High resolution seismics for optimised survey results in fluid mud area’s

General practice and principles

In many of the world’s most important ports and harbours the presence of unconsolidated material suspended in the water column requires the hydrographic surveyor to pay particularly close attention to good survey practices and techniques. The high-frequency pulses emitted by most echo sounders reflect off even a very sparse accumulation of material in the water column. Low-frequency transmissions, though able to penetrate this low-density material, are subjected to alterations in the reflected pulse.

All modern echo sounders and high resolution seismic profiling systems utilise similar basic modes of operation. The area beneath the transducer is pulsed by a transmit beam. This beam reflects off the bottom and the returned signal is received and processed. The elapsed travel time is converted to a range, and then a depth, by applying the velocity of sound. The point on the bottom represented by the return signal alters the pulse in amplitude and frequency. Transducer characteristics, as well as angle of incidence and reflective properties of the bottom determine the overall quality of the return signal.

Echosounder vs. High resolution seismic profiling

High resolution seismic profiling is in principal similar to low frequency echosounder techniques:

- Frequency range veries from 20 to 40 kHz and transducers are exchangeable
- Transceiver send/receive parts are similar

The major difference of the techniques is in the signal treatment and the resulting output.

- Echosounding focuses on providing a direct single depth value per channel.
- To define top and bottom of fluid mud in traditional echosounding requires 2 channels: high and low frequency.
- High resolution seismics focuses on acquiring the return signal in its raw form of a frequency that has sediment penetrating characteristics (Low frequency) and in such a way that each return per ping is comparable.
- The acquired acoustic return signal from a single ping holds information on the top and bottom of the mud layer

Figure 1 shows a high resolution seismic record with the echosounder low and high frequency digitisation projected. Though it compares to the digital form of the paper roll of the low frequency, the seismic record digitally holds information on frequency and amplitude alterations. These characteristics can be used for autotracing.and calculating density.

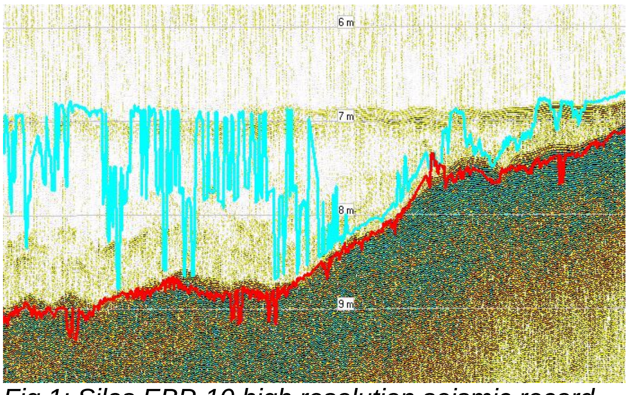

Fig 1: Silas EBP-10 high resolution seismic record with 210 kHz (blue) and 33 kHz (red) echosounder channels projected

Echosounder operation

In fact the echosounder technique requires a-priori settings for digitising a depth value from the acoustic return. These settings include:

- Operating frequency selection: ratio reflected signal/transmitted signal on low density contrast is frequency dependant.
- Output power and gain settings.

- Detection sensitivity for reflected pulse (treshhold).

Especially in area's with soft bottom types not a single setting can be used to arrive at a stable digitisation. Damping of the signal by sediment particles in the watercolumn and mud layers and variable waterdepth and layerthickness all influence the strength of the returnsignal. Most echosounders accommodate for these effects by auto power and (variable) gain settings. The echosounder automatically changes its settings to acquire stable depth digitisation.

All settings are a-priori settings. If not chosen correctly or in multilayer conditions, as often is the case in muddy areas, the incorrect transition is digitised, erroneous data is recorded. If noticed after the survey resurvey is the only option. The on-line surveyor has to tweak the settings during the survey based on the echo roll presentation most likely continuously. In figure 1 the settings of the 210 kHz frequency results in spiky data that is only partially correct.

The use of multibeam echosounders in soft bottomtypes is even more critical. Detection algorithms need to compensate for angle of incidence. In figure 3 shows a cross section of a 240 kHz multibeam dataset showing the effect of digitising the solid bottom around the nadir and the top of the very soft layer in the side beams. The result of this inconsistent digitisation provides unreliable results. The use of higher frequencies are required and will better describe the top of the fluff in most cases. Detection of layers underneath the fluff will remain problematic and introduce uncertainty in the results.

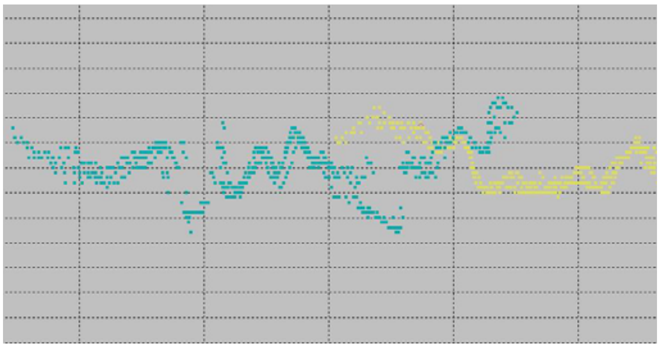

Fig 2: Crossection of multibeam data in a shallow lake environment where a 30-40 cm thick organic fluff layer covered the original peaty bottom. The 240 kHz 3x3 degrees multibeam system digitised the base of the fluff in the nadir section and gradually switched to the top of the fluff in the outer beams.

High resolution seismics

Storing the complete acoustic return in full waveform honours the true raw measurement information. Processingspeed and storage capacity are no longer a (financial) blockage to do so. Ethernet connectivity and easy accessible hard disks make fast data storage and retrievement possible and large datasets can be validated and processed efficiently and fast.

With no technical barrier to store the raw data in digital form, the advantages are clear:

- Rawdata reduces the need for resurvey in case of inappropriate digitisation settings of the real-time depthvalues output (real-time density calculation).
- Advanced autotracing techniques in postprocessing result in more stable depth digitisation and results are calculated in fast batchprocessing procedures.
- Top fluff and base are derived from single measurement with clear interrelationship.
- Stable depth digitisation reduces time effort for despiking.
- Manual correction in cases autotracing parameters do not apply based on visual interpretation of acoustic profile.
- Spikes caused by f.i. misfiring or extreme roll automitical recognition and interpolation possible.
- Acoustic information can be calibrated with in-situ density data to map iso-density levels (advanced feature in combination with f.i. RheoTune).

- In combination with very low frequency transducers the system can be used for geotechnical and object surveys.

Contrary to the echosounder the seismic registration requires fixed power and gain settings. Balancing for layertracing can automatically be done in the autotracing procedures when settings are known. Automatic settings of echosounders are generally not stored and will hamper the autotracing settings. This prohibits the use of the echosounder tracing algorithms and the seismic profiling simultaneously. Alternatively real-time depthvalues can be derived from the seismic record based on previously established coefficients.

Fig 3 shows a typical high resolution seismic record of 33 kHz frequency with autotraced top fluff and base fluff. The line was resurveyed with the dualfrequency and multibeam echosounder and depthdata is projected on the profile. All echosounder digitisation techniques fail to follow the expected interface with changing thickness of the fluffy mudlayer. Autotracing in the seismic profile does follow the visually obvious transitions.

If another frequency is chosen the autotraced depth values will not change due to that choice (fig 4). The choice of frequency will only affect the accuracy of the derived depthvalue and not the reliability. The frequency can also affect the stability of the autotracing procedures. In general, higher frequency transducers (30 kHz to 40 kHz) will provide more precise depth digitisation, due to both frequency characteristics and more-concentrated (i.e., narrow) beam widths. A major disadvantage of higher frequency transducers is that there is high signal attenuation suspended sediments (fluff). Lower frequencies, 15 kHz tot 30 kHz, will thus be able to provide better stable results when disturbance in watercolumn are to be expected and the magnitude of fluff layer is large or relatively dense layers are expected.

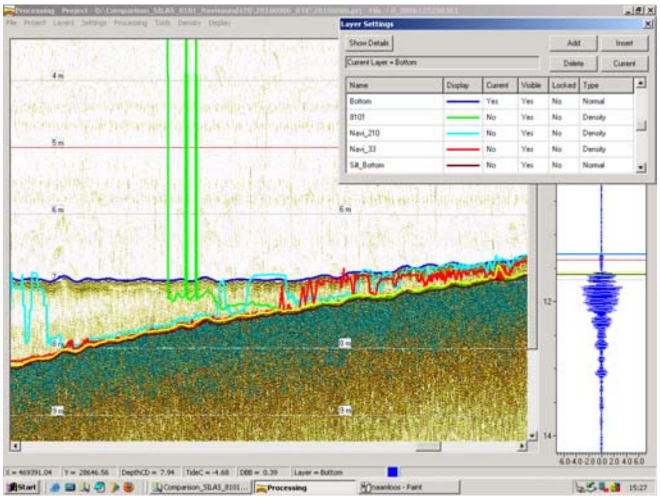

Fig 3: Silas EBP-10 high resolution seismic record (33 kHz source signal) with in postprocessing autotraced top and base of fluff layer (Dark Blue + Yellow). Light blue (SB-210kHz), green (MB-240kHz) and red layers (SB-33kHz) are results from standard echosounder.

Summary

High resolution seismics has advantages over standard echosounder techniques in soft and fluid mud conditions:

- Storage of raw broadband data (traveltime related)
  - Vertical profile of subbottom stored
  - Redigitisation without need of resurveying
  - Acoustic profile replaces "paper roll"
- Stable digitisation of top and bottom fluff
  - Advanced autotracing function (instantaneous process in validation)
  - Real-time autotracing function based on similar routine optional
  - Top and bottom results from same measurement
  - Remaining spikes edited on "paper roll" presentation

   - Easy export based on soundvelocity model for mapping
- System requirements are nearly similar to single beam echosounder.
- In combination with in-situ density probing the system can be calibrated for mud iso-density level mapping

Silas EBP-10
The Silas EBP-10 systems provides an easy to use combination of survey grade echosounder and high resolution seismic system. A wide frequency range is supported:
Echosounder: 200 kHz – 1 MHz
Seismics: 3 – 40 kHz
Easy set-up with Ethernet connectivity and a wide range of tasks can be handled:

- Fluid mud survey
- Nautical depth survey (in combination with in-situ density/yieldstrength probe)
- Pipeline detection survey
- Site Investigation

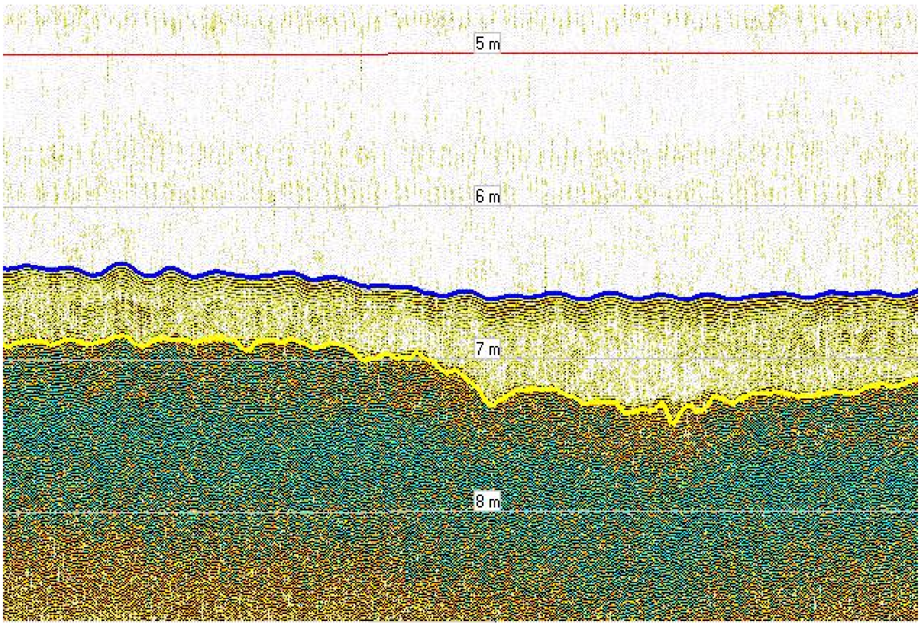

Fig 4: Silas EBP-10 high resolution seismic record (33 kHz source signal) with in postprocessing autotraced top and base of fluff layer. Digitisation is derived from the single frequency response. Reflection is not frequency but mud density dependent.