St. Anthony Falls Laboratory

Channel

Spring 2009

Institute of Technology | University of Minnesota

RENEWABLE ENERGY RESEARCH AT SAFL: NEW INITIATIVES IN WIND & HYDRO

THE LAST PRINT ISSUE!

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The St. Anthony Falls Laboratory is a research unit of the University of Minnesota's Institute of Technology in the Department of Civil Engineering. The laboratory is also closely affiliated with the Department of Geology and Geophysics, and the Department of Ecology, Evolution, and Behavior.

Cover: Model wind turbines in the SAFL wind tunnel

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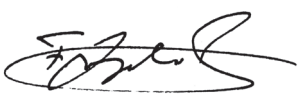
THE DIRECTOR'S PERSPECTIVE

The Spring 2009 issue of the SAFL Channel celebrates the end of its printed era. We will be transitioning to an electronic format (featuring the same spectrum of articles, images, and news, in an easy-to-read email format), and encourage all of our subscribers to make the change with us. By evolving with the digital age, and in keeping with SAFL's efforts to promote a healthier planet, we will be able to inform our readers more efficiently and less expensively.

The transition to an earth-friendly paperless version fits well with the renewable energy theme of this issue, which highlights two major projects- tidal power and wind power- currently taking place at the lab. Both projects will utilize multi-scale high-resolution CFD tools, and laboratory and field experiments, to resolve tidal and wind turbine wakes for optimization of turbine arrays. Both projects involve collaborating with numerous partners, among which is Barr Engineering. Barr's VP of water resources, Nels Nelson, has kindly agreed to be featured in the Alumni Spotlight. Also included in this issue is the recent result of SAFL's research on road salt in Minnesota waters, a long-term study conducted by Professor Heinz Stefan and his team.

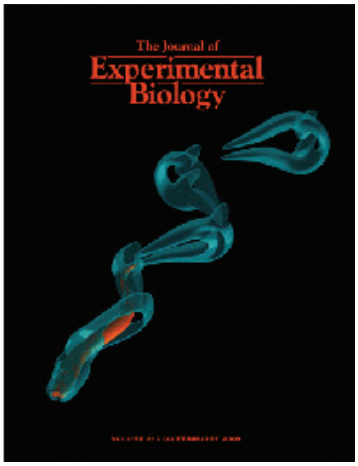
It is with a keen eye to the future that we welcome new directions for the lab and its newsletter. One significant upcoming event is a special symposium on fluid dynamics, in honor of Roger Arndt's contributions to the field. We are pleased to host a distinguished panel of invited speakers, and have chosen to conduct the symposium just prior to the 62nd annual APS conference being held in Minneapolis Nov. 22-24. Stay tuned to the SAFL website for additional upcoming information, and registration links. We look forward to seeing you here!



—Fotis Sotiropoulos

Professor and Director, SAFL

honors & awards



The Feb. cover of *The Journal of Experimental Biology* (212, 4) features images generated by the work of postgraduate researcher **Iman Borazjani** and SAFL director **Fotis Sotiropoulos** in simulating aquatic swimming.

Sotiropoulos and **Borazjani** also recently won an award for a video depicting the same research. The video was selected as a winner of the prestigious Gallery of Fluid Motion competition, presented at the 61st Annual American Physical Society Division of Fluid Dynamics meeting in San Antonio, Texas, Nov. 23-25, 2008.

Researchers at SAFL have recently received a grant from the DOE to help generate clean energy for New York City. SAFL director **Fotis Sotiropoulos** will lead a team of researchers in developing computational models for optimizing underwater turbines for Verdant Power's Roosevelt Island Tidal Energy (RITE) project.

Prof. **Efi Foufoula-Georgiou** was named an IonE Fellow; the invited Borland Lecturer at AGU Hydrology Days; Chair of the Horton Medal Committee, AGU; Member of the Advisory Committee on Helmholtz Research Centers, Germany; and Guest Editor, Journal of Geophysical Research-Earth Surface.

Prof. **Chris Paola** was named IT Distinguished Professor, UMN; and the Leverhulme Visiting Professor (Imperial College, London), Leverhulme Trust.

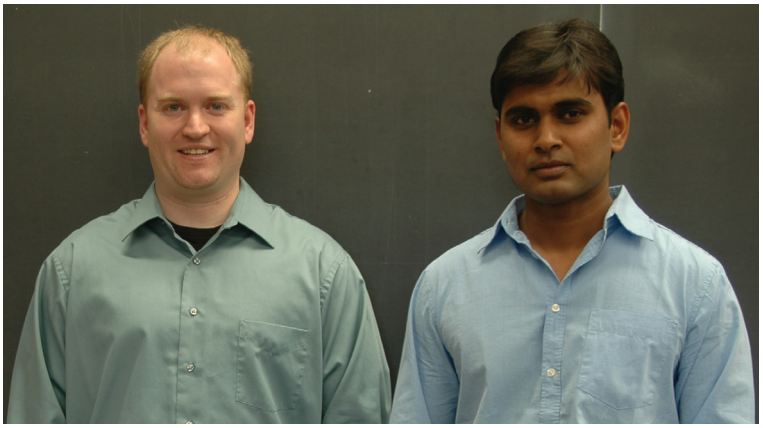
SAFL alums **John Martin** (PhD '07) and **Ben Sheets** (PhD '04), and Prof. **Chris Paola**, are among the authors of "Sequence stratigraphy of experimental strata under known conditions of differential subsidence and variable base level," the cover article for April's *AAPG Bulletin*.

Professor **Fernando Porté-Agel** (PI) and **Fotis Sotiropoulos** (co-PI) were awarded funding from Xcel Energy and the Initiative for Renewable Energy and the Environment to study atmospheric boundary layer wind and turbulence and their interaction with wind turbines, as part of a collaborative research project with WindLogics and Barr Engineering.

Graduate students **Eric Merten** and **Andrew Sander**, and Profs. **Omid Mohseni** and **Heinz Stefan** received the "2009 Outstanding Leadership Award" from the Freshwater Society.

Graduate student **Leonardo Chamorro** was awarded a UMN Doctoral Dissertation Fellowship for the 2009/10 academic year.

Filiz Dadaser-Celik (PhD '08) is the first-place recipient of the Universities Council on Water Resources 2009 PhD Dissertation Award in the field of Water Policy and Socioeconomics. Dadaser-Celik's graduate research analyzed the hydrologic, social, and economic aspects and requirements for the restoration of the Sultan Marshes in Anatolia, Turkey, under the guidance of Professors Heinz Stefan and Patrick Brezonik.

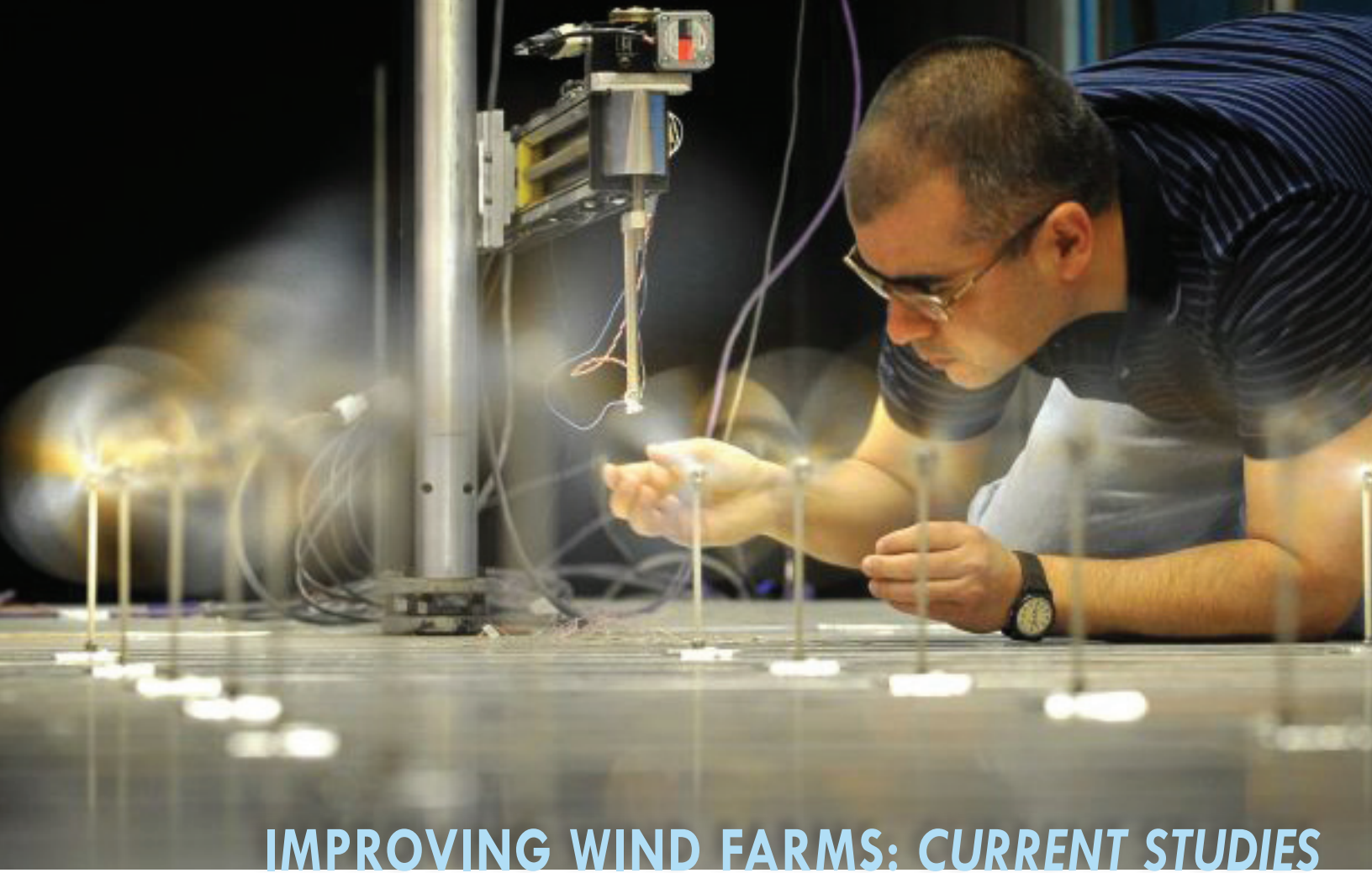


The winners of the 2009 Anderson Award are **Andy Erickson**, research fellow for Prof. John Gulliver, and **Arvind Singh**, graduate student advised by Prof. Efi Foufoula-Georgiou. Both recipients presented their research at the April 22 award ceremony.

Graduate student **Vamsi Ganti** is the recipient of the 2009 Edward Silberman Fellowship Award. Ganti, advised by Prof. Efi Foufoula-Georgiou, presented a summary of his research at the Feb. 18 award ceremony.

The recipient of the 2009 Lorenz G. Straub Award was presented on Jan. 28 to **Marco Ghisalberti**, postdoctoral fellow at the School of Environmental Systems Engineering, University of Western Australia, for his doctoral thesis, "Momentum and scalar transport in vegetated shear flows."

Graduate student **Paola Passalacqua** was the recipient of this year's Outstanding Student Paper Award at AGU for her paper, "River network extraction from LiDAR using backwards-in-time diffusion?"



IMPROVING WIND FARMS: *CURRENT STUDIES*

To improve efficiency of wind power, scientists at the University of Minnesota's St. Anthony Falls Laboratory think small scale.

By JIM DAWSON

Reprinted with permission from the Star Tribune

ABOVE
Graduate student Leonardo Chamorro adjusted a wind sensor that can measure fluctuations caused by wind turbine models in the SAFL wind tunnel.

In the long wind tunnel at the University of Minnesota's St. Anthony Falls Laboratory, miniature wind turbines stand waiting for the lab's scientists to turn on the flow of air. The dozen or so turbines, just several inches tall, are arranged in patterns similar to the layouts of the real 300-foot-tall wind energy turbines that populate wind farms across Minnesota's southern tier.

While the small turbines look like toys, they are really a critical part of a $1 million collaboration between the laboratory and two Minnesota companies -- WindLogics and Barr Engineering -- to improve efficiency at wind farms.

Wind turbines, with blades typically about 300 feet long, create wakes that disrupt the flow of air to other turbines.

Understanding the effects of this wake turbulence is critical because even a slight decrease in the power output of a turbine can cost a lot of money.

"If you look at a 1 percent reduction in output from a 100-megawatt wind farm, you are talking about the loss of $100,000," said Fotis Sotiropoulos, director of the St. Anthony Falls lab.

The goal of the collaboration, said U of M scientist Fernando Porte-Agél, is to develop high-resolution computer models that, by providing good information on wind fields and turbulence, "can guide the design of wind projects so we can know where to put the turbines."

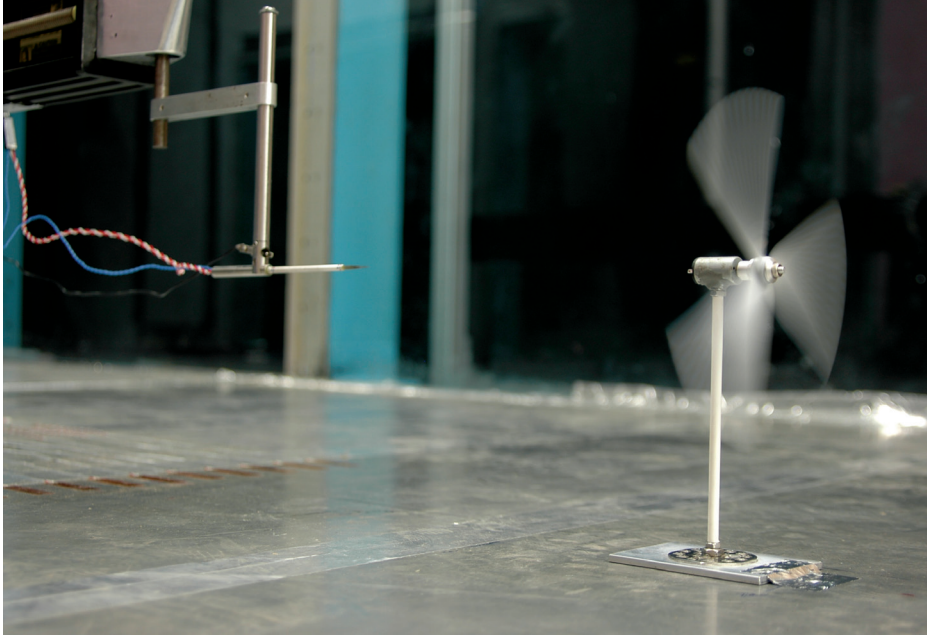
Loss of efficiency isn't just an occasional problem. On wind farms across the country, "the output of

turbines is a few percentage points below what the models predict they should be," said John Wachtler, an environmental engineer at Barr Engineering in Minneapolis.

"Nobody is sure why, and when you spend $3 or $4 million for a turbine you don't want to see a 3 or 4 percent decrease in output from what you expected," he said. "One possibility [for the lower power output] is that we're not able to model short bursts and other changes in the wind on the turbines."

Wind energy is of growing economic importance in Minnesota. The state gets more of its energy from wind — on a percentage basis — than any other state in the country. It ranks fourth for total output — 1,725 megawatts of wind energy — behind Texas, Iowa and California.

The power generated by wind farms along Buffalo Ridge in southwestern Minnesota has outstripped the ability of the grid to carry the power, so the newer farms are being constructed in the southeast part of the state, Wachtler said.



ABOVE
Miniature turbine models in the SAFL wind tunnel help researchers simulate the turbulence caused by their movement.

LEFT AND BELOW
Small adjustments in turbine arrays can drastically influence efficiency of harnessing wind power.

MODEL TURBINES

To develop a realistic computer model of the wind patterns that will affect not only a particular wind farm, but an individual turbine in the middle of that farm, researchers are doing "multiscale modeling," Porte-Agél said.

They start with existing models that see the atmosphere on a very large scale. Then, using data from that model, they move to models that see wind patterns and atmospheric turbulence on an ever-smaller scale, until they wind up with an accurate prediction for the exact site where a wind turbine will be placed.

At least, that is the goal. "The models that industry uses now are rather coarse," Sotiropoulos said. "So nobody really knows the effect of atmospheric turbulence on a wind turbine."

To make a useful model, he said, "we want to go from a regional scale, which is on the order of kilometers, to a local scale, which is on the order of 100 meters, down to 1 meter. *[Continued on next page]*

[Continued from previous page]

The current models are good at the kilometer scale, he said, "approximate" at the wind farm scale, and essentially nonexistent at the 1-meter scale that would be critical in deciding exactly how to place turbines.

After including atmospheric data, which is notoriously complex, modelers must include local topography. Is the wind farm on flat prairie or it near hills or a valley? Is the surrounding land smooth, or is it rough? Is there a forest nearby?

Once the models are refined enough to look at what is happening on a wind farm, then understanding the effect on a turbine of turbulence being created by other turbines is critical. "When you are extracting energy from the wind, you have to slow the wind down and it creates wake turbulence and that has an impact on the turbines downwind," said Bob Conzemius, a senior scientist at the WindLogics research center in Grand Rapids, Minn.

Which is why the "toy" turbines are arrayed in the wind tunnel. By testing different turbine layouts, scientists can observe which patterns result in the least interference.

"We don't understand how the wakes interact, and this will help with that," Conzemius said.

The data from the wind tunnel will be fed into the models and then compared with very precise measurements being taken at a wind farm near Prairie Island. By combining data from the existing models with data from the wind tunnel and testing it against what is happening on the real wind farm, scientists hope to find out what can be done to make wind farms as efficient as they should be.

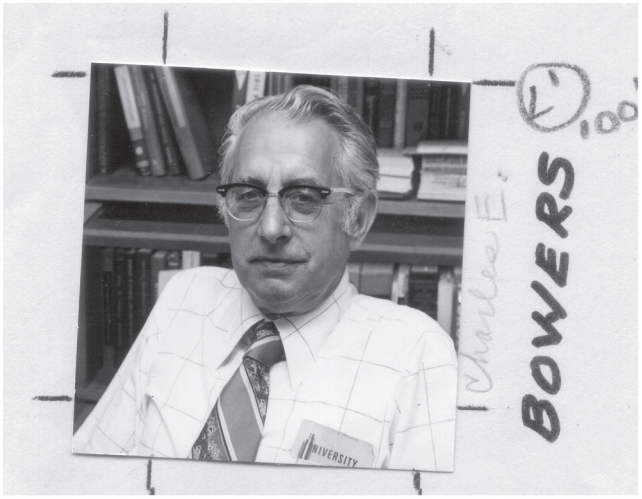
This story is provided by the Inside Science News Service. Dawson is editor of the Washington, D.C.-based news service, which is supported by the not-for-profit American Institute of Physics, a publisher of scientific journals. He was a reporter at the Star Tribune for 20 years and a science writer for 13 of those years. His e-mail is jdawson@aip.org.

In Memoriam

Charles Edward Bowers, an esteemed U of M civil engineering professor and researcher, passed away on December 22, 2008. Bowers was beloved by students and faculty throughout the St. Anthony Falls Laboratory and the Department of Civil Engineering.

Bowers came to the University of Minnesota's St. Anthony Falls Laboratory in the fall of 1947 for graduate study, the recipient of a Standard Oil Fellowship. After receiving a Master's degree in Civil Engineering (advised by Lorenz G. Straub), he continued to work at SAFL throughout his career, eventually retiring as professor emeritus thirty-seven years later.

Bowers was born September 3, 1919 on a ranch near Hanna, Wyoming. He remained in his home state for college and graduated from the University of Wyoming in 1942 with a degree in civil engineering.



Prior to coming to the University of Minnesota he was employed for five years at the David Taylor Model Basin, where he worked on mine sweeping and torpedo systems during World War II. One of his duties during the period was the conduct of a project to determine the cross-sectional dimension of a modernized Panama Canal. He then met his wife Audrey and married her on June 29, 1946.

The pair soon moved to Minnesota where Bowers began working at SAFL as a graduate student. When Bowers earned his degree in 1949, he took employment with the U.S. Bureau of Reclamation. Later, Bowers was invited to return to the lab as an assistant professor in 1951 and eventually became a full professor, retiring in 1984 as professor emeritus. In 2000, Bowers moved to Santa Barbra, California to live near his son.

As a professor, Bowers taught courses and supervised research in hydraulic engineering and hydrology. His research at SAFL included a study of fluctuating pressures in spillway stilling basins; computer analysis of various operation plans for headwater reservoirs on the Mississippi River; mathematical modeling of selected watersheds in Minnesota; flood forecasting on Minnesota watersheds; and several model studies of large dams. He authored of co-authored over 40 papers and reports and produced a number of motion pictures on hydrology, one of which was on the 1965 flood of record for the Minnesota River.

Bowers taught in the areas of water resources engineering, hydrology, and hyrologic design, and he developed an advanced hydraulic laboratory course particularly suited for students who selected hydraulics as a specialty. He also worked on designing both laboratory equipment and building additions. He developed a strong presence in hydrology and was mentor to many students who earned M.S. and Ph.D. degrees in that field. He worked one-on-one with these students developing their computer skills, serving as academic advisor to many graduate students, a great many of whom carried a life-long respect for him.

Bowers received the Collingwood Award of the American Society of Civil Engineers for the Panama Canal study. He was elected to membership in Sigma Tau, Tau Beta Pi, and Sigma Xi, and was listed in Who's Who, Who's Who in Engineering, and American Men of Science. In 1984 he was named Outstanding Teacher of the Year in the Institute of Technology of the University.

Memorials for Bowers can be made to a fund already established in his name: Fund 4722 Charles E. Bowers Faculty Teaching Award. This award was established to reward an outstanding professor who demonstrates exceptional interest and commitment to teaching students in the Institute of Technology.

(Thanks to Mary Marsh, Edward Silberman and Charlie Plain for contributing.)

ABOVE
Ed Bowers (with wife Audrey) at Frank Tsai's wedding in 1964. (The Bowers are standing behind Ed Silberman, signing the guestbook.)

ABOVE LEFT
SAFL portrait of Ed Bowers

BELOW LEFT
Ed Bowers at SAFL, circa 1964.

Alumni Spotlight:

Nels Nelson

SAFL graduation year: 1980
Degrees: B.A. (History, Carleton College);
B.S. and M.S. (Civil Engineering, UMN)
Advisor: Charles Edward Bowers
Anderson Award Recipient: 1979
Nels Nelson is completing a 15-year service as head of the Water Resources Management group at Barr Engineering; he continues to serve as Chairman of the Board. He has over 30 years of experience specializing in water resources management and planning and environmental review and assessment.

BARR ENGINEERING IS A CLOSE RELATIVE IN THE SAFL FAMILY. Beginning with Douglas Barr, who received his graduate degree from the lab prior to founding the company in 1953, dozens of SAFL graduates have gone on to become engineers at Barr, continuing to build on the strong ties between the two institutions. Nels Nelson, vice president of water resources management at Barr, is one such graduate, and kindly agreed to be interviewed for this issue of the SAFL Channel.

Your advisor at SAFL was C. Edward Bowers, who passed away this year. Thinking back on your experiences as a graduate student here, what memories of him stay with you?

Ed Bowers was known for his fundamental decency and respect for his students. He was a gentleman to undergraduates in class and to the grad students who worked for him. I also recall how careful he was in his teaching – I expect there are thousands of engineers still practicing who remember his clear, thoughtful approach in class. On a side note, you could see his organization and precision in the graphs and figures he prepared. I actually permanently changed my style of handwriting as I tried to emulate his lettering!

Why do you think so many SAFL graduates are drawn to working for Barr after they graduate?

Well, I think both the culture and technical approach are similar. Culturally, we've got a lot of common history – Barr's roots go back to a consulting practice started by Adolf Meyer, a U of M professor. Doug Barr studied at SAFL and eventually worked for Dr. Meyer (although there was some doubt as to whether Minnesota needed two people consulting in hydrology), so a lot of our culture grows out of SAFL's values. And we've tried to stake out a practice handling more complex projects so there is some similarity in technical approach, especially with SAFL's applied research mission.

How did your career evolve in the direction of becoming a company leader and manager?

I went into engineering after getting a liberal arts degree and doing some traveling, which gave me a slightly different perspective on the importance of organization and corporate culture. At first, I think, my habit of asking abstract questions about these subjects was not a career-enhancing trait. After it became clear that I wanted to stay at Barr, Allan Gebhard, our president at the time, started giving me assignments having to do with corporate issues. I enjoyed that and kept doing it. There comes a day when the people you've looked up to and worked with begin to retire and scale back, and you realize that for better or worse, you've got to help lead.

How do you see the various collaborative efforts and partnerships SAFL and Barr have had over the years continuing into the future? (eg: The recently established Distinguished Barr Lecture Series?)

I've come to realize that we practitioners have to respect research as a separate and different activity. In some areas the applications of research are obvious – for example, the applied research that SAFL has done on the effectiveness of stormwater treatment devices. However, a lot of research is simply investigating interesting questions about the world around us. Some of these problems are one of a kind and others are purely theoretical, so the work may not have immediate application. Likewise, as problems come up in industry, consulting and government, we may not get an elegant solution – we have to get the job done on a schedule with the available tools.

The danger is that the two communities can become permanently stratified, like one of Dr. Stefan's meromictic lakes, with the academics talking only to the academics and the folks in government and industry speaking to each other. So, just as with

lake stratification, mixing the two layers requires an input of energy. In management terms, that means time and money. I don't think there will be an easy matching up of new practical problems and new theoretical solutions but as we increase the contact between the two communities, we certainly improve our odds of transfer occurring.

To get back to your question, in general the best model for collaboration seems to be the one that Dr. Foufoula developed where an outside party such as Barr contributes staff time to work with researchers to help them with the research, or to take the research further and apply or expand their findings.

SAFL and Barr collaborated on a project this past year to develop an ArcGIS tool that predicts floodplain inundation from stream gauging data and high-resolution topography data. How successful was this collaboration? What strengths did each organization bring to the table? How do you see this project proceeding in the future?

Personally, my role was working with Efi Foufoula in the early stages to define a working relationship that would allow us to collaborate on these projects. She wanted to be sure that knowledge developed in the NCED program was being transferred to practitioners. Miguel Wong helped identify areas of possible collaboration, including this one. Christie Shostal and others built the tool in collaboration with SAFL's Patrick Belmont.

You've also been an active participant in developing a restoration plan for the LeSueur River. If funded, what (if any) roles will Barr and SAFL play in the implementation of the restoration steps? How will the knowledge already on-hand inform the plan itself?

Frankly I'm an interested onlooker at this point. It's another step in the side-by-side collaboration mode. NCED staff (Peter Wilcock, Patrick Belmont and Jeff Marr) met with Barr folks (Len Kremer, Tom MacDonald and Miguel Wong) to see how we could work together on a plan to cut sediment loads to the Minnesota River. Since the LeSueur River contributes a big load to the Minnesota River, they decided to focus there for testing the control strategies. They are using the data and findings from NCED's initial sediment budget assessment and making plans for the practical tasks of designing and implementing stream restoration projects. The group used data from NCED's monitoring stations to identify locations for evaluating soil erosion controls in uplands, ravines, bluffs, terraces, and the river channel itself. Now the team is talking to the Minnesota Board of Water and Soil Resources and the LeSueur Soil and Water Conservation District to firm up the planning process – to define the stakeholders, scope of work, timeline, and sources of funding for the remainder of the work.

Do you have any words of advice for current or future students?

Graduating is important but take the time to enjoy your time at SAFL and the interactions with professors and fellow students.

Thank you donors!

SAFL gratefully acknowledges the following individuals, who have generously provided support during this past calendar year.

Mrs Geneva N Anderson
Prof Roger E A Arndt
Nadyne A Balke
Barr Engineering Co
Mr Curtis W Bauers
Mr George Bugliarello
Mr Ronald E Carlson
CH2M Hill Foundation
Sam Chanen
Chevron Energy Technology Co
Clara Margolis Revocable Trust
Coleman Family Fdn Inc
Mr Thomas J Condon
ConocoPhillips Co
Kenneth H Corens
Chengwei Ding
Dr Christopher R Ellis
Ms Karen S Erickson
Dr Xing Fang
Prof Efi Foufoula-Georgiou
Charlotte Frank
Ms Stacy N Glass
Ms Cuiling Gong
Mr Carlton K Gutschick
Mr George G Hebaus
Mr Harry M Howe
Kathleen B Kelly
Dr John M Killen
Labor & Delivery Nurses-North Memorial Health Care
Karin J Margolis
Dr M Gamal Mostafa
Mostafa Family Trust
Mr Nels P Nelson
Dr Joseph J Orlins
Mr John W Osberg
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Mr Sheldon I Silberman
Edward Silberman
Charles C S Song
Prof Fotis Sotiropoulos
Kay Tart & Family
The Teagle Fdn Inc
Mr C K Teng
Texas Instruments Fdn
Dr Joel W Toso
Dr Frank Y Tsai
Uni-Systems LLC
Prof Vaughan R Voller
Dr Alwin C H Young

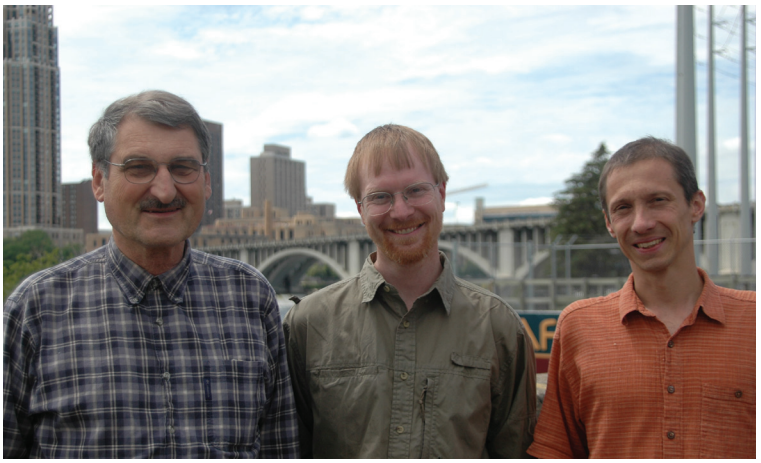
If you would like to discuss designating a gift for any purpose, please contact Sally Euson at (612) 625-6035 or email euson@umn.edu.

congrats grads

Craig Taylor (M.S. '08) with advisor Heinz Stefan

Tim Erickson (M.S. '08) with advisor Heinz Stefan

John Gaffney (M.S. '09) with advisor Chris Paola (advisor Kimberly Hill not pictured)



Eric Merten (Ph.D. '09) with advisors Heinz Stefan and Jacques Finlay

Not pictured: James Cook (M.S. '09) Advisors: Miki Hondzo, Ray Holzaski, and Michael Semmens

in other news

>>"The Mississippi"-Old Man River Goes Green: Director Fotis Sotiropoulos was interviewed Nov. 19 by *PBS Nightly Report* about research on the Mississippi River by both the hydropower industry and the U.S. Department of Energy to improve existing traditional hydro turbine design and make it more fish-friendly.

>>Break It Down: Dam Busters: The NCED/SAFL Marmot Dam model was featured in "Break It Down" on the *National Geographic Channel* Feb. 5, Feb. 6 and Feb. 12.

>>Road Salt Hits Headlines: Prof. Heinz Stefan's research on the effects of road salt on local water quality received the following media coverage: Feb. 10: Fox9 News; KARE 11; MSNBC; Star Tribune; UMN News; UMN News video; WCCO Radio; Feb. 11: KSTP-TV; MPR; WCCO TV; Feb. 13: Christian Science Monitor; Feb. 19: U of M Moment blog; Feb. 20: Science Daily; March 3: Discovery Channel News, and more.

>>SAFL on Flooding: SAFL experts were called on to help explain the reasons behind the Red River Valley flooding. Prof. John Gulliver and Associate Director of Applied Research Jeff Marr provided insights to *MinnPost* and *Star Tribune* March 30.

>>Wind Power: Tunnel vision at U: SAFL's latest study on wind turbine arrays made headlines in the *Star Tribune* on May 1.

>>Underwater Sensors Help Scientists Monitor Water: Professors Miki Hondzo and Bill Arnold (CE) are leading a project that uses remote sensors to track pollutant loads in storm water runoff that drains into Minnehaha Creek. The data is then sent to SAFL for analysis. Coverage in *Star Tribune* and on *Kare11* on May 20.

MN Lakes Get Salty

MINNESOTANS KNOW THAT ROAD SALT KEEPS OUR ROADS SAFE DURING THE WINTER, BUT DO WE KNOW WHERE ALL THAT SALT GOES WHEN THE ICE MELTS? PROFESSOR HEINZ STEFAN RESEARCHES THE EFFECTS OF ROAD SALT ON LOCAL WATER QUALITY, AND HAS RECENTLY PUBLISHED HIS FINDINGS FOR THE LOCAL ROAD RESEARCH BOARD.

ABOVE
Instrumentation used to measure water quality in lakes.

Research at the St. Anthony Falls Laboratory has revealed that road salt used throughout the winter is making the state's lakes and rivers saltier, which could affect aquatic life and drinking water. The research indicates that better training of snow plow drivers and more judicious use of road salt could help lessen the impact and save the state money.

The researchers studied 39 lakes, three major rivers, 10 tributaries and numerous observation wells, and the results are alarming. They found that approximately 70 percent of the road salt being applied in the metro area is retained in our watershed. The university researchers recently reported their findings to the Local Road Research Board. Nearly 350,000 tons of sodium chloride, commonly referred to as road salt, are applied for de-icing in the Twin Cities metro area every year.

"Nobody has asked the question of where the salt ultimately goes after the winter season is over," said research team leader Stefan. "Our study has been concerned with that question in particular."

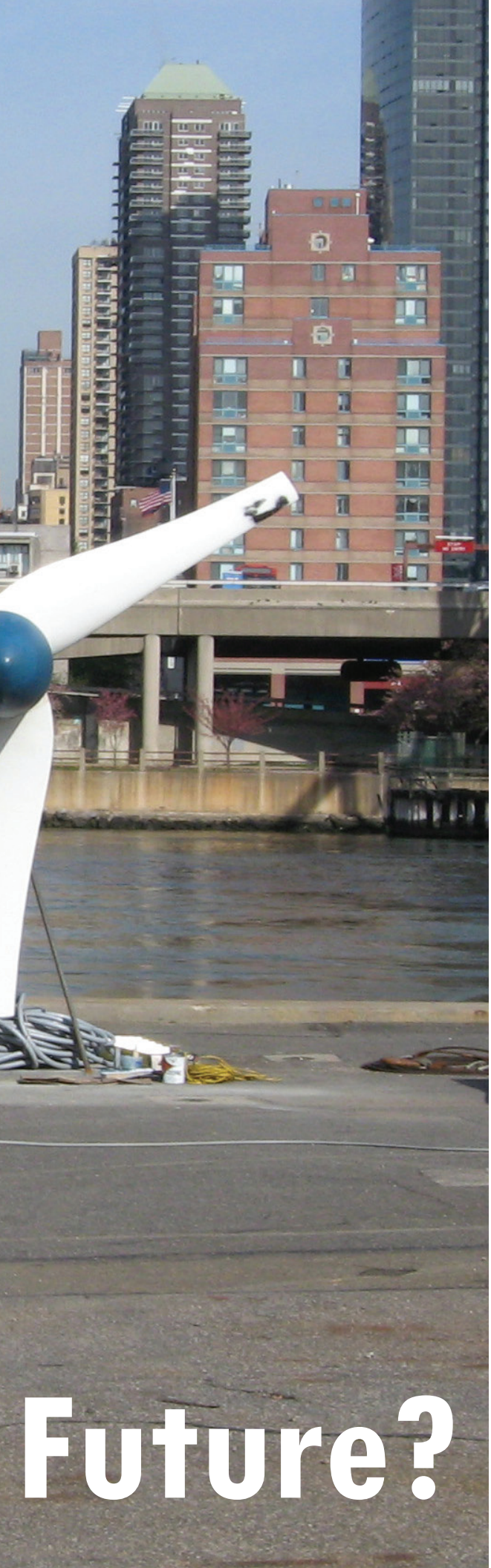
Stefan's team (including Eric Novotny, Andrew Sander, Dan Murphy and Omid Mohseni) tracked the movement of chloride applied by humans throughout the water system, distinguishing it from geological or natural origins. They found that the chloride concentrations (salinity) in 39 metro area lakes have increased over the past 22 years, following a similar trend in road salt purchases by the state of Minnesota. Both show a marked increase from 1984 to 2005, which if continued would double salinity in these lakes in about 50 years. Compare this with a near zero concentration in the 1950s, when road salt application began.

The effects could be severe. Continuous levels of chloride concentration (as low as 250 mg/L, the equivalent of one teaspoon of salt in five gallons of water) have been shown to be harmful to aquatic life and to affect the taste of drinking water. In 2008, the Minnesota Pollution Control Agency listed five metro area streams as already impaired by chloride. Increases in sodium and chloride have been shown to decrease the biodiversity in wetland areas, altering the development of wood frogs, decreasing the number and types of fish available, and increasing mortality rates of organisms that rely on an aquatic system. Increases in sodium and chloride have also been shown to increase mobilization of heavy metals in the soil along major highways.

To help reduce the effects, researchers recommend more judicious use of road salt through increased training of snow plow drivers to get the most out of the road salt they apply. Applying sodium chloride to pavement temperatures below 15 degrees Fahrenheit is generally not effective. At higher temperatures, researchers suggest using only one to three cups of salt per 1000 square feet. These recommendations are working at the University of Minnesota. Since training began two years ago, the university has reduced use of road salt by 41 percent and saved more than $50,000 in the first year.

More information about professor Stefan's research at the St. Anthony Falls Laboratory can be found at www.safl.umn.edu. More information on road salt application training through the Minnesota Pollution Control Agency can be found at www.pca.state.mn.us/programs/roadsalt.html.

The Wave of the



Future?

RESEARCHERS AT SAFL HAVE RECENTLY RECEIVED SUPPORT TO HELP GENERATE CLEAN ENERGY FOR NEW YORK CITY. DIRECTOR FOTIS SOTIROPOULOS WILL LEAD A TEAM OF RESEARCHERS IN DEVELOPING COMPUTATIONAL MODELS FOR OPTIMIZING UNDERWATER TURBINES FOR VERDANT POWER'S ROOSEVELT ISLAND TIDAL ENERGY (RITE) PROJECT.

NEW YORK CITY'S EAST RIVER typically conjures images of a hard working river flowing past a hard working city— certainly not visions of clean energy and a hydraulic lab in Minnesota. Yet this is the latest in SAFL's ever-increasing list of renewable energy research projects: to help bring tidal power to the Big Apple, via the East River.

In a collaborative project with Verdant Power (as well as national labs and private industry) to generate clean energy from tidal, river, and ocean currents, the current focus on the Roosevelt Island Tidal Energy (RITE) project is jointly funded by the U.S. Department of Energy and the University's Initiative for Renewable Energy and the Environment (IREE).

For Verdant, a world leader in developing free-flow turbine technologies, the road hasn't been easy— over $2 million has been spent on aquatic life and regulatory studies, and the strengths of the currents in the East River (which is a tidal strait, with tides that reverse direction every six hours) wreaked havoc on earlier turbine models. But last summer, a pilot-scale project with six newer, stronger turbines was installed and has powered a nearby parking garage and supermarket.

LEFT
Verdant Power turbines ready for placement in the East River

Now that the test array has proven successful, the challenge is to improve the current turbine blade design structure which will allow for larger, more-powerful, and more cost-effective tidal power turbines. This will increase overall efficiency and performance of a field-scale array, which is where SAFL's expertise comes in. SAFL director, Fotis Sotiropoulos, will lead a team

"The purpose of the research is not just to bring power to NYC, but to help advance the technology which will be able to provide far greater amounts of power from appropriate tidal, river, and ocean current resources all over the world."

— Dean Corren, director of Marine Current Technology at Verdant

of researchers in developing computational models for optimizing the multi-turbine arrays for the Roosevelt Island site and elsewhere.

Using SAFL's CFD models, researchers can analyze the design and enhance the environmental compatibility of the system at the rotor, turbine, and array levels. Turbine wakes will be analyzed in order to determine turbine-turbine and turbine-channel interactions on the macro level for array optimization and feedback to the turbine design process. With improved technical design and site arraying factors, the development of cost-effective commercial projects becomes a more immediate reality.

"I think that this new project, along with our recent Xcel Energy wind-power project, places SAFL, IREE, and the Institute of Technology in a great position to provide national research leadership in wind- and water-based renewable energy systems," said Sotiropoulos.

The source funding, which comes from the DOE's newly expanded Advanced Water Power Projects program, resulted in the selection of just 14 research teams who will receive up to $7.3 million for advanced water power projects that will advance commercial viability, cost-competitiveness, and market acceptance of new technologies that can harness renewable energy from oceans and rivers.

UNDERWATER WINDMILLS

At the East River site, the current six-turbine array has been a demonstration and test project intended to lead to larger commercial projects—specifically, a 30-turbine field that has been proposed to the Federal Energy Regulatory Commission.

In the current test array, five of the six 5m diameter 35kW turbines have grid-connected generators and one turbine is a dynamometer. The turbines have axial-flow rotors with three fixed pitch blades, and downstream rotors which allow passive turbine yaw to capture energy in both flow directions. The most critical subsystem of the Kinetic Hydropower System (KHPS) is the rotor itself— the kinetic energy capture prime mover. The rotor is uniquely designed to accomplish several simultaneous objectives: It has high power conversion efficiency, fixed pitch for simplicity and scalability, and even in a variable water flow resource can operate at near constant speed with high load-matching efficiency. This allows it to directly drive a high-reliability, low-cost, direct grid-connected induction generator, which is necessary for providing competitively priced electricity.

In order to reach the commercialization of the KHPS, it is necessary to extend these state of the art rotors to capture energy from higher water velocities and deeper resources that can accommodate larger rotor diameters, changes which are significant enough to require a completely new blade hydrodynamic design cycle. This new cycle will include hydrodynamic and structural modeling, analysis, and design, along with design for manufacture and fabrication technique development (which will be followed by extensive strength and fatigue testing and full-scale hydrodynamic testing). As part of this collaborative process, SAFL's role will be CFD modeling of the rotor and turbine system.

The new rotor design will involve a new structural design and manufacturing technique, and a new hydrodynamic design including a new airfoil shape to allow for thicker sections, requiring a thorough and careful full blade redesign to maintain the present high performance of the rotor. Required factors will be strength, fatigue resistance, corrosion resistance, cost-effective manufacture, cost-effective logistics, final assembly, and deployment capability.

In order to succeed in this challenging engineering undertaking, SAFL will play an important role in a team of organizations with specialized capabilities, whose interactive collaboration is designed to ensure a successful and timely result for this ground-breaking project

FOR MORE INFORMATION see www.safl.umn.edu

FAR LEFT
Roosevelt Island and NYC's East River

LEFT
Underwater turbine image, courtesy of Verdant Power

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