US FOREST SERVICE NORTHERN RESEARCH STATION

Research *Review*

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# Keeping Our Water Safe and Abundant: Hydrology Research on Experimental Forests

Water is vital to life and health at both the personal and societal levels. Just as humans cannot thrive without clean and adequate water, no country, region, or city without clean, reliable, and adequate water can function well. Although civilizations have built infrastructures to obtain and transport water, the ultimate source of the water is always the natural world. Surface water and ground water both depend on lands where precipitation falls into watersheds or reservoirs or is pumped from springs or wells. In most of the northeastern and midwestern United States, this source is the highlands and northern forest lands. Providing clean water is considered the most vital of the ecosystem services provided by our forest and wetlands. Forested watersheds in the United States provide drinking water to more than 180 million people.

## U.S. FOREST SERVICE PROTECTS OUR NATION'S WATER SOURCES

Protecting our water sources was a primary purpose for which the U.S. Forest Service (USFS) was established in 1891. The USFS commitment to our nation's water quality is twofold—protecting the 193 million acres of National Forest System lands that provide water to 66 million people, and studying the fundamental science of watershed hydrology for most of the major forest types of the United States. Much of the agency's long-term watershed research happens on specially designated lands (often within the National Forest System) that are set aside solely for scientific study. The Northern Research Station (NRS) has three experimental forests (EFs) that have specialized in watershed processes for more than half a century. The Hubbard Brook EF in New Hampshire, the Fernow EF in West Virginia, and the Marcell EF in Minnesota are places where NRS scientists study the basics of the hydrological cycle in the major forest and wetland types and determine the effects of forest management on water resources.

*continued on page two*

***The national forests were created in part for "securing favorable conditions of water flows," the importance of which has grown as populations have grown.***

Abigail Kimball, Chief, U.S. Forest Service

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## Hubbard Brook Experimental Forest

The longest-running, most comprehensive ecosystem study in the world is ongoing on the Hubbard Brook Experimental Forest. Established in 1955 in central New Hampshire's White Mountain National Forest, the Hubbard Brook EF is a "research treasure" where NRS scientists and their numerous cooperators can study the effects of forests and forest management on the hydrological cycle, erosion, and water quality in a typical New England granite-based northern hardwood forest type (beech-birch-maple). The Hubbard Brook watershed was chosen for its special characteristics suited to small watershed studies: its central brook is fed by a network of smaller streams that drain north- and south-facing slopes flowing over shallow soils on water-tight New Hampshire granite bedrock. Nine stream gauges (see page 3) were installed, the first in 1955. In 1963, Robert Pierce, the lead USFS scientist, and his colleagues Herbert Bormann and Gene Likens (then at Dartmouth College) began using the small-watershed technique for early cooperative work. The work they began has, during the past 56 years, advanced our fundamental understanding of nutrient cycling in forests and stream ecosystems. In addition, Hubbard Brook scientists were ideally placed to study numerous environmental problems. For example, they were the first to report, and ultimately prove, the occurrence of acid precipitation (aka, acid rain) in North America in 1968.

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**Some of the 40,000+ bottles of water samples in storage at the Hubbard Brook EF headquarters, from five decades of year-round monitoring The samples are typically analyzed for 18 different chemical parameters and have produced a massive amount of data on meteorology, hydrology, biogeochemistry, forest growth, and population dynamics.**

Now, scientists at the Hubbard Brook EF have expanded on their early nutrient cycling studies and long-term monitoring and are tracking calcium through the entire ecosystem. They are evaluating calcium's role in regulating the structure and function of base-poor (that is, acidic, low pH) forest and aquatic ecosystems. In 1999, with NSF funding, NRS scientists applied 56 tons of calcium (the amount estimated to have been leached by acid precipitation) as crushed calcium silicate rock back onto one of the watersheds. Data from this work will be used to improve our understanding of the possible impact of calcium depletion due to acid precipitation, provide increased knowledge of the role of calcium in ecosystem process, and develop models that can be used on larger, regional landscapes.

## Fernow Experimental Forest

For the last 50 years, the Fernow EF has been internationally recognized as a teaching and demonstration forest in the central Appalachian Mountains. The Fernow—named for Bernhard Fernow, a pioneer in American forestry research—was established in 1934 and is located near Parsons, WV, within the Monongahela National Forest. Early research addressed practical and applied forest management issues. After the Fernow EF reopened following World War II, a new research program was begun to study the silviculture of mixed hardwood forests and watersheds. Watershed research began in 1951 to study water use by forests and critical issues about how roadbuilding, best management practices, and forest management affect water runoff, flooding, and soil erosion. Scientists have demonstrated that although streamflow can be increased by practical forest management, cutting a forest does not create a high flood hazard when the forest floor is protected from erosion. They developed guidelines for determining site quality from topographic and soil features; improved logging methods that are practical and profitable; and poineered best management practices for West Virginia.

In the Fernow's 20-year-old whole-watershed acidification study, researchers found quite different effects than those found at the Hubbard Brook EF. Differences in climate and geology—lack of an all-season snowpack, bedrock composed of sedimentary rock instead of granite, and lack of Ice Age glaciation in West Virginia—have produced a very different picture in the central Appalachians. Here, acid precipitation affects only stream chemistry and no obvious effects on tree health have been observed yet.

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**Stream gauge on watershed #4 on the Fernow Experimental Forest, with heavy storm runoff going over the weir (the dam with the v-notch in the foreground), which was installed onto bedrock). Note that the water is clear, a sign of a healthy forest.**

## Marcell Experimental Forest

The Marcell EF in northern Minnesota was established on the Chippewa National Forest in 1960 to study biogeochemistry and hydrology in boreal ecosystems that include peatlands in their watersheds. Peatlands occur across the United States but are more common in boreal forests of the northern United States and Canada. Boreal peatlands occur in low-relief post-glacial landscapes where organic matter has accumulated under waterlogged conditions that inhibit normal decomposition. The soils are thus rich in organic matter and store vast amounts of carbon. Peatlands occupy about 340 million acres in North America, mostly in Canada and Alaska and about 23 million acres in the continental United States, mostly in the northern Great Lakes region. Peatlands such as those in the Marcell EF are classified as either fens or bogs according to their hydrology and chemistry. Fens have water contribution from groundwater, upland runoff, and precipitation, whereas bogs have contributions only from the latter two. The chemistry of bogs is driven by the production of acids by bog species, whereas fen chemistry is driven by the inputs of nutrient-rich, near-neutral groundwater.

The Marcell EF has six watersheds equipped with measuring instruments, each consisting of a mineral soil upland surrounding an organic soil peatland. Weather, precipitation, streamflow, groundwater levels, and water chemistry are routinely measured, and most records now date back nearly 50 years. Watershed studies evaluated various forest management options on water yield and water chemistry. Those options included clearcutting of aspen uplands, clearcutting of black spruce bogs, prescribed fire in a harvested fen, upland nitrogen fertilization, and conversion of aspen uplands to conifer forests using cattle grazing to control aspen regrowth. Based on our field results, computer models have been developed to simulate streamflow responses to timber harvests. These results were instrumental in evaluating best management practices and establishing harvest rate guides for forests throughout the region. Pioneering studies at the Marcell EF evaluated the sources and sinks of both carbon and mercury in the experimental watersheds. Ongoing work focuses on understanding the importance of localized hotspots that affect nutrients, carbon, and mercury availability at the watershed scale.

*The ability to think several generations ahead depends on a solid knowledge of riparian ecosystems—not only how they function today, but how they are likely to react over time to both disturbance and attempts at restoration*

Sandy Verry, retired Forest Service Research Hydrologist, Marcell Experimental Forest

## WHAT MAKES THESE EXPERIMENTAL FORESTS SO VALUABLE?

**Since 1908, the Forest Service's experimental forests have been the canvasses on which many of the most inventive minds in U.S. Forest Service research have worked out their ideas. Replicated, decades-long studies allowed us to first describe our region's resources and then to develop the stewardship principles and best management practices we use today. The Northern Research Station has responsibility for 22 of the 80 experimental forests nationwide.**


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**Vincent Levasseur at Hubbard Brook EF**

The importance of the Forest Service's network of experimental forests cannot be emphasized enough. Because the experimental forests are a part of a long-established, government forestry research organization, they have an unequaled history of continuity. Scientists have been able to take measurements and maintain their data over decades. Indeed, some of the NRS experimental forests have 50-year-old hydrology datasets. Sometimes, much of those sets are the work of one individual over an entire career. Such records are of great value in that one of the major sources of sampling variation—changing personnel—is not relevant. Until his retirement in 2000, Vincent "Vinnie" Levasseur had performed "the weekly rounds" every Monday at the Hubbard Brook EF for 30 years, measuring precipitation despite the ruggedness of the terrain and the winter snowpack. Likewise, Art Elling weathered tough Minnesota winters collecting data every Tuesday for 35 years until his retirement in 2005. Down at the Fernow EF, John Campbell spent 35 years taking the samples until his retirement. Now, Doug Owens is on his 17th year of service and training up another generation of technicians. In addition, there are special personnel at the Fernow EF—the only logging crew actually employed by the Forest Service (all other logging work is done by contractors). The Fernow logging crew provides continuity of action; its members have been applying cutting treatments since 1949.


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**Art Elling at Marcell EF**


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**Doug Owens (left) and John Campbell at Fernow EF**

Now, new generations of scientists and graduate students can observe research plots that were established long ago and then studied decades later; now other workers can come back and restudy them as much as 70 years later. Not only do the records still exist, the trees do too! Sometimes three "scientific generations" who have worked on one site can still get together. At the Marcell EF, Dr. Roger Bay was the assigned hydrologist from 1956 to 1968; he passed on the torch to Dr. Sandy Verry, who worked from 1967 to 2004; Dr. Steve Sebestyen started in 2007. Such dedication and continuity by both scientists and technicians is rare and invaluable in the scientific enterprise and a major part of what makes the Forest Service's experimental forests such "research treasures."


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**Roger Bay, Sandy Verry, and Steve Sebestyen (left to right) at Marcell EF**

*Let clean waters flow.*

*Barack Obama, Inaugural Address*

# References and Resources

## Official Forest Service Web Sites & Contacts:

US Forest Service, National Experimental Forest (EF) Network: www.fs.fed.us/research/efr/

USFS/Northern Research Station, EF Network: www.nrs.fs.fed.us/ef

USFS/NRS, Hubbard Brook EF (contact John Brissette, USFS/NRS, 271 Mast Rd, Durham, NH 03824; 603-868-7636; email jbrissette@fs.fed.us; www.nrs.fs.fed.us/ef/locations/nh/hubbard-brook/

USFS/NRS, Fernow EF (contact Mary Beth Adams, USFS/NRS, Nursery Bottom, Parsons, WV 26287; 304-478-2000, x 130) email mbadams@fs.fed.us; www.nrs.fs.fed.us/ef/locations/wv/fernow/

USFS/NRS, Marcell EF (contact Randy Kolka, USFS/NRS, 1831 Highway 169 East, Grand Rapids, MN 55744; 218-326-7115; email rkolka@fs.fed.us; www.nrs.fs.fed.us/ef/locations/mn/marcell/

## Research & Monitoring Network Web Sites

Hubbard Brook Ecosystem Study: www.hubbardbrook.org

Hubbard Brook Research Foundation: www.hubbardbrookfoundation.org

Ecotrends Network—HB, Fernow, Marcell: www.ecotrends.info/EcoTrends/index.jsp#

EPA Clean Air Status and Trends Network (CASTNET)—HB, Fernow: www.epa.gov/castnet/

HydroDB and ClimDB—HB, Fernow, Marcell: www.fsl.orst.edu/climhy

Mercury Deposition Network (MDN)—Marcell: nadp.sws.uiuc.edu/mdn/

National Atmospheric Deposition Program (NADP)—HB, Marcell, Fernow: nadp.sws.uiuc.edu/

National Science Foundation Long-Term Ecosystem Research (LTER)—HB: www.lternet.edu

NRCS Soil Climate and Analysis Network (SCAN) nadp.sws.uiuc.edu/

Organization of Biological Field Stations (OBFS)—HB, Fernow www.obfs.org/

UNESCO Biosphere Reserve—HB: www.unesco.org/mabdb/br/brdir/directory/biores.asp?mode=&code=USA+13I

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Campbell, J.L., Driscoll, C.T., Eagar, C., et al. 2007. **Long-term Trends From Ecosystem Research at the Hubbard Brook Experimental Forest.** GTR-NRS-17. Newtown Square, PA: USDA Forest Service, Northern Research Station. www.nrs.fs.fed.us/pubs/3119

Kolka, R.K., Sebestyen, S.D., Verry, E.S., Brooks, K.N. [In preparation, 2010]. **Peatland Biogeochemistry and Watershed Hydrology at the Marcell Experimental Forest.** Boca Raton, FL: CRC Press

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Our research themes are (1) Managing Forests with Disturbance, (2) Urban Natural Resources Stewardship, (3) Sustaining Forests, (4) Providing Clean Air and Water, and (5) Natural Resources Inventory and Monitoring.

There are 157 NRS scientists working at 20 field offices, 22 experimental forests, and universities located across 20 states, from Maine to Maryland, Missouri to Minnesota.