2*	6.0	16.0	48.3	1.4	63.0	6.8	19.16	*5.99*	27.6	8.62
Ponaganset Reservoir Subbasin																			
011151843	23	5.7	**20.9**	38.5	31.4	18.0	7.8	2.8	1.5	3.0	35.8	26.9	0.0	10.0	0.8	0.6	0.32	17.94	9.63
Subbasin total..........		5.7	*20.9*	38.5	31.4	18.0	7.8	2.8	1.5	3.0	35.8	26.9	0.0	10.0	.8	0.6	0.32	17.94	9.63
Regulating Reservoir Subbasin																			
01115176	13	11.0	6.0	37.1	30.4	18.9	9.3	3.1	1.2	7.8	27.7	41.9	1.4	14.1	2.8	73.69	3.32	143.95	6.49
01115110	14	9.2	1.7	40.3	32.5	17.6	6.9	2.2	.6	1.1	44.6	42.1	.1	9.3	2.3	3.75	0.60	42.30	6.78
01115115	15	15.7	1.4	63.2	26.2	6.7	2.6	1.0	.3	2.7	38.0	29.5	1.6	25.9	2.1	23.0	4.62	26.73	5.37
01115098	16	8.9	3.6	18.5	32.6	27.3	15.1	4.8	1.7	8.4	8.5	61.9	2.1	17.1	.3	13.11	2.66	32.05	6.51
01115119	17	14.0	8.9	14.1	30.1	27.5	15.9	7.8	4.6	37.9	9.1	22.4	2.4	10.6	**13.3**	.0	.0	1.90	14.86
01115120	18	15.6	4.	18.5	34.9	27.7	13.8	3.8	1.2	21.3	14.5	34.4	8.2	12.6	8.0	2.68	4.99	3.37	6.26
Subbasin total..........		11.0	4.2	38.6	30.6	18.1	8.8	2.9	1.1	8.1	29.7	40.8	1.4	15.4	2.1	54.52	2.87	116.36	6.13
Westconnaug Reservoir Subbasin																			
01115274	10	7.9	0.1	50.9	41.3	7.0	0.7	0.1	0.0	5.4	35.8	39.4	0.1	19.3	0.0	5.69	4.14	6.71	4.88
01115273	11	15.1	1.5	30.2	42.9	20.3	5.2	1.2	.3	10.4	9.1	60.1	1.0	9.3	9.6	.21	.30	3.55	5.17
011152745	12	6.7	2.5	34.4	42.2	15.8	5.5	1.6	.5	34.2	1.1	51.5	.0	.0	13.2	2.08	13.86	1.64	1.96
Subbasin total..........		10.0	0.7	43.3	*41.9*	11.7	2..4	0.5	0.1	***8.9***	25.2	46.6	0.4	14.8	3.9	7.98	3.61	11.9	5.38
Scituate Reservoir Basin																			
Basin total		9.3	9.4	43.4	36.3	13.2	4.7	1.5	0.8	6.1	26.9	41.8	0.8	13.6	2.7	215.9	2.29	601.58	6.39