Aqueous geochemistry and hydrology of Roaring Brook, Mill River watershed, central Massachusetts

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INTRODUCTION

The Mill River watershed, in the Connecticut River valley of west-central Massachusetts, has been the focus of interdisciplinary research since evidence of the endangered dwarf wedge mussel was found there in 1995. An investigation of the aqueous geochemistry, water quality, and hydrology of the Mill River is being done to determine extent of human impact in the area. Characterization of Roaring Brook, a 11 km long tributary flowing through relatively pristine forested areas in the northwest portion of the Mill River watershed, could provide a baseline for comparing contamination and human influence in more impacted areas. Characterization of Roaring Brook focused on four components: aqueous geochemistry, bedrock, soil, and hydrology.

METHODS

Aqueous geochemistry. Water samples were collected from 24 sample sites during late June 1998. Figure 1 shows the location of each of the sample sites within the watershed. RB-100 and RB-200 were the two long-term sampling sites which, in addition to the June collection, have had collection and analyses done since the spring of 1997. The collected water samples were analyzed at Smith College for Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NO_3^{-}, SO_4^{2-}, Cl^{-}, acid neutralizing capacity (ANC), and aqueous silica. The cation concentrations were analyzed by Perkin Elmer 3030 Atomic Absorption Spectrometer, anions by ion chromatography, ANC by Gran titration, and silica by molybdate blue spectrophotometry.

Bedrock. Bedrock samples were collected from five sites (see figure 1) in the watershed. Thin sections were made from the samples and a petrographic microscope used to identify mineralogy.

Soil. Ten soil samples were collected from a 77 cm deep soil pit dug in stratified drift on the hillslope above Roaring Brook at site RB-161 (see figure 1), an area of hemlock forest. A mechanical grain size analysis was done using stacked sieves. Atomic absorption analyses were done on extractions from six of the samples to determine the concentration of exchangeable Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} in the soil.

Hydrology. A gauge station for continuous monitoring of stream stage level was set up at RB-100. A datalogger was installed which stored the data collected from a pressure transducer calibrated to stage level. The datalogger continuously averaged stage measurements and recorded data points every ten minutes. RB-100 discharge was measured at three different stage levels, establishing a stage-discharge relationship.

RESULTS AND DISCUSSION

Bedrock. Roaring Brook watershed is in an area of mixed schist-quartzite and schist-marble bedrock covered with thin till (Segerstrom, 1955; Willard, 1956). Figure 2 shows the mineralogy of the five bedrock specimens examined in thin section. The rocks were examined for the presence of carbonate since water alkalinity may be affected by contact with calcium carbonate bedrock. Significant amounts of carbonate were found at RB-110 in the eastern part of the watershed and minor amounts in the schist at the RB-400 headwaters. The other three samples were non-calcareous schist-quartzite.

Soils. The top 3 cm of the soil is a dark rusty brown organic layer, overlying about 5 cm of a very dark organic rich layer, perhaps part of a decayed tree. The third layer, from 8-12 cm depth, is significantly redder than the underlying layers and may not be continuous. Below 12 cm depth, the mean grain size is 0.42 mm, and the soil is uniform except for changing from olive brown to olive at about 35 cm. Figure 3 shows the exchangeable base cations at six depths in the RB-161 soil pit. The concentration of exchangeable cations is highest in the top layer and decreases with depth. Below 8 cm, all exchangeable bases have a concentration less than 0.2 meq/100g. Ca^{2+} and Mg^{2+} dominate the top two layers, and Na^{+} is less than 0.06 meq/100g at all depths. It is common for the exchangeable bases in soils to be found in the order Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, and it is not rare for Na^{+} to be present only in trace amounts (Thomas, 1982).

Hydrology. Figure 4 shows a hydrograph of Roaring Brook at RB-100 from the end of September through the beginning of December, 1998. A stage of 0.35 corresponds to a discharge of 6 cfs, and a stage of 0.58 is a discharge of 14 cfs. Given the rocky bed surface and small size of the stream, discharge measurements could not be made accurately during low flow without an artificial flume or weir construction. Four major peaks of stage during the autumn indicate that flow was over 8 cfs, and on one occasion, over 14 cfs. Four periods of very low stage also occurred. The town of South Deerfield, Massachusetts, takes water from Roaring Brook and some fluctuations in the stream stage may result from this. The town has applied to take out up to 1.85 cfs, a significant proportion of the daily discharge at low flow conditions.

Aqueous geochemistry. Figure 5 shows the average percentage of each type of ion for the June 1998 analyses. Ca^{2+} and HCO_3^- dominate the system with 37% and 39%, respectively, and the other five ions contribute a total of 23%, with K^+ and NO_3^- concentrations being lowest.

Figure 6 presents the yearly variation of ion concentrations at RB-100 and RB-200 from June 1997 through the end of October 1998. Most of the graphs show a moderate increase in concentration during the summer months which may be a result of less dilution during times of low flow. The trends of Na^+, NO_3^-, and SO_4^{2-} are discussed below.

Na^+: The graph of does not show much variation through the year, just a slight increase during the summer. The absence of a winter peak for Na^+ and Cl^- concentrations indicates that the Roaring Brook watershed is not highly impacted by road salting.

NO_3^-: The concentration of nitrates at RB-100 increased by a factor of three to four during July and August and may be a result of agricultural runoff. The summer increase at RB-200 was not nearly as dramatic, indicating that the source of the high nitrate levels occurs between RB-200 and RB-100 or from one of the three tributaries between the two sample sites. The normal range of NO_3^- in groundwater is 0.1 to 10 ppm (Davis and DeWiest, 1966), so even the high values of 2.1 ppm are not a cause for major concern. During June of 1998, when nitrate levels were still at a low base level, the concentration at the headwaters was 0.36 mg/L, just slightly lower than at RB-200 (0.43 mg/L) and RB-100 (0.46 mg/L).

SO_4^{2-}: For most of the year, the SO_4^{2-} concentration at RB-100 was about 1.4 mg/L greater than at RB-200. During July and August, however, the concentration decreased slightly at RB-200 and increased at RB-100. The RB-100 concentration is up to 6.5 ppm more than at RB-200, a 2.5 times difference. The June 1998 analyses show that the three tributaries that enter the main stem of Roaring Brook downstream of RB-200 have higher sulfate concentrations than any of the water samples collected upstream.

CONCLUSIONS

Geochemical analyses of the Roaring Brook water samples support qualitative observations that the watershed is a relatively pristine region with downstream areas being subjected to more intense human impact. The introduction of certain ions from land use practices, such as nitrates, may be seasonally significant, and the proposed increase in water extraction by the town of South Deerfield would affect the hydrology and ecology of the stream. Continued sampling and analysis of Roaring Brook water would help characterize long-term patterns of geochemical variation and human impact.

REFERENCES CITED

Davis, Stanley, and Roger DeWiest, 1966, Hydrogeology: New York, John Wiley and Sons, 463 p.

Segerstrom, Kenneth, 1955, Geologic map of the Williamsburg quadrangle, Massachusetts, surficial geology: United States Geological Survey, map GQ-80.

Thomas, G. W., 1982, Exchangeable cations, *in* A. L. Page, R. H. Miller, and D. R. Keeney, eds., Methods of soil analysis, part 2, chemical and microbiological properties, Agronomy Monograph no. 9: Madison, American Society of Agronomy, p. 159-165.

Willard, M. E., 1956, Geologic map of the Williamsburg quadrangle, Massachusetts, bedrock geology: United States Geological Survey, map S-Ga3, GQ-85.

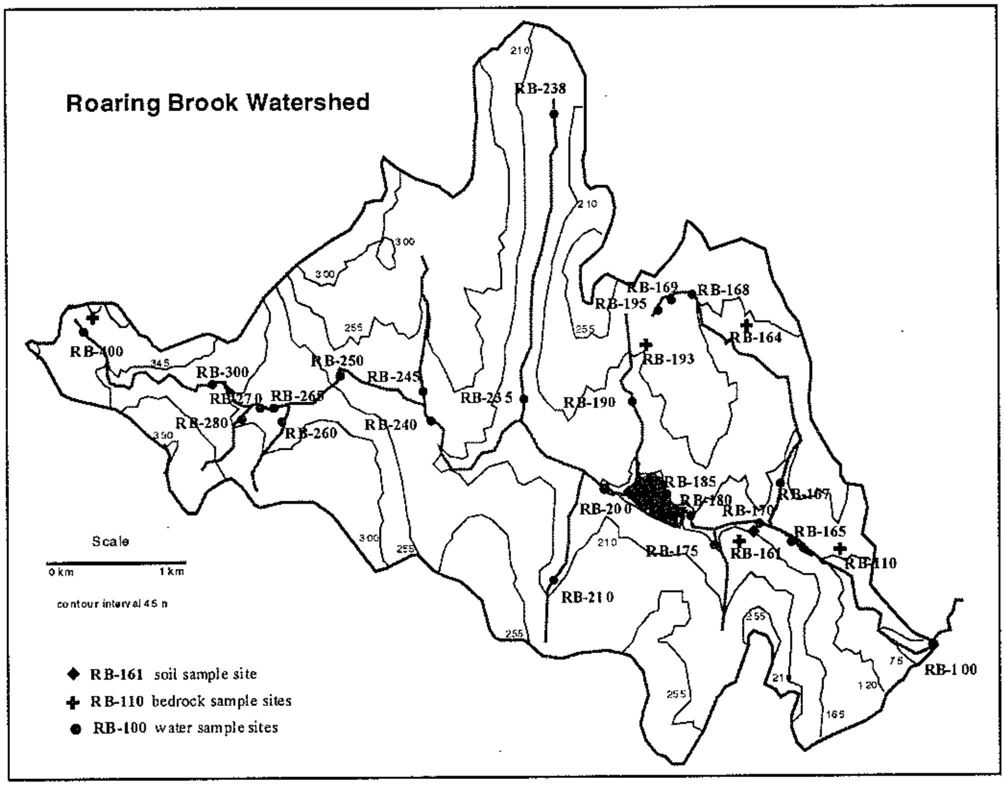

Figure 1. Contour map of the Roaring Brook watershed, showing sampling sites for water, soil, and bedrock.

Bedrock Sample #	mineralogy	rock type
RB-110	quartz, carbonate, biotite, epidote, amphibole, sphene	schist-marble
RB-161	quartz, muscovite, biotite, plagioclase	schist-quartzite
RB-164	quartz, muscovite, biotite, plagioclase, potassium feldspar	schist-quartzite
RB-193	quartz, biotite, plagioclase, amphibole, opaques, sericite mica	schist-quartzite
RB-400	quartz, carbonate, plagioclase, amphibole	schist-quartzite

Figure 2. Mineralogy of bedrock samples collected in the Roaring Brook watershed.

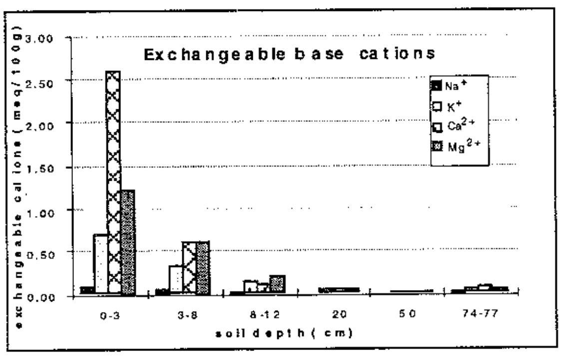

Figure 3. Exchangeable base cations in RB-161 soils.

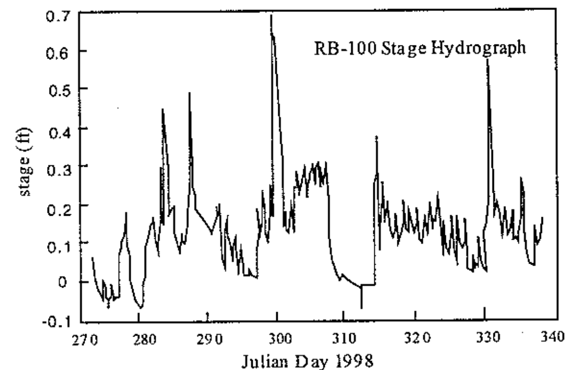

Figure 4. Roaring Brook stage level 9/30/98 to 12/4/98

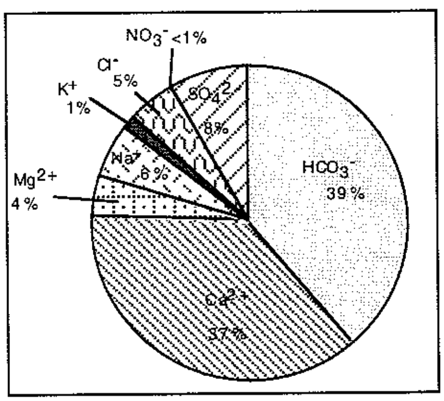

Figure 5. Average ion proportion in Roaring Brook water samples, June 1998.

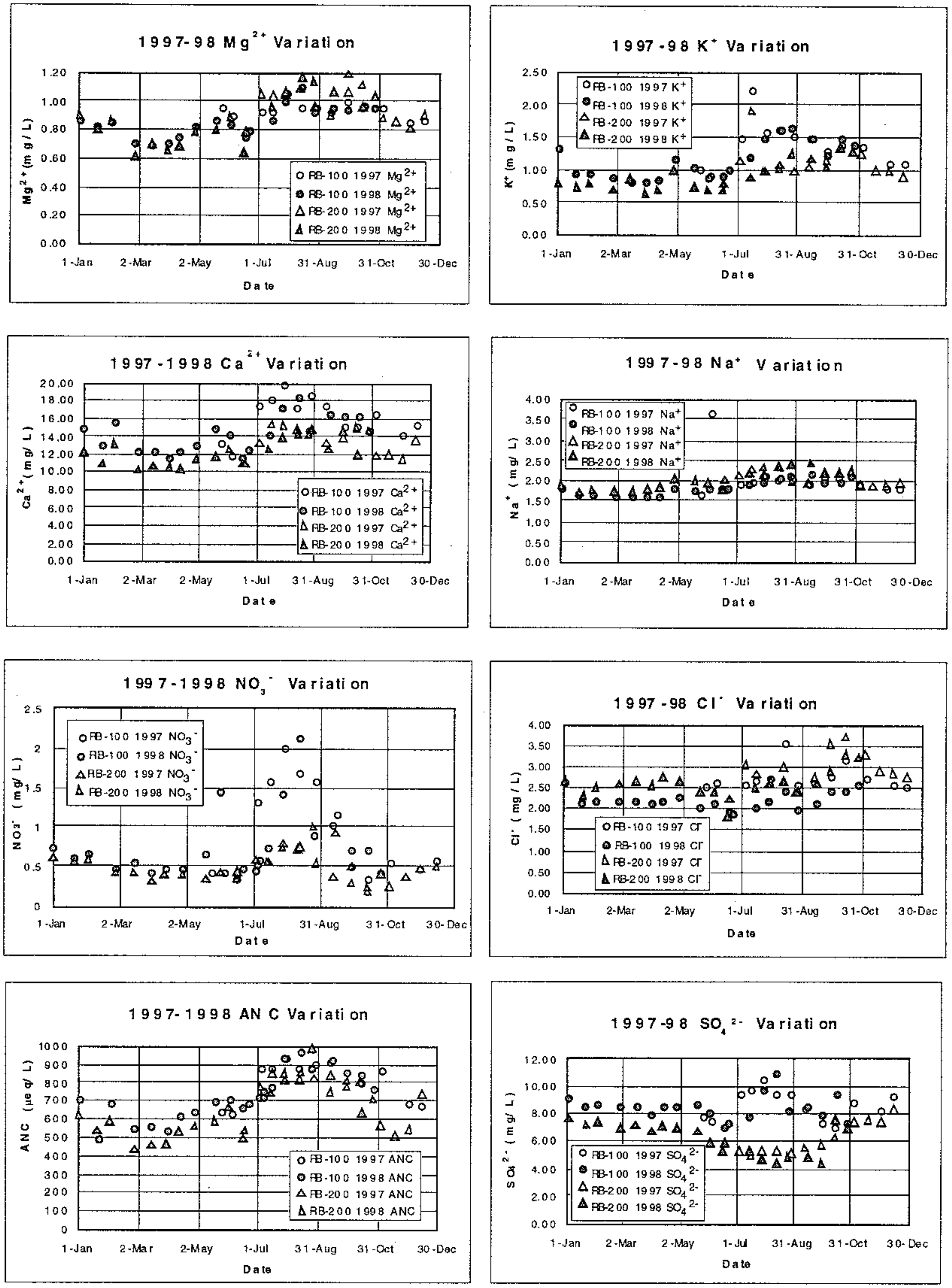

Figure 6. Annual trends in ion concentrations at RB-100 and RB-200.