

P.O.L.

RRS 'CHALLENGER'

**CRUISE 106
18-28 SEPTEMBER 1993**

**CRUISE 107
26 OCTOBER - 6 NOVEMBER 1993**

NORTH CHANNEL

CRUISE REPORT NO. 18

1994

PROUDMAN OCEANOGRAPHIC LABORATORY

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PROUDMAN OCEANOGRAPHIC LABORATORY

CRUISE REPORT NO. 18

RRS CHALLENGER

CRUISE 106, 18 - 28 September 1993
CRUISE 107, 26 October - 6 November 1993

North Channel

1994

M.J. Howarth, A.J. Harrison, P.J. Knight

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ABSTRACT The objectives for CHALLENGER 106 were:- <ol style="list-style-type: none"> 1. To deploy 12 moorings at 6 sites in the North Channel and to service a long term Acoustic Doppler Current Profiler (ADCP). 2. To obtain CTD, nutrient and ship ADCP measurements in the North Channel. 3. To recover 7 Argos/Decca drogued buoys deployed on Challenger 105. 4. To service an ADCP and a current meter/transmissometer mooring off Cumbria. 5. To deploy 2 ADCPs and recover 1 of them on the Clyde sill (for Menai Bridge). 6. To deploy and recover trial 75 kHz and 1 MHz ADCPs. The objectives for CHALLENGER 107 were:- <ol style="list-style-type: none"> 1. To deploy 1 mooring and recover 11 moorings at 6 sites in the North Channel and to service a long term ADCP. 2. To service 3 moorings in the North Channel for MAFF. 3. To obtain CTD and ship ADCP measurements in the North Channel. 4. To deploy and recover 4 Argos/Decca drogued buoys. 5. To service an ADCP and a current meter mooring off Cumbria. 6. To recover 1 ADCP on the Clyde sill (for Menai Bridge). 7. To service 2 moorings in the Clyde sea for Menai Bridge. 8. To deploy and recover trial 75 kHz and 1 MHz ADCPs. All the objectives for Challenger cruises 106 and 107 were achieved:- <ol style="list-style-type: none"> 1. 30 moorings were deployed. 26 moorings were recovered by Challenger and one by a fishing vessel. 3 were missing - a waverider, a thermistor chain and a current meter mooring. 2. 193 CTDs were recorded; only 95 nutrients were determined. 3. 11 drogued buoys were deployed and 10 recovered. The eleventh buoy was lost because its transmitter failed. In addition two of the holey sock drogues were lost, one during recovery. 	
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1. PERSONNEL

SHIP'S OFFICERS

	CHALLENGER 106	CHALLENGER 107
Master	G.M. Long	G.M. Long
Chief Officer	T.J. Boulton	J.D. Noden
2nd Officer	P.D. Gauld	J.T. Morse
3rd Officer	J.C. Holmes	J.C. Holmes
Chief Engineer	D.C. Rowlands	D.C. Rowlands
2nd Engineer	J.R.C. Clarke	J.R.C. Clarke
3rd Engineer	J.R. Crosbie	R. Perriam
Bosun	R. Macdonald	R. Macdonald

CHALLENGER 106, SCIENTISTS

M.J. Howarth	(18 - 27 September)
N.G.C. Ballard	
D. Flatt	
A.J. Harrison	(18 - 26 September)
P.J. Knight	
R.C. Marsden	
R.I.R. Palin	(24 - 26 September)
R.R.J. Player	
L.M. Porter	(18 - 22 September)
A. Reeve	(MAFF, Lowestoft)
E. Saltvold	(Aanderaa, Norway; 18 - 22 September)
R.W. Powell	(RVS)
D. Jones	(RVS)
D. Teare	(RVS)

CHALLENGER 107, SCIENTISTS

A.J. Harrison	
N.G.C. Ballard	
T. Collings	
D. Flatt	
P.D. Glorioso	
T. Hargreaves	
P.J. Knight	
J. Lawson	
R.W. Powell	(RVS)
A. Taylor	(RVS)
J. Reed	(MAFF, Lowestoft; 26 - 29 October)
L.J. Van Elp Fernand	(MAFF, Lowestoft; 26 - 29 October)
D. Boon	(School of Ocean Sciences, Menai Bridge; 29 Oct - 1 Nov)
A. Hammerstein	(School of Ocean Sciences, Menai Bridge; 29 Oct - 1 Nov)
R. Midgley	(School of Ocean Sciences, Menai Bridge; 29 Oct - 1 Nov)

2. INTRODUCTION

The flow through the North Channel of the Irish Sea is being measured for a 15 month period, from July 1993 to September 1994, as part of a study of shelf edge and shelf sea exchange rates, contributing to the shelf edge (SES) and modelling (NORMS) components of the Land Ocean Interaction Study Community Research Project. For this period surface currents are being measured with NERC's OSCAR HF radar system deployed on the Mull of Galloway. The master unit is sited at Portpatrick and the slave further south, at Crammag Head, Figure 1. The system has a range of 20-30 km, sufficient for complete coverage of the North Channel, and a spatial resolution of 1 km. For the same period a Broadband 150 kHz RDI Acoustic Doppler Current Profiler (ADCP) has been deployed in the centre of the Channel (Figure 1 and site E, Figure 2) to measure the currents' vertical variations. The ADCP has been set up to measure currents in 5 m depth slices from 12.5 to 120 m above the sea bed in a water depth of 140 m. In addition, sea levels are being recorded by permanent tide gauges at Port Erin, Portpatrick and Port Ellen (Islay) and by temporary tide gauges at Bangor and Portrush in Northern Ireland, to determine along and across channel pressure gradients.

The main purpose of Challenger cruises 106 and 107 was to make detailed measurements of vertical and horizontal gradients in the current, temperature and salinity fields to aid interpretation of the long term data sets described above and to improve the volume flux calculations. The timing of the cruises was selected for autumn or winter, when the water column in shelf seas is well-mixed. (In the North Channel tidal mixing is sufficiently large for there to be minimal stratification at any time of the year but thermal stratification occurs in summer at either end of the channel.) To accomplish this, four types of measurement were planned :-

1. Moorings at 6 sites (A, D, E, F, G, H, Figure 2).
2. Spatial CTD, ADCP and surface monitoring survey of the North Channel region.
3. Repeated transects across the North Channel making CTD and ship ADCP measurements.
4. Drogued Argos / Decca buoys. The buoys were deployed for the duration of each cruise only.

A brief outline of each set of measurements is given.

1. Moorings

Current meter moorings were deployed at D, E, F and G; 250 kHz POL ADCPs in sea-bed frames at D and G; 150 kHz RDI ADCPs in sea-bed frames at E (referred to above) and at H and thermistor chains at A and E. All the pop-up frames were fitted with rope spoolers so that the ballast weight could be recovered. A meteorological buoy and a waverider were deployed at E. All the instruments (except the thermistor loggers and the waverider) were set to record data every 10 minutes. Details of the times and positions are given in Table 1, of the equipment deployed in Table 2 and schematic diagrams of the moorings are included at the end of the report. The majority of the moorings were to be deployed on Challenger 106 and recovered on Challenger 107. In addition the Fisheries Laboratory at Lowestoft had 3 current meter moorings at A, B and C which were serviced on Challenger 107.

2.1. CTD

Sensors - temperature, conductivity, pressure, fluorescence, transmittance, dissolved oxygen, upwelling and downwelling irradiance.

Rosette - Challenger 106 three 10 l Niskin bottles, one fitted with electronic thermometers.

Challenger 107 one 10 l Niskin bottle fitted with electronic thermometers.

CTD calibration / check - temperature and salinity only. The bottom bottle was fitted with three electronic reversing thermometers, against which CTD temperatures were checked. The salinity of a water sample from this bottle was determined with a laboratory salinometer and used to calibrate the CTD salinities.

The CTD was fitted with an acoustic beacon and a 200 kHz altimeter. On Challenger 106 the bottles were fired at the bottom, mid-depth and the surface (on the upcast) and water samples taken for nutrient determination - on board for total oxidised nitrate, phosphate, ammonia and nitrite. Samples were preserved for silicate analysis at the Fisheries Laboratory, Lowestoft. The CTD sensor serial numbers are listed in Table 4 and the CTD positions are listed in Tables 5 and 6 and shown in Figures 4 and 6.

2.2. Surface monitoring

Sensors - thermosalinograph, transmittance, fluorescence, surface irradiance (port and starboard)

Calibration - thermosalinograph against CTD measurements and checked against laboratory salinometer measurements. During both cruises the thermosalinograph temperature reading was between 0.8 °C and 0.9 °C low. The salinity measurement drifted by about 0.1 during each cruise (from 0.10 to 0.21 low on Challenger 106 and from 0.14 to 0.04 low on Challenger 107).

The surface transmissometer and fluorometer were primarily being operated to test their functionality and were not calibrated. During Challenger 106 the Level A controlling their data logging was very unreliable.

2.3. Ship-mounted ADCP

Set-up - seventy-five 4 m bins; blanking interval 4 m; 10 minute sample interval; error velocity check 1.0 m s⁻¹; 25% limit for percent good check. The clock in the controlling PC gained on average 33 s per day during both cruises.

2.4 Underway and CTD data logging

The data from this equipment were all logged by the shipborne computer system - the thermosalinograph and the ADCP were logged continuously from the beginning to the end of the cruises, as were total surface irradiance, water depth and the navigation data (derived from main chain Decca, Satnav and GPS).

3. The same equipment (CTD, ADCP, surface monitoring) was used during the repeated cross channel transect as was used during the spatial survey (see 2 above).

4. Drogued Argos/Decca buoys

The drogues, 7 m holey socks, were deployed with a drop line of 30 m (see Figure 7 for the rig layout). The buoys transmitted their position using the Argos satellite system and also recorded internally the Decca position every 10 minutes. The times and positions of the drogue deployments and recoveries are given in Table 3.

3.1 CHALLENGER 106 SPECIFIC OBJECTIVES

1. To deploy 12 moorings at 6 sites in the North Channel (A, D, E, F, G, H, Figure 2) and to service an ADCP at E.
2. To obtain CTD, nutrient and ship ADCP measurements in the North Channel.
3. To recover 7 Argos / Decca drogued buoys deployed on Challenger 105.
4. To service an ADCP and a current meter / transmissometer mooring off Cumbria (J).
5. To deploy 2 ADCPs and recover 1 of them on the Clyde sill (I, for Menai Bridge).
6. To deploy and recover trial 75 kHz and 1 MHz ADCPs.

3.2 CHALLENGER 106 NARRATIVE

Loading at Ardrossan of POL equipment, principally related to the moorings and the ADCPs, started at 13.00 GMT on Thursday 16 September 1993. In addition to staff from the Proudman Oceanographic Laboratory (POL) and the Research Vessel Services (RVS), participants included Alison Reeve (Fisheries Laboratory, Lowestoft to measure nutrients) and Erik Saltvold (Aanderaa Instruments, Norway to observe the methods used to deploy Aanderaa equipment, particularly thermistor chains).

RRS Challenger sailed at 09.00 on Saturday 18 September, one hour later than planned because of the late delivery of fuel. After clearing the harbour (see Figure 3 for the cruise track) surface monitoring of temperature, salinity, transmittance and fluorescence and of the ship's position and the water depth was started. The ship's ADCP was switched on at 10.47, the PC clock having been reset at 09.30. At 16.30 Challenger reached site E. The acoustics on the RDI ADCP frame there confirmed the frame's position but the guard buoy was missing. The met. buoy (ED) was deployed by 16.47, the waverider (EE) by 17.15 and the surface current eta rig (EB) by 18.41, see Table 1 for deployment times and positions and Table 2 for a list of equipment deployed. Schematic diagrams of the rigs are shown in Figure 8 onwards. From 19.00 onwards hourly CTDs were recorded at E, see Table 5 for CTD times and positions and Figure 3 for a map of CTD positions. The 20.00 CTD was missed because four sets of acoustics were wire tested between 19.30 and 20.30 and showed one set of leads to be faulty.

The last CTD profile in this series (11) was recorded at 06.00 19 September. A pop-up current meter rig was deployed sub-surface buoy first at F from 08.20 - 08.45. At G a 250 kHz ADCP (GA) was deployed at 10.01 and a surface current eta rig (GB) by 11.04. Although the wind speed was between 20 and 30 knots conditions were good enough for mooring deployment since the wind direction was from the southeast. However the next mooring site, D, which was reached at 13.00, was more exposed and so the sea was too rough for deployments. Shelter was therefore sought in Belfast Lough from 14.00 onwards and the crane used to move buoys and frames round the after deck in preparation for the next deployments.

At 05.00 on 20 September CTD profile 12 was recorded at the mouth of Belfast Lough and at 06.00 CTD profile 13 was recorded at site D. Conditions had improved sufficiently (the wind speed had fallen to 20 knots, from the south) for the deployment of a 250 kHz ADCP (DA) at 06.18 and for a 'U' shaped current meter rig (DB) between 07.59 and 08.16. Site E was visited and the eta buoy was missing. Both eta buoys were fitted with Argos transmitters for determining their position. The system was interrogated and the position of both buoys found to be a couple of miles to the north of their respective deployed positions. The RVS RDI 150 kHz ADCP was deployed at HA at 10.47 and the pressure recorder at HB at 10.52. At site I one set of acoustics was successfully wire tested from 13.35 - 13.50, followed by the deployment of a 250 kHz ADCP in a 'L' shaped mooring (IA), 13.55 - 14.06, and a 1 MHz ADCP (IB) at 14.36. From 15.14 until 09.15 the next day CTD profiles 18 -31 were obtained along the Clyde Sill and in the North Channel, finishing at E.

From 09.43 to 10.15 21 September the thermistor chain rig at E (EC) was deployed. The moorings at E were then checked and the waverider was missing. The deployment of the thermistor chain at A, started at 12.17, was delayed whilst a shallower site was found by steaming westward - the initial depth was 160 m, whilst it was deployed in 144 m of water at 13.05 (14 m deeper than planned). Both thermistor chain moorings were single point, marked by 6 m long spar buoys. In both cases the buoys appeared to be riding low in the water, perhaps because of the strong tidal currents (up to 1 m s^{-1} during the deployments). The positions of both eta rigs (EB, GB) as obtained via Argos was now checked. Both were sighted at the positions of the last Argos fix (EB at 14.58 and GB at 17.15). EB had moved

9.5 km in a direction 330° and GB 4.7 km in a direction 340°. Since both moorings appeared to be anchored, i.e. to have moved intact under the action of tides and waves, and since the spring / neap cycle was approaching neaps the moorings were left alone, to be recovered before the end of this cruise. A CTD transect (profiles 32 - 42) across the North Channel, taking CTDs a G, F, E, D and 54° 43'N 5° 33'W (off the mouth of Belfast Lough) was repeated 2.5 times from 17.45 until 03.30 the next day.

At 06.00 **22 September** L. Porter and E. Saltvold were transferred to a small boat at the mouth of Loch Ryan, off Stranraer. Two CTDs (43, 44) were then recorded close by. A trial 1 MHz ADCP was deployed at IC at 09.33 and a course set to make CTD measurements between Islay and Malin Head (47 - 54, 16.45 - 22.45). Two CTD profiles were recorded close to the Irish coast on the way back to I. (The shipborne computer's level C failed to record the first, 55, but the data were later recovered from the Viglen PC.)

The two 1 MHz ADCPs at I were recovered at 07.37 (IC) and at 08.23 **23 September** (IB). The toroid at IA was visible. A CTD (57) profile was recorded. The rest of the day was spent recovering the Argos / Decca drifting buoys. Three were recovered (1, 4, 7) at 13.30, 15.00 and 17.04. The positions of the buoys had been monitored each day by collecting information from Barry using Marinet. From this it was known that one of the seven buoys was lost because Argos positions ceased after two days. Recovery of the remainder was made difficult because a) the strong tidal currents soon decreased the value of Argos updates and b) for four of the buoys the HF radio direction finding signal was weak or missing. The latest Argos positions were obtained by Telexing Toulouse direct. At 17.48 CTD 58 was recorded at H and the acoustics of HA and HB checked. Throughout the night the same transect across the North Channel as two nights ago was repeated 2.5 times (CTDs 60 -70, 21.18 - 06.35 the next day). Between 22.47 and 23.09 at the deepest site, F, two sets of acoustics were wire tested for future use on STABLE.

At 07.08 **24 September** recovery of the eta rig EB was started and completed by 07.25. Its position had not changed since it was last visually checked on 20 September. At 09.24 the recovery of the RDI ADCP at E (EA) was started. The recovery was completed at 09.47 and the rig was redeployed at 10.32. The met. buoy and the thermistor spar were both visible.

The eta mooring GB was recovered between 12.36 and 12.50, as for EB it had not moved since the rig was checked on 20 September. Argos / Decca buoy 10 was recovered at 14.07. The drogue was anchored to the sea floor so that the drop line had to be cut and the drogue lost. At 14.45 RRS Challenger was hove to off Portpatrick awaiting the arrival of R. Palin by small boat. At 15.30 R. Palin was aboard and RRS Challenger sailed straight to E to deploy the trial 75 kHz ADCP (EG, at 16.36). Another Argos / Decca buoy (5) was recovered at 17.42. The thermistor spar buoy at A was checked at 19.40 and CTD 71 recorded. A course was now set for site J, off the Cumbrian coast.

The 1 MHz ADCP at station JA was recovered from 07.05 - 07.28 25 September and redeployed from 08.15 - 08.23. The current meter / transmissometer rig (JB) was recovered between 08.35 and 08.46 and redeployed from 10.20 - 10.29. After CTD 72 had been recorded at 10.45 RRS Challenger headed west, for the western Irish Sea, passing to the south of the Isle of Man. The weather was sunny and calm. From 16.35 onwards CTDs 73 - 83 were recorded whilst zig-zagging northward up the western Irish Sea back to E.

From 05.44 - 06.22 26 September the 75 kHz ADCP (EG) was recovered and then RRS Challenger steamed to Portpatrick to transfer A. Harrison and R. Palin to a small boat (07.00). The last of the Argos / Decca buoys (8) was recovered at 08.15, although its drogue was missing. From 08.47 - 09.09 the thermistor chain rig EC was recovered because of doubts that the rig, marked by a 6 m spar buoy, would survive the strong tidal currents at spring tides. For the same reason the marker buoy of the current meter mooring at DB was changed from a spar buoy to an eta rig toroid at 10.40. CTD 84 was then recorded at D, followed by a section across the North Channel to Crammag Head (85 - 88), reached at 14.40. A course was now set southward along the Irish coast for CTDs 89 - 95. At 16.00 RRS Challenger stopped for half an hour for repairs to the stern gland seal, which was leaking, and one CTD site was therefore missed out.

The last CTD (95) was recorded at 02.00 27 September and recording of the ADCP stopped at 04.43 (its PC clock was 291 s fast). J. Howarth boarded the pilot cutter at Dublin at 05.24 and RRS Challenger docked at Barry at 06.00 28 September.

4.1 CHALLENGER 107 SPECIFIC OBJECTIVES

1. To deploy 1 mooring and recover 11 moorings at 6 sites in the North Channel (A, D, E, F, G, H) and to service an ADCP at E.
2. To service 3 moorings in the North Channel for MAFF (A, B, C).
3. To obtain CTD and ship ADCP measurements in the North Channel.
4. To deploy and recover 4 Argos / Decca drogued buoys.
5. To service an ADCP and a current meter mooring off Cumbria (J).
6. To recover 1 ADCP on the Clyde sill (I, for Menai Bridge).
7. To service 2 moorings in the Clyde sea for Menai Bridge (CS6, CS8).
8. To deploy and recover trial 75 kHz and 1 MHz ADCPs.

4.2 CHALLENGER 107 NARRATIVE

26 October

At 05:00 Challenger set sail from Barry. The state of the sea was calm and the weather was overcast. At 08:00 the log was reset, the ship ADCP was switched on, the Chernikeef representative disembarked by pilot boat and Challenger headed for site J. The ship ADCP clock was checked with the Satellite Navigation clock at 08:50.

ADCP timed	08:58:06
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Satellite Navigation timed	08:59:19
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The non-toxic supply was switched on at 09:00. At 09:40 the clock on the PC logging the ship ADCP data was reset.

New ADCP timed	09:41:36
----------------	----------

Satellite Navigation timed	09:41:36
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At 09:46 surface values of temperature and salinity started to be recorded. Depths, light and GPS also started to be recorded. At 10:55 surface values of fluorescence and transmittance started to be recorded.

27 October

At 08:00 the state of the sea was still calm and the weather was still overcast. Challenger

was still on route to site J. By 09:20 Challenger had arrived at site J and both rig JA (1 MHz L-shaped ADCP) and rig JB (U-shape mooring) were sighted. Between 09:30 and 09:57 mooring JA was recovered. Between 10:35 and 10:56 mooring JA was redeployed with a new battery fitted to the toroid light. Between 11:14 and 11:26 mooring JB was recovered. At 11:30 CTD No.1 was performed but it was changed to No. 96 in order to continue on from Cruise 106. Between 12:09 and 12:25 mooring JB was redeployed, again with a new battery fitted to the toroid light. By 12:30 Challenger was heading for site C (MAFF mooring), where it arrived at 20:00. The service of the MAFF moorings was scheduled for first light on 28 October.

28 October

At 06:00 the state of the sea was still calm and the weather was still overcast. At 07:00 it was noted that the ship ADCP was not displaying speed and depth to the ship. Therefore the ADCP had to be restarted from the menu. Between 07:05 and 07:39 MAFF mooring C (current meter rig) was recovered. Between 08:50 and 09:08 MAFF mooring C was re-deployed. The ship ADCP clock was checked with the Satellite Navigation clock at 09:00.

ADCP timed	09:12:38
------------	----------

Satellite Navigation timed	09:11:23
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At 09:10 Challenger headed for site B (MAFF mooring). The sea state was slight and the weather was overcast, wind force 3. At 09:45 Challenger arrived at site B. Between 09:50 and 10:11 MAFF mooring B (current meter rig) was recovered. Between 11:20 and 11:42 MAFF mooring B was re-deployed. At 11:45 Challenger headed for site A (MAFF mooring). Between 11:56 and 13:26 MAFF mooring A (current meter rig) was recovered. Between 15:09 and 15:50 MAFF mooring A was re-deployed.

At 16:00 Challenger headed for site E. Between 16:50 and 17:10 mooring EB was deployed. ExplorOcean's EG and G acoustic current meter was used in addition to the S4's as a trial. Between 17:30 and 18:00 it was attempted to deploy mooring EG (75 kHz experimental ADCP). However the ADCP would not start up and the attempt to deploy it was therefore aborted. At 18:00 Challenger headed for site D to start drogue deployments. Drogue number 5 was deployed at 19:00 however it was not deployed in the specified position because the position of 5° 37'W was mistaken for 5° 27'W. Drogue number 4 was deployed at 19:33 at site E (54.751°N 05.342°W). Drogue number 1 was deployed at 20:03 at site F (54.785°N

05.283°W). Drogue number 10 was deployed at 20:52 at site G (54.865°N 05.204°W).

29 October

At 00:15 CTD transects across the channel were started, at a position just outside Belfast Lough (Station 5 (100)). The next stations were D, followed by E, F, G and then back again along the same track until 07:00. At 07:00 Challenger headed for Stranraer. Between 08:00 and 08:10 the ships ADCP clock was checked with the Satellite Navigation clock. Liam Fernand (MAFF) took the opportunity to take a copy of the data.

ADCP timed	08:06:47
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Satellite Navigation timed	08:05:10
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The clock on the PC logging the ship ADCP data was reset.

ADCP timed	08:06:00
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Satellite Navigation timed	08:06:00
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At 10:00 the state of the sea was calm and the weather was fair. J. Reed and L.J. Van Elp Fernand (both MAFF) disembarked at Stranraer and D. Boon, R. Midgley and A. Hammerstein (all Menai Bridge) embarked. Challenger headed for site I to deploy a 1 MHz ADCP and to service the Menai Bridge Clyde sea moorings. At 12:00 the non-toxic supply was switched back on, it had been off for approximately one hour. At 12:34 Challenger arrived at site I. Between 12:40 and 12:43 mooring IB (1 MHz experimental ADCP) was deployed, and by 12:50 Challenger was heading for the Menai Bridge moorings in the Clyde sea. Challenger arrived at site CS6 at 15:00. The state of the sea was calm and the weather was fair. Between 15:33 and 15:56 the CS6 (current meter rig) mooring was recovered. Between 16:21 and 17:15 a calibration was carried out on the meters recovered from mooring CS6. The CTD frame was lowered to 3 m depth and values of temperature and conductivity were taken. These values were then compared with Aanderaa values obtained by meters from CS6 at the same depth and time as the CTD.

30 October

At 00:00 the CTD survey southeast of Arran was continuing. At 06:00 Challenger arrived back at site CS6. Between 06:15 and 07:40 the meters on the CS6 mooring were calibrated for re-deployment. At 08:45 Challenger headed towards site CS8. Challenger arrived at site CS8 at 10:15. Between 10:29 and 11:03 mooring CS8 (current meter rig) was recovered

(approximately one nautical mile west of original position). Between 11:15 and 12:15 the meters taken off mooring CS8 were calibrated against the CTD, with both lowered to 3 m depth. Also a full CTD was carried out during this calibration at 15:20. At 16:30 Challenger arrived back at site CS8. Between 16:35 and 16:58 mooring CS8 was re-deployed. At 18:00 the CTD survey west of Arran and on until the Mull of Kintyre and Northern Ireland coast commenced.

31 October

At 00:00 the CTD survey was continuing. The last CTD was done at 06:54, before heading to site I. At 07:50 the state of the sea was calm and the weather was cloudy. Challenger arrived at site I to start the recovery phase. Between 07:52 and 08:24 mooring IB was recovered (1 MHz experimental ADCP). Between 08:30 and 09:10 mooring IA (250 kHz L-shaped ADCP) was recovered. At 09:20 Challenger headed for site H, where it arrived at 12:00. Between 12:25 and 12:53 mooring HB (WLR) was recovered. Between 13:13 and 13:32 mooring HA (RVS - RDI ADCP) was recovered. At 13:35 Challenger headed for site E, where it arrived at 15:20. Between 15:26 and 15:38 mooring EG (75 kHz experimental ADCP) was finally deployed at the second attempt. At 15:40 the CTD transect across the North Channel started at site E.

1 November

At 00:00 the CTD survey was continuing. The last CTD took place at 07:00 at the Belfast Lough position. The sea state was slight and the weather was cloudy. The wind was force 1 to 2. At 09:00 Challenger arrived back at site D. Between 09:19 and 09:54 mooring DA (250 kHz ADCP) was recovered, with only its pellets visible on the surface when the mooring was sighted. At 10:00 Challenger headed for site E to search for EE mooring (wave rider). Between 11:00 and 12:00 Challenger arrived at site E and there was no sign of the EE mooring. At 12:00 Challenger headed for site G, where it arrived at 12:50. Between 12:58 and 13:35 the GA mooring (250 kHz ADCP) was recovered and again only its pellets were visible on the surface when the mooring was sighted. At 13:40 Challenger headed for Stranraer. At 14:45 the ADCP information to the ship's log was not working so it had to be re-started from the menu. This might have interrupted the ship ADCP recording mode temporarily. At 15:32 the non-toxic supply was switched off for 5 minutes. At 15:50 D.

Boon, R Midgley and A. Hammerstein (all Menai Bridge) disembarked at Stranraer. At 16:00 Challenger headed back towards site G to look for drogue number 10 which was deployed there. It was recovered at 19:06 (54.880°N 05.356°W). CTD transects across the North Channel were started at 20:00.

2 November

At 00:00 the CTD transects across the North Channel were continuing. The last CTD took place at site D at 07:20. At 07:30 the sea state was slight/moderate and the weather was overcast. The wind force was 3 to 4. Between 07:45 and 08:30 there was no sign of the DB mooring (u-shaped) which was last seen on 1 November so the search was abandoned and Challenger headed on to site E. At 08:45 Challenger arrived at site E, and between 09:02 and 09:44 mooring EB (ETA) was recovered. Between 11:10 and 12:18 moorings EG (75 kHz ADCP) and EA2 (RDI ADCP) were recovered. By 13:00 Challenger was heading for site A. There was no sign of the AB mooring (thermistor chain) between 14:00 and 15:00 so by 15:05 Challenger was heading for one of the last known drogue positions. Drogue number 4 (54.634°N 05.394°W) was recovered at 16:00, and drogue number 1 (54.933°N 05.492°W) was recovered at 19:03. Between 20:30 and 20:50 mooring EA3 (RDI ADCP) was redeployed. CTD transects across the North Channel resumed at 21:00.

3 November

At 00:00 CTD transects across the North Channel were continuing. The last CTD to take place was CTD 83 (178) at 07:01. At 08:15 the sea state was slight and the weather was overcast. The wind as force 2 to 3. Between 09:00 and 09:45 a 1 MHz ADCP was tested by lowering it over the stern of the stationary ship. Challenger headed for site D at 10:00, where it arrived at 15:50. At 16:00 Challenger encountered a trawler (Investor M, B684) with MAFF mooring A entangled in its nets. The mooring was released in position latitude 54° 42.53'N and longitude 05° 17.37'W. Between 16:30 and 22:00 there was an unsuccessful drag for the missing AB mooring (thermistor chain). CTD transects across the North Channel were started at 22:30.

4 November

At 00:00 CTD transects across the North Channel were continuing. The last CTD to take place was CTD 91 (186) at 05:30. At 08:00 the sea state was calm and the weather was overcast. The wind was force 1. The search for the drogue started at 09:30, and by 12:04 drogue number 5 (54.900°N 05.795°W) had been recovered. The buoy seemed to have been dragged under the surface and appeared at slack water. At 12:05 Challenger headed for site E. At 12:45 the sea state was calm and the weather was sunny. The wind was force 1. At 13:39 Challenger arrived at site E and the met. buoy was sighted. Between 13:46 and 14:00 mooring ED (met. buoy) was recovered. By 14:30 Challenger was heading towards Barry with CTD's taking place on route between Ireland and the Isle of Man. The first CTD took place at site E. The last CTD took place at 23:40, and at 23:45 Challenger headed for port.

5 November

At 08:00 the sea state was slight and the weather was overcast. The wind was force 1 to 2, and Challenger was still heading for Barry. At 09:07 the surface sampling was switched off. At 13:26 the ship ADCP was switched off.

PC clock timed 13:27:32

Satellite navigation timed 13:23:32

At 14:00 Challenger was expected to arrive at Barry at 19:30.

5. EPILOGUE

5.1 Mooring DB

This mooring, a 'U' shaped current meter mooring (1 S4 and 1 Aanderaa), was seen in position on 1 November, but was missing the next day when recovery was due. On 11 November the toroid was sighted at 54° 45.39'N 5° 28.64'W (about 1 mile north-northwest of the deployed position) by the roll-on roll-off ferry 'Viking Trader'. The toroid and its anchor only were recovered by the MAFF research vessel 'Cirolana' during the first week in December - it appeared that the swivel attaching the ground line to the toroid anchor had come undone. A search for the mooring was conducted on 11 January 1994 from MRV

'Lough Foyle' and a regular echo observed on the ship's sonar fish-finder at 50 m depth at the position the mooring had been deployed. However when dragging was attempted on **24 February** from MRV 'Lough Foyle' no contact was made either via the fish-finder or with grapnels.

5.2 Mooring FA

This pop-up current meter mooring (1 S4 and 3 Aanderaas) was deployed on **19 September** in the Beaufort's Dyke in 275 m of water. It was found floating on the surface at $54^{\circ} 27.58'N$ $5^{\circ} 12.07'W$ (about 20 miles south of the deployed position) on **26 October** by a long line fishing vessel ('Sparking Line'), recovered and returned to POL on **29 October**. The entire mooring (all the instruments, buoys, wires, shackles, swivels etc.) had been recovered and was in good condition. There was no sign of damage from trawling. The release (a spherical Benthos release mounted on a 'D' bar) had fired, for reasons that are not obvious (apparently not related to tidal current strength or to ascertainable external activity). The current meter records show that the rig came to the surface at 11.00 on **14 October**, about an hour after slack water.

6. CONCLUSIONS

All the specific objectives for Challenger cruises 106 and 107 were achieved :-

1. 30 moorings were deployed - 20 (at 8 sites) in the North Channel for POL and MAFF, Lowestoft, 6 (at 3 sites) in the Clyde Sea (for the School of Ocean Sciences, Menai Bridge) and 4 (at 1 site) off the Cumbrian coast (for POL and the School of Ocean Sciences, Menai Bridge). 26 moorings were recovered by Challenger and one (FA) by a fishing vessel. 3 were missing - a waverider at EE; a thermistor chain, logger and spar buoy at EC; an Aanderaas and a S4 current meter and a 40" sub-surface buoy at DA.
2. 193 CTDs were recorded. On Challenger 106 240 surface, middle and bottom water samples were collected for nutrient determination.
3. The ship's ADCP was operated continuously throughout both cruises.

4. 11 drogued buoys were deployed and 10 recovered - the duration in the water was between 4 and 12 days, average 8 days. The eleventh buoy was lost because its transmitter failed 2 days after deployment. In addition two of the holey sock drogues were lost, one during recovery.

The major obstacle to mooring operations and to drogue recoveries were the strong tidal currents (up to 1.5 m s^{-1} at spring tides). This environment was too severe for the eta rigs deployed on Challenger 106 (EB1 and GB) - the rigs shifted position and the wire angles were too great for the S4s to work correctly. For EB2 on Challenger 107 the anchor weight was doubled (to 1 tonne) and a heavier meter ballast weight (115 kg as against 35 kg) was used. The rig did not move but still the wire angles (up to 20°) were too large at the top meter.

The strong tidal currents also restricted recovery of the pop-up bottom frames to slack water, since the frames, which have little excess buoyancy and are tethered to their ballast weights once they have been released, are dragged under by currents greater than 0.5 m s^{-1} .

Throughout the two cruises very little time was lost to bad weather (only 16 hours on Challenger 106) or to breakdowns. Challenger is very well suited to the operations undertaken and is generally well equipped. Irritating failures occurred over locating the Argos / Decca buoys on Challenger 106 (on several of the buoys the direction finding radio signal was very weak because the transmit frequency had drifted; this problem was rectified for Challenger 107) and with the thermosalinograph, whose salinity measurements drifted considerably.

7. ACKNOWLEDGEMENTS

It is a pleasure to thank the master, officers and crew of RRS Challenger for their willing assistance and cooperation. Without it, and the support of the RVS technicians, the programme of work could not have been completed. We also want to thank Anton Edwards (DML) for deploying 7 drogued buoys at the end of Challenger 105.

Table 1a. Times and positions of POL rig deployments and recoveries.

Rigs EB1 and GB were recovered off position, see Challenger 106 narrative.

Rig	Mooring	Latitude N	Longitude W	Depth (m)	Deployed	Recovered
<i>AB</i>	Thermistor chain	54° 40.26'	05° 14.88'	144	13:05 21/09	Lost
<i>DA</i>	250 kHz ADCP	54° 44.53'	05° 28.01'	95/ 90	06:18 20/09	09:19 01/11
<i>DB</i>	U shaped cm	54° 44.75'	05° 27.98'	100	08:16 20/09	Lost
<i>EA1</i>	150 kHz ADCP WLR	54° 46.04'	05° 24.33'	144		09:24 24/09
<i>EA2</i>		54° 46.05'	05° 24.40'	143/146	10:32 24/09	11:40 02/11
<i>EA3</i>		54° 46.10'	05° 24.30'	146	20:50 02/11	
<i>EB1</i>	eta surface cm	54° 45.48'	05° 22.00'	138/134	18:41 18/09	07.08 24/09
<i>EB2</i>		54° 45.48'	05° 21.04'	138/139	17:10 28/10	09:02 02/11
<i>EC</i>	Thermistor chain	54° 44.71'	05° 23.39'	141/135	10:15 21/09	08:49 26/09
<i>ED</i>	Met. Buoy	54° 45.92'	05° 23.85'	137/146	16:47 18/09	13:46 04/11
<i>EE</i>	Waverider	54° 45.92'	05° 23.27'	150	17:15 18/09	Lost
<i>EG1</i>	75 kHz ADCP	54° 46.18'	05° 21.88'	138/138	16:36 24/09	05:57 26/09
<i>EG2</i>		54° 46.13'	05° 22.06'	133/143	15:38 31/10	11:10 02/11
<i>FA</i>	Pop-up cm	54° 47.25'	05° 17.33'	275	08:45 19/09	Trawled
<i>GA</i>	250kHz ADCP	54° 52.25'	05° 12.33'	64/ 67	10:01 19/09	12:58 01/11
<i>GB</i>	eta surface cm	54° 51.51'	05° 12.80'	74/ 52	11:04 19/09	12:36 24/09
<i>HA</i>	150 kHz ADCP	54° 59.83'	05° 29.96'	139/127	10:47 20/09	13:13 31/10
<i>HB</i>	WLR	54° 59.59'	05° 29.93'	138/144	10:52 20/09	12:25 31/10
<i>IA</i>	250 kHz ADCP	55° 21.83'	05° 26.42'	40/ 39	14:06 20/09	08:30 31/10
<i>IB1</i>	1 MHz ADCP	55° 21.43'	05° 25.87'	41/ 40	14:36 20/09	07:53 23/09
<i>IB2</i>		55° 21.35'	05° 25.87'	42/ 40	12:43 29/10	07:52 31/10
<i>IC</i>	1 MHz ADCP	55° 21.75'	05° 26.03'	39/ 42	09:33 22/09	07:00 23/09
<i>JA1</i>	1 MHz ADCP	54° 07.15'	03° 26.89'	25		07:05 25/09
<i>JA2</i>		54° 07.23'	03° 26.54'	25/ 27	08:23 25/09	09:30 27/10
<i>JA3</i>		54° 07.08'	03° 26.57'	27	10:50 27/10	
<i>JB1</i>	U shaped cm & transmissometer	54° 06.96'	03° 27.01'	26		08:37 25/09
<i>JB2</i>		54° 07.21'	03° 27.10'	24/ 26	10:29 25/09	11:14 27/10
<i>JB3</i>		54° 07.18'	03° 27.08'	26	12:25 27/10	

Table 1b. Times and positions of MAFF rig deployments and recoveries in the North Channel during Challenger 107.

Rig	Mooring	Latitude N	Longitude W	Depth (m)	Deployed	Recovered
<i>A1</i>	U shaped cm	54° 40.92'	05° 16.46'	140		12:56 28/10
<i>A2</i>	U shaped cm	54° 41.29'	05° 14.69'	140	15:50 28/10	
<i>B1</i>	U shaped cm	54° 38.25'	05° 22.13'	109		09:50 28/10
<i>B2</i>	U shaped cm	54° 38.10'	05° 22.01'	107	11:42 28/10	
<i>C1</i>	U shaped cm	54° 36.35'	05° 27.18'	45		07:20 28/10
<i>C2</i>	U shaped cm	54° 35.95'	05° 27.11'	42	09:08 28/10	

Table 1c. Times and positions of Menai Bridge rig deployments and recoveries in the Clyde Sea during Challenger 107.

Rig	Mooring	Latitude N	Longitude W	Depth (m)	Deployed	Recovered
<i>CS61</i>	Aanderaa	55° 33.39'	04° 55.44'	85		15:33 29/10
<i>CS62</i>		55° 33.51'	04° 55.28'	89	08:34 30/10	
<i>CS81</i>	Current Meter	55° 44.42'	05° 11.77'	174		10:29 30/10
<i>CS82</i>		55° 43.84'	05° 10.86'	170	16:58 30/10	

Table 2. Equipment on Moorings.

Rig	Mooring	Equipment
<i>AB</i>	Single point	40 m thermistor chain 1682 at 15-55 m below the surface: logger 11: 6 m spar 2 / light 2
<i>DA</i>	Pop-up	250 kHz ADCP POLDOP 9: frame 15: acoustics 3B
<i>DB</i>	U	S4 1831, Aanderaa RCM4 3277 at 70 and 55 m above the sea bed: 40" sub-surface 4: 6 m spar 5, replaced by eta toroid 3
<i>EAI</i>	Pop-up	150 kHz RDI ADCP 1149: pressure recorder WLR 1038
<i>EA2</i>	Pop-up	150 kHz RDI ADCP 1148: pressure recorder WLR 444: acoustics 7A, 8A
<i>EA3</i>	Pop-up	150 kHz RDI ADCP 1149: pressure recorder WLR 445: acoustics 7A, 8A
<i>EB1</i>	Eta	S4 1196, 1112 (RVS) at 5 and 15 m below the surface: toroid 3: Argos beacon 3603: 32" sub-surface 8
<i>EB2</i>	Eta	S4 1112(RVS), 1119(RVS), EG&G SACM 016997 (on loan) at 5, 15 and 16 m below the surface: toroid 2: Argos beacon 3603: 32" sub-surface 10
<i>EC</i>	Single point	50 m thermistor chain 1756 at 35-85 m below the surface: logger 7: 6 m spar 5 / light 4
<i>ED</i>	Single point	Met. buoy
<i>EE</i>	Waverider	Waverider
<i>EG1</i>	Pop-up	75 kHz ADCP: frame 23
<i>EG2</i>	Pop-up	75 kHz ADCP: acoustics 3A: frame 23
<i>FA</i>	Pop-up	S4 1113, Aanderaa RCM7 9559, 9632, 9631 at 240, 160, 90, 20 m above the sea bed: 48" sub-surface buoy 3: acoustics 1B: back-up buoyancy six 17" spheres above bottom Aanderaa
<i>GA</i>	Pop-up	250kHz ADCP POLDOP 7: frame 18: acoustics 5A
<i>GB</i>	Eta	S4 1644, 1119(RVS) at 5 and 15 m below the surface: toroid 2: Argos beacon 3604: 32" sub-surface 10
<i>HA</i>	Pop-up	150 kHz RDI ADCP (RVS): Oceano acoustics (RVS)
<i>HB</i>	Pop-up	Pressure recorder WLR 445: acoustics 1A: frame 10
<i>IA</i>	L	250 kHz ADCP POLDOP 3: acoustics 6A: frame 17: toroid 3 / light 4
<i>IB1</i>	Pop-up	1 MHz ADCP POLDOP x: acoustics 2B: frame 2: compass C3
<i>IB2</i>	Pop-up	1 MHz ADCP DOPOL 1a: acoustics 2B: frame 2
<i>IC</i>	Pop-up	1 MHz ADCP DOPOL 1a

Table 2 continued. Equipment on Moorings.

RIG	MOORING	EQUIPMENT
JA1	L	1 MHz ADCP POLDOP 1a
JA2	L	1 MHz ADCP POLDOP 10a: acoustics 2B: frame 2: compass C3: toroid 5
JA3	L	1 MHz ADCP POLDOP 1a: acoustics 4A: frame 3: toroid 5 / light 3
JB1	U	Aanderaa RCM4 568, 6443 at 14, 6 m above the sea bed: transmissometers at 13, 5 m above the sea bed: toroid 6
JB2	U	Aanderaa RCM4 568, 6443 at 14, 6 m above the sea bed: transmissometer 1, 2 at 13, 5 m above the sea bed: toroid 6 / light 3: 40" sub-surface
JB3	U	Aanderaa RCM4 4387, 6443 at 14, 6 m above the sea bed: transmissometer 3, 6 at 13, 5 m above the sea bed: toroid 6 / light 5: 40" sub-surface 6

Table 3a. Argos / Decca drifting buoy deployments (Challenger 105) and recoveries (Challenger 106).

To each buoy was attached a 7 m holey sock drogue via a 30 m drop line.

BUOY		DEPLOYMENT			RECOVERY		
No	Site	Time Date	Latitude N	Longitude W	Time Date	Latitude N	Longitude W
1	H	17:30 14/09	54° 59.7'	05° 29.4'	13:30 23/09	55° 14.5'	05° 53.8'
3	D	19:06 14/09	54° 44.25'	05° 37.86'	Transmitter failed		
4	E	19:41 14/09	54° 46.19'	05° 22.87'	15:00 23/09	55° 15.5'	05° 52.0'
5	E	19:43 14/09	54° 46.18'	05° 22.83'	17:42 24/09	54° 47.6'	05° 22.0'
7	F	20:18 14/09	54° 48.36'	05° 17.96'	17:04 23/09	54° 56.0'	05° 25.5'
8	F	20:21 14/09	54° 48.37'	05° 17.97'	08:15 26/09	54° 46.7'	05° 18.6'
10	G	20:57 14/09	54° 51.47'	05° 13.04'	14:07 24/09	54° 52.0'	05° 11.4'

Table 3b. Argos / Decca drifting buoy deployments and recoveries on Challenger 107.

To each buoy was attached a 7 m holey sock drogue via a 30 m drop line.

BUOY		DEPLOYMENT			RECOVERY		
No	Site	Time Date	Latitude N	Longitude W	Time Date	Latitude N	Longitude W
1	F	20:03 28/10	54° 47.1'	05° 17.0'	19:03 2/11	54° 56.0'	05° 29.5'
4	E	19:33 28/10	54° 45.1'	05° 20.5'	16:00 2/11	54° 38.0'	05° 23.6'
5	D	19:00 28/10	54° 44.2'	05° 27.2'	12:04 4/11	54° 54.0'	05° 47.7'
10	G	20:52 28/10	54° 51.9'	05° 12.2'	19:06 1/11	54° 52.8'	05° 21.4'

Table 4. CTD and surface profiling sensor serial numbers on Challenger 106 and 107.
 On 107 the downwelling 2π PAR on the CTD was u/s and the only water bottle on the rosette was number 26t.

Type	Model	Serial Number
Vertical Profiling CTD	Neil Brown MK3b	1117
Fluorimeter	Chelsea Instruments	229
Transmissometer	Seatech	104
Downwelling 2π PAR	PML	1
Upwelling 2π PAR	PML	2
Acoustic Beacon	10kHz	6
B.O.box	RVS	OSG1
Reversing thermometers	SIS	250 254 255
10L water bottles	Niskin	26t 17 16t
Surface monitoring equipment		
Fluorimeter	Chelsea Instruments	234
Transmissometer	Seatech	103
Starboard 2π PAR	PML	3
Port 2π PAR	PML	7
Thermosalinograph	Ocean Data 103 Housing remote	TSAL-2 sal-2 1

Table 5. CTD stations on Challenger 106.

CTD No	Sept	Start	End	Latitude (N)	Longitude (W)	Rig
01	18	19:04:27	19:28:38	54 44.94	5 20.04	E
02	18	21:04:33	21:29:40	54 42.94	5 17.47	E
03	18	22:06:09	22:22:39	54 43.67	5 18.21	E
04	18	23:00:36	23:21:12	54 44.54	5 19.04	E
05	19	00:01:01	00:23:37	54 44.48	5 18.07	E
06	19	00:59:53	01:22:45	54 45.33	5 17.36	E
07	19	01:56:52	02:19:32	54 45.79	5 18.67	E
08	19	02:56:13	03:21:51	54 46.21	5 19.17	E
09	19	03:56:32	04:16:54	54 45.74	5 18.96	E
10	19	04:56:04	05:17:19	54 45.80	5 18.74	E
11	19	05:53:49	06:18:50	54 45.81	5 18.36	E
12	20	05:01:48	05:20:29	54 42.04	5 34.35	
13	20	05:46:31	06:08:59	54 44.83	5 28.34	D
14	20	15:11:16	15:30:35	55 21.19	5 24.95	I
15	20	16:15:26	16:29:43	55 18.88	5 20.32	
16	20	17:10:56	17:28:12	55 15.90	5 13.32	
17	20	18:12:07	18:23:47	55 12.89	5 6.13	
18	20	19:04:23	19:19:06	55 10.30	5 1.00	
19	20	19:57:39	20:10:09	55 9.94	5 10.07	
20	20	20:54:49	21:07:58	55 9.89	5 19.86	
21	20	22:01:27	22:15:39	55 9.77	5 29.89	
22	20	23:06:37	23:30:34	55 9.53	5 39.35	
23	21	00:30:12	00:49:18	55 9.71	5 49.42	
24	21	01:43:02	01:58:15	55 10.00	5 59.45	
25	21	02:35:05	02:46:32	55 5.04	5 57.75	
26	21	03:31:22	03:42:23	55 0.15	5 55.05	
27	21	04:18:56	04:33:13	55 0.16	5 47.81	
28	21	05:16:10	05:33:06	55 0.12	5 40.54	
29	21	06:27:44	06:43:32	54 56.93	5 30.69	H
30	21	07:43:40	08:02:54	54 53.72	5 27.74	
31	21	08:53:16	09:10:31	54 46.10	5 24.00	E
32	21	17:43:29	17:55:42	54 52.50	5 13.48	G
33	21	18:42:24	19:07:59	54 47.92	5 17.81	F
34	21	19:41:15	19:58:32	54 46.05	5 23.96	E
35	21	20:21:18	20:33:43	54 44.93	5 27.47	D
36	21	21:14:41	21:22:10	54 42.91	5 32.84	
37	21	21:58:53	22:11:19	54 44.61	5 28.05	D
38	21	22:48:58	23:05:25	54 45.80	5 24.15	E
39	21	23:50:47	00:19:56	54 46.62	5 16.96	F
40	22	01:14:12	01:26:01	54 51.58	5 12.26	G
41	22	02:01:43	02:27:54	54 46.95	5 16.59	F
42	22	03:09:47	03:31:20	54 47.01	5 23.91	E
43	22	06:22:40	06:30:50	55 4.12	5 6.90	
44	22	07:27:18	07:35:27	55 7.95	5 12.02	
45	22	13:02:24	13:15:52	55 23.82	5 55.02	
46	22	14:35:01	14:48:52	55 30.08	6 9.92	
47	22	16:43:47	16:53:23	55 41.26	6 39.28	
48	22	17:38:36	17:49:03	55 40.23	6 51.44	

Table 5 continued. CTD stations on Challenger 106.

CTD No	Sept	Start	End	Latitude (N)	Longitude (W)	Rig
49	22	18:22:45	18:32:07	55 40.13	7 1.00	
50	22	19:07:13	19:15:17	55 40.17	7 10.48	
51	22	20:02:13	20:56:05	55 35.64	7 10.31	
52	22	20:56:05	21:04:54	55 30.98	7 9.84	
53	22	21:46:00	21:53:37	55 26.44	7 8.56	
54	22	22:34:30	22:41:45	55 22.05	7 9.96	
55	23	00:00:03	00:01:16	55 22.03	6 49.57	
56	23	01:25:28	01:39:56	55 21.79	6 29.72	
57	23	08:28:53	08:46:02	55 21.57	5 26.12	I
58	23	18:45:57	19:05:25	55 1.24	5 32.09	H
59	23	20:06:52	20:22:00	54 56.16	5 21.68	
60	23	21:15:54	21:28:48	54 51.96	5 13.57	G
61	23	22:18:44	22:42:21	54 47.90	5 17.80	F
62	23	23:43:03	23:59:50	54 44.90	5 22.60	E
63	24	00:27:21	00:41:57	54 44.05	5 27.66	D
64	24	01:10:39	01:20:30	54 43.01	5 32.71	
65	24	01:49:06	02:04:13	54 44.10	5 27.67	D
66	24	02:33:16	02:55:25	54 44.61	5 22.33	E
67	24	03:26:51	03:55:33	54 47.06	5 16.92	F
68	24	04:35:10	04:46:49	54 51.72	5 13.19	G
69	24	05:24:58	05:54:05	54 47.32	5 17.30	F
70	24	06:17:54	06:36:43	54 46.43	5 23.41	E
71	24	18:44:41	19:01:04	54 44.69	5 13.71	A
72	25	10:41:58	10:49:23	54 7.62	3 26.85	J
73	25	16:34:10	16:46:05	53 59.96	4 59.88	
74	25	17:58:01	18:14:37	54 6.07	5 13.93	
75	25	19:31:23	19:39:14	54 12.18	5 28.23	
76	25	20:15:46	20:22:07	54 15.05	5 34.14	
77	25	21:03:58	21:12:03	54 16.60	5 27.86	
78	25	22:46:49	23:00:15	54 18.05	5 4.19	
79	26	00:24:38	00:39:22	54 27.23	5 18.26	
80	26	01:08:20	01:20:34	54 30.21	5 22.97	
81	26	01:47:57	02:06:26	54 32.65	5 17.86	
82	26	02:38:25	02:56:24	54 35.09	5 12.01	
83	26	03:33:18	03:59:34	54 37.76	5 6.09	
84	26	10:54:59	11:06:23	54 44.73	5 27.42	D
85	26	11:55:07	12:04:27	54 40.03	5 27.62	
86	26	12:37:25	12:53:07	54 40.28	5 20.37	
87	26	13:36:48	14:00:26	54 40.19	5 9.95	
88	26	14:36:47	14:49:17	54 40.05	5 0.58	
89	26	17:01:54	17:22:05	54 25.74	5 9.68	
90	26	18:19:41	18:38:53	54 18.02	5 16.04	
91	26	20:41:17	20:48:22	54 5.89	5 43.67	
92	26	22:01:37	22:07:22	53 59.97	5 58.02	
93	26	23:12:13	23:23:50	53 53.03	5 58.00	
94	27	00:18:53	00:27:50	53 45.97	5 58.09	
95	27	01:53:45	02:03:05	53 34.06	5 57.96	

Table 6. CTD stations on Challenger 107.

CTD No	Oct	Start	End	Latitude (N)	Longitude (W)	Rig
096	27	10:19:50	10:30:40	54 7.40	3 26.66	J
097	28	08:08:28	08:18:07	54 35.96	5 26.11	C
098	28	10:27:09	10:42:19	54 38.57	5 21.66	B
099	28	13:30:27	13:48:05	54 41.21	5 15.91	A
100	29	00:07:09	00:17:10	54 42.77	5 32.85	
101	29	00:51:09	01:04:02	54 46.21	5 28.95	D
102	29	01:33:18	01:47:13	54 47.12	5 24.31	E
103	29	02:24:23	02:47:41	54 48.41	5 17.60	F
104	29	03:25:47	03:36:54	54 52.86	5 12.65	G
105	29	04:19:06	04:44:08	54 47.86	5 16.76	F
106	29	05:18:25	05:31:16	54 45.48	5 21.09	E
107	29	15:04:05	15:25:22	55 33.07	4 56.12	CS6
108	29	16:19:52	17:12:38	55 33.04	4 56.11	CS6
109	29	18:39:56	18:51:07	55 26.71	5 0.94	
110	29	19:29:33	19:39:14	55 21.87	5 4.81	
111	29	20:23:50	20:30:29	55 23.42	5 14.26	
112	29	21:03:12	21:10:27	55 21.00	5 16.98	
113	29	21:55:52	22:03:29	55 18.01	5 11.33	
114	29	22:40:37	22:47:50	55 17.08	5 4.47	
115	29	23:23:25	23:30:47	55 18.96	5 0.05	
116	30	00:29:21	00:38:34	55 23.77	4 51.63	
117	30	01:11:13	01:20:54	55 25.34	4 57.29	
118	30	02:24:25	02:34:04	55 31.13	4 47.15	
119	30	03:06:35	03:18:11	55 31.13	4 53.45	
120	30	04:21:39	04:30:24	55 39.63	4 56.43	
121	30	04:56:09	05:11:42	55 38.44	5 1.91	
122	30	06:12:34	06:20:00	55 33.42	4 55.79	CS6
123	30	11:13:59	11:27:35	55 44.20	5 11.43	CS8
124	30	14:56:36	15:32:29	55 45.53	5 13.56	
125	30	17:11:43	17:25:02	55 44.03	5 10.45	CS8
126	30	17:55:41	18:07:36	55 46.12	5 15.51	
127	30	18:45:58	18:57:32	55 42.66	5 19.78	
128	30	19:26:34	19:39:00	55 40.35	5 25.31	
129	30	20:22:53	20:39:54	55 35.47	5 25.22	
130	30	21:19:42	21:29:35	55 25.61	5 28.30	
131	30	22:08:36	22:16:58	55 19.28	5 28.12	
132	30	23:33:26	23:41:53	55 14.65	5 33.96	
133	31	00:20:36	00:31:26	55 14.72	5 44.46	
134	31	01:01:16	01:13:14	55 16.04	5 50.74	
135	31	01:38:37	01:52:55	55 15.90	5 50.61	
136	31	02:22:20	02:36:51	55 14.44	5 51.54	
137	31	03:06:38	03:22:22	55 13.42	5 55.40	
138	31	04:05:36	04:21:44	55 10.61	5 58.06	
139	31	06:54:47	07:03:31	55 22.46	5 24.97	
140	31	11:40:13	11:54:41	54 59.86	5 30.05	H
141	31	15:35:42	15:51:06	54 46.43	5 22.01	E
142	31	17:17:18	17:36:38	54 47.41	5 18.03	F
143	31	18:17:51	18:29:10	54 51.69	5 13.26	G
144	31	19:09:25	19:29:52	54 47.71	5 17.65	F

Table 6 continued. CTD stations on Challenger 107.

CTD No	Oct/ Nov	Start	End	Latitude (N)	Longitude (W)	Rig
145	31	20:22:00	20:37:32	54 45.09	5 21.11	E
146	31	21:37:12	21:49:15	54 44.20	5 27.48	D
147	31	22:42:26	22:49:21	54 43.03	5 32.83	
148	31	23:44:09	23:54:40	54 44.92	5 28.35	D
149	1	00:49:20	01:08:00	54 46.80	5 24.40	E
150	1	01:55:17	02:16:46	54 48.69	5 17.80	F
151	1	03:09:26	03:19:38	54 52.84	5 12.74	G
152	1	04:20:09	04:44:57	54 48.36	5 17.58	F
153	1	05:45:27	05:57:04	54 45.40	5 20.88	E
154	1	07:00:54	07:10:30	54 44.02	5 27.67	D
155	1	08:07:06	08:43:03	54 43.09	5 32.84	
156	1	20:30:50	21:01:33	54 52.55	5 12.25	G
157	1	21:32:49	21:51:39	54 46.61	5 17.47	F
158	1	22:33:37	22:47:24	54 45.23	5 21.92	E
159	1	23:32:06	23:44:09	54 44.50	5 27.67	D
160	2	00:26:24	00:33:37	54 43.00	5 32.97	
161	2	01:32:16	01:44:20	54 45.18	5 28.53	D
162	2	02:33:03	02:49:27	54 46.90	5 24.27	E
163	2	03:35:28	03:54:00	54 47.00	5 18.28	F
164	2	04:32:13	04:40:41	54 51.78	5 13.96	G
165	2	05:30:28	05:47:28	54 46.85	5 17.89	F
166	2	06:28:11	06:39:48	54 45.29	5 20.79	E
167	2	07:20:08	07:31:24	54 44.29	5 27.55	D
168	2	20:49:25	21:08:13	54 46.19	5 24.22	E
169	2	21:35:29	21:49:13	54 44.46	5 27.71	D
170	2	22:24:54	22:37:09	54 42.88	5 32.73	
171	2	23:28:36	23:42:42	54 44.62	5 27.85	D
172	3	00:29:34	00:43:50	54 45.97	5 22.86	E
173	3	01:29:43	01:46:57	54 47.07	5 18.08	F
174	3	02:30:19	02:40:56	54 51.63	5 13.33	G
175	3	03:31:03	03:55:10	54 47.77	5 17.89	F
176	3	04:30:28	04:44:50	54 46.11	5 23.45	E
177	3	05:31:16	05:44:21	54 45.13	5 28.37	D
178	3	07:00:41	07:07:29	54 42.91	5 32.68	
179	3	22:30:50	23:28:09	54 45.36	5 23.39	E
180	3	23:34:53	23:46:33	54 44.46	5 27.38	D
181	4	00:28:49	00:38:13	54 42.90	5 33.12	
182	4	01:30:03	01:47:04	54 44.95	5 27.93	D
183	4	02:28:51	02:47:11	54 46.51	5 23.65	E
184	4	03:36:43	04:00:27	54 47.86	5 17.80	F
185	4	04:30:05	04:39:43	54 51.47	5 13.01	G
186	4	05:30:34	05:52:56	54 47.85	5 17.88	F
187	4	14:14:13	14:26:02	54 41.18	5 23.02	E
188	4	15:48:04	16:00:11	54 31.48	5 14.84	
189	4	17:11:40	17:21:02	54 25.40	5 6.65	
190	4	18:37:17	18:47:15	54 15.82	5 16.23	
191	4	20:54:10	21:00:27	54 6.08	5 44.01	
192	4	22:06:00	22:45:43	53 59.90	5 58.10	
193	4	23:41:33	23:50:44	53 45.93	5 58.08	

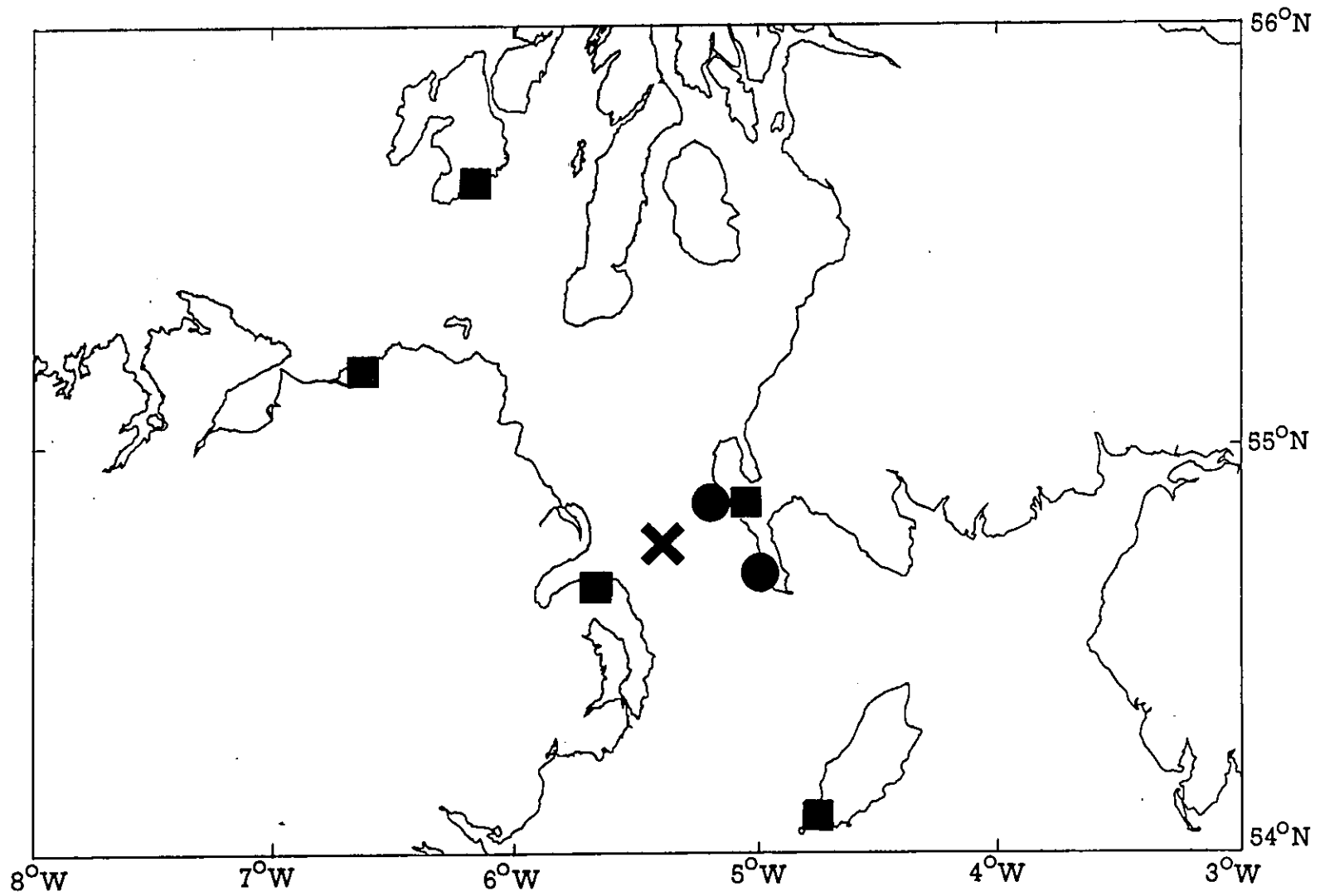


Figure 1. Map of the North Channel showing the sites of the OSCR HF radar master and slave units (●), of the long term ADCP (X) and of the tide gauges (■).

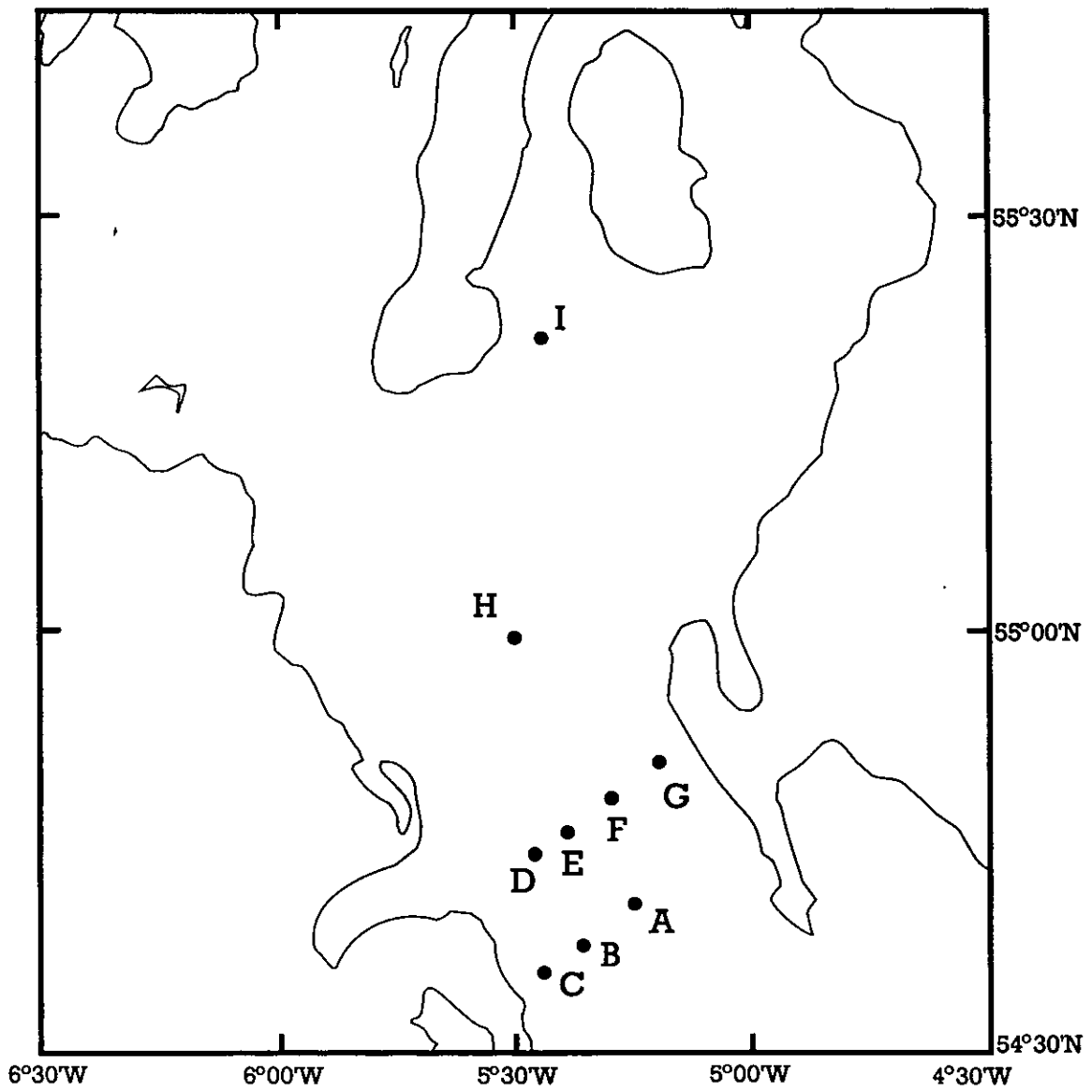


Figure 2. Map of the North Channel showing the rig positions.

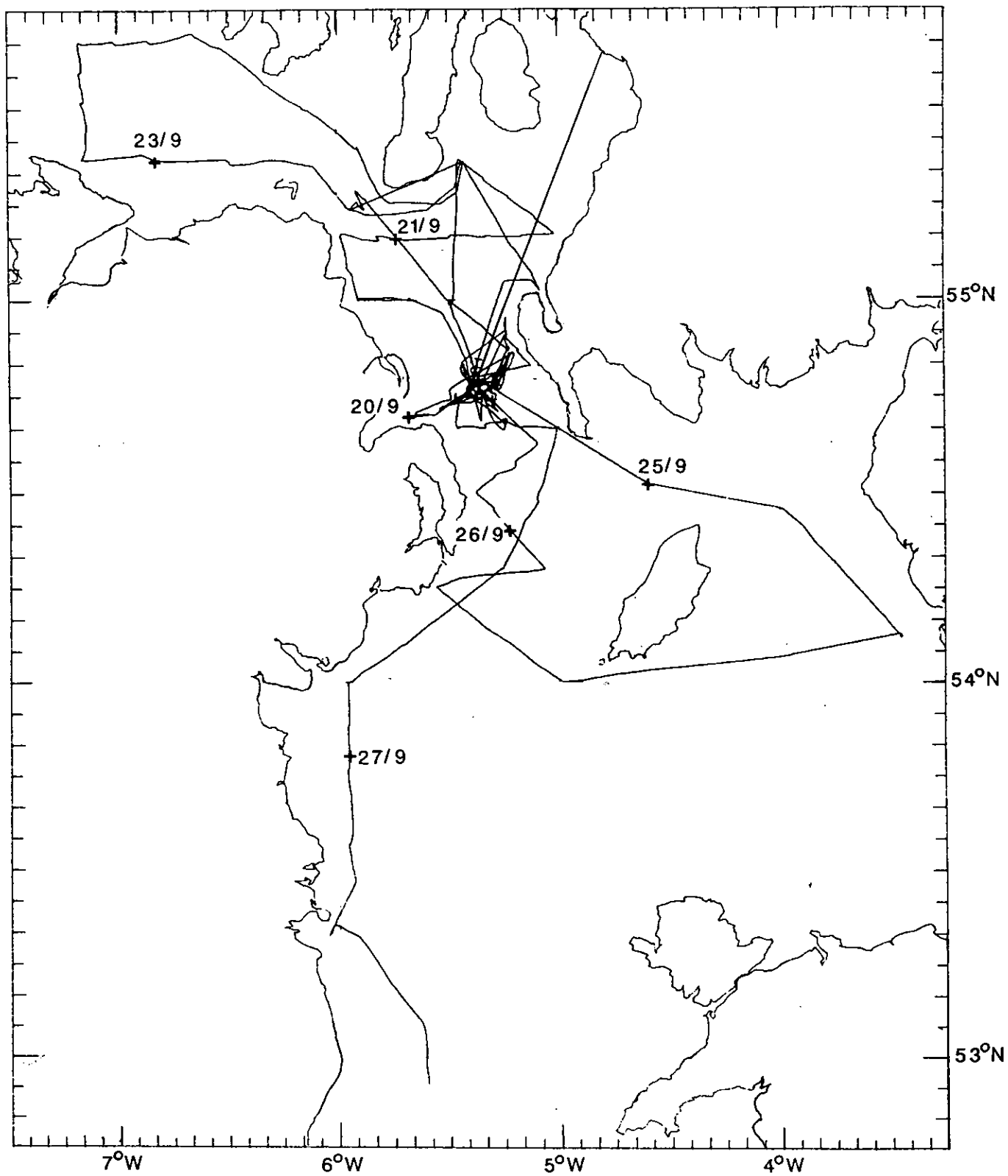


Figure 3. Cruise track for Challenger 106, 18 - 27 September, 1991. The crosses show the position at 00.00 on the day marked.

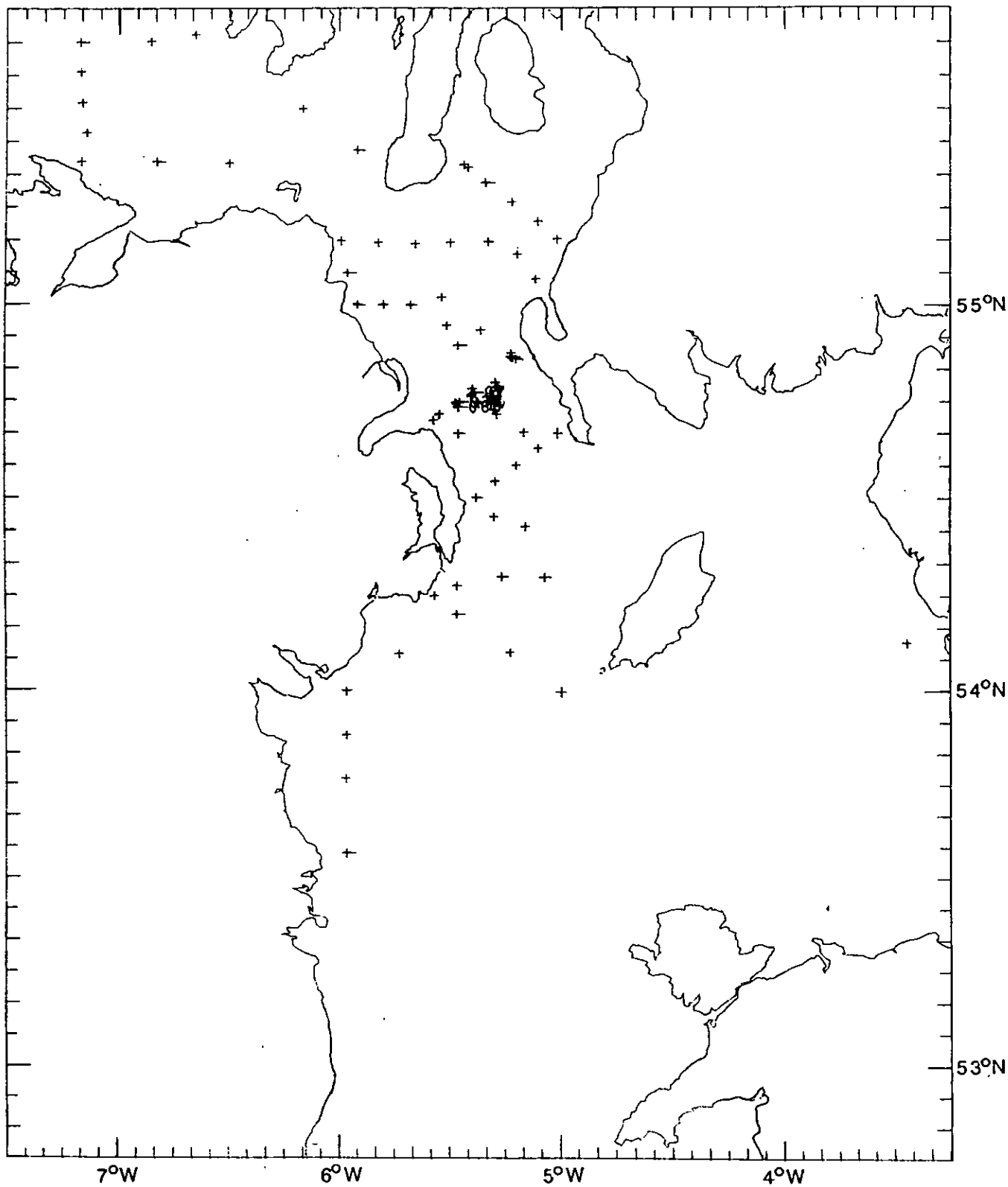


Figure 4. CTD positions for Challenger 106.

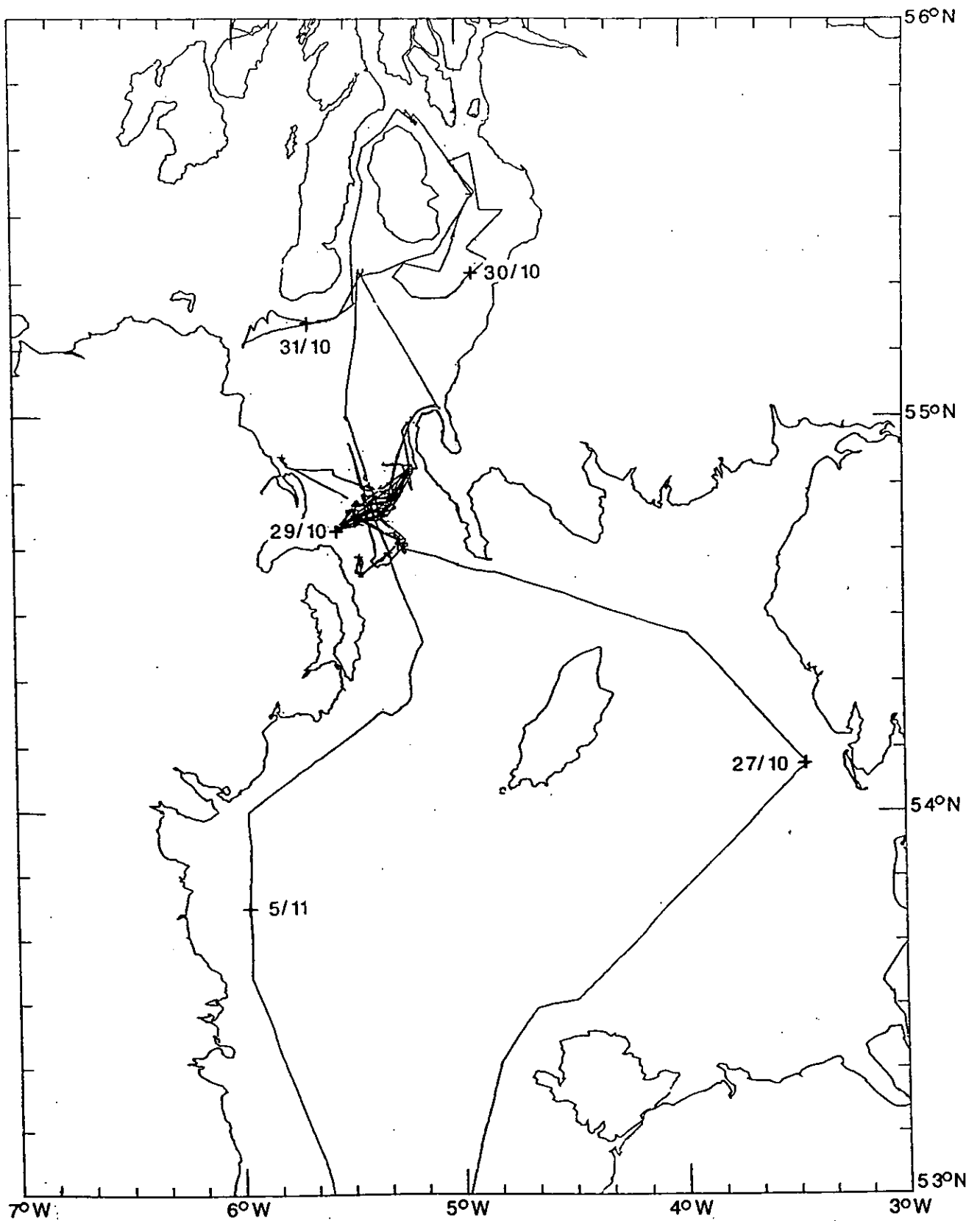


Figure 5. Cruise track for Challenger 107, 26 October - 5 November, 1993. The crosses show the position at 00.00 on the day marked.

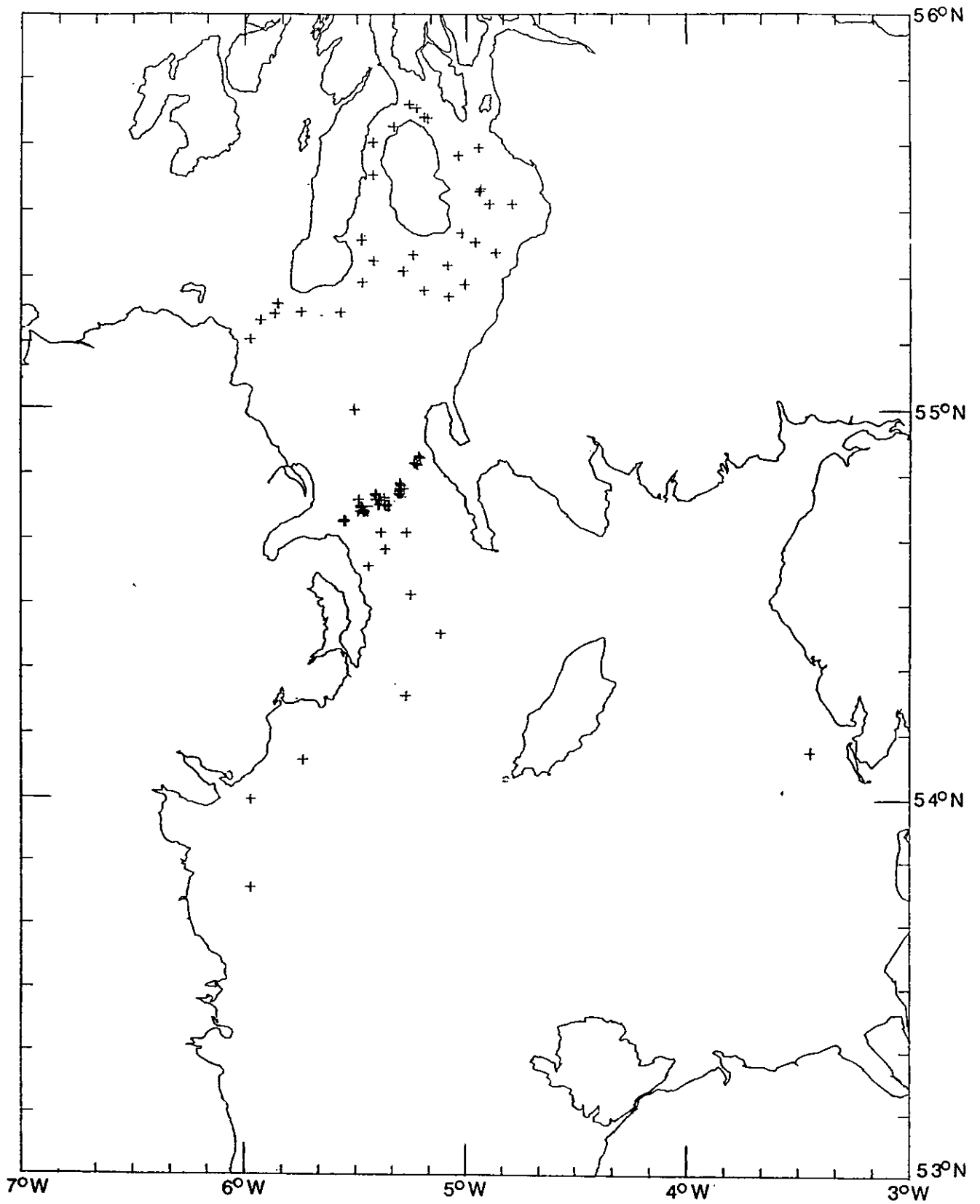


Figure 6. CTD positions for Challenger 107.

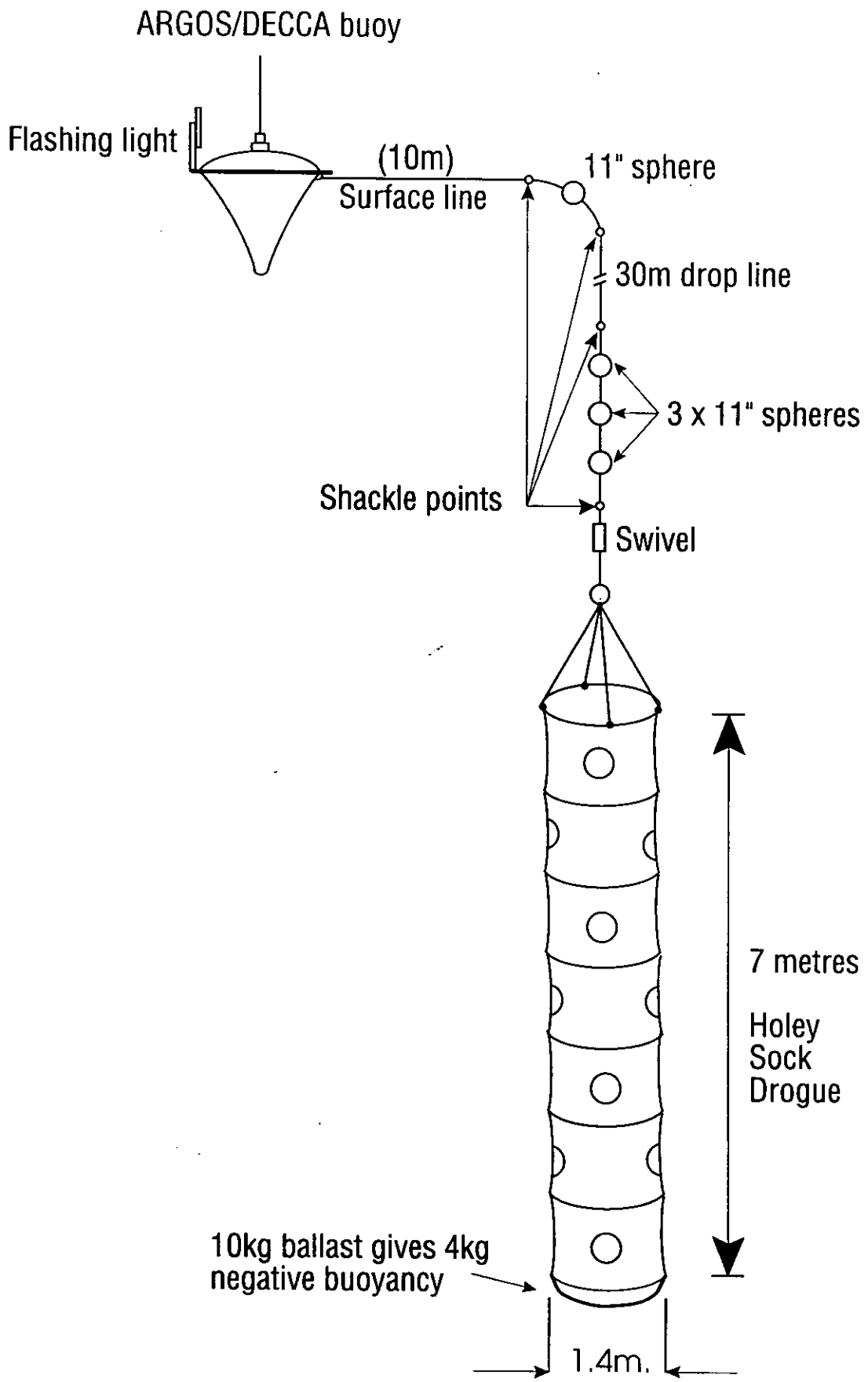
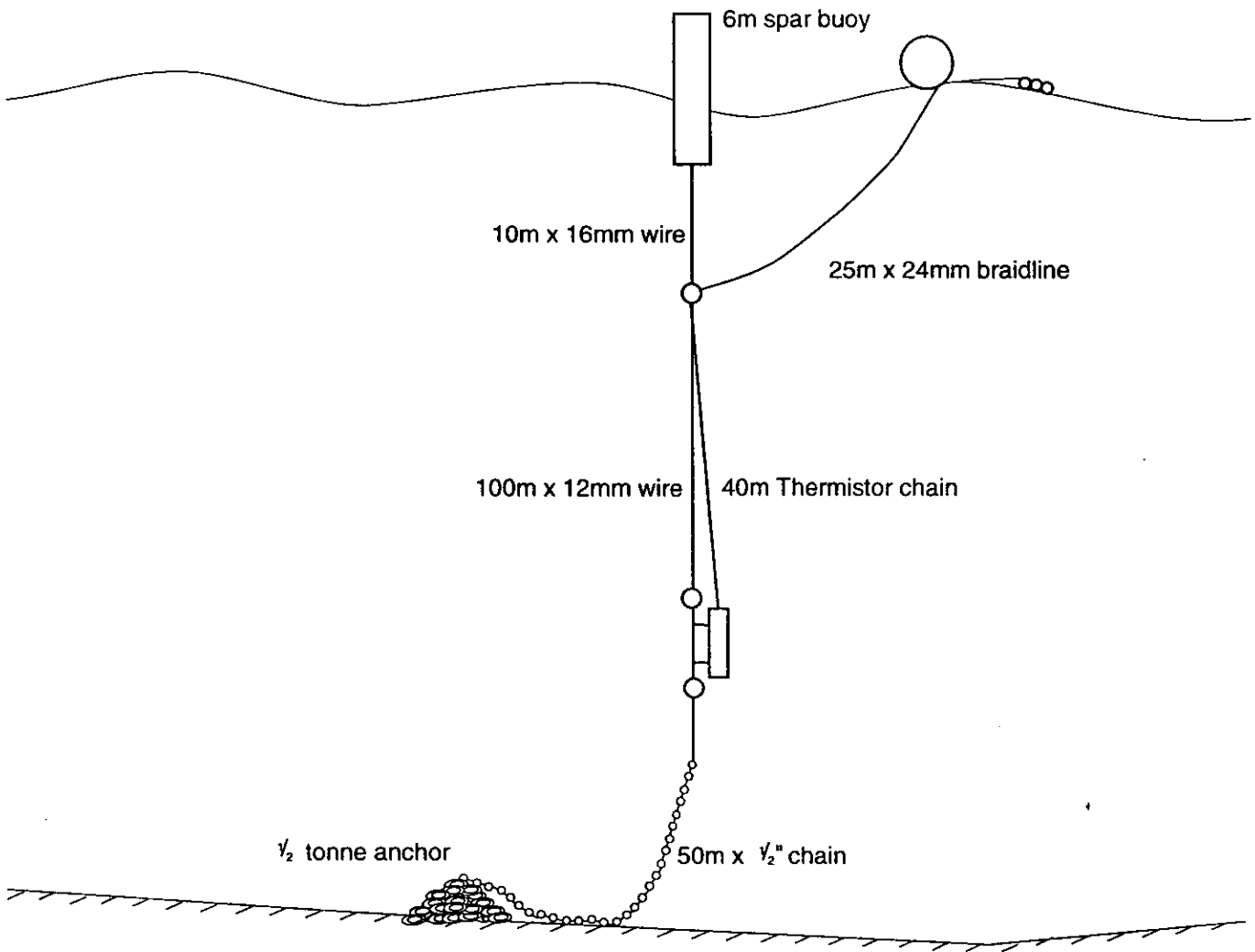


Figure 7. Schematic diagram of the rig layout for the drogues.

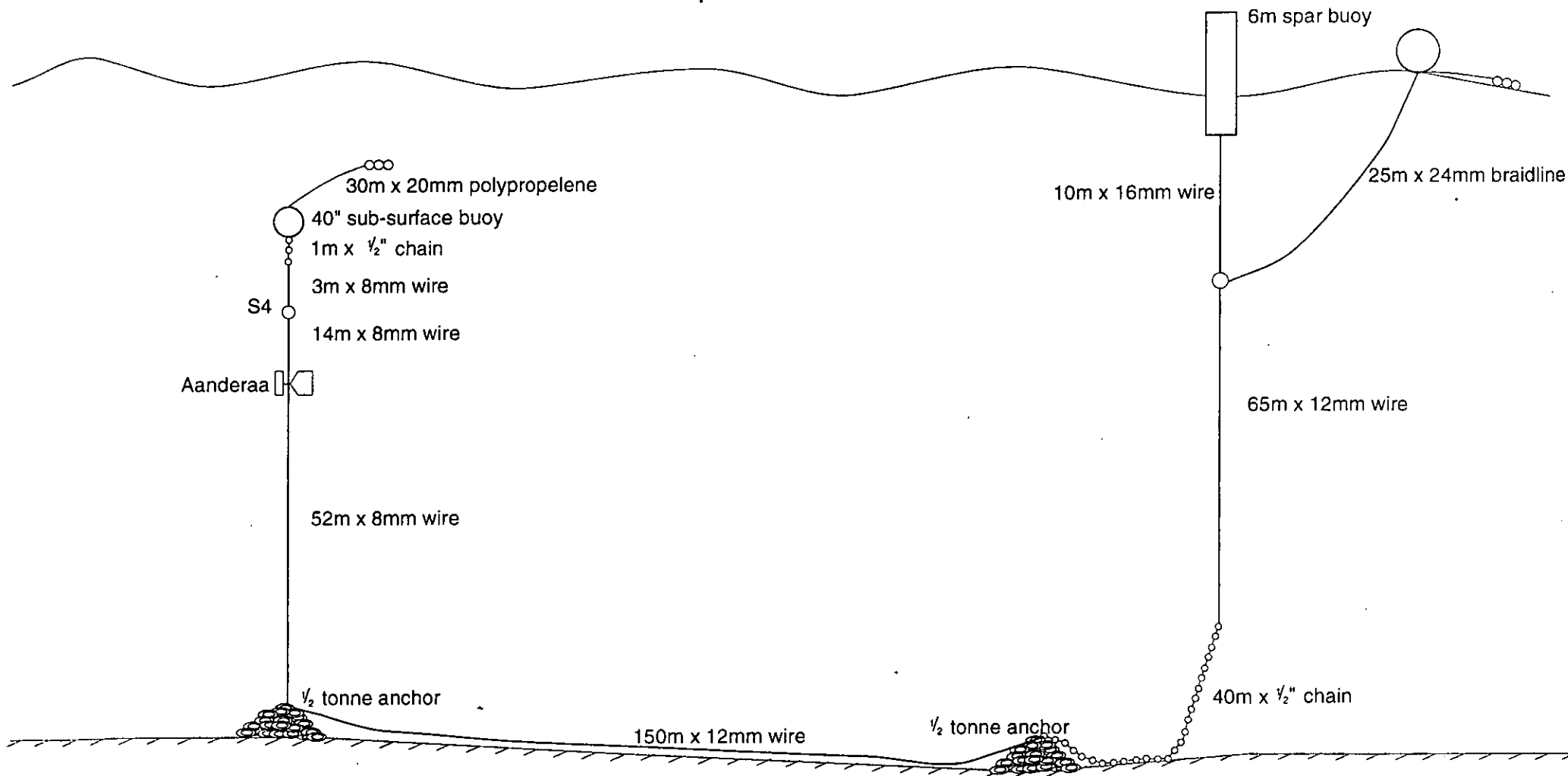
AB

Thermistor Chain



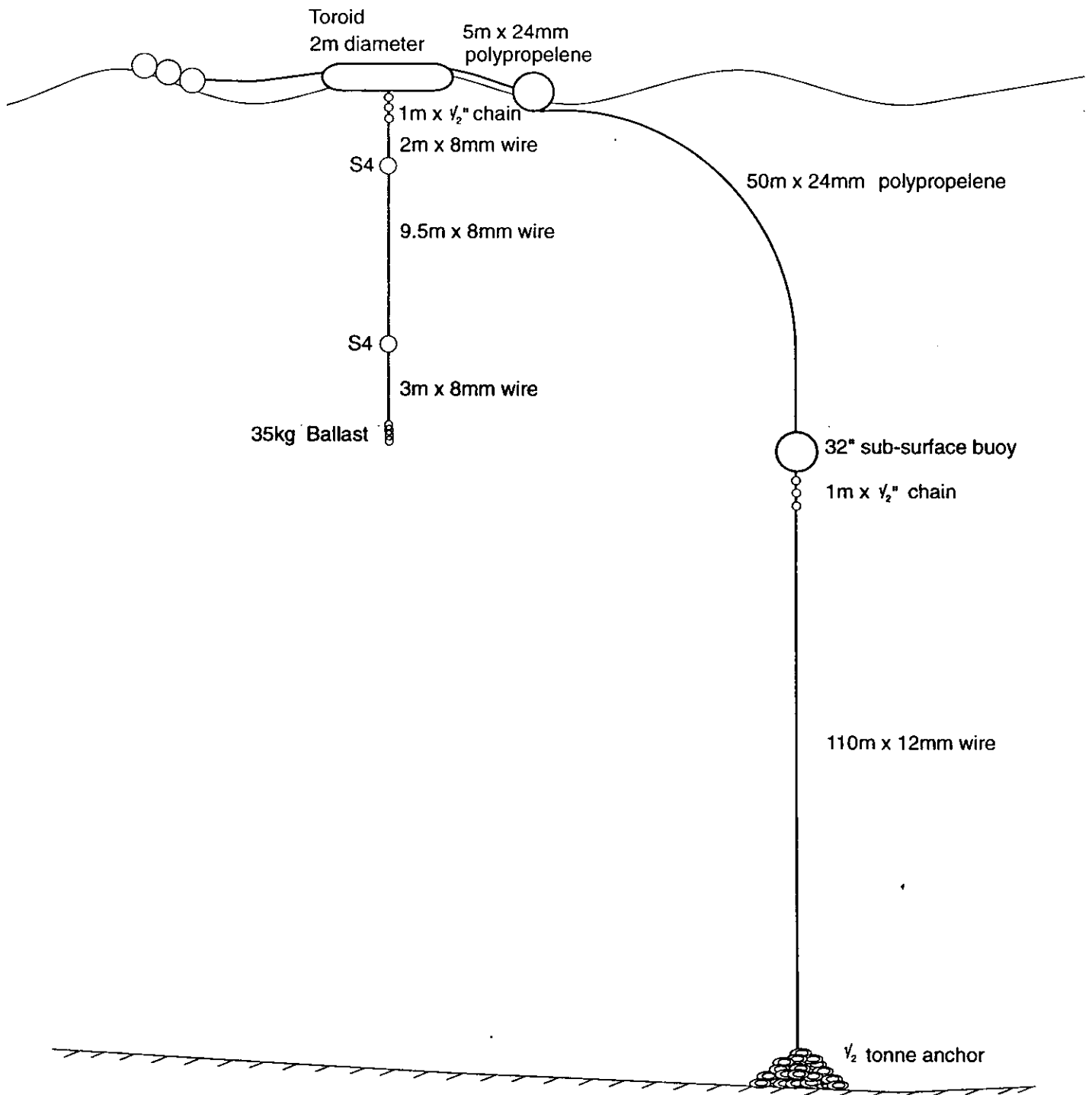
DB

'U' shaped current meter



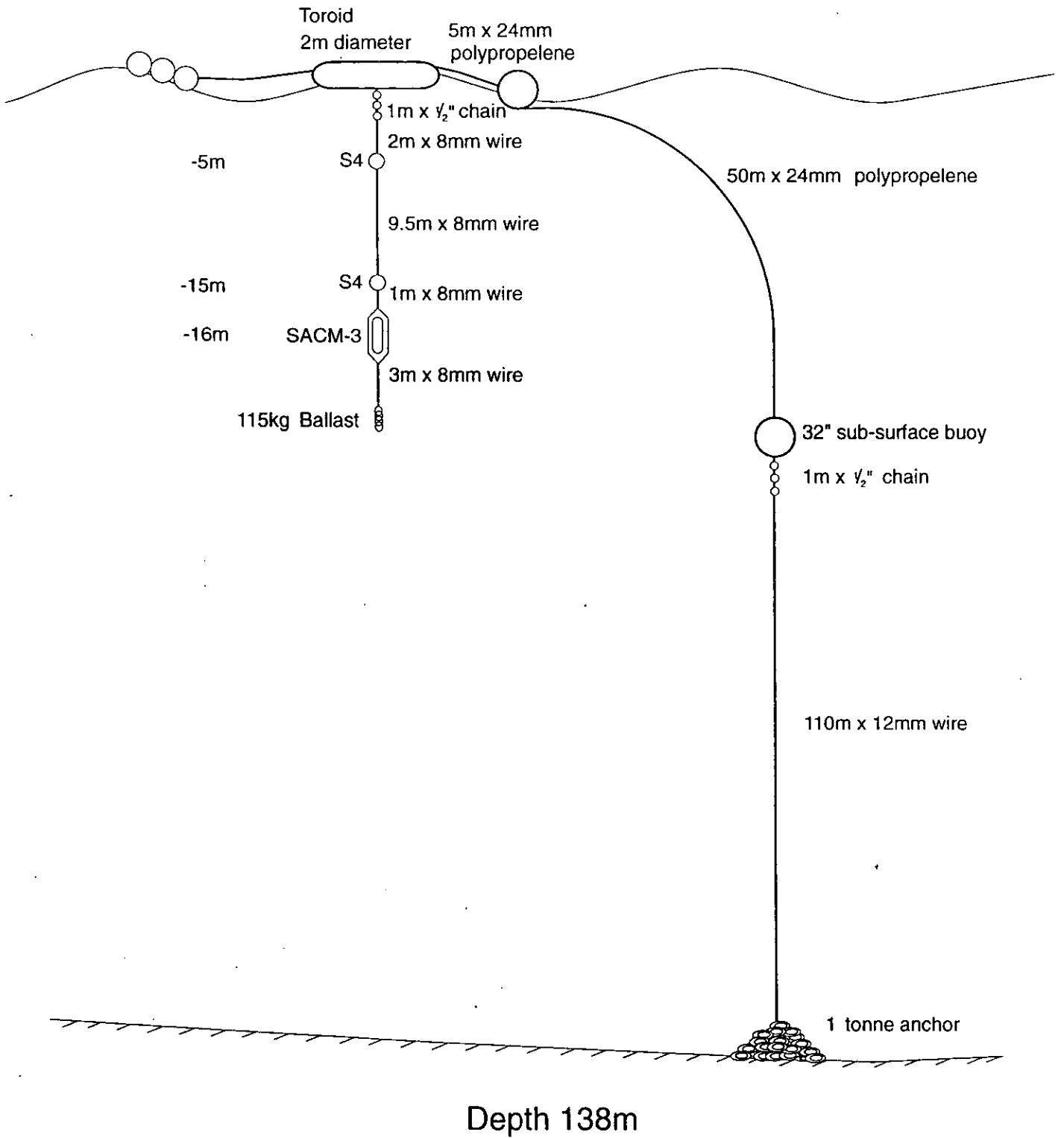
EB 1

Surface current meter (ETA)



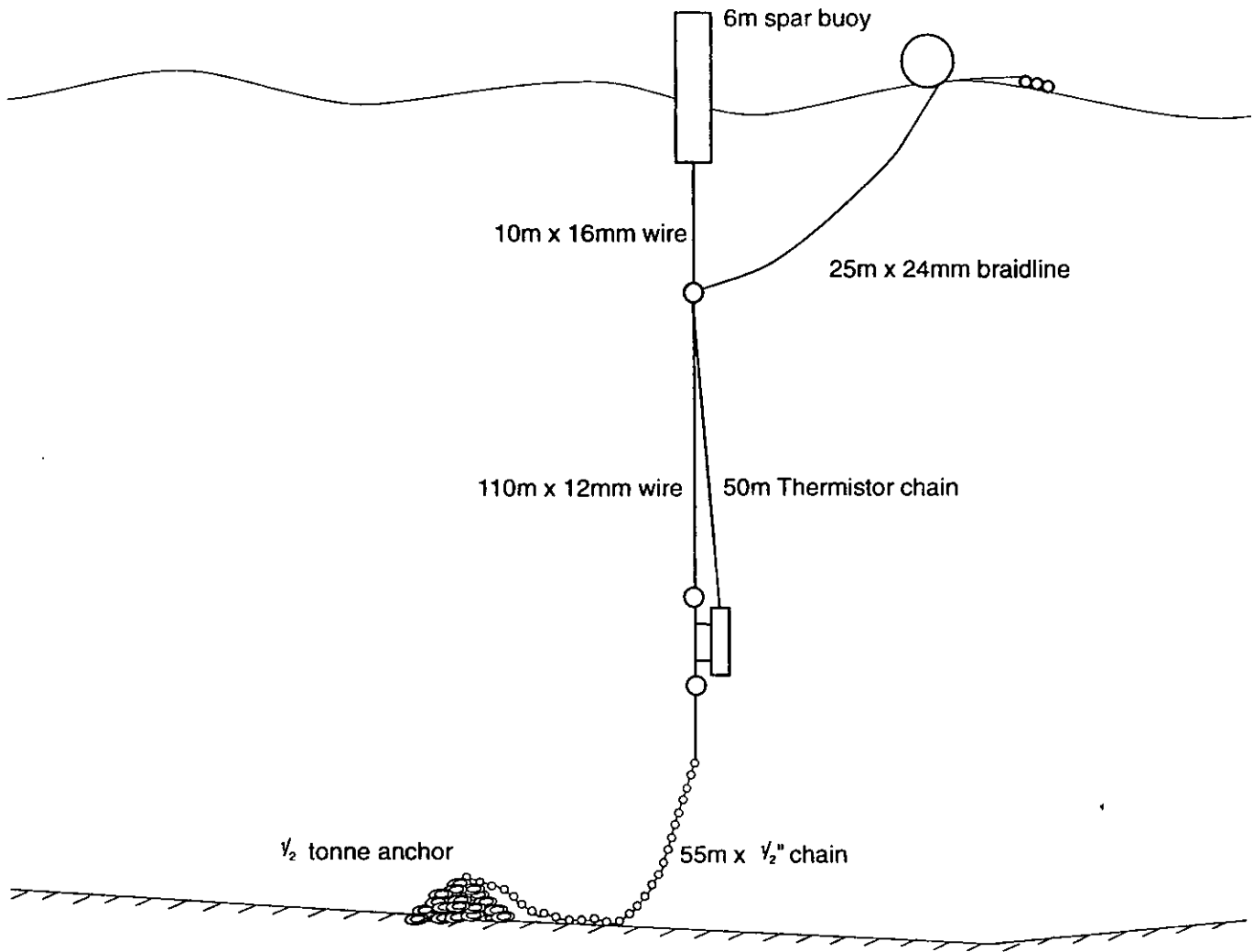
EB2

Surface current meter



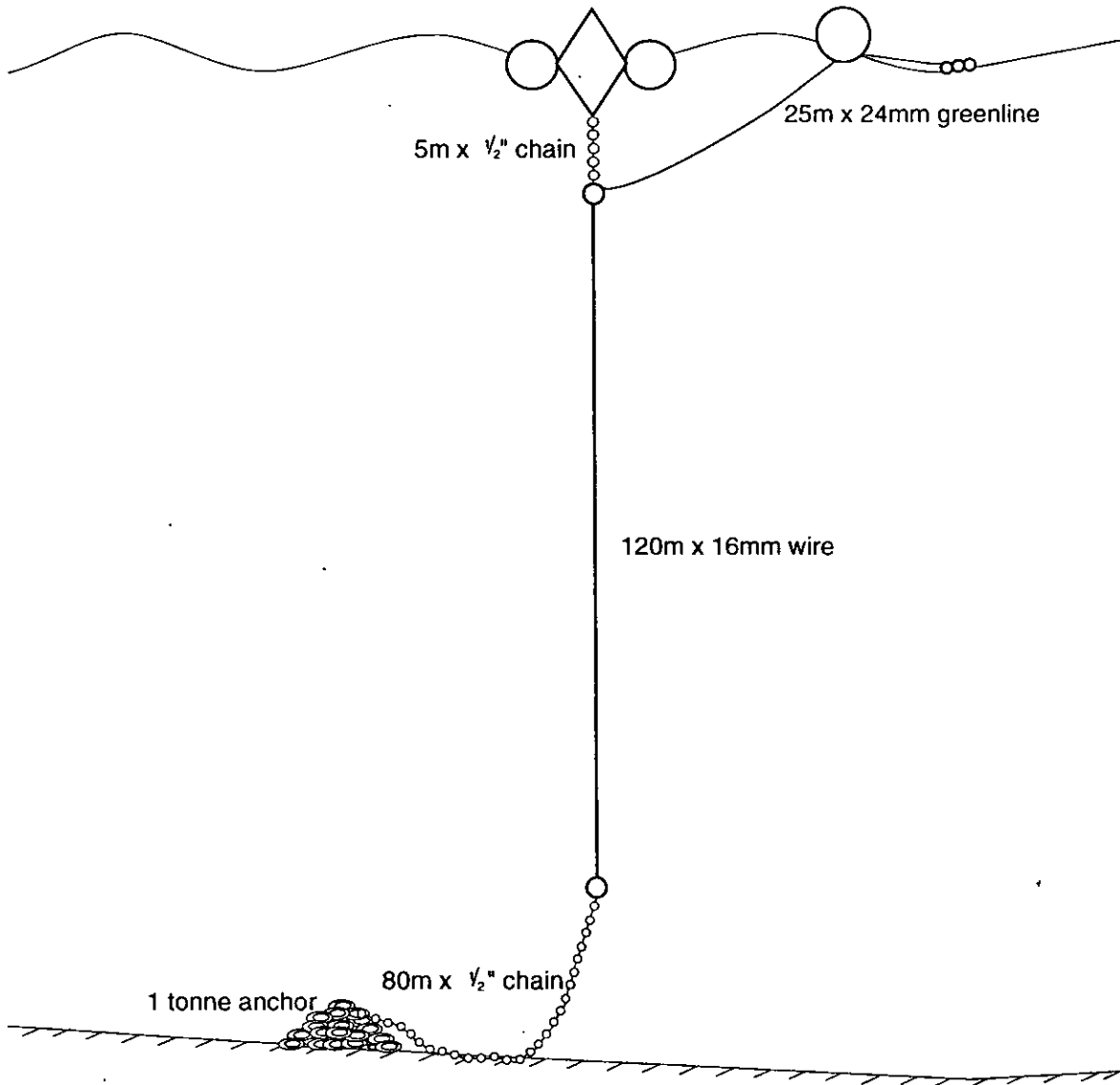
EC

Thermistor Chain



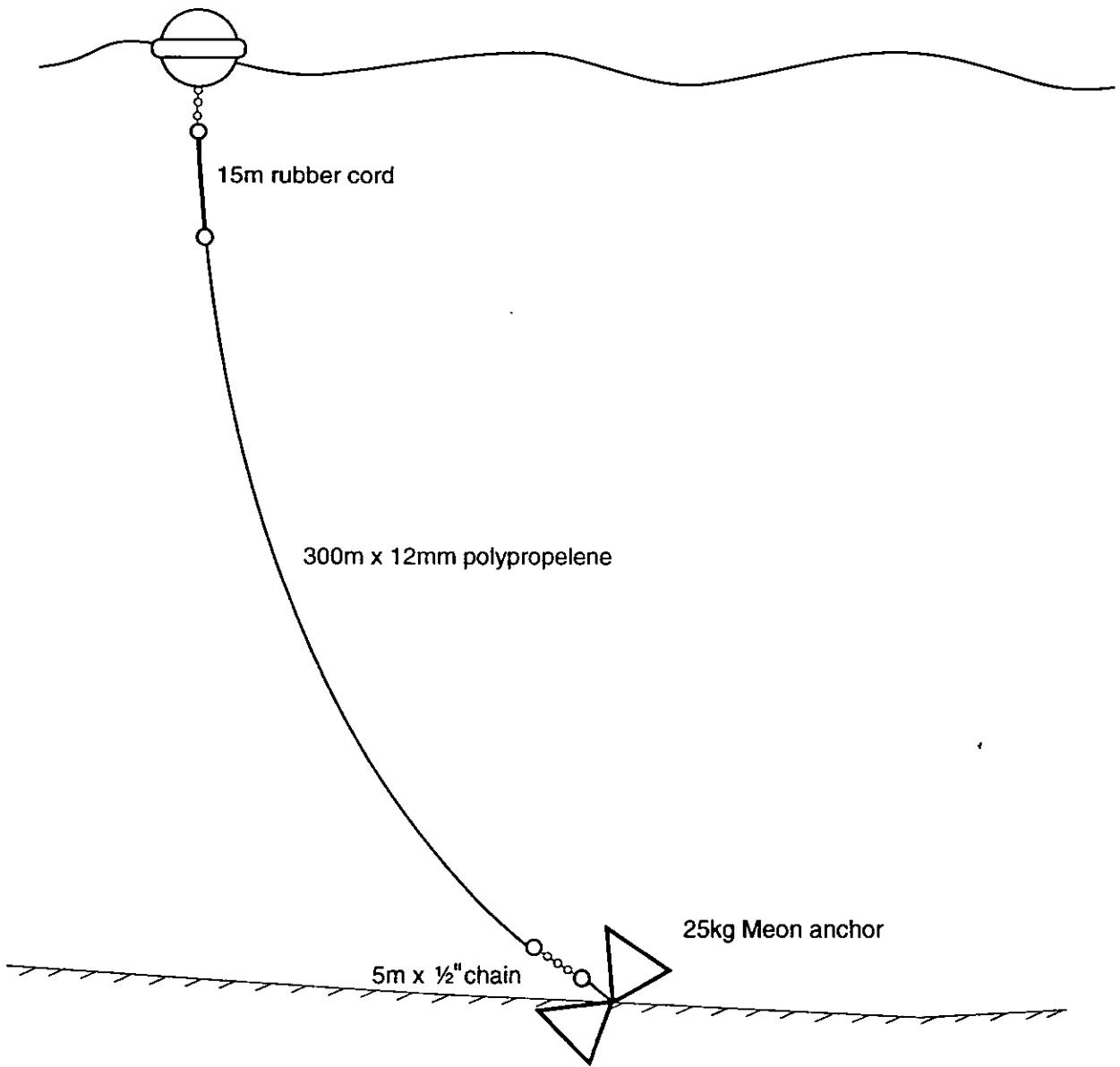
ED

Met. Buoy



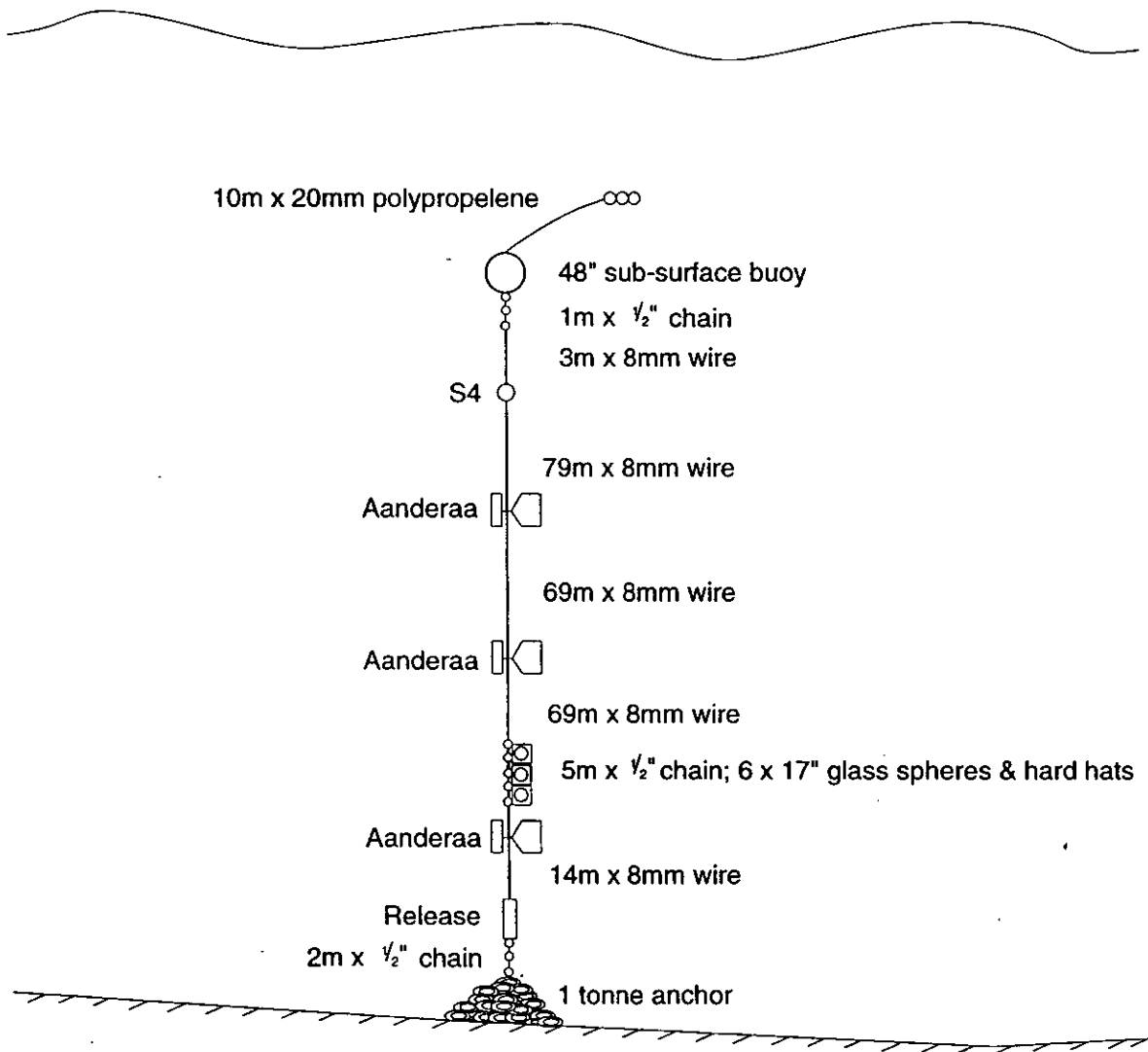
EE

Waverider



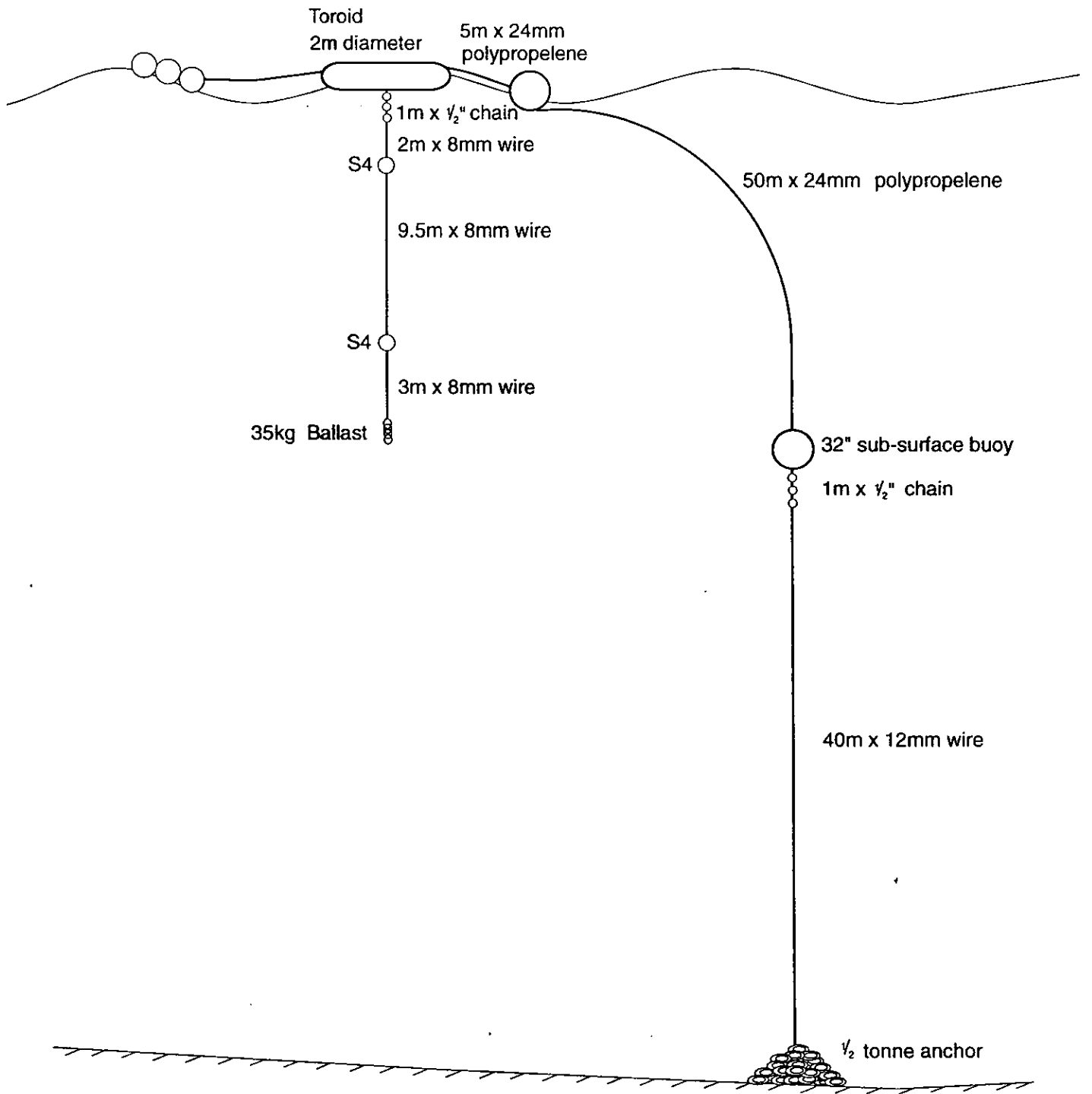
FA

Pop - up Current Meter



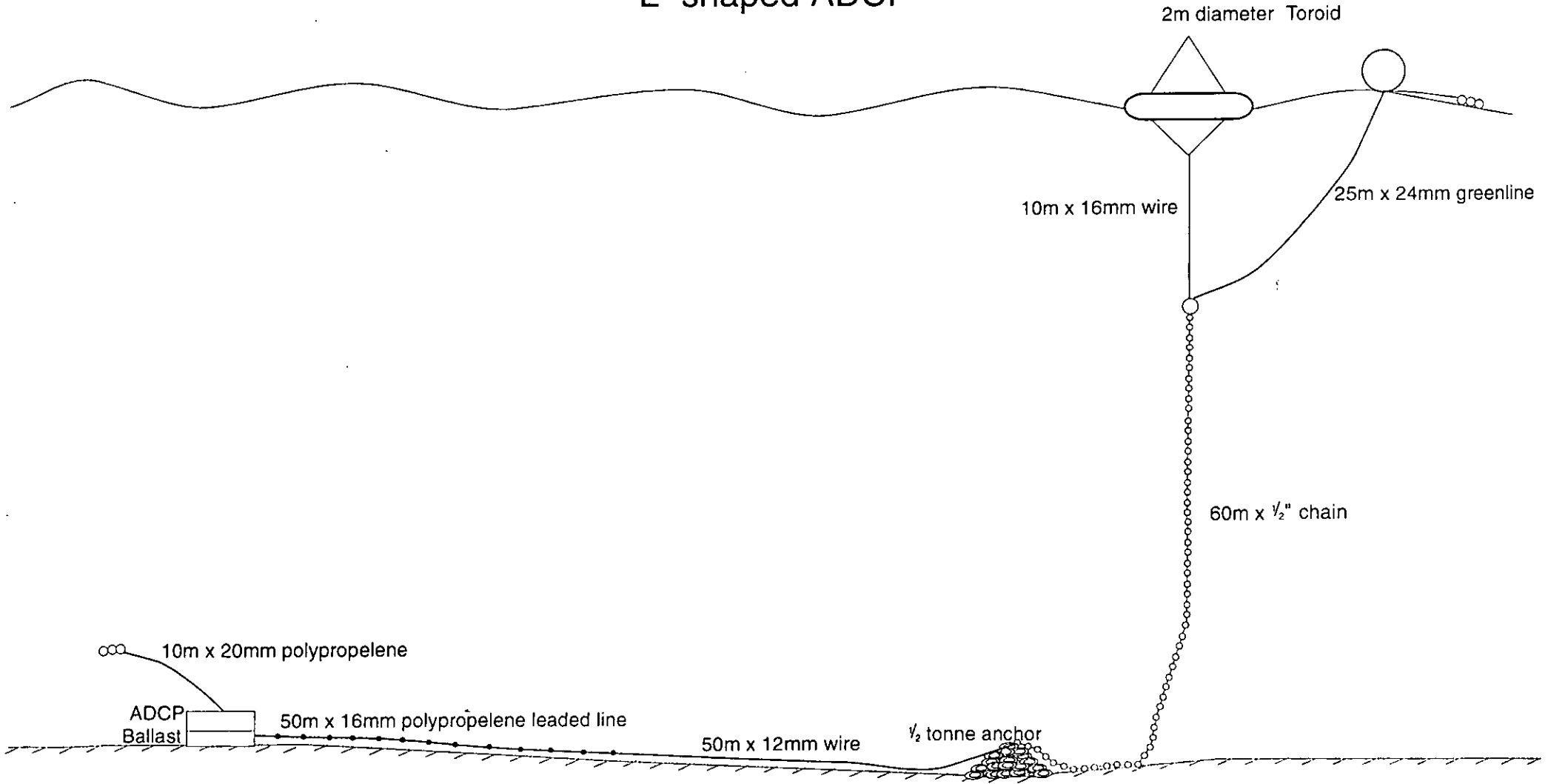
GB

Surface current meter (ETA)



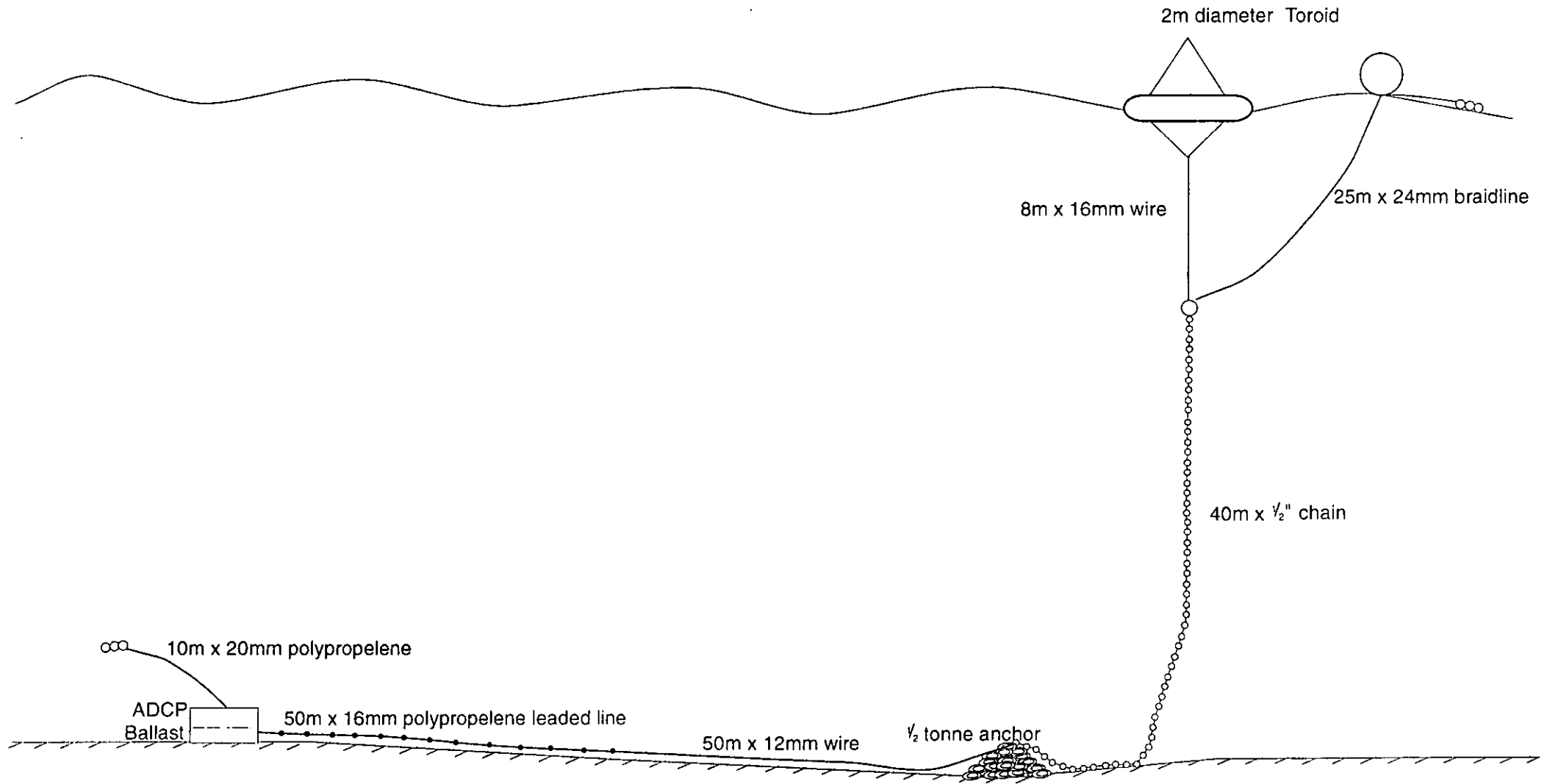
IA

'L' shaped ADCP



JA

'L' shaped ADCP



JB

'U' shaped current meter and transmissometer

