QUALITY OF WATER

POLLUTION

The main stem of the Millers River contains treated effluent from Winchendon, untreated domestic sewerage from South Royalston, Athol, Orange, and Erving and untreated sanitary wastes from industries, industrial wastes from textile mills, foundries, papermills and machine manufacturing concerns. The Otter River, the main southern tributary to the Millers River contains treated effluent from Gardner, untreated sewage from Baldwinville, industrial wastes from plating plants, paint manufacturing concerns, foundries and papermills. Beaver Brook, a small southern tributary having its confluence with the Millers River near South Royalston, receives treated effluent from the Fernald State School in Templeton. For the most part, the other tributaries within the basin are relatively free of pollution.

The ground water, unlike the major streams, is not polluted except very locally. Some local domestic wells are moderately high in nitrates and there are local areas of high chloride contamination. The major objectionable constituent in ground water is iron which seems to be excessive in only a few wells in the basin.

MINERAL CONSTITUENTS OF SURFACE WATERS

Figure 1 shows the linear relation between specific conductance and concentration of dissolved solids for 52 samples from the four sampling sites within the basin. Mean values of dissolved solids (S) for each of the sampling sites were statistically examined and found to be different. Because the samples were collected at the four sites on the same dates, a significant difference of mean values of S at each site suggests different types of water.

Further statistical investigations were made with each group of S values to define the suggested water types. Findings showed that values of S for water in East Branch Tully River near Athol are different from S values of Otter River at Baldwinville; both are different from S values of Millers River at Erving and at South Royalston. Therefore, three types of water, based on S values, are suggested: (1) East Branch Tully River, lowest of S values, is termed natural water; (2) Otter River at Baldwinville, highest of S values, is termed inferior water; and (3) Millers River at South Royalston and at Erving, intermediate S values between natural and inferior waters, is termed blended water. East Branch Tully River water has similar S values to water of the Millers River above its confluence with Otter River and to most other Millers River tributaries. Other comparisons show that natural water plus inferior water is similar to the blended waters. The areal concentration of dissolved solids of surface waters in the basin is shown in figure 2 for a period of extreme low flow.

The range in chemical character of surface waters is illustrated by the diagrams in figures 3, 4, and 5. A plot of the major cations and anions for all the chemical analyses of surface waters in the basin (fig. 3) indicates a range in chemical character extending from noncarbonate hardness exceeding 50 percent to noncarbonate alkali exceeding 50 percent. A plot of the natural water (East Branch Tully River near Athol, fig. 4) shows the close grouping of samples of low concentration. On the other hand, the plot of inferior water (Otter River at Baldwinville, fig. 5) shows considerable variation in chemical character and concentration.

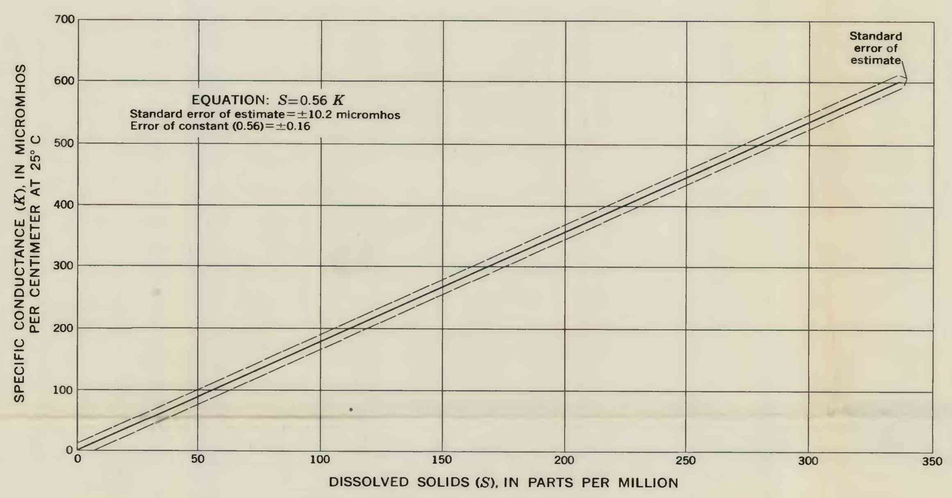


FIGURE 1.—GRAPH SHOWING DISSOLVED SOLIDS-SPECIFIC CONDUCTANCE RELATION. *All samples from the four sampling sites; East Branch Tully River near Athol, Millers River at South Royalston, Millers River at Erving and Otter River at Baldwinville, plot as a significant linear regression passing through the origin.*

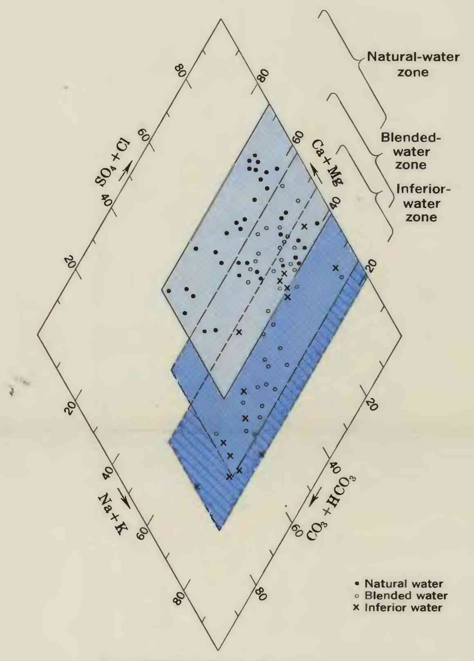


FIGURE 3.—WATER-ANALYSIS DIAGRAM. *The overlapping of the three water types is caused by the tendency for inferior and blended waters to approach the natural water zone with increasing stream discharge.*

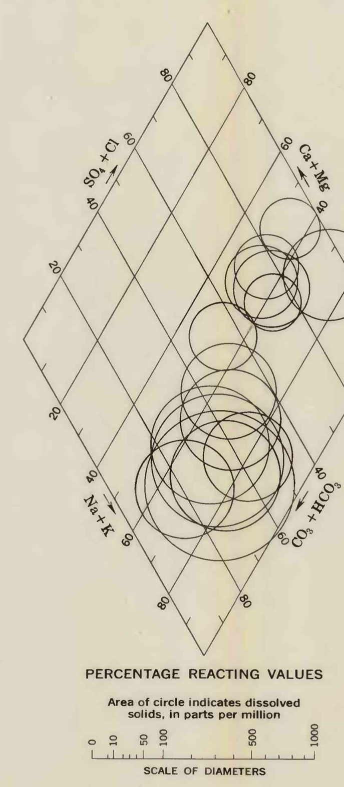


FIGURE 5.—WATER-ANALYSIS DIAGRAM OF INFERIOR WATERS. *All samples with greater than 50 percent* $CO_3 HCO_3$ *were obtained below a discharge that is exceeded 90 percent of the time.*

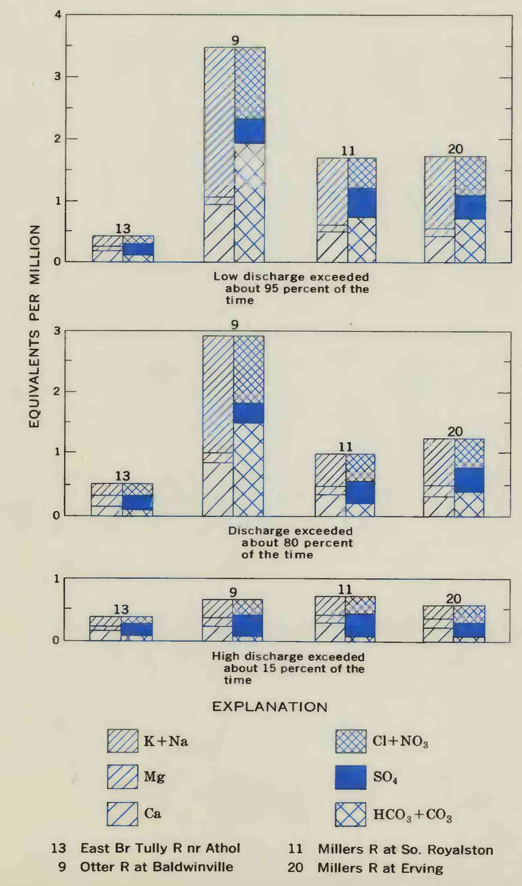


FIGURE 7.—GRAPH SHOWING CONCENTRATION OF CHEMICAL CONSTITUENTS FOR THREE STREAMFLOW DISCHARGES. *The natural water (13) changes very little for the three discharge periods. However, as discharge increases the inferior water (9) becomes nearly equal in concentration to the blended waters (11 and 20) and the natural water (13).*

ORGANIC CONSTITUENTS IN SURFACE WATER

Biochemical oxygen demand (BOD) and dissolved oxygen concentration (DO) are indexes of water pollution by organic matter. BOD is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic (free oxygen) conditions and is a determination of the strength of the polluting wastes in a stream. DO is the amount of free oxygen in the stream and is dependent on temperature and pressure. Inadequate DO in surface water may contribute to an unfavorable environment for fish and other aquatic life and also cause odoriferous products of an aerobic (without bound oxygen) decomposition.

The spatial distribution of BOD for streams in the basin during a time of low flow and high temperature, August 1966, (fig. 8) confirms the patterns of natural, blended, and inferior water based on concentrations of mineral constituents (fig. 2).

Annual monthly ranges of BOD and DO for natural, blended and inferior waters (figs. 9 and 10) show some apparent anomalies. For example, the gradient of the Millers River increases above Athol (fig. 8), the blended Millers River water is aerated and its DO content approaches that of the natural water (fig. 10, March, April and May). Furthermore, the combination of higher flows and high DO probably causes the lower BOD range in blended water than in natural water during the April measurements (fig. 9).

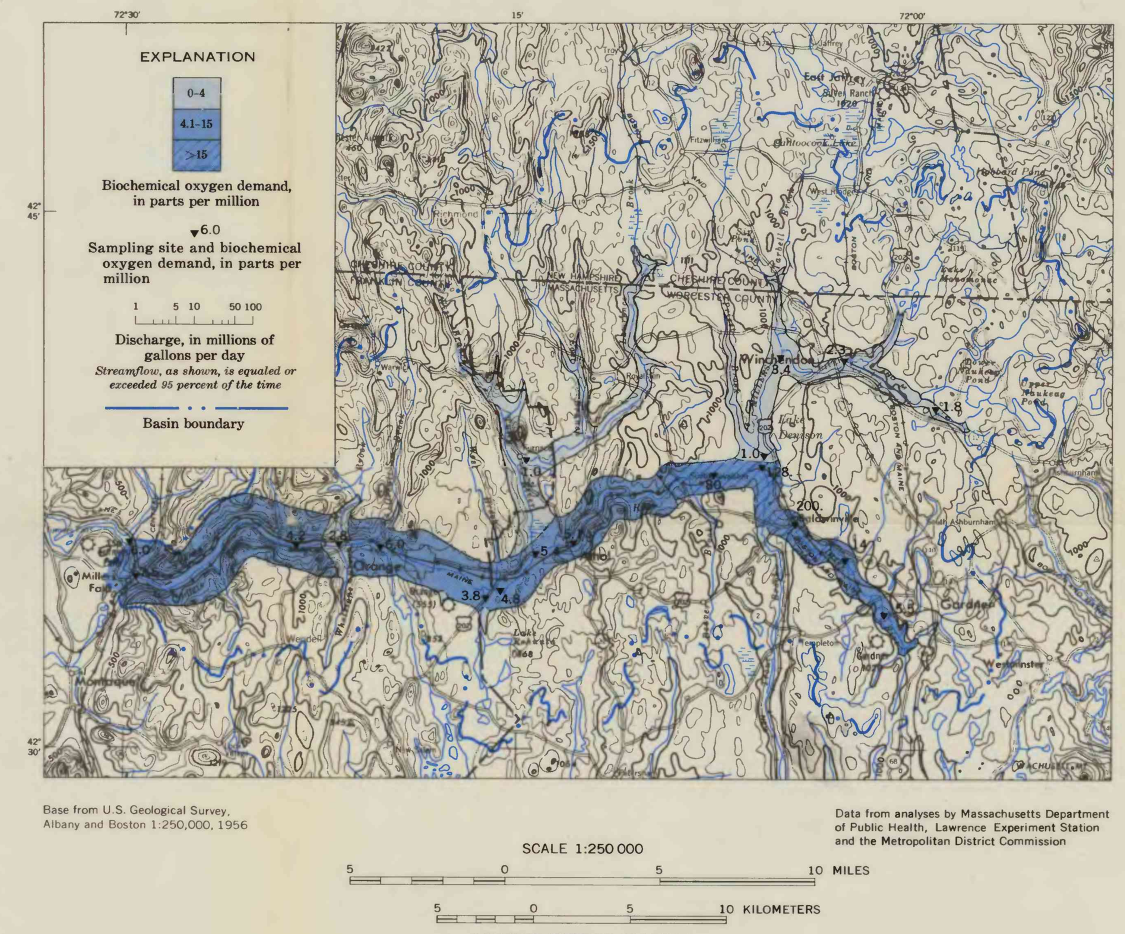


FIGURE 8.—MAP SHOWING DISTRIBUTION OF BIOCHEMICAL OXYGEN DEMAND. *High BOD values generally reflect sites of contamination.*

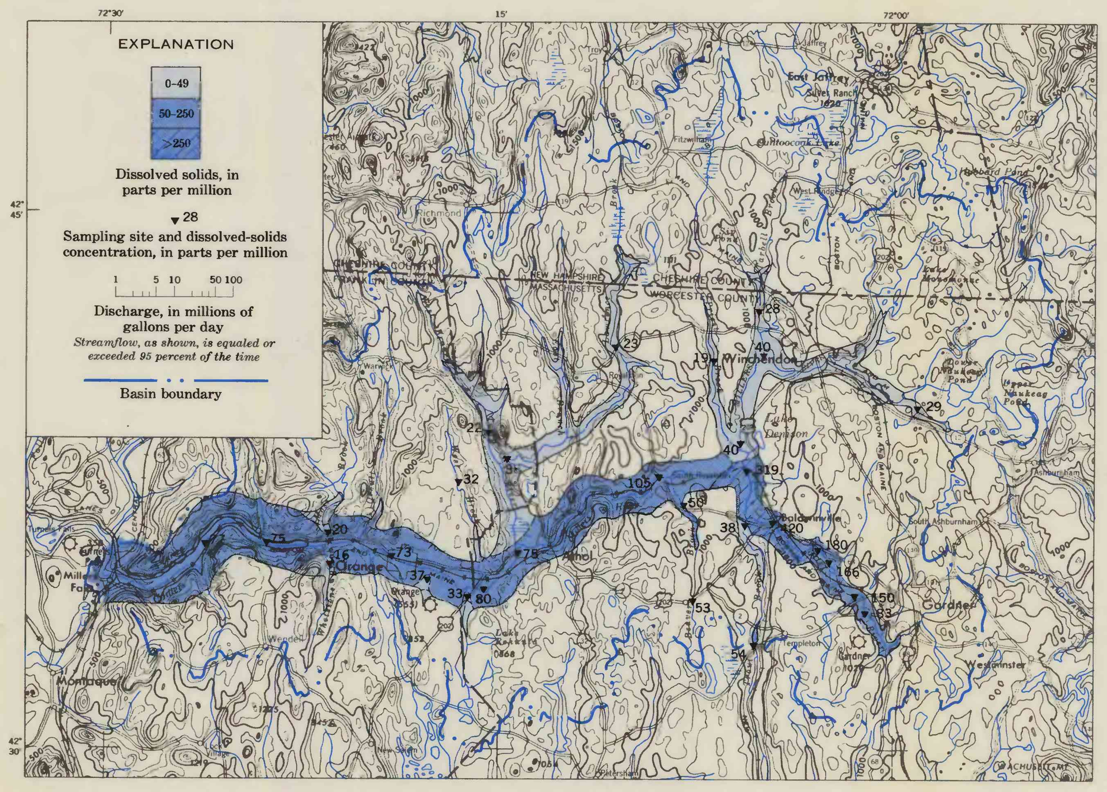


FIGURE 2.—MAP SHOWING CONCENTRATION OF DISSOLVED SOLIDS IN STREAMS. *Three major water types are suggested by the dissolved solids concentrations; (1) natural waters, 0–49 ppm, (2) blended waters (50–250 ppm, and (3) inferior waters, greater than 250 ppm.*

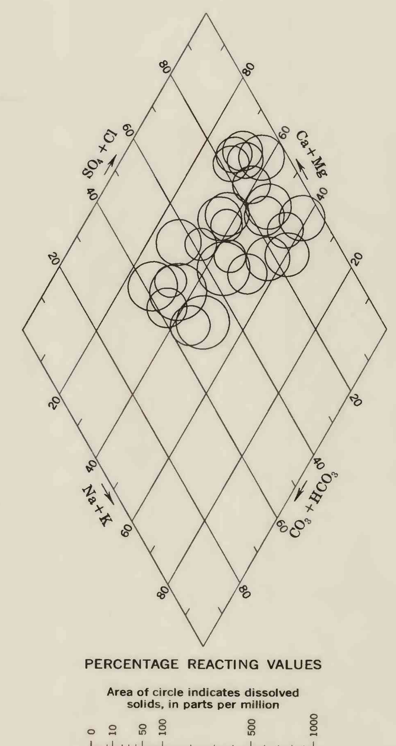


FIGURE 4.—WATER-ANALYSIS DIAGRAM OF NATURAL WATERS. *The concentration of dissolved solids for natural waters changes very little.*

The relationship between discharge and concentration of dissolved solids, for streams in the basin is shown (fig. 6) for the three types of water. This relation is also shown (fig. 7) by a general classification of low, medium, and high flows and the concentration of chemical constituents at the four sampling sites. The relations exhibited in figures 6 and 7 are also apparent in figure 5 by the variation of the length of the radii of the concentration circles. The high concentrations (longer radii, fig. 5) are for low discharge periods and the radii of the circles becomes shorter (lower concentrations) as the data trends upward, on the graph, for the samples taken at higher discharges.

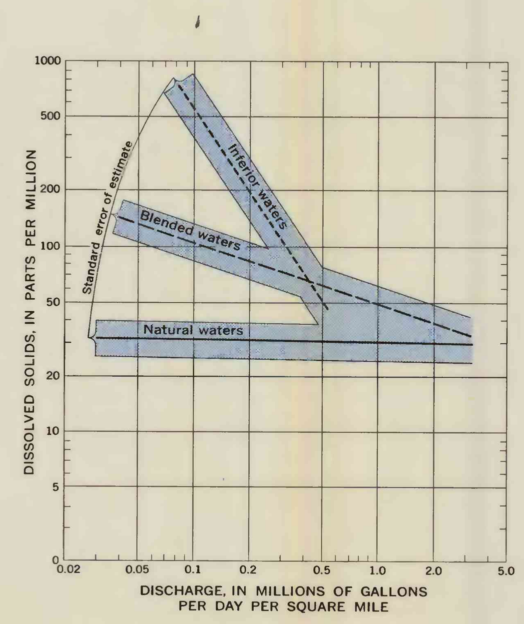


FIGURE 6.—RELATION BETWEEN DISSOLVED SOLIDS AND STREAM DISCHARGE. *The steepness of the slopes of the relations indicates the different water types. The natural waters relation is an almost horizontal line showing only a small change in dissolved solids for a large change in discharge. The inferior waters relation is indicative of a large change in dissolved solids for a small change in discharge.*

Average concentrations of other important mineral constituents, besides the major cations and anions, are listed in table 1. Iron is commonly greater than the maximum of 0.3 ppm recommended as a public health standard (U.S. Public Health Service, 1962). The Otter River has the greatest range and highest average concentration of iron. The least range and lowest iron concentration was found in the Millers River at Erving, near the mouth of the river. Suspended organic material from the upstream pollution sources have caused flocculation of the iron. The average silica concentration is highest on Otter River, but East Branch Tully River exhibits the greatest range. Silica concentration of the East Branch Tully River is a function of discharge. The Otter River silica content is partially caused by contamination. Color is highest on East Branch Tully River. Lower values of color at the other sampling sites (table 1) is again caused by color flocculation with the suspended organic material which pollutes the Otter and Millers River.

TABLE 1.—*Concentrations of selected mineral constituents*

	Millers River at Erving	Millers River at South Royalston	Otter River at Baldwinville	East Branch Tully River near Athol
Iron (ppm)				
Maximum	0.54	2.9	[1]7.1	1.6
Minimum	.28	.01	.05	.14
Mean	.34	.91	1.34	.51
Manganese (ppm)				
Maximum	.19	.18	.23	.17
Minimum	.0	.0	.0	.0
Mean	.07	.08	.08	.05
Silica (ppm)				
Maximum	7.9	7.9	10	8.1
Minimum	3.3	3.8	3.6	1.5
Mean	5.4	5.5	6.7	5.0
Chloride (ppm)				
Maximum	21	69	77	5.8
Minimum	8	9.4	8	2.4
Mean	13	18	33	3.8
Color				
Maximum	30	65	50	90
Minimum	5	5	6	12
Mean	15	21	28	36
Hardness (ppm)				
Maximum	27	34	86	46
Minimum	15	14	16	10
Mean	21	24	47	16
pH range	5.5–7.0	5.5–7.0	5.4–7.4	5.4–6.3

[1]Without the extra high maximum the weighted mean is 0.70.

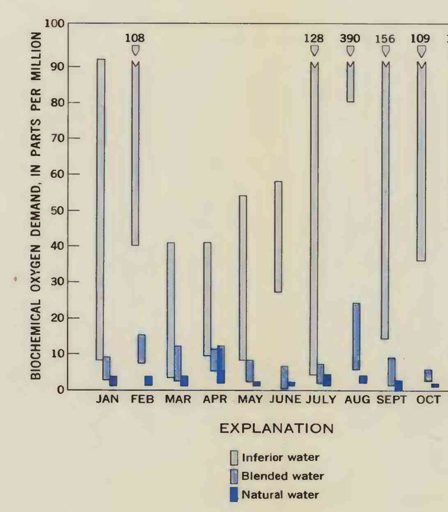


FIGURE 9.—GRAPH SHOWING MONTHLY RANGES OF BIOCHEMICAL OXYGEN DEMAND. *In every month the amount of oxygen required by bacteria to decompose organic matter under free oxygen conditions is greatest for the inferior water. BOD data from Metropolitan District Commission*

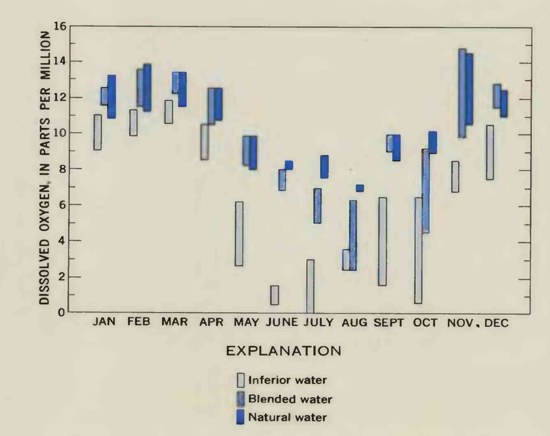


FIGURE 10.—GRAPH SHOWING MONTHLY RANGES OF DISSOLVED-OXYGEN CONCENTRATIONS. *During the summer months the amount of dissolved oxygen in the inferior water is not sufficient to maintain aerobic (free oxygen) conditions. DO data from the Metropolitan District Commission.*

CHEMICAL QUALITY OF GROUND WATER

The ground water in the basin is of satisfactory chemical quality for municipal and most industrial uses. The chemical quality reflects its geologic and hydrologic environments. The parameter that best describes the chemical character of the water is the dissolved solids content. In the basin the dissolved solids content is low as a result of (1) a high rate of recharge, maintained by a normal precipitation of about 43 inches per year, (2) the low concentration of dissolved solids in the precipitation, (3) short residence time due to the permeability of the sands and gravels, from which most of the samples were taken, (4) the relative chemical stability of the source materials, which are sands and gravels derived from crystalline rocks, and (5) the low solvent power of the ground water because of its mean annual temperature of 48°F.

Pollution of ground water within the basin is minor as shown on the map showing quality of groundwater from selected aquifers and wells and on figure 11 (with a few exceptions) by a maximum nitrate concentration of 15 ppm compared with a limit of 45 ppm for potable water (U.S. Public Health Service, 1962) and a generally low chloride concentration. Chloride content is locally high in wells contaminated by salt applied to keep highways snow and ice free in winter.

Iron concentration is extremely variable as shown on the map. Iron rich lenses within the sand and gravel aquifers probably cause the spatial variability of iron in the ground water. Hardness, carbon dioxide, and the principle anions and cations also show the general lack of pollution of ground water.

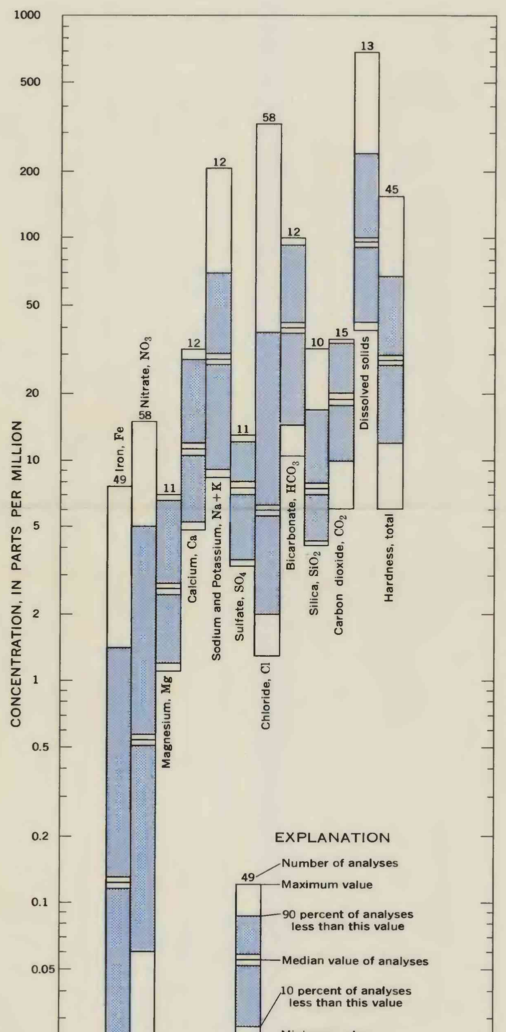
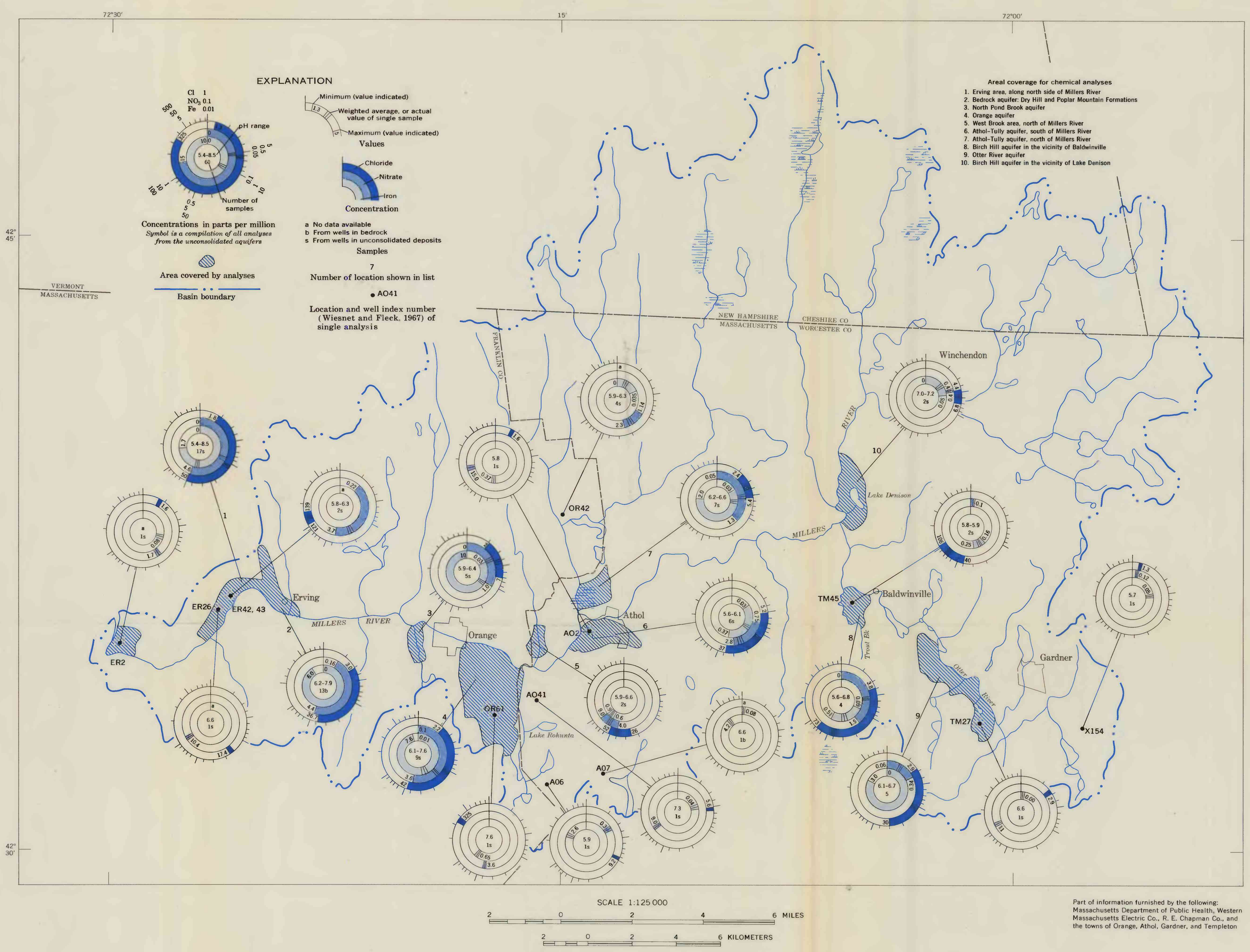


FIGURE 11.—GRAPH SHOWING RANGES OF CHEMICAL CONSTITUENTS IN THE GROUND-WATER AQUIFERS. *The patterned areas indicate significant ranges. For example, the maximum chloride value is 3 times the maximum bicarbonate value; however, because there are almost 5 times more chloride than bicarbonate analyses, the absolute range of these two ions is spurious as indicated in the graph where 50 percent of the bicarbonate values are greater than all but 10 percent of the chloride values.*



MAP SHOWING RANGES OF CHLORIDE, NITRATE, IRON, AND pH CONCENTRATIONS IN THE GROUND WATER OF SELECTED AQUIFERS AND WELLS.
The weighted average chloride, nitrate, and iron values remain relatively constant throughout the basin, with these values having ranges of 4–39, 0.2–6.5, and 0.02–0.75 parts per million, respectively.

SUSPENDED SEDIMENT IN SURFACE WATERS

The suspended sediment load carried by streams in the basin is small. However, for streams which are polluted by papermill "white waters" the suspended load is largely organic matter, consisting of white cellulose fibers drained or drawn from paper wastes of paper machines.

A significant relation between discharge and suspended sediment load does not exist for the data of this report.

Table 2 shows, for comparison purposes, means and extremes of load (tons per day) and concentration (ppm) of sediment at 5 sampling sites in the basin.

TABLE 2.—*Concentration of suspended sediment at selected river sites*

River Site	Units	Suspended mineral material			Suspended volatile material			Range in discharge
		Maximum	Minimum	Mean	Maximum	Minimum	Mean	(cfs)
Otter River at Baldwinville	tons per day	21	0.2	3.1	46	0.6	5.9	8.4–98
	ppm	122	1	42	242	3	77	
Millers River near Winchendon	tons per day	3.4	0	.4	3.4	.1	.6	7.8–274
	ppm	9	0	3	14	1	5	
East Branch Tully River near Athol	tons per day	3.7	[1]t	.7	1.0	0	.4	2.2–227
	ppm	13	1	5	11	0	2	
Millers River at South Royalston	tons per day	24	1	7.5	24	.7	7.2	6.2–477
	ppm	46	1	18	38	2	14	
Millers River at Erving	tons per day	10.2	2.5	6.7	11.3	1.3	5.6	55–912
	ppm	27	1	9	18	1	6	

[1]Trace.

CONCLUSIONS

Table 3 is used to determine that most (the major exception is the Otter River) of the tributary streams (the natural waters) may be rated as good and are suitable for bathing and recreation, irrigation and agricultural uses, and good for fish habitat and are acceptable for public water supply with filtration, disinfection and iron removal.

Many portions of the main stem of the Millers River (referred to as blended water below the Otter River confluence) may be rated as poor and are suitable for recreational boating, irrigation of crops not used for consumption without cooking and habitat for wildlife and common food and game fishes indigenous to the region. These waters require special treatment and disinfection.

Limited portions of the Millers River and the Otter River (inferior waters) are suitable only for transportation of sewage and industrial wastes and for power and other industrial uses. These waters are below the "poor source" rating of table 3.

In general ground water is of satisfactory quality over the basin. However, very local areas exist where chloride and iron exceed drinking water standards. With minor treatment most water containing excess iron is acceptable for domestic use. The excess chlorides are limited to locations where major highway salting is practiced.

TABLE 3.—*Ranges of promulgated standards for raw water sources of domestic water supply*[1]

	Excellent Requiring disinfection only	Good source Treatment such as filtration and disinfection	Poor source Special treatment and disinfection
BOD (5-day) Maximum day or sample (ppm)	1.0–3.0	3.0–4.0	over 4.0
Dissolved oxygen average (ppm)	4.0–7.5	4.0–6.5	4.0
pH Average	6.0–8.5	5.0–9.0	3.8–10.5
Chlorides Maximum (ppm)	50 or less	50–250	over 250
Color Units	0–20	20–150	over 150

Maximum limits of mineral constituents for drinking water[2]

Mineral	Concentration (ppm)
Iron (Fe)	0.3
Manganese (Mn)	.05
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Dissolved solids	500
Chloride (Cl)	250

[1]McKee and Wolf, 1963, p. 93.
[2]Public Health Drinking Water Standards, 1962, p. 7.

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Piper, A. M., 1945, A graphic procedure in the geochemical interpretation of water-analyses: Am. Geophys. Union Trans. 1944, pt. 6, 25th Ann. Mtg., p. 914–928.
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WATER RESOURCES OF THE MILLERS RIVER BASIN, NORTH-CENTRAL MASSACHUSETTS AND SOUTHWESTERN NEW HAMPSHIRE

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1969