STROUD™
WATER RESEARCH CENTER

2009 Annual Report

A YEAR IN REVIEW

"In much the same way as one goes about reforesting the riparian area to protect a stream, one tree at a time, we are laying the foundation for a sustainable future — for ourselves and our most precious resource, fresh water.

Photo: Dave Moser

Photo: © Barry Lewis, GreenTreks Network, Inc.

Photo: David H. Funk

2009 At a Glance

A. Stroud scientists conducted a planning expedition to the Rio Sierpe in Costa Rica to establish a baseline of data from which to measure water quality changes and create a comprehensive watershed management plan.

B. The Education department received funding from the National Science Foundation, validating the Center's innovative teaching ideas, including *Model My Watershed*, which will introduce Pennsylvania school children to their watershed and allow them to model the impact of various land use planning options.

C. Stroud scientists provided the Department of Justice with research and expert testimony that could affect the protection of 100 million acres of US wetlands.

D. Thirty-two college interns joined the Center to gain first hand experience as researchers under the tutelage of our senior scientists.

E. Stroud scientists and educators teamed up with Longwood Gardens to develop *Cultivating an Ecosystem Esthetic*, a multi-faceted program aimed at teaching Longwood visitors best management practices to create beautiful, carbon-neutral landscapes.

F. Stroud research defining the benefits of streamside forests served as a basis for Pennsylvania's proposed stormwater regulation policy requiring mandatory 100 foot-wide riparian forest buffers.

G. Stroud scientists called attention to the significant role of inland waters in the carbon cycle and climate change in the *Boundless Carbon Cycle*, a paper they coauthored with European colleagues that was published by *Nature Geoscience* magazine.

H. Stroud scientists published the first paper detailing the quantity and quality of the Congo River's dissolved organic carbon, its photochemical properties and processes, and how its reactivity contributes to greenhouse gases and oceanic carbon.

I. Dr. Jinjun Kan agreed to head the Microbial Ecology department, to build on the work begun by Tom Bott more than four decades ago, and bring new expertise that will expand the Center's influence.

J. Stroud research on the effects of temperature changes on macroinvertebrates and fish provided the technical data for revisiting existing legislation protecting streams and rivers from thermal pollution.

K. The Center's watershed education programs served more than 3,500 students, teachers and adults showing them how to monitor water quality and make more informed decisions that affect water quality and availability.

L. Stroud scientists identified significant biological differences in Pennsylvania's best streams that could affect the regulations for their protection and management.

Board of Directors

2009

Message
FROM THE DIRECTOR

ONE TREE AT A TIME

As director of the Stroud Water Research Center, I lead a staff of exceptional scientists who are dedicated to understanding everything they can about fresh water. All of us here take pride in knowing that our research has made important contributions to the scientific community's knowledge of freshwater ecosystems and has provided both individuals and policy makers with the tools they need to become good stewards of the water and the land through which it flows.

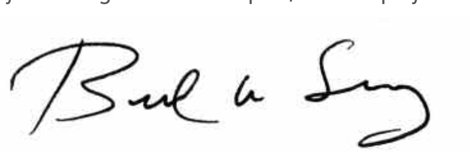
Over the last four decades our scientists and educators have accomplished a lot — and last year was no exception. For example, the National Science Foundation awarded us, and colleagues at the University of Delaware, a significant grant to establish the Christina watershed as one of only six critical zone observatories in the country. Our charge is to assess the impact of human land uses on carbon exchanges among land, water and the atmosphere, an important element in assessing global climate change. In addition, the US Department of Justice requested our expert testimony in its efforts to protect the remaining 100 million acres of the nation's wetlands. And Pennsylvania is using our research to improve oversight of its highest quality streams, while our 20-year study of a streamside forest served as a basis for the state's proposed stormwater regulations. While our studies often have their origins in nearby waterways, their findings have implications for our global water resources.

As I look back at the amazing journey that has brought us to this point, I am confident that we have built a solid foundation for meeting the challenges that lie ahead. Fresh water, the life blood of all living things on Earth, is under siege, and each project that we have undertaken has expanded our knowledge of this irreplaceable resource. Because of the complexity of our work, each has also tested us as an organization, and with your help we continue to grow stronger.

In 2008 we added a fish ecologist, who has enabled us to embark on critical research on thermal pollution of streams and rivers. Now, as we await the imminent arrival of our new molecular microbiologist, we are developing projects to explore exciting new areas of microbial ecology. Our long-term success rests on our ability to attract such exceptional scientific talent — but it doesn't stop there.

Because we are determined to have our science make a difference, our educators continue to develop innovative programs that ensure our findings are most effectively disseminated for use by individuals and policy makers, both here and around the world.

So much of what we have done — and what we hope to accomplish — depends on you, our friends. Together we have created something special — and, just as we plant a forest one tree at a time, so we as an institution grow one friend at a time. I am grateful for the support you have given us in the past, and I hope you will continue to stand with us in these difficult and exciting times.



Stroud scientists are leading a study of the Christina River Basin to understand the impact of centuries of settlement, deforestation, agriculture, and development on the carbon cycle. The research aims to settle scientific debate on whether human induced erosion modifies greenhouse gas emissions from the landscape and impacts climate change.

Photo: Leslie Kipp

Moving Freshwater Science Forward:

ESTABLISHING A CRITICAL ZONE OBSERVATORY IN THE CHRISTINA RIVER BASIN

In 2009, the National Science Foundation (NSF) awarded the Stroud™ Water Research Center and the University of Delaware a $4.3-milllion grant to establish a Critical Zone Observatory (CZO) encompassing the entire Christina River drainage basin, which includes four major streams: the White Clay, Red Clay and Brandywine Creeks and the Christina River. One of only six CZOs in the nation, these observatories have been established to apply the disciplines of hydrology, geology, and biology to address large, fundamental and complex questions about the Critical Zone — the area from ground water aquifers to the tree tops — that sustains most life on earth.

The new observatory in the Christina River Basin places the Center among an elite group of watershed scientists and will attract the attention and interest of earth surface scientists from around the world. "It's going to catalyze the kind of intense data collection, sharing, discourse and collaboration that really makes science tick, moving it forward in ways we could only dream of before," says Stroud scientist, Anthony Aufdenkampe, one of the project's leaders. He adds, it will place the Stroud Water Research Center at the hub of exciting new collaborations and developments in freshwater science.

Studying The Effects Of Human Induced Erosion On Climate Change

The Christina River Basin CZO is the only one of the observatories located in a densely populated area that has experienced extensive human development over a long period of time. Since they first arrived in the 17th century, settlers in the 565 square-mile Christina watershed have cut down its old-growth forests, tilled the fields they cleared, erected mills and factories along its streams and rivers, and built cities, highways, suburbs and shopping malls to serve a growing population of more than 500,000 people. Today, the watershed which is comprised of five counties and 60 cities and towns in Delaware, Maryland, and Pennsylvania, is virtually unrecognizable from its original state.

The scientific goal of the Christina River Basin CZO partners is to understand the consequences of this kind of development on a watershed's ability to consume greenhouse gases and mitigate global climate change. In particular, the team will determine whether processes involving large-scale soil erosion and stream transport increase the production of carbon dioxide or the sequestration of carbon in floodplain and coastal sediments, significantly enhancing our understanding of the role of inland waters in the global carbon cycle. "Carbon is transformed and destabilized at the point when soil leaves the terrestrial ecosystem and enters aquatic systems, as happens during erosion," says Stroud scientist Lou Kaplan. "What we don't know is how that happens, or the ultimate fate of the mobilized carbon. Understanding this could yield important information to the debate about climate change."

"Soils contain 85% of all the active carbon on Earth," states University of Delaware soil scientist Donald Sparks, principal investigator of the Christina River Basin CZO, S. Hallock du Pont Chair in Soil and Environmental Chemistry, and Director of the Delaware Environmental Institute. "The opportunity to combine our expertise in soil science at the University of Delaware with the expertise in aquatic biogeochemistry of the Stroud Water Research Center," says Sparks, "represents the type of scientific collaboration essential to address the complex and critical environmental issues on which the CZO is focused." To get a complete picture of how the interaction of carbon and minerals caused by erosion could alter the earth's climate — and the role humans play in the process — we need to take a whole


Photo: Anthony Aufdenkampe

Centuries of development make the Christina River watershed the perfect natural laboratory to study how large-scale erosion processes transform and destabilize carbon, and the consequential effects of its respiration, sequestration and transport on the carbon cycle.

CZO team members will study the biological, chemical and geological changes to the watershed and incorporate them into a scalable, predictive model. Shown left to right: Stroud Water Research Center scientist Anthony K. Aufdenkampe, Donald L. Sparks, the University of Delaware S. Hallock du Pont Chair of Soil and Environmental Chemistry, Stroud senior research scientist Louis A. Kaplan, and assistant professor of Plant and Soil Science at the University of Delaware, Kyungsoo Yoo. Hidden from view: graduate student Chunmei Chen.

watershed approach," said Aufdenkampe. "With the huge amount of data that has been collected since the earliest studies in the 1950's," team member and Stroud scientist Denis Newbold continued, "the Christina watershed is an ideal natural laboratory to study biological, chemical, and geological changes caused by humans over time and to put all these activities into a scalable, predictive model."

Building The Data Infrastructure To Support 21st Century Science

Nineteen percent of the CZO grant monies are being directed towards the acquisition and implementation of critical technologies required to collect and share data, a requirement NSF designed to ensure that the data generated, and their overall investment, are both well leveraged. For example, collecting water chemistry measurements used to require a labor-intensive process that yielded a relative handful of measurements per week. The infusion of funding allows the Center to purchase and install six, new field-deployable dissolved organic carbon analyzers and other stream chemistry sensors in locations throughout the watershed. These new sensors will add a dozen new variables to data that scientists can collect and will transmit those data every three minutes, revolutionizing our understanding of stream processes. In addition, data processing time will be reduced from weeks to seconds, getting information into the hands of those that can use it virtually instantaneously. Says Audenkampe of the new technology, "This is a total game changer for us and every other scientist who will utilize the data output."

The new technology infrastructure will go far beyond serving the needs of scientists studying effects of human induced earth movement on the carbon cycle; it will also give Stroud scientists, local agencies, and policy makers the tools to study water quality in a watershed that provides drinking water for more than half the population of Delaware and nearly all of Chester County, Pennsylvania. Data and results will be transferred wirelessly to an open, web-based platform accessible to anybody, providing a useful resource to all organizations that monitor water quality to maintain standards consistent with the Clean Water Act, including the Environmental Protection Agency, the US and Delaware Geological Surveys, the Chester County Water Authority, the Delaware River Basin Commission, which is comprised of representatives from four states, and the Christina Basin Water Quality Management Committee — whose representatives from 15 local, state and federal agencies are charged with providing scientific input to policy makers.

The tools and focus of the CZO will also establish an extraordinarily complete and integrated knowledgebase and monitoring network. This will be of great value to the scientific community at large, as well as the Stroud Water Research Center's Education department, which will translate its scientific findings into accessible language and public programs for students, teachers, and community groups.

Facilitating Collaborations That Will Move Freshwater Science Forward

Stroud scientists have been collaborating with their University of Delaware colleagues for years across a number of projects, including the study of earthworm invasion on the soil structure and hydrology of important North American forests. With the CZO, that long-term collaboration is further strengthened.

CZO status enriches both organizations with an increased ability to attract qualified post-doctoral researchers and graduate students, key individuals that provide the manpower and intellectual resources essential to research hypotheses, and produce and analyze data in every scientific organization.

Already the CZO has enabled Stroud educators to collaborate with Penn State's Dr. Chris Duffy, whose watershed-scale numerical model is now being incorporated into *Model My Watershed,* a Web 2.0 educational project conceived by Stroud educators and scientists to teach students about their watersheds. Also funded by NSF, this program is intended to increase interest in science, technology, engineering and math careers.

Finally, in addition to the CZO grant, NSF is providing incentives in the form of a new line of funding for other scientists across the nation to pursue research in collaboration with the CZOs, to leverage their datasets, infrastructure and expertise. This supplementary commitment guarantees visibility and will stimulate an ongoing stream of new collaborators, ideas, and proposals to bolster the potential for significant scientific discovery.

Links

- To learn more about the Christina River Basin Critical Zone Observatory, go to: http://www.udel.edu/czo/
- To read the news release in the University of Delaware's *UDaily*, go to: http://www.udel.edu/udaily/2010/sep/observatory092809.html

The 565 square-mile Christina River Basin, home to the CZO, provides the drinking water for more than half the population of Delaware and nearly all of Chester County, PA.

Research findings have placed the Center in a position to establish an approach to examining wetland-stream connections that could help protect the remaining 100 million acres of public and privately held US wetlands from development.

Photo: Dave Arscott

Protecting our Wetlands:

HOW APPLIED SCIENCE COULD SAVE 100 MILLION ACRES

There are no national laws designed specifically to protect our wetlands, which could account for the fact that Pennsylvania has already lost half of its wetlands to agriculture and development, according to the Pennsylvania Campaign for Clean Water. By 1990, in fact, the US Fish and Wildlife Service reports that 22 states had lost 50% of their wetlands and seven states, including California, had lost as much as 80%. More than 100 million of the nation's 221 million wetland acres have been converted to farmland and urban development, significantly altering the ecosystem.

Why this matters is a subject that concerns many because wetlands serve vital functions that go far beyond simply providing habitat for wildlife. Wetlands sequester harmful pollutants that would otherwise end up downstream and in our drinking water. They reduce the flooding that causes many deaths and billions of dollars in crop losses and property damage annually. They improve water quality by taking up dissolved nutrients like nitrate and, they help recharge groundwater aquifers, the source of drinking water, where water infiltrates the surface and percolates through the subterranean landscape.

Under current laws, however, to protect what is left of the wetlands in the United States requires demonstrating the existence of an endangered species, or for those wetlands that are in proximity of the coast, the application of the Coastal Zone Management Act. The Clean Water Act also provides protection for wetlands if one can demonstrate a definitive physical, chemical and biological connection between it and a stream that is protected under the Act, as defined by the 2006 Supreme Court decision, Rapanos v. United States.

Linking Wetlands To Protected Downstream Waters

With this in mind, the US Army Corp of Engineers, one of the two governmental organizations charged with enforcing the Clean Water Act, approached the Stroud™ Water Research Center for expert advice on wetland-stream linkages. Their goal was to recommend to the US Department of Justice an organization capable of independent research and expert testimony to characterize the physical, chemical, and biological connections between a wetland area and a stream covered by the Clean Water Act. The characterization of such connections would help the courts decide whether the Army Corp of Engineers or the Environmental Protection Agency (EPA), the other agency entrusted with enforcing the Clean Water Act, had jurisdiction to protect the wetlands from dredge-and-fill activities or chemical and physical pollution.

This nine-month project placed the Center in a position to establish an effective approach to examining wetland-stream connections that could help to protect the remaining 100 million acres of public and privately held US wetlands from development.

The project was a perfect fit, taking advantage of the knowledge the Center could bring to bear from its extensive experience with hydrological and chemical tracers in the New York City watershed study, to its understanding of stream metabolism and carbon cycling — work the Center pioneered in the 1990s — as well as its comprehensive knowledge of macroinvertebrates and fish communities and their respective functions in freshwater ecosystems.

"First we had to establish that there was actually a physical connection or hydrological flow from the wetland to the stream," said senior scientist Denis Newbold. Stroud scientists relied on hydrological tracers, including bromide salt, to demonstrate water movement from the wetland area to the stream.

Then chemical tracers were employed to characterize the functional role of the wetland stream channel in sequestering or delaying the downstream transport of pollutants, including heavy metals like zinc, and its role in the removal of nutrients like nitrate — a component of fertilizers and a major contributor to ocean dead zones — from the stream surface waters.

To characterize the biological connections, Stroud scientists took an ecosystem perspective and looked at the aquatic food web. "We studied everything from the organic molecules that sustain the microbial communities of these water bodies, to the invertebrates or insects that eat the microbes, and the fish populations that eat the insects," said senior scientist Louis Kaplan. What they found was evidence of the biological support of downstream communities by the energy exported from the wetland in the form of dissolved organic carbon.

In addition, there was much data to support that insects and fish required both stream and wetland habitats throughout various stages of their life cycles for feeding, refuge, breeding and nurseries. In fact, some insect species depended on the wetland exclusively. "Without wetlands many of the fish species we found would not be viable," said Willy Eldridge, who heads the Center's fish molecular ecology group. While the Center found redfin pickerel, eastern mudminnow, some native catfish, pirate perch, tessellated darter, and bass and sunfish species, the most obvious connection between the wetlands and larger streams and rivers was established by the presence of the American eel. "American eels are born in the Atlantic," says Eldridge, "but they migrate into streams and rivers where they feed and grow, only to return as adults to the ocean where they spawn and die." Their presence in the headland waters of the wetlands as well as the stream, underscored the physical connection of these waters and the essential nature of both areas as habitat for the species.

Left: Stroud scientist Anthony Aufdenkampe and research technician Sara Geleskie calculate wetland discharge as part of their efforts to establish a hydrological connection between the wetland in question and a protected stream. Right: Research technician Dave Montgomery records the location of traps set to determine the presence of eels in the wetland complex to demonstrate the biological and hydrological connections of the wetland and protected downstream waterways.

Providing The Template For Evaluating Jurisdiction

"We've shown how a function in a wetland has ramifications for downstream waters," said Dave Arscott, one of the principal investigators on the project and the Center's assistant director. In fact, the holistic approach taken by Stroud scientists to establish the physical, chemical, and biological connections between the two water bodies that prompted this study, has created a virtual template for future evaluations, laying the framework of how to approach the character of a specific wetland when determining the jurisdiction of the US government under the Clean Water Act — and for wetlands everywhere this is welcome news.

The Department of Justice requested the Stroud Water Research Center take the knowledge gained from this research and develop educational materials to ensure that those who participate in related legal proceedings in the future will have a basic understanding of wetlands and their connections, increasing the odds that wetlands will receive protection.

Links

- To learn more about source water protection and the role of the Environmental Protection Agency, go to: http://cfpub.epa.gov/safewater/sourcewater/index.cfm
- To learn more about the Clean Water Act and the 2006 Rapanos v. United States decision go to: http://www.epa.gov/watertrain/cwa/ and http://en.wikipedia.org/wiki/Rapanos_v._United_States

Research Projects

Physical, chemical, and biological connections between a headwater wetland complex and downstream waters, U.S. v. D. Donovan, No. 96-484

Funded by: US Department of Justice, Environment and Natural Resources Division

To assist with a legal decision regarding the jurisdictional determination of a wetland dredge and fill permit, Stroud scientists studied and characterized the hydrological, chemical, and biological linkages between a wetland complex and a downstream estuary.

Principal Investigator: Louis A. Kaplan

Collaborators: Bernard W. Sweeney, David B. Arscott, Anthony K. Aufdenkampe, Thomas L. Bott, William H. Eldridge, John K. Jackson, J. Denis Newbold

Nutrient balances in an estuarine salt marsh

Funded by: Kent County, Delaware

This study was designed to determine whether salt marshes are a net producer or consumer of nutrients and whether nutrients from Kent County's wastewater treatment plant are significantly contributing to low oxygen conditions in the Murderkill River estuary. Kent County will use this information to determine whether the treatment plant should be moved.

Principal Investigator: Anthony K. Aufdenkampe

Collaborator: William Ullman (University of Delaware)

Consequences of erosion and deposition in the Fly River, Papua New Guinea, on carbon cycling and climate change

Funded by: National Science Foundation

This three-year research project on the Fly River in Papua New Guinea, one of the more dynamic sediment delivery systems in the world, aims to determine whether the combined effects of mountain erosion and deposition in flood plains and estuaries have important local or global consequences for carbon cycling and climate. In 2009 we conducted extensive field sampling and installed soil water and soil gas collection systems for 2010 sampling efforts.

Principal Investigator: Anthony K. Aufdenkampe

Collaborators: Miguel Goni (Oregon State University), Rolf Aalto (University of Exeter, United Kingdom), Wes Lauer (Seattle University), Bill Dietrich (University of California, Berkeley)

Earthworm invasion: Investigating changes in soil chemistry and carbon sequestration

Funded by: U.S. Department of Agriculture (USDA)

Human activities over the last 100 years have introduced exotic earthworms into many pristine northern forests. These earthworm invasions are moving north at 15-30 feet per year, bringing with them radical changes to forest ecology and soil chemistry. Our study is designed to examine whether earthworms increase or decrease carbon storage in forest soils, with consequences to greenhouse gases and climate change. In 2009 we conducted extensive field sampling and installed soil water and gas collection systems for sampling in 2010.

Principal Investigator: Anthony K. Aufdenkampe

Collaborators: Kyungsoo Yoo (University of Delaware), Cindy Hale (University of Minnesota, Duluth)

The first assessment of Congo River organic matter chemistry and reactivity

Funded by: Stroud Water Research Center

The Congo River is the second largest river in the world, but little is known about it because regional conflict has made its study logistically difficult. In 2009 Stroud scientists published the first paper detailing the quantity and quality of the river's dissolved organic carbon, its photochemical properties and processes, and how its reactivity contributes to greenhouse gases and oceanic carbon.

Principal Investigator: Anthony K. Aufdenkampe

Collaborators: Rob Spencer, Peter Hernes and Johan Six (University of California, Davis), Aron Stubbins (Old Dominion University), Robert Holmes (Woods Hole Research Center)

Christina River Basin Critical Zone Observatory: Quantifying carbon sequestration resulting from human induced erosion

Funded by: National Science Foundation EAR 0724971

In collaboration with the University of Delaware, Stroud scientists established one of six Critical Zone Observatories in the United States and began to establish the sensor and data infrastructures required to test a set of hypotheses about the connections between land use and climate change. The study aims to determine whether large-scale, human-induced soil erosion might transport, bury and sequester carbon in floodplain and coastal sediments, modifying greenhouse gas emissions from the landscape.

Principal Investigators: Anthony K. Aufdenkampe and Louis A. Kaplan (Stroud Water Research Center) and Donald L. Sparks (University of Delaware)

Collaborators: J. Denis Newbold, David B. Arscott, Charles L. Dow, Susan E. Gill (Stroud Water Research Center), Kyungsoo Yoo and Jim Pizzuto (University of Delaware), Rolf Aalto (University of Exeter, United Kingdom), George Hornberger (Vanderbilt University)

Easter Island: Reconstructing the failure of a civilization

Funded by: The Marsden Fund, New Zealand

The collapse of the once thriving human population on Easter Island has been largely attributed to environmental degradation, but questions still remain regarding the causative factors. Our study will determine the sequence and timing of the collapse of humans, seabirds, forest trees and soils by detailed dating and analysis of sediment cores from bogs for DNA, pollen, charcoal, soot, and fecal steroids.

Principal Investigator: Anthony K. Aufdenkampe

Collaborators: Troy Baisden (Institute for Geological and Nuclear Science, New Zealand), Mark Horrocks (Microfossil Research Ltd.), John Flenley (Massey University, New Zealand)

Testing a proxy of historical nutrient status using diatom-bound nitrogen isotopes

Funded by: The American Chemical Society, Petroleum Research Fund

Climate science relies on interpreting proxies of past environmental conditions in dated sediment and ice cores. Our study will develop a rapid approach to analyzing the stable isotopes of proteins within the glass shells produced by diatom algae, which is likely to be an improved proxy for historical nutrient status because of its uniform biological source. Although we will initially apply the results of our studies to studies of ocean sediments, the technique will be transferable to lakes, ponds and rivers.

Principal Investigator: Anthony K. Aufdenkampe

Collaborator: Katarina Billups (University of Delaware)

Abandoned mine drainage remediation and stream function

Funded by: Pennsylvania Department of Environmental Protection (Growing Greener)

Abandoned mine drainage (AMD) impacts thousands of stream miles in PA. This study of stream ecosystems in PA's anthracite and bituminous mining regions looks at the effects of AMD on macroinvertebrate community composition, nutrient utilization, ecosystem metabolism, leaf litter degradation and microbial enzymatic functions. The study also evaluates the effectiveness of AMD remediation on stream biological communities and functions and its implications for cleaning up the Chesapeake Bay.

Principal Investigator: Thomas L. Bott

Collaborators: John K. Jackson, J. Denis Newbold and Bernard W. Sweeney (Stroud Water Research Center), Matthew McTammany (Bucknell University), and Steven Rier (Bloomsburg University)

Monitoring growth and environmental parameters in algal growth systems

Funded by: Philadelphia Renewable Energy

This study assessed whether algae could be grown in experimental ponds and harvested as a biofuel.

Principal Investigators: Thomas L. Bott, Bernard W. Sweeney

Water quality analysis of Costa Rica's Rio Sierpe and its tributaries

Funded by: Blue Moon Fund

Stroud scientists conducted a planning expedition to the Rio Sierpe in Costa Rica to assess water and habitat quality, determine the feasibility of establishing a multi-year monitoring program, and establish working relationships with local individuals and organizations invested in the water quality of the river and its tributaries. We designed a monitoring program to provide a baseline of data on human land-use impacts, evaluate ecosystem services, and set conservation targets and guidelines. This project will ultimately lead to a management plan for the watershed and a model for conservation in other tropical watersheds.

Principal Investigator: Bernard W. Sweeney

Collaborators: William H. Eldridge, Dave B. Arscott, and Anthony Aufdenkampe (Stroud Water Research Center), Wills Flowers (Florida A&M University)

Long-term research in environmental biology (LTREB): How stream ecosystems respond to reforestation and climate in a tropical dry forest

Funded by: National Science Foundation DEB 0516516

More than twenty years of research on tropical streams near the Maritza Biological Station in northwest Costa Rica provide the framework for this study, which examines stream responses both to large-scale, passive re-establishment of tropical dry forests and to the natural moisture gradients (wet versus dry seasons, rain versus dry forest sites) that define much of the character and environment of the Guanacaste Conservation Area.

Principal Investigator: John K. Jackson

Collaborators: Louis A. Kaplan, J. Denis Newbold, Thomas L. Bott, Anthony K. Aufdenkampe (Stroud Water Research Center), Julio Calvo (Instituto Tecnológico de Costa Rica Escuela de Ingeniería Forestal, Costa Rica)

Spatial and temporal variation in water quality among Exceptional Value streams in Pennsylvania

Funded by: William Penn Foundation

This research project continued our work with local watershed groups to use macroinvertebrates in streams to monitor water quality throughout the Schuylkill River basin. In 2008 and 2009 we added Exceptional Value streams outside of the Schuylkill River basin, including North Central Appalachian, Central Appalachian, Northern Appalachian Plateau and Uplands ecoregions in the Delaware and Susquehanna River basins, to help us better understand the fauna in southeastern Pennsylvania.

Principal Investigator: John K. Jackson

Collaborator: Bernard W. Sweeney

Implications of parthenogenesis and hybridization for stream insect communities

Funded by: Pennswood No. 2 Research Endowment and the Stroud Endowment for Environmental Research

This multi-year research project has focused on the discovery of reproduction without males by several species of mayfly in the White Clay Creek and streams throughout eastern North America. The study attempts to understand how this form of "virgin birth" is possible and why it persists in nature.

Principal Investigator: David H. Funk

Collaborators: Bernard W. Sweeney, John K. Jackson

Macroinvertebrate monitoring of water quality

Funded by: Various public and private sources

A series of ongoing macroinvertebrate monitoring projects use aquatic insects, such as mayflies, stoneflies, and caddisflies, to assess water quality in: Flint River, GA; Mississippi River, MO; White Clay Creek, PA and Susquehanna River, PA. Where data are available, we compare current conditions with conditions observed 5, 10, 20 and 30 years ago.

Principal Investigator: John K. Jackson

Collaborator: Bernard W. Sweeney

Effects of elevated and fluctuating temperature regimes on macroinvertebrate and fish in Pennsylvania's warm water streams and rivers

Funded by: Pennsylvania Department of Environmental Protection

This laboratory project investigates macroinvertebrate and fish responses to artificial changes in water temperature, including abnormally warm thermal regimes that approach or exceed physiological and regulatory limits, and daily temperature changes that simulate warm effluent discharges from power plant operations.

Principle Investigators: John K. Jackson, Bernard W. Sweeney, William H. Eldridge

How organic molecules from the watershed influence energy flow in stream ecosystems

Funded by: National Science Foundation DEB 0516449

We grew young deciduous trees in chambers enriched with the stable isotope of carbon, harvested and composted the trees, and extracted the compost to prepare a "tea" of complex, microbially-modified molecules. We are now studying how these molecules are used for energy in both artificial laboratory streams and 1st through 5th order natural streams.

Principle Investigator: Louis A. Kaplan

Collaborators: J. Denis Newbold and Anthony K. Aufdenkampe (Stroud Water Research Center), Robert H. Findlay (University of Alabama), and Peggy H. Ostrom (Michigan State University)

Biofilm ecology in Philadelphia's East Park Reservoir distribution system and the efficacy of control strategies

Funded by: Philadelphia Water Department

Most microorganisms in nature grow attached to surfaces, encased in a protective matrix or biofilm. Our research focuses on the growth and control of microbial biofilms in the East Park Reservoir distribution system. Ultimately, we will test different disinfectant agents for their ability to inactivate distribution system biofilms.

Principal Investigator: Louis A. Kaplan

Collaborators: David A. Stahl (University of Washington) and Anne K. Camper (Montana State University)

Connecting the hydrologic cycle from hill slopes to river networks

Funded by: National Science Foundation EAR 0450331

This collaborative research will generate the first model that links the water and carbon cycles of river catchments by focusing on how water and organic molecules interact with one another and move through hill slope soils, individual stream reaches, and the entire river network.

Principal Investigator: Louis A. Kaplan

Collaborators: J. Denis Newbold and Anthony K. Aufdenkampe (Stroud Water Research Center), and George M. Hornberger (Vanderbilt University)

Long-term research in environmental biology (LTREB): Changes in stream ecosystems in response to a maturing streamside forest

Funded by: National Science Foundation DEB 0424681

This project addresses long-term changes in a stream ecosystem in southeastern Pennsylvania to evaluate best management practices for streamside lands and provide a time frame for ecosystem recovery during reforestation. Education and outreach programs will transmit the findings to farmers and landowners for implementation, to public officials and community groups for policy considerations, and to teachers and students.

Principal Investigator: Louis A. Kaplan

Collaborators: J. Denis Newbold, Anthony K. Aufdenkampe, Thomas L. Bott, John K. Jackson, Bernard W. Sweeney, Charles L. Dow

Dynamics of organic particles in river ecosystems

Funded by: National Science Foundation (NSF) DEB 0543526

The upstream reaches of a river network supply downstream reaches with food energy in the form of microscopic organic particles. Some particles are consumed near their source, while others travel all the way to the ocean. To understand and quantify how small streams influence downstream rivers, we are using innovative methods such as tracing with fluorescent dyes, respirometry, flow cytometry, stable isotope analysis, and simulation modeling to study the movement of microscopic organic particles. We are also developing special educational resources under NSF's Research Experience for Teachers (RET) program.

Principal Investigator: J. Denis Newbold

Collaborators: Anthony K. Aufdenkampe and Louis A. Kaplan (Stroud Water Research Center), Aaron I. Packman (Northwestern University), and James N. McNair (Academy of Natural Sciences of Philadelphia)

Evaluating the seasonal effects of short-term temperature change on macroinvertebrates and fish in streams and rivers

Funded by: PPL Corporation

We conducted laboratory studies to test the effects of of rapid warming and cooling of river water on fish and macroinvertebrates during a 24-hour period in both winter and summer to better understand the impact of thermal discharges.

Principal Investigator: Bernard W. Sweeney

Collaborators: William H. Eldridge, John K. Jackson

Macroinvertebrate community response to invasive algae in the Opuha River, New Zealand

Funded by: National Institute for Water and Atmospheric Research (NIWA), New Zealand and the New Zealand Department of Conservation

Didymosphenia geminata, also known as "rock snot" and didymo, a freshwater, diatom algae is invading New Zealand and parts of the United States. Research findings on the effects of the algae on macroinvertebrate community structure, as well as the efficacy of releasing high flows from an irrigation storage dam to control the algae along a New Zealand stream were synthesized for publication.

Principal Investigator: David B. Arscott


Photo: Anthony Aufdenkampe

Stroud Water Research Center scientists Mike Gentile and Denis Newbold, and Rafael Morales, station manager for the Maritza Biological Station in Costa Rica, collect flow measurements from the Rio Sabala as part of a study to determine how climate change may impact the diverse species that populate the wet, semi-arid and arid areas of our planet, and teach us more about climate feedbacks to carbon cycling processes.

Education Projects

The science of water through the world of art

Funded by: Point Lookout Farmlife and Water Preserve Foundations

This program at Point Lookout Preserve gives students and teachers new ways of thinking about stream ecosystems and stewardship through the creative processes of art and science. High school and elementary school students from Delaware and Pennsylvania participated in programs that combined watershed science, artistic exercises, canoeing, and introductions to the art of the Brandywine Valley with a focus on the art of the Wyeth family.

Water quality and stream health in eastern Pennsylvania

Funded by: NASA

Center educators, along with the Central Bucks School District, the Heritage Conservancy and the Peace Valley Nature Center, provided community programming to show the impact of almost four decades of suburban expansion, rural development, dam construction and environmental regulations on the quality of Bucks County streams.

Consortium for scientific assistance to watersheds (CSAW)

Funded by: Pennsylvania Department of Environmental Protection, Growing Greener Stewardship Funds

Center educators provided technical assistance to county conservation districts, municipal environmental advisory committees, watershed associations and citizen action groups as part of a partnership of nine organizations across Pennsylvania whose goal is to teach conservation groups how to conduct effective watershed assessments and restoration efforts.

Integrating the carbon and water cycles within an ecosystem esthetic approach to landscapes

Funded by: National Science Foundation DEB 0917930

Stroud educators and scientists developed and began implementation of *Your Livable Landscape: Cultivating an Ecosystem Esthetic*, a collaborative education program that builds on the landscape practices of Longwood Gardens and the science of the Stroud Water Research Center. The program teaches Longwood visitors the connections among landscape practices, stormwater runoff, and the mobilization and mineralization of carbon. Through the program, visitors to Longwood Gardens will learn about beautiful landscaping techniques that allow rainwater infiltration, reduce stormwater runoff and sequester carbon.

Model My Watershed

Funded by: National Science Foundation

Stroud educators and scientists launched *Model My Watershed*, an innovative, three-year program to develop, test and disseminate a watershed-modeling tool set for Philadelphia area secondary schools. The goal of the program is to engage and excite students about the diverse STEM (science, technology, engineering and math) careers needed to address environmental issues. Using an interactive, hydrologic modeling toolset, students make real world decisions based on real scientific data and models and learn to predict how environmental changes in their watersheds affect the hydrologic cycle.

The rain barrel project

Funded by: Anonymous donor

Working with teachers at three Media, PA schools, Stroud educators demonstrated to hundreds of secondary school students practical solutions to reduce stormwater problems. Students incorporated their learning into artwork they designed and applied to 40 rain barrels, which were installed in public spaces throughout the borough of Media. The project culminated with a community workshop and demonstration of how rain barrels reduce the negative impacts of urban runoff.

Schuylkill Sojourn

Funded by: Private Donations

Stroud Water Research Center provided the educational programming for *Reading the River: The Science of the Schuylkill*, for the 11th annual Schuylkill River Sojourn. In an effort to increase interest in and stewardship of the river, and to explain the impact of various land uses on it, Stroud scientists and educators discussed the history, science and health of the Schuylkill River watershed, and conducted water chemistry and quality tests throughout the 112-mile sojourn.

Summer institute: How best management practices are protecting your drinking water

Funded by: PA Department of Environmental Protection and the Environmental Grants Program

Stroud educators conducted a week-long summer program of field experiences and hands-on activities designed to convey effective and innovative methods to protect water quality. The 20 participants learned how to incorporate best management practices for agriculture, stormwater, and integrated pest management into their educational programs.

Upland Country Day School curriculum development

Funded by: The Applestone Foundation

Center educators worked with Upland Country Day School to develop quantitative watershed activities and curricula for the school's 5th grade science programs.

Watershed citizenship learning community

Funded by: National Science Foundation

In collaboration with Cabrini College, Stroud educators began development of *Watershed Ecology* and *Watershed Citizenship* curricula for non-science majors, which uses the watershed as the vehicle to instill lifelong interest in watershed stewardship and an understanding of the science associated with the preservation and conservation of freshwater resources.

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2009

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It is only by knowing how healthy streams and rivers work, and what happens when they become polluted, that we can determine how to protect this vital resource now and for generations to come. Your gift to the 2009 Annual Fund enabled us to continue the freshwater research and watershed education programs that are helping to protect, preserve and restore fresh water everywhere. With loyal support from you, the Friends of the Stroud Water Research Center, our work will continue for many years to come.

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Photos: Andrea Monzo

With the help of generous sponsors, friends of the Stroud Water Research Center celebrated local, sustainable agriculture and the clean, fresh water our farmers and producers depend on to produce our food at its first annual Sustainable Feast.

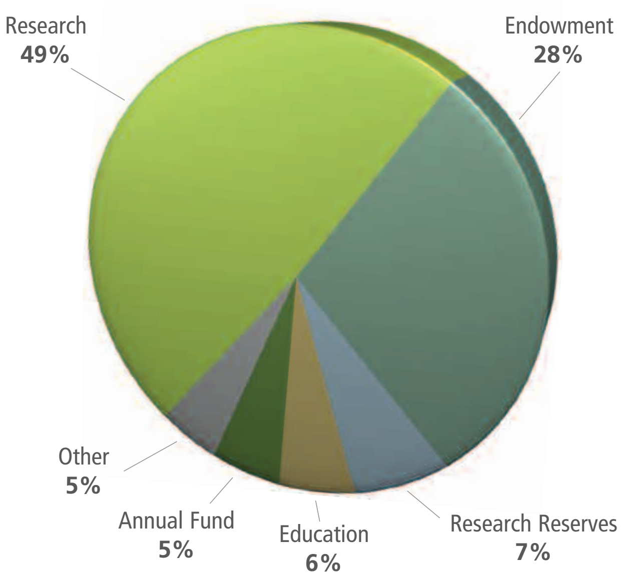
Financials

2009

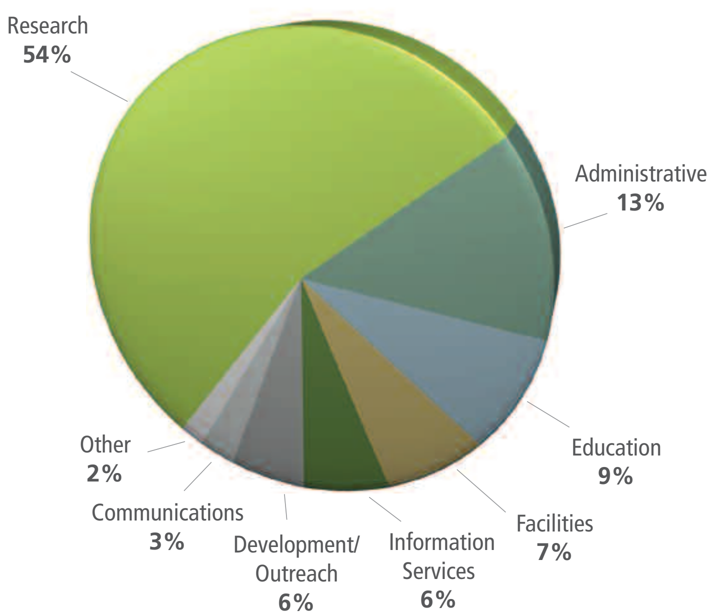
Operating Statement
for the year ended December 31, 2009

Revenues & Support	
Research Programs (Grants & Contracts)	$2,212,803
Endowment	1,287,498
Research Reserves	324,114
Education/Public Programs	260,514
Annual Fund	240,687
Other Contributions & Income	210,626
Total Revenues & Support	**4,536,242**
Expenditures	
Research	2,459,361
Administration	594,300
Education	396,545
Facilities	337,262
Information Services	289,721
Development/Outreach	254,623
Communications	122,241
Other	82,189
Total Expenditures	**4,536,242**

2009 Operating Revenues & Support



2009 Operating Expenditures



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2009

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* *The Maritza Station staff is employed by the Asociación Cento de Investigación Stroud, a non-governmental organization in Costa Rica which serves as the umbrella organization for all the Center's research and education activities in Central and South America.*

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