Sounding Better!
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Using Surface Sound Velocity from Your Multibeam to Guide SVP Adjustments in Challenging Environments

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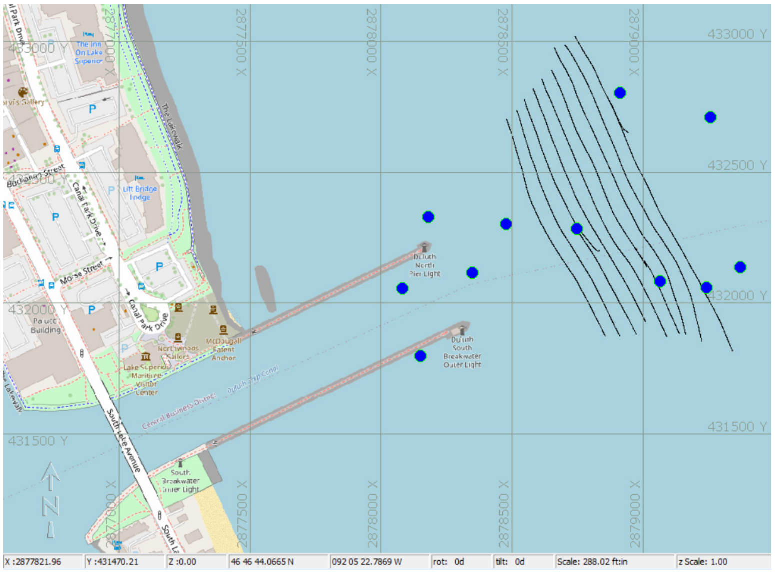
- SVP Adjust Tool (SVP Adjust)
- Sound Velocity Editor
- TIN Model Program
- Target Editor

At one point or another, sound velocity **will** get the better of your multibeam data. Even when your head and profiler probes are calibrated, you've collected a healthy number of sound velocity casts throughout the survey day, and you've carefully accounted for spatial variability, sometimes it still is not enough.

In some situations, you can take advantage of HYPACK's Sound Velocity Adjustment tool and use an existing cast to adjust part or all of the cast to help remove outer beam curvature caused by the applied sound speed not matching the conditions the sound wave was actually traveling through. If you have not checked out Mike Kalmbach's article, "SVP Adjustments in MBMAX64," on using the SVP Adjust tool, it is worth reading to better understand how to use it effectively.

But sometimes you begin using SVP Adjust and quickly realize the sound velocity environment is simply too complex to correct in a targeted way. Before long, you have spent hours trying different combinations of casts, interpolation settings, and SVP adjustments, yet you still do not feel any closer to a solution that truly "saves" the data.
This is exactly what happened during a survey at the Duluth Entry, where the St. Louis River flows between breakwalls into Lake Superior. The survey team collected 11 casts within an area smaller than 0.05 square miles (**Figure 1**). On paper, that sounds more than sufficient, yet no combination of interpolation settings, cast selection, or SVP adjustments could fully flatten the data.

Figure 1. Survey area near Duluth, MN. Blue dots represent sound velocity profiles, and black lines show multi-beam tracklines.



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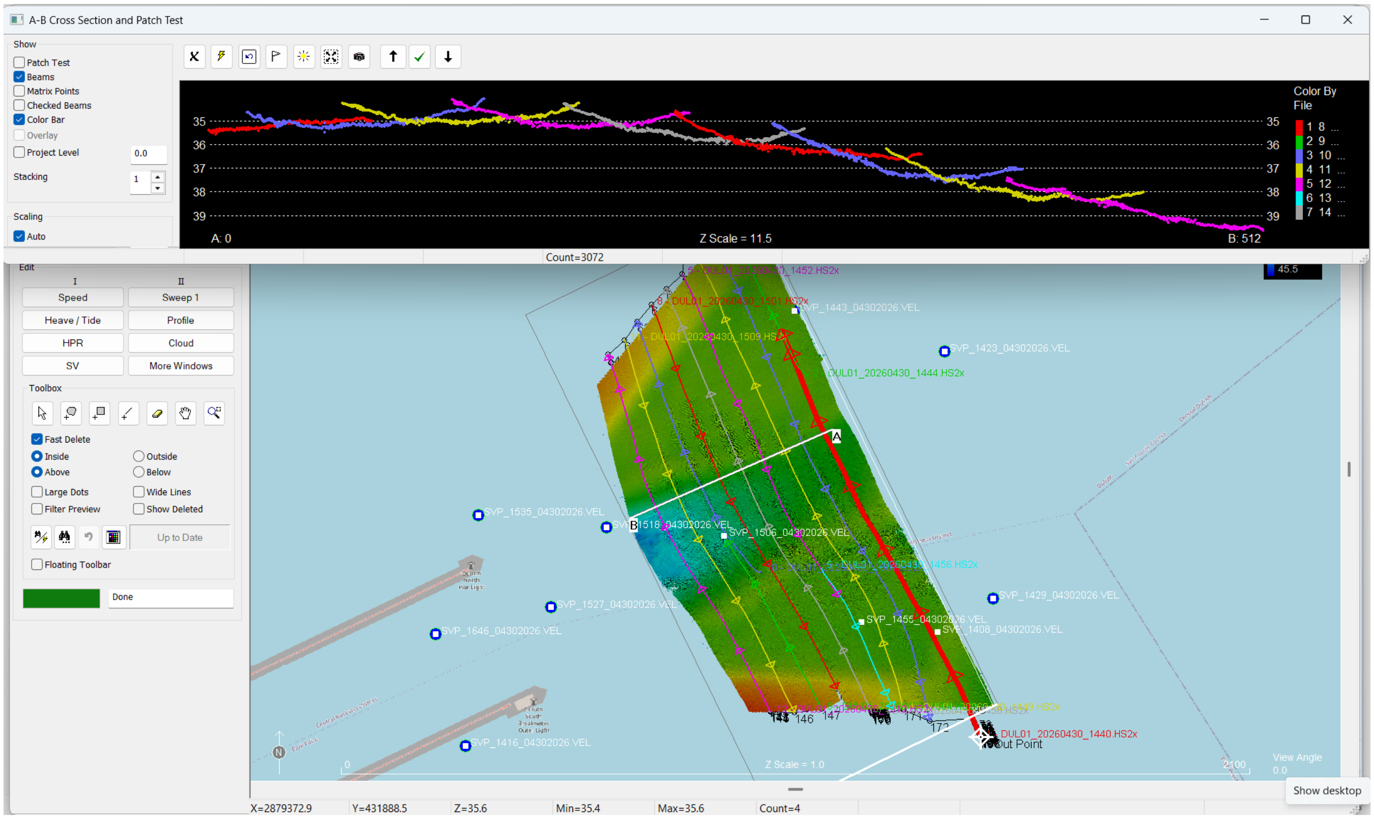
What do I mean by “flatten”?

Figure 2 shows the familiar “smile” patterns in an across-track profile of multibeam data, even with sound velocity corrections applied using casts interpolated by time and position. This pattern indicates that the sound speed profile used in ray tracing is introducing bias when converting two-way travel time into range, causing sounding positions to shift progressively with beam angle.

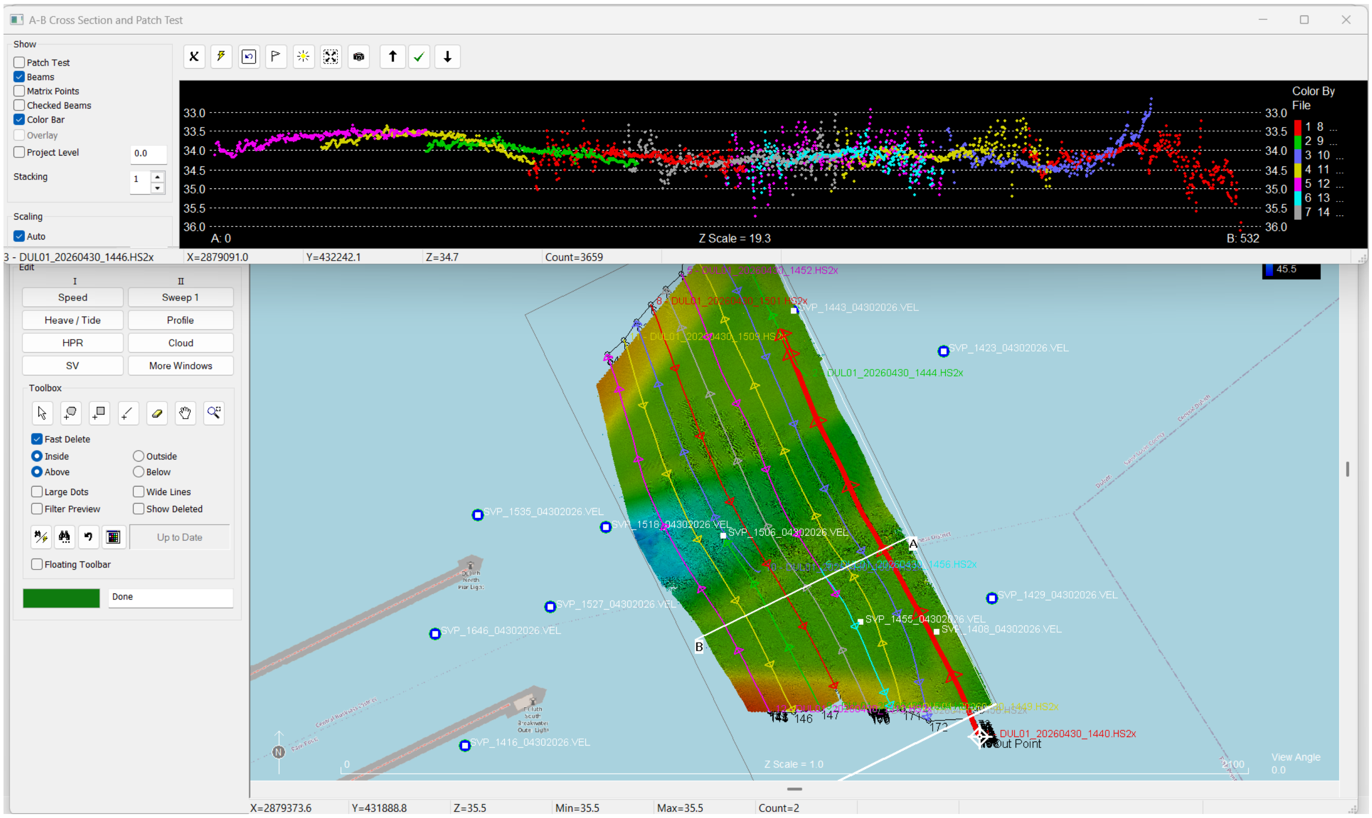
Figure 2. Characteristic “smile” artifacts in the multibeam swath caused by the applied sound speed being too fast relative to the actual water column conditions.



In post-processing, the measured beam angle and two-way travel time measured by the sonar remain fixed, while the SVP applied in MBMAX64 is used to recompute each beam’s ray path and range, shifting where the sounding is ultimately placed on the bottom. As you move away from nadir (the center beam), each beam follows a longer, more oblique path that can interact more with a layered water column. Because of this geometry, any mismatch between assumed and actual sound speed progressively increases with beam angle, so small errors build up and visibly distort the swath.

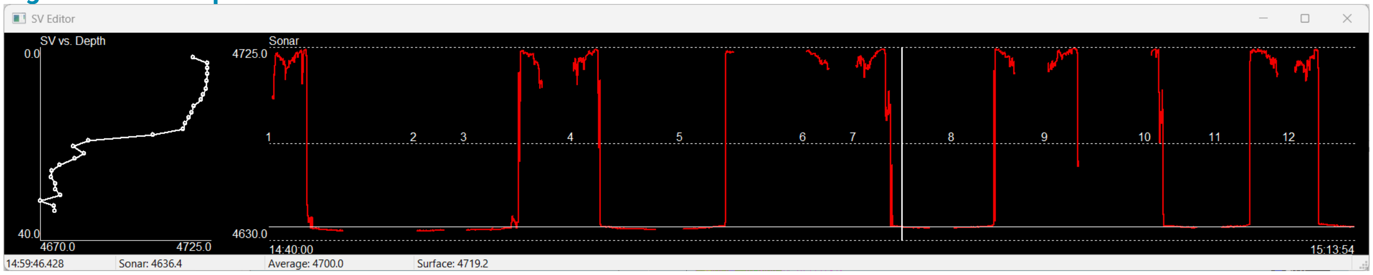
When the applied sound speed is too fast, travel times are converted into ranges that are too short. Across the swath, this produces the upward-curving “smile.” A “frown” is the opposite case. When the applied sound speed is too slow, the ray tracing converts travel times into ranges that are too long. This is exactly what we see on the opposite side of the river entry, where the data shows mostly “frowns” and generally the swaths aren’t as defined (**Figure 3**).

Figure 3. Characteristic “frown” artifacts in the multibeam swath caused by the applied sound speed being too slow relative to the actual water column conditions.



In this dataset, both “smiles” and “frowns” appear within the same survey area, pointing to a complicated sound speed environment that the applied casts aren’t fully capturing. The reason becomes clear when looking at the MBMAX64 sound velocity plot from the head-mounted probe. **Figure 4** shows an approximately 90 ft/s transition in surface sound speed associated with a sharp boundary between lake water and river water flowing through the entry point.

Figure 4. Sound speed measured at the sonar head.



We could jump straight into the SVP Adjust tool, but since we already know we are dealing with a tough, highly variable sound speed environment, it makes sense to step back and take a more informed approach. MBMAX64 actually has a feature I hadn’t even noticed until Josh Sampey mentioned it to me: You can export surface sound velocity as an XYZ file. Turns out it has been around for a while!

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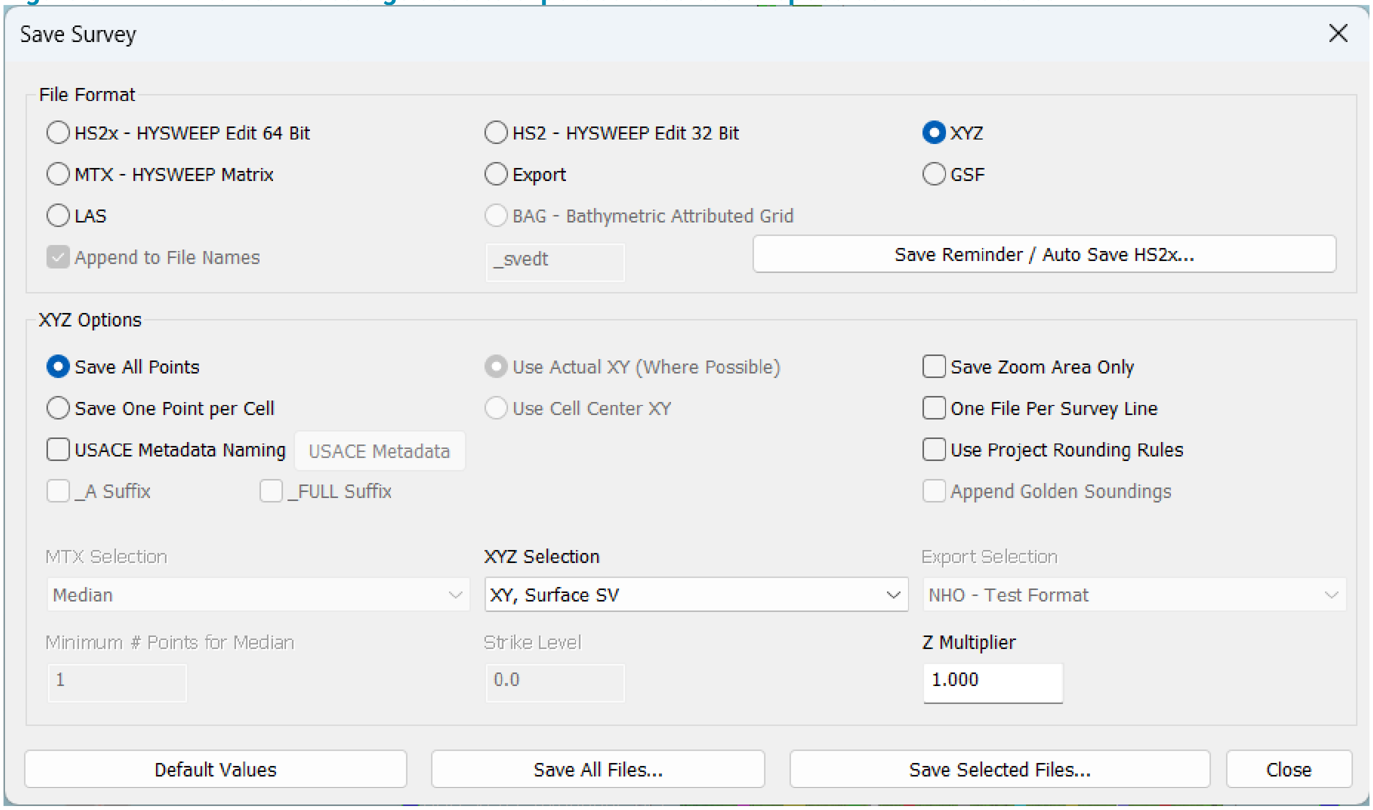
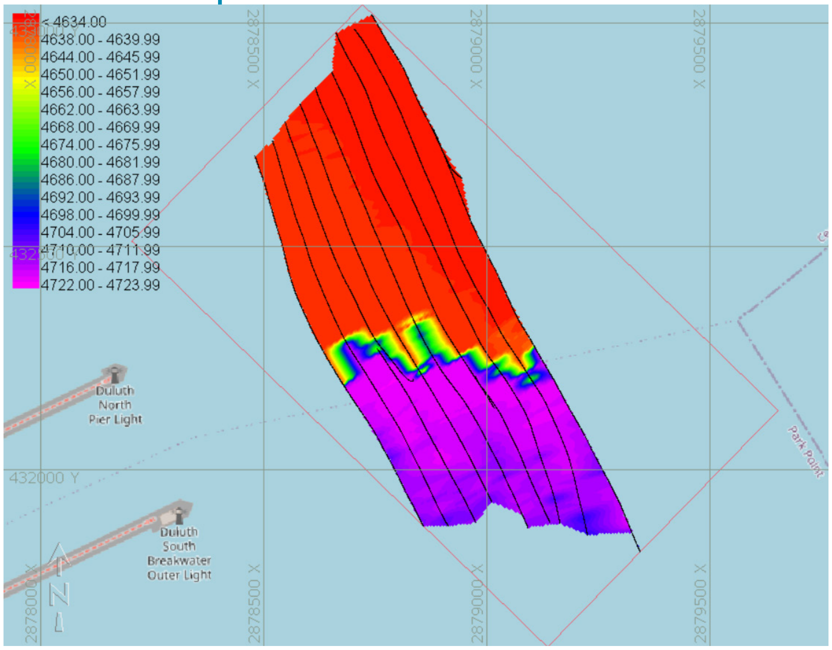
Simply configure the save parameters in MBMAX64 as shown in **Figure 5**.

Figure 5. MBMAX64 save settings used to export surface sound speed as an XY dataset.



This produces a surface sound speed dataset along the survey tracklines. From there, the XYZ data can be loaded into the TIN Model program; I used a TIN “Max Side” length of 0 and then exported it as a matrix. The result is effectively a spatial map of surface sound speed conditions (**Figure 6**).

Figure 6. Spatial map of surface sound speed conditions.



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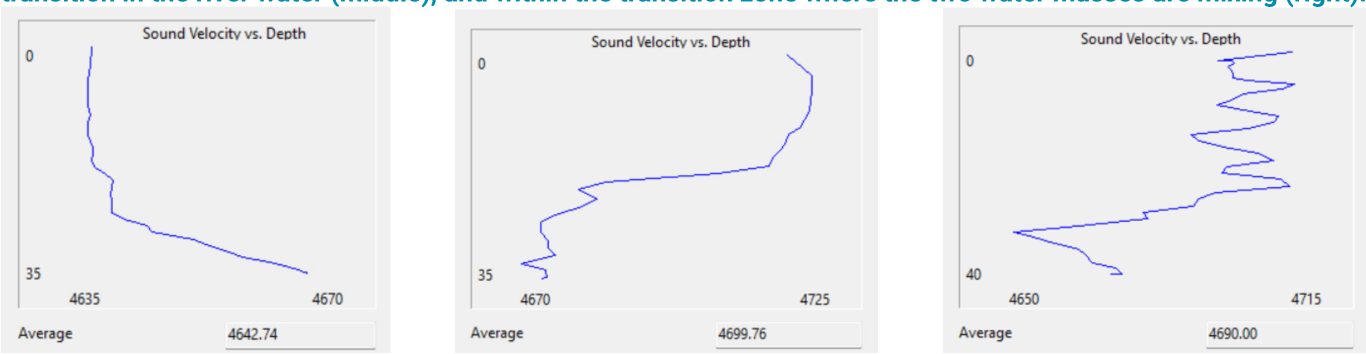
Now we can clearly visualize where the transition between the lake and river water takes place, and use this map to guide how we correct the data. As the surface SV map suggests, the transition is extremely sharp rather than gradual. North of the transition zone, surface sound speed is relatively consistent and slower, associated with colder lake water. South of the transition, surface sound speed is much faster and more variable, associated with river water conditions.
How does this compare to the collected casts?

The northern casts show slower near-surface sound speed values, as expected (**Figure 7a**). The southern casts show faster near-surface values (**Figure 7b**). However, both sets of casts converge deeper in the water column at around 4760 ft/s, indicating more uniform conditions at depth. A cast collected directly within the transition zone captures the mixing interface, where variability is significantly higher due to the interaction of the lake and river water (**Figure 7c**).

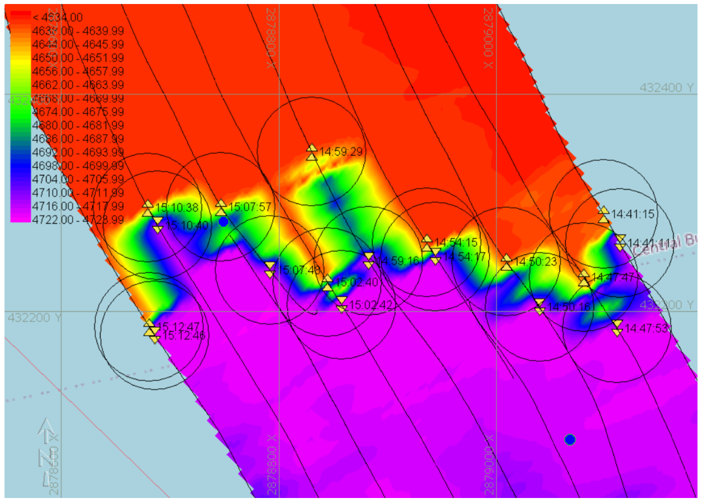
Figure 7. Sound velocity versus depth casts collected north of the transition in the lake water (left), south of the transition in the river water (middle), and within the transition zone where the two water masses are mixing (right).



At this point, my thought process was the following: Because the transition zone is so spatially narrow and abrupt, interpolation of the SVP may not be very useful here. It may be more effective to apply casts based on nearest spatial relevance. In other words, treat the river and lake sound speed regimes separately, assigning representative casts to each side of the transition.

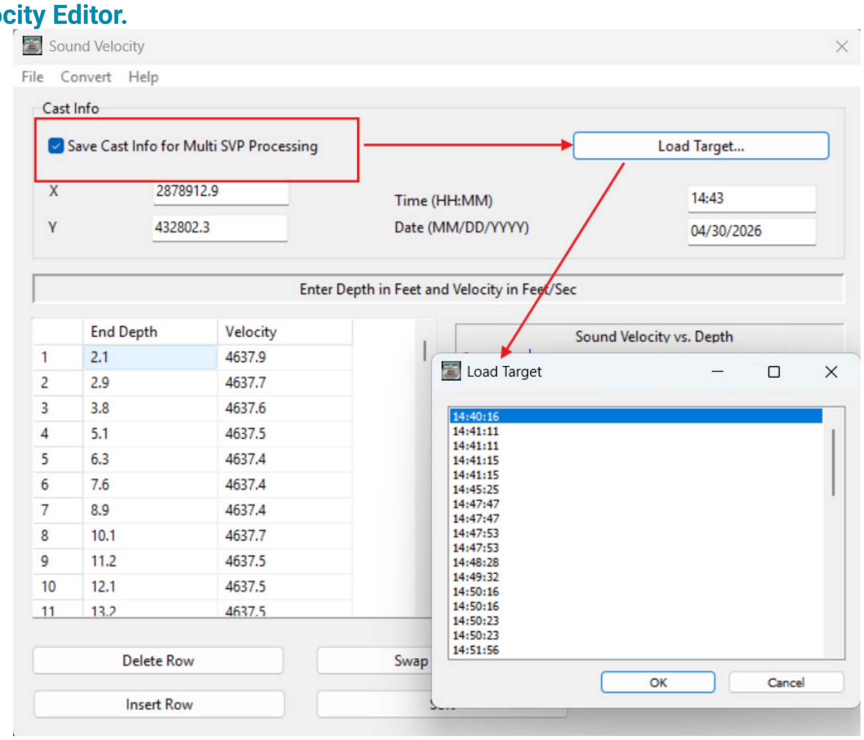
To test this, the first step I took was to create targets marking the approximate transition boundaries. This can be done either in MBMAX64 or directly in the Shell. I placed targets along each trackline where it crossed the northern edge of the transition zone, and another set where it crossed the southern edge. To make them easier to distinguish in **Figure 8**, I used double upward arrows for the northern boundary targets and double downward arrows for the southern boundary targets.

Figure 8. Surface sound velocity map showing targets placed along the northern and southern boundaries of the transition zone.



Next, I chose one sound velocity cast that best represented the lake region. In the Shell, hovering over a cast and selecting Open launches the Sound Velocity Editor. From there, I enabled the option labeled Save Cast Info for Multi SVP Processing, which activates the Load Target function. This feature is typically used to associate a sound velocity cast with a known geographic position when the profiler does not have integrated GNSS. In this case, however, it can be repurposed by assigning the transition boundary targets instead (**Figure 9**).

Figure 9. Sound Velocity Editor.



I loaded the first northern boundary target, then used File -> Save As to create a new cast file. Repeating this process for each northern target effectively generated multiple instances of the same representative cast, each positioned along the northern side of the transition boundary. I then repeated the same workflow using a representative southern cast for the southern targets. The result was a new set of strategically positioned casts that better respected the abrupt horizontal gradient in sound speed.

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Once the updated casts were applied, the swath began to flatten out back in MBMAX64.
The northern side within the lake water (**Figure 10**) showed the greatest improvement, with the “smiles” reduced substantially, while the southern side near the incoming river water showed a smaller but still noticeable improvement (**Figure 11**).

Figure 10. Improved multibeam swath with increased overlap north of the lake–river water boundary.

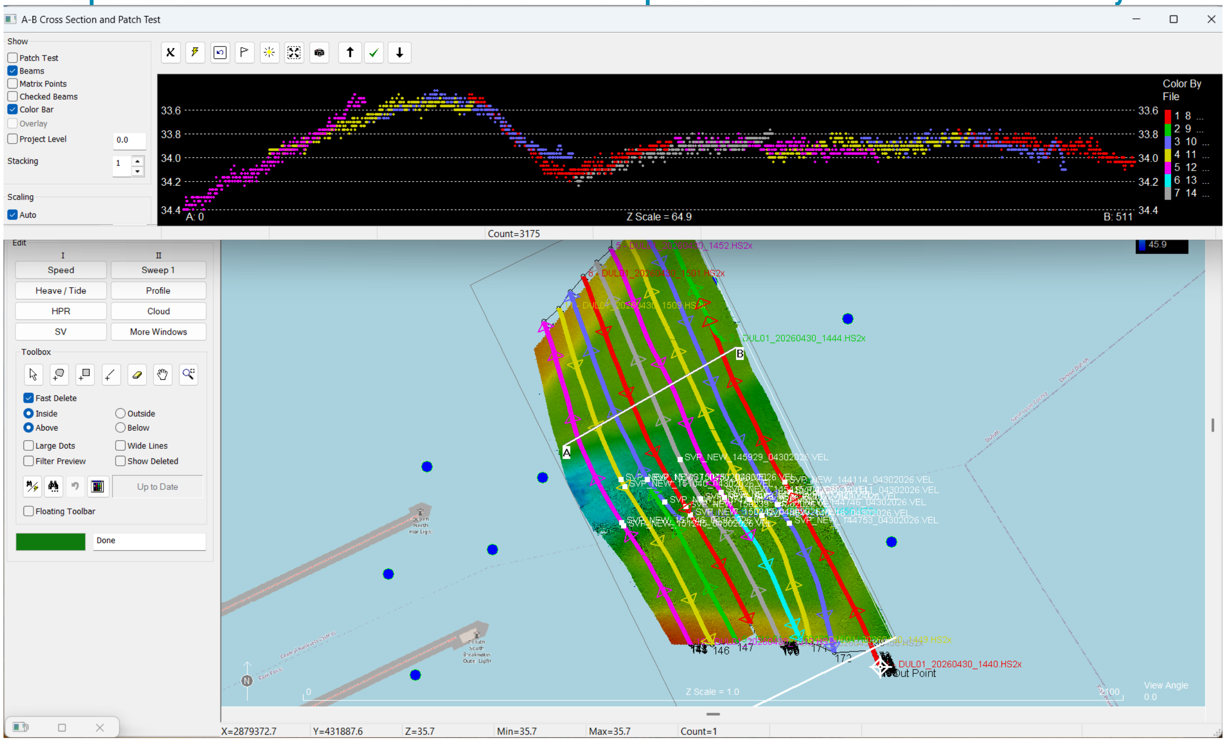
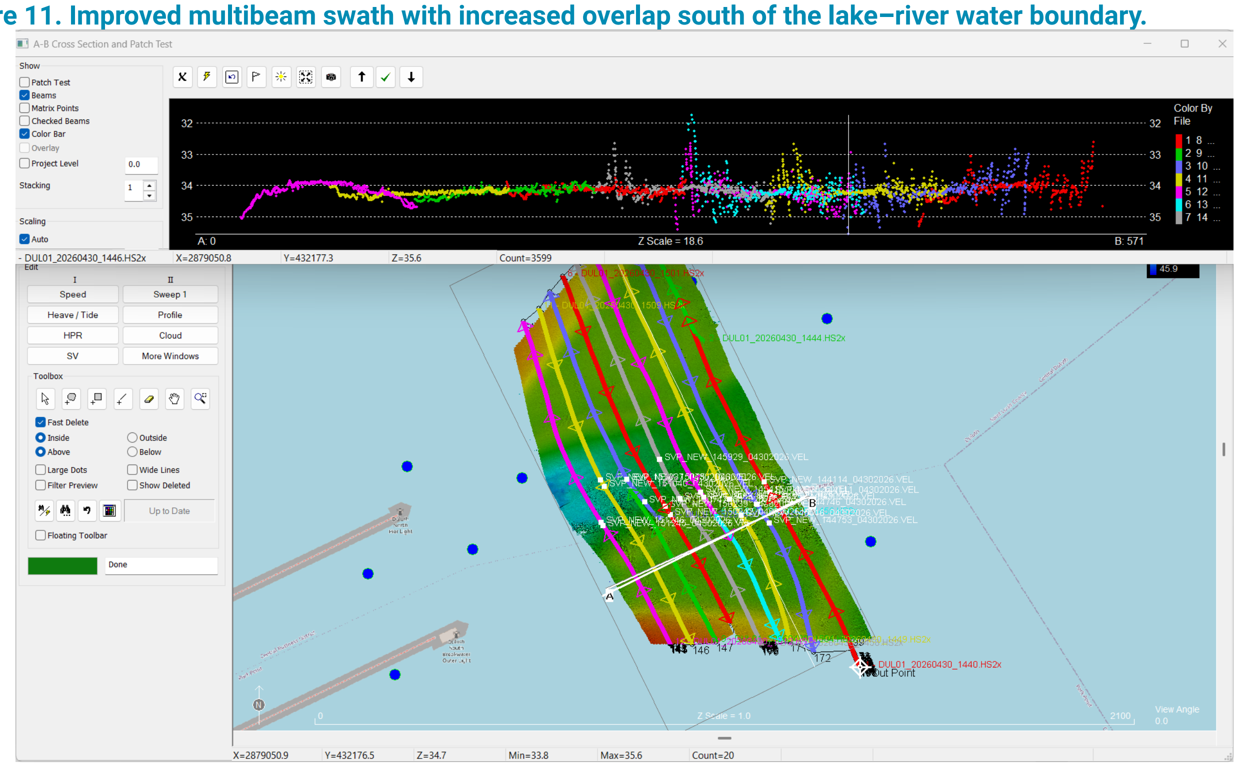


Figure 11. Improved multibeam swath with increased overlap south of the lake–river water boundary.



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Let's Solve Water

At this point, the next step would be to continue refining the southern region separately. Because this area appears more spatially variable, I would likely bring additional original casts back into the solution to better constrain the remaining “frowns.” From there, SVP Adjustments could be applied selectively only in localized problem areas, guided by the spatial sound speed map.

Another factor working in favor of this dataset is survey overlap. If recollection is not possible, trimming the outer beams to a 90° swath width using the MBMAX64 beam angle filters can sometimes salvage data in challenging sound speed environments, again because sound speed mismatches produce increasingly large refraction-related positioning errors toward the outer beams as beam angle increases away from nadir.

I am still not certain whether this dataset can be fully corrected given how complex the sound speed environment was. The southern river water area in particular may never resolve into a clean bottom, as the apparent noise may reflect rapidly shifting, highly mixed water masses within the water column that are too temporally dynamic to model well with discrete casts. It is also important to remember that there is often no single “correct” sound speed solution in environments like this. Different combinations of casts, interpolation strategies, and profile adjustments may improve certain areas while slightly degrading others. The goal is typically to find the most physically reasonable solution that minimizes systematic artifacts while preserving as much usable data as possible.

Hopefully this workflow provides another useful troubleshooting tool to keep in your pocket the next time sound speed challenges a multibeam survey. If anyone has additional ideas or alternative approaches they would try for a dataset like this, I would genuinely like to hear them. These situations are often solved through experimentation and shared experience, so feel free to send me an email at amanda.whaling@xylem.com with suggestions or workflows that have worked well for you.

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