

ENVIRONMENTAL monitor

spring 2012

Application and technology news for environmental professionals

Filled to the BRIM

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at Devils Lake

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Welcome...

Welcome to the Spring issue of the Environmental Monitor. We've made some changes this time around, including a greater number and variety of stories. Check out the summaries from the best of the EM Online, and make sure to read our call for submissions in the back of the magazine. We're looking for great new research and projects to feature. Don't miss our stories on using mollusks to test water quality, studying Siberia, and a new school of robotic fish.

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Cover Photo by Jackie Lorentz/University of North Dakota

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EM Online Recent Features



Researcher Tracks Hibernation Patterns of Primates

By Audrey Rabalais

Stony Brook University graduate student Caitlin Karanewsky has been studying the mouse lemur's hibernating patterns for four years, tracking the ways environmental cues affect the animal's deep sleep period. Though they are a species of "least concern," rising temperatures could put the mouse lemurs in danger.



Monitoring Platform Protects Penobscot Indian Nation

By Jeff Gillies

The Penobscot Indian Nation is protecting the heart of their culture with a water quality monitoring platform in the Penobscot River's Dolby Pond impoundment.

"We're the only ones out there on a continuous basis saying, 'What's going on in Dolby Pond?'" says Angie Reed, the tribe's water resources planner.



Oregon Land-Use Plan could be Win for Conservation

By Alexandra Hazlett

A parcel of reclaimed land will be divided into three parts, and a new tide gate design will allow landowners to better control flooding without harming fragile salmon populations. Tide gates, which allow water to drain out into a river but prevent estuarine backflooding, prevent access critical "over-winter habitat" for juvenile salmon.

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Dynamic Data Fuels Watershed Improvement

By Jeff Gillies

University of Louisville researcher Raja Nagisetty takes spot samples to confirm the system results.

Photo: Mike Croasdaile

A continuous stream of data from a small Kentucky watershed is helping researchers find out what's keeping an impaired creek from meeting its potential.

The data will help identify the problems in the Brushy Creek watershed that keep the creek from meeting its designated uses identified under the Clean Water Act. Previous work by the state found that the creek's support for warm water aquatic habitat is impaired.

"We're trying to find the cause of the impairment," said Mike Croasdaile, a professor of civil and environmental engineering with the University of Louisville's Stream Institute.

Croasdaile and Raja Nagisetty, a post-doctoral fellow with the Stream Institute, are coordinating the monitoring project for the Pulaski County Conservation district, funded through a 319(h) grant from the Kentucky Division of Water.

The monitoring system includes five YSI 600OMS sondes measuring temperature, conductivity, and turbidity every 15 minutes. An additional YSI 6920 V2-2 measures temperature, conductivity, turbidity, pH, and dissolved oxygen every 15 minutes and broadcasts the data online every hour via a NexSens 3100-iSIC cellular data logger.

The continuous measurements have shown very low dissolved oxygen levels that may have gone unnoticed if the researchers were relying on spot samples alone, Croasdaile said. During monthly spot sampling, the dissolved oxygen was always above surface water standards, but the sonde data showed prolonged periods during late summer where dissolved oxygen was very low. Throughout the summer of 2011, oxygen levels were dropping below 2 milligrams per liter, which is too low for organisms like big fish to handle.

The researchers are taking spot samples to measure E. coli levels, which have been extremely high. Though E. coli isn't measured continuously, Croasdaile said the researchers will look for correlations between their E. coli data and sonde data to identify parameters that could help predict high pathogen levels. The method could also work for nutrients.

"We're using the sondes to develop predictive models for some of these other parameters which you can't measure continuously," he said. "If you know when the stage is rising and you know what the turbidity is, then maybe you can make a decent estimate of the phosphorous concentration."

Having their data published online with a NexSens cellular data logger has helped quality control, Croasdaile said. It allows the researchers to keep an eye on things and check that everything is working. If it isn't, they can quickly replace a sensor or troubleshoot a problem.

While scientists have been measuring conductivity and dissolved oxygen for decades, data from traditional spot sampling can only show a snapshot in time. The long time-series of data made available by sondes can help scientists use these parameters as a diagnostic tool to understand the problems in a watershed, Croasdaile said.

"When you use these sondes, you get a high-resolution time series and you really get a dynamic view of the ecosystem and the water quality," he said. "The time series really helps us interpret the behavior of the system. You just don't get that with grab samples." ■

Banking on a Wetland

New mitigation bank in Southwest Ohio the first of its kind

By Audrey Rabalais

Southwest Ohio's first wetland mitigation bank is in early stages of development, but has already been deemed "great." Five Rivers MetroParks, based in Dayton, saved 364 acres of earth from becoming a landfill to construct the Great Miami Wetland Mitigation Bank (GMWMB). A mitigation bank gives developers destroying wetlands the option to purchase credits that will make up for lost land resources. The GMWMB is the only bank in Ohio to offer stream restoration credits. It is also the only mitigation bank in Ohio to be owned, designed and managed by a conservation organization.

The GMWMB will contain 61.2 acres of restored wetlands, 77.5 acres of wetland and riparian buffer, 220 acres of prairie and forested habitat and 4,920 linear feet of restored headwater stream habitat. Construction began in fall of 2011. Mike Enright, a wildlife biologist with Five Rivers Metroparks, said he hopes to have emergent vegetation in the wetland by the end of the summer and forested wetland in four to five years.

"We have a whole mosaic of habitats," Enright said.

The Clean Water Act requires developers who will disturb a wetland to receive a permit from the United States Army Corps of Engineers. A 2008 update to the act included mandatory compensatory mitigation of wetlands lost because of human activity. Developers can restore an existing wetland, construct a new one or buy credits from an organization managing a mitigation bank, such as Five Rivers MetroParks. An EPA estimate shows that the 46 mitigation banks that existed in the United States in 1992 ballooned to more than 500 after 2009.

It is no surprise that the GMWMB is suddenly a hot commodity for Southwest Ohio developers. After the project is complete, approximately 5,300 credits will be available for area developers to purchase, promoting economic growth in the area. Five Rivers MetroParks recently received approval to sell 30 percent of the available credits before construction, and they have already sent out contracts for them.

"One of the big things most people don't realize is wetland and stream mitigation credits are worth a lot of money now," Enright said. "We have people lined up to buy credits."

Credits will cost approximately \$50,000 per acre of land and \$300 per foot of restored stream area. Revenue will fund the cost of construction and eventually convert the area into a MetroPark with hiking trails and other perks for outdoor enthusiasts.

The GMWMB is unique in its ideal wetland features. It has hydric soil, formed under saturated conditions, a high groundwater table and huge amounts of subsurface tile. Luckily for Five Rivers Metroparks, this means the land needs very little maintenance and construction.

A further benefit, Enright said, are the prairie and forested areas that will naturally buffer the wetland, a feature most mitigation banks lack. This should create a more diverse habitat to attract native wetland species. Enright said Five Rivers MetroParks will introduce rare amphibians such as spotted salamanders and wood frogs that may not make it to the area on their own. The parks will also manage invasive species that have no problem finding new habitats. These organisms often compete with native species for resources, removing vital niches and disrupting the natural ecosystem.



Photo: Fondriest Environmental

Research team installs telemetry pole.



"We are so excited about this because MetroParks has a long history of controlling invasives well," Enright said. "We think that being the owner and manager puts us in a unique position to control invasives before they get out of hand."

Five Rivers MetroParks eradicates invasive species such as purple loosestrife and garlic mustard with mechanical removal, herbicides and biological controls.

While wetlands are known to facilitate diverse habitats, filter water and provide flood control, their effect on greenhouse gases is less certain, especially for man-made wetlands. Amy Burgin, an aquatic ecologist and Terry Loecke, a soil scientist, will be studying the GMWMB to determine how gases are exchanged with the atmosphere in newly created wetlands. The married pair, now both professors at the University of Nebraska in Lincoln, lived near the area during the conception stages of the bank.

To study the site remotely, consultants will install a network of sensors measuring a variety of soil and weather parameters. These sensors will send data to a NexSens mast-mounted 4100-iSIC data logging system. The solar-charged system uses radio-to-cellular telemetry to send data to NexSens WQData center using iChart software. With this system, Burgin and Loecke can view and manage real-time data from the Trotwood bank site in Nebraska.

"We can sit here in Lincoln and look at the wetlands knowing the conditions exactly," Burgin said. "We were thrilled with that."

Burgin and Loecke will measure soil oxygen, a possible indicator of carbon balance and greenhouse gas emissions. They will also be measuring soil moisture, salinity and temperature. These control variables will predict the amount of greenhouse gases released from the wetland and how much carbon will remain stored. If their results are consistent, the pair hopes this site can be a model for other wetlands.

"It's kind of a picture we're hoping to color in," Loecke said. "We're just wanting to have confidence in the data that we have."

The data is valuable to Five Rivers MetroParks as well. Enright said the data created by Burgin and Loecke will be important performance criteria to present to regulatory organizations.

"The sensor system that will be put in is absolutely unique," Enright said. "No other mitigation project has a sensor system like this."

If current trends continue, the Great Miami Wetland Mitigation Bank could be a win for the diverse stakeholders involved, while creating a new wildlife and better habitats, in the Southwest Ohio area. ■

STUDYING SIBERIA: The POLARIS Project

By Audrey Rabalais

The Northeast Science Station in Cherskiy, Siberia is on the forefront of climate change research.

Each summer since 2008, several hard-working college undergraduates wrap up their spring semesters, take their very last final and pack their bags for the summer destination they've anticipated for months: sunny Siberia. These students have a unique interest in arctic research, which is why they were chosen for the Polaris Project, an annual month-long expedition into northeast Russia funded by the National Science Foundation (NSF). The program unites professors, researchers and students who are on the cutting edge of climate change research.

"If you want to see the impact of global warming, the arctic is the place to look," said Polaris Project founder Max Holmes. "It's the canary in the coal mine."

The Polaris Project is based at the Northeast Science Station in northeast Siberia, just south of the Arctic Ocean. The station facilitates arctic research and provides a boarding house for those brave enough to do it. Holmes, a senior scientist at Woods Hole Research Center in Massachusetts, first visited the station in 2003, and four years later accepted a project grant from the NSF. He wanted to see more undergraduates interested in ecology and climate change doing arctic research in Russia.

The research in Siberia focuses on the movement of carbon and other nutrients in the ground, water and atmosphere. Permafrost acts as a carbon sink - the frozen soil stores billions of tons of carbon by some estimates. When temperatures rise and the permafrost melts, it multiplies the effect by releasing the sequestered carbon into the atmosphere as carbon dioxide, accelerating the warming cycle even more.

Carbon can also wash into nearby watersheds, such as the Kolyma River which flows right by the Northeast Science Station. The Kolyma River is part of the only major river basin in the world to be completely underlain by permafrost. Two-year Polaris Project student Erin Seybold and Polaris Project faculty member John Schade studied what happens to carbon that enters the watershed.

They tracked carbon and other nutrients that come from thawed permafrost substrate in small headwater streams

high in the watershed. As these nutrients move through water, microorganisms can change their form, either into a gas or a different chemical compound. The stream could also simply move these nutrients to larger bodies of water and eventually out to the ocean.

"I think a lot of climate scientists and people who are interested in knowing what the effects of global warming will be are looking at this area to see how these stored soil carbons will respond," Seybold said.



Max Holmes calls the arctic the "canary in the coal mine" for climate change.

To track the nutrients, Seybold used a chloride tracer tracked with a YSI Pro Plus meter using the conductivity probe to see where it was in the stream. The YSI meter held baseline data that was later used to perform analyses.

While the climate research being performed at the Science Station is of incredible importance, it's not the only beneficial outcome of the program.

Many Polaris Project undergraduates never performed their own research before entering the program, much less in the arctic tundra. Schade said the faculty wanted to focus on undergraduate students because they still have an open mind and are not yet attached to a specific research niche. However, they have an independent drive to learn, especially those of Polaris Project mettle.

"What we're trying to do here is train the next generation of arctic researchers," Schade said.

Polaris Project faculty members recently submitted a paper based on Seybold's research for publication - a rare accomplishment for an undergraduate student.

Though environmental research is the heart of the Polaris Project, Holmes also looks for team members with non-science backgrounds who wish to incorporate science into their career. Photographer and oceanographer Chris Linder, research associate at Woods Hole Oceanographic Institution, epitomizes this balance. Linder has shot videos and photographs on several arctic assignments. He has (Continued on page 8)



Students pack up and head out on a research mission.

(Continued from page 7) captured the beauty of the Arctic from the decks of ships and underwater in a wetsuit, but Siberia is the only place he had to wear a head net.

"It's the hottest arctic location I've ever been in," Linder said. "If the wind's not blowing, the bugs are all over you."

Summer temperatures in Siberia can climb to the high 80's (degrees Fahrenheit) during the day, something that shocks many of the students. However, temperatures at night can plummet, requiring researchers to don the parkas and sleeping bags they expected to use.

"I usually say that on average they will be perfectly comfortable, but they will never actually achieve that state," Holmes said.

Linder has the advantage of watching the group grow from awkward strangers at the beginning to close friends by the end of the month. Through a harsh climate and late nights in the laboratory, the total immersion experience of Polaris brings the individual students together to form a tight-knit group of friends.

"You really bond with the people you go through this with," Seybold said. "Not only are you in this crazy remote place that most people will never see, but you're living on a barge."

Group dynamics certainly come into play when unpredictable arctic weather takes a turn for the worse. In 2010, the students took a boat trip to another part of the tundra. The weather that day was so warm, Schade and Holmes said, that the group was swimming in the Arctic Ocean. Just as they were preparing to leave, storm clouds rolled, the temperature immediately dropped 30 degrees and all the mosquitoes disappeared. As the rain began to pour, the Northeast Science Station director and his son

panicked and left to seek help. Though Schade trusted them to return, he was concerned that the students may also be panicking. Instead, they were laughing around a fire they built. The group ate fish they caught from the ocean that night and slept body-to-body on the floor of a fisherman's cabin.

"It just showed me how remarkable this group is and how they came together as a unit," Schade said. "It gives you a different idea of what 'hardship' means."

For the students, the Polaris Project is a formative experience that matures them both socially and professionally. Seybold said that students from her two years in Polaris travel to conferences, attend graduate school and write papers on arctic research. Seybold is now a Fulbright Scholar, continuing her arctic research in Norway.

"Polaris really supports students to launch a career," Seybold said.

Faculty members and organizers hope the Polaris Project will continue to support itself by churning out unprecedented climate change research that can only come from the arctic and fostering a new generation of students excited about science. Linder in particular enjoys capturing the story behind the research to excite others.

"Earth science field work is half adventure and half lab work," Linder said. "The adventure side of it is often overlooked."

The Polaris Project team will continue to have adventures for at least another three years, thanks to another NSF grant, time enough to continue making strides in climate change research in the arctic. ■



The project forges a close bond among participants.



Observation Post

By Jeff Gillies

Grand Valley State University's buoy floats in Muskegon Lake, monitoring water quality.

Photo: Scott Kendall

Most observatories examine the distant sky. But on Michigan's Muskegon Lake, an observatory looks under the water.

Launched in the spring of 2011 by Grand Valley State University's Annis Water Resources Institute, the Muskegon Lake Observatory project is no telescope. It's a buoy system that carries dozens of sensors measuring weather and water parameters at multiple depths, collecting long-term data with an intensity never before seen on the lake.

At 4,150 acres, Muskegon Lake sits between Lake Michigan's eastern shore and the mouth of the Muskegon River. A history of industrial pollution earned the lake a spot among the Great Lakes Areas of Concern, a list of water bodies bordering the lakes that the U.S. and Canadian governments consider especially polluted. The people who brought the buoy to the lake say the observatory will give researchers new insight into the lake's inner workings, give managers a way to track progress of environmental restoration, and

give teachers a tool to help students learn scientific principles in the context of their local environment.

Watching the relationships between trends in any of the dozen parameters measured every 15 minutes at the buoy can change the way a scientist thinks about the dynamics of the lake, said Scott Kendall, research biologist with the institute and the observatory manager.

"It's that ebb and flow of time-series information that allows you to interpret how these things interplay with each other in the ecosystem," he said.

The system features a 5-foot surface buoy tethered to a small underwater buoy that supports PAR and nitrate sensors and line of six multi-parameter sensors and five temperature sensors at several depths. An acoustic Doppler current profiler resting on the lake bottom measures current speed and direction. The big surface buoy carries solar panels, a meteorological station, (Continued on page 10)

(Continued from page 9) and a data logger that beams data back to the water resources institutes's lab on the lake's southeastern shore. From there the data is published to the buoy's website for all to see (www.gvsu.edu/buoy).

The system began recording data in May 2011 after the project team launched the buoy with the help of the Laurentian, the 80-foot research ship operated by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory. This first round of data will give researchers a rich source of baseline data and help comprehend ongoing ecosystem changes, according to Bopi Biddanda, aquatic microbial ecologist with the institute and principle investigator on the project.

"Come next year or in ten years, we'll have this data to compare," he said. "Whatever we are measuring, there will be background data."

Leon Gereaux, a graduate student at the institute, uses the observatory data to understand seasonal changes

within the lake. He hopes to analyze a full-year's worth of data and develop models of ecosystem drivers.

"By closely following trends in temperature, nutrients, phytoplankton abundance, dissolved oxygen and other variables, one can really take the pulse of the lake ecosystem through the different seasons," he said.

The data could also play a role in efforts to end Muskegon Lake's tenure as a Great Lakes Area of Concern. In the world of Area of Concern management, the ultimate goal is to get off the list by restoring habitat and cutting pollution. Escaping the list is a rare feat; only a handful of the original 43 sites have done it. But local environmental officials think

Muskegon Lake is close, according to a recent update of the state's cleanup plan for the lake. The plan aims to correct the lake's official environmental impairments by 2017.

One key to moving towards shaking off the Area of Concern label is showing measurable progress. The observatory can help with that, Kendall says. For example, according to the U.S. Environmental

Protection Agency, one of the lake's official problems is "eutrophication or undesirable algae." The buoy carries sensors for dissolved oxygen, chlorophyll, and phycocyanin at four depths. In time, researchers and regulators will have an intensive long-term data set to evaluate the trends in the parameters tied directly to algae growth and eutrophication.

Data from the observatory can also provide insights into the lake's other official impairments. For example, according to the EPA, the lake suffers from "degradation of fish and wildlife populations" and "loss of fish and wildlife habitat." The buoy doesn't count fish, nor does it measure habitat. But observatory data is already showing researchers new information that may indicate where and when fish can and can't thrive in the lake.

When six months of the observatory's temperature or dissolved oxygen data from multiple depths are layered in a line graph, the separation between the lake's warmer top layer and cooler bottom layer is plain as day. The transition between the two layers occurred at around 6 meters in the summer of 2011, and dissolved oxygen readings below this line are much lower than those from above, occasionally even dipping into anoxia.

If oxygen in the lake's bottom layer is as low across the lake as it is at the buoy site, Muskegon Lake may have a slice of cold water habitat that isn't accessible to fish like lake sturgeon.

The project is funded by a \$560,000 grant through the Great Lakes Restoration Initiative, a federal program coordinated by the EPA. As an EPA-funded project, the data must meet strict quality control standards. A 115-page quality assurance plan assembled by the project team details the steps to make sure the sensors are delivering accurate, precise measurements. That includes testing sensors in the lab fresh from the lake, before they're cleaned and recalibrated.

"We're doing regular laboratory checks of uncleaned sensors and we're also monitoring the time-series data," Kendall said. "We know that data is good."

The institute didn't just have managers and scientists in mind when they designed the project. Kendall envisions local teachers using the data to meet state science curriculum requirements. A lesson on photosynthesis, for example, could use a graph of dissolved oxygen levels rising throughout the day and falling after the sun goes down.

"It's a way to get out of the book and into the local environment and learn how to mix theory with practice," Kendall said. ■

“By closely following trends, one can really take the pulse of the lake ecosystem.”

System Description

The GVSU Muskegon Lake buoy includes a multi-parameter weather station, temperature string, fluorometer, underwater PAR sensor, nitrate sensor, acoustic Doppler current profiler, and several multi-parameter water quality sondes.

The Lufft WS600 weather station was selected to measure air temperature, humidity, barometric pressure, wind speed, wind direction, and precipitation. The integrated unit features an internal compass for wind correction, making it ideal for deployment on moving platforms.

An MB-100 data buoy with SDL500 data logger serves as the mounting platform and sub-surface junction box for the suite of water sensors. Near the surface, a YSI 6600 sonde, Turner C3 fluorometer, Satlantic SUNA nitrate sensor, and LI-COR LI-192SA PAR sensor are mounted to an instrument cage. Within the water column, four additional YSI sondes and a NexSens T-Node temperature string are deployed and attached along a single communications cable.

On the other side of the surface buoy, a Teledyne RDI Workhorse Monitor acoustic Doppler current profiler (ADCP) is bottom-mounted to obtain a 3D profile of water currents across the entire water column. The ADCP utilizes power and communications from the surface buoy, eliminating the need to pull the unit for data upload and battery replacement.

Data is transmitted by cellular telemetry to a computer at the Annis Water Resources Institute and then posted to a publicly available website.



Photo: Scott Kendall

The Muskegon Lake Observatory buoy will be redeployed this spring for another season.



Iridium Satellite Telemetry

By Mike Voellmecke

Advanced environmental data logging systems in remote locations require wireless telemetry in order for researchers and environmental professionals to have real-time data access. Not only does real-time data access minimize the amount of time required to visit sites and manually upload data, but it enables project personnel to quickly diagnose system issues to ensure that quality data is continuously gathered. Otherwise, sensors may go days or even weeks gathering corrupted data or not functioning altogether.

The methods for wireless telemetry are almost as extensive as the parameters that can be recorded. They include land-line telephone, cellular, Wi-Fi, Ethernet, Bluetooth, VHF, UHF and spread spectrum radio, and satellite. Site conditions and budgetary constraints typically determine the most appropriate method. Ethernet and Wi-Fi work for very close range systems and are relatively inexpensive. Radio extends the range to up to a mile or more if line-of-sight is present. Cellular works well anywhere that reliable service from a major provider is available, but requires a cellular account subscription. But what about the most remote monitoring stations, in locations where not even the largest cellular provider has extended its coverage map?

The Iridium Satellite Constellation

For such applications, satellite telemetry is required. One of the leading satellite telemetry companies in the environmental monitoring field is Iridium Communications Inc. Iridium maintains a network of 66 cross-linked, low-Earth orbit (LEO) satellites with seven in-orbit spares. Compared to other satellites, those in the Iridium constellation orbit the Earth at a relatively low 780 km above Earth's surface. They travel at a blazing 17,000 miles per hour, completing an orbit of the Earth in just 100 minutes.

Data Transfer

During orbit, the satellites project 48 spot beams measuring about 250 miles in diameter on the Earth's surface. All spot beams overlap so that no holes exist in the coverage net, and each satellite has a total 48-beam footprint spanning 2,800 miles

in diameter. Much like cellular networks, which pass signals from one cell tower to the next as a mobile device moves through a network, the satellites pass data from spot beam to spot beam and satellite to satellite as the constellation orbits.

Environmental monitoring applications utilize Iridium's Short Burst Data (SBD) service to send Mobile Originated SBD (MO-SBD) messages. At the monitoring site, or Field Application (FA), a serial connection passes data from the sensors to a satellite modem. The system's antenna then sends the MO-SBD message from the modem to the satellite constellation, which eventually sends the data Earthward to the Gateway SBD Subsystem (GSS) located at the main Iridium gateway in Tempe, Arizona. The GSS provides connection to the Internet cloud, enabling the end user's host computer system to gather and display the data on a PC.

Service and Reliability

Iridium's unique cross-linked, LEO constellation offers a high level of service and many advantages over similar systems. The low orbit minimizes the physical distance that transmissions must pass and therefore, minimizes the latency, or time delay, experienced in the transmission

process. Small messages of 70 bytes take just 5 seconds to reach the GSS, while messages of the maximum size of 1960 bytes take only about 20 seconds.

The overlapping spot beams and high number of satellites in orbit mean that multiple beams and satellites are usually visible from a given location. Therefore, the potential for missed connections and dropped calls is very low; studies performed by Iridium and by independent sources have both shown a greater than 98% connection success rate.

Redundancy at all steps of the transmission process further ensures system reliability. Since the satellites are programmable from the ground, in-orbit spares can quickly be sent to fill in the void left by a failed satellite. This was the case in early 2009, when an obsolete Russian satellite collided with one from the Iridium constellation. It took Iridium's network operators just three days to re-route communications that would have been handled by this satellite and just 20 days to fully commission a spare to take its place. For comparison, without in-orbit spares, it would take months to repair the system. Environmental data logging applications are unlikely to be adversely affected even if a satellite fails. Since there are 66 cross-linked satellites in orbit, a single satellite failure affects less than 1/66 of the Earth at any given moment. Even if the monitoring site fell within this area, data is still stored by the on-site logger to be transmitted at the next successful communication.

At the ground level, Iridium maintains a backup ground command center, emergency power supplies, and additional ground stations that serve as backup Tracking, Telemetry and Control (TTAC) sites and receive incoming commercial traffic if the GSS receiver fails. Dedicated TTAC sites report satellite health and safety information to the Satellite Network Operating Center (SNOC), the nerve center of the Iridium network, and facilitate the process of sending corrective actions from the SNOC to the satellites. The team that operates the SNOC continuously monitors overall system performance to ensure that Quality of Service (QoS) requirements are met.

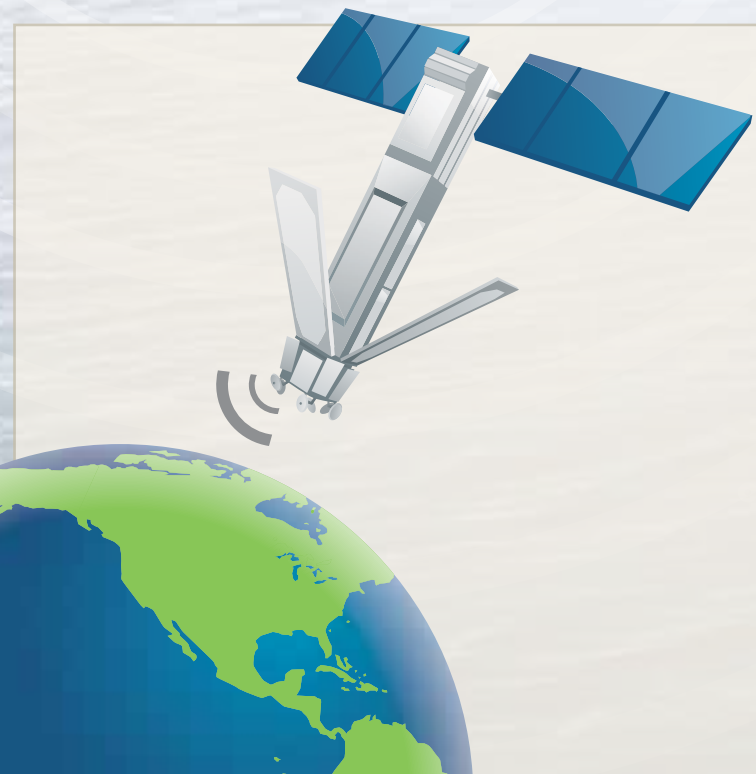
The Future of the Iridium Constellation

While the forces of gravity largely keep the Iridium satellites on track, they do require some energy inputs to function properly. The current group of satellites contains solar-charged batteries to maintain continuous communications and more than 100 kilograms of fuel each to maintain proper orbit. As this fuel runs out, new satellites will need to be launched to replace the existing constellation. Iridium has named its next-generation constellation "Iridium NEXT" and plans to launch the system from the first quarter of 2015 through 2017. The NEXT satellites are interoperable with the current satellites to ensure continuity of service throughout the transitional period. This will result in a seamless transition with no noticeable reliability issues for existing subscribers. ■

Recent Iridium Telemetry Projects

- With nearby natural gas drilling in the Marcellus Shale and other industrial runoff, a Pennsylvania conservancy group put grant awards toward establishing real-time water quality monitoring stations at 16 locations in western PA. Each site is equipped with data loggers that use Iridium satellite telemetry to transmit data without relying on cellular networks.
- A coal fired power utility needed to monitor water temperature at two river locations to ensure that operations were not negatively impacting water conditions. The sites were located five miles from the plant, making radio telemetry cost-prohibitive. The limited parameters and infrequent measurements made Iridium satellite telemetry a better option.

- A river basin commission established a large network of real-time water quality monitoring stations throughout New York and Pennsylvania. While many sites had cellular coverage, nearly half of the deployment sites were in rural areas without landline access or cellular coverage. The commission selected Iridium telemetry to transmit data from these remote sites.
- An offshore oil platform recently utilized Iridium satellite telemetry for real-time measurements of basic weather data, along with water temperature, conductivity, and salinity. The platform was located miles away from cellular coverage, making satellite telemetry an ideal candidate for data transmission.



Filled to the BRIM

By Jeff Gillies

Devils Lake in North Dakota faces high salinity and sulfate concentrations from massive flooding.



Photo: Jackie Lorentz/University of North Dakota

Scientists researching North Dakota's Devils Lake often focus more on water quantity than quality, and for good reason. They have too much.

Since 1993, the lake has risen 30 feet. Its volume has swelled by seven times and its surface expanded by 260 square miles, submerging homes, farms, and businesses.

"You have to look at Devils Lake to see how dramatic the flooding is," says Xiaodong Zhang, associate professor of earth systems science and policy at the University of North Dakota. "There are street signs that are barely above the water. Some roads go to into the water and just disappear."

The flooding has led to extensive research asking why there is suddenly so much water and how much more they can expect (an exceptionally strong recent flood cycle is mostly to blame). State, federal and local officials who have grappled with the extra water for decades are expanding controversial man-made outlets that pump Devils Lake water to the neighboring watershed. Such decisions hinge on critical issues of water quantity, but when moving water from one watershed to another, water quality is just as important.

"The more we looked at it, a deeper issue is that many people don't know the water quality," Zhang says. "There's no such continuous monitoring of the quality of the water even

though we all know the level of the lake. That's released every day."

To address that lack of water quality monitoring, Zhang launched a NASA-funded buoy in the fall of 2011 equipped with a meteorological station and sensors that continuously measure several water quality parameters. Before Zhang pulled the buoy out of the lake for the winter, it floated in the eastern-most section of the lake, once a separate body of water called Stump Lake. Water began spilling into Stump Lake in 1999, and by 2007 it had risen 31 feet and the two lakes had merged into one.

The buoy's sensors measure temperature, turbidity, dissolved oxygen, chlorophyll, and salinity. Salinity is particularly important in Devils Lake, which has no natural outlet. As long as the lake level stays below 1,458 feet above sea level, the lake's only natural water loss is through evaporation. Evaporation leaves behind dissolved solids like undesirable sulfates and makes the water ten times saltier than a normal lake.

The result? "Nobody wants this water," Zhang says.

Which is a problem, because they're going to get it anyway. In an effort to slow the rising water, the North Dakota State Water Commission in 2006 switched on pumps at a man-

made outlet that originally moved water out the lake's west end and into the Sheyenne River at 100 cubic feet per second. The commission later increased the capacity of the west end outlet and began construction on an even bigger outlet on the lake's east end. A third outlet is under development, this one a gravity-operated system that will move between 20 and 600 cubic feet per second, depending on how high the lake rises.

The outlets have been controversial with downstream communities and governments because the connections form an unnatural link between the Devils Lake basin and the Sheyenne River, which flows into the Red River and Lake Winnipeg in Canada. Outlet opponents are concerned that Devils Lake water will taint their rivers with sulfates, new fish pathogens, and invasive species. The outlets will operate under U.S. Environmental Protection Agency standards that limit the amount of sulfates allowed in the Sheyenne. An assessment by the International Joint Commission, a bi-national group that advises the U.S. and Canadian governments on issues related to waters that straddle the border, determined that the risk of the outlets introducing new fish pathogens is low.

Opponents also worry about the effect of additional water flowing from Devils Lake into their already flood-prone rivers. Major floods struck the Sheyenne River in 2009 and the Red River in 2009 and 2011. The State Water Commission says that the flow from the outlets will be cut back if there is a chance of contributing to downstream floods, but without controlled water diversions from the rising lake, the effects on Sheyenne River flooding could be even worse.

That's because if Devils Lake rises another five feet from its current level and surpasses 1,458 feet above sea level, it will eventually spill over into a ravine that forms a natural channel between the former Stump Lake and the Sheyenne River. If that happens, scientists estimate that it would likely be just the third time in 4,000 years that the two basins were joined by water flowing through the ravine. According to the U.S. Army Corps of Engineers, a spillover could escalate into a torrent of water flowing at at least 12,000 cubic feet per second for 19 days, causing catastrophic flooding along the Sheyenne. The State Water Commission is in the process of building a dam-like control structure in the ravine to manage the flow in the case of a spillover.

To make matters even worse, Stump Lake's water has the highest sulfate concentration in Devils Lake, so a spillover will send the lake's lowest-quality water into the Sheyenne.

“It would be just the third time in 4,000 years that the two basins would be joined by water.”

Despite this, sulfate monitoring has been limited to spot sampling, Zhang says. That's one reason he chose to put the buoy in Stump Lake. Though the buoy doesn't measure sulfates, its continuous salinity measurements can give a good indication of sulfate concentrations, he says.

According to the USGS, there's a 10 percent chance the lake could rise high enough to spill in the next 20 years. In the meantime, Zhang stresses that the buoy will serve a greater purpose than acting as a sentinel for sulfate levels when it goes back in the water this spring. The measurements will give researchers and managers new tools to understand what drives water quality in the lake as well as what drives water quantity. With this data, they'll be able to model how the lake's salinity, dissolved oxygen, and algae production respond to environmental changes in rain, snow cover, or temperature.

"If you just pick salinity out, it really takes the whole thing out of context," he says. "We want to elevate our overall understanding of the lake." ■



Photo: Jackie Lorentz/University of North Dakota

Professor Xiaodong Zhang oversees the buoy in the Stump Lake section of Devils Lake.

Metabolic Process

Stream study could impact usage regulations

By Audrey Rabalais

Photo: Sandra Villamizar

The Merced River water level drastically fluctuates because of human interaction with the ecosystem.

It's a scene from a pastoral landscape painting: The Merced River flows out of Yosemite National Park, through the majestic Sierra Nevada mountain range and into the fertile San Joaquin Valley. The lower part of the river's watershed is sought after for high-thrills rafting as well as agriculture. Farmers harness the river to irrigate orchards, vineyards, row crops and dairies in the valley.

Because of the wide variety of human interventions, the Lower Merced River's ecosystems and biological quality suffer. Water flow levels in the river drastically fluctuate and nutrient concentrations can vary. A group of researchers at the University of California, Merced are monitoring the river's metabolism to determine its biological response to human activity. Their data could impact guidelines for agriculture and recreation pertaining to the Lower Merced River.

"Making the decision about water allocations is a difficult one when there is not complete understanding of how the river system responds to such a variety of human interventions," said UC Merced graduate researcher Sandra Villamizar.

The UC Merced group, lead by engineering professor Tom Harmon, chose to monitor the river by gathering metabolism data rather than the more popular method of simply measuring stream flow, temperature and dissolved oxygen levels. Metabolism data refers to information about the activity of plants and animals in the river. This method analyzes the direct impact of human activities to the ecological community below the surface of the water. Researchers believe that they can physically observe and mechanically quantify a link between human-induced alterations and the river's metabolism estimates.

If the team's hypothesis is supported by stream metabolism data, those dependent on the river for recreation and agriculture may have to alter their practices. Reservoir release schedules may change and irrigation drainage practices could experience new regulations. Because the Lower Merced River and its watershed are an archetype of many other regulated rivers around the world, Harmon said the hypothetical changes in guidelines have the potential to be applied in other areas.

"In all but the wettest years, there are competing demands for the water, and the resource must be carefully managed," Harmon said.

Harmon's group uses both time and space observations to gather data. Cleverly hidden from vandals in the rusty remains of an old water pump, Harmon said the water quality monitoring equipment acts as a "sentinel in one location, watching all the time." It measures dissolved oxygen, temperature and other nutrients in the water. Some species, such as the Chinook salmon, found in the Lower Merced, are sensitive to changes in water temperature, which can be affected by effluent.

Knowing what nutrients are in the river, such as nitrogen and phosphorus, can alert researchers of specific types of runoff such as from fertilizers or pastures. Measuring dissolved oxygen is especially important for stream metabolism data.

Photosynthesis, the method by which plants make their own food, requires carbon dioxide and releases oxygen as a byproduct into the ecosystem. Animals then breathe in this oxygen and release carbon dioxide as a byproduct. Dissolved oxygen levels can indicate how much plant productivity or community respiration is occurring. Either of these processes could be impeded by poor water quality or toxins.

A NexSens data logger receives measurements from the parameter sensors. At the beginning of the project, Villamizar said the team first used a radio system to transmit data from the river to the lab. However, vegetation blocking the signal and distance challenged the system. They now use a NexSens cellular telemetry system that transmits data to a remote computer.

"This is critical long-term data because we do not always know in advance when a reservoir operation change will happen or when a storm will arrive," Harmon said. "Even if we did, we would probably not have the resources to scramble and sample very often."

The team supplements the data from the monitoring station with spot-sampling and observations during bi-weekly rafting trips. These recreational outings are not only a break from lab research, but offer researchers a look at the entire river during different seasons and weather conditions. They are also able to see where outside influences from canals, pumps and groundwater are located in the river's path.

Unfortunately, these raft trips are occasionally docked due to another one of the Lower Merced River's inconsistencies – water level. During dangerously high flow periods, the river could reach up to 5,000 cubic feet per second. The river experiences the other extreme during low flow periods, with levels near 10 cubic feet per second.

"During most of the years, except for wet years, this low flow condition occurs simultaneously with the irrigation season and warm periods," Villamizar said. ■



Photo: Sandra Villamizar

Researchers install a cellular telemetry system to transmit data in real-time.

LimnoTech's BUFFALO RIVER PROJECT

By Cathy Whiting

The Buffalo River watershed encompasses approximately 445 square miles and drains portions of Buffalo and Wyoming counties in Western New York, including three major subwatersheds: Cayuga, Buffalo, and Cazenovia Creeks. Land use within the watershed is primarily agricultural and woodland in the upper basin; and mostly developed and industrial in the lower basin. The terrain consists of gently rolling dissected glacial plateau along the Lake Erie shoreline. The river passes through a heavily industrialized part of Buffalo before entering Lake Erie.

A portion of the Buffalo River has been designated an Area of Concern (AOC) pursuant to the U.S.-Canada Great Lakes Water Quality Agreement. The AOC includes approximately 6.2 miles of the Buffalo River and the entire 1.4 mile stretch of the City Ship Canal, adjacent to the river. The AOC impact area is characterized by historically heavy industrial development in the midst of a large municipality.

LimnoTech, a water resources and environmental consulting firm in Ann Arbor, Michigan, conducted bathymetry surveys and hydrologic monitoring of the Buffalo River in 2008 to generate data for hydrodynamic modeling of the river. Hydrodynamic and water quality measurements were collected to help establish boundary conditions for the model, support model calibration, and provide information on flow and suspended solids variability over time and a range of flow conditions. This work was part of a series of studies conducted to develop a comprehensive assessment of current conditions in the river, and to provide the data necessary to complete a Feasibility Study (FS) for the Buffalo River AOC.

System Description

Instrumentation was installed in the river to collect velocity and suspended solids data over a six-week period in late 2008. The installations included a downstream transect near the mouth of the river, a midstream transect, and an upstream transect at the end of the navigational channel.

The data collected at the monitoring stations included velocity, surface water elevation, and turbidity. The

velocity measurements were collected using side-looking Acoustic Doppler Current Profilers (ADCP) (SonTek Argonaut-SL500), which provided average channel velocities by measuring a broad spectrum of current velocities across the width of the channel. The ADCPs were mounted on pilings at the downstream and midstream locations and on a concrete wall along the bank at the upstream location. In addition, an up-looking ADCP (Teledyne/RDI Workhorse Sentinel) was installed at the mid-stream transect, in approximately the middle of the channel. The Sentinel measured the vertical velocity profile of the water column.

Surface water elevations were monitored at 15 minute intervals using pressure transducers (In-Situ LevelTroll 500). The transducers were located with the ADCPs at the upstream and downstream transects. The surface water elevations were surveyed to vertical reference points located on shore near the equipment installation locations.

Turbidity and temperature were monitored at 15 minute intervals using YSI 6136 turbidity sensors and turbidity also was measured using optical back scatter (OBS) meters. The YSI turbidity sensors were installed on monitoring buoys (NexSens prototype portable data buoys) located in the channel next to each of the ADCP installations. Two sensors were placed on each buoy at approximately 25% and 75% of the river depth to capture the vertical stratification of the river. The OBS meters were installed at the upstream and downstream monitoring buoys at a depth of 75% of the river depth.

All monitoring data was recorded by internal instrument data loggers, or by external data loggers. OBS and YSI turbidity sensor readings were correlated to local suspended sediment concentrations by collecting four series of surface water samples during the monitoring period. Discrete water samples were collected at each of the monitoring buoy installations. These samples were analyzed for total suspended solids concentrations (TSS). The TSS results were coupled with the OBS and YSI raw output readings to provide a suspended sediment calibration curve specific to the river.



Photos courtesy LimnoTech

Results

The Buffalo River is typically characterized as a slow-moving river; study data demonstrated average low flow conditions of approximately 150 cfs and peak high flow conditions of approximately 6,500 cfs. Due to the low river gradient (17 cm/km) and the generally low flow conditions, both the direction and magnitude of flow in the lower Buffalo River are frequently affected by seiche-related changes in Lake Erie water levels (a seiche is a standing wave or oscillation in a contained body of water). Oscillations in velocity direction and changes in water levels were demonstrated as a result of Lake Erie seiche events and the wave effects in the river. Seiche-induced water-level changes occur over a period of approximately 14 hours; the waves propagate over a period of approximately 1.75 to 2 hours. Smaller internal wave oscillations were observed as a result of the upstream boundary of the navigation channel.

The hydraulic and hydrodynamic conditions of the Buffalo River were modeled over varying flow conditions to demonstrate the flood elevations and velocity and shear stress distributions over a range of flow and seiche conditions. The existing three-dimensional model developed by Joe Atkinson at the University at Buffalo was upgraded to the three-dimensional USEPA EFDC modeling framework and the original model grid was extended upstream. The upgraded model was calibrated to highly resolved velocity and water level

data collected during fall 2008. The velocities and shear stresses computed by the model for the various events are consistent with the river's function as a dredged navigation channel. Results from model simulations demonstrate low velocities and bottom shear stresses throughout the AOC during low flow conditions. During moderate flow events (1-yr interval) model results demonstrated higher velocities in the upstream areas and attenuation of seiche impacts in upstream reaches. An increase in velocities and shear stress was demonstrated during high flow events (10-yr and 100-yr intervals) in narrow sections of the river.

The hydrodynamic modeling studies and investigation of sediment bed properties supports an improved understanding of the sediment transport within the Buffalo River AOC, and an understanding of the long-term stability of the system under wet weather and high seiche conditions. ■

About the Author

Cathy Whiting is a senior project engineer and project manager at LimnoTech with more than 20 years of environmental engineering and consulting experience. Her recent area of focus is the design and implementation of field sampling plans.

**Product Spotlight:
Weather**

Lufft WS501 Weather Sensor

Measurement of multiple essential weather parameters in one compact sensor



The Lufft WS501 is compact, cost-effective multi-parameter weather sensor offering a variety of measurement parameters for land- and buoy-based weather stations. The sensor simultaneously measures air temperature, humidity, pressure, solar radiation, and wind with an integrated electronic compass for corrected wind direction on moving platforms.

The WS501 features an integrated KIPP & Zonen CMP 3 pyranometer for shortwave solar radiation measurements that range from 300 to 2800nm. The thermopile sensor construction measures the solar energy that is received from the total solar spectrum and the whole hemisphere; it does not require any power and is designed for continuous use.

Temperature is measured using a highly accurate NTC-resistor, while humidity is measured using a capacitive humidity sensor. Both sensors are located in a ventilated radiation shield to reduce the effects of solar radiation.

Absolute air pressure is measured using a built-in MEMS sensor. The relative air pressure referenced to sea level is calculated using the barometric formula with the aid of local altitude, which is user configurable on the equipment.

The WS501 wind sensor uses four ultrasound sensors to take cyclical measurements in all directions. The resulting wind speed and direction are calculated for the measured run-time sound differential.

The weather sensor's housing is rated IP66 for both high-pressure water jets from all directions and dust. It is available with a low-power setting option for remote stations with solar power. Measurement output protocols available include SDI-12, Modbus RTU, UMB, and ASCII. Surge protection, additional power supply, and converter accessories are available for specific project needs. ■



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**Product Spotlight:
Water Quality**

Thermo VERSA STAR

A versatile benchtop meter for advanced electrochemistry laboratory operations



Thermo Orion's VERSA STAR Benchtop Meter has the quality, accuracy, and variety of features to meet even the most demanding laboratory research needs.

Plug-and-play connection with interchangeable pH, conductivity, dissolved oxygen, pH/ISE and pH/LogR modules provide great project versatility. Four of the five modules can be used at any time, with results displayed simultaneously on the meter's large backlit, color-graphic LCD screen. Multiple modules of the same parameter can be utilized at once, proving the meter's ability to meet specific needs through custom configuration. When switching modules, there is no need to power off, as the changes are automatically recognized.

The pH modules each allow for 5-point calibration with automatic recognition for USA/NIST and DIN buffers. The pH/ISE offers six measurement techniques, and the pH/LogR module provides the most advanced electrode diagnostics; no sensor is needed for temp-compensated readings. Two stirrer probe ports are available, eliminating the need for a stir plate. An optional electrode arm with newly designed probe holder is ideal for secure probe placement in the sample.

The conductivity module measures conductivity, total dissolved solids, salinity, and resistivity capabilities, with

a choice of practical salinity or natural sea water curves for salinity readings. The dissolved oxygen/RDO module automatically recognizes both polarographic and RDO probes. Multiple calibration options are available, and salinity and barometric pressure are automatically compensated for.

The VERSA STAR features a large non-volatile memory, capable of holding up to 2,000 time-stamped data points, as well as an RS-232 and two USB ports for simple data view, analysis, and transfer. Each module offers calibration editing and compensation, available with the included software package. The meter is rated IP-54 splashproof and works with almost any AC power source via an included power adapter. The meter's 3-year replacement warranty ensures a lasting and useful life. ■



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**Product Spotlight:
Data Logging**

NexSens micro-T Temperature Logger

*A mini self-contained, self-powered
temperature logger*



The NexSens micro-T Temperature Logger is a self-contained, self-powered package measuring just over 0.5 inches in diameter. Consisting of a computer chip, temperature sensor, and battery enclosed in a 16mm thick stainless steel housing, the logger can be securely hidden in many important monitoring areas and environments.

Each micro-T has a unique ID to ensure traceability when installed in a secure or hidden environment, as well as a non-volatile memory that stores up to 2,048 temperature measurements at a sample interval of 1 to 255 minutes (the DS1922L stores up to 4,096 readings).

Complete kits are available, which include the micro-T loggers, software, USB connection, and underwater housing in one package. The USB reader enables the user to setup deployments, upload data, and view the logger status with micro-T Software.

The temperature logger uses its enclosure as an electronic communications interface. It can be connected to a computer by simply touching the device to the USB reader. Each logger has a data contact, called the "lid," and a ground contact, called the "base," to allow for this connection.

Data management is simple with NexSens micro-T software, providing a user-friendly interface compatible with any Windows-based operating system. It includes a unique historical report creation tool that can generate customized output with data from all loggers in a single database. While creating a report, users can include specific information about the monitoring site, location, sensors, and project.

A full line of accessories are available for mounting and deploying micro-Ts anywhere. Options include double-sided adhesive pads, keychain fobs, and underwater housings. ■



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**Product Spotlight:
Water Quality**

YSI Pro30 Conductivity Meter

*A rugged and reliable handheld
meter for accurate measurement*



YSI's Pro30 conductivity meter is YSI's most durable and easy-to-use conductivity instrument to date. The handheld meter simultaneously measures salinity, conductivity, specific conductance, total dissolved solids (TDS), and temperature easily and accurately with a single sensor.

The Pro30's four-electrode conductivity sensor is built directly into the cable bulkhead and designed for long-term use. The weighted field sensor is very easy to maintain and clean with a small conductivity brush, allowing years of use and accurate data collection.

Also featured on the Pro30 is a one-button 'Quick Cal' function that stores previous calibration values and walks the user through the calibration process if necessary, proving the meter's ease-of-use and short start-up time.

The meter stores 50 data sets and provides continuous battery status and low battery indication; the keypad and display are backlit for low-light conditions and can even be viewed with polarized sunglasses. Two alkaline C-cell batteries provide the unit with approximately 400 hours of battery life.

The Pro30 also features durable quarter-turn locking military spec (MS), bayonet-style cable connectors. It has both 1m drop test and IP67 waterproof ratings (with battery cover on or off), along with rubber over-molded protective casing.

The display and user-replaceable cable are sold separately at lengths of 1, 4, 10, 20, or 30-meters, allowing the unit to fit exact application or project needs. Cables 4-meters and longer include a cable management kit, making the use of long cables easy and convenient.

The Pro30 has an industry leading 3-year meter warranty and 2-year cable and sensor warranty, ensuring a lasting and useful life. ■



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Back to School

Robotic Fish Make a Splash

By Kelly Blumenschein

contaminants through both the food chain and aquatic environment. They're also mobile, and can give insight into the extent of a spill and how wide-ranging its effects might be.

Tan hopes that the robotic fish will "dynamically and adaptively collect information as a mobile wireless network in water." Field tests are planned for the summer of 2012, and the team is hopeful for eventual deployment and industry-wide use.

Currently on Generation III of the robots, the team is working to optimize the fish mechanism, shape, and material to achieve the best performance.

"For environment-monitoring robotic fish, we are not modeling after specific species. Instead, we take a general fish shape that would house all electronics and other components with minimal volume; We then try to fine-tune the body/tail shape to optimize speed etc., using both simulation and experimentation," Tan said. With each revision, the team works toward a more energy-efficient, agile, and quick-moving robotic fish.

The initiative began as a student project for an educational outreach program. Shortly after arriving at MSU seven years ago, Tan taught a class in which one of the College of Engineering staff members, Drew Kim, enrolled. For the class project, Tan and Kim decided to develop an interesting robot to be used for community involvement and education to excite K-12 students about science and engineering.

A tadpole with an artificial muscle tail was the first prototype developed. Tan describes the initial version as "an Easter egg with a wiggling tail... at that time, we were not thinking seriously about water quality yet."

After recognizing the project's potential, Tan set to work on creating the next version.

To build the fish, advanced fabrication techniques such as 3D printing are used to create and assemble the parts. GPS units, 3D compasses and water quality monitoring sensors are installed on the robo-fish. This is a lot of equipment for such a small prototype, as surface-swimmers are between 20-30 cm in length; diving fish, currently under development, may reach 50-60 cm in length.

Using mathematical models and control theory, the team is developing prototypes that will be able to mimic the movements of a network, or school of fish. Eventually, the robo-fish should be able to sense the distance, movement, and wakes of surrounding robotic fish and make a decision about which direction to swim.

As successful as the project has been so far, Tan and his team are now running up against a considerable hurdle: the size and cost of current sensors.

"If I look at the cost, I have a robotic fish that may cost a couple thousand dollars, and a single water-quality sensor may cost more than that," Tan said. "The sensors are also very large - no serious and sufficient effort has been put into miniaturizing these sensors, making them smaller, and cheaper."

Such sensors would allow Tan and his team to create and research many more robotic fish, eventually making the robotic fish themselves cheaper and more easily accessible, he said.

Tan compares the dilemma to what came first, the chicken, or the egg? His hope is that manufacturers in the industry will notice the trend of smaller robotic devices: researchers and professionals are looking for smaller, cheaper, more cost effective sensors that facilitate wider use of monitoring technology. Regardless, Tan's team will continue to move forward. "Until then, we will continue to buy whatever is available," Tan said. ■



Photo courtesy Xiaobo Tan

Dr. Xiaobo Tan holds a robotic monitoring fish.

About MSU College of Engineering

Dr. Tan is the Director of MSU's Smart Microsystems Laboratory where the robotic fish are being developed. Established in Fall 2004, the mission of SML is to enable smarter, smaller, integrated systems by merging advanced modeling, control and design methodologies with novel materials and fabrication processes. Along with robotic fish, research in SML is focused on electroactive polymer sensors and actuators, modeling and control of smart materials, bio- and micro-manipulation and adaptive autonomous cyber-physical systems.

Drew Kim is now the Assistant to the Dean on Recruitment, Scholarship, and K-12 Outreach for the College of Engineering. Tan and Kim have developed very close collaboration on K-12 outreach with the help of an NSF-supported Research Experiences for Teachers (RET) Site program, where Tan is the Principal Investigator (PI) and Kim is a co-PI and project manager.

This RET Site program aims to establish a strong partnership between MSU, the NSF Engineering Research Center (ERC) for Wireless Integrated MicroSystems (WIMS), school districts, and industry on advancing pre-college science and engineering education.

During the 2010 Gulf oil spill, machines were used under water to cut pipes and prepare them for repairs that would eventually stem the flow of oil. Robots succeeded where it was too difficult or dangerous for human workers to go. Innovative research aims to extend robot aid to another area where humans aren't well-suited to be - swimming with the fishes.

Alongside a team of researchers and students, Dr. Xiaobo Tan, an associate professor in the Department of Electrical and Computer Engineering at Michigan State University, is developing robotic fish that will eventually monitor water quality in real-time. Tan's research could be the next step in preventing, monitoring and/or restoring issues such as algal blooms, toxic contaminants and oil spills. Fish and other aquatic species have long been indicators of the health of a waterway at large (See also our profile of a bi-valve monitoring system on page 27). They accumulate

Breaking the Sonde Barrier

The YSI EXO represents the next generation of water quality instruments from YSI. The advanced sonde platform offers a wide range of capabilities to those dedicated to monitoring natural aquatic environments such as oceans, estuaries, rivers, lakes, and groundwater. With a highly efficient power management platform, robust construction, and chemistry-free anti-fouling system, EXO allows accurate data collection for up to 90 days between service intervals.

Users can choose the new EXO1 sonde with four sensor ports or the new EXO2 sonde with six sensor ports and a central anti-fouling wiper. Sensor parameters include temperature, conductivity, depth, dissolved oxygen, pH, ORP, total algae (phycocyanin and chlorophyll), turbidity, and fluorescent dissolved organic matter (fDOM). The sonde can also output 4 calculated parameters including salinity, specific conductance, total dissolved solids (TDS) and total suspended solids (TSS).

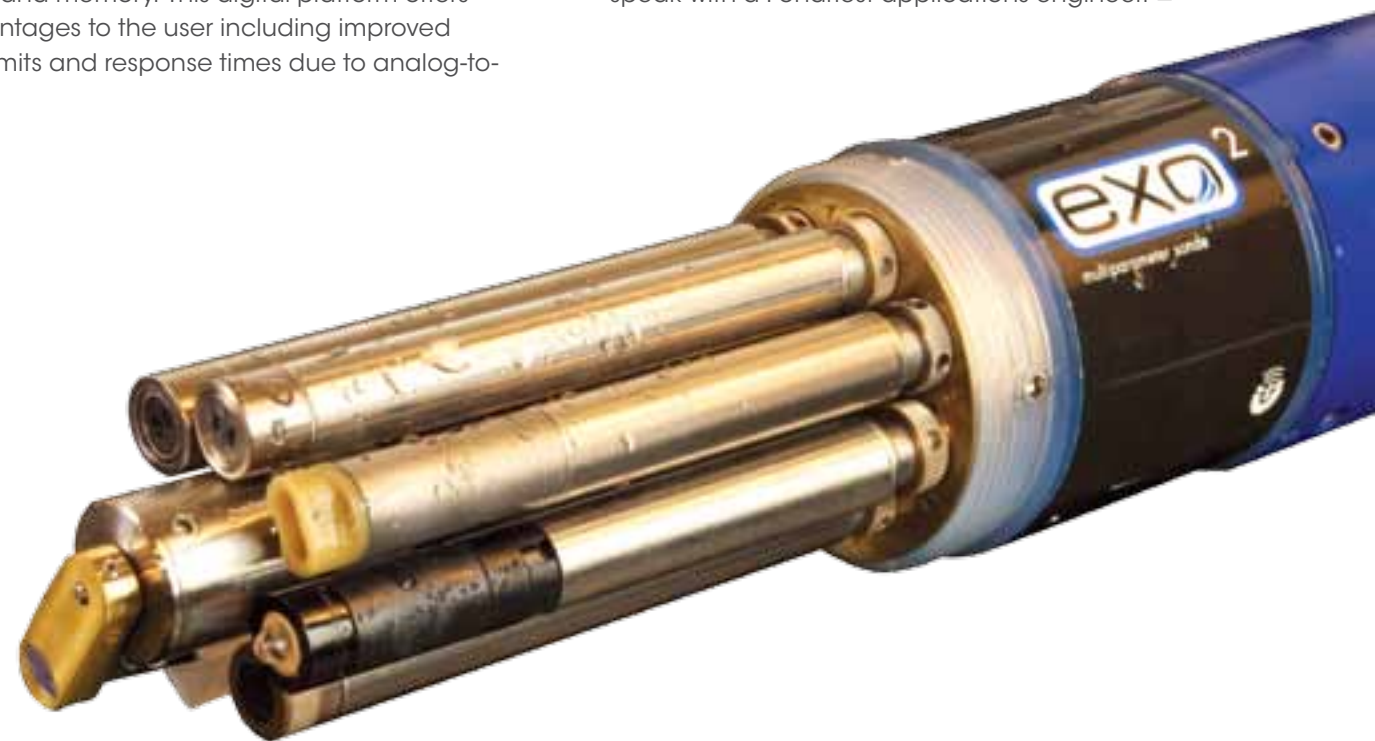
All EXO sensors are digital sensors with on-board signal processing and memory. This digital platform offers many advantages to the user including improved detection limits and response times due to analog-to-

digital electronics contained close to sensing element. This results in cleaner signals, reduced interference, and faster signal processing.

Built-in sensor diagnostic and calibration data allows users to calibrate multiple sensors in one sonde and distribute to various other sondes in the field. Wet-mateable connectors allow for swaps in wet conditions, while active port monitoring automatically detects each sensor and verifies operation. The sonde also scans for configuration errors and monitors memory status to help ensure successful deployments.

EXO uses copper-alloy parts and anti-fouling wipers to prolong deployments and improve data accuracy. The patented reinforced structure, welded titanium tubes, improved power management, and stable sensor performance allows the user to gather highly accurate water quality data for longer periods of time with fewer interruptions.

Learn more at Fondriest.com or call 888.426.2151 to speak with a Fondriest applications engineer. ■



Q&A Joel ALLEN

Q Why would you use bivalves to measure water quality?

A The approach we're advocating is to use a sentinel that is actually in the water of interest to continuously provide feedback on water quality. The advantage of the bivalves is that they don't move very much, they're sedentary for the most part, they're very robust, and the measurement is fairly straightforward.

Q How exactly do you use bivalves (clams, mussels, etc.) to measure water quality?

A We adopted and further developed methodology to monitor bivalve gape movements. The gape is the distance the two shells of a bivalve are open. We measure how far the open the bivalve is in a time-relevant way. Primarily they'll respond to irritants to the gills.

Bivalves are obligate filter feeders, bringing water and its constituents in through their incurrent siphon. They filter out food particles and bathe their gills in that fresh water and they excrete waste and used water out through their excurrent siphon. You've got multiple routes of exposure.

We measure responses to chemicals added to the water - we expose them to different compounds in the lab. They can also respond to more transient changes - changes in light intensity, temperature, conductivity.

Q How quickly do the bivalves react to the contaminants in the lab?

A When you introduce a contaminant, it will take a period of time for the concentration to equilibrate in the laboratory exposure vessel. We tried to make the 95% percent replacement rate about an hour - we want it to take an hour to get to the desired concentration rate

We can see responses on the order of 15-20 minutes post contaminant introduction, depending on the final contaminant concentration. We're looking at a group response. A certain portion of the individuals will be closed at any time. When the bivalves are responding to a common stimulus, the average gape value will go to zero as will the variability between individuals.

Q Are there any in-stream installations that you're working on outside of the lab?

A We're working with a group in the upper Mississippi River. We've got several sites up there where we've been using bivalves. Usually they're co-located with an infrastructure - a drinking water or power plant intake. That's for ease of use. Drinking water intakes/producers are an important stakeholder because they don't want to be drawing contaminated water into their systems.

The chamber receives water directly off the drinking water intake or a second pump that's co-located with the water intake. You're pumping water from the river into the chamber, and you've also got a YSI measurement and S-Can UV spectrometer. We use the NexSens iChart software to transmit the data back to the laboratory. ■



H. Joel Allen, PhD
EPA Office of Research and Development
National Risk Management Research Laboratory

Latest Research:

Allen's work has dealt with online toxicity monitors using biosentinels, specifically using bivalve organisms (clams, mussels, other mollusks) to monitor water quality. When water quality changes, bivalves can isolate themselves from their environment by closing their shells. Laboratory exposures provide an indication of the sensitivity of this approach. We spoke with Allen about the research and its applications. Some of his responses have been paraphrased to meet space limitations.

Background:

Joel Allen, PhD has been working with the EPA since 2002, when he joined as a post-doctoral fellow. An aquatic toxicologist, his interest in online toxicity monitors began in graduate school when a professor ran a project looking at bivalve responses to water quality.

Share Your Project

Many of our features come directly from our customers - their ideas, projects, needs, and solutions. If you have a project you're proud of, or new research we should know about, get in touch with us! We're always on the lookout for new ideas, like the following:

- Q&A profiles of industry leaders
- Technology questions
- Customer applications of monitoring equipment
- Projects that break new ground in research or other issues
- Customers located outside the Great Lake states
- Installations dealing with issues less-frequently covered, such as bridge scouring
- Anything that you'd like to see written about

Don't hesitate to contact us with questions, suggestions or other thoughts. We write the *Environmental Monitor* to inform and entertain our readers, and we couldn't do it without your input.

Please email customercare@fondriest.com or call 888.426.2151 for more information.



FONDRIEST R · E · N · T · A · L

when your
research
demands
quality data

While it often makes sense to purchase systems outright, many short-term monitoring projects make it cost-prohibitive. Fondriest offers many real-time monitoring systems with weekly and monthly rental rates to meet project requirements.

Fondriest offers an extensive range of competitively-priced instruments for rent. Leasing on equipment for water quality testing, soil sampling, weather monitoring, and much more is available. Fondriest's rental equipment includes the latest monitoring technology, along with the field supplies needed to get the job done.



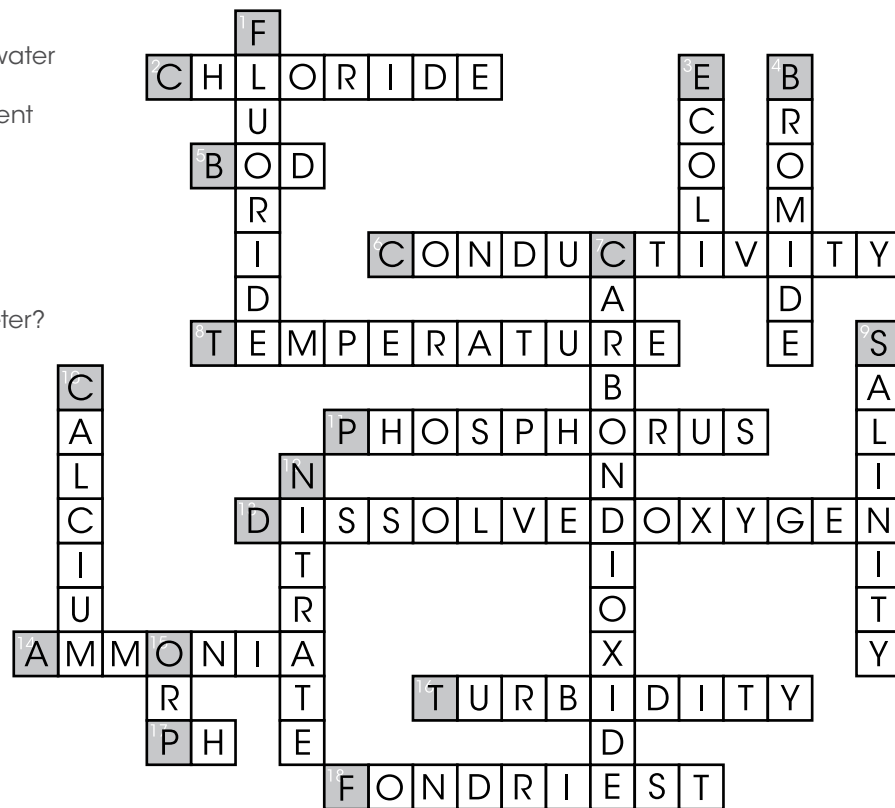
Water Quality Parameters

Across

2. Salt component naturally occurring in water
5. A five day test
6. Water's ability to pass an electrical current
8. Signals migration and reproduction
11. Nutrient for algae
13. Required for fish to breathe
14. More toxic at high pH and temperature
16. Affects water clarity
17. Acidity or alkalinity
18. Where should you buy your next DO meter?

Down

1. Often added to drinking water
3. Fecal coliform bacteria that comes from human/animal waste
4. High levels of this in hydraulic fracturing wastewater
7. Used by plant/algae for photosynthesis
9. Proportional to conductivity
10. Water hardness is affected by this mineral
12. EPA maximum contaminant level is 10mg/l
15. Measure of oxidizing/reducing potential



Visit fondriest.com/news to find the answers!

The Fondriest Preferred Rental Program simplifies and expedites the process of environmental monitoring equipment rental, offering the following benefits:

- Schedule your rental by phone or email. We'll assign an account manager to ensure you get personalized service and your equipment needs are handled professionally and quickly.
- Reserve equipment up to 30 days in advance with a signed rental agreement and credit card or purchase order; we'll hold it until your project begins.
- Shipping costs can be added to the quoted rental price, or we can ship using UPS, FedEx, or DHL shipping accounts.
- We offer flexible time frames to meet your project requirements. If you need to extend the lease, simply call or email your rental account manager.
- You won't have to tell us your rental preferences every time you reserve equipment. We keep a detailed record of your rental history.
- We keep your project shipping address and contact information on file, thus simplifying your order process.

This personalized approach to the rental business lets you focus on the project at hand — we take care of the rest. Contact us at 888-426-2151 to learn more about how we can assist with your next monitoring project.



fondriest.com/rental

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*Florida Gulf Coast University
Wireless Wetland Monitoring
Li Zhang, PhD.*

