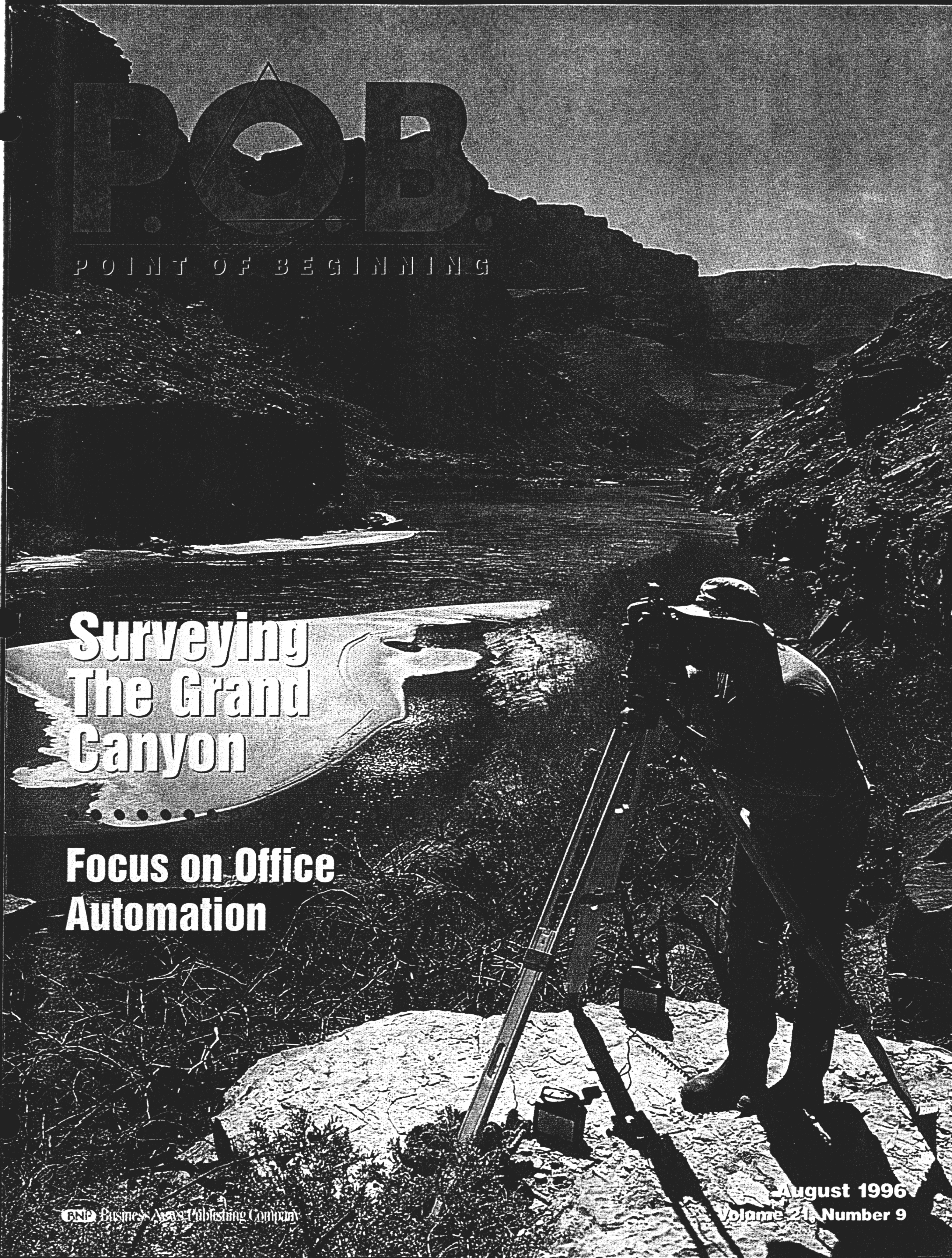
P.O.B.
POINT OF BEGINNING
Surveying The Grand Canyon
Focus on Office Automation
August 1996
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About the Cover

Surveyor Mark Gonzales of Applied Technology Associates Inc. of San Diego, Calif., completes a conventional survey of a shoreline and beach on the Colorado River before the river's first man-made flood thunders through in March 1996. The purpose of the "beach/habitat-building test flow" was to restore some of the natural processes of the pre-dam river system. Article begins on page 26.

Photo courtesy of **Denise J. Smith.**

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A Grand Experiment

Surveyors and scientists join forces to document the man-made flood of 1996.

by **Denise J. Smith**

Surveying has played an important role in the history of the development of the Grand Canyon. U.S. Army Maj. John Powell was the first to take on the task of surveying the natural wonder in 1869, and over the years surveyors have examined the Grand Canyon for many reasons, from rail line development to dam sites.

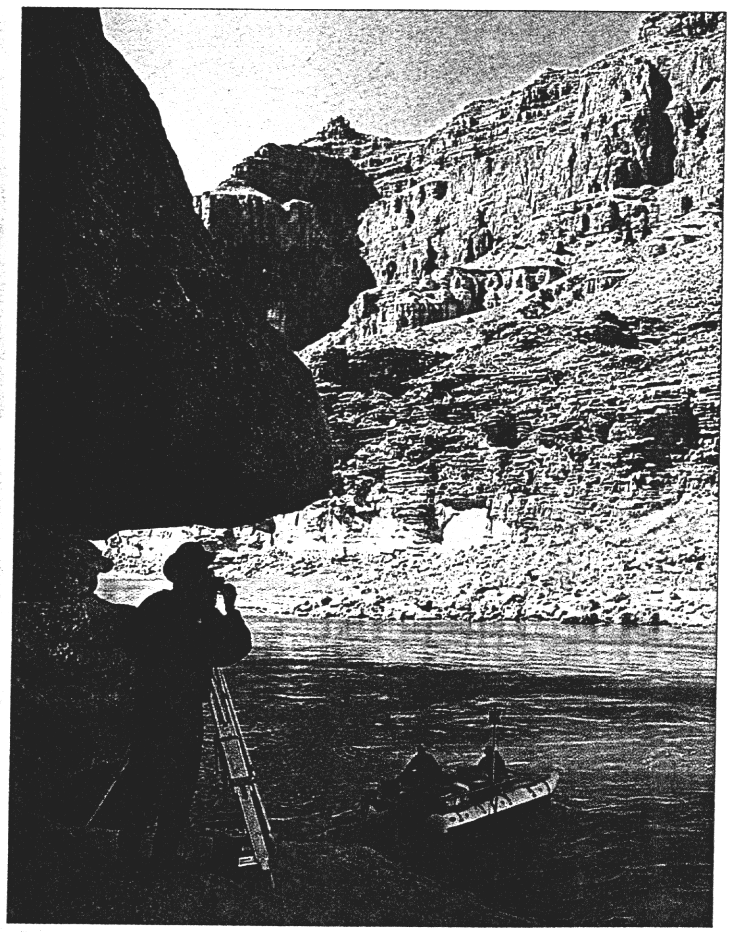
Today, much of the surveying activity has been assumed by Glen Canyon Environmental Studies (GCES), a satellite organization of the U.S. Bureau of Reclamation begun in 1982. Its purpose is to study effects of Glen Canyon Dam on the Colorado River's environmental and cultural resources in both Glen and Grand canyons. Naturally, surveying is the means best-suited to establish a baseline measurement and then continue monitoring changes in a variety of environmental factors, such as changing shoreline and habitat due to erosion and deposition from fluctuating water levels caused by the operation of Glen Canyon Dam.

Short- and long-term monitoring of ecosystem dynamics is one of the chief goals of GCES. With data collection and management, GCES is able to coordinate a management style of the river ecosystem that adapts to the many concerns and interests involved. GCES has developed a comprehensive Geographic Information System (GIS) which helps integrate physical, biological and economic data into a single management strategy.

The Problem

The Colorado River through Glen Canyon and Grand Canyon was once a sediment-rich source for a continuous cycle of sandbar erosion and deposition. Since Glen Canyon Dam was completed in 1963, however, much of the sediment supply has been cut off. Now the only significant sources of sediment are from tributaries downstream from the dam.

Pre-dam seasonal flood flows averaging 93,000 cubic feet per second (cfs) have been replaced by more seasonally constant flows of 7,000 to 18,000 cfs regulated by hydroelectric power demands at the dam. Such flows are less effective in redistributing large amounts of sand which affect wildlife habitat, endangered species like the willow fly-catcher, Kanab ambersnail and humpback chub, as well as recreational concerns like camping beaches for the 20,000-plus people that raft the Colorado River through the Grand Canyon each year.



Survey volunteer Evan Wallman tracks the hydro boat with the shore station at the Crash Canyon study area of GIS site #5.

The Man-Made Flood

GCES research indicated that occasional periodic spike flows were necessary for the river ecosystem to maintain its vitality. Scientists determined that a test flow should be conducted to check their predictions before spike flows were implemented as part of the long-term operation plan of Glen Canyon Dam.

Dubbed as a "beach/habitat-building test flow," the first man-made flood in the history of the Colorado River was scheduled for late March 1996. Its purpose was to rebuild high elevation sandbars, deposit nutrients, restore backwater channels and provide some of the dynamic natural processes of the pre-dam river system.

The event started on March 22 with four days of steady flow at 8,000 cfs. Horizons Inc. of Rapid City, S.D., took aerial photographs of the existing conditions. On March 26, the flows increased by 4,000 cfs per hour until the test flow of 45,000 cfs was established. The flow remained at 45,000 cfs for seven days, and then was down-ramped over the course of two days back to 8,000 cfs, which was maintained for four

Photos by Denise Smith

more days. Horizons repeated the aerial coverage during post-flood conditions.

Test flow monitoring was scheduled for three study areas at 45, 65 and 122 miles downstream from Lee's Ferry, a town about 10 miles downstream from Glen Canyon Dam. Each area, a pre-existing GIS site (#3, #5 and #7, respectively) established by GCES, contained three representative areas well-suited for scientific study. The study areas were chosen for their natural tendency for sand erosion and deposition.

Topographic Survey

A dual combination of terrestrial and hydrographic surveying was utilized to monitor the effects of the test flow. In pre- and post-flood conditions, beaches and shorelines were surveyed conventionally to provide baseline data for areas flooded during high flow. Those same areas were mapped hydrographically at 45,000 cfs.

At the Carbon Creek location in GIS site #5, the beach was mapped using conventional means at a pre-flood flow of 8,000 cfs. A Sokkia SET3CII total station was set up on one of 2,000 GIS network ground control points established by GCES in the last five years. With two rodmen choosing points, several hundred data sets were gathered in a TDS/HP data collector in just a few hours. The rodmen chose points along the shoreline or randomly on the beach, as well as breakline points defining the toe and crest of sharp slopes.

After the point coordinates and elevations were calculated, contours of the area were generated from a TIN model of the survey area to yield a topographic map of the beach before the high water was released. The beach contours were then tied to the hydrographic mapping of the river bottom to give a complete picture of the study area at 8,000 cfs. Once the water went up to 45,000 cfs, the study area (including newly submerged beaches) was mapped hydrographically.

All coordinate data are in the Arizona State Plane Coordinate System-Central Zone.

Hydrographic Survey

Since river flow and sediment transport are perhaps the two greatest factors in the dynamics of the ecosystem, researchers at GCES recognized the significance in being able to generate a map of the river bottom. Working with scientists and researchers from several agencies studying sediment transport in the river, the GCES team could see that developing a map, hydrographically, of the river bottom would be the best way for scientists to study how sediment shifted over time at various flow levels.

Mark Gonzales, one of four surveyors with Applied Technology Associates Inc. of San Diego, Calif., contracted to GCES, spent a great deal of time developing a hydrographic system for use on fast water while recovering from a serious knee injury sustained in a fall in the Grand Canyon. "While this particular hydrographic survey application may be unique in its ability to measure depth from a dynamic water surface, it was adapted from existing technology," Gonzales said. "It's taken three years of improvements and modifications to have our system working this well in such a harsh environment."

How It Works

The hydrographic survey system requires two stations to bring the required data together: a boat rigged with sonar to measure water depth, and a shore station to track the exact path of the boat to give each depth sounding a coordinate location. The boat, an 18' "mini-snout" made up of two rubber pontoon floats attached to an aluminum deck, is rigged with an 8' vertical boom which has a target mounted on top for tracking and a pair of disk-shaped transducers mounted on the bottom to transmit and receive the soundings. The target is made from a 10" diameter by 10" high cylinder of PVC pipe and covered with adhesive reflective foil. The boat also carries the sonar instrument and a computer to record the data. At a cost of $125,000, fully equipped, the hydro boat is the heart of the system.

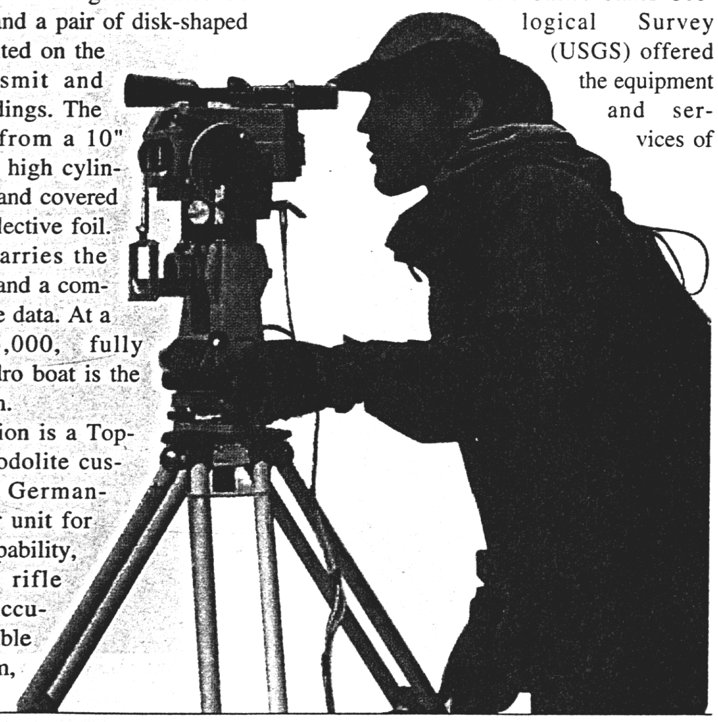
The shore station is a Topcon DT-05A theodolite customized with a German-made IBEO laser unit for better tracking capability, and a Bushnell rifle scope for more accurate and comfortable sighting. A modem, radio antenna and small computer are also part of the shore station, collecting and transmitting data to the computer on the boat.

GCES contracted the help of an electrical engineer and a master machinist to integrate the individual components into a single custom instrument. They calibrated the entire unit to track vertically and horizontally via the crosshairs in the rifle scope.

The hydro team consists of four people: an instrument person operating the sonar and computer on the hydro boat, two trackers to spell each other at the shore station and the boatman. The role of the boatman in this type of survey cannot be overemphasized. Boatman Kenneth Grua, a member of Gonzales' team at GIS site #5, is among the very best. He has been as much a part of the three-year development of the system as Gonzales himself. Grua brought with him expert knowledge of the river and the ability to maneuver a boat wherever needed.

GCES put together a hydro rig for each of the three study areas to fulfill the requirements of the test flow experiment. Using all of its backup equipment, GCES provided three hydro boats and enough hydrographic survey equipment for two of the test sites. Gonzales' colleague, John Nagy, led a crew at GIS site #3 (rivermile 45), while Gonzales headed up the team at GIS site #5 located at rivermile 65.

The United States Geological Survey (USGS) offered the equipment and services of



the hydrographic crew from the Western Marine and Coastal Survey office in Menlo Park, Calif., to complete the work at the third location, GIS site #7 at rivermile 122. Tom Reiss and Kristin Brown used a Geodimeter 464 to track the target on the hydro boat provided by GCES. Will Lawler, of Lawler and Co. of Mobile, Ala., assisted with software operations.

At each designated hydro site, the shore station was unloaded and set up. In the case of this test flow experiment, the location of the shore station had to be selected at a point high enough to be used during the high-flow period, which raised the river level by up to 14'. A back sight was also set up at each hydro site. Enough tripods were brought along to leave two at each site for the duration of the experiment just to cut down on setup time.

Putting It All Together

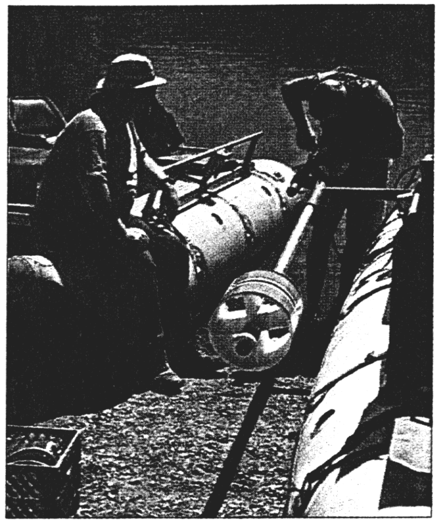
Getting hydrographic data on three study areas in each GIS site required an all-out team effort from daybreak until nightfall. Every task took time, including negotiating the river and small rapids in the upstream direction to return to each area for the daily survey session.

Once at the hydro site, the shore station was set up and backsighted, and work began in earnest. The shore station tracked the hydro boat through a grid pattern to get coverage of the area. Grid coverage of the site, comprised of lines spaced 5 to 10 meters apart and running parallel and perpendicular to the flow of the river, had been defined in advance.

Gonzales created a series of line files for the grid coverage based on the coordinates of the area. Those grid lines were linked to an indicator showing the boatman how far left or right of the line the boat was located. With this feedback, the boatman could guide the boat steadily along each line of the pattern.

While the hydro boat followed the grid pattern, the shore station tracked the target on the boat, using the laser to gather distance measurements at the rate of 20 points per second. All of the data was collected in a tiny computer—a DOS-based processor with no screen or keyboard—connected to the shore station. The computer paired the distance and angle collected at the same point in time and sent the synchronized data string to a modem, which in turn transmitted the data via radio signal to the computer on the boat.

The raw data sent to the boat was pro-



Surveyor Mark Gonzales and survey volunteer Evan Wallman rig the hydro boat with a collapsible boom which flips up 90° to put the tracking target above the boat and the sonar transducers below water level.

cessed by the on-board computer using HYPACK software from Coastal Oceanographics of Durham, Conn. It converted the data to x, y coordinates on the river bottom and matched them to the appropriate depths gathered from the sonar.

"The data collected by the shore station is used two ways," Gonzales said. "First of all, it allows us to utilize real-time navigation which tells us the boat's in exact position. Secondly, it accurately positions the depths read by the sonar."

A latency calibration was performed before the test flow began, which synchronized the four-point-per-second rate of raw data from the shore station to the 20 pings per second generated by the depth sounder.

Because the boat needed depth readings for navigational purposes, the data files will be processed at a later date—again using HYPACK—to produce actual x, y, z coordinates by converting water depths to elevations.

As necessary, the hydrographic data can be combined with conventional shoreline data to produce TIN models of the study area, from which contour maps and sediment volumes can be generated.

Logistics

Collecting data on the river at 45,000 cfs presented one of the greatest working challenges of the entire experiment. The high flow made running the river, especially upstream, dangerous and sometimes impossible.

One hydro site was completely inaccessible for two days at high flow because a whirlpool filled with floating debris blocked the boatman's only access route to the site. The scientists and surveyors agreed, though, that they needed to collect at least some data from the site, so they mapped with the hydro boat on the outer edges of the whirlpool.

Perhaps the greatest challenge, though, was keeping all of the boat's instruments, computers and power supply (a 350-watt generator and marine batteries) functional in the river environment, where water and sand find ways into the tiniest cracks and connections with unnerving regularity.

On the first day of high flow, Gonzales' hydro boat took a wave of water that shut down its entire on-board computer and sonar. A few hours of drying and re-rigging with back-up equipment had the boat back on the river collecting data, and the crew better prepared to ward off the next splash.

Surveying Aids Research

The proliferation of dam construction during the middle years of this century has led to the greater prominence of sediment transport research, and surveying has increased the amount of information available to researchers in this field. In the Colorado River system, a great deal of work is being done by researchers from USGS and Utah State University.

One of the researchers, Ned Andrews with the USGS office in Boulder, Colo., said, "When the flow of the river is doubled, the amount of sediment it carries increases by nine-fold. At 45,000 cfs, the river is moving three-quarters of a ton of sand per second [past a given point at rivermile 65]."

Andrews said his and other researchers' main point of interest is the act of sand being scoured from the bottom of the channel then deposited by eddy currents onto the beaches. "As an observation tool, the survey capability of GCES is outstanding," he said. "We can see exactly how the sediment load has been rearranged." For example, the large sandbar at Carbon Creek increased in depth by an additional 12' of sand, most of that in the first 48 hours of the test flow.

The data gathered by GCES allows a real-life model to be studied closely. The knowledge gained will help scientists perfect numerical models to predict the results of similar events more accurately. ▲