SEABED MOBILITY AND SHALLOW-WATER SWATHE SOUNDING

Sandwave Migration

The use of swathe systems in a highly mobile, shallow-water environment poses significant problems for the hydrographic surveyor. Several physical factors encountered when gathering swathe data are introduced and described as contributing to degradation of the accuracy model.

The extent of influence by physical/environmental characteristics and the tidal solution on bathymetry must be understood so that methods to obtain accurate bathymetry suitable for safe navigation, seabed migration modelling and future research projects can be employed by the surveyor in real time. Lack of space prevents detailed discussion of such factors here, but this by no means reduces their importance, briefly covered by the author in a paper presented at the Swathe Bathymetry Seminar, Southampton Institute, University College in January 2005.

Scope of Study
For the present purposes, shallow water is defined as the drying line to the 20m contour. The surveys for this study were conducted during the period 12th to 22nd April 2004 and 22nd April to 6th June 2004, respectively, off the coast of East Anglia in the United Kingdom. MV Confidante, a 30m-survey vessel with 1.3m draught, equipped with a dual-head, multi-beam system was used. The primary study area lies north of Great Yarmouth on Cockle Shoal and Cross Sands. Two processing software programmes were used to check consistency of seabed migration and therefore validity of the migration data. Surveying was conducted in a controlled manner, producing survey data at International Hydrographic Organisation (IHO) S44 Order 1 accuracy. Having accounted for all interfaced equipment accuracy and environmental factors, the resultant horizontal and vertical accuracies were Â± 1.5m and
Â± 0.5m respectively.

Mobile Shallow Water
Studies on the migration of bedforms have been presented in many papers posted on the World Wide Web, and in professional publications. However, ripples and mega-ripples have been studied in less detail overall. One factor may be that the rate of change was not apparent prior to swathe investigations and, secondly, high rates of change dictate that any study of this motion needs to be conducted daily, if not hourly, for a significant period of time so that the same features are tracked. A breakdown of levels of relief for bedforms is provided in Table 1. The migration of a large sand-wave, sandbank or dune is of less potential hazard to the mariner due to the small overall rate of change compared to mega-ripples and small (1.5- 7m) sand-waves. For this reason the mariner requires a greater understanding of their mobility.

Extreme Migration
A review of the literature on the morphodynamics of the seabed revealed none with as large a bathymetric and horizontal migration rate of mega-ripples and sandwaves as those experienced off the coast of East Anglia. For this reason the migration within this area has been classed as â€˜extremeâ€™. Extreme migration presents survey difficulties unlike those experienced when using swathe systems in sand-wave fields that migrate only a few metres horizontally in a month. Figure 1 represents seabed migration on Cockle Shoal over the period 17th April (black) to 19th April (blue). Figures 2 and 3 represent seabed migration on Cross Sands over the periods indicated.

Swathe Data Degradation
With the exception of the swathe system being set to work with inaccuracies, and a poor sound velocity observation regime, several practical factors are related to the degradation of data. Primary factors include the following:

- tidal stream and seabed type
- tidal stream - squat and settlement
- time taken to run adjacent or additional lines
- weather
- processing software
- tides
  - co-tide model
  - 30 day analysis
  - proximity of tide gauges
  - GPS / RTK tides

Tidal Stream

Significantly different to a current, tidal current or tidal stream is a result of the rise and fall of the tide based on tide-raising forces, causing an alternating horizontal movement of water. Current is a long-term affect of approximately 30 days or more duration, produced primarily by meteorological effects (IHO, (1994) Hydro- graphic Dictionary, Part 1 Volume 1, Special Publication No. 32, Fifth Edition, Monaco). Two error components are produced from the effect of tidal stream. A combined phenomenon is squat and settlement, the other component is sediment transport, which creates some of the complexities of shallow-water swathe sounding in the first place.

Stream and Sediment

There is a mathematical relationship between the rate of tidal stream and the physical size, and therefore type, of sediment that can be transported. Time period, rate and size will also be a determining factor as to the volume of sediment that can be transported. Leeder (1982 Sedimentology: Process and Product) described the vector forces on sediment particles and explained how a slow flow rate provided sufficient turbulence and therefore uplift force to move small loose grain sediments. That is, sand is uplifted (erosion) more readily into the water column than are all the other sediment types due to its physical characteristics.

Hjulstrom Curve

The charted tidal streams for the survey area reach a maximum of 3 knots (1kt = 51.4cm/sec). Using relative velocity calculations, however, the tidal stream was noted to be higher than the charted ranges but no meters were deployed to provide more quantitative evidence. Suffice to say that the area supports large sediment movement as the seabed is primarily sand and the tidal stream has a velocity consistent with not just sediment transport but also erosion as per the Hjulstrom Curve shown in Figure 4.

Effect on Statistics

The combined result of a higher frequency swathe system, swathe overlap, increased dataset relative to SBES and mobile seabed makes the processing of a dataset more complicated. For example, a pockmark, ripple or small mega-ripple that was present on a survey line thirty minutes ago may, in mobile conditions, no longer exist on the next pass at overlap or mid-swathe. This creates a vertical and horizontal misclose that can cause misrepresentative statistical analysis and/or poor statistical cleaning. Such an effect occurs not only at mega-
ripple scale and below but also at sand-wave scale, over a day or more.

Squat and Settlement

A correction table, or real-time correction, could be applied to survey
data for squat and settlement if tidal stream is measured. Despite monitoring survey-vessel speed over ground via differential Global Positioning System (dGPS), squat and settlement are dependent on speed through the water and depth. This means that the tidal stream needs to be monitored using tidal-stream (current) meter, Acoustic Doppler Current Profiler (ADCP) or onboard speed log. Alternatively, precise GPS could effectively provide depths corrected for tide, squat and settlement in real time with respect to Chart Datum. Without such equipment, misclose could be up to 10-30cm or greater, depending on size of survey vessel, location of swathe transducer, rate of tidal stream, direction of travel and whether or not the swathes are overlapped. This occurrence was observed during survey operations on Cockle Shoal and Cross Sands.

Tide Gauges

Without a proven GPS tide solution, offshore tide gauges are fundamental in achieving surveys of Order 1 or greater for swathe surveys. This is not to say that the gauges will be required to remain deployed throughout the entire survey period. Although this is optimal, a minimum of thirty-day analysis will allow the co-tide chart to be modified at local level, which will reflect any weather factors encountered during the survey and thus increase accuracies. It is imperative to recognise the local-level component for such mobile areas, as changing seabed topography will alter tidal-stream rates and flow direction. The issue of tides and mobility becomes circular as the two drive one another. Thus the co-tidal model created in one year may differ little, or considerably, in later years, mostly due to the change in topography.

Conclusion

It should be well understood that sandwaves change given certain environmental conditions. For charting purposes, practice dictates that sandwave areas should be surveyed "â€¦following periods of calm weather and neap tides when sandwave amplitudes are greatest." (UKHO, 2004). This is important, but what is the length of time required for good weather conditions to achieve this? With swathe systems, due to the enormous data acquisition, accuracy and precision capabilities, the real factor that determines when to survey is the safety of the survey vessel. To get accurate depth data, the factors discussed in this paper need to be understood so that the surveyor can develop the correct sounding and processing plan. Such a plan is driven by the mobility of the area, and thus the surveyor must first assess the rate of seabed migration in order to model the area, rather than try in vain to get the largest amplitude.

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