CHALLENGER 46

✓ INDEXED

CRUISE REPORT

CRUISE RVS Cruise North Sea 46/89; PML Thames Plume Study. This is a process cruise contributing to the NERC North Sea Project.

VESSEL RRS *Challenger*

PERIOD 12-20 February 1989

SCIENTIFIC PERSONNEL

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ACKNOWLEDGEMENTS

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The Department of the Environment is supporting estuarine plume research at PML through partial funding of plume modelling activities under Contract No. 7/7/286.

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 in the Thames Estuary 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 sedimnet/water interface by controlled on-board incubations of undisturbed sediment cores collected from within the survey area.

NARRATIVE

Sat 11 Feb — Scientific personnel embark at Great Yarmouth 1500. Load scientific equipment and commence commissioning and testing.

Sun 12 Feb — Depart Great Yarmouth 1500. Proceed to Sunk Buoy off Harwich to pick up pilot at 2400. Commence continuous underway recording of environmental variables - salinity, temperature, optical transmission, nutrients.

Mon 13 Feb — Proceed to mouth of Thames reaching selected anchor station position off Gravesend at 0430. Rig CTD, check sensors, wash 'clean' bottles for metal sampling. Day grab for observation of bed type - mixed mud and pebbles. 0800 unsuccessful attempt to box core. 1000 commence hourly CTD casts over 24h with full chemical sampling operations.

Tues 14 Feb — Complete anchor station operation 1030. Pick up pilot 1100 and proceed to Oaze channel for grabbing/coring commencing at 1330. Proceed to sediment trap station (51°40.22'N 1°26.56'E) and deploy two sequential sediment traps in vertical array on moored rig at 1800. Proceed towards Sunk Buoy for pilot exchange. Make extra easterly transect from Sunk Buoy whilst awaiting pilot rendezvous at 2100. Then proceed riverwards along the northerly channel, with continuous sampling operations, turning seaward at Oaze deep and proceeding seaward along the southerly channel towards Margate.

Wed 15 Feb — Drop pilot off Margate at 0600 and commence first circuit around the SW-NE transects covering the outer part of the plume grid with occasional coring/grabbing and CTD/metal bottle casts at selected sites. Complete first circuit of outer grid at approx 2400.

Thur 16 Feb — 0000 commence second circuit of outer grid in reverse direction with additional transects off the English south-east coast.

Fri 17 Feb — Return to Margate for pilot at 0800. Commence second circuit of inner grid with pilot changeover off Gravesend (with 4h stopover for repairs to ship's radar). Drop pilot at Sunk Buoy 2000 and then proceed into third circuit of the outer grid.

Sat 18 Feb — Continue third circuit, with occasional coring/grabbing and CTD casts at selected sites. Third circuit completed with pick-up of pilot off Margate at 2200. Proceed riverward.

Sun 19 Feb Proceed upriver as far as the Thames Flood Barrier (16nm above Gravesend) and then return seaward, anchoring off Gravesend at 0900. Carry out anchor station operations with CTD casts until 1300 and then depart for sediment trap site to retrieve equipment at low water slack (ca. 1700). Rig located in position and surface marker buoy picked up. Rope securing the surface buoy to subsurface buoy and instrument line was severed by the ship's propellor whilst manoeuvering for retrieval position. Master unwilling to grapple for instruments immediately on safety grounds. Await high water slack at ca. 2300 for recovery attempts which were unsuccessful. Depart for Great Yarmouth, dropping off the pilot at Sunk Buoy.

Mon 20 Feb Arrrive off Great Yarmouth about 0400 and await midday high water. Tie up at Great Yarmouth ca. 1400. Unload equipment.

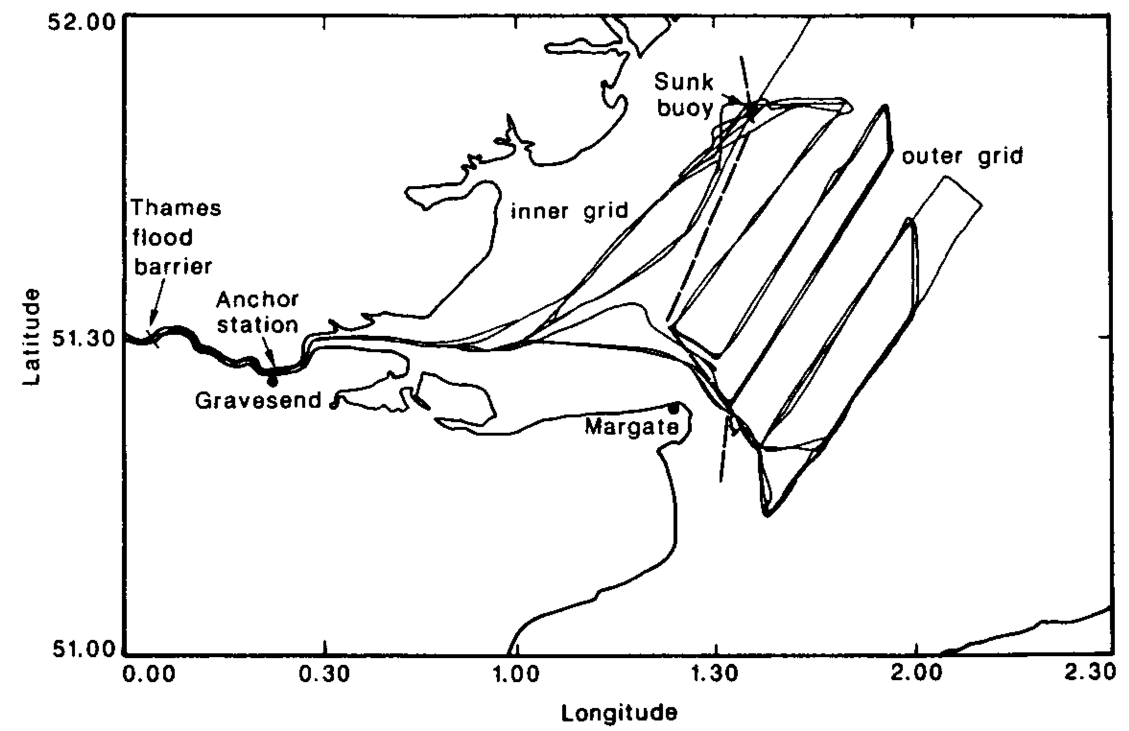

Figure 1. Plot of the complete track traversed during the Thames plume investigation, February 1989.

SUMMARY

This cruise complemented the earlier studies of the Humber Estuary plume in December 1988 (see report on RVS Cruise CR42/88) and employed the same strategies and procedures.
The period of this cruise was shortened from the initially planned two weeks in order to free time for sand wave experiments in the southern North Sea. This reduced the possible number of grid circuits which could be accomplished and did not allow measurements through the full spring-neap tidal range. Additionally, pilotage requirements necessitated careful on-site rescheduling of the planned transects with an artificial division of the grid into inner (pilotage compulsory) and outer (pilotage not required) regions - see Figure 1 - in order to utilise time and facilities most efficiently. Two sequential sediment traps were lost, otherwise the cruise was highly successful in achieving the planned objectives.
Three full circuits of the initially planned grid (see Figure 1) were completed, together with additional transects to the north and south of the grid and a more extensive riverward incursion into the Thames, appropriate to the relatively low river discharge conditions encountered. Continuous recording of environmental variables, including nutrients, and underway pumping for the collection of discrete samples for other chemical analyses, including particulate and dissolved metals, were carried out throughout these circuits. Collection and pre-storage treatment of samples for metal analysis employed meticulous 'clean' techniques. CTD casts with 'clean' bottle sampling, box cores and Day grabs were taken at selected sites around the grid (Figure 2).
The intended 24h anchor station in the Thames mouth at the beginning of the cruise period was successfully carried out; the 24h anchor station planned for the end of the cruise was drastically curtailed in order to allow time for the attempts to retrieve the lost sediment traps.
On-board experiments were carried out throughout the cruise: (1) to determine rates and equilibrium states of particle/water metal exchange using radiotracer techniques, and (2) to measure the rates of exchange of metals and nutrients across the sediment/water interface.
For (1), natural water samples were incubated under controlled temperature conditions following the addition of radiotracer dissolved metals. The uptake of metals by suspended particles was examined by sub-sampling at appropriate intervals and filtering. Filtrates and separated particles were returned to the laboratory for radiochemical counting. Rates of uptake 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 at environmental temperature. Rates of transfer of nutrients and metals across the sediment/water interface were obtained directly by sampling the water overlying the incubated sediment at suitable intervals. Samples of pore water were abstracted from the cores for indirect estimations of chemical fluxes based on diffusion theory. Advective (storm and tide) effects were examined by subsequent controlled disturbance of the incubated sediment surface.

RESULTS

Hydrography

Figure 3 and 4 show the computer generated plots of near-surface distributions of salinity and temperature recorded during a single circuit of the grid.

The distributions of hydrographic parameters did not alter significantly throughout the period of the cruise. These showed a diffuse ill-defined plume lacking fine structure apart from the suggestion of a weak front east of Margate. The CTD casts showed that the water column within the plume was generally homogeneous. However, vertical gradients of salinity and associated variables as well as of suspended particulate load were observed at the anchor station around the time of maximal tidal currents.

Sediment characteristics

The grab samples showed mixed sediments in the inner sampling zone and along the southern and northern boundaries of the outer plume zone. Appreciable amounts of silt occurred in the deep channels that lie between the SW-NE oriented sand banks; further eastward, coarse sands predominated. As expected, sediments were generally more reducing in samples collected from close to the estuary mouth, although oxygen penetrated more deeply into these sediments, presumably due to higher bioturbational activity. Examination of the box cores for the presence of benthic macrofauna revealed abundant active bioturbators in sediments from the inner zone, especially in Barrow Deep whereas macrofauna

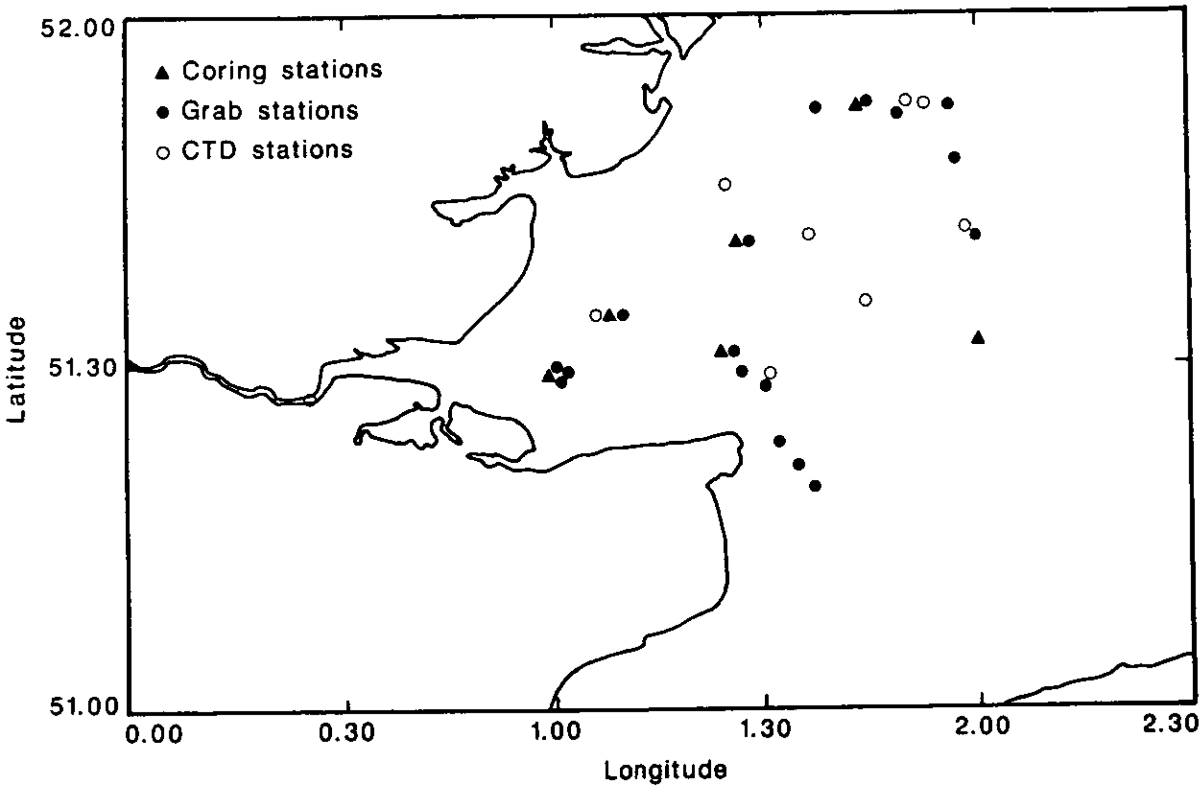

Figure 2. Positions of station for CTD profiling combined with 'clean' water bottle sampling, Day grab sites and box core sites during the investigation of the Thames plume investigation, February 1989.

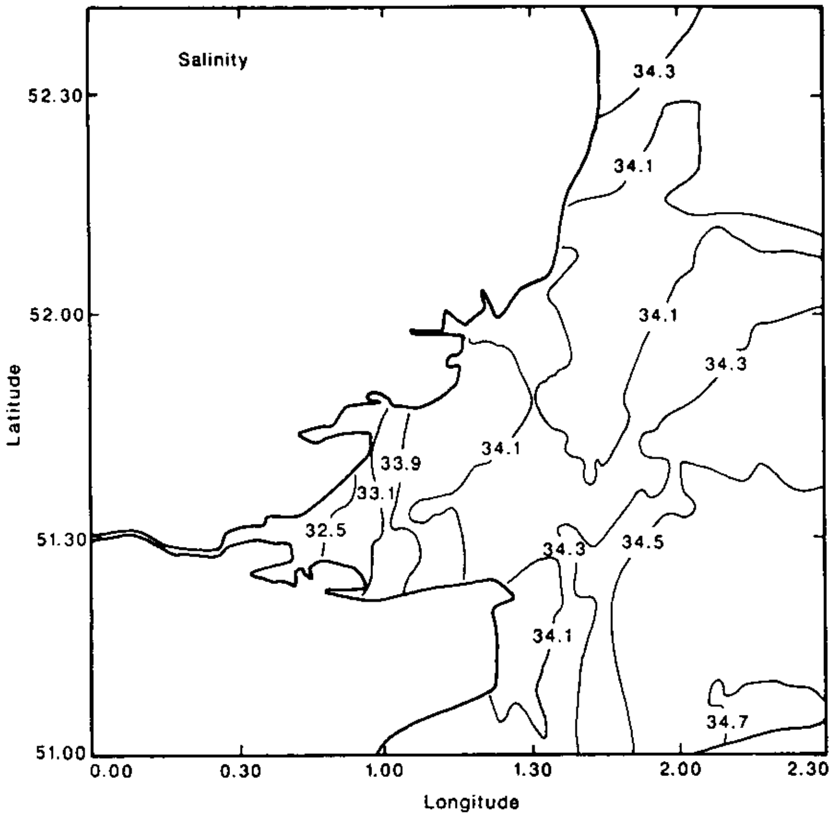

Figure 3. Near-surface salinity distribution in the plume of the Thames Estuary, February 1989.

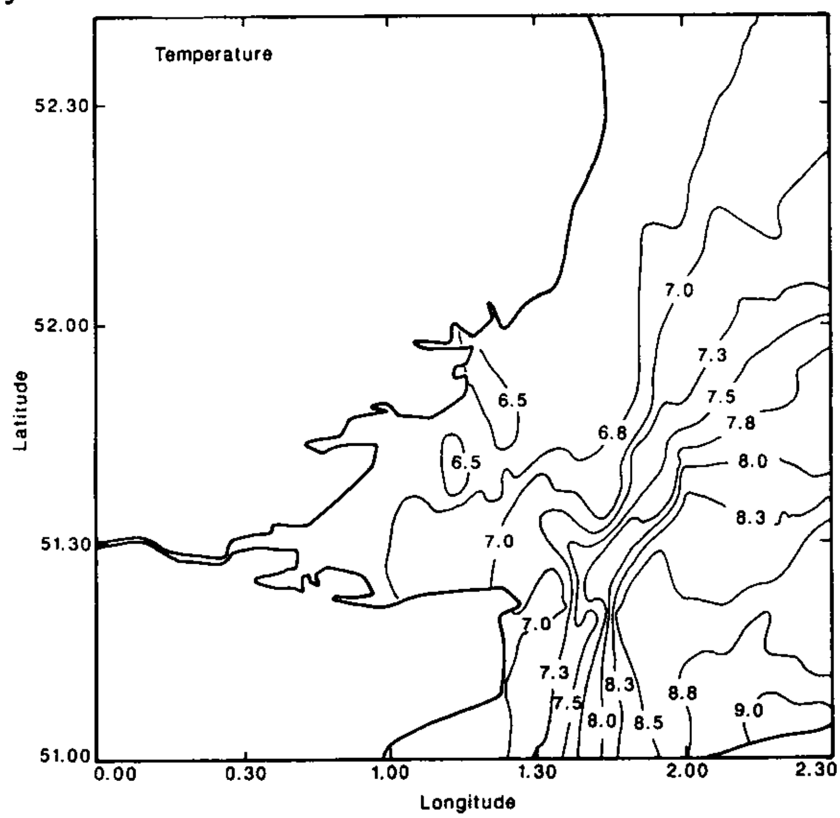

Figure 4 . Near-surface temperature distribution in the plume of the Thames Estuary, February 1989.

were very sparse in the sandy cores from the eastern boundary of the samping grid.
The pattern of redox conditions was reflected in carbonate alkalinity, which showed the steepest vertical gradients in the most reducing sediments.
Observations of nutrients in sediment pore waters are sumarized in Table 1. The data reveal that concentration levels of phosphate, silicate and ammonia in the sediment pore water decreased with distance from the estuary mouth whereas those of nitrate and nitrite increased. Vertical concentration profiles were steepest near the estuary mouth and decreased with distance seaward.

Table 1. Ranges of pore water nutrient concentrations in the upper 10cm of sediments from the Thames plume zone.

	Concentration range (μM)		
Nutrient species	Inner plume	Central plume	Outer plume
Ammonia	10 - 100	8 - 60	4 - 30
Silicate	8 - 40	8 - 30	6 - 9
Nitrate	2 - 20	10 - 20	11 - 15

Water column chemistry

The continuously recorded nutrient data for the Thames plume mostly showed basic features relative to salinity which were similar to those observed in the Humber plume, with nitrate and silicate covarying closely and being strongly correlated inversely with salinity. Phosphate, ammonia and nitrite were likewise more uniform in concentration, with distributions which were largely independent of salinity. A distinctive feature of the nutrient distributions in the Thames Estuary was the pronounced influence of discharges to the vicinity of the Beckton sewage works which were recorded during the extended riverward transect.

On board experiments

Table 2 shows that quasi-equilibrated K_d values (ratios of the amount of particle associated metal on a wt/wt basis to the concentration of dissolved metal) for metals in the Thames plume were of the same order of magnitude but generally lower than those recorded during the previous Humber plume investigation.

Measured diffusional fluxes of nitrate, silicate and nitrite generally reflected the observed pore water profiles. Thus, silicate fluxes were always positive (fluxes being defined as positive when mass transfer is from the sediment to the overlying water; negative fluxes in the reverse direction) and reduced from +811 down to +40 $\mu M\ m^{-2}\ d^{-1}$ with increasing distance from the

Table 2. Quasi-equilibrium K_d values in waters from the Humber and Thames plume zones.

Observations	K_d values			
	Cd	Cs	Mn	Zn
Humber Estuary plume; Dec. 1988; salinity range, 28.3 to 34.3°/oo; suspended solids, 2.2 to 55.2 mg/l.	$4 \pm 3 \times 10^2$	$5 \pm 3 \times 10^2$	$5.3 \pm 4.1 \times 10^4$	$5.6 \pm 5.7 \times 10^3$
Thames Estuary plume; Jan. 1989; salinity range, 21.0 to 34.4°/oo; suspended solids, 16.4 to 325 mg/l.	$5.4 \pm 4.0 \times 10^2$	$3.2 \pm 1.9 \times 10^2$	$3.3 \pm 1.4 \times 10^4$	$3.7 \pm 1.5 \times 10^3$

estuary mouth. Nitrate and nitrite fluxes were generally negative, ranging from -2400 to -700 and -85 to -20 $\mu M\ m^{-2}\ d^{-1}$, respectively, with increasing distance from the estuary mouth. However, there was one exception to this, positive fluxes of nitrate (+362 $\mu M\ m^{-2}\ d^{-1}$) and nitrite (+42 $\mu M\ ^{-2}\ d^{-1}$) were encountered in the vicinity of the sludge dumping grounds in Barrow Deep.
Diffusive fluxes of other components were more variable. Ammonia fluxes were mostly negative, ranging between -3500 and -700 $\mu M\ m^{-2}\ d^{-1}$, except for substantial positive fluxes in the Barrow Deep and at the eastward boundary of the observations where the highest flux was measures despite the lowest pore water gradient. Phosphate fluxes were low or negative, falling within the range +5 to -37 $\mu M\ m^{-2}\ d^{-1}$. except for a relatively high positive fluxes (up to +73 $\mu M\ m^{-2}\ d^{-1}$) in the Oaze Deep.
The consequences of sediment surface mobilization (as is effected by wind stresses or strong tides) were examined by stirring induced resuspension of sediment in the microcosm after the undisturbed flux measurements were completed. Due to differences in sediment characteristics, the uniform increase in stirring rate used throughout these experiments resulted in large differences in the degree of sediment resuspension. Suspended particulate

loads ranged in these experiments from 160 to 4448 mg/l. Most importantly, observed chemical fluxes correlated more closely with the degree of sediment resuspension than with either the characteristics of the pore water profiles or the calculated diffusive fluxes. For example, ammonia fluxes were generally positive (within the range +256 to +2476 $\mu m\ m^{-3}\ d^{-1}$), except for cores collected from the innermost region of the plume. These showed minimal resuspension accompanied by negative fluxes. Phosphate and silicate fluxes were consistently negative whereas nitrate was released from sediments only when the resuspended load exceeded 1400 mg/l.

Report prepared by: A W Morris, 10 July 1989

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