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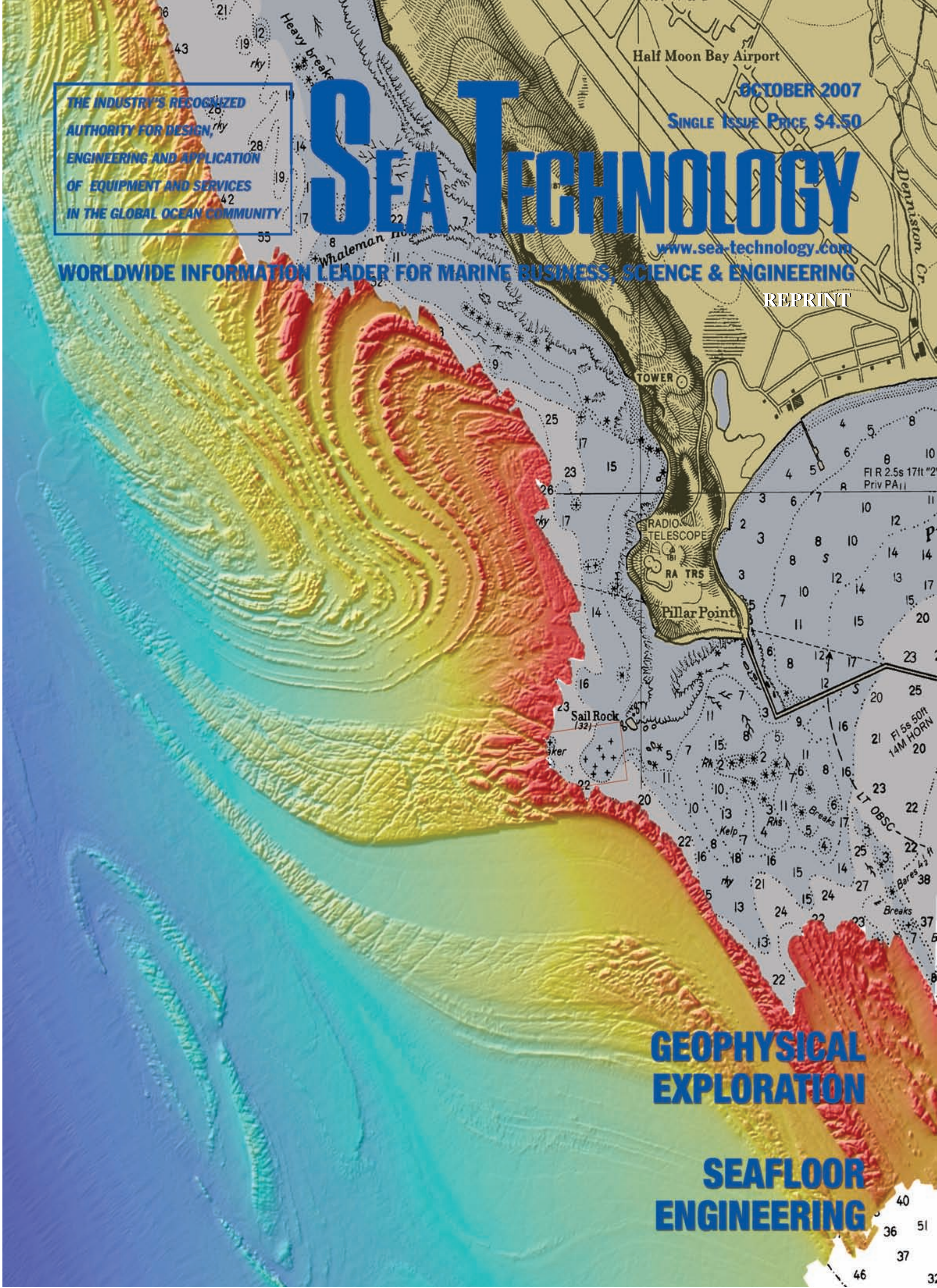

GEOPHYSICAL EXPLORATION

SEAFLOOR ENGINEERING

Acoustic Doppler Velocimeters Offer Clues to Wave Behavior

Steve Elgar and Britt Raubenheimer Use ADVs for New Insight On Deflection and Diffraction Caused by Complex Bathymetry

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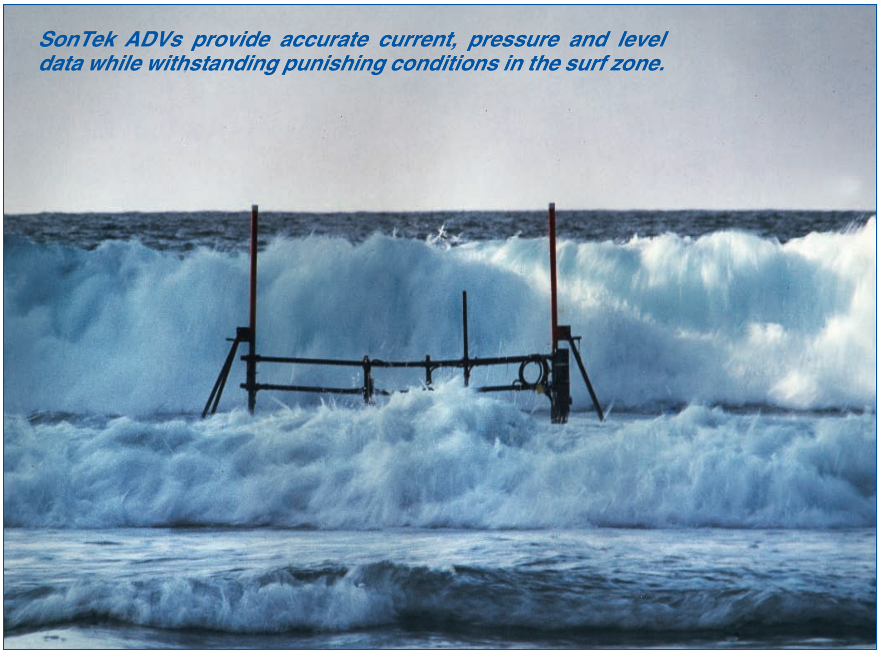
SonTek ADVs provide accurate current, pressure and level data while withstanding punishing conditions in the surf zone.

Much of the current understanding of waves and nearshore circulation is based on studies conducted on long, straight beaches. But add in complex bathymetric features like undersea canyons, and wave action becomes “like a house of mirrors at an amusement park—bent, twisted, contorted,” said Steve Elgar of the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Massachusetts.

For a harbormaster, park director, development official or naval battle planner along a canyon-furrowed coastline, sorting out those contortions in local waves and currents is vital. Understanding cross-shore and alongshore currents, wave action and sediment transport in the nearshore environment can have tremendous economic impacts and could be a matter of life and death.

Waves dragging along the edges of the canyon slow down and refract, Elgar explained, while waves traveling over the depths of the canyon maintain their speed and keep a straighter course. Long, low-frequency infragravity waves may be reflected by the shoreline and canyon walls, bouncing back out to sea or getting trapped in pockets near the beach. The results of this reflection and refraction can push, pull and redirect water in unexpected ways.

“One of our grad students, Jim Thomson, made the analogy that canyons can act like the windshield of a car,” noted Britt Raubenheimer of WHOI, Elgar’s wife and long-time co-researcher. “On a bright, sunny day, you can partially see your reflection in the windshield and partially see through. Some waves go deep into the canyon, and some propagate across the canyon and go on their merry way. If you want to understand and predict the waves, you have to understand that.”

Added Elgar, “If you account for reflection and refraction and you’ve got a steep area, your model is a lot more accurate—like a factor of 10.”

Nearshore Canyon Experiment

To understand the blend of reflection and refraction, Elgar and Raubenheimer joined researchers from nearly a dozen other institutions to study waves influenced by some of North America’s most dramatic offshore canyons—the Scripps and La Jolla canyons, which reach to within meters of the beach north of San Diego, California.

Along the canyon-influenced shoreline, surfers tackle three-meter monster waves just a mile from a kiddie beach. Complex rip currents create dynamic systems of jets and eddies. And sand mysteriously accretes or washes away.

The Nearshore Canyon Experiment (NCEX) was funded by the U.S. Navy’s Office of Naval Research and the National Science Foundation to test an array of wave monitoring technology—from pressure meters to radar antennae to balloon-mounted video cameras—and develop a comprehensive model covering waves, circulation and sediment transport.

Elgar and Raubenheimer conducted several experiments and provided data

Elgar and Raubenheimer deployed seven SonTek ADVs in a Navy study of the behavior of waves and sand in mine-studded landing zones.

(Right) Huge tripods position ADVs at precise heights in the swash zone above San Diego, California, in Britt Raubenheimer's study of current and sediment movement.

to other NCEX researchers to ground-truth remote observations and models.

Growing Understanding of Setup

The Elgar and Raubenheimer team observed that wave setup—uplift of areas of the sea surface, a vast "pile" of moving seawater—was creating significant cross-shore and alongshore currents.

Raubenheimer and grad student Alex Apotsos charted the dynamics of setup and the currents it created. They measured the momentum of the waves directed toward shore, the increase in sea level when the waves break and the corresponding currents in the surf zone—including undertow and rip currents—which turned out to be highly impacted by reflection and refraction caused by the canyons.

Meanwhile, Raubenheimer explored the movement of water and sediment from areas of high setup to zones of lower setup—a strong flow that appears to be a critical element in alongshore currents and sediment transport along beaches impacted by canyons.

"In fact, it could be the No. 1 thing driving currents if you're in a place that has canyons and complex bathymetry," said Elgar. "It's got nothing to do with the angle of the waves—it's all got to do with the fact that you've got big waves in some places and small waves in other places. People have always theorized about this, but nobody's measured it before."

Based on the team's observations, Apotsos (now an American Geophysical Union Congressional Science Fellow) created sample models to describe and predict wave setup over complex bathymetry.

Array of Sensors

To measure wave setup and its effects, Elgar, Raubenheimer and Scripps Oceanographic Institute colleague Bob Guza deployed 25 acoustic

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Doppler velocimeters (ADVs) in the surf zone along about two miles of beach. SonTek (San Diego, California) ADVOcean probes were placed at one and 2.5-meter depths and then cabled to dataloggers on shore. Elgar placed SonTek Triton-ADVs outside the surf zone in five meters of water, and Thomson (now at the University of Washington) placed a pair of Triton-ADVs in 15 meters of water on either side of the La Jolla Canyon—a mile from shore—to observe the reflection of long-period infragravity waves off the canyon walls.

The Triton-ADVs, with onboard memory and reliable batteries, were great for long deployments far from shore, said Elgar.

"For the Tritons, you just have to have a single pipe jetted in the sand," he noted. "You don't need a tripod and cables—you just slip the current meter over the pipe and you're done. Then we have a little team that goes out to change batteries every two weeks."

While Elgar handled measurements in deeper water, Raubenheimer monitored the swash zone with an innovative array of SonTek acoustic current meters mounted on tripods two, five and eight centimeters above the sand.

"We have questions about how strong the flows are alongshore," she explained. "Strong flows, even though there is very shallow water depth, could affect sediment transport along the beach."

In fact, transport was so substantial that Raubenheimer observed sand accretion of two centimeters or more in just minutes. As a result, she found herself moving sensors hourly to keep them at the proper level above the beach. Raubenheimer's work is opening doors to understanding the impact of alongshore flow from wave setup differentials, as well as the effect of peaked, forward-pitched waves on the movement of sand in the swash zone.

Illustrations Abound

During the data collection phase of NCEX, Elgar and Raubenheimer observed a scene that underscored the importance of the project. A sewage spill sent 300,000 gallons of raw sewage into the ocean off Torrey Pines Golf Course, right in the study area.

Unsure of which way the currents would carry the sewage, state officials were forced to close miles of beach, both north and south of the spill. With accurate models, closures could have been focused on the areas that the flows were most likely to reach, noted Raubenheimer, avoiding millions of dollars of lost tourist revenue in beach communities that were untouched by the spill.There is still plenty to learn, and data from the NCEX projects are still being analyzed.

"It's pretty preliminary, but I'd say the models have a lot of skill," said Elgar. "They certainly predict rip currents, where we measure rip currents."

Ultimately, perfecting good models will be invaluable.

"We've got 25 current meters out there, and they've got 25,000 dots on their maps," Elgar noted.

Teaming accurate equipment with reliable models could answer overarching questions.

"If there's one sensor in the surf zone for 20 minutes beaming information to a satellite, can you combine that with a model to make a decision on whether to green-light a naval operation?" asked Elgar. "Or can a model help you decide whether this is where you want to spend $50 million over the next 20 years on a state park? And if you do, how much do you need to budget for dredging?"

Those are big questions. Models are on the way to help answer them, bolstered by the insight that Elgar and Raubenheimer are developing and the data they are gathering on the elaborate effects of complex bathymetry on waves and currents. /st/

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