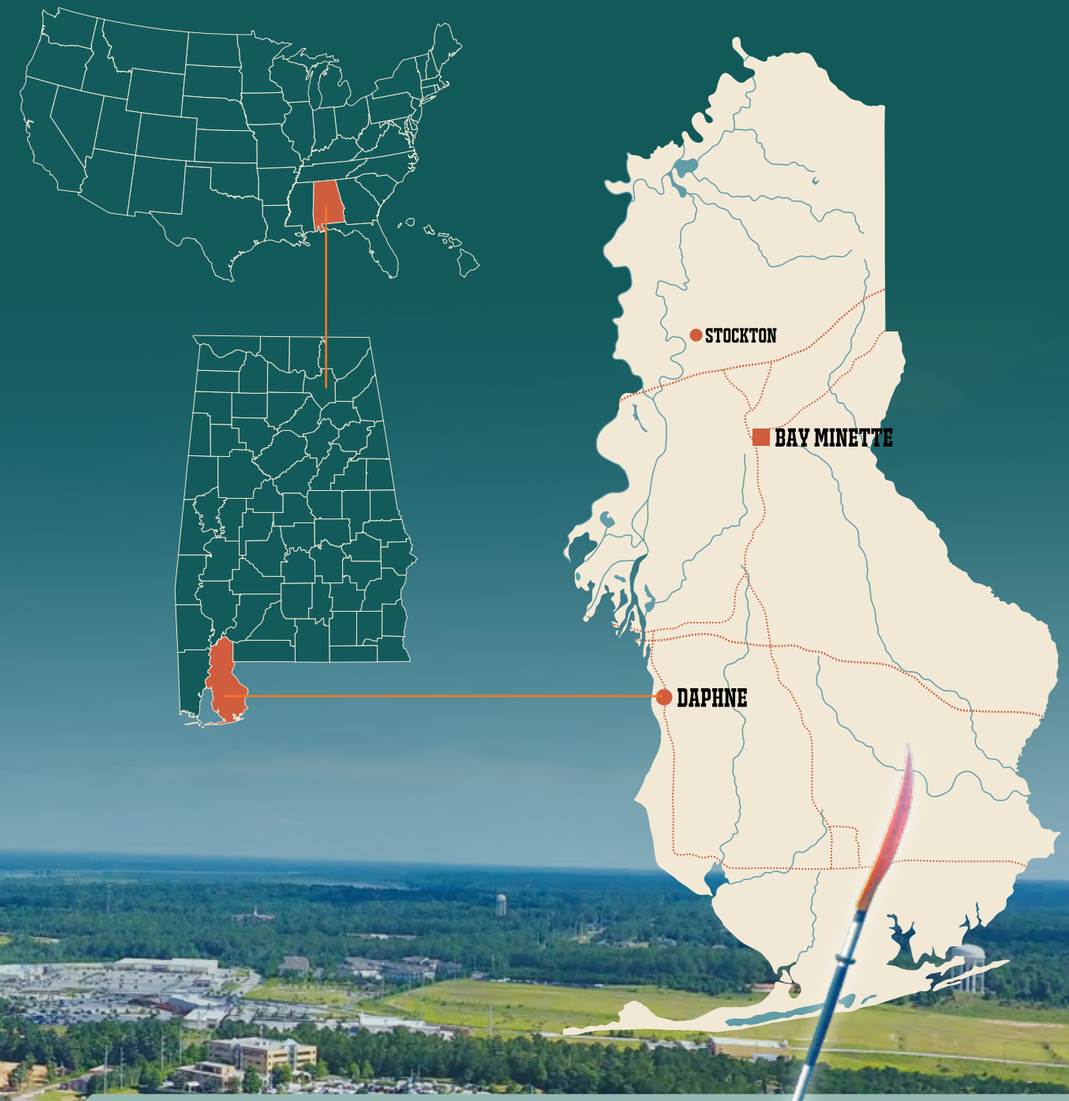
CLEVER KAYAK RIG NAVIGATES TRICKY BATHYMETRY CHALLENGE

STEVE WERBLOW

It was a small lake, but a big challenge. Covering about 43 acres (17 ha), the lake is at the center of the Lake Forest subdivision in Daphne, Alabama and is completely surrounded by private property. Bret Webb, associate professor of Civil, Coastal and Environmental Engineering at the University of South Alabama, was starting a month-long study of sedimentation in the lake to help authorities evaluate flood storage capacity and potential restoration activities, but he was having trouble reaching the water. There was no public boat access, and thick vegetation prevented surveying elevations above the water level.



The lake created for the Lake Forest subdivision is completely surrounded by private property, making access difficult for surveyors.
Photo: Dr. Bret Webb

THE JAGYAK

Bret Webb of the University of South Alabama is a master at cobbling together clever solutions in challenging situations. When he realized he couldn't launch his instrument-laden JagSki watercraft at Lake Forest, he rigged a bathymetry-surveying kayak—the JagYak.

JagSki Challenge

When his team had completed what it could accomplish on foot, it was time for Webb to launch his JagSki, a Kawasaki Ultra LX personal watercraft outfitted with a **SonTek HydroSurveyor/RiverSurveyor-M9 Acoustic Doppler Profiler (ADP)** and **YSI Portable SeaKeeper multiparameter sampling system**. With a top speed of 40 knots and the ability to run in just a few inches of water, Webb figured the maneuverable JagSki would make quick work of mapping the lake bed.

Getting the JagSki into the lake ended up being a bigger challenge than expected. Webb attempted backing down a footpath to the lake, but the path's angle was too steep, and Webb ended up cramming the impeller and water intake full of mud and vegetation, disabling the JagSki. Recovering the craft from the lake, he also damaged his trailer and hitch. Webb realized he needed a more nimble approach.

Resourceful

Like the hero of the television series *MacGyver*, Webb is a master of cobbling together clever fixes with the tools close at hand. Instead of working with paper clips and chewing gum, Webb specializes in PVC and electronics. After all, he had already built a JagSki. He just needed to find a suitably lighter platform.

Inspired by literature he had read about kayak-based surveying, Webb committed part of his grant money to purchasing a kayak. Then he went to a home improvement store to stock up on parts to mount the M9 to the hull. He dubbed his creation the JagYak in honor of University of South Alabama's mascot, the Jaguars. The concept was simple, he says, but confesses that making the first cut was tough.

"You go to the store not anticipating spending $600 on a kayak, then the first thing you do when you go home is cut a 5-inch hole in the bottom. There's a little trepidation there," Webb laughs.

After cutting a length of 5-inch (12.7-cm) PVC pipe to act as a sleeve for the M9, Webb fashioned a collar that could fasten on either side of the kayak's hull to create a waterproof seal around the instrument. Originally, he also constructed a waterproof enclosure for his laptop in hopes that he could reference the M9's HydroSurveyor software as he paddled, but the computer kept overheating during testing.

"It's probably not smart to take a computer on a kayak anyhow, so this was likely a blessing in disguise," Webb concluded.

Onboard Capabilities

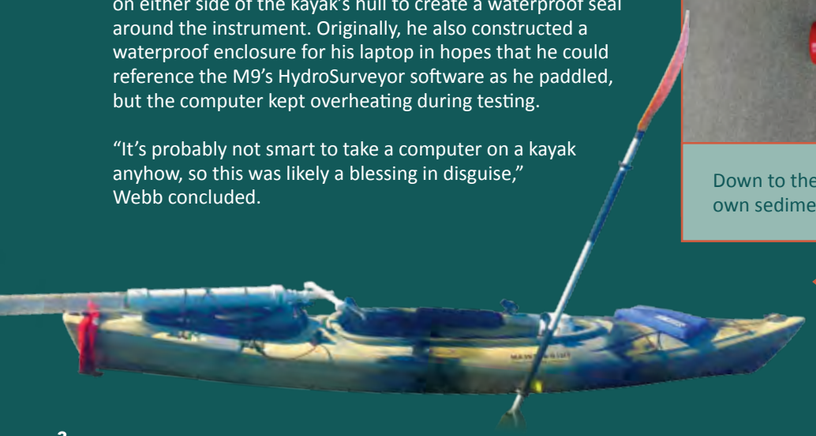
Instead of running the system through his laptop on the water, Webb utilized the dual-function capability of the M9, switching from its HydroSurveyor mode—which would have enabled him to navigate with a display of his line plan on his laptop screen and view his measurements in real-time—to its RiverSurveyor function. The switch allowed instrument-based datalogging of depth and velocity readings that Webb processed afterwards on his laptop, which was left safely in his truck during his survey forays to the lake.

Isaac Jones, product manager at SonTek, notes that the M9 offers users the choice between RiverSurveyor or HydroSurveyor mode.

"RiverSurveyor and HydroSurveyor modes are different firmware packages for the M9 hardware, allowing users to optimize the system for their needs," Jones explains. "RiverSurveyor firmware optimizes the M9 to emphasize velocity measurements and calculate discharge."

HydroSurveyor mode is optimized for depth measurement, with less emphasis on velocity, and displays real-time and historical data on a map. That makes HydroSurveyor mode better suited for bathymetry. Users specify the package they want when they purchase an M9, and can unlock the other mode if their needs change—for instance, if they need to switch from river measurements to lake bathymetry surveys.

Down to the bottom of his budget, Bret Webb built his own sediment sampler from PVC plumbing parts.



Webb's JagYak offered mobility, shallow-water access, and a highly maneuverable platform for his SonTek M9 acoustic Doppler profiler and home-made sediment sampler. Photos: Dr. Bret Webb

Counting Strokes

Counting his paddle strokes and navigating by compass and transect plan printouts, Webb was still able to follow his survey plan. And because the water level in the lake was constant, vertical data from absolute RTK (Real Time Kinematic satellite navigation) were not necessary, he notes. He just surveyed the water level into NAVD88 and corrected the measured depths to accurate labeled elevations.

The M9 uses five of its nine acoustic beams at a time—selecting the optimum frequency for sampling conditions at the moment—to measure five discrete depths in a 50-degree swath. The ADP is equipped with an integrated GPS, so each data point is geolocated.

In all, between wading measurements and data from the JagYak, Webb's bathymetric survey included position and elevation measurements for more than 12,000 discrete locations.

Webb supported his M9 data with readings from a CastAway-CTD, a palm-sized instrument from SonTek that provides vital data for correcting sound-speed variations in depth and velocity readings—a vital step in ensuring accurate depth measurements. Lowering the CastAway and reeling it back up at a steady rate provides geolocated conductivity, temperature and depth readings for the water column.

"Even though there were no salinity changes in the reservoir, there were certainly temperature differences, and even some conductivity differences, that could affect the speed value," Webb points out. "There were a couple of deep spots right in front of the dam where there was a fairly substantial change in temperature [with depth] in those holes."

"I would never collect data without using a CTD profiler," he adds. "And since I was on a kayak, the CastAway CTD was ideal due to its size and built-in GPS."

The PVC sleeve contains a SonTek M9, used to survey the lake bottom; the orange SonTek CastAway provided quick conductivity, temperature and depth data for correcting sound-speed variations.

Stretching the Boundaries

Bret Webb built the ideal sampling platform to map shoals and pools in Daphne, Alabama's Lake Forest—mounting a 9-beam HydroSurveyor/RiverSurveyor-M9 Acoustic Doppler Profiler on an ocean kayak. But before his JagYak touched the water, he had to tackle another challenge with a computer rather than pipe adhesive.

"We needed to determine the volume of sediment that had accumulated since the time of construction," he explains. "To do that required a comparison of two surveys: pre-construction and present-day."

"The only pre-construction survey we had was from 1958, and while of very good quality, it did not have any coordinate reference or stated vertical datum," Webb notes.

"Furthermore, the survey contained no recognizable features or landmarks that could be used for geo-referencing, because the entire area has changed substantially due to development since 1958!"

"We had to get very creative," he says.

Ultimately, Webb and his team found a U.S. Geological Survey (USGS) quadrangle map from about the same year as the pre-construction survey, and stretched and scaled the 1958 survey over the map until the 20-foot contours of both charts were in perfect alignment. Webb could then geo-reference the 1958 survey using known coordinates from the USGS quadrangle.

In all, Webb and his team manually digitized more than 800 elevations from the 1958 survey. That set the stage for a 12,000-point survey of Lake Forest and a new understanding of sedimentation in the system.

Massive Buildup

Webb's study of the lake bottom indicated that more than 313,000 cubic yards of sediment have collected in Lake Forest since 1958, an accumulation of approximately 16,200 tons per year. Depth has been reduced by 5 to 10 feet in most of the lake, and pool volume has been reduced by 55 percent since development began—from 356 acre-feet in 1958 to less than 197 acre-feet in 2016.

The lake has experienced significant sediment buildup on more than 78 percent of its area; shoals of five feet or more have built up on more than 19 acres of the lake bottom. At the same time, significant erosion has occurred in front of the dam, leaving deep pools that are susceptible to low dissolved oxygen levels. If that hypoxic water is drawn to the upper levels of the water column by wind or surface cooling, it could be released into the spillway and discharged into Mobile Bay, Webb notes.

Quantifying the massive buildup of sediment in Lake Forest was an important step in helping decision makers understand the lakes potential role in capturing floodwater and its expected reserve of sediment storage. Through his survey, Webb determined that the lake had enough capacity to capture sediment for the next 90 years at the rate it has been flowing since it was built. Quantifying the amount of sediment already in the lake also helped him estimate the staggering cost of dredging and sediment relocation. With Bret Webb's detailed maps in hand, decision makers will have a great tool for planning the future of Lake Forest—made possible by a scientist with a creative mind and a talent for improvisation.

The M9's HydroSurveyor mode allows users to track their survey patterns on an onscreen map in real time. Without his laptop, Webb counted his paddle strokes and navigated by compass to maintain his pattern.
Data: Dr. Bret Webb

Webb's creativity extends well beyond clever workshop projects. To chart changes in lake bottom elevations, he manipulated a 1958 survey map to exactly fit a 2016 USGS quadrangle map.
Data: Dr. Bret Webb

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Attracting Alligator Attention

Mapping Alabama's Lake Forest in a modified kayak provided University of South Alabama's Bret Webb with a detailed bathymetric survey. It also provided a few thrills.

"I have never before worked in an area with so many active alligators," Webb says. "They were very curious the entire time we were working, especially the little baby alligators. So every time I attracted the attention of a baby alligator, I was quickly looking around to find out where big momma was!"