FINE RESOLUTION ACOUSTIC MAPPING RELATED TO SEDIMENT EROSION SHEAR STRENGTH

S J Hearn (1), H J Williamson (1), M C Ockenden (1) and C B Waters (1).

(1) HR Wallingford Ltd., Howbery Park, Wallingford, Oxon OX10 8BA, U.K.

1. INTRODUCTION

This report describes a field investigation which was undertaken to study the erosion properties of mud and sand mixtures. The main objectives of the study were to measure the distribution of mud and sand in a local intertidal area and to relate the physical properties of the these sediments to the mud/sand composition. The site chosen for this study was Blue Anchor Bay, in the Severn Estuary, U.K. (Fig. 1). This site contained a variety of bottom sediments including areas where mud and sand occurred together either in layers or as a homogeneous mixture.

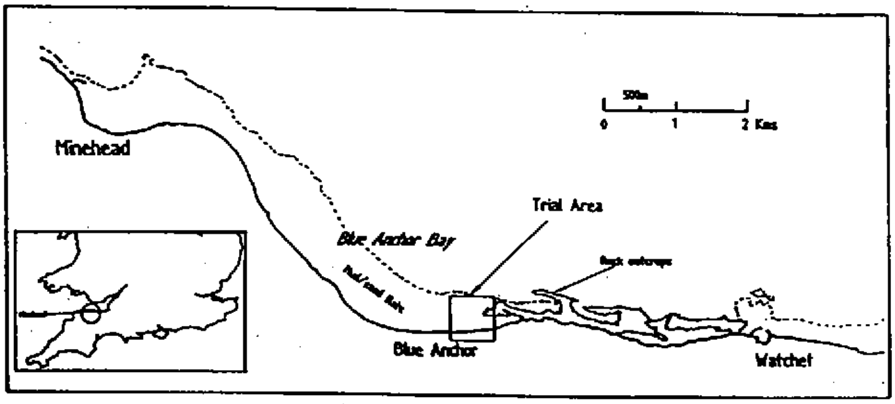

Fig 1 Blue Anchor Bay location plan

An overall acoustic mapping of the bed sediments was undertaken using a USP RoxAnn parallel processing system for analysing echo-sounder signals.

A new instrument was used to measure the surface erosion shear strength at a number of positions. Surface sediment samples were collected for laboratory analysis of mud and sand content and density.

2. METHODOLOGY

The site at Blue Anchor Bay was chosen for the field study because the inter-tidal area included a range of bed sediment types. The large tidal range, (up to 11.8m during the study period), allowed use of the USP RoxAnn system from a 7m survey launch during the high water period and direct access by foot and hovercraft during the low water period.

2.1 Acoustic Mapping

Acoustic mapping from the USP RoxAnn processor, water depths and position were recorded simultaneously, on a PC based navigation and logging system on the survey launch, using the following equipment:

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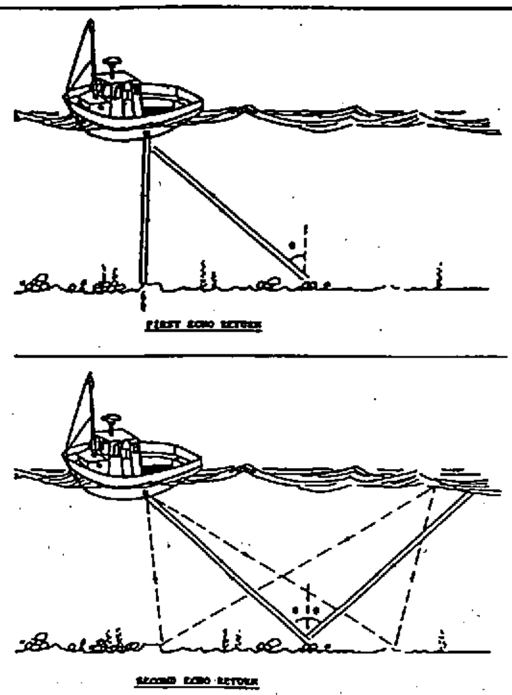
Acoustic mapping:	USP RoxAnn parallel processor interfaced to Koden CVS 106 120kHz echo sounder with overside transducer. E1 and E2 data provided at 3Hz.
Bathymetry:	Raytheon DE719C 208kHz echo sounder with in-hull transducer. Depth data provided at 10Hz.
Position:	Trimble 4000RL on land at reference station, and 4000DL on launch. Data provided at 1Hz. Linked by M-Tel 5 channel telemetry for 1 second data position corrections transfer from RL to DL.
Nav/data logging:	24v DC IBM PC with 110 Mbyte hard disk, twin floppy drive, 8 serial interface ports, integral printer and VDU, separate helmsman's VDU, interface to 4000DL position fixing system, USP RoxAnn processor and DE719C echo sounder.



The origin of the first and second echoes
a) the first echo : both paths shown can, in principle, produce echoes returning to the transducer at the same time.
b) the second echo : the paths assumed in the analysis are the continuous lines. The dashed lines represent other, less probable paths.

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Fig 2 Origin of USP RoxAnn first (E1) and second (E2) echoes

The USP RoxAnn processor (Chivers, Emerson and Burns, 1990)) "extracts two indices: one from the first echo (E1) and one from the second echo (E2) received by the echo sounder transducer fitted to the vessel (Fig. 2). These are then used in combination to identify the nature of the seabed surface material i.e. silt, sand, gravel, rock. The first echo is the direct reflection from the seabed, the second has been reflected twice at the seabed and once at the sea surface before returning to the transducer. In shallow water more multiple echoes may be observed, depending on the transmit power of the echo sounder and the noise level of its receiving electronics. Each echo must, however, include at least one stage of non-specular reflection for a signal to be able to return to the transducer. This is often the oblique back-reflection from the seabed for the first echo (and odd numbered succeeding echoes) and from the sea surface for the second echo (and even numbered multiple echoes)".

The E1 data is a measure of the surface bed roughness and is generated by analysis of the first echo sounding return. The higher the E1 value, the rougher the bed, because of enhanced reflection from the bed surface. The E2 data is generated from the strength of the second echo sounding return and is a measure of the bed hardness. Soft bottom types yield low E2 values because of attenuation of the acoustic signal. The values of E1 and E2 are used to characterise the bottom sediment type into E1 and E2 "boxes". The USP RoxAnn "boxes" are defined by ground truthing data of bottom sediment to determine the range of E1 and E2 values for a certain sediment type. The "boxes" are then used to quantify the sediment type distribution over the mapped area.

2.2 Bed Shear Strength

The bed erosion shear strength was determined using a recently-developed instrument (ETSU, 1992). The field erosion bell (Fig. 3) consists of a circular inverted bell-shaped funnel of 84mm diameter which fits inside a cylindrical perspex tube of 90mm diameter with a small annular space around the edges. The bell is positioned just above the bed sediment. Water is drawn up through the centre of the bell by smooth pumping and is replaced by water drawn down the sides of the bell. The bell is shaped so that the water flow across the surface of the bed is laminar and flows radially towards the bell centre, exerting an even shear stress across the whole of the bed. The water removed through the bell is replaced into the column by recirculation and flows through a diffuser to minimise other circulations in the column.

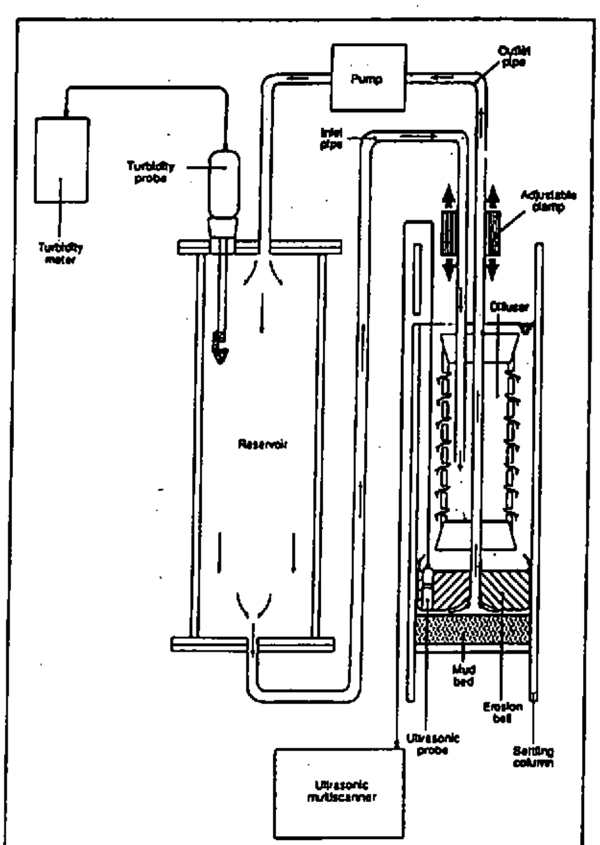

Fig 3 Diagram of erosion bell apparatus

The applied shear stress at the bed is a function of the flow through the bell head and the gap between the base of the bell and the bed sediment. The field instrument was calibrated in the laboratory using hot wire shear stress probes. Erosion is recorded as an increase in suspended sediment in a reservoir in the recirculating system, measured with an optical backscatter probe.

3. FIELD MEASUREMENTS

The survey launch was used during the high water periods on 13 and 14 October 1992 to do repeat surveys of an area of 500m x 500m. Acoustic mapping and bed levels were observed along eleven north-south lines at 50m spacings with additional east-west cross-check lines. The mean survey vessel speed over the ground was about 2m/s. Depth data was logged at 10Hz, which gave bed levels at 0.2m intervals. The USP RoxAnn data was logged at 3Hz, giving E1 and E2 values at intervals of about 0.7m.

Ground truthing data on sediment bottom type was collected to calibrate the USP RoxAnn system to derive E1 and E2 "boxes" for bottom classification. Thirty seven bed samples were used to correlate E1 and E2 combinations with bottom type to characterise the data for ranges of E1 and E2. Size grading was determined for some samples at the Sedimentology laboratory at HR Wallingford. This enabled further definition of the finer sediment areas. Additional data points were added to this plot by combining inspection of the E1 and E2 data set with the observer's visual knowledge of the area.

Figure 4 shows the USP RoxAnn sediment classification "boxes", based on the ground truthing data and USP RoxAnn calibration, which is applicable to the Blue Anchor Bay site. The stratification of the site did not allow further separation of the mud and sand areas in terms of sand content, and there was in general substantial variability in the E1 and E2 values recorded for similar observed surface bottom types. This was attributed to the effect of layering of mud and sand in different subsurface thicknesses, which affected the USP RoxAnn data but was not quantified by a 2-D survey.

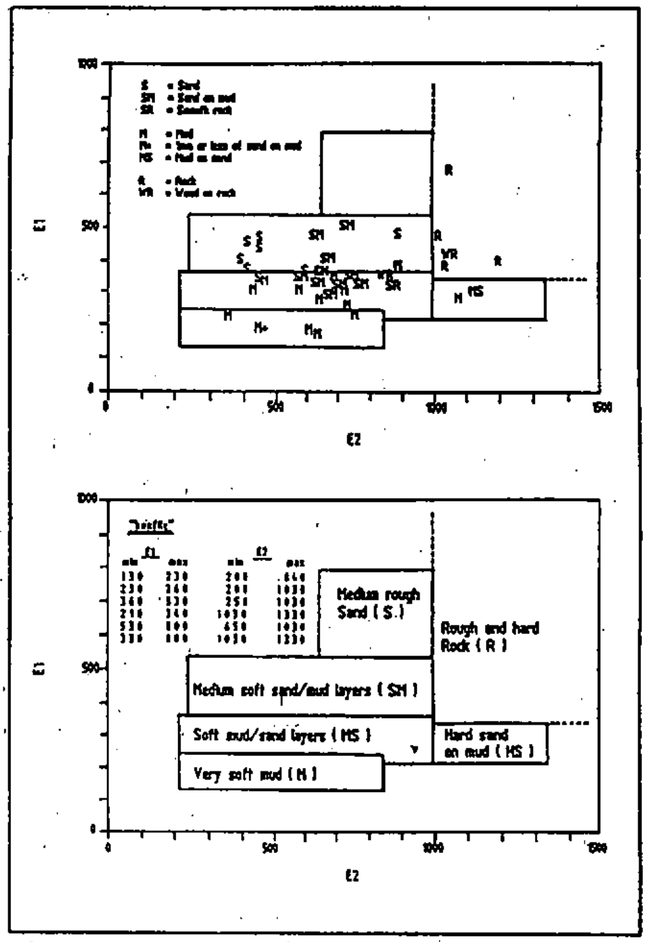

Fig 4 USP RoxAnn calibration data

The bottom sediment classification from the USP RoxAnn survey is shown in Figure 5. The bulk of the survey area was classified as mud, or mud and sand in layers, which is indicated as M, MS or SM on the acoustic mapping chart. The acoustic bed survey was very useful in obtaining a large data set of the spatial distribution of bottom sediments. The acoustic survey highlighted considerable variation in the bottom material on a small length scale of 10m or less, which is considered to be due to the dynamic nature of the site. The USP RoxAnn survey indicated the coverage of bottom type, which could be statistically used to quantify the surface sediments at the site.

From the mapping chart it can be derived that the area is made up of less than 5% rocky surface, approximately 5% of surface sandy deposits, and a large area of soft mud occupying approximately 35% of the area near LW mark. The mud and sand layers form the dominant bottom type for the area, covering about 55% of the site. The chart indicates that there is more mud in the site further towards the LW mark. There is a band of sand/mud layers (SM) to the inshore edge of the site, and a large region of mud sand layers (MS) in the mid-shore region. There is a band of predominantly muddy sediments (M) in the offshore region of the site. This information may suggest that the amount of sand decreases further offshore. The USP RoxAnn data also shows small patches of hard sand or rock (HS and R) across the site.

Surface shear strength measurements were made at 16 sites within the 500m x 500m area using the erosion bell. The bell was deployed from a small hovercraft which allowed easy access to difficult sites and reduced the set up time at each location. At each location the bell was positioned just above the bed surface and the shear stress was gradually increased, using the pump flow controller, until erosion was observed as a rise in suspended sediment concentration. Measurements of flow, turbidity and gap were then measured over a period of about 3 minutes.

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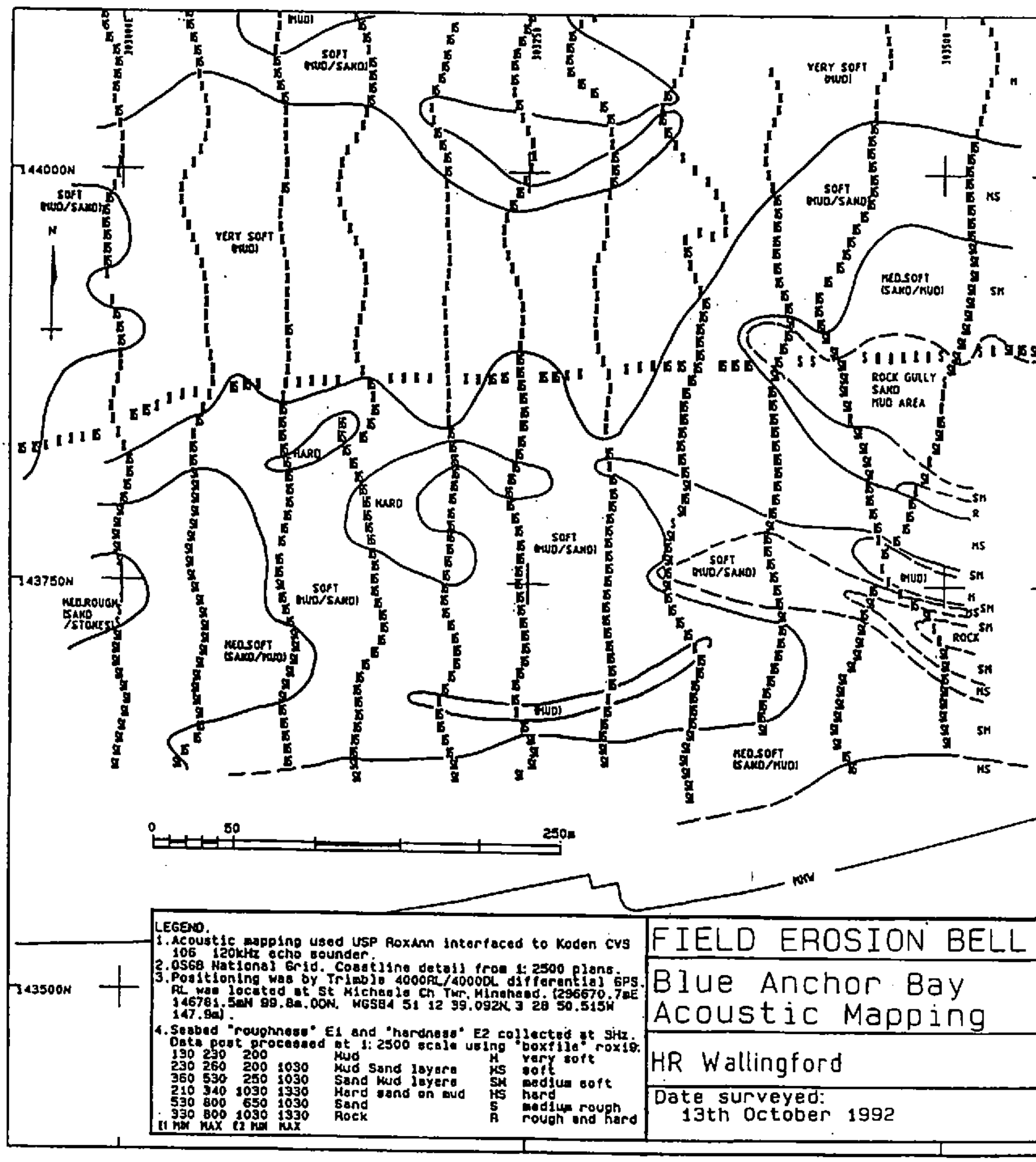

Fig 5 Acoustic mapping of bed sediments

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Surface sediment samples were taken at each of the 16 sites and these were analysed subsequently for density and sand concentration. Measured surface shear strengths varied between 0.14 and 1.89 Nm^{-2} and it was difficult to find any trend in shear stress distribution by geographical area. Variations are thought to be due mainly to local site characteristics such as cliffing areas, gully regions, algae cover etc.

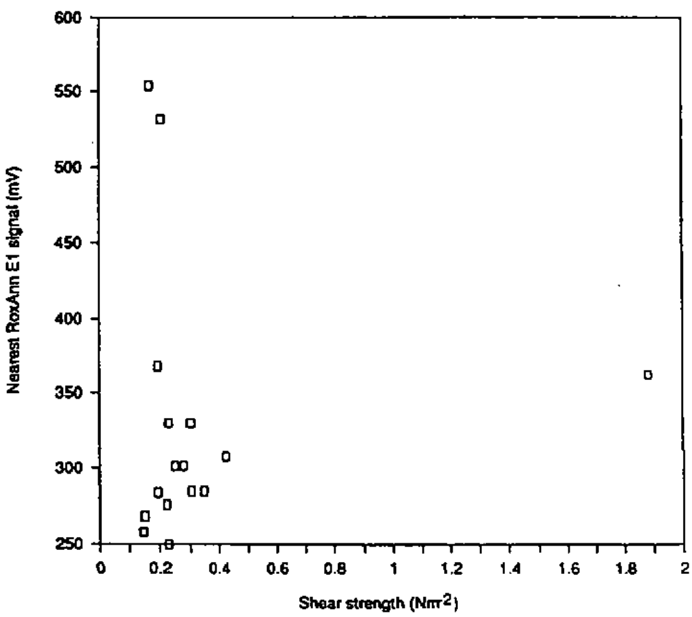

Fig 6 Comparison of USP RoxAnn E1 signal and Field Erosion Bell shear strength

There was more apparent correlation between the measured sediment properties and the E1 signal (roughness) than from the E2 signal (hardness). This suggests that the layering of sediments in Blue Anchor Bay confused the second echo return. Figure 6 shows a plot of the nearest E1 signal and the surface erosion shear strength. Apart from the 3 outliers at high shear strength or high E1 values, there may be a correlation between the two variables. Further measurements are clearly required to establish the relationship.

4. CONCLUSIONS

Vertical layering in the sediment structure was a characteristic feature of the Blue Anchor Bay site. The USP RoxAnn system cannot be used to quantify stratification within the sediments, but the data provided useful 2-D information on the spatial coverage of the site, which could not have been obtained easily otherwise.

There was considerable variation in the measured surface shear strengths, mainly due to local site characteristics. The USP RoxAnn E1 signal (roughness) showed some correlation with shear strength, but layering of sediments appeared to confuse the E2 (hardness) signal.

5. REFERENCES

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(2) ETSU, 1992. In-situ erosion of Cohesive Sediment. Energy Technology Support Unit, Harwell, UK. Report No. ETSU-TID-4112.

6. ACKNOWLEDGEMENTS

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