Water Resources of the Providence Area Rhode Island

By H. N. HALBERG, C. E. KNOX, *and* F. H. PAUSZEK

WATER RESOURCES OF INDUSTRIAL AREAS

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A description of the water resources of the area, their present use, and possible development

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WATER RESOURCES OF THE PROVIDENCE AREA, RHODE ISLAND

By H. N. Halberg, C. E. Knox, and F. H. Pauszek

ABSTRACT

The Providence area, as the term is used in this report, consists of 320 square miles in northeastern Rhode Island. The city of Providence is near its center. The largest ground-water supplies are in the glacial outwash deposits of sand or gravel. Municipal and industrial wells in these deposits commonly yield between 10 and 1,000 gpm (gallons per minute). A gallon or two of water per minute can be obtained from wells tapping the widely distributed deposits of glacial till. Water can also be obtained from wells tapping the underlying bedrock, which is sedimentary, igneous, and metamorphic. Municipal and industrial wells tapping bedrock yield from 5 to 200 gpm. Ground water in the Providence area is satisfactory for most purposes after minimum treatment, except for the iron and manganese content and hardness of water from some wells. Ground-water temperature ranged from 51° to 60° F and averaged about 56° F.

Unlimited quantities of saline water can be obtained from Narragansett Bay.

The Blackstone River is the largest and most developed stream in the area. The average flow at Woonsocket, 1930–55, was 468 mgd (million gallons per day), including about 12 mgd diverted from the Nashua River, and the flow may be expected to exceed 78 mgd 95 percent of the time; the flood of August 1955 was the greatest recorded in more than 200 years.

The Branch River is the principal tributary to the Blackstone River and is affected by regulation of upstream reservoirs. The average flow at Forestdale, 1941–45, was 102 mgd, and the flow may be expected to exceed 12 mgd 95 percent of the time.

The Woonasquatucket and Moshassuck Rivers form the Providence River at Providence and their drainage basins contain many ponds and reservoirs. The average flow of the Woonasquatucket River at Centerdale, 1942–55, was 43.4 mgd and the flow may be expected to exceed 8 mgd 95 percent of the time.

The Pawtuxet River is a tributary to the Providence River; its basin contains many lakes and reservoirs, including Scituate Reservoir. The average flow at Cranston, 1940–55, was 249 mgd, adjusted for storage and diversion, and the flow may be expected to exceed 41 mgd 95 percent of the time.

Water from streams in the Providence area is generally of satisfactory chemical quality, except for the high iron and manganese content and color of some water. Municipal and industrial wastes discharged into some of the larger streams make the water unsuitable for use without considerable treatment. The water is mostly soft, slightly acid, and contains less than 100 ppm (parts per million) of dissolved solids.

The major public water-supply systems of the area obtain most of their water from reservoirs on small streams. In 1954, about 60 percent of the 110 mgd of fresh water withdrawn for all purposes was obtained from public-supply systems, about 39 percent from private industrial systems, and less than 1 percent from private domestic systems. Of the total amount, 96 mgd was obtained from surface-water sources and 14 mgd was drawn from wells. An additional 359 mgd of saline water from estuaries was used almost entirely for condenser cooling in the generation of thermoelectric power.

Many additional water-supply systems can be developed in the Providence area. Because of the discharge of industrial and municipal wastes, quality rather than quantity of water is likely to limit additional municipal and industrial development of water supplies from the larger streams. Except for this pollution and the occurrence of iron, manganese, and color in some water, the quality of ground and surface water in the Providence area is fair to good. Moderate to large quantities of ground water may be obtained in many places from the glacial outwash along the river channels, in the buried preglacial valleys, from other places where there are water-bearing deposits of sand and gravel of appreciable thickness, or where pumping induces recharge of aquifers by surface water.

INTRODUCTION

The orderly and economical development of our water resources to meet increasing demands requires a knowledge of the occurrence and use of water. Specifically, information is required about sources of water, quantity available, chemical and physical quality, amount used, effect of use on the quantity and quality, and the magnitude and frequency of floods. Such information is essential to the planning, construction, and operation of water-supply systems that will satisfy increasing industrial and domestic demands, the requirements of defense mobilization, and demands for water at times of disaster.

This report summarizes information about the water resources of the Providence area, which has been collected since 1887. The report may be used for initial guidance in planning water-supply projects by naming sources of water, describing quantity and quality, and giving the ranges in water levels; however, additional investigations will be required for the design of many specific water-supply facilities.

The report was prepared in the field offices of the U.S. Geological Survey, under the direction of C. G. Paulsen and his successor L. B. Leopold, chiefs, Water Resources Division. Most of the basic data used were collected by the Geological Survey as part of its cooperative programs with the Rhode Island Department of Public Works, the Rhode Island Development Council, and the Corps of Engineers, Department of the Army (figs. 1 and 2). These programs were directed by H. B. Kinnison and his successor, C. E. Knox, district engineers for surface water, and J. E. Upson and his successor G. C. Taylor, Jr., district geologists for ground water. Collection and analysis of certain water samples were directed by F. H. Pauszek, district chemist for quality of water. Additional data were obtained

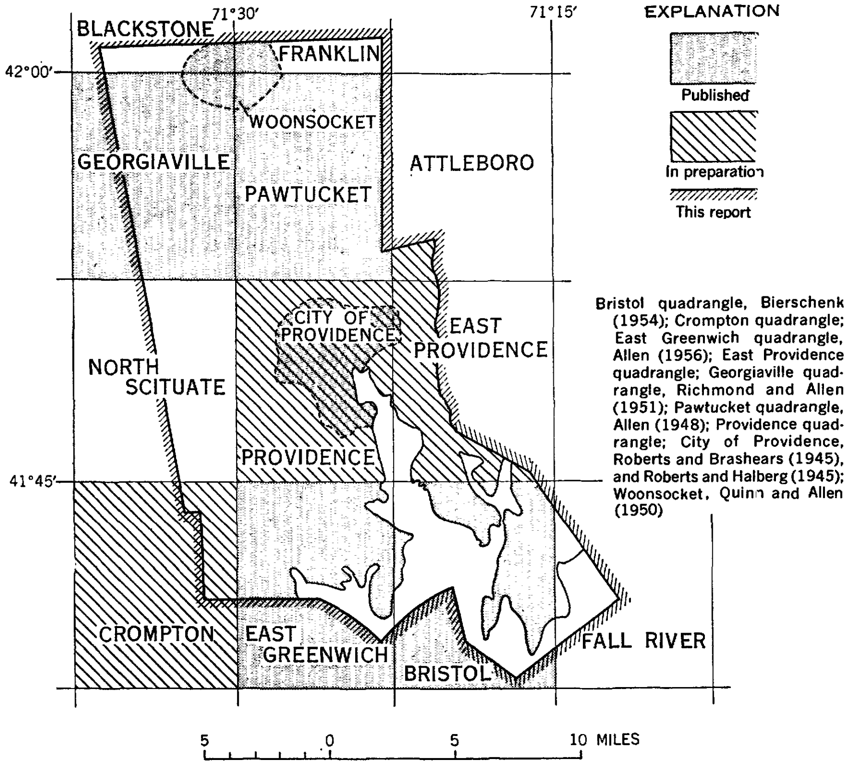

FIGURE 1.—Status of cooperative ground-water investigations in the Providence area, 1957.

from industries, public officials, and individuals. Many of the ground-water data used in the preparation of this report have been or are to be published by the State in a series of cooperative Federal-State reports on the ground-water resources of the cities of Providence and Woonsocket, the Bristol, East Greenwich, East Providence, Georgiaville, Pawtucket, and Providence quadrangles, and the entire State (fig. 2). K. A. MacKichan, chief, Hydrologic Studies Section, Branch of General Hydrology, assisted by J. C. Kammerer, geologist, was responsible for staff coordination.

The Providence area, as the term is used in this report, consists of 320 square miles in northeastern Rhode Island. It extends from the Massachusetts-Rhode Island State line on the north and east to the western boundaries of the towns or cities of North Smithfield, Smithfield, Johnston, Cranston, and West Warwick; on the south it extends to Greenwich, Narragansett, and Mount Hope Bays, and the southern boundaries of the towns of Warwick and West Warwick (pl. 1).

Period of record (1920, 1930, 1940, 1950)	Drainage area, in square miles	Gaging station	Number on plate 1
	93.3	Branch River at Forestdale, R. I.	1
	416	Blackstone River at Woonsocket, R. I.	2
	433	Blackstone River at Albion, R. I.	2.5
	38.3	Woonasquatucket River at Centerdale, R. I.	3
	92.8	Pawtuxet River at Fiskeville, R. I.	3.5
	63.8	South Branch Pawtuxet River at Washington, R. I.	4
	200	Pawtuxet River at Cranston, R. I.	5

FIGURE 2.—Extent of published records for gaging stations in the Providence area.

The Providence area is near the center of the Narragansett Bay drainage basin (fig. 3). Most of the area lies in the Seaboard Lowland section of the New England physiographic province. The northwestern part is in the transition zone between the lowland and the New England Upland section. About half the area lies below an altitude of 200 feet. The valleys and plains are underlain by glacial outwash deposits; the uplands are underlain mostly by till and exposed bedrock.

Large quantities of water are used in the manufacture of textiles, jewelry, rubber products, machinery and other metal products, and to supply the commercial activities and domestic needs of the population.

The availability and quality of water ranges widely. To simplify the description of the water supply, the area was divided into the following subareas: Tidewater, Blackstone River, Woonasquatucket River, and Pawtuxet River (fig. 4).

TIDEWATER SUBAREA

The relatively low lying area adjacent to the Seekonk and Providence Rivers and Narragansett Bay is referred to as the Tidewater subarea in this report. It consists principally of a glacial outwash plain that extends from southern Cumberland and Lincoln on the north to Greenwich Bay and Warren on the south. The town of Bristol and small areas elsewhere in the subarea, however, are underlain principally by glacial till (pl. 1). Physiographically the area is a part of the Narragansett Basin with altitudes generally less than

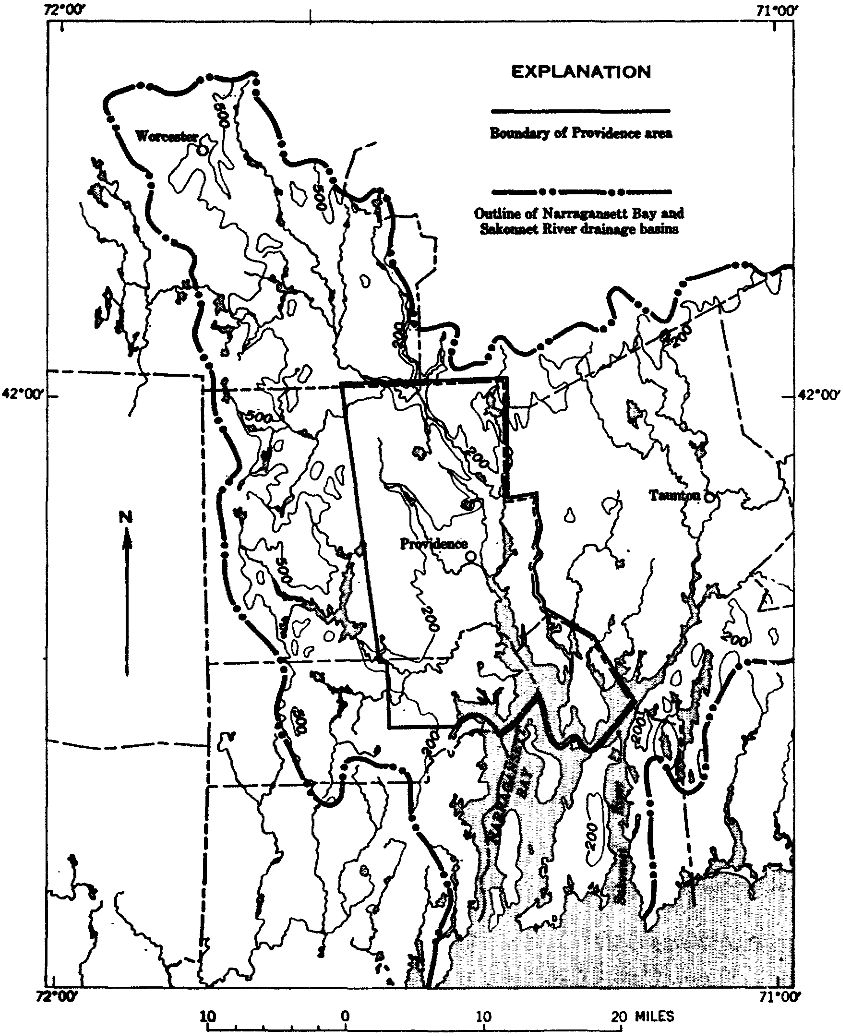

FIGURE 3.—Map of drainage basins tributary to Narragansett Bay and the Sakonnet River, showing location and altitude of the Providence area.

100 feet above sea level. The outwash consists of intercalated beds of clay, silt, sand, and gravel.

The Tidewater subarea is heavily populated and highly industrialized and includes parts or all of the cities of Providence, Pawtucket, Warwick, Cranston, and Central Falls; and the towns of East Providence, Barrington, Warren, and Bristol. Manufacturing is the principal industry. The major products include textiles, jewelry, machinery, fabricated metals, and rubber goods. Public water-supply systems obtain water from impounded small streams or from wells.

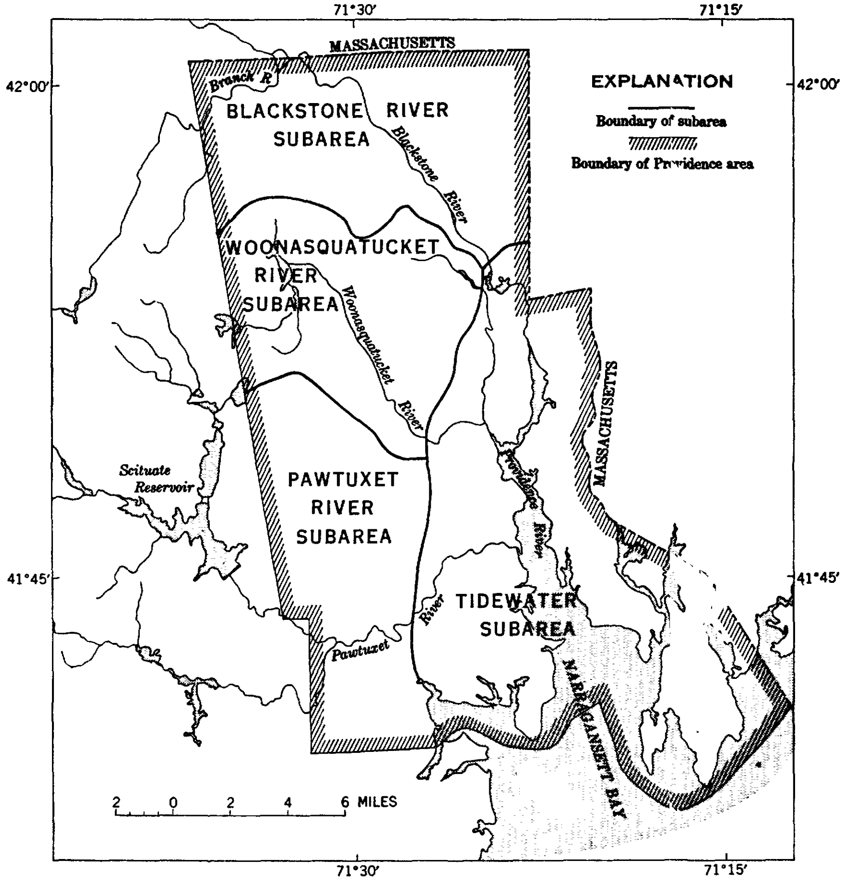

FIGURE 4.—Boundaries of subareas in the Providence area.

Self-supplied industrial water is drawn mostly from the large streams but is supplemented by water from wells.

GROUND WATER

The outwash deposits are the chief source of ground water. The silt and clay do not readily yield water to wells, but large quantities may be obtained from the intercalated sand and gravel lenses, wherever they lie below the water table.

West of the Providence River much of the outwash consists of thin beds of sand overlying finer materials interbedded locally with deposits of sand and gravel. The outwash occupies and overlies preglacial river channels, along which the deposits reach their greatest thickness. As the best places to obtain large quantities of ground water are where the outwash is thickest (and most permeable), it is in these preglacial river channels that the best supplies of ground water are found. The axes of these channels can be traced on plate 1 by following the areas of greatest thickness.

One such buried channel follows the course of the Blackstone River to Lonsdale; from there it extends southward to Saylesville, enters the Tidewater subarea and follows the Moshassuck River south from Saylesville to the center of Providence; it then runs west along the Woonasquatucket River. At Olneyville the buried channel turns south again, passing through Cranston and Warwick.

The deposits in the buried channel are as much as 224 feet thick near Saylesville, as much as 200 feet thick in the Woonasquatucket River valley, and as much as 280 feet thick near the Pawtuxet River. About 1.4 mgd was pumped in 1954 from the outwash where the buried channel coincides with the present Woonasquatucket River valley. Farther south in northeast Cranston a well that taps deposits in this buried channel is capable of yielding about 1,300 gpm.

Roberts and Brashears (1945) report another buried channel beneath the Seekonk River near its confluence with the Providence River. The channel trends southward in East Providence, under the Providence River, and beneath the eastern part of Providence and Cranston (pl. 1). A well tapping the deposits in this buried channel at Sassafras Point in Providence yields about 600 gpm.

A third buried valley extends southward from East Providence to Barrington (pl. 1). It enters Massachusetts near East Providence, reenters Rhode Island beneath the Barrington River, and follows a course through the village of Barrington passing under Narragansett Bay at Barrington Beach.

Much of the outwash east of Narragansett Bay is fine grained, but as in the outwash west of the Bay, the fine-grained deposits are interbedded with sand and gravel. Where the sand and gravel have an appreciable saturated thickness or where they are so located as to be able to receive recharge from a body of surface water, moderate to large quantities of ground water can be obtained. The East Providence Water Department has four wells tapping a gravel deposit in the outwash plain close to the East Providence Reservoir on the Tenmile River. Their combined yield is 3,700 gpm.

Farther south, in Bristol County, the majority of coarse-grained outwash deposits are in Barrington. Two wells of the Bristol County Water Co. in Barrington (at *V* on pl. 1) tap coarse deposits and are capable of yielding about 2 mgd. The only other place in Bristol County where appreciable quantities of ground water can be obtained is in Warren where moderate amounts are available. However, the outwash in Warren is commonly less than 30 feet thick, and the present draft on the only known body of coarse material apparently has resulted in salt-water encroachment. Additional development of large ground-water supplies in these deposits is not considered feasible.

Appreciable quantities of fresh water could be obtained by induced recharge by pumping water from the coarse-grained material in the buried channels wherever they are close to and hydraulically connected with a fresh-water stream. If saline water is present nearby, however, the possibility that it may be induced to enter the aquifer must be considered.

Wells tapping outwash in the Tidewater subarea, as in the remainder of the Providence area, range in depth from 10 to 150 feet. The depth to the static water level in most wells is between 5 and 30 feet below the land surface. Yields of most municipal and industrial wells tapping the outwash deposits range from 10 to 1,000 gpm and the median yield is about 100 gpm. The above data on yields and water levels apply to outwash deposits in the entire Providence area as well as to the Tidewater subarea.

Till in the Providence area is an unstratified mixture of rock fragments ranging in grain size from clay to boulders. It is important as a source of small quantities of water, sufficient for domestic or stock needs but insufficient for large supplies. Till probably underlies the outwash deposits almost everywhere and is exposed at the surface in some places, generally in the hilly parts of the Tidewater subarea. It ranges in thickness from a few inches to about 100 feet but is commonly about 20 feet thick in most of the subarea. Wells tapping till are generally dug wells, 10 to 30 feet deep which, because of their large diameters, offer appreciable space for storage of water. Wells completed in till yield less than 2 gpm unless layers of sand and gravel are penetrated (Allen, 1953, p. 28). The characteristics of till and wells completed in till described above apply to the entire Providence area as well as to this subarea.

The bedrock in most of the Tidewater subarea is of sedimentary origin (fig. 5). Wells tapping sedimentary rocks yield sufficient water for domestic needs and small industrial supplies. The range in yield of most municipal and industrial wells tapping the bedrock in this subarea and in the entire Providence area is 5 to 200 gpm; the median yield is about 30 gpm. The range in depth of most bedrock wells is from 70 to 550 feet; the depth to the static water level is generally between 5 and 50 feet below the land surface.

Contamination of ground water by encroachment of saline water may occur in areas adjacent to the sea or to saline estuaries if groundwater levels at the shore are drawn below sea level and if there is hydraulic continuity between the salt-water body and the aquifer from which the water is pumped, or if the seaward extension of the aquifer already contains salt water. Such contamination of ground water apparently has occurred in a few places in the Providence area. In Warren, salt-water contamination was indicated in water from wells of the Crown Fastener Corp.—the water contained 1,360 ppm of

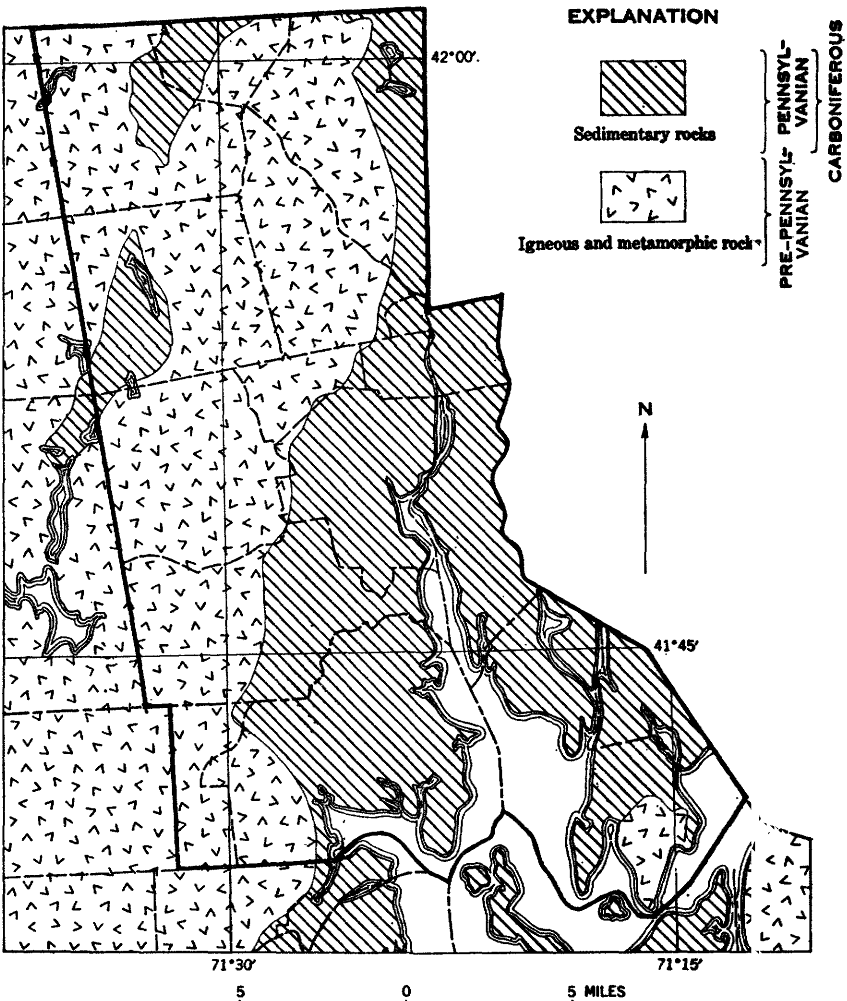

FIGURE 5.—Generalized bedrock geologic map of the Providence area (after Allen, 1953).

chloride in 1946. Salt-water contamination has been noted also in wells near the Runnins River in East Providence, and in some wells near the estuaries of the Seekonk and Providence Rivers and along the tidal reach of the Woonasquatucket River in downtown Providence. Careful control of the rates and distribution of pumping from wells near these tidal-water bodies will be required in the future to avoid more extensive salt-water contamination.

The quality of water from the unconsolidated deposits—outwash and till—is slightly better than that of water from the bedrock formations, as indicated in table 4. The quality of water from each aquifer varies widely and may vary as much in one part of the Providence area as in any other.

Iron is the constituent in water from the outwash deposits that most affects the utility of the water. Manganese occurs in appreciable quantities in water from some wells, although concentrations in the samples analyzed generally were less than 0.04 ppm. Small concentrations, as low as 0.3 ppm of iron or manganese (or both), are capable of staining; however, suitable treatment will remove both substances. In the Providence area about 1 sample in 4 contained a concentration of iron greater than 0.3 ppm.

The dissolved solids in 26 water samples from the outwash deposits ranged from 43 to 329 ppm, and the hardness in 29 samples, expressed as $CaCO_3$, ranged from 16 to 179 ppm (fig. 6). The median concentration of dissolved solids was 90 ppm and the median hardness was 51 ppm.

Only a few analyses of water from the till are available, but they indicate that the quality of water from the till is about the same as that of water from the outwash deposits.

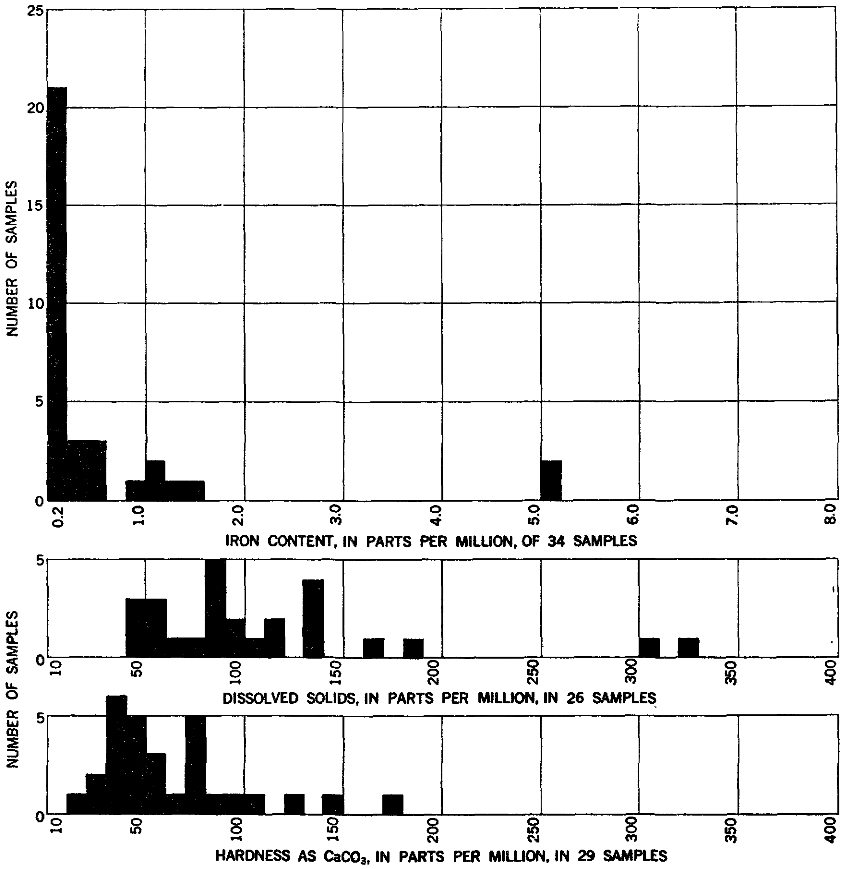

FIGURE 6.—Selected chemical characteristics of water from the outwash deposits. Taken in part from Allen (1953, table 10).

The iron content of water from the sedimentary rocks is greater than that from the outwash deposits (fig. 7 and Allen, 1953, p. 52). About 1 sample in 2 has an iron content greater than 0.3 ppm. The concentration of dissolved solids in water from the sedimentary rocks ranges from a small to a fairly large amount and the water is soft or moderately hard. The median concentration of dissolved solids in 22 samples was 136 ppm and the median hardness in 27 samples, expressed as $CaCO_3$, was 90 ppm. The pH ranged from 6.6 to 8.1. Several analyses of water from the sedimentary rocks are given in table 4.

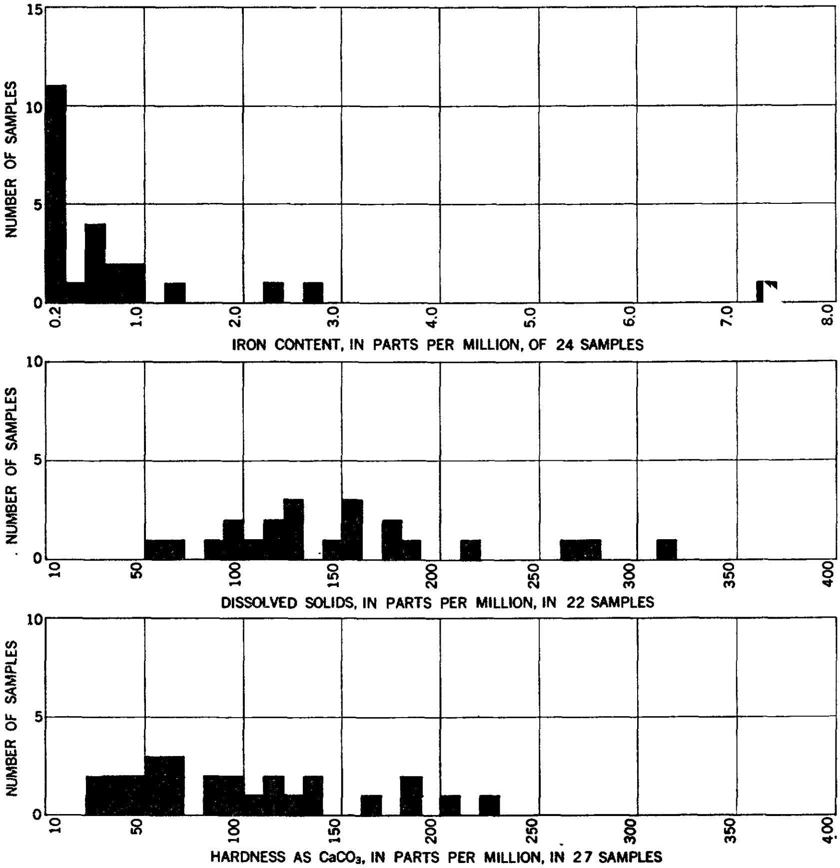

FIGURE 7.—Selected chemical characteristics of water from sedimentary rocks Taken in part from Allen (1953, table 10).

Analyses of water from two wells sampled in 1928 and 1954 are given in table 4. The iron concentration in water from one well changed appreciably and the other changed very little. The greater change was in water from a well in Central Falls which contained 1.4

ppm of iron in 1928 but only 0.13 ppm in 1954. The reason for the change is not known. The hardness of the water was 220 and 210 ppm, respectively. The concentration of iron in water from a well in Providence (*R* on pl. 1) was about the same in 1928 and 1954—2.8 and 2.3 ppm; the hardness of the water was 139 and 126 ppm, respectively.

In general, the temperature of water in wells that range in depth from 30 to 60 feet is 2° to 3°F above the mean air temperature (Collins, 1925). The temperature generally rises about 1°F for every 50 to 100 feet of increase in depth of wells. Hence the temperature of ground water in the Providence area can be expected to be about 53° to 54°F. Allen (1953) found the average temperature of ground water in Rhode Island to be 54.4°F. The temperature of ground water in the Providence area ranges from 51° to 60°F and averages about 56°F, based on the temperature of water from 29 wells (table 4).

The temperature of ground water is nearly constant throughout the year, except where the temperature may be affected by infiltration of surface water or by manmade modifications. This constant temperature makes ground water more desirable for use in cooling or air conditioning than surface water, which has a higher temperature in the summer.

SURFACE WATER

An unlimited quantity of saline water is available in Narragansett Bay. Water may be obtained also from the streams tributary to the bay. Most of the streams have dams near their mouths, so that fresh water is available above the dams. The salinity of the water in the tidal reaches of the streams and in the bay is affected by tidal action and, in the northern part of the subarea, by streamflow.

A greater total quantity of water, mostly saline surface water, is used in this subarea than in all other parts of the area combined. In 1954 359 mgd of saline water was used, of which 356 mgd was used for cooling condensers at 3 powerplants on the Seekonk and Providence Rivers and 3 mgd was used as cooling water by several industries in East Providence, Pawtucket, and Providence. In addition, the streams supplied about 18 mgd of fresh water to industries. The availability of fresh water in the subarea is described in subsequent sections of this report where each river is discussed in more detail.

Studies in 1930–31 by the U.S. Coast and Geodetic Survey (Haight, 1936) and in 1951–52 by the Narranganset Marine Laboratory (Wehe, 1953) show that the water of Narragansett Bay and the Providence and Seekonk Rivers is very saline. Narragansett Bay is a large body of water with little fresh-water inflow. The salinity is 28,000 to 31,000 ppm near Conimicut Point, as compared to a salinity of about 35,000 ppm in the North Atlantic Ocean. The salinity of the Seekonk

River, the tidal estuary of the Blackstone River, ranges from 15,000 to 26,000 ppm. This marked fluctuation is due mainly to the interaction of tidal flow and streamflow. The salinity of water in other tidal estuaries entering Narragansett Bay is probably less than that in the bay proper, and probably varies greatly.

The temperature of water in the bay ranges from about 35°F in the winter to about 75°F in the summer; during the summer the temperature at the surface is slightly higher than the temperature at the bottom.

BLACKSTONE RIVER SUBAREA

The Blackstone River, which is formed near Worcester, Mass., by the union of several brooks, flows southeastward through the northern part of the Providence area to the estuarial Seekonk and Providence Rivers and into Narragansett Bay. The lower few miles of the Blackstone River are known as the Seekonk River. The drainage area of the Blackstone River at India Point is 540 square miles and 30 percent of the area is in Rhode Island. The Branch River, the largest tributary of the Blackstone River, drains an area of 97.5 square miles and empties into the Blackstone River a short distance upstream from Woonsocket. The drainage basin is hilly and contains many small ponds.

The Blackstone River flows through a densely populated manufacturing district. Waterpower was first developed on the Blackstone River in 1671 when Joseph Jenckes, Jr., built a water wheel at Pawtucket to operate a forge, sawmill, and carpenter shop. The first successful cotton mill in the United States, built at Pawtucket in 1793, used water of the Blackstone River to develop power. The success of this mill resulted in the construction of others to develop waterpower on the river until the Blackstone River became one of the most completely utilized streams in the world. At present the chief industries in the Blackstone River valley are the manufacture of cotton and woolen goods and textile machinery. Although not as dependent on waterpower from the Blackstone River as the early industries, present-day industry still uses the river as a source of water.

BLACKSTONE RIVER

Powerplants and small reservoirs affect the daily flow of the river, and storage of water in the many ponds and reservoirs when the plants are closed for the weekend causes a sharp reduction in flow. Water from the Nashua River basin is diverted into the Blackstone River basin for the supply of the city of Worcester, Mass. This diversion amounted to about 12 mgd during 1953. Practically the entire flow of two minor tributaries, Crookfall Brook and Abbott Run, has been appropriated for the city water supplies of Woonsocket and Paw-

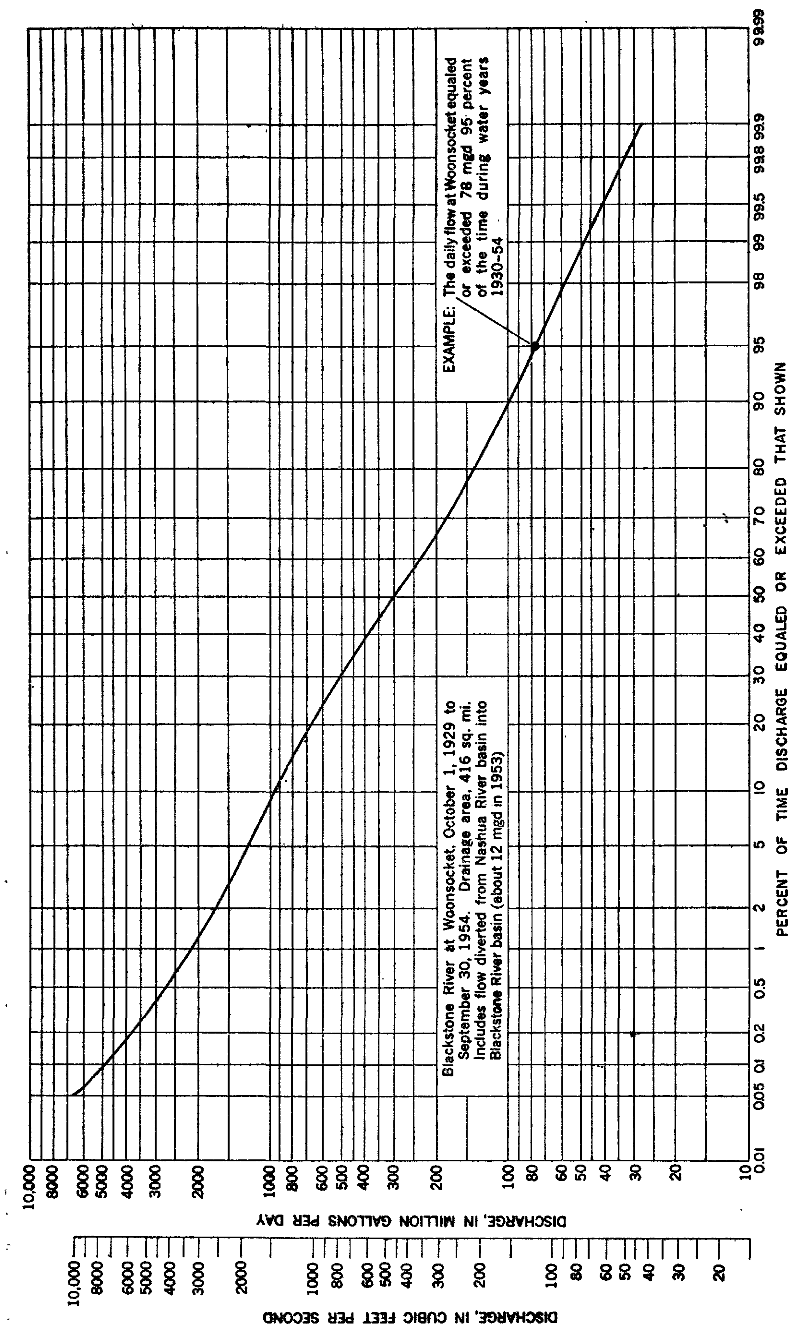

FIGURE 8.—Duration curve of daily flow, Blackstone River.

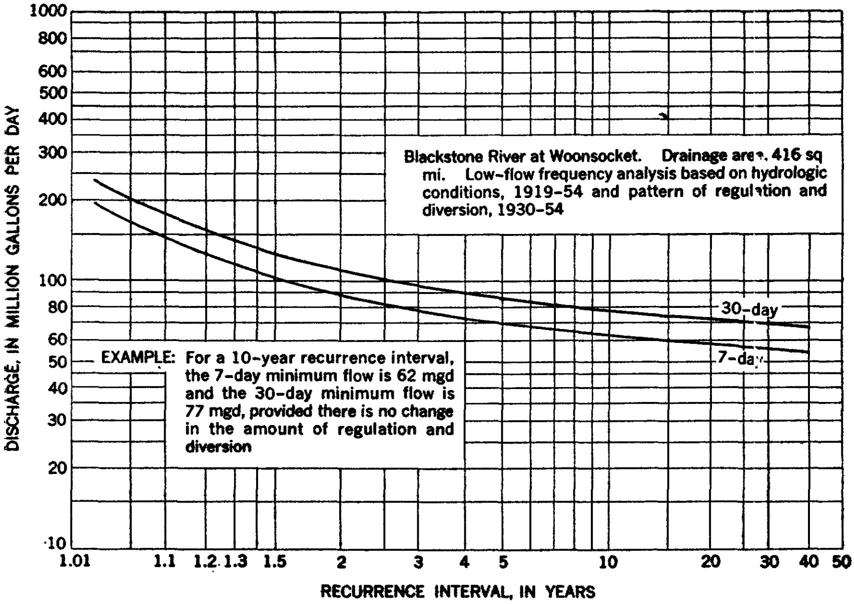

FIGURE 9.—Low-flow frequency curve, Blackstone River.

tucket, but this use does not appreciably affect the flow of the Blackstone River.

The average flow of the Blackstone River at Woonsocket for 1930–55 was 468 mgd (fig. 2 and table 6). Like the flow of most streams in New England, the flow of the Blackstone River is generally high or moderate in the late winter or spring and lowest in the summer or fall. The quantity of water available from the river, including the diversion from the Nashua River, is illustrated by the flow-duration curve (fig. 8) and the low-flow frequency curve (fig. 9; see also tables 1 and 2). The flow-duration curve show the percentage of time that the flow equaled or exceeded different quantities during 1930–54, and the low-flow frequency curves show the average recurrence interval of different flows based on the period 1919–54. These curves can be used to determine the probable occurrence of low flows, assuming that precipitation and other hydrologic conditions during 1919–54 are typical and that the diversion into the basin and operation of storage reservoirs remain unchanged from that during 1930–54. For example, under those conditions, the flow in the vicinity of Woonsocket may be 78 mgd or greater 95 percent of the time, and the average flow for 7 days may be less than 78 mgd at average intervals of 3 years or about 8 times in 25 years.

Information concerning major floods in the Blackstone River basin extends back more than 200 years. The flood of August 1955, which reached an elevation of 129.2 feet above mean sea level at the Woonsocket gaging station, was the greatest on record (fig. 10). It was

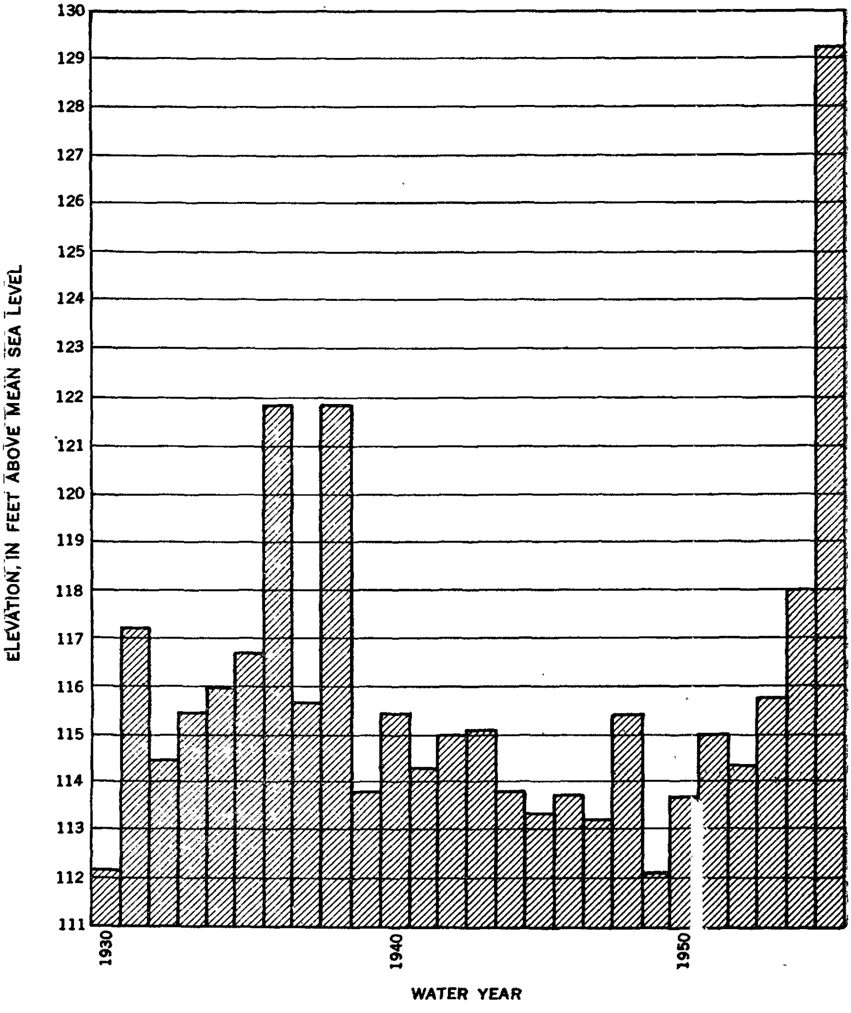

FIGURE 10.—Maximum annual elevation of Blackstone River at Woonsocket, water years 1930–55.

caused by heavy rains in Massachusetts and was increased by a surge of water released by the failure of Horseshoe Dam on the Mill River. This peak occurred while the Blackstone River above the Mill River was still rising. The natural peak, which occurred about 8 hours later, reached an elevation of 128.3 feet above mean sea level.

According to F. C. Williams (written communication, 1955) great floods occurred in 1818, 1876, 1877, 1886, 1927, 1936, and July 1938. Before the flood of 1955, the 1886 flood was the greatest known; flood records extend back to 1732. The floods of 1938 and 1936 are the next largest.

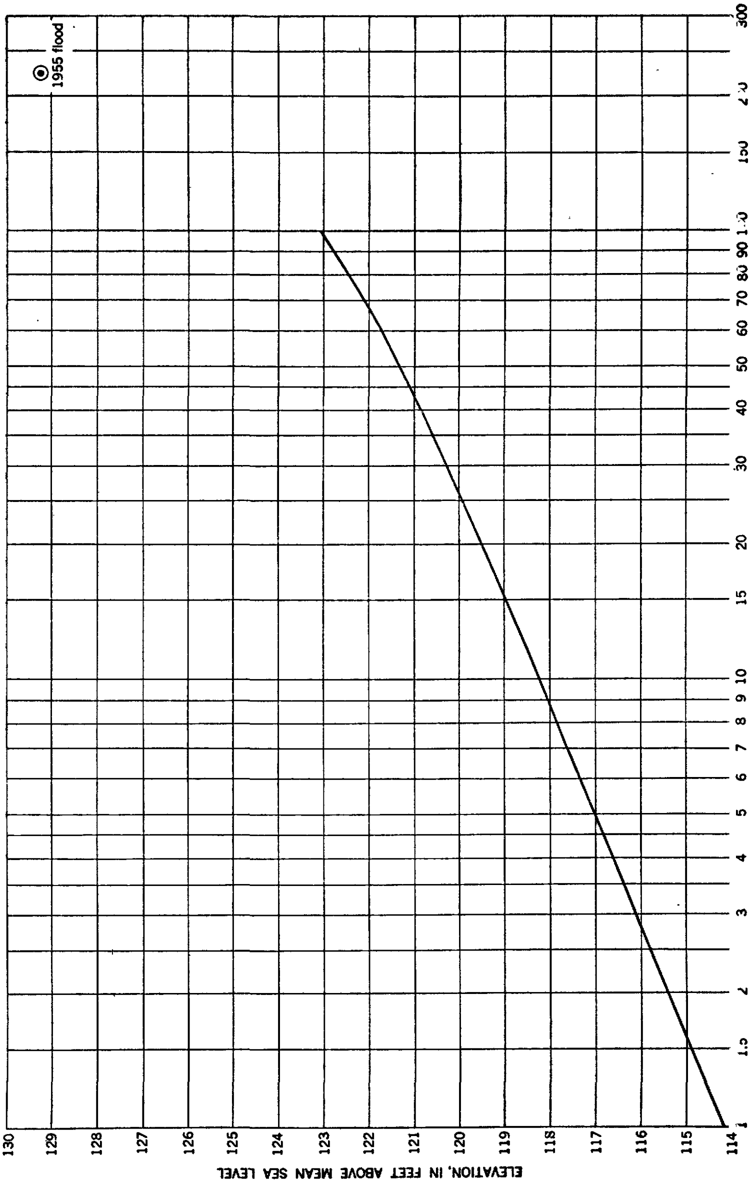

FIGURE 11.—Flood-stage frequency curve, Blackstone River at Woonsocket.

The frequency of floods is important in the design or use of any structure such as a warehouse or factory built on a flood plain. A flood-frequency graph has been prepared to show the probable average interval in years between floods of different magnitudes (fig. 11). This graph is based on the flood records for water years 1930–55. However, the floods of August 1955, July 1938, and March 1936 are the highest, third highest, and fourth highest, respectively, since flood records began in 1732, and have been plotted accordingly. Most floods occur during the spring breakup, but floods greater than 113.3 feet above mean sea level have occurred during every month of the year except May (fig. 12).

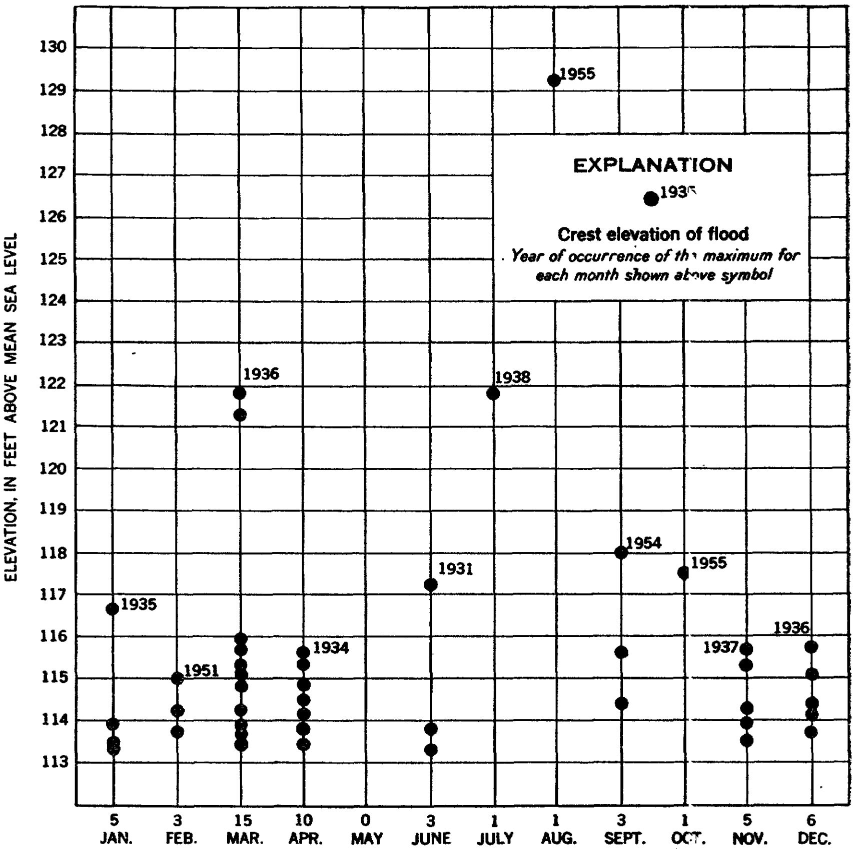

FIGURE 12.—Occurrence of floods by months, Blackstone River at Woonsocket.

Samples of water taken from the Blackstone River were soft and contained moderate amounts of dissolved solids during both high and low flows. Acidity of the water was a striking characteristic; a low-flow sample collected October 8, 1952, had a pH of 5.3. On May 15, 1953, when the flow was more than 3 times the low flow just cited, the pH was 5.2. Iron was present at both times in high concentrations, 0.89 and 1.3 ppm, respectively, and apparently was an effective agent, owing to hydrolysis, in maintaining an acidic condition. If not removed or substantially reduced in concentration, the iron would impair the utility of the water. Other constituents were not present in sufficient concentrations to affect water utility (table 5). A high concentration of manganese in the river water has been reported, but it was not indicated by the analyses used for this study.

BRANCH RIVER

The flow of the Branch River is affected by Wallum Lake and Wilson Reservoir on the Clear River and Pascoag Reservoir on the Pascoag River—these tributaries are outside the area shown on plate 1. The reservoirs on the Clear River were built by the Clear River Reservoir Co., which was organized in 1836, to provide water for power at four mills. At present the reservoirs provide water for processing only. The released water also dilutes polluting substances at the villages downstream during periods of low flow.

The Pascoag Reservoir was originally constructed to provide water for power and processing at three mills. At present water is used for processing, boiler feed, and sanitary purposes. Storing water in the lakes and reservoirs when the plants are closed for the weekend causes very low flows downstream. This condition is typical of regulated

TABLE 1.—*Low-flow frequency at stream-gaging stations in the Providence area*

[Frequency of annual minimum discharge for periods of 7 and 30 days adjusted to 35-year period, 1919–54, on basis of long-term streamflow records outside the area]

Number on plate 1	Stream and location	Drainage area (square miles)	Discharge, in million gallons per day, for recurrence interval indicated									
			Minimum 7-day					Minimum 30-day				
			2-yr	5-yr	10-yr	20-yr	40-yr	2-yr	5-yr	10-yr	20-yr	40-yr
1	Branch River at Forestdale	93.3	16	11	9.2	7.6	6.4	21	16	13	11	9.9
2	Blackstone River at Woonsocket [1]	416	89	70	62	58	54	110	86	77	72	67
3	Woonasquatucket River at Centerdale	38.3	12	9.4	8.2	7.3	6.6	15	13	12	11.2	10.7
4	South Branch Pawtuxet River at Washington [2]	63.8	21	16	12	9.6	7.6	27	22	20	18	17
5	Pawtuxet River at Cranston [3]	200	74	62	57	53	49	83	74	70	68	66

[1] Includes about 12 mgd diverted from Nashua River for city supply of Worcester, Mass., above station and flow diverted around station in Hamlet Trench. Based on pattern of regulation and diversion 1929–54.

[2] Does not include water diverted from Carr Pond for municipal supply of Coventry, Warwick, and West Warwick. Based on pattern of regulation and diversion 1941–54.

[3] Does not include water diverted from Scituate Reservoir for the municipal supply of Providence, North Providence, Cranston, Johnston, Smithfield, and Warwick. Based on pattern of regulation and diversion 1940–54.

TABLE 2.—*Duration of daily flow, 1930–54*

Number on plate 1	Stream and location	Flow, in million gallons per day, which was equaled or exceeded for indicated percent of time																						
		1	2	3	5	7	10	15	20	25	30	40	50	60	70	75	80	85	90	93	95	97	98	99
1	Branch River at Forestdale	520	410	360	300	260	230	190	160	140	125	100	78	45	26	23	19	17	14	13	12	10	10	8
2	Blackstone River at Woonsocket [1]	2,400	1,700	1,500	1,250	1,100	960	780	680	580	510	390	310	230	180	155	140	115	100	88	78	66	59	48
3	Woonasquatucket River at Centerdale	190	160	140	120	100	90	71	60	50	45	36	30	25	21	20	18	15	12	9	8	6	5	4
4	South Branch Pawtuxet River at Washington [2]	370	280	240	200	180	170	150	130	110	97	78	62	50	41	34	26	17	11	8	7	6	5	4.5
5	Pawtuxet River at Cranston [3]	1,000	800	680	550	480	410	330	280	250	215	180	150	130	110	100	94	80	65	50	41	33	28	23

[1] Includes about 12 mgd diverted from Nashua River for city supply of Worcester, Mass., and flow diverted around station in Hamlet Trench.

[2] Does not include water diverted from Carr Pond for municipal supply of Coventry, Warwick, and West Warwick.

[3] Does not include water diverted from Scituate Reservoir for the municipal supply of Providence, North Providence, Cranston, Johnston, Smithfield, and Warwick.

streams in the Providence area, and is illustrated by the hydrograph of daily flow for the Woonasquatucket River (fig. 13).

The average flow of the Branch River for 1941–55 was 102 mgd (fig. 2 and table 6). The quantity of water available from the river is given by the low-flow frequency data (table 1) and the flow-duration data (table 2). Although records of flow have been collected only since January 1940 the duration data were extended to 1930 and the low-flow frequency data to 1919 by correlation with the flow of other streams in the vicinity. The data on duration of flow and low-flow frequency show the flow that may be expected to occur if the storage reservoirs in the basin are operated as they were during 1941–54 and if precipitation and hydrologic conditions during 1919–54 are typical.

The greatest flood since collection of records began in 1940 occurred on August 19, 1955, when the river reached a stage of 10.52 feet above gage datum at Forestdale (discharge 4,240 cfs). A much greater flood (discharge 5,800 cfs) occurred in March 1936.

The concentration of dissolved solids in water from the Branch River should not affect its usefulness. However, it may contain an undesirable concentration of iron and manganese, and have a brown color. Two samples of water from the Branch River were analyzed; one was collected at low flow and the other at high flow. The low-flow sample contained a greater concentration of dissolved solids (124 ppm) than the high-flow sample (45 ppm)—a common characteristic of stream water. The pH of the low-flow sample was 7.2 and that of the high-flow sample was 5.7. The former indicates an almost neutral condition of the water and the latter a slightly acidic condition.

The low-flow and high-flow samples had a color of 13 and 50 units, respectively. The latter had a coffeelike color, which is not only displeasing in appearance, but the color-producing substances such as tannins or industrial contaminants are capable of staining. Consequently, this water would be unsuitable for most uses unless the color were removed.

The low-flow sample contained 0.63 ppm of iron, an undesirable concentration and unless reduced or removed by suitable treatment could cause deposits and stains. Analyses of the two samples are given in table 5.

GROUND WATER

The saturated outwash deposits consist of sand and gravel and some silt and clay and are the sources of the largest quantities of ground water in the subarea. Silt and clay yield little water, but they are intercalated with lenses of sand and gravel that yield larger quantities of water. The thickest and most productive outwash deposits

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are along the Blackstone River and Abbott Run. Other permeable thick outwash deposits extend southwestward from Woonsocket and along the Branch River (pl. 1.). Where an aquifer comprising mainly permeable sand and gravel is in hydraulic continuity with a stream or pond, withdrawals from the aquifer may lower the water level below that of the stream or pond. Surface water may then be drawn into the aquifer and sustained yields may be obtained. Pumping from two wells of the Pawtucket Water Works along Abbott Run probably causes the water from the stream to flow to the wells. Together these wells yield 1,700 gpm.

Available data on the geology suggest that the outwash deposits are largely coarse grained and therefore potentially highly productive. Hence, wells in the deposits probably would have high yields. One large-capacity well at Ashton has been pumped at the rate of 650 gpm (Quinn and others, 1948) and the town of Cumberland's public-supply well at Berkeley yields 1,100 gpm.

Till is found at the surface of a large part of the Blackstone River subarea (pl. 1). It occurs at the surface mostly in the hilly areas and generally is not at the surface in the major river channels or in outwash areas, but probably underlies the outwash almost everywhere. The till ranges in thickness from a few inches to about 100 feet but is commonly about 20 feet thick in most parts of the subarea.

Wells in the till generally yield less than 2 gpm unless they penetrate lenses of sand or gravel; then the yield is greater. Most wells tapping till are dug wells 10 to 30 feet deep.

Bedrock in the Blackstone River subarea is either crystalline (igneous and metamorphic) or sedimentary (fig. 5). Wells tapping the bedrock generally supply sufficient water for the needs of homes or industries requiring small quantities but will not supply industries requiring large quantities (p. A-8). Wells tapping sedimentary rock seem to yield more water than wells tapping crystalline rock (Allen, 1953, p. 27). The yield of wells tapping bedrock underlying sand or gravel is generally greater than the yield of wells tapping exposed bedrock or bedrock underlying till. As the sand and gravel lenses commonly occur in the lowlands and the till or bedrock that has no mantle of glacial drift commonly occurs in the uplands, wells tapping bedrock in lowlands have greater yields than wells tapping bedrock in the uplands.

Water from the outwash deposits, till deposits, and sedimentary rocks in the Blackstone River subarea has about the same quality as elsewhere in the Providence area and is described on page A-9.

The chemical character of water from the crystalline rocks is similar to that of water from sedimentary rocks, except that water from crystalline rocks is likely to contain less iron, to be a little softer, and to have a more uniform chemical quality (table 4). Although the iron concentration is generally less than in water from sedimentary rocks, of 6 samples analyzed, 4 contained concentrations in excess of 0.3 ppm. The pH ranged from 7.1 to 7.5. Other constituents were not present in excessive amounts. Water from the crystalline rocks either is suitable for many uses or, if undesirable quantities of iron occur, can be made suitable by treatment to reduce the iron content.

The temperature of ground water in the Blackstone River subarea is about the same as that of ground water elsewhere in the area and is described on page A-12.

WOONASQUATUCKET RIVER SUBAREA

The Woonasquatucket River rises in the town of North Smithfield and flows southeastward to become the Providence River at its confluence with the Moshassuck River at Memorial Square in the city of Providence. The area drained by the Woonasquatucket and Moshassuck Rivers is 74.8 square miles. Most of the Moshassuck River and the lower part of the Woonasquatucket River flow through the industralized Tidewater subarea. The chief industry in the Woonasquatucket River valley is the manufacture of textiles.

The Woonasquatucket Reservoir Co., an association of the mills on the river, operates Mountaindale Pond and Waterman, Slack, and Stillwater Reservoirs to store water during high flows for release when needed by the mills downstream. The only two mills producing hydroelectric power in 1954 used an average of about 19 mgd of water. Eight other mills used an average of 3.7 mgd during 1954 for processing, boiler feed, cooling, and sanitary purposes. Operation of the ponds and reservoirs causes a decrease in flow downstream when the mills are closed and water is stored over the weekend (fig. 13).

WOONASQUATUCKET RIVER

The average flow of Woonasquatucket River at Centerdale for 1942–55 was 43.4 mgd (fig. 2 and table 6). The quantity of water available from the river is given by the low-flow frequency data (table 1) and the flow-duration data (table 2). Although records of flow have been collected only since 1941, the duration data were extended to 1930 and the low-flow frequency data to 1919 by correlation with data for other streams in the vicinity. The data on duration and low-flow frequency show the flow that may be expected to occur if the storage reservoirs in the basin are operated in the same manner as during 1941–54 and if precipitation and other hydrologic conditions during 1919–54 and 1930–54 are typical.

The greatest flood since 1941 occurred on September 11, 1954, when the river reached a stage of 7.03 feet above gage datum at Centerdale with a discharge of 1,100 cfs. The flood of March 1936 reached a

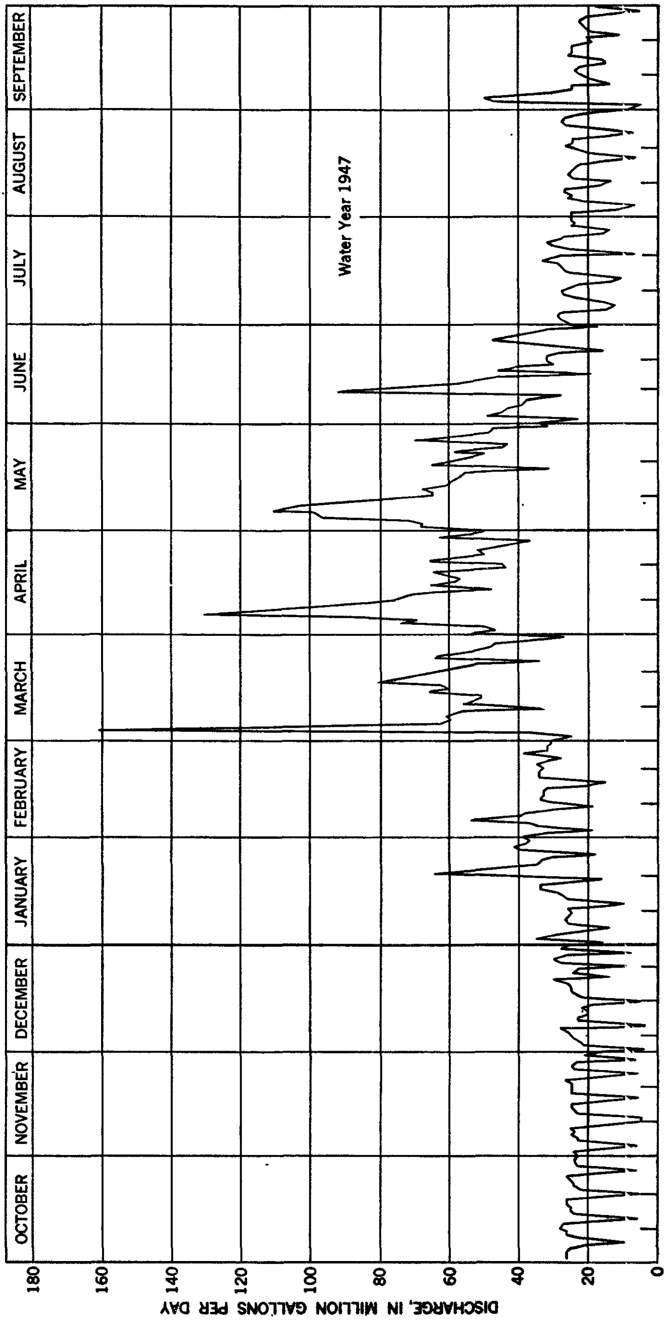

FIGURE 13.—Hydrograph of daily flow, Woonasquatucket River.

peak discharge of 1,000 cfs at Collins and Aikman Corp. dam three-fourths of a mile downstream from the Centerdale gaging station.

Only one chemical analysis of water of the Woonasquatucket River was made for this study (table 5). The water sample was collected during a period of moderate flow. The concentration of dissolved solids was 77 ppm and hardness was 16 ppm. Iron was present in a concentration of 0.38 ppm. On the basis of mineral content, the water was satisfactory for most domestic and industrial uses.

GROUND WATER

The sand and gravel in the outwash deposits are the principal sources of ground water in the Woonasquatucket River subarea; however, these deposits are not as extensive nor as thick as they are in the Tidewater and Blackstone River subareas. The principal outwash deposits are along the river and as much as 4,000 feet wide at Stillwater Reservoir (Richmond and Allen, 1951, p. 38). Most of these deposits are less than 50 feet thick (pl. 1).

Although the geologic evidence available points to large yields from wells in the outwash in this subarea, reports on too few wells are available in indicate the magnitude of the yield. A well near Spragueville (at *H* on pl. 1) has been pumped at 200 gpm and a well near Slack Reservoir has been pumped at 600 gpm. However, only a very small part of the potential supply has been developed.

Till underlies a large part of the Woonasquatucket River subarea (pl. 1). Wells in the till generally yield less than 2 gpm unless they also penetrate lenses of sand or gravel. The chemical quality of water from the outwash deposits and till is described on page A–9. The depth of wells in till is described on page A–8.

Most of the Woonasquatucket River subarea is underlain by crystalline rocks, but there are some sedimentary rocks south of Wonnasquatucket Reservoir (fig. 5). The yield of wells tapping bedrock has been described on page A–8, and the chemical quality and temperature of the water from bedrock are described on pages A–11 and A–12.

PAWTUXET RIVER SUBAREA

The Pawtuxet River, formed by the North and South Branches at River Point in West Warwick, flows generally east-northeastward to its mouth at Pawtuxet Cove, an arm of the Providence River. The principal tributaries are the North Branch Pawtuxet River, formed by the confluence of the Moswansicut and Ponaganset Rivers (now partly inundated by Scituate Reservoir) and the South Branch Pawtuxet River, formed by the confluence of the Flat and Big Rivers in the Flat River Reservoir area. The drainage basin of 230 square miles is hilly and contains many lakes, swamps, and reservoirs. The valleys of the main river and of the two branches are thickly populated near their junction. The manufacture of textiles, including dyeing, bleaching, and finishing—all of which are processes that require large quantities of water—is the chief industry in the river basin. The factories were first established along the river to take advantage of its waterpower. Now the river water is used primarily for process water and associated mill uses.

The flow of the South Branch Pawtuxet River is affected by regulation of Flat River Reservoir and other reservoirs and by diversion from Carr Pond. Flat River Reservoir was built about 1875 and has a usable storage capacity of 1,870 million gallons. The water is used for processing and power development. The Kent County Water Authority diverts water from Carr Pond for the public supply of Coventry, Warwick, and West Warwick. (See p. A-31.)

The Quidnick Reservoir Co., an association of mills on the South Branch Pawtuxet River, was organized in 1846 to furnish water to the mills for power and other purposes. Water was originally stored in Quidnick Reservoir, Flat River Reservoir, Tiogue Lake, and Coventry Center Pond, but Quidnick Reservoir is now used only for recreation. Only two of the mills use the water for production of electric power. The other mills use the water for processing, boiler feed, and cooling.

The flow of the Pawtuxet River is affected by regulation and diversion on the North Branch as well as by operations on the South Branch. The city of Providence obtains its water from Scituate Reservoir and five smaller reservoirs (combined usable capacity, about 40,000 million gallons). Scituate Reservoir was built in 1926. Under the Providence water-supply act the city must release an average of 70 mgd from the reservoirs including that used for its water supply. The quantity released to the river to maintain the flow is the difference between the 70 mgd released and the quantity diverted but must not be less than 72 million gallons per week.[1] The flow is also affected by the operation of powerplants.

SOUTH BRANCH PAWTUXET RIVER

The average flow of South Branch Pawtuxet River at Washington for 1941–55 was 80.1 mgd, adjusted for diversions from Carr Pond (fig. 2 and table 6). Storage and release of water in the reservoirs in the basin reduce the flow on weekends when the mills are shut down and make it more uniform on weekdays when they are operating. Seasonal fluctuations in flow are also reduced. The quantity of water available from the river is given by the flow-duration data (table 2) and the low-flow frequency data (table 1). Although records of flow

[1] Chapter 1278 of the Public Laws of 1915 as amended, Section 6.

have been collected only since October 1940, the duration data in the table were extended to 1930, and the low-flow frequency data to 1919, by correlation with data for nearby streams. These tables can be used to predict the probable flow of the river if water is stored and released as it was from 1941 to 1954 and if hydrologic conditions during 1930–54 and 1919–54 are typical.

The greatest flood since 1940 reached a stage of 4.11 feet above gage datum at Washington on September 12, 1954 (discharge 1,320 cfs). The flood of March 1936 reached a peak discharge of 1,810 cfs.

The chemical quality of water samples collected on September 22, 1955, and January 9, 1956, was very good. Dissolved solids were 33 and 34 ppm, respectively. This is lower than the mineral content of other surface water considered for this report. With the exception of iron content and color, there was very little difference in the chemical quality of the two samples. Concentration of iron was 0.68 ppm on September 22, 1955, and only 0.15 ppm on January 9, 1956. The higher concentration of iron would cause discoloration and would be objectionable for many industrial uses. A light-yellow color was present in the water collected on September 22, 1955. This, too, would be undesirable. However, both iron and color can be removed successfully with proper treatment. Two analyses are given in table 5.

PAWTUXET RIVER

The average flow of Pawtuxet River at Cranston for 1940–55 was 249 mgd, adjusted for diversions from Scituate Reservoir (fig. 2 and table 6). The regimen of daily flow of the Pawtuxet River follows a pattern similar to that of the South Branch Pawtuxet River—low flow on weekends when the mills are not operating, and nearly constant, higher flow the remainder of the week. The range in seasonal flow is also greatly reduced by operation of the reservoirs. Duration data (table 2) and low-flow frequency data (table 1) show the quantity of water available. Although records have been collected only since December 1939, the duration data in the tables were extended to 1930 and the low-flow frequency data to 1919 by correlation with data for nearby streams. These tables can be used to predict the probable flow of the river if water is stored and released in the same manner as it was from 1940 to 1954 and if hydrologic conditions during 1930–54 and 1919–54 are typical.

Historical data on storms and floods in this basin date from 1801. The flood of February 1886, the greatest flood known, was caused by 7 to 8 inches of rain falling within a 48-hour period on a snow cover estimated to contain water equivalent to 2 inches of rain. The 1886 flood in the lower valley was about 7 feet higher than the floods of March 1936 and July 1938—the most severe floods of recent years. Other significant floods occurred in 1801, 1815, 1869, 1877, 1927, November 1932, and September 1938. The greatest flood since December 1939, when the gaging station was established at Cranston, reached a stage of 8.85 feet above gage datum on September 13, 1954 (discharge 2,010 cfs).

Water in samples from the Pawtuxet River was very soft and generally low in mineral matter. Even the concentration of 80 ppm of dissolved solids in water collected October 2, 1953, is relatively low. However, 0.36 ppm of iron was present, a concentration sufficient to stain laundry, porcelain, and enamelware. If water containing this concentration of iron were used in sensitive industrial processes, the product would be stained. Reduction of the iron content would improve the chemical quality of the water. Comprehensive analyses of two samples of water from the Pawtuxet River are given in table 5.

GROUND WATER

The sand and gravel in the outwash are the principal sources of ground water in the Pawtuxet River subarea; however, these deposits are not as extensive nor as thick in most places as they are in the Tidewater subarea. Outwash deposits less than 50 feet thick and less than 1 mile wide extend upstream along the North Branch Pawtuxet River for about 1 mile from River Point, and along the South Branch Pawtuxet River near Centerville and Crompton. Deposits of about the same width and thickness extend downstream from River Point along the river to the valley of Meshanticut Brook. From there, downstream to the Tidewater subarea and in the valley of Meshanticut Brook the outwash deposits are much wider and thicker (pl. 1). Although geologic evidence indicates moderate yields from wells in this subarea, reports on too few wells are available to indicate the magnitude of the yield. Large sustained yields of ground water could be obtained from aquifers adjacent to the river or ponds if surface-water infiltration could be induced through pumping.

At present, only moderate quantities of ground water are developed in the subarea. Three driven wells in West Warwick supply a total of about 21,000 gpd (gallons per day) for use in a dairy (Allen, 1953, p. 63). Ground water is used by other industries near River Point and wells of the Kent County Water Authority in Coventry furnished about 0.89 mgd in 1954.

Till underlies a large part of the Pawtuxet River subarea, and rests on crystalline bedrock throughout most of it, but some sedimentary rocks underlie the eastern edge of the subarea (pl. 1 and fig. 5). The chemical quality of water from the bedrock and till and the yields of wells in these aquifers are about the same as elsewhere in the Providence area and have been described on pages A-8 and A-11.

PUBLIC WATER-SUPPLY SYSTEMS

The public water-supply systems may be an economical source of water for industries requiring small quantities of water or water of good sanitary quality. The major water systems in the area in 1954 were those of East Providence, Pawtucket, Providence, Woonsocket, Bristol County, and the Kent County Water Authority (fig. 14). A gravel-walled well for the public supply of southern Lincoln has been installed in the southeastern part of the town, to be used in 1957. Its yield is 1 mgd. Information for these and other water-supply systems in the area is given in table 7.

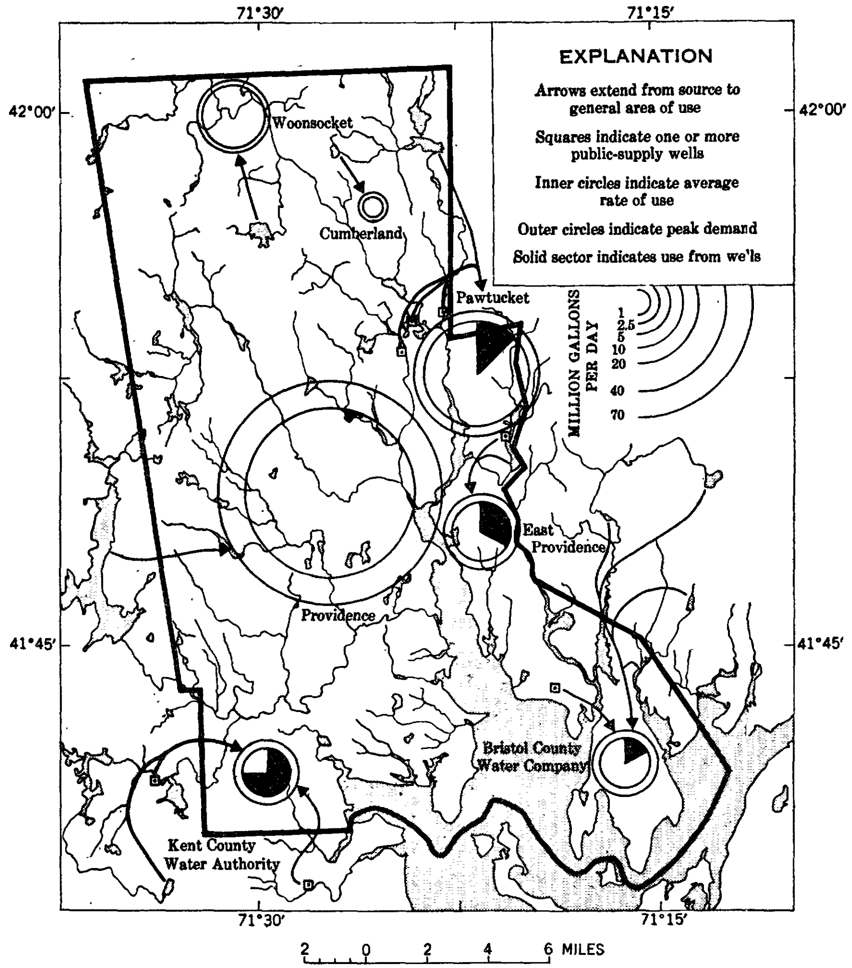

FIGURE 14.—Source of and demand on public water supplies serving 5,000 or more people, 1954.

The quality of the water furnished by the major public water-supply systems in the area is well within the standards prescribed by the U.S. Public Health Service (1946); however, surface water from the East Providence system is slightly more mineralized than water from the other systems (fig. 15). The iron and manganese content of a sample of surface water was high and exceeded the limit of 0.3 ppm recommended by the U.S. Public Health Service. Comprehensive analyses of water from several water-supply systems are given in table 8.

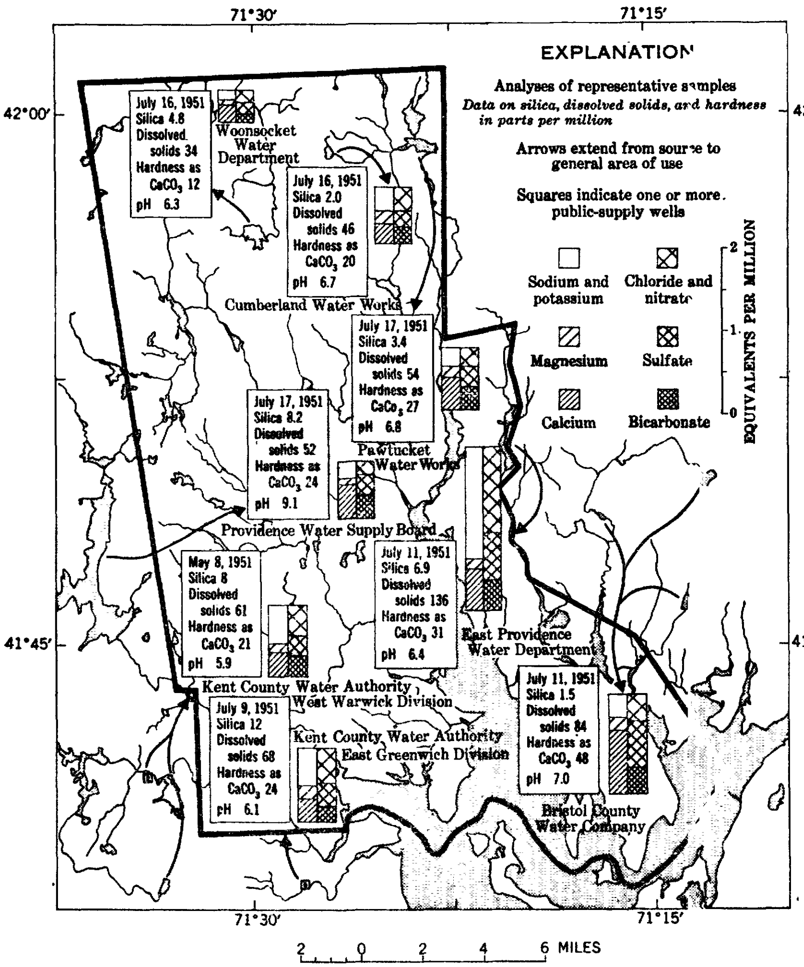

FIGURE 15.—Chemical quality of water from public supplies serving 5,000 or more people, 1951. Data taken from table 8.

Water for the Bristol County Water Co. is impounded in four reservoirs, Warren Reservoir (Kickamuit Reservoir) in Rhode Island and Warren Reservoir (Swansea Reservoir) in Massachusetts on the

Kickamuit River, and Shoe Factory Pond (Shad Factory Reservoir) and Warren Upper Reservoir (Anawan Reservoir) in the Palmer River basin. They have a combined capacity of 429 million gallons and a safe yield estimated at 4.6 mgd, but the draft is limited to 4 mgd, the capacity of the pipeline from Shoe Factory Pond. Two gravel-walled wells in Barrington (at *V* on pl. 1) are estimated to have increased the safe yield of the system by about 2 mgd. (See Maguire and assoc., 1952, exhibit V-2, p. 81.)

The town of Cumberland is served by a municipally owned system and the Pawtucket Water Works. The municipal supply is taken from Sneech Pond and from a standby well at Berkeley and serves about 6,000 people. The Pawtucket Water Works serves about 8,000 in the Valley Falls area.

The East Providence Water Department supplies about 38,000 people in the town. The water is obtained (1957) by impounding the flow of the Tenmile River in East Providence Reservoir and from four wells. The usable capacity of the reservoir is 400 million gallons and its estimated safe yield is 10 mgd. The four wells had a combined yield of 3,700 gpm (in 1957).

The Kent County Water Authority supplies West Warrick, part of Warwick, and Oaklawn and Fiskeville in Cranston. Parts of Coventry, East Greenwich, and the Potowomut section of Warwick, all outside the Providence area, are also served. The East Greenwich Division of the authority obtains water from 2 wells along the Hunt River, 1 in East Greenwich and 1 in the Potowomut section of Warwick. The West Warwick Division obtains water from Carr Pond and a well field in Coventry and buys water from the Providence Water Supply Board. The authority is now (1957) searching for additional sources of ground water.

Water supplied by the Pawtucket Water Works is obtained from Pawtucket Reservoir (Diamond Hill and Arnold Mills Ponds) and Robin Hollow (Cumberland Mills Reservoir) and Happy Hollow Ponds. Four gravel-walled wells are used as an auxiliary supply. Maguire and associates (1952, exhibit V-2) estimated the safe yield of the reservoirs as 13.5 mgd. The Pawtucket Water Works is now (1957) endeavoring to increase the supply by locating additional sources of ground water.

The Providence Water Supply Board obtains its water by impounding the flow from 92.8 square miles of the North Branch of Pawtuxet River basin in 6 reservoirs having a combined usable capacity of about 40,000 million gallons. Scituate Reservoir is the largest; its usable capacity is 36,600 million gallons. The safe yield of the system is estimated to be 85 mgd (Maguire and assoc., 1952, p. 31).

Water for the Woonsocket supply is obtained by impounding the flow of Crookfall Brook, a tributary of the Blackstone River. Two reservoirs have a combined usable capacity of 920 million gallons and an estimated safe yield of 3.5 mgd (Maguire and assoc., 1952, p. 154). The present supply cannot be depended upon to meet demands during dry years. The city is considering wells or Harris Pond as an additional source of water.

SUMMARY OF WATER USE

Public water-supply systems in the Providence area furnish more fresh water than all private water-supply systems (table 3). In 1954 about 60 percent of the fresh water used was obtained from public-supply systems, about 39 percent from private industrial systems, and less than 1 percent from private domestic systems (fig. 16). About 13

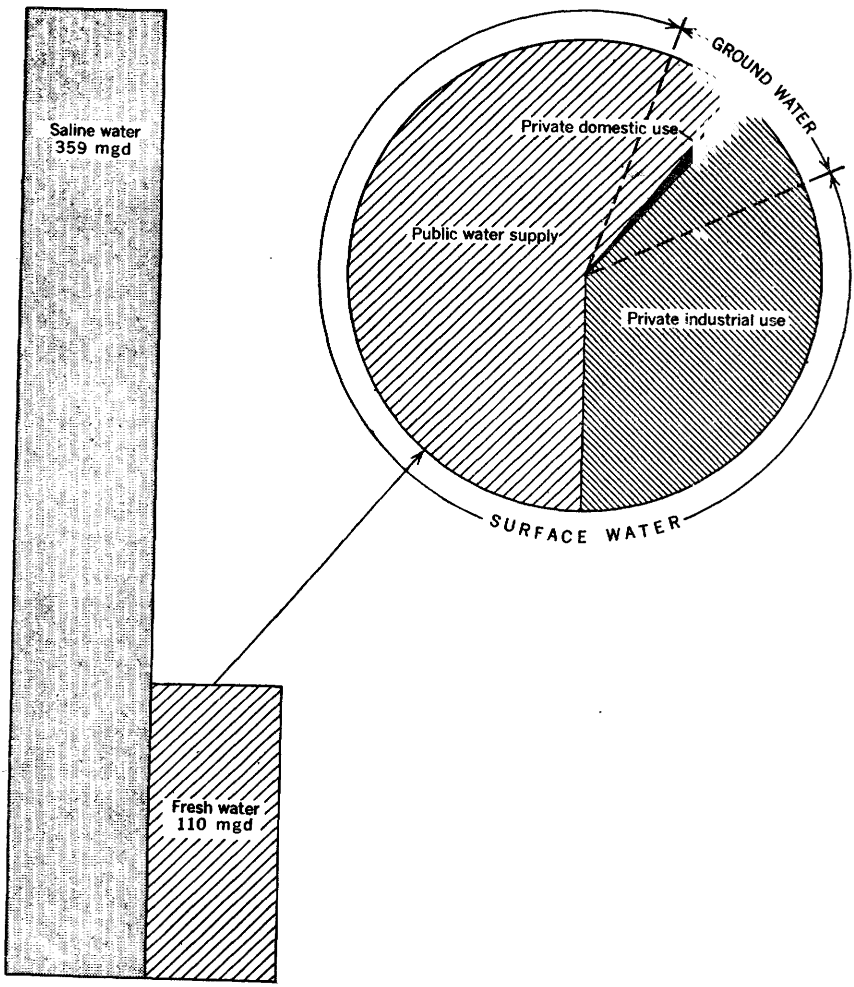

FIGURE 16.—Use of water in the Providence area, 1954.

percent of the water used was ground water and 87 percent was surface water. In addition to the fresh water, 359 mgd of saline water from estuaries was used, 356 mgd of which was used for condenser cooling in the generation of thermoelectric power.

The public water-supply systems in the Providence area furnish water to about 630,000 of a total population of 648,000 (1950 census). During 1954 the average use was 66 mgd, of which 61 mgd was surface water and 5.5 mgd was ground water. The Providence Water Supply Board, operating the largest system in the area, supplies about 57 percent of the people in the area.

Industries used 52 percent of the water furnished by public supply systems, 42 percent was used for domestic purposes, and 6 percent was used by municipal governments or was lost by leakage. A negligible amount was used by farms or for agricultural needs.

During 1954 35 mgd of fresh surface water was withdrawn by industry from private sources exclusive of water withdrawn for waterpower. Ground water was withdrawn from private industrial sources at the rate of 7.5 mgd.

TABLE 3.—*Average use (in million gallons per day) of fresh water in the Providence area, 1954*

Type of use	Public supply			Private supply			All sources		
	Ground water	Surface water	Total	Ground water	Surface water	Total	Ground water	Surface water	Total
Industrial	2.0	32.7	34.7	7.5	[1] 35.0	[1] 42.5	9.5	[1] 67.7	[1] 77.2
Public (including leakage)	.6	3.5	4.1	----	------	------	.6	3.5	4.1
Domestic	2.9	24.7	27.6	.9	------	.9	3.8	24.7	28.5
All uses	5.5	60.9	66.4	8.4	35.0	43.5	13.9	95.9	109.8

[1] Fresh water only, does not include 359 mgd of saline water from estuaries, of which 356 mgd is condensing water for thermoelectric-power production, nor water used for hydroelectric-power production.

About 18,000 people in the Providence area obtain their domestic supplies from privately owned sources, practically all of which are wells. In 1954 these people used about 0.9 mgd, assuming that the average daily use is 50 gallons per person.

Some water is used in the area for watering livestock, irrigating truck crops and pastures, and spraying orchards. Some of this water is withdrawn from public supplies and some from private sources. The quantity used for these purposes in 1954 was so small that it was not included in the tabulations.

POSSIBILITY OF FURTHER DEVELOPMENT

Many additional water-supply developments can be made in the Providence area. Because of the discharge of industrial and municipal wastes, quality rather than quantity of water is likely to be the limiting factor for additional development along the larger streams. Except for this pollution and the occurrence of iron, manganese, and color in some water, the quality of ground water and surface water in the Providence area is fair to good. Moderate to large quantities of ground water may be obtained in many places—along the river channels, in the buried preglacial valleys and in the large bodies of glacial outwash, and wherever there are deposits of sand and gravel. Ground water in the area has a nearly uniform temperature. (See p. A–37 for information on laws and regulations regarding the use of water.)

Early in the last century the streams in the Providence area were used to develop waterpower, supply process water, and transport wastes from mills. Dams were built on many of the streams to store water during periods of high flow for release during periods of low flow and to store water during weekends and holidays when the mills were not operating. Use of the streams has resulted in a pronounced change in flow characteristics. Seasonal low flow has been increased and high flow, to a degree, has been reduced. The flow is very small on weekends and holidays when the mills are not operating.

The use of surface water for development of power has given way, over the years, to other nonconsumptive uses, such as manufacture processing. The present uses, often attended by disposal of wastes into the streams, are more likely to degrade the quality of the water. The greatest effect occurs during low flows. Nevertheless, the streams can support a great deal of additional use, especially if industrial and municipal wastes are treated. In some places, if large quantities of water are required seven days a week, additional local storage may be necessary to make water available when other mills on the stream are not operating.

The best places for additional ground-water development are in the areas of outwash, especially where the preglacial river channels are filled or partly filled with glacial outwash, containing lenses of sand and gravel. The best place for obtaining large quantities of ground water is in the Tidewater subarea, in the outwash body that extends from southern Cumberland and Lincoln to Greenwich Bay and west from the Providence River and Narragansett Bay to a line running south from Olneyville. Large quantities of water can also be obtained locally from deposits of sand and gravel in the body of outwash that extends from Pawtucket to Warren on the east side of Narragansett Bay. The most promising places in this area are in East Providence near the Tenmile River and in Barrington. Outwash deposits in Warren yield moderate supplies, but present development and the proximity to salt water preclude much additional development. Outwash deposits in Bristol are too thin and of too small extent to furnish much ground water.

Sustained yields can be obtained from water-bearing sands and gravels hydraulically connected with the rivers and ponds, if water levels in the sands and gravels are lowered by pumping and surface-water recharge is induced. Conditions for such induced recharge seem to be favorable along the Blackstone River from Woonsocket to Lonsdale, in the Abbott Run, Branch River, Woonasquatucket River, and Pawtuxet River valleys. Till and bedrock yield only small quantities of water, sufficient for the needs of households, small farms, or industries requiring small quantities of water. Both ground water and surface water may contain objectionable concentrations of iron. If the iron is removed the water is suitable for most uses.

A large part of the water furnished by the public-supply systems of the area is used by industry. The water available at the source of most of the large public-supply systems is sufficient to support considerable expansion. The large public-supply systems furnish or sell water to many of the smaller communities.

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BASIC DATA

Water laws.—Certain aspects of the development and use of water resources in Rhode Island are under the supervision of the Department of Public Works through its Division of Harbors and Rivers, the Department of Health, and the Department of Agriculture and Conservation through its Division of Fish and Game.

Chapter 636 of the Rhode Island General Laws of 1938 states that any person may set up and maintain a water mill or dam on a stream to form a pond on his own land to supply water to a mill or upon the land of another, with the other's consent. Any person aggrieved or injured by the flowage or interruption of water by such a dam may take action for damages. No person owning a dam may detain the natural flow of a stream more than 12 hours out of 24 hours, except on Sundays, whenever the owner of a dam within 1 mile downstream requests that the natural flow be allowed to pass his dam.

Rhode Island has no laws relating to the control or development of ground-water resources.

The electors of any town may take land, water, rights of water, and rights of way to develop or enlarge a public water supply.

The Division of Harbors and Rivers of the Department of Public Works has jurisdiction over the safety of dams and reservoirs. The chief of the division is required to inspect them periodically to determine their condition. He may request that the owners of the dams or reservoirs supply him with plans of the structures. He may order the water drawn out of a reservoir if in his opinion the dam is unsafe and he may determine what alterations, additions, and repairs are necessary to make the dam safe. No dam or reservoir may be constructed or substantially altered until plans and specifications of the proposed work have been approved by the chief of the division.

The Department of Health has jurisdiction over the safety of public water supplies. Swimming in public water-supply reservoirs or their pollution with sewage or industrial wastes is prohibited.

The Department of Health, through its Division of Sanitary Engineering, has jurisdiction over pollution of the water of the State, both tidewater and inland water of any river, stream, brook, pond or lake. If the chief of the division finds that anyone is polluting the water of the State, he may require him to prevent the pollution by some practicable and reasonably available system or means. The Division of Sanitary Engineering has classified the water of the State according to the recommendations of the New England Interstate Water Pollution Control Commission.

The Department of Agriculture and Conservation, through its Division of Fish and Game, has jurisdiction over the use of equipment such as weirs and traps for taking fish and for the protection and control of certain fish.

The Federal government, through the Corps of Engineers, Department of the Army, has jurisdiction over navigable waterways and any project involving navigable rivers or tidewaters is subject to its approval.

The State Department of Public Works, through the Division of Harbors and Rivers, also has jurisdiction over navigable waterways, and any project involving navigable rivers or tidewaters is subject to the approval of the chief of the division. The division has jurisdiction over the marking of channels, supervision of harbors and tidewaters, and issue of permits for construction in tidewaters.

TABLE 4.—*Chemical analyses of water from selected wells penetrating different aquifers*

[Chemical analyses in parts per million]

Sampling site on plate 1	Date of collection	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color
Igneous and metamorphic rocks																				
X	Oct. 19, 1954	55	15	0.33	0.01	24	5.5	14		50	36	18	0.0	12	177	82	42	276	7.1	3
Q	Oct. 26, 1954	56	9.3	.49	.00	17	.5	4.2		43	6.3	6.5	.0	3.3	80	44	9	126	7.3	2
J[1]	Nov. 8, 1946	--	10	.05	--	30	8.1	--		67	80	15	Trace	4.4	174	109	54	--	7.4	--
J	Oct. 15, 1954	57	--	.61	--	--	--	5.9		33	19	13	--	9.4	--	60	33	173	7.1	2
K	Oct. 18, 1954	54	12	.22	.00	13	.6	7.0		27	7.7	8.5	.0	10	79	35	13	120	7.1	2
DD	Oct. 21, 1954	59	13	.35	.00	32	6.6	23		58	30	45	.0	17	249	107	59	382	7.5	2
Sedimentary rocks																				
M	June 26, 1928	56	17	1.4	--	52	24	11	0.8	168	66	25	--	10	319	228	91	--	--	--
M	Oct. 20, 1954	58	--	.13	--	--	--	3.9		138	50	35	--	4.9	--	210	97	489	7.6	
B	Oct. 14, 1954	54	13	.42	.00	17	3.5	9.9		14	22	14	.0	30	127	57	45	198	6.9	
U	Oct. 23, 1954	55	17	.69	.00	15	1.6	11		61	8.2	5.5	.2	.2	98	44	0	143	8.1	
E	Oct. 20, 1954	59	7.1	.10	.00	27	.7	6.2		59	23	5.5	.0	4.5	117	70	22	191	6.9	
R	June 23, 1928	--	25	2.8	--	43	7.6	13	1.2	128	30	23	--	.1	220	139	34	--	--	--
R	Oct. 22, 1954	53	--	2.3	--	--	--	13		88	40	--	--	.1	--	126	54	345	7.4	2
S	do	52	17	.94	.00	38	4.3	6.8		84	34	16	.1	.2	189	112	44	288	8.1	6
G	Oct. 15, 1954	57	9.9	.53	.01	12	3.1	8.4		11	36	10	.0	.5	92	43	34	138	6.6	3
W	Oct. 19, 1954	57	14	.85	.00	35	2.6	5.2		78	23	14	.0	2.2	154	98	34	252	8.0	3
BB	Oct. 21, 1954	58	20	.48	.02	12	2.1	7.4		34	17	6.5	.0	.0	89	39	11	127	6.9	3

See footnotes at end of table.

TABLE 4.—*Chemical analyses of water from selected wells penetrating different aquifers*—Continued

[Chemical analyses in parts per million]

Sampling site on plate 1	Date of collection	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color
Glacial Outwash																				
V[1]	Sept. 27, 1950			0.50						19		14		0	73	32	16		5.6	
V	Oct. 21, 1954	51	12	1.3	0.01	8.6	2.7	7.2		12	23	10	0.0	.3	82	33	23	125	6.4	2
Z[2]	Apr. 25, 1949		11	.05		16	4.6			68	24	26				59	4		6.5	
Z	Oct. 16, 1954	55	9.8	.29	.03	18	4.2	28		62	30	24	.1	7.3	189	62	11	296	6.6	3
A[1]	Jan. 27, 1947		8.8	.05		16	7.5			28	41	12	0	3.1	111	71	48		6.0	
	Oct. 25, 1954	56	6.9	.07	.00	11	1.4	14		30	18	12	.0	4.7	91	33	9	149	7.0	2
C	Oct. 14, 1954	58	8.2	.24	.03	24	4.3	.7		6	15	18	.1	41	136	78	73	233	6.1	4
L[1]	Jan. 27, 1947		12	0		25	7.3			67	37	3	0	13	168	93	38		6.8	
L	Oct. 18, 1954	54		.01				13		49	29	14		16		74	34	235	6.6	3
P	May 13, 1924		8.0	.08		12	3.5	21	3.3	23	24	27		16	136	45	26		6.8	
P	Oct. 25, 1954	60	7.2	.15	.00	10	1.3	6.4		14	19	6	.1	5.2	68	30	19	112	6.5	2
F[1]	Jan. 5, 1948		9.2	0		11	4.5			16	24	4	0	13	86	46	33		6.8	
F	Oct. 14, 1954	56	7.8	.14	.00	8.6	1.0	3.2		15	6.2	6	.0	6.7	60	26	13	85.1	6.9	3
N	Oct. 25, 1954	52	7.2	1.6	.01	15	3.2	12		42	31	18	.0	5.2	132	51	16	227	6.8	2
O	Oct. 18, 1954	58	15	.51	.01	31	11	35		46	109	32	.1	3.0	301	123	85	464	6.8	3
T	Oct. 22, 1954	54	15	1.2	.04	26	10	60		134	51	52	.2	.3	329	106	0	537	7.4	3
H	Oct. 14, 1954	53	7.8	.29	.00	5.5	.5	8.9		8	11	12	.0	.4	59	16	9	93.9	6.7	5
CC	Oct. 21, 1954	51	8.0	1.2	.00	9.0	3.0	7.6		7	26	8	.1	8.6	83	35	29	122	6.0	2
AA	do	60	7.1	.17	.00	17	.8	6.3		12	24	4	.1	23	101	46	36	144	6.4	2
Glacial till																				
Y	Oct. 19, 1954	65	7.7	.15	.01	40	7.0		11	62	46	20	.0	31	244	129	78	391	6.7	2
D[1]	Jan. 27, 1947		7.4	0		14	4.4			[3] 34	19	9	0	18	93	53	25		8.6	
D	Oct. 14, 1954	55		2.1					15	66	13	4.0		.2		40	0	164	7.3	2
T	Oct. 15, 1954	59	6.7	.90	.01	12	2.7		13	38	25	5	.0	7.1	107	41	10	177	7.6	3

[1] Analyses made by Rhode Island Dept. of Health.
[2] Analysis by W. H. Betz and L. D. Betz.
[3] Includes the equivalent of 3 ppm of CO_3.

TABLE 5.—*Chemical analyses of selected surface water*

[Chemical analyses in parts per million]

Number on plate 1	Stream and location	Date of collection	Discharge (Mgd)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color
	Providence River basin																				
1	Branch River at Forestdale	Oct. 2, 1953	19	3.5	0.63	0.00	8.1	1.3	26	7.0	58	18	19	0.0	1.3	124	26	0	184	7.2	13
	Do	Apr. 20, 1954	433	4.2	.06	.00	2.5	1.0	4.2	1.5	6.0	12	3.7	.0	.9	45	10	5	48.5	5.7	50
2	Blackstone River at Woonsocket	Oct. 8, 1952	273	4.4	.89	.15	9.9	2.3	21	6.5	3	52	21	.2	7.5	133	34	32	217	5.3	15
	Do	May 15, 1953	659	4.2	1.3	------	7.8	1.1	9.6	2.4	4.1	29	11	.2	2.8	81	24	21	199	5.2	20
3	Woonasquatucket River at Centerdale	Oct. 18, 1954	36	5.5	.38	.00	5.2	.8	12		15	14	10	.2	1.8	77	16	4	94.3	7.3	20
	Pawtuxet River basin																				
4	South Branch Pawtuxet River at Washington	Sept. 22, 1955	76	6.4	.62	.00	2.3	.8	3.3	.3	8	5.3	4.1	.3	.2	33	9	3	42.5	6.3	25
	Do	Jan. 9, 1956	148	7.7	.15	.00	1.8	1.0	3.4	1.2	6	6.3	4.2	.3	.6	34	9	4	47.2	6.0	7
5	Pawtuxet River at Cranston	Oct. 2, 1953	105	4.2	.36	.01	4.1	1.3	13	1.9	21	15	11	.1	.8	80	16	0	109	6.5	7
	Do	Apr. 22, 1954	439	4.5	.08	.00	3.3	1.2	6.0	1.5	7.5	12	7.0	.0	1.9	52	13	7	62.5	5.9	20

TABLE 6.—*Summary of streamflow data*

Number on plate 1	Gaging station	Drainage area (square miles)	Elevation of gage (feet above mean sea level)	Period of record	Average flow		Maximum flow			Minimum daily flow		Remarks
					Quantity (mgd)	Years	Quantity (cfs)	Gage height (feet)	Date	Quantity (mgd)	Date	
1	Branch River at Forestdale.	93.3	[1] 180	January 1940 to September 1955.	102	15	4,240	10.52	Aug. 19, 1955	3.4	Oct. 7, 1948	Flood of March 1936 reached a flow of about 5,800 cfs.
2	Blackstone River at Woonsocket.	416	107.42	February 1929 to September 1955.	[2] 456	26	32,900	21.8	do	[3] 14	Aug. 11, 1934	
3	Woonasquatucket River at Centerdale.	38.3	[1] 95	July 1941 to September 1955.	43.4	14	1,100	7.03	Sept. 11, 1954	2.2	Oct. 13, 19, 1941	Flood of March 1936 reached a flow of 1,000 cfs.
4	South Branch Pawtuxet River at Washington.	63.8	[1] 230	October 1940 to September 1955.	[4] 80.1	15	1,320	4.11	Sept. 12, 1954	1.8	Aug. 27, 1944	Flood of March 1936 reached a flow of 1,810 cfs.
5	Pawtuxet River at Cranston.	200	[1] 10	December 1939 to September 1955.	[5] 249	15	2,010	8.85	Sept. 13, 1954	14	Sept. 4, 1944	

[1] Figure is approximate.
[2] Adjusted for diversion from Nashua River basin; diversion averaged about 12 mgd.
[3] Flow in Hamlet Trench not included.
[4] Adjusted for diversion from Carr Pond.
[5] Adjusted for diversion from Scituate Reservoir.

TABLE 7.—*Summary of information on public water supplies, 1954*

Community or system	Source or supplier	Storage (millions of gallons)		Treatment	Population served	Average quantity used		Peak demand (mgd)	Rated capacity of source or supplier (mgd)		
		Raw	Finished			Total (mgd)	Per capita (gpd)		Streams	Wells	Treatment
Barrington	Bristol County Water Co.										
Bristol	do										
Bristol County Water Co.	Reservoirs in Kickamuit and Palmer River basins; wells.	429	3.321	Stream water: prechlorination, coagulation, sedimentation, filtration, postchlorination and fluoridation. Well water: aeration, filtration, chlorination and fluoridation.	32,300	[1] 3.28	102	5.57	4	2	7.5
Central Falls	Pawtucket Water Works										
Cranston	Providence Water Supply Board.				53,400						
	Kent County Water Authority.				1,500						
Cumberland	Pawtucket Water Works				8,000						
	Sneech Pond and well [2]	223	1.105	Chlorination and fluoridation	6,000	.394	66	.796			
East Providence	Tenmile River impounded in East Providence Reservoir.	400	3.39	Stream water: aeration, coagulation, treatment with activated carbon, sedimentation, filtration, chlorination, pH adjustment. Well water: not treated.	38,000	[3] 3.94	104	6.92	10	4	4.1
East Smithfield Water District.	Purchased from Providence Water Supply Board.				[4] 3,600	[4] .23	64				
Johnston	Providence Water Supply Board.										
Kent County Water Authority.					[5] 40,000	([6])	73	[7] 5.21			
East Greenwich Division.	Wells		.375	Chlorination		1.25				6	
West Warwick Division	do			do		.89				1.4	
	Carr Pond	218	.770	Chlorination and stabilization		.47			.41		
	Purchased from Providence Water Supply Board.			Chlorination		.30					
Lincoln	Cumberland Water Works				260						
	Pawtucket Water Works				3,760						
	Woonsocket Water Department.				3,500						

See footnotes at end of table.

TABLE 7.—*Summary of information on public water supplies, 1954*—Continued.

Community or system	Source or supplier	Storage (millions of gallons)		Treatment	Population served	Average quantity used		Peak demand (mgd)	Rated capacity of source or supplier (mgd)		
		Raw	Finished			Total (mgd)	Per capita (gpd)		Streams	Wells	Treatment
North Providence	Providence Water Supply Board.				11,400						
	East Smithfield Water District.				800						
	Pawtucket Water Works				1,750						
North Smithfield	Woonsocket Water Department.				2,500						
	Five other systems				950	.072	76				
Pawtucket Water Works	Abbott Run impounded in Pawtucket Reservoir, and Robin Hollow and Happy Hollow Ponds; wells.	2,731	20	Aeration, coagulation, sedimentation, filtration, chlorination, fluoridation, and pH adjustment.	135,000	[8] 13.88	103	21.48	13.5	6.1	30
Providence Water Supply Board.	Scituate Reservoir and five smaller reservoirs in North Branch Pawtuxet River basin. (Rated capacity for all reservoirs, 85 mgd.)	39,746	54.49	Coagulation, sedimentation, filtration, chlorination, and fluoridation.	[9] 372,000	[10] 37.92	[10] 102	[10] 68.56			105
Smithfield	East Smithfield Water District (serving Esmond and Georgiaville).				2,800						
	Four other systems				750	.040	53				
Warwick	Warwick Water Department.		.075				55				
	Purchased from Providence Water Supply Board.				[4] 37,500	[4] 1.98					
	Purchased from Kent County Water Authority.					[11] .07					
	Kent County Water Authority.				[11] 5,500						
Warren	Bristol County Water Co.										
West Warwick	Kent County Water Authority.										

Woonsocket	Crookfall Brook impounded in Woonsocket Reservoirs 1 and 3. (Total rated capacity 3.5 mgd.)	920	5.05	Chlorination	55,600	4.86	87	6.89	--------	--------	--------

[1] Of which 0.66 mgd is from wells.
[2] Well auxiliary supply, capacity 1 mgd, not used in 1954.
[3] For year ending Sept. 15, 1954.
[4] Included in figure for Providence Water Supply Board.
[5] Served by entire system, population 36,000 in Providence area.
[6] Entire system supplied 2.91 mgd, of which 2.06 mgd was supplied to the Providence area.
[7] Supplied to entire system.
[8] Of which 1.90 mgd is from wells.
[9] Does not include population served through Kent County Water Authority.
[10] For year ending Sept. 30, 1954; includes water sold to Warwick Water Department, Kent County Water Authority, State institutions, and East Smithfield Water District.
[11] Included in figure for Kent County Water Authority.

TABLE 8.—*Chemical quality of water*

[Chemical analyses

Public supplier	Type of water	Date of collection	Silica (SiO_2)	Iron (Fe)[1]	Manganese (Mn)[1]	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
Bristol County Water Co.	Finished	July 11	1.5	0.01	0.06	16	1.9	6.0	0.7
East Providence	Finished surface.	---do	6.9	.22	.53	9.8	1.6	29	2.0
	Well	---do	9.3	.03	.01	9.3	1.6	4.6	.2
	-----do	June 23	10	.00	.00	9.8	1.8	5.0	.4
Pawtucket Water Works.	Finished	July 17	3.4	.10	.00	8.3	1.5	4.6	.8
	Well	July 23	13	.02	.00	17	3.2	18	2.3
Providence Water Supply Board.	Finished	July 17	8.2	[2] .02	.00	9.0	.5	3.2	.7
Kent County Water Authority.									
Coventry	Wells	---do	7.4	.07	.04	4.7	.8	5.4	1.2
Warwick	-----do	July 9	12	.01	.00	6.5	1.9	7.9	1.2
	Finished (wells and stream)[3]	May 8	8	.0	.0	6.4	1.2	([2])	11
Woonsocket	Raw	July 16	4.8	.22	.00	3.9	.5	3.2	.6
Cumberland	Raw surface	---do	2.0	1.9	.00	5.1	1.8	4.2	1.4

[1] In solution at time of analysis.
[2] Analysis Oct. 9, 1953.

from the major public supplies, 1951

in parts per million]

Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color
21	0	28	9.8	0.2	0.6	84	48	30	140	7.0	7
22	0	40	23	.2	4.7	136	31	13	226	6.4	5
13	0	20	5.5	.1	2.6	63	30	19	99.4	6.2	0
16	0	19	5.8	.0	2.7	64	32	20	103	6.2	2
17	0	13	6.1	.2	1.0	54	27	13	84.7	6.8	20
56	0	24	18	.0	1.4	128	56	10	212	6.9	7
13	2	13	4.0	.1	.5	52	24	10	74.6	9.1	7
9	0	7.8	6.5	.1	2.8	46	15	8	66.9	6.4	7
13	0	15	8.2	.2	4.6	68	24	13	105	6.1	2
17	0	12	13	.0	.9	[4] 61	21	7	----------	5.9	5
6	0	6.5	4.4	.1	1.1	34	12	7	45.0	6.3	15
12	0	10	5.8	.2	1.4	46	20	10	69.2	6.7	22

[3] Analysis by Rhode Island Dept. of Health.
[4] Sum of determined constituents.

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