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# The U.S. Geological Survey Hydrologic Benchmark Network

*In the ever-changing landscape of the North American continent, there are few medium to large-scale rivers that remain largely undisturbed.*

## Introduction

In 1962, Luna B. Leopold, then Chief Hydrologist of the U.S. Geological Survey (USGS), proposed the establishment of a network of "hydrologic benchmarks" on the nation's rivers (Leopold, 1962). The main purpose of the Hydrologic Benchmark Network (HBN) is to provide a long-term database to track changes in the flow and water quality of undisturbed streams and rivers (rivers draining undeveloped lands), and to serve as a reference for discerning natural from human-induced changes in river ecosystems. In the ever-changing landscape of the North American continent, there are few medium- to large-scale watersheds that remain largely undisturbed. The HBN is the only nationwide network of environmental monitoring stations that tracks the health of rivers draining medium sized, undisturbed basins in the United States. HBN watersheds range in size from 2 $mi^2$ to 254 $mi^2$ though one watershed has an area close to 2,000 $mi^2$. HBN watersheds are larger than typical research watersheds in which most ecosystem research is conducted, but are small enough to be responsive to anthropogenic atmospheric inputs and climate change. The HBN thus provides a frame of reference to evaluate changes in river chemistry and flow patterns in large or developed watersheds, such as those commonly sampled as part of State and Federal monitoring programs (for example USGS National Water-Quality Assessment Program (NAWQA; http://water.usgs.gov/nawqa/), U.S. Environmental Protection Agency 305-B program; http://www.epa.gov/305b/).

## History of HBN

The HBN was started in 1963 and gradually grew to include 57 river-gaging stations and 1 lake-stage station in 39 States by 1990 (fig. 1). Most of the stations were at the outlet of watersheds that were virtually free of human activities, located in places such as in national parks and forests, wilderness areas, or nature preserves. Streamflow was monitored continuously at each station, and samples were collected every month for water-quality analyses. The frequency of water sampling at HBN stations was decreased to quarterly in 1986 because of budgetary restrictions. Sampling was discontinued in October 1997, except for a small study in the eastern United States that focused on the initial response of rivers to decreases in industrial emissions mandated by the Clean Air Act Amendments of 1990 (http://www.epa.gov/oar/oaq_caa.html/).

All HBN watersheds were evaluated in 2002 to determine whether upstream development had made them unsuitable as reference watersheds. The 36 sites that best met the network criteria were selected for continued streamflow monitoring and water sampling was reinitiated at 15 of those 36 sites (fig. 1); additional sites are to be added in coming years by developing monitoring partnerships with private and public sector cooperators. Dr. Leopold's vision of a benchmark network for the United States has thus been re-established, with the promise of a new era of improved surveillance over how our actions affect the world in which we live, and the water on which we depend.

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## Previous Studies that used the HBN

The more than 40 years of HBN's existence have resulted in the publication of more than 40 scientific papers that have relied on HBN data to tell their story. These papers include:

- the first descriptions of 57 HBN basins and the types of data collected at each site (Cobb and Biesecker, 1971);
- a comparison of water chemistry from HBN basins with similar but developed watersheds (Biesecker and Leifeste, 1975);
- an analysis of acid-precipitation-induced trends in pH, alkalinity, and sulfate for 10 to 15 years of record at 47 HBN stations (Smith and Alexander, 1983);
- a principal-components analysis to discern whether patterns in sulfate concentrations from 30 HBN basins could be used as analogs for regional patterns of atmospheric sulfate deposition (Lins, 1986);
- a compilation of streamflow characteristics for 57 HBN basins, including an analysis of streamflow trends for periods ranging from 13 to 65 years (Lawrence, 1987).

In 1990, the USGS reevaluated the environmental characteristics of HBN watersheds to ascertain the suitability of each site according to the original design criteria. The result of this evaluation was four reports that describe the environmental characteristics and water quality of 56 HBN basins in the eastern, midwestern, west-central, and western regions of the United States (http://water.usgs.gov/pubs/circ/circ1173/). HBN water-quality data is much easier to evaluate with the aid of these detailed compilations.

In the late 1990s, Clow and Mast (1999) reassessed the effect of acid rain on trends in stream chemistry at five HBN basins in the northeastern United States. Results indicated that sulfate concentrations in stream water were decreasing at all five HBN stations that paralleled a downward trend in sulfate concentrations in precipitation. The decline in streamwater sulfate concentration was accompanied by a decline in calcium and magnesium concentrations. This unexpected result was attributed to a depletion of soil buffering capacity caused by long-term exposure to acid rain.

## Improved Methods of Trend Detection

Environmental scientists must provide resource managers with temporal trends in stream water quality so those managers

1 Minam River, Oregon

2 Vallecito Creek, Colorado

3 Red Butte Creek, Utah

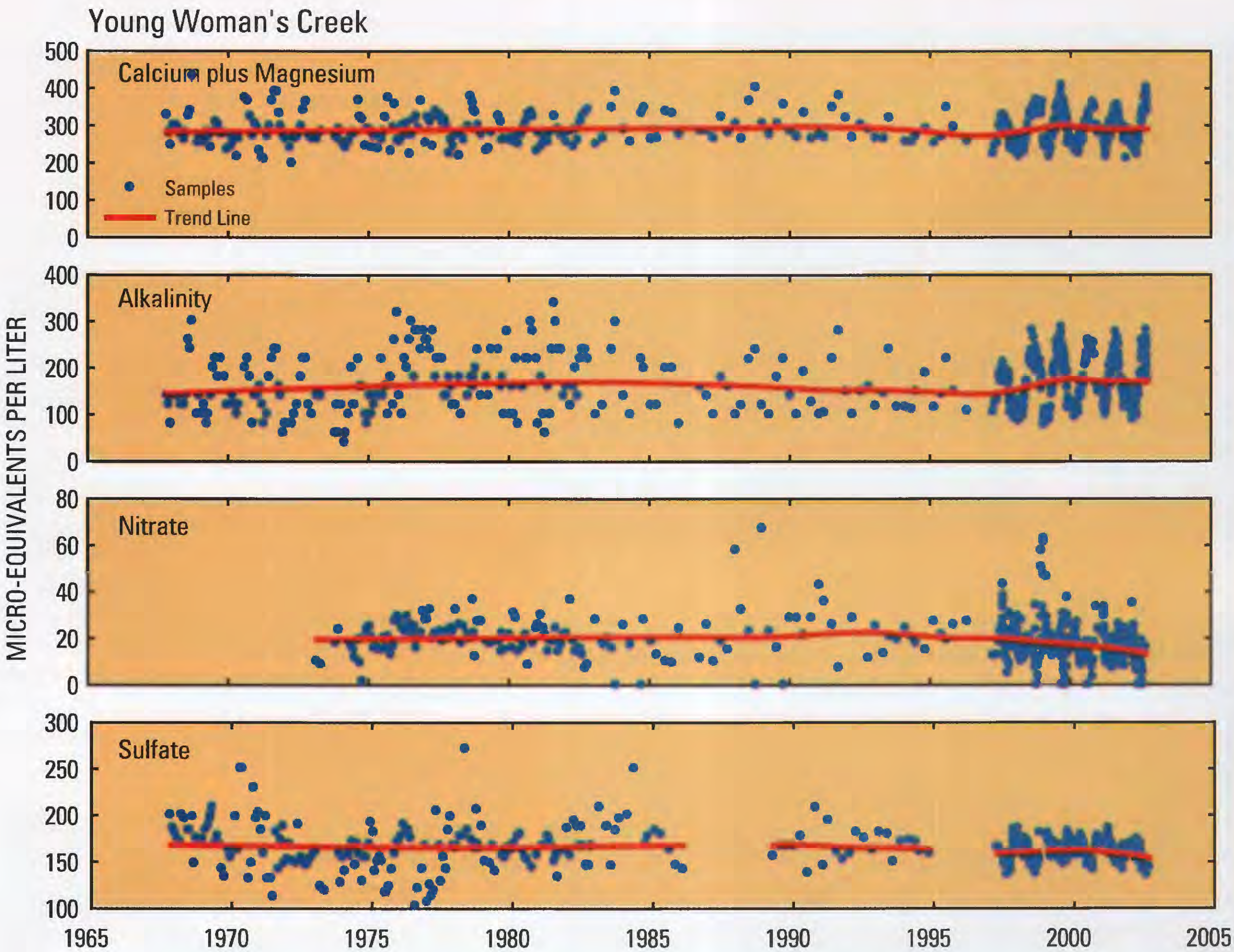


**Figure 2**. Concentration and temporal trends of calcium plus magnesium, acid-neutralizing capacity, nitrate, and sulfate for Young Woman's Creek in north-central Pennsylvania from 1968 to 2004.

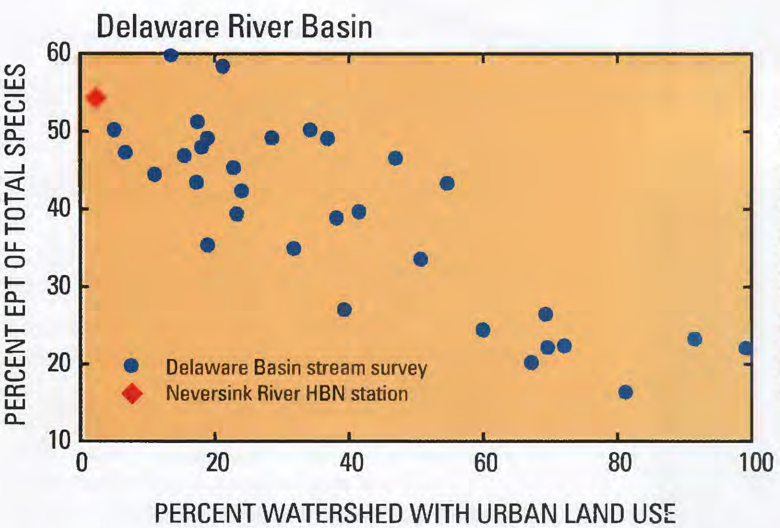


**Figure 3**. Effect of urbanization on stream macroinvertebrate populations in streams of the Delaware River Basin. EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness is an index of river health based on the populations of mayfly, stonefly, and caddisfly, respectively (modified from Fischer and others, 2004).

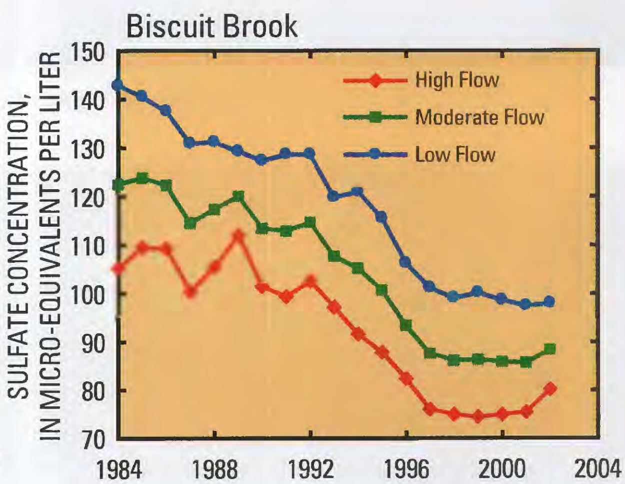


**Figure 4**. Trends in sulfate concentrations during high flow, moderate flow, and low flow conditions for the Biscuit Brook watershed in the Catskill Mountains in southeastern N.Y. High flow shows an upturn in sulfate concentrations during the last 2 years of record that is not apparent at low flow. (Murdoch and Shanley, 2006b.)

# HBN in 2006

The HBN of 2006 has fewer stations than the original network of Dr. Leopold, but modern sampling strategies and equipment allow a far more detailed understanding of how the Nation's streams and rivers are changing than was feasible in the 1960s when the HBN began. In 2003, 15 of the original HBN stations were equipped with refrigerated, automated samplers and telemetry systems that allow program coordinators to monitor stream conditions and adjust sampling frequency to capture unique stream conditions or special sampling needs. The automated sampling system is designed to collect samples through a wide range of flow conditions and to transmit data by satellite. About 25 water samples are collected annually at each HBN water-quality station and refrigerated on site until retrieved by field personnel who visit the sites regularly. Flow-based automatic sampling assures that samples are collected through the range of flow conditions at each site during each season of the year. Samples are analyzed for major anions and cations, pH, dissolved organic carbon (DOC), dissolved organic nitrogen (DON), acid neutralizing capacity (ANC), silica, and aluminum. HBN basins are often used for investigations of local concern that supplement HBN data collection, provide additional water-quality data such as pathogens, pesticides, stable isotopes, and phosphorus for periods of months to years, and offer the opportunity to collaborate with other local, State, and Federal agencies as well as academia and the private sector. This flexible monitoring capability allows a baseline of long-term data to be maintained while supporting regional and national investigations of emerging environmental issues.

# A Vision for HBN

The HBN places a priority on building collaborative monitoring strategies with other agencies and maintaining a network of streams draining undisturbed watersheds at which ecosystem change can be monitored through time. By developing partnerships with other government agencies, academia, and the private sector HBN sites could become a focus for monitoring atmospheric deposition, soil chemistry, forest health, and wildlife populations to create the first network of undisturbed, medium-sized watersheds in which the interactions of multiple components of the environment could be tracked in an integrated manner. Partnerships with Federal agencies such as the U.S. Forest Service and the National Park Service, and local agencies such as the New York City Department of Environmental Protection, have already been established. The Hydrologic Benchmark Network provides the first crucial building block for the long-term surveillance of the Nation's undeveloped ecosystems by providing flow and water quality data from rivers that drain undisturbed, medium-sized watersheds.

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On-line source for HBN data, publications and site information is http://water.usgs.gov/hbn

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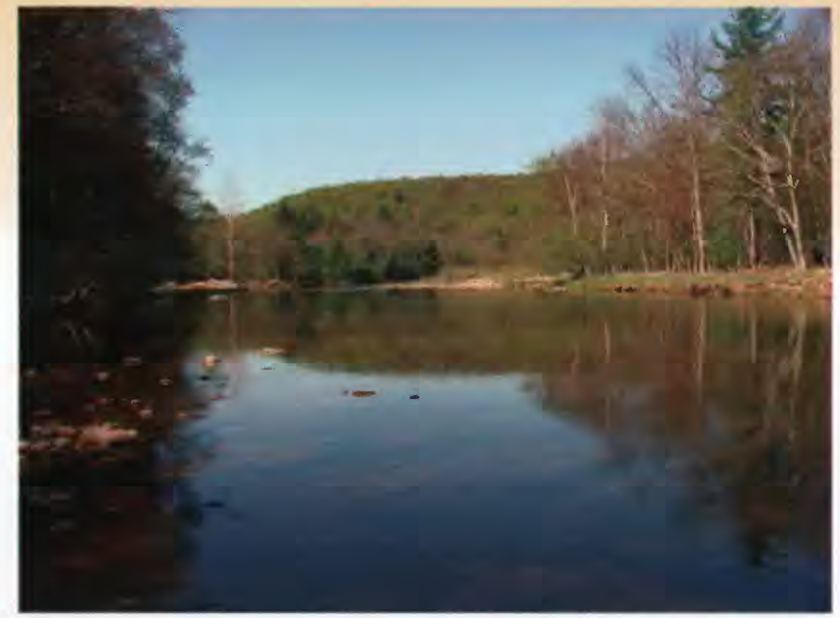
**Figure 1**. Approximate locations of the Hydrologic Benchmark Network monitoring stations, United States.

can make informed land management decisions. The HBN provides water-quality data to identify trends for rivers draining undisturbed, "benchmark" watersheds (fig. 2) (Murdoch and Shanley, 2006a). Measures of river health from HBN watersheds can be compared to those from watersheds affected by human activity, and thus the effect of that activity on water quality can be assessed (fig. 3). Decades of data have typically been required to accurately detect trends in water quality caused by atmospheric pollution however resource managers cannot wait decades to make land management decisions. Scientists need methods to detect trends in water quality for much shorter time periods than have been required in the past.

Data from selected HBN stations were used during the late 1990's to identify and implement a strategy for early detection of water-quality trends. The frequency of water sampling was increased to include the annual range of flow conditions at each site. The study concluded that if sufficient samples were collected to identify a statistically significant annual correlation between river flow and water quality, trends at high, median, and low flow could be detected for the HBN rivers. The stronger the trends, the shorter the period of record needed for trend detection. The study further showed that the effects of acidic deposition can be detected in HBN-scale rivers in the northeastern United States, and that changes in sulfate deposition rates during the past 15 years were first detectable in the rivers at high flow (Murdoch and Shanley, 2006b) (fig. 4). The HBN is providing data for early detection of water-quality trends in 15 rivers draining undeveloped watersheds across the United States.

Kawishiwi River, Minnesota 4



Neversink River, New York 5

Sopchoppy River, Florida 6

## Creating Attainable Water-Quality Goals for Developed Watersheds

Undisturbed basins contain many of the chemicals in low concentrations that are used in concentrated forms for agricultural and industrial activities. Regulations have been adopted that set stream water concentration thresholds on many naturally occurring and man-made chemicals. Fines or costly cleanup requirements are imposed where those thresholds are exceeded, but in some areas natural concentrations of those same chemicals are present and no clean-up strategy will completely remove them from the environment. In other cases a certain amount of a pollutant or landscape development could be accomodated without causing ecosystem degradation (fig. 3). Knowledge of background concentrations for environmental pollutants, and the thresholds of environmental disturbance above which environmental degradation occurs, is critical for establishing rational and cost-effective mitigation objectives.

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