Seasonal Cycles in Streamwater Quality on Catoctin Mountain, Maryland

In 1980, the U.S. Congress mandated the National Acid Precipitation Assessment Program (NAPAP) to study the effects of acidic precipitation (acid rain). In 1982, the U.S. Geological Survey (USGS) was selected to be the lead Federal agency under NAPAP to monitor the composition of precipitation and its effects on the environment. In 1982, the USGS began to monitor precipitation and streamwater on Catoctin Mountain in north-central Maryland (fig. 1); the effort has continued through the present. Beginning in 1990, funding for these data-collection and interpretation activities was supplemented by the Maryland Department of the Environment and the Maryland Department of Natural Resources. The collection and interpretation of long-term precipitation and streamwater-quality records, such as those at Catoctin Mountain, provide valuable information for management decisions. At the local level, the information can be used to identify periods when streamwater quality may pose a danger to aquatic resources, such as finfish; at the national level, the information can be used to assess the effectiveness of the Clean Air Act Amendments.

Watersheds (the land area contributing water to a stream) serve as integrators of inputs that watersheds receive. The composition of the water entering the watershed (precipitation and waters influenced or discharged by human activities, such as agricultural runoff, industrial wastes, road salting, sewage effluent) and the watershed processes (hydrological and geochemical) that act on the inputs determine the quality of the streamwater in the watershed. The purpose of monitoring precipitation and streamwater quality on Catoctin Mountain is to (1) identify hydrological and geochemical processes in forested watersheds that are affected by acid rain, and (2) provide a long-term record of water quality to identify any changes that occur over time. Selected results of the USGS studies in the Hauver Branch watershed (fig. 1) are presented here.

SEASONAL CYCLES IN AMOUNT OF STREAMFLOW

Since monitoring of streamflow and streamwater quality on Catoctin Mountain began in 1982, repetitive seasonal cycles in the amount of streamflow of Hauver Branch have been observed (fig. 2). Streamflow is high in the winter and spring and low during the summer and fall, despite the fairly even distribution of rainfall throughout the year. The seasonality in streamflow is caused by the different amounts of water taken up by the forest vegetation during the year. During the growing season, vegetation needs a large amount of water that is obtained from the shallow subsurface by its root systems. Most of the precipitation during this period is utilized by the vegetation, so it is not available to contribute to streamflow. Streamflow is sustained by the discharge of ground water that is not accessible to plant roots. In contrast, during the nongrowing season, vegetation re-

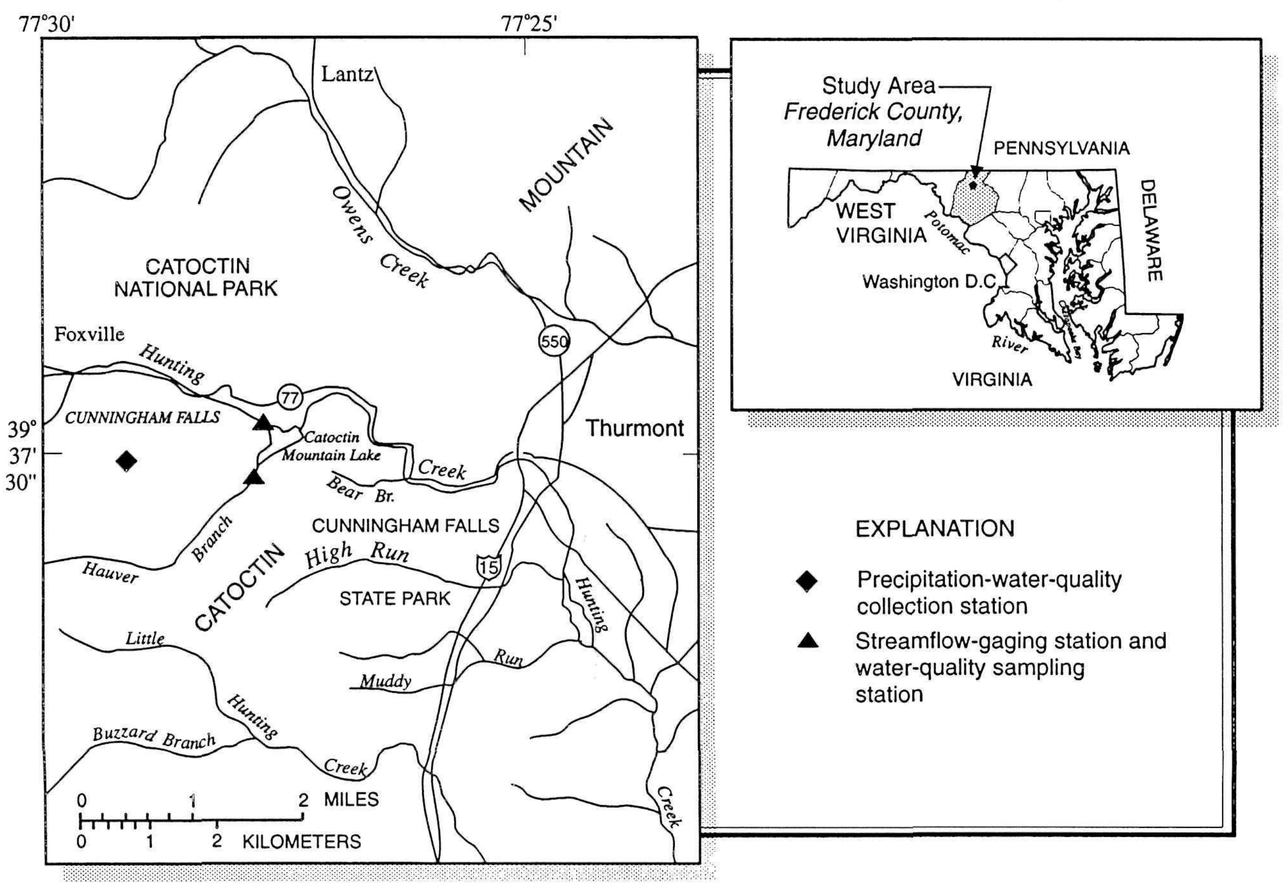

Figure 1. Location of study area.

quires little water, allowing the precipitation to percolate through the soil zone to become shallow ground water; discharge of shallow and deep ground water contributes to streamflow. The additional shallow ground water available during the nongrowing season causes increased streamflow. The seasonal difference in the mixture of ground water from shallow and deep sources is one of the hydrological processes that controls total streamflow.

SEASONAL CYCLES IN STREAMWATER QUALITY

Streamwater quality also shows repetitive seasonal cycles. Depending on the dissolved component of the streamwater, concentrations may be in-phase or out-of-phase with streamflow. Concentrations of two types of dissolved constituents in Hauver Branch—one derived from acid rain (sulfate) and the other generated within the watershed (bicarbonate)—are illustrated in figure 2. The concentrations of sulfate and bicarbonate in streamwater indicate the extent to which the watershed has been affected by acid rain. In general, streamwater with low sulfate and high bicarbonate concentrations has been little affected by acid rain. In Hauver Branch, sulfate concentrations and streamflow are highest during the winter and spring; that is, sulfate concentration in streamwater is in-phase with the amount of streamflow. The sulfate from acid rain is retained by minerals commonly found in the soil zone and is stored in the soil during the growing season when soil-water content is less than that during the nongrowing season. During the nongrowing season, the sulfate is remobilized by waters percolating through the soil zone. Thus, shallow ground water in the soil zone has higher concentrations of sulfate than does deep ground water, which is present chiefly within the bedrock zone beneath the soil zone. In contrast to the concentration of sulfate in streamwater, bicarbonate concentration is out-of-phase with streamflow; that is, bicarbonate concentration is highest during the summer and fall when streamflow is lowest. In the Hauver Branch watershed, bicarbonate is chiefly generated by geochemical processes that occur in the bedrock zone of the watershed. Thus, deep ground water contains higher concentrations of bicarbonate than shallow ground water. Geochemical processes control the distribution of sulfate (shallow ground water) and bicarbonate (deep ground water) in the watershed. The hydrological processes, which control the sources of water contributing to streamflow, and the geochemical processes, which control the distribution of dissolved constituents in the watershed, combine to determine the streamwater quality throughout the seasons, year after year.

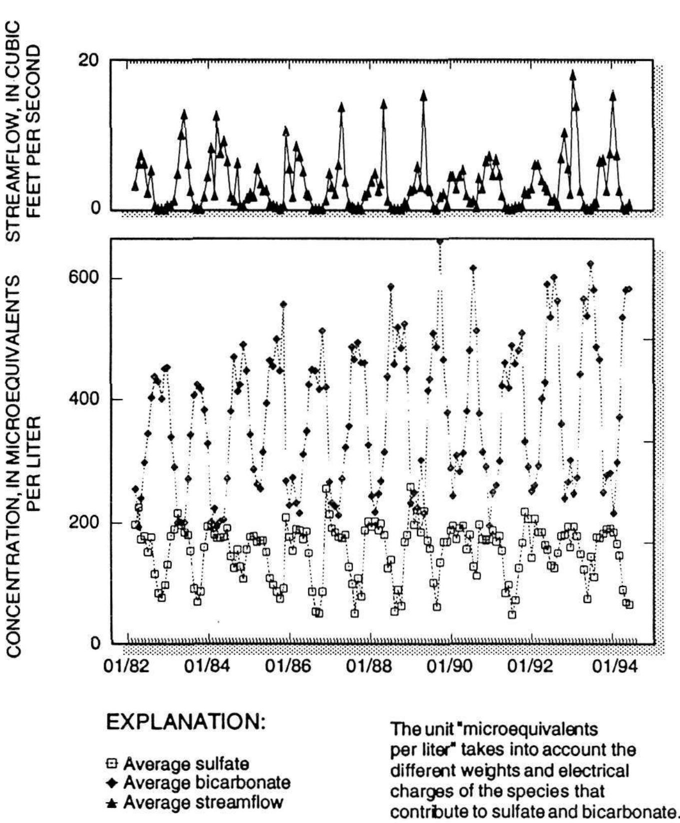

Figure 2. Seasonal cycles in monthly average amount of streamflow and monthly average concentrations of sulfate and bicarbonate in Hauver Branch streamwater.

IMPLICATIONS OF RESULTS

Forest vegetation affects the amount and timing of streamflow and the sources of water that contribute to streamflow. In the Hauver Branch watershed, the changes in streamflow and water quality, caused by seasonal effects of forest vegetation, occurred in a regular and predictable manner over the past 12 years (fig. 2). Similar patterns in streamflow and water quality have been observed in other forested watersheds in the United States, Europe, and Great Britain.

A major objective of the Clean Air Act is to reduce emissions from the burning of fossil fuels that cause acid rain. A reduction is expected in the number of streams and lakes that have become acidified and an increase in the number of streams and lakes that have recovered from acidification. Regional and national monitoring programs designed to assess the effectiveness of such Acts commonly contain budgetary constraints that limit the collection of water-quality samples to one, or at most, several, per year. If the sampling is not performed on the same part of the cycle each year, results could be misinterpreted as deterioration, or improvement, of surface-water quality, when there actually has been no change. Misinterpretation could lead to expensive increases in emission controls, or a relaxation of beneficial controls. Small-scale studies, such as those performed at Catoctin Mountain, help identify fundamental processes that may be applied to larger geographical areas. Using knowledge of processes identified by small watershed studies can result in cost-effective large-scale monitoring programs.

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