MBES Swath Angle in Relation with Data Processing Quality, Time and Cost

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SUMMARY

The goal of this research was to investigate and determine the differences in uncertainty and surveying coast at different beam angle limits. To achieve this objective, six MBES data sets were each processed by five surveyors with different levels of experience in MBES data processing. Each project was processed three times, using 45°, 60° and 75° beam angle filter limits in the HYSWEEP MBES Editor. Each surveyor was timed to determine the total time spent in editing each MBES data set, using each of the three beam angle limits. An analysis was conducted for the time taken to process each data set, along with the resultant sounding uncertainty. Finally, a virtual area was created to determine the cost of the survey as a function of swath angle.

This research was conducted in cooperation with HYPACK Inc. (www.hypack.com), and the Hydrographic Survey Research Group (HSRG) in the Arab Academy for Science and Technology and Maritime Transport (AASTMT) (www.aast.edu). HYPACK provided the project with a work station for data processing, sample MBES data, and five HYSWEEP licenses. HSRG conducted the data processing, analysis and the documentation.

1. SURVEY PROJECTS DATA

HYPACK provided several MBES data sets from different locations that were used in conducting the research. These projects were used for either basic training of the surveyors or to measure their actual processing performance and the resultant uncertainty. The project that was used for training the survey team was named Sample HYSWEEP Survey. Projects that were used in measuring processing performance are named Philadelphia, New York, Before Dredging, After Dredging and Artificial Reef.

2. STANDARD DEVIATION COMPUTATION

As a preparation for the data processing the Total Propagated Uncertainty (TPU) was computed for each sounding project to ensure that the processed data will meet the International Hydrographic Organization (IHO) standards (IHO, 2008). The TPU EDITOR module of HYPACK was used in computing TPU for each project. The TPU EDITOR has 3-tabbed dialogues where the user must enter the general, environmental and sensor information.

Figure 1 illustrates the TPU graph for the surveying projects. In the Graphs, the red horizontal line represents the estimated standard deviation computed according to IHO Special Order (in yellow).

Figure 1: Depth uncertainty for the survey projects.

The IHO depth uncertainty is then extracted from the Depth Uncertainty graph (m) and then converted to one-sigma standard deviation according to the associated project depth unit. The computed one-sigma standard deviation is used in MBES data processing in Phase III of the HYSWEEP Editor module of HYPACK.

3. MBES DATA PROCESSING

MBES data processing, using HYPACK (HYPACK, 2010),went through several steps: applying corrections, reading parameters, raw data review (Phase I), swath-based editing (Phase II), area-based editing (Phase III) and saving the results. During data processing, the processing time was kept between the start of the first step and the end data storage.

For each cell, the HYSWEEP Editor computes the SD, based on the distribution of z-values contained in the cell. Cells with an SD value that exceeded the value derived in Standard Deviation Computation were then visually examined in order to remove any remaining outliers. Finally the data is stored in two XYZ ASCII format files. The first file stored the depth value for each data point as the Z-value. The second file stored the SD value for each data point as the Z-value.

4. UNCERTINITY ANALYSIS

The goal of this step was to examine the changes to the standard deviation of each data set, upon completion of processing, according to the surveyor (editor) and the beam angle limit.

The SD output HYSWEEP Editor Phase III stores the data in three columns; the X and the Y (Easting and Northing), the 3rd column represents the 1σ SD. For each data set, every surveyor generated a separate 'SD' file using the 45°, 60° and 75° Beam Angle limits.

The resulting files were imported into an Excel spreadsheet, converted to 2σ SD, and correlated according to its SD value from 0.00 to 0.91 (US Survey feet or meters according to the project depth unit) using separation steps of 0.02 horizontally. At the end of each column, the total number of occurrences for each SD step value is shown.

The uncertainty analysis is summarized in Table 1 where the second and third rows summarize the σ SD of 68% and 2σ SD 95% of the data points for each project. The last row summarizes the percentage of data points that meets IHO Special Order standards.

Table 1: Uncertainty summary in 2σ SD (meters).

	Before Dredging			After Dredging			Artificial Reef		
	45°	60°	75°	45°	60°	75°	45°	60°	75°
maximum	0.53	0.55	0.57	1.55	1.74	2.25	1.62	3.09	6.43
68%	0.06	0.06	0.09	0.04	0.08	0.20	0.07	0.17	0.2
95%	0.08	0.08	0.15	0.12	0.15	0.29	0.13	0.29	0.33
Special Order %	98	98	95	98	95	56	87	74	62

The Beam Angle Limit has proven to have a significant effect on achieved uncertainty. This is shown in Figure 2 where: SD increases as beam angle increases

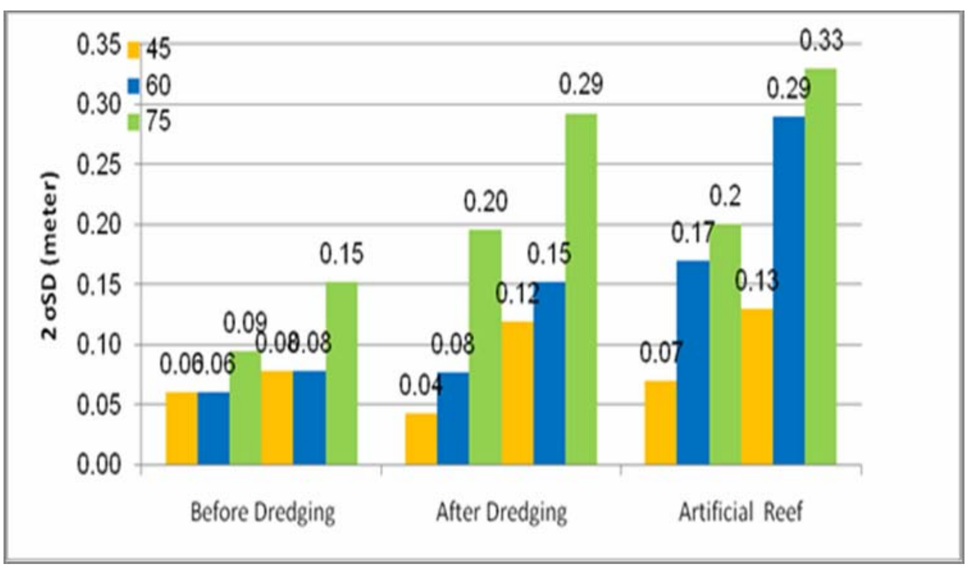

Figure 2: 68% and 95% 2σ SD sounding uncertainty (the first three bars from the right in each project are 68% and the second three bars: 95%)

5. PROCESSING TIME ANALYSIS

Table 2 provides average processing times for the three surveyors for each survey project and the three processing angles are listed as the Beam Angle Limits of 45°, 60° and 75°.

Table 2: Processing time (Min per km) for the Beam Angle 45°, 60° and 75°.

Processing Angle	Philadelphia	New York	Before Dredging	After Dredging	Artificial Reef
45°	20	33	5	7	2
60°	28	42	8	17	2
75°	49	68	11	25	3

The results show that: Increasing beam angle limit will increase processing time.

6. VIRTUAL SURVEY AREA

A ‘virtual’ survey area was created to investigate the previous results in terms of time, and its equivalent cost, for both field and office work. The dimension of the survey area was taken 1km x 10km and the investigation was conducted using an average depth of 10m. It is assumed that the area is parallel to the coastline along with its 10km side. Three scenarios were used for conducting the survey by using the Beam Angle Limits of 45°, 60° and 75°. In all the three cases the swath to swath overlap was set to 30%.

Using the equation (50TH MULTIBEAM SONAR TRAINING COURSE, 2009)

$$v_{min} = C\tan(\alpha)\cos\left(\frac{\theta}{2}\right)$$

$v_{overlap}$	$speed\ that\ maintain\ ping\ to\ ping\ overlap\ \left(\frac{m}{s}\right)$
v_{min}	$minimum\ speed\ \left(\frac{m}{s}\right)$
C	$speed\ of\ sound$
α	$for-aft\ beam\ angle$
θ	$swath\ width\ (degree)$

The 45° swath angle speed = 1500 tan (1.5) cos (45°) =27 m/s = 53 knots.
The 60° swath angle speed = 1500 tan (1.5) cos (60°) = 19 m/s = 38 knots.
The 75° swath angle speed = 1500 tan (1.5) cos (75°) =10 m/s = 19knots.

According to sonar configuration, the computed limits of the survey speed are very high. However, as a quality control measure, we have limited the maximum speed for the ‘virtual’ survey to 5 knots (9.26 km/hr) (Engineering and Design, 2004).

According to the processing time analysis, there are several factors that could affect the estimated processing time for the virtual area other than the processing angle. These factors include; editor experience level, type of survey, sea state, seabed complexity and raw data size. For the purpose of illustrating the effect of processing angle on the office cost, two different scenarios were studied:

1. a simple seabed and standard survey operation where the average processing times are 5, 8 and 11 min/km. (45°, 60° and 75° degree Beam Angle Limits, respectively). (Survey **S**)
2. a complex seabed or dredged area survey where the average processing times are 7, 17 and 25 min/km. (Survey **D**)

According to a 2010 survey conducted by HYPACK on several private hydrographic survey agencies, it was found that the average daily rate for a MBES survey ship is $5,000 and the office work is $1,200. This is based on 8 working hours per day. Based on this cost model, the estimated costs of collecting and processing the data from our virtual area could be computed and compared, using each of the Beam Angle Limits.

7. AVERAGE DEPTH OF 10m

The costs for collecting data over our virtual area with a uniform depth of 10m, using different beam angle limits and our estimated cost of $5,000 per survey day are shown in Table 3.

Table 3: Field cost computation for average depth of 10 meters.

Swath (angle)	Depth (m)	Line Spacing (m)	line spacing with 30% overlap	Number of lines	Total Length (km)	Time (hr)	Time (Days)	Field Cost ($)
90°	10	20	17	60	598	65	8	40,000
120°	10	35	29	35	350	38	5	25,000
150°	10	75	63	17	168	18	2	10,000

The costs for processing this data collected over our virtual area with a uniform depth of 10m are shown in Table 4.

Table 4: Office cost computation for standard survey operation in average depth of 10 meters.

Swath (angle)	Total Length (km)	Processing time (hr)	Processing time (Days)	Office Cost ($)
90°	598	50	6.3	7,560
120°	350	47	5.9	7,080
150°	168	31	3.9	4,680

Table 5 summarizes the total data collection (Field) and data processing (Office) costs, along with the total cost for each Beam Angle Limit.

Table 5: Total cost computation for standard survey operation in average depth of 10 meters.

Swath (angle)	Field Cost ($)	Office Cost ($)	Total Cost ($)
90°	40,000	7,560	47,560
120°	25,000	7,080	32,080
150°	10,000	4,680	14,680

The costs for collecting data over virtual area with a complex bottom and an average depth of 10m would be the same as the costs for collecting the data over the uniform bottom. The costs for processing this data collected over virtual area with a complex seabed and an average depth of 10m are shown in Table 6.

Table 6: Office cost computation for dredging survey operation in average depth of 10 metres.

Swath (angle)	Total Length (km)	Processing time (hr)	Processing time (Days)	Office Cost ($)
90°	598	70	8.8	10,560
120°	350	99	12.4	14,880
150°	168	70	8.8	10,560

Table 7 summarizes the total data collection (Field) and data processing (Office) costs for a complex bottom with an average depth of 10m, along with the total cost for each Beam Angle Limit.

Table 7: Total cost computation for dredging survey operation in average depth of 10 meters.

Swath (angle)	Field Cost ($)	Office Cost ($)	Total Cost ($)
90°	40,000	10,560	50,560
120°	25,000	14,880	39,880
150°	10,000	10,560	20,560

8. UNCERTAINTY vs. COST

Uncertainty versus cost could be inferred by combining the uncertainty results and virtual survey area costs for standard and complex area.

8.1. Standard Area

Using the 95% of Uncertainty values for the Before Dredging study:

- At 45° the 95% 2σSD: 0.08m

- At 60° the 95% 2σSD: 0.08m
- At 75° the 95% 2σSD: 0.15m

Total Costs for the standard survey operation, over the 10m deep seabed (as listed in Table 5):

- 45° Beam Angle Limit = $48,000
- 60° Beam Angle Limit = $32,000
- 75° Beam Angle Limit = $15,000

Moving from 45° to 60° Beam Angle Limit Savings = $16,000, Increased Uncertainty = 0 m .
Moving from 60° to 75° Beam Angle Limit Savings = $17,000, Increased Uncertainty = 0.07m

Increasing the beam angle limit from 45° to 60° did not affect the uncertainly of the survey results and yielded a saving of $16,000. Increasing the beam angle limit from 60° to 75° yielded a saving of $17,000, but resulted in an increase of 7cm to the average uncertainty of each sounding.

8.2. Complex Area

Using the 95% of Uncertainty values for the Artificial Reef study:

- At 45° the 95% 2σSD: 0.13m
- At 60° the 95% 2σSD: 0.29m
- At 75° the 95% 2σSD: 0.33m

Total Costs for the Dredged, Complex, Area over the 10m deep seabed (as listed in Table 7):

- 45° Beam Angle Limit = $51,000
- 60° Beam Angle Limit = $40,000
- 75° Beam Angle Limit = $21,000

Moving from 45° to 60° Beam Angle Limit Savings = $11,000, Increased Uncertainty = 0.16m.
Moving from 60° to 75° Beam Angle Limit Savings = $19,000, Increased Uncertainty = 0.04m.

Increasing the beam angle limit from 45° to 60° resulted in a cost savings of $11,000, but increased the average uncertainty of each sounding by 16cm. Increasing the beam angle limit from 60° to 75° resulted in an additional saving of $19,000, but increased the average uncertainty of each sounding by an additional 4cm.

9. CONCLUSIONS

Although using smaller MBES swath angles will reduce the processing time per km, the number of survey lines will increase causing both the total field and office times to increase. This results in a higher total survey cost.

Sounding uncertainty should be taken into account when selecting the swath angle. Different factors could affect the uncertainty such as seabed complexity, type of the survey and sea state. In all aspects, decreasing the Beam Angle will improve the uncertainty.

Factors that influence the time required for MBES data processing include the Beam Angle Limit, seabed complexity, and raw data size.

Increasing the beam angle limit for a survey will result in lower overall survey costs (particularly data collection costs), but will result in a greater average depth uncertainty for each sounding.

10. FUTURE STUDY

During this research, standard processing techniques were used; however, this work could be expanded to investigate the same objectives using an automated processing approach such as CUBE (Calder B.R., and L. A. Mayer, 2001). Estimating the required time of processing is important for survey planning but it is a function of several factors. Therefore more effort could be spent in its modeling in order to incorporate all factors in one estimating function.

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BIOGRAPHICAL NOTES

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Dr. Mesbah is currently the Dean of Education Affairs and Scientific Research in Arab Academy for Science and Technology and Maritime Transport, Alexandria, Egypt. He worked in Faculty of Marine Science, King Abdulaziz University (KAAU), Saudi Arabia from 1989 until 1998 during which he was appointed as a chairman of Marine Physics department. In U.S.A., he worked as an adjunct research professor at Naval Postgraduate School (NPGS), CA during (1986-1987). He joined the Civil Engineering Department, faculty of Engineering, Alexandria University as a lecturer and the Institute of Coastal Research in Alexandria as a visiting researcher from 1987 to 1989.

Mohamed MOHASSEB

Dr. Mohasseb is currently the head of surveying operation in Egyptian Naval Hydrographic Office and Hydrographic survey instructor in Arab Academy for Science and Technology and Maritime Transport (AASTMT), Alexandria, Egypt. He had his CAT B certificate from US naval oceanographic office in 1998, Master of Science degree from AASTMT in 2001, PhD degree from AASTMT in 2006 with the award of best desertion, CAT A and Master of Science with the award of Outstanding Academic and practical performance from University of Southern Mississippi 2009.

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Pat Sanders is President of HYPACK, a software company that creates products for the hydrographic survey industry. He is also serving his second tour as President of The Hydrographic Society of America. He holds a BSE and MSE in Civil Engineering from the U. of South Florida and an MSIA from Carnegie-Mellon U. Pat resides in Durham, CT, USA.

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