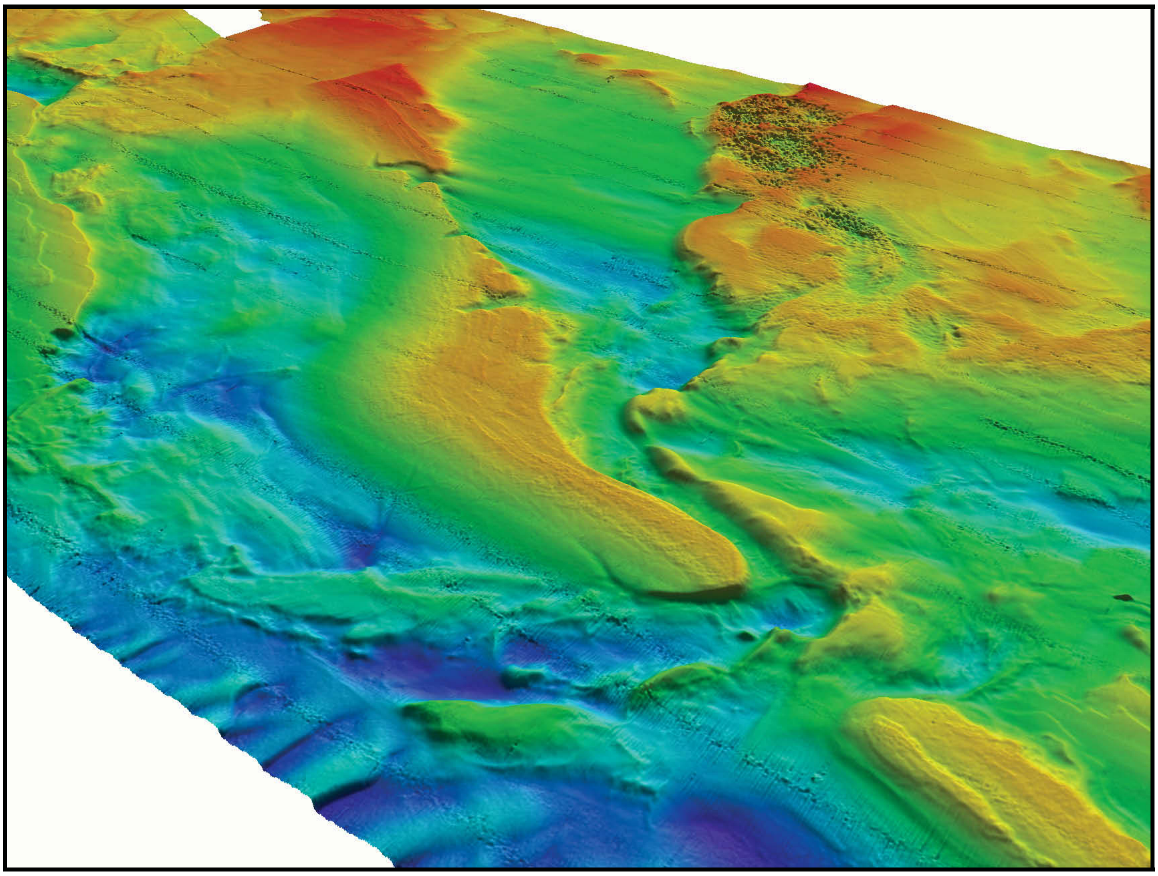
Submerged Palaeo-Arun River: Reconstruction of Prehistoric Landscapes and Evaluation of Archaeological Resource Potential

Integrated Projects 1 and 2



Final Project Report for English Heritage

Appendices

16th March 2004

Seafloor Imaging & Processes Group,
Department of Earth Science & Engineering, Imperial College,
Exhibition Road, London SW7 2AZ, UK
Tel: 020 7594 6527/020 7594 6443
Fax: 020 7594 7444
Email: s.gupta@imperial.ac.uk

ENGLISH HERITAGE

Imperial College London

Submerged Palaeo-Arun River: Reconstruction of Prehistoric Landscapes and Evaluation of Archaeological Resource Potential

Integrated Projects 1 and 2

Appendix 1
&
Appendix 2

Prepared for

English Heritage
23 Savile Row
London
W1S 2ET

Seafloor Imaging & Processes Group,
Department of Earth Science & Engineering,
Imperial College,
Exhibition Road, London SW7 2AZ, UK
Tel: 020 7594 6527/020 7594 6443
Fax: 020 7594 7444
Email: s.gupta@imperial.ac.uk

Table of Contents

List of Figures

List of Tables

Appendix A

A Cruise Report: Joint multibeam, chirp, side-scan and boomer seismic survey of Arun palaeo-river system (7th March – 25th April 2003)

A.1 INTRODUCTION & OBJECTIVES

This report details the combined swath and geophysical survey of the Arun palæovalley in the northern English Channel (Fig. A-1).

The English Channel is an area of continental shelf which has been subject to several major sea-level fluctuations during the Holocene. These fluctuations enabled the creation of various landforms which were subsequently submerged. Although many river systems traverse, what is now the southern English coast, the river Arun is thought to record the eustatic changes with little external tectonic influence. This is important as the offshore unfilled valley and infilled sections have the potential to record the interaction of base-level fluctuations and climatically controlled variation in sediment input from river catchments.

The now submerged landscape sculpted by the fluvial and marine processes is thought to contain significant archeological potential, due in part to the close proximity of Boxgrove. Further offshore, the area is currently being dredged since the fluvial system during the late Quaternary deposited significant amounts of sand and gravel, which are being extracted.

Thus, an in depth understanding of the morphology and stratigraphy of the environment may enable the prediction of possible archaeologically interesting sites, as well as a detailed interpretation of the valley evolution. The project therefore has a bearing on the evolution of submerged landscapes on the English Channel shelf, the evaluation of aggregate resources, and early human colonisation of Britain. The objective of the survey was therefore to acquire data facilitating accurate interpretation of this complex environment.

High resolution marine geophysical sensors including a multibeam sonar, sub-bottom profiler/side-scan sonar and boomer seismic profiler were deployed to map both the surface topography and subsurface geology. This high-resolution, integrated survey approach should enable significant progress to the objectives. The mapping was conducted by a team from Imperial College London using equipment from the British Universities Marine Geophysical Consortium and funded by English Heritage.

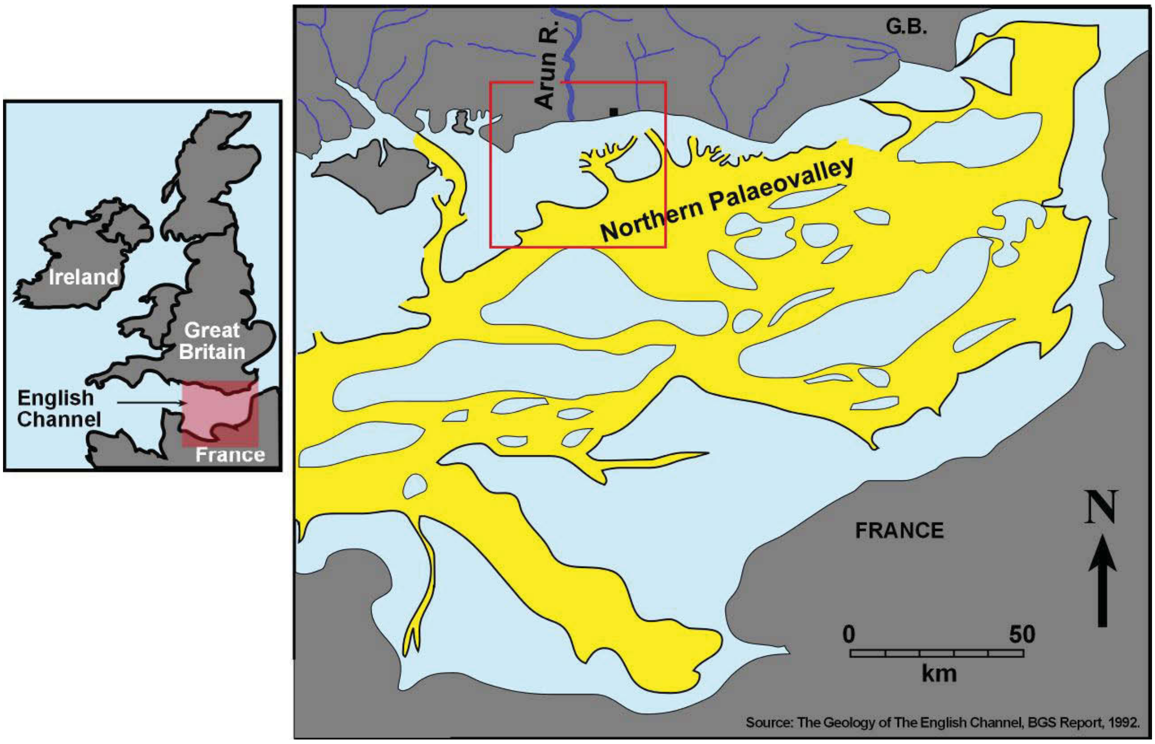


Fig. A-1. Location of Northern Palæovalley system within the English Channel. The river Arun is labelled and the general survey area bounded by the red box. Figure adapted from BGS report 1992.

A.2 CRUISE PREPARATION

A.2.1 Vessel Selection

The equipment used during the survey is not permanently installed on a single vessel, so a vessel of opportunity was required. To enable a comprehensive evaluation, a list of considerations was complied and used to assess the suitability and cost efficiency of potential vessels (see below).

- Costs
    - Day-rate
    - Fuel
    - Berthing/Mooring
    - Mobilisation/Demobilisation
    - Equipment set-up and calibration
    - Provisions
    - Permits
    - Weather downtime
    - Vessel downtime

    - Survey downtime
- Specification
    - Length
    - Draft
    - Transiting/Survey speed
    - Displacement
    - Design
    - Single/twin engine
    - Certification
- Capabilities
    - Transit speed
    - Fuel capacity
    - MCA Range Licence
    - No of Personnel
    - Operational weather/sea limits
- Facilities
    - Accommodation
    - Safety equipment
    - Communications equipment
    - Navigation equipment
    - Wheelhouse space
    - Power
- Survey Requirements
    - Pole Mounting for Multibeam
    - A-Frame/Crane for Chirp
    - Tow wire and Winch (preferably plus a spare)
    - Back-deck space
    - Stowage for survey instruments
    - Separate UPS (Uninterruptible Power Supplies) for Instruments and processors
    - Established vessel reference point (for MRU)
    - Good acoustic properties
    - Calibration of know off-sets

For safety and staffing reasons it was decided to operate daylight hours only from a convenient port with overnight berthing facilities. As the nearest port which isn't cut off from the sea at low tide Brighton Marina was chosen. The shallow depth and restricted manoeuvring constrained the vessel length to less than 15 metres and draft to less than 1.5 metres. The distance of 14 miles from Brighton to the survey site meant a fast vessel was essential. To deploy the towed Chirp sub-bottom profiler a crane or A-frame was required as was plenty of back deck space for the Boomer catamaran and streamer. Two potential survey vessels were visited and assessed: the Xplorer of Portsmouth and the Wessex Explorer.

A.2.1.1 Xplorer of Portsmouth (Fig. A-2 and Fig. A-3)

12 metre survey catamaran with twin engines capable of transiting at 18 knots

- Large back deck with crane and winch
- 1.4m draft
- Large wheel house with dual power supply
- Capable of comfortably accommodating 7 persons
- Caries mounting pole for Reson 8125 which could be modified for the 8101
- Differential GPS system
- MCA 60 mile licence

Fig. A-2. The Xplorer of Portsmouth.

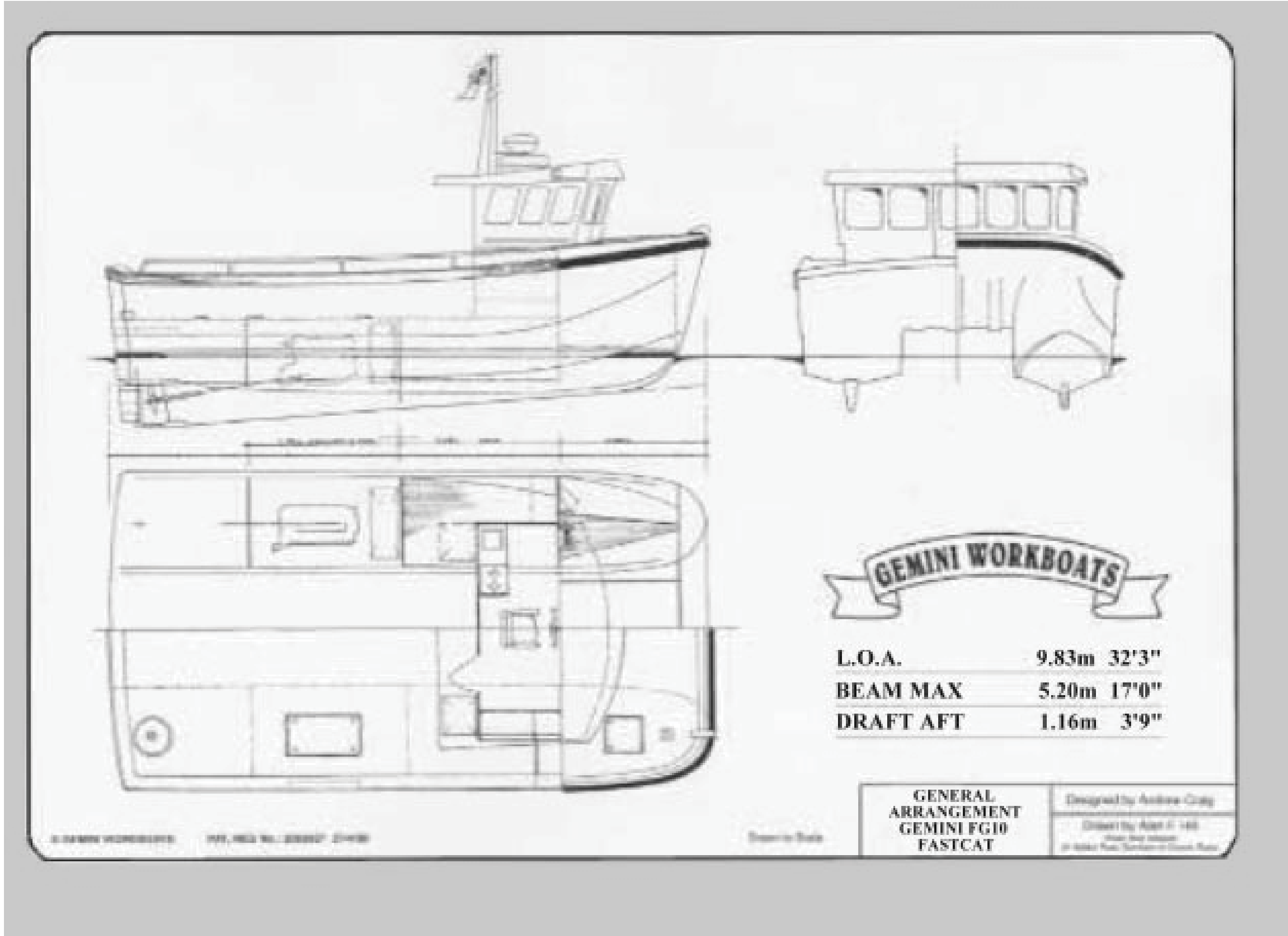


Fig. A-3. The Xplorer of Portsmouth detailed view.

A.2.1.2 Wessex Explorer (Fig. A-4)

15.2 metre single hulled survey vessel

- Capable of 10 knots transit speed
- Small back deck with fixed A-frame
- 1.4m draft
- Small wheel house with single power supply
- Capable of comfortably accommodating 5 persons
- Carries a Reson 8101 mounting pole
- DGPS system
- MCA 60 mile licence

Fig. A-4. The Wessex Explorer.

For the purposes of carrying, deploying and powering the survey instruments and processors, transiting to the survey site and offering a stable working platform with adequate wheel house space the Xplorer of Portsmouth was superior. The Wessex Xplorer would be able to operate in rougher sea conditions due to its size, but was deemed inferior on most other points.

A.2.1.3 Final vessel selection

Savings on charter rates, fuel and berthing also made the Xplorer an economical choice so it was commissioned for a period of 50 days from 8th March to 25th April 2003. The Xplorer was chartered from Sea-Trax Ltd., ‘The Haven’, 33 The Drive, Southbourne, West Sussex, PO10 8JP.

A Charter Agreement was drafted to confirm the terms and conditions:

> *Following a visit by a group from Imperial College in December, it was agreed that your survey vessel the Xplorer would be chartered for a period during the spring of 2003 for geophysical mapping of parts of the English Channel off Littlehampton, West Sussex.*
>
> *It is our understanding that the following arrangements have now been made:*
>
> *The charter period will be from 10th March 2003 to 26th April 2003*
> *Access will be allowed to the vessel during the 8th and 9th March for loading and installation of instruments and equipment during which time the boat will be undergoing modifications to the hull at Shamrock Quay Boatyard, Southampton*
> *The vessel shall be provided in a seagoing state with all safety equipment onboard including lifejackets for all crew, life rafts with capacity for all crew and suitable emergency communications equipment*
> *The Vessel shall be ready for survey operations no later than the 11th March*
> *The charter fee will be £350 per day's survey operation*
> *On days when survey work cannot be performed for any reason other than vessel failure the charter fee shall be £200 per day*
> *During periods when the vessel is unfit for survey operations, the charter fee will not be payable*
> *Supplementary costs to include fuel, berthing fees and provisions will be paid in addition to the charter fee*
> *The decision to put to sea will rest solely with the skipper, based on his view of the current and forecast weather conditions*
> *The vessel and it's skipper shall be available for a nominal period of 10 hours operation per day, this includes time taken to transit to and from the survey area*
> *The Skipper will provide his own accommodation onboard the vessel*
> *Imperial College personnel will stay in local accommodation*
> *The security of all equipment provided by Imperial College will be the direct responsibility of Imperial College at all times*
> *Sea-Trax shall be responsible for all of it's equipment at all times and must make reasonable endeavours to ensure any failure is rectified as soon as possible*
> *The skipper/vessel shall hold relevant MCA certification for operation within 60 miles of a safe haven with up to 12 persons onboard and be fully insured for injury caused to any person(s) onboard*
>
> *Please indicate by signing and dating the bottom of this letter that you agree with the arrangements stated above and your company 'Sea-Trax' will comply with all conditions contained within them. If the arrangements are not to your understanding or satisfaction please inform Imperial College at your soonest opportunity.*

A.2.2 Existing Data

Planning the position of the survey site and locating the filled and underfilled sections of the Arun Palaeovalley was achieved using a variety of existing data sources:

A.2.2.1 Admiralty Charts

The United Kingdom Hydrographic Office compiled Admiralty Charts display a variety of useful data types including depth points, depth contours, seabed types and navigational information. Chart 2450 - Anvil Point to Beachy Head was used to establish the approximate location and geometry of the under filled sections of palaeovalley.

A.2.2.2 Analogue Boomer Records

Boomer seismic data provided by Hanson Aggregates and United Marine Aggregates was interpreted to provide more information on where the palaeovalley is under filled and where terraces may exist. Information on the internal geometry and distribution of the channels was also useful.

A.2.2.3 Single Beam Echosounder Data

Bathymetry data provided by the dredging industry along seismic lines was gridded and imaged to give more detailed depth information than the Admiralty Charts. This data clearly showed the steep eastern margin of the main palaeovalley.

This combined information was used to delineate the area of interest by the following coordinates:

0 deg 27' W, 50 deg 40' N
0 deg 27' W, 50 deg 35' N
0 deg 20' W, 50 deg 35' N
0 deg 20' W, 50 deg 40' N

This area is bounded in yellow in Fig. A-5.

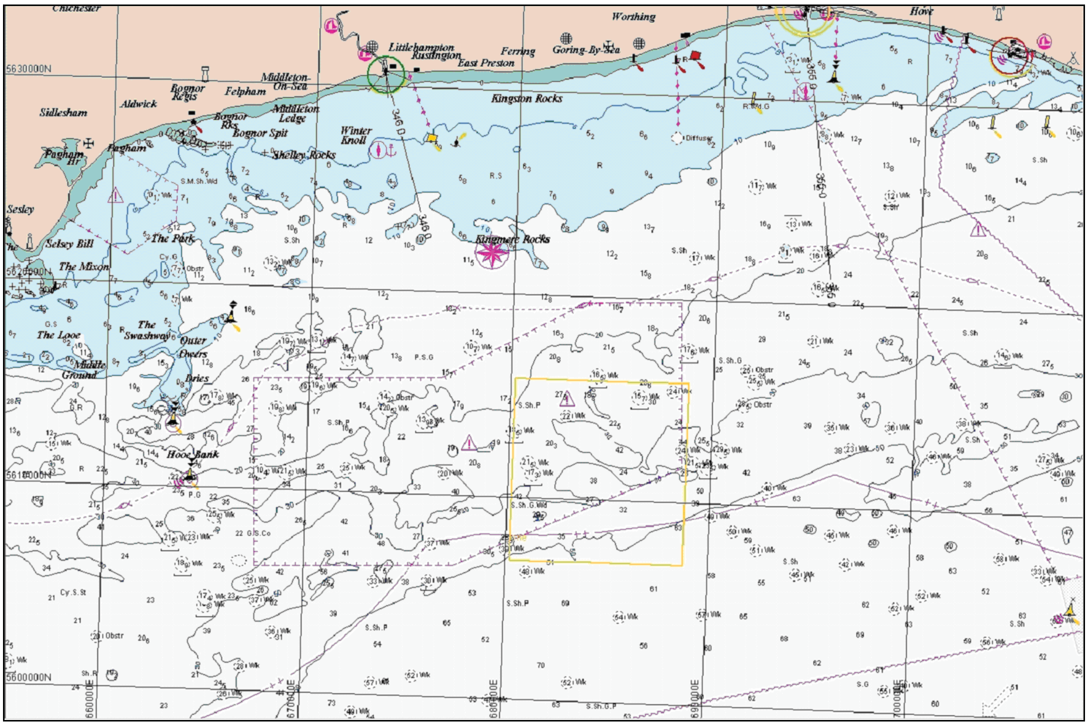


Fig. A-5. C-Map electronic chart showing the location of the survey site.

A.2.3 Datums and Map Projections

An objective of the project is to integrate existing and newly acquired datasets to achieve a multidimensional and multi disciplined interpretation of the environment. To do this a common mapping framework is required. This consists of a planar representation of horizontal positions on a map projection, and a vertical reference datum for all depths.

A.2.3.1 Projections

Traditionally, the National Grid of Great Britain map projection, based on the OSGB36 datum is used for the charting of coastal surveys, including the dredge site surveys of the Arun area. Due to inaccuracies in the conversion from WGS 84 positions given by GPS to OSGB 36, the recent convention is to use Universal Transverse Mercator projection zones instead, which are based on the WGS 84 datum. UTM zone 30N was selected as the project map projection as it covers an area from 0° W to 6° W and 48° N to 56° N. The scale factor at the centre of the survey site is 1.0000165544199, and it ranges from 1.000013390683 in the east to 1.000020410891 in the west. The difference of 0.000007 shows there is no significant scale distortion.

A.2.3.2 Geodetic Parameters

Spheroid	:	WGS 84
Datum	:	WGS84
Semi-Major axis	:	6378388.00
Inverse Flattening	:	297.00
Latitude of Origin	:	0°
Central Meridian	:	3° W
Scale Factor @ CM	:	0.9996
False Easting	:	500 000
False Northing	:	0
Projection	:	UTM
Zone	:	30N
Unit	:	Meter
Time	:	UTC

A.2.3.3 Datums

The vertical datum used for referencing all soundings is Chart Datum Brighton. This is 3.52 m below Ordnance Datum Newlyn (The level to which all orthometric heights in the UK are referenced). Chart Datum corresponds with Lowest Astronomical Tide as defined in Fig. A-6.

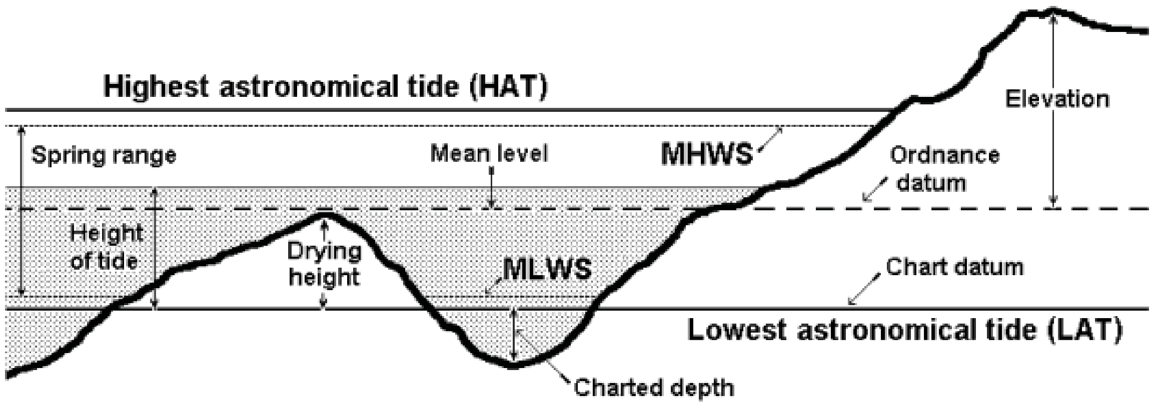


Fig. A-6. Tidal heights and datums.

A.2.4 Site Visits

Site visits to Littlehampton, Worthing and Brighton Marina were carried out to find a suitable location for installing the tide gauge. The location must have direct access to sea water which is unaffected by local features at all states of the tide. The River Arun at Littlehampton Quay offers direct access, but the water level is affected by Littlehampton Bar, a gravel bank that dries 30cm from LAT. There was also concern about fresh water input affecting the pressure readings of the tide gauge.

Worthing Pier was found to have a ladder which would enable access to the water, but the gauge was likely to be at risk due to the exposed position. Despite being further from the survey site, the fishermen's quay at Brighton Marina was deemed the most suitable location. This offered vertical access to the water via a ladder and floating pontoon and the logging unit could be secured to a nearby life buoy box.

A.2.5 Permits

Permits for bathymetric and geophysical survey work are not required in UK waters. However, due to the vessel having limited manoeuvrability whilst towing, and the presence of fishing and dredging and leisure traffic, several cautionary measures were taken. These included a visit to the Littlehampton Harbour Office, where the Harbour Master advised us to keep one mile clear from Littlehampton entrance.

The details of the vessel, equipment used and operating hours were issued to the Maritime and Coastguard Agency who instructed the United Kingdom Hydrographic Office to issue a Notice to Mariners for the area bounded by the following coordinates:

50deg 47' N 0deg 35' W
50deg 47' N 0deg 29' W

50deg 36' N 0deg 17' W
50deg 36' N 0deg 27' W

This was broadcast daily by Solent Coastguard on VHF channel 67 and a wide berth was requested.

A.2.6 Safety

Due to the hazardous nature of small boat operations, several safety precautions were put in place. These included ensuring adequate safety equipment was onboard the vessel and all persons were briefed by the skipper on emergency procedures when boarding the vessel. Imperial College personnel attended a one day sea survival course at Warsash Maritime Centre which is compulsory for further offshore work within the UK academia. J. Pye carried out a thorough COSH and health and safety assessment.

.

A.2.7 Survey Line Plan

A.2.7.1 Multibeam & Chirp/side-scan

An average depth over the survey site of 30m was estimated. The shallowest charted depth is 18.8m and the deepest is 50.0m. Using these depths approximate max, min and mean swath width may be calculated based on the fact that coverage is 7.4 times water depth.

Min swath width: 140m
Mean swath width: 222m
Max swath width: 370m

A 20% overlap between swaths was planned to allow for deviations from the line and erroneous outer beams. The survey site was divided into three areas and the line spacing was calculated based on the minimum sustained depth in each area:

Area	Min Depth	Line Spacing
North	20m	125m
Middle	25m	150m
South	30m	180m

The main lines were drawn at a bearing of 70°/250° which is approximately into/with the tidal stream; this prevents the vessel being drawn off course by the current. Six lines per day of length 6km were planned and are shown as coloured blocks in Fig. A-7. In addition six perpendicular cross lines were added to enable a QC check on the overlapping areas of data. The lines were numbered to allow for wide line turns of < 200m radius which is necessary when towing the GeoChirp tow fish.

The line plan was intended as an aid to planning the field work only and was by no means rigid. The intention was therefore to adapt the plan based on the data acquired and the prevailing sea conditions.

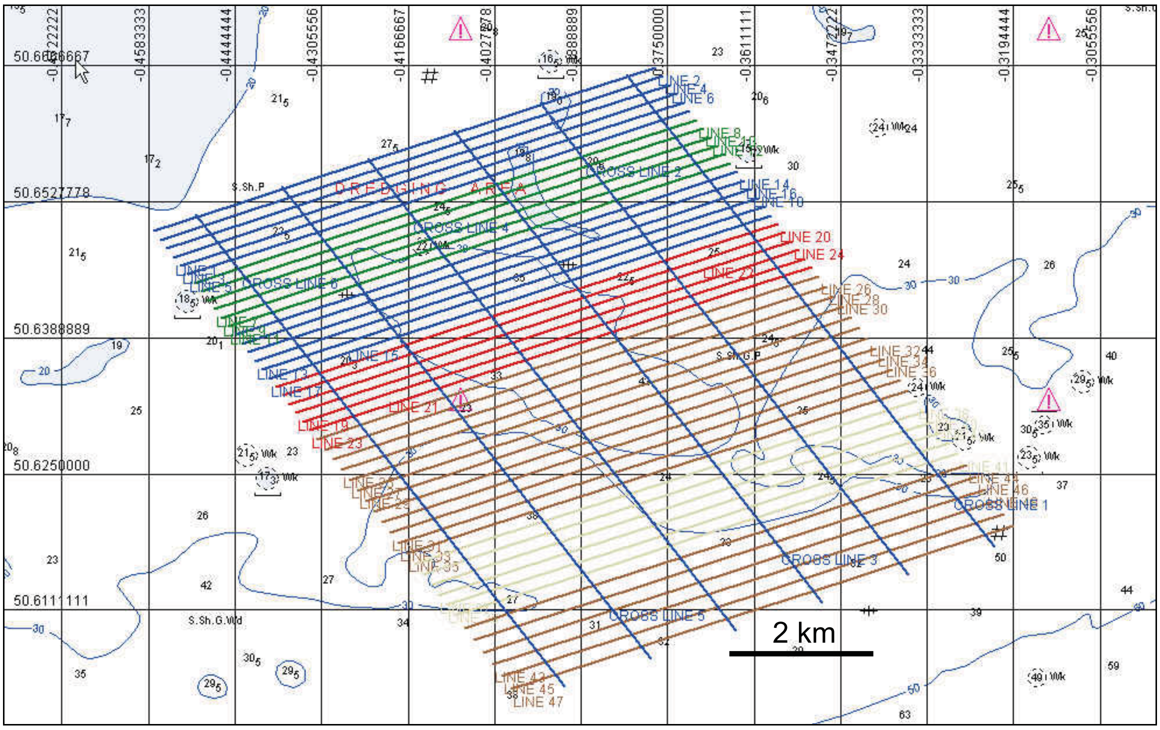


Fig. A-7. Line plan overlaid on C-Map electronic chart.

Since the chirp/side-scan system had not been operation since its trials, it was decided to deploy the equipment simultaneously and adapt to the multibeam conditions. It was also considered that as the multibeam does not record true backscatter, that the side-scan data may facilitate further investigations.

A.2.7.2 Boomer Seismic

The initial line plan for the boomer seismic part of the survey was based upon an exploration approach. Since the main portion of the survey was over an area with no previous data, it was decided to take a broad approach and concentrate on areas if there was something specific. The initial line plan is shown in Fig. A-8. The completed multibeam survey is shown, since this data was used to formulate the line plan.

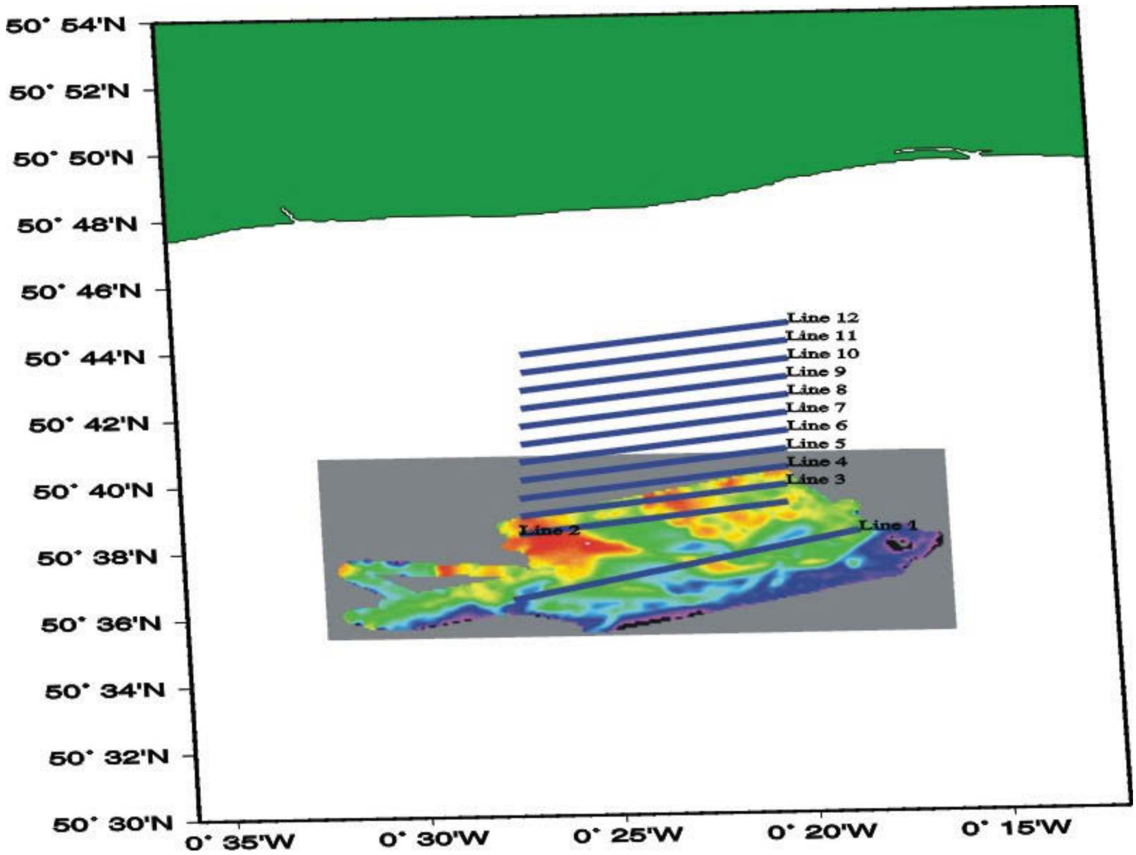


Fig. A-8. Initial line plan for the boomer seismic survey. Covering the multibeam area should enable significant cross-correlation between the methods.

A.3 SWATH BATHYMETRY

A.3.1 Sensor Details

A.3.1.1 Reson 8101 Multibeam Echosounder

The 8101 multibeam system is designed for high resolution shallow water operations. It comprises of two ceramic transducers; a linear transmit array and a cylindrical receive array. The long, thin transmit array produces a fan shaped beam which is 1.5° wide in the along track direction and 150° wide in the across track direction. Sets of transducer elements in the receive array divide the wide transmit beam into 101 focused beams by listening to 1.5° wide equiangular sectors. The curved face of the receive array means that beam steering is not required, and the width of the beams is constant with beam angle. The specifications of the 8101 are listed in Table A-1.

Table A-1. Reson 8101 specifications.

No. of Beams	101
Individual Beam Angles	1.5° along track, 1.5° across track
Depth Range	1 - 300 metres

Operating Mode	EABS (Equiangular Beam Spacing)
Operating Frequency	240 kHz
Angular Sector	150°
Maximum Coverage	7.4 x water depth in up to 70m water depth
Range Resolution	5cm
Pulse Repetition Rate	7.24/sec at 100m range
	5.80/sec at 125m range
	4.84/sec at 150m range
	4.15/sec at 175m range
	3.63/sec at 200m range
Sound Velocity Data	SVP-C continuous measurement at transducer
	Full water depth SVP twice per day
Heave Compensation	TSS POS MV Inertial Motion Unit
Heading	TSS POS MV dual phase GPS
Position	TSS POS MV DGPS
Data Logging	PC running Reson 6042 logging software on Windows
Off Line Processing	Caris Hydrographic Information Processing System

Two methods of detecting the seabed are used on the 8101. Amplitude detection is used for the centre beams; a time series of amplitude measurements is taken for each beam and the two-way travel time is logged for the point with greatest amplitude. For the outer beams phase detection is used. The phase of the returning beam is measured and the two-way travel time is given for the point at which the phase is zero. This is because the amplitude does not vary significantly for the outer beams. Between the inner and outer beams a combination of the two methods is used. In all cases, the horizontal uncertainty of each beam is equal to the beam foot print dimensions listed in Table A-2.

The two way travel times and beam angles are used collectively with the sound velocity data to calculate the position for each sounding.

The backscatter intensity profile for each beam is logged in the 8101 which when merged produce results similar to side-scan sonar. A time varying gain is applied which may be adjusted by the operator to account for losses in the water column.

Table A-2. Reson 8101 beam footprint dimensions with water depth and beam angle.

Beam Angle	20 m Water Depth	25 m Water Depth	30 m Water Depth
	Along x Across (in meters)	Along x Across (in meters)	Along x Across (in meters)
70	1.53 x 4.48	1.91 x 5.60	2.30 x 6.72
60	1.05 x 2.10	1.31 x 2.62	1.57 x 3.14
50	0.81 x 1.27	1.02 x 1.58	1.22 x 1.90
40	0.68 x 0.89	0.85 x 1.12	1.03 x 1.34
30	0.60 x 0.70	0.76 x 0.87	0.91 x 1.05
20	0.56 x 0.59	0.70 x 0.74	0.84 x 0.89
10	0.53 x 0.54	0.66 x 0.67	0.80 x 0.81
0	0.52 x 0.52	0.65 x 0.65	0.79 x 0.79

A.3.1.2 POS MV

The Position and Orientation Systems for Marine Vessels (POS MV) is an Inertial Navigation System (INS) which integrates GPS phase measurements to achieve the following outputs:

Position (latitude and longitude)

Velocity (north, east, vertical)

3D attitude (roll, pitch and true heading)

Heave

Acceleration vectors

Angular rate vectors

The system uses 200Hz data from the Inertial Motion Unit (IMU), aided by Differential GPS to output an accurate position solution at up to 100Hz. This also helps the system compute a position during GPS outages or degraded differential GPS corrections. A GPS Azimuth Measurement System (GAMS) is used to compute vessel heading using two GPS phase antennas mounted a distance of ~ 4m apart. Double differencing is used to compute the carrier wave phase ambiguity and the phase integer is measured to within 2cm. The accuracies achieved are detailed in Table A-3.

Table A-3. POS MV accuracies.

Position:	0.5 - 4.0m
Velocity:	0.05m/s
Roll and Pitch:	0.05°
True Heading (4m baseline):	0.05°
Heave:	5% of heave amplitude or 5cm

The POS MV is linked to the CSI MBX-3 DGPS system. This comprises of an antenna that receives GPS corrections from a position on land where the errors are calculated and broadcast by radio in real time.

The Pulse per Second (PPS) signal is taken from the GPS data packet to time synchronise all observations with GPS time (UTC) to an accuracy of 1 millisecond. This removes any latency between an observation being taken and logged by the computer.

A.3.1.3 Tide Gauge

A Valeport Model 740 pressure transducer measures sea level to 1cm accuracy. It consists of a small titanium vented strain gauge transducer linked via a 20m cable to a logging unit. The logger is powered by 4 "D" type cells, which, together with the 128kbyte memory allows operation for over 900 days at a 20 minute cycle with 10 second bursts. The unit is linked to a laptop PC where the burst rate, cycle time and delayed start can be set, and the data downloaded.

A.3.1.4 Sound Velocity Probe

The Navtronics SVP-20 sound velocity profiler directly measures the speed of sound using the digital "time of flight" method providing mm/s resolution (Table A-4). Pressure is measured using a strain gauge, and temperature is measured with a fast response Platinum Resistance Thermometer. Data is stored in the internal 8MB memory, and is downloaded using the Datalog 400 software. Recordings and readings can be depth or time triggered, continuous or burst sampled or conditional sampled on a specific parameter.

Table A-4. Speed of sound measurement specification.

Sensor:	Time of Flight
Range:	1400 to 1600m/s
Accuracy:	+/- 0.05m/s
Resolution:	0.001m/s
Response	Time: 145µs

A.3.2 Methods

A.3.2.1 Vessel Configuration

On a vessel of opportunity, the successful installation, calibration and interfacing of sensors is critical to the quality of data, particularly as the equipment had not previously been installed on the vessel. Firstly, a vessel reference point (VRP) must be established, from which all measurements are referenced. This normally corresponds with the centre of gravity. On a catamaran however, the CoG is between the two hulls, so a central point on the back deck was used just aft of the wheel house. The exact position is detailed in Table A-5.

Table A-5. Vessel Reference Point location.

Vessel beam:	5.2m
Distance from port side to VRP:	2.69m
Vessel length:	12m
Distance from stern to VRP:	4.84m
Distance from waterline up to VRP:	0.92m

The set-up of each component is described below:

A.3.2.1.1.1 Multibeam

The vessel was configured with the multibeam mounted on a double aluminium pole on the starboard side. This was secured to the hull via a pivot and gate arrangement. The pivot facilitated the raising of the sonar head for transiting. When lowered, two 4mm wire ropes were lead fore and aft to 4:1 purchase systems which were used to tension the wires to deck points using stretch resistant Kevlar ropes. High tension was applied to prevent any fore-aft movement and therefore any variation in the sonar head pitch. The V-shaped gate meant that the pole would repeatedly locate in the same position, thus preventing the need to recalibrate sonar head orientation. Several patch tests were carried out to test the reliability of this (see Section A.3.5). The SVP-C was secured to the pole just above the sonar head using tie wraps. Data link cables were lead up the centre of the pole and secured using electrical tape to prevent drag and therefore noise in the water. Offsets from the acoustic centre of the transducer to the vessel reference point are detailed in Table A-6

Table A-6. Transducer offsets.

X (port/starboard, starboard is positive)	2.440m
Y (fore/aft, fore is positive)	1.090m
Z (up/down, up is positive)	-2.270m

A.3.2.1.1.2 POS M/V

The POS M/V dual GPS antennas were mounted on two 25cm^3 boxes fabricated from 6mm gauge aluminium. These were secured to eyes on opposite sides of the wheelhouse roof using bottle screws. The antennas were seated inside choke rings to prevent multipath errors and had a clear view of the horizon in all directions. Offsets from the VRP to the primary antenna and from the primary antenna to the secondary antenna are detailed in Table A-7 and Table A-8.

Table A-7. VRP to Primary Antenna offsets.

X (port/starboard, starboard is positive)	1.270m
Y (fore/aft, fore is positive)	2.680m
Z (up/down, up is positive)	2.620m

Table A-8. Primary Antenna to Secondary Antenna offsets.

X (port/starboard, starboard is positive)	-3.060m
Y (fore/aft, fore is positive)	0.000m
Z (up/down, up is positive)	0.000m

The Inertial Motion Unit (IMU) was secured to a wooden deck board just aft of the wheel house. Its position is coincident with the VRP and its orientated is fore/aft to within 5°. Any error inside 5° is subsequently corrected for during the POS calibration (see Section A.3.6).

A.3.2.1.1.3 DGPS

The DGPS receiver was initially mounted on the wheel house roof, however a poor signal to noise ratio meant that other mounting locations were tested. The starboard rail near the stern was found to provide the best signal, possibly as it is furthest from other GPS, RADAR and communications beacons. The Trinity House Lighthouse DGPS service broadcasts DPGS corrections on 307.5 kHz at 100bps from St. Catherine's Point of the Isle of Wight 40 miles west of the survey area. As the nearest DGPS station, these corrections were used to calculate the position solution.

A.3.2.1.1.4 SVP

The Navtronics SVP-20 was lowered on a 150m length of rope from the upstream side of the vessel to prevent it going under the hull. Prior to deployment, the depth and speed logs would be cleared and set; the recordings were depth triggered at one metre intervals. To allow the sensor to settle, it was held at 1m depth for 30 seconds before being slowly lowered. It was deployed and recovered by hand twice daily before and after survey operations. On recovery the uplink cable was connected to the PC and the data downloaded using the SVP controller. The time and position was recorded in the file name of each SVP log. This file would then be imported into the 6042 database manager so that refraction corrections could be applied to data processed in real-time.

A.3.3 Interfacing

All processing and PC units were connected to a UPS (Uninterruptible Power Supply) to prevent data loss in the event of temporary power failure. The units included:

Reson 8101 Processor
POS M/V Processor
Windows PC
MBX-3 DGPS Processor
SVP-20 Processor
SVP-C Processor
12 Port Digiboard
Dual Flat Screen Monitors
Helmsman’s Monitor

These were connected with a combination of serial and Ethernet cables and communications were tested using the I/O tester program in 6042. The Windows 98 operating system caused a few networking issues by failing to recognise COM port 2 unless a connection was made after booting up. A schematic diagram of the configuration is shown in Fig. A-9.

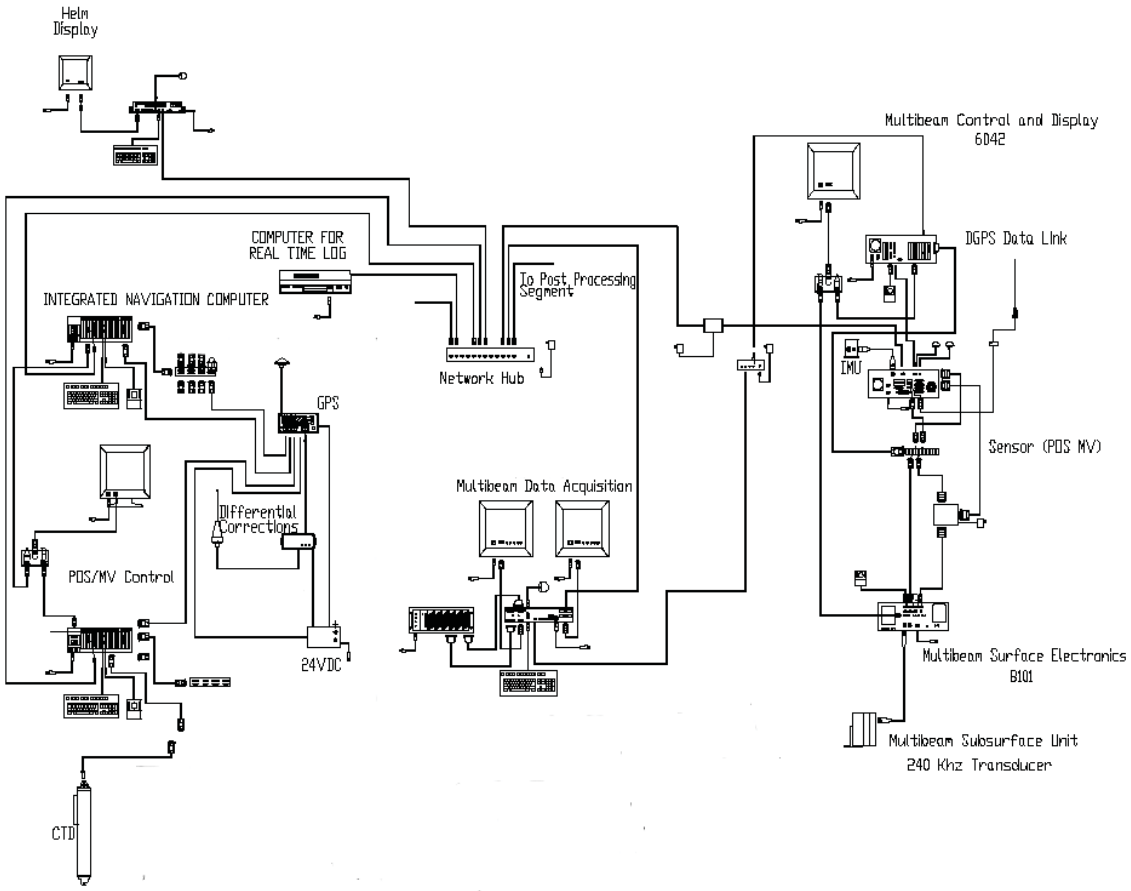


Fig. A-9. Schematic diagram of interfacing configuration.

A.3.4 Calibrations

Once operational, the sonar and navigation systems were calibrated to correct for any orientation errors, and constrain the IMU to the heading derived from the two GPS receivers.

A.3.4.1 GAMS

The GPS Azimuth Measurement System requires lock on at least 5 satellites in order to resolve the phase integer ambiguity of the L1 carrier wave. Once lock has been achieved, the vessel is turned in a tight figure of eight formation. This introduces movement in the IMU, and rapid phase changes in the L1 wave. Once the baseline vector between the two GPS receivers has been accurately calculated, the IMU is constrained by the heading through a Kalman Filter. This process took around 40 minutes to complete.

A.3.4.2 Patch Test (Residual Bias Calibration)

Patch tests are performed to quantify any residual biases in the alignment of the sonar head. If the head is perfectly aligned, it will have the same orientation as the gyro/motion sensor. This test (actually a series of reciprocal lines run at varying speeds, depths, and bottom terrain – see Fig. A-10) must be performed carefully to ensure that subsequent data collected when surveying is accurate and reliable. The Patch test determines (and provide corrections for) the following potential biases: (1) residual pitch offset, (2) residual roll offset, (3) residual positioning time delay, and (4) residual azimuthal (yaw) offset. The determined offsets and delays will be used to correct the initial misalignments and calibrate the system. Each of these bias tests is described below.

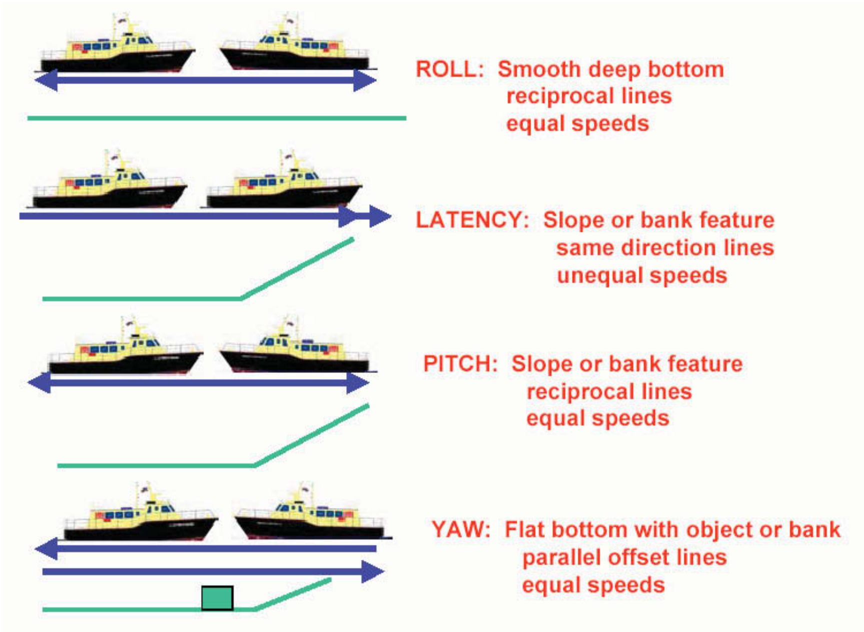


Fig. A-10. Summary of patch test runs.

Data acquisition. Accurate positioning is required for the patch test so the GAMS calibration must be complete and DGPS must be active. The weather should be calm to ensure good bottom detection and minimal vessel motions. Since most of the lines to be run will be reciprocal lines, it is important to have capable vessel steering and handling, so slack tide is ideal. The lines should be run in water depths comparable to the typical project depths encountered. The order the lines are run is not important although at least two sets of reciprocal lines be run for redundancy. Although the outer beams of multibeam sonar are subject to a smaller grazing angle, these beams should provide good data provided the appropriate corrections are applied from the patch test. Vessel speed should be regulated such that 50% forward overlap is obtained. The maximum speed may be calculated using the following equation:

$v = S \cdot d \cdot \tan(b/2)$

where:

v = maximum velocity (m/s)

S = sounder sampling rate per second (1/t)

d = depth

b = fore-and-aft beam width angle

For the Reson 8101 in 30m water depth, this is ~6 knots.

Positioning time delay test and pitch bias test. Two or more pairs of reciprocal lines are run at different speeds to check for biases in both positioning time delay (latency) and pitch bias. Latency is determined from runs made over the same line in the same direction, but at differing speeds. (Both these biases may exist simultaneously and must be discerned and separated during the test data processing). These lines should be run in an area with a smooth, steep slope--10° to 20°, if possible. The slope should ideally be at least 200 m long in order to obtain good samples. A channel side slope or target may have to suffice if no other relief is available. At least two pairs of reciprocal lines should be run both up and down slope, at velocities differing by at least 5 knots to best assess the time delay. Pitch is determined from the runs made over the same lines at the same speed in opposite directions.

In the absence of any slopes of 200m length, the pitch and latency tests used wrecks. For determining pitch a wreck located at 50° 37' 37" N 000° 19' 05" W (40m water depth) was used. Another wreck at 50 38 04 N 000 20 08 W (32m water depth) was used for latency.

Roll bias test. In an area of flat topography, one pair of reciprocal lines approximately 200 m in length are sailed to test for roll biases. Roll bias will best show up in deep water. Depending on the beam width, these lines are run at a speed to ensure significant forward overlap of the beam's footprint.

Two tests were performed at 50° 37' 28" N 000° 26' 39" (27m water depth) and 50° 37' 36" N 000° 19' 05" W (40m water depth).

Azimuthal (Yaw) offset test. Two adjacent parallel pairs of reciprocal lines are sailed normal to a prominent bathymetric feature such as a shoal or channel side slope, in shallow water. Features with sharp edges such as wrecks should not be used since there is more ambiguity in the interpretation. The adjacent lines have an overlap of about 15% and the feature should be wide enough to ensure adequate sampling. This width is generally greater than three swath widths. These lines are run at a speed to ensure significant overlap of the beam forward footprint. A shoal feature at 50° 26' 38" N 000° 29' 09" W (30m water depth) was used to measure yaw.

A.3.4.3 Bias Determination

A.) Positioning time delay (latency) bias. This delay is computed by measuring the along-track displacement of soundings from the pair of coincident lines run at different speeds over the steep slope or other prominent topographic feature. Lines run in the same direction should be used so as to avoid the effect of pitch offset errors. The equation to compute time delay is:

TD = da / (vh - vl)

where:

TD = time delay in seconds

da = along-track displacement

vh = higher vessel speed

vl = lower vessel speed

The survey lines are processed, plotted and compared while assuring that no corrections are made for positioning time delay, pitch error, roll error and gyro. The time delay is then averaged by getting several measurements of the displacement in the along-track direction. This process is performed iteratively until the profiles and contours match or achieve a minimum difference.

B.) Pitch offset bias. The pitch offset bias is determined from the two pairs of reciprocal lines run over a slope at two different speeds. The important characteristic of pitch offset is that the along-track displacement caused by pitch offset is proportional to water depth. Thus the deeper the water, the larger the offset. The pitch offset can be computed using the following equation:

a = tan -1 [(da / 2) / (depth)]

where:

a = pitch offset

da = along-track displacement

depth = water depth

The lines are processed while only applying the positioning time delay correction and the static offsets of the sensors. The pitch offset is then averaged by taking several measurements of the displacement in the along-track direction. This process is performed iteratively until the profiles and contours match or reach a minimum difference. Unless kinematic GPS (i.e., RTK DGPS) positioning is employed, determining da to a reasonable level of accuracy is difficult in shallow water.

C.) Azimuthal (Yaw) offset bias. Parallel lines run normal to a bathymetric feature will be used for the measurement of the azimuthal offset. One pair of adjacent lines run in opposite directions is processed at a time to remove any potential roll offset. The azimuthal offset can be obtained from the following equation:

y = sin -1 [(da /2) / XI]

where:

y = azimuthal offset

da = along-track displacement

X = relative across track distance for beam i

The survey lines are processed with only the positioning time delay and pitch offset corrections and static sensor offsets. The azimuthal offset is averaged by several measurements of the displacement da over the feature and knowing the across-track distance X at the location of the measurements. This process is performed iteratively until the profiles and contours match or achieve a minimum difference.

D.) Roll offset bias. Roll bias is computed using the pairs of reciprocal lines run over a flat, deep area. Generally this offset is the most critical in deeper water and should be carefully measured. For small angles of less than 3 deg the roll offset can be estimated by the following equation:
$r = \tan^{-1} [(dz / da) / 2]$

where:
r = roll offset
dz = depth difference
da = across-track distance

The survey lines are processed while applying the positioning time delay, pitch offset, gyro offset corrections, and static sensor offsets. The roll offset is averaged by several measurements of the across track displacement da along the test swaths. This process is performed iteratively until the profiles and contours match or achieve a minimum difference.

The patch test application in 6042 was used to automate the computations. It also enabled a visual assessment of biases by displaying contours, depth coloured beams and grid cells. The quality of the solution derived by 6042 is evident from the residual error plot. If this resembles a parabola a reliable solution has been achieved. Worked examples are shown in Fig. A-11 - Fig. A-20 and results are detailed in Table A-9.

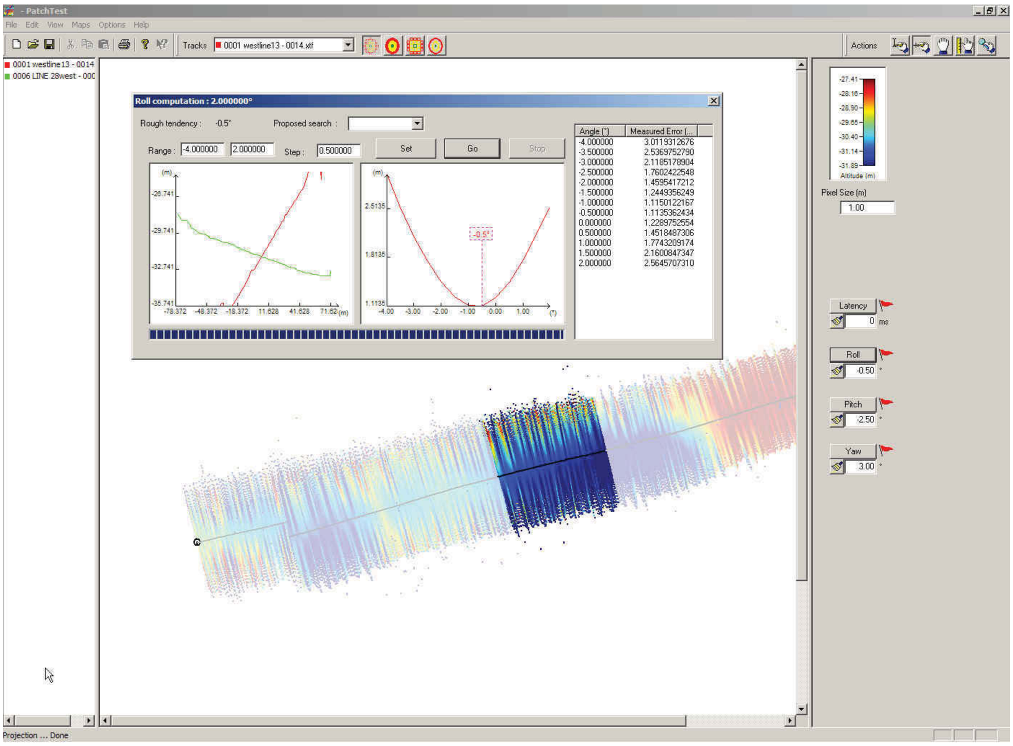


Fig. A-11. Roll test on Line28west-0001 and Westline13-0014.

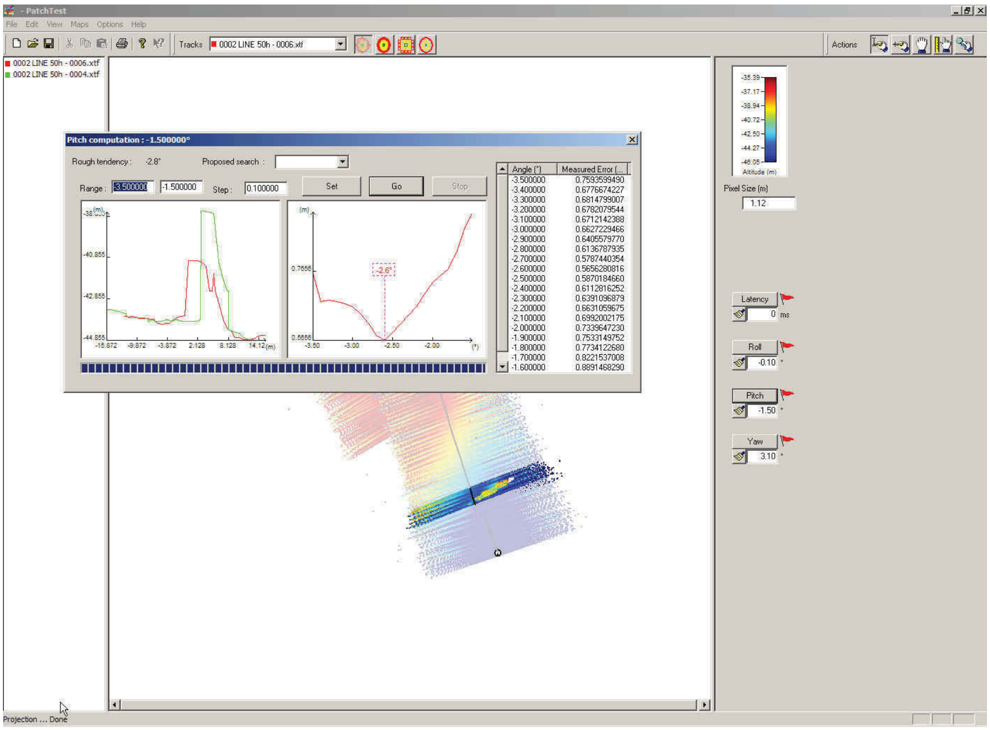


Fig. A-12. Pitch test on lines 50h0006 and 50h0004 over a ship wreck.

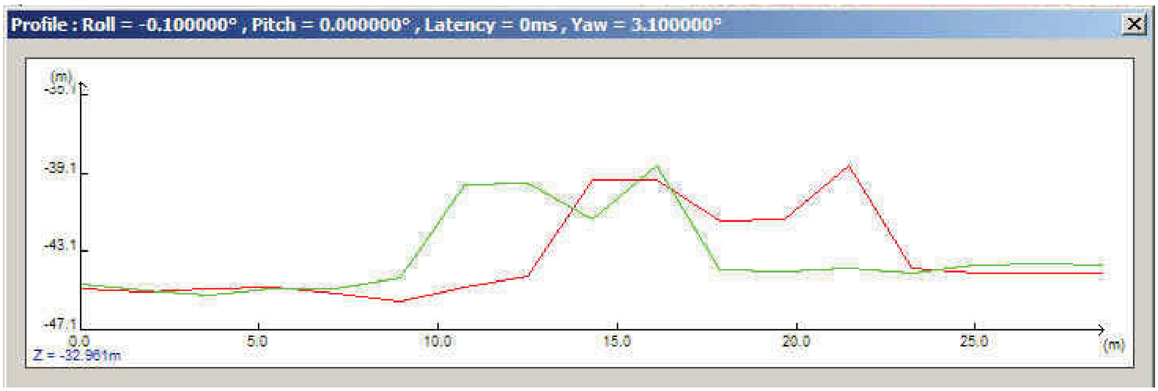


Fig. A-13. Pitch profile on lines 50h0004 and 50h0006 – pitch correction not applied.

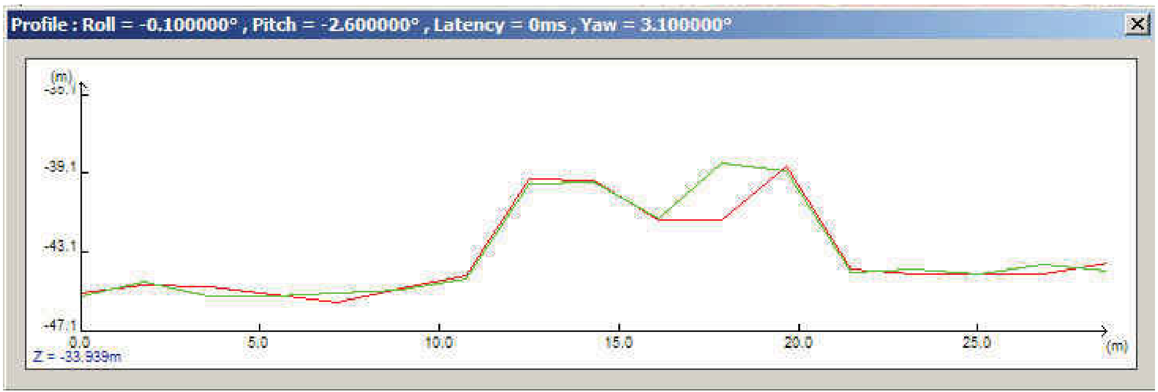


Fig. A-14. Pitch profile on lines 50h0004 and 50h0006; -2.6° pitch correction applied.

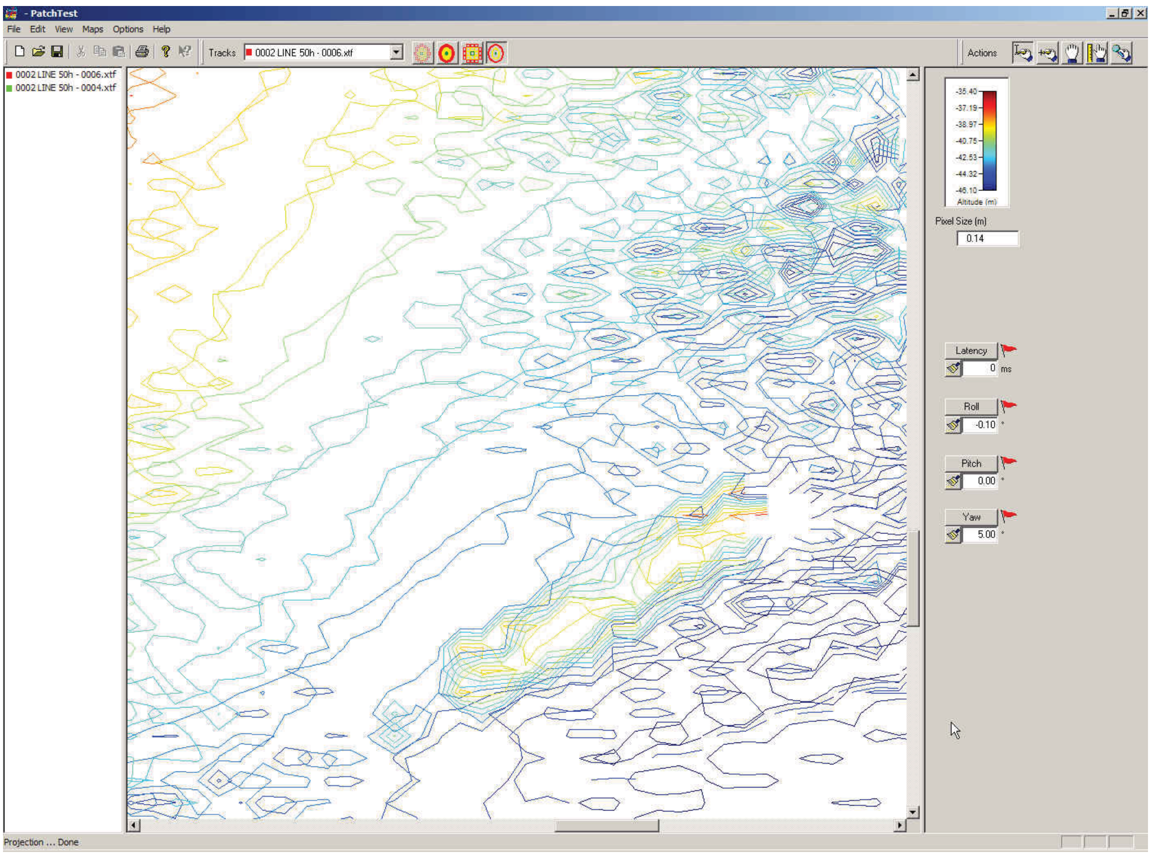


Fig. A-15. Lines 50h0004 and 50h0006 contoured over a wreck. Pitch correction has not been applied.

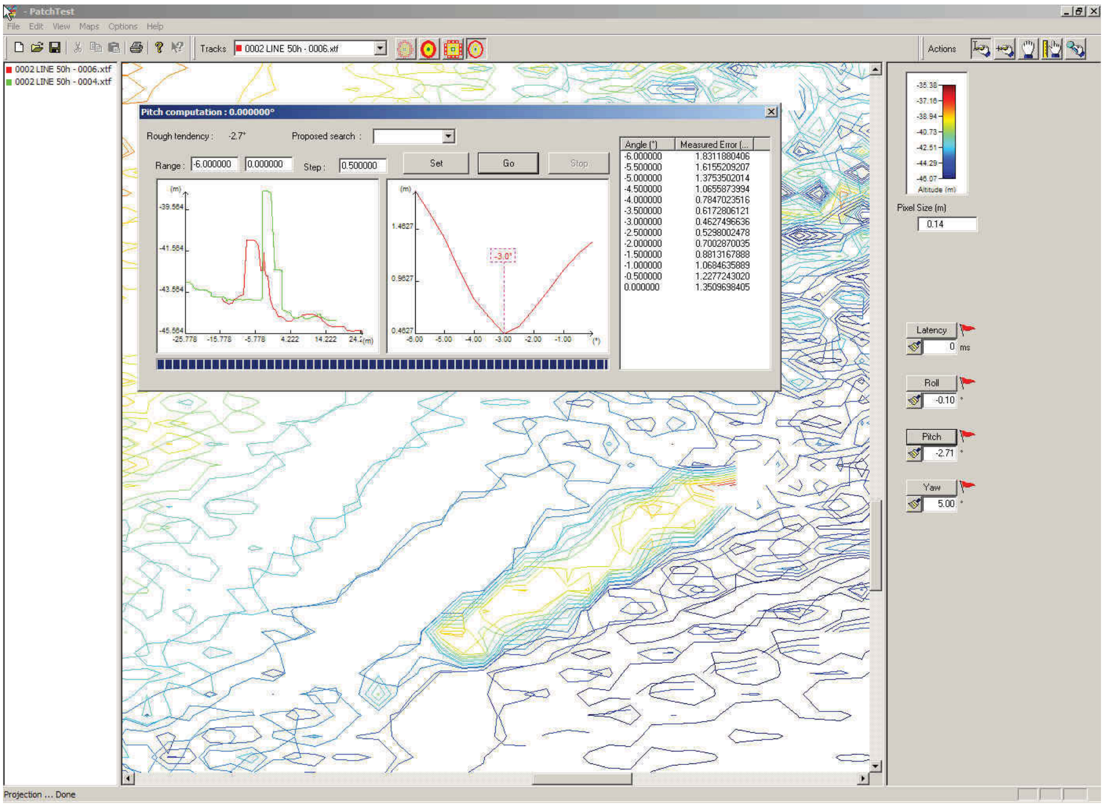


Fig. A-16. Pitch correction calculated and applied to show improved contour definition of the wreck in Fig. A-16.

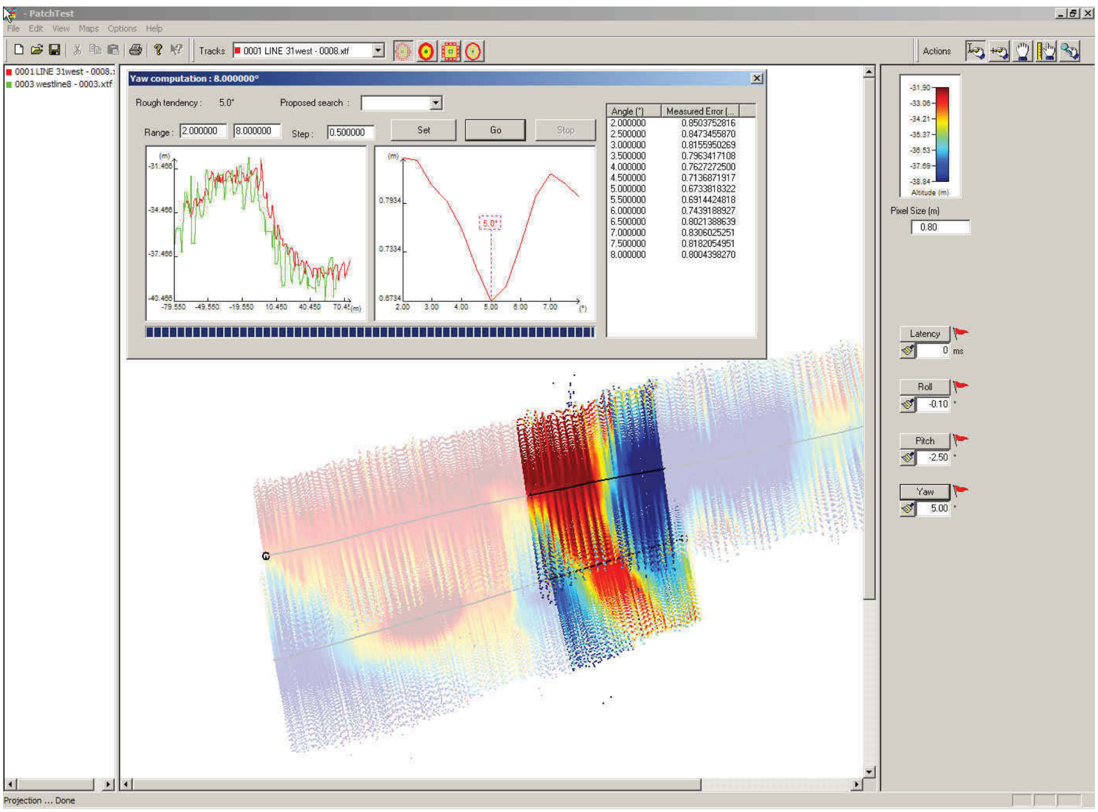


Fig. A-17. Yaw test on lines 31west-0008 and westline8-0003 over a shoal bank.

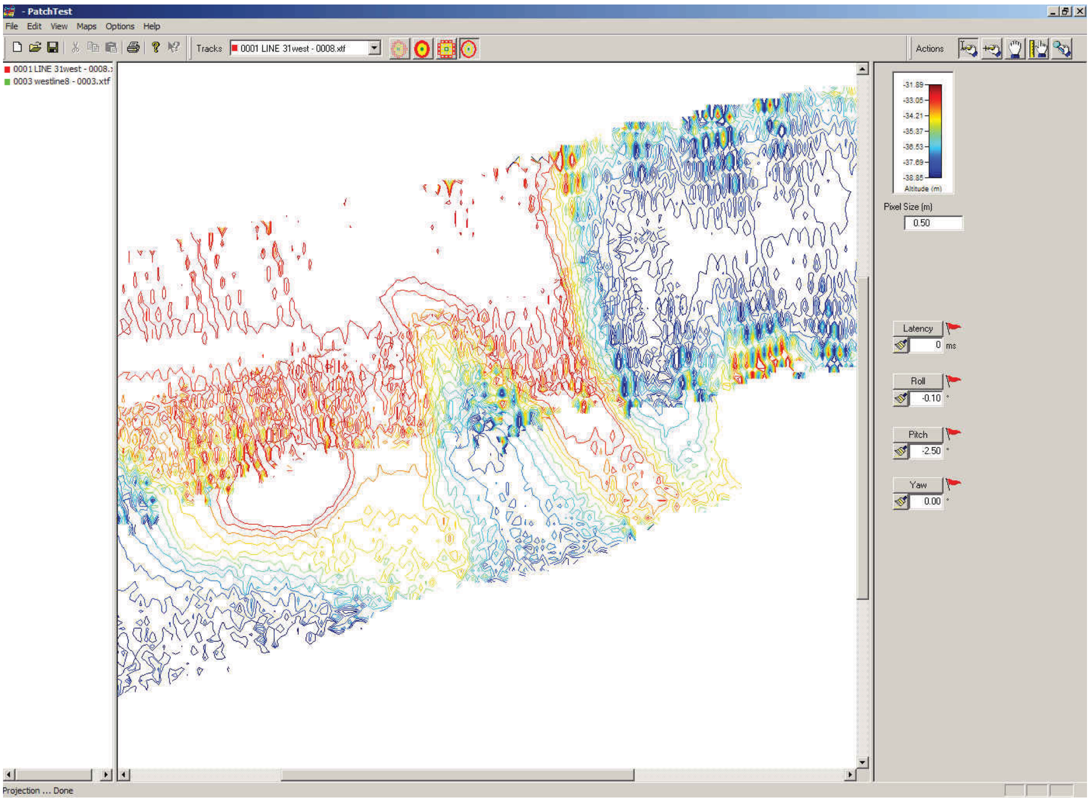


Fig. A-18. Contoured representation of Fig. A-17 with no yaw correction applied.

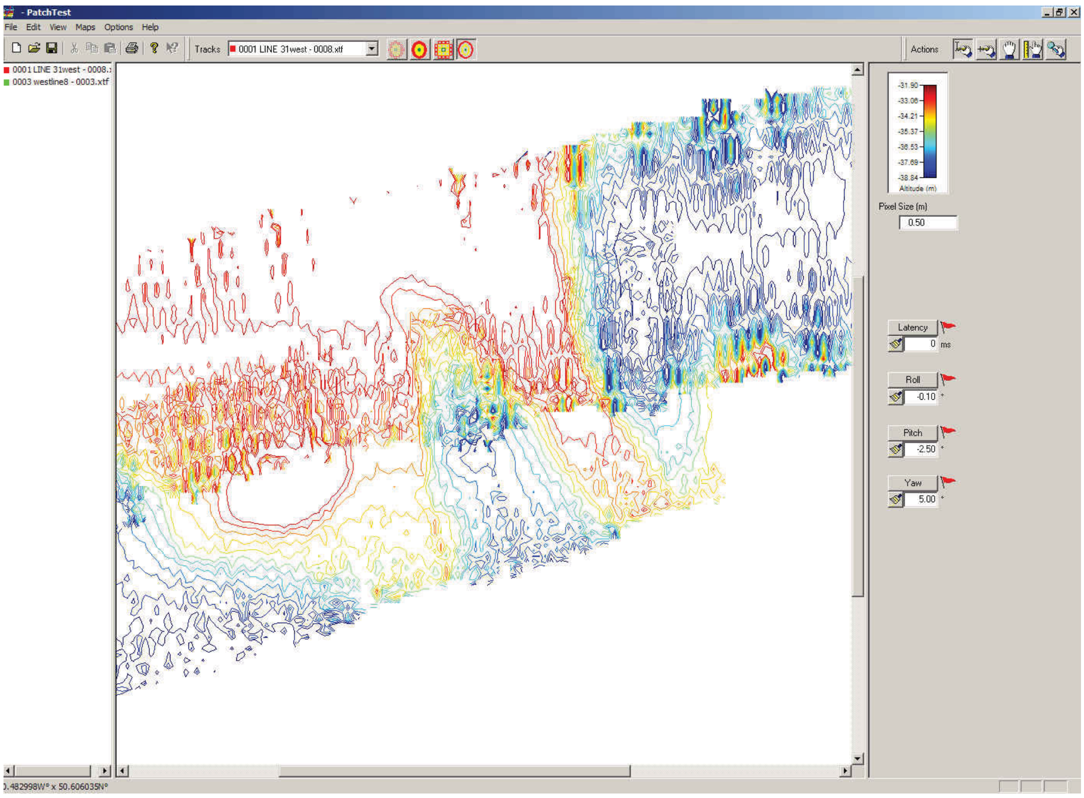


Fig. A-19. Contoured representation of Fig. A-17 with 5° yaw correction applied.

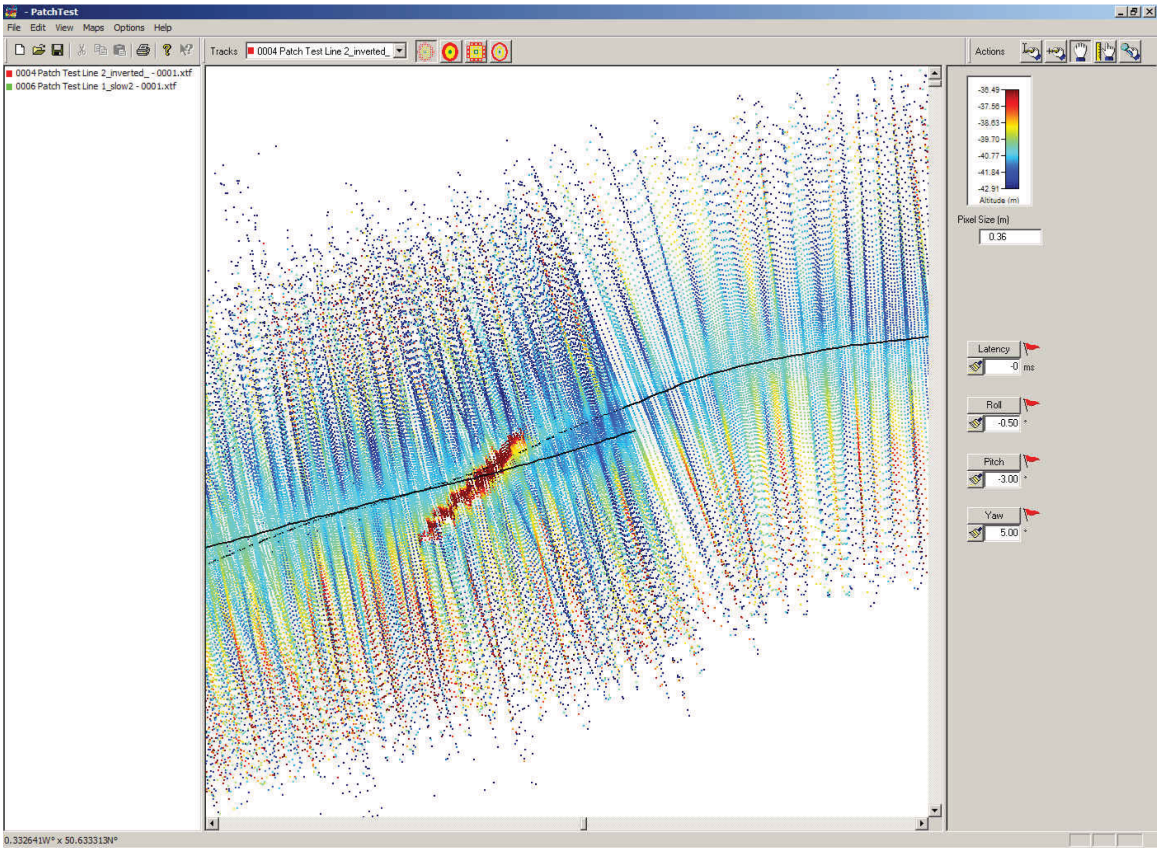


Fig. A-20. Latency test over a wreck using Patch Test Line 1_slow2-0001 and Patch Test Line2_inverted_-0001.

Table A-9. Results of each patch test..

Latency	File Name	Heading	Offset	Speed	Result
Line 1	Patch test line 2_inverted-0001	92°	0	3.35 m/s	0.00 sec
Line 2	Patch test line 1_slow2-0001	75°		2.64 m/s	

Pitch	File Name	Heading	Offset	Speed	Result
Line 1	Line 50h-0006	271°	0	2.52 m/s	-3.00°
Line 2	Line 50h-0004	150°		2.36 m/s	

Yaw	File Name	Heading	Offset	Speed	Result
Line 1	Line 31west-0008	251°	85m	1.81 m/s	5.00°

Line 2	Westline8-0003	74°		2.96 m/s	

Roll	File Name	Direction	Offset	Speed	Result
Line 1	Line 28west-0001	251°	0	3.03 m/s	-0.50°
Line 2	Westline13-0014	72°		2.41 m/s	

Roll	File Name	Direction	Offset	Speed	Result
Line 3	Line 50h-0006	271°	0	2.52 m/s	-0.10°
Line 4	Line 50h-0004	150°		2.36 m/s	

Roll	File Name	Direction	Offset	Speed	Result
Line 5	Line 30b - 0002	71°	0	2.82 m/s	-0.10°
Line 6	Line 30b - 0008	250°		3.43 m/s	

Based on the reliability of each solution, the final results are estimated as:

Roll -0.50°
Pitch -3.00°
Yaw 5.00°
Latency 0.00 sec

These values are entered into the Vessel Configuration File used in Caris HIPS & SIPS for post-processing.

A.3.5 Online Software

The 8101 raw data is controlled via the Built-In Test Environment (BITE) Screen, whilst the survey control, online QC and recording is performed using the Windows 6042 software. Performance of the POS MV may be monitored using the POS Controller

A.3.5.1 Bite Screen

Firstly the logging modes were set to produce the following outputs:

Rθ: R-Theta (range and beam angle) provides all soundings, their quality values, date/time, and the selected speed of sound.

Side-scan Full-New: Side-scan data is not compressed. All data points are used for the side-scan image.

Depth gates to permanently remove any flyers less than 10m or greater than 60m depth were entered, and the projector was entered as facing forward (it can be installed facing either way).

The display is then switched to the main sonar display screen using the BITE button where the "sonar wedge" (Fig. A-21) is displayed and the following parameters are adjusted:

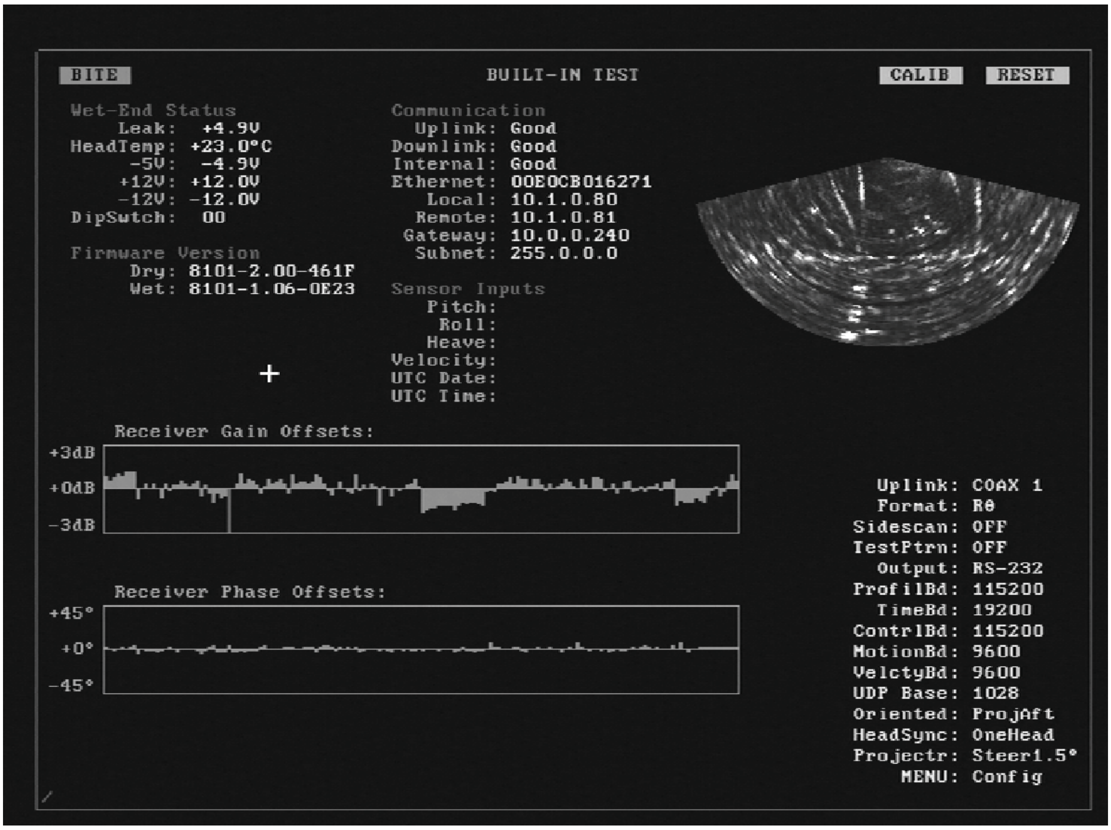


Fig. A-21. Built In Test Environment (BITE) Display.

Range: The Range setting determines the ping rate and how far the beams will see. It is set so that the outer beams just reach the seabed.

MaxRate: This menu selection allows the operator to limit the number of pings per second and therefore, the associated bathymetry packet output transfer rate. The ping range available is from 1 to 40 per second. The ping rate was never limited.

TxPower: This menu selection allows the operator to increase, or decrease, the amount of power (acoustic energy) transmitted into the water. The selections are OFF, and power settings of OFF, 1 through to 7, and FULL. Each increment is approximately 3dB. This was adjusted to keep the RxGain between 10 and 20.

TxPulse: The transmit pulse width selection allows the operator to change the pulse width of the transmitted signal. For a given power setting, the narrower the pulse width, the higher the degree of resolution that can be obtained; but the range capability will suffer. A longer pulse width increases the average power of the transmit pulse and increases the range but decreases the resolution. This was kept at around 75μs.

RxGain: This menu item allows the operator to select the amount of receiver gain applied to the returned sonar signal. RxGain has two independent settings; TVG and FIXED. TVG has a range of 1 to 45 in 1dB steps while FIXED gain is a nonlinear scale. This is influenced by the amount of power transmitted.

GainMode: This was constantly set to TVG.

AutoGain: The automatic receiver gain function analyzes the bottom return and automatically increases or decreases the receiver gain accordingly. The AutoGain menu item controls the level of signal amplitude threshold to which the sonar return is compared. Operator settings are OFF and 1 to 10. The lower the selected number, the lower the threshold and therefore, the lower the gain setting selected by the Sonar Processor. A typical setting is 4. However, the optimal setting will vary with bottom type and other environmental conditions.

Unlike settings in 6042, parameters set using the BITE screen directly affect what is and isn't logged, and the quality of the results. It was therefore critical that the BITE display was constantly monitored for changes in depth, noise and intensity, and corresponding adjustments were made to the parameters.

A.3.5.2 6042

Reson 6042 integrates the navigation, sonar, SVP, tide and motion data to record database files of all raw data. In addition, real-time quality control and navigational information is displayed. Firstly a master database is created which contains geodetic parameters, definition of the vessel and the definitions of the different sensors used i.e. drivers and interfacing, offsets and patch test results, DGPS system etc.

Before going on-line, the controller is opened and a line from the line plan is selected. Output files are assigned and various displays may be opened. During normal operations, the following were used:

Navigation Display: Shows C-Map electronic chart, vessel position, survey lines & sounding grid.

Helmsman's Display: Shows distance to port or starboard of the survey line being sailed.

Swath Display: Shows processed soundings from subsequent pings connected with a line.

Raw Multibeam Display: Scatter plot of raw observations.

Side-scan Image Display: Shows the backscatter either as slant range corrected or raw.

Alert Display: Pops up whenever a sensor timeout of more than 5 seconds occurs

Timeplot Display: Used to monitor the PPS signal

The line database manager was used to produce the line plan shown in Fig. A-22 by generating winglines and crosslines from a single line drawn on the chart. Several sounding grids were generated using the sounding grid utility. The grid cells are filled with data in real-time and displayed on the navigation display. Mean depth, max depth, min depth, count and standard deviation are recorded for each cell to enable QC checks. Once online, the controller is used to start, stop and pause recording.

A.3.5.3 POS Controller

The POS controller is used to initiate the POS calibration and display accuracy and positional information from the sensors:

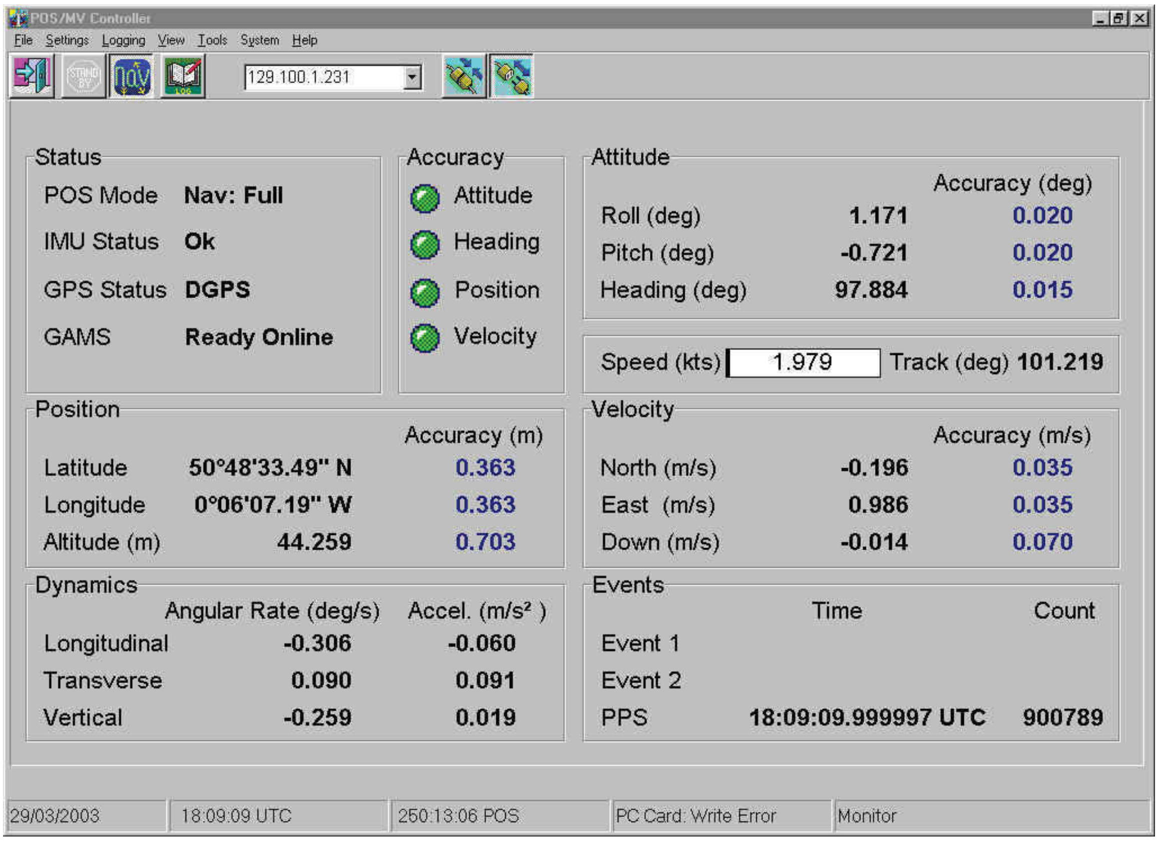


Fig. A-22. The POS controller.

Status for POS, IMU, GPS and GAMS was recorded at 15 minute intervals, along with accuracies for position, attitude and velocity.

A.3.6 Data Management

At a ping rate of 4/sec, the 8101 collects 1,454,400 soundings per hour. Working with limited computing resources this large volume of data required careful handling.

A.3.6.1 Data Outputs

The 6042 acquisition computer recorded three data types:

Database files: Containing all raw sounding, motion and navigational observations

Points files: Containing ASCII xyz positions of all soundings, using the SVP entered in database setup

Grid files: Statistical information based on the points files at a grid resolution defined using the sounding grid utility.

A.3.6.2 File Formats

A data structure is automatically created by 6042 to store the following data types:

Database: The so-called project database with all the settings. In this folder will also be stored, the databases with the raw data (*.db) and the filtered databases (*.filt.db).

DtmData: All points files. (*.pts)

DxfToQxf: DXF files and DXF files converted to QXF files. (*.dxf and *.qxf)

Export: Data that is exported to another format like ASCII. (*.*)

Graphics: Folder to store screen captures. (*.*)

GridData: The Sounding Grid files created with the 'Sounding Grid Utility, plus filled ones stored under a different name. (*.grd)

Import: Data that is imported, for example the tide files, are stored here. (*.*)

LineData: The line databases created with the 'Line Database Manager'.(*.mdb)

Logfiles: Logfiles created while running the Alert Display or importing SVPs. (*.txt and *.log)

Mapping: The project files of QINSy Mapping (Terramodel) (*.pro)

Results: The results of positioning calculation (position and node parameters) (*.res)

A.3.6.3 Recording Media

Data was recorded to the PC hard drive and backed up daily to Panasonic 4.7GB single sided DVD-RAMs. A second copy of the data was made on 4.7GB DVD-Rs.

A.3.7 Tides

Accurate knowledge of the tidal level at the survey site is required for reduction of soundings to Chart Datum. This can either be obtained from observations, or predicted from tidal models.

The Valeport 740 portable tide gauge discussed in Chapter 2.3 was used as the primary source of observed tides. Data from the Permanent Service for Mean Sea Level tide gauge at Newhaven was provided by Proudman Oceanographic Laboratory to enable an assessment of data quality.

A.3.7.1 Tide Gauge Installation

The chosen location for installing the tide gauge was Brighton Marina (discussed in Chapter 1.5). A vertical ladder allowed access to the water and a good securing point, whilst the tide board on the opposite wall provided a simple method for levelling the gauge so it related to Chart Datum.

The gauge was inserted inside a nine meter length of 50mm diameter plastic drainage pipe to protect it from damage, and the pressure transducer was secured 0.555m from the bottom. 8mm diameter holes were drilled through the pipe at 0.25m intervals to allow water ingress.

The pipe was then lowered through a drainage hole in the dockside until it reached the seabed. The calibration procedure described below was performed and the tide readings checked against the tide board. The pipe was then secured to the ladder using tie wrapped passed through the drilled holes to prevent any movement.

The sample rate had been set at 10 minutes with a 60 second burst rate (each reading was averaged over a 60 second observation period to null the effect of wave movement). To initiate logging, the PC cable was removed from the logging unit and replaced with a switch plug.
Download times are shown in chapter 4 and the data is presented and analysed in chapter 6.

A.3.7.2 Tide Gauge Calibration

To calibrate the tide gauge two measurements must be made at significantly different water levels. This can be achieved by fixing the gauge and waiting several hours for the tide to rise or fall, or by simulating a fall in tide by raising the gauge. The later method was chosen for convenience.

The pipe was raised from the seabed a distance of 1.665m so that a marker 50cm above the transducer was on the waterline. The height of the tide was read from the tide board as 2.05m. A simulated tide height of 0.385m (2.05m – 1.665m) was entered into the TideLog software as the first calibration value. The pipe was then lowered to the seabed and the true tide height of 2.05m was entered as the second calibration value. Once the calibration was complete, a check was made by comparing the values on the TideLog real-time display with tide board readings.

A.3.7.3 Predicted Tides

The WXtide32 version 2.6 program was used to compile a time series of predicted tide heights at 15 minute intervals for Shoreham, the nearest port to the survey area. This dataset was then formatted as a 6042 .tid file and entered in the set up for each recording session to reduce the grid and points files to Chart Datum in real-time. This improved the quality of the gridded depth display on the navigation screen.

A.4 DATA ACQUISITION

A.4.1 Personnel

Dave Burden (Seatrax) – Skipper	8th March – 25th April
Andy Palmer-Felgate (Imperial College) – Marine Surveyor	8th – 30th March 16th – 23rd April
Jonathan Pye (Imperial College) – Marine Geophysicist	7th March – 25th April
Ben De Mol (Imperial College) – Marine Geologist	22nd – 24th March, 1st – 16th, 24th – 25th April
Julie Dickinson (Imperial College) – Seismic Stratigrapher	23rd March
Sanjeev Gupta (Imperial College) – Sedimentologist	15th, 16th, 20th & 27th March 24th – 25th April
Jenny Collier (Imperial College) – Marine Geophysicist	10th, 11th & 20th March 1st – 2nd & 16th April
John Dennis (Imperial College) – Head Technician	8th – 12th & 30th March 25th April
Bernard Coakley (University of Alaska, Fairbanks) – Marine Geophysicist	15th – 20th March
John Fraser (Reson) – Multibeam UK Sales Manager	9th – 13th March
Kim Kool (Reson) – Multibeam European Sales Manager	12th – 13th March
Anthony Gleeson (TSS) – POS MV Technical Support	10th – 11th March
Lisa McNeil (SOC) – Marine Geologist	22nd March
Carol Cotterill (SOC) – Marine Geologist	22nd March, 23rd April
Phil Cole (SOC) – Marine Geophysicist	1st – 2nd & 23rd April

Tim Henstock (SOC) – Marine Geophysicist 1st – 2nd & 17th April

A.4.2 Daily logs

Daily logs are included within the daily progress reports. A complete narrative for all the fieldwork can be found in Section A.7. Table 4.1 summarises the activities of each day.

A.4.3 Daily Progress Reports

Daily progress reports were made during the fieldwork detailing survey statistics and timing.

A.4.4 Weather conditions

Weather forecasts for 24 and 48 hours issued by the Met Office were used as the primary source of meteorological information (www.met-office.gov.uk/datafiles/inshore). Other sources included:

Current observations at a weather buoy located in the channel at 49.90 N 002.90 W:
http://www.ndbc.noaa.gov/station_page.phtml?$station=62103

Wind forecast for 5 days south of Isle of Wight: http://www.onlineweather.com/v4/uk/sailing/SF23.html

Wind, sea, tide and pressure observations at a weather station in Hayling Bay.
www.chimet.co.uk

General 10 day forecast for Brighton: http://uk.weather.com/weather/local/BN1

The information was useful in deciding whether to put to sea, and which area was likely to have the best conditions.

The forecast and observed weather conditions are detailed in the daily progress reports.

A.4.5 Acquired Data

A.4.5.1 Navigation

A total of 429km of survey lines were sailed. Track plots of the lines are shown in Fig. A-23.

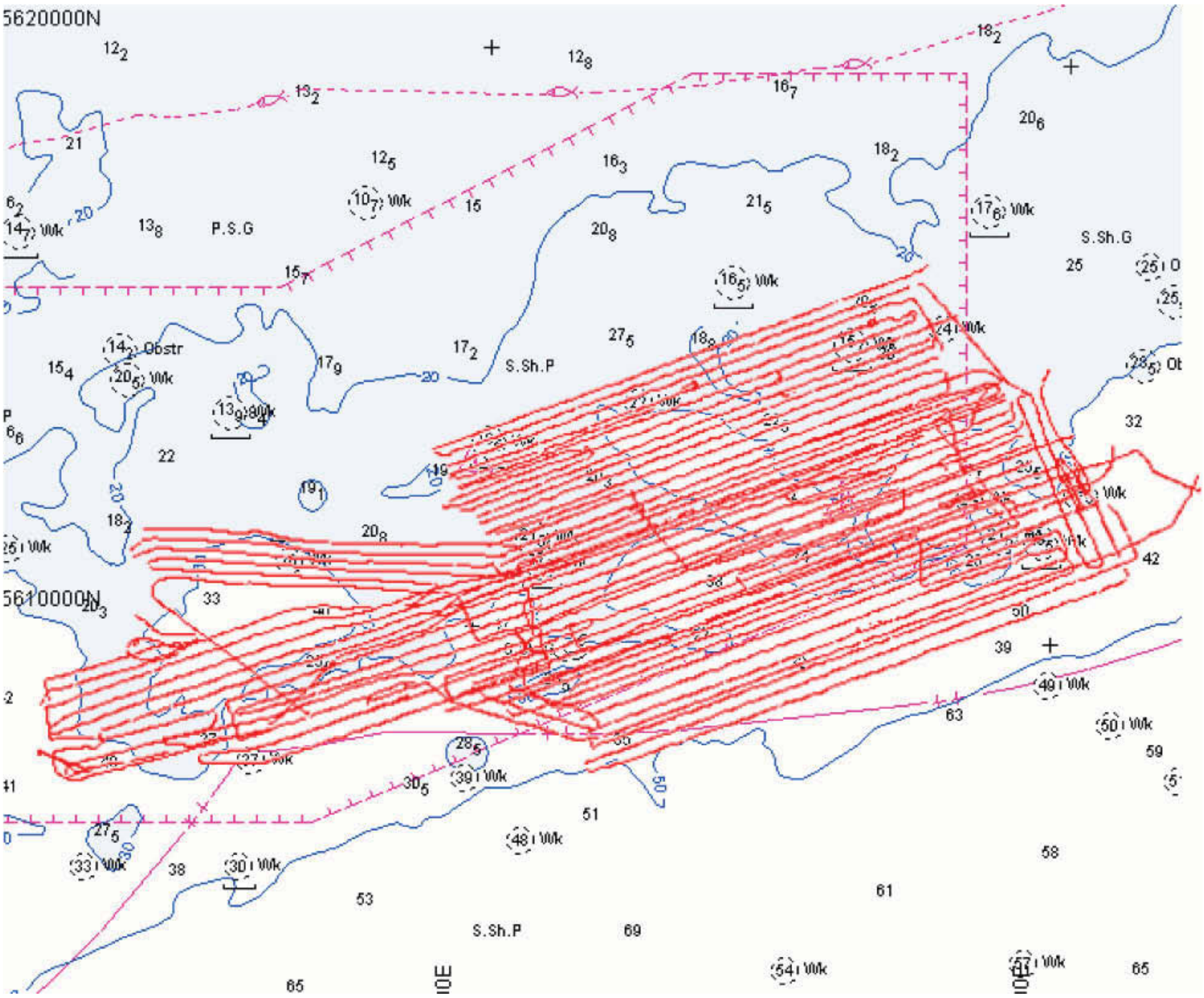


Fig. A-23. Track plots.

A.4.5.2 SVP positions

Twenty one SVPs were taken. The time, date, position and water depth of each profile is detailed in Table A-10. Plots of SVP positions are shown in Fig. A-24. For analysis of the profiles see Chapter 6.3.

Table A-10. SVP acquisition details.

Name	Date	Time	Lat	Lon	Water Depth
SVP1500hrs17_03_03.log	17/03/2003	15:00	50 48 03	000 05 27	9.1
SVP0945hrs18_03_03.log	18/03/2003	09:45	50 39 20	000 19 28	32.4
SVP1312hrs18_03_03.log	18/03/2003	13:12	50 36 55	000 27 12	40.5
SVP0945hrs19_03_03.log	19/03/2003	09:45	50 38 04	000 19 40	39.4
SVP1530hrs19_03_03.log	19/03/2003	15:30	50 36 11	000 26 19	36.9
SVP0945hrs20_03_03.log	20/03/2003	09:45	50 38 46	000 18 40	32.4
SVP1730hrs20_03_03.log	20/03/2003	17:30	50 39 20	000 19 28	29.3
SVP0945hrs21_03_03.log	21/03/2003	09:45	50 39 47	000 20 03	30.3
SVP1700hrs21_03_03.log	21/03/2003	17:00	50 38 41	000 14 39	36.4
SVP1000hrs22_03_03.log	22/03/2003	10:00	50 38 20	000 17 54	44.5
SVP1040hrs23_03_03.log	23/03/2003	10:40	50 40 10	000 20 04	28.3
SVP1710hrs23_03_03.log	23/03/2003	17:10	50 38 30	000 18 38	36.4
SVP0945hrs24_03_03.log	24/03/2003	09:45	50 38 04	000 18 49	30.3
SVP1715hrs24_03_03.log	24/03/2003	17:15	50 39 31	000 18 34	32.4
SVP1015hrs25_03_03.log	25/03/2003	10:15	50 38 15	000 16 36	45.5
SVP1700hrs25_03_03.log	25/03/2003	17:00	50 38 34	000 22 32	28.3
SVP0945hrs26_03_03.log	26/03/2003	09:45	50 38 22	000 16 11	48.0
SVP1645hrs26_03_03.log	26/03/2003	16:45	50 37 12	000 28 14	28.8
SVP1045hrs27_03_03.log	27/03/2003	10:45	50 39 07	000 19 02	29.8
SVP1430hrs27_03_03.log	27/03/2003	14:30	50 37 09	000 25 32	30.3
SVP1115hrs28_03_03.log	28/03/2003	11:15	50 38 49	000 19 29	31.3
SVP1630hrs28_03_03.log	28/03/2003	16:30	50 36 06	000 30 39	34.9
SVP1050hrs29_03_03.log	29/03/2003	10:50	50 37 25	000 26 48	30.3
SVP1630hrs29_03_03.log	29/03/2003	16:30	50 38 01	000 31 45	26.8

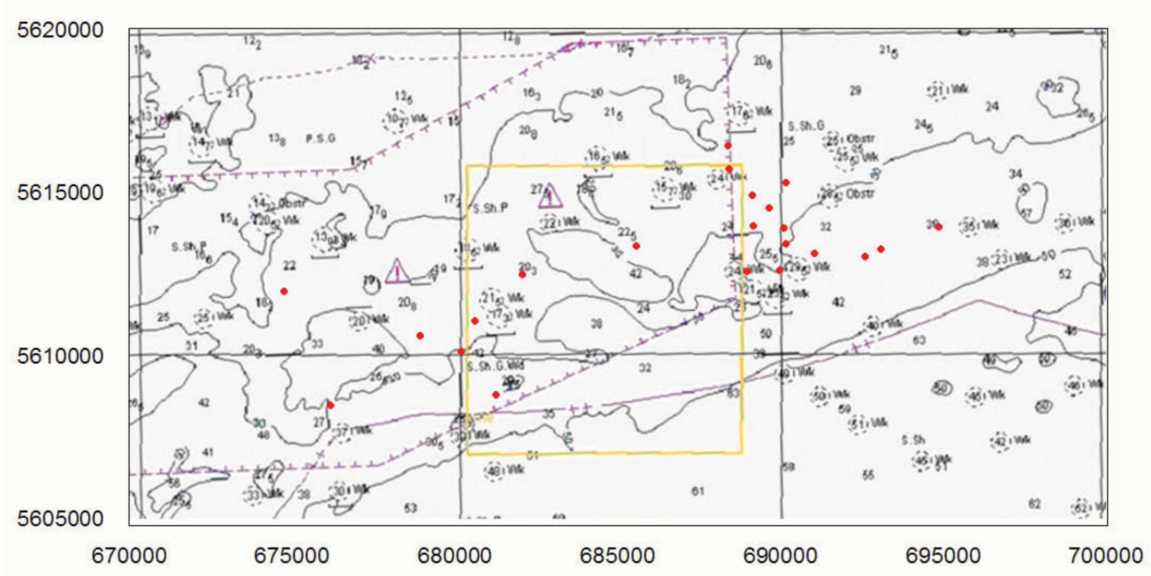


Fig. A-24. SVP locations (UTM grid).

A.4.5.3 Tides

The Tide Gauge began logging at 1352 hrs on 15th March. Tide data was downloaded from the logging unit to laptop PC at the times shown in Table A-11. The difference between the tide gauge and tide board reading was recorded at these times.

Table A-11. Tide downloads.

Date	Time	Downloaded File name	Rec height	Obs Height
16/03/2003	09:12:18	ObservedTide15to16_03.txt	5.52m	5.6m
18/03/2003	18:12:23	ObservedTide16to18_03.txt	0.68m	0.5m
21/03/2003	18:42:22	ObservedTide18to21_03.txt	0.74m	0.6m
22/03/2003	16:22:22	ObservedTide21to22_03.txt	4.64m	4.6m
25/03/2003	08:24:33	ObservedTide22to25_03.txt	2.50m	2.4m
30/03/2003	12:45:19	ObservedTide25to30_03.txt	4.10m	4.1m

A.4.5.4 Online QC

The real-time grid display was used to show statistical information about the soundings. This enabled a quality assessment in the field. Examples of standard deviation, count and mean depth displays are shown in Fig. A-25 to Fig. A-27.

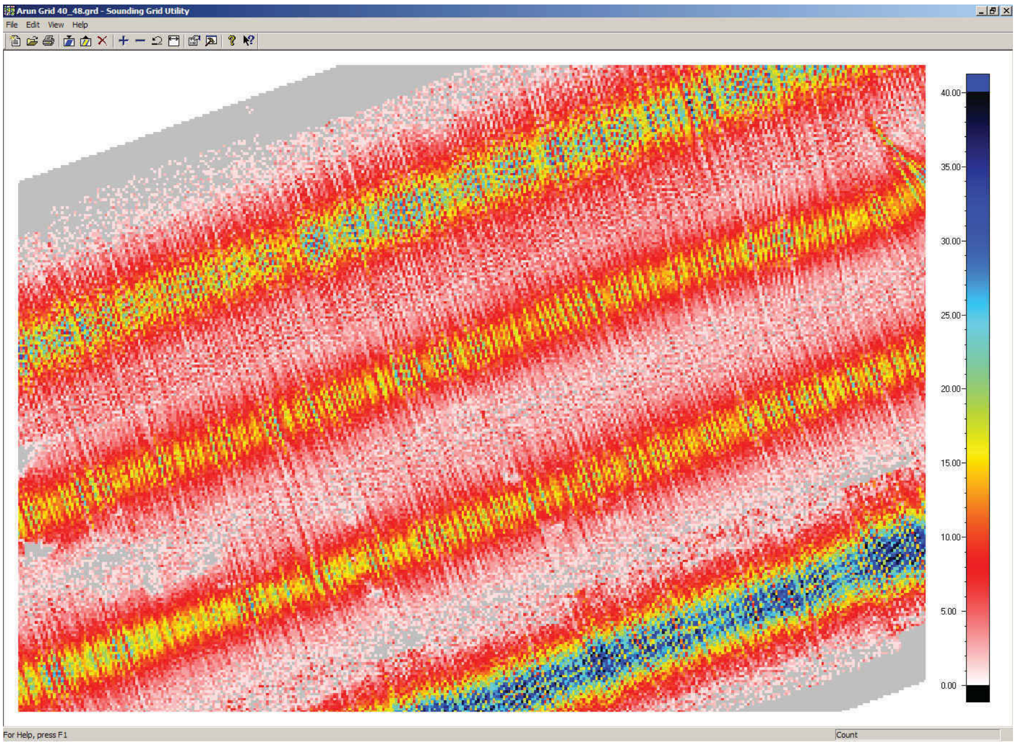


Fig. A-25. Grid showing the number of soundings per 4x4m cell.

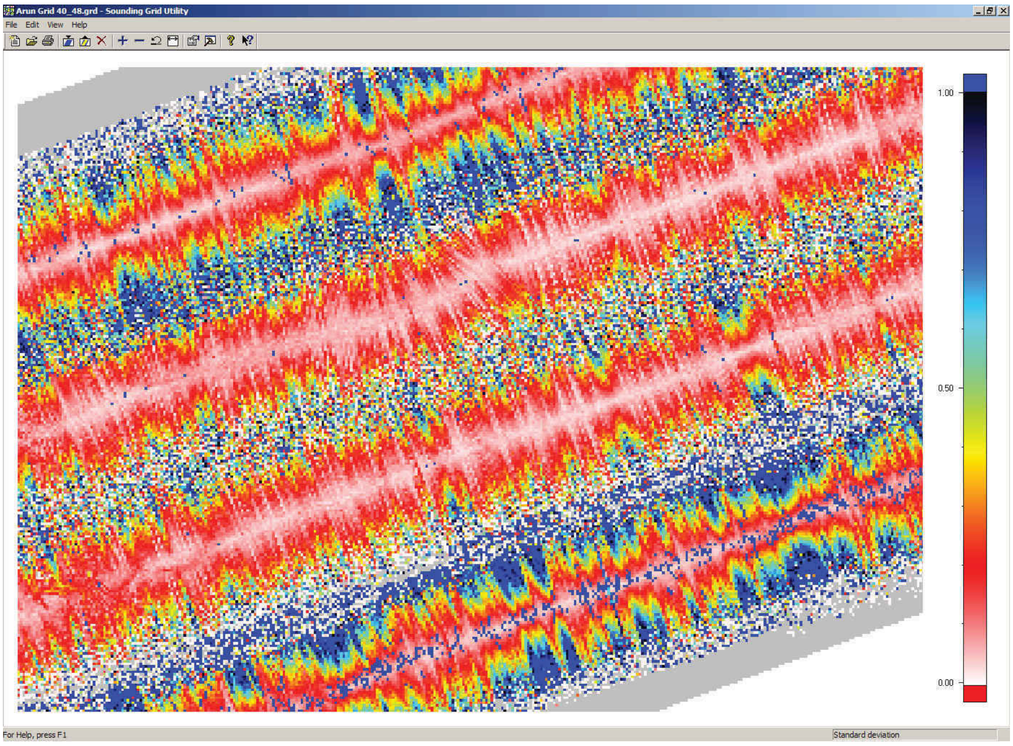


Fig. A-26. Grid showing the standard deviation of soundings in each cell.

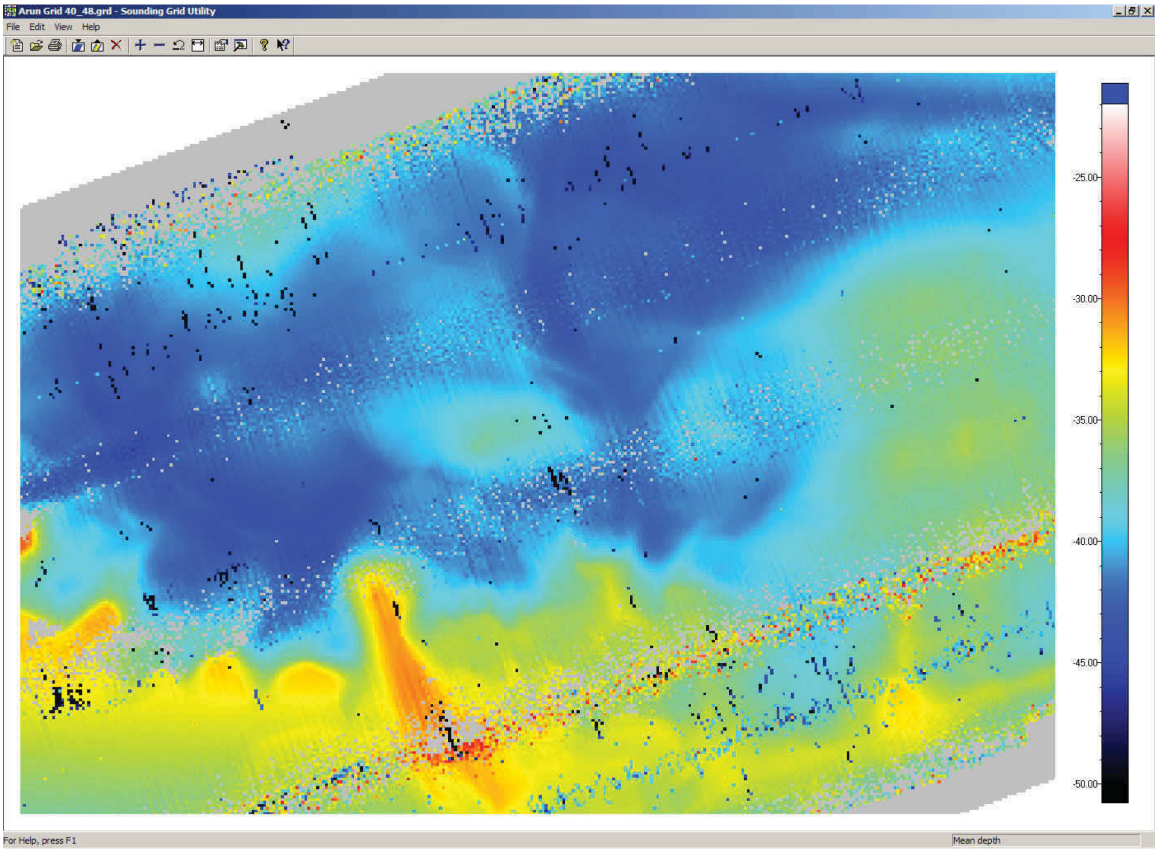


Fig. A-27. Grid showing the mean depth of soundings in each cell.

Further data analysis was carried out following initial processing as described in Section A.6.

A.4.6 Time analysis

Time use was categorised into working at sea, working in port, passage, weather downtime and equipment downtime. Passage is not used to refer to transits to and from the survey site, and work is performed preparing equipment or backing up data during these times. Fig. A-28 shows the time use for each day.

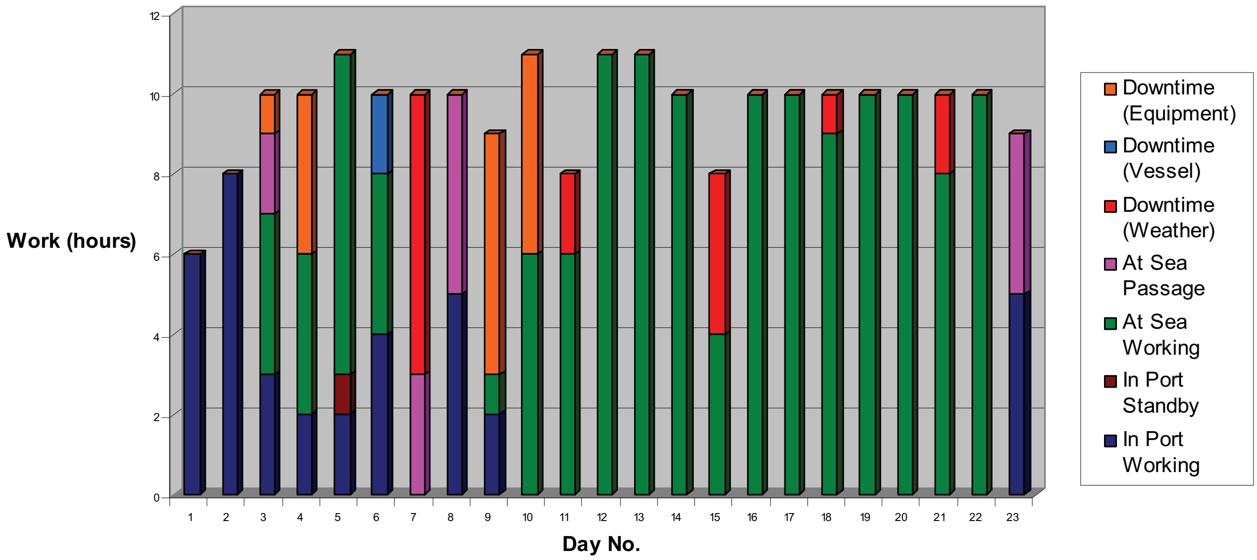


Fig. A-28. Time usage chart.

A.4.7 Equipment Performance Summary

A total of 16 hours of equipment downtime was accrued during the survey. As can be seen is Fig. A-28, most of this occurred at the beginning of the survey. This was primarily due to the equipment being out of use for a long period prior to the survey, so little maintenance had been performed. Table A-12 lists all equipment related failures, and their solutions.

Table A-12. Equipment performance.

Date	Problem	Solution
10/03/03	PC fails to detect signal from PPS box. PPS signal is being received from GPS however.	Solved on 11/03/03…
11/03/03	PPS problem continues	GPS card wiring found to be faulty and tampered with in POS unit – rewired
13/03/03	Two breaks identified in aft beam of multibeam pole	Pole dismantled and taken to ASW welders for repair
16/03/03	DGPS signal cannot be picked up	DGPS antenna moved to stern of vessel and earth wire connected to earthing plate
17/03/03	PPS problem recurs	COM 2 connection made to PC after boot up
19/03/03 27/03/03	Navigation jumps causing the data logging to stop	Close all non-essential applications on PC
25/03/03	Heading error increases from 0.01° to 0.4°	A 360° turn was performed to regain lock on 6 satellites and solve GAMS solution
29/03/03	.db files not written for 2 lines, .pts files not written for one line	Use .grd and .pts files to fill in areas where data was lost

All system related problems would probably benefit from an upgraded operating system from Windows NT to Windows 2000, and a more powerful processor with more RAM than the current 120MB. A new CSI DGPS receiver was purchased to replace the existing antenna, but as moving it to the stern of the vessel increased the signal to noise ratio by over 60%, the new one was not used. A temporary solution was implemented to the GPS card in the POS unit by re-wiring it; however damage to the screw threads securing the card will need a permanent repair.

A.4.8 Line data archive index

Data is archived on DVD-R and DVD RAM using the following file structure:

Database (all *.db raw data files)

- DtmData (all *.pts xyz point files)
- DXfToQxf
- Export (all *.xtf format raw data files)
- Graphics
- GridData (all *.grd 6042 format grids)
- Import (all *.txt tide files)
- LineData (all *.pro line files)

LogFiles	(all *.log Sound Velocity Profiles)
Mapping	
Results	(all *.res results files)
Support	
TEMP	

Each line is split at 30MB intervals for ease of handling. DVD-R copies are stored in room RSM 4.21 and DVD RAM copies are stored in room RSM 3.37.

Table A-13. Daily events summary.

Arun Paleovalley Multibeam Survey Daily Events Summary					
Day	**Date**	**Day No.**	**Work Completed**	**Personnel Onboard**	**Location**
Thursday	06/03/03		Loaded Chirp into van at Imperial College		Southampton (in boatyard)
Friday	07/03/03		Collected multibeam from Cardiff from Cardiff University and delivered (with the chirp) to Southampton		Southampton (in boatyard)
Saturday	08/03/03	1	Loaded multibeam, chirp, POS MV, processors, PC's etc onto vessel ashore at Shamrock Quay boatyard	APF, JP, JD, DB	Southampton (in boatyard)
Sunday	09/03/03	2	Networked GPS, multibeam, POS MV, Chirp. Set up all acqusition software, moved tow fish onto pontoon	APF, JP, JD, JF, DB	Southampton (in boatyard)
Monday	10/03/03	3	Vessel lauched and Chirp loaded. Multibeam and POS brackets collected and installed. POS calibration performed. PPS and Chirp power failures detected	APF, JP, JD, JF, DB, JC, AG	Southampton - Portsmouth
Tuesday	11/03/03	4	Find solution to PPS problem, client demonstation using 8125, attempt patch test calibration	APF, JP, JD, JF, DB, JC, AG, Reson Clients	Portsmouth
Wednesda	12/03/03	5	Re-measure sensor offsets, client demonstration using 8125, deploy and detect 1m cube sonar target	APF, JP, JF, DB, JD, KK, Reson Clients	Portsmouth
Thursday	13/03/03	6	Assemble and deploy 8101. Detect breaks in pole, repair pole, client demonstration	APF, JP, JF, DB, KK, Reson Clients	Portsmouth
Friday	14/03/03	7	Transit to Brighton attempted, but abandoned due to strong winds. Tide gauge installed in Brighton Marina	DB	Portsmouth/Brighton
Saturday	15/03/03	8	Transit to Brighton. Tide gauge calibrated. DGPS problem identified and solved.	APF, JP, DB, BC, SG	Brighton
Sunday	16/03/03	9	Patch test attempted but DGPS problem recurs. DGPS fixed, but PPS problem back	APF, JP, DB, BC, SG	Brighton
Monday	17/03/03	10	PPS fixed. Transit to survey area but need to re-calibrate POS. Chirp deployed and tested for cross-talk	APF, JP, DB, BC	Brighton
Tuesday	18/03/03	11	Four lines completed	APF, JP, DB, BC	Brighton
Wednesda	19/03/03	12	Seven lines completed	APF, JP, DB, BC	Brighton
Thursday	20/03/03	13	Eight lines completed	APF, JP, DB, BC, JC, SG	Brighton
Friday	21/03/03	14	Seven lines completed. Patch test calibration data acquired	APF, JP, DB	Brighton
Saturday	22/03/03	15	One line completed due to worsening sea conditions	APF, JP, DB, BDM, CC, LMN	Brighton
Sunday	23/03/03	16	Four lines completed, vessel refuelled	APF, JP, DB, BDM, JD	Brighton
Monday	24/03/03	17	Four lines completed, additional patch test data acquired. Patch test computations solved.	APF, JP, DB, BDM	Brighton
Tuesday	25/03/03	18	Four lines completed and exploration performed to the west	APF, JP, DB	Brighton
Wednesda	26/03/03	19	Second paleochannel discovered. Six lines completed.	APF, JP, DB	Brighton
Thursday	27/03/03	20	Five lines completed	APF, JP, DB, SG	Brighton
Friday	28/03/03	21	Six lines completed	APF, JP, DB	Brighton
Saturday	29/03/03	22	Eight lines completed	APF, JP, DB	Brighton
Sunday	30/03/03	23	Demobilise and transit to Portsmouth	APF, JP, DB	Brighton - Portsmouth
Monday	31/03/03	24	Complete demobilisation and return multibeam to Cardiff University	APF, JP, DB, JD	Portsmouth

A.5 DATA PROCESSING

A.5.1 Caris HIPS and SIPS

Caris Hydrographic Information Processing System and Sonar Information Processing System (HIPS & SIPS) is a Windows based processing and GIS software package into which all raw data was loaded. The software enables editing of all sensor data, sound velocity correction and georeferencing of soundings, tidal corrections, automatic cleaning of outliers, and the creation of grids and field sheets. Grids were created and updated with new data on a daily basis to assist with survey planning and QC.

A.5.1.1 Caris Settings

Firstly a vessel configuration file was made containing vessel dimensions, equipment, sensor offsets and mounting angles as detailed in Chapter 3. This was loaded into a new project containing projection and survey area information. Data was converted from database to XTF format using 6042 then imported into project folders for each day. All information was logged as "ship data" rather than "sensor data".

A.5.1.2 Data Processing Methodology

The workflow used in HIPS is shown in Fig. A-29.

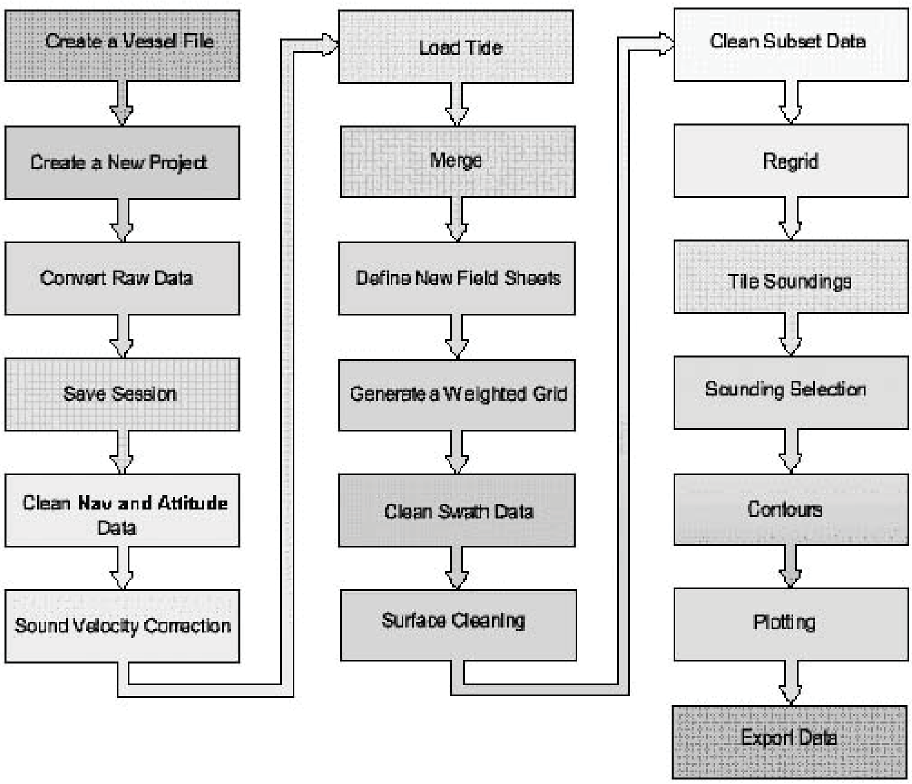


Fig. A-29. HIPS & SIPS workflow.

During the survey this procedure was followed up to the generation of a weighted grid. This was then exported and plotted in GMT.

A.5.2 Processing Procedures

A.5.2.1 Navigation Filtering

A visual check on the track plots revealed several very large navigational spikes. These were located using a speed jump search of 10 knots and the offending points were deleted with interpolation i.e. a linear interpolation between the adjacent points was used to reposition the point on line.

A.5.2.2 Motion Filtering

Motion data was left unfiltered, but checked visually for any large errors.

A.5.2.3 Sounding Filters

A basic swath filter to flag and reject soundings of depth <10m or >60m was applied to all lines using the batch processor utility.

A.5.2.4 Refraction Correction

The mean sound velocity was approximated at 1482.5 m/s. This value was used to create a vertical linear sound velocity profile for the purpose of quickly loading all data and applying an approximate refraction correction. Each SVP will be individually applied during post-processing.

A.5.2.5 Tide

For simplicity, predicted tide file for Shoreham was reformatted as a Caris .tid file and used to reduce all soundings loaded into the project to Chart Datum. Observed tide data will be applied during post-processing.

A.5.2.6 Grids

Line data was merged into overlapping georeferenced easting/northing/depth files and gridded using the slant range weighting technique. This gives a higher weighting to beams of low slant range, and a low weighting to less reliable outer beams of high slant range. The initial grid cell size was calculated as the mean footprint dimension which equals 2 metres. Holes in the grid were filled using a 7x7 interpolation matrix based on a minimum of 5 neighbouring cells.

A.5.2.7 Backscatter

Backscatter data was recorded as 16 bit, but converted to 8 bit during import to reduce file sizes. Seven sample files were processed to give an initial idea of data quality. The first return was automatically digitised and used for the slant range correction based on flat bottom assumption. The despeckle option was used to remove bright spots.

A.5.2.8 Mosaics

Once slant range corrected, multiple backscatter files were selected and mosaiced using the auto seem method.

A.6 DATA ANALYSIS

A.6.1 Multibeam

Grids were exported from Caris as ASCII XYZ files and loaded into Surfer8. The data could then be analysed as a Digital Elevation Model (DEM). The data which was not logged in the database file due to a PC problem (see chapter 4.7) was merged with the Caris file to complete the grid. The Caris 2m grid was re-sampled to 8m to speed up data analysis by reducing the file size. Charts, 3D views and profiles were produced to display the characteristics of the data and enable a detailed understanding of the morphology.

Fig. A-30 shows a plan view perspective of the Caris 2m grid with depth colouring and sun illumination. This shows several areas between swaths where unreliable outer beams and lower density soundings are causing some artefacts. There are also areas of striping due to sound velocity errors induced by the dummy SVP applied to this dataset. The vertical correlation of swaths is reasonably accurate indicating the predicted tide file applied matched the actual water depths in the area. Fig. A-31 shows the data projected in 3D to give a perspective view of the data. This shows several areas of data spikes which will be edited during further post-processing. Fig. A-32 shows a profile across the valley. The steep eroded channel margins are clearly visible.

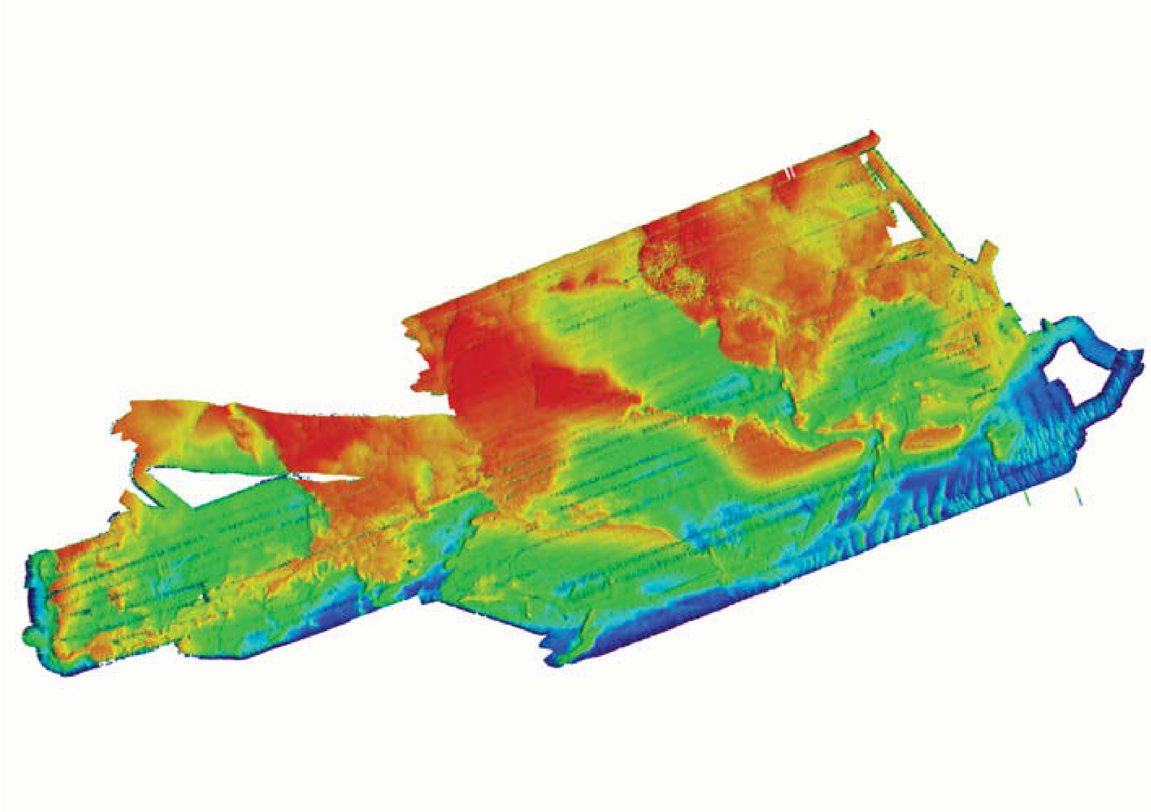


Fig. A-30. Caris 2m grid.

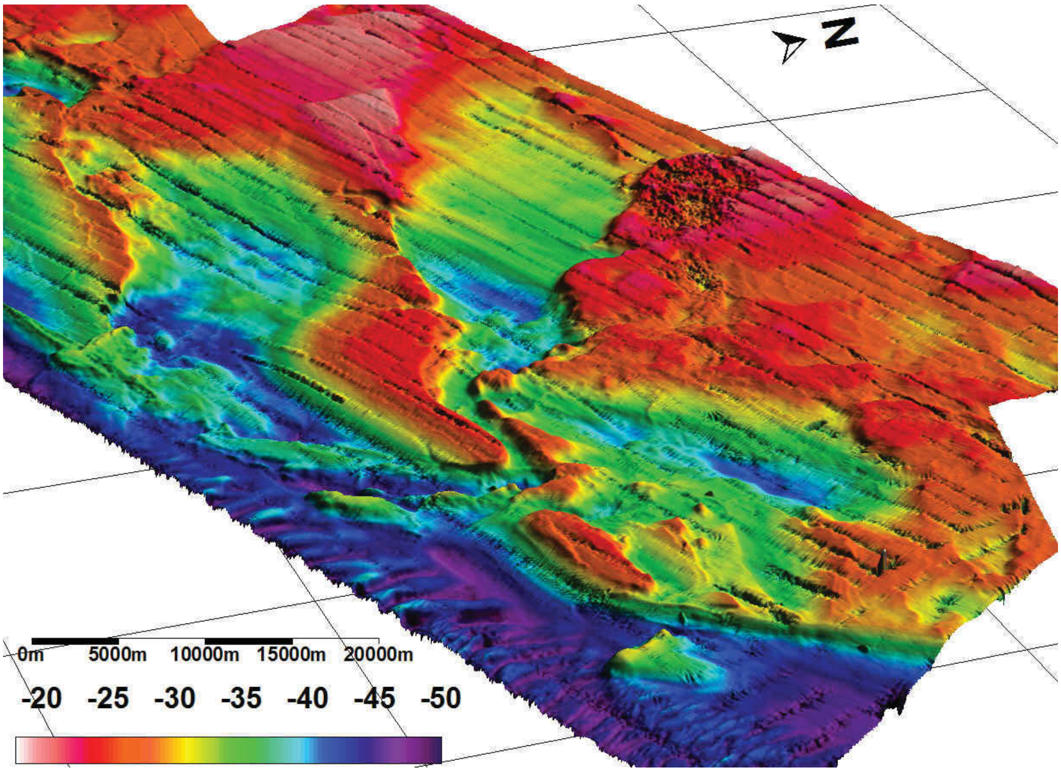


Fig. A-31. Perspective view of grid resampled to 8m cell size.

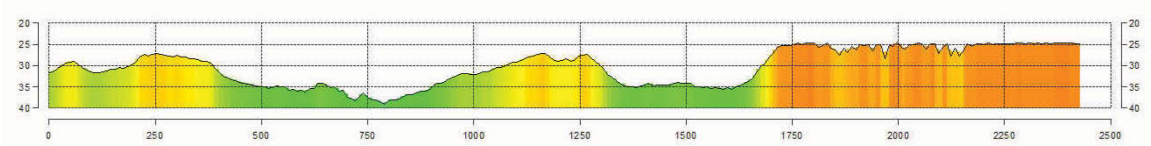


Fig. A-32. Profile through the middle of the valley.

Fig. A-33 shows a comparison plot using the pre-existing singlebeam data to produce a depth shaded image for depths between 30 and 35m, with contours from the multibeam data at 30m and 35m overlaid. This would reveal any horizontal shift indicating positional errors, or vertical differences due to tide, vertical datum or sounding error. The correlation is very close giving confidence in the reliability of the data. Fig. A-34 shows a chart produced for the complete dataset.

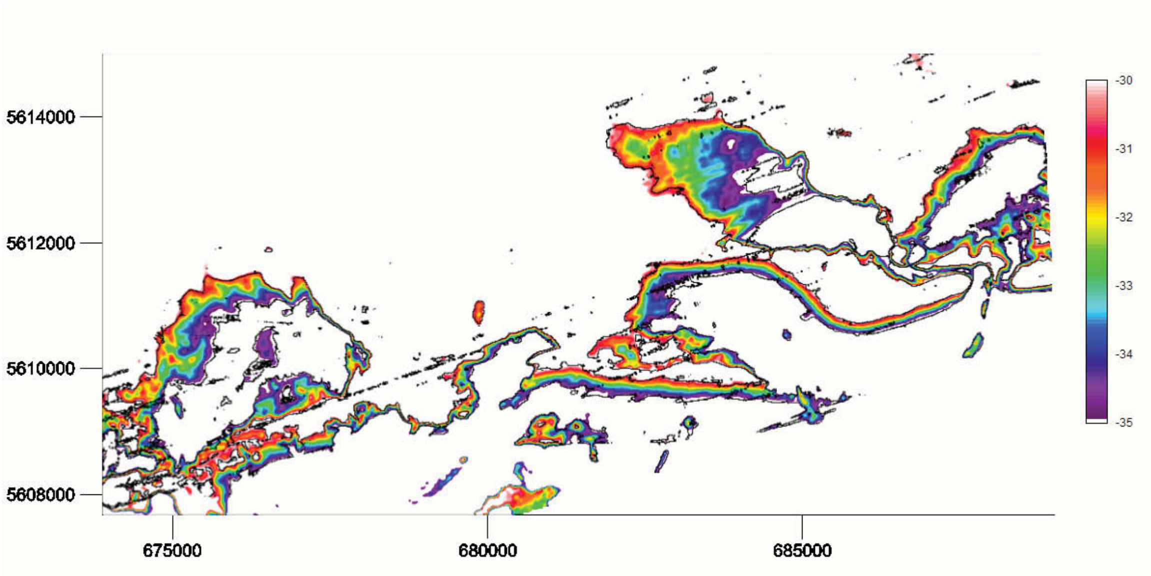


Fig. A-33. Overlay of depth coloured bathymetry from singlebeam data and contours from multibeam data. Contours are at 30 and 35m.

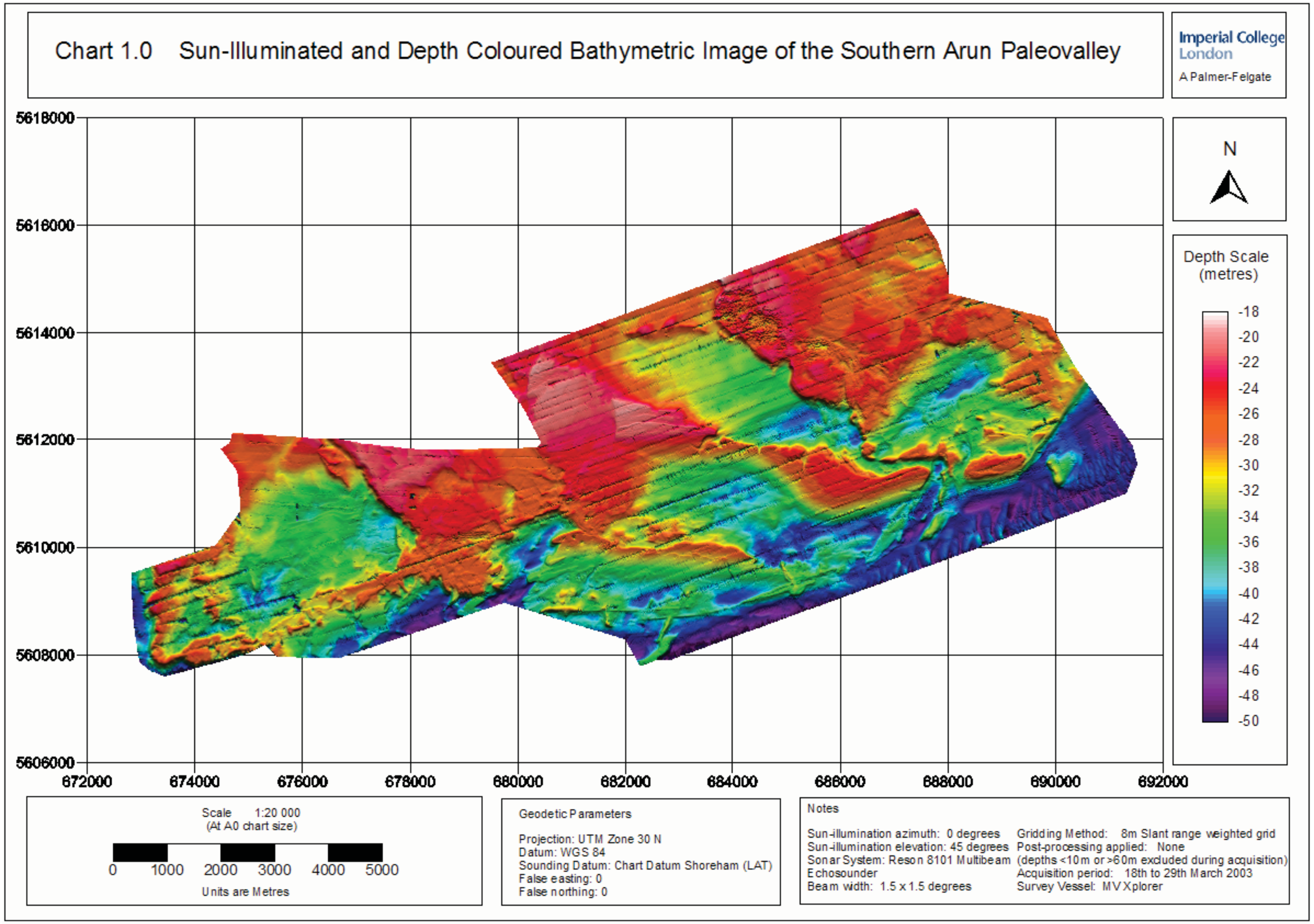


Fig. A-34. Chart of the complete swath bathymetry dataset.

A small backscatter mosaic is shown in Fig. A-35. The area is known from core samples to comprise of sand and gravel surface layers which is evident from the change in backscatter intensity and sand ripple bedforms. Single backscatter plots of bedrock areas (Fig. A-36) and sand waves (Fig. A-37) have also been processed to reveal high resolution of finer scale features than those detected from the bathymetry.

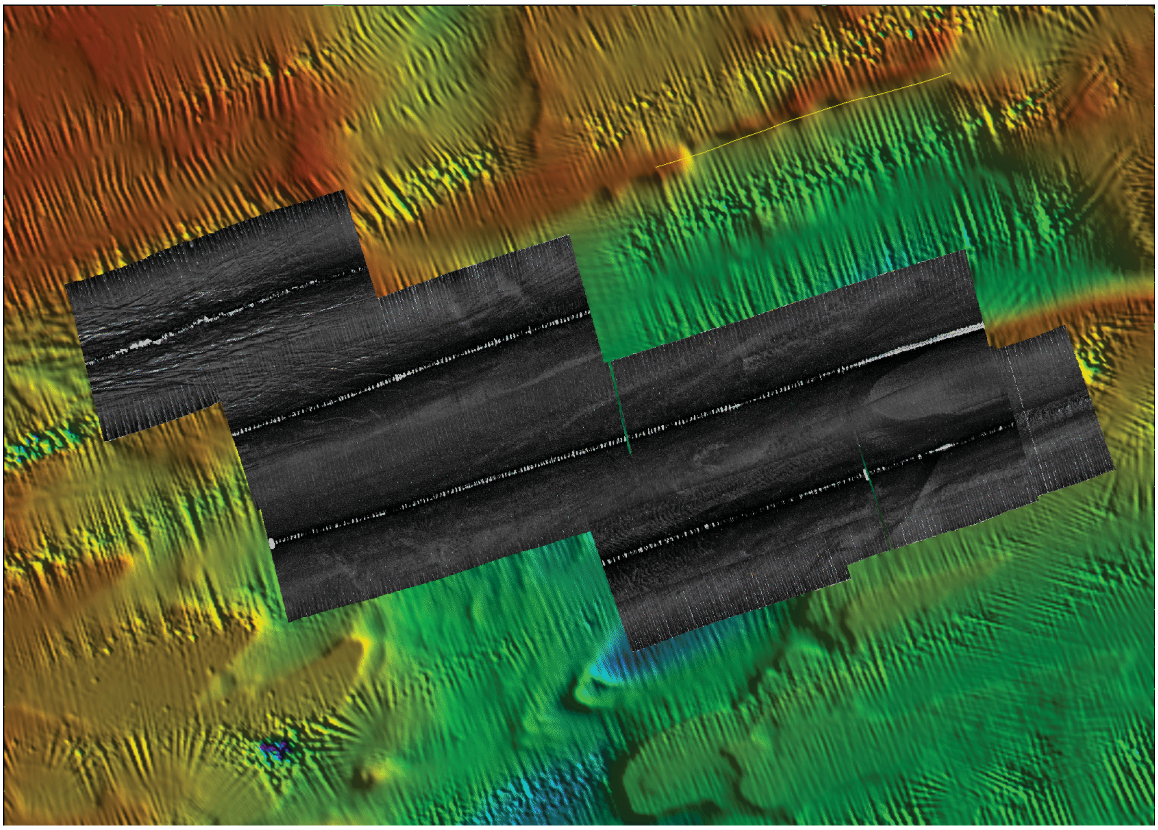


Fig. A-35. Backscatter mosaic overlaid on bathymetry.

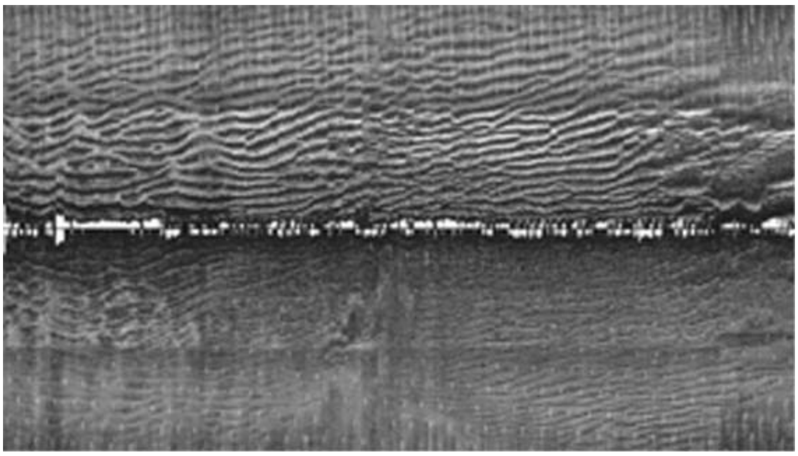


Fig. A-36. Backscatter over sand ripples.

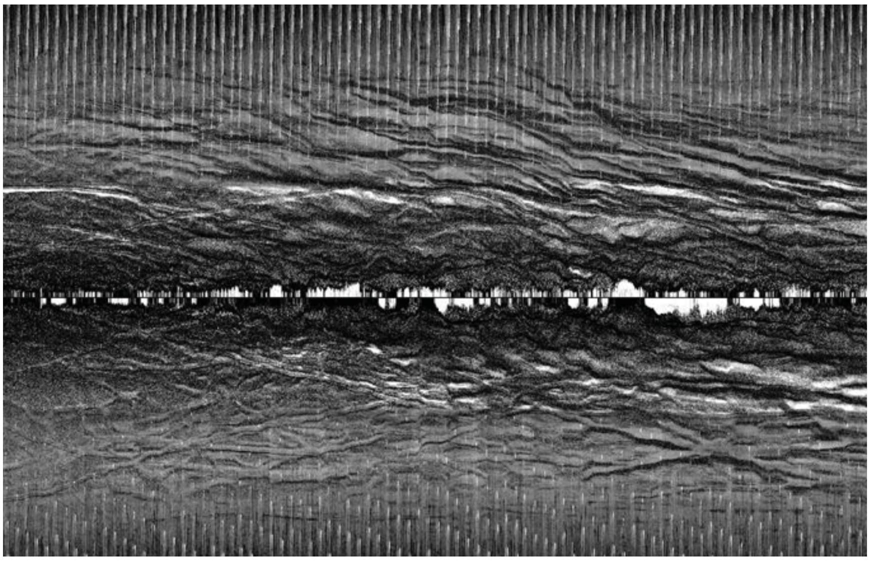


Fig. A-37. Backscatter over bedrock.

A.6.2 Sound Velocity Profiles

Sound velocity profiles have been plotted together in Fig. A-38 to show the change with depth and distribution. The general trend is for sound velocity to increase with depth due to increasing pressure. There is no evidence of any temperature change with depth as this would result in a negative profile. Variations in salinity are unlikely to affect the profile in this well mixed tidally dominated environment.

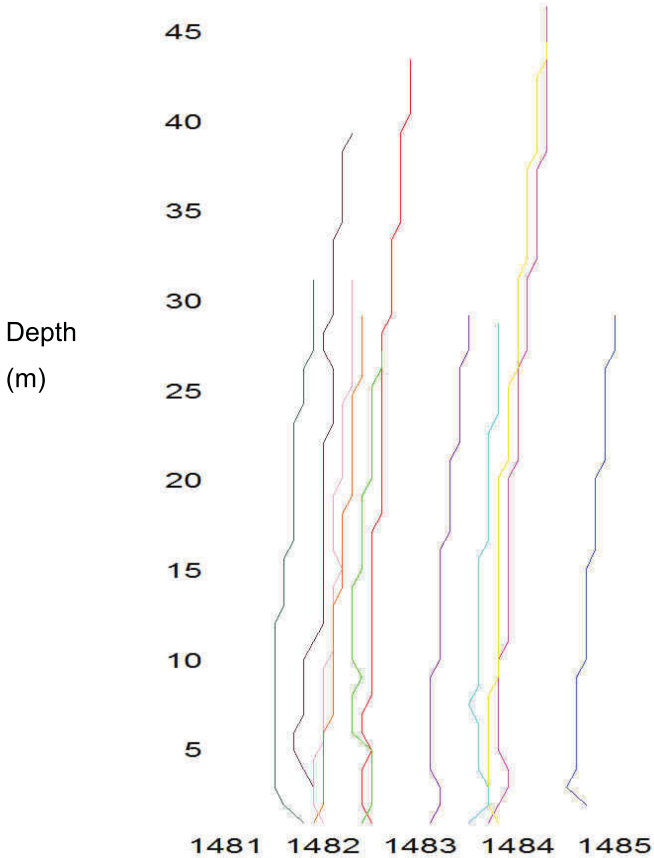


Fig. A-38. Graph of sound velocity (m/s, x axis) with depth (m, y axis) for a selection of SVPs.

A.6.3 Tide

Tidal curves from the observed tide at Brighton Marina were plotted against the predicted tide used for reduction of soundings. The resulting graph (Fig. A-39) shows no phase difference between the two datasets showing that the time difference between high and low tide is very small. During spring tides there is an amplitude difference between the two, with the predicted low tide being lower than the observed low tide by ~40cm. The high tide heights are very similar. During neap tides the situation is reversed with the low tides being close, and the observed tides ~50cm higher at high water. To find out which dataset will provide the best sounding reduction will require a test on several swaths of data.

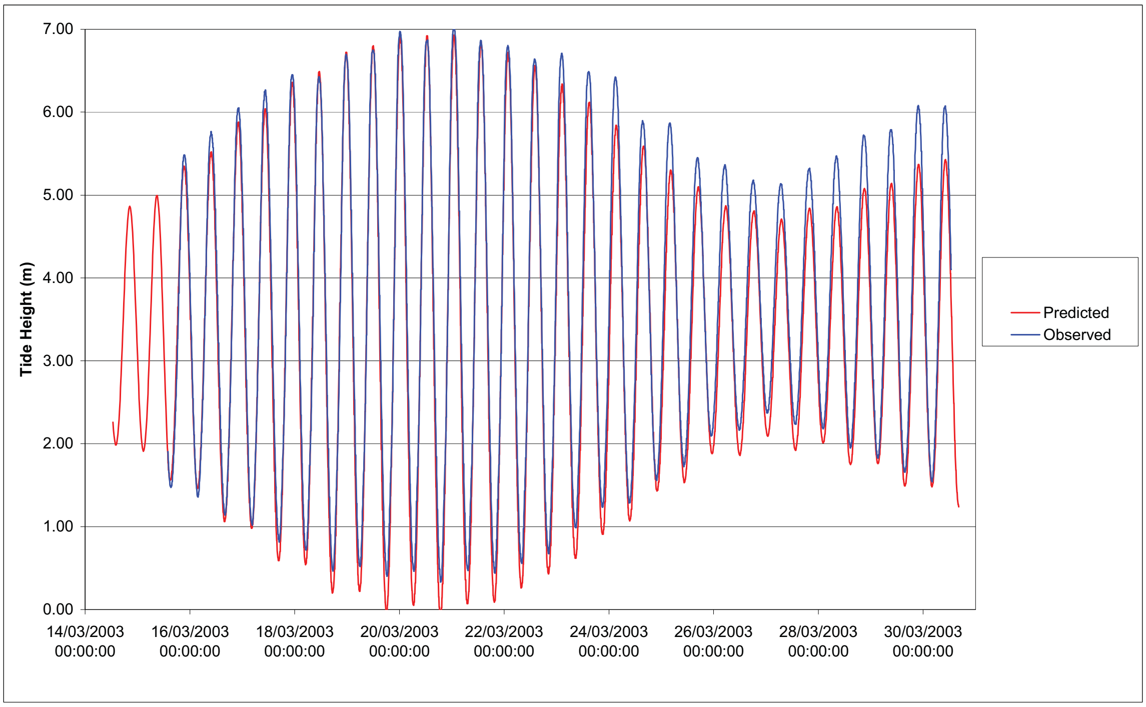


Fig. A-39. Plot of observed and predicted tidal heights throughout the survey period.

A.6.4 Data Potential and Limitations

Swath bathymetry data quality has been demonstrated to be externally reliable in position and depth through comparison with highly reliable Hydrographic Office data. The internal reliability of the data has been assessed through standard deviation and data density displays. This shows a large degree of variability due to the acquisition method which is inherently inconsistent. On average however the relative accuracy of soundings (which is vital for identifying morphological features) is high. Artefacts from beam refraction, tide and uncorrected motion are evident in the data and will be suppressed through detailed post processing.

The backscatter data mosaic shows significant potential for seabed classification and identification of large scale bedforms. Core logs will be used to ground truth the seabed type where possible, thus resulting in a calibration of backscatter intensity. The potential to merge the bathymetry, backscatter and sub-bottom profiles into a composite dataset will enable a greater understanding of each component.

A.7 CHIRP & SIDE-SCAN

A.7.1 Overview

Chirp and side-scan instrumentation was combined on one fish (Fig. A-40 and Fig. A-41). Optionally, side-scan sonar transducers could be deployed independently on a dedicated fish (Fig. A-42). The chirp/side-scan dual profiler system was deployed concurrently with the multibeam. As such, there was no specific line plan, rather that important features were investigated by all three methods. The GeoAcoustics dual geophysical sampling system combines the GeoChirp sub-bottom profiler system with a dual frequency side-scan sonar system. Each component has a separate deck unit, through which the data is transferred from the fish to a separate logging computer, described later. The basic dual profiler configuration is shown in Fig. A-43.

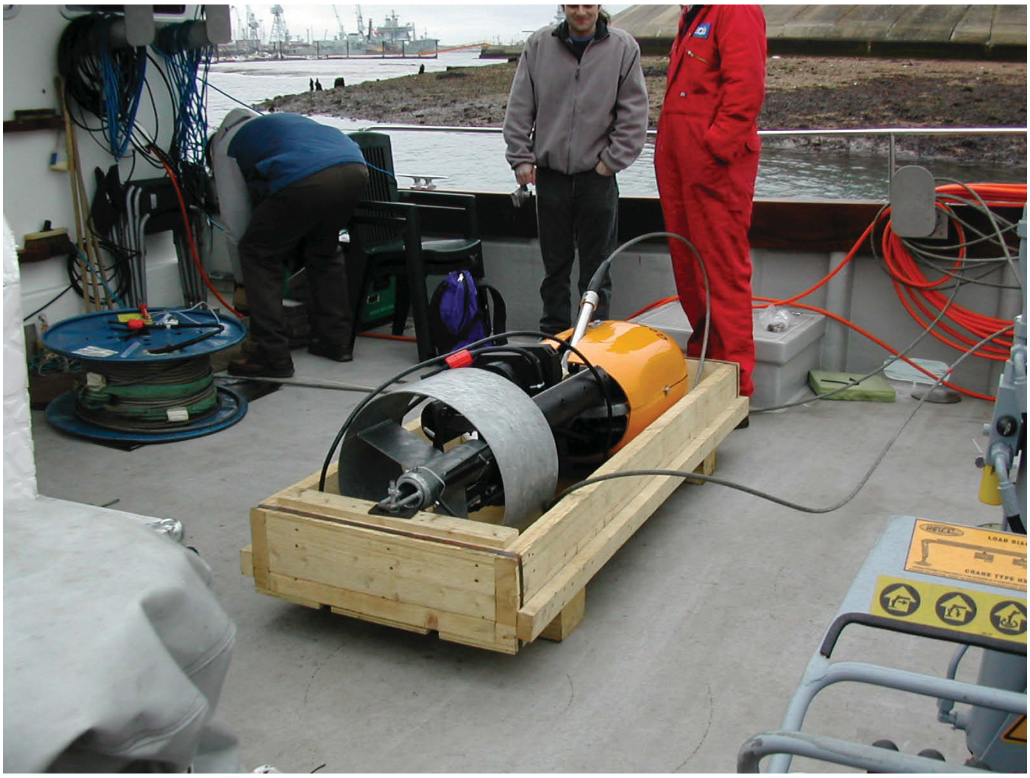


Fig. A-40. Dual profiler fish in case during mobilisation. Large fin acts as stabilizer.

Fig. A-41. Dual profiler fish prior to deployment. Yellow fibreglass case contains the four chirp transducers, with the side-scan sonar transducers along the side. Fish is 'head heavy' due to lead weights to aid level buoyancy in water during survey.

Fig. A-42. Small, side-scan only fish. Torpedo shape allows for better 'flying' and easier deployment/recovery.

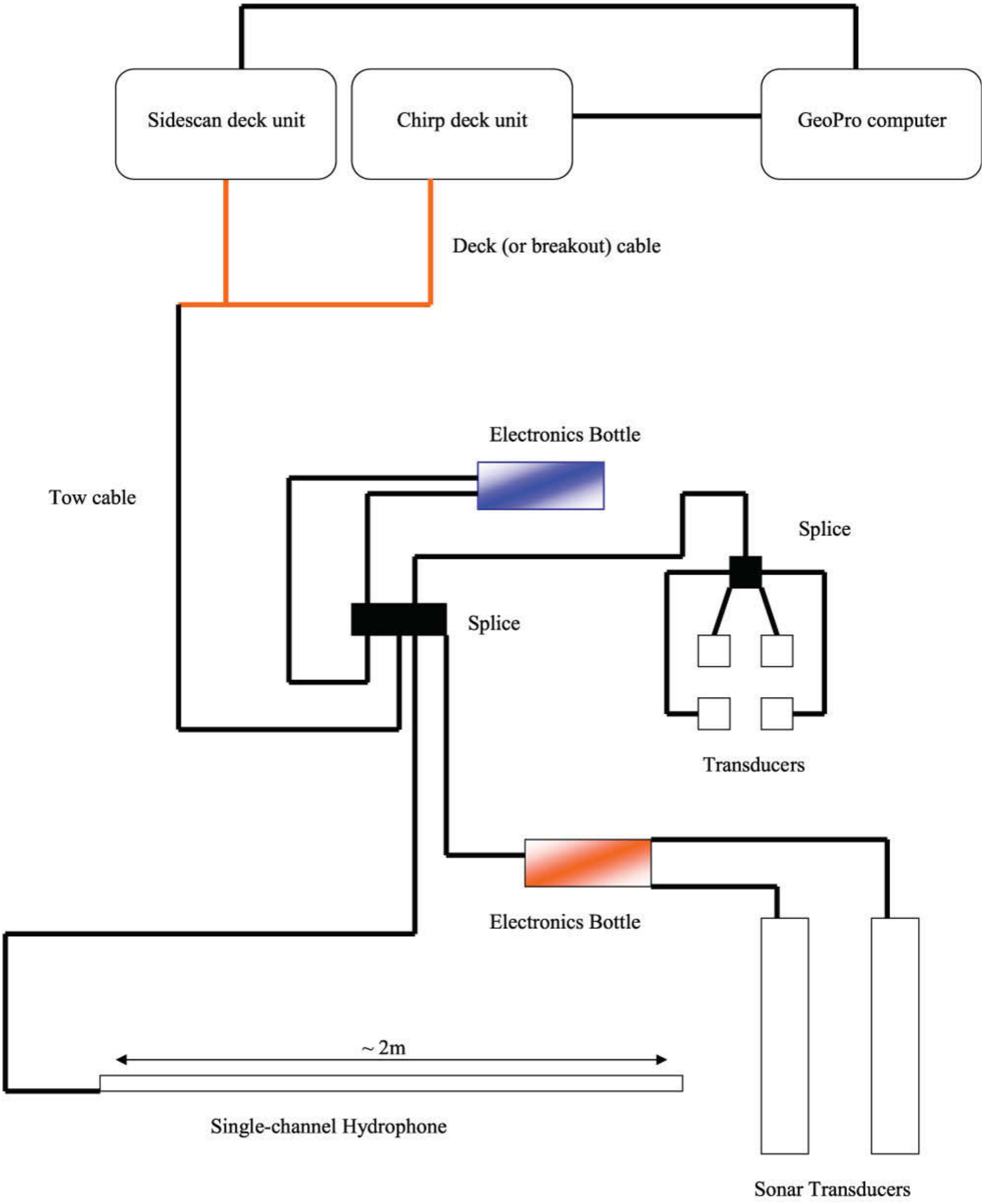


Fig. A-43. Basic dual profiler system configuration (GeoChirp and side-scan sonar)

A.7.1.1 GeoChirp

The GeoChirp system consists of four transducers that create the source wavelet that penetrates the seafloor and is then recorded on a single channel hydrophone that is towed behind the fish. In this respect it is similar to standard seismic acquisition.

A.7.1.2 Side-scan Sonar

The sonar system consists of two transducers which operate at frequencies designed to minimise cross-talk. Sonar beams create a swath, measuring returns and the relative intensity of the objects e.g. solid bedrock will give a higher intensity return compared with mud. As with the chirp, the signal is received via an electronics 'bottle' before transferred to its individual deck unit.

A.7.2 Technical Specification

A.7.2.1 GeoChirp

The chirp system is designed such that all four transducers operate simultaneously to achieve maximum performance in terms of signal strength and source signal shape. Unlike the side-scan sonar and multibeam methods, the chirp is similar to conventional seismic, with the source occurring over a specified length of time (16 or 32 ms) which limits the number of pulses to a maximum of 4 or 8 'shots' per second, depending upon the sweep time. The chirp system can operate at two different frequency ranges, depending upon the conditions and requirements of the user. The differences are outlined in Table A-14.

Table A-14. GeoChirp signal specification.

	Frequency range kHz	Penetration m	Resolution cm
High Penetration	2 – 7	10 – 40	12.5
High Resolution	1.5 – 11.5	5 – 25	7.5

The wide range in penetration values stated is because of the diffractive nature of different seabed forms. Solid bedrock, for example will diffract more energy at the higher frequency range, reducing penetration than say clay which will absorb and transmit the energy.

The single channel streamer, that records the transmitted signal is comprised of eight hydrophones which convert the pressure changes along its total length of 2 m and converts them into digitally rendered changes in velocity. The theoretical bandwidth of the streamer is 0.5 – 15 kHz, allowing for frequency changes occurring within the subsurface.

A.7.2.2 Side-scan Sonar

The side-scan sonar system essentially consists of two transducers and an electronics bottle that converts the signals. To minimise cross-talk with other geophysical components, the side-scan can operate at either 100 kHz or 500 kHz. The specific details are listed in Table A-15.

Table A-15. Side-scan sonar signal specification.

	Frequency kHz	Range	Beam width	Pulse width
100 kHz	114 +/- 50	1km at 50m height	50˚ by 1˚	166 µs
500 kHz	410 +/- 50	200m swath at 20m height	40˚ by 0.5˚	88 µs

The actual transducers are fitted onto either the single fish, or the combined profiler system with a 10˚ downward focus. This ensures bottom returns at both frequencies.

A.7.3 Controls, Indicators and Connections

The GeoAcoustics system has three computer units to control, monitor and record the information gathered during surveying: the two deck units and the GeoPro. The latter is essentially an Apple Macintosh running Helios (Geoacoustics modified Mac OS 9.2 with acquisition software).

As illustrated in Fig. A-43, the data from the equipment is relayed via a multi-core armoured tow cable to a multi-core soft deck cable, with a breakout box to split the data into the individual deck units.

Data communications between the three units is via 50Ω BNC cables, with the connections important to ensure valid data recording. To aid future use of the system, the cables have been labelled at both ends. Fig. A-44 to Fig. A-46 show the front panels of each unit.

Fig. A-44. Front connection panel of GeoPro computer.

Fig. A-45. Front connection panel of Chirp deck unit. Signal out, contains the data going into the acquisition computer. The two key connections relay the fire from the software and when to record the hydrophone data.

Fig. A-46. Front connection panel of side-scan deck unit. If the processed data is being recorded, the gains, TVG and AGC controls will need to be adjusted.

Essentially, channels one and two contain side-scan sonar information, with channels 3 and 4 recording the chirp. This information will also be required by the acquisition software, so any alterations on the deck unit need to be matched by the software.

The GeoAcoustics system is designed so that raw data coming into the deck units is then partially processed before being recorded. However, as the exact alterations undertaken by the deck units are not fully documented, the raw data is always recorded where possible. The chirp aspect of this decision means that despite the ‘raw channel’ appearing to record no data on the acquisition software, it does infact contain very important information.

When running the small side-scan only fish, it is possible to record two sets of side-scan data simultaneously (processed and raw).

Whilst the chirp deck unit has its own internal trigger system, which was used during the boomer survey, the dual profiler system is controlled via the acquisition software running on the GeoPro. However, depending upon conditions, it may be beneficial to use the internal trigger. To do this, switch from EXT to INT on the KEY mode. Note that after powering up the system, the key mode is automatically turned off.

Powering up the GeoAcoustics system causes several LEDs to flash and some to stay on. On the chirp deck unit, the XMIT red LED should flash twice, if it fails to, there is a problem within the unit. Manuals and GeoAcoustics tech support should be consulted. The GAIN led will also light up on the deck unit. Assuming the fish is in the water, this led should always be kept either at green or between green and orange (okay, under).

During data acquisition the KEY OUT LEDs will flash green as the trigger pulse is sent from the GeoPro to the deck units. The various channel LEDs as well as the EXT, PROCESSED (KEY and SIGNAL) LEDs should flash as the recorded data are sent back. On each pulse/shot the red XMIT on the chirp deck unit and the green XMIT led on the side-scan deck unit should flash. Also during acquisition the SIG leds on the side-scan deck unit should remain green. Assuming that only raw data is being acquired, no light and/or red could indicate problems within the connections, probably salt build-up.

A.7.4 Data Acquisition

The problems with the Geoacoustics equipment did not allow for significant data acquisition compared to the multibeam or boomer seismic; although during the last week of the boomer survey, the small side-scan fish was also deployed.

A.7.4.1 Daily Progress Reports

Since the dual profiler system was deployed with the multibeam, the daily reports should contain information about both the chirp and side-scan survey aspects. During the side-scan-only survey, the information is recorded within the boomer survey daily reports.

A.7.4.2 Navigation

Navigation during the combined and side-scan-only surveys was recorded through the GeoPro as NMEA strings directly from the Xplorer’s Trimble-based DGPS and through Burden’s Navmaster software, which recorded a position every eight seconds.

As with all geophysical surveys accurate positioning is important for subsequent data processing and analysis. Since the GeoAcoustics equipment is towed behind and below the ship during acquisition, an approximate constant is added for the re-positioning, known as layback. Layback is determined from the GPS antenna to stern distance, plus the amount of cable flaked out behind. On the Xplorer, the GPS antenna was 4.5m aft. Within the acquisition software, the layback distance can be removed from the data. However, how the calculations are made with the cable running at an angle are not specified.

During the side-scan-only survey, the small fish was towed from the front of Xplorer, between the two hulls. This was aft of the GPS antenna, but the acquisition software does not allow negative numbers for layback.

A.7.4.3 Equipment Performance

Downtime due to equipment failings was very high with the GeoAcoustics equipment. PSU problems at the start of the survey required the GeoPro to be sent back to Great Yarmouth, losing a week as a result.

Another problem that was originally blamed on the pitching of the boat, was the chirp miss-firing. However, using the deck unit as a trigger for the later boomer survey also presented problems, with the timing unit changing from one shot/second up to 12 and often completely off. This has still to be rectified, since a 'draw' is required to replicate the problem. Table A-16 gives an indication of the GeoAcoustics equipment:

Table A-16. Breakdown of problems with GeoAcoustics hardware/software during dual-system survey and side-scan-only survey.

Date	Problem	Resolution
10/03/2003	Failure of GeoPro to boot	Checked PSU, request replacement from GeoA.
	Chirp won't 'ping'	
11/03/2003	Chirp won't 'ping'	Replaced fuses with altered standard ones, request new fuses from GeoA.
12/03/2003	Failure of GeoPro to boot	Replaced PSU, still failed to boot
12/03/2003	Failure of GeoPro to boot	
17/03/2003	Failure of GeoPro to boot	GeoPro sent back to GeoA, with old PSU.
22/03/2003	Failure of GeoPro to boot	Nothing altered, but unit suddenly okay.
22/03/2003	Banding on sidescan	Never resolved, beyond cleaning and
22/04/2003	Banding on sidescan	replacement of lube on all connectors every day.
22/03/2003	Dropped data on chirp	Never resolved. Assummed to be
29/03/2003	Dropped data on chirp	weather and ship related. Unit to be sent back to Geo A for tests.
04/04/2003	Miss-firing trigger on chirp	Never resolved.
24/04/2003	deck unit into boomer system	Unit to be sent back to GeoA for tests.

A.7.4.4 Online QC

Monitoring of the equipment during the survey was principally based on monitoring the side-scan response plots and the amplitude signal for the chirp. In particular, banding noticed on the side-scan and high background 'noise' on different side-scan channels indicated probable salt-degraded signal connections.

A.7.5 Survey Data

The two sets of data acquired using the GeoAcoustics system are shown in Fig. A-47 and Fig. A-48. A full breakdown of all acquisition parameters for all the data acquired during the survey is given in Table A-17.

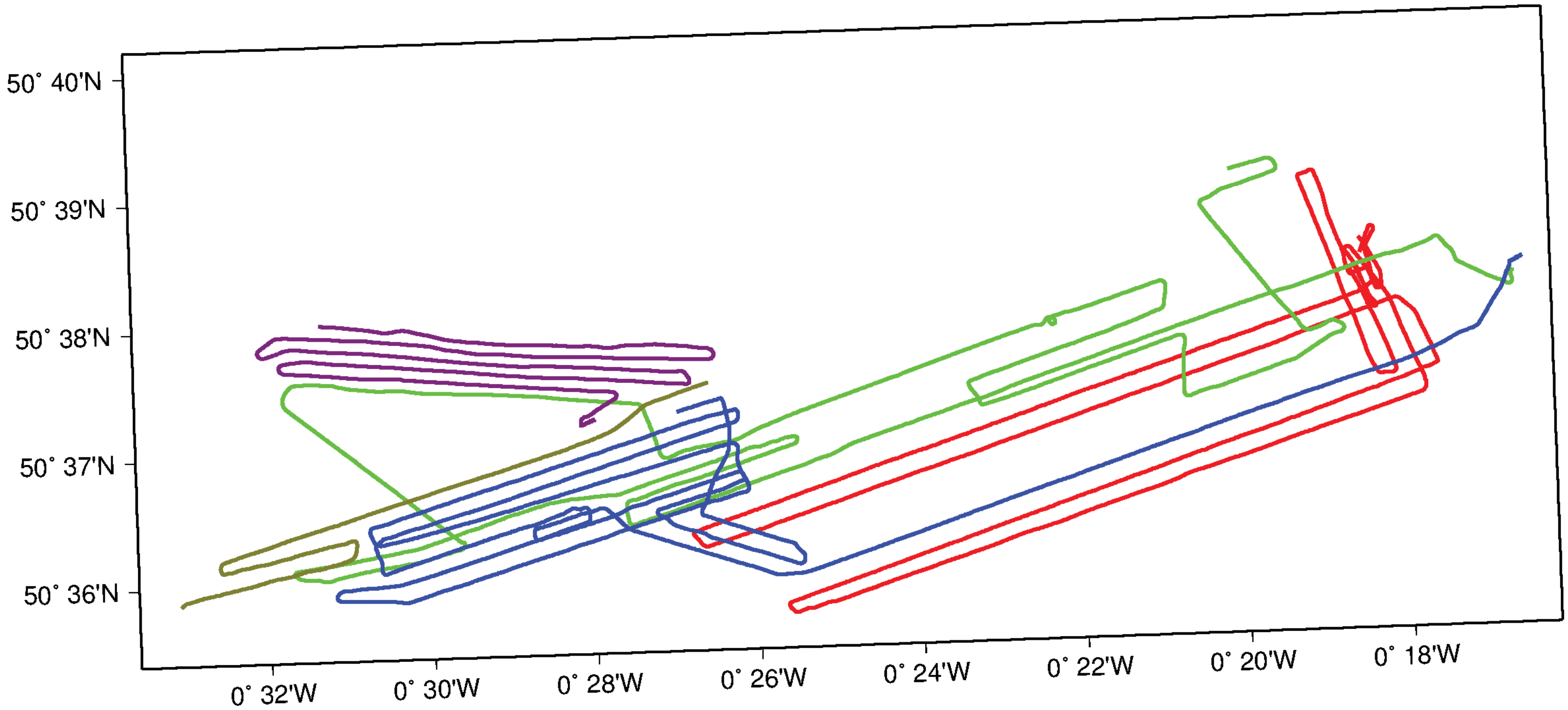


Fig. A-47. Final track plot of dual profiler system. Approximately 200 km of data was acquired. Colours indicate days of acquisition: red, 24/3/03; green 25/3/03; blue 26/3/03; pale brown 27/3/03; purple 29/3/03.

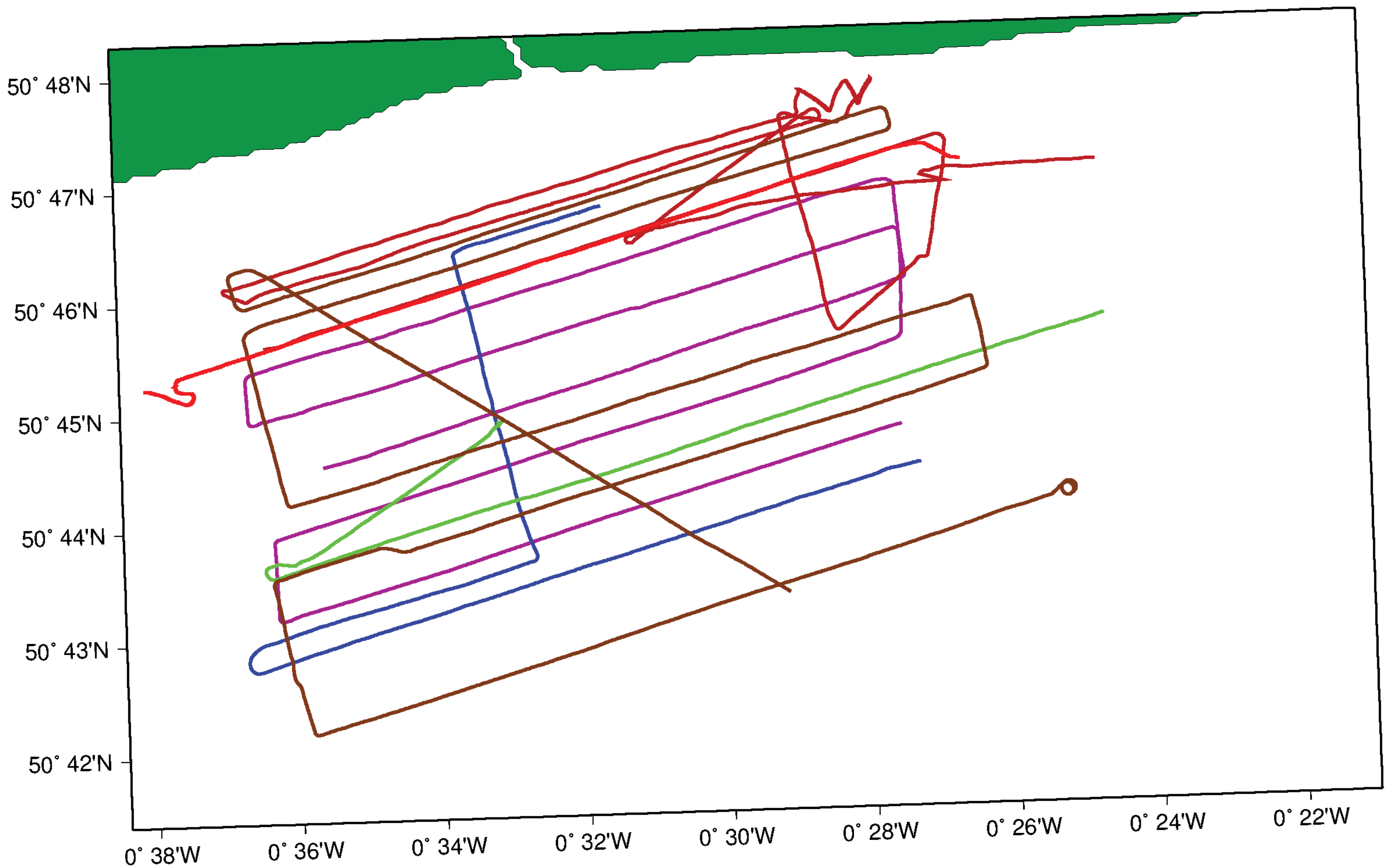


Fig. A-48. Final track plot of side-scan-only survey acquired during boomer seismic survey. Colours indicate days of acquisition: 16/4/03 purple; 17/4/03 blue; 18/4/03 green; 21/4/03 maroon; 22/4/03 brown; 24/4/03 red.

Table A-17. List of all Chirp and side-scan data acquired during IC Arun survey March/April 2003.

Date	Line No.	Start time	Start Lat 50˚	Start Long 0˚	End time	End Lat 50˚	End Long 0˚	Sidescan			Chirp		
								Frequency (Hz)	Range (m)	Samples	Sample rate (μs)	Duration (ms)	Layback (m)
22/03/2003	1	10.26:14	38' 25.06	17' 52.25	10.45:51	37' 57.25	19' 09.94	500	122	4096	40	500	14.5
	2	10.47:06	37' 58.78	19' 18.10	10.57:38	37' 48.24	20' 16.88	500	122	4096	40	260	14.5
	3	10.57:58	37' 48.01	20' 18.78	11.00:42	37' 45.41	20' 33.77	500	122	4096	n/a	n/a	14.5
	4	11.00:51	37' 43.72	20' 34.76	11.03:09	37' 40.85	20' 47.01	500	92	1024	n/a	n/a	14.5
	5	11.06:07	37' 34.58	21' 01.57	11.22:51	37' 17.37	22' 29.90	500	46	1024	40	200	14.5
	6	11.24:53	37' 15.13	22' 40.53	11.32:15	37' 06.04	23' 23.54	500	46	1024	40	200	14.5
	7	11.34:25	37' 03.50	23' 35.96	11.51:01	36' 44.54	25' 05.40	500	46	1024	40	200	14.5
	8	11.52:02	36' 44.37	25' 11.41	11.54:25	36' 42.23	25' 24.80	500	92	2048	40	200	14.5
	9	11.54:36	36' 39.79	25' 24.54	11.58:25	36' 36.04	25' 46.45	500	23	512	40	200	14.5
	10	11.58:43	36' 36.93	25' 48.73	11.58:59	36' 34.20	25' 49.04	500	107	1024	40	200	14.5
	11	12.00:37	36' 34.24	25' 59.71	12.01:54	36' 33.93	26' 06.90	500	98	1024	40	200	14.5
	12	12.03:23	36' 29.74	26' 15.01	12.15:45	36' 20.48	27' 12.76	500	31	1024	40	200	14.5
	13	12.17:51	36' 16.53	27' 20.39	12.20:54	36' 18.85	27' 34.05	500	107	1024	40	200	19.5
23/03/2003	1	11.10:35	40' 23.50	20' 26.69	11.12:41	40' 19.89	20' 27.97	500	107	1024	40	200	19.5
	2	11.17:15	40' 12.30	20' 30.58	11.27:54	40' 00.96	21' 14.95	500	46	1024	40	200	19.5
	3	11.28:02	40' 00.35	21' 15.52	11.32:56	39' 55.99	21' 39.12	500	107	1024	40	200	19.5
	4	11.33:04	39' 56.82	21' 40.38	12.42:38	38' 45.35	27' 23.06	500	107	1024	40	200	19.5
	5	12.42:58	38' 44.87	27' 24.54	13.53:28	39' 59.37	20' 37.35	500	107	1024	40	200	19.5
	6	13.55:24	39' 57.78	20' 29.30	14.01:01	39' 38.54	20' 04.75	500	46	1024	40	200	19.5
	7	14.01:21	39' 36.87	20' 04.71	14.11:24	39' 06.97	19' 32.45	500	92	1024	40	200	19.5
	8	14.11:35	39' 07.68	19' 34.76	15.12:22	37' 39.39	26' 46.55	500	214	2048	40	200	19.5
	9	15.12:45	37' 39.27	26' 47.35	15.17:14	37' 47.35	26' 51.25	500	183	4096	40	200	19.5
	10	15.17:25	37' 48.39	26' 52.24	15.40:04	38' 11.13	24' 54.47	500	214	2048	40	200	19.5
	11	15.40:10	38' 11.75	24' 54.25	15.56:04	37' 27.27	23' 52.01	500	214	2048	40	200	19.5
	12	15.56:11	37' 28.67	23' 52.04	17.03:04	38' 33.11	18' 26.51	500	214	2048	40	200	19.5
24/03/2003	1	10.12:10	38' 25.25	18' 26.13	11.58:29	36' 22.72	26' 46.32	500/100	214	2048	40	200	24.5
	2	11.59:23	36' 14.89	26' 50.97	12.55:21	37' 52.09	18' 03.68	500/100	183	4096	40	200	24.5
	3	12.55:27	37' 52.87	18' 01.80	14.29:32	35' 45.25	25' 36.06	500	183	4096	40	200	24.5
	4	14.29:37	35' 48.75	25' 38.01	15.30:12	37' 11.74	17' 48.36	500	183	4096	40	200	24.5
	5	15.30:19	37' 11.46	17' 47.16	15.47:00	38' 18.86	18' 45.49	500	183	4096	40	200	24.5
	6	15.47:01	38' 18.47	18' 46.20	15.53:46	37' 56.16	18' 15.75	500	183	4096	40	200	24.5
	7	15.53:47	37' 55.36	18' 18.03	15.58:35	38' 12.48	18' 43.96	500	183	4096	40	200	24.5
	8	15.58:36	38' 12.34	18' 41.89	16.10:51	37' 26.98	18' 14.63	500	183	4096	40	200	24.5
	9	16.10:52	37' 25.72	18' 14.75	16.45:17	38' 09.48	18' 37.02	500	183	4096	40	200	24.5
	10	16.45:21	38' 08.12	18' 34.29	16.50:45	38' 06.59	18' 12.01	500	183	4096	40	200	24.5
	11	16.50:45	38' 06.46	18' 16.87	17.00:10	38' 48.20	18' 45.53	500	183	4096	40	200	24.5

25/03/2003	1	10.31:17	38' 10.06	16' 44.48	12.05:18	36' 27.35	27' 26.72	500	214	2048	40	200	24.5
	2	12.05:18	36' 29.51	27' 27.64	12.08:05	36' 29.19	27' 30.00	500	214	2048	40	200	24.5
	3	12.08:06	36' 29.21	27' 30.36	12.21:24	36' 54.09	25' 41.41	500	214	2048	40	200	24.5
	4	12.21:24	36' 54.35	25' 41.49	13.29:48	36' 09.23	31' 39.19	500	214	2048	40	200	24.5
	5	13.29:49	36' 08.46	31' 39.06	13.31:33	35' 59.30	31' 29.14	500	214	2048	40	200	24.5
	6	13.31:34	36' 00.56	31' 29.19	13.41:35	36' 10.70	29' 39.06	500	214	2048	40	200	24.5
	7	13.41:35	36' 11.96	29' 39.55	14.04:06	37' 22.36	31' 43.03	500	214	2048	40	200	24.5
	8	14.04:07	37' 22.48	31' 42.97	14.06:41	37' 34.14	31' 36.35	500	214	2048	40	200	24.5
	9	14.06:41	37' 34.12	31' 36.23	14.30:43	37' 20.50	27' 27.62	500	214	2048	40	200	24.5
	10	14.30:44	37' 20.46	27' 27.53	14.35:49	36' 56.46	27' 10.16	500	214	2048	40	200	24.5
	11	14.35:49	36' 56.38	27' 10.20	14.36:41	36' 55.14	27' 02.58	500	214	2048	40	200	24.5
	12	14.36:41	36' 55.11	27' 02.49	15.03:17	37' 49.58	22' 39.50	500	214	2048	40	200	24.5
	13	15.08:29	37' 56.53	22' 09.97	15.15:35	38' 09.38	21' 01.63	500	214	2048	40	200	24.5
	14	15.15:35	38' 09.36	21' 01.52	15.19:07	37' 56.05	21' 00.55	500	214	2048	40	200	24.5
	15	15.19:08	37' 55.99	21' 00.61	15.38:06	37' 26.09	23' 19.48	500	214	2048	40	200	24.5
	16	15.38:06	37' 26.07	23' 19.56	15.41:39	37' 16.10	23' 03.88	500	214	2048	40	200	24.5
	17	15.41:49	37' 16.36	23' 02.36	15.56:53	37' 43.67	20' 48.35	500	214	2048	40	200	24.5
	18	15.56:54	37' 43.91	20' 48.38	16.04:02	37' 17.29	20' 31.84	500	214	2048	40	200	24.5
	19	16.04:03	37' 17.53	20' 31.89	16.12:15	37' 31.23	19' 21.05	500	214	2048	40	200	24.5
	20	16.12:15	37' 31.09	19' 20.89	16.16:28	37' 43.02	18' 48.51	500	214	2048	40	200	24.5
	21	16.16:28	37' 42.87	18' 48.35	16.21:25	37' 46.67	19' 16.85	500	214	2048	40	200	24.5
	22	16.21:26	37' 46.69	19' 16.88	16.34:16	38' 44.00	20' 27.35	500	214	2048	40	200	24.5
	23	16.34:21	38' 44.40	20' 27.66	16.41:37	38' 59.33	19' 33.44	500	214	2048	40	200	24.5
	24	16.41:37	38' 59.26	19' 33.37	16.44:40	39' 03.52	19' 50.49	500	214	2048	40	200	24.5
	25	16.44:40	39' 03.53	19' 50.50	16.49:52	38' 55.31	20' 36.85	500	214	2048	40	200	24.5
26/03/2003	1	10.10:18	38' 12.83	16' 41.40	11.16:31	35' 59.11	25' 25.57	500	183	4096	40	200	24.5
	2	11.16:31	35' 59.12	25' 25.61	11.36:37	36' 31.58	27' 57.39	500	183	4096	40	200	24.5
	3	11.36:38	36' 31.56	27' 57.45	11.41:53	36' 24.28	28' 38.27	500	183	4096	40	200	24.5
	4	11.41:53	36' 24.27	28' 38.30	11.44:23	36' 18.70	28' 38.13	500	183	4096	40	200	24.5
	5	11.44:24	36' 18.74	28' 38.08	12.05:02	36' 46.83	26' 14.48	500	183	4096	40	200	24.5
	6	12.05:03	36' 46.87	26' 14.46	12.08:41	36' 36.80	26' 14.24	500	183	4096	40	200	24.5
	7	12.08:42	36' 36.79	26' 14.28	12.44:04	35' 51.23	30' 25.62	500	183	4096	40	200	24.5
	8	12.44:04	35' 51.20	30' 25.66	12.50:03	35' 52.44	31' 07.43	500	183	4096	40	200	24.5
	9	12.50:03	35' 52.47	31' 07.45	12.53:00	35' 57.74	30' 55.70	500	183	4096	40	200	24.5
	10	12.53:00	35' 57.75	30' 55.67	13.14:37	36' 25.93	28' 04.77	500	183	4096	40	200	24.5
	11	13.14:38	36' 25.97	28' 04.72	13.39:44	36' 04.73	30' 32.58	500	183	4096	40	200	24.5
	12	13.39:45	36' 04.72	30' 32.61	13.45:00	36' 22.04	30' 28.51	500	183	4096	40	200	24.5
	13	13.45:00	36' 22.05	30' 28.47	14.15:00	37' 10.12	26' 16.32	500	183	4096	40	200	24.5
	14	14.15:00	37' 10.12	26' 16.24	14.18:24	37' 14.58	26' 25.63	500	183	4096	40	200	24.5
	15	14.18:24	37' 14.58	26' 25.66	14.55:36	36' 26.66	30' 41.43	500	183	4096	40	200	24.5
	16	14.55:36	36' 26.67	30' 41.47	15.00:02	36' 20.09	30' 18.47	500	183	4096	40	200	24.5
	17	15.00:03	36' 20.10	30' 18.89	15.27:34	37' 00.41	26' 19.06	500	183	4096	40	200	24.5
	18	15.27:34	37' 00.41	26' 18.48	15.32:30	36' 42.86	26' 11.14	500	183	4096	40	200	24.5
	19	15.32:30	36' 42.88	26' 11.17	15.42:13	36' 30.92	27' 10.48	500	183	4096	40	200	24.5
	20	15.42:13	36' 30.92	27' 10.55	15.56:12	36' 03.74	25' 33.01	500	183	4096	40	200	24.5
	21	15.56:12	36' 03.72	25' 32.95	16.09:27	36' 28.32	26' 41.00	500	183	4096	40	200	24.5
	22	16.09:27	36' 28.34	26' 41.03	16.20:20	37' 21.66	26' 23.84	500	183	4096	40	200	24.5
	23	16.20:20	37' 21.69	26' 23.89	16.31:10	37' 09.20	27' 35.13	500	183	4096	40	200	24.5

27/03/2003	1	11.03:35	39' 01.35	19' 24.76	11.58:50	37' 18.82	27' 22.62	500	183	4096	40	200	24.5
	2	11.58:51	37' 18.77	27' 22.66	12.03:00	37' 05.84	27' 53.66	500	183	4096	40	200	24.5
	3	12.03:00	37' 05.81	27' 53.68	12.35:46	36' 12.40	32' 32.02	500	183	4096	40	200	24.5
	4	12.35:46	36' 12.40	32' 32.05	12.39:00	36' 08.44	32' 23.24	500	183	4096	40	200	24.5
	5	12.39:00	36' 08.43	32' 23.21	12.52:25	36' 20.37	30' 59.52	500	183	4096	40	200	24.5
	6	12.52:25	36' 20.38	30' 59.50	12.56:00	36' 09.97	31' 07.65	500	183	4096	40	200	24.5
	7	12.56:00	36' 09.96	31' 07.69	13.09:41	35' 54.02	32' 59.78	500	183	4096	40	200	24.5
	8	13.09.41	35' 53.98	32' 59.80	13.13:40	35' 49.57	32' 51.16	500	183	4096	40	200	24.5
	9	13.13:40	35' 49.55	32' 51.13	13.15:09	35' 51.66	32' 44.95	500	183	4096	40	200	24.5
29/03/2003	1	13.08:30	37' 11.60	28' 05.84	13.16:16	37' 26.73	27' 49.05	500	183	4096	40	200	24.5
	2	13.16:16	37' 26.73	27' 49.08	13.40:55	37' 39.59	31' 43.11	500	183	4096	40	200	24.5
	3	13.40:55	37' 39.61	31' 43.15	13.46:00	37' 44.78	31' 23.33	500	183	4096	40	200	24.5
	4	13.46:00	37' 44.75	31' 23.31	14.25:55	37' 29.11	26' 51.84	500	183	4096	40	200	24.5
	5	14.25:56	37' 29.09	26' 51.78	14.29:00	37' 35.01	27' 02.10	500	183	4096	40	200	24.5
	6	14.29:00	37' 35.01	27' 02.14	15.01:04	37' 49.75	31' 47.60	500	183	4096	40	200	24.5
	7	15.01:04	37' 49.75	31' 47.68	15.06:41	37' 56.45	31' 43.05	500	183	4096	40	200	24.5
	8	15.06:41	37' 56.44	31' 43.02	15.46:15	37' 40.32	26' 32.25	500	183	4096	40	200	24.5
	9	15.46:15	37' 40.32	26' 32.22	15.50:01	37' 46.82	26' 50.76	500	183	4096	40	200	24.5
	10	15.50:01	37' 46.82	26' 50.79	16.31:12	38' 01.76	31' 49.72	500	183	4096	40	200	24.5
16/04/2003	1	10.18:18	44' 33.43	35' 28.11	11.54:46	46' 11.89	27' 25.58	500	183	4096	n/a	n/a	tbc
	2	11.56:49	46' 21.24	27' 27.49	13.00:16	45' 28.16	36' 04.30	500	92	2048	n/a	n/a	tbc
	3	13.03:04	45' 23.57	36' 29.25	14.38:38	46' 27.47	27' 28.64	500	107	1024	n/a	n/a	tbc
	4	14.39:23	46' 23.58	27' 28.28	17.12:04	44' 48.29	27' 20.33	500	92	2048	n/a	n/a	tbc
17/04/2003	1	08.45:21	44' 25.08	27' 23.02	11.44:51	46' 48.09	31' 30.18	500	122	2048	n/a	n/a	tbc
18/04/2003	1	09.53:23	45' 40.66	24' 45.22	12.22:45	44' 52.65	33' 12.22	500	122	2048	n/a	n/a	tbc
21/04/2003	1	10.08:28	45' 37.60	36' 08.71	12.16:13	47' 29.67	28' 40.12	500	122	2048	n/a	n/a	tbc
	2	14.29:11	46' 06.39	36' 18.54	16.14:59	46' 29.36	31' 16.09						
22/04/2003	1	08.01:33	44' 11.57	25' 07.96	13.10:15	46' 01.85	35' 06.95	500	92	2048	n/a	n/a	tbc
	2	16.16:57	44' 17.62	31' 34.09	16.45:47	43' 15.86	29' 00.19	500	92	2048	n/a	n/a	tbc
24/04/2003	1	08.26:36	47' 05.88	26' 35.23	10.04:30	45' 15.70	38' 03.72	500	92	2048	n/a	n/a	tbc

A.7.5.1 Line data archive

All the data acquired during the survey was recorded onto the acquisition hard drive, with daily back-ups on 2Gb Jaz disks. Subsequently, back at Imperial, all data was transferred to PC computer Arun 1 and thereafter on DDS4 Dat tapes.

A.7.6 Data Processing

Due to the combined profiler system, the acquisition software records the data into a MUSE SEG-Y format – containing two channels of side-scan sonar, two channels of chirp seismic and one channel which can be used to record audio commentary. The data is of variable length because the number of samples for the chirp is different from the side-scan sonar, so standard SEG-Y programs cannot view the data. Because of this unusual format, there are a limited number of ways to extract the data for further analysis, since the GeoAcoustics package is designed for all data manipulation to be done on the GeoPro. To date (May, 2003) there are three known means of extracting the data: a) write a program that takes the number of samples in the header and extracts the data; b) use SonarWeb which can extract the side-scan and chirp separately, creating a swath and co-incident links between the data or c) ProMAX 2003 (vers 2.0 or later) which can separate the data using a couple of tweaks.

Since the chirp seismic will be analysed and compared with the boomer seismic, it was decided to use the ProMAX software. Extraction of the data is via SEGY Import and then an IF statement. As previously mentioned, although all the data is combined into one file, the different aspects are indicated by a change in certain header values. Knowing that this information is contained within byte 181 of the header that ProMAX can read, allows the data to be split into five parts: a) Header = 0, b) Header = 256, c) Header = 512, d) Header = 768 and e) Header = 1024. Parts where the header is zero or 256 contain side-scan data, 512 and 768 contain the chirp seismic data. Processing of the side-scan sonar will be similar to that undertaken with the multibeam, mosaicing of the data, removal of noise and potential use of statistical analysis.

The Chirp seismic data is different from conventional seismic in that it has only one trace per shot, so the scope of data processing is significantly reduced. However, a very important detail with the data collected using the towed, submerged fish is the removal of the towed depth. This should move the data to an equal plane, with the seabed and its correct depth. Further data analysis will concentrate upon trying to remove the multiples, to ascertain whether any information from deeper in the seabed can be observed/analysed.

The processing software with the chirp/side-scan acquisition computer is limited in its capabilities, hence the required splitting of the data.

A.7.7 Data Examples

Examples of side-scan sonar imagery are shown in Fig. A-49 and Fig. A-50.

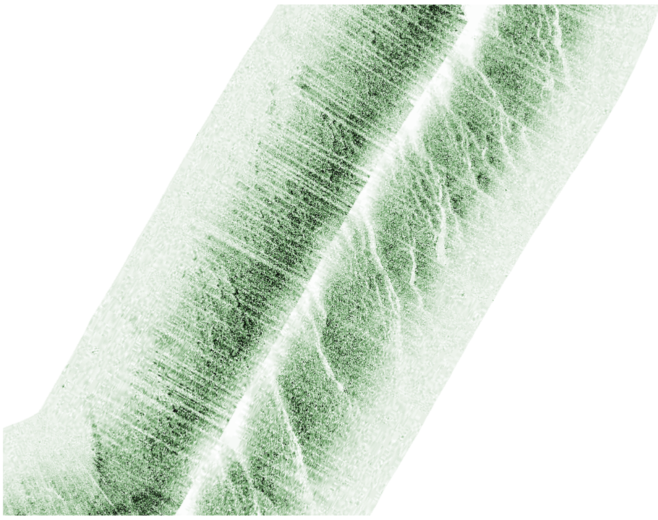


Fig. A-49. Example of side-scan data over bedrock. Image can be compared to Fig. A-37.

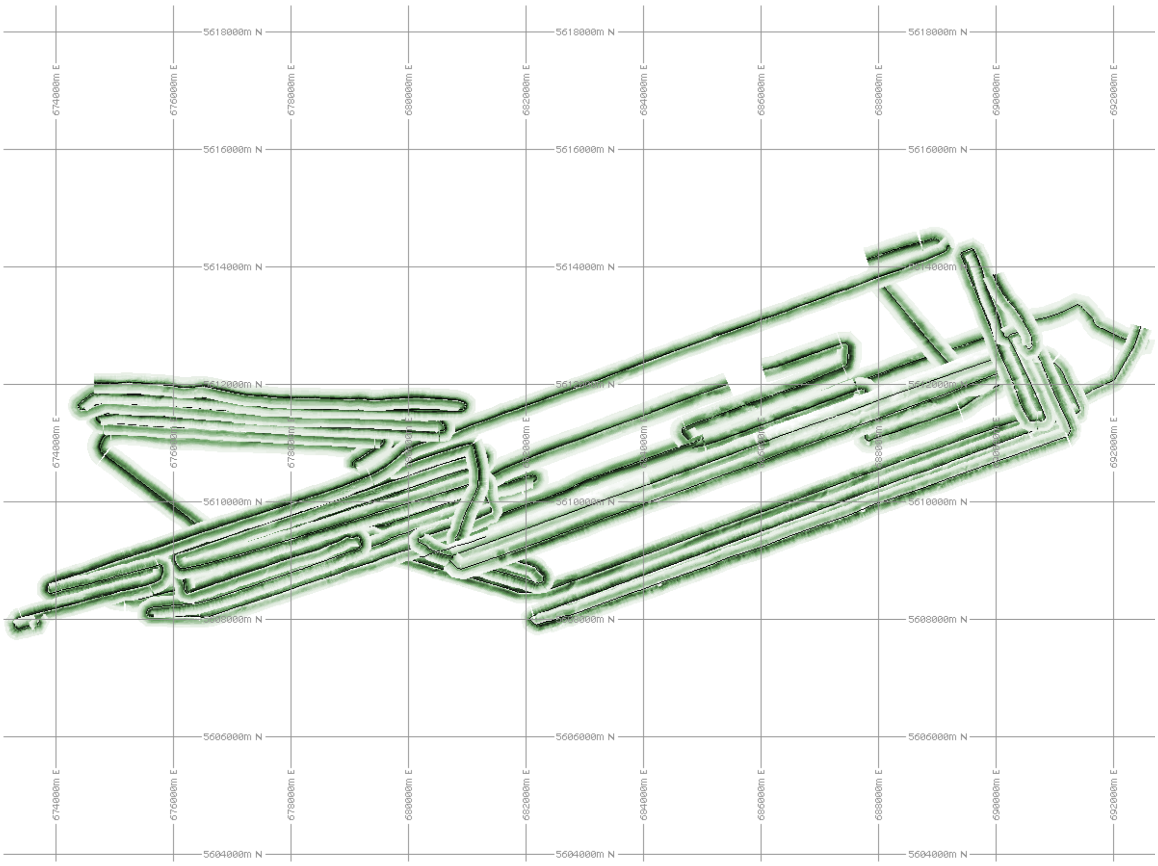


Fig. A-50. Mosaic of side-scan data acquired during multibeam survey.

A.8 BOOMER SEISMIC

A.8.1 Overview

Since the majority of the Arun palæo-river system is infilled, accurate crustal imaging is required to fully investigate the evolution of the river meanders. The second part of the survey, therefore, comprised a detailed 2D seismic survey, covering an area from the southern part of the multibeam grid to within 1 nautical mile of Littlehampton port.

The boomer seismic equipment comprises an Applied Acoustics catamaran with the boomer plate, a 90m (60m active) multichannel streamer, a capacitor charging unit, a Strataview seismograph and an acquisition computer with dual DDS-4 tape drives, running Geometrics seismic controller software under Windows NT.

A.8.2 Theory of Operation

The boomer consists of an electrical coil which is magnetically coupled to the plate, sitting behind a rubber diaphragm. Energy contained in the capacitors is discharged into the coil, causing induced currents in the plate which result in an outward force. The rubber diaphragm forces the plate back slowly against the coil after each repulsion, creating the source signal.

This signal is then transmitted through the water, sediment etc as per usual seismic operations. The signal is then recorded on the multichannel streamer which transfers the signal through the seismograph. The seismograph continually measures the variation in pressure (and therefore signal) along the entire streamer. This information is then relayed to the PC running the acquisition software. The data is recorded in SEG-D format (8058, revision 1) onto DDS-4 tapes, usually in a dual configuration, so that backups are automatically created.

The trigger (in this survey, the chirp deck unit) causes the capacitor to discharge and the boomer to ‘fire’. At the same instant, the Strataview seismograph takes a snapshot of the pressure variations along the streamer and relays it to the acquisition computer. There is a slight delay between the shot and the recording of the data, however this is minimal.

The basic configuration of the boomer system is shown in Fig. A-51.

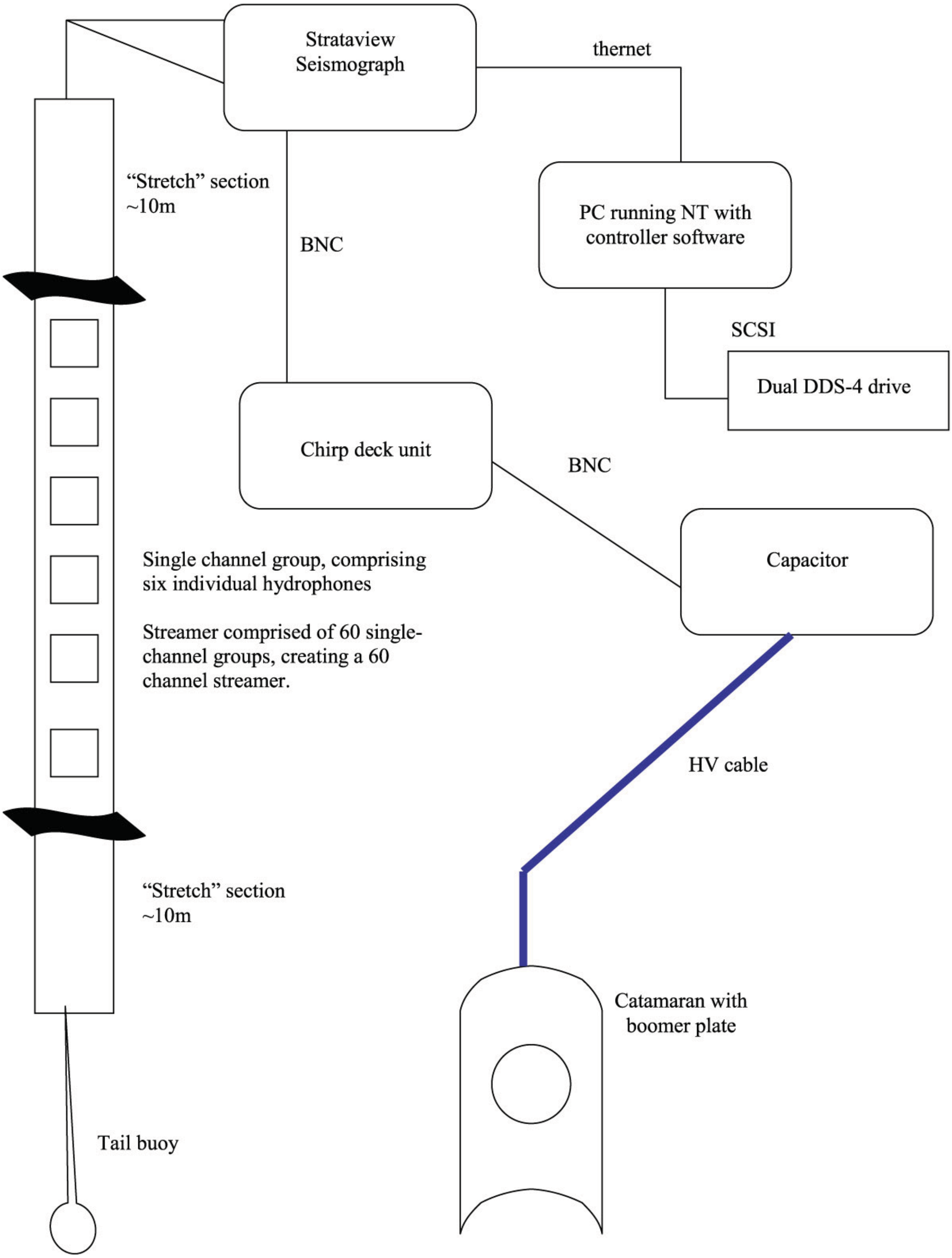


Fig. A-51. Basic boomer seismic configuration, shown with chirp deck unit as trigger system.

A.8.3 Technical Specification

The boomer plate can disperse a maximum of 300J a shot at 2 pulses/second. This approximately corresponds to a 0.5 – 3 kHz sweep over 400 µs and a maximum resolution of 75cm and penetration of 70m. The catamaran and boomer system are shown in Fig. A-52 and Fig. A-53.

Fig. A-52. Catamaran with boomer plate in the centre. Blue cable is the HV as indicated in Fig. A-51.

The streamer has an observed frequency limit of 5/6 kHz, with signals being resolved around the 70Hz limit at the lower end.

Fig. A-53. Streamer flaked on Xplorer back deck.

The acquisition computer runs NT with a fast SCSI interface to dual DDS-4 tapes, these have a native 20 Gb capacity, with the number of shots varying with shot interval, sample length and sample rate.

A.8.4 Data acquisition

A.8.4.1 Daily progress reports

Reports detailing the acquisition, weather, personnel and equipment reliability were detailed in individual daily reports for the boomer seismic survey.

A.8.4.2 Navigation

As with the chirp/side-scan survey, the navigation during the boomer survey was recorded on the GeoPro as raw NMEA strings and via Burden's NavMaster program which took readings from the DGPS every 10 seconds.

Unlike the multibeam survey, no software-based mapping was used for line planning, or monitoring. Planning was done on sheet charts of the area, with lines approximated on Burden's NavMaster software. Whilst this was good, there was no helmsman's display to indicate how far off line the ship was, and a line database could not be created.

Navigation for the seismic is not recorded within the headers, resulting in the GeoAcoustics GeoPro running and recording the navigation separately. Unfortunately it is not possible to link the triggering with the navigation, so up to 0.5s delay might exist within the data.

A.8.4.3 Weather

The boomer seismic equipment was more weather dependent than the other geophysical equipment, which made the weather predictions and conditions crucial to the data quality recorded. Although the Met Office reports were monitored via the web and collected daily from Brighton Marina, conditions out at the survey area were often different. Hence steaming out was often the only way to be sure of what the conditions were actually like.

A.8.4.4 Acquisition testing

Initial acquisition used a sample rate of 125µs and a record length of 250ms. However, over the shallower portions of the grid, it was found that 62µs sample rate gave a better definition of the subsurface. Testing within the Solent indicated that for reliable triggering; only one shot per second could be achieved to allow the capacitor to charge up fully from the Xplorer's main generator, when coupled with the high sample rate and relatively long record length.

A.8.4.5 Online QC

Monitoring of the seismic data quality was limited due to limited computer power of the acquisition system. However, as shown in Fig. A-51, the acquisition screen does enable a degree of quality control. The pseudo-stacks formed from each shot give a general breakdown of overall seismic quality; whilst the shot record and frequency plots for each channel enable individual channels to be monitored.

A.8.4.6 Time Analysis

Fig. A-54 illustrates the breakdown of the daily survey time according to days, assuming a minimum of 10 hours/day for weather downtime. Transit to and from the survey site is counted as "at sea passage" since this varied considerably depending on weather, time and fuel situation. In general there was a 50:50 split between data acquisition time and weather downtime, as indicated by Fig. A-55, with "at sea working" only comprising 36% of the entire survey time.

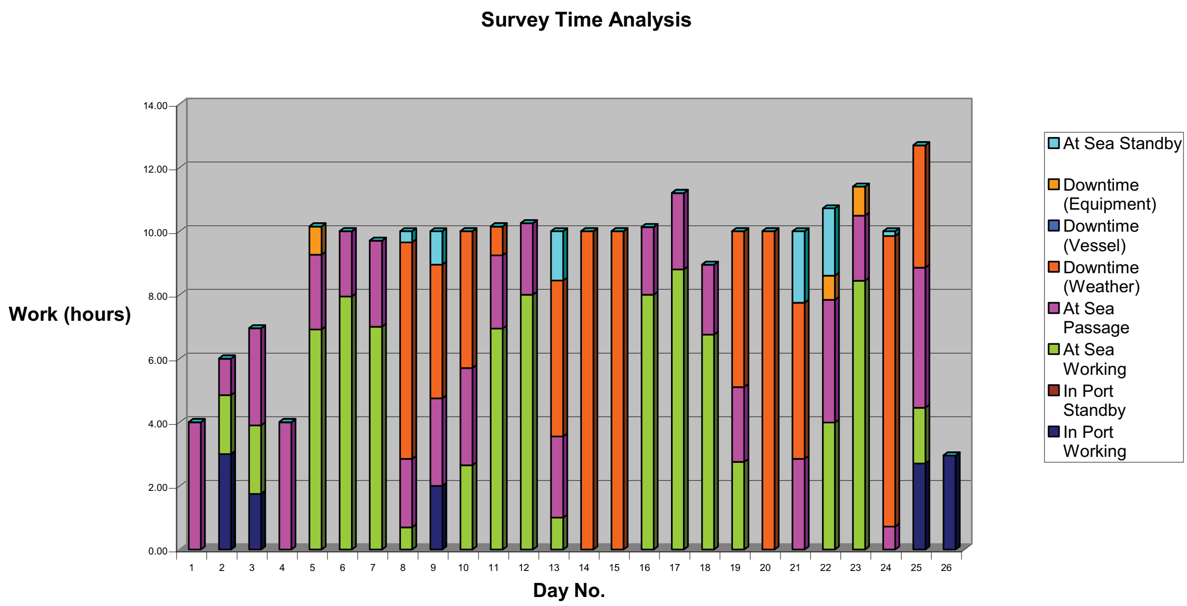


Fig. A-54. Daily survey time analysis for boomer survey.

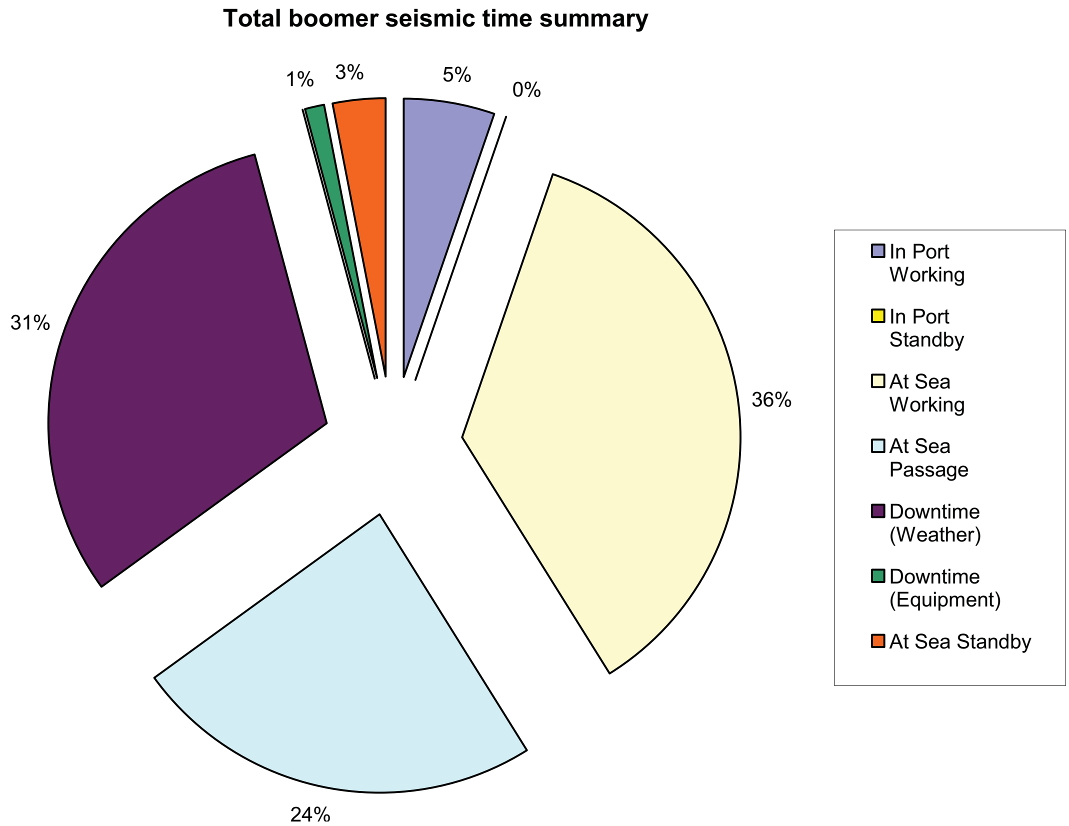


Fig. A-55. Survey time analysis for entire boomer survey.

A.8.4.7 Equipment performance

The only major problem during the survey, apart from the weather was the failure of one tape drive at the end of the survey. This meant that 3 days' worth of surveying currently has no back-up. An intermittent failure of the chirp deck unit to fire every second also caused problems, with the cause still unclear.

A.8.5 Survey Data

Overall out of 23 days surveying, approximately 86 hours of boomer seismic acquisition was achieved, roughly 650km of seismic. The final track plot, shown in Fig. A-56 includes all data, though there is some overlap where weather conditions worsened and its affect on the data quality is not yet fully explored. Table 8.1 gives a full breakdown of all acquisition parameters during the acquisition of all the IC Arun survey boomer seismic data.

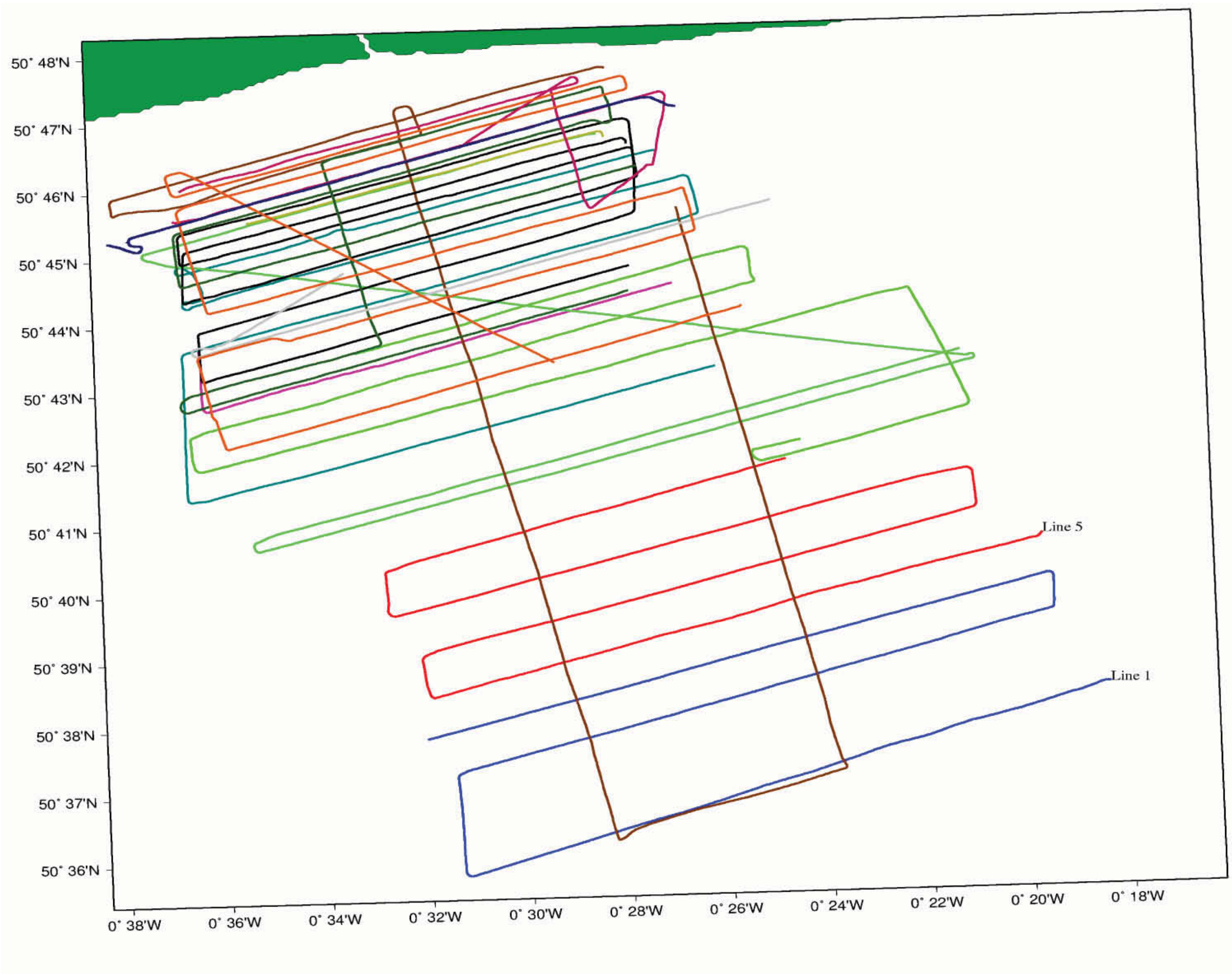


Fig. A-56. Boomer seismic track plot Colours indicate individual day's acquisition: 4/4/03 blue; 5/4/03 red; 6/4/03 green; 9/4/03 purple; 10/4/03 turquoise; 11/4/03 light green; 12/4/03 light brown; 15/4/03 brown; 16/4/03 black; 17/4/03 dark green; 18/4/03 light purple; 21/4/03 maroon; 22/4/03 orange; 24/4/03 dark blue. Lines 1 and 6 are indicated for general reference only, the dense survey over the in-filled valley make numbering impossible.

A.8.5.1 Line data archive

As mentioned above, apart from the final three day's worth of data, all data was dual copied on DDS4 Dat tapes during each acquisition day. One copy is stored in RSM Rm 3.42 (Hess, 3D Seismic Geoscience) and another in RSM Rm 3.37 (Dr J. Collier's office).

Table A-18. List of full boomer seismic survey acquired during April 2003.

Date	Line No.	Start time	Shot No.	Start Lat 50˚ N	Start Long 0˚ W	End time	Shot No.	End Lat 50˚ N	End Long 0˚ W	Sample rate (µs)	Duration (ms)	Weather conditions
04/04/2003	1	09.44:06.47	740	38.39631010	18.42347430	12.17:25.17	9553	35.76454390	31.16903060	125	250	Okay
	2	12.19:17.77	9554	35.83540790	31.34433220	12.34:17.89	10433	37.16149400	31.42395330	125	250	Okay
	3	12.35:37.25	10434	37.26372750	31.39866510	14.41:39.62	17992	39.49606530	19.49642060	125	250	Okay
	4	14.42:35.37	17993	39.52742270	19.43312980	14.48:34.47	18340	39.93748300	19.41401470	125	250	Okay
	5	14.50:39.15	18341	40.02771870	19.57157330	16.10:44.09	23143	37.76372500	32.21990040	125	250	Okay
05/04/2003	6	09.09:12.00	1	40.57811480	19.66427440	11.45:05.31	9298	38.42809850	31.76568850	125	250	Moderate, swell incr
	7	11.46:57.00	9299	38.46856090	31.93005300	11.52:05.99	9608	38.91744570	32.04387120	125	250	Moderate, swell incr
	8	11.54:34.00	9609	39.08042100	31.86127010	13.25:32.62	14939	41.01383350	21.04117640	125	250	Moderate, swell incr
	9	13.27:27.00	14940	41.09932320	20.89342970	13.31:55.39	15209	41.45814420	20.93725390	125	250	Moderate, swell incr
	10	13.34:38.00	15210	41.61492050	21.11619580	14.45:42.83	19436	39.66834470	32.39151080	125	250	Moderate
	11	14.48:07.00	19437	39.71627060	32.70820580	14.54:51.48	19752	40.21347730	32.72637850	125	250	Moderate
	12	14.57:30.00	19753	40.32709960	32.60705900	16.30:50.14	25350	41.83989570	24.59794370	125	250	Moderate
06/04/2003	13	10.02:00.00	1	42.09514260	24.43863400	10.11:44.40	580	41.96968320	25.28099990	125	250	Okay to moderate
	14	10.11:55.00	581	41.96587170	25.29620410	10.15:34.09	798	41.82637190	24.99132670	125	250	Okay to moderate
	15	10.15:43.00	799	41.83009650	24.96711530	10.41:00.03	2315	42.53734190	21.03713760	125	250	Okay to moderate
	16	10.43:33.00	2316	42.71766310	21.01757060	11.06:50.47	3712	44.29714510	22.06338810	125	250	Okay to moderate
	17	11.09:00.00	3713	44.28907150	22.26802310	13.11:41.87	11022	41.85590130	36.30451830	125	250	Okay to moderate
	18	13.13:58.00	11023	41.98918150	36.48339510	13.17:59.54	11265	42.31957240	36.52861370	125	250	Okay to moderate
	19	13.19:26.00	11266	42.37976810	36.42885330	15.35:30.94	19396	44.46159810	25.18133820	125	250	Okay to moderate
	20	15.37:09.00	19397	44.55422760	25.19949040	15.42:33.00	19720	44.92730160	25.25538940	125	250	Okay to moderate
	21	15.44:52.00	19721	44.96245680	25.54325280	16.36:30.00	22812	43.52869430	33.33405960	125	250	Okay to moderate
09/04/2003	22	09.18:53:00	1	44.43795510	27.02823150	10.38:46.00	4778	42.74518360	36.13638660	125	250	Okay
	23	10.40:55.00	4779	42.85638150	36.26120400	10.52:46.92	5491	43.76622970	36.24075600	125	250	Moderate
	24	10.54:14.00	5492	43.81285090	36.07061910	11.08:21.59	6339	44.08053350	34.35853990	125	250	Rapid decrease
10/04/2003	25	08.48.55:00	1	45.25378750	27.47914210	08.56:30.07	456	45.09396550	28.44170350	62.5	125	Moderate to okay
	26	09.46:18.00	457	46.43378480	27.21116350	11.06:23.00	5246	44.37920250	31.30117290	62.5	125	Moderate to okay
	27	11.11:11.00	5247	44.31319520	30.70954590	11.15:51.32	5528	44.24563960	30.13256200	62.5	125	Okay to good
	28	11.22:41.00	5529	44.15034270	29.28385560	12.33:27.00	9747	46.06167850	26.52366430	62.5	125	Okay to good
	29	12.35:28.00	9748	45.96318070	26.35167500	12.40:08.92	10029	45.58542290	26.23104920	62.5	125	Okay to good
	30	12.42:25.00	10030	45.47195830	26.35030250	14.17:35.00	15703	43.62138150	36.55363300	62.5	125	Okay to good
	31	14.19:41.00	15704	43.48429170	36.63301410	14.46:22.70	17304	41.45608590	36.61430380	62.5	125	Okay to good
	32	14.48:17.00	17305	41.41517190	36.42290900	16.17:00.70	22618	43.24623180	25.92311650	62.5	125	Okay to good
11/04/2003	33	09.10:42.00	2	46.69910610	28.46276940	10.15:40.63	3778	45.10440090	37.33134450	62.5	125	Okay to good
	34	10.21:03.00	3779	44.92846480	36.83379300	12.27:15.62	11326	43.29338950	21.12135900	62.5	125	Okay to good
	35	12.32:42.00	11327	43.19074010	21.12175870	14.39:55.00	18934	40.65109450	35.18572330	62.5	125	Okay to good
	36	14.43:45.00	18935	40.83397550	35.12034040	16.30:39.00	25292	43.42154830	20.89074550	62.5	125	Okay to good
12/04/2003	37	10.01:25.00	1	46.73089100	28.30519020	10.53:05.00	3068	45.49469110	35.39497070	62.5	125	Poor

15/04/2003	38	08.38:46.00	1	47.69082060	28.22118230	09.46:33.00	4047	45.92488040	37.89026900	62.5	125	Moderate to okay
	39	09.50:59.00	4048	45.70347370	37.82209550	10.56:39.00	7979	46.77710540	31.70373380	62.5	125	Moderate to okay
	40	11.05:49.00	7980	47.01786480	32.19152700	13.26:45.39	16398	36.23831950	28.27615660	62.5	125	Moderate to okay
	41	13.30:38.00	16399	36.33376140	28.04404230	14.29.19:00	19915	37.19812640	23.72728580	62.5	125	Moderate to okay
	42	14.31:56.00	19916	37.36093050	23.77743260	16.22:23.00	26542	45.64740920	26.66481590	62.5	125	Moderate to okay
16/04/2003	43	08.33:17.00	1	46.32774210	28.11250170	09.56:53.00	4168	45.11779230	36.47954520	62.5	125	Good
	44	09.58:47.00	4169	44.97872510	36.54967400	10.06:18.00	4620	44.40118460	36.57821150	62.5	125	Good
	45	10.09:47.00	4621	44.41916580	36.29431440	11.52:52.00	10809	46.06761560	27.42577660	62.5	125	Good
	46	11.54:39.00	10810	46.18898450	27.42387460	12.04:13.00	11384	46.91281140	27.56041210	62.5	125	Good
	47	12.06:29.00	11385	46.90738960	27.91098330	13.03:33.25	14807	45.37946240	36.55815820	62.5	125	Good
	48	13.05:39.00	14808	45.21579100	36.63654780	13.08:38.00	14987	44.96148880	36.61486600	62.5	125	Good
	49	13.10:34.00	14988	44.95362230	36.44712880	14.37:21.00	20196	46.50312950	27.58626540	62.5	125	Good
	50	14.39:24.00	20197	46.39216200	27.47112360	14.48:36.00	20747	45.59397420	27.48088310	62.5	125	Good
	51	14.50:31.00	20748	45.49700730	27.68900920	15.50:36.00	24350	43.94016610	36.11644180	62.5	125	Good
	52	15.53:07.00	24351	43.79030230	36.28682370	15.59:25.04	24729	43.23291410	36.26115250	62.5	125	Good
	53	16.01:54.00	24730	43.22839310	36.01034370	17.11:49.54	28920	44.79860140	27.37410530	62.5	125	Good
17/04/2003	54	08.50:41.00	1	44.35763960	27.80148810	10.12:45.00	4905	42.74582650	36.52265260	62.5	125	Good
	55	10.17:13.00	4906	42.99080770	36.45018900	10.50:45.00	6918	43.75404050	32.67185270	62.5	125	Good
	56	10.52:28.00	6919	43.90203190	32.75977880	11.21:57.00	8688	46.36284540	33.68688110	62.5	125	Good
	57	11.24:53.00	8689	46.46601670	33.45744070	12.20:46.00	12042	47.40461910	28.04562810	62.5	125	Good
	58	12.23:05.00	12043	47.23888820	27.96191290	12.27:09.00	12287	46.92861220	27.87315090	62.5	125	Good
	59	12.30:56.00	12288	46.89644070	28.46036980	13.20:56.00	15286	45.40349360	36.64452590	62.5	125	Good
	60	13.23:08.00	15287	45.21887910	36.71156610	13.29:46.32	15685	44.64083460	36.63126660	62.5	125	Good
	61	13.32:56.00	15686	44.64656670	36.33844830	15.01:34.00	21002	46.26862310	27.21865940	62.5	125	Good
18/04/2003	62	09.55:22.00	1	45.64917030	24.89911660	11.33:40.00	5898	43.57058140	36.28206110	62.5	125	Moderate
	63	11.42:58.00	5899	43.76600140	35.74657840	12.15:10.00	7832	44.78192870	33.27666110	62.5	125	Rapid decrease
21/04/2003	64	10.06:05.00	1	45.58793990	36.50104720	11.12:25.00	3979	47.31799030	26.92123750	62.5	125	Moderate to okay
	65	11.17:52.00	3980	47.00260540	26.83180360	11.30:02.00	4710	46.25894750	27.06798420	62.5	125	Moderate to okay
	66	11.33:15.00	4711	46.16734490	27.29771570	11.48:27.00	5623	45.62435520	28.32925110	62.5	125	Moderate to okay
	67	11.50:57.00	5624	45.76275590	28.48140020	12.12:22.00	6904	47.50766390	29.09304240	62.5	125	Moderate to okay
	68	14.27:11.00	6905	46.06945710	36.45568620	15.50:45.00	11917	47.47928540	28.54306690	62.5	125	Moderate to okay
	69	15.54:04.00	11918	47.49754080	28.83353600	16.13:29.00	13084	46.46749160	31.14501140	62.5	125	Moderate to okay
22/04/2003	70	08.07:24.00	1	44.19857840	25.21038740	09.34:03.00	5199	42.18096430	35.75165600	62.5	125	Okay to good
	71	09.35:36.00	5200	42.27192250	35.84914610	09.50:49.00	6113	43.51496080	36.32082930	62.5	125	Okay to good
	72	09.52:33.00	6114	43.58343320	36.11559480	10.01:06.00	6627	43.81078820	34.86055950	62.5	125	Okay to good
	73	10.05:29.00	6628	43.82557800	34.20928490	10.54:38.00	9549	45.23664620	26.34506830	62.5	125	Good
	74	10.56:14.00	9550	45.35967680	26.31759780	11.02:36.00	9932	45.86280620	26.47759520	62.5	125	Good
	75	11.04:50.00	9933	45.84786470	26.67842130	12.40:53.00	15695	44.21016910	36.02072540	62.5	125	Good
	76	12.42:39.00	15696	44.31302720	36.13855250	12.58:40.77	16656	45.70435650	36.64174260	62.5	125	Good
	77	13.00:57.00	16657	45.81438370	36.38475380	14.08:59.00	20749	47.36512990	27.58928210	62.5	125	Good
	78	14.12:46.39	20750	47.55052770	27.78737920	15.15:19.12	24485	45.95804720	36.59844950	62.5	125	Good
	79	15.23:48.46	24486	46.27942260	36.40959220	16.45:04.56	29351	43.28999290	29.06703600	62.5	125	Good
24/04/2003	80	08.33:29	1	47.21419500	27.44721990	09.48:20.01	4489	45.39656500	37.37504250	62.5	125	Moderate to poor

A.8.6 Data Analysis

Data analysis of the seismic data will be undertaken within ProMAX with several aspects covered. Initially, the data will be accurately positioned in relation to DGPS records and the first 6 channels combined to form a pseudo-stack for initial interpretation. This should enable specific locations to be highlighted for future.

Online QC and processing was limited by the available software, however by taking one channel from every shot, the acquisition software could create pseudo-stacks that enabled some degree of artefact location and monitoring of weather/data quality issues. Fig. A-57 shows a screenshot over an infilled river system during good weather.

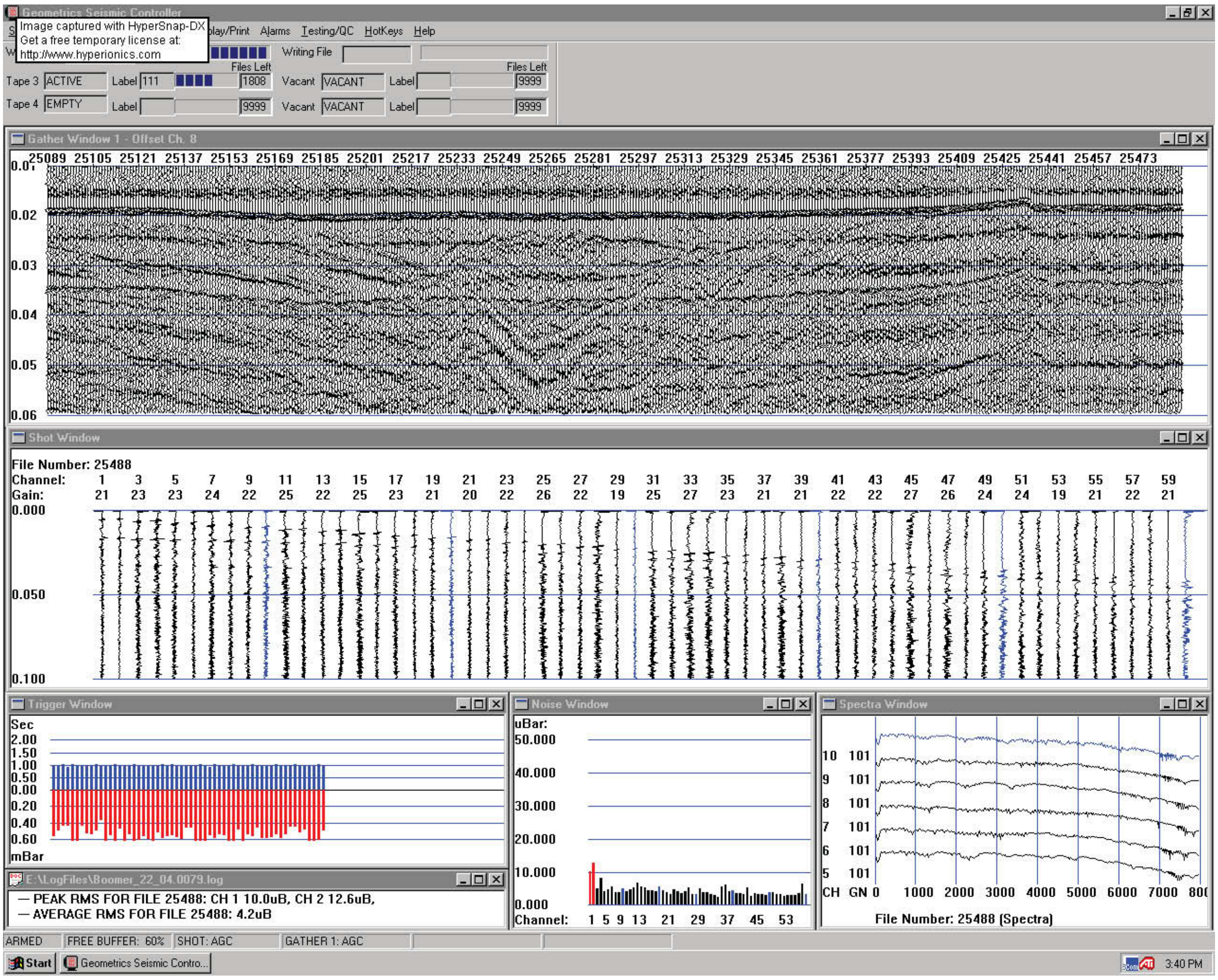


Fig. A-57. Screen-grab of data acquisition software. From top to bottom and left to right: Pseudo-stack, single channel from each shot positioned and showing river system infilled with possibly some earlier tectonic influence.

Appendix B

B Fieldwork Report: Vibrocore Survey of the palaeo-Arun Valley, 25th – 30th June 2003

B.1 INTRODUCTION

This report details the collection of vibrocores from the Arun Palaeovalley in the Northern English Channel. The swath bathymetry and seismic profiles already available for the study area provide an extensive dataset of the interpretation of the complex valley system. However, vibrocores give us an actual record of the sediment present beneath the sea floor. Furthermore, the coring provides an opportunity to retrieve sediments that could be used to date the fluvial, systems and thereby determine the timing of events within the system. Although a suite of vibrocores have been collected previously, the principle dating method to be employed – optically stimulated luminescence (OSL) dating – requires that the sediment not be exposed to light. Hence, these cores cannot be used as the have been contaminated by light since their collection. This vibrocore survey also allowed cores sites to be picked that would tie with the recently acquired boomer seismic data. The survey was conducted by Andrews Survey, aboard the Strilbas whilst under contract to Hanson Marine Aggregates Limited. A 65m hydraulic vibrocorer was used.

B.2 CORE SITE SELECTION

The location of the vibrocores were selected with three main objectives in mind and with the following priority:

- To obtain sand-dominated sediments to date with OSL dating.
- To obtain cores that are located with proximity to the boomer survey lines shot during the April 2003 geophysical survey to calibrate the dataset.
- To obtain cores that contain organic horizons (e.g. peat) that can be dated using radiocarbon dating.

For this 10 vibrocore sites were chosen (Table B-1) based on information gained from previous vibrocore surveys conducted by Hanson and UMA, and the associated seismic survey data. Four cores were chosen to target sand-dominated horizons, three cores were chosen to corroborate seismic profiles, and three cores were chosen to gain samples for organic horizons.

Table B-1. Position of vibrocores.

Core Name	Core type	Northings[a] (m)	Eastings[a] (m)	Latitude (degrees)	Longitude (degrees)
VC1	Sand 1	5614619	683942	50 39 15.6339 N	0 23 51.7907 W
VC2A	Sand 2	5614619	684062	50 38 58.3870 N	0 23 45.1044 W
VC3	Sand 3	5614410	681392	50 39 11.7529 N	0 26 1.8915 W
VC4	Sand 4	5616179	679252	50 40 11.3526 N	0 27 47.6812 W
VC5	Peat 1	5615067	678883	50 39 35.7955 N	0 28 8.39587 W
VC6	Peat 2	5614442	681710	50 39 12.4311 N	0 25 45.6569 W
VC7	Peat 3	5613138	687407	50 38 23.7621 N	0 20 58.2139 W
VC8	Seismic 1	5618257	679522	50 41 18.2618 N	0 27 30.3083 W
VC9	Seismic 2	5614922	681567	50 39 28.1160 N	0 25 52.0847 W
VC10	Seismic 3	5614424	683313	50 39 10.0410 N	0 24 24.1383 W

a – the easting and northing co-ordinates in Table B-1 refer to WGS84 co-ordinates, which was the requested configuration for the navigation software used by Andrews Survey. This was also converted to WGS84 latitude and longitude co-ordinates.

B.3 FIELDWORK

The fieldwork aboard the Strilbas was conducted from 25th – 30th June 2003. The coring in the Arun Palaeovalley started as 23:15 on Saturday 28 June, and took a total of eight hours, concluding at 07:15 on Sunday 29th June. A 6m hydraulic vibrocores was used to extract the cores, which was placed at the top of a metal frame with tripod leg support.

The coring process was conducted systematically by the following steps:

- Place a plastic core-liner within the steel core-barrel and secure in place. Fit the cutter and trap ay the base of the core.
- Secure the core-barrel to the vibrocorer at the head of the frame.
- Winch the frame to an upright position and place over the back of the ship.
- Once the ship is in the right position, winch the frame down to the seabed.
- With the frame on the seabed coring commences until the corer has penetrated 6m.
- The frame and core is then winched out of the sea bed and brought back to the surface and placed on the back of the ship for removal of the core-barrel from the vibrocorer.
- The coreliner is removed from the core-barrel and the liner is labelled and cut into one-metre lengths for easy handling.

Prior to the commencement of coring the core-liners to be used needed to be prepared. For OSL dating it is important to stop the sediments to be dated from being exposed to light. Consequently, the core-liners for cores VC1-VC4 were spray painted black on the outside to prevent light exposure of the sediments once that were extracted from the seabed. This was mostly successful although there was a tendency for the paint to be scraped off the core-liner during the coring process.

Of the 10 sites targeted, eight were successfully attempted and recovered. Two of the sites (VC 6 & VC7) were not attempted because of time and weather (tide) constraints. These two cores were deemed of lowest priority because they targeted peat horizons that could be accessed by vibrocores previously taken by Hanson Aggregates Marine Ltd. The following presents a summary of the initial results and actual position of the cores taken. The details of the location of the cores and the associated seismic stratigraphy are presented in Fig. B-1 to Fig. B-9.

Table B-2. Summary of initial vibrocore results

Core Name	Northings (m)	Eastings (m)	Recovery (m)	Sediment description
VC1	5614635	683923	4.5	Clay
VC2A	5614099	684062	1.5	Crs gravels at top, f-m sand
VC3	5614410	681384	5.0	f-m sand
VC4	5616185	679229	4.15	Very sandy (f-crs), gravel (f-m/crs)
VC5	5615055	678876	3.2	f-m gravely sand, no peat
VC6	Not cored	-	-	-
VC7	Not cored	-	-	-
VC8	5618257	679511	2.84	Top 1m gravely m-crs sand, f-m sand with organic staining
VC9	5614933	681571	4.44	Thin gravely sand veneer, above clay with 3 zones of organics
VC10	5614422	683299	4.43	Clay

B.3.1 Diary of Fieldwork

Wednesday 25 June

15:30 – Arrived at Newhaven Harbour for ship-to-shore transfer to Strilbas by pilot boat.

16:00 – Arrived on Strilbas, introduced to Captain and given safety briefing.

Thursday 26 June

09:00 – Preparation of core-liners for Arun Palaeovalley survey by painting them black on the outside.

12:00 – Awaiting the completion of coring work being conducted by Andrews Survey for other contracts before commencing work on the Imperial College cores.

Saturday 28 June

23:15 – Commence coring of Arun Palaeovalley sites.

Sunday 29 June

07:15 – Finish coring of Arun Palaeovalley sites, a total of 8 cores accomplished.

07:30 – Strilbas moves to next contract site and coring begins in the next area.

12:00 – Survey crew is on weather standby, sea conditions are too rough for coring of next site and transfer planned for later this evening is cancelled in favour of the following morning.

Monday 30 June

06:30 – Departed Strilbas for ship-to-shore transfer to Brighton Marina by pilot boat.

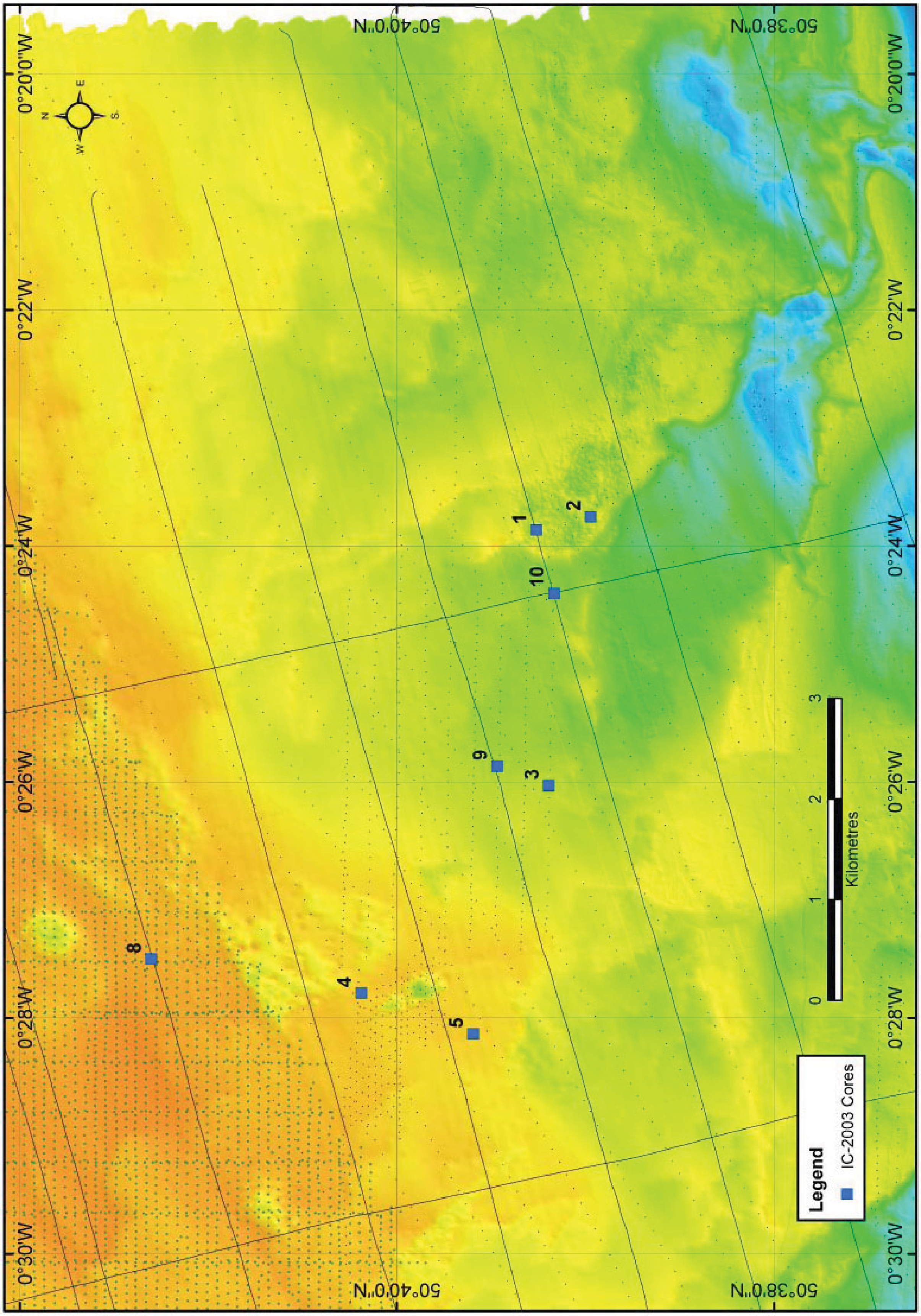
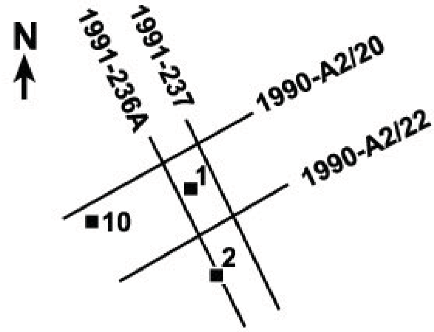
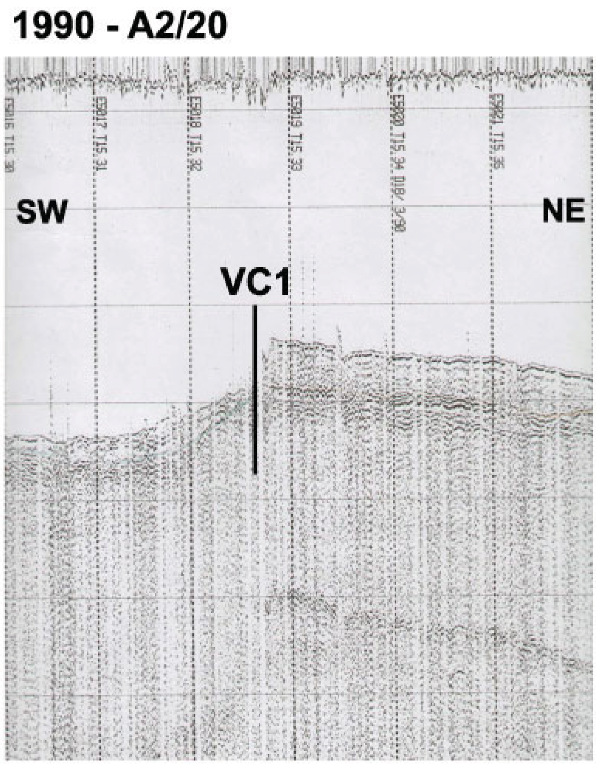


Fig. B-1. Position of virbrocores collected by Imperial College on June 29, 2003. Lines from industry seismic survey are shown for reference.

VIBROCORE 1

Position - 683923E 5614635N
Recover - 4.5m
Target - sandy lithology
Result - clay with thin gravel venner





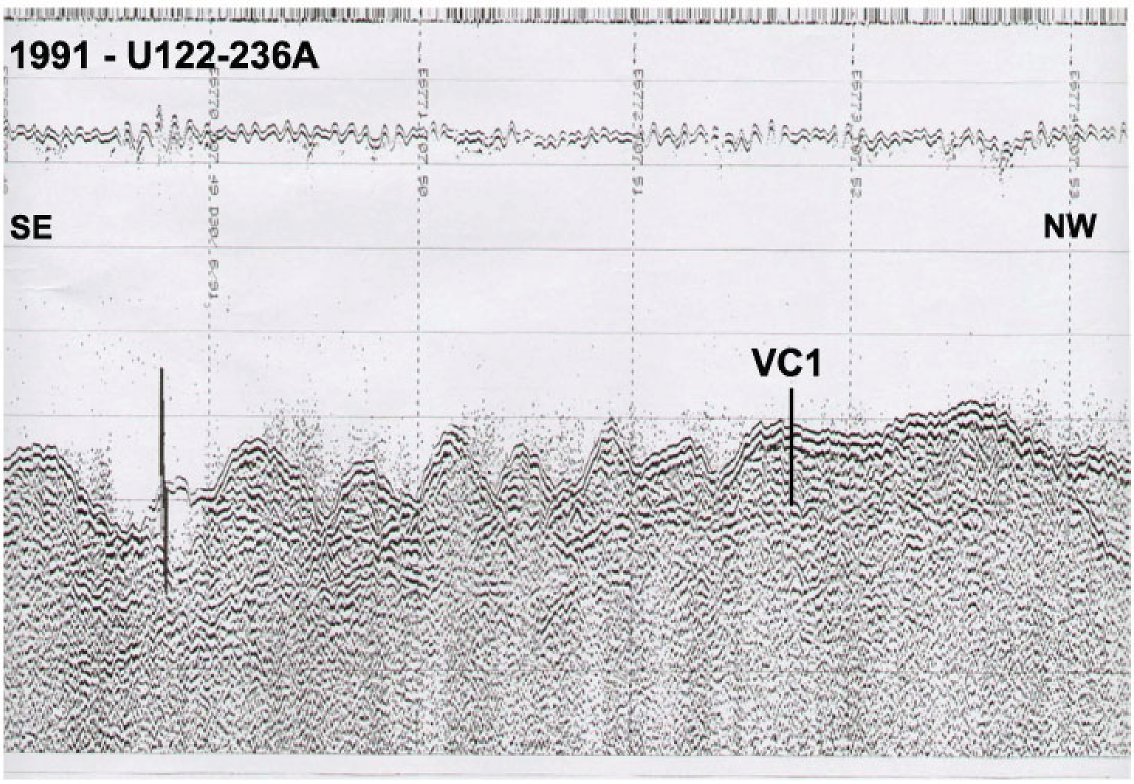
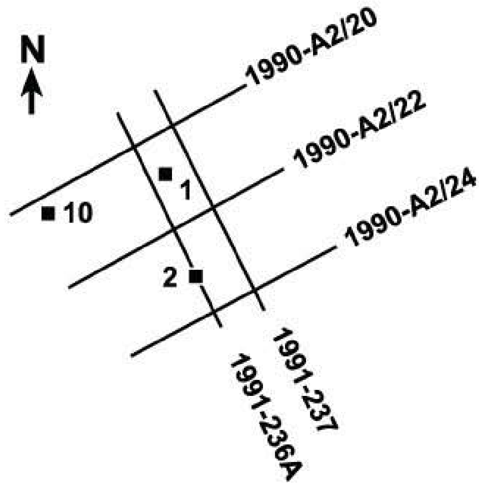


Fig. B-2. Stratigraphic position of Vibrocore 1 with reference to associated seismic profiles.

VIBROCORE 2A

Position - 684062E 5614099N
Recover - 1.5m
Target - sandy lithology
Result - coarse gravel venner overlying f-m sand



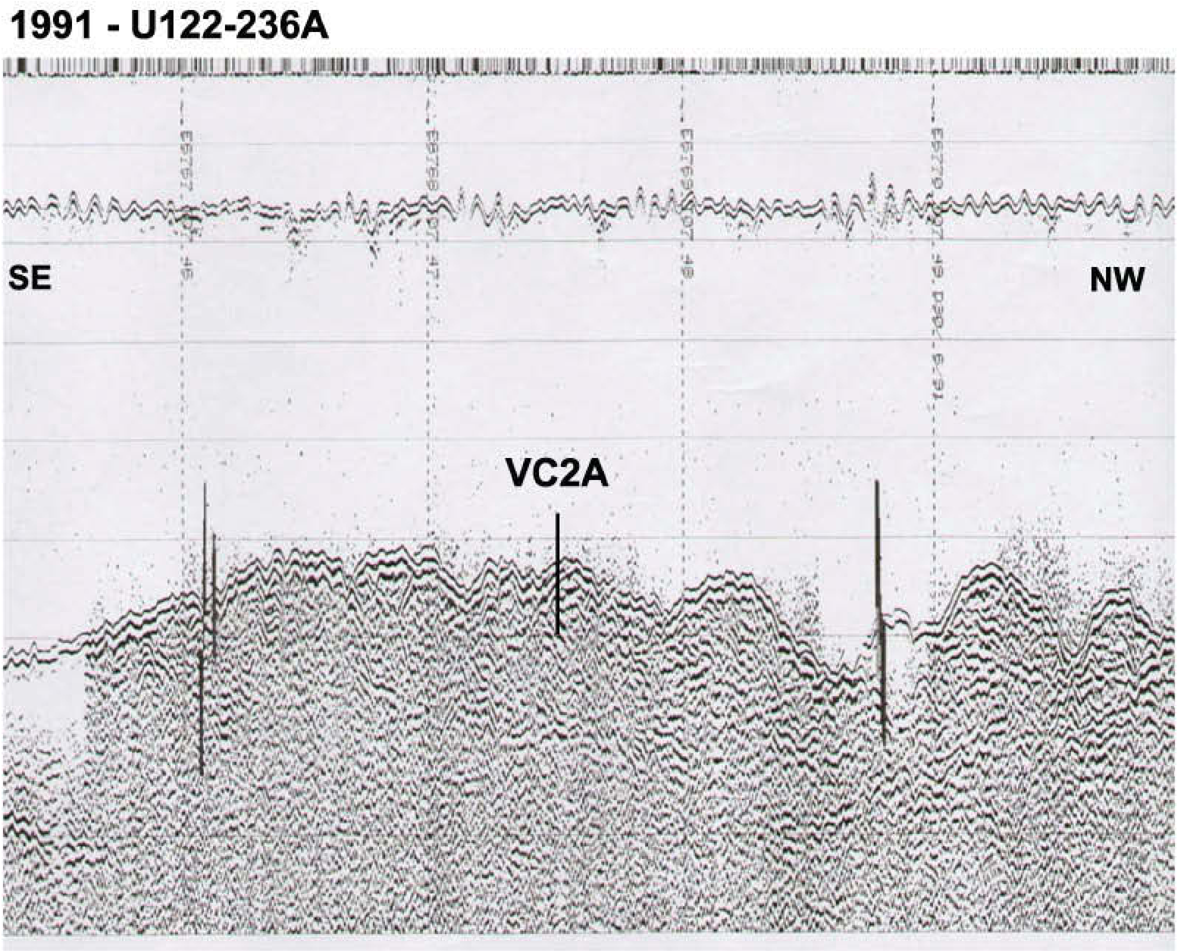
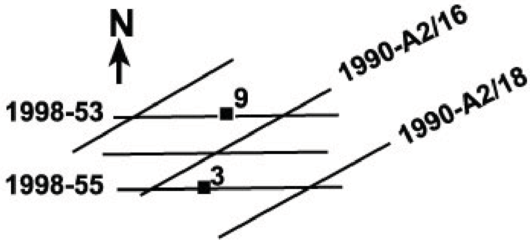


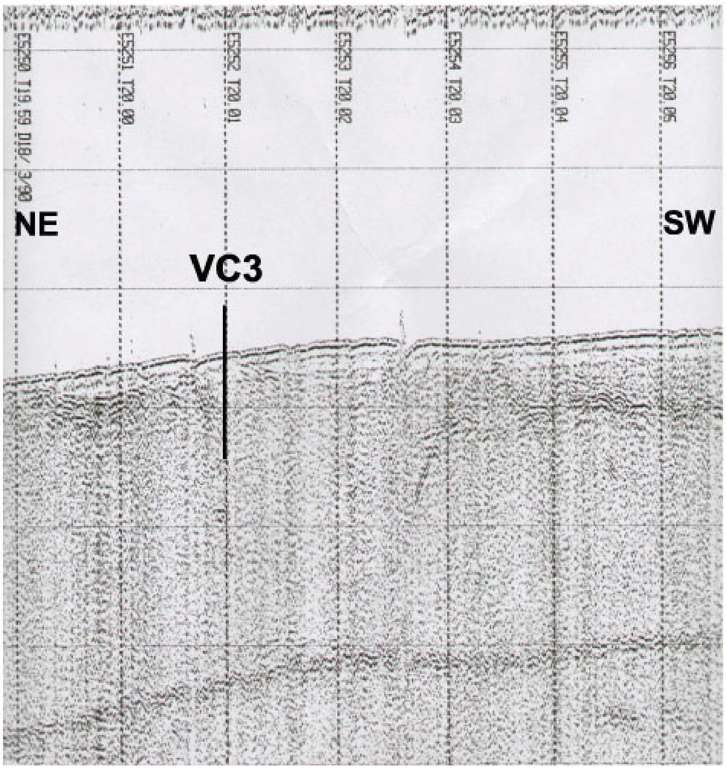
Fig. B-3. Stratigraphic position of Vibrocore 2A with reference to associated seismic profiles.

VIBROCORE 3

Position - 681384E 5614410N
Recover - 5m
Target - sandy lithology
Result - f-m sand with thin gravle venner



1990 - A2/16



1998 - Line 55

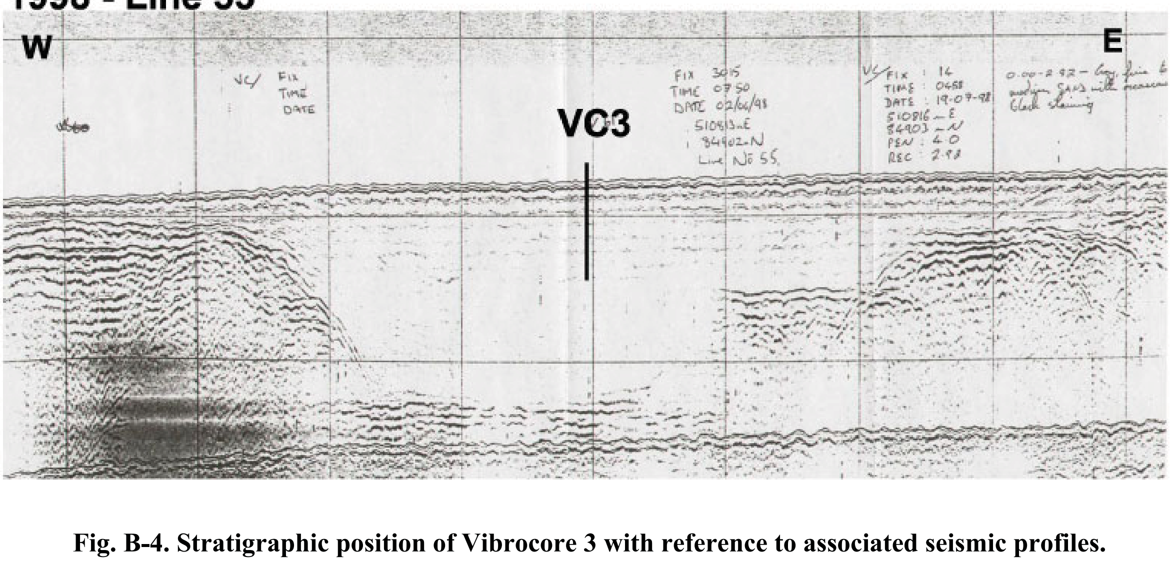
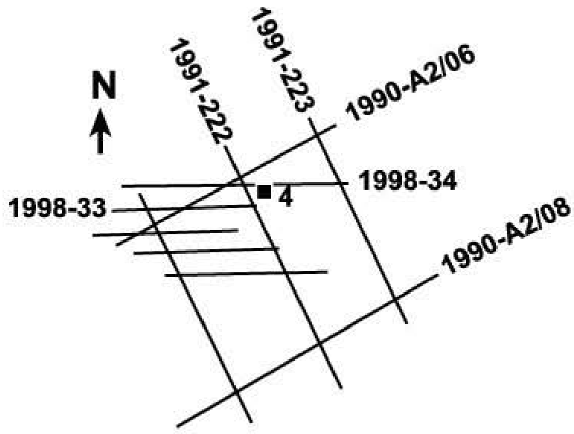


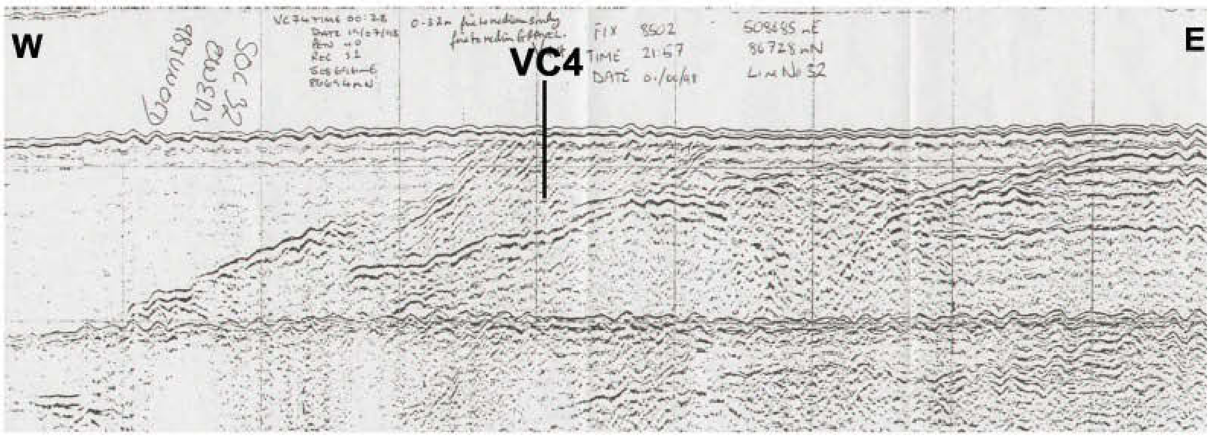
Fig. B-4. Stratigraphic position of Vibrocore 3 with reference to associated seismic profiles.

VIBROCORE 4

Position - 679229E 5516185N
Recover - 4.15m
Target - sandy lithology
Result - very (f-crs)sandy (f-m) gravel



1998 - Line 33



1991 - U122-222

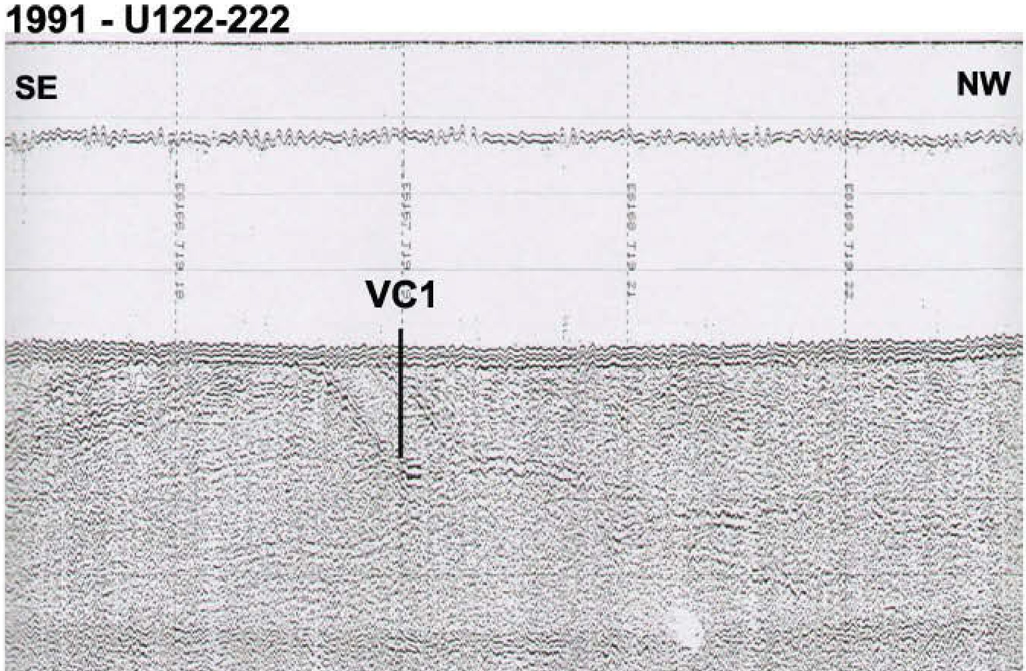
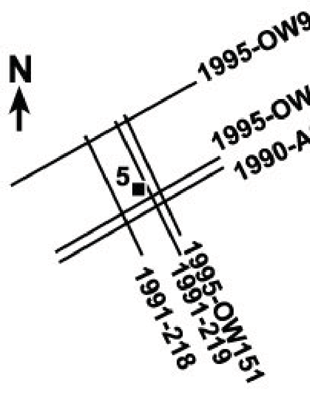


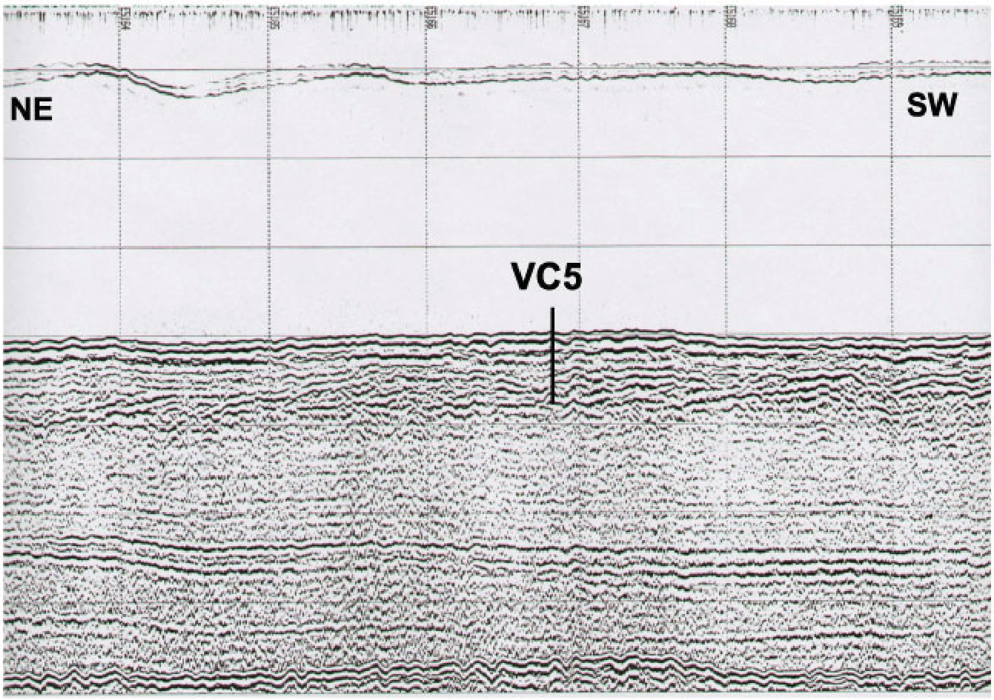
Fig. B-5. Stratigraphic position of Vibrocore 4 with reference to associated seismic profiles.

VIBROCORE 5

Position - 678876E 5615055N
Recover - 3.2m
Target - peat horizons
Result - f-m sand



1995 - OW96



1991 - U122-219

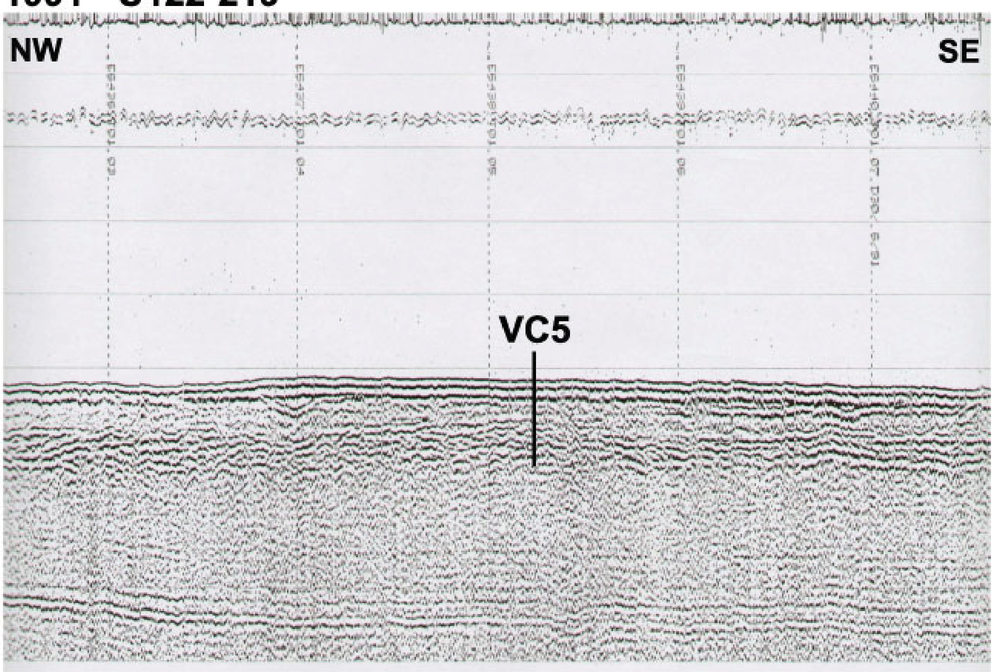
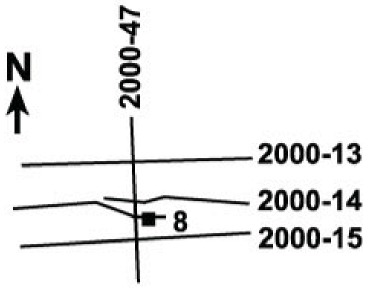


Fig. B-6. Stratigraphic position of Vibrocore 5 with reference to associated seismic profiles.

VIBROCORE 8

Position - 679511E 5618257N
Recover - 2.84m
Target - correlation with seismic profile
Result - top 1m gravelly m-crs sand, f-m sand with organic staining



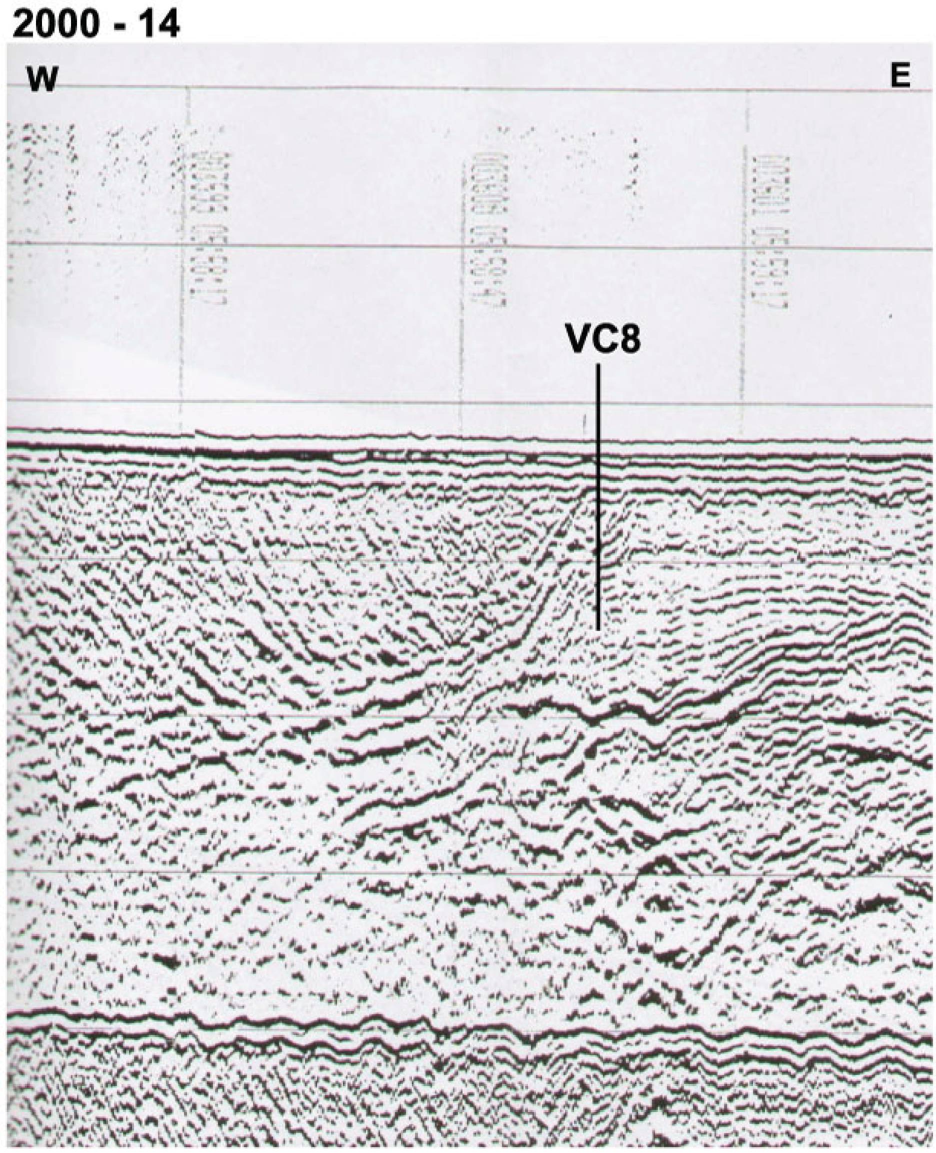
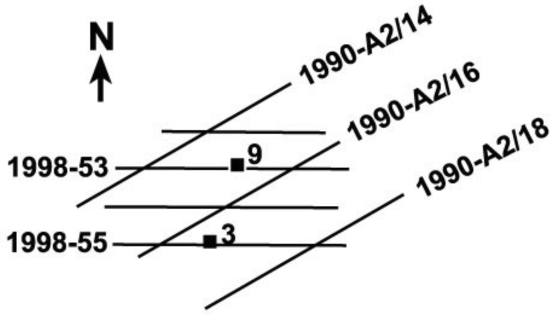


Fig. B-7. Stratigraphic position of Vibrocore 8 with reference to associated seismic profiles.

VIBROCORE 9

Position - 681571E 5614933N
Recover - 4.4m
Target - correlation with seismic profile
Result - clay with 3 zones of organic staining



1998 - 53

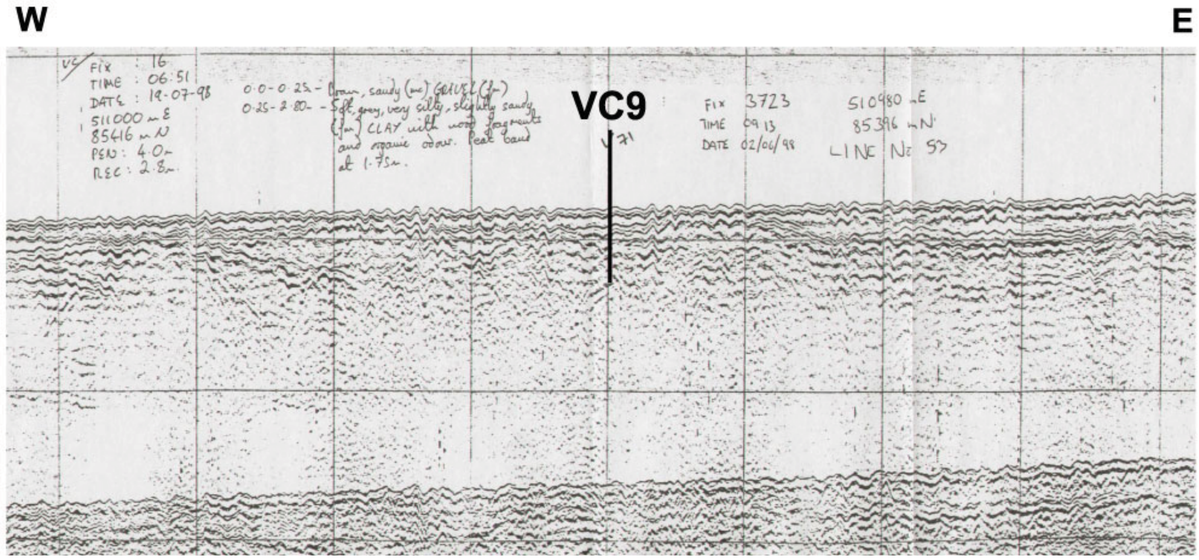
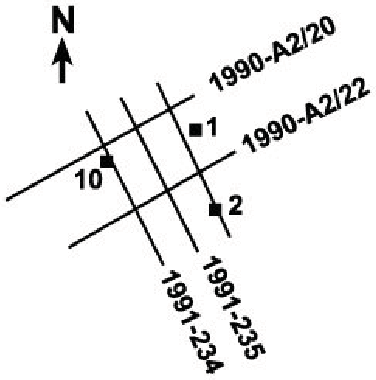


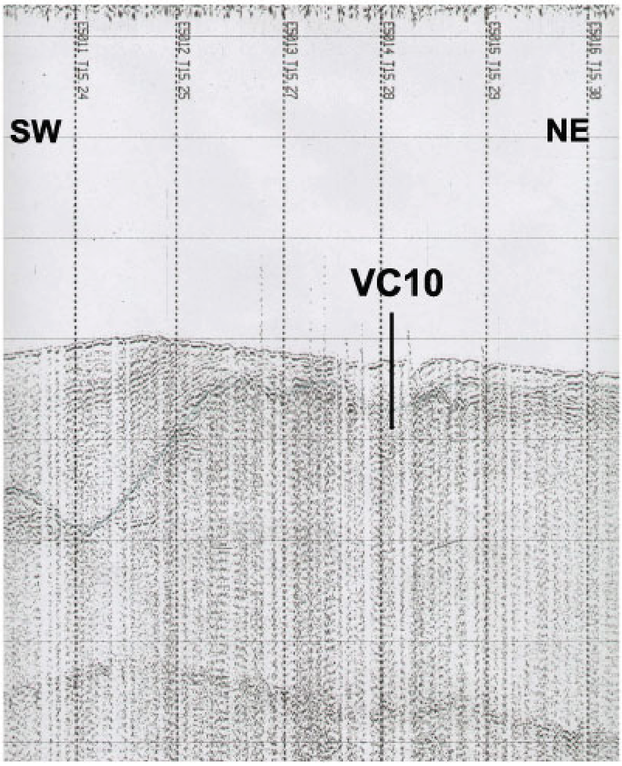
Fig. B-8. Stratigraphic position of Vibrocore 9 with reference to associated seismic profiles.

VIBROCORE 10

Position - 683299E 5614422N
Recover - 4.43m
Target - correlation with seismic profile
Result - clay with upper 1m sand dominated



1990 - A2/20



1991 - U122-234

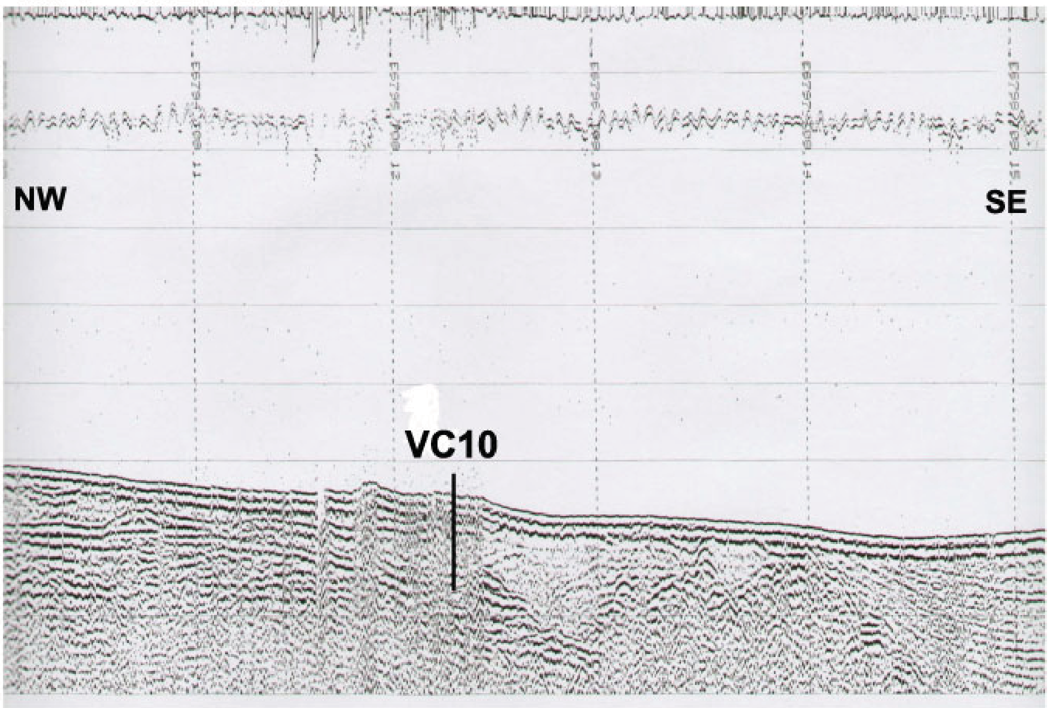


Fig. B-9. Stratigraphic position of Vibrocore 10 with reference to associated seismic profiles.