xylem
Let's Solve Water

Application Note
SonTek, a Xylem brand • XA00333

Revealing the Mysteries of the Tijuana River Estuary

SonTek Technical sales expert Matt Klipfel uses the SonTek-RS5 ADCP to gather highly precise tidal flow data at the mouth of the Tijuana Estuary, where waters merge with the southern California Pacific coast.

Understanding the Estuary

To put it bluntly, the situation around the Tijuana River and its estuary just north of the U.S.-Mexico border stinks.

Once a seasonal river with a sprawling estuary, the Tijuana River has taken to flowing year-round with what Tijuana River National Estuarine Research Reserve (TRNERR) lead science coordinator Jeff Crooks calls "urban drool"—runoff from irrigation, car washing, sidewalk scrubbing, and other human uses. Worse, the failure of two of the four wastewater treatment plants on the river in recent years has led to summer flows that are almost pure, raw sewage entering the Pacific at the mouth of the Tijuana.

Homeowners complain about odor and eroding beaches. Tourists are frustrated. Business owners who depend on

SonTek
a xylem brand

beach visitors are worried. And scientists are afraid for the health of the estuary and the organisms that live there. All combined, this puts the Tijuana River Estuary under the microscope.

"We need to know in much greater detail what is the role of the estuary in retaining and removing pollutants and how does that change during storm events compared with sewage release events—and the fundamental question, what's the total load of pollutants to the ocean?" says Trent Biggs of San Diego State University (SDSU).

Crooks adds, "We're planning a restoration on 80 acres [32 hectares] or so, and our bathymetry and water quality research is providing important pre-restoration information."

Both researchers eagerly participated in surveys of the Tijuana River Estuaries with SonTek acoustic Doppler current profilers (ADCPs), which provided detailed data on the bathymetry of the river channel and tidal creeks, as well as on the movement of water in the system.

Crooks points out that estuaries are very different than rivers and require site-specific research. "When you try to make a rating curve for the estuary, it's completely backwards—it's not what happens with rivers," he says. "In the estuary, the tide comes in and the current slows down, then stops at the highest water level."

Watersheds are drainage basins where rain, snowmelt, and urban runoff flow through creeks, streams, and rivers to the sea. Coastal San Diego has 12 major watersheds connecting the mountains to the ocean. The Tijuana River Watershed spans 1,750 square miles, mostly in Mexico, and includes Tijuana and Tecate. *Courtesy TNERR.*

Precious Ecosytem

Just 10% of California's historic coastal wetland habitat remains, Crooks notes, making the Tijuana River Estuary a precious fragment of an endangered ecosystem. The estuary is a nursery for young California halibut and baby leopard sharks. It is also home to ground-nesting birds, including three endangered species. The salt marsh serves as a buffer against storm surges and a filter that captures contaminants from the river before they reach the ocean.

But that vital 1,000 hectares is threatened by deforestation and urbanization in its 450,000-hectare watershed. As the river winds through the watershed on its 193-kilometer path from the highlands of Baja California to the Pacific, it passes the factories and neighborhoods of Tijuana, then the ranchettes and developments of southern San Diego County. A pair of broken-down sewage treatment plants pour raw wastewater into the channel. The river also picks up

SDSU Research Lead Dr. Trent Biggs explains the tidal flows in the Tijuana Estuary and strategizes the optimal placement of ADCP transects for precise data collection. L to R: Dr. Trent Biggs, Callie Summerlin, Dr. Xue Fan, Jeff Crooks, Matt Klipfel and Julian Gutierrez.

Located on the San Diego coast, the Tijuana River National Estuarine Research Reserve protects the estuary's natural and cultural resources and is part of the National Estuarine Research Reserve System (NERRS), a network for research, education, and stewardship.

eroded sediments that have filled 75 percent of the original tidal prism and raised elevations so significantly that much of the old salt marsh has converted to upland habitat, according to Crooks.

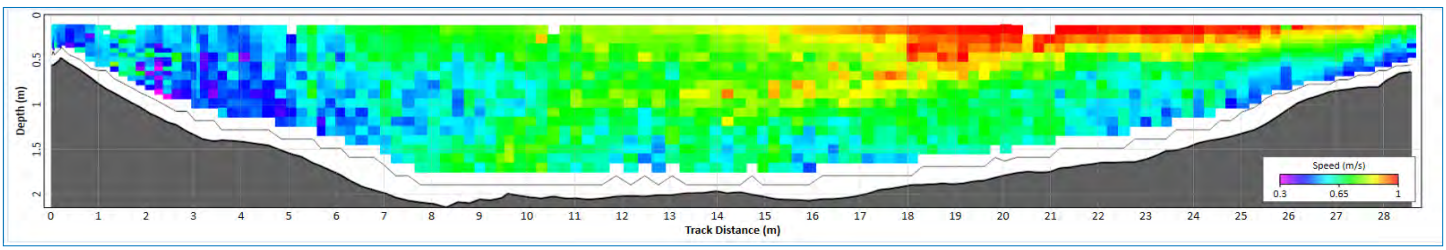
Ironically, those sediments could help reduce beach erosion north of the Tijuana River's mouth, but the four dams along its course prevent the historic winter floods that used to push sand and silt out of the estuary and into the ocean. Today, the sand and silt that migrate downstream chokes the estuary instead.

"It's those two processes: more sediments getting delivered during small and medium-sized events, and then the lack of large [flow] events that would help scour the system," says Biggs.

The movement of sediment within the estuary also dramatically changes the bathymetry of the system frequently. Sandbars forming at the mouth of the river can even trap sewage in the estuary if they are not cleared by reserve managers. The result is a dynamic system that is tricky to manage and where it is difficult to track discharge with typical long-term monitoring solutions.

What Lies Beneath

Researchers have mapped the estuary and studied changes in the marsh. But they understood little about what happened beneath the surface of the river and its tidal creeks, both in terms of the shifting sediment and their active currents. Biggs contacted senior application engineer Xue Fan at SonTek for help surveying the bathymetry of the river and several of the tidal creeks in the Tijuana River estuary, as well as a detailed look at the water movement.



Transect across the Tijuana River Mouth during out-going tide, showing unexpected surface and near-bottom velocity features in the cross section. This was the first time the flow across the Tijuana River Mouth was known to be measured.

In late 2023, Fan and SonTek regional sales representative Matt Klipfel used a SonTek M9 ADCP to conduct a bathymetric survey. Mounted on a remote-controlled YSI rQPOD remote surface water vehicle, the M9 employs nine transducers to map depth and analyze the speed and direction of currents throughout the water column.

They returned in March 2024 with a SonTek RS5 ADCP to conduct discharge measurements at the river mouth. The RS5 is smaller than the M9, with five transducers and a 3.0 MHz signal optimized for shallow depths over a wide range of changing flow conditions. With the RS5, Fan and Klipfel created a detailed time series of water velocity, direction, and discharge through a complete outgoing tidal cycle.

The two surveys highlighted the power of the SonTek ADCPs. They showed not only a strong sense of how the channels change as water and sediment move around the system, but also how river water and ocean water behave when they meet—often differently than expected.

For instance, in the March transect, the SDSU and TRNERR teams observed velocities that were uncharacteristically high along the bottom, while water closer to the surface moved surprisingly sluggishly. That is an unusual velocity structure compared to most river systems, notes Fan.

SonTek Senior Application Engineer, Dr. Xue Fan, reviews RS5 data as it is being collecting in real-time during one of the many transects being conducted during the all-day exercise.

SONTEK-RS5

- Velocity and Discharge
- Depth to 6M
- Single 3.0 MHz Beam

VS

SONTEK-M9

- Discharge and Bathymetry
- Depth to 80M
- Multi-Frequency 3.0 MHz/1.0 MHz

Biggs adds that he was surprised at the dynamics of salty ocean water and river water in the estuary.

"The top half-meter or 50 centimeters of the estuary looks like fresh river water, and the bottom meter looks more like ocean water, so there's much less mixing than we had anticipated," he explains. "There's a lot of salinity-driven stratification of the water column, and that has really important consequences for pollutant removal, mixing, and dilution because if the river flows are sliding on top of a salty under-layer, then it has less time spent in the estuary and likely has less potential for pollutant removal. So we're still trying to understand those dynamics."

Ideal Tool

Fan says she carefully considers the best approach to help researchers achieve their objectives, even if the best answer turns out to be a non-ADCP solution. However, she realized that Biggs' request was a perfect application for the ADCPs.

"You get instantaneous geometry, you get instantaneous velocities, and in that way, you get a snapshot in time into what discharge is doing at that moment," Fan notes.

"In the estuary in particular, there are flow reversals, there's some slack water, and there's sedimentation happening, so the water is pretty murky in some areas," she adds. "The M9 and the RS5 have our SmartPulse auto-adaptive feature that adapts automatically in changing environments, choosing the optimum frequency, acoustic signal type, and cell size for the depth and conditions. You don't have to manually program the instrument for a particular situation."

Fan notes that the RS5 also features a coded pulse-coherent signal to minimize ambiguity, which is especially important in the changing velocities and directions of the estuary. The ADCPs also back up their bottom tracking signal with RTK-corrected GPS location data, which was extremely helpful where strong currents along the channel bottoms created moving bed conditions that can challenge traditional bottom tracking.

The results of the bathymetry and discharge surveys revealed details that stationary level gauges can't capture.

In one of the first site studies conducted in 2023, SonTek's Matt Klipfel and Dr. Xue Fan use the SonTek-M9 to conduct the first bathymetric survey that was used to examine scour of the river mouth to develop a bathymetric baseline to compare to satellite imagery to infer suspended sediment load.

Students from San Diego State University receive an overview from Dr. Jeff Crooks on the upcoming ADCP bathymetric surveying in the estuary using the SonTek-M9. This survey examined river mouth scour and will help model water quality changes throughout the estuary and coastline.

Survey and photo credits: Dr. Jeff Crooks, Research Coordinator (TRNERR), and SonTek acoustic experts Dr. Xue Fan and Matt Klipfel.

San Diego State University students:

Elise Piazza
Cassandra Huneau
Tate Mckay
Yzatis Silva
Alexandra Grant
Donna Altamirano
Callie Summerlin
Stephany Garcia

"We weren't aware that we had such a complex site with such a complex flow structure," Fan says. "This is very valuable information because normally, at gauging sites, you make basic assumptions about the flow structure, and all your equations use those assumptions to get to the final discharge data."

Resilience Shows Through

TRNERR researcher Crooks says the bathymetry, discharge, and water quality monitoring efforts reveal serious water quality challenges, but also provide signs of hope for the Tijuana River and its estuary. Despite the dramatic loss of tidal prism to capture pollutants, the plants, soils, and microbial community are still helping clean up the water before it reaches the sea.

"I'm not happy that sewage is just flowing into it, but it's better to flow through a wetland and out to the ocean than just through a straight concrete channel out to the ocean, which was the original plan in the 1960s," he notes. "In general, I've been more impressed by the resilience of the estuary than by its vulnerability."

That, Crooks notes, provides a promising place to start as he and his colleagues restore more of the estuary.

Advanced technology like the SonTek-RS5 ADCP is crucial in tracking tidal flows, helping to mitigate and solve similar challenges globally.

"I've been more impressed by the resilience of the estuary than by its vulnerability."

The Next Generation

Research in the Tijuana River National Estuarine Research Reserve has provided not only great insights into the dynamics of water movement and bathymetry in the estuary, but a wonderful training ground for a new generation of researchers.

Trent Biggs and Natalie Mladenov of San Diego State University (SDSU) have been working with SDSU's Dan Sousa, Stephany Garcia, Pablo Bryant, Callie Summerlin, Elise Piazza, Alex Grant, Eva Scrivner, Julian Guiterrez, and Jillian Maloney on data collection and analysis in the estuary. Biggs also credits Yongping Yuan of the U.S. Environmental Protection Agency—which has funded the project—and Morgan Rogers of the International Boundary and Water Commission for invaluable help on research, along with scientists from NASA and the JW Sefton Foundation.

Xue Fan, senior application engineer for SonTek, says her company is deeply committed to introducing students to hydrology, from elementary school through university and graduate levels.

"In the elementary schools, we teach the water cycle and water resources, and how we measure water cleanliness," Fan says. "We're also really seeing an uptick in university students who get exposure to modern instrumentation in hydrology, which is still up-and-coming. It's so important to expose these students to as many different instruments as we can, whether they're our instruments or others, because they're the ones who in 10 or 20 years will be making the decisions about water resources for all of us. They need to know what's out there—what methods, what instruments, what they can have at their fingertips as they make those decisions."

SDSU student Callie Summerlin conducts a transect measurement with the SonTek-RS5. The process was conducted by various members of the survey team throughout the entire tidal cylce to asses the flow of water (and pollutants) within the estuary.

"They're the ones who in 10 or 20 years will be making the decisions about water resources for all of us."

SonTek, founded in 1992 and advancing environmental science in over 100 countries, manufactures affordable, reliable acoustic Doppler instrumentation for water velocity measurement in oceans, rivers, lakes, harbors, estuaries, and laboratories. Simply put, our instruments use sound waves to tell you how fast water is moving, where it is moving, and even if it is not moving at all. Our customers are scientists, engineers, hydrologists, research associates, water resource planners and anyone that needs to collect velocity (speed) data in every kind of body of water imaginable. SonTek is located in San Diego, California and is a brand of Xylem Inc.

SonTek

a xylem brand

SonTek, a Xylem brand
9940 Summers Ridge Rd.
San Diego, CA 92121

+1.858.546.8327
sontek@xylem.com
SonTek.com

Sound Principles.
Good Advice.

SonTek.com