Measuring Discharge in Shallower Rivers: *ADCPs go from Rio to Pro*

River monitoring supports many different activities – from determining water reserves to designing flood defenses, and even to sports / leisure uses. As part of monitoring, the data collected include water currents, depth, and discharge -- the net volume of water transported downstream.

After 1990, river discharge measurements changed from mechanical to acoustic instruments. For measurements made from moving boats and floats, Teledyne RD Instrument's (TRDI) river Acoustic Doppler Current Profilers (ADCP) have become the de-facto standard.

The ADCP is accurate, samples rapidly, and displays discharge results as soon as the river section is complete. Rich views of the currents come from high-density sampling through the water column and along the boat path. Stemming from these advantages, TRDI has an unmatched user / experience base and a best-in-class reputation for reliable products and dependable data quality.

TRDI is excited to introduce RiverPro, a new 1200 kHz river ADCP, for moving discharge measurement. This sleek new moving boat system has been designed with a mind for accuracy and an eye for simplicity. The device targets shallow / moderate water depths: slow 20-cm shallows to speedy, 30-m deep rivers.

RiverPro's performance and features build on Rio Grande 1200 kHz ADCP yet include innovative features popular with users of RiverRay ADCPs. When combined with Q-View – TRDI's easy-to-use QA/QC software-- RiverPro can simplify the hydrologist's life on the river and at the office. Using RiverPro, you can leave the river confident you are right on Q.

Rio Grande ADCP

RiverPro ADCP

Figure 1.Comparison of river ADCPs: Rio Grande and RiverPro

ADCP	Ideal Field Environment	Range (m)
StreamPro ADCP	Shallow Streams	0.1-- 6 *(with extended range option)*
RiverPro ADCP	**Deep Stream to Shallow Rivers**	**0.2 -- 25**
RiverRay ADCP	Shallow to Deep Rivers	0.4 -- 60

1 RiverPro ADCP

Although in different colors, RiverPro resembles the Workhorse Rio Grande ADCP. Most notable is the familiar Janus transducer with beams angled at 20 degrees off vertical. Inside however you find major changes that set RiverPro apart. In RiverPro, the transducers are all modular so a single beam is replaceable; no longer must the whole transducer assembly be refurbished. Small skids on RiverPro's face resist damage to the transducers when the trimaran float is dragged up a river bank.

- ✓ *Auto adaptive pinging / Optional upgrade for Manual setup*

For users wanting a choice of manual or automatic operation, an upgrade is available that enables manual setup. For replicating how you configured a Rio Grande, select manual setup from where you can customize. You choose between general purpose and high-speed pinging; their legacy is Rio Grande's modes 1 and 12. Choosing manual setup maintains a fixed set of depths for measuring currents irrespective of water depth. Within the WinRiver II software, a wizard assists users in manual setup.

Be default, the RiverPro ADCP operation is fully-automated. Embedded intelligence not only takes care of auto-setup at the riverbank but optimizes measurements while underway. It does this by adapting the setup to changes in water depth and flow conditions. As a result, bin sizes and depths change across the section (see Table 1).When river conditions are identified to be non-turbulent, RiverPro will choose a setup that records low-noise velocity data; its legacy is Rio Grande's mode 11.

Water Depth	0.2–0.5m	0.5–1.5m	1.5–3m	3–6 m	6–15 m	>15m
Surface layer	N/A	0.12 m *2 cells @ 6 cm*	0.24 m *2 cells @ 12 cm*	0.36 m *3 cells @ 12 cm*	0.6 m *5 cells @ 12 cm*	0.6 m *5 cells @ 12 cm*
Deep layer	2 cm	6 cm	12 cm	24 cm	48 cm	96 cm

Table 1: Depth cell sizes for RiverPro's automatic setup

For optimizing its data pings, the RiverPro ADCP uses a bootstrapping process. Each ping is set automatically for the ambient water conditions—considering depth, speed, and level of turbulence. Starting with a robust ping suitable for fast flows, the ADCP emits a series of test pings that are tuned progressively to match better with the observed water conditions. This refinement permits RiverPro data to satisfy the requested precision and accuracy without averaging batches of profiles and without requiring users to specify expected flow conditions.

- ✓ *Surface bins for minimal top extrapolation*

Compared with RiverRay, River Pro's steeper beam angle and higher acoustic frequency permit more measurements in a shallow depth. This includes measuring closer to the bed and closer to the surface. Added to the profiling capability is a new short-range measurement that fills the critical surface layer. Before, these values for water speeds were extrapolated based on deeper data.

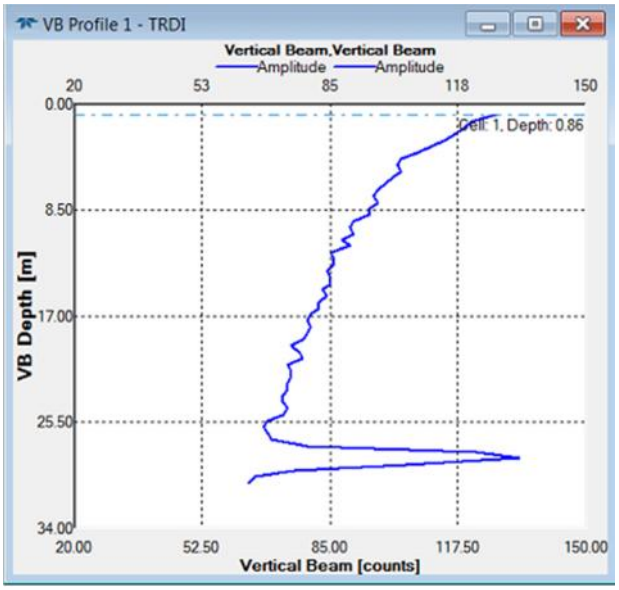
In shallow waters, each beam is setup independently of the others for optimal bottom tracking near riverbanks.

- ✓ *Vertical beam: depth measurement, vertical speed, echo intensity*

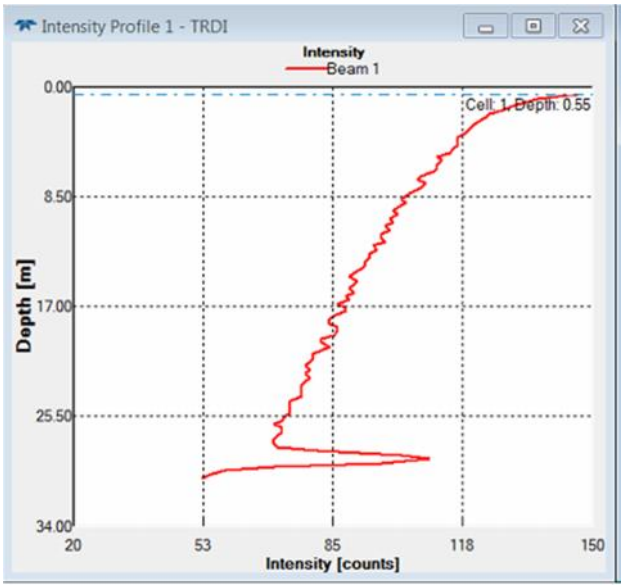
RiverPro ADCP includes a vertical beam for a direct range to bed measurement. Due to its lower frequency of 600 kHz, this beam will reach deeper. In sediment-filled waters, this can avoid the need for adding an echo sounder to record the bottom contour of the section.

On a separate ping, the vertical beam also measures profiles of up/down speed and echo intensity. And due to its different frequency, the vertical beam records different backscatter information from the slant beams.

In the future, echo intensity will be calibrated for all beams to help interpreting data sections for sediment content. Impressive agreement between echo data on different beams is now possible (Fig. 4). Note the strong echo return from the riverbed at 28m depth.



Vertical beam(600kHz, 0.5 m cell size)



Beam 1 (1200kHz, 0.3 m cell size)

Figure 2. Comparison of RiverPro ADCP Echo Intensity. Data: Mississippi River, Baton Rouge LA

- ✓ *Integrated GPS for geo referencing (like cell phone)*
- ✓ *GPS data merged into standard ADCP data format*

For users wanting general position information or geo-referencing, RiverPro comes with an integrated GPS. This data is now part of the ADCP data format so no more do you have to keep track of multiple files for a single section when you share data sets.

RiverPro uses the same compass as RiverRay and StreamPro. Within the WinRiver II software, the compass calibration now permits resetting the compass to factory defaults.

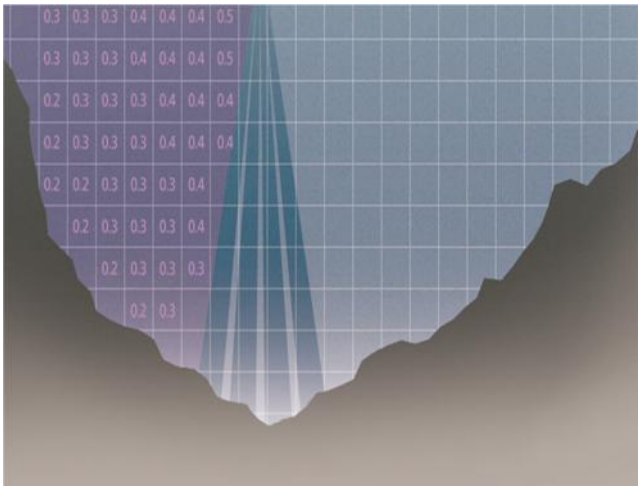


Figure 3. River section showing ADCP measurement grid

Figure 4. Trimaran float

✓ *Trimaran float: low immersion depth and flow distortion*

RiverPro rides in a trimaran float from Teledyne Ocean Science that offers both improved stability in dynamic river conditions and a quick-fit mounting – making it more portable and easier to install. Maximizing the measured area is important for accurate discharge measurements in shallow sections. Therefore, this float holds the ADCP close to the surface with minimal protrusion below the hull. Similarly, to mitigate biased results, the float has other design advantages: reduced drag, less flow disturbance, and improved handling at high water velocities and in waves.

Furthermore, sharing the same diameter as RiverRay, RiverPro fits in a RiverRay float. This allows users to swap out their ADCPs when they arrive at deeper river sections. In addition to some cost savings, this flexibility avoids the hassle of transporting multiple floats.

✓ *Wireless Bluetooth(R) communications and LED status lights*

More than a dozen years ago, Teledyne RDI introduced Bluetooth(R) wireless communications to its moving discharge ADCPs. Although widespread today, this innovation was much enjoyed by operators who found stumbling over power / comms cables to be inconvenient. RiverPro continues our wireless comms tradition by offering a long-range Bluetooth(R) link from the float to a data acquisition PC on the riverbank.

Although troubleshooting hardware in the lab can be demanding, doing the same in the field is more difficult. With this in mind, RiverPro is equipped with bright and visible LEDs that relay ADCP status without the need for opening the watertight case.

✓ *Compatible with WinRiver II and Q-View QA/QC software*

RiverPro is compatible with TRDI's WinRiver II software, which has a development team in regular contact with the USGS. WinRiver II acquires, displays, and record discharge transects in a simple, complete, and thorough process. The software permits efficient and flexible playback and post-processing that includes export of data and summary tables. WinRiver II is well documented, easy to use, and widely deployed, both within the US and abroad.

New for RiverPro data. WinRiver II provides profile plots of the vertical beam data (up / down speed, echo intensity) and can export those data using ASCII output.

River Pro also works seamlessly with TRDI's Q-View QA/QC software. You can save time, effort, and expense by taking advantage of instant data qualification in the field, customizable and flexible quality rules, speedy processing, and automatic, high quality, report generation.

- ✓ *Advantages Of RiverPro ADCP's new electronics*

Built upon the electronics stack of RiverRay ADCPs, RiverPro shares the same efficient implementation of algorithms and faster ping rate due to its DSP processing. Similarly, there is reduced size for electronics due to the use of high-density, surface mounted design. RiverPro has lower power consumption (3V operating voltage for DSPs) by using integrated circuits developed for cellular phones.

- ✓ *Advantages Of BroadBand signal processing*

Like all TRDI ADCPs, RiverPro provides users with data that have high resolution in time, space, and velocity -- even in shallow water. Compared with profiling products using narrowband signal processing, RiverPro's data views provide 2–5 higher resolution. Further, BroadBand signal processing permits 2–4 times improved accuracy for a given ADCP operating frequency.

2 Field testing

Two RiverPro ADCPs were tested at several sites that covered much of the expected conditions for RiverPro users. Discharge measurements were required to be within 1% of a reference ADCP. In addition, reliable operation of the ADCP, internal GPS, and Bluetooth(R) communications were evaluated as well as proper performance of automatic and manual setups.

Figure 5. Ship track for measurements at the confluence of the Mississippi and Missouri Rivers

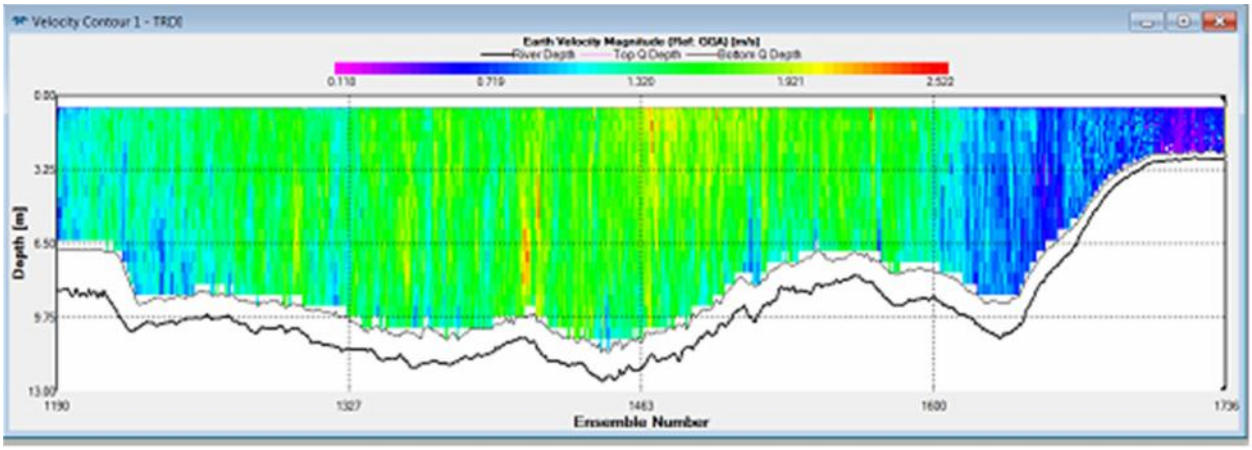


Figure 6.: Contour plot of water speed at the confluence of the Mississippi and Missouri Rivers

River Sites

River	Site	Q(m^3/sec)	Area(m^2)	Width(m)	ΔQ/Q (%)	ΔA/A (%)
Mississippi	Knox Landing	7803±0.6%	8329±0.2%	880.5±0.3%	-0.4%±0.7%	0.8%±0.6%
Mississippi	Baton Rouge	7283±1.5%	9886±0.3%	767.0±0.5%	0.0%±1.8%	0.4%±0.9%
Mississippi	St. Louis	7049±0.7%	5365±0.8%	528.7±0.6%	-0.3%±1.1%	-2.2%±1.4%
Missouri	St. Charles	3126±0.8%	2305±0.5%	390.8±0.3%	-0.3%±1.2%	-0.2%±0.9%
Missouri	Omaha	1486±1.5%	1174±0.9%	218.6±0.8%	0.1%±1.3%	-1.0%±1.3%
Confluence	St. Louis	7190±1.1%	5524±2.0%	608.7±0.7%	-0.4%±2.3%	-0.2%±2.3%

Irrigation Canals, Imperial Irrigation District

Site	Q(m^3/sec)	Area(m^2)	Width(m)	ΔQ/Q (%)	ΔA/A (%)	Reference ADCP
Check 13	1.784±1.0%	8.54±0.4%	7.96±1.5%	-1.4%±2.3%	-2.4%±2.9%	Rio Grande
Check 13	1.880±2.7%	8.40±1.7%	7.96±0.6%	-0.5%±2.9%	-0.9%±1.8%	RiverRay
Lyons Rd	23.63±2.0%	43.14±0.9%	20.52±1.9%	-3.1%±3.2%	N/A	Rio Grande
Lyons Rd	23.41±1.4%	43.33±1.4%	20.51±1.9%	1.8%±2.0%	N/A	RiverRay

Table 2. Field Test Summary. Discharge, area, and width measurements are listed together with relative differences from reference ADCPs used simultaneously at the same sites

You can see that for larger river sections, uncertainties are smaller (see Table 2). At those sites, RiverPro ADCP measurements closely match reference data. Measurements from the canals all match the reference data within the uncertainty shown.

3 Summary

3.1 RiverPro ADCP –Top 10 List

- ✓ *Auto setup for pinging; optional upgrade for manual setup*
- ✓ *Vertical beam: depth measurement, profiles of up/down speed and echo intensity*
- ✓ *Surface bins reduce size of extrapolated area, especially in shoals*
- ✓ *Wireless Bluetooth(R) communications over long range*
- ✓ *Onboard GPS for geo-referencing; GPS data merged into standard ADCP data format*
- ✓ *Greater dynamic range for echo intensity; in future, calibrated data are expected*
- ✓ *Stable trimaran float designed for minimum ADCP immersion depth, less flow distortion*
- ✓ *RiverPro is sized to use the same float as RiverRay*
- ✓ *Bright and visible LEDs for status, troubleshooting*
- ✓ *Modular transducers for simpler, faster, less expensive repairs*

3.2 Comparative Performance of River ADCPs

	RiverPro ADCP	RiverRay	StreamPro	Rio Grande
Water Profiling Range:	**0.2 – 25 m** ***(2 depth cells at 0.2 m)***	0.4 – 60 m	0.1 – 2 m max: 6 m *(upgrade)*	0.5m – 20 m *(1200 kHz)*
Bottom Tracking Range:	**0.2 – 30 m**	0.25 – 100 m	0.1 – 7 m	0.3 – 30 m
Beam Angle	**20 deg.** ***Can measure 94% of range to bed***	30 deg. *(85% range to bed)*	20 deg. *(94% range to bed)*	20 deg. *(94% range to bed)*
Final data collected on computer *(avoids download of raw data)*	✓	✓	✓	✓
Manual setup available *(for advanced users)*	✓	Partial	✓	✓

Table 3. Comparison of high-level specifications for TRDI River ADCPs