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CRUISE REPORT

CRUISE RVS Cruise, North Sea 42/88: PML Humber Plume Study. This is a process cruise contributing to the NERC North Sea Project.

VESSEL RRS *Challenger*

PERIOD 15-29 December 1988

PERSONNEL		
	A W Morris	PML - Principal Scientist
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	P G Watson	PML
	D Harper	MAFF
	K Fileman	MAFF
	A Turner	PPIMS
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	P J Statham	U of Southampton
	R Lloyd	RVS (to Dec 21)
	A Fern	RVS (from Dec 21)
	R Powell	RVS

SCIENTIFIC OBJECTIVE

To characterise and model the processes controlling the transport of effluent species from large estuaries to the sea.

SPECIFIC OBJECTIVES

1. To define the spatial and temporal characteristics of the plume of water originating from the Humber Estuary and the Wash by repetitive sampling for selected conservative and non-conservative constituents around a grid enclosing the plume.

2. To determine the transport pathways for non-conservative constituents in relation to suspended particle/water exchanges through controlled experiments on board the research vessel.

3. To characterise the transfers of nutrient and metal species across the sediment/water interface by controlled on-board incubations of undisturbed cores collected from within the survey area.

ITINERARY

Wed 14 Dec Travel to Great Yarmouth; embark 1300; load and commission equipment.

Thur 15 Dec Depart Great Yarmouth 1500; commission and start-up recording instruments underway to Broken Bank, arriving 2000; check presence of rigs by radar; Day grabbing at 'blue site' completed 2400.

Fri 16 Dec Proceed to 'yellow site' for Day grabbing, completed 0400; box core at site of rig D, then attempt to recover rig; unsuccessful - chain snapped; grappling search abandoned at 1300; proceed to mooring 2 - found and successfully recovered by 1500; proceed to mooring 3 - found and partial recovery (frame sheared) by 1615; proceed to intersect planned plume track at 2300; commence first track circuit with continuous recording of environmental variables and underway pumped water sampling (this recording and sampling was continued throughout the cruise). Day grabs at approx. half hourly intervals.

Sat 17 Dec Continue first grid circuit until 1030 then sail for Grimsby to exchange ship's officer; recommence first circuit 1330.

Sun 18 Dec Continue first circuit with Day grabbing.

Mon 19 Dec First circuit completed 0100; commence second circuit, no grabbing but with box cores at selected sites.

Tues 20 Dec Second circuit completed 1230; box core sample then commence zig-zag course from east of Spurn Point towards the mouth of the Humber 1900 with CTD dips at approx. hourly intervals.

Wed 21 Dec Complete CTD track by 0500; rendezvous Humber pilot 0900 and anchor on station in Humber mouth 1030; collect box core; commence 25 hour time-series sampling with hourly CTD dips 1215; changeover of RVS computer operator.

Thur 22 Dec Finish anchor station sampling 1300; Proceed to Silver Pit for box core then start third circuit of grid.

Fri 23 Dec Continue third circuit.

Sat 24 Dec Complete third circuit 0900; deploy sediment trap rig; commence shortened fourth circuit east of Humber mouth.

Sun 25 Dec Finish shortened circuit 0700; complete recovery of sediment trap rig 1100; commence fifth circuit 1600.

Mon 26 Dec Complete fifth circuit and proceed to Wash area for box core; make zig-zag transects towards Humber mouth.

Tues 27 Dec Anchor in Humber mouth 0900; box core; start second 25 hour time-series with hourly CTD dips at 1100.

Wed 28 Dec Finish anchor station 1200; depart for Great Yarmouth.

Thur 29 Dec Dock Great Yarmouth 0300; unload ship and depart for Plymouth 1400.

Summary of procedures

The objectives of this cruise were fully achieved.
The earlier cruise work in the Broken Bank area was a last-minute inclusion carried out at the request of Dr J Huthnance (POL) and Dr M Collins (U of Southampton). This involved collection of grab samples and retrieval of moored rigs.
Five full circuits of the plume area were completed together with three shortened circuits. Figure 1 shows the track followed by the ship throughout the cruise and highlights the spatial coverage achieved. Continuous recording of environmental variables, including nutrients, and discrete underway pumped sampling were carried out throughout these circuits. Collection and pre-storage treatment of samples for dissolved and particulate metal analyses employed meticulous 'clean' techniques. CTD casts, box cores and Day grab samples were taken at selected sites and appropriate times around the grid. Figure 2 shows where water samples, grab and box core samples were taken and the locations of the CTD profiling stations.
Two 25 hour time-series of observations of chemical variables were undertaken at the mouth of the Humber to obtain information on the fluxes of chemicals from this estuary to the coastal sea. The fluxes estimated in this way are to be compared with the best estimates of river and effluent discharges to the estuary provided by the Humber Estuary Committee. In addition to continuous recording of near-surface environmental variables and nutrient concentrations, hourly CTD profiles of the vertical characteristics of the water column accompanied by water bottle sampling for metals and suspended particle analyses were carried out.
On-board experiments were carried out continuously during the cruise. These were designed: (1) to determine rates and equilibrium states of particle/water metal exchange using radiotracer techniques, and (2) to measure the rates of sediment/water exchanges of metals and nutrients.
For (1), natural water samples were incubated under controlled temperature conditions following the addition of radiotracer dissolved metals. The uptake of radiotracer was examined by sub-sampling at intervals and filtering. Filtrates and separated particle populations were returned to the laboratory for radiochemical counting. Rates of uptake of radiotracer and equilibrium partition coefficients will be calculated from these kinetic data.
For (2), undisturbed cores sub-sampled from box cores were incubated in purpose-built experimental equipment. Cores were maintained at environmental temperature. Rates of transfer of nutrients and metals across the sediment/water interface were obtained by sub-sampling the water overlying the sediment at suitable intervals. Samples of pore water were abstracted from these cores for indirect estimation of nutrient and metal fluxes based on diffusion theory. Advective (storm and tide) effects were examined by subsequent controlled disturbance of the sediment surface.

RESULTS

Hydrography

Figures 3 and 4 are computer generated plots of the near-surface distributions of salinity and temperature recorded during a single circuit of the grid. These show that the plume of the Humber Estuary/Wash discharge, which can be considered as bounded by the 34.2 isohaline, was well defined although the river discharge was abnormally low for the season.
The data in these plots have not been amended to take account of tidal excursion during the finite period of the observations. Nevertheless, the

'lens' of low salinity, low temperature water observed within the plume is too large a spatial structure to be attributable to experimental artefact. Moreover, this feature persisted throughout the cruise period. The way in such a marked spatial feature is generated will be fully examined in our subsequent modelling studies. Provisionally, we propose that it is formed by tidal pulsing of water emitted from the Humber Estuary. This being so, it will provide a very useful time marker for kinetic interpretations of reactive chemical distributional data.
Except for the measurements taken in the estuary mouth, the water column within the plume was found to be well-mixed. In contrast, marked vertical gradients of salinity, temperature and suspended solid concentration were observed at the anchor station around the time of maximal tidal currents.
It is clear that the acquired data fully satisfy our present requirements with respect to developing and validating a basic hydrographic model which is the fundamental first stage of plume model development.
The grab survey showed a predominance of sandy gravels. Mainly sand with interspersed silt layers was found in the Humber mouth; silt was also observed in Silver Pit and in the Wash region, mixed with sand and gravel. The sands were oxic, with near-surface redox potentials of around +400mV; the siltier regions showed redox potentials of -40 to -50mV. Size analysis of sediments is in progress.

Water column chemistry

A proportion of the discrete chemical samples remains to be analysed and the continuously recorded data are presently being processed so that only preliminary chemical interpretations are available at the present time.

Figure 5 shows continuously recorded outputs of dissolved nutrient (nitrate, silicate, phosphate, nitrite) concentrations compared with salinity and temperature. These data cover one 12h period of the cruise. As expected for the winter season, nitrate and silicate covary closely and are both inversely correlated with salinity, confirming their principal land source and their utility as pseudo-conservative constituents. Phosphate and nitrite show much more uniform conentrations, largely independent of salinity.

On board experiments

The first few kinetic and equilibrium results indicate significant spatial variability in long-term Kd values (the ratio of the amount of particle associated metal on a wt/wt basis to the concentration of dissolved metal) and the rate at which apparent equilibrium is approached. Values are most noticeable disparate in samples near to the estuary mouth. Clearly, the differences arise from spatial contrasts in suspended particle type. The variations in Kd values and rates will be compared with hydrodynamic conditions and with the chemical characteristics of the particle populations, when this information is fully available.
Measured exchange fluxes of nutrients and metals across the sediment/water interface can be summarises as follows (fluxes are defined as positive when transport is from the sediment to the water column):
(1) With undisturbed cores, positive fluxes were generally observed for silicate (up to 600uM $m^{-2}d^{-1}$) and phosphate (up to 40uM $m^{-2}d^{-1}$), with negative fluxes of nitrate (range, -100 to -4000uM $m^{-2}d^{-1}$) and nitrite (range, -5 to -18 uM $m^{-2}d^{-1}$). Ammonia fluxes were variable in direction, ranging from +600 to -2000uM $m^{-2}d^{-1}$.
(2) The magnitudes of these fluxes show regional variations which in part are

relatable to the sediment type. They are not simply related to surficial pore water concentrations or to vertical concentration gradients.
(3) In general, controlled disturbance of the sediment surface resulted in relatively insignificant releases of silicate and phosphate but appreciable releases of nitrite and ammonia. Regional variations are significant.
(5) Generally, positive fluxes were recorded for the metals Fe, Mn, Zn, Cd and Pb, with a few regional exceptions, most noticeable in the Wash. Negative fluxes of Cu and Ni were consistently observed. Some regional trends in the magnitudes of these fluxes are apparent.
(5) Sediment disturbance consolidated the general positive diffusive fluxes of metals, reversed the flux direction for Ni and ameliorated or reversed the direction of Cu flux.

Acknowledgements

The excellent service provided by the Master, Capt G Long, and his officers and crew throughout this cruise is most gratefully acknowledged.
RVS personnel provided us with invaluable logistical, instrumental and computing support.
The results are being used for plume modelling developments supported by the Department of the Environment under Contract No 7/7/286.

Report prepared by: A W Morris, 21 April 1989

Report authorised by: B L Bayne, 21 April 1989

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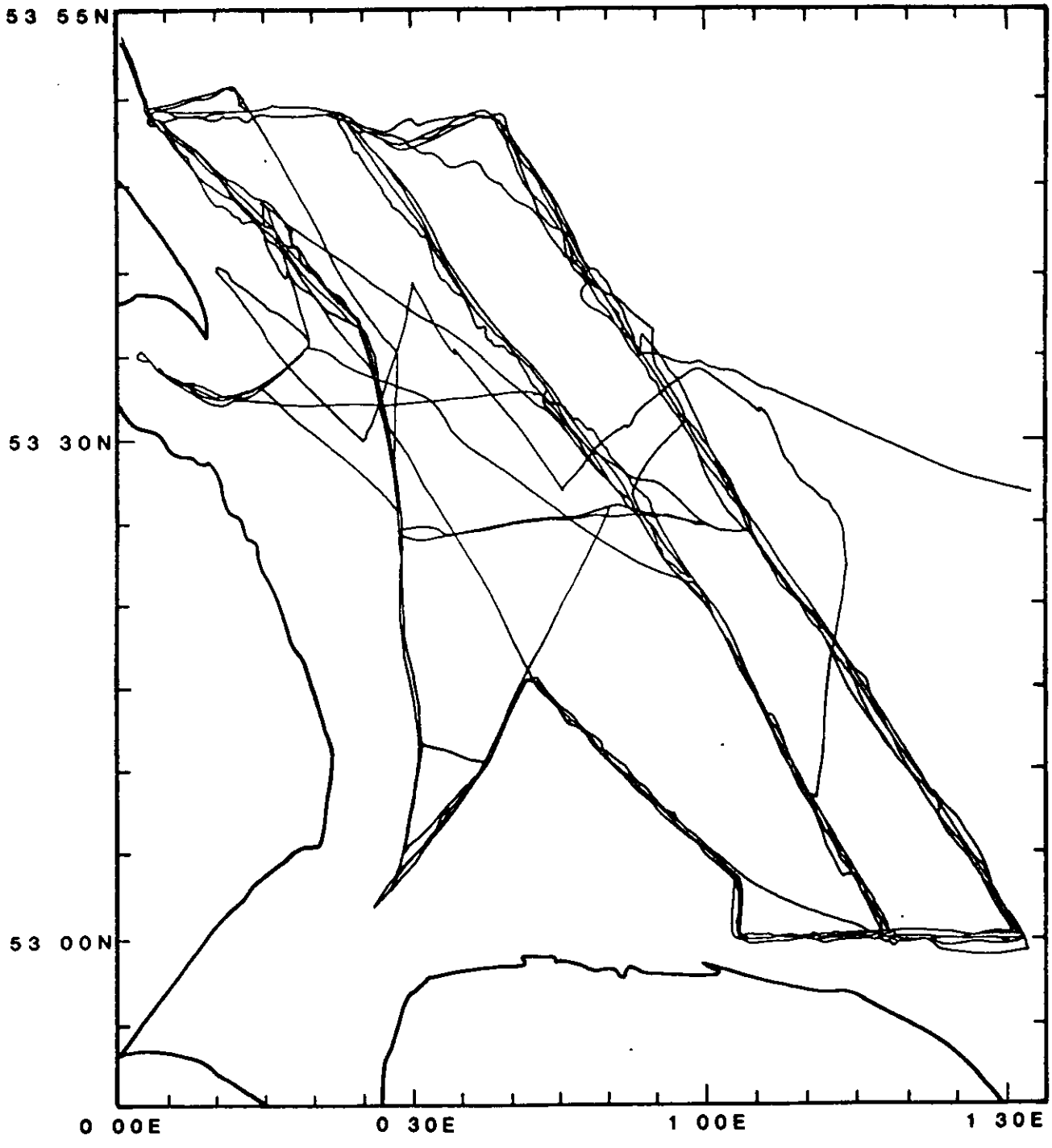

Figure 1. Plot of the complete track traversed during the Humber/Wash plume investigation, December 1988.

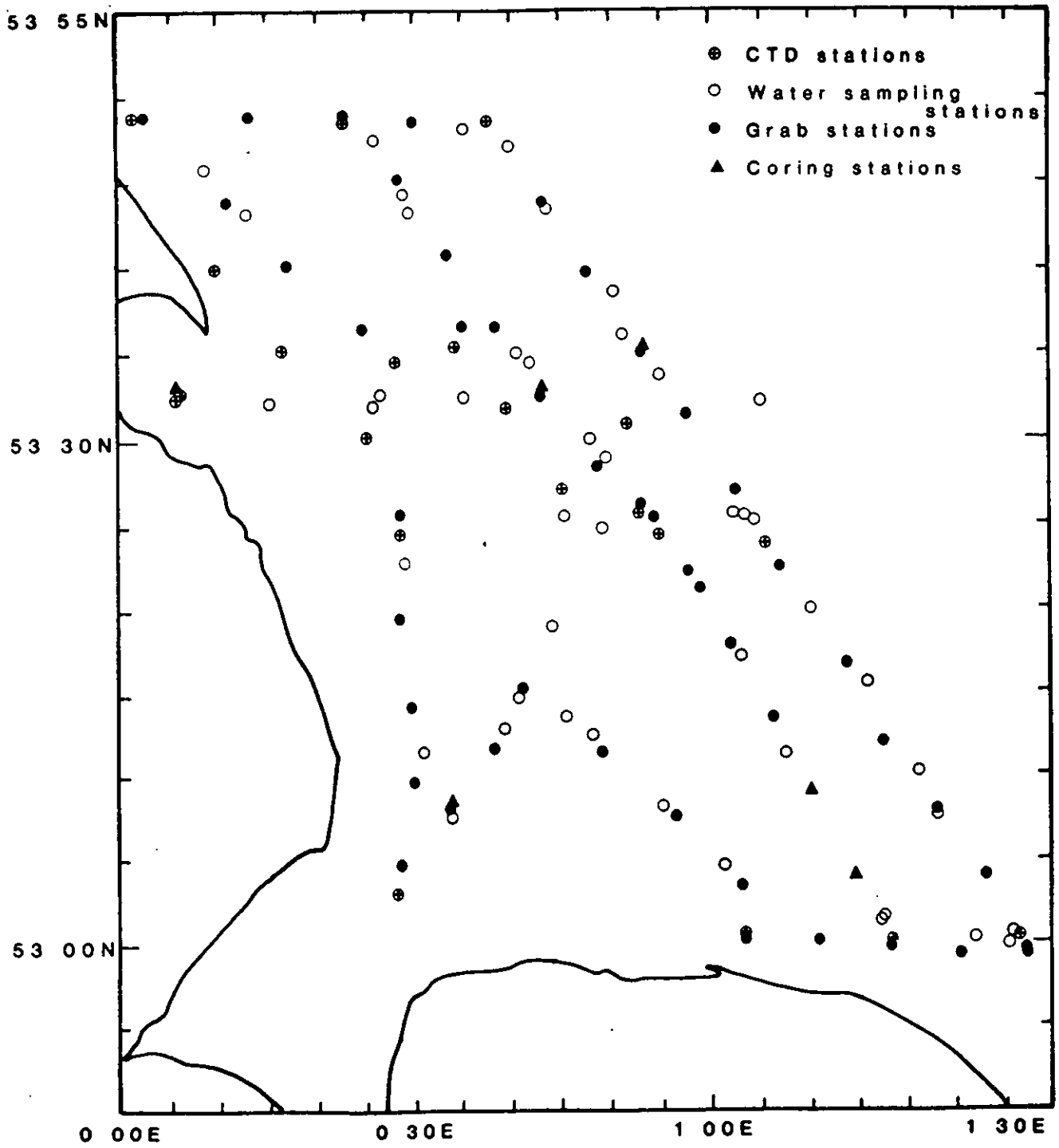

Figure 2. Positions of stations for CTD profiling and water bottle sampling, pumped water sampling, Day grab sites and box core sites during the investigation of the Humber/Wash plume, December 1988.

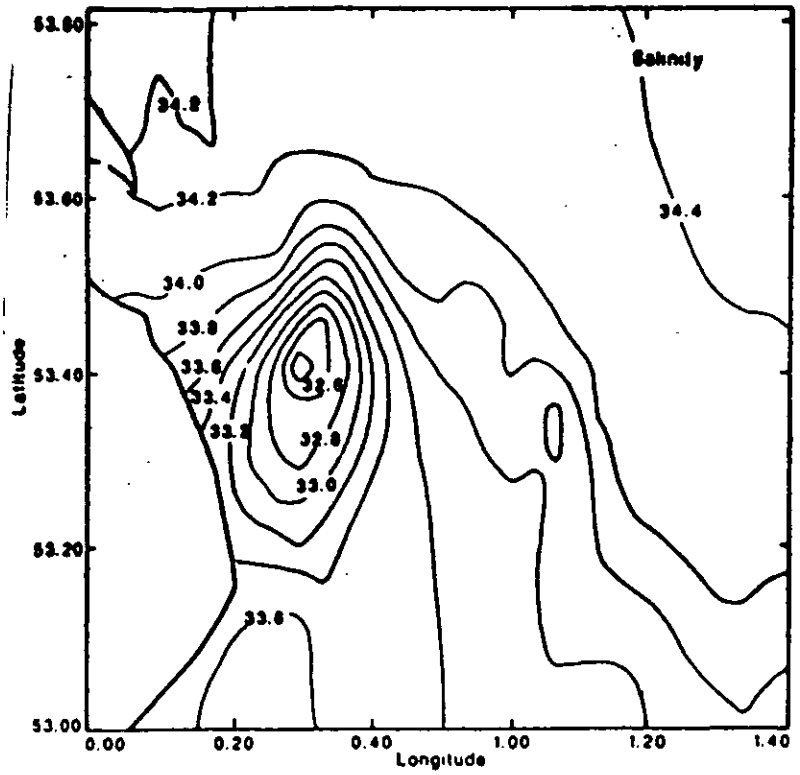

Figure 3. Near-surface salinity distribution in the plume of the Humber/Wash system, December 1988.

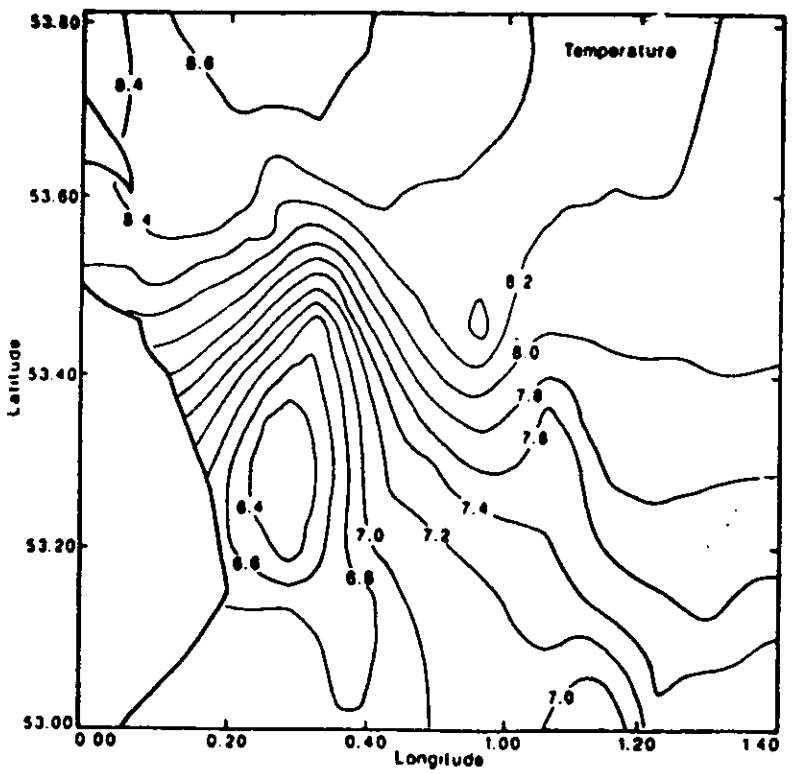

Figure 4. Near-surface temperature distribution in the plume of the Humber/Wash system, December 1988.

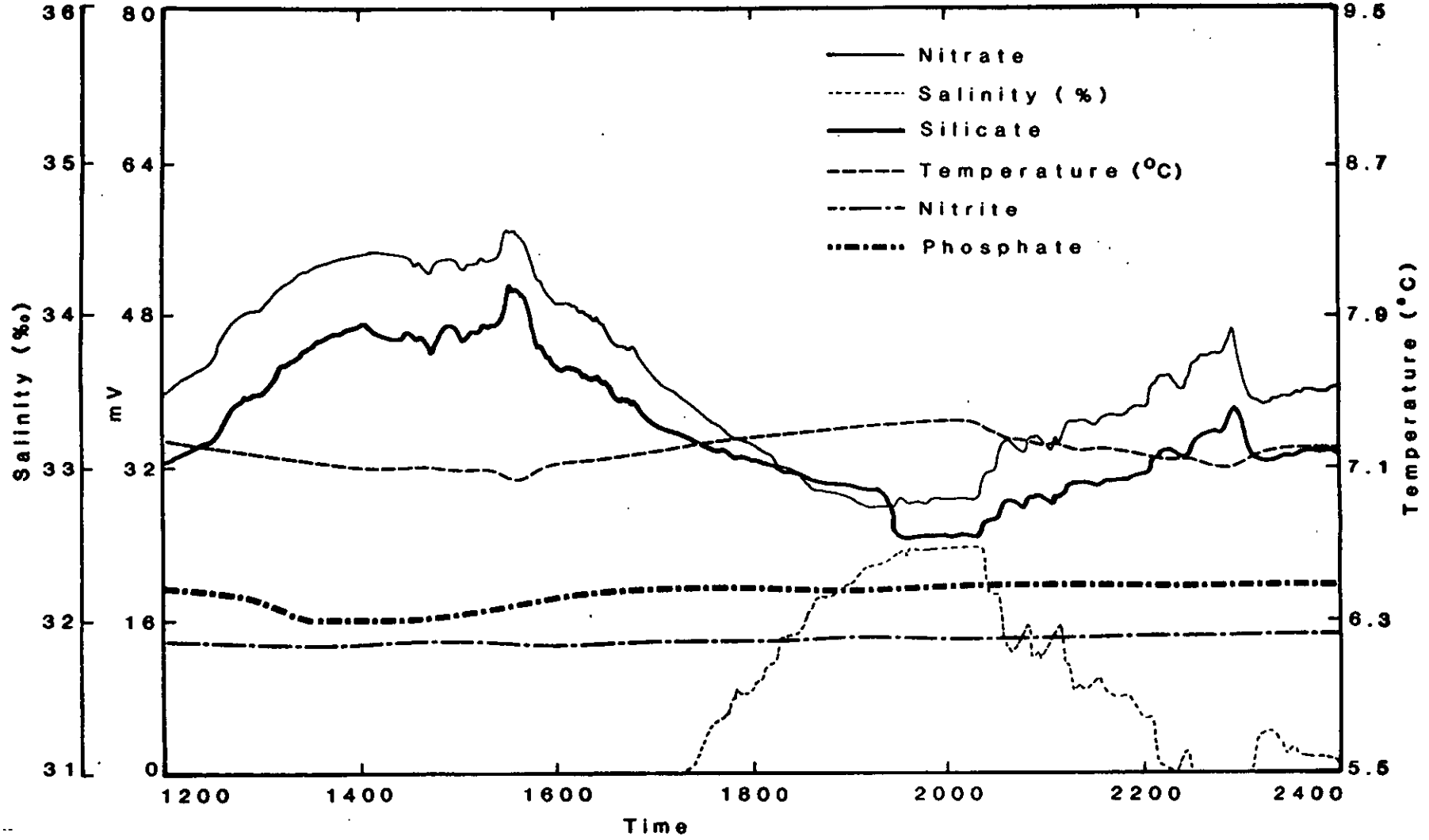

Figure 5. Continuous records of salinity, temperature, nitrate, silicate, nitrite and phosphate over a 12h period.