Measurement of Streamflow Under Ice in Alaska Using Streampro Section-by-Section Software

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Introduction

Teledyne RD Instruments (TRDI) Streampro software offers the use of a section-by-section (SxS) method for measuring flow under ice that has not been tested in winter conditions or in comparison with traditional measurement methods. Use of the SxS software can save significant time and effort by not requiring ice-rod depth soundings or multiple velocity measurements in sections deeper than 2.5 ft. Streampro SxS measurements contain more velocity data and therefore should result in more accurate measurements.

Measuring Equipment

Before any measurements could be made, we needed to devise a way to keep the Streampro electronics and batteries warm, as battery life is drastically reduced in the cold.

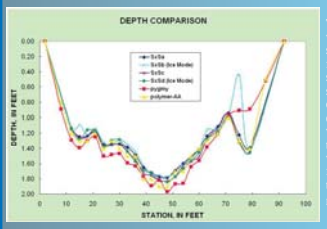
We used an Otter Box waterproof PDA case and sodium acetate re-useable heat packs to keep the PDA screen functioning and batteries warm.

The transducer head was attached to a section of ice rod with a *foot* to hold to the bottom of ice. The standard cord length attached to the transducer head is 1 ft, but any length cord can be requested from TRDI to accommodate ice thickness.

The main electronics unit was placed in a cooler with hot water bottles; this did not interfere with the Blue Tooth communications.

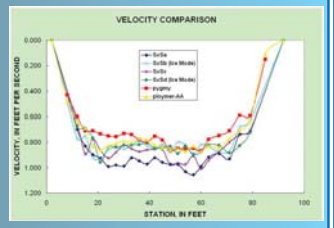
Mode Comparison

Four transects were made at Sheep Creek near Willow with the Streampro; two using the ice mode and two without, along with two separate meter measurements (one pygmy and one Polymer-AA).



Though this site was an optimal site to test the low flow mode of the section-by-section software, the option was not enabled because velocities greater than 0.82 ft/s were expected from the results of the meter measurement.

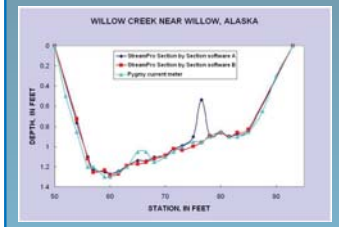
Though the data is noisy due to the inappropriate measurement mode, this site shows the differences in velocity and resulting discharges made by checking the ice mode box.

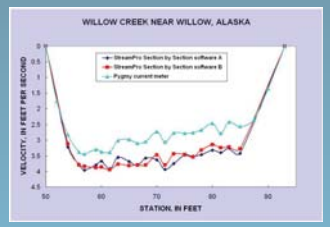


Discharges from the pygmy, Polymer-AA, two Streampro transects in ice mode, and two Streampro transects in regular mode are 83.1, 84.5, 90.5, 88.4, 97.0, and 93.9 ft³/s, respectively.

Method Comparison

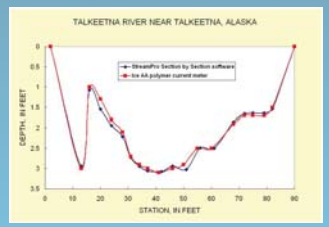
To compare the results of Streampro measurements under ice to standard meter methods, we conducted measurements with standard meters followed immediately by the Streampro in the same holes; therefore the width portion of our channel cross-sectional area was fixed. Depths and average velocities were compared at each station of each measurement.

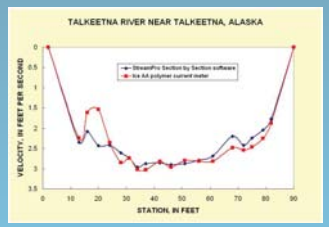


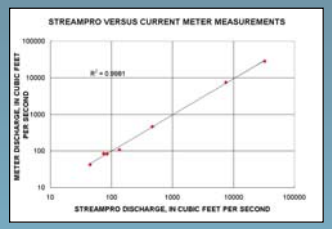


On Willow Creek, a shallow stream, the Streampro measured depths matched well with those read from the wading rod at most stations. The Streampro A depths show an erroneously shallow depth at station 77, for unknown reasons. Whatever interfered with the beams did so for the entire 40 seconds of sampling to render this result. The ice mode was not used during this measurement resulting in higher average velocities for the Streampro at each section. Using the ice mode, a no-slip boundary would have been used for the top and bottom velocity estimates (rather than the default power curve), decreasing the average velocity for each section. Discharges from the Streampro were 133 and 135 ft³/s, and discharge from the pygmy meter was 108 ft³/s.

The Talkeetna River had moderate depths compared to other sites we measured. The Streampro measurement of both velocity and depth compare well at this site for most stations. The ice mode was used and final discharges were 468 ft³/s for the Streampro and 462 ft³/s with the Polymer AA meter, a difference of 1.3 percent.

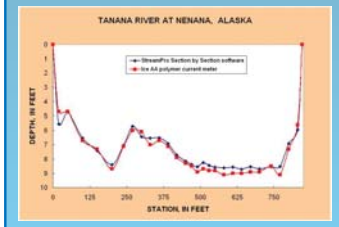


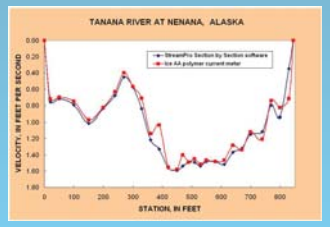




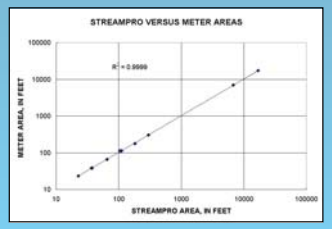
Generally, the Streampro discharge was found to be equal to or greater than the meter discharge. The difference in discharges measured with the Streampro versus the standard meters varied from -11.9 to +14.4 percent, though only two measurements (of 11 total) resulted in the meter measuring significantly more discharge than the Streampro. A scatterplot comparison of the measurement methods has an R2 value of 0.998; however, the differences between the measurement methods often exceeded the rated error for ice measurements (>8 percent).

A scatterplot comparison of the measurement areas (below) has an R2 value of 0.999, indicating that the differences in discharges seen above arise mainly from the difference in velocity measurements (Streampro versus meter).





The Tanana River was one of the deeper sites for Streampro testing. The Streampro and meter data are in fair agreement across the entire river. The ice mode was used at this site. We have noticed that differences in depth measurements occur on some of the deeper rivers with silt and gravel bottoms. This is likely attributable to the ice rod sinking slightly into the substrate during bottom soundings for depth. The Streampro on the other hand sees the bottom without disturbing it and may even read shallower depths during periods of bed load transport (not frequent under ice conditions). Velocity measurements were similar for the two methods at this site and resulting discharges were 7530 ft³/s for the Streampro and 7550 ft³/s for the Polymer AA, a difference of 0.3 percent.

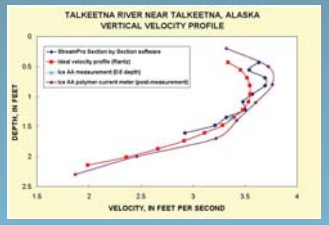


The Streampro, when used in ice mode, showed good agreement with meter measurements of velocity and depth over a wide range of conditions. Optimal conditions for agreement between the Streampro and meter measurements seem to be streams deeper than 2 ft with velocities over 1 ft/s. We have not had the opportunity to test the low noise mode because of the restrictions in depth necessary for use.

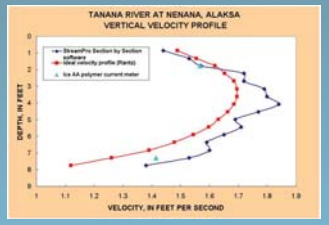
Vertical Velocity Profiles

For several measurements, random stations were chosen and Streampro vertical velocity profiles were compared with ideal velocity profiles constructed from meter velocities using Rantz's (1982) typical vertical velocity curve under ice. Streampro SxS data can be viewed in WinRiver (similar to standard ADCP measurements) using BBsub.exe from the TRDI tools package. This view shows the velocity data from each ping at each station and therefore the relative noisiness of the data, or the amount of agreement between successive pings.

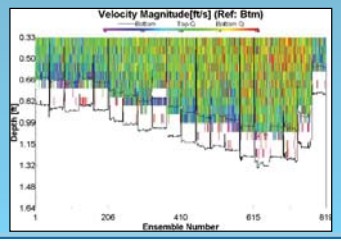
Willow Creek is a good example of how roughness affects the entire water column in shallower streams. Here the Streampro velocity profile deviates from the profile we assume when making a single point (0.6 depth) measurement to represent the entire range of velocities. The Velocity Magnitude Contour plot from WinRiver shows the wide temporal variability in velocity in small streams due to the influence of boundary roughness over a greater percentage of the stream cross-sectional area.

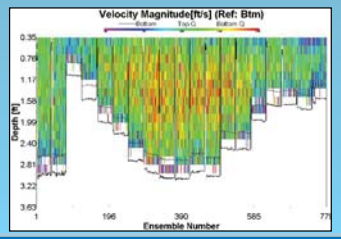


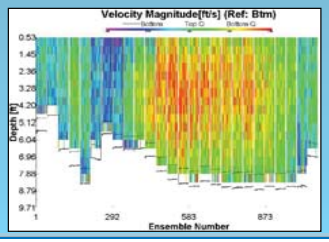
At the Talkeetna River, an ideal profile constructed from a 0.6 depth velocity measurement is shown alongside the Streampro vertical velocity profile and one measured with a meter at variable depths. Both the meter and Streampro profiles deviate from the ideal (assumed) curve, especially near the top of the water column. The Velocity Magnitude Contour plot shows a more well-developed thalweg in this medium depth stream, as boundary roughness does not have such a pervasive affect.



The Tanana River shows that in deeper streams, the true vertical velocity profile approaches the ideal. Because the velocity curves are similar, the calculated discharges were nearly identical. The Velocity Magnitude Contour plot shows a well-developed thalweg and generally less noisy data than in shallower streams.







Summary

The Streampro SxS mode allows for faster, easier, and higher resolution measurement of streamflow under ice. It performed reliably over a wide range of depth and velocity conditions (in streams deeper than 2 ft with velocities over 1 ft/s), but cannot completely replace the use of standard meters, which are still needed to measure flows in multiple ice layers, very deep channels, and at cross-sections that present a wide range of relative depths. Assuming the Streampro measures velocities correctly over the range of depths, it must be determined what can cause differences between measured velocities by the Streampro and a meter at the same point within a vertical velocity profile and which best represents the true velocity (and therefore the more accurate calculation of total discharge). This process potentially calls into question the quality of historical ice measurements.

The Streampro SxS software is still fairly new and could use some improvements as well as bug fixes. Some of the problems we encountered include:

- if a mistake is made during field data entry it cannot be revisited and corrected
- the exported data summary may contain computational mistakes
- the low noise mode should be automatically enabled in sections where conditions are suitable
- confusion about what information should be entered into the *ice rod* box

Use of the ice mode is necessary for properly calculating discharges by creating a no-slip boundary for top and bottom water column estimates, approximating Rantz's under ice curve. To enable the ice mode, the *Ice* box must be checked for each section which then allows the user to enter the transducer depth (below bottom of ice rod foot) and the ice rod reading. In situations of a section deeper than 13.8 ft, this feature enables the user to place the transducer head deeper in the water and estimate any unmeasured velocities between it and the bottom of ice. With improved Streampro SxS software and documentation, ice measurements will be faster, easier, and more accurate with the Streampro.

References

Rantz, S.E. and others (1982) Measurement and Computation of Streamflow. U.S. Geological Survey Water-Supply Paper 2175: 631 p.