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Science and Management

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Taking blood samples from a young bald eagle to obtain mercury levels at Acadia National Park

Air and Water Quality

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Mercury Contamination at Acadia National Park

Colleen Flanagan, Ecologist, NPS Air Resources Division,
and Bill Gawley, Biologist, Acadia National Park

In 1994, USEPA researchers investigating mercury concentrations in fish from 120 Maine lakes made an unexpected discovery. Two fish containing some of the highest tissue mercury burdens in the sample set had been collected from lakes in Acadia National Park (NP). This was something of a surprise because the park is located in a relatively pristine spot away from industrial activities. Since then, park staff and researchers from the University of Maine, the U.S. Geological Survey (USGS), and others have been studying mercury contamination at Acadia NP in an effort to understand the sources, cycling patterns, and ecological effects of this heavy metal. Elevated and pervasive levels of mercury have been found across the park landscape, in surface waters, sediments, and animals as diverse as fish, eagles, salamanders, and tree swallows. Data from lake sediment cores indicate that the current rate of mercury deposition is about four times greater than what scientists think deposition rates were before industrialization. While mercury concentrations in streams from Acadia National Park's Mount Desert Island fall within the statewide range, they are unusually high within the regional context of coastal and Downeast Maine.

The major source of mercury in the park's environment is deposition from the atmosphere – a result, in part, of emissions from coal-burning power plants in the Midwest. Once emitted to the air, mercury can travel great distances before it returns to the earth with rain, snow, dust, or fog. The park's steep slopes, high peaks, and exposure to coastal fog create an environment conducive to trapping polluted air masses, and the forests that are located on southwest-facing slopes of Acadia NP are hardest hit because they directly intercept polluted air masses drifting eastward across the U.S. Forested areas act as air filters, collecting and concentrating mercury on foliage, which later washes to the ground in rain or snow (throughfall), or drops with the leaves (litterfall). Coniferous forests capture more mercury from the air than deciduous forests because collectively their needles have more surface area to filter the mercury than broadleaf trees. Washed to the ground, mercury collects in the soil and eventually moves into streams and lakes. It is a heavy metal but can vaporize easily from land and water surfaces and repeatedly reenter the atmosphere, particularly during wildfires.

Forested areas act as air filters, collecting and concentrating mercury on foliage, which later washes to the ground ....

Bill Gawley preparing to remove a sample from Mercury Deposition Network precipitation collector.

By May 1995, field work for an NPS-funded research project to determine the extent of mercury contamination in aquatic environments was underway. That same year, Acadia NP became one of the first NPS units to join the Mercury Deposition Network, part of the National Atmospheric Deposition Program located at the University of Illinois, monitoring mercury levels in precipitation. In subsequent years, the park hosted researchers from the University of Maine, Orono, and the USGS investigating mercury cycling and flux in soils, streams, leaf litterfall, and throughfall. Other investigators studied mercury concentrations in fauna representing various levels of the food chain, from plankton to top predators. The vast extent of wetlands within the park provides environments conducive to increased methylation, a process in which naturally occurring bacteria act on mercury to create methylmercury, the mercury compound that accumulates in organisms and magnifies in concentration with each level of the food chain.

Toxic effects of mercury to fauna include reproductive and neurological impairment and decreased survival. Mercury is persistent in the environment, and wet deposition monitoring shows that levels in precipitation are holding steady. Methylmercury has been found in tissues of invertebrates, amphibians, a number of bird species, and seals, as well as fish. A 1997 University of

Maine research project examined golden shiner minnows for effects of mercury on predation avoidance behavior, but more studies of behavior, reproductive health, and survival of mercury-contaminated animals need to be undertaken. A spring 2011 mercury science meeting will prioritize such research inquiries and address natural resource managers' questions about mercury in the environment.

In June 2010, the NPS Air Resources Division, Acadia NP staff, and science communication interns at the Schoodic Education and Research Center began a collaborative project to communicate mercury research results from Acadia NP to increase public awareness about the issue of mercury contamination.(See box below.) This joint venture may serve as a model for future science communication projects in national parks.

Communication of mercury research results from Acadia P increases awareness about the issue of mercury contamination. Continued coordination with federal and state air quality regulatory agencies is essential in the effort to reduce mercury emissions, and thus mercury deposition in the park, from national and international sources. Reducing emissions is the first step toward improving ecosystem conditions.

Mercury impacts on natural resources have also been documented in other national parks, including parks in the Great Lakes Region. Studies assessing mercury deposition and its effects in additional parks are currently in progress. Forthcoming risk assessment results for NPS Inventory and Monitoring parks will identify national parks most sensitive to mercury contamination.

Dr. Sarah Nelson (University of Maine) with throughfall collector used in mercury research project.

These outreach products are available online.

Video podcast: http://nature.nps.gov/air/Multimedia/podcast/acadia_mercury/acadia_mercury.cfm

Fact Sheet: http://www.nps.gov/acad/naturescience/upload/ACAD_Mercury_FactSheet_2010.pdf

Web pages: http://www.nps.gov/acad/naturescience/airquality.htm and http://www.nature.nps.gov/air/permits/aris/ACAD/index.cfm

Additionally, diagrams, talking points, and slideshows are accessible from http://nrpcsharepoint/ard/ (>Documents >Shared Documents >Acadia) on the internal NPS nework.

Visit http://www.nature.nps.gov/air/AQBasics/mercury.cfm for more information.

Marcellus Shale Gas Production
Across the Northeast Region

Alan Ellsworth, NER Hydrologist

The Marcellus Shale is a sedimentary rock formation underlying the area from central New York to southern West Virginia. The rock formation is believed to contain as much as 363 trillion cubic feet of recoverable natural gas, which alone would provide a sufficient quantity of gas to supply current U.S. needs for more than 15 years (Soeder and Kappel, 2009). A relatively new drilling technology known as horizontal hydraulic fracturing (or fracking) and an increased price of natural gas have made this shale play (formation) viable for production. Other shale gas plays are found in the Northeast, e.g., Utica Shale, but the Marcellus has received the most attention due to its enormity.

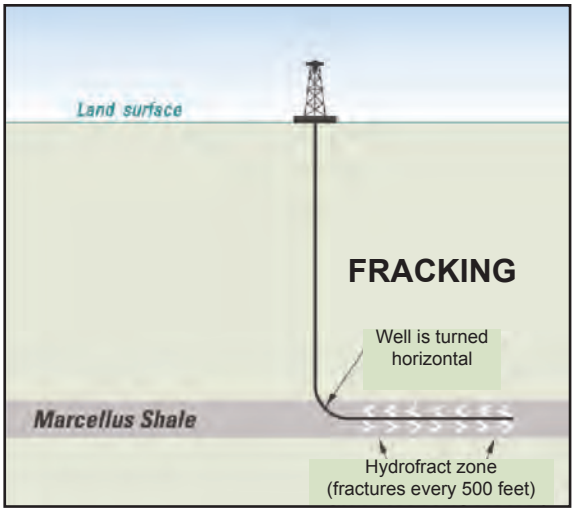
...wastewater and mud ... from drilling ... contain extremely high total dissolved solids, radionuclides, and residual chemicals ....

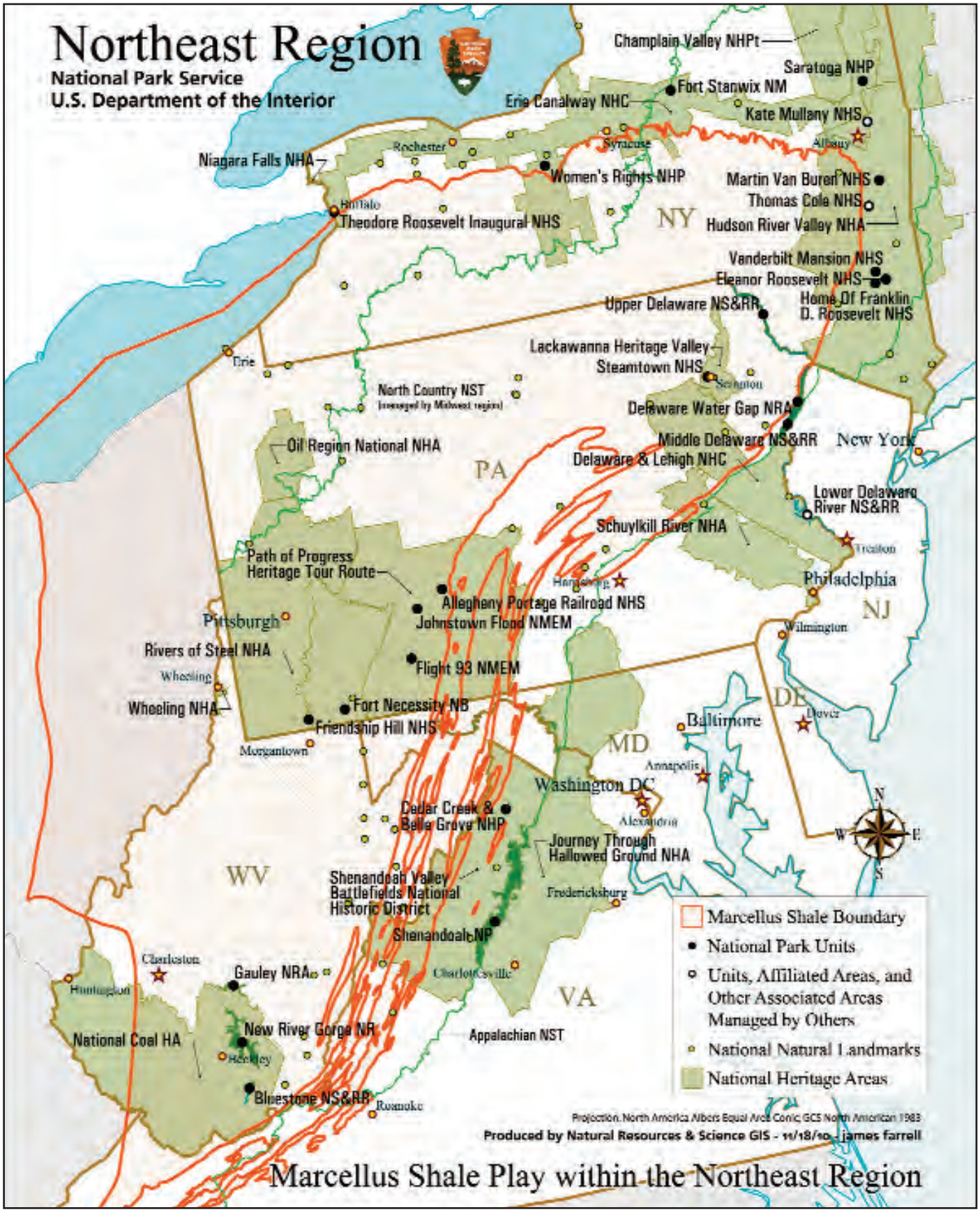
Horizontal hydraulic fracturing is accomplished by drilling vertically to the depth of the shale formation, which is generally found between 0.6 – 1.5 km below the surface. When the gas-containing shale is intercepted, the drill bit is maneuvered to travel horizontally through the center of the formation for a distance of up to 1.6 km. Water, biocides, surfactants, sands, and other chemicals are forced into the borehole under extremely high pressure to induce fractures in the shale that allow gas to rise to the surface for collection (below right). As much as 3 to 5 million gallons of water may be used for each fracking event and as many as six wells may be placed on each well pad (roughly 2.5 ha production area). Flowback (or produced) wastewater is collected at the well head and reused for fracking or shipped away for treatment. The wastewater and mud produced from drilling have been found to contain extremely high total dissolved solids, radionuclides, and residual chemicals that were introduced for the fracking process.

In early 2008 Upper Delaware Scenic and Recreational River (SRR) staff alerted NPS regional and national natural resource and science staff to potential gas production in their area. In response to a Northeast Regional Office (NERO) Technical Assistance Request, the NPS Natural Resources Program Center prepared a multidisciplinary summary report on Marcellus Shale development (NPS 2009). The summary report was coordinated by the Geologic Resources Division and included input from the Water and Air Resources Divisions, NERO staff, and Upper Delaware SRR staff. The summary report includes a description of the shale formation surface area, NPS interests across this formation, potential environmental concerns, protective legislation, and methods to engage permitting agencies.

James Farrell, NERO GIS Specialist, prepared a map with NPS units, National Natural Landmarks and Heritage Areas, and partnership lands within the Marcellus Shale play as an outreach tool (opposite page). This visual representation helps indicate why the NPS is involved in shale gas production discussions--to insure development occurs with best management strategies in place to protect these areas managed for the public. Staff from NERO and the Upper Delaware SRR presented a poster-sized rendition of this map at the 2009 PA Natural Gas Summit at Penn State University. The map has also been shared with potentially affected NPS management areas, other federal partners, river basin commissions, universities, and shale gas developers.

Public opinion of shale gas production has remained divided as private landowners and state governments stand to gain revenue from leases and taxation of production companies, and others contend that the potential for contamination of water is unacceptably high. The NPS has remained engaged in discussions focused on identifying available data and research needs, and commenting on proposed development regulations. A nine-park unit proposal (led by USGS and NPS) to sample well water for baseline data prior to development was approved to begin in FY 2011 through the USGS-NPS Water Quality Partnership Program. Comments were provided in support of an EPA study of nationwide groundwater effects from hydraulic fracturing that will begin in FY 2011, and for a Department of Energy research well that is expected in Pennsylvania in the near future. Regulatory reviews from NPS have been provided to New York State, the Commonwealth of Pennsylvania, and the Delaware River Basin Commission. The NPS also remains active in protecting public interests through routine conference calls and meetings with federal and state partners, river basin commissions, and other interested parties. Holly Salazer, NER Air Resources Specialist, acts as the coordinator for Marcellus Shale issues and can be contacted at Holly_Salazer@nps.gov.





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Other Impacts of Marcellus Shale Development:

Air, Sound, and Night Sky

Holly Salazer, NER Air Resources Coordinator

Beyond impacts to water quality and quantity from gas extraction from the Marcellus shale beds, the National Park Service is concerned about impacts to air, soundscapes, and night skies. Impacts to these resources are less understood and deserve attention as development moves forward. A greater understanding of all resource impacts will provide a better picture of how the environment may change in our region.

Air Quality

There are air quality concerns with each phase of natural gas development: exploration, production, processing, treatment operations, and transmission facilities. In addition to these specific development phases, basic construction activities, truck transportation, and off-gas flaring are also components of development that need to be considered in terms of air quality. For almost all activities, the three main pollutants of concern are nitrogen oxides (NOx), volatile organic compounds (VOC), and particulate matter (PM2.5).

Persistent exposure to [high levels of odor] may cause illness such as headaches and nausea.

Both NOx and VOC emissions contribute to the formation of ozone. Ozone formation may not be an issue on a site-by-site basis, but can have significant impacts on a regional basis. Most of the natural gas development that is occurring is located in rural areas that in the past have not violated federal standards for ozone levels. That may change with the increase of well development and operation on a large scale. Impacts of higher ozone levels include both public health concerns and effects on ozone-sensitive plant species.

Diesel and PM2.5 emissions can be attributed to the construction, transport, and equipment operation of natural gas activities. A large number of trucks are needed to transport equipment and water to and from well pad sites. With increased truck traffic, comes increased levels of PM2.5, NOx, and VOC, which all can impact public health and regional visibility.

It is important to note that natural gas development also involves emissions of toxic pollutants. Hazardous Air Pollutants (HAP) are released during well drilling and hydrofracturing, wastewater collection, gas compression, and transmission via pipelines. HAPs that have been identified as potential concerns include benzene, ethane, isoprene, and toluene. Radionuclides, such as radium and radon, have also been identified as emissions from wastewater treatment of hydraulic fracturing fluids.

To better understand air quality impacts, it helps to consider other areas of the country where natural gas development has occurred on a large and longer-term scale. Texas offers a good case study where the state has experienced significant development of natural gas resources over the past decade. The Barnett Shale in Texas covers approximately 5,000 square miles and contains approximately 22,000 natural gas and oil wells. In 2009, the Texas Commission on Environmental Quality (TCEQ) undertook the Barnett Shale Air Study which primarily focused on benzene and carbon disulfide emissions, but also included over 100 secondary target compounds. The monitoring and field assessments during the study included multiple natural gas and oil emission source types including, but not limited to, those associated with drilling, fracturing, well-heads, storage tanks, compressor stations, saltwater disposal wells, and natural gas processing facilities. In general, benzene concentrations were detected above short-term health comparison values at two sites (out of 94 monitoring sites) and detected above the long-term health-based comparison values at 21 monitoring sites.

Another important air quality concern coming out of this report was the detection of several chemicals at concentrations that could cause odorous conditions. Persistent or recurrent exposure to levels which significantly exceed the threshold at which people can perceive odors may cause illness such as headaches and nausea. As a result of the 2009 study, the TCEQ has installed new stationary monitors in the Barnett Shale area to better assess the influence of oil and gas activity on ambient concentrations of VOCs, particularly benzene, and the state has decided to continue focused monitoring studies throughout 2010. The 2009 study results, health effects review, and subsequent sampling and surveys can be found at
http://www.tceq.state.tx.us/implementation/barnettshale/bshale-next

Acoustical Environment and Soundscapes

The NPS Natural Sounds Program (NSP) was established in 2000 to help parks manage sounds in a way that balances the varying interests of park visitors with that of the protection of park resources. The NSP is located in the Natural Resource Program Center in Fort Collins, Colorado and provides staff with expertise

in acoustical monitoring, data collection and analysis, NEPA compliance, and education and outreach. The work of the NSP can help protect, maintain, or restore the acoustical environment of parks and can help us better understand how energy development may be impacting park resources.

The NSP has been at the forefront of researching how visitor experience and wildlife are impacted by noise. There is now a large body of information related to responses of visitors and wildlife to different types of noise. While very few studies are specific to natural gas drilling, existing studies can be generalized to other noise sources with similar characteristics and can provide a park with a basic understanding of how park soundscapes and acoustical environments may be impacted.

Articles and information on noise impacts to visitors can be found at http://nature.nps .gov/naturalsounds/PDF_docs/VisitorExperience_Soundscapes_AnnotatedBiblio_17Aug10.pdf . Articles and information on noise impacts to wildlife can be found at http://nature.nps .gov/naturalsound /PDF _docs/wildlifebiblio _Aug08.pdf

Three articles associated with noise impacts on avian communities from oil and gas development are listed below. The Bayne et al. 2008 article published in Conservation Biology can be helpful to park managers because the research focuses on the noise generated from compressor stations and well pads which would be important factors in understanding how park soundscapes may be affected in the Marcellus Shale region. The researchers found that areas near generally noiseless energy facilities (i.e., well pads) had greater density of bird species than areas near noise-producing energy sites (i.e., compressor stations). Even though it is limited, research such as this can help frame how the NPS can approach protection of acoustical environments and soundscapes and help provide direction in the development of best management practices for noise mitigation in the Marcellus Shale region.

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Night Sky

The identification of dark night skies as a resource for NPS protection has grown tremendously over the past decade. Impacts to night skies from light pollution, including poorly designed outdoor lighting, have begun to be quantified by the efforts of the NPS Night Sky Program, which was established in 1999. The Night Sky Program is located in the Natural Resource Program Center in Colorado and has been engaged servicewide in identifying sources of night sky diminution not only from outdoor lighting, but also energy development.

In the Marcellus Shale region, the potential for impacts to night sky from energy development is shared by state park systems, whose managers also understand the value of preserving dark night skies. For example, Cherry Springs State Park in north central Pennsylvania was declared the first Dark Sky Park by the Pennsylvania Department of Conservation and Natural Resources in 2000 due to its exceptionally dark skies. The park has become known as one of the best places on the eastern seaboard for stargazing and the study of astronomy. At the same time, Marcellus Shale development is occurring within miles of the park. Well pad operations such as off-gas flaring, equipment lighting, and truck transport have been identified as impacting the night sky resource of the park.

Through better understanding of how natural gas development affects the quality of water, air, and soundscapes, and night skies, best management practices can be developed to help mitigate impacts and help preserve the exceptional resources of the region.

This night sky camera is ready for a night of data collection. The photo is from the Schoodic Education and Research Center at Acadia National Park. Data there are being captured by cooperator Island Astronomy Institute. Acadia has one of the (if not *the*) darkest night skies along the eastern seaboard.

Monitoring Stream Water Quality and Biota

At Hopewell Furnace

Ronald A. Sloto, Hydrologist, U.S. Geological Survey

French Creek flows through the heart of Hopewell Furnace National Historic Site (NHS), which is near its headwaters. Baptism Creek, a tributary to French Creek, flows through a wooded, undisturbed part of Hopewell Furnace and has its headwaters in the park. French Creek was designated as a State Wild and Scenic River by the Commonwealth of Pennsylvania in 1982 because of its outstanding natural and scenic values. It also bears the Commonwealth's designations of High Quality Waters--Cold Water Fishery and Exceptional Value Stream. French Creek is listed in the National Park Service (NPS) Nationwide Rivers Inventory, a listing of free-flowing river segments in the United States that possess one or more "Outstandingly Remarkable" natural or cultural values judged to be of more than local or regional significance. Outstandingly Remarkable Values listed for French Creek include (1) hydrologic – it is the northernmost, least developed, free-flowing river within the Piedmont physiographic province; (2) historic – there are river-related National Historic Register sites and a Historic District within the corridor; and (3) geologic – the area includes the unique Falls of French Creek.

...although the study looked at...metal contamination, it found instead a water quality problem related to something [else].

The smelting of iron ore with elevated concentrations of metals, such as arsenic and cobalt, took place at Hopewell Furnace from 1771 to 1883. Arsenic is a carcinogen, and cobalt is a possible carcinogen. The potential for environmental contamination from the release of these metals during smelting was the impetus for a study being conducted by the U.S. Geological Survey (USGS) at Hopewell Furnace NHS. As part of the study, suppoeted by the USGS/NPS Water Quality Partnership Program, benthic macroinvertebrates were collected, along with streamflow and streambed-sediment samples, at four study sites on French Creek and one control site on Baptism Creek in the park. In addition, a habitat survey was completed for each site. Laboratory analysis of the streamflow and streambed-sediment samples did not show the presence of elevated concentrations of metals. However, analysis of the macroinvertebrate samples indicated degraded conditions at the sites on French Creek compared to the control site on Baptism Creek. The site on Baptism Creek had more pollution-sensitive species, while the sites on French Creek had more pollution-tolerant species. The habitat survey showed that habitat conditions were degraded at three of the four sites on French Creek compared to the control site on Baptism Creek. Habitat degradation was related to the lack of riparian buffers and sedimentation. So, although the study looked at problems of metal contamination, it found instead a water quality problem related to something other than the presence of metals.

One source of trouble might be Hopewell Lake, a 68-acre impoundment on French Creek in the adjacent French Creek State Park. The outlet of Hopewell Lake is a short distance upstream of Hopewell Furnace NHS. Hopewell Lake is a top release impoundment, meaning that the water released from the lake to French Creek flows over the spillway. The water originates from the surface of the lake and is heated by the sun in the summer months. This may result in elevated temperatures in French Creek below the dam. It was suspected that elevated stream temperature may negatively impact the water quality and stream biota in French Creek. A study of temperature variations in French Creek was beyond the scope of the USGS study; however, in April 2010, the Mid-Atlantic Network Vital Signs Moni-

Tony Trease, U.S. Geological Survey hydrologic technician, uses a multiparameter meter to make an instantaneous in-situ water-quality measurement on Baptism Creek.

toring program (partnering with USGS) began monitoring water quality at the park. This program will monitor water temperature, as well as dissolved oxygen, pH, and specific conductance (an indirect measurement of dissolved solids) at 15-minute intervals. The monitors, which are anchored in the stream, are deployed in both French and Baptism Creeks. The program includes monthly grab samples for laboratory analysis in addition to the two in-situ water quality monitors. The monitors are serviced and calibrated by a hydrologic technician from the nearby USGS office in Exton, Pa. Data from the monitors are downloaded at regular intervals and provided to the NPS.

Water-quality monitoring site on French Creek.

The water quality monitors include a built-in pressure transducer that measures the height of the water column in the stream (stream stage). This provides information on the flow conditions under which the water-quality data were collected. Stream water quality differs depending on whether the stream is at low flow (base flow) or high flow (flood flow), and the stream-stage data collected by the monitors allow better interpretation of the water-quality data. Any differences noted in the data from Baptism and French Creeks may hold some answers as to why Baptism Creek has a different distribution of macroinvertebrate species than French Creek. An analysis of the data from the water-quality monitors may also provide insight into the effects of Hopewell Lake on water quality in Hopewell Furnace NHS.

Water flowing over the Hopewell Lake spillway provides flow for French Creek.

Air Resource Information for Natural Resource Condition Assessments

Holly Salazer, NER Air Resources Coordinator

Natural Resource Condition Assessments (NRCA) are used to evaluate current resource conditions within our national parks. These assessments provide a summary and synthesis of existing park data that help inform ongoing park resource planning efforts such as resource stewardship plans and general management plans. The National Park Service's Air Resources Division (ARD) in cooperation with the Northeast Region developed guidance to gather and interpret air resource information in an effort to have air resources included in the NRCA process. This information, along with other planning guidance, is available online at http://www.nature.nps.gov/air/planning/index.cfm under the Condition Assessment tab.

The air resources NRCA guidance identifies sources for air quality data that would be relevant to understanding the air resource conditions of a given park. The guidance highlights three principal air resource indicators: ozone, acid deposition (nitrogen and sulfur), and visibility. Assessment methods are provided, and helpful links to information and data resources are also included. When air quality monitoring is not located at a park, the ARD has developed a table of Air Quality Estimates that provides interpolated 5-year average values (2004-2008) for each of the three air resource indicators for 271 park units. This table is included on the air planning website as well. It also identifies related resources that a park may want to further investigate, such as ozone sensitive plant species. Finally, the guidance provides threshold levels of ozone, atmospheric deposition of nitrogen and sulfur compounds, and visibility metrics that can be considered good, moderate, or of significant concern.

Each year ARD assesses and reports on air quality conditions and trends in about 150 parks as a part of the program's annual performance and progress report. The most recent annual report is for 2008 and can be found online at http://www.nature.nps.gov/air/Pubs/pdf/AQ_Trends_In_Parks_2008_Final_Web.pdf Park managers can use both the NRCA and the annual ARD report to inform park management decisions that help protect park air resources.

Emerging Contaminants

In the Waters of the Northeast Region

Alan Ellsworth, NER Hydrologist

Water polluted by waste from pharmaceuticals, personal care products, and endocrine-disrupting compounds has recently been labeled as affected by 'emerging contaminants.' While the introduction of these contaminants may not be new, the term "emerging" has evolved in this context to indicate a new awareness of their presence and associated effects in waterways. Wastewater treatment systems are frequently not designed to process these chemicals. Recent studies have shown that these contaminants are found in remote environments in addition to areas below wastewater outfalls in more populous areas (KellerLynn, 2009; Battaglin and Kolpin, 2009). There is a need to identify the presence of these contaminants in National Park Service (NPS) waters, and determine what their effects are on the biota of these areas and how the NPS can help to insure that potential harm is avoided.

Endocrine disruptors in waters have been linked to changes in sex ratios, development, and reproduction success in fish (Scholz and Klüver, 2009). Sources include both natural (e.g., phytoestrogens from plant material) and synthetic (e.g., phthalates from plasticizers and surfactants). The increased use of pharmaceuticals to treat behavioral conditions and control birth rates, and of antibiotics for humans and livestock operations has led to an increase in dosing of these products to waterways (Phillips, et al., 2010).

The NPS Natural Resources Program Center developed a scoping report regarding emerging contaminant presence, issues, and research needs (Landewe, 2008). This publication notes a study by Swartz, et al. (2006).(http://pubs.acs.org/doi/full/10.1021/es052595%2B) that found septic systems near Cape Cod National Seashore were not effective in removing compounds that may act as endocrine disruptors. Also mentioned is a national inventory of organic waste contaminants by Kolpin, et al. (2002) that identified water contamination at Lowell National Historical Park and within the Boston area national park units. The Phillips et al. (2010) report includes sampling near wastewater treatment plants that receive pharmaceutical effluent within a supply area for New York reservoirs, which could suggest a source of pollution to Delaware River waters.

A series of research proposals have been developed in response to the observed need to increase our knowledge base of presence and effects of emerging contaminants in NPS waters within the Northeast Region. Robin Lepore (DOI Northeast Regional Solicitor) and Alan Ellsworth (NPS NER Hydrologist) met with EPA Region 1, USFWS, USGS, and Commonwealth of Massachussetts staff to share common interests involving emerging contaminants in the Sudbury, Assabet, and Concord (SuAsCo) Rivers (fig.1). These rivers comprise the system defined as the SuAsCo Wild and Scenic Rivers which flow through Minute Man and Lowell NHPs and the Great Meadows National Wildlife Refuge. These rivers are effluent-dominated and through this cooperative effort a study has been initiated by EPA to examine the extent and effects of endocrine-disrupting chemicals. In an attempt to inventory a larger spectrum of national park waters, Paul Bradley of the USGS-South Carolina Water Science Center proposed to examine occurrence and biodegradation of contaminants of emerging concern at Shenandoah NP (VA), Gettysburg NMP (PA), and along the Farmington National Wild and Scenic River (CT), whose waters may be contaminated by wastewater treatment plants upstream or airborne deposition. Funding for this effort and opportunities to initiate a more national scope of NPS waters are still being explored.

Figure 1. Confluence of Sudbury, Assabet, and Concord Rivers (SUASCO). This area comprises a designated 29-mile Wild and Scenic River complex.

A USGS study of groundwater and community septic system connectivity at Fire Island National Seashore is described on page 12. Further investigations at Fire Island are currently examining how this water is expressed through submarine transport into the Great South Bay (fig .2). The established hydraulic connection between the Fire Island aquifer and high seasonal-use septic inputs leads to an examination of whether emerging contaminants are transmitted via this pathway and how they may be affecting the associated ecosystem health. Pat Phillips (USGS-NY) worked with Fire Island NS and regional aquatic staff to develop a proposal to analyze these waters for organic wastewater compounds.

The NPS needs to remain active in working with cooperators to identify emerging-contaminant pollution and support evaluation of associative effects. As managers of public lands that are generally considered protected pristine environments, it behooves the NPS to offer these areas as natural laboratories and strive to improve their condition. Progress has been made in improving wastewater treatment technologies (Phillips, et al., 2005) and NPS managers should encourage treatment plant operators to employ these in their watersheds as soon as practicable.

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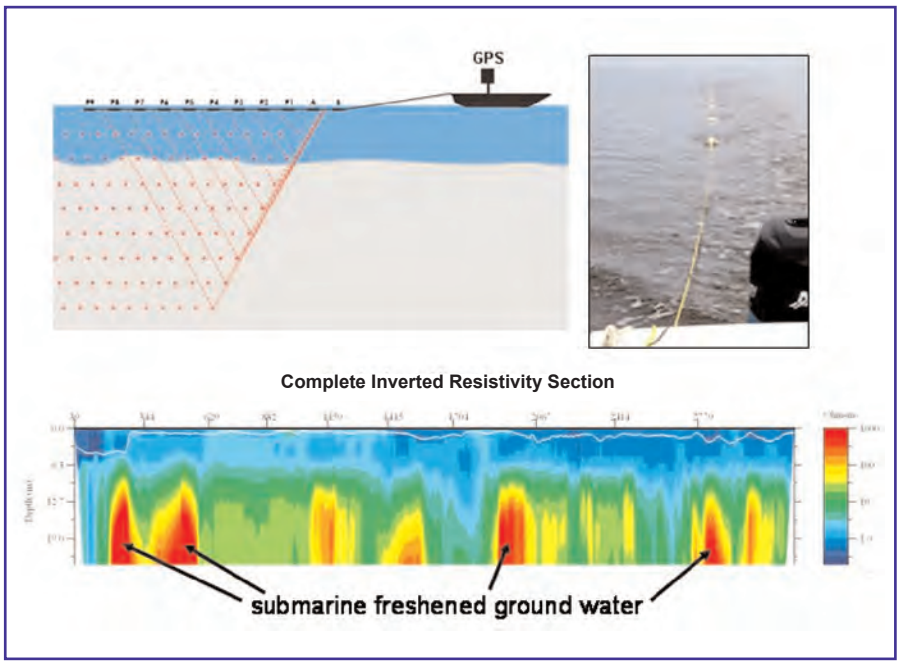


Figure 2. Continuous resistivity profiling is performed by towing a streamer with multiple electrodes behind a boat (upper panels), and then using inversion software to convert measurements of the apparent electrical resistivity of the water-sediment system into resistivity profiles (lower panel). Higher resisitivity values (red) indicate low-salinity groundwater.

Following the Freshwater

At Fire Island National Seashore

In the summer months, about 2.2 million people spend time on Fire Island National Seashore (NS), located on a 32-mile barrier island along the south shore of Long Island, New York. The presence of all these visitors has a heavy impact on the quality of the island's fresh groundwater that eventually flows into the Great South Bay on its north shore and the Atlantic Ocean on its south shore. Most (80%) of this freshwater, carrying nutrients and contaminants, is eventually discharged into the bay and the back-barrier estuaries where there is seagrass habitat, shellfish, finfish, and intense recreational activity by visitors. Therefore, in the interests of the surrounding ecosystem, the National Park Service and the U.S. Geological Survey have devoted much attention to the island's groundwater (freshwater) hydrology. A project proposed in 2010 (not funded) would sample groundwater during summer months for emerging contaminants, hormones, and other endocrine disruptors associated with septic tank discharges. These contaminants are discussed in the story by Alan Ellsworth on page 10.

A three-year study begun in 2004 focused on describing and modeling the groundwater flow and measuring levels of nitrogen that enter the bay from Fire Island NS. One product of that study was the report *Analysis of the Shallow Groundwater Flow System at Fire Island National Seashore, Suffolk County, New York* by Christopher E. Schubert (http://pubs.usgs.gov/sir/2009/5259/pdf/sir2010-5259_508.pdf). Because the hydrology of groundwater is relevant to the proposed study of emerging contaminants, and because the hydrology of freshwater on an island surrounded by saltwater is itself quite interesting, it is worthwhile to briefly present it here. Most of this discussion is taken (much condensed and simplified) from the paper by Schubert.

The freshwater supply used at Fire Island NS comes from the Magothy aquifer (also pumped in areas of New York, New Jersey, and Maryland). The Magothy aquifer lies below, and is not connected to, the island's shallow freshwater lens. These two groundwater reservoirs are separated by unconsolidated material containing brackish water and a clay layer, the confining unit of the Magothy aquifer (see fig.1).

The source, or recharge, of the freshwater is rain, snow, and the discharge from sewer and septic systems that percolate to the water table. The fresh groundwater

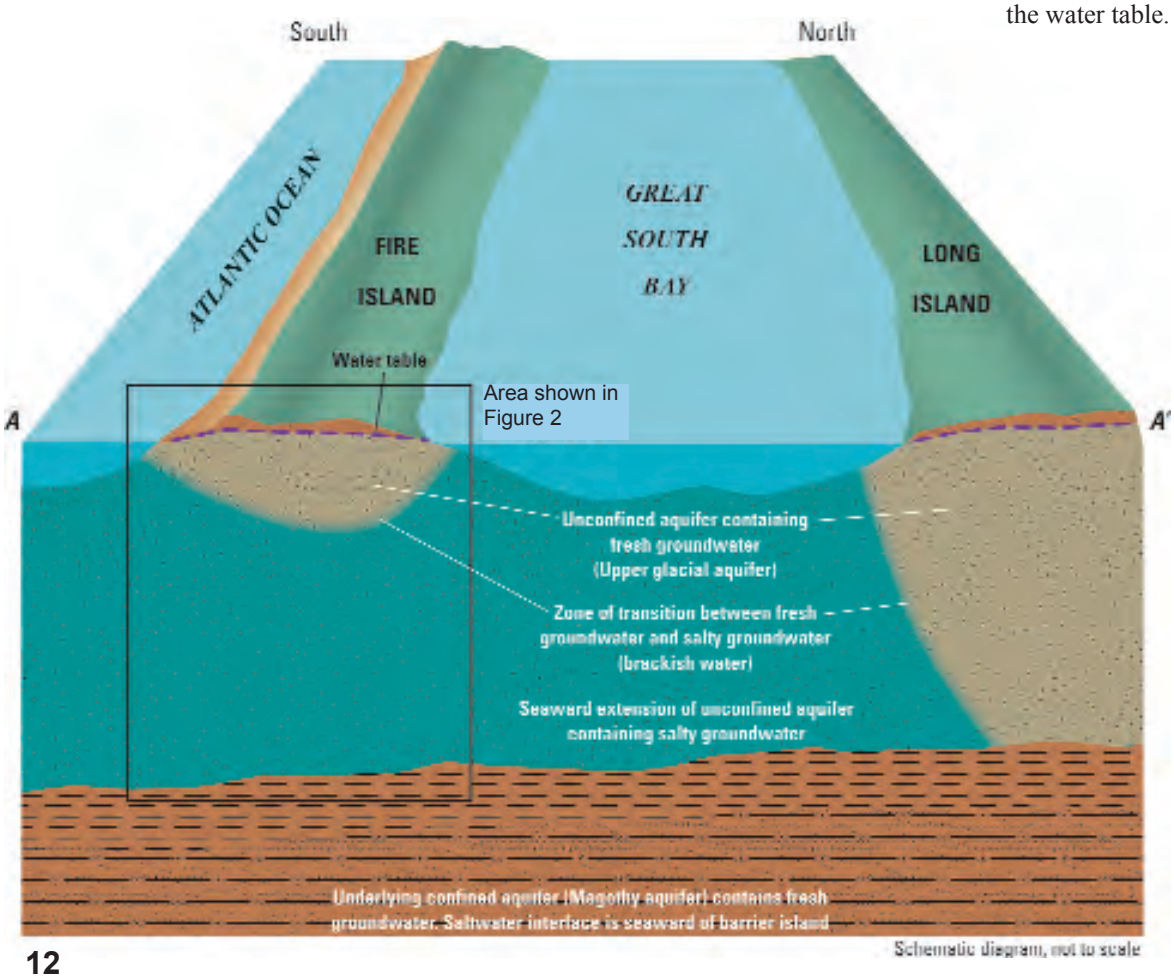


Figure 1. Block diagrams show that Fire Island is underlain by an aquifer system that consists of unconsolidated deposits of clay, silt, sand, and gravel along the southern shore of Long Island. (from Schubert, 2010)

lens is bounded laterally by marine surface waters and below by saline groundwater. Between this freshwater reservoir and denser saltwater there is a zone of diffusion that acts as a relatively impermeable boundary. The fresh groundwater gradually seeps across the seabed and discharges into marine waters near the shore or into saline groundwater.

The level of the freshwater table rises near the shore under the influence of wave action and tidal pumping. Near the ocean shoreline where these influences are strongest, groundwater flow divides (see Figure 2), with some of it seeping out into the ocean, but most flowing north into the bay. The model of this flow indicated that, from the point of recharge to the point of discharge at back-barrier estuaries or the ocean, median travel time was 3.4 years, and virtually all groundwater was found to be younger than 20 years.

Although 81% of Fire Island NS is recreational and open space, wastewater from developed areas, mostly unsewered, was found to contaminate the groundwater in undeveloped areas downgradient. This wastewater passes through sandy soils with little capacity for biodegradation. Then it flows into the estuaries where it may threaten the health of the vegetation, fish, and other wildlife that live there. Understanding the composition of the groundwater, the path of its flow, and its effect on the ecosystems that receive it will provide the insight necessary to inform the park's efforts to protect the life in its waters.

Thanks to Michael Bilecki, Chief of Resource Management at FIIS, for bringing this research to our attention and providing materials for the story.

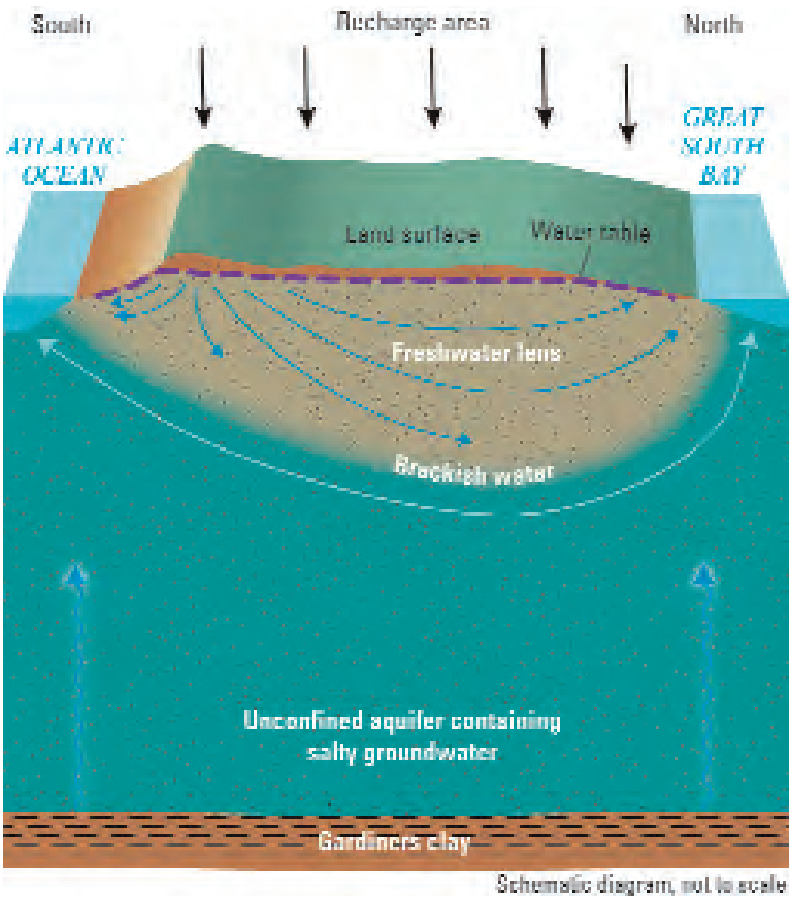


Figure 2. The directions of fresh and brackish groundwater flows beneath Fire Island, N.Y. are toward the Atlantic Ocean and Great South Bay. (from Schubert, 2010)

So Why Don't We Hear Much About Acid Rain Anymore?

A Shenandoah National Park Story

Jim Schaberl, Ecologist, Air and Water Resources, Shenandoah National Park

Air pollution impacts a range of concerns at Shenandoah National Park (NP) from reduced visibililty to high tropospheric ozone that can harm visitors and terrestrial ecosystems alike. A less apparent impact comes in the form of atmospheric deposition of airborne emissions which can occur in precipitation and fog (wet forms) or deposited as tiny particles on a sunny day (dry forms). Deposition components, or "species" of elements as chemists call them, are sources of acid deposition – or "acid rain." Two of the biggest culprits in acid deposition are various species of nitrogen (N) and sulfur (S), that, when combined into molecules like nitrates and sulfates, are acidic and can be harmful to ecosystems.

Probably the most publicized acid rain topic of the past is not at Shenandoah NP but the acidification of lakes in the Northeastern states. Long-term studies in the Adirondacks of NY, conducted by scientists from Syracuse University, provided a lot of information to the media about acid impacts to lake systems. Regulatory changes were implemented by EPA in 1995, in part as a result of such long term scientific studies demonstrating the negative impacts of acid deposition in (especially) aquatic systems.

EPA regulations targeting acid deposition resulted in reduced emissions from various sources which lowered deposition rates

of N and S in the past decade or more across the eastern U.S. Monitoring of lake water chemistry and biota in northern systems has indicated certain levels of recovery as a result of cleaner air (Driscoll et. al. 1998). Recovery trends in lake systems are success stories of Clean Air Act regulations.

At Shenandoah NP we are fortunate to have one of the longest water quality monitoring programs in the National Park Service. A cooperative relationship between the park and the University of Virginia (UVA) formed the Shenandoah Watershed Study (SWAS) in 1979. SWAS objectives focused on measuring the impacts of acid deposition in relatively undisturbed watersheds across the park. Sampling was stratified across bedrock types from the acid-sensitive siliciclastic to the better buffered basalt types (see page 15).

UVA scientists have documented and published results of their work over the years and have defined two primary impact categories of stream acidification: chronic and episodic. Chronic acidification is the longstanding condition of relatively consistent low pH and Acid Neutralizing Capacity (ANC) values – where only certain organisms can survive and fish and macroinvertebrate species that can't tolerate these conditions are lost. Episodic acidification is more nuanced; stream pH drops significantly during a precipitation event and may drop to levels especially harmful to aquatic biota – conditions referred to as acid shock. Timing of these episodic events is critical. Two back-to-back events when ANC values drop to zero during a sensitive spring season could destroy an entire population of aquatic organisms (Rice et. al 2007). Park fish and macroinvertebrate inventories in acid-sensitive watersheds have been found to have significantly lower species diversity and abundance (see chart page 14) after these events than before these episodes. Hindcast models indicate no park streams had poor ANC values in 1900, indicating that acid impacts to biota are most likely the result of anthropogenic deposition (Sullivan et. al. 2008).

Is it getting any better?

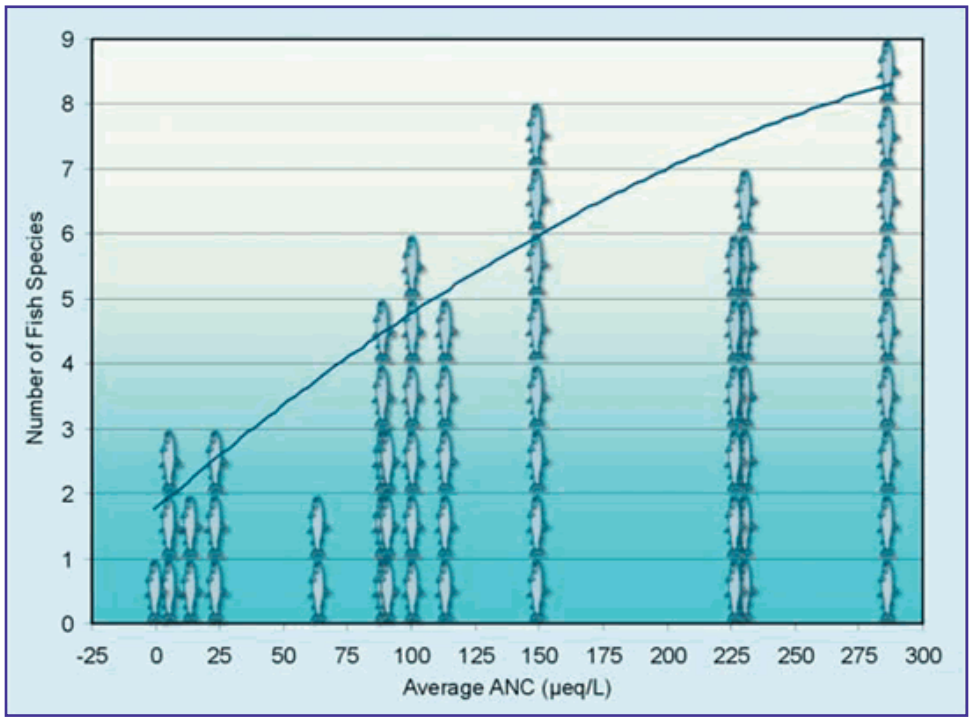
Although air monitoring data at Shenandoah from 1997-2008 show a slight decreasing trend for deposition of N and S (National Park Service, ARD 2009), SWAS program water quality data show little to nonimprovement, unlike the northern study area trends. In the North, EPA regulations brought about some recovery in lake waters, and that got media attention. That's why we don't hear much about acid deposition any more. But, at Shenandoah NP, we still have acid streams.

Why is there no improvement in Shenandoah NP streams (versus northern lakes)?

UVA scientists documented that the unglaciated soils of Shenandoah adsorb S – essentially bankrolling S in the soils across the park. The S in soils slowly leaches to streams and contributes to acidity. Recent streamwater chemistry modeling of future projections documented that some of the most sensitive watersheds may not recover for a century or more even if S deposition ended today (Sullivan et. al. 2008). With the number of coal-fired power plants currently operating in the Ohio Valley and Mid-Atlantic states, an end to S deposition certainly isn't possible in the near term.

Tracking recovery – the benefits ofm-long-term monitoring

Both the Adirondack Lakes study and the Western Virginia Streams study (includes SWAS) have been very influential in the promulgation of new acid deposition regulations. Because of the longitudinal data and volume of research published from these studies, EPA has recently identified both the Adirondacks and Western Virginia as the two primary study areas to track acid deposition and the effect of regulations on recovery for the eastern U.S.



Number of documented fish species in a stream as a function of their respective stream Acid Neutralizing Capacity (ANC), Shenandoah National Park, VA (taken from Sullivan et. al. 2003).

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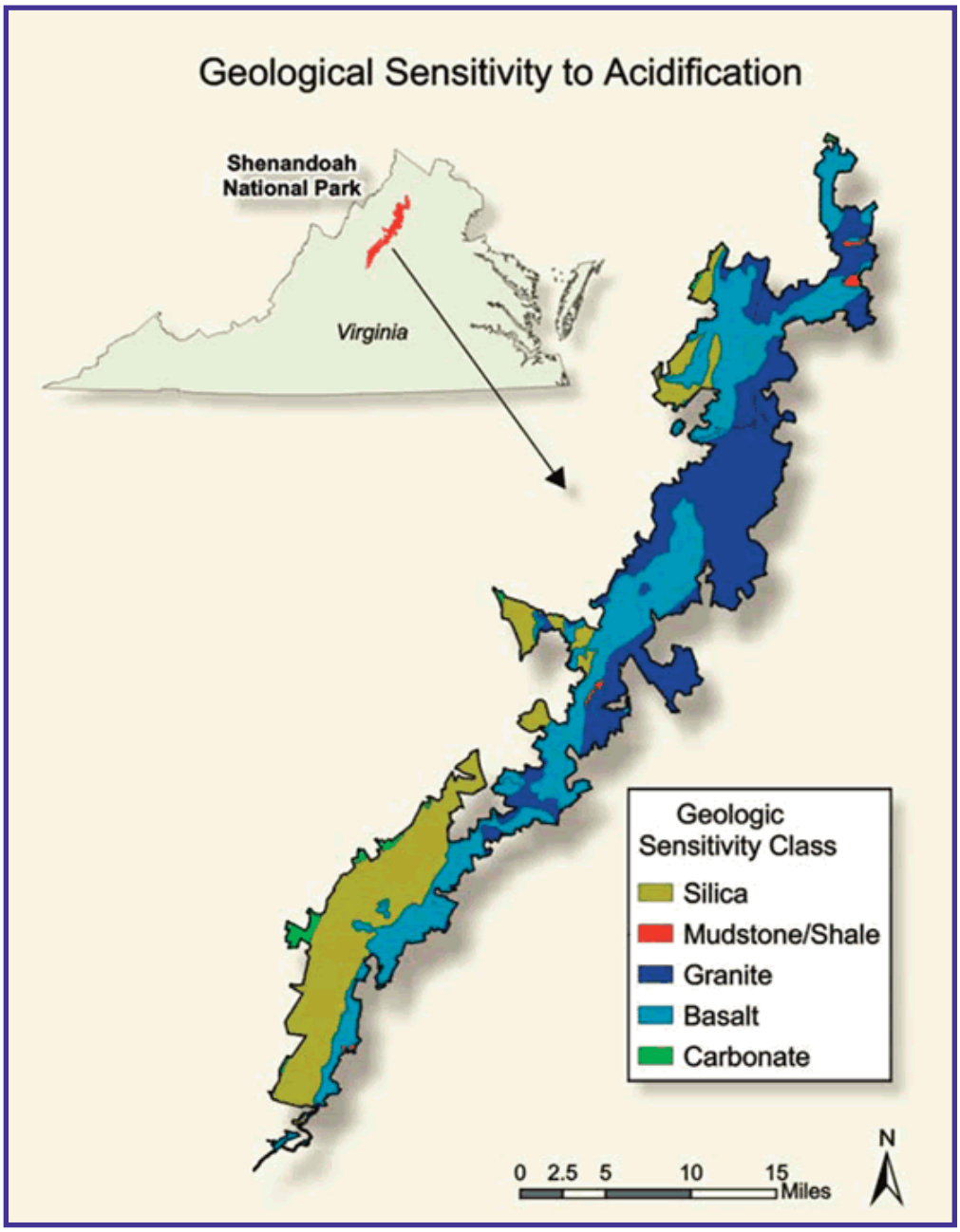

Distribution of watersheds in relation to major bedrock classes at Shenandoah National Park according to Shenandoah Watershed Study. Bedrock types are listed in order of sensitivity, silica being the most sensitive.

HELP WANTED ON GULF COAST

"Ologists" needed as Resource Advisors (READs) to monitor on-going Gulf oil spill clean-up operations. Work will be on Gulf Island National Seashore and Bon Secour Wildlife Refuge lands. Assignments are 14-21 days, 12 hour (or longer) days.

READs are on-the-ground monitors for oil spill clean-up crews on the Gulf Coasts of Mississippi, Alabama and Florida and are assigned to the Incident Command in New Orleans.

READs gather information on critical habitat, nesting shore birds, turtles (during the summer), and seasonal nesting for eagles; ensure minimal disturbance for overwintering bird populations; and provide information for the development and implementation of the Shoreline Treatment Recommendation documents. The READS also monitor wildlife populations related to disturbance activities from clean-up crews and equipment.

It's a long day, 6:00 am until 6:00 pm, and sometimes later. It's great work, getting to see all kinds of birds; working along shorelines where you'll see dolphins, rays, schools of fish; and the beaches are beautiful.

Go to http://inside.nps.gov/waso/waso.cfm?lv=3&prg=1006 Fill out the form and send it to The Emergency Incident Coordination Center (EICC). Or contact Michael Bilecki and he can put you in as a name request.

P.S. There are also positions needed for finance, time keepers, etc.

National Park Service--Northeast Region

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Please let *Science and Management* know of projects and practices at your park or network that might be useful to colleagues elsewhere. Contact the editor at bmb4@psu.edu.

Sound science is the foundation for good resource management decisions. The National Park Service invests in science programs to responsibly protect and manage the precious resources entrusted to our care. The power of this research is multiplied when the information is shared. This publication, *Science and Management*, is brought to you from the Northeast Region's Natural Resources and Science Division. Its goal is to share with park staff, scientists, and the public, the innovative resource management work being done throughout the region.

Dennis Reidenbach, Regional Director