Multibeam Processing Tests – Preliminary Results

(St. Marys River Testing – 5/1/2008 & 5/2/2008)

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Introduction

We are evaluating various multibeam processing methods for channel clearance and strike detection. (In this context, strikes are objects above a channel's design grade posing hazards to navigation). For obvious reasons, it's important to use methods insured to locate strikes. On the other hand, it's expensive to mobilize dredging equipment so it's best to avoid false detection. And automated data cleaning is clearly preferred to manual methods! These are the trade-offs examined.

The Rock Cut

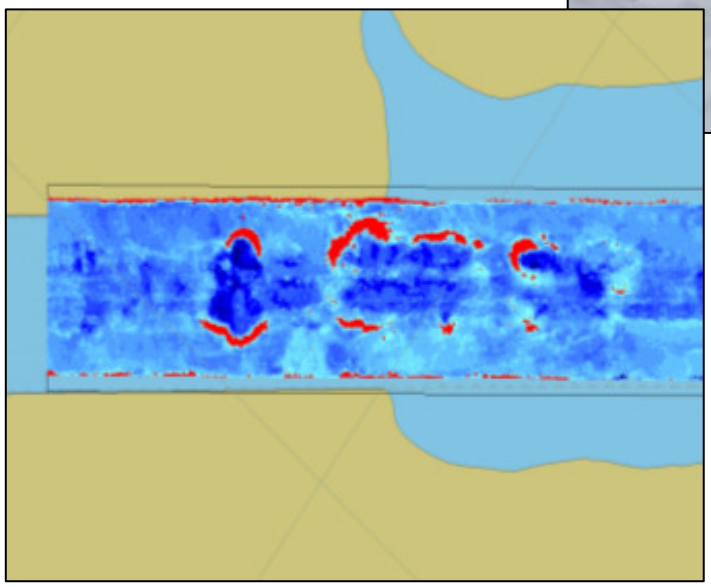
Testing is done in the rock cut channel of the St. Marys River in the Upper Peninsula of Michigan. The rock cut is a 300' wide passage, initially excavated in 1909 and deepened through the years to current depth of 28.5 feet. Large, loose rocks frequently find their way into the channel and are detected by the Army Corps or Engineers using (1) the multibeam S/V Bufe and (2) the derrick barge Nicolet, equipped with multibeam sonar and a sweep bar. This combination makes for the ideal test location in that strikes located by multibeam can be verified to great accuracy by the sweep bar.

Photos, clockwise from top:

- Multibeam S/V Bufe
- Derrick Barge Nicolet
- Nicolet sweep bar and lowering

apparatus. One tenth foot gradations can be seen in the foreground under the cable.

As a point of interest … Here is the thousand foot bulk carrier Edgar B Speer, traversing the rock cut under very different circumstances. It was stranded for 3 days in January, 2004 due to ice.



The contour map shows how the channel was disturbed as the ship tried to free itself. Areas shown in darker blue are scoured. Red areas are above the 28.5 foot project depth.

Multibeam data collected by USACE S/V Bufe.

Survey Equipment

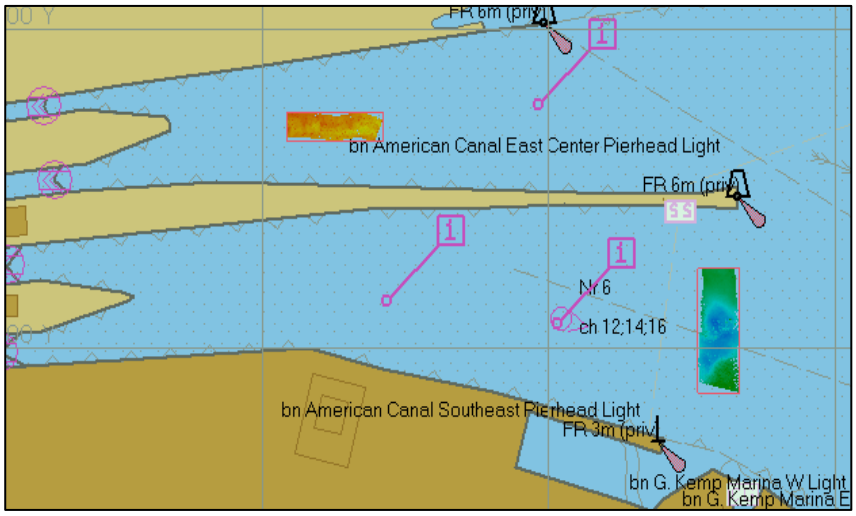
The 26 foot multibeam S/V Bufe is equipped with the following:

- Reson Seabat 8125 multibeam sonar,
- Applanix POS/MV inertial navigation system using DGPS,
- Odom Digibar 2 sound velocity profiler,
- Herrin HD3011 telemetry tide gauge located just outside the rock cut.

The 8125 is a 120 degree system with 0.5 degree resolution across and along track. The maximum rate of 40 pings per second is used, providing a very high resolution survey.

Patch Test Calibration

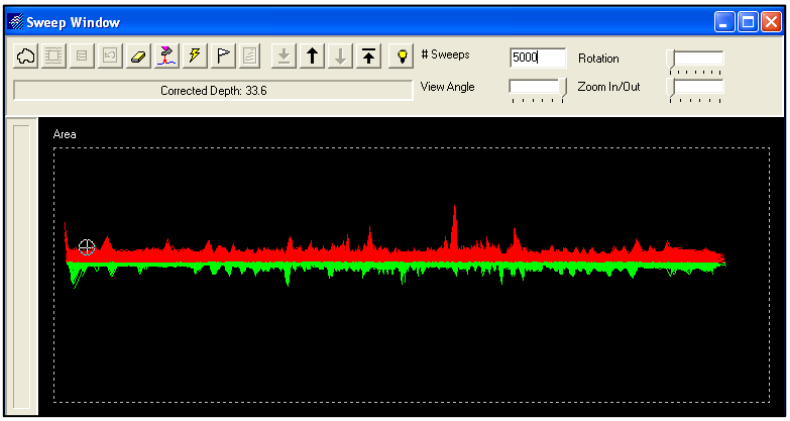
Before conducting a survey which is to be measured to 0.1 foot, a thorough patch test was done. The traditional area is at the western approach to the Soo Locks.



Lock Calibration

The Soo locks offer a great location for depth calibration. The locks were closed and low pool depth of 33.8 feet was verified with a lead line. The Hysweep bar check verified proper depth measurement across the entire sweep. Well, with the single exception of beam 150, which randomly measured up to 0.5 foot shallow. Beam 150 was excluded from test data processing.

The profile graph in green and red shows about 5000 sweeps collected in the lock. The dividing line between green and red is at the lock depth of 33.8 foot. We can see about 0.2 foot noise above and below the actual depth, which is typical for the

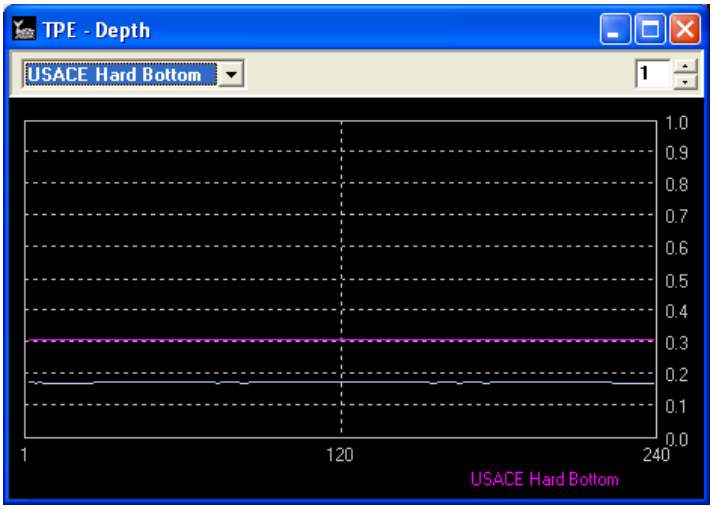


Seabat 8125. The upward spike slightly to the left of center is beam 150.

There is no noticeable degradation in accuracy across the full 120 degree swath.

TPE:

The Hysweep TPE (Total Propagated Error) graph at right estimates system depth accuracy slightly under +/- 0.2 across the swath. This compares well with empirical results from lock testing.



Multibeam Processing Methods:

Three Hysweep methods are used initially:

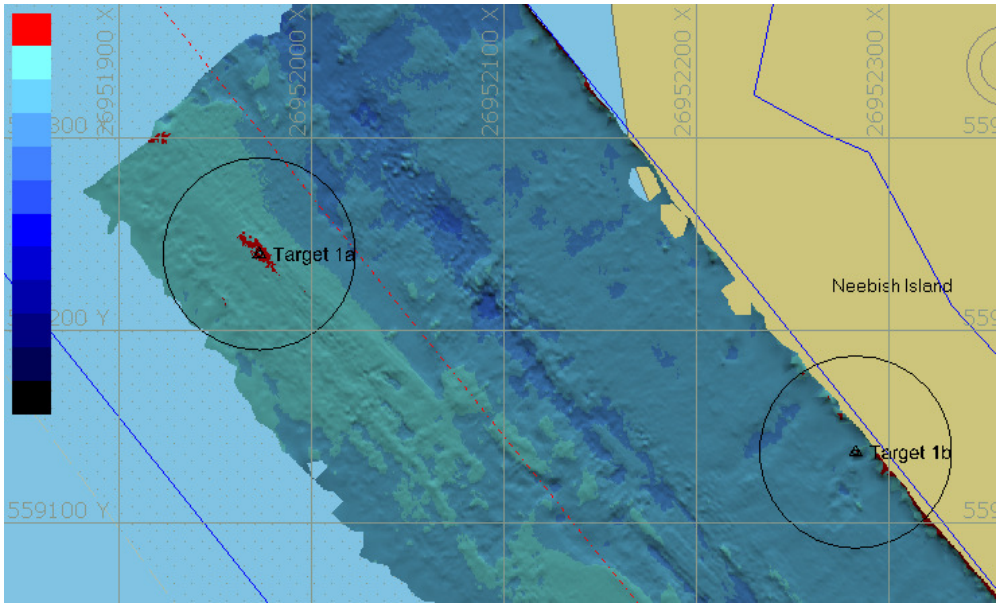
- **MB Auto** – Survey is edited with Hysweep MBMAX, using only automatic filters for data cleaning. Fast. The clean soundings are then gridded into 1' x 1' cells three times; selecting minimum, median then average depth.
- **MB Manual** – Survey is edited as above, and then reviewed and remaining flyers are removed by hand. Slightly more time consuming, but the time spent is worthwhile in providing a reality check not available with totally automated processing.
- **CUBE** – The MB Auto results are further processed using CUBE (Combined Uncertainty and Bathymetric Estimator). CUBE saves a depth estimate the sounding nearest the estimate at one foot node spacing.
- **Three Hit Rule** – The full edited survey is searched for cells containing 3 soundings above grade. 3 hits provides strike locations, or at least areas requiring a closer look.

Because of the high resolution of this survey, an average of 10 – 15 soundings fall within each 1 x 1 cell. This is enough for averaging and CUBE post-processing.

Targets:

Two targets, 1A and 1B, are examined in detail. Target 1A is large and unconsolidated. Target 1B is small and quite consolidated.

The depth of each has been accurately measured with the Nicolet sweep bar.



Full Survey with Targets 1A and 1B marked

Target 1A:

Position:

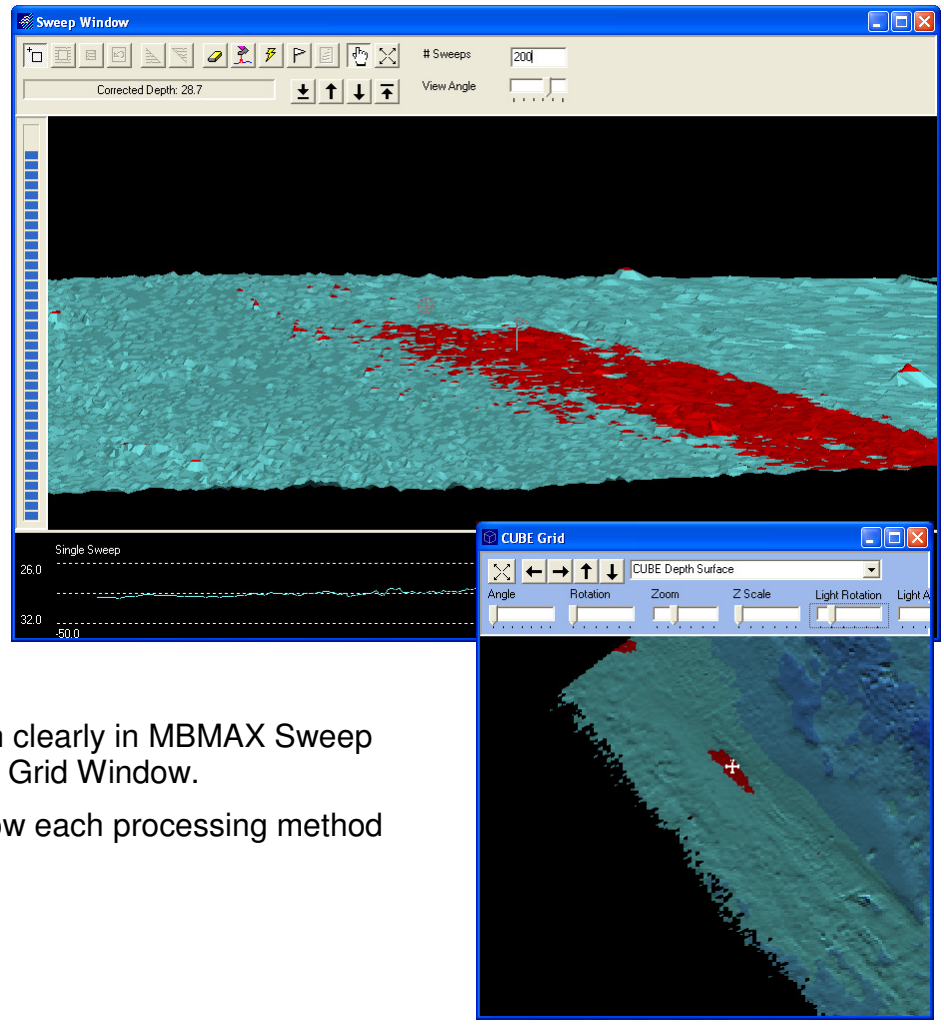
26951973X,
559240Y,

Bar Sweep Depth = 28.3,

Line = 005_1125.HSX,

Sweep Number = 1954.

Description: Rock fragments deposited by the prop wash of passing freighters. Area above grade is about 10 x 35 feet.



The target is shown clearly in MBMAX Sweep Window and CUBE Grid Window.

The table shows how each processing method fared.

Summary:

Processing Method	Detection Depth	Predominant Depth	Remark
MB Auto, Average Depth	28.3	28.4	Good comparison.
MB Auto, Median Depth	28.4	28.4	Good comparison.
MB Auto, Minimum Depth	27.8	28.3 to 28.4	Flyer strongly influenced strike depth.
MB Manual, Average Depth	28.3	28.4	Good comparison.
MB Manual, Median Depth	28.4	28.4	Good comparison.
MB Manual, Minimum Depth	28.1	28.3 to 28.4	Detected slightly shallow
CUBE Depth	28.4	28.4	Good comparison, flyers removed by CUBE.
CUBE Sounding	28.3	28.4	Ditto.
3-Hit Rule			Strike easily detected.

All methods detected this target above grade. Median, average and CUBE methods were all within a tenth of actual depth. The minimum methods reported a shoaler depth than actual.

Target 1B:

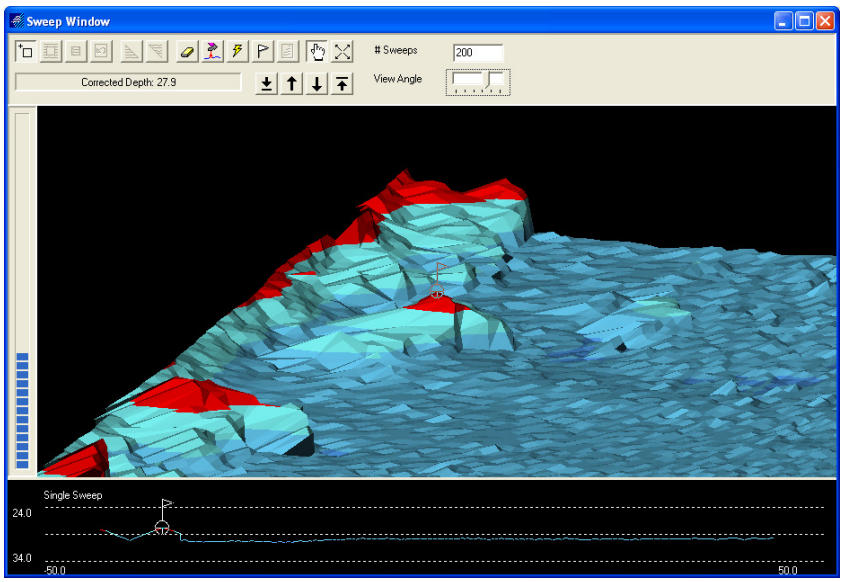
Position = 26952286X, 559136Y,

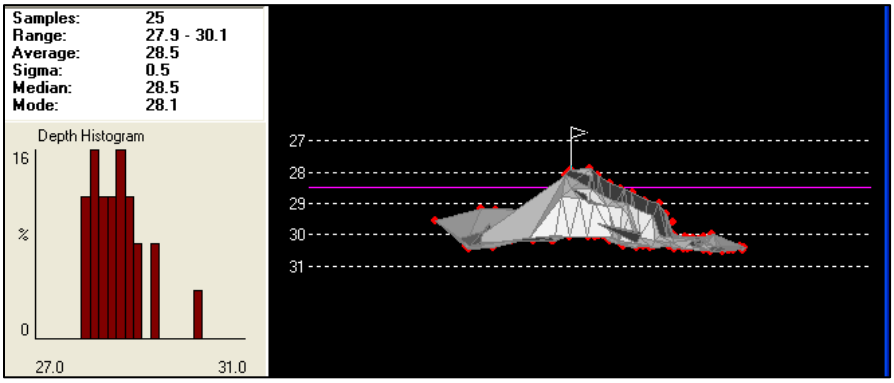
Bar Sweep Depth = 27.8,

Line = 002_1116.HSX,

Sweep Number = 766.

Description: A large rock near the north side vertical cut. About 3.5 feet in diameter. Easily visible in MBMAX Sweep and Cell Windows.





Processing Method	Detection Depth	Cells Above Grade	Remark
MB Auto, Average Depth	28.1	1	Measured deeper than actual
MB Auto, Median Depth	28.1	3	Measured deeper than actual
MB Auto, Minimum Depth	27.8	5	Good comparison
MB Manual, Average Depth	28.1	1	Measured deeper than actual
MB Manual, Median Depth	28.1	3	Measured deeper than actual
MB Manual, Minimum Depth	27.8	5	Good comparison
CUBE Depth	---	---	Not detected
CUBE Sounding	---	---	Not detected
3-Hit Rule			Easily detected.

Summary:

Minimum depths provided the most accurate representation of the object, both in depth and extent. Average and median depth methods detected the object but showed it deeper than the sweep bar and smaller in extent. CUBE removed the object completely.

Conclusions:

Preliminary …

- For extended shoals the average, median and CUBE methods provide better results - remove multibeam noise and flyers.
- For small objects the minimum depth method seems better – object can be biased deeper or lost entirely in the statistics.
- Statistics in our current version of CUBE has potential of removing small objects altogether. It would be a good idea to try other CUBE methods when they come on line later this year.
- 3-hit rule, although somewhat arbitrary and strongly dependent on sounding density, worked fine in both cases here.
- Combination of MBMAX phase 2 filters with manual review is best. The manual review serving as blunder / reality check is not an exercise in tedium.

References:

http://www.lre.usace.army.mil/greatlakes/hh/outflows/discharge_measurements/st_marys_river/