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RV EDWARD FORBES CRUISE 5/75
2 APRIL – 14 APRIL 1975

INVESTIGATION OF TURBIDITY STRUCTURES IN THE SEVERN ESTUARY & UPPER BRISTOL CHANNEL

CRUISE REPORT NO 23

1975

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Institute of Oceanographic Sciences
Crossway
Taunton
Somerset

CONTENTS

SCIENTIFIC PERSONNEL

			Dates
R Kirby	SSO	Senior Scientist	1 4 75-14 4 75
W R Parker	SSO		1 4 75-9 4 75
G P Le Good	SO		1 4 75-9 4 75
M R Lees	SO		9 4 75-14 4 75
M A S Moore	ASO		1 4 75-14 4 75
C N Puckett	ASO		9 4 75-9 4 75

ITINERY

1 4 75	Commission Edward Forbes in Barry.
2 4 75	Sail from Barry morning tide to work off Avonmouth.
3 4 75	Enter Barry for engine repairs. Sail evening tide.
4 4 75	Work between English and Welsh LV and Barry. Enter Barry evening tide.
5 4 75	Crew Leave.
6 4 75	Sail from Barry on morning tide to work in Bridgwater Bay.
7 4 75	Work off Avonmouth. Enter Avonmouth on evening tide due to unfavourable forecast.
8 4 75	No work possible due to weather.
9 4 75	Crew Leave.
10 4 75	Sail from Avonmouth on morning tide to work off Avonmouth. Enter Avonmouth on evening tide due to unfavourable forecast.
11 4 75	Sail from Avonmouth on morning tide to work in area between Avonmouth and Newport Deep. Enter Barry on evening tide to repair ship's refrigerator and scientific equipment.
12 4 75	Sail from Barry on morning tide to work in Bridgwater Bay. Enter Barry on evening tide to pick up repaired scientific equipment.
13 4 75	Sail from Barry on morning tide to work in Bridgwater Bay.
14 4 75	Work between English and Welsh LV and Barry. Enter Barry on evening tide.

SUMMARY

Vertical profiles and horizontal traverses of turbidity were obtained by repeat visits to approximately 100 standard stations established on cross sections of the Severn. The vertical profiles were measured to investigate the nature and variations of the structure of fine sediment suspensions in estuaries. The horizontal traverses provided information on changes in suspended solids on a regional basis at shallow depth and together with the vertical profiles allow the changes in the three dimensional distribution of turbidity on both a semidiurnal and on a Neap-Spring timescale to be investigated. Recorded turbidity profiles were complex and showed wide variations on both timescales.

OBJECTIVES

The cruise was one of a series commenced in 1974 to investigate the structure of estuarine suspensions as part of the IOS Cohesive Sediment Mobility Project, in the Severn Estuary. On this cruise the emphasis of the work was on examining the temporal and spatial variations in turbidity structure in the area between The Shoots Channel and $3^{\circ}30'W$. The day to day programme was based on the series of standard cross-section lines and stations established for the purpose of these investigations (see track chart). The cruise dates were selected to run from a Neap to a Spring tide and attempts were made to visit each station on the ebb and the flood of a Neap and a Spring tide at least. More information will be gathered in the future so that ultimately we will understand in a predictive sense what types of structure to expect in different parts of the estuary on different tides and weather conditions.

The equipment used for the investigation is a tow fish upon which are mounted 2 siltmeters operating over the range 300-50,000 ppm, a depth sensor, a spot reading and a continuous reading conductivity meter. The fish is towed at 5 knots at 3m below the surface to determine the horizontal variations in turbidity and lowered rapidly (15-20 secs) to the bed, on each of the standard stations to provide virtually instantaneous vertical turbidity profiles. An MS26 echo sounder was also used to investigate the fine sediment in the estuary.

NARRATIVE

Echo sounder records obtained on the first leg, 4 4 75 and 5 4 75, revealed large quantities and very widely distributed deposits of fluid mud. These presumably occurred at the sites where it is commonly encountered but also occurred in the main channel between the English and Welsh LV and the Holms Islands and over a huge area in Bridgwater Bay as a single layer 1m thick, where it has never been found before. For some reason there was more fine sediment on the bed as a static suspension (fluid mud) than we had experienced before, despite previous visits at Neap tides. Siltmeter traverses and vertical profiles on 2 4 75, 4 4 75 and 5 4 75 indicated an extremely low suspended solids content for the estuary in the overlying water body at all states of the tide, confirming that a large proportion of the sediment was on the bed as a static suspension. With the exception of the Avonmouth area vertical turbidity structures were developed in an embryonic condition. There was no sign of active dense suspensions in the deep channel between the Holms Islands but at some sites profiles down into static fluid mud were obtained. This was an ideal situation since the objective of the survey was to study the types of structure which developed on the rise from Neaps to Springs as energy levels increased and entrainment progressed.

Unfortunately an engine failure of the vessel prevented the whole estuary being surveyed at this Neap condition.

On the second leg (6 4 75, 7 4 75 and 7 4 75) profiles confirming previous observations that the clean marine water penetrates earlier and persists longer on the north side of the estuary were obtained. More turbid water is present close to the English side. Some suspensions with the highest concentration near surface were obtained on this leg, particularly on the channel margins. This may suggest a high level source from the banks themselves. This leg showed the commencement of the formation of sequences of turbidity structure which were more fully developed on leg 3, (10 4 75 to 14 4 75).

On the third leg the echo sounder showed that all the fluid mud had disappeared from the channels and from Bridgwater Bay and was presumably entrained into the water column.

Observations from slack water to the maximum ebb and flood tide revealed a repeatable sequence of turbidity structures. At the maximum flood and ebb velocity an active, completely developed suspension occurs in which the vertical concentration is constant. As the velocities

decrease the structure starts to evolve and a high level step develops which subsides down the profile with time accompanied by an increasing turbidity at the base. This may be due to settling. With further velocity decreases several steps may be present and ultimately a dense layer up to 5m deep and with a concentration of 50,000 ppm is formed on the bed at slack water. These deposits may either persist as active suspensions or may be stationary (static suspensions or slack water fluid muds).

There is no information at present about the temporal or spatial continuity of steps in the structures.

When the tide turned these dense suspensions were re-entrained as active suspensions and a further sequence of turbidity structures developed. During re-entrainment turbidity reversals were more common in the profiles than on the falling stage and frequently only one major step is present. Eventually a completely homogenized profile is re-established. Logarithmic profiles were never observed. This complete sequence of suspension structures is only developed in the deep channel environments and in Bridgwater Bay. The same sequence appears to occur whether the vessel remains at one station or steams over several cross sections.

Meteorological conditions also appear to exert an important influence on the upper portions of the suspension profiles. On windy days when surface waves occur the upper layers remain virtually homogeneous due to mixing produced by wind and stress on the water surface. On calm days, such as conditions encountered on 13 4 75 in traverses in Bridgwater Bay however, the settling sequence could be seen to commence right at the water surface and a turbid layer only 15 cm below a clean upper layer was seen from the ship. This layer settled until the vessel was sailing in clean water with dense layers commencing at 3-6m. In these conditions the vessel produced a chocolate coloured wake. What may be settling convection was observed on previous cruises but not recognised on the records. On re-entrainment the dense sediment rose from the bed by processes which gave rise to "dense suspension streets" visible at the water surface as a series of chocolate coloured strips, orientated along the axis of the stuary. The water within the turbid streets was exceptionally turbulent whilst mushroom shaped turbulent eddies of dense chocolate brown water were seen rising through the clear, relatively still water, at the margins of the streets. The streets propagated laterally in this way until the whole estuary was chocolate coloured and

a homogeneous vertical turbidity distribution was established. Such calm conditions appear to be essential for calculations of mixing length to be performed on the turbidity data. Horizontal tows across the developing dense suspension streets on 13 4 75 showed virtually clear water in between the streets, a highly variable margin and a high more constant turbidity level within the streets.

Future surveys will attempt to study these phenomena in a more quantitative manner.

EQUIPMENT PERFORMANCE

Ship Equipment

Various features of the vessel, including failures of the main engine and the scientific AC supply occurred and had a major effect on the programme. These points have been dealt with separately in a report to RVB.

Scientific Equipment

1. The Decca Maglog used for logging navigational data and fix positions was unserviceable on the first day of the survey. A PC board was replaced by a Decca engineer on 3 4 75 after which time the apparatus performed satisfactorily.

2. The cables to the IOS turbidity array on the tow-fish was cut by the ship's propellor at 2045 on 4 4 75. These were repaired on 5 4 75, the crew leave day, with no loss of survey time.

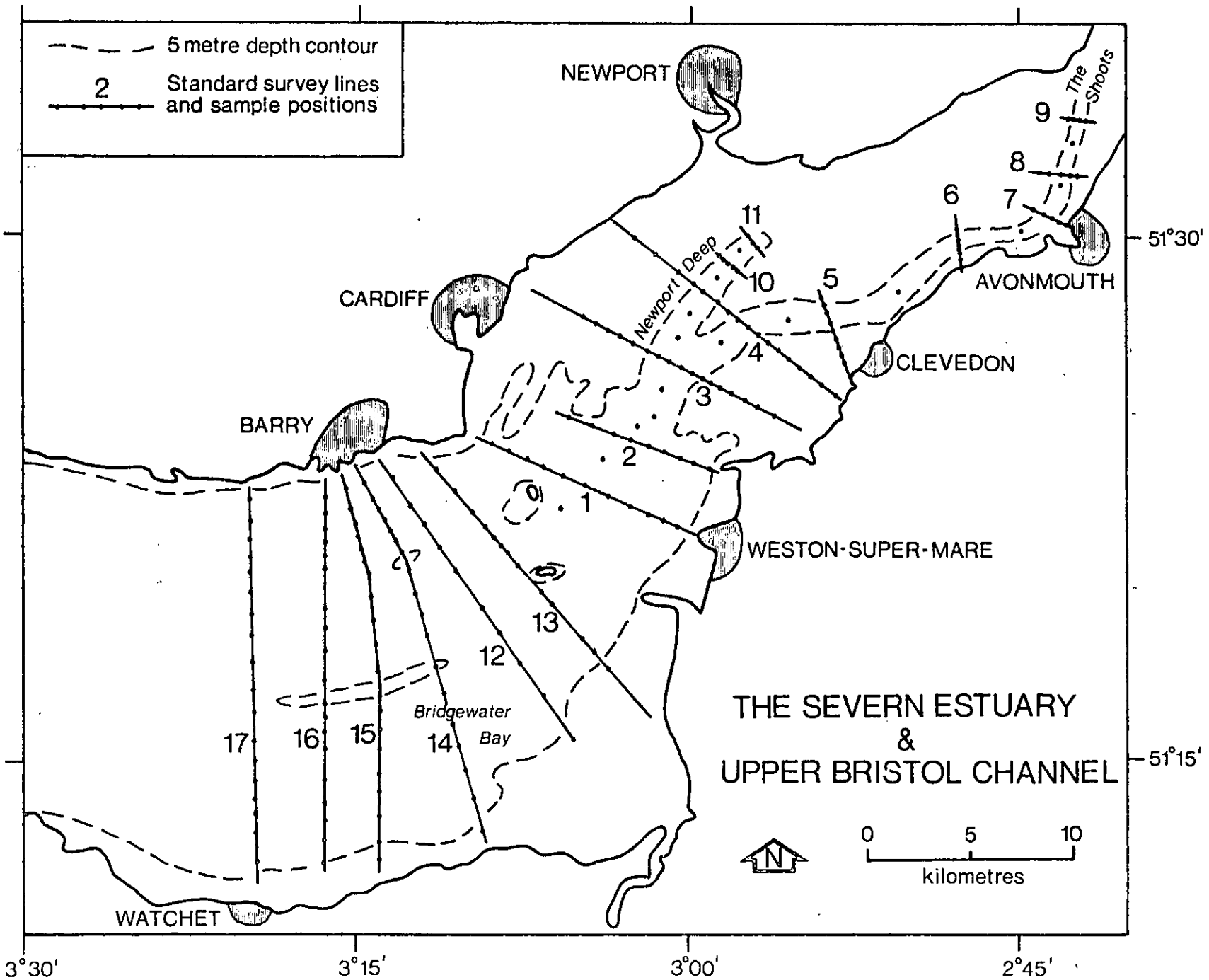
On 7 4 75 the scientific AC failed and at one time sent a 320 volt surge into the scientific equipment. The Bryans recorder used to draw the vertical profiles went unserviceable and a slight smell of burning was noticed. All the other equipment survived. When the AC supply was restored the Bryans recorder appeared to work normally. However, on 11 4 75 the amplifier, which was the item which overheated on 7 4 75, broke down. The X amplifier also became unstable. The recorder was put ashore and repaired in the MSES/RVB electronics laboratory on 12 4 75.

3. The IOS MS26 echo sounder broke down on 13 4 75, and could not be repaired before the end of the cruise. However, by this time all the important information had been obtained from this machine.

4. The calibration of the depth sensor altered on 12 4 75. The instrument was recalibrated at sea and still found to be linear so the survey continued. The reason for the calibration shift was not ascertained.

ACKNOWLEDGMENTS

We are indebted to the crew of RV Edward Forbes for their hard work on our behalf and particularly for the high degree of interest they showed in our research.


5 metre depth contour
2 Standard survey lines and sample positions
NEWPORT
CARDIFF
BARRY
WESTON-SUPER-MARE
CLEVEDON
AVONMOUTH
WATCHET
Newport Deep
The Shoots
Bridgewater Bay
THE SEVERN ESTUARY & UPPER BRISTOL CHANNEL
0 5 10
kilometres
N
51°30'
51°15'
3°30'
3°15'
3°00'
2°45'