Side-Scan Sonar And Multi-beam Surveys in Dredging Projects

Are Both Techniques Necessary?

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Both side-scan sonar and multibeam have evolved from expensive and complex systems to user-friendly and affordable techniques. Although both systems are tools to describe the morphology and nature of the seabed, they have inherent differences with both their merits and demerits. Although some hydrographers start to question the use of a side-scan sonar in projects in which a multibeam is already being deployed, it must be stressed that both techniques produce complementary results and that the integration of both systems offers a synergy that increases highly the value of the obtained survey results.

Introduction

The dredging industry relies on a number of geophysical tools to visualize the seabed and to solve a number of problems frequently encountered such as the location of suitable sand for reclamation purposes, the identification of debris on the seabed and the mapping of rock outcrops.

The survey department of Dredging International has been using in particular dredging projects a combination of side-scan sonar and multibeam equipment to analyse the seabed characteristics.

This presentation will focus on the advantages and disadvantages of both techniques and demonstrate that in many projects the use of a side-scan sonar next to a multibeam increase significantly the quality and diversity of the obtained results.
Side-scan sonar has been for a long period the only available instrument for mapping seabed features on a broad scale. Side-scan sonar images consist of a series of lines, one per transmission-reception cycle, displayed perpendicularly to the survey track. On each side of the track, a single line segment represent the echoes received from the seafloor for a given ping as a function of slant range [1]. The side-scan sonar image reflects as well the composition and distribution of the seabed sediments as each sediment type absorbs and reflects a different amount of the acoustic energy produced by the sonar transducers. The resulting side-scan sonar image presents therefore different acoustic facies (from dark to pale) that can be translated in sedimentological facies by ground truth operations such as grab sampling [2].

Many hydrographers who have worked with side-scan sonar in the early days remember that although acquisition was straightforward, the processing of hundreds metres of paper roll was something of a nightmare. Patience of a monk was a primary necessity to translate the features visible on the paper recordings to a line drawing on a track plot. The raw side-scan sonar image suffered from numerous distortions and artefacts because of a number of reasons such as (i) the transversal scale, function of the slant range, was different from the longitudinal scale, (ii) the longitudinal scale would vary as it was function of the vessel's speed, (iii) the survey track was rarely straight and (iv) the attitude of the tow fish (heading, roll and pitch) was not constant. However in the last 20 years the digitalisation of the raw side-scan sonar signals and the development of new software programs made it possible to create fully corrected mosaic images similar to corrected aerial photographs, that can be superimposed on depth charts of arbitrary scale, datum and projection method.

Since the early 1990's the development of multibeam systems provided a new method for describing the morphology of the seabed [3]. Multibeam echosounders emit a fixed number of beams from a single transducer. Incident energy is emitted upon the seafloor and then either absorbed or reflected back to the transceiver. A multibeam system measures both the elapsed time and strength of the acoustic-electric signals being returned to the transceiver. This returned signal is converted into a digital depth calculation [4]. The received acoustic echoes contain as well information on the nature of the seafloor itself. By analysing the backscatter intensities of the received beams it is possible to make a classification of the seabed sediments [5], [6].

In the following case studies multibeam surveys were carried out together with side-scan sonar. We will comment on the benefits that the side-scan sonar results presented next to the ones obtained with multibeam.

Case Study Lulu Island, Bahrein

Dredging International, operating under the DEME group, was responsible in 2004 for the creation of an artificial island of 552 000 m² called Lulu Island located 200 m off the Bahrain Financial Harbour of Manama, Bahrain. The purpose of this reclamation was the creation of residential and leisure development, including hotels, shops marinas and leisure facilities.

Photo 1: Side-scan sonar fish fixed at the extremity of a steel pole. Note the echosounder transducer attached to the sonar fish.

Photo 2: Multibeam transducer being attached at the extremity of a steel pole.

The main objectives of the multibeam and side-scan sonar surveys were:

- to chart the access channels and to detect all obstacles between the sand borrow areas and the dumping site to provide a safe navigation for the dredging vessels as coastal waters are extremely shallow;
- to detect all obstacles that could hamper the dredging operations in the reclamation area in which a superficial muddy upper layer had to be removed;
- to map the presence of sandy sediments in the sand borrow areas.

A GeoAcoustics side-scan sonar system was used coupled to a digital TritonElics acquisition and processing system. As water depths were extremely shallow the tow fish was fixed to a pole. Such a fixed towfish deployment (photo 1) is the appropriate solution to survey shallow waters: (i) the exact position of the towfish and hence of all objects lying on the seabed is known with great accuracy as all offsets between the positioning antenna and the sonar fish are constant and (ii) the depth of the sonar fish is constant even during turns and sudden ship's manoeuvres what makes the side-scan sonar operation a less stressful activity than when using a towed fish.

All recordings were carried out with the 410kHz frequency and a slant range of 60 to 80m was used.
A Reson Seabat 8101 multibeam echosounder was used during the project. The transducer was installed at the end of a pool fixed on the ship's bow (photo 2). An Octans II sensor provided heading and attitude information. All acquisition and processing were performed with the help of QINSy software.

A significant advantage of side-scan sonar is that the slant range is independent of the water depth. This is particularly true when working in very shallow waters [7]. With a water depth of for example 5m, high resolution side-scan sonar images were produced over a width of twice 60m while the swath coverage of the multibeam amounted to twice 20m.

The advantage of being able to scan the seafloor with the side-scan sonar over a distance twice as wide as the multibeam track interval was made clear to the survey team during the first measuring day. The side-scan sonar recording revealed a small but nevertheless impressive coral reef (figure 1) that rose above the flat seabed. The reef, with a water depth at its summit of less then 1 metre, was positioned exactly on the next multibeam track. Without the detection of the reef with the side-scan sonar, the multibeam transducer positioned at the bow would have been crushed when sailing the adjacent track.

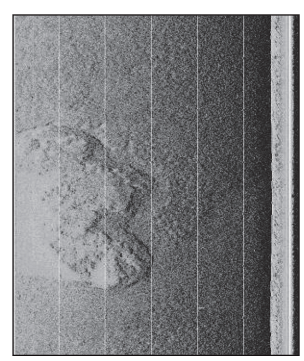

Figure 1: Port side-scan sonar channel of a small coral reef; slant range 60 m, distance between white lines: 10m.

Side-scan sonar therefore was used through the entire survey as a safety tool and was carried out along all multibeam tracks although a complete coverage would have been obtained with recordings every three multibeam tracks.

A problem encountered during most of the side-scan sonar surveys is that the processing time exceeds the processing time of multibeam data. However the project needs were such that one day of side-scan sonar and multibeam acquisition had to be processed in one day. Such a ratio of 1 to 1 is difficult to reach for side-scan sonar data, as a lot of time is lost during the bottom tracking. Digitising the exact position of the seabed is of capital importance for the creation of sonar mosaics and for the calculation of the correct positions of features on the seabed. The whole process of bottom tracking was eliminated by mounting a high-resolution shallow-water echosounder transducer on the sonar fish (photo 1). The height of the sonar fish was measured continuously by this transducer and was defined as the primary fish height in the acquisition software. As fish height data were of excellent quality even in turbid waters, bottom tracking was limited to a fast control allowing sonar mosaics to be created in a ratio of 1 day processing for 1 day of acquisition.

Having created the side-scan sonar mosaics, it became clear that they were an excellent tool for gaining insight in the sedimentological characteristics of the seabed sediments. This was of primary importance, as large quantities of sand were needed to carry out the reclamation work of Lulu Island. Figure 2 is a fragment of one of the side-scan sonar mosaics that were created. The large number of dredging marks on the seabed reveals the former sand dredging activities carried out in the framework of other projects. Figure 3 is the sedimentological interpretation of the mosaic shown in figure 2. These maps were used to detect the remaining presence of sand and to locate the presence of coral reefs that could damage the suction pipe of the dredger.

Case Study Weissebank, Germany

DEME Building Materials (a DEME subsidiary for winning, processing and supply of sea aggregates on the North-European market) extracts coarse sand and gravel on the Weissebank area located 45 miles off the North German coast. Extraction of the aggregates is performed with the 5000 m^3 trailing suction hopper dredger Charlemagne in water depths of around 25 m.

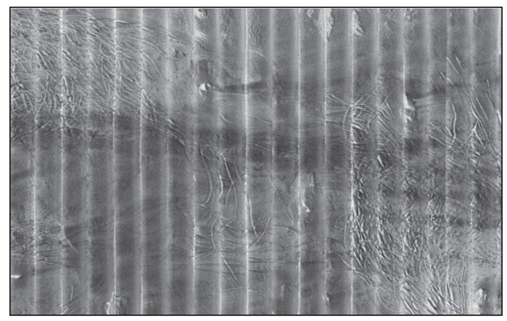

Figure 2: Fragment of a side-scan sonar mosaic (approx. 1200m by 750m). Note the numerous dredging marks.

A multibeam and side-scan sonar survey was carried out in March 2005 to monitor the topographic evolution of the seabed and to map the remaining patches of coarse sand and gravel in order to assist with dredging planning.

A GeoAcoustics side-scan sonar system was used coupled to a digital Coda acquisition and processing system. As the survey was carried out with the dredger Charlemagne some logistic problems concerning the deployment of the equipment had to be solved.

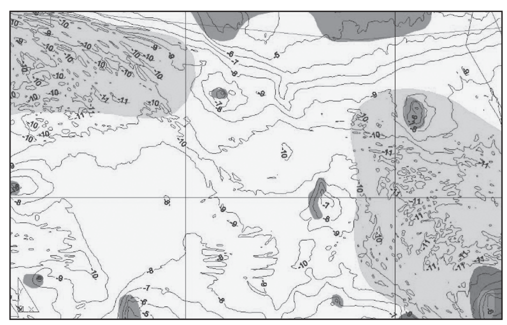

Figure 3: Fragment of the sedimentological interpretation (approx. 1200m by 750m) of the sonar mosaic shown in figure 2. Colours represent the sediment type.

The sonar fish has to be towed, as there was no possibility of using a fixed pole. Towing could however not be performed from the afterdeck due to the important ship's wake. The sonar fish was therefore towed on starboard with the help of a steel tube of 4m length. As the fish had to be lowered beneath the ship's hull in order to obtain good data on both channels, a lot of cable would have been veered out due to the impressive ship's draft. As this would not be a very safe option another deployment method had to be found. A hydrodynamic lead fish of 50kg was used to pull the sonar fish to a maximum depth with a minimum length of cable (photo 3). This method was used through the entire survey and gave excellent results.

All recordings were carried out with the 410kHz frequency. The sailed tracks had an interval of 150m. A range of 80m per channel was used during the side-scan sonar survey. This setting allowed a complete coverage of the seabed in order to produce a sonar mosaic of the entire area.

Photo 3: A 50kg lead weight made it possible to bring the sonar fish to a suitable depth while using a short length of cable.

A Reson Seabat 8101 multibeam echosounder was used during the project. The transducer was installed on a pole located on the ship's port side. The pole was attached to a steel plate that could move vertically allowing the transducer to be lowered under the ship's hull (photo 4). An Octans II sensor provided heading and attitude information. All acquisition and processing were performed with the help of QINSy software.

The acoustic facies visible on the sonar mosaic (fig. 4) could be used for mapping the different sediment types and for detecting the remaining areas suitable for aggregate extraction.

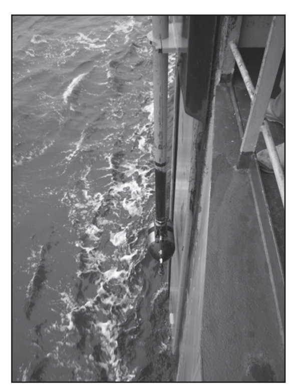

Photo 4: The Reson Seabat 8101 transducer attached to the extremity of a steel pole.

Case Study Tricolor

Side-scan sonar is still the most suitable tool when searching for debris lying on the seabed. A multibeam system can produce excellent results in this application only when positioned very close to the seabed. Magelas has been involved in the last 10 years in a large number of wreck removal projects in which both side-scan sonar and multibeam have been used simultaneously. In nearly all cases smaller debris could only be detected with side- scan sonar.

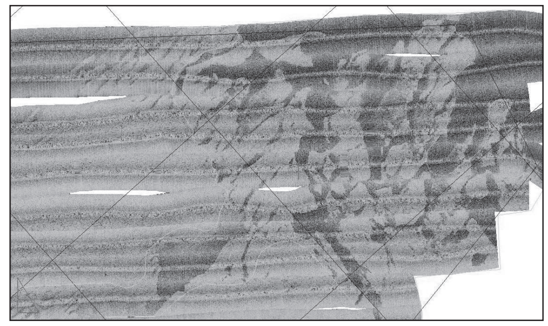

Figure 4: Section of a side-scan sonar mosaic (approx. 2.5 by 2.5km) recorded on the Weissebank area. The darker patches represent the coarsest sediment.

This is not surprising when the resolution of both techniques is compared. When working in a water depth of 30m, a Reson Seabat 8101 will produce one data point per 2m in a transversal direction while a side-scan sonar will have a transversal resolution of ± 10cm (while using a slant range of 80m).

As an example of a debris survey, the case of the Tricolor is presented. The 1987-built Tricolor was lost following a collision with the container ship Kariba. The Tricolor was en route from Antwerp to Southampton and transported nearly 3000 cars. The vessel suffered severe damages and went down in less than half an hour. A multibeam and side-scan sonar survey was carried out to prepare the removal of the wreck and all debris.

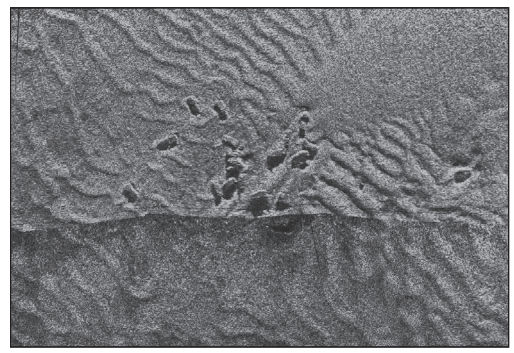

Figure 5: Fragment of a side-scan sonar mosaic (approx. 130m by 90m) showing multiple car wrecks from the Tricolor.

A GeoAcoustics side-scan sonar system was used and all recordings were made with the 410kHz frequency. An Atlas Fansweep was used for the multibeam survey. All multibeam data was processed in a regular grid of 1m by 1m. Water depth around the wreck was around 30m.
Figure 5 gives an example of a section of the side-scan sonar mosaic on which several cars can be clearly observed.

Multibeam data from the same seabed section was processed into several end products such as Shaded Relief Images and 3D images (figure 6). A careful analysis of these images reveals some seabed anomalies but a clear detection of the cars cannot be performed.

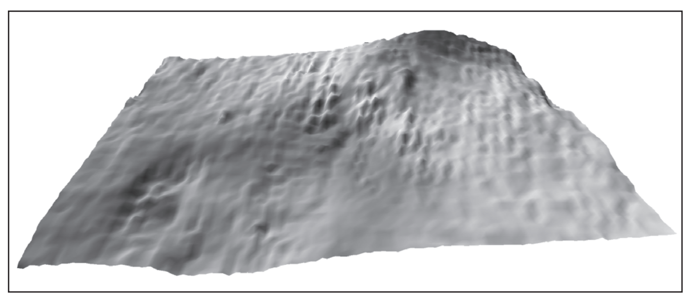

Figure 6: Fragment of a 3D surface (approx. 130m by 90m) based on a 1m by 1m grid derived from the multibeam recordings.

References

[1] **Cervenka, P. and de Moustier, C.**, Sidescan Sonar Image Processing Techniques, IEEE Journal of Oceanic Engineering, 18 (2), 108-122, 1993.

[2] **De Moor, G. and Lanckneus, J.**, Acoustic teledetection of sea-bottom structures in the Southern Bight, Geologie, Belg. Vereniging voor Geologie, 97 (2), 199-210, 1988.

[3] **Locat, J. and Sanfaçon, R.**, Multibeam Surveys – A Major Tool for Geosciences, Sea Technology, June 2002, 39-47, 2002.

[4] **Kearns, T.A.**, Remote Sensing and Multibeam Hydrography, Sea Technology, October 2002, 21-27, 2002.

[5] **Preston, J.**, Acoustic Classification by Sonar, Hydro International, 8 (3), 23-25, 2004.

[6] **Bentrem, F.W., Avera, W.E. and Sample, J.**, Estimating Surface Sediments Using Multibeam Sonar, Sea Technology, June 2006, 37-40, 2006.

[7] **Kamoshita, T., Sata, Y. and Komatsu, T.**, Hydro-Acoustic Survey Scheme For Sea-Bottom Ecology Mapping, Sea Technology, June 2005, 39-43, 2005.

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