Annex 9.1

South Humber Channel Marine Studies: Bathymetry & Hydrography Survey Report

(IECS)

the INSTITUTE of ESTUARINE and COASTAL STUDIES

THE UNIVERSITY OF HULL

Institute of Estuarine and Coastal Studies (IECS)

South Humber Channel Marine Studies: Bathymetry & Hydrography Survey Report

Report to Yorkshire Forward

Institute of Estuarine and Coastal Studies
University of Hull

October 2010

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Yorkshire Forward

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Reference No: ZBB752A-F-2010

For and on behalf of the Institute of Estuarine and Coastal Studies	
Approved by:	Nick Cutts
Signed:	
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Date:	October 2010

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1 INTRODUCTION AND AIMS

Yorkshire Forward is currently investigating the feasibility of a potential commercial development in the Humber Estuary between the Humber Sea Terminal and Immingham Port (Figure 1). This area may provide a suitable location for a variety of developments e.g. multi-user marine facility or tidal power generating farm. However, in order for any such development to take place a host of studies relating to the planning and design of the marine elements of the development are required.

The Institute of Estuarine & Coastal Studies was commissioned in association with Roger Tym & Partner to undertake a bathymetry and hydrographic survey in the vicinity of the potential development area. The aim of the survey was to assess the physical characteristics of the proposed development area and provide data to inform the hydrodynamic and sediment transport modelling component.

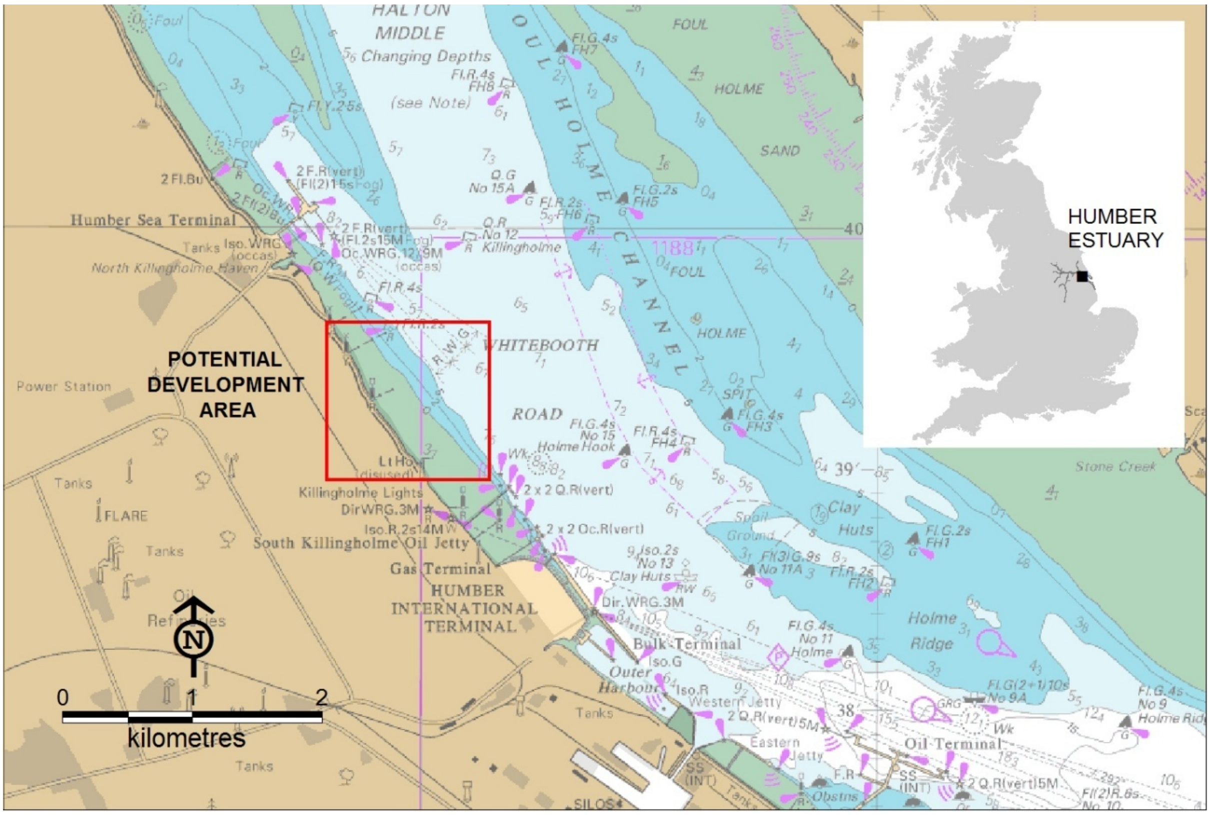


Figure 1. Potential development area in the Humber estuary

The information provided in this report will ultimately be used to assess the potential impacts to seabed morphology/topography in the vicinity of the proposed multi-user marine terminal in the Humber Estuary.

2 BATHYMETRY

2.1 Methodology

2.1.1 VESSEL

IECS undertook a Bathymetric Survey on the 30th and 31st March 2010 using the survey vessel 'Lizzard', a shallow draught 8m catamaran capable of operating extremely close to shore near to the high water spring tide mark. On both occasions the boat departed from Hull Marina at around 0600h to be on site for 0700h.

2.1.2 SURVEY EQUIPMENT

The equipment used for the survey included a SonaVision multibeam RoxSwath Acoustic Ground Discrimination System (AGDS) (Figures 2a & b) and peripherals. The peripheral equipment included a multi beam (7 beam) transducer head (Figure 2c), an electronic compass/ pitch and roll sensor (Figure 2d) and a GPS (Figure 2e) which are linked to the system either via the AGDS or through the ruggedized laptop which processes the data using RoxMap software.

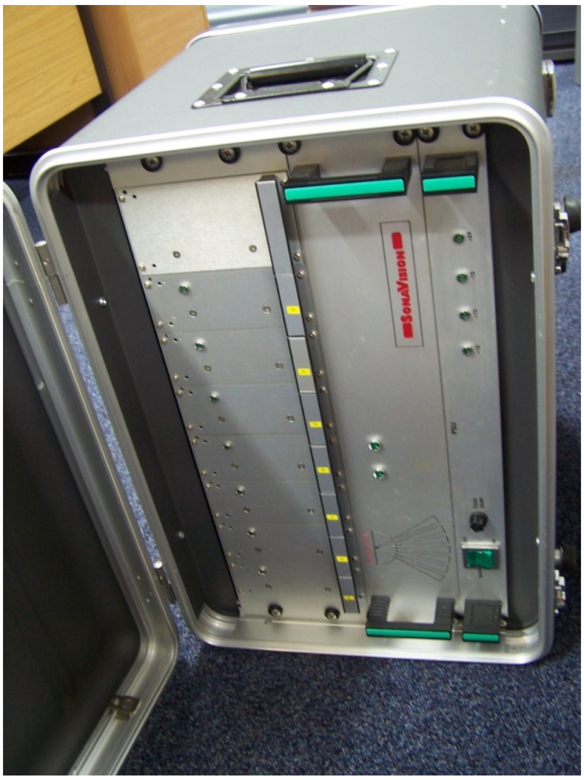


Figure 2a: AGDS

Figure 2b: AGDS

Figure 2c: Multi beam (7 beam) transducer head

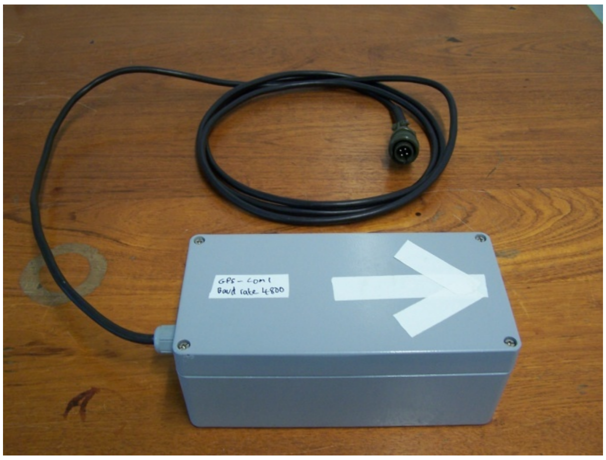


Figure 2d: Compass/ pitch and roll sensor

Figure 2e: GPS

All the equipment was tested using the laptop to make sure data was being received from all peripherals prior to commencing the survey.

2.1.3 SURVEY

The survey area extended southeast from the Humber Sea Terminal to the Humber International Terminal and extended northeast into the estuary by approximately 1200m from the mean high water neap tide mark.

Where possible, the survey path followed a grid of pre-determined transects running both adjacent (at 50m intervals) and parallel (at 100m intervals) to the shore covering the entire study area (Figure 3). The inshore transects were set as close to the high water spring tide mark as the draught of the vessel would allow.

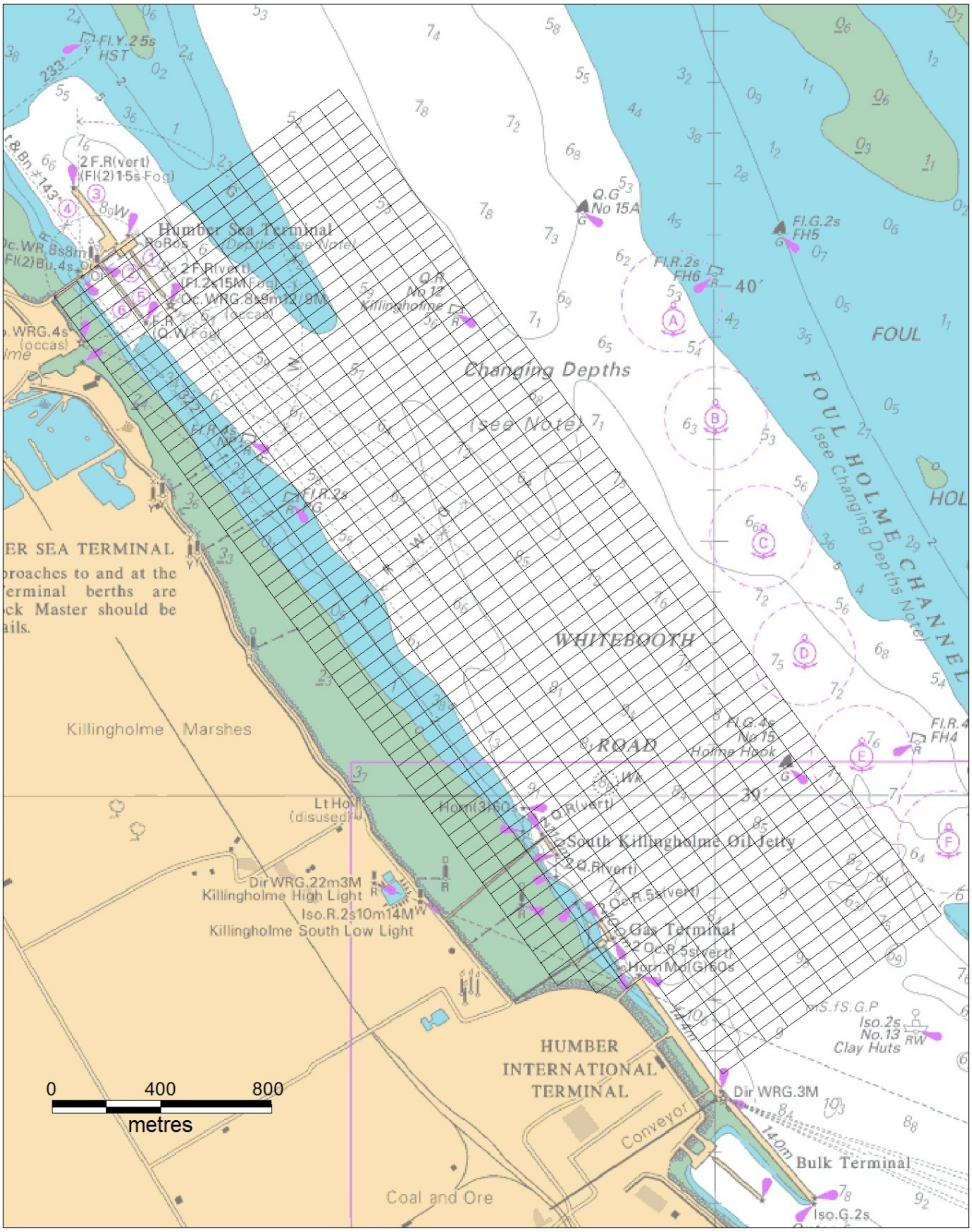


Figure 3. AGDS transects

On completion of the transects, the data was checked on board to identify areas of low or missing coverage. It was found that these areas were often where the transects aligned adjacent to the shore, had crossed areas of high tidal flow causing the line taken by the vessel to waver. These areas were resurveyed with additional transects until coverage was complete. Coverage was easier to obtain by the parallel transects particularly when heading against the tidal flow, where it was easier to maintain a slower, more suitable vessel speed.

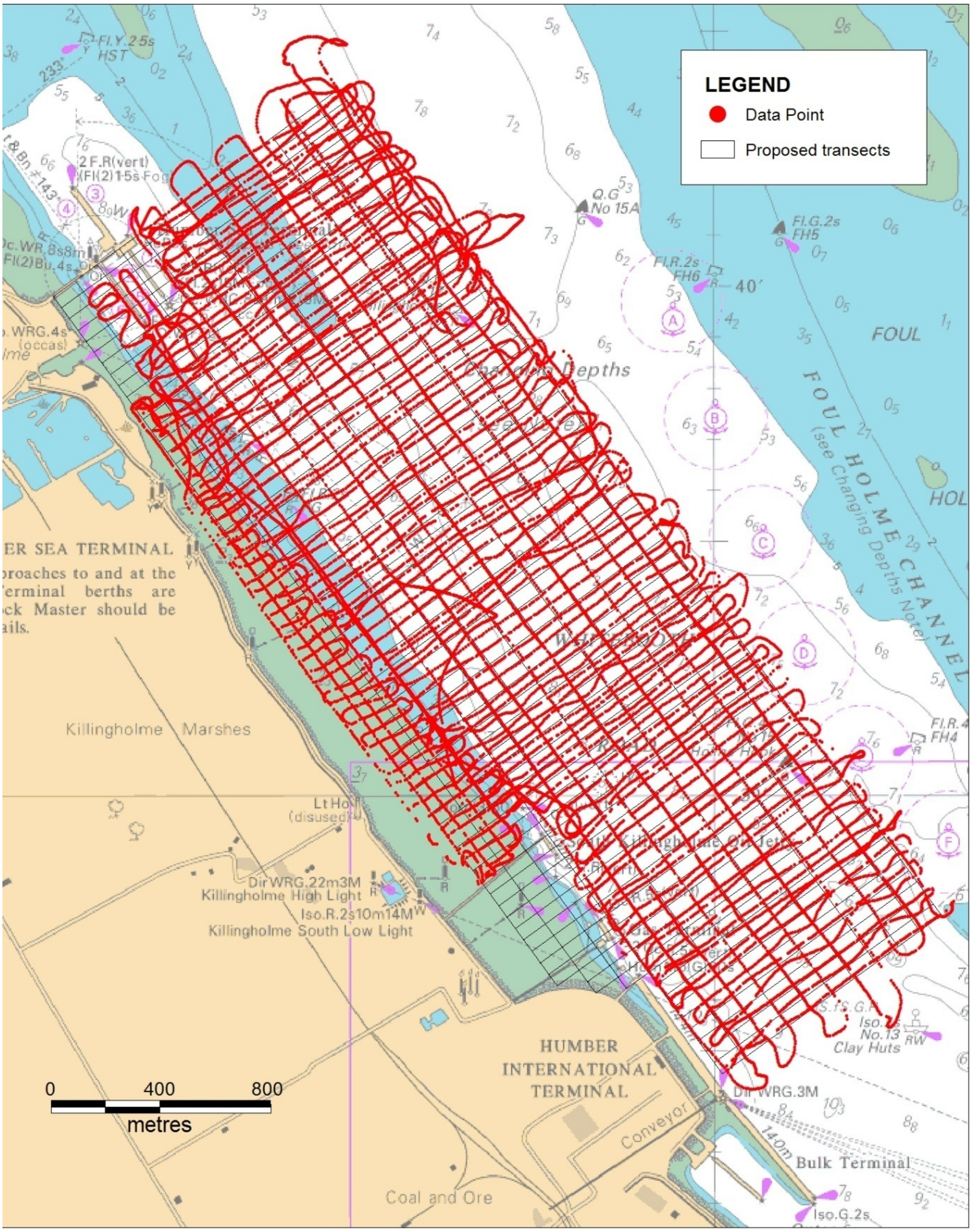


Figure 4. AGDS track and data points

Deviation from the transect also occurred while avoiding large vessels. Data recording was continued while off-course and this data was included in the final analysis.

2.2 Data Processing

The depth data obtained from the AGDS is unusable in its raw form due to the survey taking place across the tidal cycle and therefore at different tidal heights. The data was transformed with reference to a known height across the survey area also accounting for the depth of the transducer in the water. The depth data was then converted to be relative to Ordnance Datum Newlyn (ODN).

This was undertaken through the following steps:

2.2.1 Transducer depth

The depth of the transducer head in the water was added to all the AGDS depth records giving exact sea bed depth relative to the water surface at each particular point.

2.2.2 Depth conversion relative to chart datum

The depth data obtained from the AGDS required time correcting. This was done by obtaining the Humber gauge tidal data from the port of Immingham, the closest available data set to the survey area. The Humber gauge records tidal height every 10 minutes every day starting at 0000h then 0010h etc relative to the known level of Chart Datum (CD). Measurements taken by the AGDS are both geo-referenced and time referenced, so by using the Humber gauge tidal data it was possible to calculate depth of river bed relative to CD. When obtained, the gauge data is depicted in the Julian format with January 1st as day 1 and December the 31st as day 365 in a non leap year (Table 1). The first figure (eg. 2) is the day of the year, the second figure (eg. 504) is the height at midnight in centimetres and readings continue thereafter at 10 minute intervals. The measurement for 0100h would therefore be 400. Heights are in cm and are relative to chart datum which is 3.9m below O.D. Newlyn when East of Albert Dock.

Table 1. An example of gauge data for January 2nd

2	:	504	484	468	452	437	419	400	386	370	351	336	320
	:	303	291	277	263	253	243	235	226	219	215	213	216
	:	221	225	227	231	234	241	248	258	271	285	304	325
	:	345	364	381	400	420	441	455	472	494	514	530	541
	:	562	583	589	607	624	632	639	641	646	649	649	649
	:	648	642	632	625	0	616	615	610	609	0	591	580
	:	568	553	535	520	498	480	464	0	432	413	396	379
	:	362	346	0	316	303	291	280	269	260	250	244	239
	:	237	235	234	242	250	256	268	280	294	312	327	344
	:	360	380	395	410	430	450	468	484	509	519	535	554
	:	571	587	601	615	627	637	646	664	672	685	683	684
	:	684	681	679	676	669	663	658	650	641	632	617	607

For example AGDS depth readings that were obtained with the time reference between 1200.00h and 1209.59h were corrected using the depth relative to CD recorded by the gauge at the port of Immingham at 1200h. This was done by subtracting the gauge depth from the depths recorded by the AGDS. The next example would be AGDS depths between 1210.00h and 1219.59h corrected by subtracting the depth obtained from the gauge at 1210h. This was undertaken for the full data set giving depth of river bed relative to Chart Datum. Figure 5 shows point depth ranges after the conversion has been done clearly showing a gradual depth increase from the intertidal area to the centre of the estuary giving a good indication that the data has been successfully converted.

2.2.3 DEPTH CONVERSION RELATIVE TO ORDNANCE DATA NEWLYN

It was a requirement of the survey to present depth data relative to Ordnance Data Newlyn (ODN) rather than Chart Datum (CD). ODN is 3.9m above CD at Immingham and so this offset was used for the conversion.

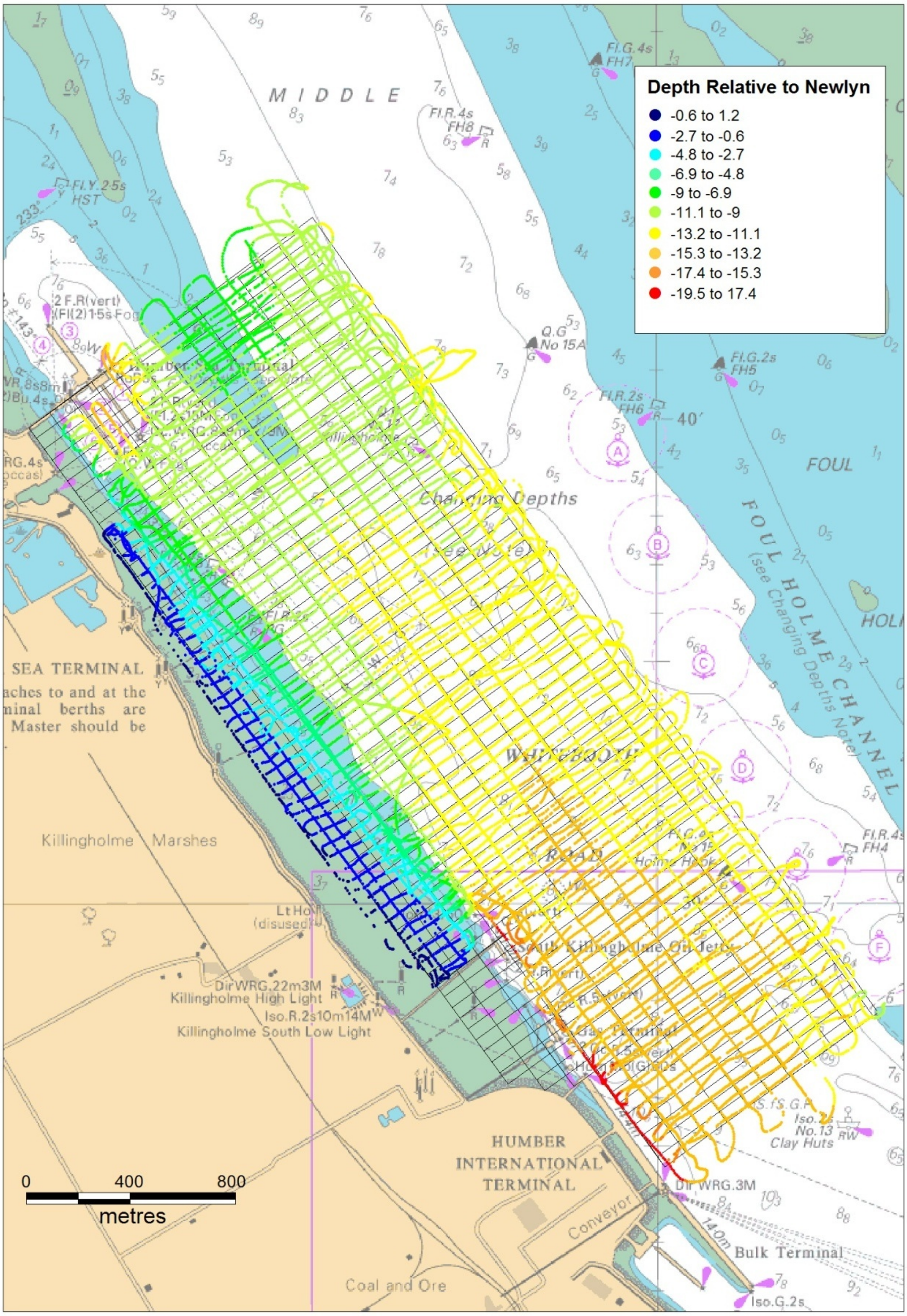


Figure 5. Point Depth Ranges Relative to ODN

2.2.4 CLEANING THE DATA SET

As is to be expected with Acoustic Ground Discrimination Systems, anomalies in the data did occur during the survey becoming more numerous at shallow depths close to the intertidal area and at the turning points at the end of a transect. These anomalies were easily identified by plotting depth against time (Figure 6) and removed accordingly (Figure 6). Once the depth data had been cleaned it could then be loaded into GIS software for spatial representation.

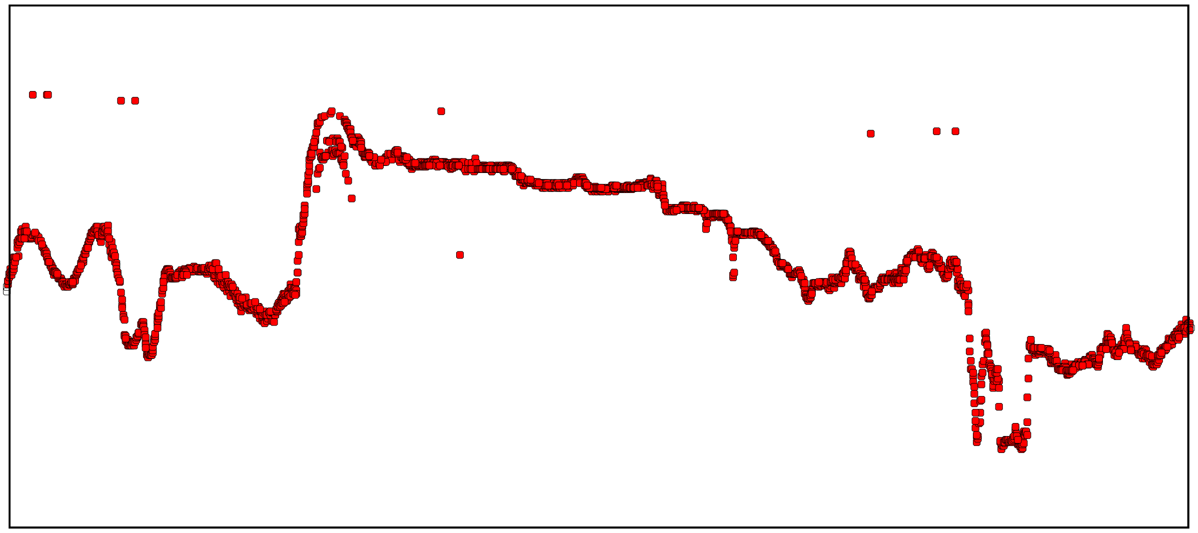


Figure 6. Unedited data set

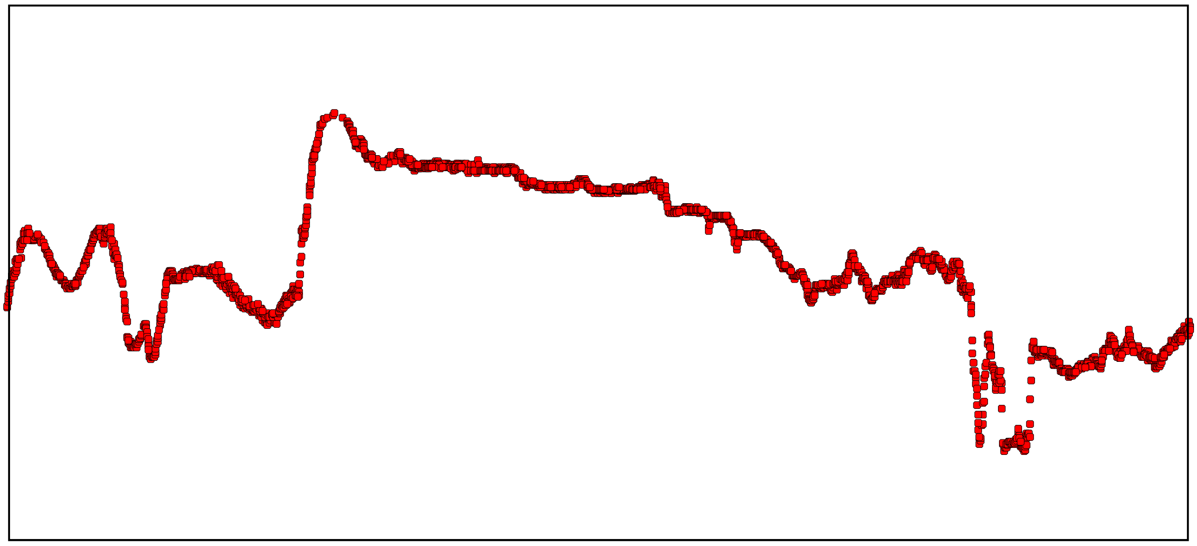


Figure 7. Edited data set

Only a small sample of the data is shown in Figures 6 & 7. In total, 30,927 point depth readings were taken over the two days. The data cleaning process removed 2,570 anomalies equating to 8.3% of the original data. The full tabulated data set (anomalies omitted) is appended to this report as a CD ROM.

2.2.5 SPATIAL REPRESENTATION

Due to the good coverage of data, an interpolation of the data could be undertaken in GIS software (Mapinfo with Vertical Mapper) to produce a full representation of the bathymetry of the study area (Figure 8).

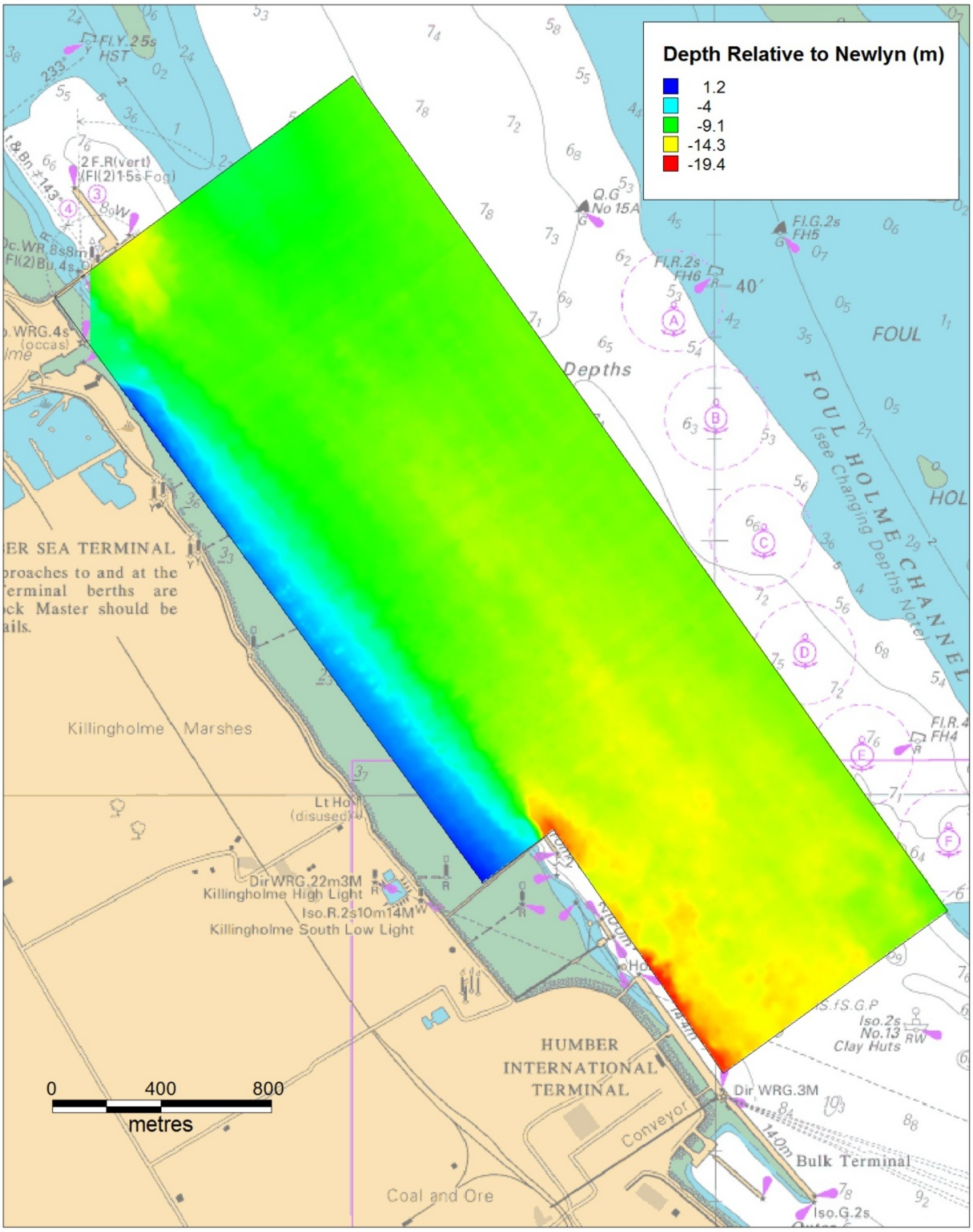


Figure 8. Interpolated depth measurements

Based on this interpolation, a depth contour chart was also produced clearly defining changes in bathymetry across the site (Figure 8).

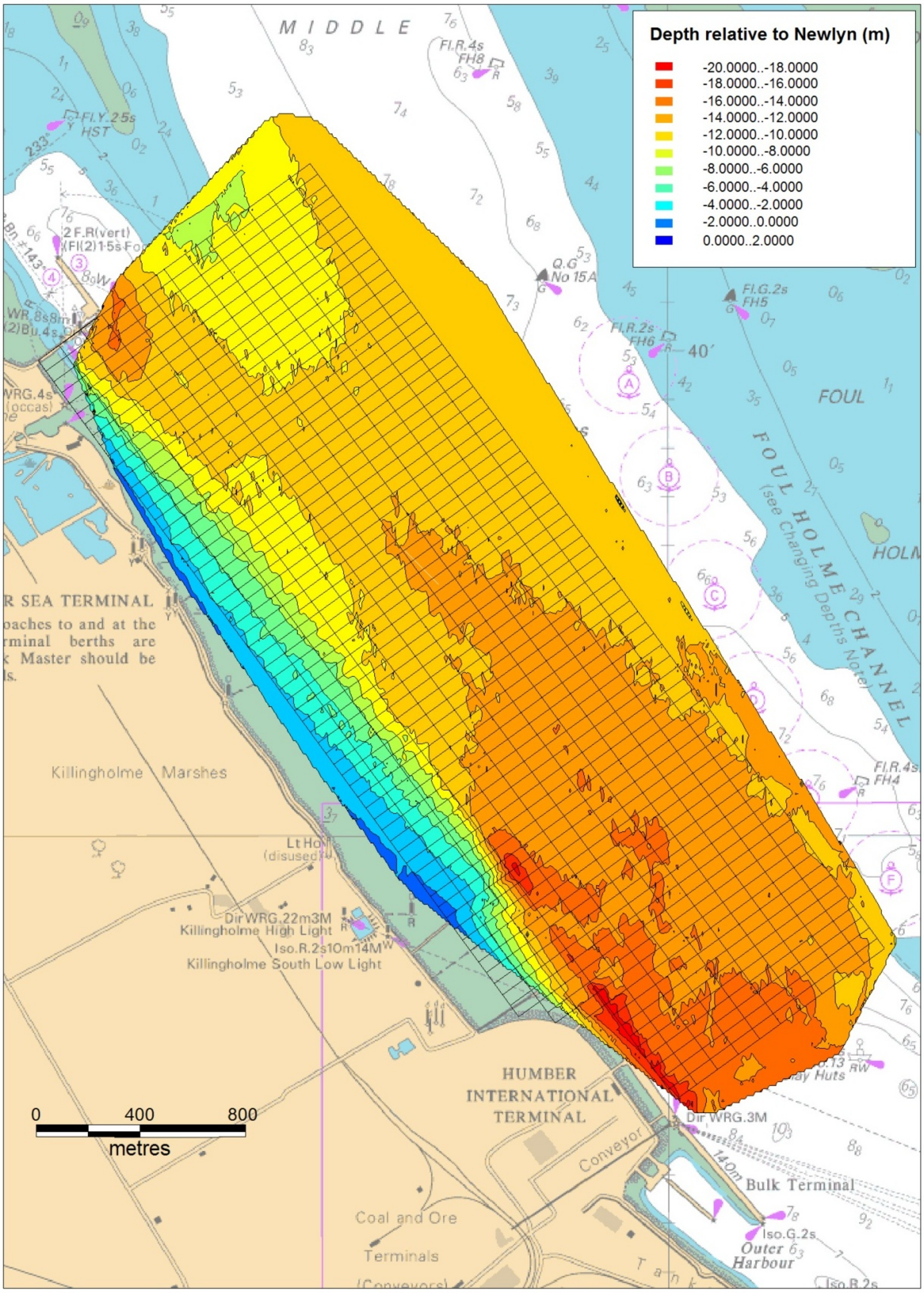


Figure 9. Depth contours

2.3 Results

There is a general trend of decreasing depth from the southern downstream end of the site at the Humber International Terminal to the northern upstream end at the Humber Sea Terminal.

Only a fraction of the intertidal area was covered by the survey due to the restricted vessel access at shallow water depths. However, the full extent of the intertidal zone is denoted on the admiralty chart and can be described as being typical of that part of the Humber in terms of extent. The lower extent of the intertidal zone covered by the survey is denoted by the ODN -4m contour (CD -0.1m) (Figure 9).

As expected, the data shows the deepest waters to be located at the berthing points of the Humber Sea Terminal (ODN -16m and -18m or CD -12.1m and -14.1m), and at the southern end of the study area at the South Killingholme Oil Jetty and the Humber International Terminal (ODN -18m to -20m or CD -14.1 to -16.1). These features are clearly visible on the GIS interpolation (Figure 9).

This reflects the key areas of activity in the area with these large capacity terminals providing multiple berths for large vessels and even the smaller South Killingholme Oil Jetty servicing large vessels of up to 60 tonne (Hames & Nixon, 2004). Subsequently, vessel traffic is high and maintenance dredging in the area is extremely frequent. HMS report dredging at Immingham Docks, dock entrances and river frontage to be continuous with river berths also being dredged on a regular basis (Hames & Nixon, 2004). Therefore, the deeper areas recorded around the terminal berths are considered to be the result of this essential maintenance dredging.

Other areas such as the approaches to the berths and the main shipping channels are also dredged but at a lower frequency. This was observed by the survey team on a number of occasions in the vicinity of the Humber Sea Terminal at depths between the ODN -12m to 16m contours (CD -8.1m to -12.1m).

Away from the berths, depths predominantly lie within the ODN -12m to -16m contour ranges (CD -8.1m to -12.1m) with marginally deeper waters within this range observed in the shipping channels and the approaches to the Humber Sea Terminal and an overall gradation to shallower waters towards the northern upstream section of the study area. The data reflects the broader depth contours as shown by the admiralty charts.

3 HYDROGRAPHY

3.1 Methodology

3.1.1 AQUADOPP SET UP AND TESTING

The Nortek Aquadopp software was installed to the hard drive of a ruggedized laptop and the Aquadopp connected via a serial port. Communication with the instrument was established and a break signal sent. This reported an identification string in order to identify that Aquadopp unit.

The Aquadopp was checked as serviceable by deploying the unit in air to record all parameters required for thirty minutes. The unit was then submerged and tested again.

The data was retrieved to the laptop via the Nortek software and analysed to read as expected. The Aquadopp memory was then erased.

The 1 MHz Aquadopp, an Aquaprofiler (2 MHz right angled head) turbidity meter, a Midas CTD profiler and a Sonardyne 7986 LRT transponder with rope canister were assembled on to the horizontal seabed frame.

The Aquadopp was deployment programmed to collect velocity and direction data for the time period 11/05/2010 12:40:00 until 02/06/2010 09:11:08. The data was recorded at 1800 second intervals with a 600 second sample interval. The Analogue input 1 line was turned on with power supplied. Battery life and available memory were checked to be adequate for the amount of sampling required.

Upon deployment all parameters were checked and the unit turned on to deployment mode. The pc was disconnected and the turbidity meter plugged in and secured. A map showing positions of the equipment on the estuary bed at site 1 and 2 is shown in Figure 10.

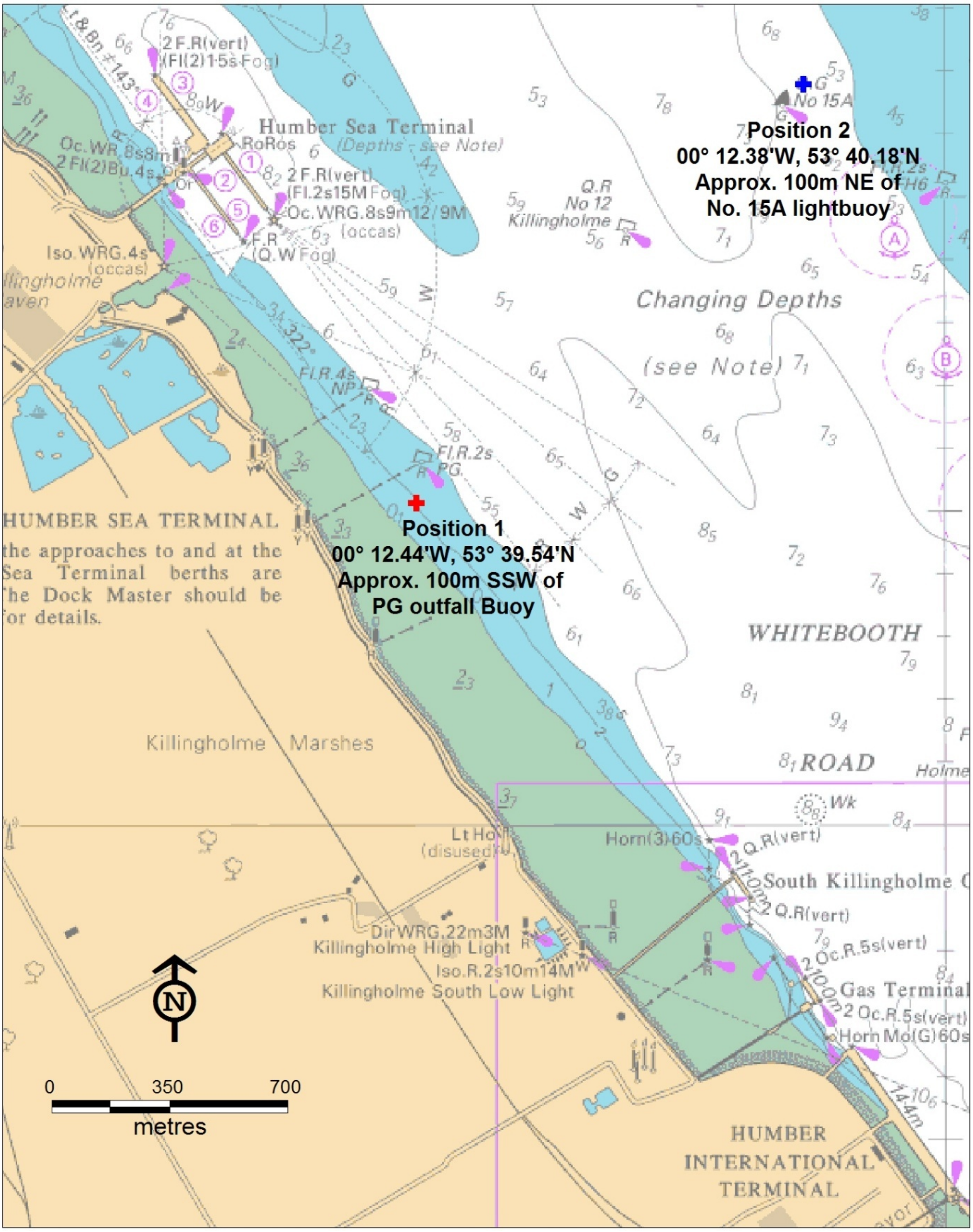


Figure 10. Position of equipment

3.1.2 AWAC SET UP AND TESTING

The Nortek AWAC software was installed to the hard drive of a ruggedized laptop and the AWAC connected via serial port. Communication with the instrument was established and a break signal sent. This reported an identification string in order to identify that AWAC unit.

The AWAC was checked as serviceable by deploying the unit in air and recording all parameters required for thirty minutes. The AWAC was then submerged and tested again.

The data was retrieved to the laptop via the Nortek software and analysed to read as expected. The AWAC memory was then erased.

The 1 MHz AWAC, its battery, an Aquaprofiler (2 MHz right angled head) turbidity meter, a Midas CTD profiler and a Sonardyne 7986 LRT transponder with rope canister were assembled on to the horizontal seabed frame.

The AWAC was deployment programmed to collect velocity and direction data for the time period 11/05/2010 12:23:11 until 02/06/2010 14:53:11. The data was recorded at 1800 second intervals with a 600 second sample Interval. The Analogue input 1 line was turned on with power supplied. Battery life and available memory were checked to be adequate for the amount of sampling required.

Upon deployment all parameters were checked and the unit turned onto deployment mode. The pc was disconnected and the turbidity meter plugged in and secured.

3.1.3 MIDAS CTD PROFILER SET UP AND TESTING

Two Midas CTD profilers were used (one for each position) to record Conductivity, Pressure and Temperature, both tested in the same way as for the Aquadopp and AWAC.

Valeport DataLog Express software was installed onto the hard drive of the ruggedized laptop.

New alkaline battery cells were placed in the CTDs. The units were then connected, one at a time, and tested by ordering them on deployment for 30 minutes and submerging them in water. The unit was recovered and reconnected to the pc and the data downloaded and analysed to ensure all parameters were recording correctly. The memory was then erased.

Position 1 monitor CTD was programmed to record a 10 second burst of data every 1800 seconds. Position 2 monitor CTD was programmed to record a 60 second burst of data every 1800 seconds as the 10 second burst did not operate on this unit. Battery life and available memory were checked to be adequate for the amount of sampling required.

Upon deployment all parameters were checked and the units turned on to deployment mode. The waterproof cap was fitted and the LED lit for five seconds indicating deployment mode.

3.1.4 SONARDYNE7986 LRT TRANSPONDER TESTING AND SET UP

Two Sonardyne LRT transponders were used (one for each position) and were both tested in the same manner.

The control unit was connected to the LRT via a communication loop. Each unit was programmed to respond to a different frequency for safety. The command to wind was sent and the unit responded as required.

Two four kilogram buoys were connected to each LRT.

The units were deployed in water and distance readings taken via the surface control unit connected to the Remote Transducer to ensure correct programming.

Upon deployment all parameters were checked.

3.1.5 Additional

The seabed frames were not visible from the surface and had no direct connection via a buoy. In this instance it was decided to connect a 25 meter high tensile cable (breaking strain 500kg, SWL 250kg) with a lead chain ball on the other end as an anchor. This was to be used as a grapple line should the LRTs fail due to the deep mud.

3.1.6 Deployment on board the River Guardian

Each data retrieval unit was tested via the ruggedized laptop and relevant software, and turned on to deployment mode just before lowering. The LRTs were also tested using the surface command unit.

The assembled seabed frames were lowered from the back of the River Guardian, by tying off one end of a rope and passing the other through two shackles on the top of the seabed frames, then lowering until the rope was slack. The GPS position of the unit was recorded.

The position of the LRTs is to be noted on lowering as the buoys can move under the seabed frame thus preventing operation. The rope was then removed by pulling the tied off end. The fail safe grapple line was deploying while the boat drifted, the lead chain anchor was dropped overboard and the GPS position recorded.

3.1.7 Retrieval on board the Calypso

The GPS positions were revisited. The surface command unit for the LRT transponders was connected to the Remote Transducer and deployed overboard. Distance from the unit was read on the surface command unit and the release signal sent.

The units were lifted by a winding drum via a winch arm to deck height then manually lifted by three people over the rails on to deck. On arrival on deck each data retrieval unit was connected to the ruggedized laptop and deployment mode turned off.

3.1.8 Data retrieval

In the lab each unit was connected to the rugged laptop and the data downloaded to the hard drive. This data was then translated to ASCII files via the relevant units software;

AWAC and Aquadopp software: Nortek AWAC AST

Midas CTD profiler software: Valeport DataLog Express

The translated data was then analysed for discrepancies and sorted into Microsoft Excel format for the Midas CTD profilers, and left in ASCII for the AWAC and Aquadopp.

3.1.9 Turbidity monitoring

Turbidity meters were deployed in the Humber estuary in conjunction with the Nortek Awqudopp and AWAC devices (Section 3.1.1 & 3.1.2). However, unfortunately the turbidity meters malfunctioned and no turbidity data was recorded. Therefore, in order to determine the range of suspended solid concentrations present in the Humber estuary, water samples were collected from the Humber Sea Terminal (Figure 11) over a range of tidal states.

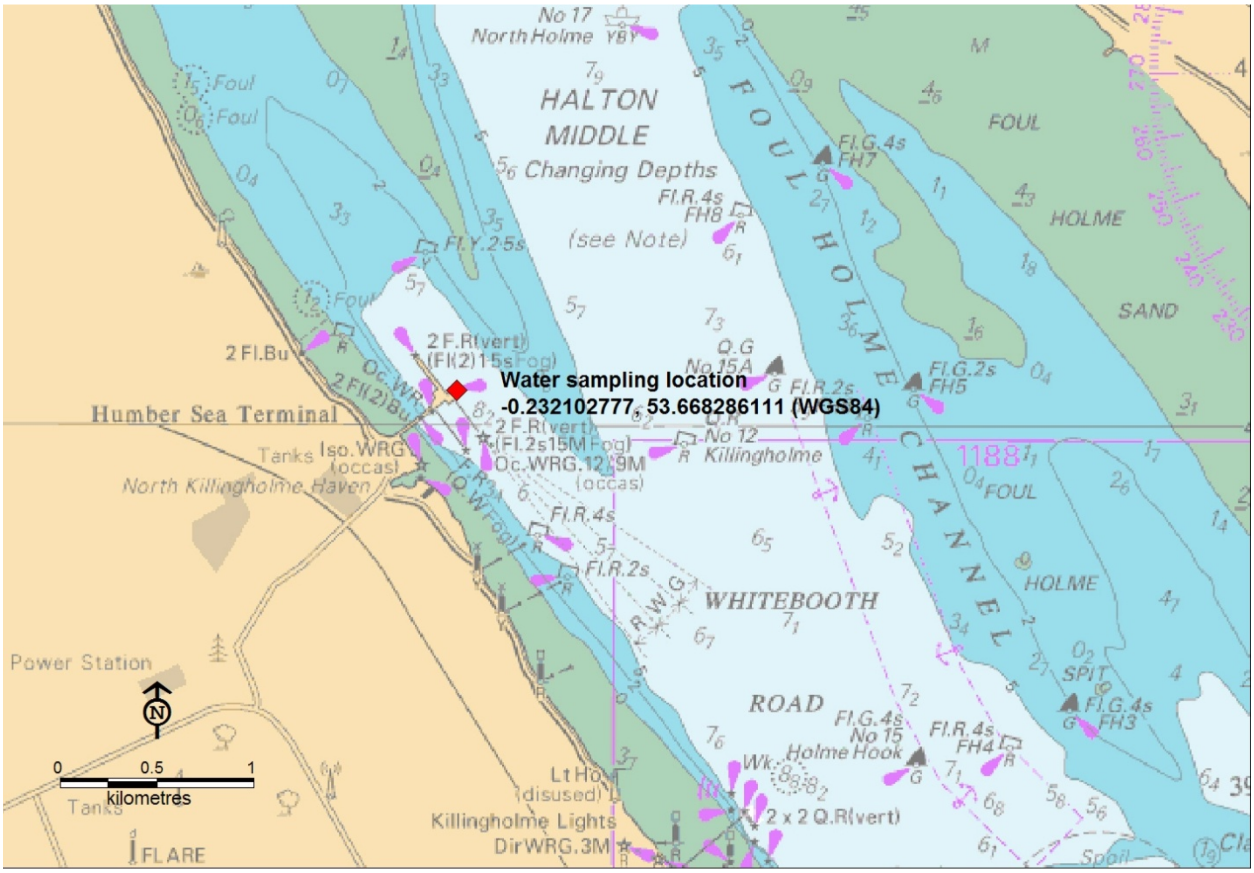


Figure 11. Water sampling location, Humber Estuary

Water samples were collected over a neap tidal cycle during flood, high water slack and ebb conditions and over a spring tidal cycle during ebb, low water slack and flood tide conditions (Table 2).

Table 2. Tide times at Immingham (53°38'N 0°11'W England) during. a, neap tide. b, spring tide.

a. 02/09/10 (Neap tide)

Tidal state	Time	Height (m)
High	11:53	5.8
	00:30	5.6
Low	05:45	2.5
	18:17	2.7

b. 09/09/10 (Spring tide)

Tidal state	Time	Height (m)
High	07:02	7.8
	19:43	7.6
Low	01:08	1.0
	13:44	0.3

Water samples were taken both surficially and at a depth of 4m. Surficial samples were taken at a depth of roughly 0.5m. Samples were taken every 20 minutes during periods of peak flow and around slack water and at half hour intervals between these. A displacement water sampler was used to take samples of 1litre of water and at each interval, 2 samples were taken from the surface and 2 samples from a depth of 4m. Upon return to the laboratory 29 samples were processed in order to establish the range of suspended solid concentrations over different tidal conditions. The remaining samples were stored for analysis at a later date, if required (Tables 3 & 4).

Table 3. Water samples collected on Thursday 2nd September 2010

Sample No.	Time	Depth	Rep	Sample processed
1	09:20	0.5m	A	X
2			B	
3		4m	A	X
4			B	
5	09:50	0.5m	A	X
6			B	
7		4m	A	X
8			B	
9	10:20	0.5m	A	X
10			B	
11		4m	A	X
12			B	
13	10:50	0.5m	A	X
14			B	
15		4m	A	X
16			B	
17	11:20	0.5m	A	X
18			B	
19		4m	A	X
20			B	
21	11:50	0.5m	A	X
22			B	
23		4m	A	X
24			B	
25	12:20	0.5m	A	X
26			B	
27		4m	A	X
28			B	
29	12:50	0.5m	A	X
30			B	
31		4m	A	X
32			B	
33	13:20	0.5m	A	X
34			B	
35		4m	A	X
36			B	
37	13:50	0.5m	A	X
38			B	
39		4m	A	X
40			B	
41	14:20	0.5m	A	X
42			B	
43		4m	A	X
44			B	
45	14:50	0.5m	A	X
46			B	
47		4m	A	X
48			B	
49	15:20	0.5m	A	X
50			B	
51		4m	A	X
52			B	
53	15:50	0.5m	A	X
54			B	
55		4m	A	X
56			B	
57	16:20	0.5m	A	X
58			B	
59		4m	A	X
60			B	
61	16:50	0.5m	A	X
62			B	
63		4m	A	X
64			B	
65	17:20	0.5m	A	X
66			B	
67		4m	A	X
68			B	

Table 4. Water samples collected on Thursday 9th September 2010

Sample No.	Time	Depth	Rep	Sample processed
69	09:40	0.5m	A	X
70			B	
71		4m	A	
72			B	
73	10:00	0.5m	A	X
74			B	
75		4m	A	
76			B	
77	10:20	0.5m	A	X
78			B	
79		4m	A	
80			B	
81	10:40	0.5m	A	X
82			B	
83		4m	A	
84			B	
85	11:00	0.5m	A	
86			B	
87		4m	A	
88			B	
89	11:20	0.5m	A	
90			B	
91		4m	A	
92			B	
93	11:40	0.5m	A	
94			B	
95		4m	A	
96			B	
97	12:00	0.5m	A	
98			B	
99		4m	A	
100			B	
101	12:30	0.5m	A	
102			B	
103		4m	A	
104			B	
105	13:00	0.5m	A	
106			B	
107		4m	A	
108			B	
109	13:30	0.5m	A	X
110			B	
111		4m	A	
112			B	

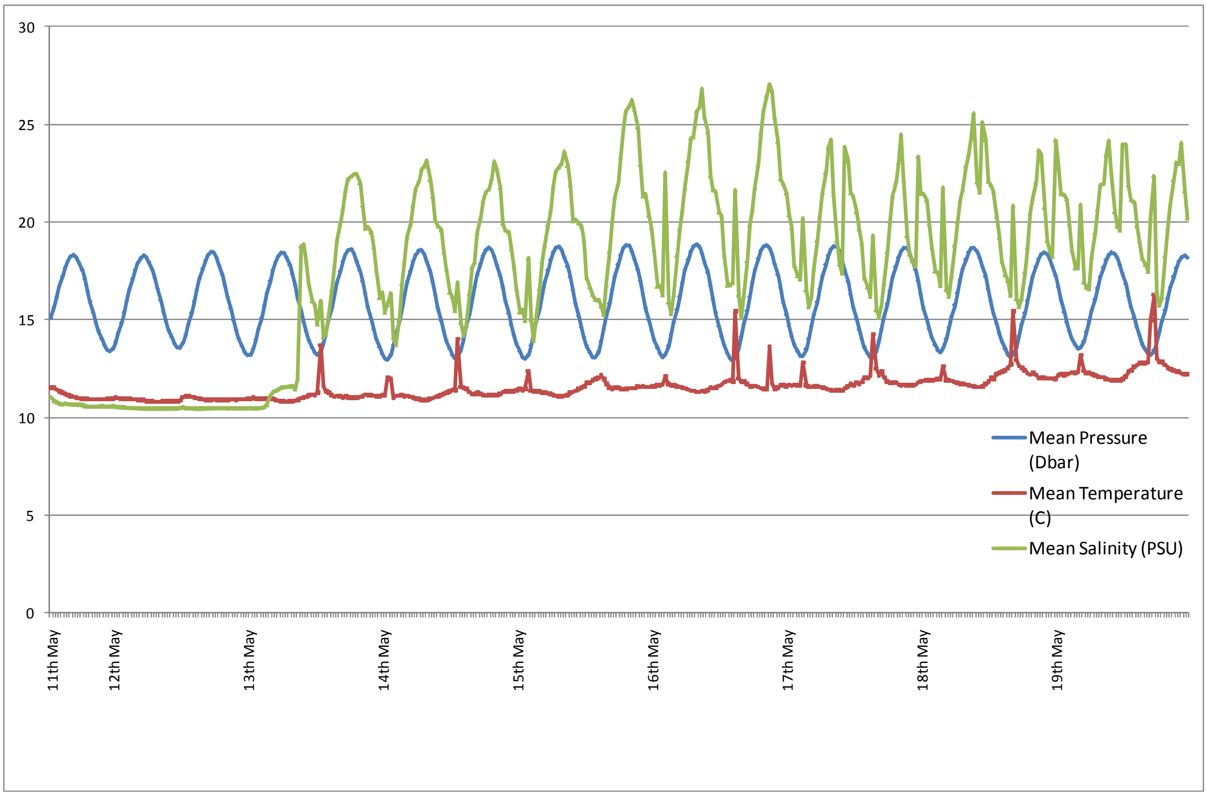
Sample No.	Time	Depth	Rep	Sample processed
113	13:50	0.5m	A	X
114			B	
115		4m	A	
116			B	
117	14:10	0.5m	A	X
118			B	
119		4m	A	
120			B	
121	14:30	0.5m	A	X
122			B	
123		4m	A	
124			B	
125	15:00	0.5m	A	
126			B	
127		4m	A	
128			B	
129	15:30	0.5m	A	
130			B	
131		4m	A	
132			B	
133	15:50	0.5m	A	
134			B	
135		4m	A	
136			B	
137	16:10	0.5m	A	
138			B	
139		4m	A	
140			B	
141	16:30	0.5m	A	X
142			B	
143		4m	A	
144			B	
145	16:50	0.5m	A	X
146			B	
147		4m	A	
148			B	
149	17:10	0.5m	A	X
150			B	
151		4m	A	
152			B	
153	17:30	0.5m	A	X
154			B	
155		4m	A	
156			B	

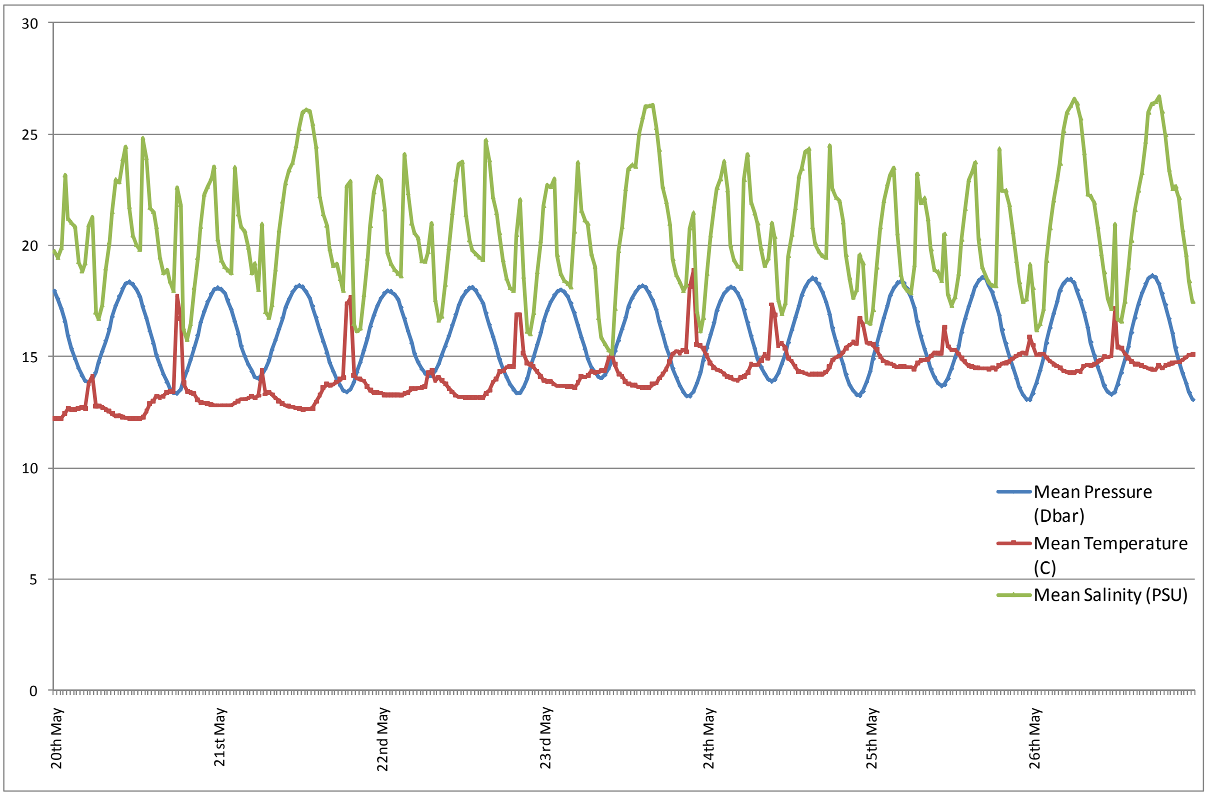
The water samples were thoroughly mixed prior to analysis to ensure re-suspended of solids. Fine grade glass fibre filter papers were dried and weighed for each sample, 500ml from each of the 29 samples was filtered through the filter paper using a Buchner funnel to draw the water through the filter. When complete the filter paper was dried overnight in an oven at 80^{o}C and reweighed. The change in weight recorded was the amount of suspended solids in 500ml of water. These values were multiplied to determine suspended solids per litre.

3.2 Data Processing

3.2.1 CTD GRAPHICAL OUTPUTS

Data from both CTDs were plotted against time showing temperature, pressure and salinity (Figure 12 for CTD at Site 1 & Figure 13 for CTD at Site 2).


30
25
20
15
10
5
0
11th May
12th May
13th May
14th May
15th May
16th May
17th May
18th May
19th May
Mean Pressure (Dbar)
Mean Temperature (C)
Mean Salinity (PSU)


30
25
20
15
10
5
0
20th May
21st May
22nd May
23rd May
24th May
25th May
26th May
Mean Pressure (Dbar)
Mean Temperature (C)
Mean Salinity (PSU)

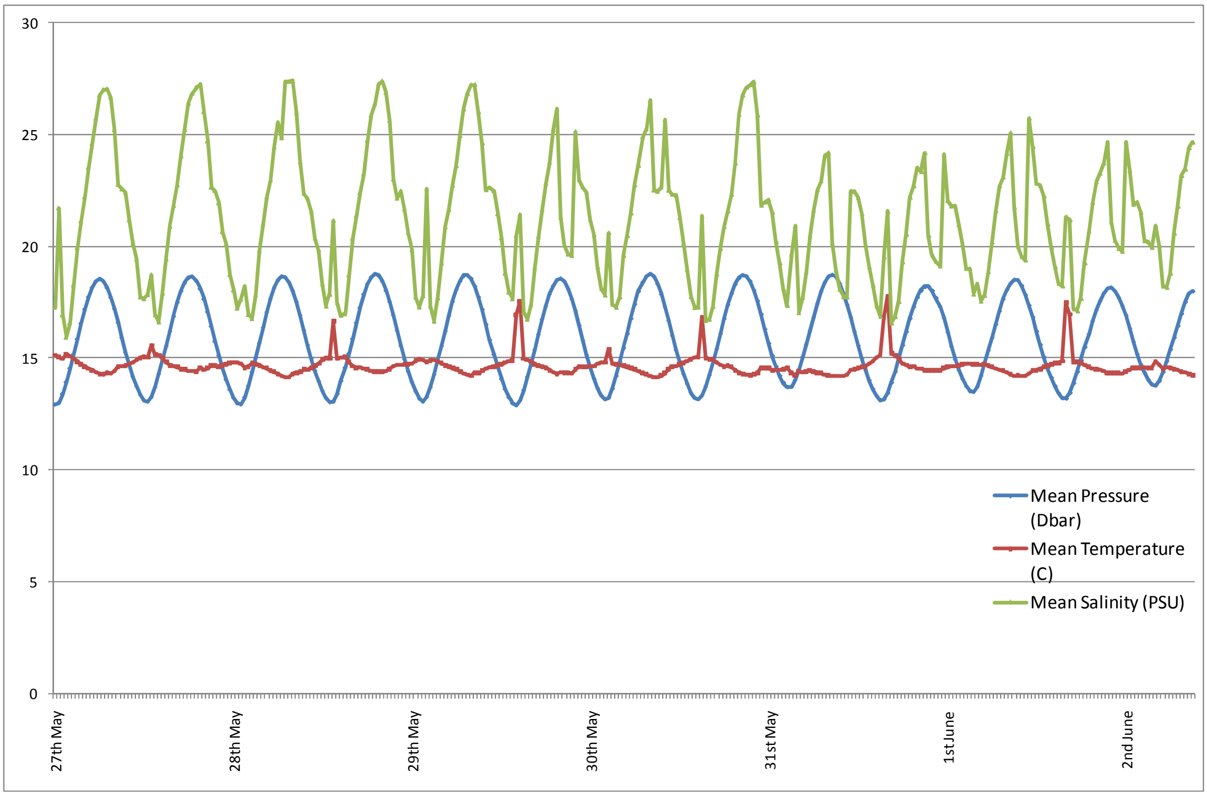
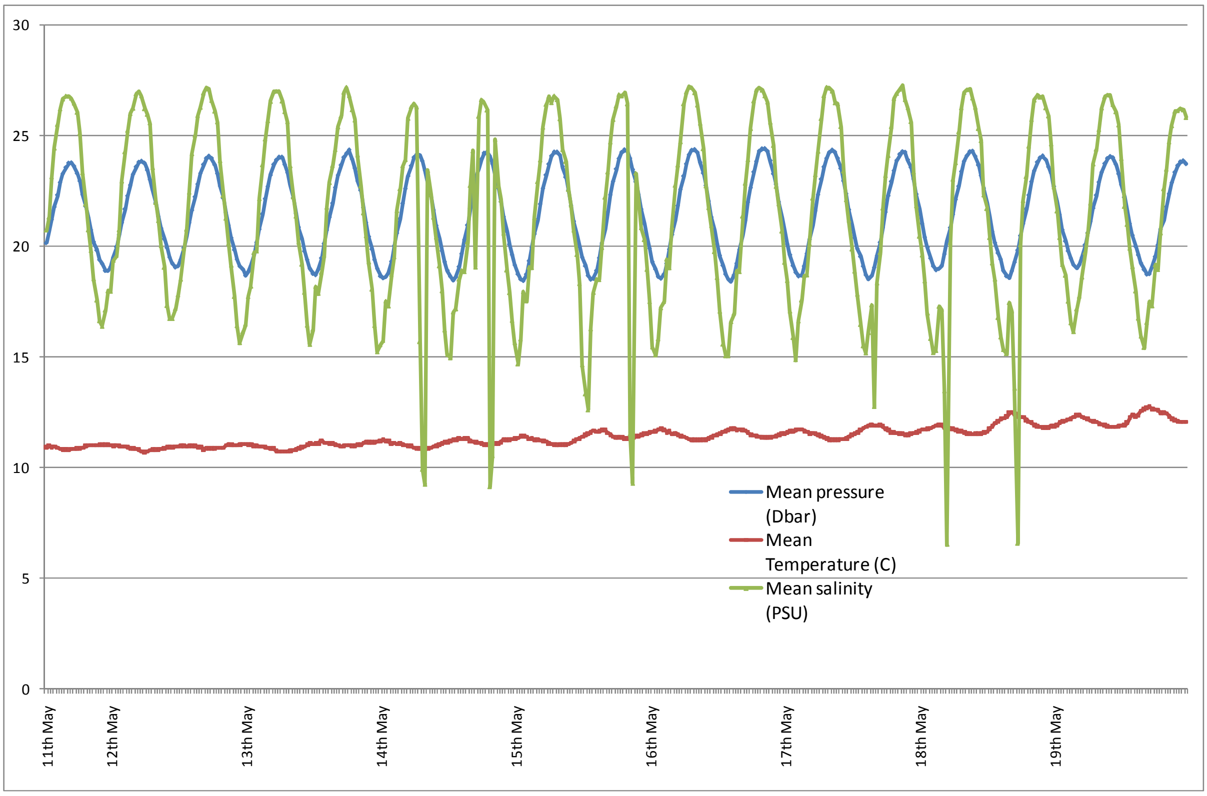
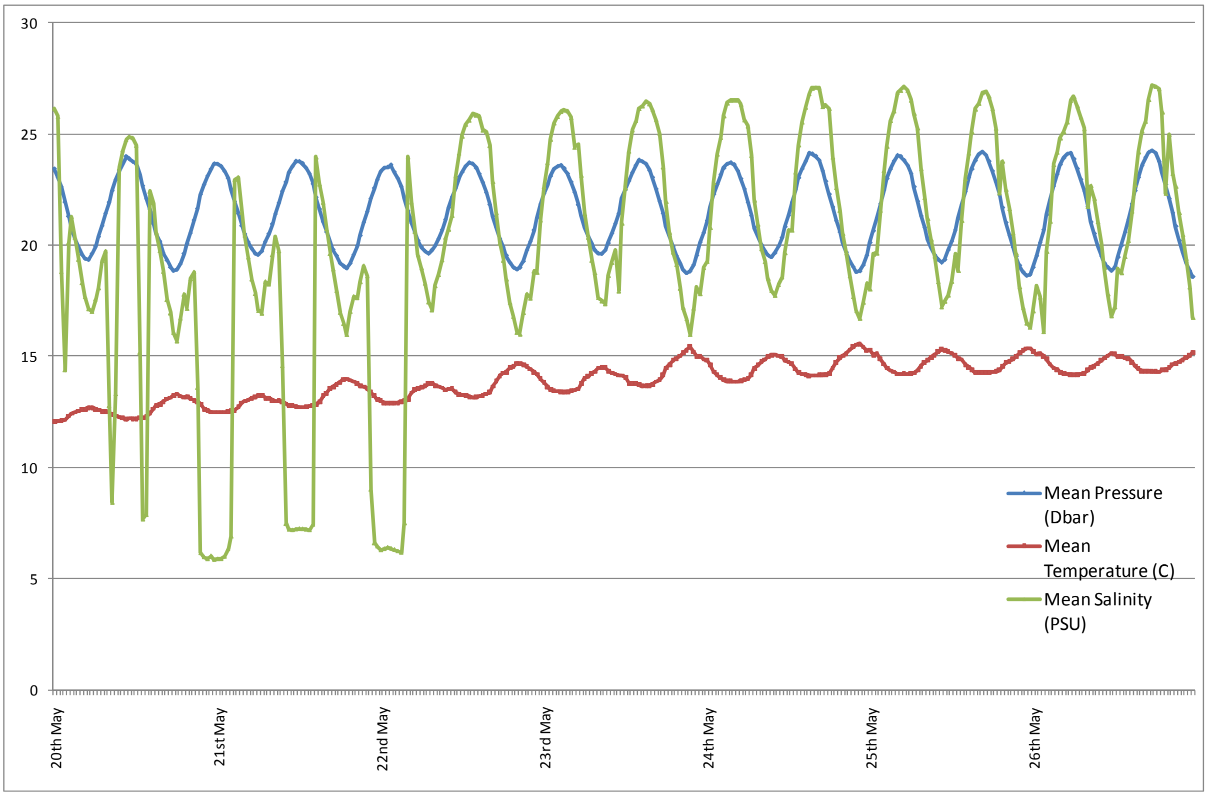


Figure 12. Mean pressure, temperature and salinity at position 1





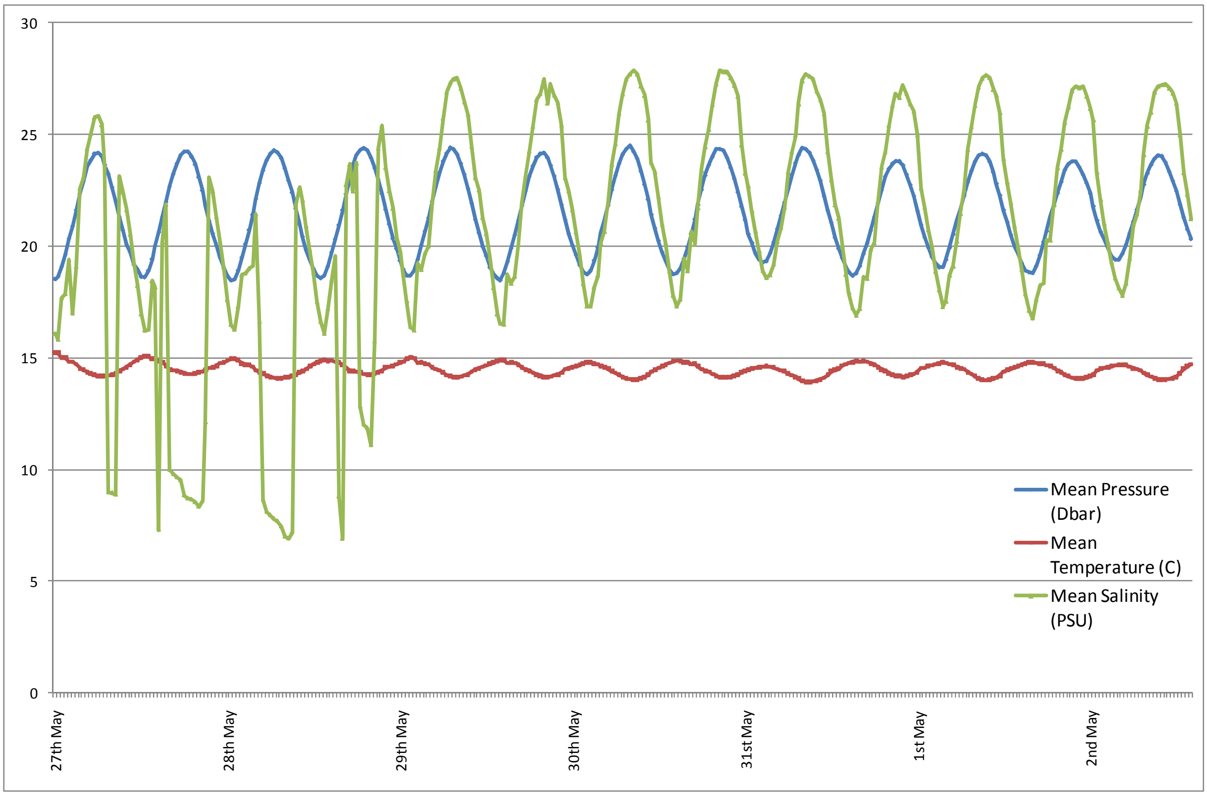


Figure 13. Mean pressure, temperature and salinity at position 2

3.2.2 POSITION 1 GRAPHICAL OUTPUTS, VELOCITY.

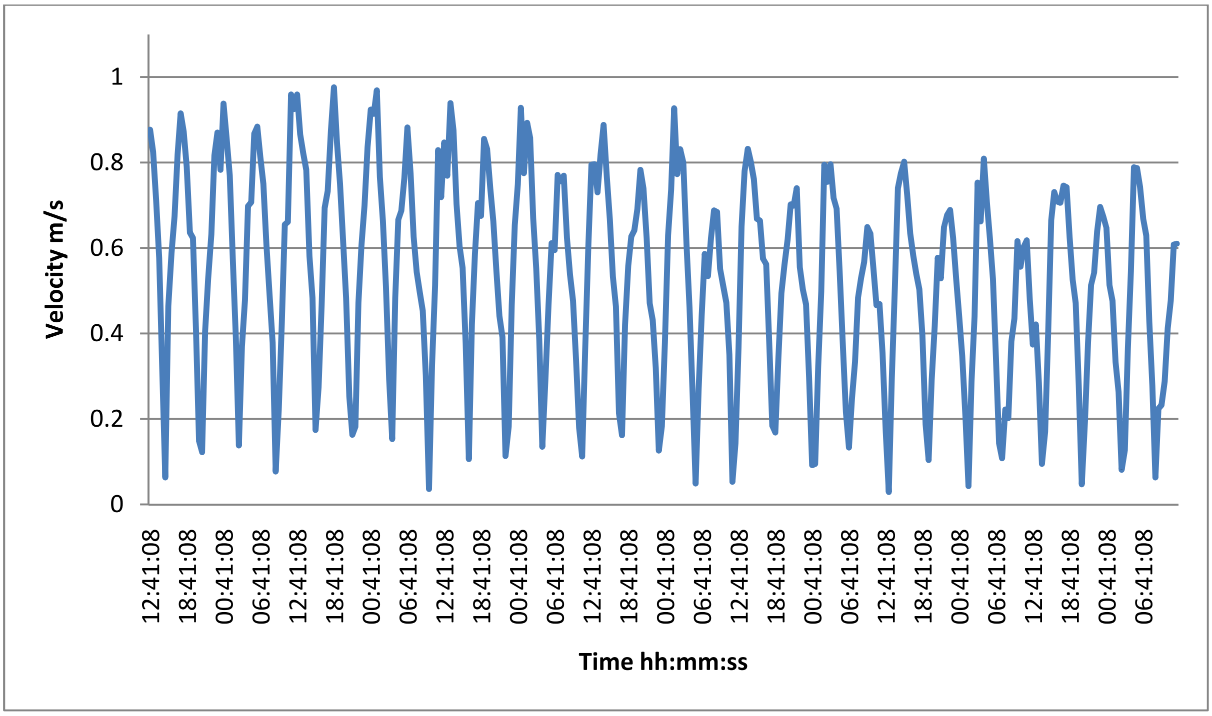


Figure 14. Position 1. Velocity @ 1.2m from 16/5/2010 12:41:08 until 23/5/2010 12:11:08

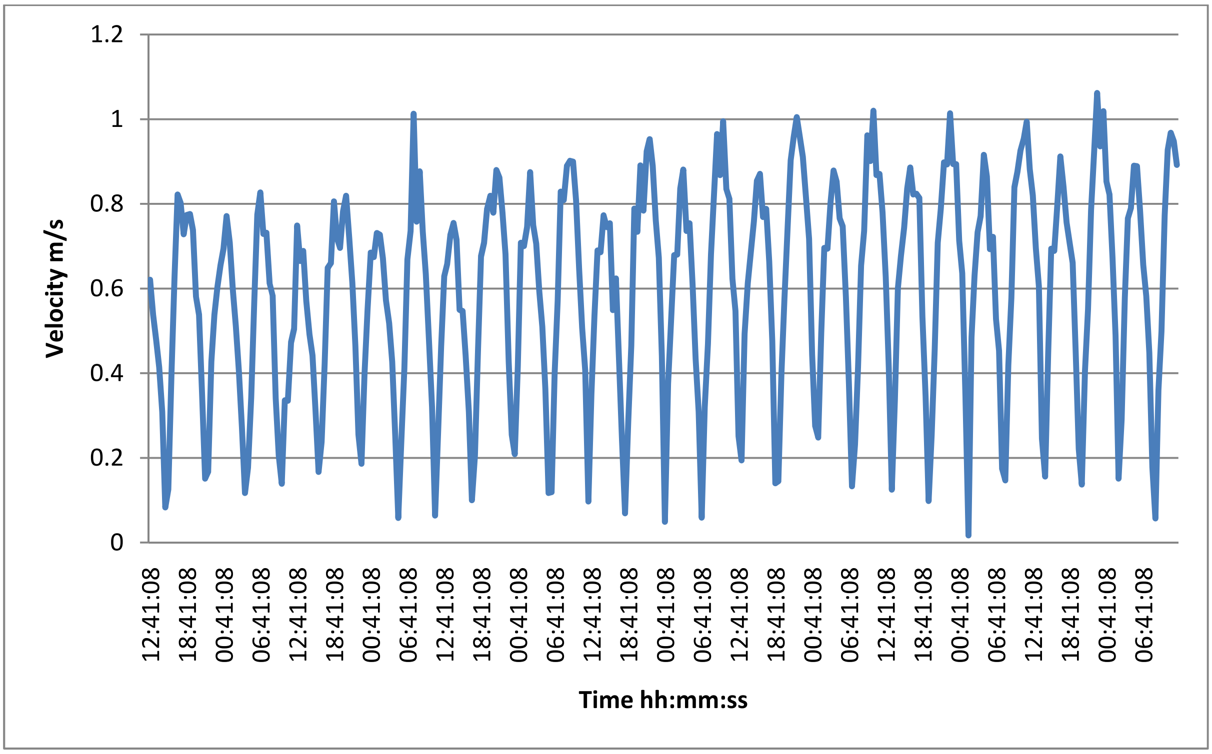


Figure 15. Position 1. Velocity @ 1.2m from 23/5/2010 12:41:08 until 30/5/2010 12:11:08

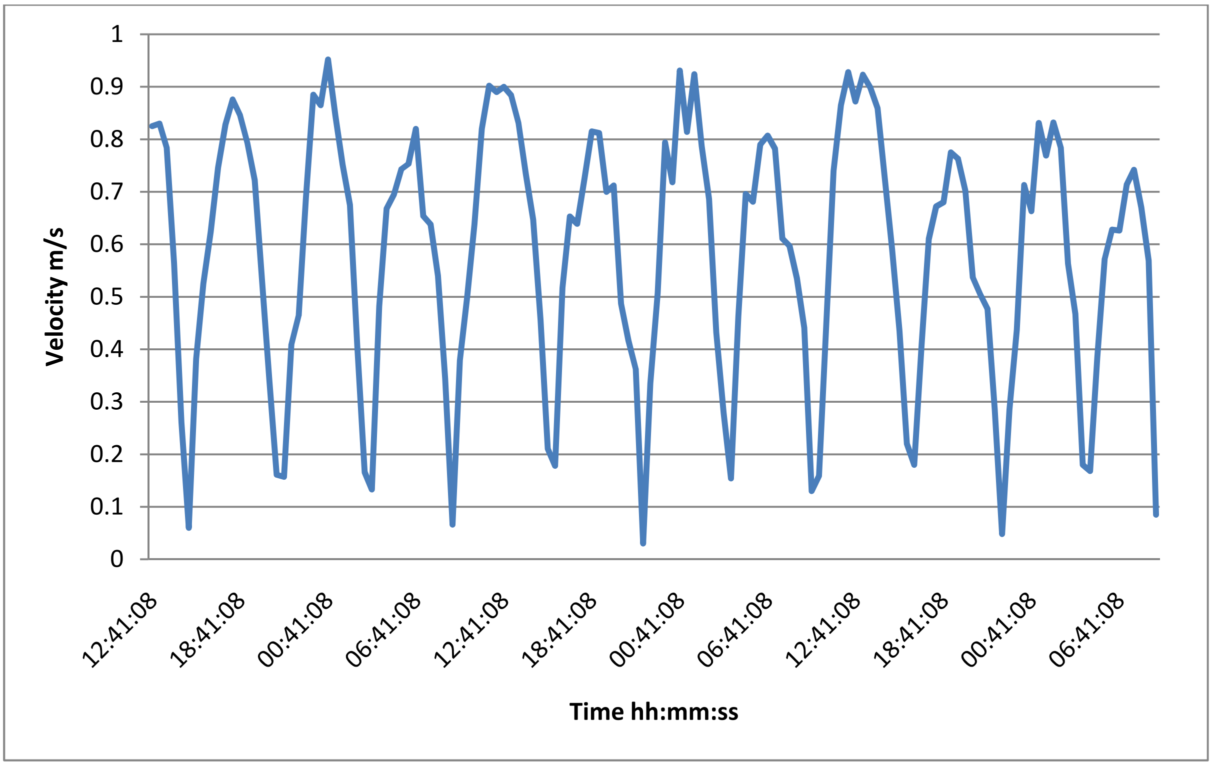


Figure 16. Position 1. Velocity @ 1.2m from 24/5/2010 12:41:08 until 2/6/2010 08:41:08

3.2.3 Position 1 Graphical outputs, Direction of flow.

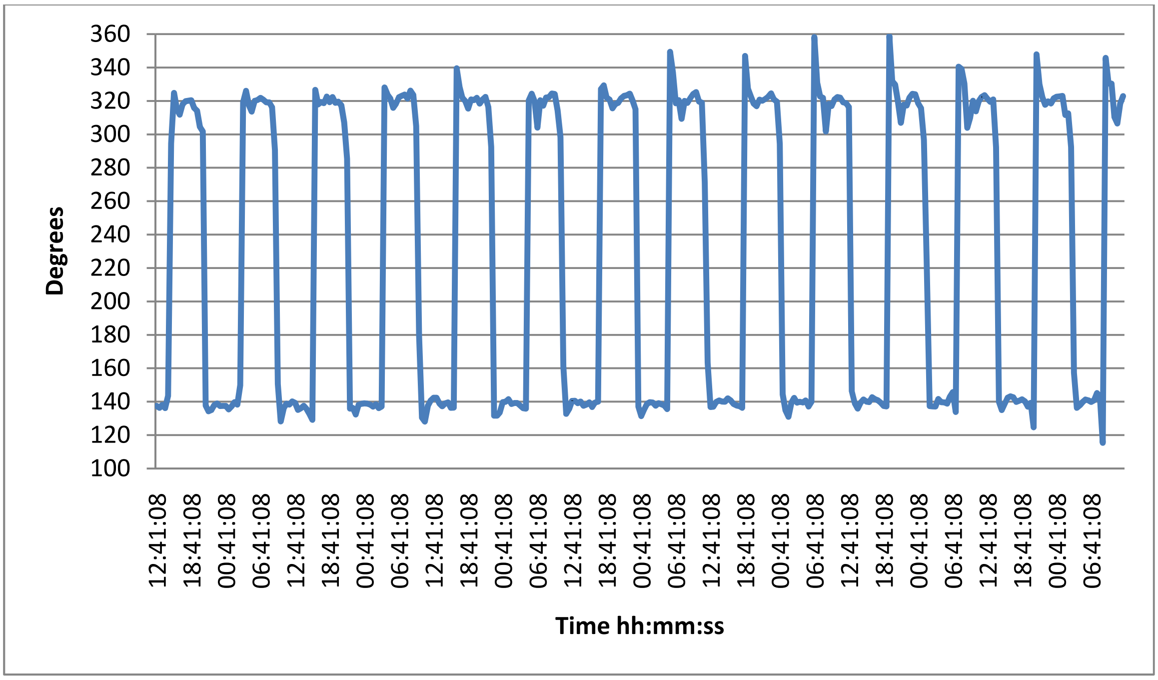


Figure 17. Position 1. Direction of water flow at 1.2m from 16/5/2010 12:41:08 until 23/5/2010 12:11:08.

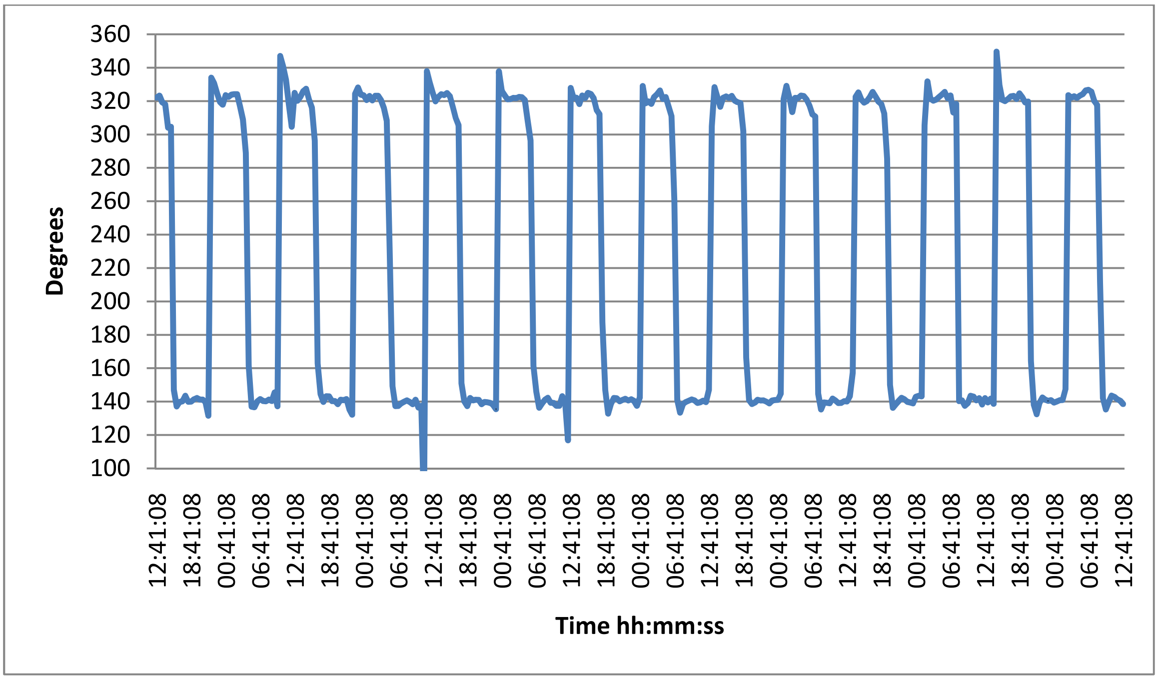


Figure 18. Position 1. Direction of water flow at 1.2m from 23/5/2010 12:41:08 until 30/5/2010 12:11:08.

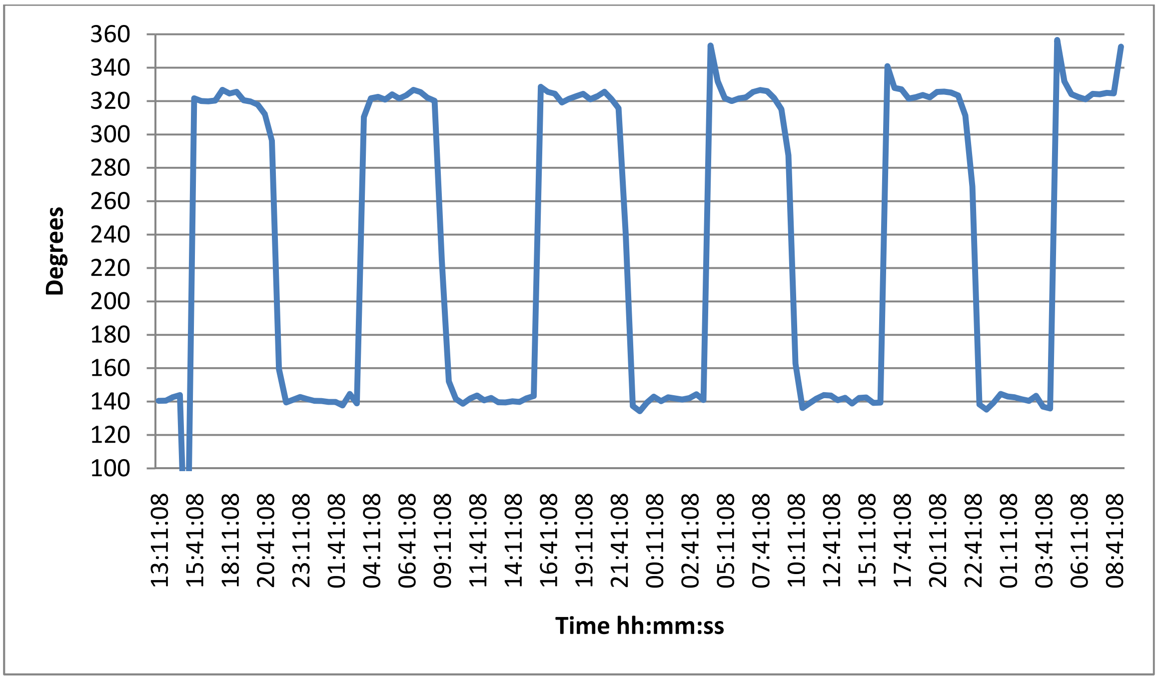


Figure 19. Position 1. Direction of water flow at 1.2m from 30/5/2010 12:41:08 until 2/6/2010 12:11:08.

3.2.3 Position 2 Graphical outputs, Velocity.

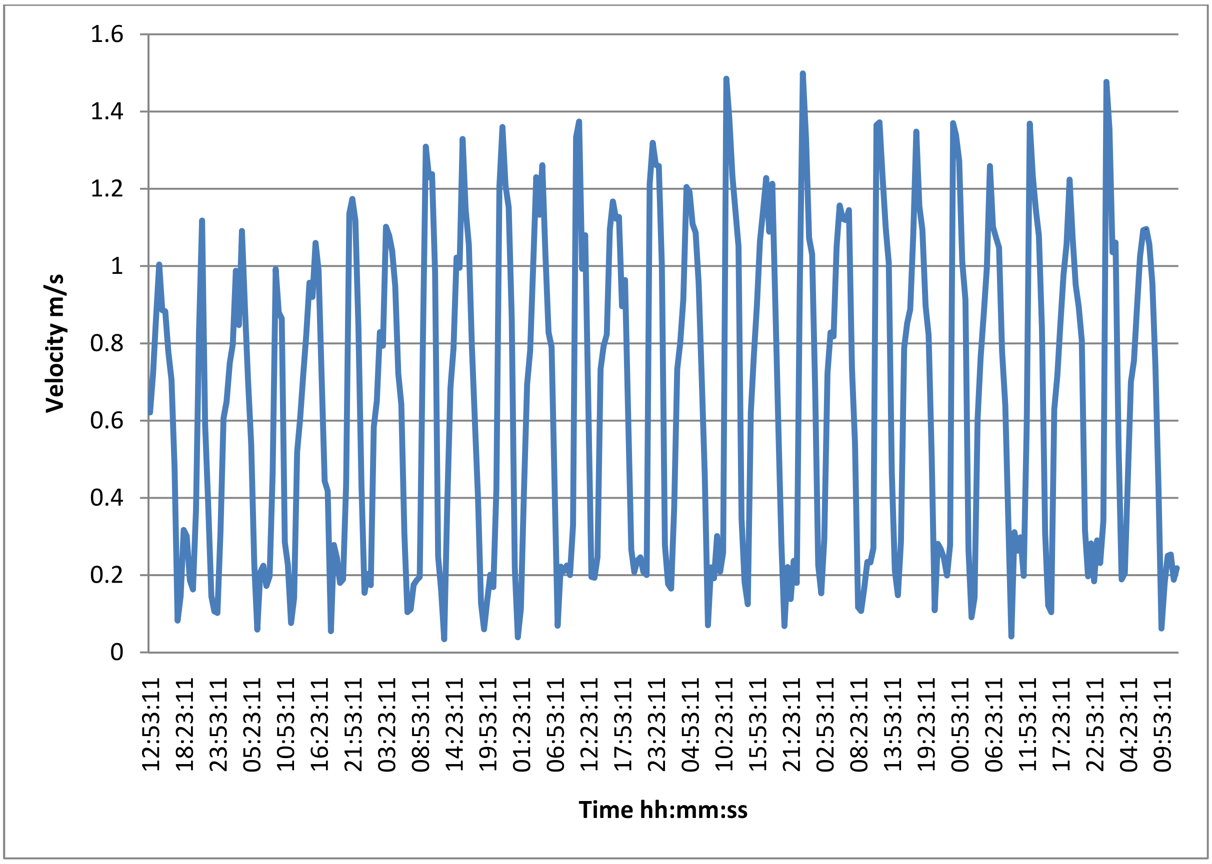


Figure 20. Position 2. Velocity at 1.2m from 11/5/2010 12:53:11 until 18/5/2010 12:23:11.

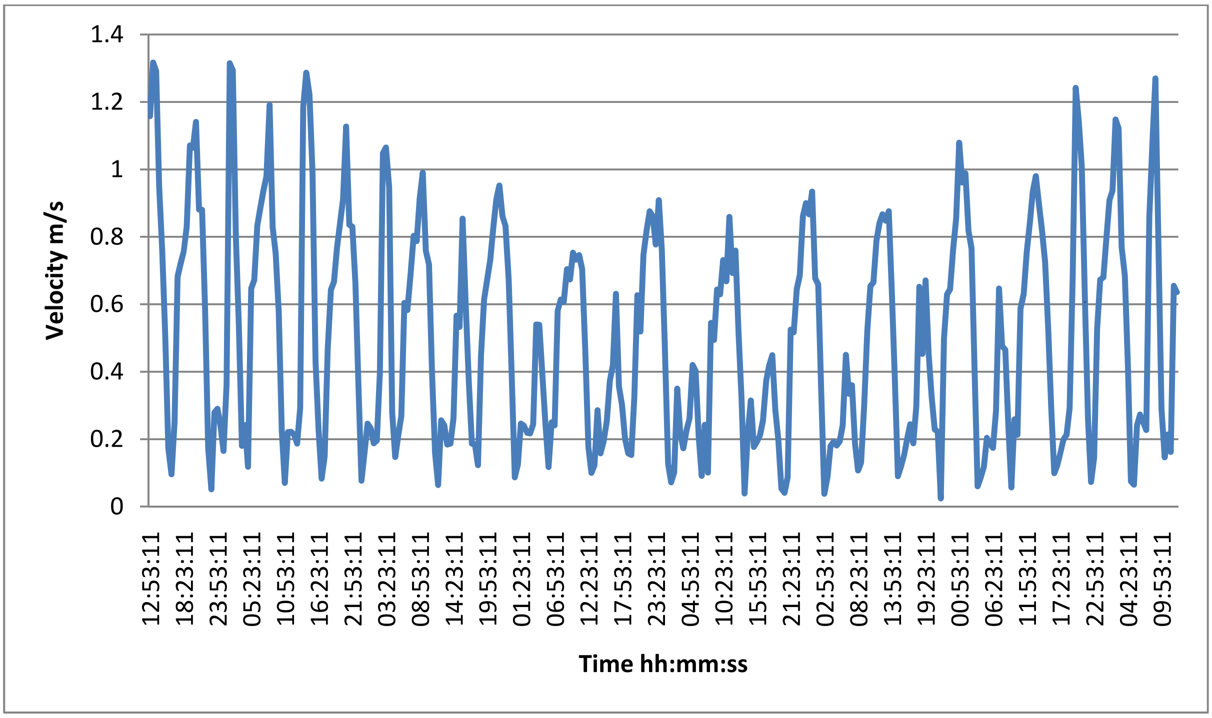


Figure 21. Position 2. Velocity at 1.2m from 18/5/2010 12:53:11 until 25/5/2010 12:23:11.

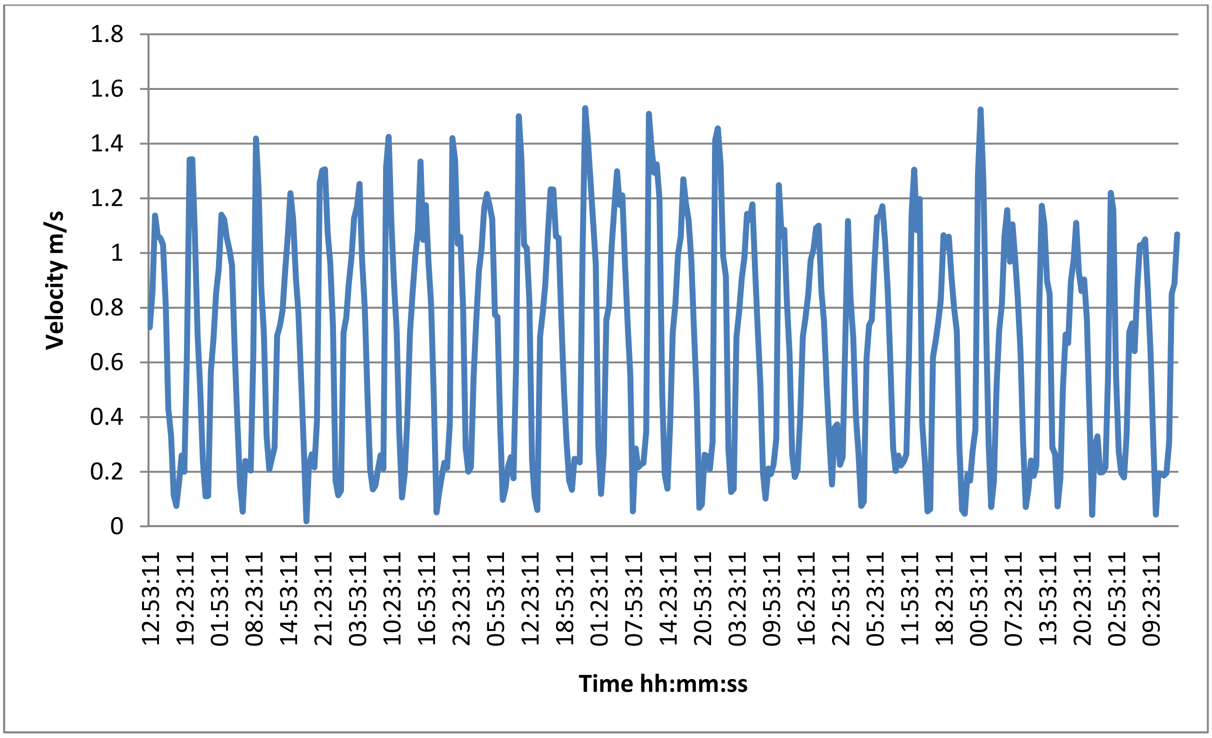


Figure 22. Position 2. Velocity at 1.2m from 25/5/2010 12:53:11 until 2/6/2010 14:23:11.

3.2.3 Position 2 Graphical outputs, Direction of flow.

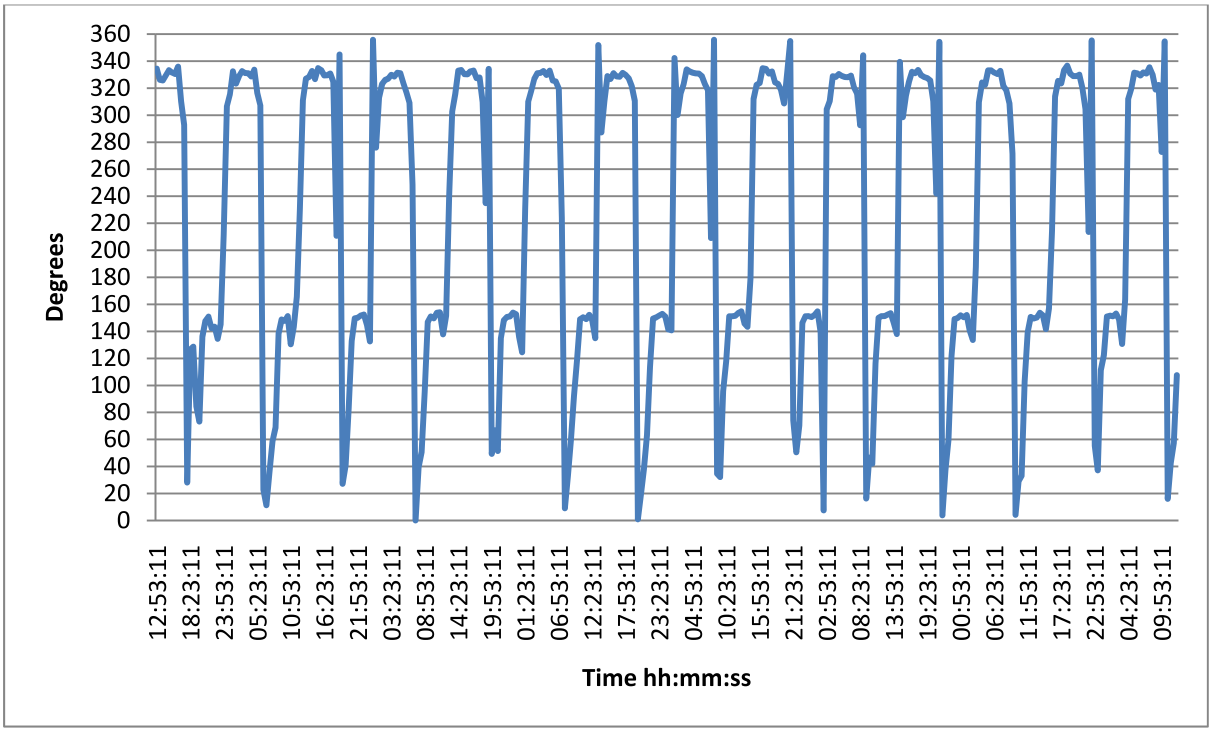


Figure 23. Position 2. Direction of water flow at 1.2m from 11/5/2010 12:53:11 until 18/5/2010 12:23:11.

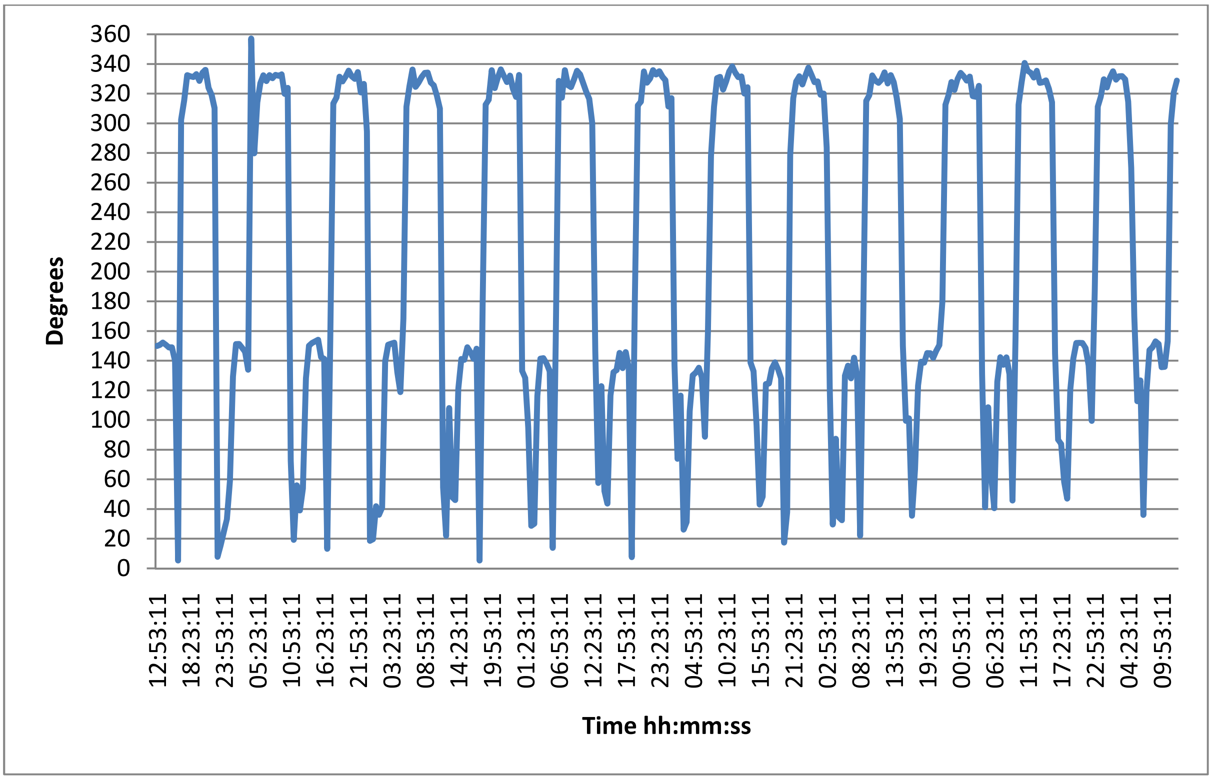


Figure 24. Position 2. Direction of water flow at 1.2m from 18/5/2010 12:53:11 until 25/5/2010 12:23:11.

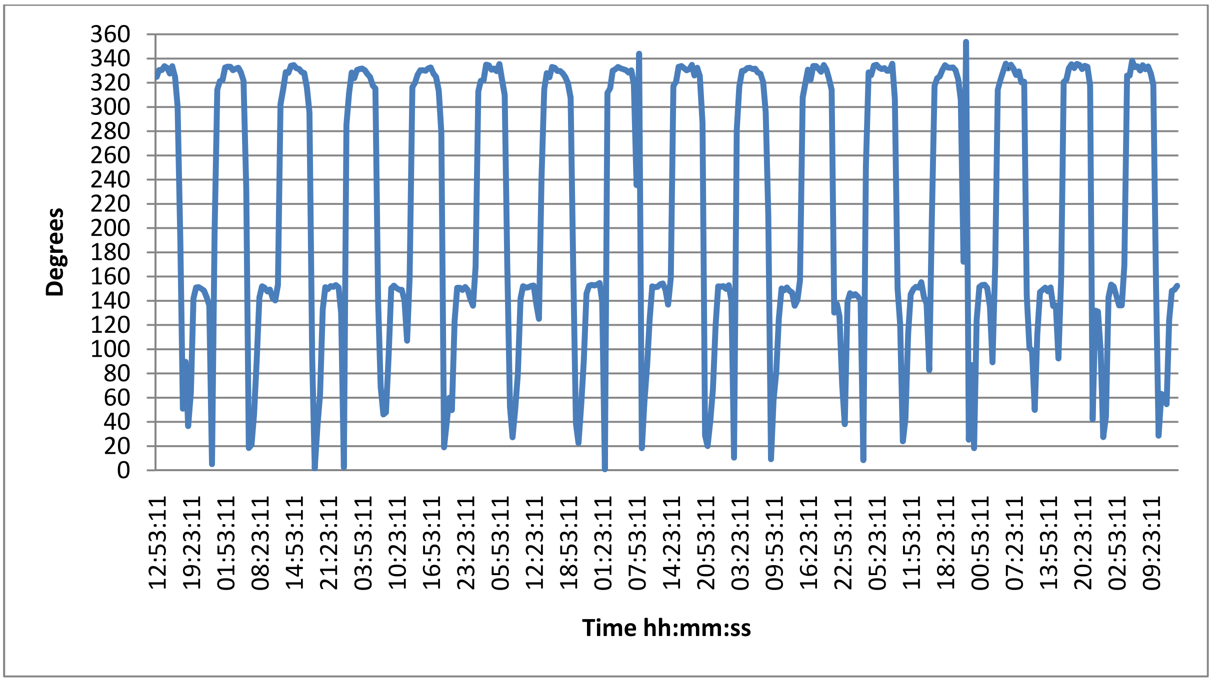


Figure 25. Position 2. Direction of water flow at 1.2m from 25/5/2010 12:53:11 until 2/6/2010 14:23:11.

3.2.4 Graphical output from suspended solid measurements

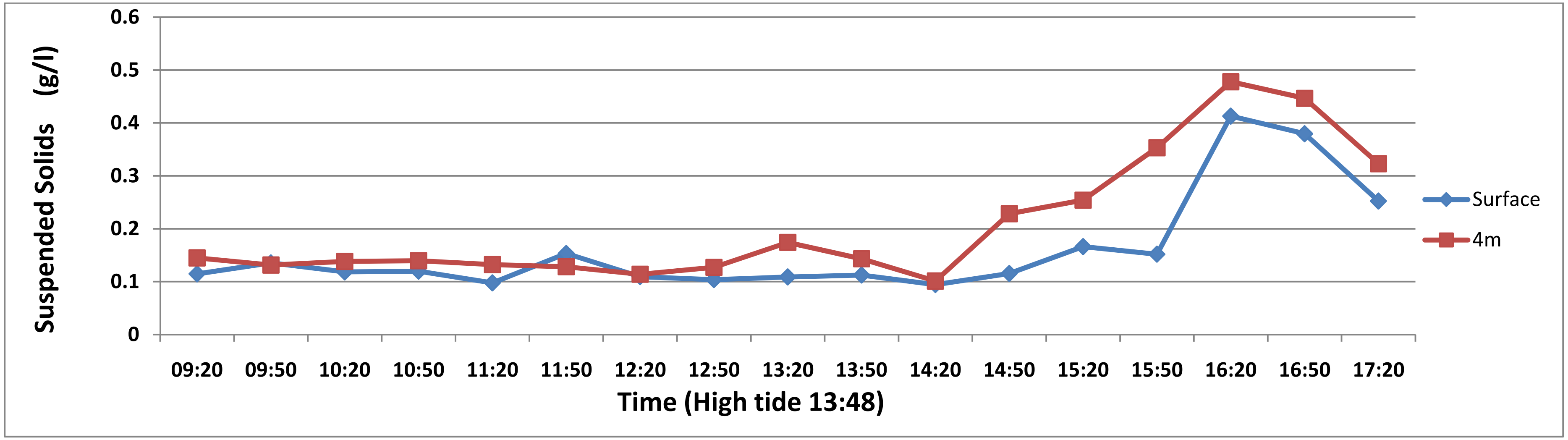


Figure 26. Suspended Solid concentrations (g/l) on 02/09/10 (high tide at 13:38).

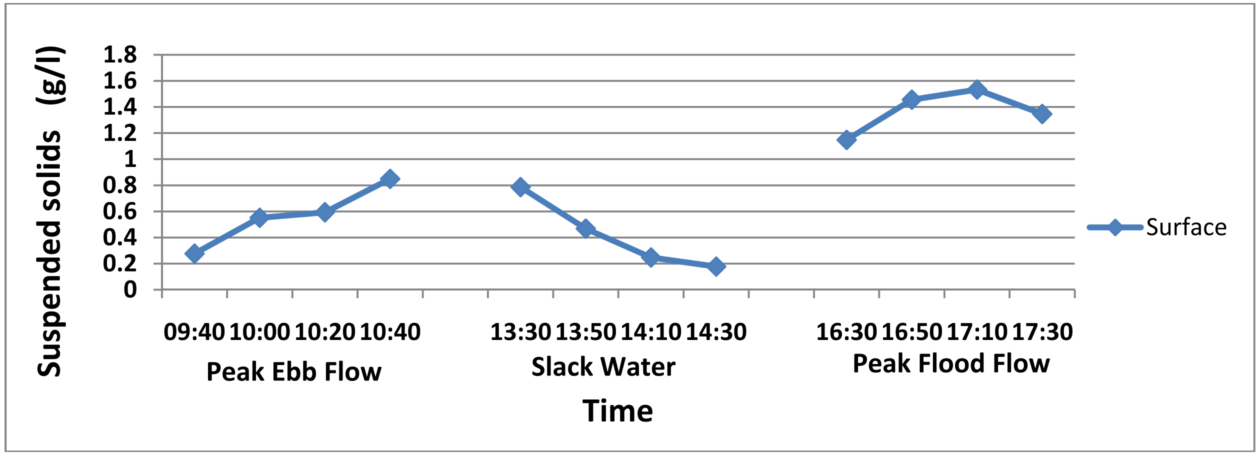


Figure 27. Surface water suspended solid concentrations (g/l) on 09/09/10 (low tide at 13:48).

Table 5. Suspended Solids (g/l) recorded on 02/09/10 (neap tide).

	Time	Surface	4m
Flood Tide	09:20	0.1146	0.1448
	09:50	0.1354	0.1314
	10:20	0.1184	0.1382
	10:50	0.1196	0.1396
	11:20	0.0976	0.1322
	11:50	0.1532	0.1282
	12:20	0.1094	0.114
	12:50	0.1038	0.127
	13:20	0.1088	0.1742
Slack High Water	13:50	0.1124	0.1432
	14:20	0.0944	0.1012
Ebb Tide	14:50	0.1154	0.2284
	15:20	0.1662	0.254
	15:50	0.1518	0.3532
	16:20	0.413	0.478
	16:50	0.3796	0.4466
	17:20	0.2524	0.323

Table 6. Suspended solids (g/l) recorded on 09/09/10 (spring tide).

	Time	Surface
Peak Flood Flow	16:30	1.1476
	16:50	1.4558
	17:10	1.5334
	17:30	1.3462
Slack Water Low Tide	13:30	0.786
	13:50	0.4682
	14:10	0.2474
	14:30	0.177
Peak Ebb Flow	09:40	0.2762
	10:00	0.5514
	10:20	0.5934
	10:40	0.8488

3.3 Results

3.3.1 PRESSURE

Pressure for both positions show very regular fluctuations. For site 1 pressure rages from approximately 13 to 18 Dbar and for site 2 approximately 19 to 24 Dbar. The instrument at position 2 was deployed at a greater depth than the instrument at position 1 which accounts for the higher pressures recorded at position 2. All pressure data relates to tidal state with low pressure corresponding to low tide and high pressure to high tide.

3.3.2 TEMPERATURE

In general the temperature readings at position 1 follow a regular pattern displaying a gradual increase toward low water and falling again as the tide floods, with temperature ranging from approximately 12˚C to 16˚C. However, in addition to this general pattern, distinct peaks in temperature reaching 18˚C were observed at low water on the majority of the tidal cycles. It is possible these peaks in temperature are the result of nearby discharges from outfalls along the south Humber bank however this would require further investigation to confirm.

Temperature fluctuations recorded at position 2, located in deeper water are more stable. The same general pattern of increasing temperature with the ebbing tide and falling temperature with the flooding tide is still apparent. Temperature ranges from approximately 11 to 15˚C.

3.3.3 SALINITY

Salinity readings for position 1, closest to the shore, are quite erratic. Although the general trend of increasing salinity during the flooding tide and decreasing salinity on the ebbing tide appear to be apparent, low water there is a distinct peak in salinity which appears to coincide with the peak in temperature. Also, at high water there is a trough in salinity. These regularly occurring peaks and troughs coincide with slack water and as such would again suggest the localised affect of a nearby outfall.

Salinity recorded at position 2 overall follows a general trend, as expected, recording an increase in salinity with pressure which reflects the effect of the flooding tide and a decrease on the ebbing tide. Low troughs in salinity occurring between the 14th - 19th, 20th - 22nd and 27th - 29th May appear to be anomalies in the data set, as readings below 10 psu are unlikely to occur at this point in the Humber estuary. As such, it is anticipated these anomalies are the result of an equipment malfunction. For the rest of the data, salinity ranges from approximately 15 psu to 27 psu.

3.3.4 CURRENT VELOCITY AND DIRECTION

Note: readings for velocity and direction are in distance from the unit, NOT depth of water and are only viable as data up to the depth of the water column.

3.3.4.1 Position 1

The maximum water velocity through the column at Position 1 was observed as expected on the ebb of the spring tide with surface waters attaining 1.305m/s. The maximum velocity on the flood of the spring tide was 1.154m/s. The minimum velocity recorded was on a flood tide at 0.017m/s measured at 1.2m from the unit.

The velocities of the water shown in Figures 14, 15 and 16 were measured at 1.2m from the unit where water was always present.

At position 1 the spring tides ranged from a depth of 6.74m on the highest spring tide to a depth of 1.44 m on the lowest spring tide. The highest tide on a neap tidal range was 5.9m in depth and the lowest tide on the neap attained 1.68m in depth.

At this position, the prevailing direction of flow in the water column during flood was *c.*310 degrees and 130 degrees during ebb. The direction of flow at the 1.2m mark is shown in degrees in Figures 17, 18 and 19.

3.3.4.2 Position 2

The maximum water velocity through the column at Position 2 was observed as expected on the ebb of the spring tide with surface waters attaining 2.201m/s. The maximum velocity on the flood of the spring tide was 1.46m/s. The minimum velocity recorded was on a flood tide at 0.012m/s.

The velocity of the water shown in Figures 20, 21 and 22 is measured at 1.2m from the unit where there is always water present.

At Position 2 the spring tides ranged from a depth of 13.72m on the highest spring tide to a depth of 7.66m on the lowest spring tide. The highest tide on a neap tidal range was 13.04m in depth and the lowest tide on the neap attained 8.2m in depth.

At this position, the prevailing direction of flow in the water column was *c.*330 degrees and *c.*150 degrees during ebb. The direction of water movement at the 1.2m mark is shown in degrees in Figures 23, 24 and 25.

3.3.5 Suspended solids

The highest levels of suspended solids in surface waters on a neap tide in flood were found to be 0.153 grams per litre and 0.379g/l on a neap tide in ebb indicating a greater particle movement during the ebb tide. The highest levels of suspended sediment were recorded as 0.478 g/l at a depth of 4m during the ebb.

The highest levels of suspended solids in surface waters on a spring tide in flood were found to be 1.533g/l, and 0.848g/l on a spring tide in ebb indicating a greater particle movement during the flood tide. The water velocity was too great to be able to take readings at a depth of 4m.

During a neap tide the levels of suspended solids in the Humber are generally highest on the ebb due to the greater velocity and turbidity of water particularly at shallow depths resulting therefore in the greatest resuspension and least deposition of solids. During spring tides the highest density of suspended sediment was during a flood tide reflecting the high levels of turbidity caused by the mixing of fresh and saline waters.

A full break down of suspended solids is shown in Tables 5 & 6 and Figures 26 & 27.

4 REFERENCES

2004. Capt. Hames, P. & Nixon, B. (Associated British Ports) Humber Management Scheme document, (Annex 1) Shipping and Navigation.