THE FIRST FIFTY YEARS

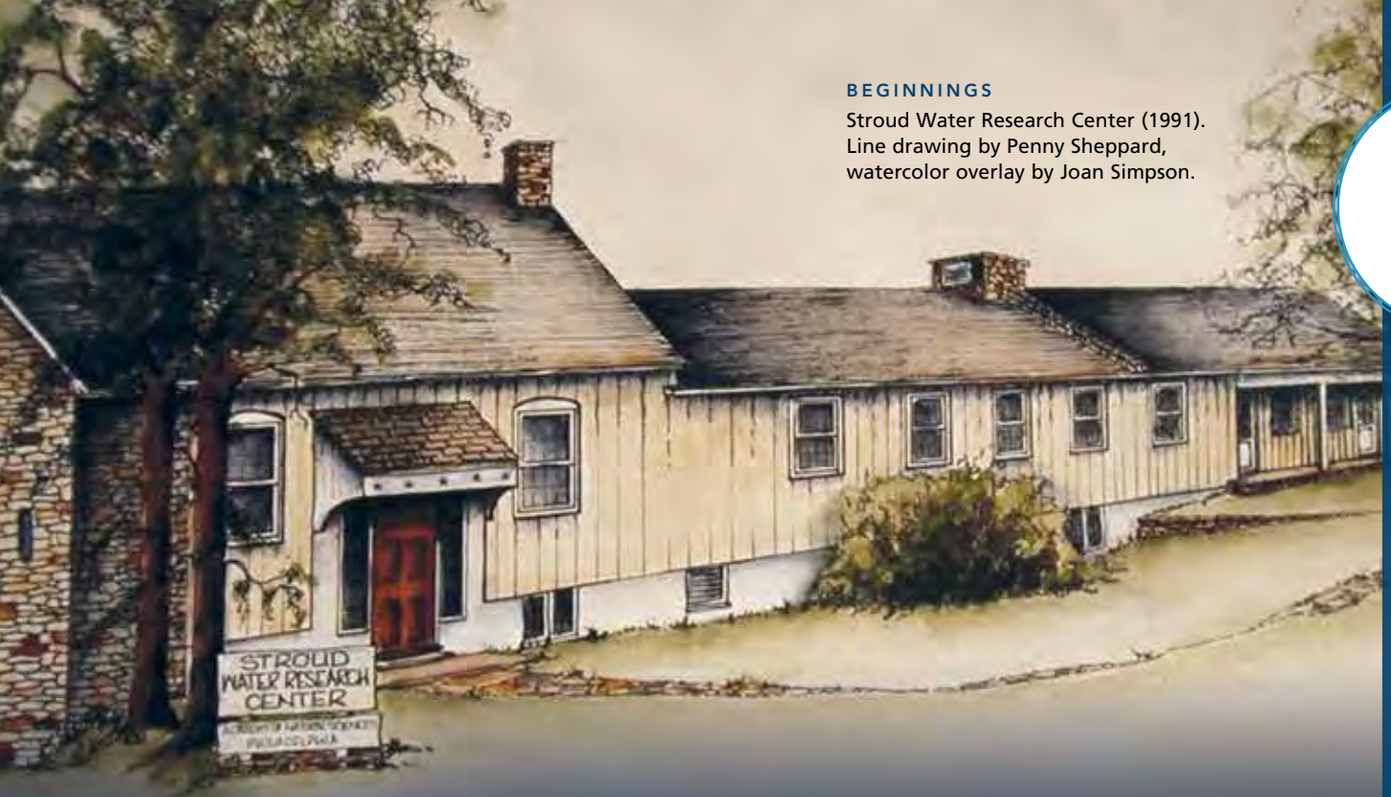
STROUD™
WATER RESEARCH CENTER

50 YEARS
Est. 1967

KEEPING IT FRESH FOR **FIFTY YEARS**

Table of Contents

Cover: A section of "Stream Language," a sculpture and stone carving by Jeffrey C. Funk that was installed outside the Stroud Center's building in 1995. Jeff, who lives in Montana, is the brother of long-time Stroud Center entomologist Dave Funk. The slate is from a quarry in southwest Virginia. Above: Introduction photo credit: Anita Bower, Community photo credit: Andrea Monzo



BEGINNINGS
Stroud Water Research Center (1991). Line drawing by Penny Sheppard, watercolor overlay by Joan Simpson.

50 YEARS *Est. 1967*

INTRODUCTION

In the late spring of 1974, many of the country's best freshwater scientists gathered at Stroud Water Research Center, then a field station of the Academy of Natural Sciences of Philadelphia, for a multiday symposium on stream ecology and future scientific collaboration.

The meeting, the second of four held around the country, included participants from Oregon State University, Idaho State University, Michigan State University and the Stroud Center, which at the time were the four principal hubs of stream and river research in North America. In the wake of the 1972 Clean Water Act, the National Science Foundation (NSF) had challenged the group to come up with ideas to address the nation's growing concern about the condition of its fresh water.

The talk was lively, and the ideas bandied about were interesting, remembered Robin Vannote, then the director of the seven-year-old Stroud Center. But the discussion mostly involved ideas for expanding the kinds of research the scientists were already doing. Vannote had grown impatient with such incremental steps forward. These were important, to be sure, but it seemed time for something bigger. What we need now, he thought, is an overarching idea that will not only make sense of the enormous amounts of data we have painstakingly collected, classified, and catalogued in countless streams but will also provide a grand hypothesis that will push the scientists and their research into uncharted waters — we need to understand how all the pieces fit together into a single whole.

So Vannote suggested they step back from the data and think of the stream itself as an organism. As he talked, he drew for his audience a verbal portrait of a river as a single interconnected system, one that begins as a tiny channel and grows larger as it moves downstream. As it joins with other streams and swells with groundwater, its channels widen and deepen until, now a large river, it flows into the ocean. What distinguishes such a system from other bodies of water, he said, is that it is continuously moving. Each part of a stream — each riffle and pool — is affected by what is happening not only immediately around it, but also upstream and downstream from it. As it flows, a stream's physical characteristics change to keep it from overwhelming its channel, and its biological communities must adapt to those changes. It's all connected, he concluded, from its headwaters to its mouth, and to really understand how a river system works, we must see it as a physical and biological continuum, striving to maintain its equilibrium in the face of constant change.

There followed, after he had finished, a moment of stunned silence. "Everyone was bowled over,"

"From headwaters to mouth, [we] reason that producer and consumer communities characteristic of a given river reach become established in harmony with the dynamic physical conditions of the channel."

— ROBIN VANNOTE , PH.D., THE RIVER CONTINUUM CONCEPT (1980)

remembered a young microbiologist named Tom Bott. "It was so simple, so elegant." It was what Thomas Kuhn, in *The Structure of Scientific Revolutions*, called a "paradigm shift," in this case, a profound change in understanding the nature of rivers, after which no one would ever again think about them in quite the same way.

"We need to take this idea to Washington [DC] immediately," said Jim Sedell from Oregon State. And so they traveled to the NSF to seek a grant that would enable them to test the theory in streams across the country.

What Vannote had described is now known as the River Continuum Concept. It was the first unified hypothesis about how streams and rivers work, and 43 years later, its influence persists. It has been cited over 8,000 times in peer-reviewed journals — more often than any other paper in the history of freshwater science. While the research that led to it was rigorous, painstaking, and complex, its message is remarkably simple: beneath the apparent chaos of a stream's ecosystem, where billions of creatures live and die seemingly at random, there exists an underlying order in which all the organisms are connected to one another.

Therefore, Vannote deduced, in what was his key insight, you should be able to look at what was happening in any particular section — or reach — of a stream and make predictions about what was simultaneously happening upstream and downstream from it. This meant, among other things, that you could determine the impact of human activities — their farming practices, their industrial sites, their sewage treatment plants, their commercial and residential developments — on downstream waters. And if you could do that, you could also suggest changes to those activities that would protect the quality of the water and the health of all who depend on it.

The River Continuum Concept was built on prodigious research into all aspects of streams and rivers. But when all the data had been analyzed and all the scientific studies read, it required something else: a leap of the imagination that transcends science. Vannote's description of a dynamic harmony, in which predictable stability stems from unpredictable change, seems not unlike what *Siddhartha* noticed in Hermann Hesse's 1922 novella:

"But today he only saw one of the river's secrets, one that gripped his soul. He saw that the water continually flowed and flowed, and yet it was always there; it was always the same and yet every moment it was new."

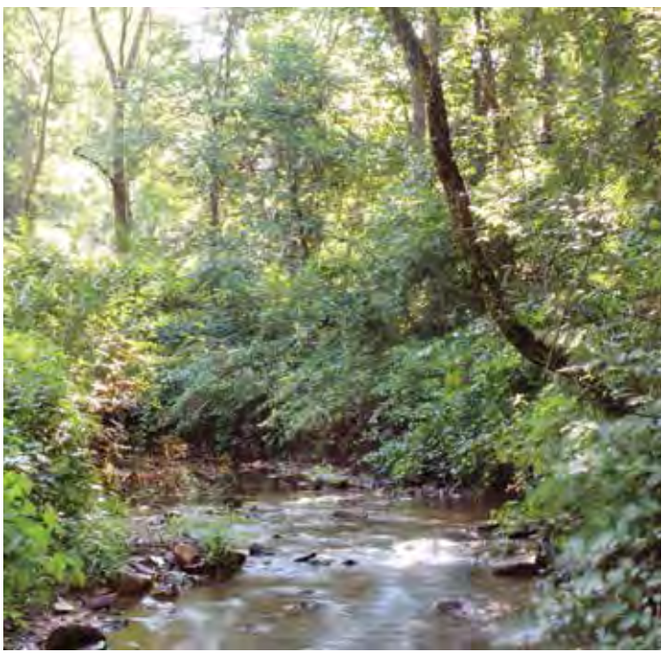
The River Continuum Concept did not, of course, spring fully formed from Vannote's brain that afternoon in 1974. It had its origins in his past work on the Red Cedar and Tennessee rivers; it built on the contributions of many of the scientists who were gathered around the table in the Stroud Center's library; it owed much to Ruth Patrick's decades-long explorations of the web of life in Conestoga Creek in nearby Lancaster County, Pennsylvania, and to the work of Luna Leopold and others on the physical characteristics of river systems.

DEFINING MOMENT

THE RIVER CONTINUUM CONCEPT (1980)

A MODEL FOR THE FUTURE

It seems more than a coincidence that the Stroud Center's organization and the River Continuum Concept reflected each other. The river was home to distinct biological communities joined together into a single, organic whole, and the collaborative research of individual scientists, and their distinct disciplines was required to fully understand it.



East branch of White Clay Creek

Most immediately, it grew out of a recently completed study, sponsored by the Rockefeller Foundation, in which Stroud Center scientists and their colleagues had spent five years intensively examining almost every aspect of life in the east branch of White Clay Creek, whose relatively unspoiled waters had led Ruth Patrick to choose it as the Stroud Center's site. The scientists believed that if they could understand how natural aquatic ecosystems function, they could use that knowledge to restore polluted streams to their original condition. The completed study, which involved every one of the Stroud Center's scientific disciplines, would become the model for all the Stroud Center's future work, no matter how far removed in space and time from its Chester County laboratory.

The first step was to gather together the best people in each discipline, from chemistry to entomology, from microbes to fish. The next was to provide each of them with a laboratory equipped with the tools they needed and then set them loose in the stream — where each would seek to expand the boundaries of his or her particular discipline and provide critical insights into the stream ecosystem's composite portrait. The scientists' goal was simple: to understand everything they could about fresh water. Fifty years later, that goal has not changed.

CYCLING BACK

In the eight years between the Stroud Center's beginnings over the Stroud family's garage in London Grove Township, Pennsylvania, and the meeting that weekend in the fall of 1974, much had been accomplished.

1966

THE STROUD FAMILY GARAGE AND ACADEMY OF NATURAL SCIENCES

The Stroud family's garage, makeshift site of the first laboratory, and the Academy of Natural Sciences, the oldest institution of natural sciences in the western hemisphere.

1966

LEAF PACK

The Stroud Center pioneered the use of the leaf pack as a scientific research tool (1966). Thirty years later, the Leaf Pack Experiment Stream Ecology Kit, now licensed by the LaMotte Company, would be one of the country's most popular watershed education products.

EARLY 1970s

Painting by Leonid Berman, a friend of the Stroud family, a frequent visitor to the Stroud Center, and an artist fascinated by water.

1967

Ruth Patrick

Robin Vannote

Joan Stroud

Dick Stroud

AN INSPIRED ENVIRONMENT

By the time the Rockefeller Foundation study was completed in 1974, the Stroud Center had applied for a grant from the Kresge Foundation for a major expansion of its already overflowing building.

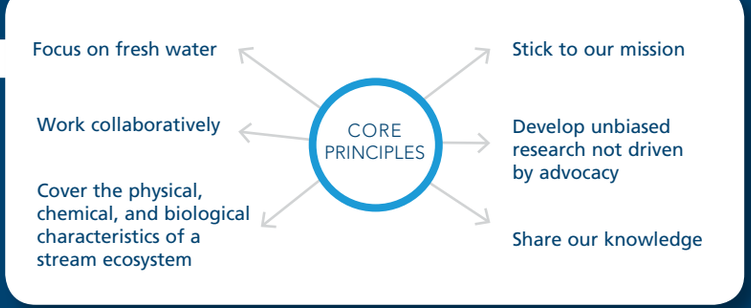
Nestled idyllically by the side of White Clay Creek, surrounded by farmland, pasture, and woods, the Stroud Center seemed a long way from the academy headquarters in the big city. In still rural Chester County there was an air of country informality, of pastoral tranquility. Joan and Dick Stroud wandered in and out, furnishing the new building with antiques, covering the walls with the wonders of art to inspire and complement the wonder of science, providing meals for scientists and visitors, attending presentations, always taking notes, always encouraging. It was a great place to work, remembered Tom Bott — at least for those who liked to work long hours.

"The clock didn't mean anything to Robin," recalls Bern Sweeney, who arrived as a graduate student in 1972 and became director in **1988.** (Future Stroud employees would learn that it doesn't mean anything to Sweeney either.)

THE IDEAL SITE AND STUDY STREAM

Patrick and Vannote identified their ideal study stream at the headwaters of the east branch of White Clay Creek, and Joan and Dick Stroud bought the property on its banks. Work on the new building began in February 1967 and was completed before the end of the year. In its basement Vannote designed and installed a wet lab, the world's first indoor stream, which enabled water from White Clay Creek to flow through the building and back to the stream, while upstairs Joan Stroud designed the high-ceilinged library as a special place for scientists and visitors to gather.

MID 1970s



OUR PRINCIPLES REMAIN CONSTANT

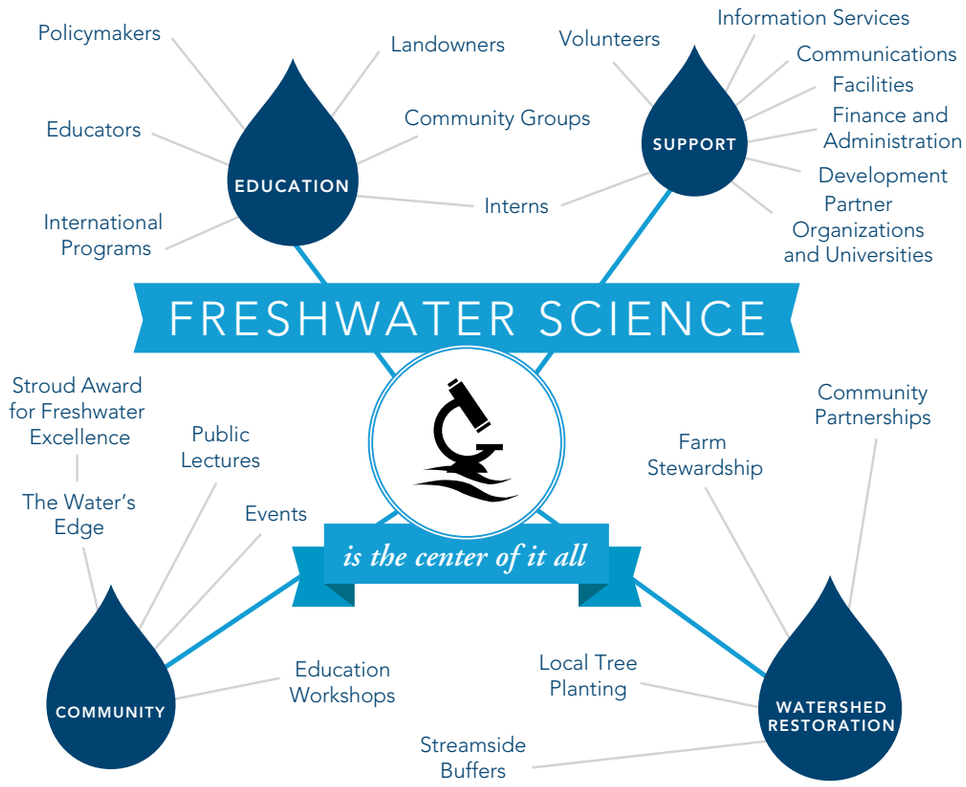
By the mid-1970s, the main lines of the Stroud Center had been set. "We started out with some basic principles," said Sweeney, "and they've persisted." As we shall see in the pages that follow, those principles have guided the Stroud Center through 50 years of remarkable growth.

50 YEARS Est. 1967

RESEARCH

The National Science Foundation (NSF) proved as interested in the River Continuum Concept as the scientists who had first discussed it around the Stroud Center's library table; in 1975, it funded a national project, composed of Stroud Center scientists and colleagues from across the country, to test whether the River Continuum Concept provides a framework for understanding the dynamic relationship between biological communities and their physical environment.

As the following descriptions of some of the projects completed over the years reveal, research remains at the center of all that goes on at the Stroud Center, providing the intellectual capital for the education, outreach, and watershed restoration programs that have grown up to support the Stroud Center's mission: *"To advance knowledge and stewardship of freshwater systems through global research, education, and watershed restoration."*



Research Technicians

Working quietly behind the scenes, in the laboratories and in the streams, the research technicians bring to the Stroud Center a multiplicity of talents and expertise. From the network of environmental sensors created by Shannon Hicks to Jan Battle's co-authorship of 21 peer-reviewed publications to Dave Montgomery's ability to fix almost anything out in the field, they provide the infrastructure, both intellectual and physical, that is essential to the advancement of science.

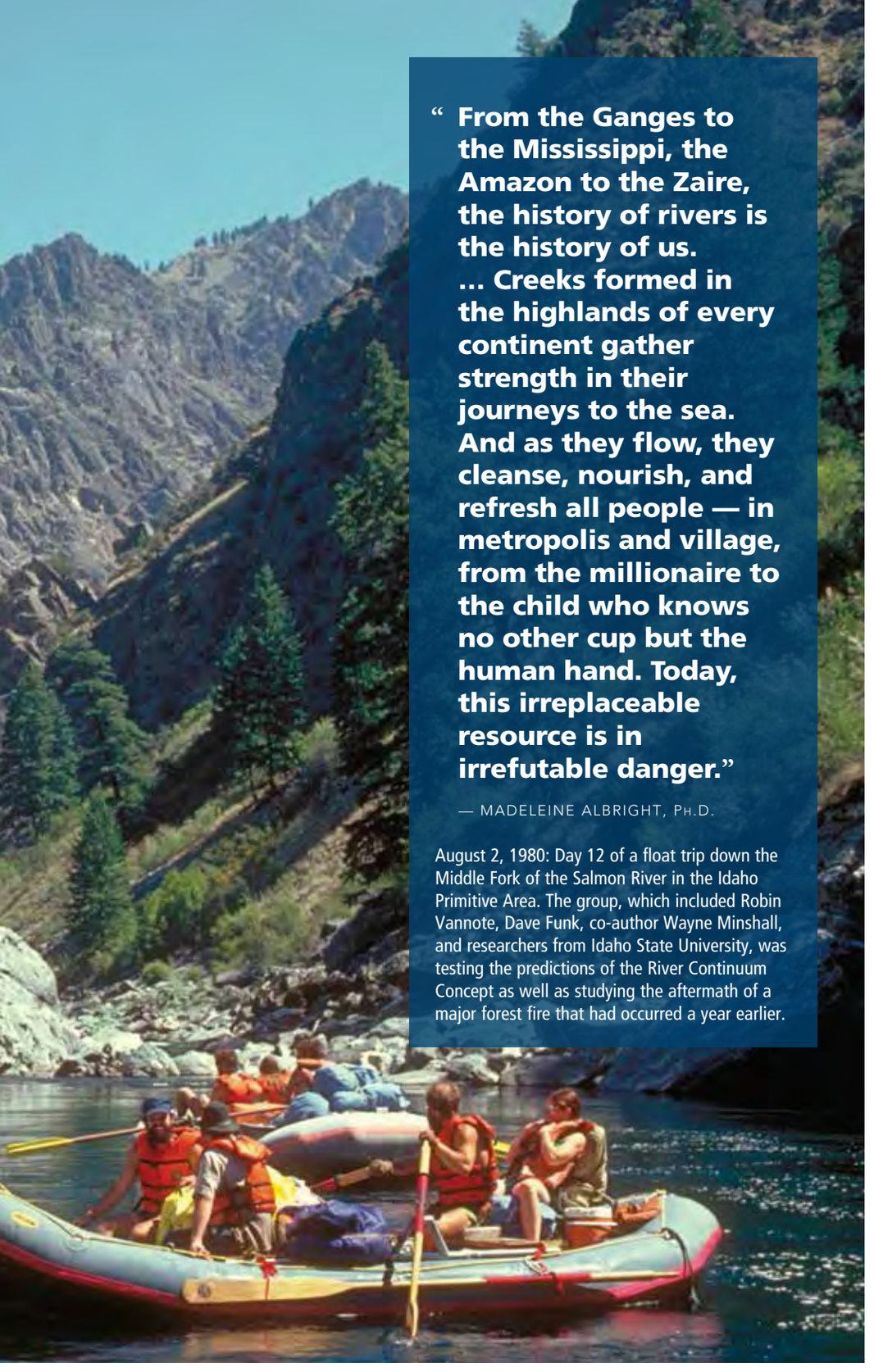
Catherine McFadden

Kelly McIntyre

Michael Broomall

Jennifer Matkov

Laura Zgleszewski



> **“From the Ganges to the Mississippi, the Amazon to the Zaire, the history of rivers is the history of us. … Creeks formed in the highlands of every continent gather strength in their journeys to the sea. And as they flow, they cleanse, nourish, and refresh all people — in metropolis and village, from the millionaire to the child who knows no other cup but the human hand. Today, this irreplaceable resource is in irrefutable danger.”**
>
> — MADELEINE ALBRIGHT, PH.D.

August 2, 1980: Day 12 of a float trip down the Middle Fork of the Salmon River in the Idaho Primitive Area. The group, which included Robin Vannote, Dave Funk, co-author Wayne Minshall, and researchers from Idaho State University, was testing the predictions of the River Continuum Concept as well as studying the aftermath of a major forest fire that had occurred a year earlier.

Sara Damiano

Matthew Wilson

David Montgomery

Jan Battle

Shannon Hicks

LANDMARK STUDY

RIVER CONTINUUM PROJECT

The River Continuum project was the Stroud Center’s first large, multistate research project, and it embodied many of the components that have come to characterize subsequent protocols:

- ✓ The study began with a hypothesis to be tested. This was not an intellectual fishing expedition hoping to discover something; it was a concentrated effort to gather data to address a significant question the scientists had already intensively studied.
- ✓ It brought together experts from a variety of disciplines (entomology, geomorphology, hydrology, algalogy, microbiology, chemistry) and focused them on answering that question. Each scientist contributed his or her particular expertise to the collective wisdom of the team.
- ✓ Many of the scientists’ techniques and insights had been sharpened during the rigorous study of White Clay Creek sponsored by the Rockefeller Foundation from 1969 to 1974, a project in which Stroud Center researchers analyzed almost every aspect of stream life.
- ✓ While the study was a basic research project, whose aim was to answer a complex scientific question about energy production and transport in a stream and river system, it had a far deeper goal: to understand how such ecosystems work and to provide solutions to the mounting problems posed by their pollution.
- ✓ It has always been a core component of the Stroud Center’s mission that the results of its research make a difference in the world.
- ✓ As a result of the study, the River Continuum Concept has reverberated beyond the walls of scientific laboratories and the pages of peer-reviewed journals. The data it generated and the many follow-up studies it continues to inspire have produced information that enables landowners, community groups, educators, and policymakers to make good stewardship decisions.

Read more about the River Continuum Concept at stroudcenter.org/continuum

LANDMARK STUDY

THE AMAZON PROJECT

It takes 55 minutes to fly the 289 miles (465 kilometers) from the historic Incan capital of Cuzco (elevation 11,152 feet) to Puerto Maldonado (elevation 600 feet) in the heart of the Amazonian rainforest, where 40 inches of rain fall each year and almost all transportation is done by boat. Deplaning at Puerto Maldonado's airport, after Cuzco's cool temperatures, is like walking fully clothed into a Turkish bath. The first blast of heat and humidity almost takes your breath away.

In the summer of 2006, a team of scientists, technicians, and educators from the Stroud Center, along with university and Peruvian collaborators, arrived at the airport to begin an extensive project funded by the Gordon and Betty Moore Foundation. Its purpose was twofold: (1) to establish a baseline of scientific data on water quality and stream health that could be used to assess, sustain, and improve conservation efforts in the area and (2) to create, test, and implement simple and inexpensive education programs and water-quality monitoring techniques for the people of the region. This was a critical time for the Andes-Amazon area, which was on the threshold of explosive growth spurred by the construction of a transcontinental highway. That road would eventually connect the Atlantic and Pacific oceans and in the process open vast tracts of previously inaccessible rainforest to agricultural and industrial development. This in turn would put unprecedented pressure on the world's largest river system, which is the source of 20 percent of the earth's water and home to the planet's most abundant biodiversity.

The project ultimately put into the field every Stroud Center scientist, technician, and educator, and it drew on every facet of the knowledge and skills they had collectively acquired over the preceding 40 years, both at the Stroud Center's main campus in Pennsylvania and its tropical research station in Costa Rica — including the language skills, which were largely self-taught, to present local workshops in basic Spanish, an effort that was very much appreciated by the participants.

Read more about the project at stroudcenter.org/research-projects/peru

Top: Stroud Center staff set off for a research site on the Madre de Dios River in the Amazon rainforest of southeastern Peru, where travel is commonly done by boat. Right: Denis Newbold, Bern Sweeney, and Tom Bott.

Right: Bern Sweeney, who had participated in the project as an undergraduate 40 years earlier, discovered and resurrected the data in 2004.

LANDMARK STUDY

THE BUCKS COUNTY PROJECT

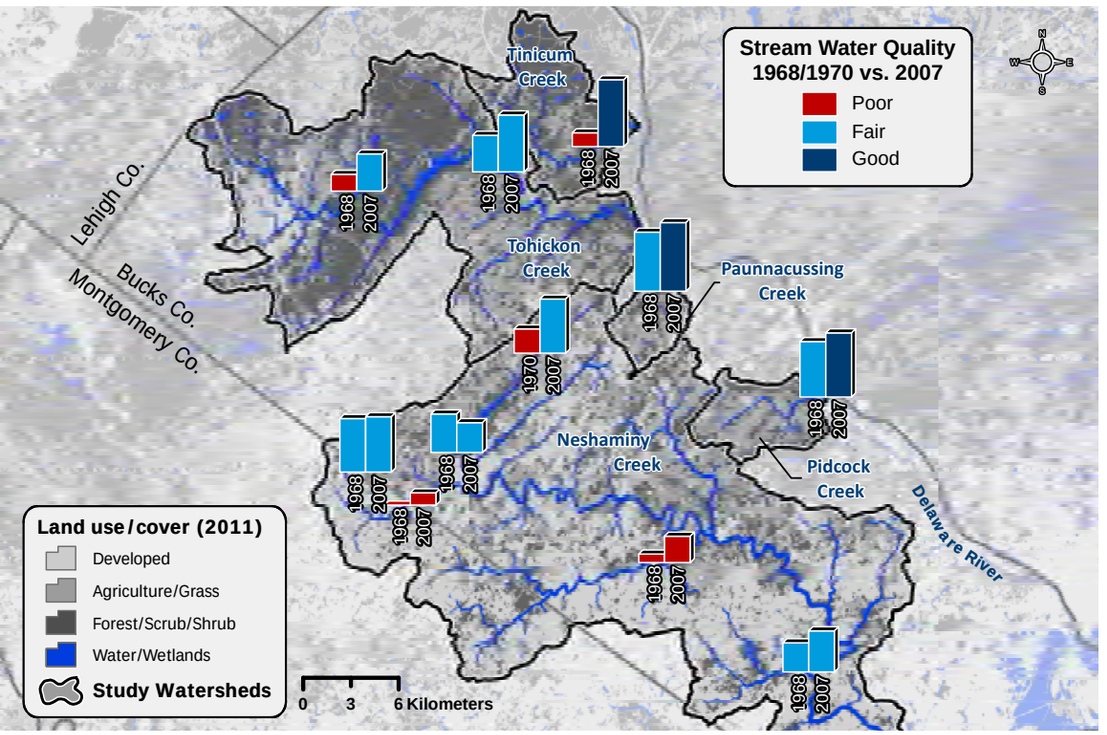
It's a fundamental axiom of science that to understand how conditions have changed you must know what they were at the outset. Setting such a baseline is a key component of water monitoring. Without it, you may be able to tell whether the quality is relatively good or bad, but you can't answer the critical question: Are things getting better or worse? Only by knowing the conditions at the outset can you measure change over time and therefore evaluate the impact on the water of new land uses, environmental regulations, conservation efforts, and population growth.

Such information is often unavailable because communities typically don't start monitoring their water sources until they already have a problem. But for reasons that are still not clear, officials at the Bucks County Division of Natural Resources and Delaware Valley University in Bucks County, Pennsylvania, set up an extraordinary program in 1967. Its goal was to establish a baseline of information on the health of the county's stream and river ecosystems and the quality of their water. It was discontinued in 1971, less than a year before the passage of the Clean Water Act (CWA), and the findings were apparently never fully analyzed nor used for planning or evaluation purposes.

Yet the program's designers had built in a set of chemical and biological measures that was unprecedented at the time. Forty years later, Bern Sweeney, who had participated in the project as an undergraduate, rediscovered and resurrected those data. The long-forgotten baseline study provided a unique opportunity to look at changes in water quality over time and to assess the impacts of two seemingly conflicting trends in the suburban county: (1) the 1972 CWA and its regulatory requirements and standards, which were intended to improve water quality; and (2) a 57-percent increase in population and the accompanying residential and commercial development, which have long been associated with deteriorating water quality.

The study involved every research discipline at the Stroud Center, and it produced encouraging results. While evidence of the adverse impact of population growth was found, as expected, in most of the streams, it was more than counteracted by the improvements required by the CWA (and also by a reduction of acid deposition mandated by a 1990 amendment to the Clean Air Act). This indicates that, with the help of smart laws and good management practices, communities can protect their water sources, even as they experience the kind of growth that has historically polluted them.

To ensure that these lessons were conveyed to the community, Stroud Center educators gave a series of workshops for teachers, students, and community volunteers, which stressed the importance of watershed protection and provided information, ranging from land-use improvements to simple water-monitoring techniques, on how to ensure it.



Map of Bucks County, Pennsylvania, showing the location and level of water quality in streams evaluated from 1967 to 1971 (before the Clean Water Act of 1972 was passed) and re-evaluated in 2007 using the same physical, chemical, and biological criteria. Water quality is indicated by color as well as by bar height.

To learn more about resources for the general public, government agencies, and citizen volunteers, visit stroudcenter.org/education

To learn more about how research can provide important information to legislators, visit stroudcenter.org/press/clean-water-act-clarification

LANDMARK STUDY

THE NEW YORK PROJECT

Top: The Ashokan Reservoir, completed in 1915, is the deepest of the 19 reservoirs and three lakes in the 2,000-square-mile watershed that serves New York City. Above left: Stroud Center scientists Charles Dow and Laura Hall Martin inject dye as part of a study to measure a stream's ability to process pollutants, particularly excess nitrogen and phosphorous. Above right: Project Coordinator Dave Arscott collects water-chemistry samples on a cold winter day.

In 1997, a truce was signed that, if it endures, will ensure clean drinking water for the millions of people who live and work in New York City far into the future. Called the Memorandum of Agreement, and spearheaded by Robert F. Kennedy Jr., it sought to end more than a century of animosity and misunderstanding between those who live in the rural areas where New York City's water originates and the millions of city dwellers and workers who depend on that water over 100 miles away.

The matter had come to a head in 1989, when the U.S. Environmental Protection Agency issued new regulations to protect the nation's drinking water, which threatened to force New York to build a multibillion-dollar treatment facility it couldn't afford. In response, the city proposed stringent controls on new development in the rural watershed communities and threatened to increase its use of eminent domain to acquire more land. That plan infuriated the upstate communities, which had long resented the city's aggressive efforts to restrict development in a region desperate for economic growth. After protracted and difficult negotiations, the parties agreed that the city would invest around a billion dollars to buy land from willing sellers only, protect its water sources, and provide economic opportunities for the region's residents and businesses.

The city's plan challenged conventional wisdom: instead of building a prohibitively expensive filtration plant to provide a technological fix at the end of the pipeline, it proposed using natural processes to protect the water at its source — which, if it worked, would lower costs, reduce the adverse environmental impact, and provide a more sustainable solution to the city's water needs.

The Stroud Center was chosen to design a scientific baseline study to evaluate the impact of the watershed restoration efforts on the quality of the water delivered to the city. The project took six years to complete, involved hundreds of test sites, and included an education component for all stakeholders. The ensuing 317-page report provided the city, state, and federal governments with an unprecedented evaluation of current water conditions and a baseline for measuring future changes. Twenty years later, the agreement is still holding, the local communities have had significant economic investment, and New York's water remains as clean as that of any city in the world.

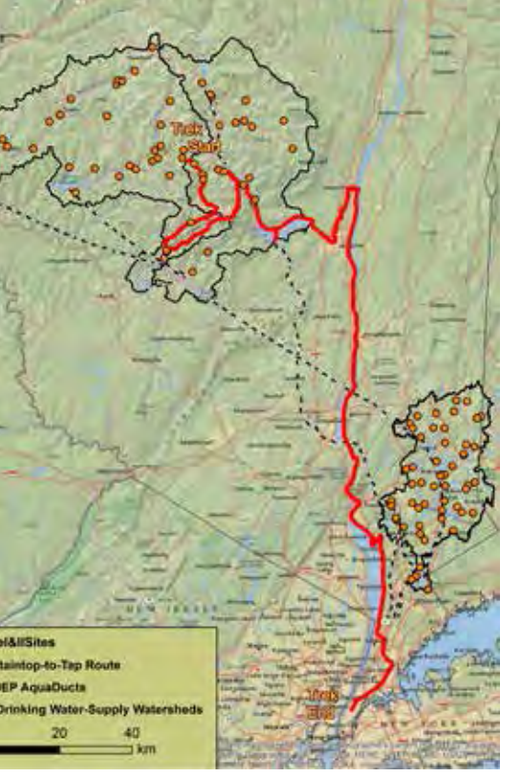
The Mayfly: The most reliable indicator of healthy streams

RED FLAG

Many of the Stroud Center's most significant findings have come from studies of mayfly responses to contaminants.

STREAM TESTED

In 2010, scientists used mayflies to test the effects of phosphorus, a nutrient commonly found in fertilizer that often enters streams in stormwater runoff.



The 110 research sites for the six-year New York project and the 200-mile route the 12 students took from the source of the city's water in the Catskill Mountains to the city itself.

THE PROJECT SPANNED:

19 RESEVOIRS

3 LAKES

110 RESEARCH SITES

2,000 SQUARE MILES

6 years

1.3 billion
GALLONS OF FRESH WATER A DAY

AND BENEFITTED:

9 million
PEOPLE WHO DEPEND ON CLEAN DRINKING WATER

LANDMARK STUDY

THE THERMAL EQUILIBRIUM CONCEPT

Entomologists David Funk (left) and David Rebuck collect macroinvertebrates in the Delaware River downstream from the Cannonsville Reservoir.

The largest and longest-lasting research project in the Stroud Center's history began as Bern Sweeney's Ph.D. dissertation in 1972. "I'd barely walked through the door as a new graduate student," Sweeney recalled, "when Ruth Patrick handed me a bunch of scientific papers and said, 'Here's a project you might want to take a look at.'"

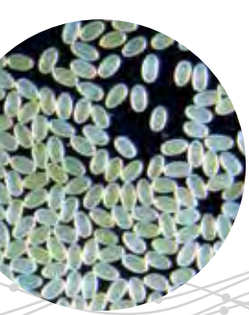
It concerned the massive die-off of stream life, and particularly insects, below both dams (where the water is very cold) and power plants (where the water is very warm). The mortality rates seemed clearly connected to the temperature changes, but since temperatures never reached lethal levels, no one had been able to pinpoint the actual cause of the extinctions.

Sweeney set up a series of experiments that convinced him that (1) temperature changes were indeed the culprit, but (2) the process was far subtler than scientists and engineers had thought. Instead of killing the insects outright, the changes affected the dynamics of larval growth and development, leading to reduced body size and reproductive capabilities in adults. Gradually, but relentlessly, local populations of species would succumb and disappear.

To those whose lives are not consumed by the fate of insects, this might not seem like a big deal. But at the time, it was so revolutionary that the National Science Foundation (NSF) and the Department of Energy (DOE) vied with each other to fund Sweeney and Vannote's million-dollar proposal to test the hypothesis. In the end, both organizations funded an expanded project, which covered 25 river systems stretching from Florida to Quebec. An unexpected byproduct of the grants was the ability to build new infrastructure — from laboratory equipment to new vehicles — that set the Stroud Center on an accelerated path of physical growth.

The two agencies' competition to give Sweeney and Vannote money — "Something that's never happened to me again," Sweeney assured me — reflected the Stroud Center's growing proficiency in applied as well as basic research. The NSF was interested in funding new scientific knowledge on the ecology of streams. The DOE was driven by a more practical consideration: they wanted the researchers to figure out how to stop the massive insect die-offs, which were spurring environmental groups to demand that the department shut down both the dams and the power plants.

The Thermal Equilibrium Concept addressed both issues, and the NSF continues to fund the graduate student — who would later become the Stroud Center's president — to explore the questions he first raised almost 50 years ago.



CLONED

In 1982, Stroud Center scientists discovered *Centroptilum triangulifer*, a parthenogenetic mayfly that consists entirely of females, reproduces without mating, and is easily cultured in the laboratory.

LOCAL HABITAT

The Stroud Center's proximity to White Clay Creek and its indoor wet laboratory make it possible for researchers to obtain streamwater and grow the food necessary for raising mayflies.

60 generations

THE APPROXIMATE DURATION THE STROUD CENTER HAS KEPT *CENTROPTILUM TRIANGULIFER* IN CULTURE.

Scientific Investigators Through the Years

The Stroud Center has been characterized by the continuity of its scientific disciplines, even as individual scientists arrive, move on, and eventually retire. The result has been the remarkable ability to apply new knowledge, new technologies, and new ways of thinking to long-term research questions and experiments that extend over many years. Pictured here are the researchers who have worked at the Stroud Center for the past 50 years.

A | LOU KAPLAN, PH.D.

Biogeochemist Lou Kaplan assembled a 40-year record of daily samples from White Clay Creek that were analyzed in his laboratory for concentrations of dissolved organic carbon. This ranks among the most comprehensive descriptions of organic carbon for a stream ecosystem worldwide. During his tenure, he mentored postdoctoral researchers and students from seven countries, and he developed a bioreactor to measure the concentration of biodegradable dissolved organic carbon in water, for which the Stroud Center was awarded a U.S. patent.

B | TOM BOTT, PH.D.

Tom Bott, the Stroud Center's first microbial ecologist, spent his long career studying the microscopic world of algae and bacteria and their roles in the microbial food web of stream ecosystems. Beginning with a comprehensive picture of microbial life in White Clay Creek, Bott and his research assistants learned how various kinds of pollution and land-use changes, usually precipitated by human activities, impacted microbial communities and their functions, both here and in other parts of the world.

C | RICK LARSON, PH.D.

Rick Larson, the Stroud Center's first organic chemist, sought to discover the types of fatty acids, which make *Cladophora* algae inedible to many aquatic insects. Because the pest algae are so distasteful to predators, they can literally take over streams and ponds if the light and nutrient conditions are right. *Photo credit: Terrence Roberts*

D | LAUREL STANDLEY, PH.D.

Laurel Standley, the Stroud Center's second organic chemist, shown working on the Stroud Center's first mass spectrometer, which she used to detect pollutants accumulating in the body tissue of algae, macroinvertebrates, and fish — and to then track how those pollutants get into streams and rivers. In 1997, she, Bern Sweeney, and Dave Funk received the first patent ever awarded to the Academy of Natural Sciences for the discovery of a mayfly species that consists only of females, reproduces as clones, and is an effective barometer of stream pollution.

E | CHARLES DOW, PH.D.

Charles Dow came to the Stroud Center in 2000 as the project coordinator for the New York project, and in 2002, he became director of information services, leading a team which provides computing, website design and content, and data analysis and management support to the Stroud Center. Trained as a scientist in the field of forest hydrology, Dow's background in data analysis allowed him to find his niche helping others do research on streams and rivers. That support encompasses gathering the geospatial data needed to assess terrestrial impacts on water quality, maintaining the decades-long water-quality datasets that are a foundation of the Stroud Center's impact on stream research, and providing data analysis to undergraduates, graduate students, colleagues, and others who seek information on how stream and river ecosystems work.

F | JOHN JACKSON, PH.D.

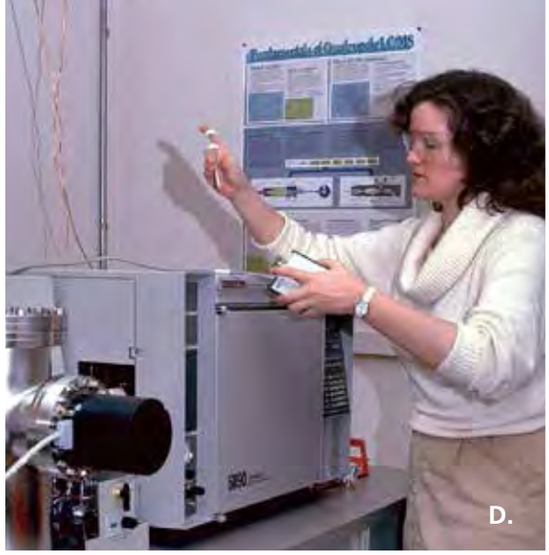
John Jackson has led the Entomology Group since 1990, specializing in ecological research on aquatic macroinvertebrates and their role in monitoring the water quality of streams and large rivers. That work has enabled landowners, private corporations, and government entities to understand the impact of their activities on fresh water and to make changes in their practices to improve and protect its health. Jackson has also led the research effort at La Estación Biológica Maritza in Costa Rica.

G | MELINDA DANIELS, PH.D.

Melinda Daniels, the Stroud Center's first geomorphologist, studies the interconnections between the physical and ecological processes in stream ecosystems. Her current research focuses on the long-term effects of riparian reforestation on both water quality and quantity, and assesses innovative practices for watershed restoration, the role of biological ecosystem engineers (both plants and animals, such as beavers, that influence the physical habitat structure) in regulating stream processes, and the impact of climate change on river-flow regimes and stream network connectivity.

H | DENIS NEWBOLD, PH.D.

Denis Newbold, who came to the Stroud Center in 1983, currently studies the factors that control how microscopic organic particles travel through stream and river networks. Originating mainly in small headwater streams — which comprise over 90 percent of all streams and almost half of all river miles — these particles supply the food webs of larger streams, rivers, and estuaries, but they can also be carriers of harmful contaminants. Using experimental streamside channels, Newbold is finding that a particle's downstream journey is regulated in large part by a complex of bacteria, other microorganisms, and organic matter that coats streambed sediments, creating a biofilm that entraps and incorporates particles before subsequently releasing them to resume their downstream transit. The longer travel times enable the organic matter to be more efficiently used within the ecosystem and also allow more effective processing of contaminants, thereby improving water quality.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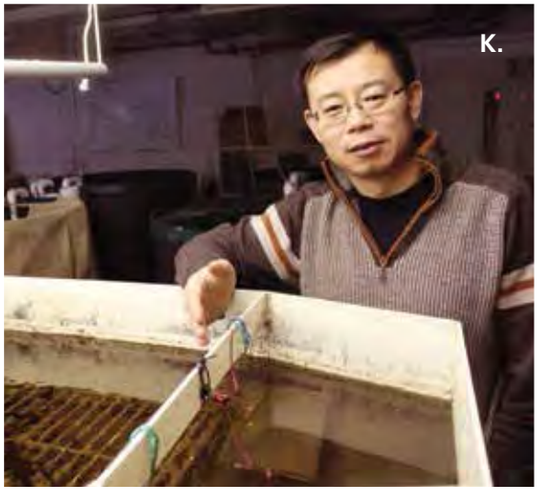
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I | ANTHONY AUFDENKAMPE, PH.D.

Anthony Aufdenkampe's research addressed broad questions about the cycling of carbon and nitrogen in streams, rivers, oceans, and land masses. He worked on a large regional — and often a global — scale, seeking to advance our understanding of biogeochemical processes by spatially integrating observations and data as materials move from weathered rock to soils to streams and eventually to the sea. He studied how the degradation of organic matter to carbon dioxide is controlled by interactions with minerals in soils and stream sediments in settings that range from the headwaters of White Clay Creek to the Amazon River, and from eastern Pennsylvania to Papua New Guinea.

J | DIANA OVIEDO-VARGAS, PH.D.

Diana Oviedo-Vargas is the newest Stroud Center senior scientist, having arrived in July 2017. She is an aquatic biogeochemist who asks big questions, and whose research seeks to advance our knowledge of the elemental cycles in streams, rivers, and estuaries and how they are linked to each other, to the water cycle, and to the terrestrial ecosystem at both the surface and the subsurface levels. Some of her current interests include: the transport and transformation of nitrogen and phosphorus in river systems and the impact of human activities, such as agriculture and urbanization, on those processes; the quantification and characterization of the multiple carbon pools and fluxes in aquatic ecosystems and the role they play in global climate change; and the effects of emerging contaminants, such as pharmaceutical products and microplastics (the tiny pieces of plastic debris now omnipresent in our waters) on the health of stream and river ecosystems.

K | JINJUN KAN, PH.D.

Jinjun Kan's use of advanced molecular approaches to explore stream microorganisms and their interactions with dissolved organic matter has brought microbiology research at the Stroud Center into a new era. Detection of fecal indicator bacteria with molecular source tracking has also added a new approach to the Stroud Center's water-monitoring program; and his laboratory's microbial fuel cell, powered by White Clay Creek sediment, has become a hot spot for education programs.

L | WILLY ELDRIDGE, PH.D.

Willy Eldridge led the fish molecular ecology section, which conducted field and laboratory experiments to assess the impact on fish populations in streams and rivers caused by changes in land and water use and extreme thermal events. By shedding light on the physical and chemical processes that structure fish communities, the research contributed to the regulation, protection, and management of freshwater ecosystems.

50 YEARS *Est. 1967*

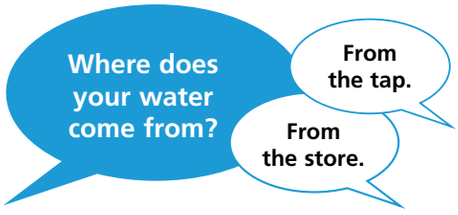
EDUCATION

Since the start of Stroud Water Research Center's formal education program in 1992, its goals have not changed: to interpret and communicate the research of Stroud Center scientists and to help people of all ages understand the sources of clean fresh water, the dynamics of stream habitats, the impact on them of human activities, and ways to combat pollution.

Often the questions people ask are very basic: Where does my water come from? What is a watershed? Why does clean water have all those tiny insects in it?

With front-row seats to some of the world's most innovative water research, Stroud Center educators can guide their students, community groups, and civic leaders deep into the realm of fresh water. While much of the content they teach has its origins in their colleagues' research laboratories, the educators are also experts in their own fields and design their own innovative watershed-education programs and teaching techniques. They work in the classroom, in the field, and in the laboratory, where they use sophisticated computer modeling and advanced instrumentation; but they do their most effective teaching in the streams themselves, connecting people directly to their watersheds, enabling them to experience firsthand the wonders of stream life. At the Stroud Center, learning is first and foremost a hands-on, boots-in-the-water experience. "We use state-of-the-art technology," said Education Director Steve Kerlin, "but we don't use it to replace the outdoor experience; we use it to deepen the students' understanding of nature."

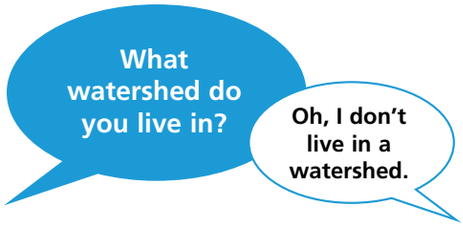
UNDERSTANDING SOURCES OF CLEAN, FRESH WATER



Early on July 7, 2007, the first morning of Mountaintop-to-Tap, the three-week trek along the 125-mile course of New York City's water supply, Stroud Center educator Christina Medved asked the students, "Where does your water come from?"

"From the tap," ventured a student from rural Delaware County, where much of New York City's water originates.

"From the store," said a Brooklyn student, whose family had migrated from the Caribbean, where bottled water is a safeguard against contamination.



One evening, when Kristen Travers asked members of her community workshop what watershed they lived in, one person replied,

"Oh, I don't live in a watershed."

The fact is that we all live in a watershed, which is an area of land that drains to the same body of water — whether a stream, river, lake, or ocean.

The Leaf Pack Network: Extending the reach of stream ecology education and research

1966

Robin Vannote first placed leaf packs in White Clay Creek as a research tool.

1990

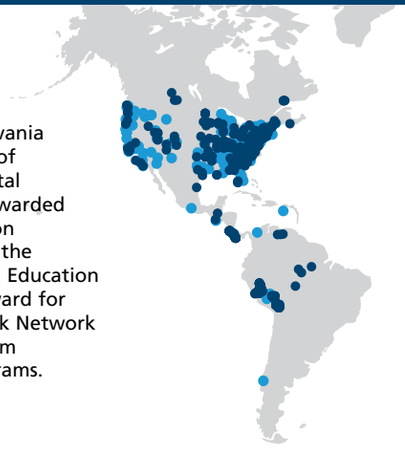
Bern Sweeney began working with a teacher at Upland Country Day School to create a curriculum for students.

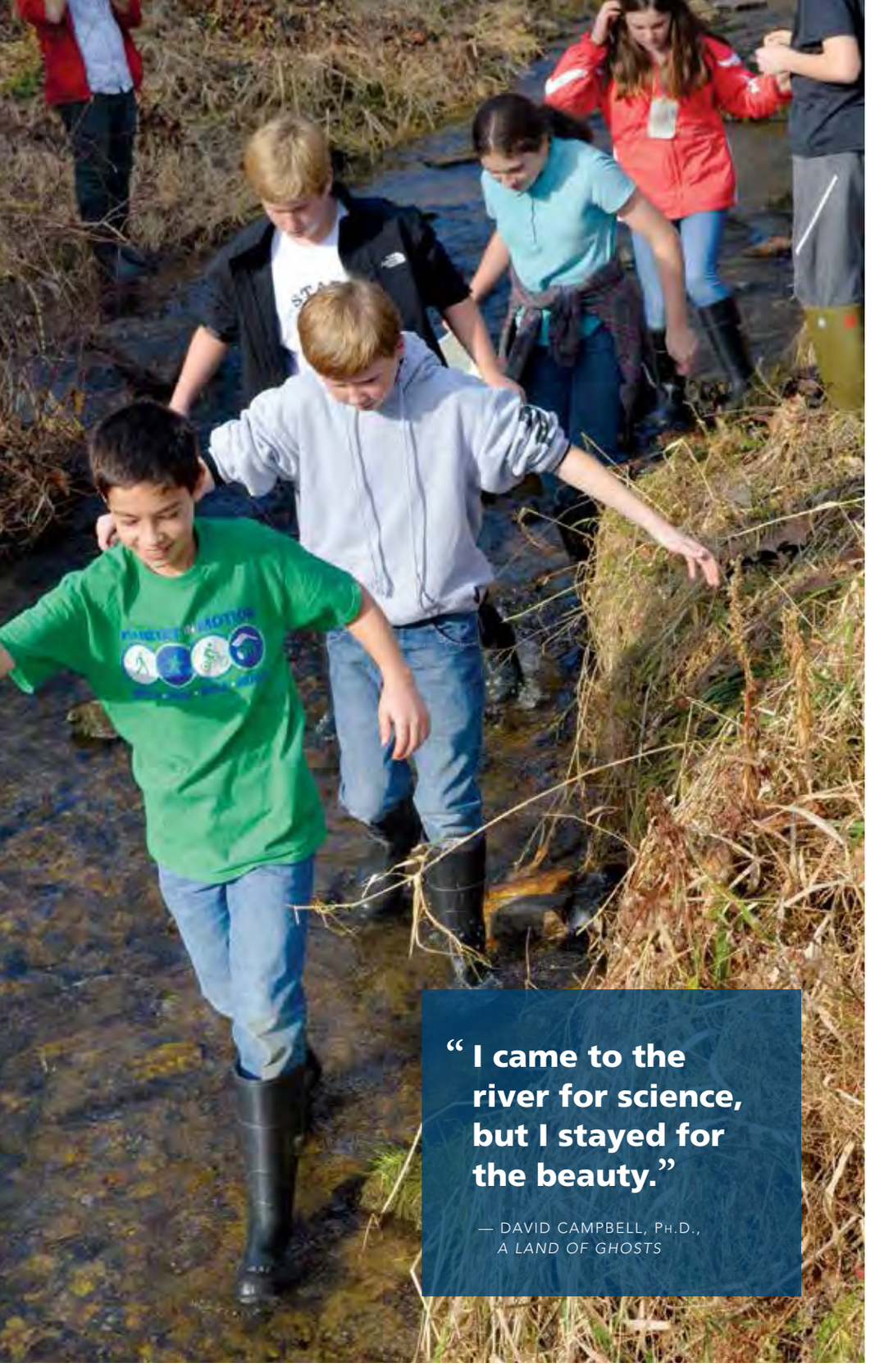
1999

The Stroud Center began producing the Leaf Pack Experiment Stream Ecology Kit through the LaMotte Company and developed the Leaf Pack Network.

2015

The Pennsylvania Association of Environmental Education awarded the education department the Outstanding Education Program Award for the Leaf Pack Network and its stream school programs.





> **"I came to the river for science, but I stayed for the beauty."**
>
> — DAVID CAMPBELL, PH.D., *A LAND OF GHOSTS*

EDUCATION PROGRAM

LEAF PACK NETWORK

One of the education department's signature programs is the Leaf Pack Network, a stream ecology kit and network of online users, which was originally developed as a research tool by Robin Vannote, who placed the first leaf packs in White Clay Creek in the late fall of 1966. The packs are bundles of native leaves that have been collected in the watershed, dried and placed in mesh bags, and then tied to a rock or tree trunk in the stream. When removed several weeks later, the packs are filled with aquatic insects and other leaf-eating animals, and the types and abundance of those macroinvertebrates are good indicators of the health of the water. Because their leaves come from the surrounding trees and bushes, the packs tell much about the impact of human land uses on stream health and the critical role that streamside forests play in protecting water quality, which has been a major focus of Stroud Center research since its inception.

In 1990, 24 years after Vannote first used leaf packs as a research tool, Bern Sweeney began working with a ninth-grade teacher at nearby Upland Country Day School to create a curriculum for students. A key component was converting the leaf pack to a teaching device, and it has subsequently become widely used by teachers, citizen scientists, stream-watch groups, and community monitors. In 1999, the LaMotte Company, a leading producer

AS OF DECEMBER 31, 2016, THE LEAF PACK NETWORK INCLUDED:

39 STATES PLUS PUERTO RICO AND WASHINGTON D.C.

712 EXPERIMENTS COMPLETED

12 COUNTRIES

102,750 MACROINVERTEBRATES IDENTIFIED

of environmental-education products, entered into an agreement with the Stroud Center to produce and market the Leaf Pack Experiment Stream Ecology Kit, which immediately became one of the company's most popular products. Meanwhile, the Stroud Center developed the Leaf Pack Network® (LPN), which enables teachers, students, and other community members to collect data from their own streams, enter the results into the online database, and share them with others around the world.

In 2008, the Stroud Center had the Leaf Pack manual translated into Spanish and invited 15 teachers, professors, conservation workers, and government officials from Central and South America for a weeklong workshop at the Stroud Center. Each participant returned home with a kit and a commitment to sponsor a local workshop, the beginning of an effort to expand the program across Latin America and ultimately around the world.

In 2015, the Pennsylvania Association of Environmental Education awarded the Stroud Center the Outstanding Education Program Award for the Leaf Pack Network and its stream school programs.

More about the Leaf Pack and the Leaf Pack Network leafpacknetwork.org

EDUCATION PROGRAM

BOOTS-IN-THE-WATER STREAM SCHOOL PROGRAMS

In an age when teachers and others are deeply concerned about students' growing disconnection from the natural world — and with the emergence of a generation of digital natives who have grown up immersed in technology — Stroud Center educators have designed field trips to take students outside and put them directly into streams. Shortly after they arrive at the campus, visiting school groups are issued rubber boots and led to White Clay Creek. As they collect and identify macroinvertebrates, measure water chemistry, and assess the physical conditions of the stream habitat, they discover the unexpectedly dynamic world that lives there.

Stroud Center education programs also make use of the latest technology, some of which was developed and tested on the campus. Model My Watershed's online GIS application, which was launched in 2015, enables users to locate a watershed, analyze its characteristics, and model changes to the landscape caused by natural events or human intervention. The Water Quality Mobile App, which Education Director Steve Kerlin developed in 2012, enables users to collect and record data from their stream studies, and its learning pop-ups help them assess the stream's health.

The new technology is used to support what the students have learned in the streams, to engage those who are more comfortable with the virtual world, and to enable teachers and students to extend the learning experience beyond a one-day field trip.

WikiWatershed: Six online tools to protect fresh water

Model My Watershed

Micro Site Runoff Model

EnviroDIY

Monitor My

EDUCATION PROGRAM

WIKIWATERSHED

Education Director Susan Gill joined with Research Scientist Anthony Aufdenkampe to develop the initial idea for WikiWatershed®, named after Wikipedia and envisioned as a virtual place where people can learn about their watersheds, post new data and information, and determine how they, as watershed citizens, can best protect their sources of fresh water. Originally developed with a National Science Foundation grant for the Christina River Basin in Pennsylvania and Delaware, WikiWatershed has subsequently expanded throughout the continental United States. It now includes six online tools, and a high school curriculum has been piloted in five states.

The Model My Watershed® program, one of the six online tools, enables users to analyze their local streams, surrounding land cover, and soil data, watch what happens when they change the land uses or implement conservation practices, and create different plans to produce the most sensitive models for future development. WikiWatershed, which is designed for scientists, teachers, students, conservation workers, municipal decision-makers, and ordinary citizens, involves the staffs of the research, education, and water restoration groups. The toolkit of online resources currently contains Model My Watershed, Micro Site Runoff Model, EnviroDIY™, Monitor My Watershed®, Leaf Pack Network, and Water Quality Mobile App.

In April 2017, WikiWatershed received the Governor's Award for Environmental Excellence from the Pennsylvania Department of Environmental Protection for its suite of tools that "equip teachers, students, local governments, and community organizations to monitor their local stream and watershed health, determine the specific location of stormwater runoff, and learn how to predict and change human impact on freshwater ecosystems."

See it in action at wikiwatershed.org

A nature-inspired outdoor classroom, with an education kiosk designed by Eagle Scout Payton Shonk, opened at the Stroud Center in 2015 to foster streamside learning.

Watershed

Leaf Pack Network

Water Quality Mobile App

CYCLING BACK

The First Interns

"What happened that summer was pretty significant for me," said Nick Collins in his understated way.

NICK COLLINS, PH.D.

That summer was 1967, when Robin Vannote hired Collins, who had just finished an exchange semester at Swarthmore College, as an intern. "I knew almost nothing about aquatic ecology," said Collins, who studied desert rodents in college. "Robin exposed me to the ecology of water; and it's been water for me ever since" — he has been on the faculty of the department of ecology and evolutionary biology at the University of Toronto at Mississauga since 1973.

"It was an exciting summer for me," said Collins, who grew up in southern California. "Not only did I not know much about water, but I'd never been east before." He worked in a makeshift laboratory above the family's garage and lived in the Strouds' house, where "I'd walk by these amazing paintings and play the grand piano" and often eat supper with Mr. Stroud. "He was just a really nice person."

"I was proud to have known him," said Collins of Vannote. "I watched him create the first indoor stream in the new building, and I remember 10 years later when he and Sweeney published their classic paper on temperature" (*Science*, 1978).

PETER WELLING

"Social Security records show I earned $306 from my summer job in 1967," remembered Peter Welling. "I was 17. My employer, the Academy of Natural Sciences, assigned me to a new division — an unproven limnology research department down the road from my parents' farm. My job was to pick bugs out of leaf packs and put them in vials of preservative according to size and species. But first I had to collect the leaf packs," a task that included dodging an aggressive donkey who roamed freely in a local stream. "My workstation consisted of a fan, boards laid across saw horses, a lab lamp, tweezers, vials, and an AM radio. The work I remember as tedious. I'm sure I missed a few invertebrates. I know for a fact I didn't turn in all the vials."

Throughout its 50-year history, the Stroud Center has provided a unique opportunity for hundreds of high school and university students to work alongside freshwater scientists and educators. In the process, they have helped advance new knowledge about streams and rivers. In 2016, the Stroud Center hosted more than two dozen interns and participants in the NSF Research Experience for Undergraduates and Teachers. Many of them gathered in front of the Moorhead Environmental Complex for a photo one sunny day, proudly wearing their Stroud T-shirts.

Read more about the intern program at stroudcenter.org/news/welcome-interns

EDUCATION PROGRAM

TREK PARTNERSHIPS

Visitors to the Stroud Center can see, just outside the large meeting hall, an exhibit of photographs and journal entries celebrating a three-week trek undertaken by 12 students and their teachers in the summer of 2006.

The trek was organized in conjunction with the Stroud Center's massive six-year scientific assessment of all the streams, rivers, and reservoirs that provide New York City's drinking water. The students traced the path of that water, from its origins in the Catskill Mountains and the fields and pastures of Delaware County to its destination — more than 100 miles away — in the water pipes of the city's five boroughs. Called "Mountaintop to Tap," the trek brought together six students from the rural watersheds, where water from hundreds of streams is collected into a series of huge reservoirs, and six students from the inner city, where that water ultimately ends up.

It was a tough experience for the students, but an exciting one, as they worked their way downstream by foot and in boats, learning about the region's science and history, discovering its wonders, meeting with its residents, public officials, and the press, and living in close quarters with others of widely diverse backgrounds. They started their journey as young people with little idea of what it takes to provide safe drinking water to New York City and ended it as eloquent spokespeople for the water system and the 9 million people who depend on it. They even starred in a film, made by Emmy Award winner Kent Garrett, which documented their journey from "Mountaintop to Tap."

The New York experience became the basis for an ongoing series of treks in collaboration with other organizations, and the Stroud Center has subsequently partnered on similar educational adventures on Brandywine Creek (with Urban Promise of Wilmington, Delaware, and the Coatesville Youth Initiative in Pennsylvania); and on the Schuylkill River (with the Schuylkill Headwaters Association).

Watch the video at stroudcenter.org/education-projects/mountaintop-to-tap-trek

Mountaintop to Tap: New York Harbor School students Asha Armstrong, Leydi Basilio, Jerriel Stafford, and Natalie Bloomfield on top of Wittenberg Mountain, high above the crystal waters of the Ashokan Reservoir.

June 17, 2011: Students from the Coatesville Youth Initiative celebrate completion of the first Brandywine Trek, a five-day journey from the river's source in northwestern Chester County, Pennsylvania, to the confluence of the Brandywine and Christina rivers in Wilmington, Delaware. *Photo: Christina Medved*

Education Directors Through the Years

Ann Faulds

Jim McGonigle

Jamie Blaine, Ph.D. (from left) Kristen Travers,

A.


B.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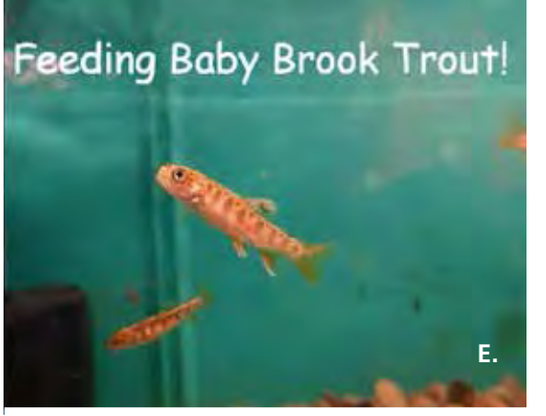

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Because of its commitment to making its research findings both widely available and accessible to lay audiences, the Stroud Center has created a variety of education and public outreach opportunities in addition to its formal education programs.

A | PUBLICATIONS

Science is the foundation of all that happens at Stroud Water Research Center, and its scientists, educators, and restoration staff have published hundreds of papers in peer-reviewed journals. They also present frequently at professional conferences, and serve on expert panels assembled by the National Science Foundation and other organizations.

B | HIGHER EDUCATION

Dave Arscott and his class at the University of Pennsylvania. Scientists and educators have taught regular courses at the University of Pennsylvania and The University of Delaware since the early 1970s.

C | PUBLIC POLICY

Bern Sweeney briefing reporters in Cusco, Peru, on the results of the Stroud Center's two-year study of water quality of streams impacted by the new international highway from Puerto Maldonado to Cusco.
Photo: Carmen Chavez

D | INTERNATIONAL WORKSHOPS

Tara Muenz leads a class on water testing techniques for community participants on Costa Rica's Osa Peninsula.

E | EDUCATIONAL VIDEOS

In 2016, the education department started producing science education videos that can be found on the Stroud Center's YouTube channel and began leading a webinar series that reaches up to 200 attendees from across the country at a time.

F | SCOUT PROGRAMS

In early 2016, Steve Kerlin launched an education initiative for Scout groups. An Eagle Scout himself, Kerlin saw a natural fit between the ideals of scouting and Stroud Center education programs, which are easily aligned with requirements for badges, advancement, service hours, and special awards. Here members of a Brownie troop plant trees near White Clay Creek.

G | PROFESSIONAL DEVELOPMENT AND TRAINING

For many years, Stroud Center educators have led trainings for teachers, Pennsylvania Department of Environmental Protection staff, state park naturalists, watershed associations, and master watershed stewards. Here Steve Kerlin and Tara Muenz give thumbs up to the North American Association of Environmental Education.


(right), and educators
Christina Medved,
and Vivian Williams


Susan Gill, Ph.D.


Steve Kerlin, Ph.D.

"Idealism" is not a word ordinarily associated with people who spend their workdays devising and administering programs to help dairy farmers manage their manure. But you don't have to talk very long with Matt Ehrhart, David Wise, and Lamonte Garber, who make up the Stroud Center's Watershed Restoration Group — and who spend a lot of time thinking about barnyards — before that word comes up.

"We want to change things," says Ehrhart, meaning more than just improving particular, often longstanding, land-use practices. The group seeks to help farmers and other landowners understand how those practices affect the quality of the water, both on their farms and for miles downstream; and they then work with them to implement new and more benign methods. Because they have been doing this work for a long time, they bring to their farm visits sound agricultural knowledge, a grasp of farmers' needs, and a network of funding sources to support improvements. But perhaps the most valuable tool in their toolkit is access to 50 years of Stroud Center research on land use, stream health, and water quality.

Healthy Streams Begin on Land

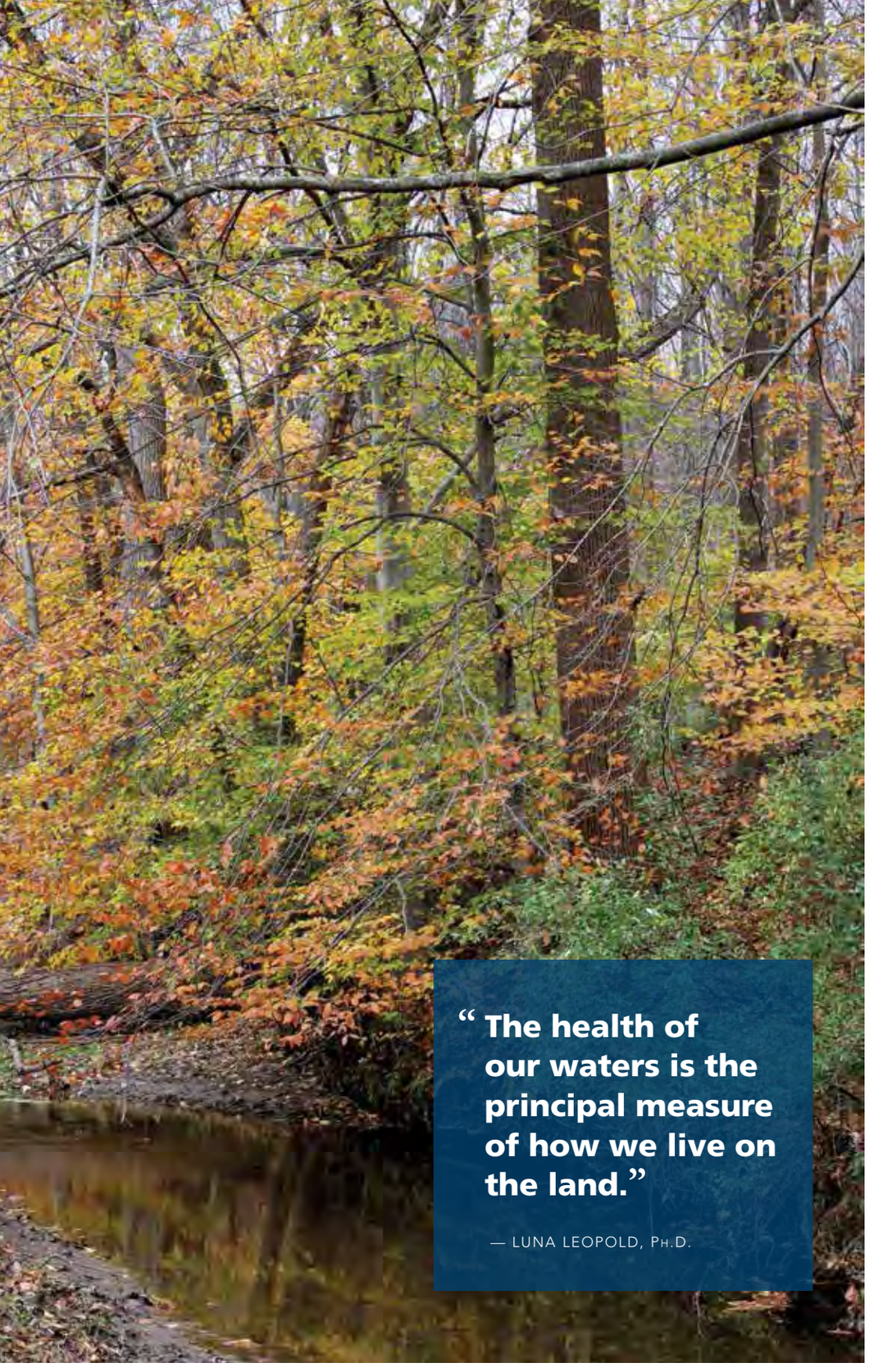
A key imperative is to plant trees, lots of trees. A forest buffer at least 100 feet wide will intercept many pollutants as they run off the land toward the stream. But its value does not end at the streambank; it also provides shade, improved habitat, and other benefits that enable a healthy stream to process the pollutants that do get into it. Even trees planted in upland areas, far from the stream itself, make a difference to the quality of the water.

Left: The Watershed Restoration Group works with farmers to make changes on land that will improve water quality. Here, a farmer has added fencing to keep cows out of a nearby stream. *Photo: Stephanie Eisenbise*

Trees improve a stream's ability to process pollutants naturally and clean their own waters.

Building on Stroud Center research, the Watershed Restoration Group has made forest buffers a central focus of its whole-farm approach to clean water.

In 2004, the Stroud Center broke new ground with a landmark study that established that streamside forests actually help streams to process pollutants that do get into their waters by:



> **"The health of our waters is the principal measure of how we live on the land."**
>
> — LUNA LEOPOLD, PH.D.

OUR NEWEST DISCIPLINE

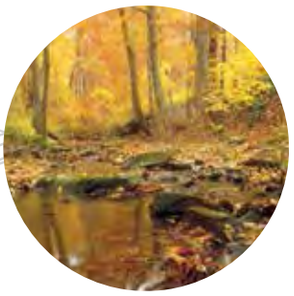
Started in 2012, the Watershed Restoration Group is the newest Stroud Center discipline, and yet in many ways it is a continuation of all that preceded it. Ehrhart, Wise, and Garber, who have worked together for years, are driven by two goals: (1) to help local farmers and landowners institute innovative practices that will lead to healthier streams and cleaner water and (2) to translate the Stroud Center's scientific research on streams, rivers, and watersheds into concrete land conservation practices.

This marriage of the theoretical and the tangible gives the group a unique position in stream restoration. "We are not interested in short-term engineering fixes," says Wise. "We have a long-term horizon. We want to encourage improvements in the watershed that will put the stream in a position to restore itself." The ability of streams to process pollutants naturally and clean their own waters is one of the most important findings of Stroud Center research, dating back to Ruth Patrick's studies on the Conestoga River in Lancaster County in the 1940s and culminating in the work on streamside forests pursued by Bern Sweeney, John Jackson, Denis Newbold, and others since the 1990s.

The Watershed Restoration Group takes a comprehensive view of the whole farm, and much of what it offers to farmers — stormwater and manure management in the barnyard and innovative practices in the fields and pastures — has immediate and tangible economic benefits, which has great appeal to landowners.

1. Supplying the shade necessary to maintain cool water temperatures and rich oxygen levels.

2. Supplying food for the entire food chain from bacteria to fish.



3. Enhancing both the quantity and diversity of stream life.

STREAMS THAT RUN THROUGH FORESTED AREAS ARE WIDER AND SHALLOWER THAN UNFORESTED REACHES, WHICH GIVES THEM:

2–5x MORE BOTTOM AREA, WHERE MOST STREAM ORGANISMS LIVE

2–5x MORE METABOLIC ACTIVITY = 2–5X MORE AQUATIC LIFE

2–8x MORE ABILITY TO CLEAN UP NITROGEN POLLUTION

Source: Sweeney, B. W., et al. Riparian Deforestation, Stream Narrowing, and Loss of Stream Ecosystem Services. *PNAS* 101, no. 39 (2004): 1432–7.

Planting trees in areas where they were uprooted centuries ago makes room for open land; however, it is a much harder sell. Trees require time, space, and money, things most farmers don't have in abundance. Nor are trees a quick fix: they need several years to reach an effective size; and they take up productive land, which is a farmer's most valuable asset. But because trees play such a critical role in stream restoration, planting them is a requirement of the watershed restoration program. And while the Watershed Restoration Group is able to provide funding through its government and foundation partners, many farmers remain reluctant to incur the additional, and very real costs, of space and time. "Often," says Ehrhart, "we have to leverage them into a buffer." Take, for example, the Amish and Mennonite communities, whose members have farmed large parts of Lancaster County, a few miles west of the Stroud Center, for generations. Known for producing bountiful crops on small parcels without modern machinery, Plain sect farmers have traditionally used every available square meter, planting right up to the streambank. For them, new trees displace old and valuable cropland. "They want to do the right thing," says Garber, who has worked with the communities for many years. "We emphasize how the entire landscape affects water quality. But it is something more specific — such as the return of fishing, hunting, and wildlife that comes with habitat restoration — that becomes the primary motivator."

Plain sect farmers discuss intensive cattle grazing systems with Lamonte Garber at a farm in Berks County, Pennsylvania, as part of a series of farmer-friendly education programs offered by the Stroud Center in partnership with other conservation organizations.

Read more about watershed restoration at stroudcenter.org/restoration

A | HARD SCIENCE

In the citizen science project funded by the William Penn Foundation, Stroud Center scientists are partnering with community groups to conduct hypothesis-driven scientific monitoring throughout the 13,500-square-mile Delaware River Watershed, which is home to over 7 million people in four states. Although water-quality monitoring has been going on for decades, it has often been a challenge for volunteers to contribute data to the actual planning and regulatory processes. By using traditional chemical and biological tools, together with innovative, inexpensive, and easy-to-use technologies such as the EnviroDIY sensor, the groups can now monitor long-term changes in water quality and quantity in ways not previously available to them. "Our goal," said project facilitator Dave Bressler, "is to help the groups build the capacity to do rigorous science." And having verifiable data, said John Jackson, "empowers the groups by giving them a credible voice in the public debate over the watershed's future."

B | SLOW WATER

In response to Hurricane Sandy, which in the fall of 2012 wreaked devastation from Florida to Canada, the National Fish and Wildlife Foundation is supporting the Stroud Center's research to mitigate flooding and protect vulnerable and often more populated downstream areas. The project, under the supervision of Melinda Daniels, seeks to (1) reduce runoff from the land and increase infiltration into the ground through the use of forest buffers, terracing steep fields, and installing level-lip spreaders (ditches that collect and infiltrate runoff) and (2) store and slow flood flows by expanding floodplain wetlands and adding large wood to small stream channels. The goal is to diminish overall flood peaks by 40 percent.

Left: David Bressler, citizen science project facilitator

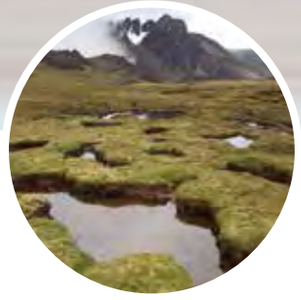
CYCLING BACK

Moving Forward, Rooted in the Past

At first, the introduction of the Watershed Restoration Group may have seemed outside of the Stroud Center's core mission. But Bern Sweeney, who had collaborated with Ehrhart, Wise, and Garber for many years, understood that the group's work is embedded in the organization's roots:

In **RUTH PATRICK'S** quest to find a clean stream on which scientists could do basic research that would produce the knowledge necessary to restore polluted streams — a quest that led her, first to the Strouds' farm on White Clay Creek and then to the establishment of the Stroud Center.

In **JOAN AND DICK STROUD'S** aspiration that the Stroud Center's research inform local conservation efforts, improve land-use practices and provide tangible benefits to farmers and other landowners.



In **ROBIN VANNOTE'S** River Continuum Concept, which established the connectivity of the entire stream and river ecosystem and stressed the vital importance of small, headwater, and even intermittent streams. Too often overlooked and undervalued, these streams, as the work of Lou Kaplan, Denis Newbold, and others have subsequently demonstrated, make up at least 80 percent of the nation's stream network.

In **BERN SWEENEY'S** enduring belief in the importance of trees to the health of streams, which has also been the focus of the Stroud Center's long-term research in environmental biology (LTREB) project that the National Science Foundation has funded since 1998.

In both the **APPLIED RESEARCH** and **EDUCATION PROGRAMS**, whose purpose is to translate basic research into language, projects, and programs that are comprehensible to nonscientists, helpful to policymakers, informative to teachers and students, and relevant to landowners.

In the **SPIRIT OF THE STROUD CENTER**, with its holistic view of the watershed, its collaborative work both internally and with outside partners, and its determination to expand the frontiers of scientific research, create education programs to spread new knowledge, and institute improvements on the land that will lead to healthier streams and cleaner water.

Photo: Halkin Mason Photography

50 YEARS Est. 1967

INTERNATIONAL PRESENCE

In 1987, Dan Janzen, the renowned evolutionary biologist, invited the Stroud Center to establish a tropical water research laboratory in northwestern Costa Rica.

Dan Janzen and Winnie Hallwachs

The proposed research station would complement the huge Guanacaste Conservation Area, which he and his wife, Winnie Hallwachs, had recently proposed to the Costa Rican government. Janzen had begun assembling vulnerable parcels of land in the early 1970s, with the goal of establishing an area large enough to preserve the region's vast biological diversity. He wanted in addition to create a replicable blueprint for conserving natural resources, protecting endangered species, and engaging local communities, particularly those who lived in areas whose critical habitats were vulnerable to powerful external forces.

Janzen's invitation excited Stroud Center scientists and supporters. Until then, almost all research into the dynamics of freshwater ecosystems had taken place in temperate watersheds, and the proposed venture would give them a base from which to understand some of the world's most vulnerable, varied, and unexplored sources of fresh water.

Things happened quickly after Janzen's invitation. Within a year, the Stroud Center had raised the funds and worked closely with Janzen to convert a small farm near the base of the Orosí Volcano into a laboratory and education facility called Maritza Biological Station. In 1989, Janzen and Hallwachs' dream of the Guanacaste Conservation Area became a legal reality. And on March 22, 1991, Costa Rica's President Rafael Calderon dedicated Maritza Station as a permanent freshwater research facility. In time, the streams flowing through the station would, like White Clay Creek, become a Long-Term Research in Environmental Biology site, funded by the National Science Foundation. To date, those streams have generated more than 30 peer-reviewed scientific papers. Guanacaste Conservation Area is now a UNESCO World Heritage Site, protecting an estimated 375,000 species, and Maritza Station has become the headquarters for the Stroud Center's tropical ecosystem studies. From there, its research projects and education programs have spread to other parts of Central and South America, while the station itself has become a resource for scientists, teachers, and land managers throughout the region.

The establishment of Maritza Biological Station marked the beginning of increasingly far-flung travels for Stroud Center researchers and educators, which over the next 30 years would take them literally around the world: to conduct research on the Amazon and Congo rivers and the streams of Papua New Guinea; to lead education workshops in Peru and organize a Leaf Pack group in Kenya in collaboration with Nobel Peace Prize winner Wangari Maathai's Green Belt Movement; and most recently, in November 2015, to journey to the bucolic country of Bhutan, high in the Himalayas, to assess water-quality conditions and help set up monitoring and citizen-science programs to enable local communities to protect their freshwater sources, which are at once an enormous economic asset and a fragile natural ecosystem.

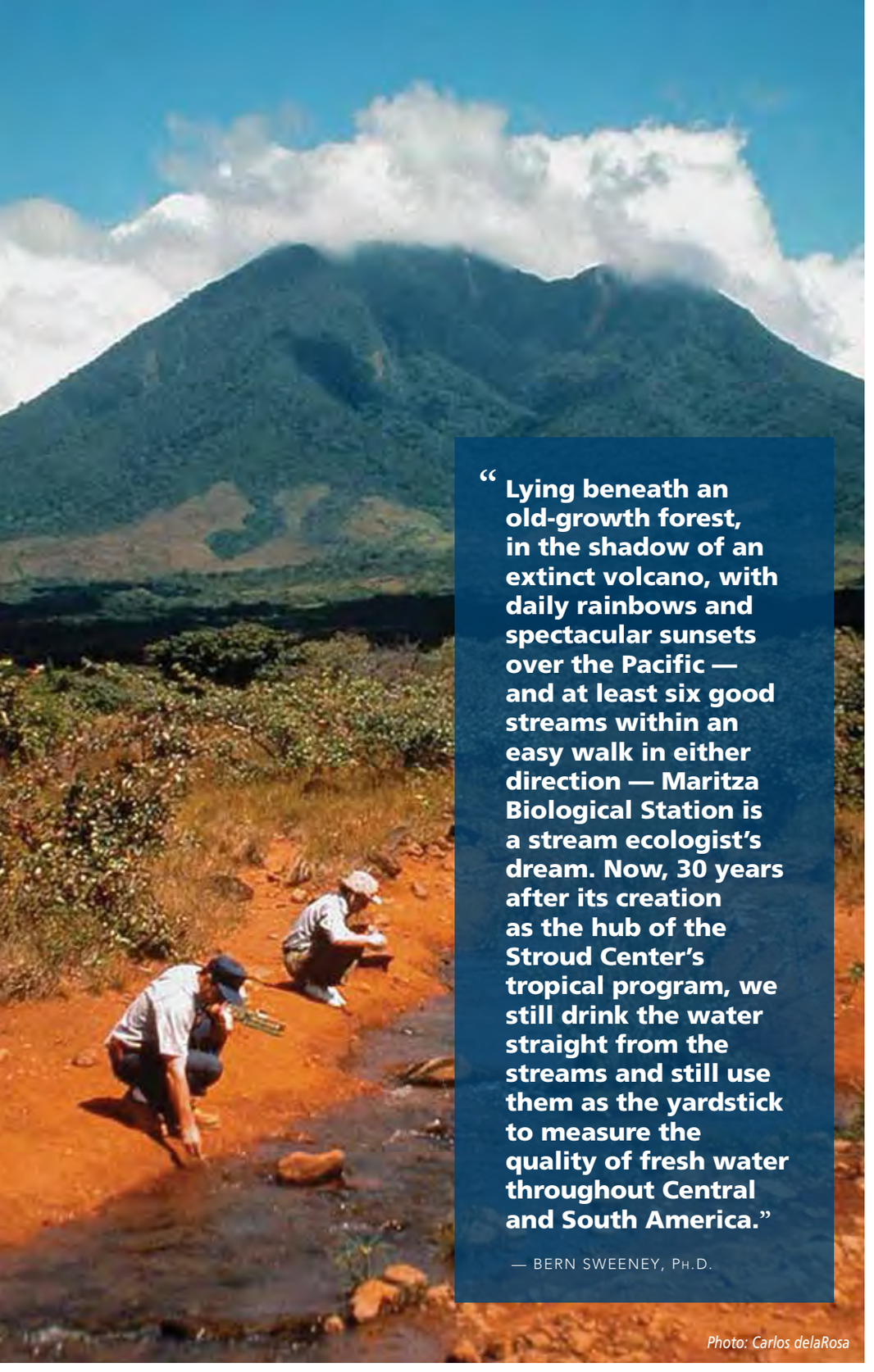
International Education

COSTA RICA

March 22, 1991. Students from the Guanacaste Conservation Area of northern Costa Rica attend the ceremony at which President Rafael Calderon dedicates Maritza Biological Station as a permanent research facility. *Photo: Dan Janzen*

PERU

Using native leaves and simple mesh bags, Bern Sweeney shows a group of Peruvian students how to make leaf packs to monitor water quality.



“Lying beneath an old-growth forest, in the shadow of an extinct volcano, with daily rainbows and spectacular sunsets over the Pacific — and at least six good streams within an easy walk in either direction — Maritza Biological Station is a stream ecologist’s dream. Now, 30 years after its creation as the hub of the Stroud Center’s tropical program, we still drink the water straight from the streams and still use them as the yardstick to measure the quality of fresh water throughout Central and South America.”

— BERN SWEENEY, PH.D.

Photo: Carlos delaRosa

Maritza Biological Station Manager

RAFA MORALES

“Maritza is like a big open library where I came to know a new world. For me, it’s my second home.”

When Bern Sweeney appointed him in 1991, Rafa Morales was a field worker on a Stroud Center research project, a high school dropout whose previous job had been a hardware store clerk in the tiny town of La Cruz. But the situation was dire: Maritza had just lost its manager, a scientist with a Ph.D., said Sweeney, “and only one guy who was left stood out, both in the quality of his work and the way he carried himself. So I turned to Rafa and said, ‘You’re in charge. I’ll be back in a month.’”

How’d that work out?

“I have never put a challenge in front of Rafa that has made him pause.”

Adds John Jackson, who has spent more time with Morales than any other staff member, “It’s often sink or swim down there, and Rafa doesn’t sink. He never says, ‘I can’t do that.’ He says, ‘Show me the way.’”

Twenty-five years later, now with a high school diploma and self-taught English, Rafa Morales is still in charge.

“He is curious about natural science, has an incredible memory, and he knows the landscape intimately,” says Sweeney. “Tell Rafa what you need … and then stay behind him.

“He is the greatest employee you could possibly have.”

AVONDALE

John Jackson and board member Anne Hannum with a group from the U.S. Department of State’s International Visitor Leadership Program. The participants spend a day at the Stroud Center attending presentations and taking tours.

KENYA

After talking with their village elders about the history and traditions of the Nyongara River, students at the Ruthimitu Primary School prepare leaf packs for a project that will bring together the entire community to discuss, assess, and protect the health of its water.

BHUTAN

In partnership with the Waterkeeper Alliance, Stroud Center scientists introduce an array of techniques, ranging from traditional insect sampling to new technologies that are inexpensive, accurate, and sustainable, all aimed at helping the people of the Himalayan nation monitor the quality of their water.

LOCATION HIGHLIGHTS

ADVANCING KNOWLEDGE AND STEWARDSHIP OF FRESHWATER SYST

STROUD WATER RESEARCH CENTER, USA

The Watershed Ambassadors program brings teachers, conservation professionals, and government officials to the Stroud Center to discuss water conservation efforts in their countries and to share ideas.

CONGO AND AMAZON RIVERS

Stroud Center scientists travel to remote parts of the world's largest and second largest rivers because most large rivers have become too polluted and impacted to test hypotheses about how they work under natural conditions.

PERU

Even in remote streams high in the Peruvian Andes, Stroud Center scientists draw crowds of local people fascinated at their ability to gauge water quality by the macroinvetebrates crawling around on rocks picked up randomly from the bottom of a creek.

Research Locations

Leaf Pack Participants

EMS WORLDWIDE

HIGH WATER

Clean water is critical to the Himalayan country of Bhutan, which has some of the world's most pristine streams and depends on the export of hydropower, primarily to India, for almost half its national revenues.

PAPUA NEW GUINEA

Understanding the downstream movement of carbon and sediment in steep mountainous rivers throughout the world has required Stroud Center scientists to study the Fly River from its headwaters to the estuary shown here.

KENYA

After giving the Joan M. Stroud Memorial Lecture in 2002, Wangari Maathai took the Leaf Pack Kit back home to Kenya and initiated a program for students in several schools. Founder of the Green Belt Movement for environmental and human rights and the empowerment of women, Maathai was awarded the Nobel Peace Prize in 2004 and invited Dick and Joan Stroud's daughter, Joanie Blaine, to attend the ceremony as her guest. Two years later, she returned to the Stroud Center as the Water's Edge speaker. She died in 2011.

50 YEARS Est. 1967

CAMPUS AND WATERSHED

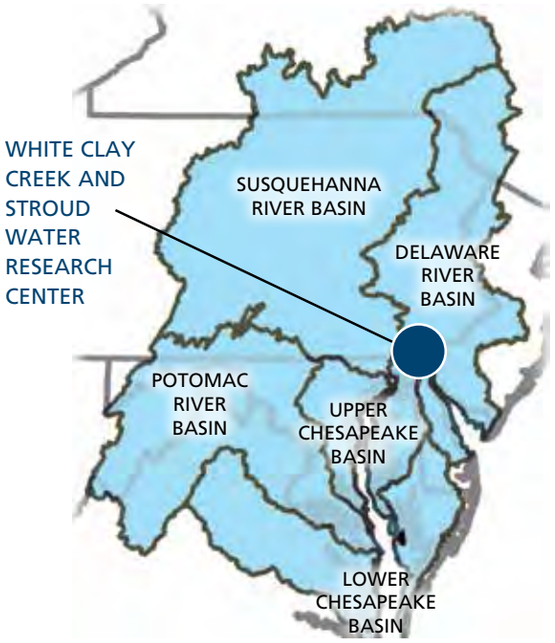
Every project and program at Stroud Water Research Center has had its origins in a stream. More often than not, that stream has been the east branch of White Clay Creek, which flows along the west edge of the Stroud Center's campus, where part of it makes a temporary detour through the building itself.

The east branch is among the world's most thoroughly studied bodies of water, probed by research scientists and technicians, explored by school children and community groups. Even unsuspecting visitors to the Stroud Center are likely to be handed a pair of rubber boots and led down to the stream.

WHITE CLAY CREEK

The White Clay's influence extends well beyond its banks, for the knowledge acquired there provides the foundation for research projects and education programs hundreds and even thousands of miles away. Over the years, the stream and its watershed have evolved into a natural laboratory, where scientists and educators cultivate and test ideas. One measure of its importance in the public eye are the official designations that state and federal agencies have extended to the watershed over the years — efforts which seek to protect it as a study site, teaching place, environmental preserve, and, not coincidentally, a primary source of drinking water for the downstream city of Newark, Delaware.

In 1981, the National Science Foundation named White Clay Creek's entire 300-acre drainage basin an Experimental Ecological Reserve because of its long-term research importance. Three years later, the Commonwealth of Pennsylvania designated the east branch an Exceptional Value Stream, the state's highest designation and one that affords it special protections against developments that could threaten its water quality. In 1998, the NSF began funding an ongoing project under its Long-Term Research in Environmental Biology program, and almost two decades later, the program continues to provide data on stream health and watershed restoration. In 2000, the White Clay was named a National Wild and Scenic River, the first time an entire watershed has been so designated.

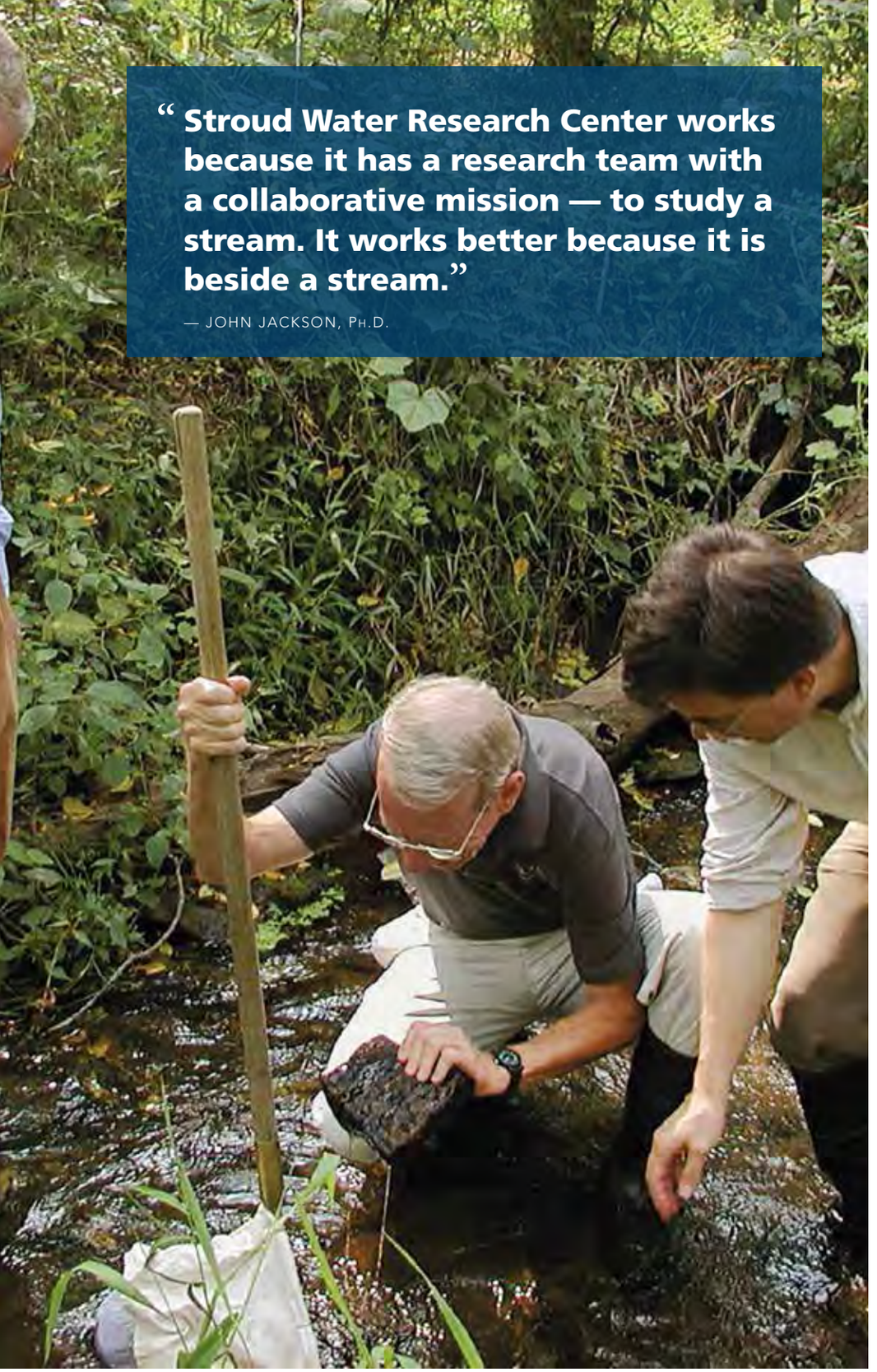


The water in the east branch of White Clay Creek is cleaner now than it was when the Stroud Center first came to its banks 50 years ago.

Trees serve as buffers against pollutants moving across the land toward the streams; their leaves sustain the food web, from algae to fish; and they deliver a series of services that enable the stream's ecosystem to actually clean itself. The impact of humans does not always have to be detrimental to the natural environment, if you approach it with care and respect. "Our goal," said Bern Sweeney," is to make White Clay Creek better because it runs through our campus."

"The best thing you can do for a stream is to plant a tree. Even better is to plant a forest."

— BERN SWEENEY, PH.D.



> **“Stroud Water Research Center works because it has a research team with a collaborative mission — to study a stream. It works better because it is beside a stream.”**
>
> — JOHN JACKSON, PH.D.

> **“A river … shapes not only the land but the life and even the culture of its valley. To think of any river as nothing but water is to ignore the greater part of it.”**
>
> — HAL BORLAND, *BEYOND YOUR DOORSTEP*

Southern Chester County, where the Stroud Center is located, has long been one of Pennsylvania’s fastest growing areas, and its residential and commercial development, as well as its proximity to Philadelphia, have put heavy demands on the region’s land and water. But if you look at the historical maps (below), you will see that the changes to the land near the Stroud Center have been of a very different order.

Left: Under the watchful eyes of entomologist John Jackson, Rod Moorhead and Johnny Fisher learn how to find macroinvertebrates under a rock Above: The Stroud Center’s longest running experiment, this malaise net has been collecting adult aquatic macroinvertebrates emerging from White Clay Creek for 50 years. It is used to capture data about insect species in streams and to determine in which direction emerging insects fly.

EARLY DAYS

From its early days of European settlement through the 1960s, the land was used largely for crops and pasture, its once verdant forests cut down long ago — as happened all across the state called Penn’s Woods.

1970–PRESENT

Beginning in the early 1970s, the maps show a dramatic resurgence of tree cover, particularly along the streambanks, which has come in response to a growing body of research, much of it produced at the Stroud Center, that revealed the critical relationship between trees and clean water.

Photo: Halkin Mason Photography

Awarded LEED Platinum, the highest level of sustainable certification based on:

- SUSTAINABLE SITES
- WATER EFFICIENCY
- ENERGY AND ATMOSPHERE
- MATERIALS AND RESOURCES
- INDOOR ENVIRONMENTAL QUALITY
- INNOVATION AND DESIGN PROCESS

MOORHEAD ENVIRONMENTAL COMPLEX

By about 2010, the rapidly growing Stroud Center, which had already undergone two major building expansions, was pressed once again for additional laboratory, education, and administrative space. With desks wedged into corners and even an office in the attic, it was clear the time had come again for new construction. And while no one was exactly sure where all the money would come from, the board of directors was determined to move ahead. Out of discussions with staff members, consultants, and architects arose a vision of a new building that would not just provide much-needed space. It would also physically demonstrate the institution's mission and values. It would be a model of sustainable construction, incorporating the latest thinking in land use, water conservation, and green energy. Its roof would be a living roof; its landscaping would be a natural classroom. "We want it to demonstrate," Bern Sweeney said, "that we walk the walk."

The result is the Moorhead Environmental Complex, a LEED® Platinum building, which opened in 2012. It is named in honor of Rod Moorhead, whose drive and generosity did so much to turn an idea into reality. Constructed with local and recycled materials, the building is powered by geothermal and solar energy. It features natural landscaping, constructed wetlands, and a green roof. As befits a water research center, it has a sustainable water cycle, from inflow to waste treatment. The result is that the largest construction project ever undertaken by the Stroud Center has actually reduced the overall environmental footprint for the entire campus and has thereby created stronger safeguards for White Clay Creek.

Since its beginnings, the Stroud Center has tried to make its campus and buildings sensitive to the surrounding landscape and the traditions of the nearby communities. The original building incorporates the remains of an 18th-century stone barn seamlessly into the Ruth Patrick Library. The main lecture hall's simple design is modeled after two local Quaker meetinghouses. Visiting scientists stay in a renovated 1720s log cabin. Inside the buildings, much of the furniture consists of Pennsylvania antiques collected by Dick and Joan Stroud, as well as more modern pieces made by local craftspeople.

Part of the sculpture, "Stream Language," by Jeffrey Funk, which was installed in January 1995 as part of the original building's expansion and renovation. Above it is the log cabin, circa 1720, which Joan and Dick Stroud restored in the 1970s and which now houses visiting scientists.

Green Building Design to Educate, Conserve, and Inspire

A | WATER USE AND TREATMENT

A wetland-wastewater-treatment and drip-irrigation system cleans all of the Stroud Center's wastewater. In addition to a traditional septic tank, the system includes two wetland cells in the courtyard behind the building that are filled with native plants and microbes to help filter wastewater and reduce nutrient discharge.

B | EDUCATION

Stroud Center educators Libby Gregg and Christina Medved describe some of the attributes of the green building to a group of young students and their teachers.

C | SUNSHADES

On south-facing windows, shades shield direct sunlight from lower windows, allowing offices to have the option of high or low lighting, depending on the amount of natural light available. Interior louvers on the upper windows reflect and distribute light across ceilings, which provides soft natural light in offices throughout most of the building.

D | GREEN ROOF

The green roof over our education classroom keeps that part of the building cooler in the summer and warmer in the winter, and it provides habitat for birds and insect pollinators.

E | FLOORING

Three different types of slate stone were quarried and fabricated within 100 miles of the Stroud Center by the Structural Slate Company of Pen Argyl, Pennsylvania.

F | SOLAR PANELS

The roof's 76 solar panels provide carbon-free energy.

CYCLING BACK

Wet Lab and Stream House

In 1999, the wet lab, which Robin Vannote had devised 32 years earlier to carry water from White Clay Creek through the basement of the original building and then back to the stream, was expanded into a new stream house, where research projects and education programs now take place in an atmosphere designed to replicate as nearly as possible the natural conditions of the creek.

50 YEARS *Est. 1967*

COMMUNITY

From its beginning, Stroud Water Research Center has striven to involve itself in the community of which it is a part.

Encouraged from the outset by Joan and Dick Stroud, the Stroud Center has always recognized that it is very much a part of the landscape and the communities that surround it. Over the years, staff members have held elected positions in their townships, served on nonprofit local boards, and given public testimony on issues affecting land use and clean water. The Stroud Center has also opened its campus and made available its scientists and educators for a variety of lectures and programs.

Because clean fresh water depends on a healthy watershed, which in turn depends on an educated and engaged citizenry, the Stroud Center looks for interesting ways to make its research accessible to local residents and businesses, to expose them to new ideas and leading thinkers, and to work with them to implement land-use and water-protection programs that benefit the region.

This section celebrates some of the ways the Stroud Center has been involved with its community over the last 50 years.

STROUD AWARD FOR FRESHWATER EXCELLENCE RECIPIENTS

Olivia Newton-John and John Easterling (2011)

John Briscoe, Ph.D. (2012)

Kathryn Sullivan, Ph.D., and Jane Lubchenko, Ph.D. (2013)

Robert F. Kennedy Jr. (2014)

Alexandra Cousteau (2015)

Jonathan Jarvis (2016)

His Serene Highness Prince Albert II of Monaco (2017)

A.

B.

A | THE WATER'S EDGE AND FRESHWATER AWARD

Bern Sweeney presents a Leaf Pack Kit to the first Water's Edge speaker, Jane Goodall, to take back to Roots & Shoots, the international youth service program she founded in 1991. Since 2003, when Goodall entered the stage reproducing the call of the chimpanzees to whom she has devoted her life, The Water's Edge has honored some of the world's most renowned environmentalists and water experts, including Wangari Maathai, William McDonough, Sylvia Earle, and Kristine Tompkins.

In 2011, the first annual Stroud Award for Freshwater Excellence was presented to Olivia Newton-John and John Easterling for their work conserving the Amazon River watershed.

C.

D.

B | THE JOAN AND DICK STROUD MEMORIAL LECTURES

Over the past 29 years, the free lecture series has presented a remarkable intellectual feast for those in attendance, with speakers ranging from Dan Janzen, founder of Costa Rica's Guanacaste National Park, to Rita Colwell, director of the National Science Foundation, and including photographer Subhankar Banerjee, whose Arctic and Desert series changed the public's understanding of these landscapes; Gus Speth, a founder of both the Natural Resources Defense Council and the World Resources Institute; Gene Likens, who founded the Institute of Ecosystem Studies; Wade Davis, National Geographic Explorer in Residence; Sandra Postel, founder of the Global Water Policy Project; and Jeff Orlowski, who filmed the Emmy Award–winning "Chasing Ice" (pictured here).

C | SUSTAINABLE FEAST

A candlelight dinner prepared by well-known local chefs and served under a starlit sky, the Sustainable Feast saluted the season's harvest with food and beverages wholly provided by local producers and vendors. The unique multicourse meal, served here at the renovated barn on Michael and Anne Moran's nearby farm, highlighted the connection between clean fresh water, sustainable agriculture, and healthy food, all enjoyed in the presence of good company.

D | EARTH DAY: UPSTREAM FESTIVAL

The Stroud Center celebrated Earth Day with its Upstream Festival, a day of stream and woodland walks, education workshops, fly-fishing demonstrations, science discussions, storytelling, and music. Here, the irrepressible landscape architect and environmental philosopher Ian McHarg entertains participants on a cold and wet Earth Day in 1997.


E.


F.


H.


I.


J.

Community (continued)

E | WILLOWDALE STEEPLECHASE/KIDS' ALLEY

Started in 1992 by W. B. Dixon Stroud Jr., the Willowdale Steeplechase celebrated its 25th anniversary in May. The Mother's Day event, whose proceeds benefit the Stroud Center and two other nonprofit organizations, is a combination of horse racing and a country fair. It includes the Kids' Alley tent, sponsored by the Stroud Center, which features science, crafts, games, and storytelling. Here Assistant Director of Education Tara Muenz and Senior Research Scientist Lou Kaplan share with children some of the small wonders of stream life.

F | TREE PLANTINGS

Mandy Cabot and Peter Kjellerup, co-founders of Dansko, current and former board members, and long-time supporters of the Stroud Center, take a short break from their Arcadian labors. They are part of a volunteer force that has planted more than 50,000 trees across southern Chester County. Each planting has been laid out as a scientific experiment to answer a specific question, and over the years the plantings have produced many peer-reviewed publications and trained several graduate students. "We are probably the only folks crazy enough to know what type of tree was planted where and when, what its size was initially, and how well it survived," said Bern Sweeney. "Every tree we plant helps to restore and protect the watershed in which we work and live."

G | STREAM WATCH

In 1991, concerned about the impact on water quality from the rapid development of the White Clay Creek watershed, the Stroud Center joined with volunteers from the White Clay Watershed Association (and later the Delaware Nature Society) to launch Stream Watch, a program designed to monitor changes in water quality and make the data available to community groups engaged in conservation efforts. Long-term studies had found substantial improvements in water quality after 1972, and while those trends continued, the rate of change slowed after the mid-1990s as the region experienced significant growth. The research findings encouraged new efforts to protect open space, and water-quality trends have shown renewed improvement in recent years.

H | WATERSHED EDUCATION OUTREACH

Stroud Center watershed restoration and education staffs offer watershed education to Amish and Old Order Mennonite school students and their teachers, often meeting at their local streams and one-room schoolhouses throughout southeastern Pennsylvania. These students typically continue the farming tradition and need information on stream-friendly practices.

I | FOREST BUFFER WORKSHOPS

In addition to sponsoring volunteer tree plantings, the Stroud Center conducts workshops for land managers, farmers, and community and political leaders on the latest research on forest buffers and the most effective methods of revitalizing deforested areas.

J | STREAM SCHOOL

Perhaps the Stroud Center's most popular and effective classroom is the 1,800-acre experimental watershed that surrounds it and which the education staff uses as a living laboratory for students of all ages to explore the physical, chemical, and biological characteristics of streams. The most compelling way to understand streams and their connection to the landscape is to put on a pair of boots and get into the water. Pictured here is the first Stream School class in 1994.

K | SUMMER EVENTS

An ever-changing series of early summer events to bring people together in support of clean water has included Sustainable Splurges (2015), where guests sampled local wine, cheeses, and chocolates at the Farm at Doe Run, and the Rally for Fresh Water (2017), which took over six dozen car enthusiasts on a scenic drive through Chester and Lancaster counties, ending with a barbecue at the Runnymede Sanctuary.

CYCLING BACK

Volunteers

FRANK KLEIN, PH.D.

From planting trees to organizing special events, hundreds of volunteers have contributed their time, expertise, and imagination to make the Stroud Center a better place. Perhaps no one has given more than Frank Klein, who volunteered in Denis Newbold's ecosystem processes laboratory from 1995 to 2015. "Frank was always a beloved presence in our laboratory," said Newbold. "One might imagine that a retired Ph.D. chemical engineer from DuPont would be an asset to any lab, and his skills as a scientist were definitely an asset to ours. He was always scrupulous and exacting in his work, but it is his endearing personality, his wide-ranging intellectual interests, and his wry sense of humor that we will most fondly remember."

He has lived a remarkable life. In 1938, at the age of nine, he and his family escaped by train from Czechoslovakia just days before German troops occupied their hometown. For the next three years, they stayed one harrowing step ahead of the Nazis — taken by smugglers on foot across the Pyrenees, suffering imprisonment and deportation — until the once-well-to-do Jewish family arrived as refugees in New York Harbor in 1941 after 32 months on the run.

JEAN PEIRSON (1927–2012)

After spending 10 years working with Ruth Patrick at the Academy of Natural Sciences of Philadelphia, followed by many years in Lou Kaplan's biogeochemistry laboratory, Jean Peirson finished her long career at the Stroud Center by volunteering for the development department. Her husband Buck was constantly lending his skill in fixing things until his death in 1992, and her daughter Sally has spent the last 45 years as a research technician in John Jackson's entomology laboratory.

Fifty years after the birth of a friendship between a conservation-minded couple intent on protecting the land and a scientist determined to restore polluted waterways, Stroud Center scientists and educators continue to carry on the work Ruth Patrick envisioned and Dick and Joan Stroud made possible.

THE FOUNDERS

DICK STROUD, JOAN STROUD, AND RUTH PATRICK, PH.D.

DICK STROUD (1917–2005)

JOAN STROUD (1922–1985)

RUTH PATRICK, PH.D. (1907–2013)

In the mid-1950s Dick and Joan Stroud moved with their children (who would ultimately number seven) to a picturesque farm in Chester County, Pennsylvania. For the next several years, Dick commuted weekly to New York City, but his heart remained attached to his family and the farm to which he returned each weekend. In the early 1960s, he became a trustee of the Academy of Natural Sciences of Philadelphia, the oldest natural sciences organization in the western hemisphere. There he met Ruth Patrick, a pioneer both as a scientist and a woman, who, in 1947, had founded the academy's limnology department, which was dedicated to the study of fresh water.

At the time, Patrick was looking for a clean, natural stream system she could use to compare with the polluted ones she was studying and seeking to remediate. The east branch of White Clay Creek, which wound through the Strouds' farm, was such a stream, and she set out to create a laboratory on its banks and assemble a multidisciplinary team to analyze its physical, chemical, and biological characteristics. She convinced Dick and Joan Stroud to buy a farm just downstream from their own, and in 1966, its renovated stone barn became Stroud Water Research Center's first permanent laboratory. A year later, Patrick used financial commitments from the Strouds to secure the Stroud Center's first grant — a comprehensive five-year study of White Clay Creek funded by the Rockefeller Foundation.

Joan and Dick Stroud brought more than financial resources to the place that carries their name. Less tangible but no less important was their deep commitment to education and the arts, which would be embodied in three of the Stroud Center's enduring principles: (1) the vital role that creativity and imagination play in scientific research; (2) the imperative to translate that research into language nonscientists can understand and programs that benefit the broader community; and (3) the belief that the Stroud Center's work should make a difference in the world.

Continuing the tradition of involvement and support, two generations of the family cut the ribbon for the new courtyard named for the father or grandfather on May 13, 2016. From left: Morris Stroud, Joanie Blaine, Anne Hannum, Seth Bradford, Katherine Bucklin, Cynthia Stroud, Lily Stroud, Dixon Stroud, and Steve Stroud.

FRIENDS AND FAMILY: CREATING A LEGACY

MORRIS W. STROUD, M.D. (1913–1990)

Dick Stroud's older brother, is shown on horseback during an early expedition to Costa Rica in 1988. He was there with his nephew, W. B. Dixon Stroud Jr., and Stroud Center scientists Lou Kaplan, Bern Sweeney, and Robin Vannote, to appraise Estación Biológica Maritza as the future base for the Stroud Center's research program in tropical stream ecology. An early and significant supporter of the Stroud Center, Dr. Stroud built the road to Maritza and later set up the Stroud Endowment for Environmental Research. At his death, he bequeathed Georgia Farm, where he and his late wife, Marion, had lived, as a study site for temperate streams. In a unique arrangement that brought together three local environmental organizations, he left the farm itself to the Natural Lands Trust, gave a permanent conservation easement on the property to the Brandywine Conservancy, and granted the Stroud Center a research agreement that guaranteed use of the land and waters for scientific purposes. Since 1991, the 574-acre Stroud Preserve has been the site of a long-term research project assessing how effectively streamside forest buffers protect fresh water.

MORRIS W. STROUD, M.D. (1913–1990)

TRUMAN WELLING (1907–2001)

A local landowner, committed conservationist, and great friend of the Stroud family, Truman Welling was a founding board member and treasurer of both the Stroud Foundation, which provided the Stroud Center's original oversight and funding, and Stroud Water Research Center, Inc., which took over those roles after the Stroud Center's separation from the Academy of Natural Sciences in 1999. His son, Peter, was one of the first two summer interns in 1967 (see page 15).

CYCLING BACK

Art and Education

Decades later, you can still see Dick and Joan Stroud's influence in the art and education programs, where students also discover the beauty and mystery of streams and rivers and are encouraged to look at the natural world imaginatively as well as scientifically. Here students from Wilmington's Cab Calloway School of the Arts canoe from the Brandywine River Museum to Jamie and Phyllis Wyeth's farm, where they will do scientific experiments on the streambank, tour the farm and studio, and talk with the artist about the connection between his work and the land and water.

ROBIN VANNOTE, PH.D.

Director, 1966–1988

Robin Vannote served as the Stroud Center's director from 1966 until 1988, when Bern Sweeney, who had arrived as a young graduate student in the fall of 1972, succeeded him.

Under Vannote's leadership, the Stroud Center evolved from a dream he had nurtured with the Strouds and Ruth Patrick to an institution at the forefront of freshwater research. With a voracious mind and boundless energy, Vannote was both a scholar and a builder. A nationally respected expert on freshwater ecosystems, he still found the time to involve himself in every detail of the Stroud Center's operations.

- He created the Leaf Pack as a research tool and placed the first packs in White Clay Creek in 1966. Fifty years later, scientists and educators around the world continue to use his invention.
- He designed the new laboratory spaces — in which White Clay Creek flowed through the building's basement, creating the world's first indoor research stream.
- In the year when Cleveland's heavily polluted Cuyahoga River caught fire, he launched a five-year project, funded by the Rockefeller Foundation, whose goal was to understand, diagnose, and mitigate the impacts of pollution on stream and river ecosystems.
- As a result of that study, he formulated the River Continuum Concept, which changed forever the scientific community's understanding of stream and river dynamics.
- He started alone in a makeshift laboratory above the Strouds' garage. He left behind five Ph.D.s, four of them running their own research laboratories.
- In the early 1980s, he added an applied research component to the Stroud Center's basic research mission to (1) attract new sources of funding, (2) work with public and private organizations to clean up polluted waterways and institute better environmental practices, and (3) build long-term data that would be used to solve real problems and find practical solutions.

Above Top: Robin Vannote, Bern Sweeney, and Bernie Anderson take a break while scouting for research sampling sites on the Potomac River in 1983. Below: The two directors pose during Vannote's visit to the Stroud Center in August 24, 2016.

20 Years and Counting

Scientific progress requires not only the embrace of new ideas and an openness to change, but also the institutional stability that gives people the confidence to take a long-term perspective. The Stroud Center has been enormously fortunate to have had the services of the people (and families) pictured on these pages for 20 years or more.

DENIS NEWBOLD, PH.D., AND TOM BOTT, PH.D. (RESEARCH SCIENTISTS EMERITI)
82 years combined (34 and 48 years)

JEAN AND SALLY PEIRSON
61 years combined (16 and 45 years)

BERNARD W. SWEENEY, PH.D.

Director, 1988–2016

When Bern Sweeney succeeded Robin Vannote as director in 1988, he had already spent 10 years overseeing the entomology group. Even as he took on the role of running an increasingly complex organization, he never gave up his love for science, and 28 years later, he is still happiest when he is wading in streams, looking for mayflies.

Those streams could be anywhere in the world, for Sweeney has expanded the Stroud Center in so many ways that it would be unrecognizable to its founders — except for this: its mission has never changed.

He has been personally involved in every aspect of that growth:

- In the early 1990s, he launched the education program for schools and public outreach initiatives to community groups.
- A few years later, he helped guide the Stroud Center to independence from the Academy of Natural Sciences, and he has led it ever since as an independent institution.
- He has overseen the creation of an endowment that now exceeds $32 million, as well as several building expansions, culminating in the Moorhead Environmental Complex, which opened in 2013.
- In 1988, the Stroud Center had 18 people and a budget of $700,000. By 2016, it had 43 full-time and 33 part-time people and a budget of $10.7 million.
- He opened Maritza Station in Costa Rica, which led to a series of tropical studies and education programs throughout Central and South America — and he taught himself Spanish so he could work directly with the local people.
- His own research on the effects of temperature changes on macroinvertebrates led to the largest project in the Stroud Center's history, and his work on streamside forests has led to significant changes in watershed legislation, restoration practices, and forest regeneration.
- His proposals for major research projects, ranging from Pennsylvania to Bhutan, have taken the Stroud Center's expertise around the world.
- In 2012, he initiated the Watershed Restoration Group, a fitting culmination to his 30-year determination to combine scientific research, environmental education, public outreach, land preservation, and forest restoration into a single program focused on protecting fresh water.

DAVID B. ARSCOTT, PH.D.

Director, Dec. 2016–Present

On December 2, 2016, the board of directors approved the appointment of Dave Arscott as the new executive director, with Bern Sweeney retaining his title of president and receiving a promotion to distinguished research scientist. Arscott came to the Stroud Center in 2003 to oversee the New York project, and he returned in 2009 as the assistant director, where he worked closely with Sweeney on all phases of the operation. He holds a Ph.D. in freshwater ecology from the Swiss Federal Institute of Technology and has worked on aquatic issues in New Zealand and Antarctica.

SHERMAN ROBERTS
45 years

DAVE FUNK
41 years

BERN SWEENEY, PH.D.
41 years

REBECCA DUCZKOWSKI AND SHELBY VONTILL
38 years combined (5 and 33 years)

THE BOARD CHAIRS

RODMAN W. MOORHEAD III AND JOHN R. S. FISHER, V.M.D.

RODMAN W. MOORHEAD III

JOHN R. S. FISHER, V.M.D.

By the late 1990s, it had become clear to many at the Stroud Center that, after 30 productive years as a field station of the Academy of Natural Sciences, it was time to strike out on their own. Situated 40 miles from Philadelphia, the Stroud Center had always been responsible for its economic well-being. It produced its own grant proposals, developed independent sources of funding, and had recently completed its first capital campaign.

In late 1998, Dick Stroud asked Rod Moorhead and Johnny Fisher to represent the Stroud Center in negotiations for independence with members of the academy's board. They employed a time-tested strategy: Fisher, the easy-going veterinarian and horse trainer, was unfailingly gracious and cheerful; Moorhead, the hard-driving investment banker, played the bad cop with gusto. Together, they brought the negotiations to a successful conclusion, and on October 1, 1999, the Stroud Center became an independent nonprofit organization.

Fittingly, Moorhead and Fisher became the co-chairs of the new organization's board, and they helped guide the Stroud Center through its ensuing years of financial, physical, and programmatic growth. After 12 years, Johnny Fisher stepped down as co-chair to become a very active board member emeritus. Rod Moorhead remains as chair, his personal generosity made manifest in the Moorhead Environmental Complex, which he did so much to build.

LOU KAPLAN, PH.D.
36 years

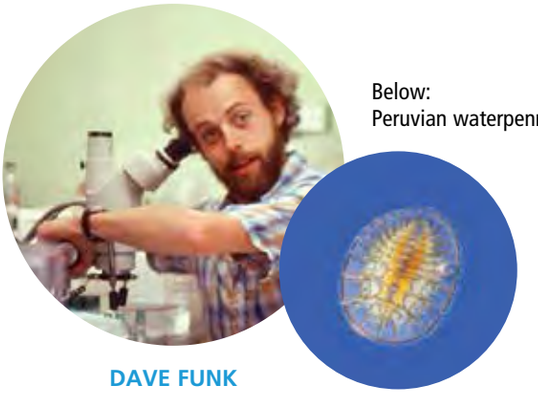
BERNIE ANDERSON
32 years

ROBERTA WEBER
31 years

HEATHER BROOKS
29 years

CYCLING BACK

A Place Where Science and People Grow Together



Below:
Peruvian waterpenny

DAVE FUNK

RENAISSANCE MAN

From his desk in the basement of the original building, there isn't much that Dave Funk hasn't touched in his 41 years at the Stroud Center. Staff entomologist, photographer, assistant director, director of facilities, early computer guru, his tracks are everywhere — including those of his bicycle throughout the watershed where he takes his daily lunchtime ride followed by a dip in White Clay Creek in summer's heat and winter's ice and snow. Inspired by Robin Vannote's aquatic insect ecology course at the University of Delaware, Funk signed up to work on the NSF River Continuum grant in 1976 and spent the next year in Idaho, where he became an expert on the Salmon River's aquatic insects. That expanded to a broader expertise, and by the 1990s, he had built a strong professional reputation as an expert on the taxonomy of North American mayflies. "He has contributed extensively and significantly on both the creative aspect of our science and the hands-on generation of data in the lab and in the field," said Bern Sweeney. His work on the genetic structure and mating habits of mayflies has led to the Stroud Center's unique ability to perform whole-life studies in the laboratory, and his photographs of aquatic insects provide an equally unique example of the Stroud Center's enduring commitment to the interplay of science and art.

JINJUN KAN, PH.D.

THE RIVER CONTINUUM REVISITED

When the River Continuum Concept (RCC) was published in 1980, the instrumentation required to understand the immense richness and diversity of dissolved organic matter (DOM) and bacteria had not yet been invented. That didn't prevent Robin Vannote and his colleagues from conjecturing about the behavior of some of a stream's smallest and most abundant life forms, based on their belief in the predictive capability of their theory.

Five years ago, armed with a new generation of technology, the Stroud Center's JinJun Kan, a microbiologist, and Lou Kaplan, a biogeochemist, joined by Jennifer Mosher and Robert Findlay, set out to test ideas first proposed by the RCC.

The just-completed studies found that both DOM and bacteria were most diverse in headwater streams, where the water and land constantly interact — and where, therefore, the sources of food are also most diverse — a discovery consistent with the RCC.

"I'm amazed how prescient their theory was," Kaplan said, "because so little was known about DOM and microbes in those days."

The fact that headwater streams are the repositories of such richness and diversity has significant policy implications, he noted, because those streams have historically been the most abused parts of a river system and consequently the most vulnerable to land-use changes.

"Vannote's theoretical framework still works," said Kan, who added that, because bacteria behave differently from the insects on which the RCC focused, "our study added a new component that makes the theory more rich."

Thirty-seven years after its publication, the RCC still motivates researchers to probe and modify its implications, using new technology to advance the knowledge of issues ranging from protecting the smallest streams to understanding the global carbon cycle.

Left: Tom Bott, Dave Funk, Denis Newbold, Bern Sweeney, and Sally Peirson welcome their former director, Robin Vannote, back to the Stroud Center for a visit on August 24, 2016.

JOHN PEPE
29 years

JOHN JACKSON, PH.D.
27 years

ROBIN VANNOTE, PH.D.
22 years

MIKE GENTILE
20 years

The Staff of Stroud Water Research Center, 2017

A | THE FULL STAFF

B | INFORMATION SERVICES

Information Services provides computing services, network administration, data management and analysis (including Geographic Information Services), and web design and development support for the Stroud Center. Pictured from left: Melanie Arnold, Heather Brooks, Charles Dow, and Elizabeth Gregg.

C | FLUVIAL GEOMORPHOLOGY

This laboratory seeks to understand how the movement of water and sediments together forms the physical basis of river ecosystems, including how watershed land-use and restoration practices influence flow regimes, habitat quality, sediment transport, and channel evolution. Pictured from left: Melinda Daniels, David Montgomery, and Jennifer Matkov. Not pictured: Valérie Ouellet.

D | ENTOMOLOGY

This laboratory studies the distribution and abundance of the aquatic insects, crustaceans, and other invertebrates that form a stream's rich and complex biological communities, examines their functional role in stream and river ecosystems, and analyzes their response to human activities in temperate and tropical watersheds. Pictured from left: Juliann Battle, Matthew Wilson, Kelly McIntyre, Sherman Roberts, Catherine McFadden, Sally Peirson, John Jackson, Michael Broomall, and David Funk.

E | ADMINISTRATION AND FINANCE

This department provides a supportive environment to facilitate and enhance research, educational, watershed restoration, and public-outreach activities. Pictured from left: Rebecca Duczkowski, Jane Sowden, and John Pepe. Not pictured: Bernard Sweeney and David Arscott.

F | BIOGEOCHEMISTRY

This laboratory identifies and quantifies the rich array of organic molecules that are found in streamwater, groundwater, soil water, and in sediments below the stream channel, and serve as the main food source to microorganisms and consequently to all biological communities. Pictured from left: Michael Gentile, Louis Kaplan, Diana Oviedo-Vargas, and Sherman Roberts.

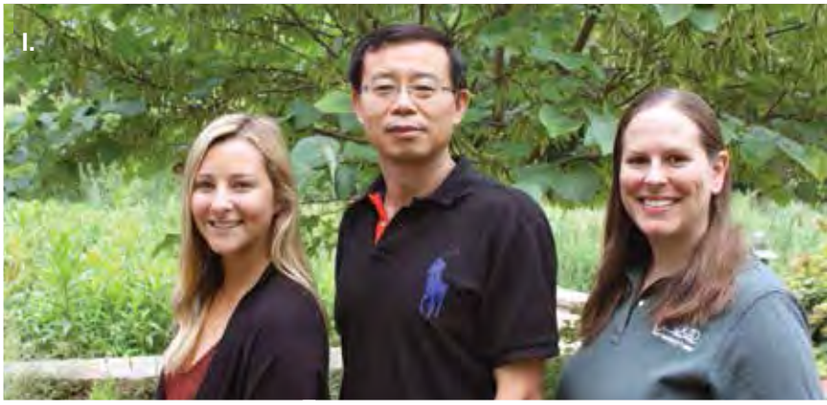
G | FACILITIES

Facilities maintains the Stroud Center's complex of laboratories, offices, meeting spaces, and libraries, as well as its 1,800-acre experimental watershed by fabricating equipment, maintaining laboratory systems, planting trees in research plots, and taking care of all the campus's buildings and grounds. Pictured from left: Solomon Romero, Javier Tinoco, William Milliken, Tonya Prigg, and David Funk.


F.


G.


H.


I.

J.


K.


L.

H | EDUCATION

This department interprets and communicates the research of our scientists and watershed restoration staff for many different audiences by developing and delivering K-12 school programs, training and professional development workshops, community outreach events, and curricula. Pictured from left: Jennifer Matkov, David Dickens, Jennifer Totora, Elizabeth Gregg, Tara Muenz, Vincent O'Donnell, and Steven Kerlin. Not pictured: William Anderson, MaryAnn Levan, and Kelli Williams.

I | MICROBIOLOGY

Using comprehensive molecular approaches, this laboratory focuses on the composition and distribution of the microbial communities that are integral to a naturally functioning aquatic ecosystem, with the goals of determining their functional roles and responses to perturbations and understanding their interactions with their environments. Pictured from left: Lauren Kennedy, Jinjun Kan, and Laura Zgleszewski.

J | DEVELOPMENT

This department works to ensure the future of fresh water by raising funds to support the research, education, and restoration efforts of the Stroud Center. This support comes from gifts of all sizes to the annual fund, and from foundations, corporate giving, major gifts, and special events. Pictured from left: Jessica Provinski, Kristine Lisi, Kay Dixon, and David Reinfeld.

K | COMMUNICATIONS

This department shares the Stroud Center's scientific, educational, and watershed restoration goals, accomplishments, and activities with the public. Pictured: Diane Huskinson.

L | WATERSHED RESTORATION

The Watershed Restoration Group works with landowners, farmers, and others to implement best-management practices and plant streamside forest buffers, with the goals of promoting freshwater stewardship and watershed restoration. Pictured from left: David Wise, Matthew Ehrhart, and Lamonte Garber. Not pictured: Matthew Gisondi and Calen Wylie.

FISH MOLECULAR ECOLOGY (NOT PICTURED)

This laboratory combines modern genetic technology with field and laboratory studies to analyze fish and other freshwater organisms with the aim of understanding their evolutionary adaptation and ensuring their long-term protection.

ORGANIC AND ISOTOPE GEOCHEMISTRY (NOT PICTURED)

By determining the identity and origin of the complex mixture of organic molecules in streams and rivers, the scientists in this laboratory can both expand scientific understanding of carbon cycles and nutrients in the ecosystem and inform decision-makers about the impact human activities have on water quality.

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- **0.11** barrels of natural oil unused[1]
- **349** lbs. of GHG emissions not generated[1]
- **115** miles not driven[1]
- **1** tree planted[1]

1. Estimate of GHGs and equivalencies for clean wind energy RECs & Carbon Offsets

Stroud Water Research Center gratefully acknowledges James G. Blaine for telling the story of our 50-year history and Caroline Chen of Chengraphix for designing this publication.