Hydraulics Research
Wallingford

SLUDGE DISPOSAL IN LIVERPOOL BAY

Eleventh bed monitoring survey November 1983

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ABSTRACT

This report describes the eleventh survey carried out in November 1983 to continue the long term monitoring of the bed sediments of Liverpool Bay. The objective of the programme is to determine whether any changes are occurring in the surface sediment characteristics as a consequence of changes in the rate of sewage sludge disposal since 1972.

1 INTRODUCTION

The DOE programme of monitoring bed sediments in Liverpool Bay for possible effects of sewage sludge disposal was initiated in 1973 following publication of "Out of Sight, Out of Mind" (Ref.1). The desirability of maintaining this check on bed conditions was reaffirmed in 1978 by the DOE/NWC Sub-Committee on the Disposal of Sludge to Sea (Ref.2) and since then, five bed surveys have been carried out (Refs. 3-6) by Hydraulics Research (HR). The last, the subject of this report was undertaken in November 1983 from the M.V. Branding with the assistance of Dr S Rowlatt of the MAFF Burnham Laboratory and is the eleventh in the overall series.

Samples were taken at sixty-five positions including the twenty-four standard sites visited on all occasions since 1973 (Fig.1). Cores were taken at 22 sites including one at the new ground for dredged spoil from the Mersey close to the standard grid position T14. Weather conditions prevented cores being taken at the deep water sites G7, 9, 11 & 13. Grab samples were taken at all 65 sites. At one site, YY2, no sample could be taken, probably because fluid mud triggered the grab before it could descend to a bed firm enough to be retained.

The top 25mm of each grab sample was removed with a flat scoop and brought back for analysis. The cores were extracted on board and split into 0 - 25mm, 25 - 100mm and 100 - bottom fractions. In two cases, the core was too loosely compacted to extract whole and a composite sample from the total was taken. Samples were stored at -20°C on return to the laboratory.

In the laboratory the samples were split into sand and mud fractions by wet sieving at 63μm. The sand fraction was not graded further and only the percentage mud by weight was recorded. The mud fraction was air dried followed by storage in a vacuum desiccator before sub-sampling for organic carbon and heavy metal determinations.

Organic carbon determinations were made by the standard wet oxidation method used previously (the organic carbon is reported as organic matter, a factor of 2.5 being used as in the past to convert carbon to the equivalent of dried organic residues).

Since 1978, HR have passed the mud fraction of samples recovered to a commercial analytical laboratory for heavy metal determinations by atomic absorption spectrophotometry. Because minor differences in pre-analytical processing and analytical methods appear to lead to differences in heavy metal concentrations, valid comparisons are only possible on results processed in a similar manner. Furthermore, recent experience has shown that for consistency in heavy metal determinations it is prudent to introduce safeguards to check strict comparability between different sample batches, particularly for a study extending over many years.

The checks instituted in the 10th survey report (Ref.6) have been continued and the results of the current survey are as comparable as possible to those of the previous four surveys for which the data is included in this report.

Interest in the effects of sludge disposal to Liverpool Bay has grown over the last two years, particularly as a result of the renewed prospects of increased quantities of sludge to be disposed of before the end of the century, if plans for new treatment works for Liverpool are implemented. One consequence has been to intensify the sampling effort so that now more than double the number of stations are visited compared with the earlier surveys. The closer sampling network has permitted much improved definition of the spatial distribution since the eighth survey. It should be borne in mind when making comparisons with earlier surveys that some of the elevations in organic matter and/or heavy metals recorded on the later surveys could have escaped previous detection because of the greater distances between sampling positions.

2 MUD CONTENTS

The mud content of each of the sixty-five sampling positions is shown in Fig.2. Where core and grab samples have been taken at the same site, the average of their mud contents has been taken. The persistence of the low mud areas to the SE of the dumping zone as well as in the direct path of the Mersey outflow is noticeable. The last three surveys show muddy beds are most prominent in the east on either side of the Mersey outflow. The earlier surveys do not demonstrate these muddy zones so clearly but it is probable that the lower density of the previous sampling pattern is the reason rather than any real change in bed condition.

These last three surveys have substantially the same coverage, are quite similar in pattern and do not give any indication of a build-up of mud.

3 ORGANIC MATTER

The distribution of organic matter in the mud fraction of the sediment is shown in Fig.3. The exceptionally high figure at R10 is due to the presence of coal. The grab sample contained considerably more than 50% weathered coal which being very friable breaks down on sieving and probably accounts for the high "mud" figure (20%) at this position. Coal was not so evident in the surrounding samples but is often present in small quantities in this area, whether as coal fragments or as partially burnt ash and clinker. Lack of mud prevented organic matter being determined at positions M12, R14 and T6.

The overall impression is that the concentration of organic matter in the mud fraction is a little higher but follows the same horizontal distribution of previous years. The "total" organic content of the surface 25mm calculated from the combined mud and organic percentage abundances (Fig.10) gives no indication of any increase compared with the previous two surveys. Its distribution is very different from that given by Fig.3 because the greater abundance of mud in the area of Mersey influence outweighs any non-uniformity in the organic concentration and results in the bulk of the organic matter being found well to the east of the dumping ground. As on all previous surveys the Mersey seems to exert the most significant influence on the distribution of the "total" organic matter and no coherent pattern of change has been observed over the eleven years of monitoring.

4 HEAVY METALS

The heavy metal concentrations have been illustrated as in previous reports. Figs. 4 - 9 show the concentration of the metals in the mud fraction of the sediment expressed in micrograms metal per gram of mud. Figs. 11 - 16 show the "total" metals expresed as the product of the metal concentration, the mud percentage, and a factor based on the mean dry bulk density of a number of cores. This "total" metal concentration is expressed as kilograms (mercury only) or tonnes of

metal in the top 25mm per square kilometre of bed. If it is assumed that the metal content of the fine sediment (< 63μ m) is mainly derived from adsorption of metals from solution, then this "total" metal figure represents the input to the area from man-made sources together with any natural sources that produce soluble metals.

HR standard sediments from the Q and T-lines (page 3, Ref.6) as well as the U.S. National Bureau of Standards River Sediment No.1645 were again analysed with those of this survey. The results were within 10% of those for the equivalent standards analysed for surveys 9 and 10 so no adjustments were necessary in this instance to compensate for analytical variability.

For the six metals depicted in Figures 4 - 9, the similarities that are particularly noticeable are the peak concentrations at M9 and M10 in the vicinity of the sludge dumping ground for lead, nickel, copper and chromium. High metal concentrations have been found in this same area on previous HR bed surveys but always associated with sediments relatively deficient in mud (less than 1 per cent). However on the present survey the mud content of the metal-rich sediment was not especially low.

The area adjoining the dredged spoil grounds in the north-east of the surveyed area (the old and new spoil grounds being close to U15 and T14 respectively), shows high values for all metals. This area has not been well-covered in previous surveys and so the detection of high values now is not indicative of change.

Over the area as a whole the concentrations of copper, zinc, chromium and particularly lead have apparently increased compared with previous surveys whereas mercury concentrations have decreased. An unexpected feature of the lead concentrations is the high values found in the G-line samples, an area previously thought to be relatively unaffected by temporal changes. Values nearly twice as high as the 1982 figures were found at all four positions.

The high lead concentration found on the present survey in the vicinity of the old ground for dredged spoil confirmed exceptionally high concentrations recorded on another coring exercise undertaken in February 1983, extra to the monitoring series (Ref.7). Then, concentrations of up to 10,000 μ g/g were found at U15.

Turning to the "total" content of each metal in the mud fraction of the surface 25mm of the bed a number of areas can be identified where one or more metals show high levels per unit area (Figs. 11 to 16). Neglecting localised elevations based solely on single stations having high "mud" contents (Q12, R10, T12) some of the individual metal distributions have features in common. For instance, "total" metal levels in the surface sediments near the new ground for dredged spoil are high. These are the result of high mud content rather than unusually high metal concentrations. It is noteworthy that the very high lead concentrations in the vicinity of the previously designated spoil ground at U15 and T15 are not evident as elevations of total metal (Fig.13) because the mud content of these stations is so low (less than 0.3 per cent). The almost exclusively muddy sediments (greater than 80 per cent mud) of U9, the YY stations and the less muddy T9, lying south of the Mersey outfall are also revealed as a zone of high "total" metals per unit area.

It appears that the "total" metal distributions are largely conditioned by the abundance of mud in the surface sediment. For the first time, however, the high concentrations of copper combined with relatively modest contents of mud (2 to 10 per cent) do provide an outlier of elevated "total" copper comprising five adjacent stations in the neighbourhood of the sludge disposal ground (Fig.15).

5 VERTICAL DISTRIBUTIONS

Mud, organic matter and heavy metal contents were determined on core strata, 0 - 25, 25 - 100 and below 100mm depth, as well as the heavy metals and organics found in the mud which was in suspension above the core at the time of extraction. The latter includes surface organics and loose flocculated sediment together with any of the fine material brought into suspension by the action of the vibro-corer. The results are shown in Table 1.

Certain stations show marked differences between the metal concentrations on the mud suspended in the water above the core and those in the topmost core stratum. This feature is particularly noticeable in the case of copper for the sludge disposal ground stations L9, L11 and M11 and for the dredged spoil grounds represented by T15, U15, and the new site near T14. In addition zinc at all

three stations near the dredged spoil grounds and lead at the new ground (near T14) show similar metal enhancements in the suspension, as does mercury at a single station (L9) in the sludge disposal zone. Higher copper concentrations are also found on the suspended material above the core at a few stations (Q7, Q11 and T8) outside the disposal grounds where the connexion with dumping is more tenuous. The pattern is not sufficiently straightforward nor the number of samples large enough to reveal the significance of the differences between the suspended and bed concentrations. Proximity to "point" sources may favour high concentrations in the sediment recovered from above the core if insufficient time has elapsed since discharge for the metal-rich input to be fully incorporated within the bed sediment. Alternatively, the higher values of the suspended sediment could be an artifice of sampling, whereby the finer and lighter fraction present in the upper few centimetres of the bed is selectively re-suspended by the action of the vibro-corer. This fraction is potentially richer in metals than the mud as a whole.

Examination of metal concentrations in the individual strata of the bed cores provides some indication of the depth to which the metals penetrate in the bed sediment. In most cases the cores were too short to reach the limit of penetration. However, an abrupt decrease in concentration of all metals points to penetrations not exceeding 100mm at Q9 and Q11 and between 100 and 200mm at K9 and L7. Beneath these levels the sediment has presumably remained undisturbed and its content of organic material falls to less than 3 per cent. Elsewhere metals are present over the full length of the cores. Lengths varied from 100 to 250mm (Table 1). The high mercury concentrations confirmed over the full depth of the core at Q13 are particularly striking. The source responsible for this mercury is not known but the haphazard occurrence of exceptionally high erratic values of this nature has been noted on earlier surveys.

6 CONCLUSIONS

The eleventh survey repeated the close sampling pattern first adopted on the tenth survey. Comparison of the concentrations in the mud fraction of the surface 25mm recorded on the two surveys suggests that organic matter, lead, copper and chromium have all increased while mercury has decreased.

The zone used for dumping dredged spoil in the north-east of the surveyed area was examined in somewhat greater detail than hitherto and disclosed high concentrations of most metals and particularly lead.

Lead concentrations were unexpectedly high to the west of the sludge disposal ground. The G-line, the western extremity of the sampling pattern, was thought previously to be unaffected by temporal changes but the nearly two-fold increase in the west is presumably a part of the widespread rise of lead levels. No related increase in lead input has been identified.

When organic carbon and metal concentrations are combined with mud abundance to yield the "total" organic material and "total" of each metal per unit area the result is similar in magnitude and distribution to previous years. Again the distribution is determined more by the proportion of mud in the sediment than the concentration of organic carbon or metal in the mud fraction. Thus the more significant peaks can be identified with the new spoil ground for dredgings and with the very muddy zone to the south of the Mersey outfall not far from the Great Burbo. Elsewhere localised elevations are to be found but apart from the outlier of high copper levels in the vicinity of the sludge ground they are all the result of a single station having higher mud contents than its neighbour.

For the first time in the course of the routine monitoring series the depth variation in the concentration of metals and organic carbon over the core length has been examined. Individual strata from twenty cores were analysed. In most instances the core length, typically 200mm, was insufficient to define the depth of penetration of man-made metals. Exceptions were four stations either on or west of the Q-line (midway between the sludge disposal ground and the Mersey outfall). In these cases the metal as well as organic carbon

concentrations diminished sharply in the basal strata below 100mm. At least in these localities the bed must be relatively stable with disturbance either by hydrodynamic forces or by benthic organisms limited to a relatively shallow surface layer.

Exceptionally high spot values of mercury concentration have occurred haphazardly on earlier surveys when only the surface 25mm of the bed sediment was analysed. This feature is again noted on the present survey with the core at Q11 displaying a mercury concentration an order of magnitude higher than average. In this instance, however, it persisted over the entire depth with similar high mercury concentrations being confirmed in all three strata of that core.

7 ACKNOWLEDGEMENTS

We thank Mr A Winters an ex-member of HR's Field Services Section for executing the sampling programme. We are also indebted for the assistance given to Mr Winters by the captain and crew of the M.V. Branding and by Dr S Rowlatt of the MAFF Fisheries Laboratory, Burnham-on-Crouch during the course of the field operations.

8 REFERENCES

1. OUT OF SIGHT, OUT OF MIND. Report of Working Party on Sludge Disposal in Liverpool Bay, Vol 1 and 2, 1972.

2. DEPARTMENT OF THE ENVIRONMENT/NATIONAL WATER COUNCIL STANDING TECHNICAL COMMITTEE. Sewage Sludge Disposal in Liverpool Bay, Research into effects 1975-1977. Report No.16, April 1979.

3. HYDRAULICS RESEARCH STATION. Sludge disposal in Liverpool Bay, Seventh bed monitoring survey, October 1978 - January 1981. Report No. DE 49, October 1979.

4. HYDRAULICS RESEARCH STATION. Sludge disposal in Liverpool Bay, Eighth bed monitoring survey, September 1980 - January 1981. Report No. DE 54, August 1981.

5. HYDRAULICS RESEARCH STATION. Sludge disposal in Liverpool Bay, Ninth bed monitoring survey, November 1981 - January 1982. Report No. DE 58, September 1982.

6. HYDRAULICS RESEARCH STATION. Sludge disposal in Liverpool Bay. Tenth bed monitoring survey, September 1982. Report No. DE 64, August 1983.

7. HYDRAULICS RESEARCH. Vertical distributions of heavy metals and organic carbon in Liverpool Bay (East). Report in preparation.

Tables

TABLE 1 - VERTICAL DISTRIBUTION OF ORGANIC MATTER AND METALS

Site	Level mm	Mud %	Organics %	Mercury µg/g	Copper µg/g	Zinc µg/g	Lead µg/g	Nickel µg/g	Chromium µg/g
K9	wac			1.45	237	570	119	56	51
	0- 25	2.65	5.13	1.01	134	290	154	50	46
	25-100	3.73	5.02	0.99	64	390	106	45	52
	100-200	6.26	2.85	0.22	30	108	51	41	46
K10	wac	-	7.01	1.49	133	420	108	51	48
	0- 25	6.93	6.09	1.29	88	340	127	44	62
	25-100	6.03	4.88	0.49	104	320	142	48	55
	100-220	9.39	5.18	1.34	96	269	147	44	46
K11	wac	-	6.31	1.25	86	380	86	49	39
	0- 25	8.44	5.97	1.04	59	253	99	44	42
	25-100	9.25	5.01	0.76	59	248	101	46	37
	100-170	9.63	4.72	1.13	69	276	124	45	50
L7	wac	-	6.28	1.32	133	400	91	50	40
	0- 25	0.27	na	0.89	110	300	62	47	68
	25-100	2.04	5.56	1.56	70	310	123	47	66
	100-220	8.85	1.40	0.25	38	82	22	45	40
L9	wac	-	3.25	0.74	231	480	127	50	32
	0- 25	4.66	7.68	0.20	97	310	243	64	49
	25-100	4.79	na	1.98	71	290	115	45	51
	100-170	1.96	3.87	0.36	65	151	91	77	47
L10	wac	-	7.10	1.68	160	470	115	45	62
	0- 25	4.13	7.06	1.81	159	440	206	56	64
	25-100	9.29	5.27	1.24	63	290	98	49	44
	100-160	6.21	7.15	0.80	118	360	186	59	65
L11	wac	-	9.86	1.70	420	430	111	55	60
	0- 25	7.44	5.46	1.26	68	280	106	57	42
	25-100	0.66	5.04	1.11	85	193	72	49	37
	100-150	8.51	5.15	1.32	81	300	96	47	43
L13	total	10.87	4.56	0.36	53	260	85	46	31
M9	wac	-	4.71	1.16	440	390	243	57	70
	0- 25	1.20	4.96	1.17	2110	440	1570	173	213
	25-100	0.98	6.23	1.95	478	430	680	80	67

TABLE 1 cont'd

Site	Level mm	Mud %	Organics %	Mercury µg/g	Copper µg/g	Zinc µg/g	Lead µg/g	Nickel µg/g	Chromium µg/g
M10	total	5.83	7.76	0.73	386	550	800	72	73
M11	wac	-	5.77	1.78	850	590	127	60	40
	0- 25	9.35	5.83	1.50	96	340	128	47	44
	25-100	6.62	4.85	1.54	75	290	111	47	38
	100-180	8.46	4.80	1.72	98	320	122	48	40
Q7	wac	-	-	1.76	1310	620	165	51	59
	0- 25	0.11	na	1.62	219	410	114	57	61
	25-100	0.05	na	0.03	370	440	116	53	45
	100-250	0.30	na	0.12	310	510	740	108	117
Q9	wac	-	-	1.90	250	550	147	53	47
	0- 25	0.79	6.94	1.51	193	890	890	47	84
	25-100	0.78	7.20	1.64	209	670	540	50	81
	100-350	28.84	2.85	0.06	22	91	32	41	39
Q11	wac	-	7.73	1.43	450	440	115	50	51
	0- 25	8.01	5.17	1.44	94	290	130	46	63
	25-100	13.80	2.56	1.12	38	127	67	40	36
	100-150	14.78	2.59	0.30	24	92	42	39	33
Q13	wac	-	5.19	2.88	110	430	159	51	48
	0- 25	0.40	5.89	16.32	178	510	436	50	87
	25-100	6.64	5.46	15.90	181	500	414	54	68
	100-200	6.98	5.53	14.13	390	550	421	49	73
T6	wac	-	-	0.78	74	104	38	28	33
	0- 25	0.20	na	1.90	252	630	1280	92	106
	25-100	0.07	na	2.08	211	490	1750	63	72
	100-150	0.38	5.38	2.26	129	490	770	54	64
T8	wac	-	na	1.88	320	580	168	67	97
	0- 25	0.84	8.05	1.73	113	800	403	69	72
	25-100	0.55	5.29	1.62	230	870	840	47	120
	100-170	0.67	8.46	2.14	193	1140	1030	57	113
T10	0- 25	0.16	na	2.86	277	600	730	58	67
	25-100	0.15	na	3.75	161	600	1720	56	62
	100-120	0.12	na	1.62	272	680	1460	62	49

TABLE 1 cont'd

Site	Level mm	Mud %	Organics %	Mercury µg/g	Copper µg/g	Zinc µg/g	Lead µg/g	Nickel µg/g	Chromium µg/g
T12	wac	-	7.73	1.94	113	580	143	50	73
	0- 25	28.05	6.24	2.07	78	420	193	48	53
	25-100	30.70	4.32	1.13	70	350	136	45	60
	100-180	59.34	4.35	1.16	73	400	134	49	55
T14SG	wac	-	7.91	4.08	10200	5000	650	73	61
	0- 25	73.07	8.01	4.03	142	720	210	56	75
	25-100	86.97	7.60	5.00	129	860	204	57	79
	100-150	9.80	7.08	4.41	130	700	211	54	97
T15	wac	-	-	0.88	5000	2600	340	62	59
	0- 25	0.22	5.08	3.81	336	1070	2800	101	143
	25-100	0.11	na	3.08	250	1090	2810	52	84
	100-150	0.15	3.51	3.21	138	510	8900	45	117
U15	wac	-	-	2.94	830	8840	253	54	53
	0- 25	0.25	na	1.94	199	650	550	40	140
	25-100	0.09	na	1.88	158	490	2220	47	431
	100-150	0.36	4.32	2.03	134	500	950	47	355

wac = water above the core

na = not available, insufficient sample

SG = Spoil ground

Figures

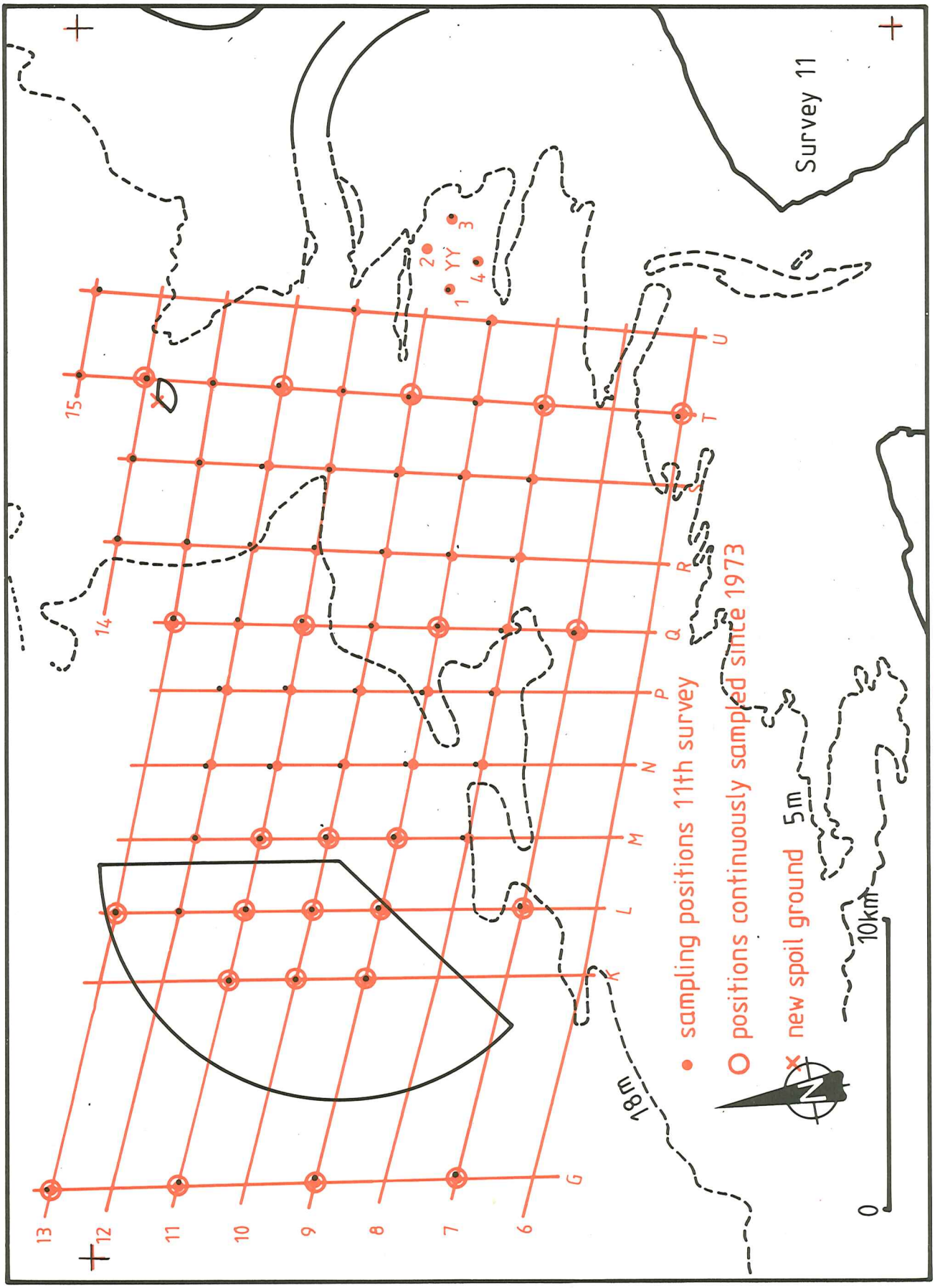

Fig 1 Monitoring positions

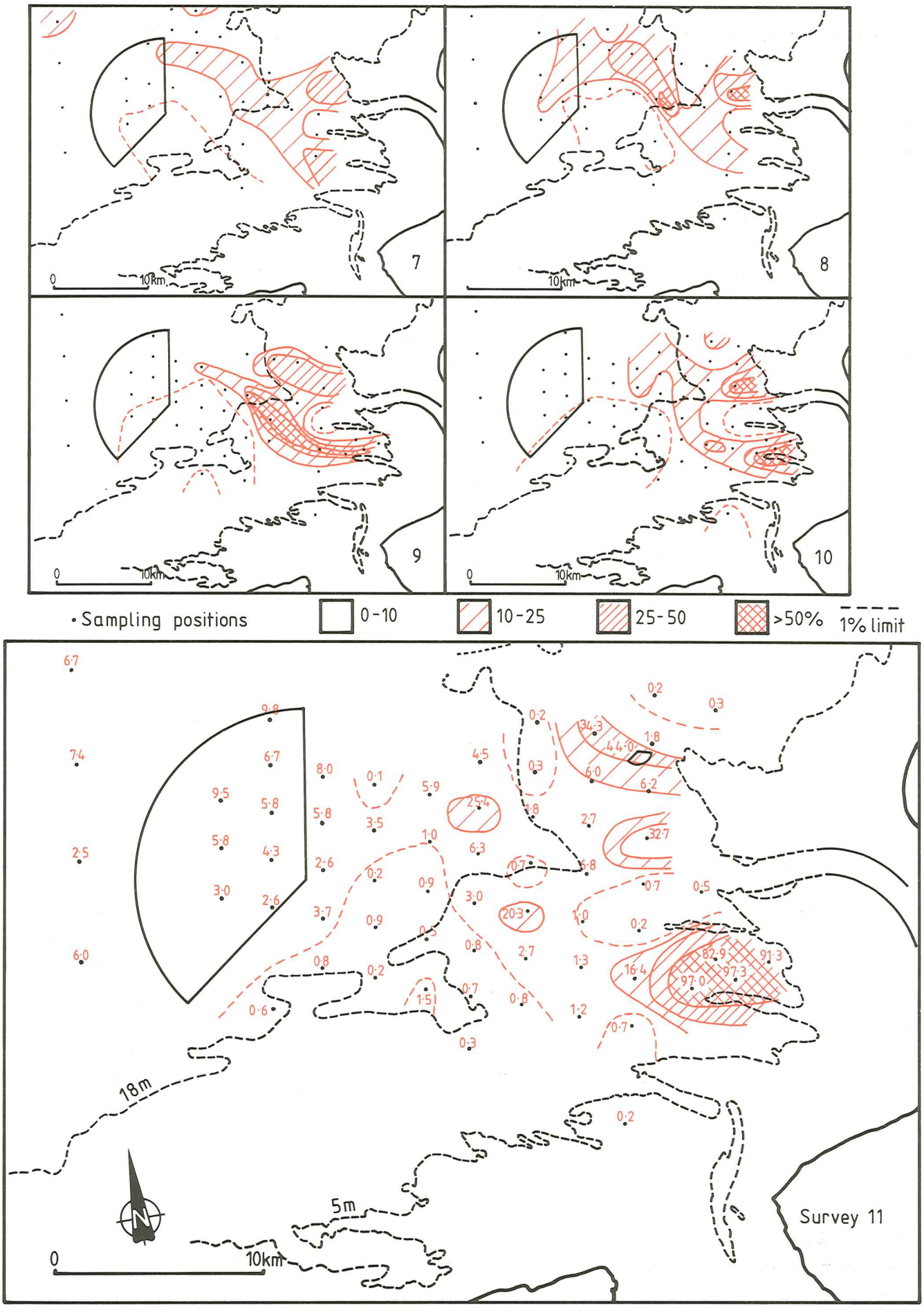

Fig 2 Mud content of the top 25mm of bed

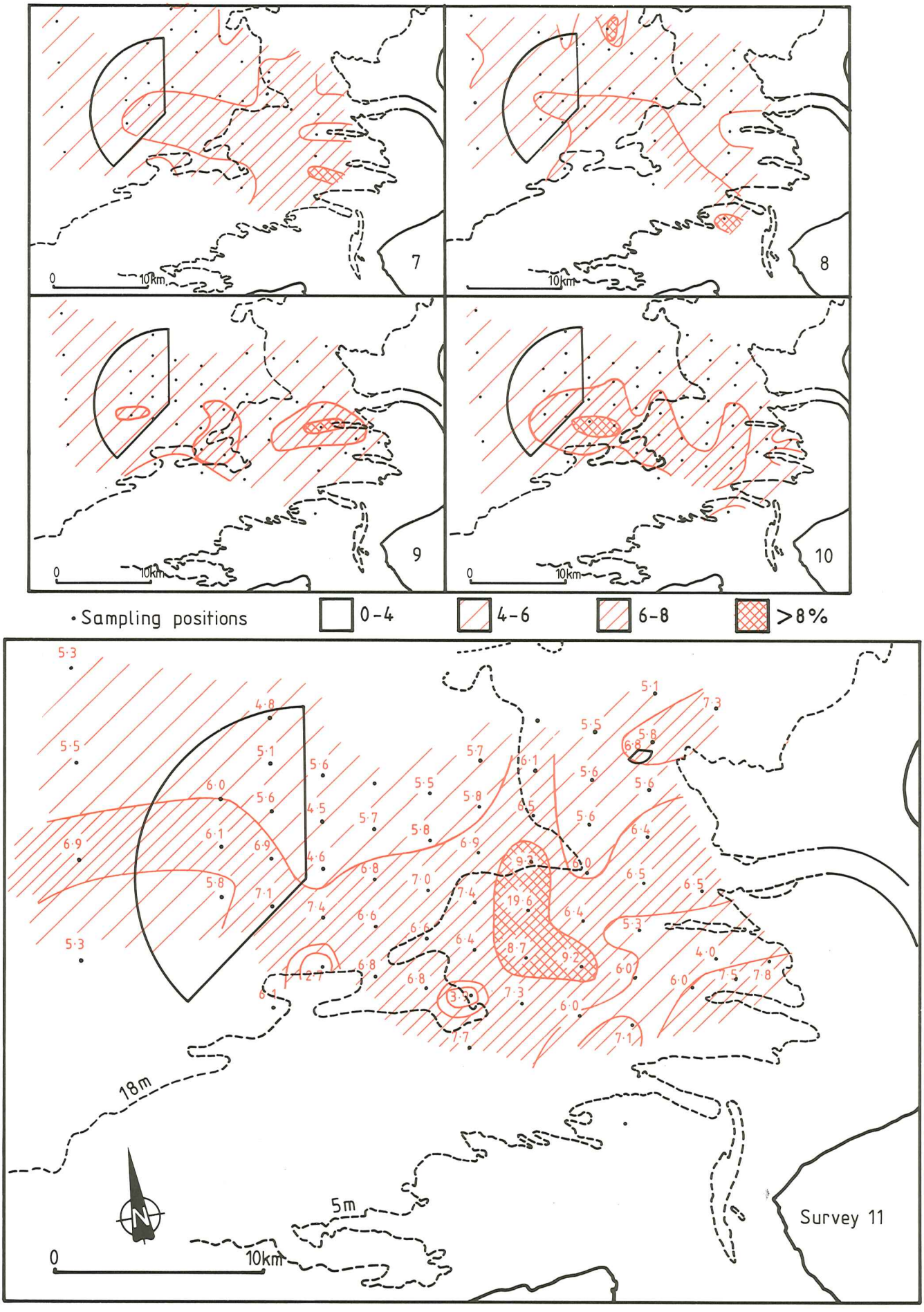

Fig 3 Organic matter content of mud from the top 25mm of bed

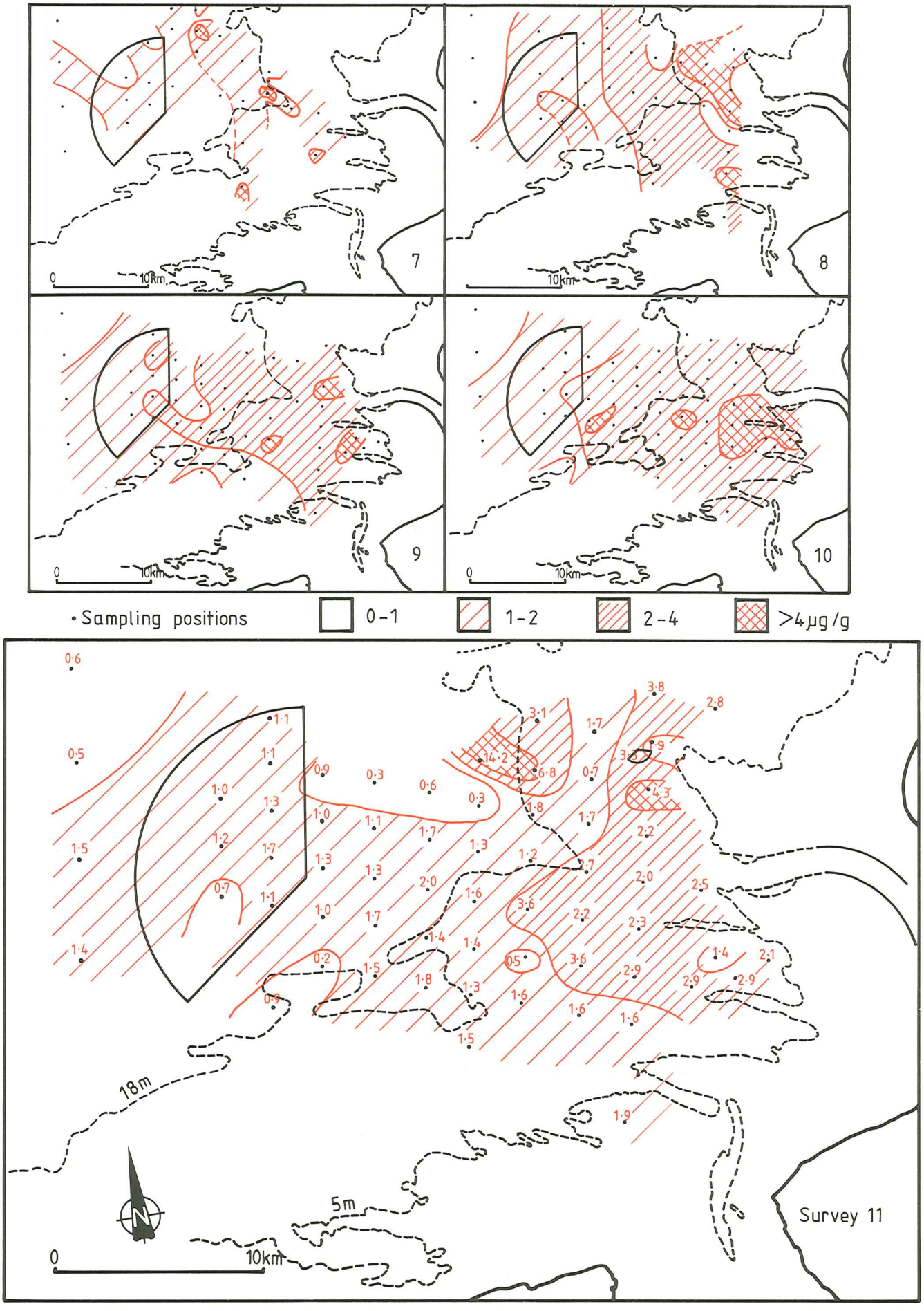

Fig 4 Mercury concentration in mud from the top 25mm of bed

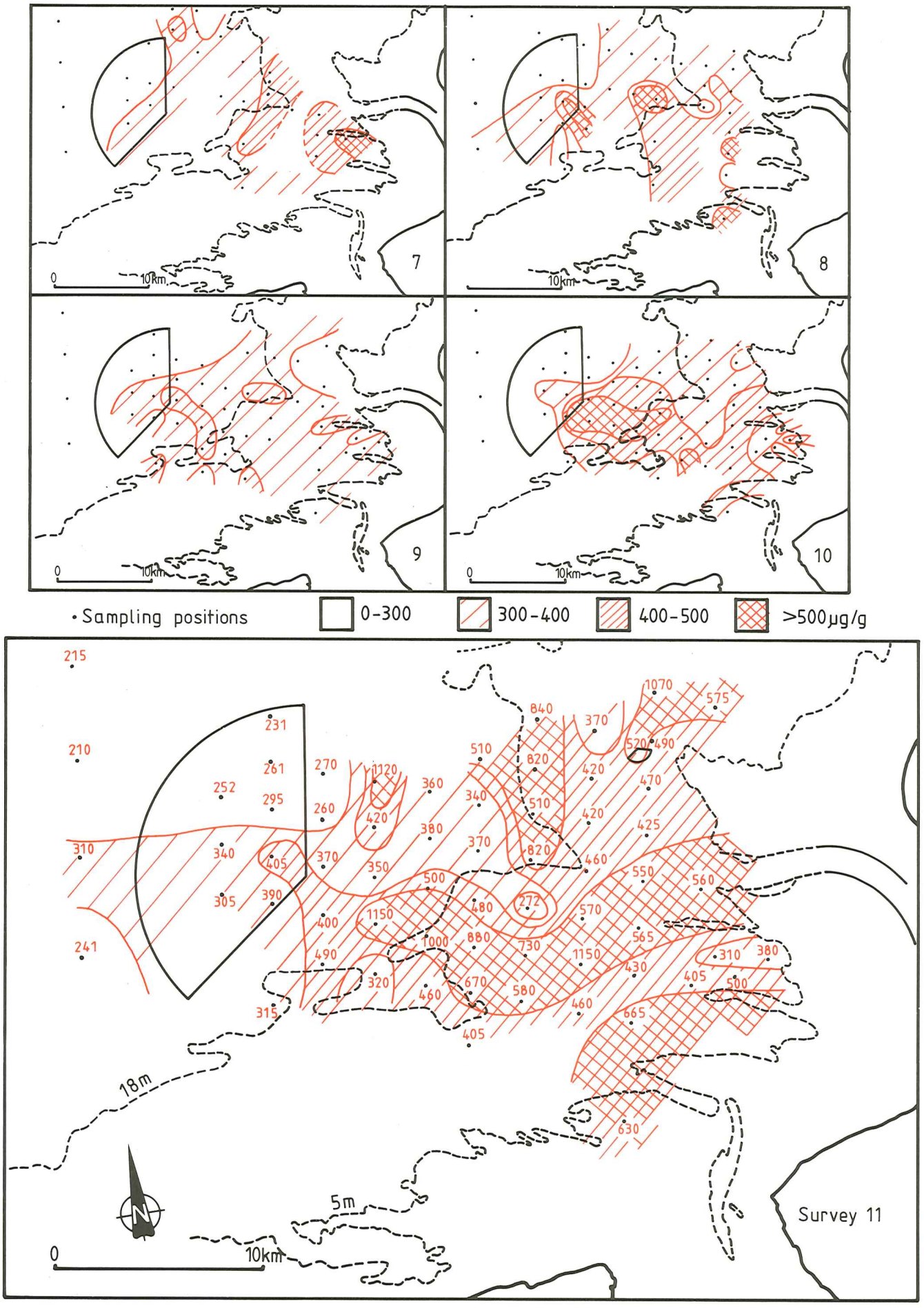

Fig 5 Zinc concentration in mud from the top 25mm of bed

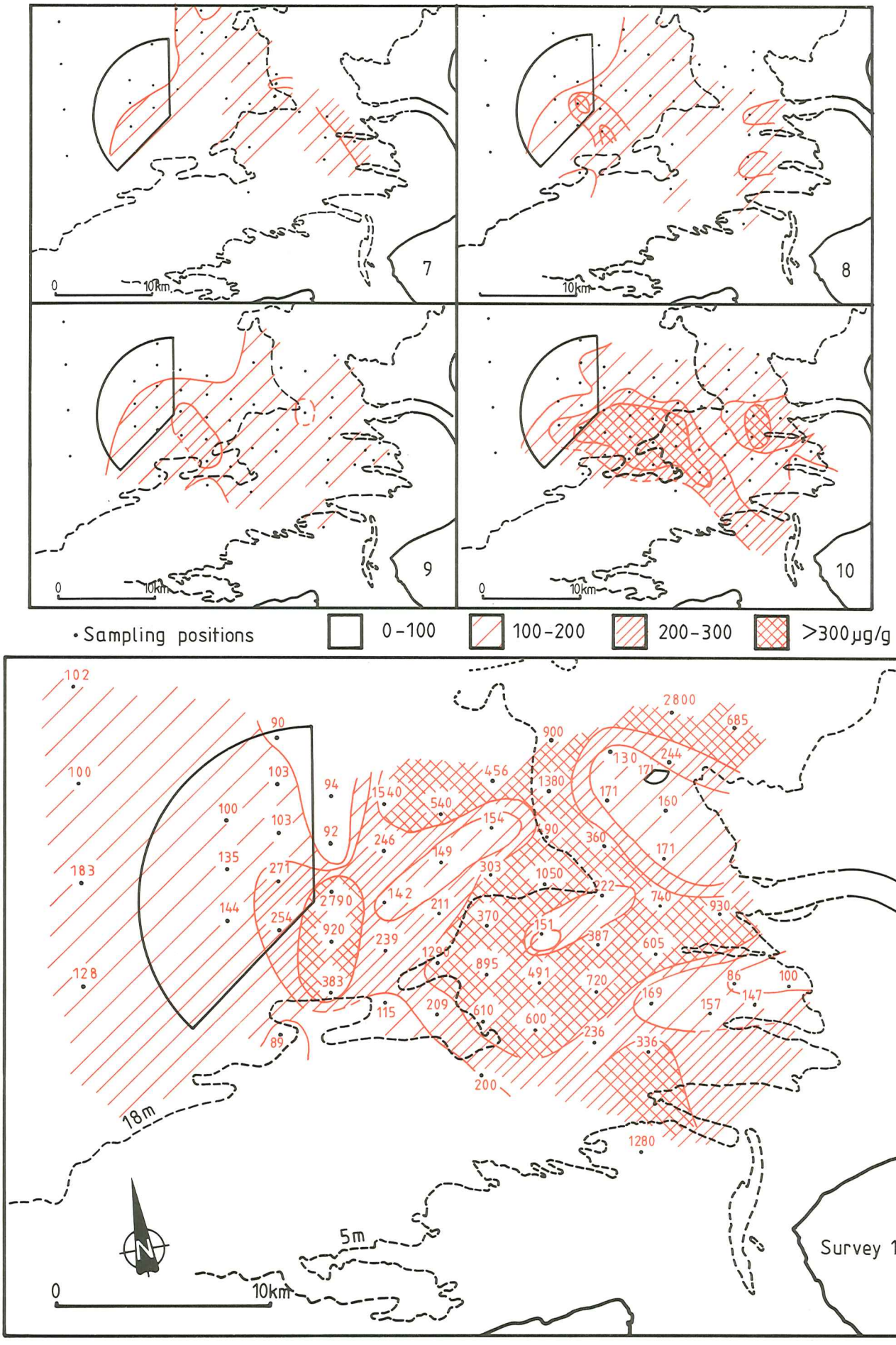

Fig 6 Lead concentration in mud from the top 25mm of bed

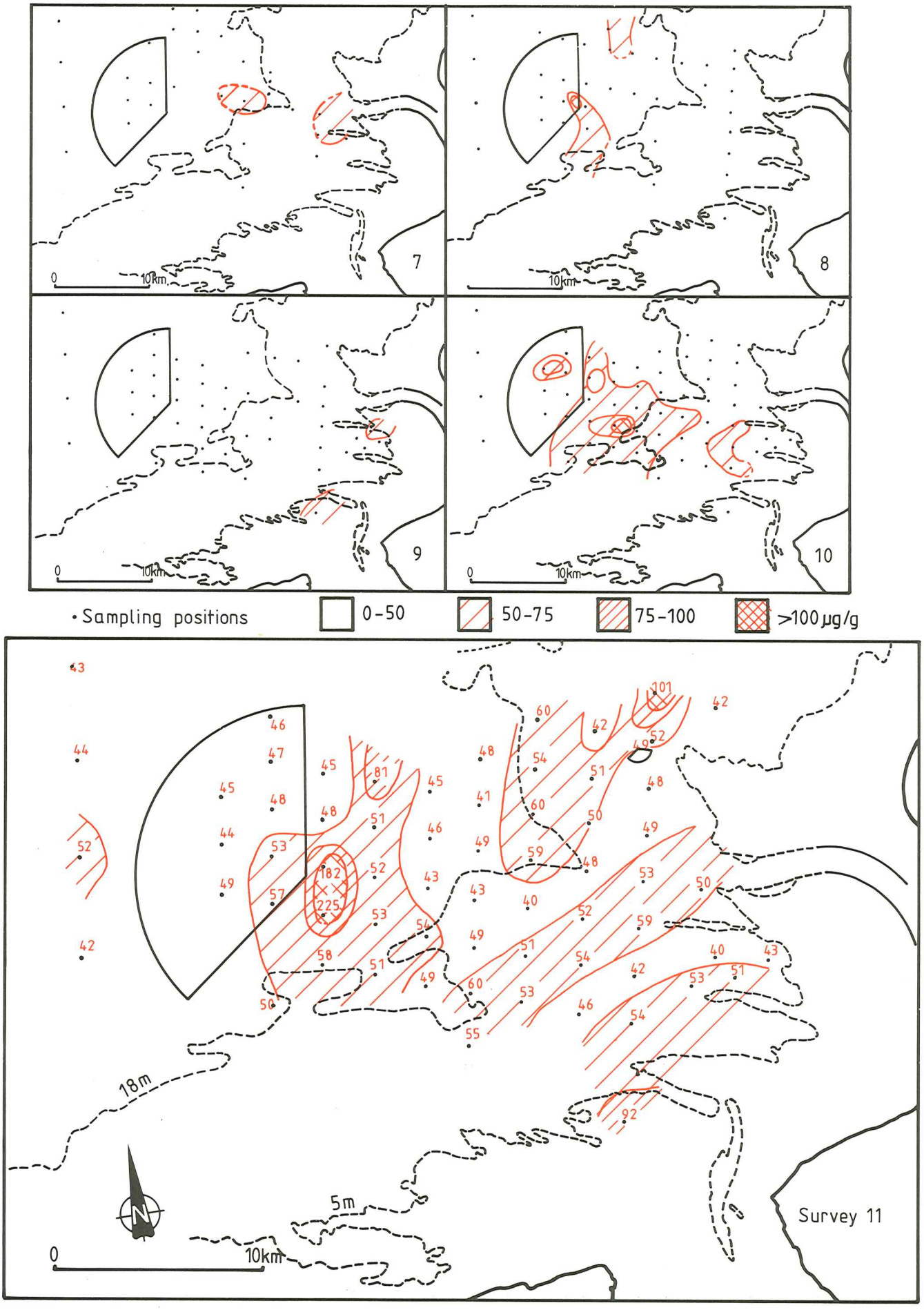

Fig 7 Nickel concentration in mud from the top 25mm of bed

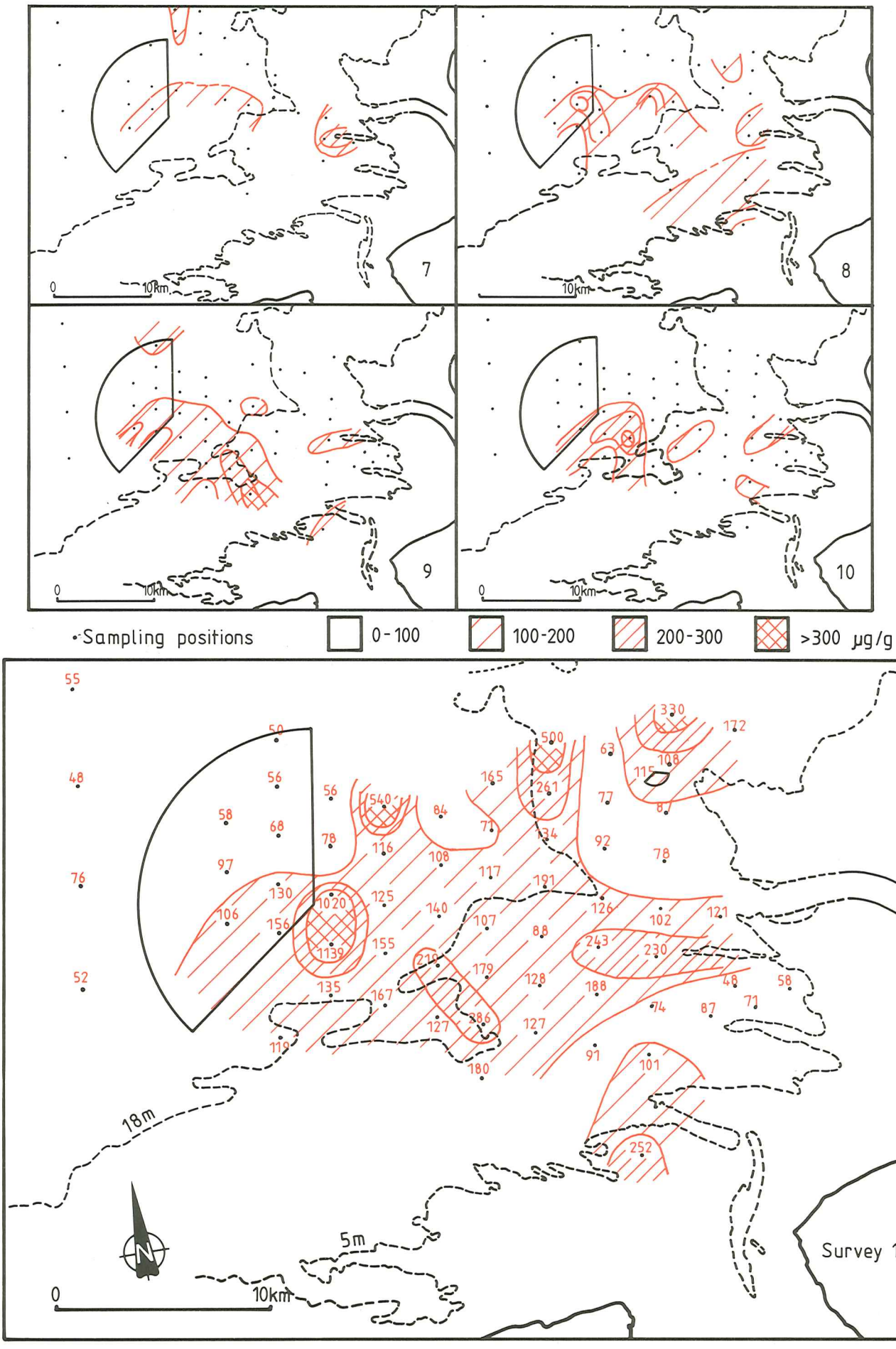

Fig 8 Copper concentration in mud in the top 25mm of bed

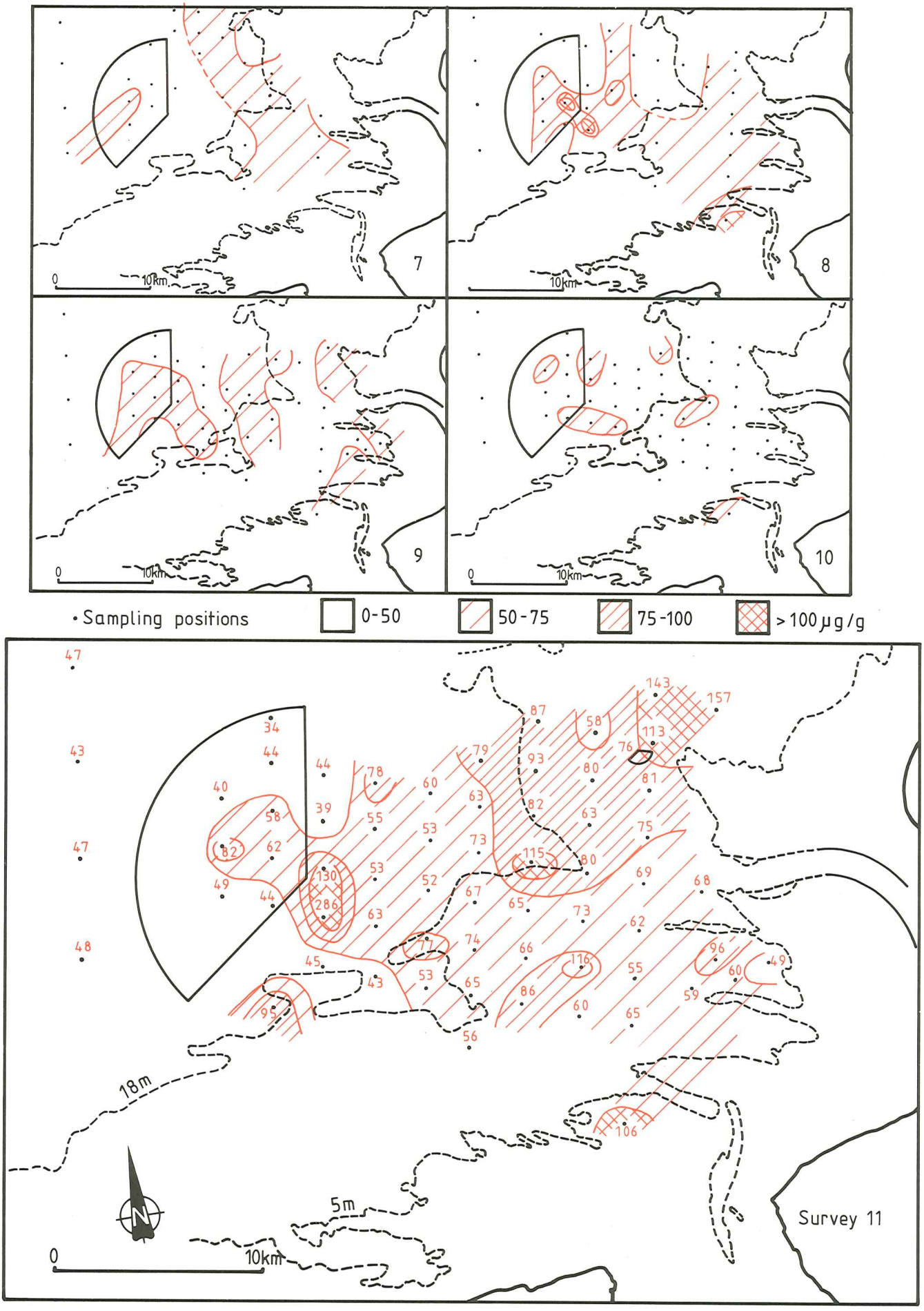

Fig 9 Chromium concentration in mud from the top 25mm of bed

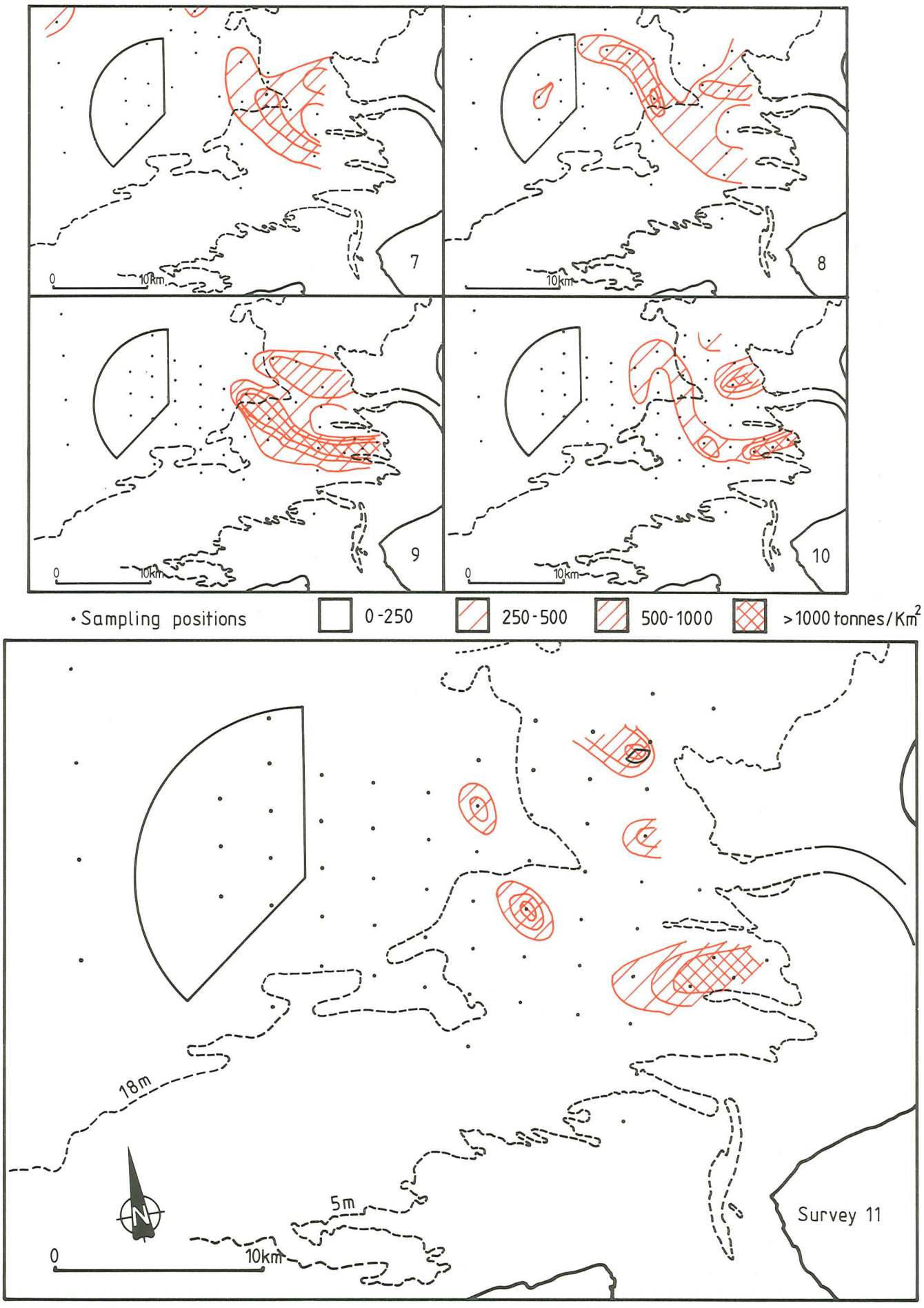

Fig 10 Total organics in mud from the top 25mm of bed

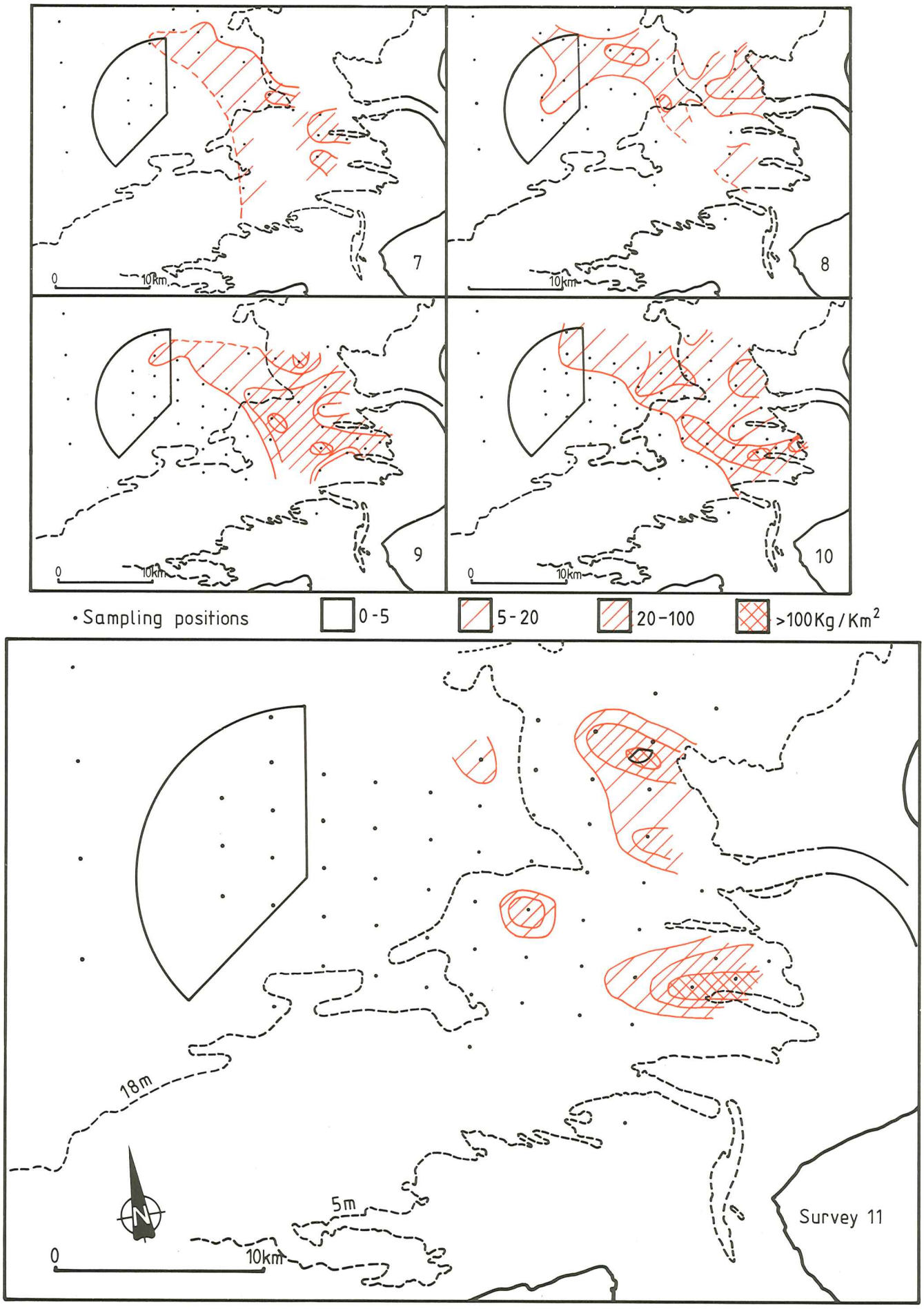

Fig 11 Total mercury in mud from the top 25mm of bed

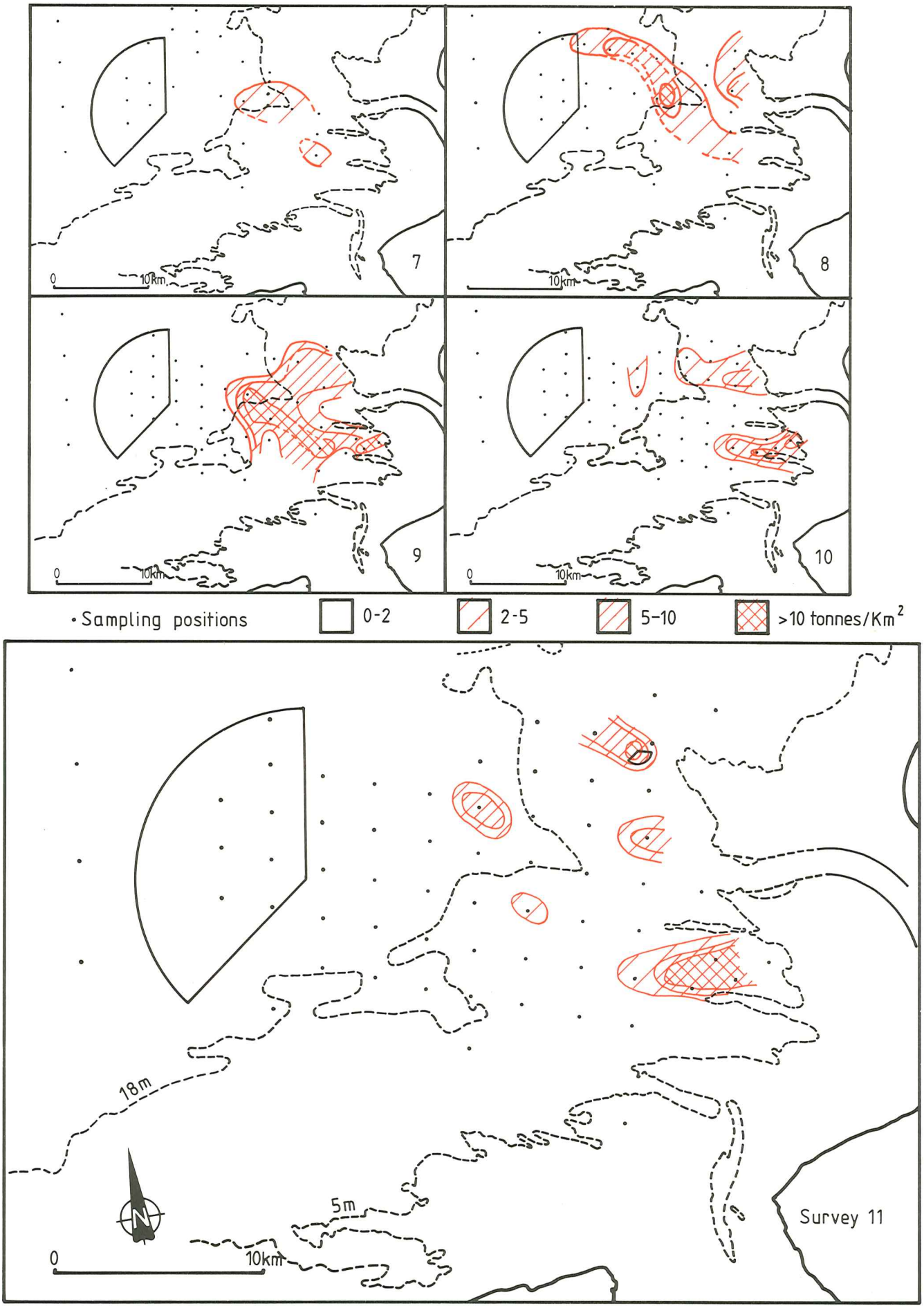

Fig 12 Total zinc in mud from the top 25mm of bed

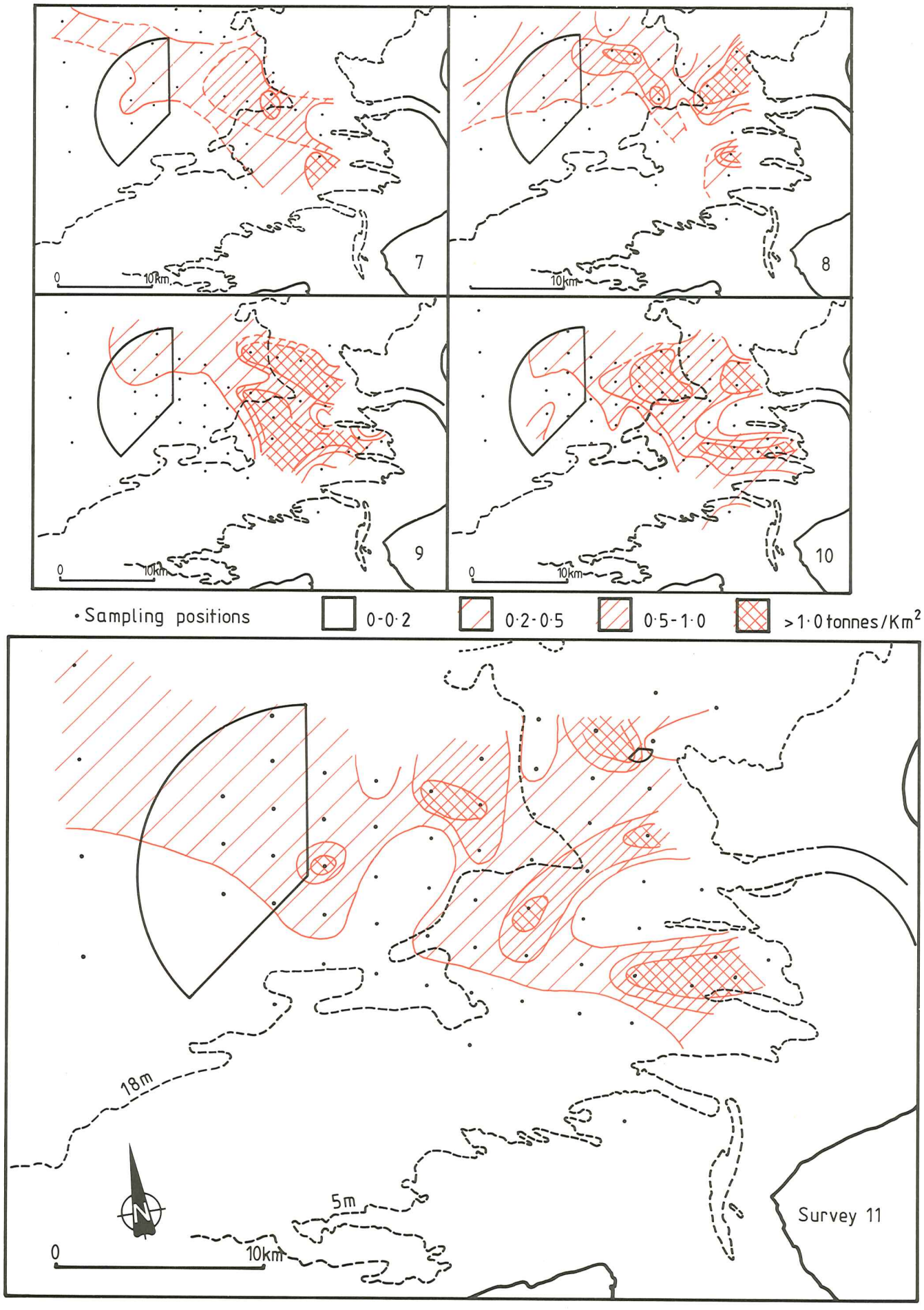

Fig 13 Total lead in mud from the top 25mm of bed

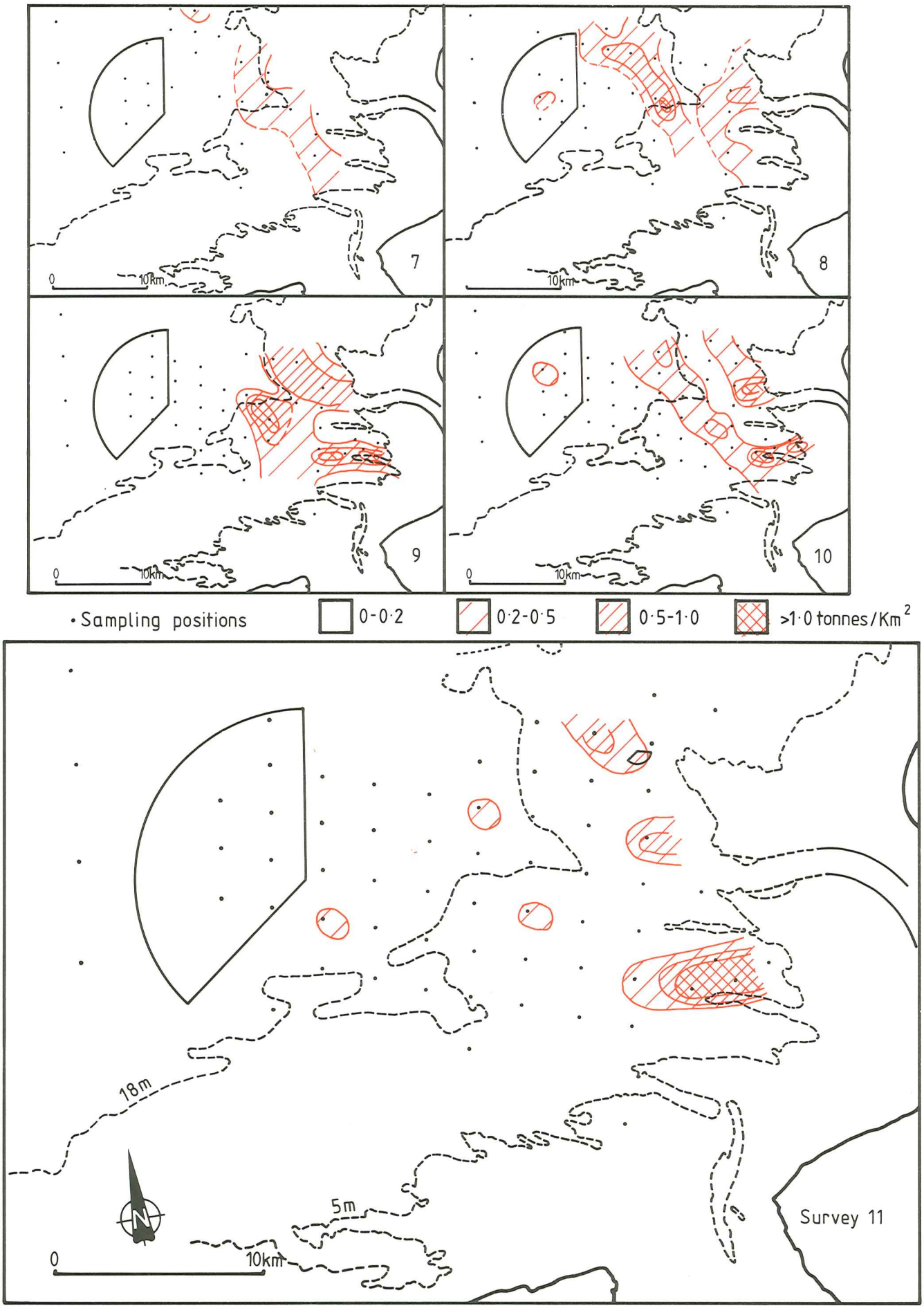

Fig 14 Total nickel in mud from the top 25 mm of bed

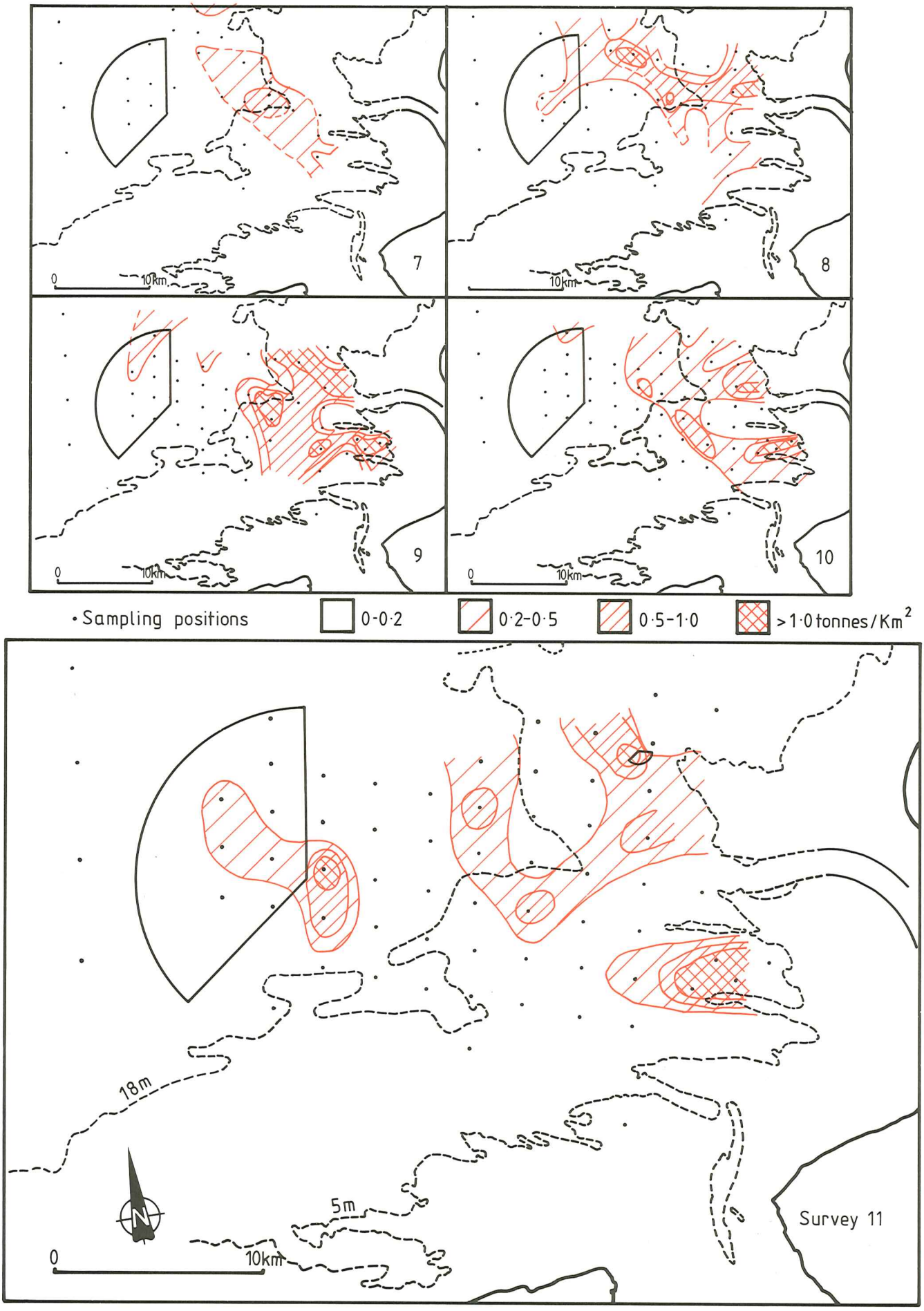

Fig 15 Total copper in mud from the top 25 mm of bed

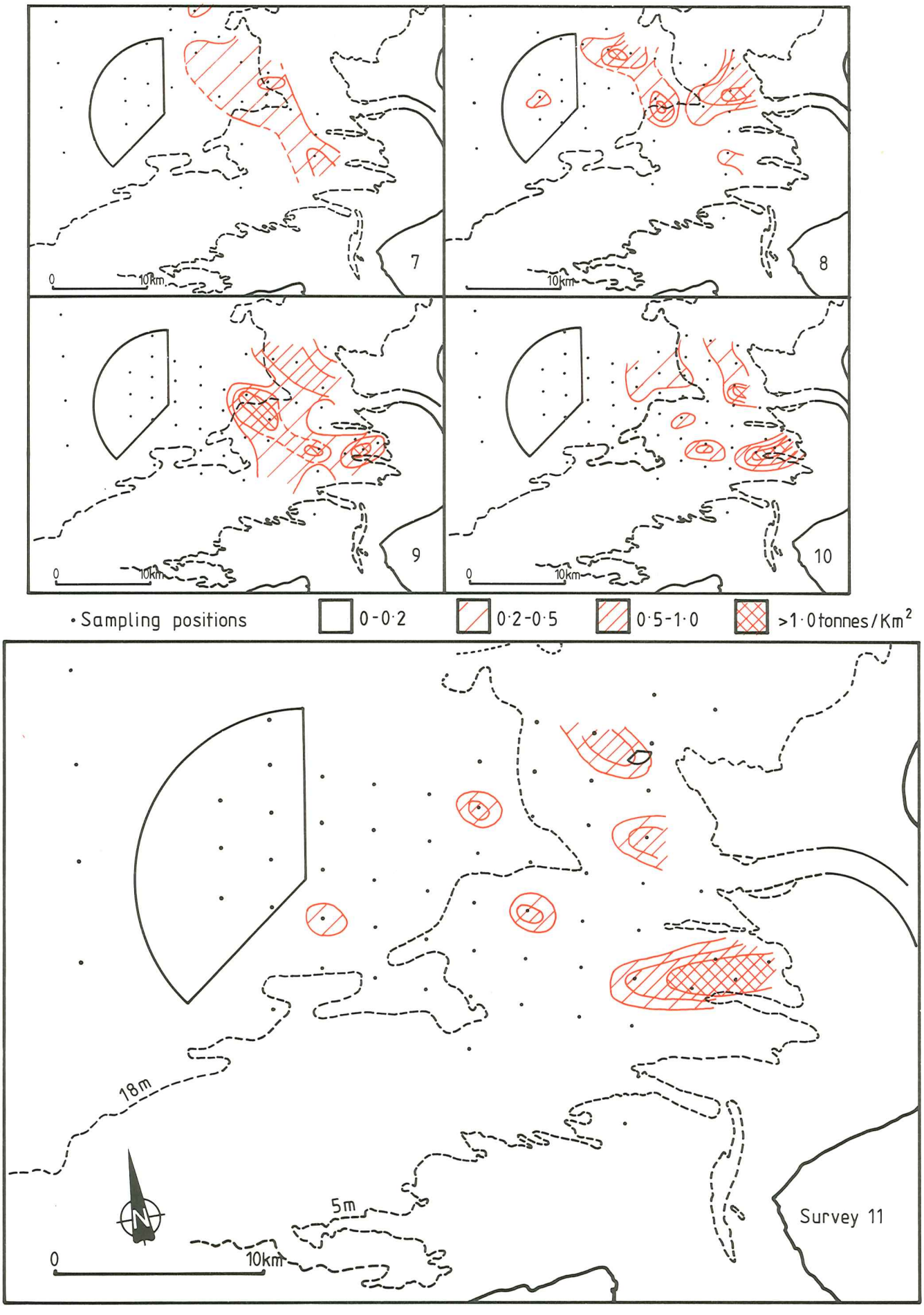

Fig 16 Total chromium in mud from the top 25 mm of bed