WATER QUALITY

GROUND WATER

Chemical analyses of water samples from 40 domestic wells finished in bedrock and 10 active municipal wells finished in sand and gravel were made by the Survey and the Massachusetts Department of Environmental Quality Engineering (MDEQE) in the spring and summer of 1982. The results of these chemical analyses are illustrated by Stiff diagrams (Stiff, 1951) in figure 14 and are summarized in tables 3 and 4. The Stiff diagrams show the measured concentrations of dissolved calcium, magnesium, sodium, iron, sulfate, and chloride, nitrogen, and bicarbonate.

The concentration of dissolved solids in 40 samples collected from domestic bedrock wells ranged from 50 to 533 mg/L and the mean concentration was 124 mg/L. The dissolved-solids concentration in one well exceeded the USEPA (U.S. Environmental Protection Agency)-recommended limit of 500 mg/L. The well is located 200 feet downgradient of a major highway, and runoff containing de-icing salts may be recharging the well, producing the high concentration of dissolved solids.

As a general rule, the concentration of dissolved solids in ground water is directly proportional to the specific conductance. Concentrations of dissolved solids measured at the 40 domestic bedrock-well sites were regressed against the specific conductances, in order to derive an equation to estimate dissolved solids from specific conductance (fig. 15). The correlation between specific conductance and concentration of dissolved solids is very high ($r = 0.98$) indicating that the specific conductance, which is easily measured, is an accurate predictor of the concentration of dissolved solids in water from bedrock.

Hardness is a measurement of the concentration of calcium and magnesium and is expressed as equivalent concentrations of $CaCO_3$ in mg/L. These ions react with soap to form residues and they precipitate to form scale in pipes. The degree of hardness is described in terms of being soft (0–60 mg/L), moderately hard (61–120 mg/L), hard (121–180 mg/L) and very hard (greater than 180 mg/L) (Hem, 1970). Characteristically, ground water from bedrock wells in the basin is moderately hard, with values of hardness ranging from 16 to 260 mg/L, and averaging 64 mg/L.

Iron concentrations in ground water from domestic bedrock wells ranged from 4 to 20,000 µg/L, and manganese concentrations ranged from 1 to 1,100 µg/L. Iron concentrations exceeded the 300 µg/L USEPA recommended limit in 6 wells, and manganese concentrations exceeded the 50 µg/L USEPA-recommended limit in 13 wells. Concentrations of manganese and iron exceeding the USEPA-recommended limits can produce an objectionable metallic or rusty taste in drinking water and may cause water to stain laundry and plumbing fixtures. High iron and manganese levels are common in Massachusetts.

Sodium concentrations in three domestic wells (D2W11, OXW32, and WBW2) were 35 mg/L, 36 mg/L, and 22 mg/L, respectively, which exceeded the 20 mg/L limit recommended the MDEQE for individuals on sodium-restricted diets. The high concentrations may be attributed to man-made sources, such as road-salt application and stockpiling, as there are no natural brines or evaporite deposits present in the basin.

Arsenic was found in the water of 33 domestic bedrock wells; however, only the concentration in 11 wells exceeded the USEPA-recommended limit of 50 µg/L. In 1979, arsenic concentrations exceeding the USEPA limit were found in several domestic wells in the town of Leicester. The USEPA, the Massachusetts Board of Health, and MDEQE analyzed water from 109 domestic wells and all municipal wells in the town of Leicester for arsenic. Only a few samples from the domestic bedrock wells contained concentrations of arsenic above the USEPA limit. These wells are now using an activated charcoal filtration and ion exchange to reduce the arsenic content. No arsenic was found in the municipal wells.

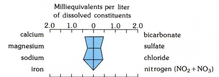
Water from municipal wells finished in sand and gravel was characteristically soft, with values of hardness ranging from 21 to 93 mg/L and averaging 45.6 mg/L. Iron concentrations ranged from 0 to 2,500 µg/L and manganese concentrations ranged from 0 to 310 µg/L. None of these wells exceeded the USEPA-recommended limits for iron and manganese. One municipal well located in Sturbridge contained 30 mg/L of sodium.

The quality of the ground water can be illustrated using Piper diagrams (fig. 16). A single water analysis is represented by three points. One point represents the proportion of anions (chloride, carbonate, and sulfate) in a water sample. A second point represents the relative proportion of cations (sodium + potassium, magnesium and calcium). A third point represents the overall composition of the water using pairs of anions and cations, specifically sulfate + chloride, calcium + magnesium, carbonate + bicarbonate, and sodium + potassium. Figure 16 shows that most water samples are characterized by high proportions of calcium relative to sodium, potassium and magnesium, and high proportions of carbonate anions relative to chloride and sulfate anions. Calcium and magnesium are responsible for the moderately hard water in domestic wells in the basin.

EXPLANATION

- ◎ **Municipal well penetrated only unconsolidated deposits**—Analysis by Massachusetts Department of Environmental Quality Engineering
- ● **Domestic well penetrated bedrock**
- D2W 3 **Well number**—Assigned by the U.S. Geological Survey
- **Basin boundary**

Milliequivalents per liter of dissolved constituents



Conversion factors—Multiply milliequivalents per liter by factor (F) to obtain milligrams per liter.

Calcium, F = 20.0	Bicarbonate, F = 61.0
Magnesium, F = 12.2	Sulfate, F = 48.0
Sodium, F = 23.0	Chloride, F = 35.5
Iron, F = 27.9	Nitrogen (NO_3), F = 62.0

Base from U.S. Geological Survey 1:24,000 quadrangles

***FIGURE 14.*—Chemical quality of ground water.**

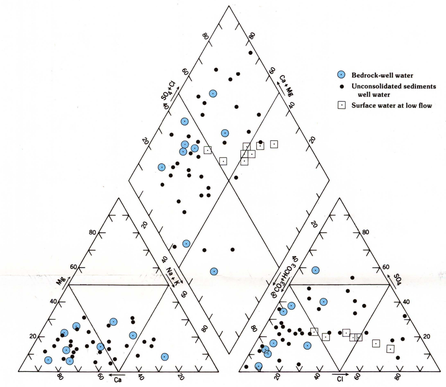


***FIGURE 16.*—Piper diagram illustrating ground-water and surface-water quality.**

SURFACE WATER

The chemical quality of surface water is within the limits recommended by the U.S. Environmental Protection Agency (1975) for domestic water supplies (table 5) and is suitable for most purposes. Eleven surface-water samples were collected at the gaging stations and low-flow partial-record stations by the Survey in August 1982. The average concentration of dissolved solids was 72.1 mg/L (table 5), well below the 500 mg/L limit recommended by the USEPA. A fairly good correlation ($r = 0.88$) exists between specific conductance of surface water in the basin and the concentration of dissolved solids (fig. 17). Hardness values ranged from 14 to 30 mg/L, typical of soft water. Surface water is generally "softer" than ground water because overland flow is in contact with earth materials a relatively short time and thus has a lower concentration of dissolved solids.

Iron, manganese, sodium and phosphorus were the only constituents to exceed USEPA-recommended limits (table 5). Iron concentrations ranged from 150 to 680 µg/L, with seven of the eleven samples exceeding the USEPA-recommended limit. Manganese concentrations ranged from 10 to 110 µg/L, with 4 of the eleven samples exceeding the USEPA-recommended limit. Sodium concentrations ranged from 2.9 to 21 mg/L, with one sample exceeding the MDEQE-recommended limit. Phosphorous concentrations ranged from 0.01 to 0.26 mg/L, with 4 of the eleven samples exceeding the USEPA-recommended limit.

Figure 18 shows Stiff diagrams illustrating surface-water quality at the eleven sites. Station 01124390 has the worst water quality of all eleven surface-water stations sampled in the basin. At this station, the concentration of iron was 340 mg/L and the concentration of phosphorous was 0.09 mg/L. Both exceeded the USEPA-recommended limits (U.S. Environmental Protection Agency, 1975, 1979).

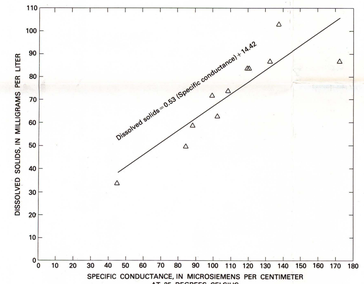


***FIGURE 17.*—Relation between specific conductance and concentration of dissolved solids in surface water.**

***TABLE 5.*—Concentrations of dissolved constituents, and physical properties of surface water in the French-Quinebaug Rivers basin.**
Samples were collected and analyzed by the U.S. Geological Survey; analyses are reported in milligrams per liter, except as indicated.
[°C, degrees Celsius; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter]

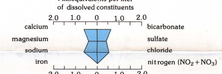
Constituent or property	Number of samples	Limit[1,2]	Range in concentration	Median	Number of samples exceeding limit
Alkalinity (Lab.) (as $CaCO_3$)	11	—	10.0-19.0	13.0	—
Calcium	11	—	3.6-9.4	7.1	—
Chloride	11	250.00	3.5-37.0	15.0	0
Dissolved solids, residue at 180 °C	11	500.00	34.0-103.0	—	0
Fluoride	11	2.40 at 47 °F[3]	0.1-0.2	0.1	0
Hardness (as $CaCO_3$)	11	—	14.0-30.0	23.0	—
Iron (µg/L)	11	300.0	150.0-680.0	340.0	7
Magnesium	11	—	1.0-2.1	1.4	—
Manganese (µg/L)	11	50.00	10.0-110.0	43.0	4
Nitrogen, $NO_2 + NO_3$ dissolved (as N)	11	10.00	0.1-0.7	0.20	0
pH	11	6.5-8.5	6.3-7.2	—	0
Phosphorus, ortho, as P	11	0.02	0.01-0.3	0.02	4
Potassium	11	—	0.1-2.2	1.6	—
Silica	11	—	3.0-11.0	5.0	—
Sodium	11	*20.00	2.9-21.0	11.0	1
Specific conductance (µS/cm at 25 °C)	11	—	43.0-277.0	—	—
Sulfate	11	250.00	4.0-10.0	8.0	0

[1]U.S. Environmental Protection Agency, 1975.
[2]U.S. Environmental Protection Agency, 1979.
[3]Annual average daily air temperature for East Brimfield, in degrees Fahrenheit.
*Limit recommended by The MDEQE (Massachusetts Department of Environmental Quality Engineering) for individuals on sodium-restricted diets.

EXPLANATION

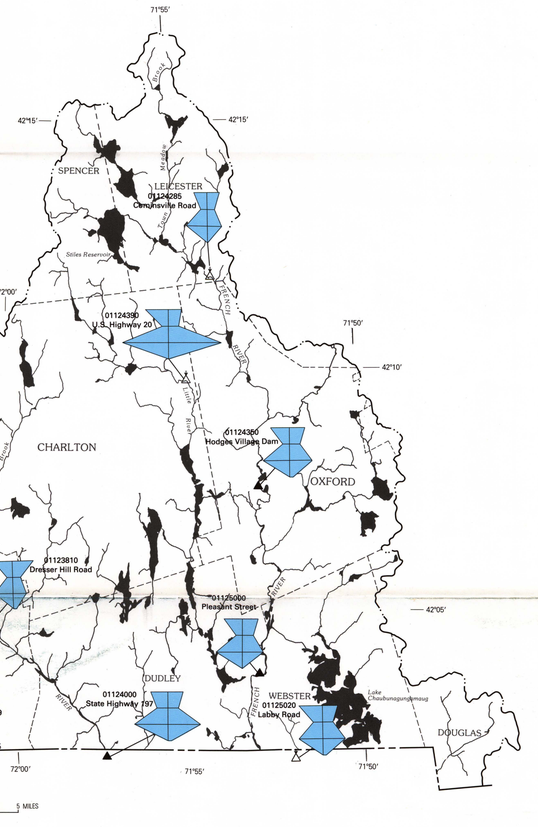
- ▲ **Gaging station**
- 01123810 **Low-flow partial-record measurement station**
- **Station number, in downstream order. Number from U.S. Geological Survey's data-collection network**
- **Basin boundary**

Milliequivalents per liter of dissolved constituents



Conversion factors—Multiply milliequivalents per liter by factor (F) to obtain milligrams per liter.

Calcium, F = 20.0	Bicarbonate, F = 61.0
Magnesium, F = 12.2	Sulfate, F = 48.0
Sodium, F = 23.0	Chloride, F = 35.5
Iron, F = 27.9	Nitrogen (NO_3), F = 62.0



Base from U.S. Geological Survey 1:24,000 quadrangles

***FIGURE 18.*—Chemical quality of surface water during low flow.**

***TABLE 3.*—Concentrations of dissolved constituents and physical properties of ground water from domestic bedrock wells in the French-Quinebaug Rivers basin.**
Samples were collected and analyzed by the U.S. Geological Survey; analyses are reported in milligrams per liter, except as indicated.
[°C, degrees Celsius; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter]

Constituent or property	Number of samples	Limit[1,2]	Range in concentration	Median	Number of samples exceeding limit
Alkalinity (Lab.) (as $CaCO_3$)	40	—	1.0–160.0	47.0	—
Arsenic (µg/L)	33	50.0	1.0–560.0	11.5	11
Calcium	40	—	4.1–90.0	14.5	—
Chloride	40	250.0	1.3–150.0	7.75	0
Dissolved solids, residue at 180 °C	39	500.0	50.0–533.0	107.0	0
Fluoride	40	2.4 at 47 °F[3]	0.1–2.1	0.2	10
Hardness (as $CaCO_3$)	40	—	16.0–260.0	51.0	—
Iron (µg/L)	40	300.0	4.0–20,000.0	18.5	6
Magnesium	40	—	0.2–12.0	2.4	—
Manganese (µg/L)	40	50.0	1.0–1,100.0	13.5	13
Nitrogen, $NO_2 + NO_3$ dissolved (as N)	40	10.0	0.19–13.0	0.10	1
pH	40	6.5–8.5	4.8–7.7	6.0	34 below 6.5
Phosphate, ortho, as PO_4	10	—	0.031–.31	0.105	—
Phosphorus, ortho, as P	40	0.02	0.0102–.1	0.01	7
Potassium	40	—	0.4–7.6	2.1	—
Silica	40	—	7.3–33.0	14.0	—
Sodium	40	*20	2.8–36.0	9.4	—
Specific conductance (µS/cm at 25 °C)	40	—	65.0–765.0	157.5	—
Sulfate	40	250.0	1.0–59.0	16.5	0

[1]U.S. Environmental Protection Agency, 1975.
[2]U.S. Environmental Protection Agency, 1979.
[3]Annual average daily air temperature for East Brimfield, in degrees Fahrenheit.
*Limit recommended by The MDEQE (Massachusetts Department of Environmental Quality Engineering) for individuals on sodium-restricted diets.

***TABLE 4.*—Concentrations of dissolved constituents and physical properties of ground water from muncipal wells in the French-Quinebaug Rivers basin.**
Samples were collected and analyzed by the Massachusetts Department of Environmental Quality Engineering; analyses are reported in milligrams per liter, except as indicated.
[µS/cm, microsiemens per centimeter]

Constituent or property	Number of samples	Limit[1,2]	Range in concentration	Median	Number of samples exceeding limit
Alkalinity (Lab) (as $CaCO_3$)	10	—	13.0–39.0	21.0	—
Calcium	10	—	6.5–26.0	14.0	—
Chloride	10	250.00	6.0–87.0	20.5	0
Hardness	10	—	21.0–93.0	44.0	—
Iron	10	300.00	0.0–2,500.0	0.03	2
Magnesium	10	—	1.3–6.9	2.15	0
Manganese	10	50.00	0.0–310.0	0.07	5
Nitrogen, $NO_2 + NO_3$ dissolved (as N)	10	—	0.106–1.8	0.65	0
Potassium	10	10.00	1.2–2.9	1.85	—
Sodium	10	*20.00	5.2–30.0	11.0	1
Specific Conductance (µS/cm at 25 ° C)	10	—	82.0–350.0	150.0	—
Sulfate	10	250.00	4.0–15.5	9.75	0

[1]U.S. Environmental Protection Agency, 1975.
[2]U.S. Environmental Protection Agency, 1979.
*Limit recommended by the Massachusetts Department of Environmental Quality Engineering for individuals on sodium-restricted diets.

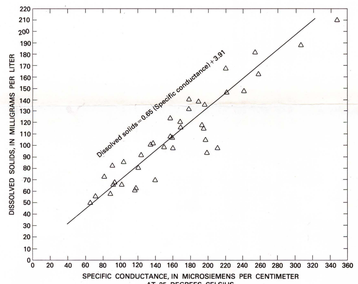


***FIGURE 15.*—Relation between specific conductance and concentration of dissolved solids in ground water from bedrock wells.**

WATER RESOURCES IN THE FRENCH-QUINEBAUG RIVERS BASIN, MASSACHUSETTS

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