LAND-USE IMPACTS ON THE HYDROLOGY AND CHEMISTRY OF THE MILL RIVER IN HATFIELD, MASSACHUSETTS

FACULTY

Robert M. Newton, Smith College, Director
Stephen Acheampong, Summit Envirosolutions, Inc
Amy L. Rhodes, Smith College

STUDENTS

Joel Bauman, Colorado College
Lynn Berkley, Beloit College
Mary Donovan, Smith College
Lena Fletcher, Smith College
Reina Foxx, California State University, Fullerton
Angela Knapp, Whitman College
Andy Logan, Amherst College
Anna Monders, Whitman College
Halle Morrison, The College of Wooster

VISITING SPONSORS

John Cooper, California State University, Fullerton
Peter Crowley, Amherst College
William Phillips, Colorado College
Richard Stenstrom, Beloit College

Land-use impacts on the hydrology and chemistry of the Mill River in Hatfield, Massachusetts

Robert M. Newton
Department of Geology, Smith College, Northampton, MA 01063

Stephen Y. Acheampong
Summit Envirosolutions, Inc, Reno, NV 89506

Amy L. Rhodes
Department of Geology, Smith College, Northampton, MA 01063

INTRODUCTION

The Mill River is an important system to study in part because of its rich ecological diversity. The lower reaches of the river contain the only known population of Dwarf Wedge mussel (*Alasmidonta heterodon*) in Massachusetts. The area known as the Great Swamp has been identified as one of the best examples of a red maple/hemlock perched swamp and is one of only 6 such swamps found in Massachusetts. West Brook, a tributary to the Mill River is being used in a test to reintroduce Atlantic Salmon to parts of the Connecticut River.

Land-use in the Mill River watershed varies from heavily agricultural and suburban areas in the eastern lowlands to nearly pristine forested subcatchments in the western uplands. A major interstate highway runs along the lower part of the Mill River and reservoirs on two of the major tributary systems export water to cities and towns outside the watershed. There are concerns that land-use could be negatively impacting the ecosystems in some parts of the watershed. The Mill River Watershed Study is a multidisciplinary study being conducted by investigators from Smith College, the University of Massachusetts, the Pioneer Valley Planning Commission and the Conte National Fish and Wildlife Refuge. The project involves both water quality and biologic assessment studies that will be used to develop a comprehensive watershed protection plan. The Keck students studied water chemistry in the watershed and tried to differentiate land-use impacts from geologic factors. In addition, three stream gauging stations have been established on the major tributaries to determine how the withdrawal of water from the reservoirs is affecting streamflow.

GEOLOGIC SETTING

The Mill River heads in the Berkshire highlands and flows south into the Connecticut River. It occupies a 125 km^2 watershed where elevations range from 45 m on the Connecticut River floodplain to 450 m in the western highlands. Physiographically the area can be divided into two distinct regions (Figure 1). The eastern lowlands occupy the floor of glacial Lake Hitchcock; a large glacial lake that formed within the Connecticut Valley as the continental ice retreated across the region approximately 12-14,000 years before present. Although this area is underlain by Mesozoic sedimentary rocks, they have no influence on the water chemistry as they are buried beneath 30 m or more of varved clay. This clay is overlain in places by an uneven veneer of glaciolacustrine or aeolian sand up to 8 m thick. The sand forms a shallow aquifer that supplies a number of domestic wells in the area. In the central part of this region, the flat topography of the lake floor coupled with the underlying varved clay accounts for the high water table conditions that form the Great Swamp. Other areas of the lake floor are extensively developed for agriculture.

The western upland region is underlain by Paleozoic igneous and metamorphic rocks that are generally irregularly covered with a thin veneer of glacial till except in areas of thicker deposits of stratified drift (Segerstrom,1955). The bedrock here plays a much more important role in controlling the chemistry of the surface water. Areas underlain by granitic rocks such as the Williamsburg granodiorite (Willard, 1956) have much lower acid neutralizing capacity (ANC) as compared to areas underlain by the marble-bearing Conway formation (Willard, 1956). This region is generally forested with some isolated agricultural areas.

Figure 1. Color infrared air photo of the central part of the Mill River watershed showing the contrast between the agricultural lowlands to the east and the mostly forested western highlands. Note Interstate Route 91 running approximately north-south through the eastern lowlands and the two reservoirs in the western highlands.

ANALYTICAL METHODS

Water samples have been collected biweekly from 12 sites (Figure 2) within the Mill River watershed since February of 1997. In addition, Keck students intensively sampled streams and groundwater throughout the watershed during the summer of 1998. To date over 750 samples have been collected and analyzed for the 14 parameters listed in Table 1.

Table 1. Measured water chemistry parameters.

Parameter	**Method**
Temperature	Temp Probe
Specific Conductance	YSI Conductivity Meter
pH	pH Meter
ANC	Gran Titration
Dissolved Oxygen	YSI Dissolved Oxygen Meter
Silica	Heteropoly Blue
Ca^{2+}, Mg^{2+}	Atomic Adsorption
Na^{+}, K^{+}	Atomic Emission
Cl^{-}, NO_3^{-}, SO_4^{2-}	Ion Chromatography
HCO_3^{-}	Calculated from ANC

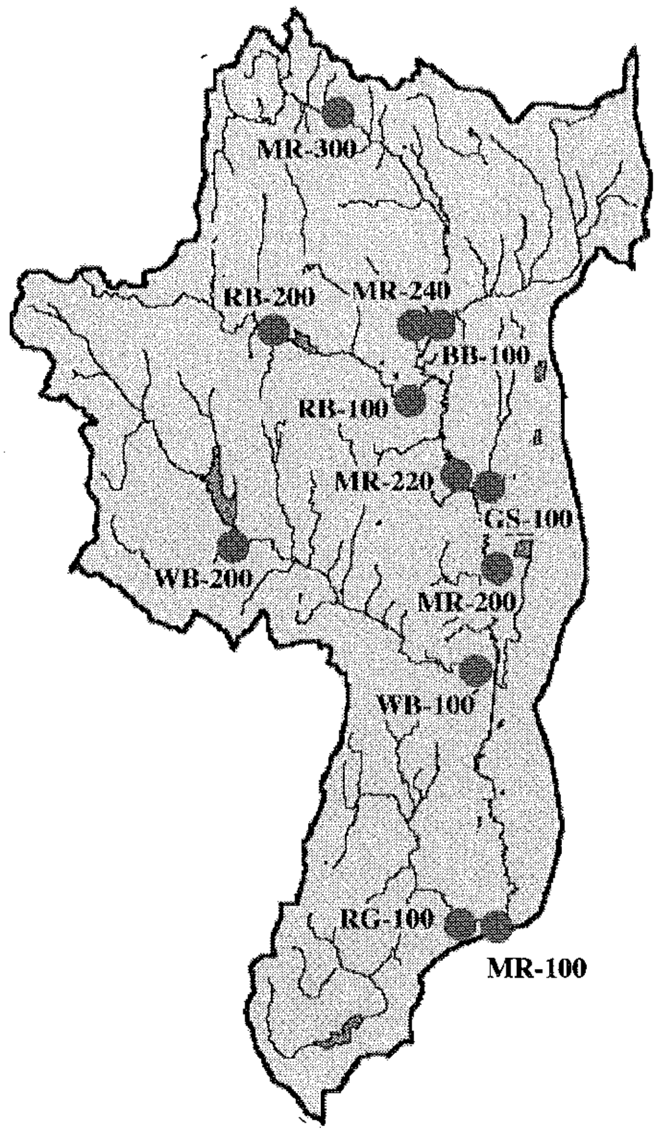

Figure 2. Map of the Mill River watershed showing the location of the 12 sites that have been sampled biweekly since early 1997.

STUDENT PROJECTS

Student projects were organized by subcatchment. Each student examined the geology and land-use characteristics in their own field area and collected and analyzed their own samples.

Lynn Berkely, Beloit College, examined changes in water chemistry that occur as rain falls through the forest canopy into the forest soils at a site within the Smith Experimental Forest that is located near the center of the watershed in West Whately. Lynn installed a series of collectors to gather rainfall, throughfall, and stemflow. She also installed both zero tension and tension lysimeters to collect soil water and was able to sample both groundwater and surface water in her study area. This data together with the mineralogic and chemical data from soil samples allows her to determine the factors that control the chemistry of stream water.

Lena Fletcher, Smith College, examined the Avery Brook subcatchment. Avery Brook is a tributary to the Northampton Reservoir and lies within the Conway State Forest. It represents an almost completely undisturbed system where the water chemistry is determined by the interaction of atmospheric deposition of acids with watershed soils and bedrock. A gage station installed at the outlet of the brook monitors the flow into the reservoir. Virtually all this water is exported from the watershed to the city of Northampton.

Reina Foxx, California State University at Fullerton, studied the West Brook subcatchment below the Northampton Reservoir. This part of the system is partially developed with some agricultural and residential areas. The water chemistry, especially in some of the tributaries, shows elevated concentrations of Cl^- and SO_4^{2-} associated with this development. A gage station installed at the outlet of West Brook shows lower discharges than expected for a watershed of this size due withdrawals from the reservoir.

Mary Donovan, Smith College, worked in the Running Gutter subcatchment. This part of the watershed is underlain mainly by Tonalite and was expected to have waters with low ANC. This turned out not to be the case but Mary did find large seasonal changes (>600 μeq/L). Many of the soils in the watershed have a relatively high base saturation and this may help explain the high ANC of this system.

Anna Monders, Whitman College, examined the Roaring Brook subcatchment. This is an interesting system as it contains a reservoir that supplies water to the town of South Deerfield and the town has applied to increase its withdrawal by another 0.5 million gallons per day. A gage station installed below the reservoir shows periods of almost no flow followed by sudden increases in discharge not associated with precipitation events. The watershed of Roaring Brook is largely undeveloped and water quality is good. There is a strong influence of rock type on water chemistry as shown by high ANC and Ca^{2+} concentrations of tributaries draining areas of more carbonate-rich rocks along the northern border of the subcatchment.

Halle Morrison, The College of Wooster, studied water quality in the Bloody Brook subcatchment. This watershed is almost completely contained within the eastern lowland and is extensively developed. It has both suburban and agricultural areas and is bisected by Interstate Route 91. The water chemistry shows heavy impact with high concentrations of SO_4^{2-}, NO_3^- and Cl^-.

Two students examined the area of Great Swamp. Andy Logan, Amherst College, looked at surface water chemistry and soils while Joel Bauman, Colorado College, studied the shallow groundwater. Andy found a large difference between the chemistry of two streams draining the swamp. The western tributary was acidic while the eastern tributary had a high ANC. The high ANC appears to be due to Ca^{2+} released from runoff from Interstate 91 while the acid system appears to be acidified by organic acids. Joel Bauman installed 24 shallow wells across the swamp and found high concentrations of Na^+ and Cl^- contaminating the groundwater in the vicinity of Interstate 91 and State Route 10. Joel also found high NO_3^- concentrations in the northern part of the swamp. It appears from these two studies that the chemistry of the water in much of the eastern part of the swamp has been significantly impacted by runoff from the highways.

Angie Knapp, Whitman College, examined the main branch of the Mill River from its headwaters in the highlands to the north to its lower reaches near its junction with the Connecticut River. Angie looked at how the various tributaries change the chemistry of the main stream as you move downstream. She also found that the headwater regions contained bedrock with some of the highest carbonate concentrations in the watershed.

SUMMARY

There are major differences in the chemistry of streams draining the agricultural lowlands as compared to those draining the western highlands. Streams in the agricultural lowlands have nitrate concentrations that are 2-3 times higher than those in the western highlands (Figure 3) and chloride concentrations that are 2-9 times greater (Figure 4). The nitrate is most likely associated with runoff from agricultural fields while the chloride is in large part from road salt runoff from interstate route 91. Variations in bedrock geology affect the ANC of streams draining the western highlands. The increase in abundance of marble in the northern part of the area accounts for the higher ANC observed there. Weathering and exchange reactions in the upper 1 meter of the soil profiles account for most of the chemical changes in rainwater as it falls through the forest canopy and moves through the soils to the streams.

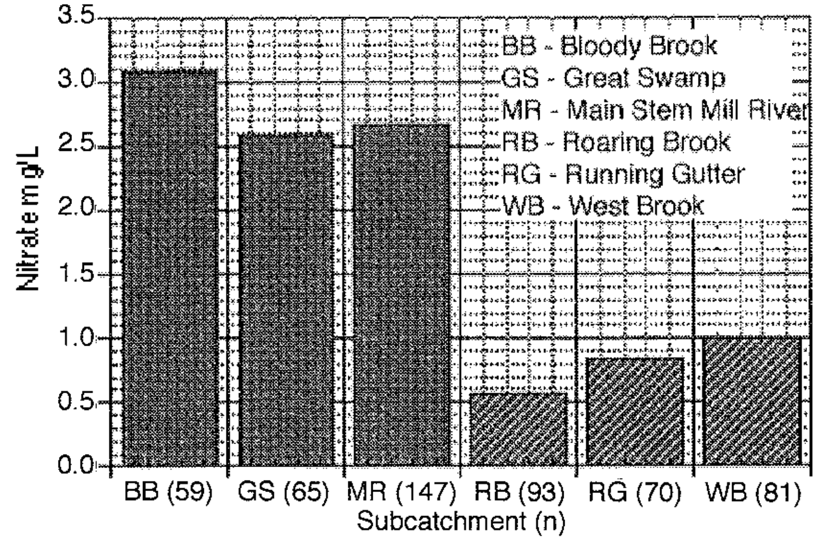

Figure 3. Average nitrate concentrations of streams in the Mill River watershed. Crosshatched represent western upland tributaries.

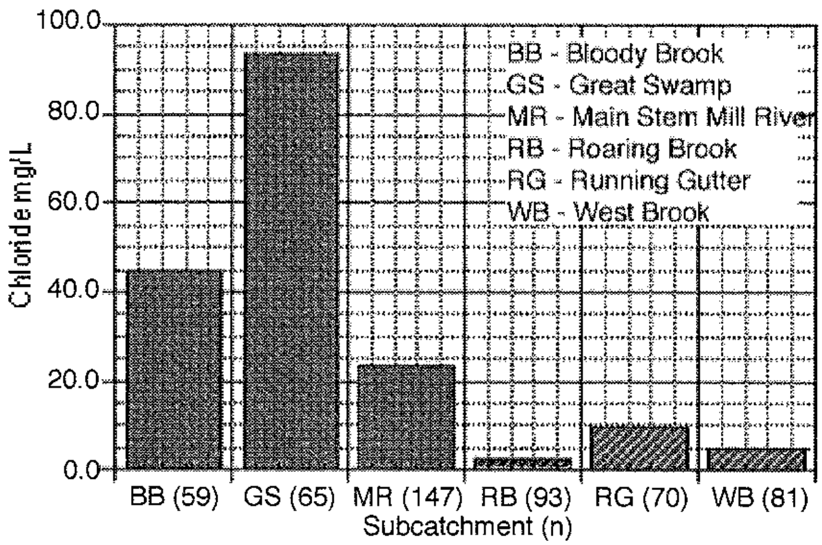

Figure 4. Average chloride concentrations in tributary streams within the Mill River Watershed. Crosshatched represent western upland tributaries.

REFERENCES CITED

Segerstrom, K., 1955, Surficial geology of the Williamsburg Quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle Maps of the United States, Map GQ 80 1:24,000.

Willard, M.E., 1956, Bedrock geology of the Williamsburg Quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle Maps of the United States, Map GQ 85 1:24,000.