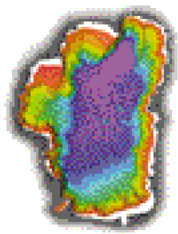
Feature Article

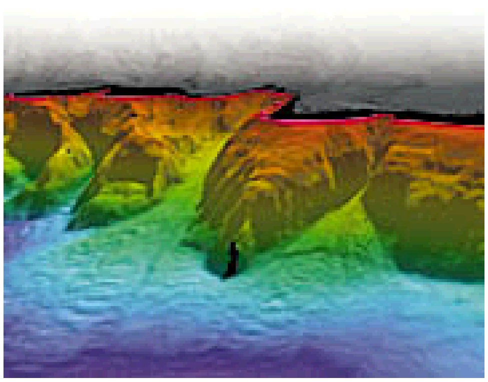
(Check out our other feature: "Across the States")



Task at Tahoe

by Beth Wierzbinski

The transparent waters of California’s Lake Tahoe shimmer in the early summer sun, as the Inland Surveyor’s silver hull cuts the surface. It’s 8 a.m. on Aug. 13, and only a few waterskiers cross the boat’s path. In a few hours, the lake’s surface will be teeming with swimmers, kayakers, skiers and pleasure boaters trying to absorb the last of the summer’s sun.



All bathymetry images and captions from Gardner, et. al 1998. USGS Open File Report 98-509. Gray scale represents land, colored represents lake bathymetry, unsurveyed areas are black.

C&C Technologies’ crew of Art Kleiner, Scott Croft and Tim Patro, of Lafayette, La., try to make the most of these early morning hours. The University of New Brunswick (UNB) in Fredericton, N.B., Canada, contracted C&C to provide accurate sounding and imagery data of the lake to the 20 m contour interval in 12 working days. UNB, in turn, is working in partnership with the U.S. Geological Survey (USGS) to deliver a promise: to supply this data to all researchers and interested parties who want it. It’s just one part of a presidential-sponsored mandate to preserve the lake.

Although the lake appears as clear as ever, its clarity has diminished to about 60' from 160', according to Secretary of the Interior Bruce Babbitt. Researchers concerned with water quality have found that sedimentation has played a role in this decline. Logging, development and tourism all want their share of the lake, but they may be taking more than the lake can share. By mapping the lake and making the data available to federal, state, tribal, local agencies and groups, and the general public, the government hopes that this collaboration can find solutions for maintaining the lake’s health—for a long, long time, since molecules deposited in the lake stay there about 700 years unless evaporated or incorporated into the sediment.

What is done now can make a difference, and the Inland Surveyor is a big part of making that happen.

The Partnership

The groundwork to bring the Louisiana vessel up to the California mountains began two years ago. The

USGS held a meeting at Lake Tahoe for researchers associated with the lake. Dr. James Gardner, a USGS marine geologist, wasn't originally supposed to be there; after all, as he will tell you, he's an ocean man through and through. But a fellow scientist in his branch who was supposed to be there couldn't go.

This map shows bathymetric contours (from Rush, 1973) available before the 1998 project. They were compiled from soundings made by U.S. Coast and Geodetic Survey in 1923.

"He asked me if I could go and talk about internal waves, when I was working on a continental margin paper," Gardner says. "It dawned on me that people didn't know what the bottom of the lake looked like. I said, 'We can do that.' Then I had lunch with Mike Shulters [acting western regional director of USGS] then the next year, the [presidential] forum happened, and it was announced as a deliverable—a bathymetry of Lake Tahoe." The definitive base map was created in 1923, performed by the U.S. Coast and Geodetic Survey with a lead weight by lowering it down into the water. This map, however, does not tell anything about the bottom of the lake, such as sedimentation processes, geological formations and cultural artifacts. At the verge of the 21st century, it was time for new methods and a new map.

The 26' Inland Surveyor on a brief break. The crew collected about a million soundings per day.

The Lake Tahoe Presidential Forum took place in July 1997, with both President Clinton and Vice President Gore attending. During the visit, President Clinton signed an executive order directing, according to the Lake Tahoe Data Clearinghouse website, "federal agencies to establish a formal interagency partnership charged with assuring coordination and efficient management of federal program projects, and activities with the Lake Tahoe Basin. The Executive Order also calls for the development of a linked natural resources database and a Geographic Information System (GIS) capability." Thus, the above-mentioned website at http://blt.wr.usgs.gov/ was established as a central source of Lake Tahoe information for everyone interested in the lake, from scientist to waterskier.
Gardner wanted to deliver on his promise, but he needed some partners. The first place Gardner looked was to his friend and colleague, Dr. Larry Mayer of the University of New Brunswick's Ocean Mapping Group. UNB is known for its hydrographic surveying program; in fact, C&C's Kleiner says a good number of their employees are UNB graduates. Gardner and UNB have a cooperative legal agreement.

"When I get involved with a USGS sea floor mapping project, I use UNB's program and I have all their expertise to fall back on," Gardner says. "This way we have a great advantage to be able to utilize their skills."

The university gets "golden data" out of it, says Mayer. "The data fulfills USGS needs, but provides data for graduate students. When USGS approaches us and says, 'We have a job to do,' we use our knowledge of state-of-the-art developments in the field to look for the most appropriate equipment and personnel for the project. In the case of Lake Tahoe, C&C Technologies had the right combination of equipment and people."

Mayer sent out letters to attain technology for the project. Once they secured their equipment, things were ready to roll.

Twelve August Days

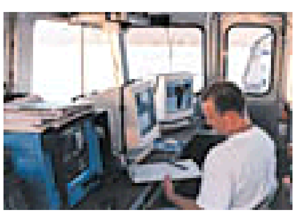
August 1998: Enter Art Kleiner and his crew. They've been around the world to survey the waters from Singapore to the Panama Canal; as Scott Croft, the systems operations manager, says, “I think I’ve spent about a year of my life on this boat.” The 26' boat, although aluminum on the outside, holds more electronics than the yachts passing by.

This Thursday morning they are mapping the area by the Truckee River. To map the bottom, C&C uses a high-resolution multibeam sonar system, the Kongsberg Simrad EM1000 High-Resolution Multibeam Mapping System (Kongsberg Simrad, Horten, Norway). As the boat travels over the water, soundings are taken and recorded. Software running on a SPARCUltra2 workstation from Sun Microsystems Inc. (Palo Alto, Calif.) displays waterfall plots of color-coded depth, sun-illuminated bathymetry, and real-time geographically referenced plots of bathymetric and backscatter coverage (Figure 2). Croft, the captain today, keeps his eye on the monitor and the colored swath as he aims for the black, unsurveyed area to the south.

The Simrad runs well in shallow and medium-depth water. The deeper the water, the wider the swath and increased number of soundings. In 150º mode, the Simrad uses multiple beams to cover an area 7.4 times the water depth, according to Kleiner. In shallow water, he says, they get about 240 soundings per second. Due to the angle of the beams, they cannot survey close to shore. “The transducer can’t hit the ground; the problem is the 150 degree beam,” Gardner explained in a meeting the day before. “We don’t want to waste time with the shallow areas; we draw the line at 20 m. For those areas, it is not the proper system; the acoustics aren’t quite right.”

However, a beam sent out on its own is not enough to get positioning data. To achieve high-accuracy readings of the lake floor, the beam’s return trip must be measured and environmental factors—such as temperature—accounted for. An Endeco Ysi model 600 conductivity/temperature sensor (YSI, Yellow Springs, Ohio), mounted at the transducer, continuously monitors temperature and corrects for refraction at the surface, according to Kleiner. The beam’s trip below the surface is measured with amplitude and phase detection.

“We have two different methods to detect the bottom,” Kleiner says. “Phase detection uses two adjacent readings, and where they cross, that’s the bottom. [Amplitude] is kind of like a flashlight—when it shines straight down it’s very good; the farther away it is the harder it is to find the center.”



Surveyor Tim Patro records the current conditions during the data collection.

Later, Mayer offers further explanation. “The Simrad decides in real time which one is the most reliable signal. Also, through the use of a CDT sensor (that measures conductivity, depth and temperature), we can calculate the sound speed profile. We need to know this because changes in sound speed with depth will affect both the travel time of the sound and thus our depth measurements, as well as cause refraction or bending of the sound waves, which will result in inaccurate depth measurements. The Simrad system uses the CDT data to correct for these factors.”

In addition, the boat itself is moving, so that could be a source of error. To account for this, the data is motion-corrected. C&C uses a motion compensator, a TSS POS-MV 320 (supplied by Survey Equipment Services, Houston, Texas) to adjust for heave, pitch, roll and yaw. The motion reference unit also acts as an inertial navigation system. GPS is used as a backup positioning system.

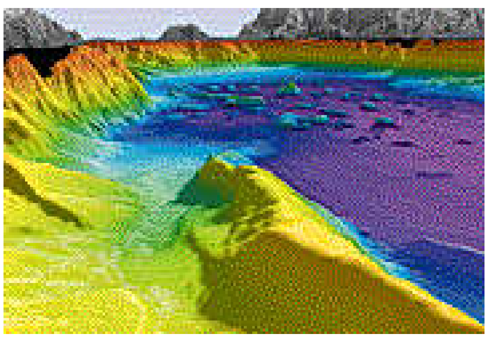
Once the beam produces a depth measurement, it also needs to be georeferenced to its surroundings for a chart to be produced. C&C takes the information that’s color-coded for depth and projects it into a local projection for their own use (data were supplied to USGS in geodetic coordinates). Project manager Kleiner chose differential GPS (DGPS) to maintain backup positioning during the mapping. The real-time differential correction data was provided by SATLOC Inc. (Tempe, Ariz.).

“The accuracy of SATLOC allows us to survey the lake without a base station,” Kleiner says. “It would have been a lot more difficult—logistics, terrain—to use a base station. Especially in the Emerald Bay area, where it is surrounded by really high mountains. We could have probably [used a base station], but I don’t think the horizontal accuracy would be all that better. Plus, we would have to put someone up in the mountains. SATLOC is effective across the nation, and the economy of the project goes way up. We don’t have to pay for the base station person. It all depends on what you’re getting out of the survey.”

C&C also uses a Trimble 4000SE (Sunnyvale, Calif.) as a backup and for quality control. “The POS and Trimble are both using the SATLOC differential corrections since the Coast Guard doesn’t reach here—it could be the mountains,” Scott adds.

Along the Way

The men from Louisiana found that alpine lake work can be tricky. For starters, the high altitude was an unfamiliar factor. “The most severe problem is the high altitude and our engine problems,” Kleiner says. “At 6,000', our engines don’t have as much horsepower. It’s made us plan our routes more accurately instead of zipping to areas. We thought we could run at 25 knots; instead, the max is 14 knots. We survey at about 7 to 8 knots.



Friday, Aug. 14, 1998. Perspective view looking south from Incline in Crystal Bay toward south Lake Tahoe.

A large “delta wedge” (light and dark blue) ~3.5km long has formed on the basin floor representing a large volume of sediment that has been funneled down this path.

“If we have to go to the other side of the lake, we survey on the way. We go slower, and we burn more fuel. Normally we can go two days between fill-ups; now it’s 1.5.” There were a few engine problems, probably to do with altitude as well, but the crew had those fixed quickly and under control.
What they didn’t have control over, though, was a more serious problem: the lake’s recreational users. The accuracy of the data depends—among other things—on straight, continuous lines. That can quickly be a challenge when waterskiers zig-zag across your path.

“Our worst problem has been in the south part of the lake and Emerald Bay,” Kleiner says. “We did it on a Tuesday morning and traffic was horrendous. We had to turn sideways and break line a couple of times. It tested our patience and our fortitude, and to see who would win. It was kind of like chicken, except it was a steel boat vs. a fiberglass boat—we win! We’re mostly concerned with swimmers, kayaks and things (waterskiers too) we can’t see, especially in the late afternoon when the sun’s in the eyes.”

Luckily, with careful driving and the extra eyes on the boat, the mapping was completed without incident.

Meanwhile, Back in the Condo

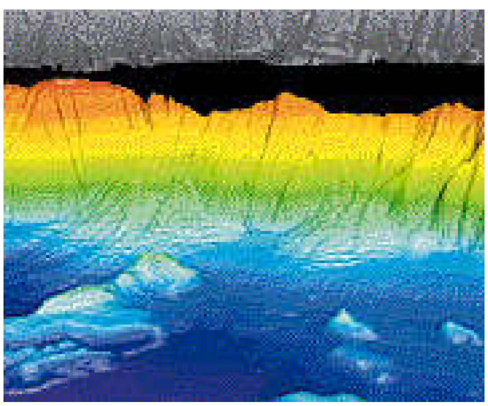
Each day, the C&C crew collected more than a million soundings, according to Kleiner. That output was stored on disks and dropped off for Jim Gardner and Larry Mayer to edit.

While Kleiner and the crew were out on the water, Gardner and Mayer worked at a nearby condo cleaning up the data from the day before. On this project, there was a remarkable turnaround. “All the data collected on day one is processed by day two,” Gardner says. “The day after, everything is finished—it’s all georeferenced. Digital data will be available to researchers for input into a GIS [currently available on the website]. The standard product for us would be an ARC/INFO export file. We did it for the scientific community who is investing the time in Lake Tahoe.” In fact, during a meeting with local researchers the day before, he asked the scientific community what areas they would like to focus on in the project's final days. One of the main areas of interest was something called backscatter, "a representation of the amount of acoustic energy, at 95 kHz, that is scattered back to the receiver from the lake floor," as explained in Gardner's formal paper on the project. Areas of backscatter can denote artifacts, such as sunken airplanes, submerged tree stumps or geological formations.

Once Gardner and Mayer got the data, they cleaned it up at the highest resolution.
"A lot of our editing philosophy came because our motivation is from the hydrographic community—we really want to see every sounding," Mayer says. "[But] When you're collecting one to two million soundings a day, there's no way to see it all. UNB Ocean Mapping Group researcher Dr. John Hughes-Clarke developed a suite of software tools that allow you to see it... you can't get away from some automatic editing. But the points are always there. If someone questions something, we can always go back and make a note." If there's only one or two returns on a point, Mayer will edit that out since it's probably an errant reading. When you're working with a million points, one return becomes statistically insignificant.

Gardner offers an explanation of each file. "There's two parts of each file: 1) depth, 2) backscatter, which is the intensity of sound that comes back. First I cleaned the navigation, then cleaned the data, then mosaiced in the backscatter. In a parallel process, I add in the depths and make a depth file. The last aspect is to put it into a low-resolution map so you can see the data. The challenge is to get all that done before Art and the crew pull in with a whole day's worth of new data."

Both men's backgrounds assist in the editing process. When looking at the data, they know what they're looking at, geologically. As a result, they can make more than an educated guess when cleaning up the data.



Saturday, Aug. 15, 1998. Perspective view looking north at Stateline Point and into Agate Bay on left and Crystal Bay on right.

The wall is marked with two relatively large failure scars. There is a small coalecsed fan at the base of the two failures that has 60 m of relief, is 1400 m wid and 650 m long.

Once the data is cleaned up, a remarkable program allows researchers to get a true 3-D experience with the data. The Fledermaus program, a product of UNB's Ocean Mapping Group and Interactive Visualization Systems of Fredericton, N.B., along with a "bat" control allows users to "fly" through the lake. It's close to virtual reality—arm movements are sensed by the controller. Researchers can pinpoint the area they want to study, and zoom in as close as possible. The image on the cover of this magazine is the primary image. From that vantage point, for example, a close zoom can be attained of the northeast section. That view shows faults, formations and displaced blocks of material rafted from the lake's west wall. The resolution is quite remarkable.

The data is now on the web in vector and raster layers, 10 m DEMs, and other formats. The standard product is an ARC/INFO export file. USGS is working with federal, local and state agencies to get their data online as well. Some data is also stored at the Menlo Park USGS offices; that data can be obtained by contacting USGS. With this data, Gardner says, lake depth, heights, gradients and positions can be calculated, and any GIS can give the user the volume from the elevations. In a paper written by Gardner, Mayer and Hughes-Clake, USGS Open-File Report 98-509 (http://blt.wr.usgs.gov/tahoe/openfile.html), this advantage is explained: "It can not be stressed too strongly that one of the great advantages of this survey is that the bathymetry is completely georeferenced with the backscatter. Consequently, each pixel on the map has a latitude, longitude, depth, and backscatter value assigned to it."

One notable result of the bathymetry was validating those early surveyors' hard work: the lake's depth, determined as 1636.7' in the August survey, wasn't too far off from the original 1646'. Not too bad for a lead weight.

And the Verdict Is...

In all, Kleiner and crew obtained more than 40 million soundings in just 12 days, despite swimmers, sun in the eyes, a vicious thunderstorm, computer fits and a visit from the media press corps. The lake gained more notoriety than its legendary serpent, Tessie, when Secretary of the Interior Bruce Babbitt descended on Aug. 12. to check progress. The day also included a meeting with local scientists, researchers and interested parties to find out what information they needed, and to give them an introduction to the project. Babbitt was shown the Fledermaus program and flew the bottom of the lake to give him a sense of the president's executive order's status. But during his visit, he emphasized one thing: this truly was a basemap for the future.

"I came out to get a sense to see what's happened in the year since the president and vice president were here last summer. I come back a year later, very encouraged to see that things are happening because of the agencies. Here we have an unique, bounded ecosystem with such an intense set of human uses.... it's a potential laboratory for answering the questions [about conservation]. It's a big task—if we can't do it here, we don't have much of a chance anywhere else—that's why it's so important. Maybe, just maybe, we're all together at the creation of something good."