Appendix 6

Report on field data collected in 2001 around Winterton, Clacton and the Humber

Southern North Sea Sediment Transport Study, Phase 2 Sediment Transport Report

Appendix 6 Report on field data collected in 2001 around Winterton, Clacton and the Humber

July 2002

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EXECUTIVE SUMMARY

As part of the Southern North Sea Sediment Transport Study Phase 2 (SNS2), CEFAS and UEA were tasked with providing oceanographic data from three key areas in order to provide a strategic overview of sediment transport rates, directions and processes.

At the end of the first stage of the contract an inception report (HR Wallingford, 2001) using existing sediment transport rates, processes and local expert knowledge identified three key areas along the study coastlines where either existing data conflicted or their was a scarcity of data. These areas were:

- **The Winterton Ness area off Norfolk between the complex banks system off Great Yarmouth and the start of the linear banks at Happisburgh**
- **The interactions between the Naze, Gunfleet Sand and the Clacton frontage**
- **The existence and magnitude direction of sediment transport pathways from the Holderness coast past Flamborough and onto Donna Nook**

In order to investigate the processes around the complex bathymetric features around Winterton Ness, a four staged approach was employed. Firstly, current meter moorings spanning the apex of the Ness were deployed and similarly along a line perpendicular to the coast out to Haisborough Sand bank. The CEFAS Minipod seabed lander, specially designed to measure sediment transport, was also deployed on the Happisburgh Line. Secondly, a 13 hour ADCP section in the shape of the apex was conducted around the Ness. Thirdly, a sediment tracer was deployed just off the Ness and fourthly a wide ranging sidescan sonar survey was undertaken to identify mobile bedforms. Moderate wave conditions during the survey curtailed some of the initial plans. Results show the highly dynamic environment off the Ness controlled mainly by tidal transport. Direct sediment transport links were observed between the foreshore and Caister Shoal indicating a high degree of "connectivity". Material was being transported offshore. Data from the fieldwork programme has been used to calibrate and validate the numerical model (see Appendix 12 to the main report).

The Clacton/Gunfleet/Naze area was investigated using a three staged approach similarly to Winterton Ness. Firstly, a Minipod and three seabed frames were deployed in a box between the Naze, Gunfleet Sand and the Clacton frontage. Secondly, a 13 hour ADCP section from the Clacton foreshore to Gunfleet Sand was undertaken and thirdly a high resolution sidescan sonar survey was completed. Results from the Minipod site adjacent to the Naze again confirmed the dominance of tides in terms of net sediment transport with a northerly transport of 4.1 and 1.26 x 10^4 kg/m for coarse and fine sand respectively.

To investigate the bedload and suspended sediment transport mechanisms across the mouth of the Humber a high quality sidescan sonar survey was undertaken during December 2001. Results showed individual flood and ebb dominated channels controlling the orientation of bedforms.

The new GIS approach to interpreting and mapping Sidescan imagery, developed by CEFAS in conjunction with the study team under this contract, has been shown to be extremely useful and a powerful technique. It enables the information from the orientation of seabed features e.g. megaripples, sandwaves etc to be mapped in a way that can contribute to the large scale understanding of the transport pathways. The sediment transport vectors thus derived have been used by the study team in forming an interpretation of sediment transport vectors within the study area.

Glossary and Acronyms

ACM	Acoustic Current Meter
ABS	Acoustic Backscatter Sensor – used to measure sand concentrations
ADCP	Acoustic Doppler Current Profiler
CEFAS	Centre for Environment. Fisheries and Aquaculture Science
CTD	Conductivity, Temperature and Depth
FSI	Falmouth Scientific Instruments
FEPA	Food and Environment Protection Act II
FTU	Formazin Turbidity Unit
GIS	Graphical Information System –e.g. MapInfo™ and ArcView™
OBS	Optical Backscatter Sensor – used to measure silts in suspension
PVD	Progressive vector diagrams
PSU	Practical Salinity Units
QTC	Questor Tangent Corporation – a seabed discrimination system
UEA	University of East Anglia

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1. INTRODUCTION

1.1 Terms of Reference

This study was commissioned by MAFF (now DEFRA) and a consortium of Local authorities to provide a strategic overview of sediment transport rates, directions and processes from Flamborough Head to the Thames estuary. A consortium comprising, HR Wallingford, CEFAS, Posford Haskoning, University of East Anglia and Brian D'Olier won the contract to complete this study.

1.2 The Study Areas

At the end of the first stage of the contract a inception report (HR Wallingford, 2001) using existing sediment transport rates, processes and local expert knowledge identified three key areas along the study coastlines where either existing data conflicted or their was a scarcity of data. These areas were:

1) The Winterton Ness area off Norfolk between the complex banks system off Great Yarmouth and the start of the linear banks at Happisburgh.
2) The interactions between the Naze, Gunfleet Sand and the Clacton frontage.
3) The existence and magnitude direction of sediment transport pathways from the Holderness coast pass Flamborough and onto Donna Nook.

For each of these locations experiments were designed by the study team as a whole and approved by the client Study board. The Winterton and Clacton/Naze experiments were more comprehensive in nature with a wide-ranging deployment of moored instruments and sidescan sonar surveys.

1.2.1 Winterton Ness

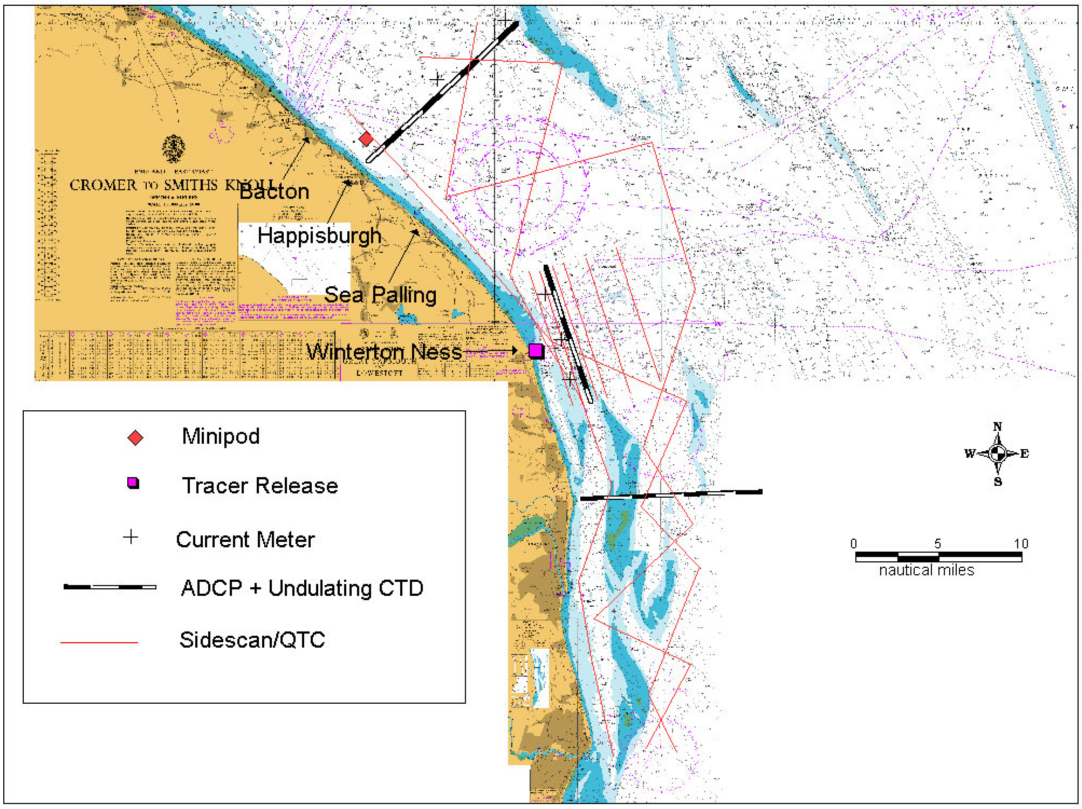

Figure 1 **Proposed survey Plan for Winterton - Spring 2001 (Admiralty charts 106 and 1536)**

The aim of the Winterton fieldwork was to:

i) To determine the fate of sediment moving down the coast from North Norfolk.
ii) To understand the conditions under which sediment transport took place.
iii) The degree of "connectivity" between sediment transport along the coast and the inshore sand banks.
iv) To provide data for calibration/validation of Numerical models.

The proposed Winterton fieldwork plan, shown in schematic form in Figure 1, consisted of three small surveys area around Winterton Ness. The northern line consisted of a Minipod and two current meter moorings perpendicular to the coast with an ADCP section/undulating CTD section, the central group consisted of three current meter moorings, a tracer release and ADCP/Undulating CTD section whilst the southern line consisted of a ADCP/Undulating CTD section only. A sidescan sonar survey was also planned around the entire area.

1.2.2 Clacton/Naze

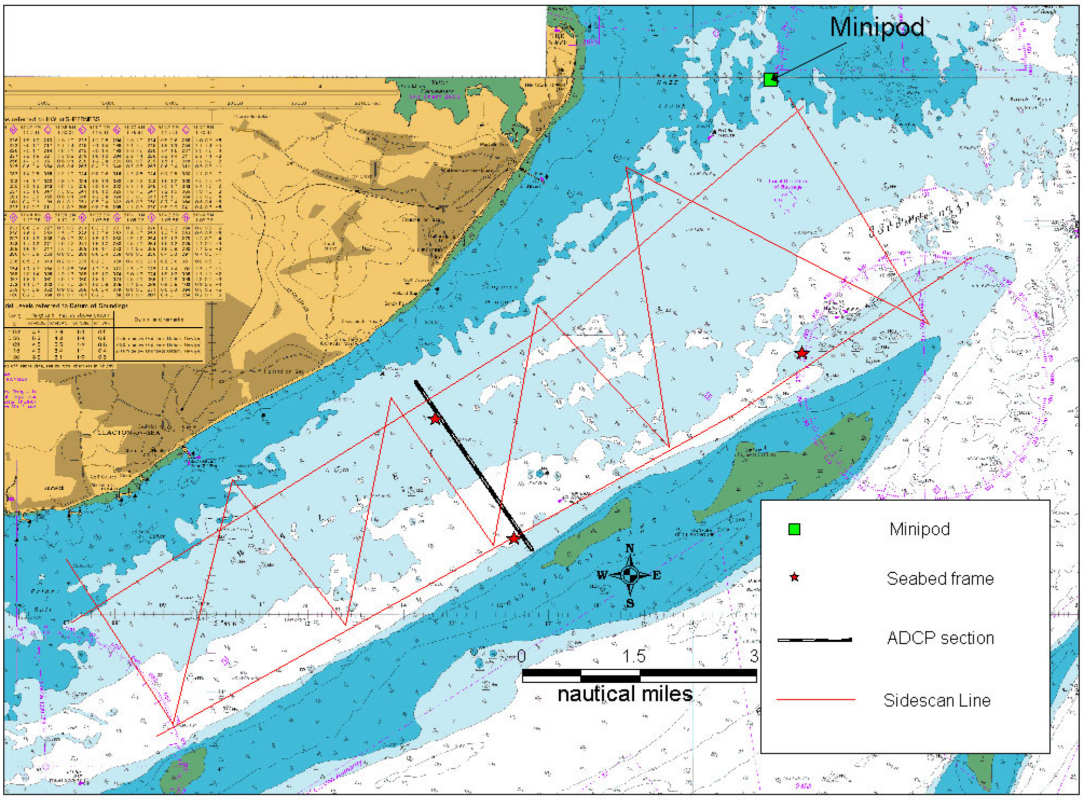

Figure 2 **Proposed survey plan for Clacton/Gunfleet area for Summer 2001 (Admiralty chart 1183)**

The aim of the Clacton/Gunfleet fieldwork was:

i) To determine if the bank-coast sediment transport link proposed by John Pethick (Essex SMP Harwich to Mardyke prepared by Mouchel) was observable.
ii) To understand the sediment circulation around the Gunfleet Sand.
iii) To determine the physical forcing parameters on the old Naze point.
iv) To provide data for calibration/validation of Numerical models.

The survey plan for Clacton/Gunfleet was similar to that at Winterton in that one Minipod deployment was planned on the Naze with three seabed frames mounted inshore Clacton, offshore Clacton and Gunfleet tip. An ADCP section was also included with an extensive sidescan sonar survey to detect and map seafloor features including bedforms indicative of mobile seabed sediments.

1.2.3 Humber estuary

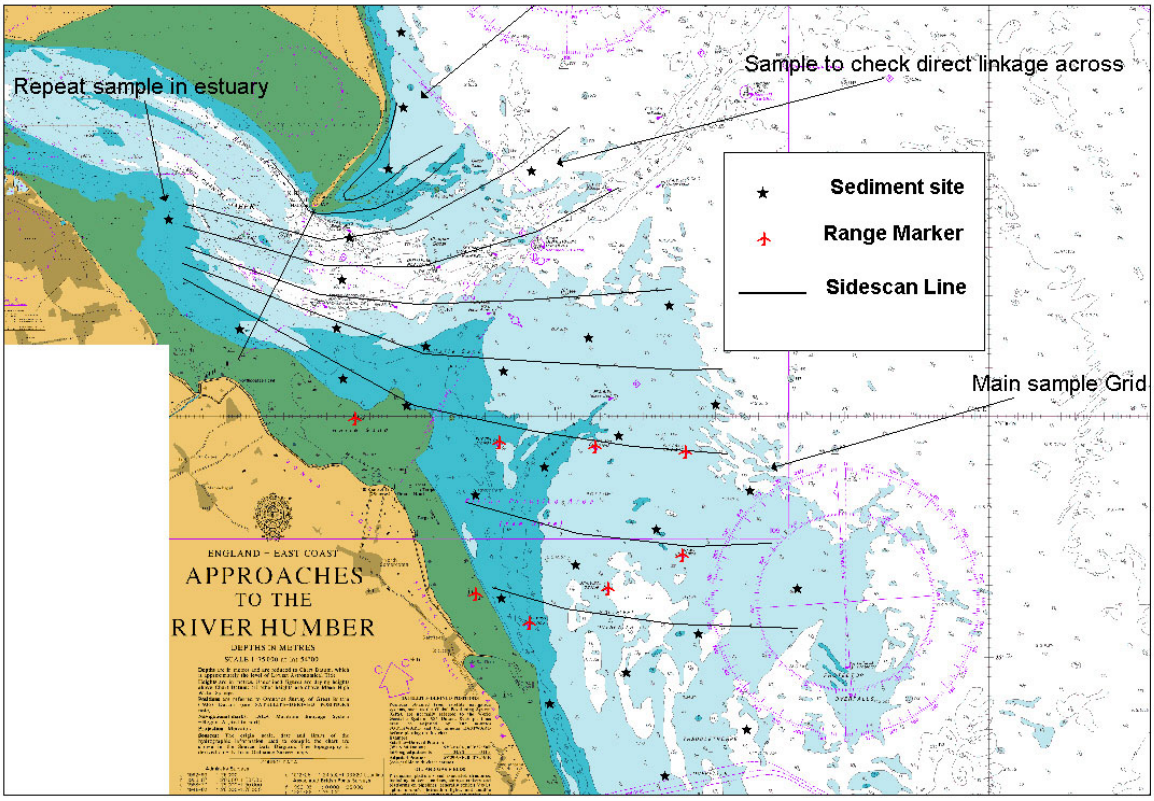

Figure 3 **Proposed survey plan for Humber/ Donna Nook area - Winter 2001. Black lines indicate sidescan sonar tracks, black stars seabed sample locations and red planes indicate the Donna Nook bombing range (Admiralty charts 107 and 1188)**

The main aim of the Humber fieldwork was to map the sediment transport features as recorded by sidescan sonar and, if possible, to identify mechanisms capable of transporting sediment, either as bedload or suspended sediment, across the mouth of the Humber. A series of transects perpendicular to the theoretical sediment transport pathway where proposed as shown in Figure 3. A series of seabed sediments were also planned to extend the coverage of the Cox (2002) mineralogical survey if weather /time permitted.

1.3 Quality Control

CEFAS operates under a formal Quality Policy. We are committed to achieving total customer satisfaction.

The Valeport Current meters have been calibrated on a Compass calibration table at CEFAS and us the manufactures speed calibration. The FSI and Nortek Vector sensors do not need calibration ad they measure the current velocity directly (by a travel-time approach and Doppler shift respectively). All pressure sensors are calibrated with a dead-weight sensor at CEFAS.

The OBS and ABS sensors were calibrated in the turbidity tank at UEA.

2 WINTERTON

The weather conditions in April 2001 did not allow all the aims of the Winterton experiment to be completed. During the fieldwork phase the aims where prioritised so as to complete as many goals as possible. Therefore, the ADCP section on the Northern and Southern lines were not completed. Similarly, wave conditions (3m northerly swell) resulted in poor sidescan sonar images, especially in the north of the survey area, and thus were curtailed. The remainder of the instrumentation/experiment went ahead as planned.

2.1 Current Meters

A total of five current meter moorings were deployed around the Winterton experimental area. Three were positioned off Winterton Ness to measure any asymmetry in current flows, whereas two further moorings extended the Happisburgh line out to the Haisborough Sand bank. Full details can be found in Norris and Rees (2002) and Appendix A.

2.2 Minipod

The CEFAS Minipod has been specifically designed to measure sediment resuspension, transport and deposition with as little as possible intrusion on the suspended sediment climate. It has an excellent track record with nearly 180 deployments and can be easily modified for different sensors.

Figure 4 CEFAS Minipod being deployed at Clacton

2.2.1 Pressure records

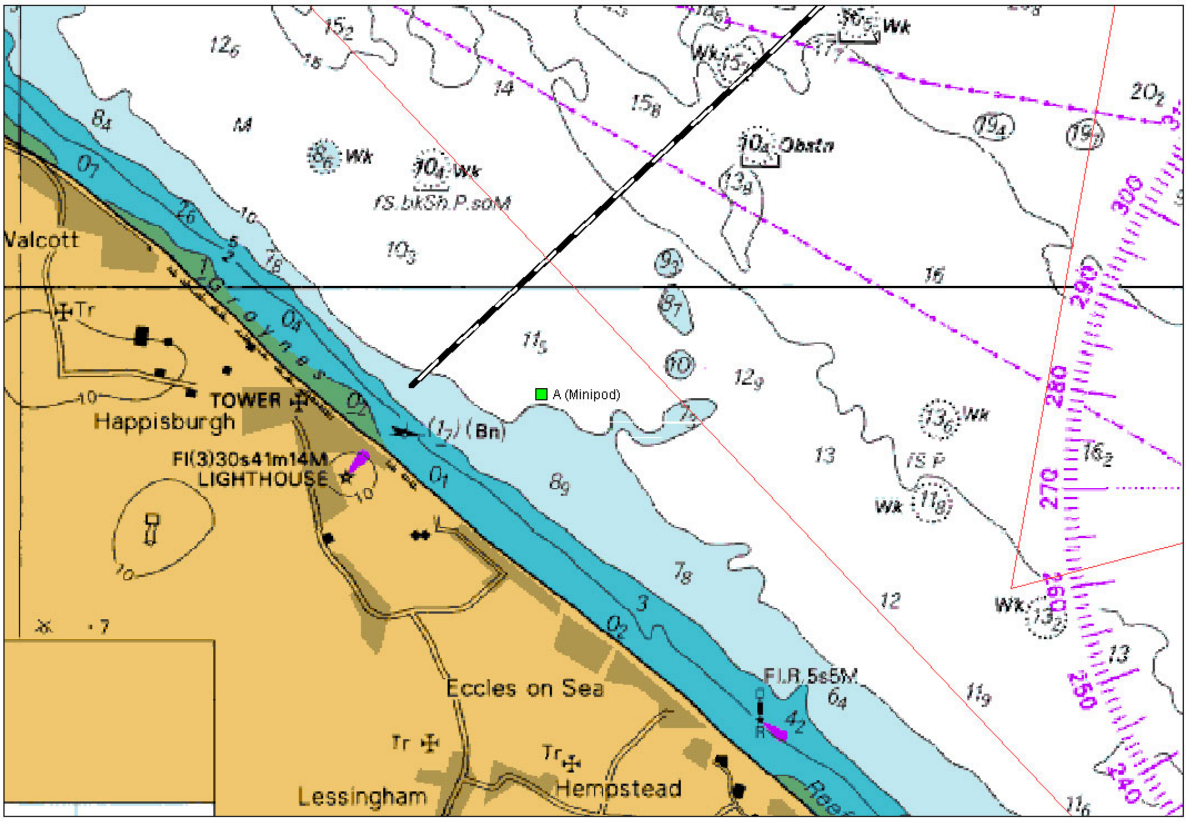

Figure 5 **Location Happisburgh Minipod (green marker) in relation to local bathymetry (Admiralty chart 106)**

The Minipod was deployed at 52° 49.567′N, 01° 33.605′E[1] as shown in Figure 5 in mean water depth of 10 m. The location is on the north edge of a small spur running east from Happisburgh lighthouse. The Minipod was set-up to record bursts of data (currents, pressures, suspended loads) every 30 minutes and produced 16 days of data from 7th April 2001 at 13:00[2] to 23rd April 2001 13:30 (see Figure 4 for picture of Minipod).

[1] All positions are WGS 84.
[2] Note all times are in GMT.

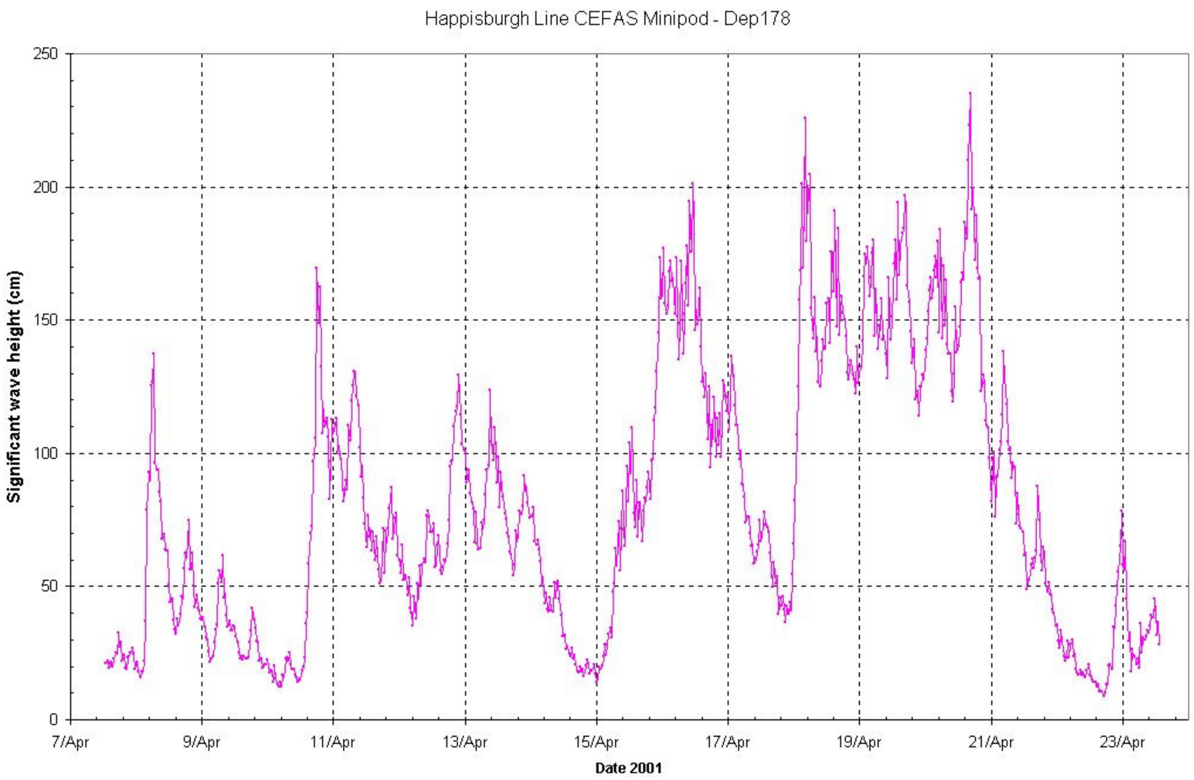

Figure 6 Significant wave Height from Happisburgh Minipod deployment

The pressure timeseries form the DigiQuartz pressure sensor on the Minipod has been processed to show the significant wave height over the period of the deployment and is shown in Figure 6. Five discrete wave events can be observed with an increasing trend in wave height. The largest wave event occurs between the 18th and 21st April with a wave height of approximately 2m. An alternative method to show the wave activity is to compute the wave orbital velocity at the seabed. This takes into account the water depth and also the wave period. Thus two waves of equal magnitude at high water and low water have different wave orbital velocities as described by Airy wave theory (Dyer, 1986). The wave orbital velocity at the seabed for the Happisburgh Minipod deployment is shown in Figure 7. This shows that the five wave events have become more pronounced, again with an increasing trend, reaching a maximum of approximately 50 cm s^{-1} around the 20th April.

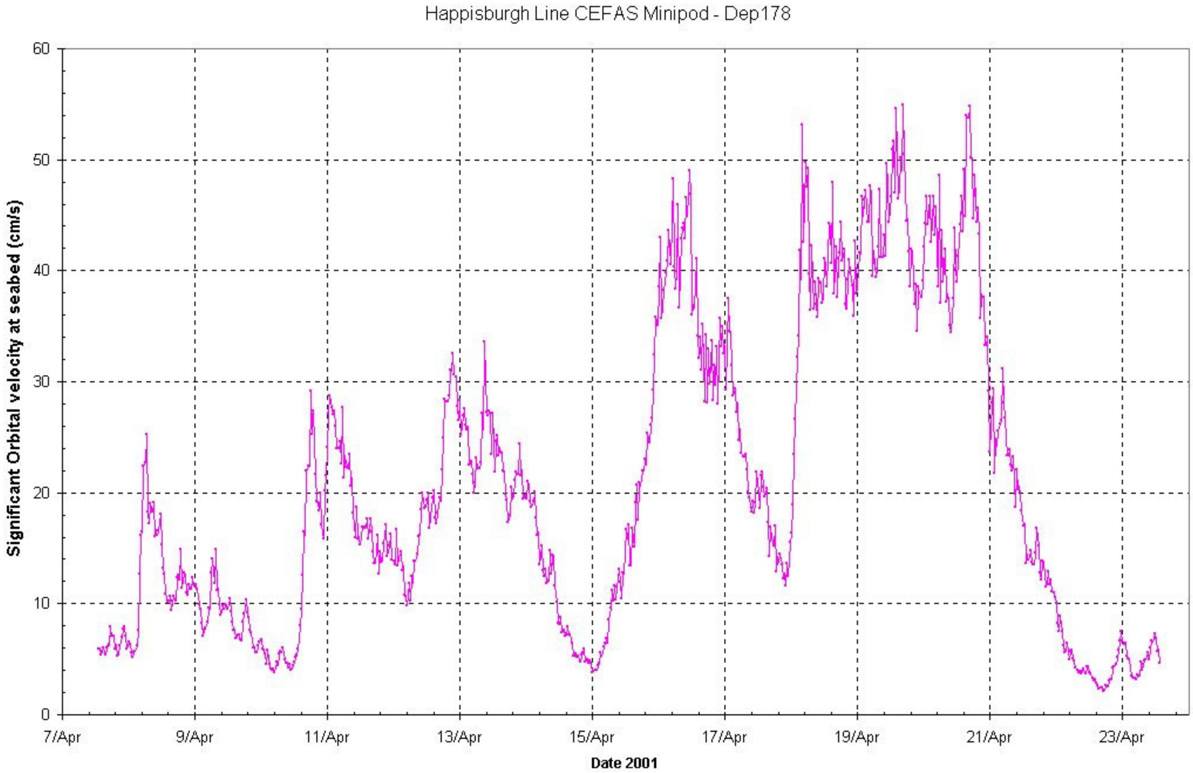

Figure 7 Wave Orbital velocity at Seabed at Happisburgh Minipod

2.2.2 Current records

The Minipod records the currents using a Nortek Vector acoustic Doppler Velocimeter which records currents at a single point in three dimensions. The burst-averaged data from Happisburgh is shown in Figure 8. The typical Spring-Neaps tidal cycle is evident with neaps around the 17th April. Also evident is the diurnal inequality with stronger velocities at high tide (flood) and weaker velocities at low tide (ebb).

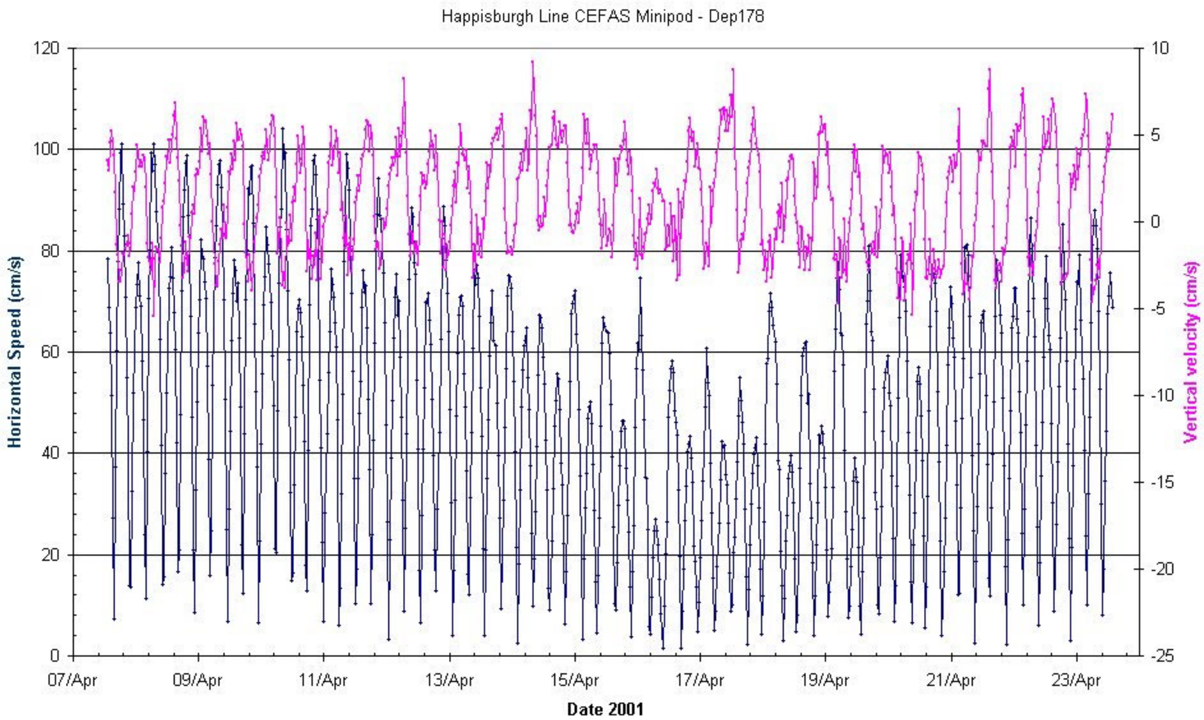

Figure 8 **Vertical and Horizontal current velocity from Happisburgh Minipod deployment - April 2001**

2.2.3 Suspended sediment records

The Minipod has two means by which to measure the suspended sediment concentration in the water column. Firstly, using a miniature optical backscatter system (MOBS) which emits an infra-red signal into the water column and measures the about of light backscattered. This device is mainly sensitive to the fines in suspension. Secondly, a transducer emits an acoustic signal (1 and 4.7 MHz) and records the backscatter from a series of points thus creating a profile of suspended sediment (ABS) and is sensitive to sands in suspension.

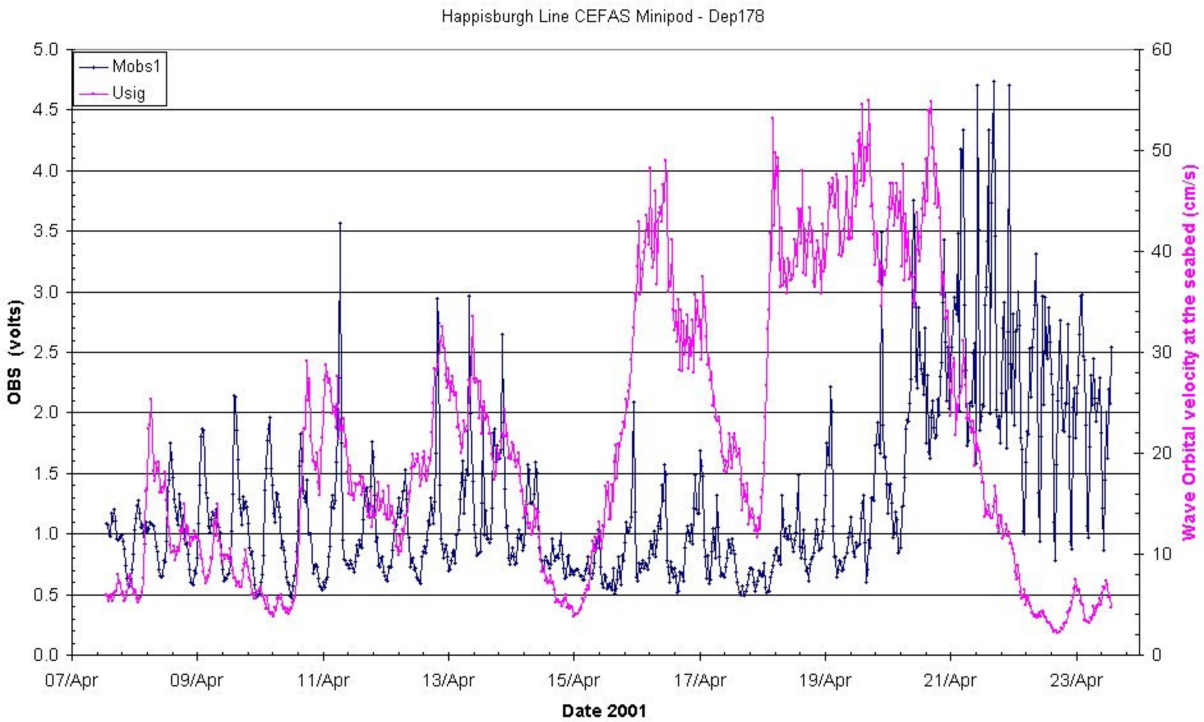

Figure 9 **Timeseries of burst mean suspended sediment concentration and wave orbital velocity at the seabed for the Happisburgh Minipod deployment**

The burst averaged suspended sediment concentration from the Happisburgh experiment, shown in Figure 9, shows that the major resuspension mechanism is the tides. The first four wave events, as described above, have little effect on the suspended sediment concentration. It is only the sustained high wave height of the fifth event that cause concentration to rise above that recorded by tidal resuspension on around the 20th April. Two possible explanations for this increase are possible:

the sustained high bed shear stresses caused by the waves are sufficiently strong to eventually overcome bed armouring and to allow the bed underneath to resuspend into the water column the high suspended sediment concentrations are transported into the area from nearby.

However, we have insufficient information to provide convincing evidence of either mechanism.

2.3 Tracer

As part of the comprehensive investigate of the wave, tide and sediment regime around Winterton Ness a fluorescent sediment tracer experiment was undertaken.

A deployment of 373 kg of a fluorescent tracer sand (mean particle size 220 µm, compared with a natural range in mean particle size of 225 to 473 µm) was made at slack water on the spring tide of 10th April 2001. The tracer was frozen prior to deploy and released onto the seabed using a 1 tonne cargo bag. The 373 kg of tracer presents 2.52E+10 particles at a position 52° 43.503′N, 01° 42.323′E.

Following the release, the tracer was tracked for a period of 7 days, involving intensive sediment sampling around the discharge site and along the coast. Tracer was detected using a broad band Ultra Violet light box. Three surveys were undertaken after 1 day (2 tides), 3 days (6 tides) and 8 days (16 tides).

Results (see Figure 10) from the survey suggest that the centroid of the tracer field moved north (20 degrees) by a distance of 118m. However, only a very small number of particles were recovered (a total recovery rate of 0.0008% on the 11th April).

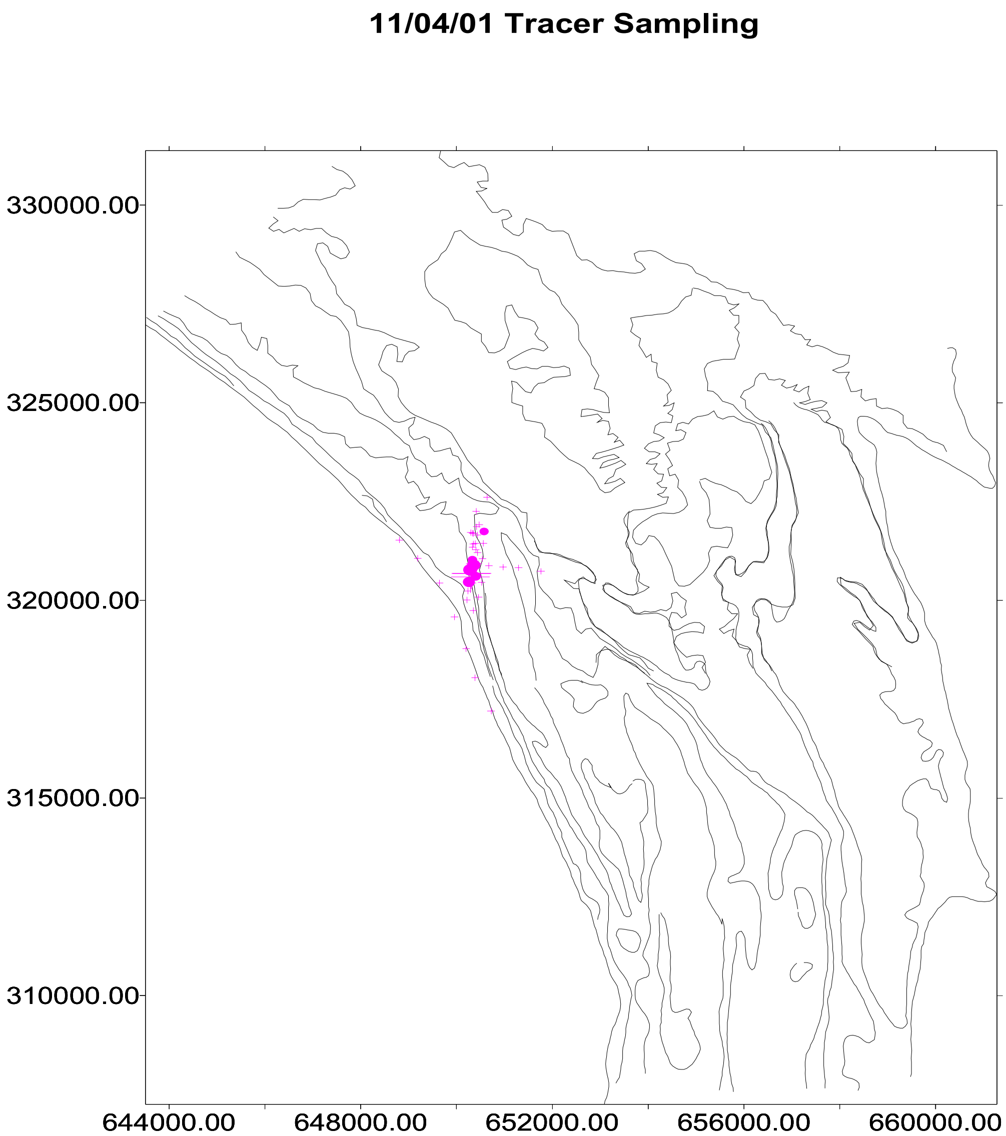

Figure 10 **Positions (axes in m) of the samples collected on the first sampling campaign (11th April) with the tracer release site indicated by a large cross and the locations where the tracer was detected indicated by circles of a diameter proportional to the concentration of tracer grains detected**

With hindsight, the moderately large wave and spring tides combined to given an extremely effective dispersion mechanism which spread the tracer cloud very quickly. The detection limit of the sampling and processing technique was of the order 1 in 1.6 x 10^5 particles which when combined with the disperse environment at the time of the survey resulted in very few particles being detected.

2.4 ADCP section

As the weather conditions were poor, it was decided to reduce the scope of the ADCP survey and concentrate effort in the crucial area around Winterton Ness. A survey was designed to characterise the hydrodynamics conditions around Winterton Ness. The design encompassed two legs around the Ness, leg "A" to the south of the Ness and leg "B" to the North forming an "arrowhead" pointing east. Note that the vessel reached the start point every hour. The full dataset is reported in Winterton ADCP Survey, 2001 with a subset of the data is shown in Figure 11 to Figure 15. The first two figures show current vectors along the ship track and indicate strength and direction (mid water). The second two figures show a vertical section along each leg contoured with speed. Note that the sections are from different times and have been chosen to show particular features.

Figure 13 (leg A) shows stronger currents offshore resulting in a strong vertical and horizontal current shear.
Figure 14 (leg B) shows less vertical and horizontal structure but does show a “jet-like” feature at around 1400m along the transect.

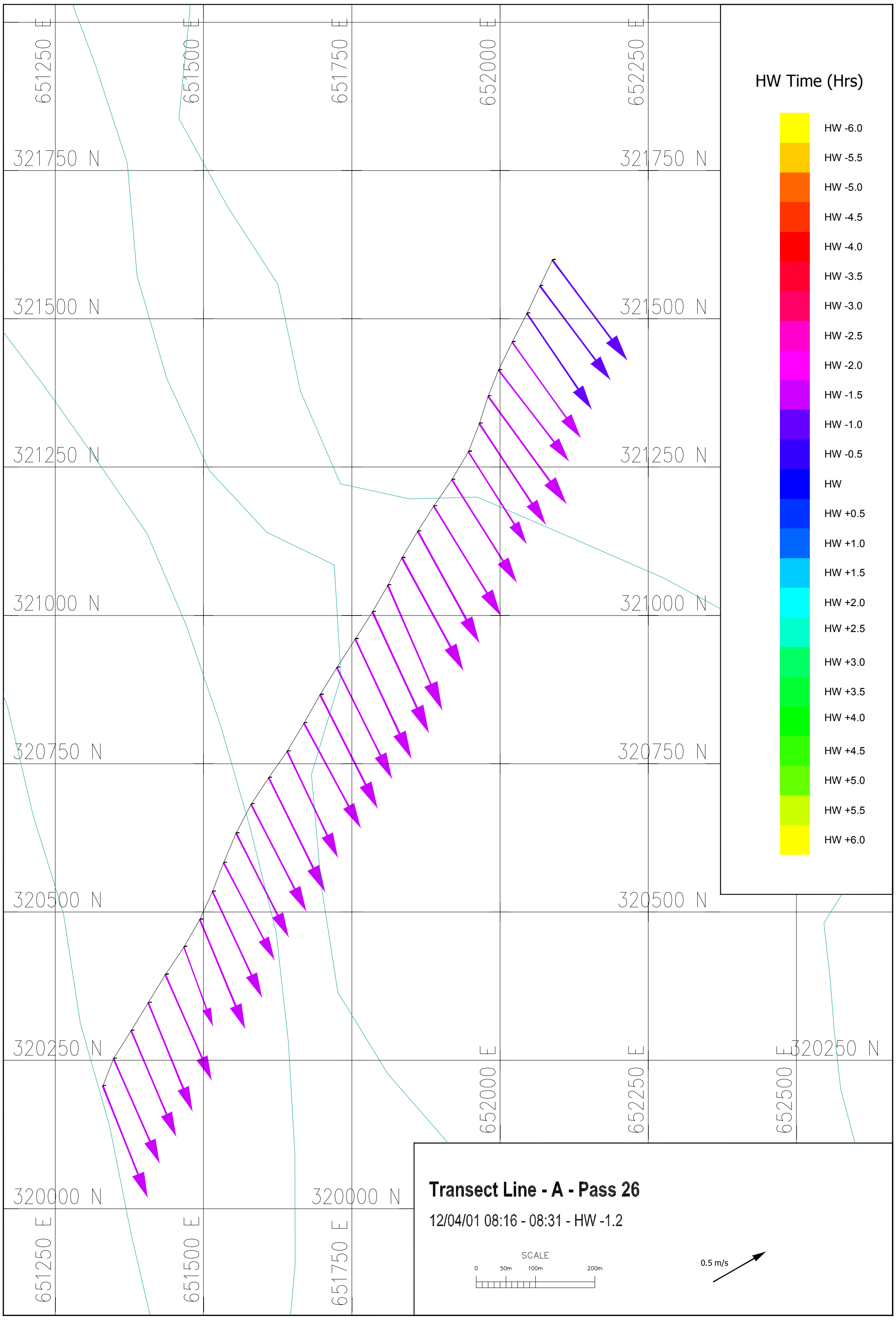

Figure 11 **Tidal vectors from Winterton ADCP - Line A Pass 26. Black line indicates vessel track**

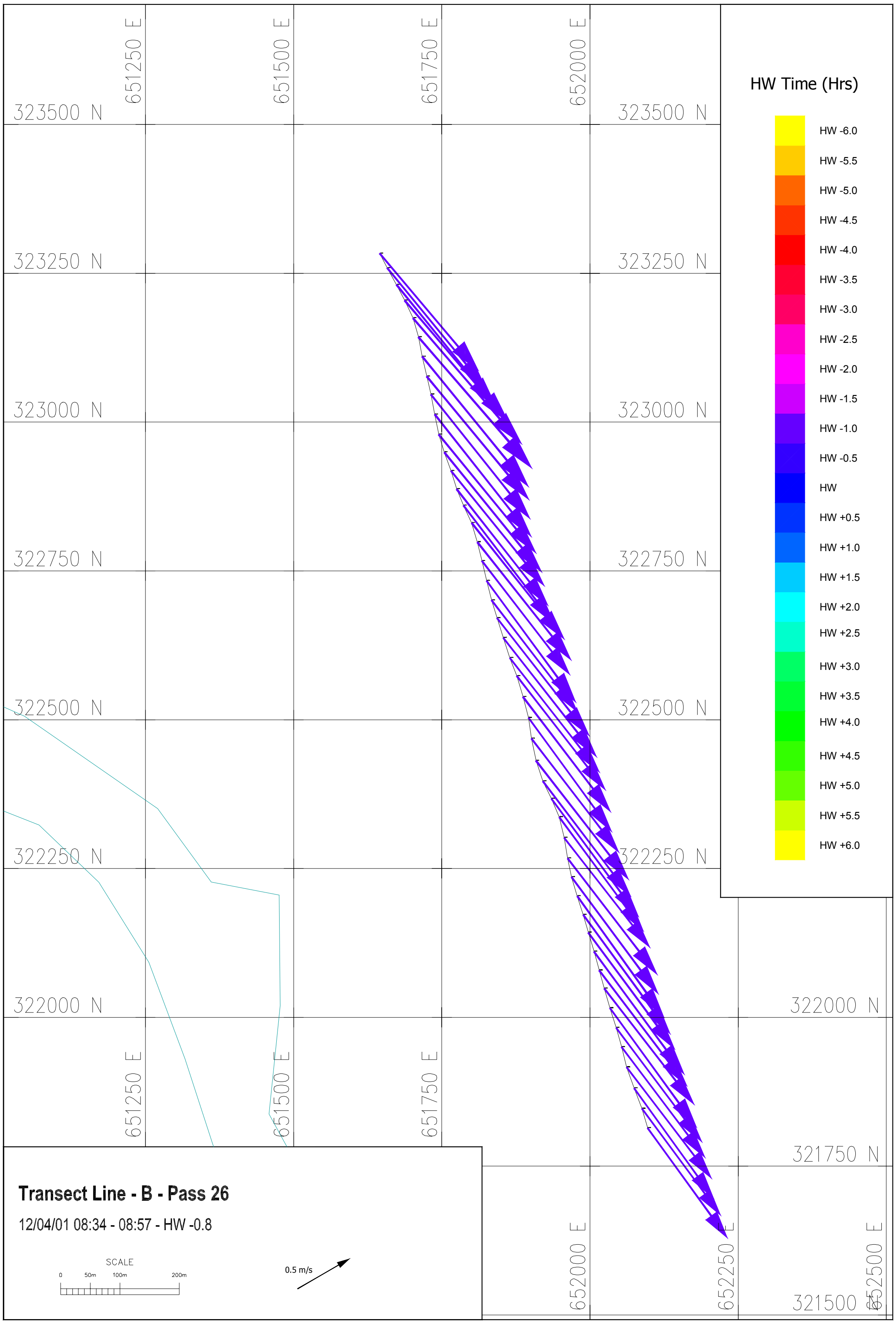

Figure 12 **Tidal vectors from Winterton ADCP - Line B Pass 26. Black line indicates vessel track**

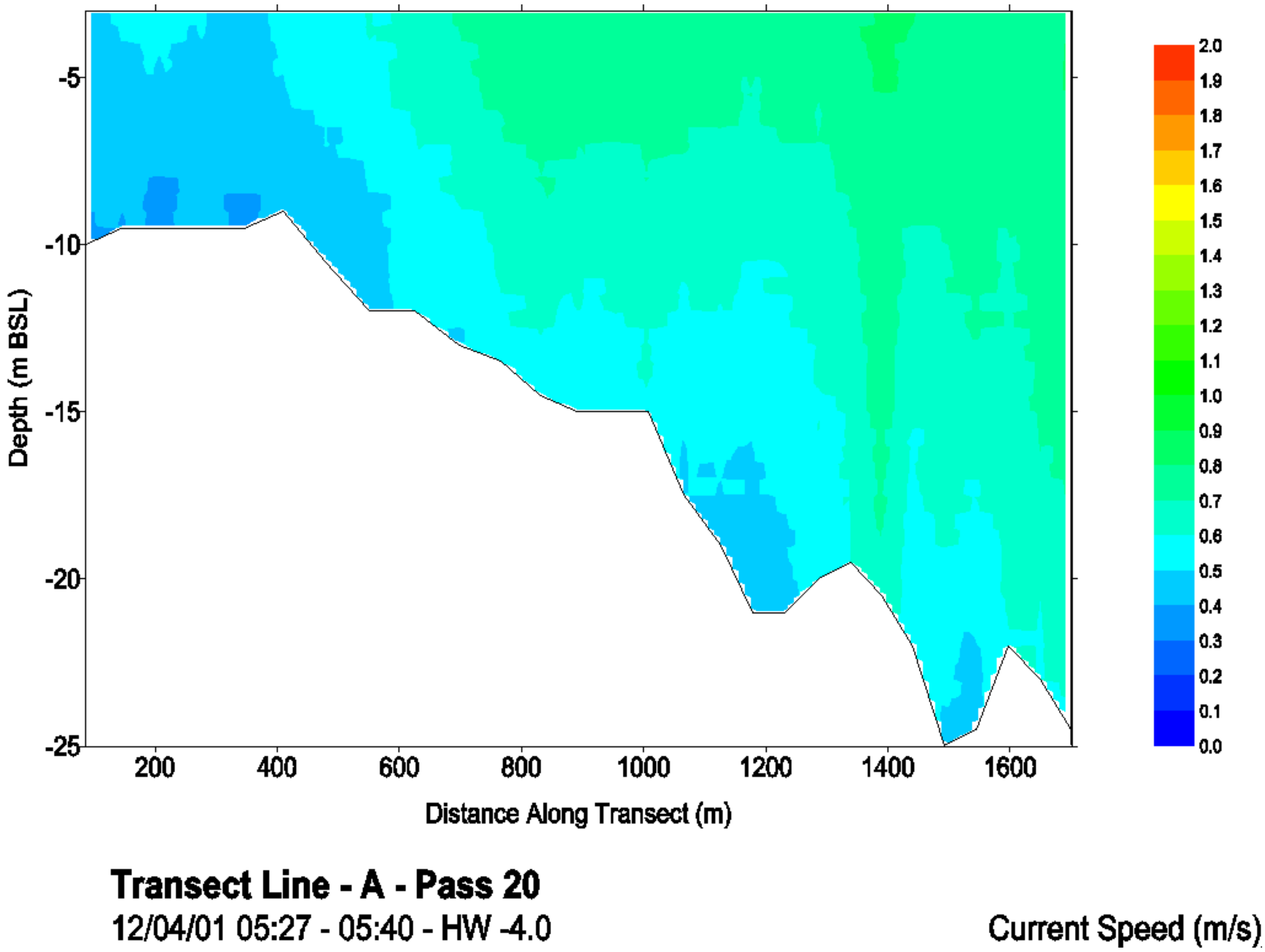

Figure 13 **Section of ADCP speed for line A, Pass 20**

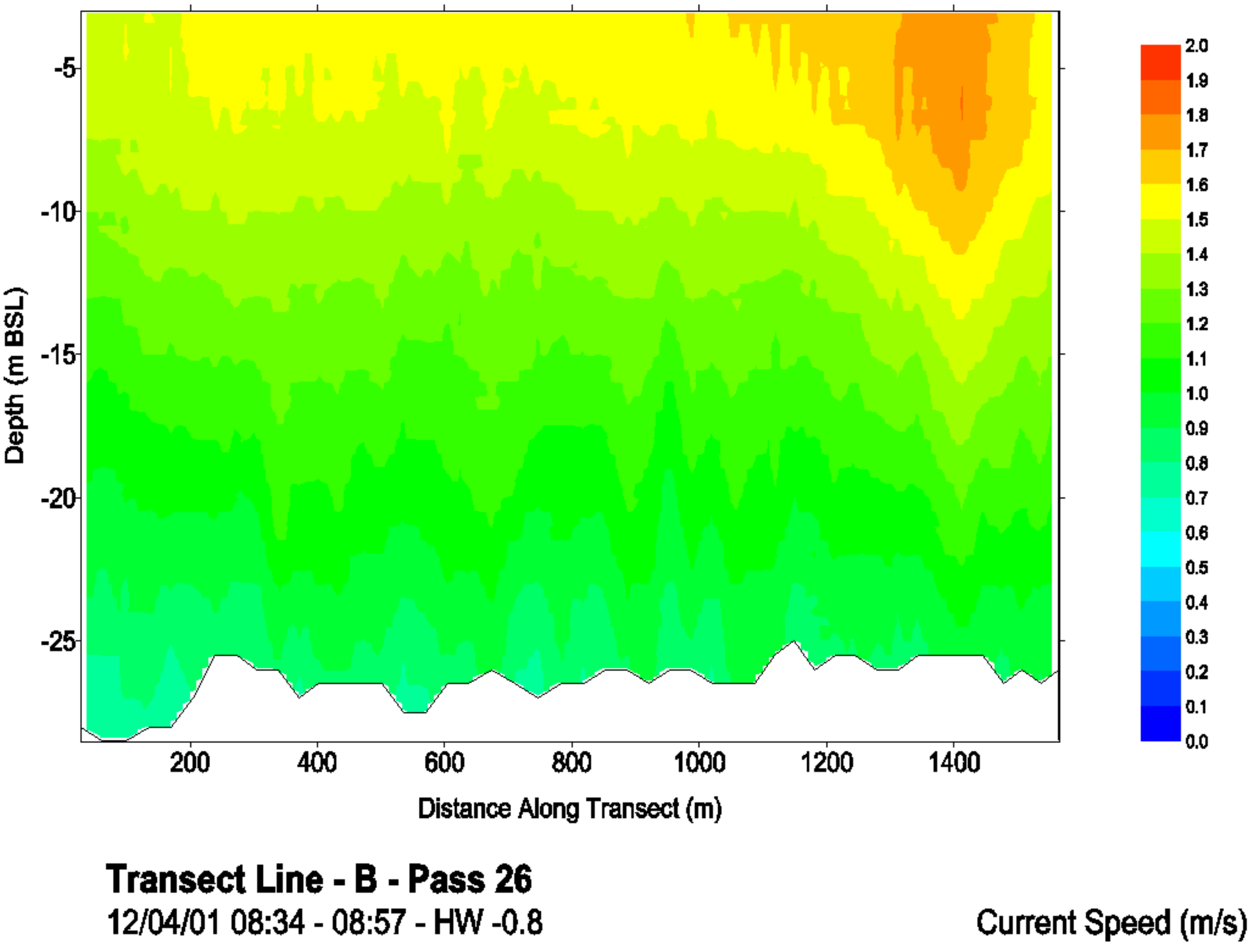

Figure 14 Section of ADCP section for Line B, Pass 26

The ADCP data can be displayed in a different format to show the movement of particles of water over the whole of the tidal cycle. These Progressive Vector Diagrams (PVDs) can be useful to show the tidal excursion at a point.

Figure 15 and Figure 16 show the PVDs from two points on the ADCP survey (Position 1 on the southern boundary of the survey and Position 5 on the northern edge of the survey[3]). On each point four PVDs are shown – from close to the seabed (red), mid water (purple), surface (green) and a depth averaged (blue). Thus at position 5 (north) there is significant difference in the end points of the PVD compared with position 1. The extent of the PVD is significantly less at position 1 (south).

[3] The five positions of the ADCP are shown clearly by the small red crosses in Figure 16.

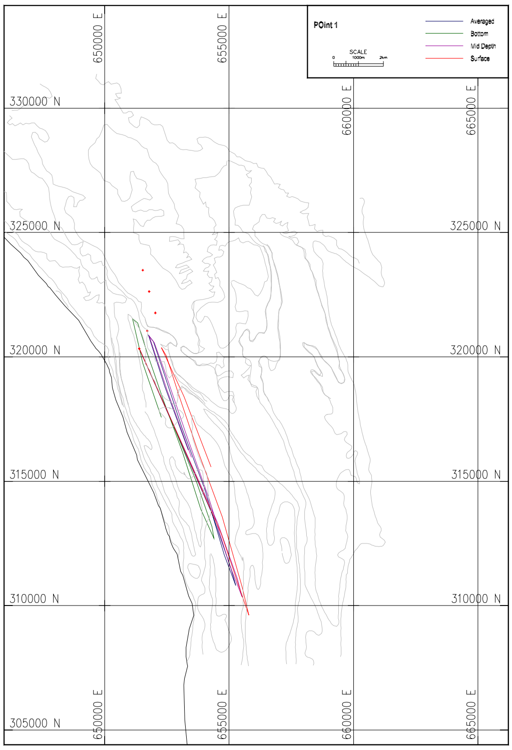

Figure 15 Progressive vector Plots from point 1 (inshore) at Winterton

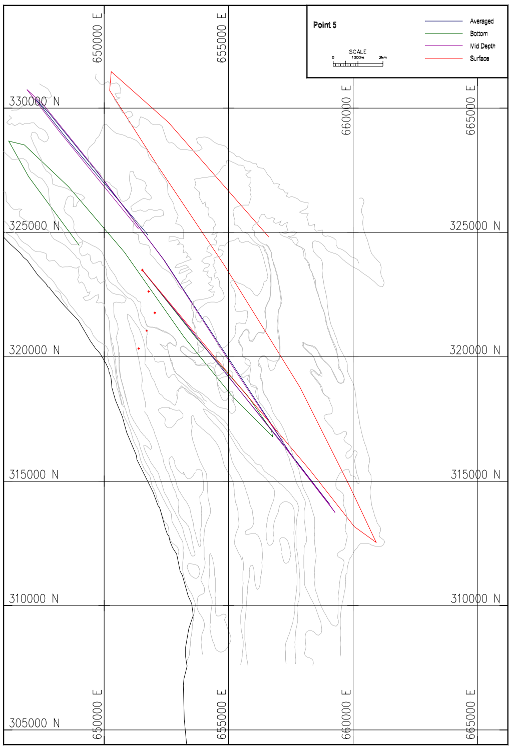

Figure 16 Progressive vector plots from point 5 (offshore) at Winterton

2.5 Sidescan Sonar

The sidescan sonar survey was conducted with a CMAX sidescan sonar fish logging into CMAX software with a 100m swathe either side. The coverage map is shown in Figure 17. All the major channels between Gt. Yarmouth and Winterton have been surveyed. However, very little data was collected from around Winterton Ness and to the North as the northerly swell caused poor imagery in these areas. The sidescan imagery has been analysed in detail and the interpretation/results are shown in section 5.1 Indicators from Sidescan sonar records.

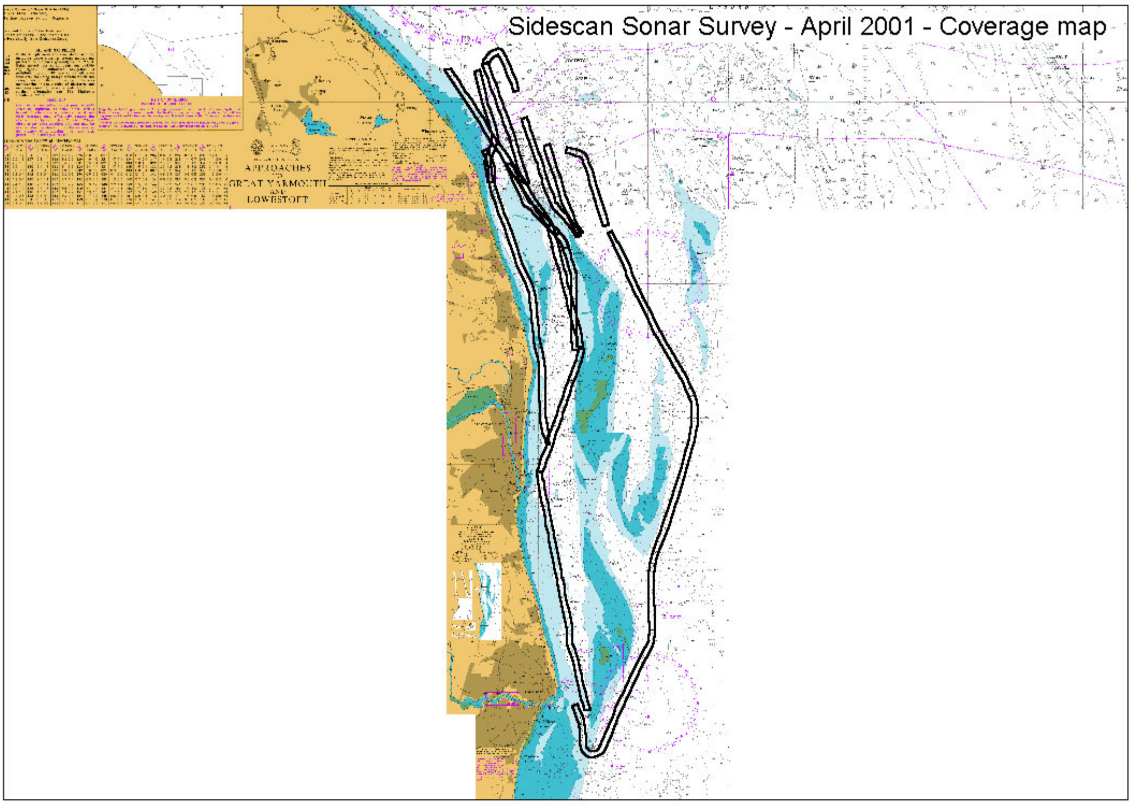

Figure 17 Winterton Sidescan Sonar coverage - April 2001 (Admiralty charts 106 and 1536)

2.6 Auxiliary Data

Whilst on the sidescan survey or deploying current meters/Minipods surface water samples (1 litre) were collected from a seawater deck wash and later analysed for suspended sediment concentration using a gravimetric procedure. The results from the full survey are shown in Figure 18 and from the area around Winterton Ness in Figure 19 and form a quasi-synoptic survey. The samples in blue were taken on the 24th April when wave conditions were significantly calmer than when the main surveyed was undertaken on the 11th and 12th April. Comparing the two surveys it is evident that concentrations are significantly reduced on the 24th April. Concentrations are generally higher inshore, typically 64 mg l^{-1} compared with around 30 mg l^{-1} offshore. However, in areas like Caister Roads concentrations reach 76 and 96 mg l^{-1}. Concentrations in the survey area generally increase southward reaching a maximum of 116 and 225 mg l^{-1} off Lowestoft Ness.

Winterton Suspended sediment results - April 2001

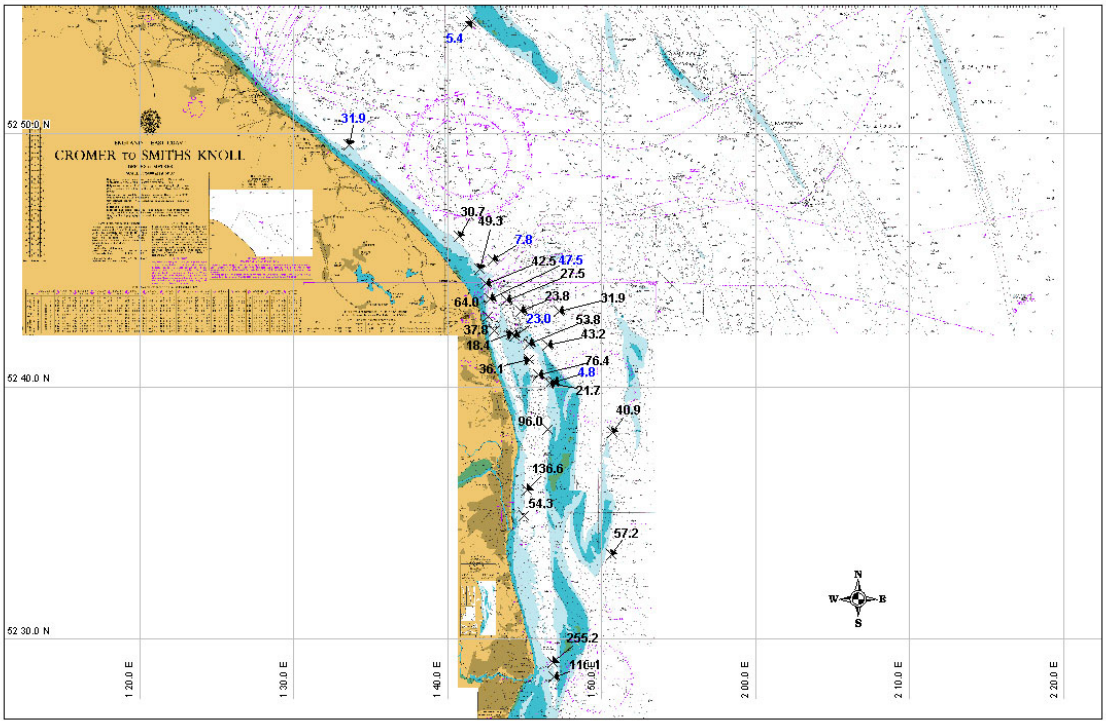

Figure 18 **Quasi-synoptic surface suspended sediment survey (mg/l) from the Winterton area. Blue labels indicate samples taken on the 24 April otherwise samples taken on 11 and 12 April 2001(Admiralty charts 106 and 1536)**

Winterton Suspended sediment results - April 2001

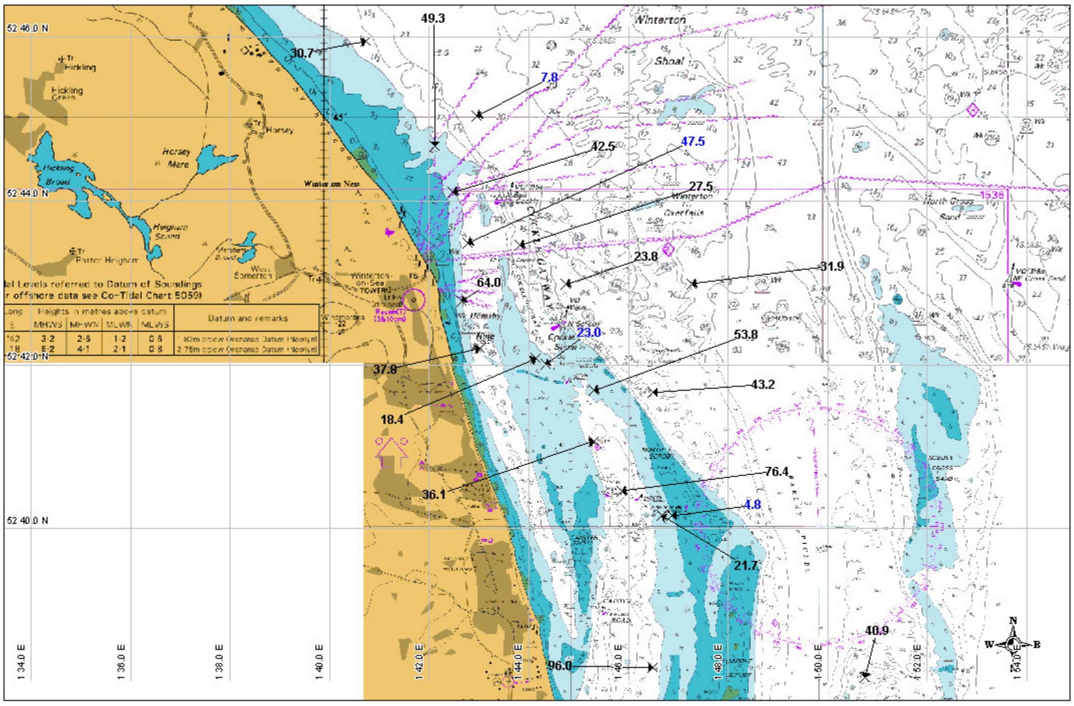

Figure 19 **Quasi-synoptic surface suspended sediment survey (mg/l) from the Winterton area showing the area immediately around Winterton Ness. Blue labels indicate samples taken on the 24 April otherwise samples taken on 11 and 12 April 2001(Admiralty charts 106 and 1536)**

3 CLACTON

3.1 Current meters

Three current meter deployed were made in the Clacton/Gunfleet area. The currents were measured using a small seabed frame containing a FSI 2D Acoustic Current meter and a CEFAS ESM2 logger with a sensor suite comprising of a pressure sensor, suspended sediment sensor and salinity / temperature sensors. Data was recorded in burst mode with bursts every 15 minutes lasting 10 minutes at a sampling frequency of 1 Hz giving 600 data points. The FSI current meter, mounted 50 cm above the seabed, recorded vector averages every minute.

Timeseries of current speed from the three currents are shown inFigure 20, Figure 21 and Figure 22 for Clacton Inshore, Clacton Offshore and Gunfleet tip locations respectively.

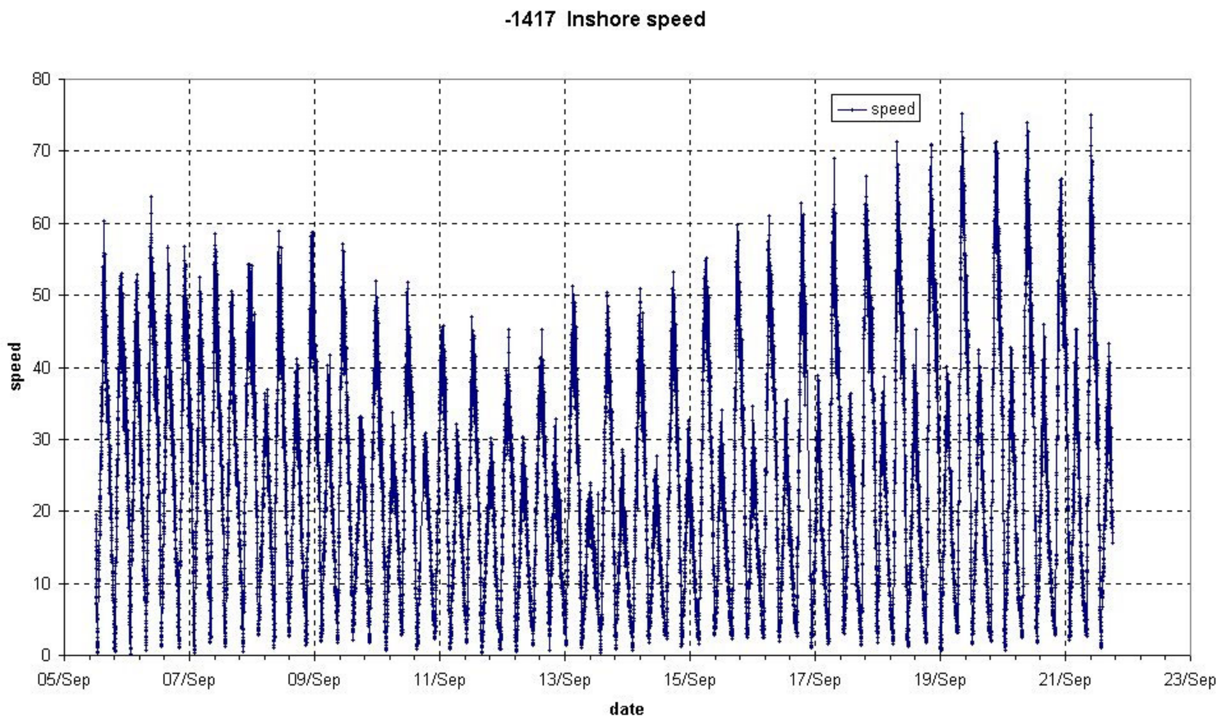

Figure 20 Current timeseries from Clacton Inshore location (current speed in cm/s)

All three records show broadly similar patterns with strong differences between flood and ebb tides and a spring-neap cycle. The maximum currents are at the Clacton Inshore site decreasing offshore.

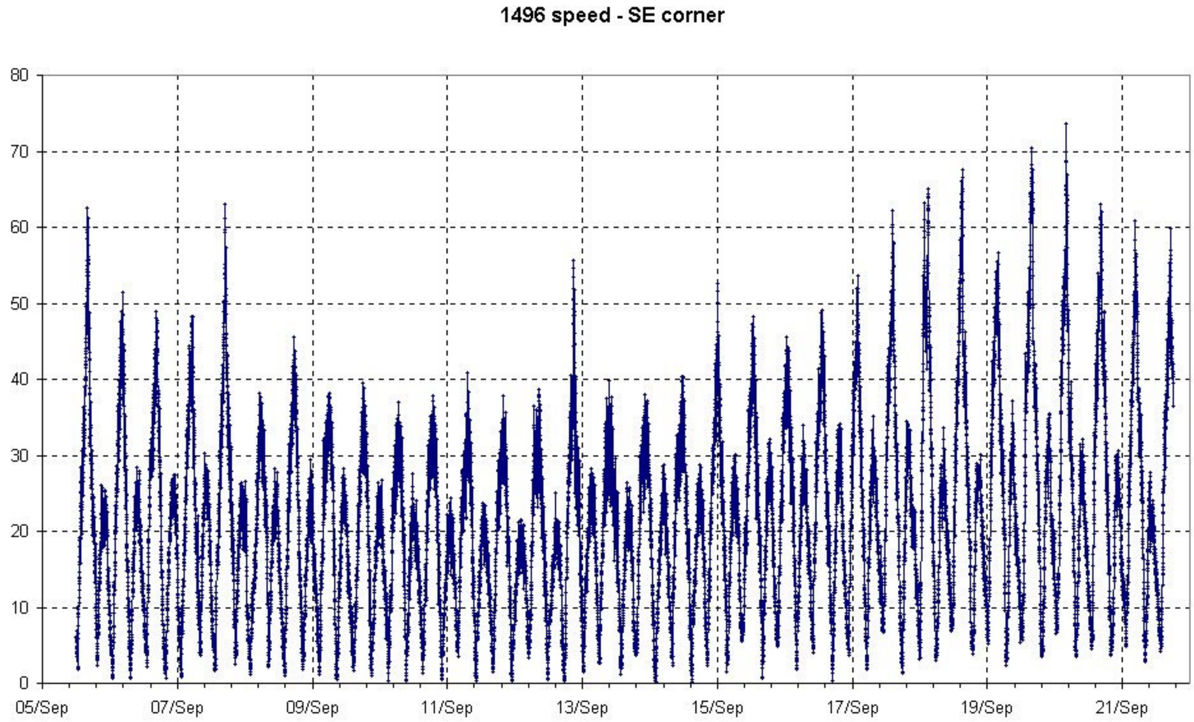

Figure 21 Current timeseries from Clacton South East location (current speed in cm/s)

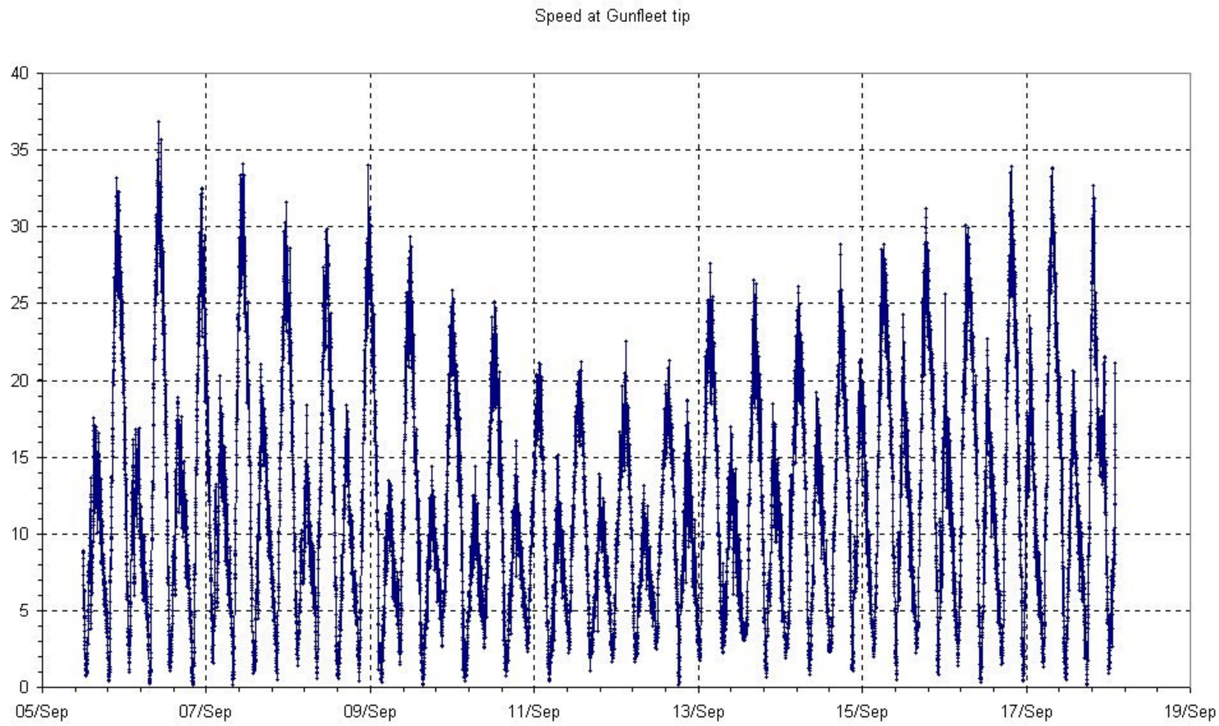

Figure 22 Current timeseries from Gunfleet tip location (current speed in cm/s)

3.2 Minipod

The first good data Clacton/Naze Minipod was on 5th September 2001 at 12:00 and the last good burst was on 25th September 2001 at 8:45. Burst were collected every 15 minutes lasting 10 minutes with currents being measured at 5 Hz and all other sensors at 1 Hz (also see Figure 4).

3.2.1 Pressure records

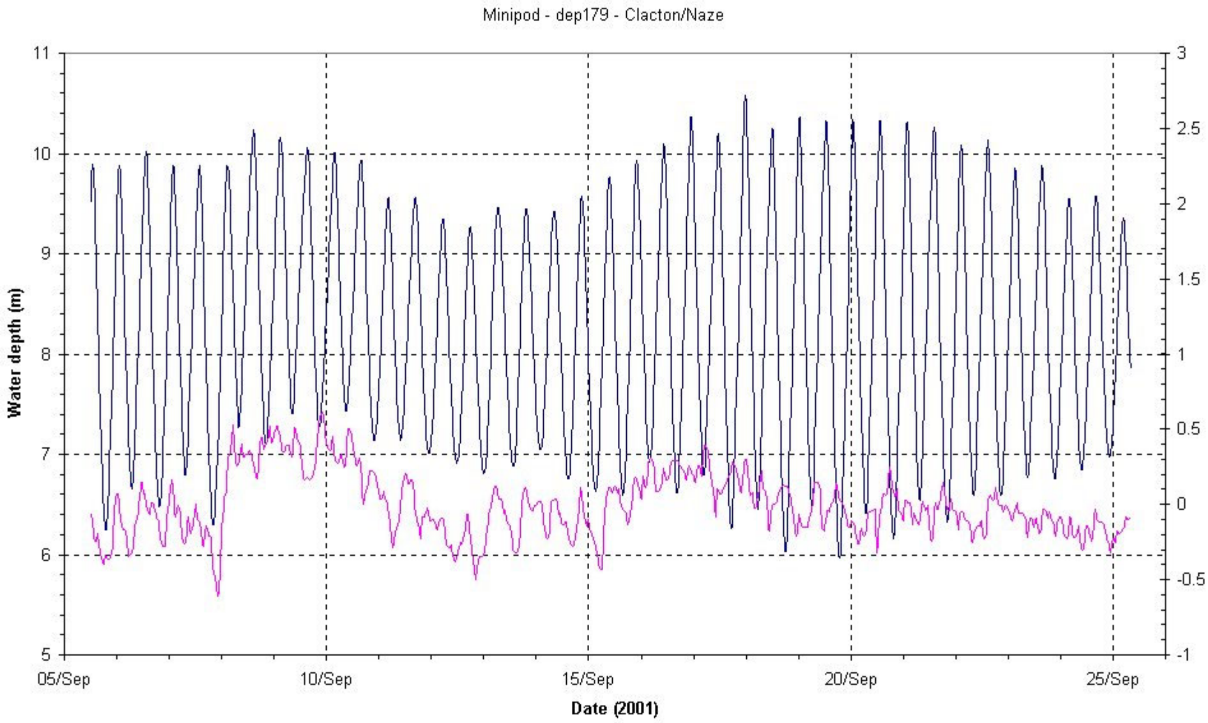

Figure 23 Burst mean depth time series from the Clacton/Naze Minipod along with detided depth

The timeseries of burst mean pressure to the Clacton/Naze Minipod deployment is shown in Figure 23 along with the detided elevation. The mean water depth is approximately 8.1 m with a 2m tidal range at springs. A small tidal surge of approximately 0.5 m is evident between the 8 Sept and 11 Sept. The tidal constituents from this analysis are shown in Figure 23 showing that 48% and 14 % of the energy lies in the M_2 and S_2 constituents.

Table 1 Tidal constituents for Pressure series from Clacton/Naze Minipod (those less than 0.05 not shown)

Tidal Constituent	Magnitude
MSF	0.07
O1	0.12
K1	0.13
2N2	0.07
MU2	0.06
N2	0.25
NU2	0.06
M2	1.3
S2	0.37
K2	0.11
M4	0.07
MS4	0.07

As well as giving tidal elevation data the pressure sensors allows us to calculate the significant wave height. Figure 24 shows the significant wave height from the Clacton/Naze Minipod and the Clacton inshore sensor further down the coast. Both timeseries agree very well with the Clacton Inshore site showing a slight reduction. The most evident feature is the large variation in wave height on a tidal time scale. There are several explanations for this which are discussed in section 6.2). Small - scale wave events are observed on the 13th and 18th September reaching a maximum of around 1 m.

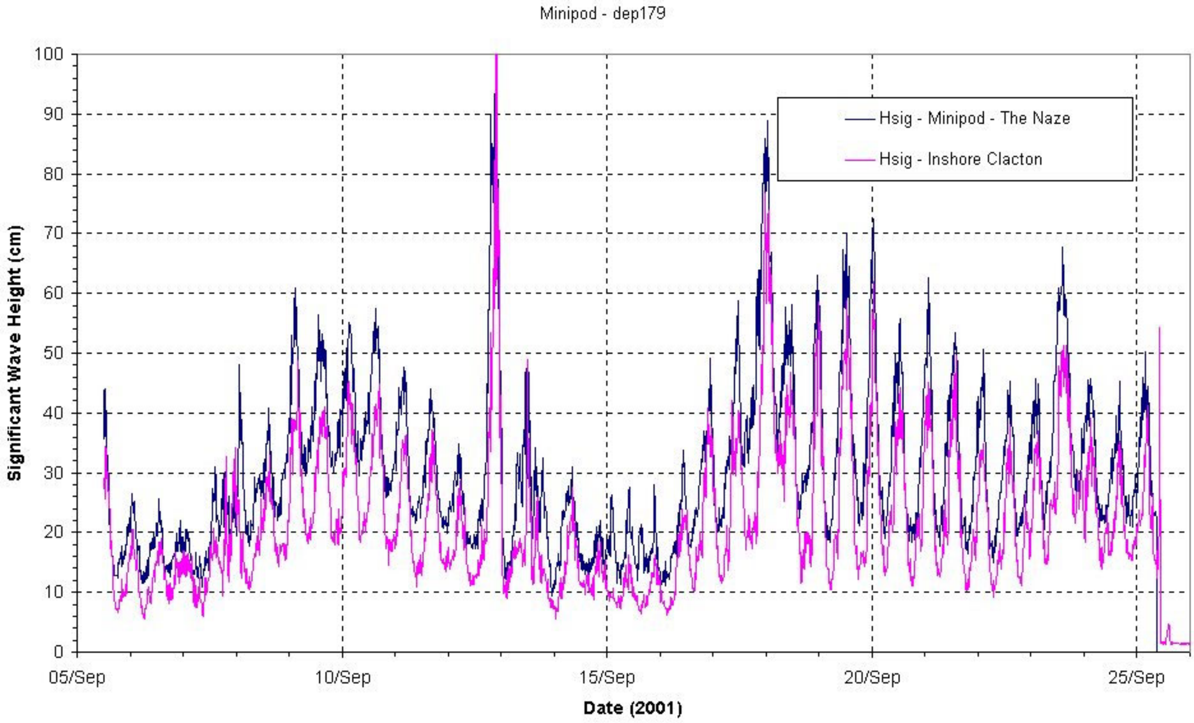

Figure 24 **Significant wave height as measured by a DigiQuartz pressure transducer on the Clacton/Naze Minipod. Also shown in red is the significant wave height record from the CEFAS ESM2 logger on the Clacton inshore bed lander using a Druck transducer**

The timeseries of wave orbital velocity at the seabed, as shown in Figure 25, show that the wave event on the 13th is not significant. However, the wave event on the 18th September is significant and produces velocities of over 30 cm s^{-1}.

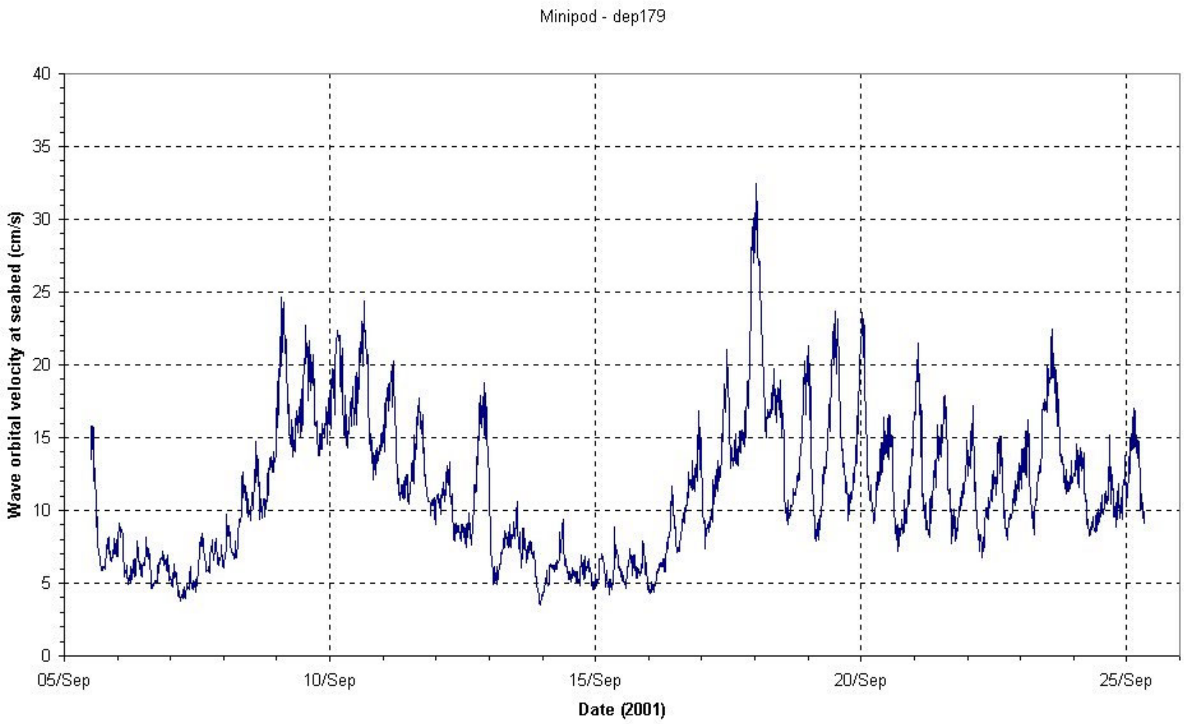

Figure 25 **Wave orbital velocity as calculated using the wave height, wave period and water depth for the Naze Minipod deployment**

3.2.1 Current records

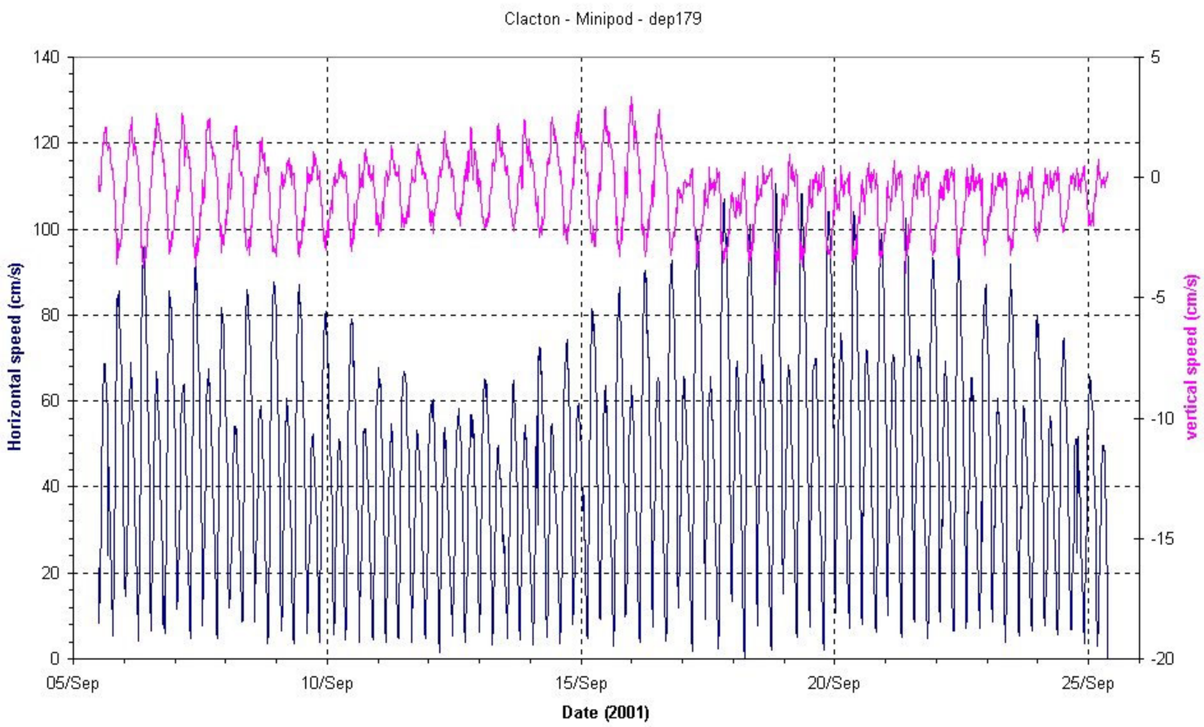

Figure 26 **Horizontal and vertical speeds (cm/s) from the Clacton/Naze Minipod deployment**

The currents from the Minipod, shown in Figure 26, agree well with the FSI current meter values. Tidal constituent data (Table 2) again shows the dominance of the M_2 and S_2 tides.

Table 2 Tidal constituent data for velocity timeseries from the Nortek Vector mounted on the Calcton/Naze Minipod

Constituent	East		North	
	AMP	PHASE	AMP	PHASE
Z0	2.73	0	6.85	0
MSF	0.28	137.6	1.66	62.3
2Q1	0.4	309.1	0.79	339.2
P1	0.39	297.5	1.18	324.3
S1	0.15	228	0.45	254.8
K1	1.04	304.1	3.16	330.9
J1	0.11	238.7	1.84	183.8
2N2	1.74	229.8	3.63	230
MU2	1.42	355.8	2.96	356
N2	4.31	185.1	10.72	184.5
NU2	0.98	181.6	2.43	181
M2	22.83	207.4	56.74	206.8
L2	0.6	228.8	1.49	228.1
S2	6.44	275.7	15.43	268.4
K2	1.85	273.9	4.44	266.7
M4	2.36	161.4	5.8	78.5
MS4	0.95	257	4.55	123.1
S4	0.39	230	1.18	232.4
M6	1.65	139.5	2.31	192.3
2MS6	2.03	193.1	2.37	240.3
2SM6	0.41	273	0.45	1.9

3.2.2 Suspended sediment records

The Minipod has two type of suspended sediment sensor, optical and acoustic, as described above. The timeseries from Optical backscatter sensors, mounted 55 and 75 cm above the seabed, are shown in Figure 27 for the Clacton/Naze deployment. The background concentration varies with the spring-neap cycle with additional tidal resuspension for periods around springs. Interestingly, the wave event on the 18th September is absent from the suspended sediment record. The tidal signals are explored further in Figure 28 for the short period 18th to 24th September (shown with current velocity). The peaks in suspended sediment concentration are in fact, two peaks. The first peak occurs at the end of the flood tide as material falls out of suspension and deposits onto the seabed. After the slack tide, the material is resuspended into the water on the start of the ebb tide. From the background concentration the peaks takes approximately 1 hour to reach a maximum implying sands rather than fines are falling out of suspension. A similar occurrence is evident at the end of the ebb tide but not as pronounced. These temporary deposits are often referred to as “fluff layers” and can be important in the transfer and fate of contaminants.

The Acoustic sediment sensor (ABS) timeseries is shown in Figure 28 with two panels for the 1 MHz and 4.58 MHz transducers. The graphs show that sand is normally resuspended into the water column at spring tides with less sand resuspension at neap tides. When resuspended sand is found through out the first 70 cm of the water column. Even at springs, sand falls out of suspension on slack tides.

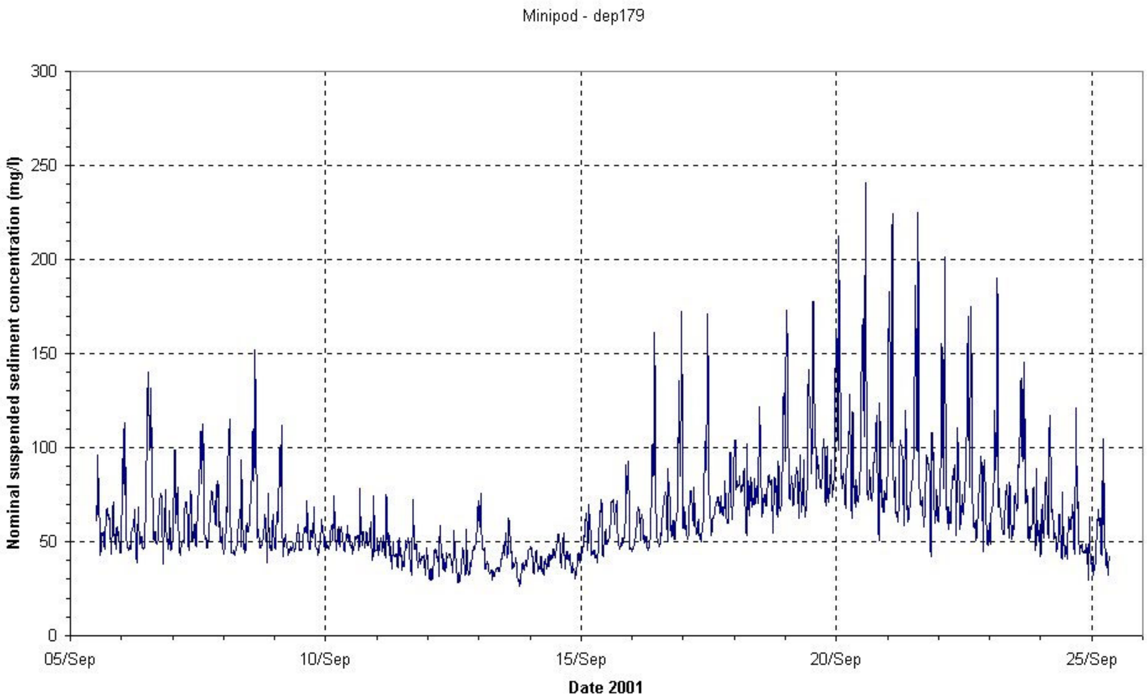

Figure 27 **Timeseries of burst mean suspended sediment concentration from Clacton/Naze Minipod (MOBS1)**

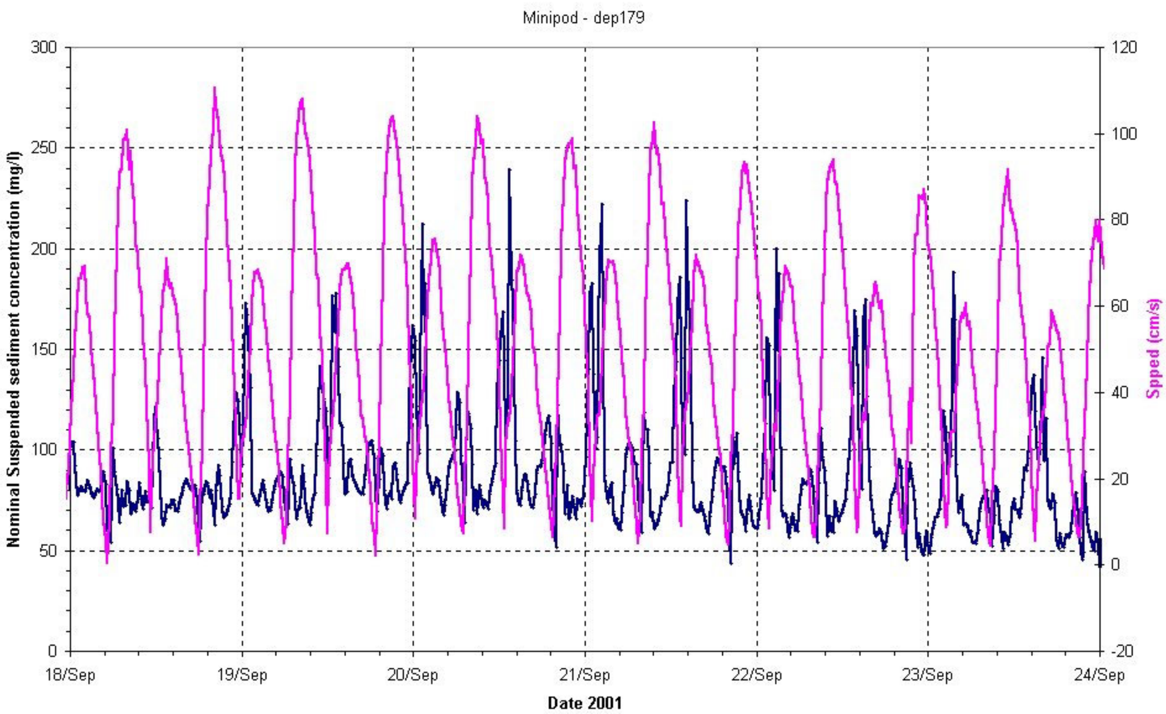

Figure 28 **Burst mean suspended sediment concentration and current speed for the period 18th to 24th September 2001 from the Clacton/Naze Minipod showing a double peak around each slack tide. Note the end of the flood tide (i.e. high tide) slack has significantly higher suspended sediment concentrations than the end of the ebb tide (low tide) slack**

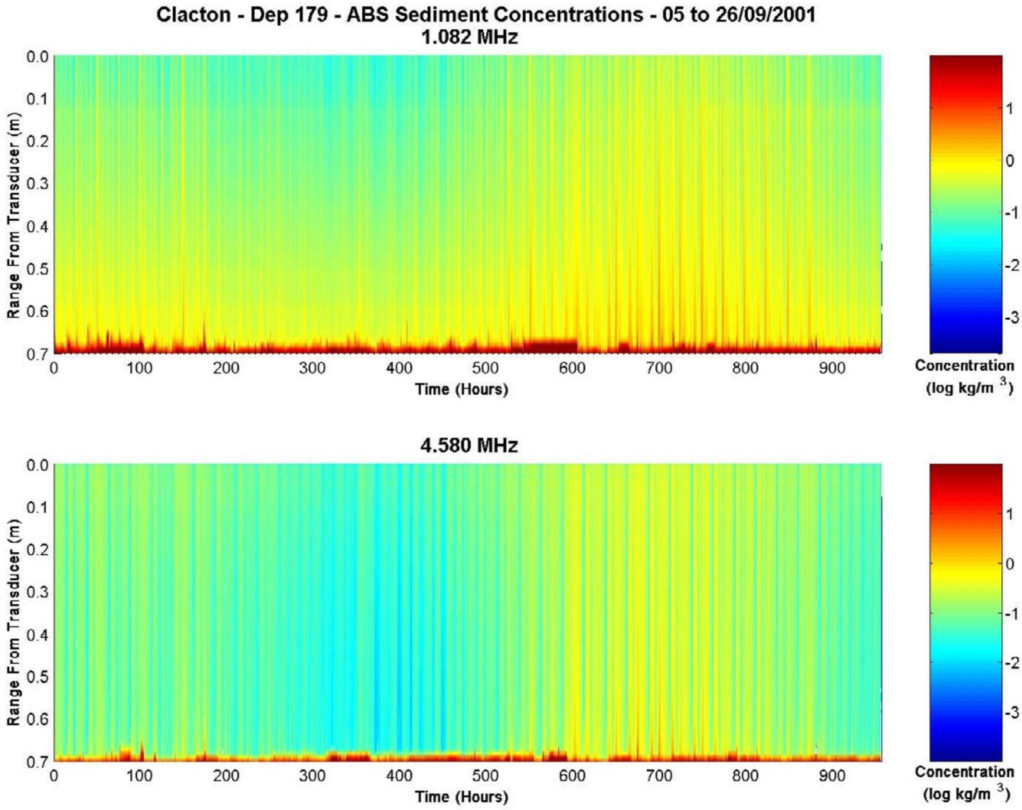

Figure 29 Contours plots of the suspended sediment concentration as measured by the Acoustic Backscatter system (ABS) on the Naze Minipod deployment

3.3 ADCP section

As part of the Clacton fieldwork a single ADCP section was conducted from the Clacton foreshore out to Gunfleet Sand as shown in Figure 30 and Figure 31. The horizontal gradient in current strength is apparent (similar to the current meter moorings) with little vertical gradients.

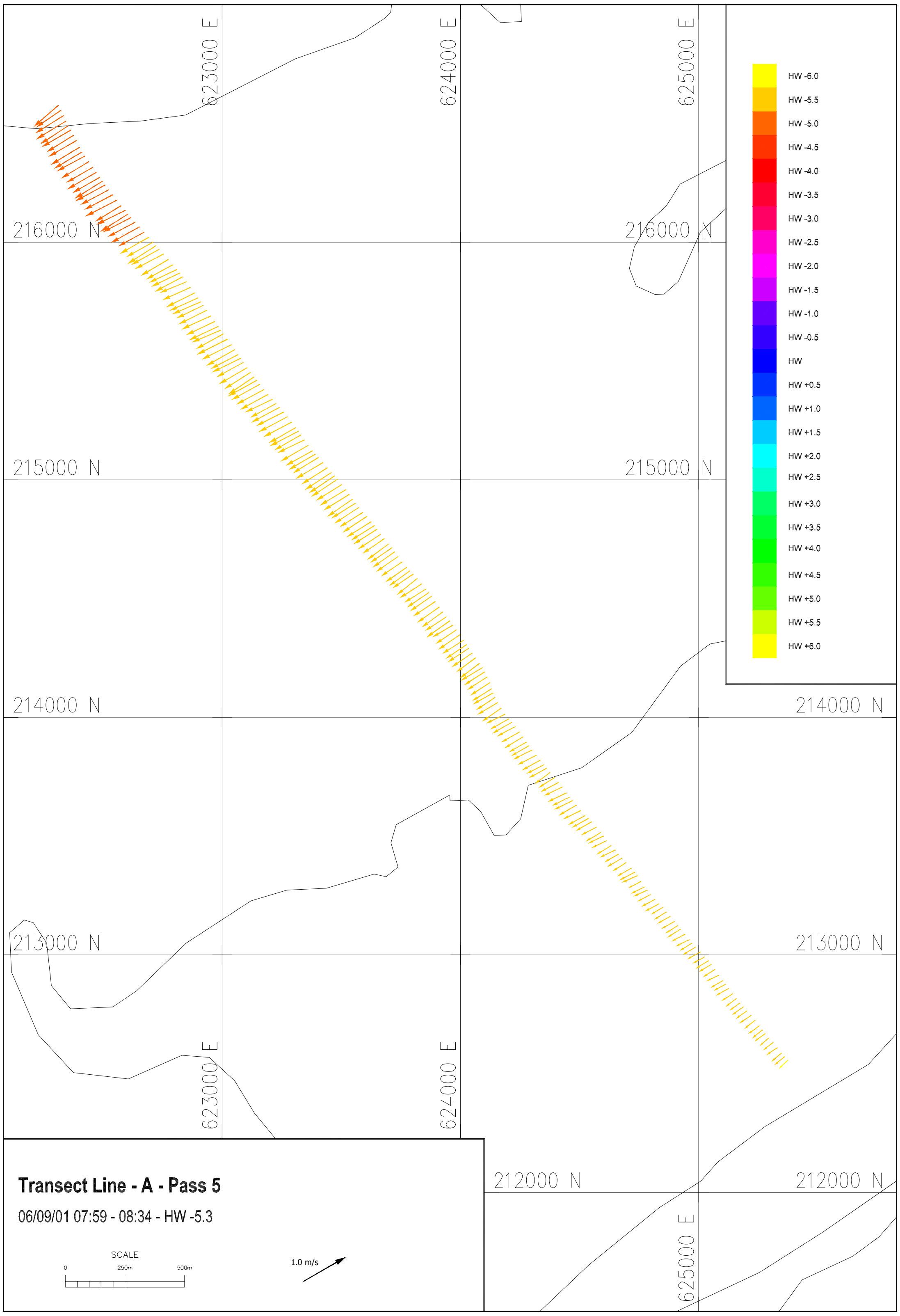

Figure 30 **Vector plot of the current direction and magnitudes) recorded along the ADCP transect on Pass 5 (07:59 to 08:34) on 6th September 2001**

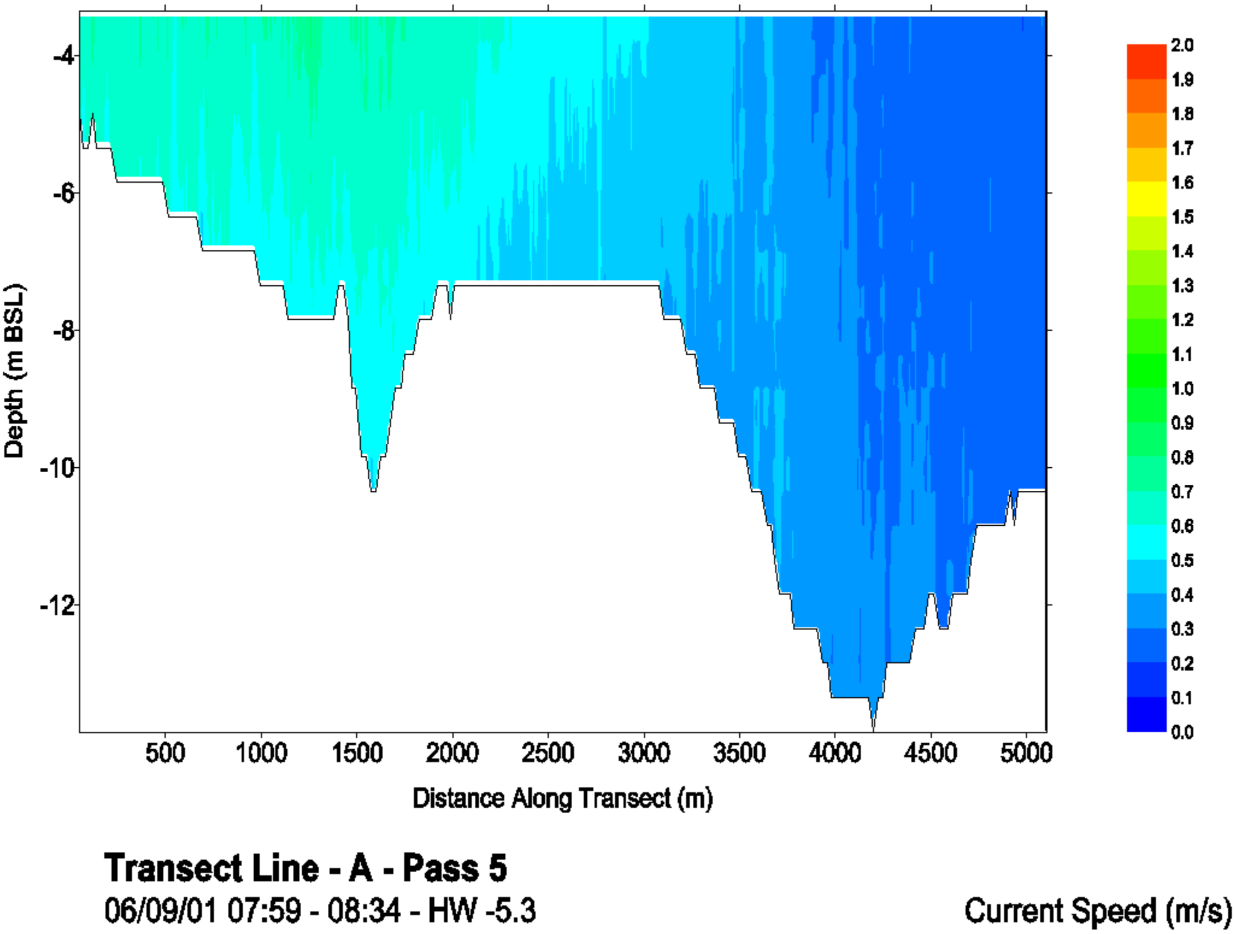

Figure 31 **Contour plots of current speed (m/s) recorded along the ADCP transect on Pass 5 (07:59 to 08:34) on 6 September 2001**

3.4 Sidescan Sonar

A sidescan survey was conducted in order to identify major sediment transport pathways. A EG&G 272 sidescan sonar fish and Triton-Elics acquisition software was used to produce a digital dataset. Port and starboard swathes of 150m were recorded at a survey speed of 5 knots. The survey coverage, shown in Figure 32, has been coloured coded to show sediment type (green indicates gravels and red indicates sands). The coverage was designed to cover as much area as possible especially around the north and south faces and northern tip of Gunfleet Sand. The area around Goldmer Gat (between Gunfleet tip and Cork Sand).

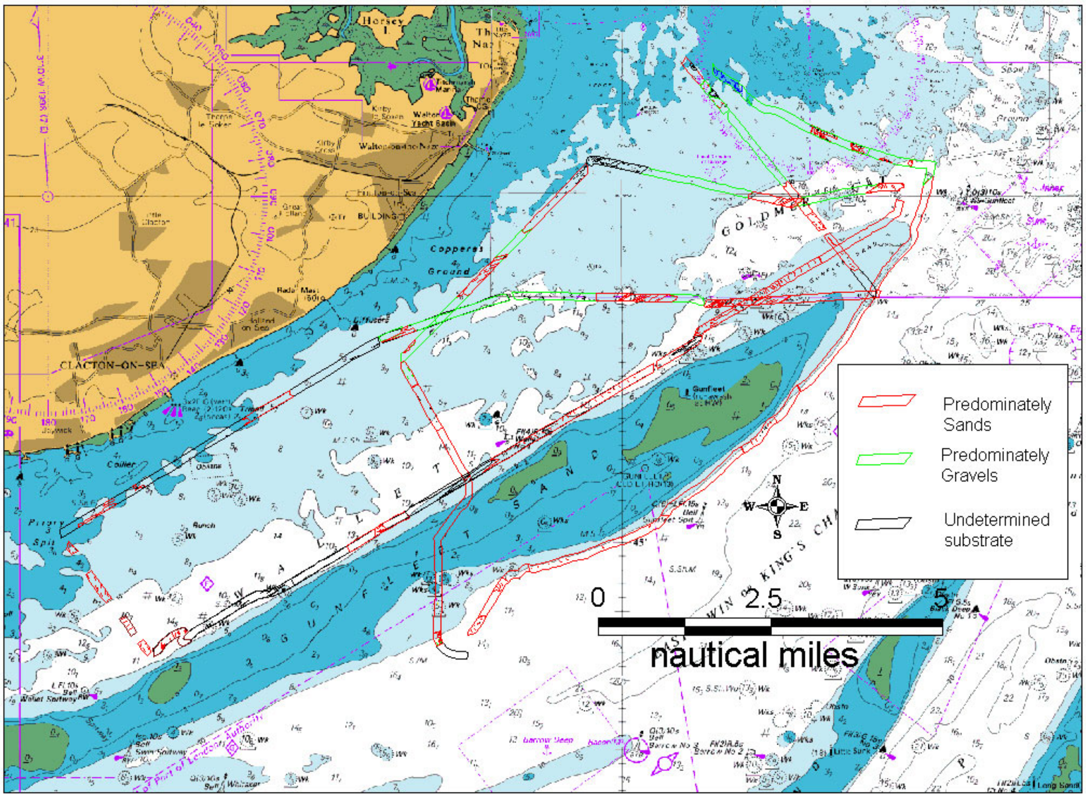

Figure 32 Sidescan Sonar coverage and basic interpretation from the Clacton/Gunfleet Survey during 14th September 2001 (Admiralty chart 1975)

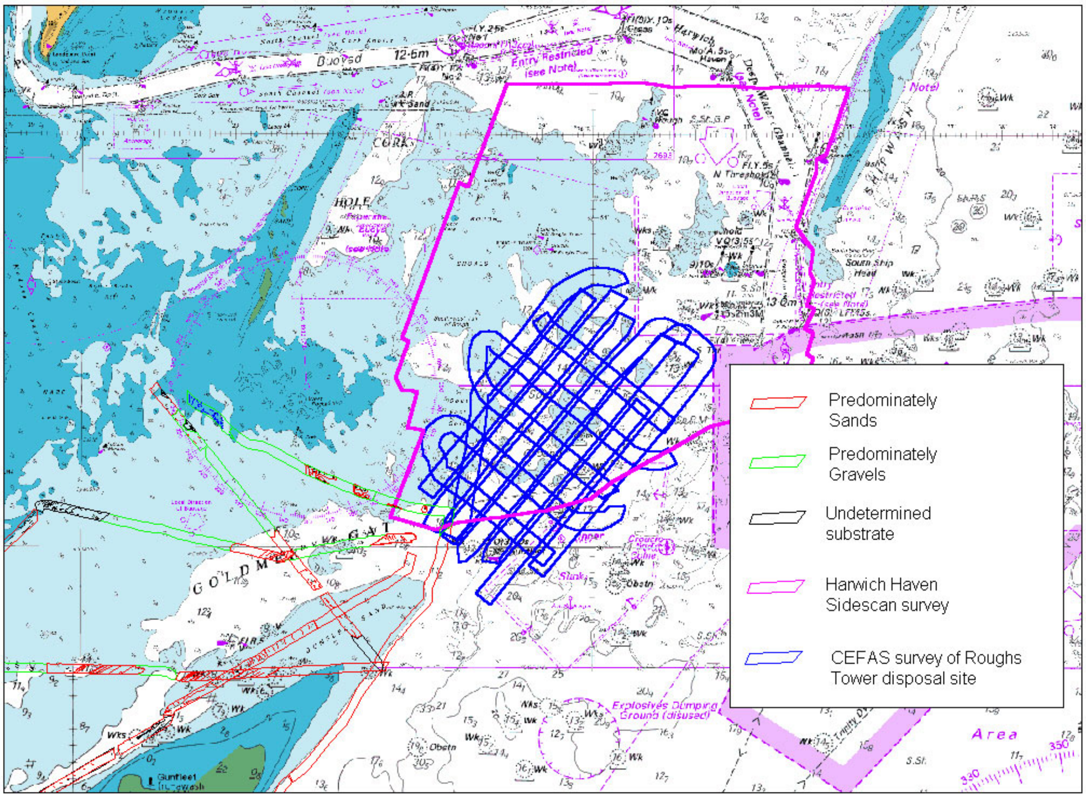

Figure 33 Chart showing SNS2 Clacton survey, part of the HHA sidescan sonar survey (in red), the 2000 CEFAS survey of Roughs Tower Disposal site and the license area of the Roughs Tower site (Admiralty charts 1975, 2052 and 2693)

Additional CEFAS sidescan sonar surveys were available for analysis for sediment transport patterns as shown below:

i) 1997 - Annual FEPA sidescan sonar survey – May, Additional survey in summer + survey at Threshold
ii) 1998 - Annual FEPA sidescan sonar survey - May
iii) 1999 - Annual FEPA sidescan sonar survey - May
iv) 2000 - Annual FEPA sidescan sonar survey - May
v) 2001 - Annual FEPA sidescan sonar survey - May, HHA survey, SNSSTS Clacton Survey

3.5 Auxiliary Data

Mounted on the leg of the Minipod and the seabed frames were sediment traps called a Booner Tubes (see Figure 4). Material from the Booner tube was used to calibrate the OBS sensors in a recirculating turbidity tank and also to determine the particle size distribution of the sediments in suspension. The particle size distribution for the Clacton inshore bedframe (see Figure 34) shows a bimodal distribution with peaks at 8 and 80 µm.

During the sidescan sonar survey and whilst deploying bedframes and Minipod surface water samples were collected for suspended sediment concentration. Results, shown in Figure 35, show higher concentrations around the tip of Gunfleet sands of around 102 mg l^{-1} compared with around 50 mg l^{-1} locally.

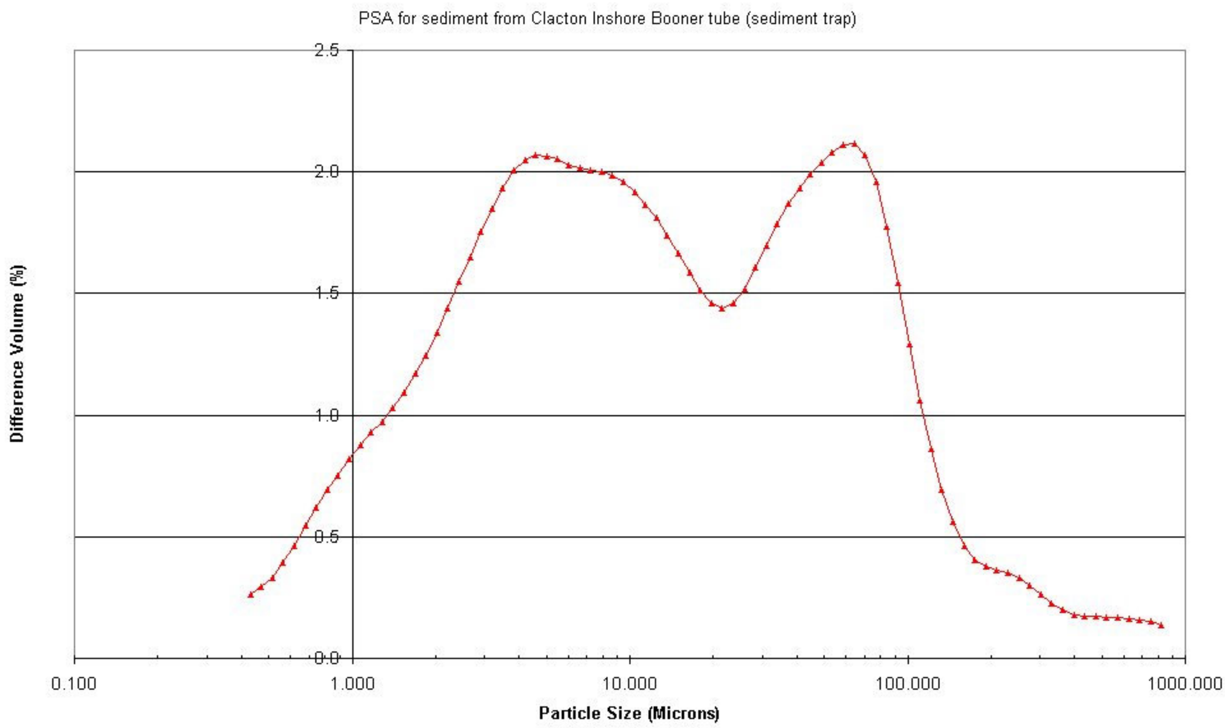

Figure 34 Particle size distribution from sediment trap (Booner tube) from Clacton Inshore Mooring

Clacton Suspended Sediment Concentration (mg/l) - Sept 2001

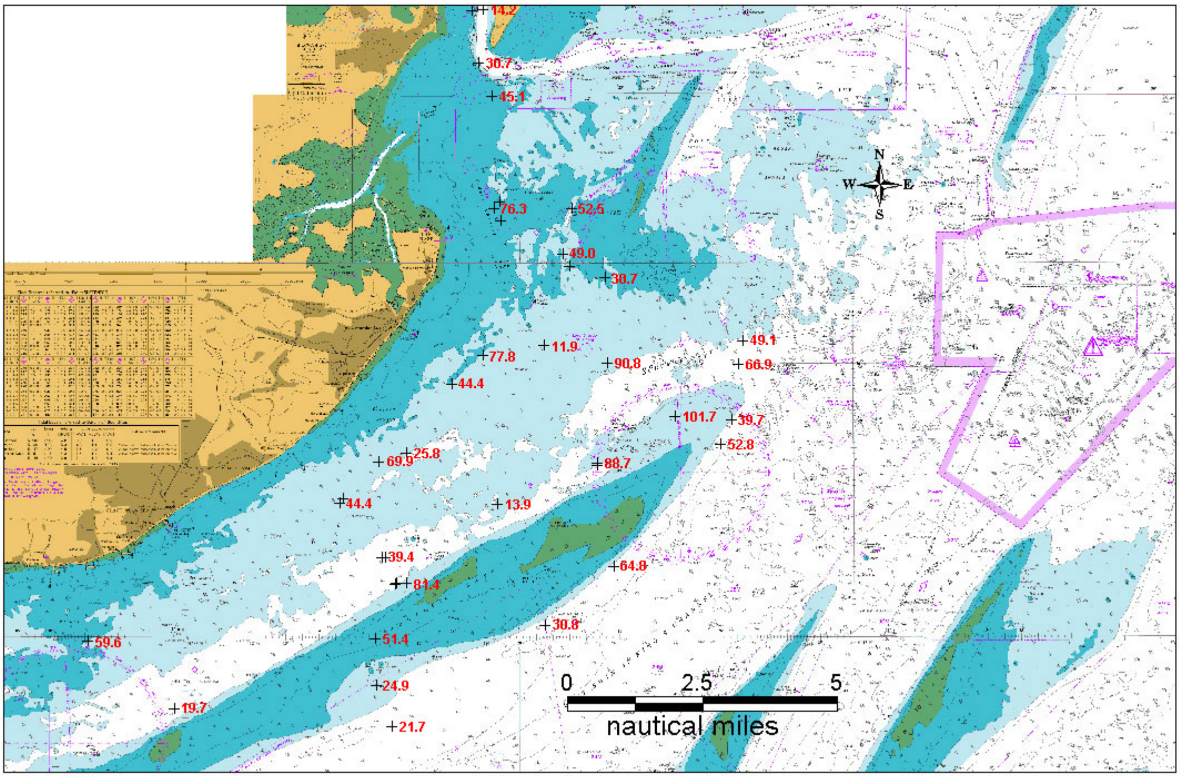

Figure 35 **Quasi- synoptic survey of surface suspended sediment concentration (mg/l) from Clacton/Harwich area during 14th and 25th September 2001 (Admiralty charts 1975 and 1183)**

Samples from the Booner tubes were used to calibrate the OBS sensors on the CEFAS ESM2 loggers. Measured amount of sediment were added to the turbidity tank and the response of the OBS sensor on each logger recorded. Water samples were also taken and analysed gravimetrically. Further sediment was added to cover the whole range of concentrations encountered at Clacton. Figure 36 shows the data along with a regression for each dataset. Regression coefficients were very high (R^2 grater than 0.9981).

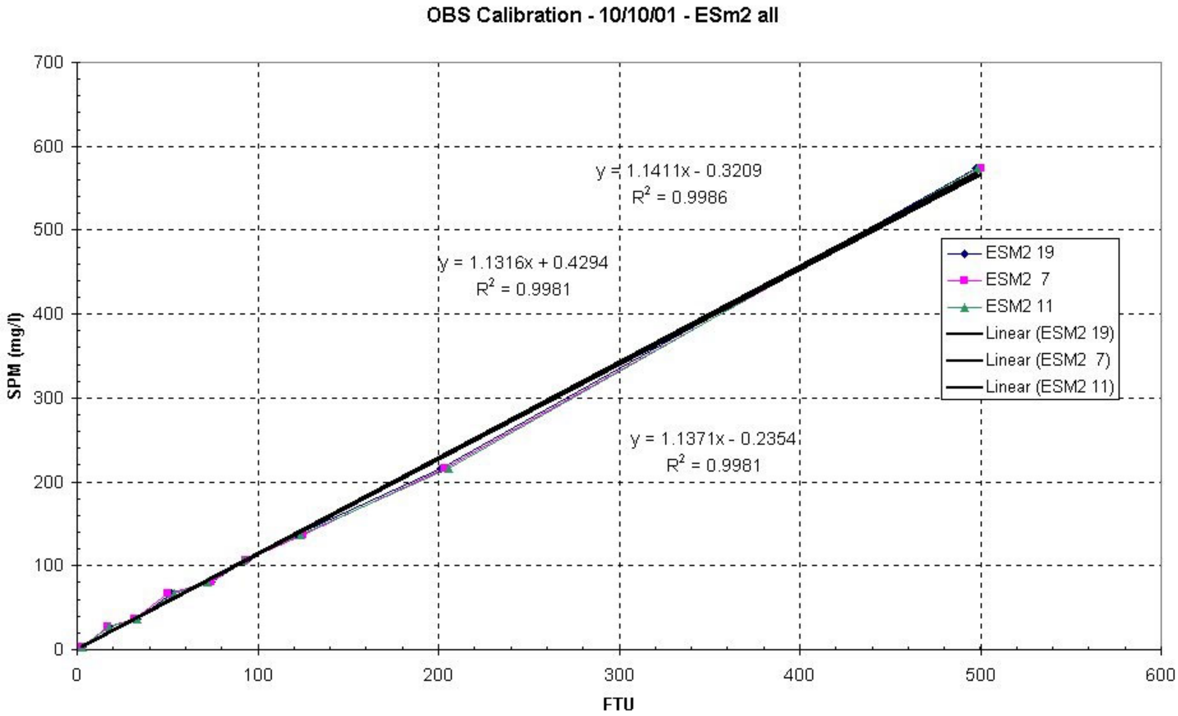

Figure 36 Calibration of ESM2 Micrologger in turbidity tank calibration

4 HUMBER

4.1 Sidescan Sonar

Whereas the Winterton and the Clacton fieldwork programmes included a deployment of seabed landers and current meters the Humber fieldwork consisted of only Sidescan sonar coverage. The surveyed was conducted with an EG&G 272 fish logged into Triton-Elics recording software. Swathes of 150m either side were recorded with a survey speed of 5 knots. The coverage of the survey, conducted on 6th and 7th December 2001, is shown in Figure 37. The chart also includes the track lines from the BGS GeoTrak 2 survey accomplished in summer 2001 kindly supplied by BGS to the Study team (*pers comms* P Balson, 2002).

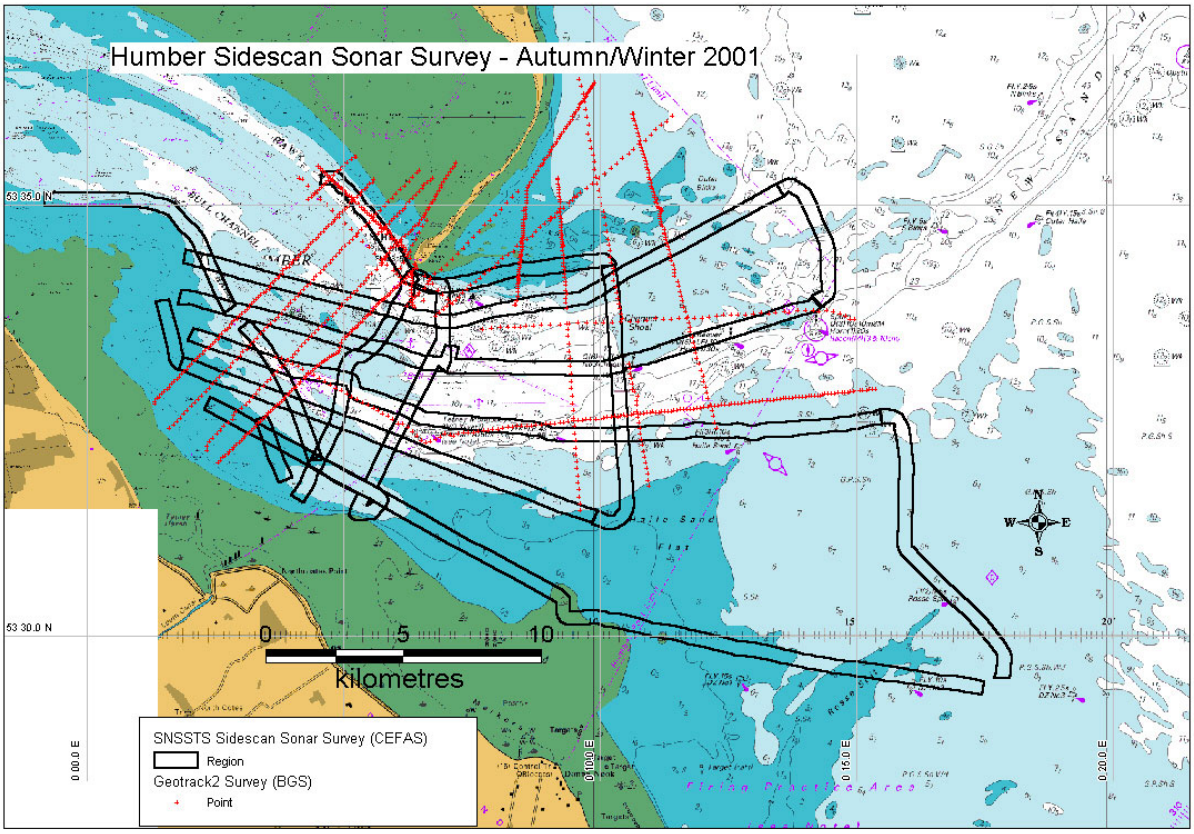

Figure 37 **CEFAS and BGS (GeoTrak 2) sidescan sonar survey of the mouth of the Humber and the Donna Nook area during Autumn/Winter 2001 (Admiralty charts 107 and 1188)**

Owing to the relative timings of the seabed and coastal work within the Humber Estuary Shoreline Management Plan Phase 2 and the SNS2 study it was not possible to combine and work up both datasets within the time for delivery of the SNS2 study. This will take place within the HESMP2 study later in 2002. However, the SNS2 dataset was analysed in conjunction with BGS, HR Wallingford and Brian D'Olier forming a direct link between the experiences of both projects. This was accomplished through a meeting held on 1st February 2002 at BGS Keyworth. The SNS2 data set has been processed to produce a sidescan sonar mosaics and subsequently analysed to produce maps of sediment transport vectors (see section 5.1).

4.2 Auxiliary Data

During the sidescan sonar survey of the Humber, surface water samples were taken at 30 minutes intervals for determination of suspended sediment concentration and salinity. The results, shown in Figure 38, indicate suspended sediment concentrations as high as 260 mg l^{-1} within the estuary decreasing to 56 mg l^{-1} offshore within the deep water channel and down to 20 mg l^{-1} to the south of the Donna Nook area. Correspondingly, the salinities follow the same pattern indicating the Humber plume heading east along the deep water channel e.g. the eastern most salinity in the channel is 31.75 PSU compared with 34.26 PSU south of Donna Nook.

Interestingly, there also appears to be an association of high suspended sediment concentrations with depth across the mouth of the Humber along the line from Spurn Point (110 mg l^{-1}), through Bull Sand Fort (51 mg l^{-1}), through Haile Channel (175 and 90 mg l^{-1}) and down to Haile Sand fort and Tetley High sands (48 and 29 mg l^{-1}).

Humber survey - Dec 2001 - Surface Suspended load (red) and salinity (blue)

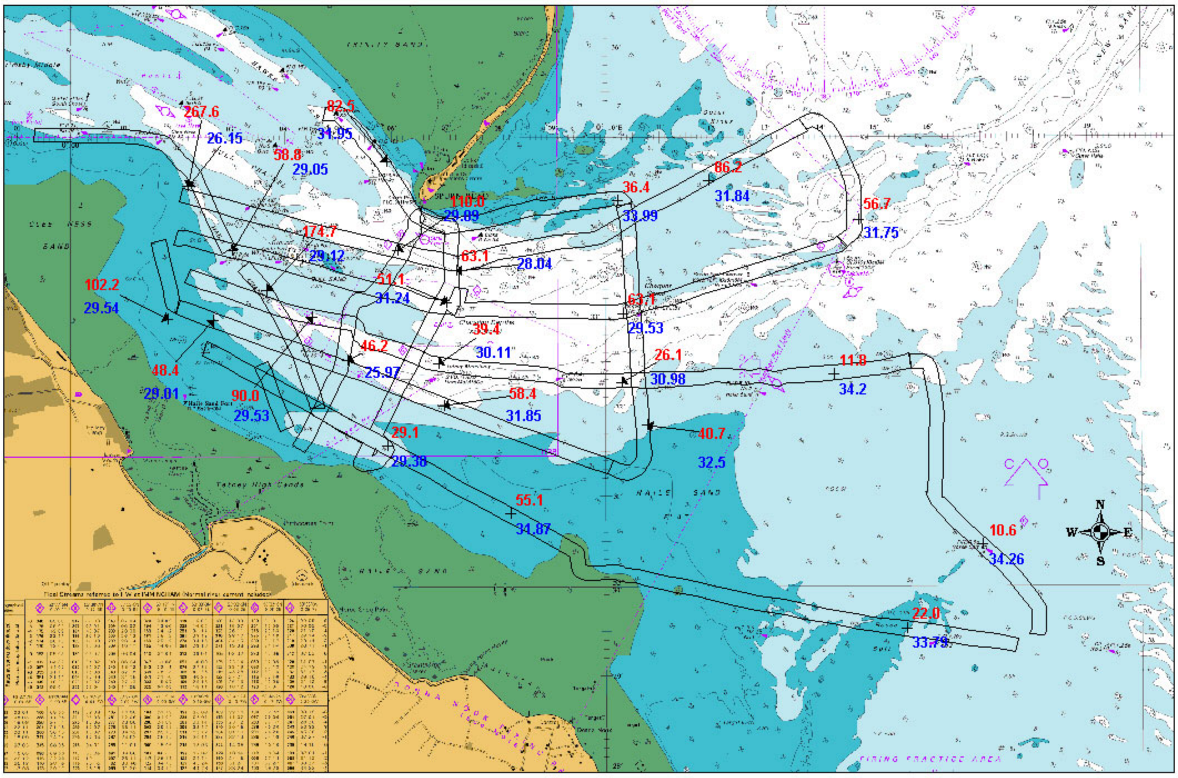

Figure 38 **Quasi-synoptic surface suspended loads (red) and surface salinities (blue) taken during the Humber survey on 6th and 7th December 2001 (Admiralty charts 107 and 1188)**

5 GIS based sediment Transport Indicators

5.1 Indicators from Sidescan sonar records

The sidescan sonar surveys from the Winterton, Clacton, Humber, and associated others surveys (see section 3.4 for full list) were mosaiced using Triton-Elics ™ software to produce geotiffs. These were then transfer to a GIS system (MapInfo ™) and geo-referenced. Note each survey was created as a single geotiff which can be several hundreds of megabytes in size. Each survey was then interpreted to produce four new layers of – megaripples, sandwaves, tidal streaks and comet marks. These were defined as:

Megaripples – either regions or bands of ripples of height typically 30 cm and wavelength 5-10m. If the asymmetry in bedforms can be identified an arrow is placed on the vector otherwise just a bar (see Figure 39).

- Sandwaves – either single sand waves or small groups with typical height one to several meters and a wavelength of up to a hundred meters
- Tidal Scour – either the movement of a bolder over a veneer of sand over gravel leaving the gravel exposed or the "sediment wake" caused by boulders/rough ground or where streaks of sand propagate over gravel
- Comet Marks – large streaks of normally sand in the wake of an obstruction - normally a wreck

Table 3 Number of sediment transport vectors created from sidescan sonar records and BGS digital dataset

Feature	Number of new observations
Megaripples	707
Sandwaves	149
Tidal Scour/streak	201
Comet Marks	10
Total	1057

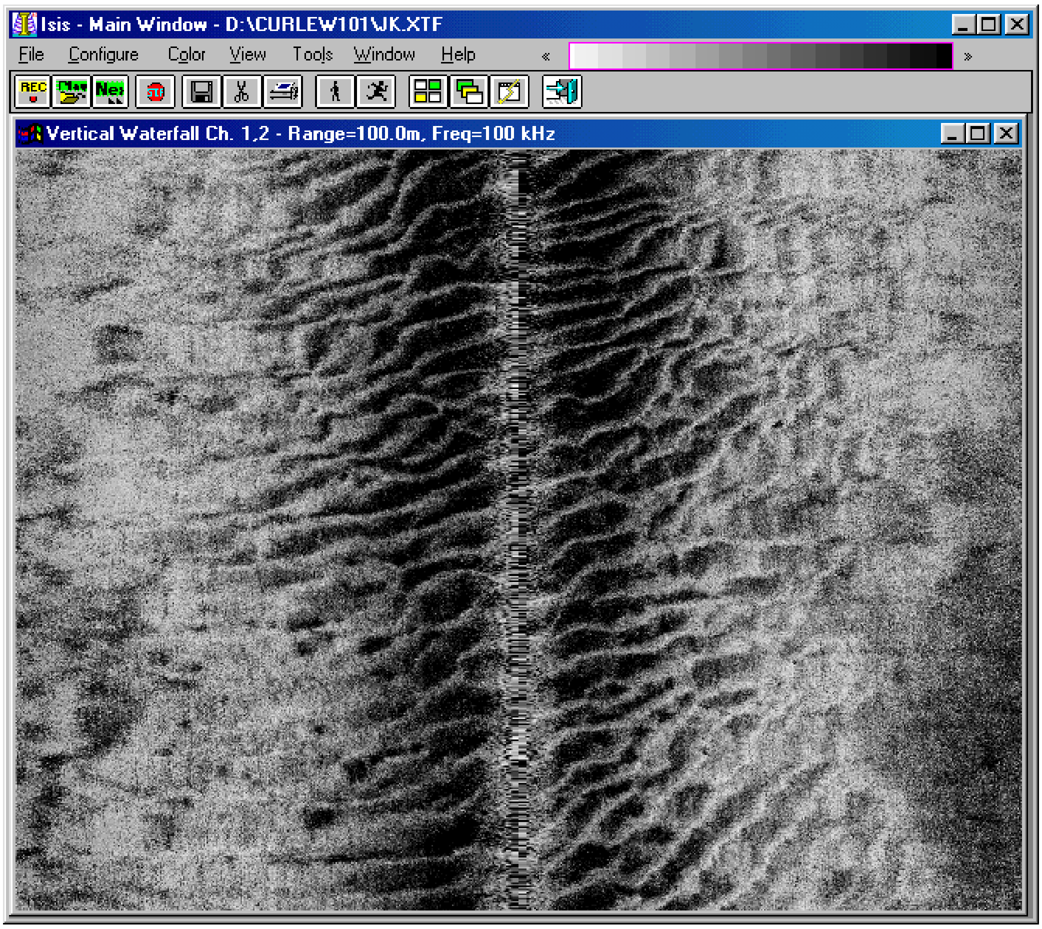

Figure 39 Image of megaripples from sidescan sonar survey around Clacton/Gunfleet

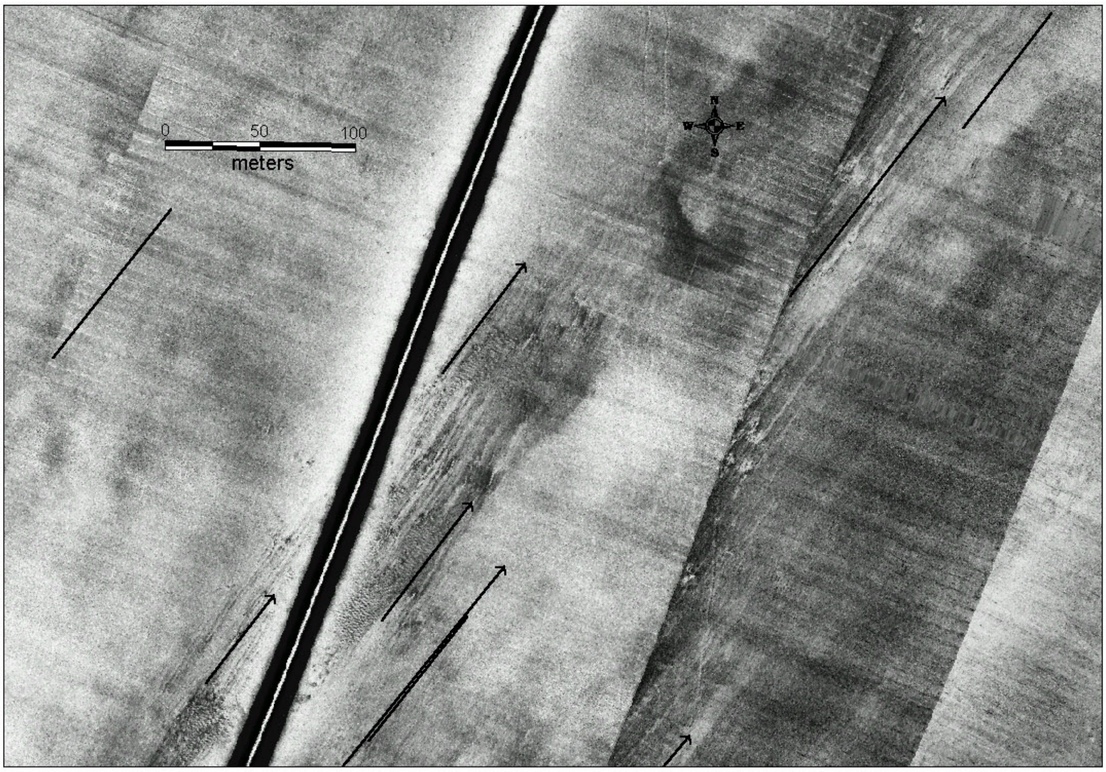

Figure 40 Mosaiced Sidescan sonar image from Harwich survey showing tidal scour/streak lines

5.2 Indicators from BGS data set

The nearshore sediment facies and sediment transport data interpreted by BGS from sidescan sonar records was further analysed to produce additional sediment transport indicators. Typical instances were:

- Where either sandwaves or megaripples did not have any transport indicators – a direction was specified if asymmetry was present otherwise single bar
- Where there was an indication of different substrates moving over others producing streaks
- Where the shape of the substrate suggested a preferred direction

All the new indicators were combined into four separate GIS layers and then used to produce updated maps of the additional sediment vectors as shown in
Figure 41 for the coastline from Holderness to Gibraltar Point, Figure 42 for the coastline of North Norfolk, and Figure 43 for the coastline from Great Yarmouth to Clacton. These have then been compared with numerical model computations to produce schematic sediment transport indicators (see main report).

The data in Figures 46, 47 and 48 have been combined with other data sources to produce a consistent map of sediment transport indicators for the Study Area (see main report and Appendix 15 – the results are also available as a GIS file).

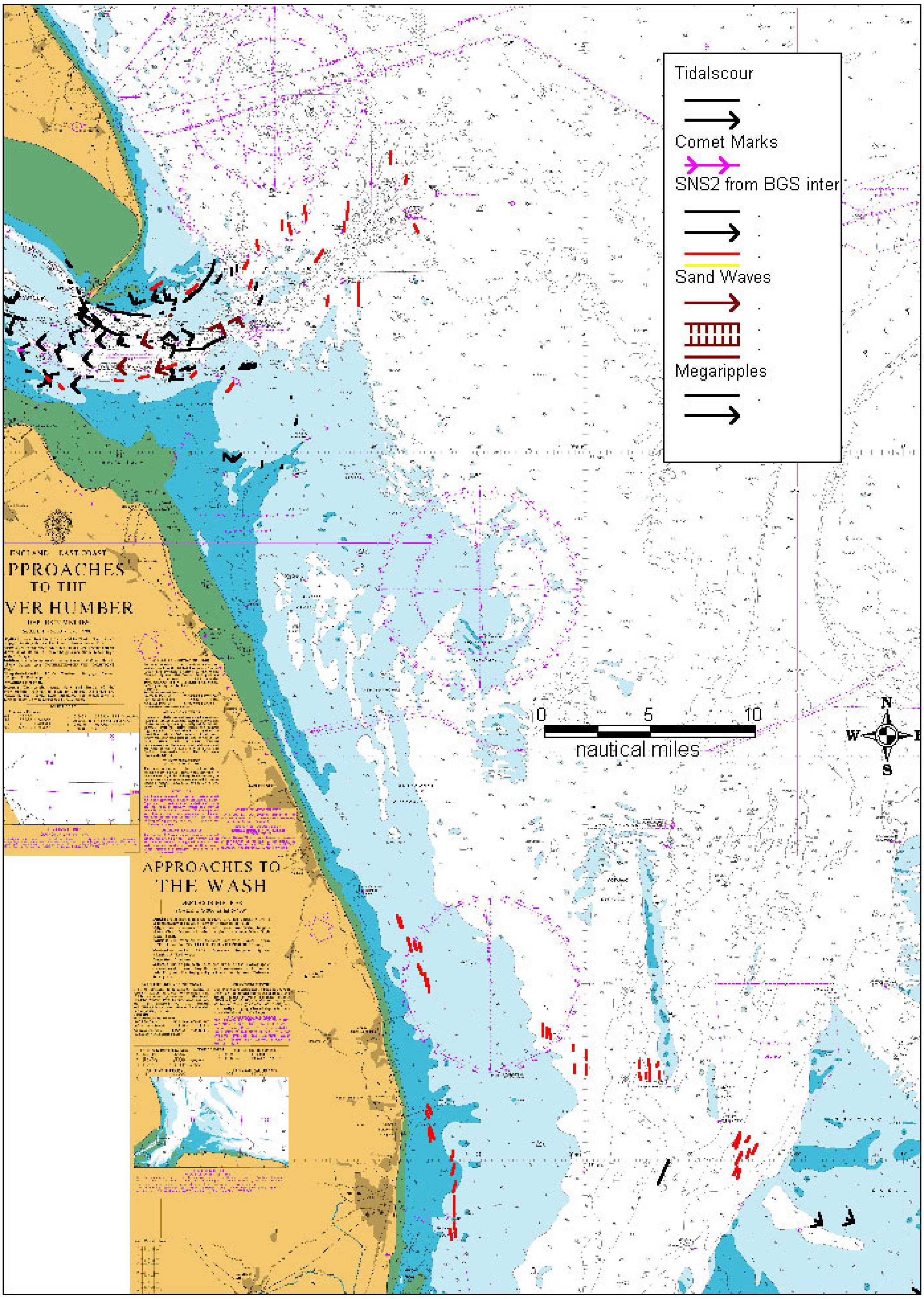

Figure 41 **Chart of the sediment transport vectors around the Humber Estuary (Admiralty chart 1190)**

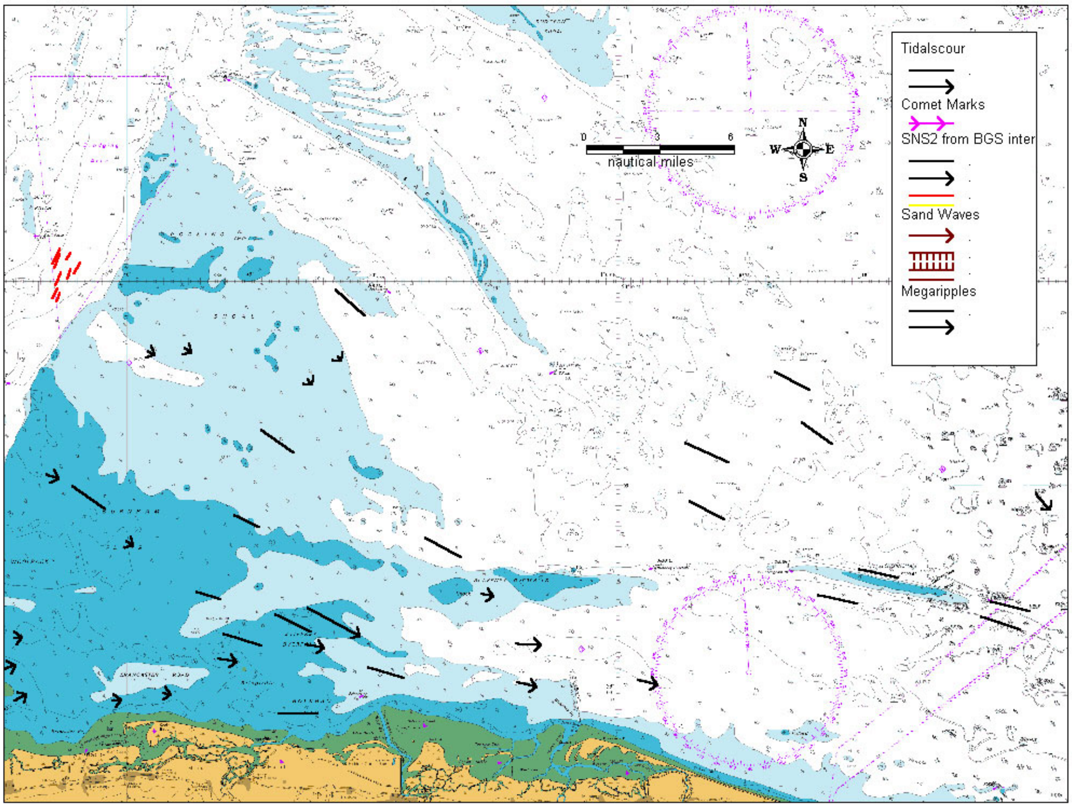

Figure 42 **Chart of the sediment transport vectors around the North Norfolk coast (Admiralty charts 108 and 1503)**

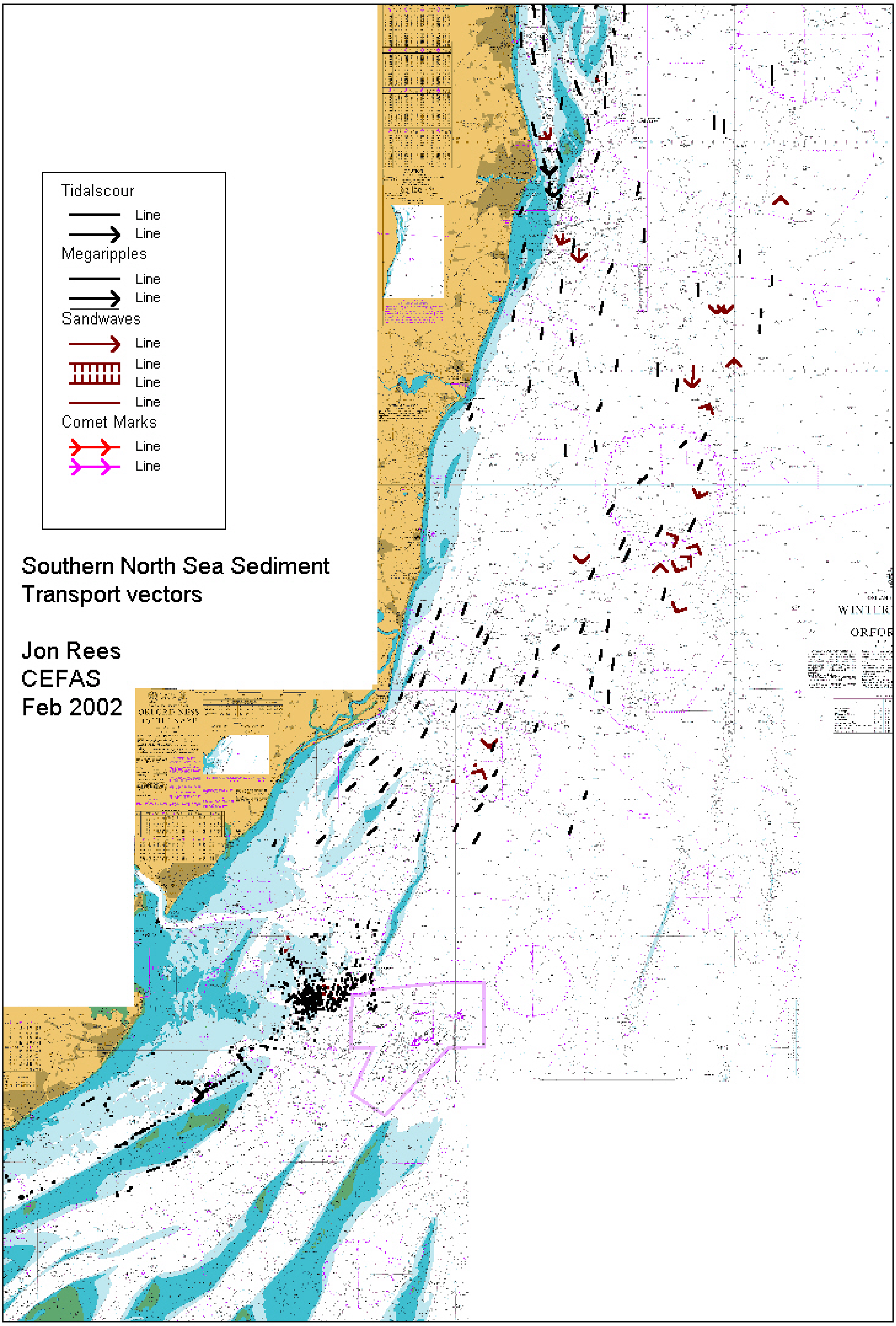

Figure 43 **Chart of the sediment transport vectors from Gt. Yarmouth to Clacton coast (admiralty charts 1504, 2052 and 1975)**

6 Discussion

6.1 Winterton

The wave and current data sets from the Winterton Minipod deployment have been further analysed to produce timeseries of bed shear stress using a non-linear wave/current interaction algorithm (Soulsby, 1997). In Figure 44, the maximum bed shear stress has been calculated for waves alone, tides alone and also for combined waves and currents (using a sand grain roughness k_s of 0.00004 m). When waves are not present, e.g. around 15th April, the stress is dominated by the currents alone. However, during wave events, e.g. 18th to 21st April, the bed stress is enhanced. The bed shear stress at this location are dominated by the currents due to tides as even during wave events the combined bed shear stress is not greater than during spring tides e.g. around 11th April with around 3 Nm^{-2}.

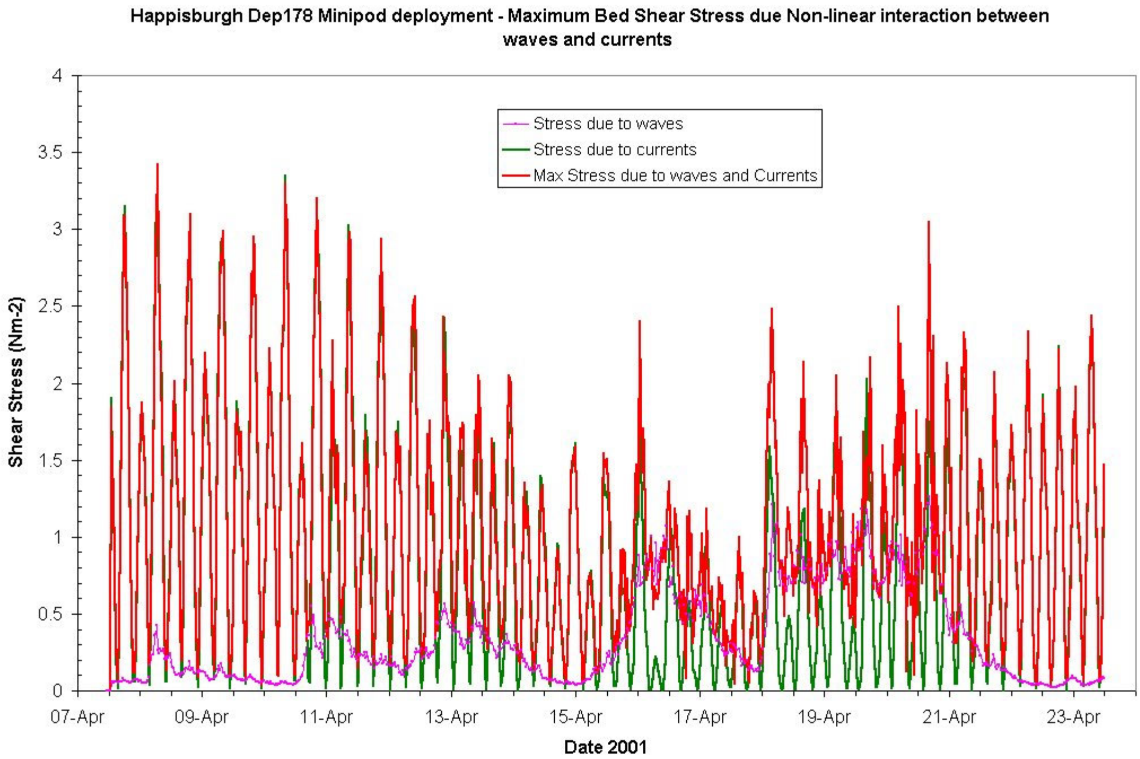

Figure 44 **Maximum Bed shear Stress due to Non-linear interaction of waves and currents from Happisburgh Minipod deployment**

The pressure record from the Minipod can be further analysed to give information on the wave period and hence possibly the generation mechanism i.e. wave spectra. The wave spectra from the Winterton Minipod deployment are shown in a 3 dimensional plot in Figure 45. The fifth wave event, i.e. 18th to 21st April or burst number 510 to 650, is the dominant wave event. The character of this event changes over the 3 days from initially locally generated waves with period 6 to 10 seconds, to local wave combined with longer waves probably generated in the Northern North Sea (periods up 16 seconds), to only local waves. All the other events are created by locally waves.

Table 4 Comparison of bed shear stress from various wave return periods for Happisburgh minipod site

Return period	Significant Wave height (m)	Mean Wave period (seconds)	Maximum Wave induced bed Shear stress (N m^{-2})
This study	2.35	7.2	3.5
5	4.5	7.2	4.4
10	4.7	7.4	4.8
50	5.2	7.7	5.9
100	5.4	7.9	6.4

Comparison of the maximum bed shear stress calculated from various wave return periods (*pers comm*, R Whitehouse) as shown in Figure 45, shows that the bed shear stress is in good agreement with that expected from less than one year storms. Note the maximum wave height of 2.35m was recorded on 20th April at 16:30 whereas the maximum wave period, of 8.8 seconds, was period recorded on the 12th April at 18:00.

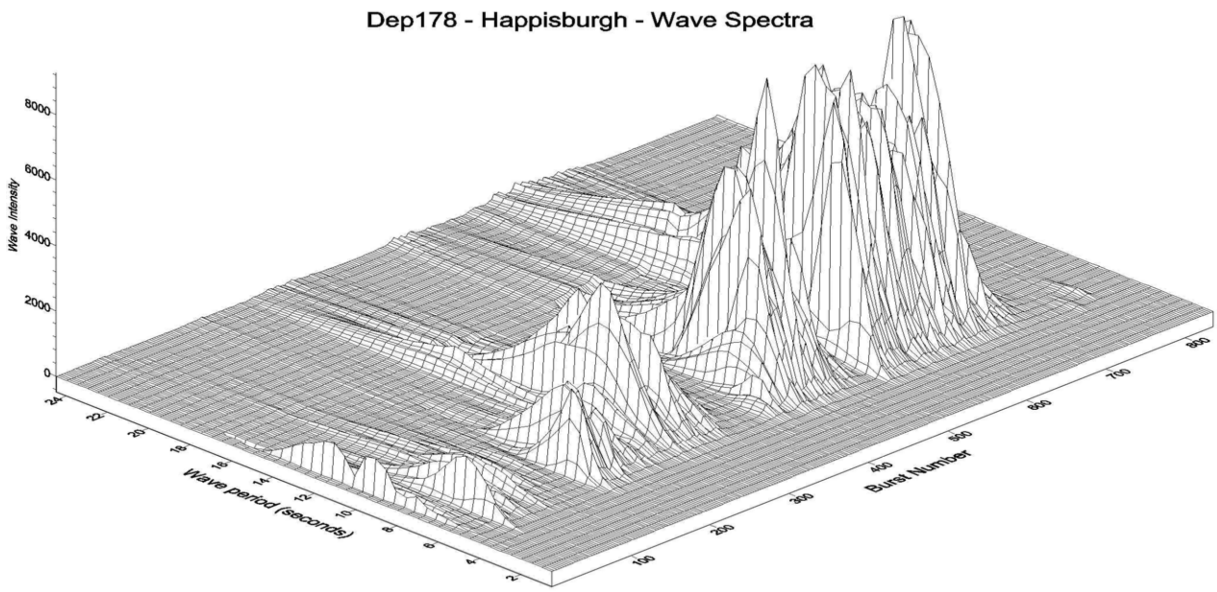

Figure 45 3 dimensional representation of the wave spectra from the Happisburgh Minipod

Sediment flux were calculated in the following manner:

1) The current meter velocity at the single Nortek Vector height was used to calculate the friction velocity, U*, assuming a drag coefficient of 0.0025.
2) The bed roughness, z0, was then estimated and hence the velocity at 5 heights from the logarithmic profile.
3) Flux calculated at 5 elevations from the seabed by multiply the velocity and the concentration from the ABS.
4) Integrate flux through water column to give net flux.

The sediment flux, current speed and direction for ABS frequency F1 (1.082 MHz) and frequency F2 (4.085 MHz) are shown in Figure 46 and Figure 47 respectively. The lower frequency ABS (F1 1.082 MHz)) is seeing coarse sand whilst the higher frequency ABS (F2 – 4.085 MHz) is seeing fine sand. Only the higher velocities during spring tides are sufficient to transport coarse sand,

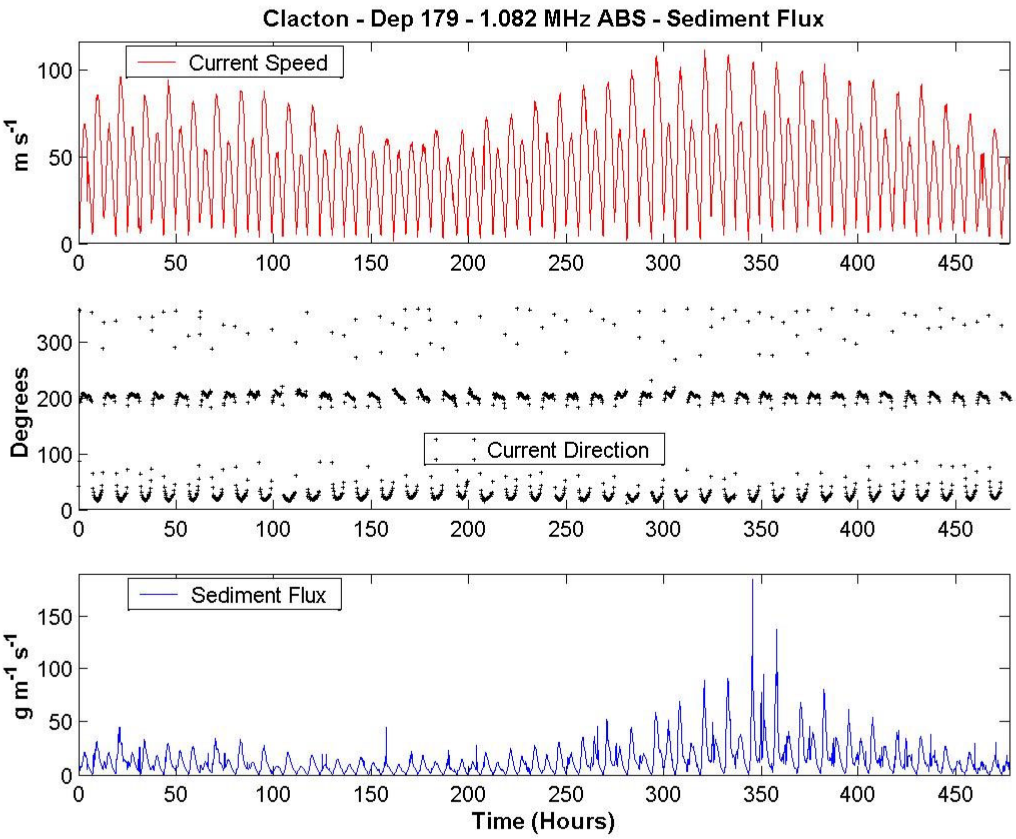

Figure 46 **Sediment flux, current speed and direction from the Clacton/Naze Minipod for F1 ABS (1.082 MHz frequency)**

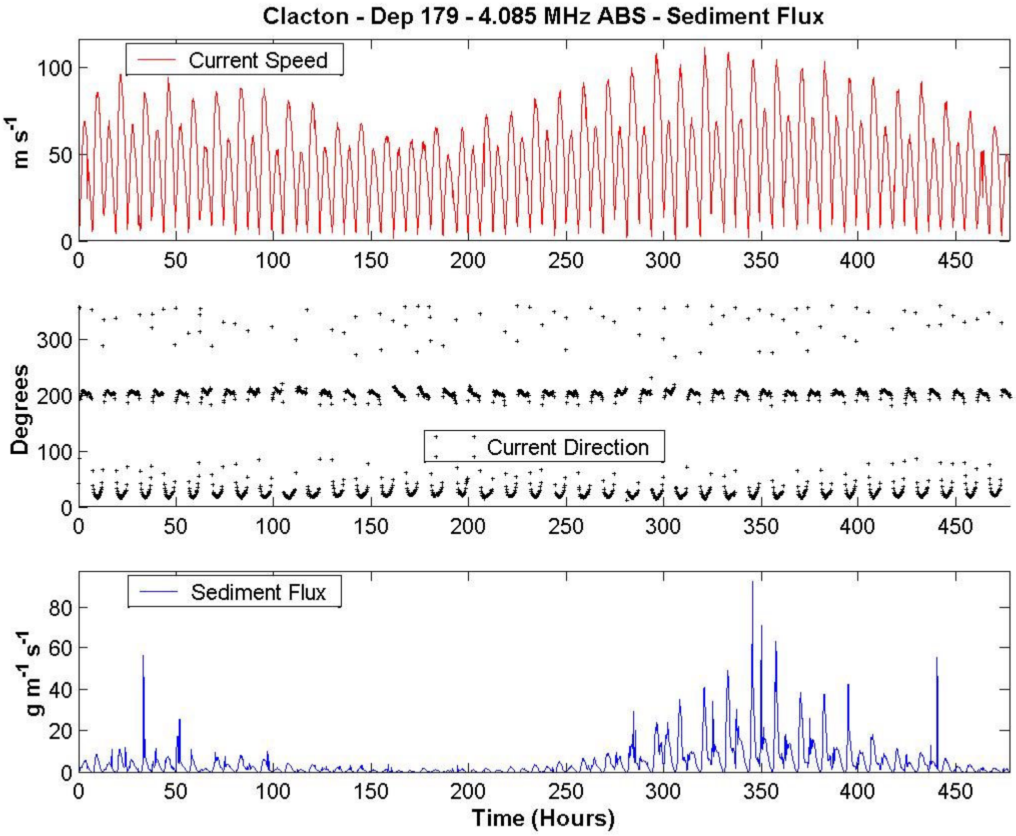

Figure 47 **Sediment flux, current speed and direction from the Clacton/Naze Minipod for F2 ABS (4.085 MHz frequency)**

Converting the sediment flux estimates into a pseudo PVD for sediment flux results in a near northerly transport vector of sediment as shown in Figure 46 and Figure 47 for ABS F1 and ABS F2 respectively. In numerical terms the14-day (Spring-Neap) sediment fluxes for Clacton (Dep 179) are:

ABS Frequency 1:
4.1×10^4 kg / m @ 009°

ABS Frequency 2:
1.26×10^4 kg / m @ 009°

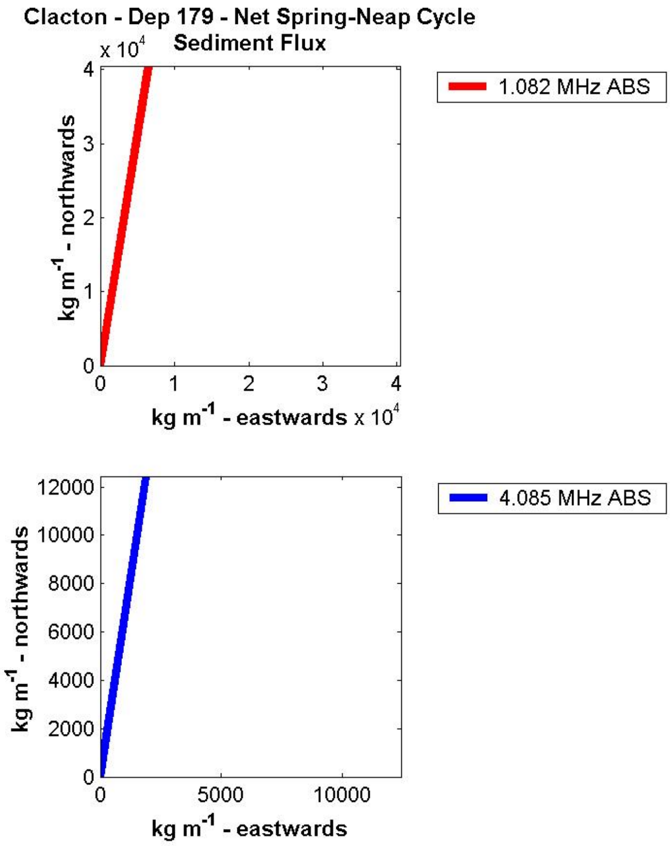

Figure 48 Net Spring-Neap cycle sediment Flux from Clacton/Naze Minipod

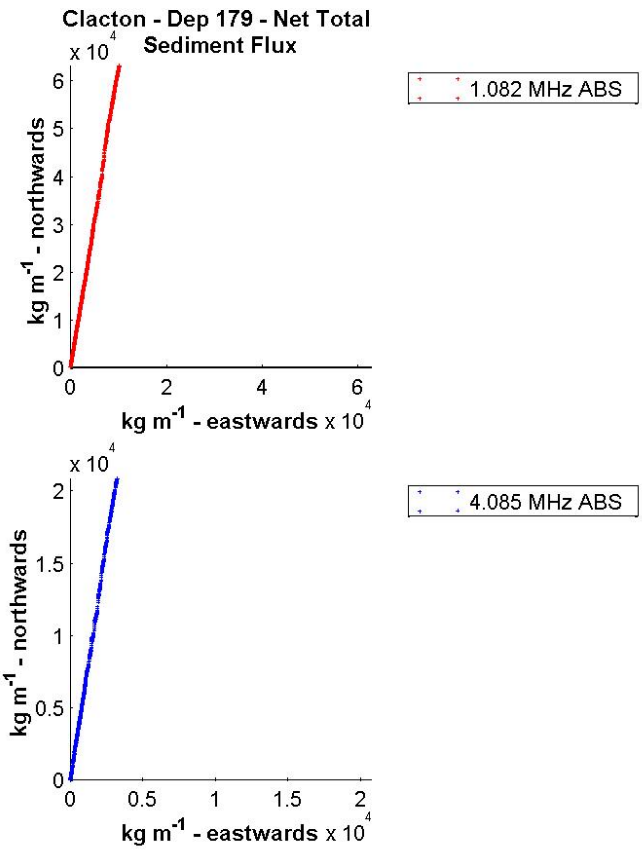

Figure 49 Net Total sediment Flux from Clacton/Naze Minipod

6.2 Clacton

The analysis of the data from the Winterton Minipod has also been applied to the Clacton dataset. Figure 50 shows the bed shear stress for currents alone, waves alone and combined waves and currents (using a sand grain roughness k_s of 0.00004 m). Again, it is evident that tidal currents dominate the bed shear stress environment with values exceeding 3 Nm^{-2}. At this location and time, the waves have little impact on the resuspension of material. Bed shear stresses at neap tides are approximately a third of those at spring tides.

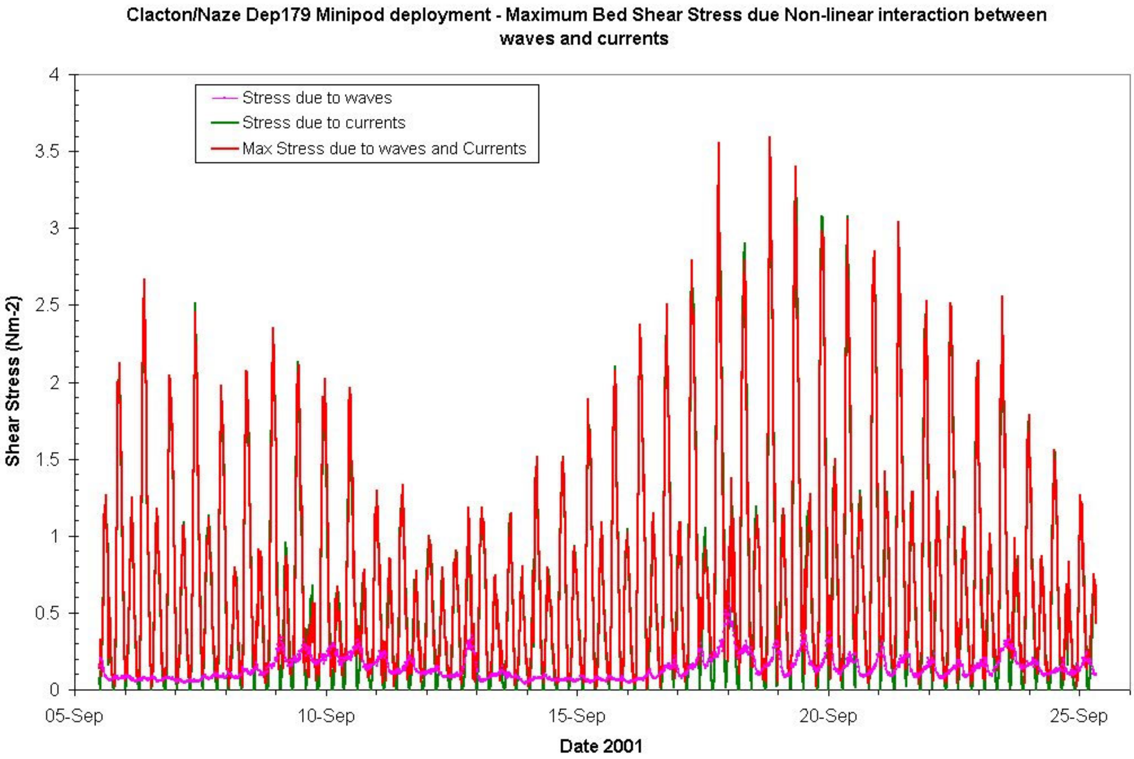

Figure 50 **Maximum Bed shear Stress due to Non-linear interaction of waves and currents from Clacton/Naze Minipod deployment**

As for the Winterton Minipod, the wave spectra from Clacton are shown in a 3 dimensional form in Figure 51. As with the significant wave height data, the first noticeable aspect is tidal nature of the signal which is evident both figures. Secondly, the majority of waves are generated locally and thirdly the largest wave event, in terms of Usig, on the 18th September (burst 1200) is also the dominant wave event in terms of wave spectra. The maximum bed shear stress for various wave return periods from the Naze minipod site (*pers comm*, R Whitehouse) has been calculated in Table 5. Note that although the maximum wave height was recorded at 12th September at 21:15, the maximum wave period was recorded at 9th September at 04:15. For the calculations in the Table the wave period is from the height of the storm on the 12th. The comparisons show that the bed shear stresses recorded are below that ascribed to a 5-year storm and are in agreement with the overall trend.

Table 5 **Comparison of bed shear stress from various wave return periods for Clacton/Naze minipod site**

Return period	Significant Wave height (m)	Mean Wave period (seconds)	Maximum Wave induced bed Shear stress (N m^{-2})
This study	1.0	4.0	3.5
5	4.5	7.4	4.5
10	4.9	7.6	5.3
50	5.5	7.9	6.5
100	5.7	8.1	7.1

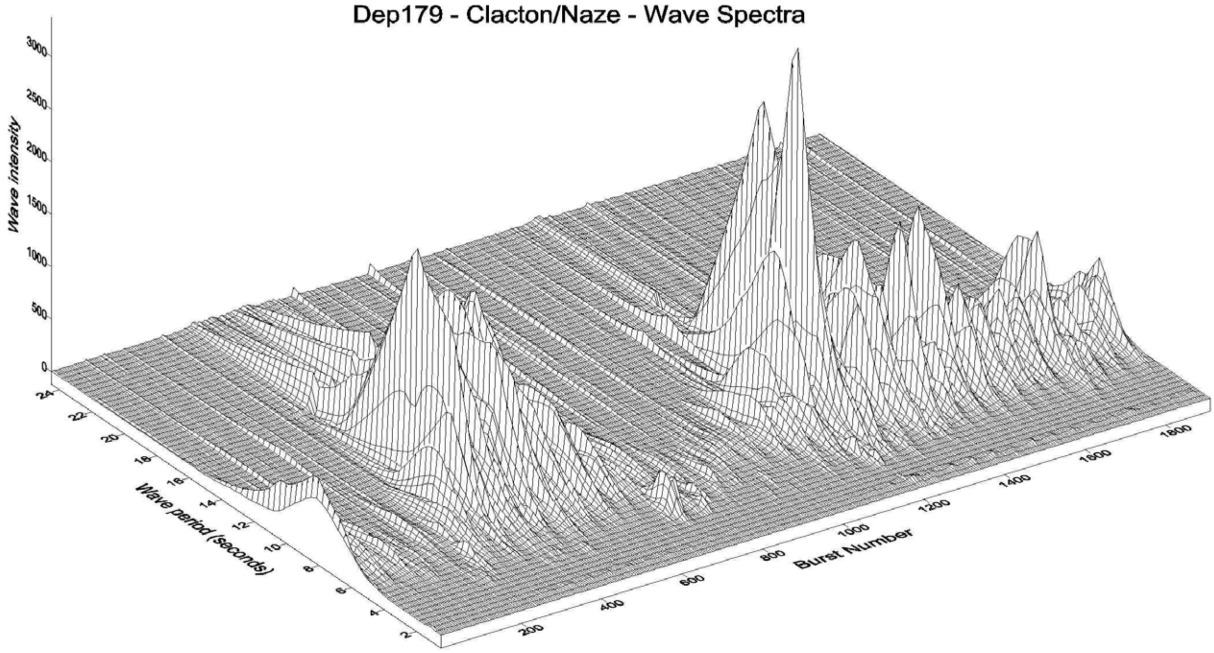

Figure 51 3 dimensional representation of the wave spectra from the Naze Minipod

It should be remembered that the waves shown above are recorded using a pressure sensor on the Minipod. There are several possible explanations of the variation in wave height in synchronisation with the tide and these have been explored in detail below:

1. An algorithm error – However, the algorithm has been used extensively and cross calibrated
2. Sheltering at low tide – as the sand banks emerge at low tide they provide shelter from the offshore waves
3. Modulation by tidal current – it is widely known that tidal current can modulate the wave height – so called "wave stretching"

Work initially by (Longuet-Higgins and Stewart, 1962, 1964) and subsequently Vincent (1979) applied classical wave theory to some wave observations in the North Sea. The latter paper assumed that the surface waves were deep-water waves (and the tidal wave is, of course, a shallow wave) and obtained an analytical solution to the modulation. In the case of Clacton we can make the assumption that both waves are shallow waves (not a bad assumption for T>8s). This produces the interesting condition of surface waves and the tidal wave moving at the same speed and therefore the surface waves will not change their position relative to the tidal wave when waves travelling in the same direction. However, when the waves are travelling in opposite direction significant modulation occurs.

We start from (Longuet-Higgins and Stewart, 1962, 1964) energy balance equation

$$\frac{\partial E'}{\partial t} + \frac{\partial}{\partial x}\left[E'\left(c_g{}' + U\right) + S_x \frac{\partial U}{\partial x} \right] = 0 \qquad (1)$$

where E and c_g are the energy and group speed of the surface waves, U is the tidal current, S_x is the radiation stress and the prime refers to modulated values. For shallow water group speed is

$\sqrt{gh}$ where h is the water depth (for the surface waves this is modulated by the tidal wave and is strictly a function of x,t). If the tidal wave is a progressive moving against the waves (in –x direction), then

$$\xi = a\sin(kx+\sigma t) \quad \text{and} \quad U = -\frac{a\sigma}{kh}\sin(kx+\sigma t)$$

where a, k and σ refer to the tidal wave.

These can all be solved fully numerically (keeping h as a function of x,t etc) but an interesting result is obtained by assuming $a_2 << h$ and $U << \sqrt{gh}$.

So, to a first approximation,

$$\frac{\partial E'}{\partial t} + \sqrt{gh}\frac{\partial E'}{\partial x} + \frac{5}{2}E'\frac{\partial U}{\partial x} = 0 \tag{2}$$

A solution of the form

$$\frac{E'}{E} = (1 + A\sin(kx+\sigma t))$$

satisfies equation (2) when

$$A = \frac{5a\sigma}{2h\sigma + 2hk\sqrt{gh} + 5a\sigma\sin(kx-\sigma t)} \tag{3}$$

Figure 52 shows the variation in the wave amplitude $\sqrt{E'}$ over a tidal cycle.

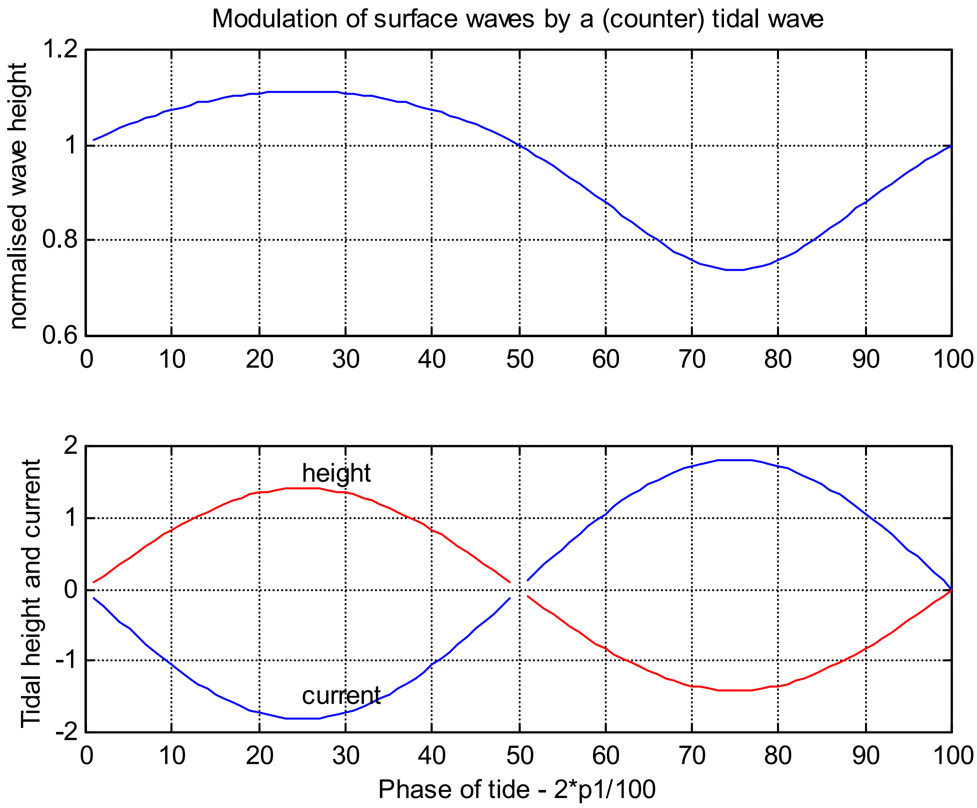

Figure 52 **Modulation of the amplitude of surface waves by a tidal wave progressing in the opposite end (tidal wave amplitude 1.5m, water depth 6m)**

Thus, the wave height can be increased by up to 1.1 during the early phase of the tide and decrease by 0.85 later the tidal phase.

This can be compared with the Peregrine (1976) paper which shows relative errors in calculating the surface wave amplitude from bottom pressures due to ignoring the current (due to ignoring changes in wavenumber). Basically for a water depth of 5m and current of $0.5ms^{-1}$, the error is less than 5% for waves with periods >6.9s, the error is 5-20% for waves 6.9-4.3s period and >20% for waves with period<4.3s. i.e. it probably cannot be ignored at Clacton.

We can eliminate (theory 1) as it is widely used and cross calibrated with other instruments. At present there is insufficient time to permit the rejection of either (theory 2) or (theory 3). Interesting, the peaks in suspended sediment concentration which occur just before and after the high water (flood) slack are higher than those at the low water (ebb) slack (see Figure 28). This anecdotal evidence suggests that possible wave sheltering is the most likely theory.

6.3 Humber

The sidescan sonar data from the Humber has been compared with that from the BGS digital facies dataset and also the recent BGS Humber GeoTrak 2 survey at a meeting with BGS on 1st February 2002. The SNS2 sidescan sonar survey was analysed in detail to produce sediment transport vectors as previously described.

7 DATA AVAILABILITY

The data collected in this study is available from CEFAS and is also hosted by the Environment Agency (Anglian Region).

The client (Great Yarmouth Borough Council) and members of the Anglian and Humber Estuary Coastal Authorities Groups (ACAG and HECAG) have full and free licence to use the data referred to in this report (including the making of copies) for such purposes as they feel fit and proper. It is recommended that the recipients of data referred to in this report are provided with a copy of this report (Appendix 12 to the SNS2 Sediment Transport Report, Report EX4526, HR Wallingford) as a mandatory condition of the data supply.

CEFAS and the study team (HR Wallingford, UEA, Compass Hydrographic Systems, Posford Haskoning and Dr Brian D'Olier) shall not be liable for the use of the data by third parties.

8 CONCLUSIONS

8.1 Winterton

The sediment tracer experiment was not as successful as planned because the strong northerly wind and the normal tidal current combined to give a highly mobile (dispersive) environment in which to place a tracer. Tracer results suggest a northerly movement but the number of particles found was very low and low confidence should be applied to this result.

During the period of the fieldwork strong northerly winds reduced the scope of the survey. However, even during these strong northerly winds, sediment transport was still dominated by tidal currents.

Direct sediment transport links were observed in bedforms between the foreshore and Caister Shoal indicating a high degree of "connectivity". The bedform orientations indicated material was being transported offshore prior to the time of the survey.

Data from the fieldwork programme has been used to calibrate and validate the numerical model (See Appendix 12 to the main report).

8.2 Clacton

The evidence of a sediment transport linkage, as proposed by Pethick from Gunfleet directly across the Wallet onto the Clacton foreshore, has been examined and the evidence gathered in this project does not support such a linkage. Sediment transport is north easterly along the northern edge of Gunfleet and south westerly along the southern edge. No evidence was found on the sidescan sonar images or Minipod/Current meter data to show an onshore transport mechanism.

Sands are mobilised by the strong current around Clacton on spring tides with fines remaining in suspension for the majority of the time.

Sediment transport vectors have been supplied to the consortium to provide a generalised sediment transport patterns for the overall synthesis of pathways.

Data from the fieldwork programme has been used to calibrate and validate the numerical model (See Appendix 12 to the main report).

8.3 Humber

The interpreted sidescan data from the SNS2 survey has been combined with evidence from the BGS seabed facies dataset to provide a basis on which bed sediment transport vectors can be assigned with confidence. The results support the idea of movement of sediment from the north side (around the Binks) to the southern shore (Donna Nook) in a direct fashion through the ebb and flood tidal excursions in the estuary mouth.

8.4 GIS

The GIS approach to interpreting and mapping Sidescan imagery has been shown to be extremely useful and a powerful technique. It enables the information from the orientation of seabed features e.g. megaripples, sandwaves etc to be mapped in a way that can contribute to the large scale understanding of the transport pathways. The sediment transport vectors thus derived have been used by the study team in forming an interpretation of sediment transport vectors within the study area. However, the digital infra structure has to be in place for handling large digital sidescan sonar surveys typically 400-500Mbytes per survey.

It should also be remembered that sidescan sonar images of bedforms show the resultant transport vector when transport last took place. This could have been during the survey, on the last tide, the last spring tide or even the last big storm.

9 RECOMMENDATIONS

1) Combine the BGS sidescan coverage (collected as part of the Humber Estuary Shoreline Management Plan Stage 2) with the SNS2 sidescan coverage to provide an improved dataset on which bed sediment transport vectors can be assigned with confidence. Owing to the relative timings of the two studies this was not possible within SNS2.

2) It is proposed that an ADCP section across mouth of Humber, from Spurn head due south is completed for 13 hours. This would confirm the location of the flood/ebb dominated channels and when combined with calibrated backscatter the relative dominance of each channel in terms of sediment flux. It should be noted that it is not possible to estimate absolute fluxes as the error bars associated with measuring the currents when integrated up over the tidal signal are large compared with the net flux (Lane et al , 1997). During the survey an anchor station would be completed at one key point with half hourly suspended sediment profiles to provide calibration of the acoustic backscatter. Downward mounted ADCP also mounted on stationary vessel. These results should be interpreted in light of the data presented by Hardisty (2002).

3) The tides at the mouth of the Humber are extremely strong and capable of moving sand for large parts of the tidal cycle. It is proposed to sidescan a small area repeatedly over a 13 hour tidal cycle to determine the absence, size, shape and the mobility of bedforms. This may produce further evidence of the transfer of sediment from Spurn Point to Donna Nook and to characterise its nature and variability.

4) Initial investigations suggest that the wave measurement system deployed at Happisburgh and off the Naze was correctly recording the modulation in instantaneous tidal elevation rather than this being an interaction between the current and the tide. However, further investigation is required to confirm this.

5) It is also recommended that all sidescan sonar surveys that are collected digitally and funded by DEFRA (and ideally other Government departments) are available at one location. This can be pursued through the formation of a digital sidescan sonar archive for datasets at the Environment Agency, CEFAS and/or other commercial bodies.

10 REFERENCES

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11 APPENDIX A – INSTRUMENT LOCATIONS

Table 6 Summary of instruments and locations of Winterton Experiment

Winterton/Happisburgh

Instrument	Identifier	Parameters	Position (WGS 84)		Sampling Height above seabed (m)
			Latitude	Longitude	
Valeport + CEFAS ESM2	B	Horizontal currents, fines concentration, tidal elevation, waves	52 52.29N	01 38.21E	10
Valeport + CEFAS ESM2	C	Horizontal currents, fines concentration, tidal elevation, waves	52 54.41N	01 41.58E	15
Valeport + CEFAS ESM2	D	Horizontal currents, fines concentration, tidal elevation, waves	52 45.04N	01 42.96E	-
Valeport + CEFAS ESM2	E	Horizontal currents, fines concentration, tidal elevation, waves	52 43.94N	01 42.49E	6
Valeport + CEFAS ESM2	F	Horizontal currents, fines concentration, tidal elevation, waves	52 42.01N	01 44.35E	4
Minipod	Dep168 and A	Horizontal and vertical Currents, tidal elevation, waves, suspended sediment concentration fines and sands	52 49.57N	01 33.61E	Ranging from 0.45 to 1.75
ADCP		Horizontal Currents	V shaped survey	V shaped survey	Profiles from near surface to near seabed
Tracer					seabed
Sidescan Sonar - CMAX		Seabed Imagery	Track lines	Track lines	seabed

Clacton/Naze

Table 7 Summary of instruments and locations of Clacton/Naze Experiment.

Instrument	Identifier	Parameters	Position (WGS 84)		Sampling Height above seabed (m)
			Latitude	Longitude	
FSI 2d ACM + CEFAS ESM2	1417	Horizontal currents, fines concentration, tidal elevation, waves	51 58.41N	01 22.15E	0.5
FSI 2d ACM + CEFAS ESM2	1496	Horizontal currents, fines concentration, tidal elevation, waves	51 46.02N	01 16.17E	0.5
FSI 2d ACM + CEFAS ESM2	1494	Horizontal currents, fines concentration, tidal elevation, waves	51 47.52N	01 14.52E	0.5
Minipod	Dep169	Horizontal and vertical Currents, tidal elevation, waves, suspended sediment concentration fines and sands	51 52.80N	01 22.72E	Ranging from 0.45 to 1.75
ADCP		Horizontal Currents	Section survey	Section survey	Profiles from near surface to near seabed
Sidescan Sonar – EG&G 272		Seabed Imagery	Track lines	Track lines	seabed

Humber

Table 8 Summary of instruments and locations of Humber Experiment.

Instrument	Identifier	Parameters	Position		Sampling Height above seabed (m)
			Latitude	Longitude	
Sidescan Sonar – EG&G 272		Seabed Imagery	Track lines	Track lines	seabed