5.0 RESULTS - PHYSICAL RESOURCES

Surface plots of the bathymetry of the study site are shown in Figure 5a for 1999 and Figure 5b for 2001. The survey area can be seen to straddle a weak scarp (note the elevation differences have been graphically enhanced). Nonetheless the active area of the dredge site is seen to be clearly located in the facing edge of that scarp, and it is possible that this represents a paleobeach environment. There are no apparent significant correlations between the sedimentary and biological communities and the bathymetry of the study area.

The licence itself appears to be geologically controlled in relation to the bathymetry and further work may be able to determine additional resource zones on the basis of the bathymetry.

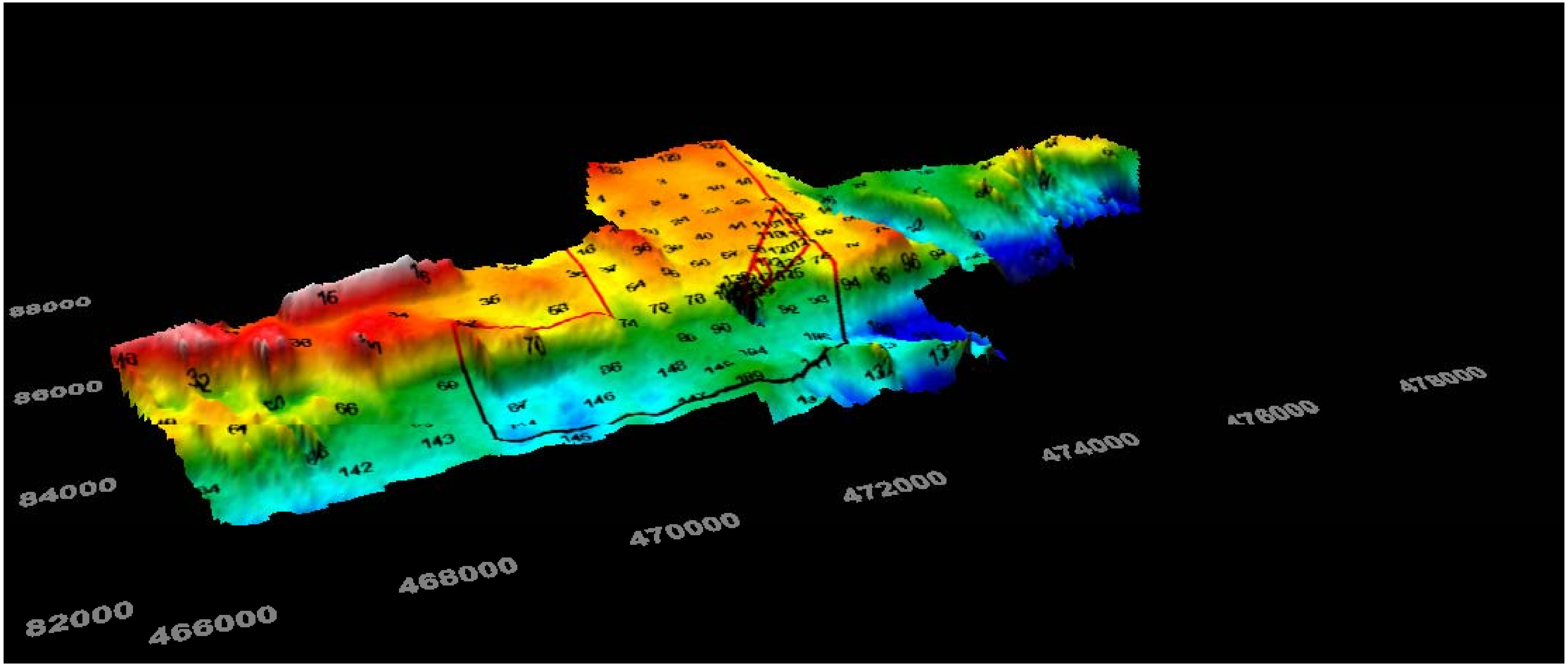

Figure 5a Surface plot of bathymetry for 1999 with grab sample positions superimposed. The survey area can be seen to straddle a weak scarp, the elevation differences have been enhanced. Nonetheless the active area of the dredge site is seen to be clearly located in the facing edge of that scarp, and it is possible that this represents a paleobeach environment.

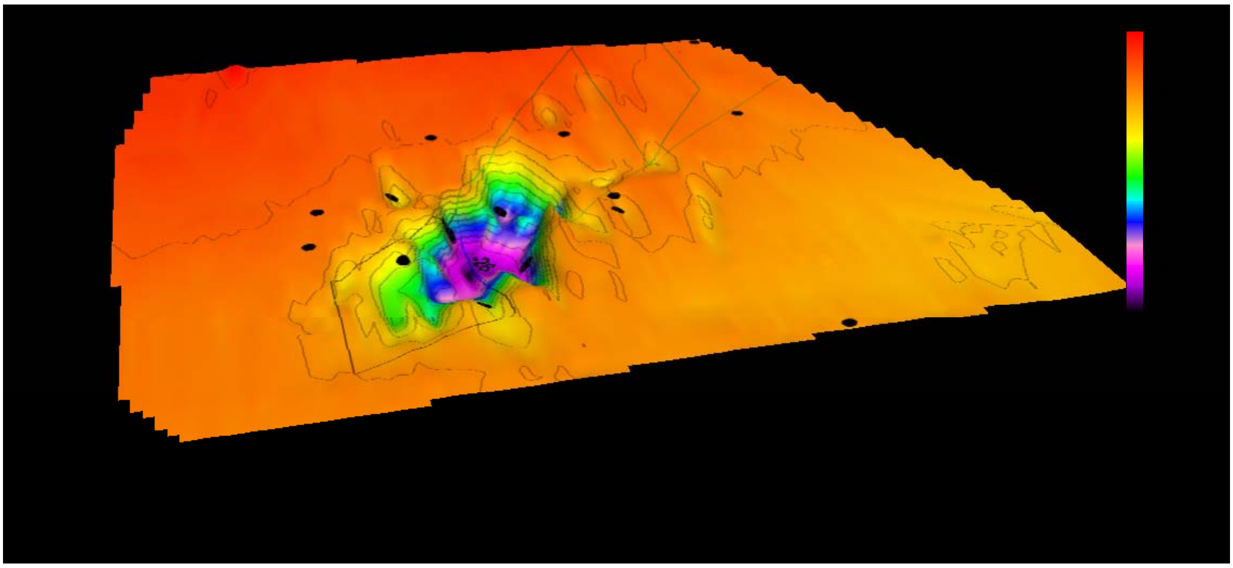

Figure 5b Surface plot of bathymetry of the active dredge area in June 2001 with grab sample positions superimposed. The location of the dredge pits, especially within the management boundaries can be clearly seen.

5.1 Nature of the Deposits in the Survey Area

The deposits in the survey area comprise mostly sands and gravels in a depth of 10-20 metres of water. The central part of the survey zone is dominated by gravels, which have been exploited by anchor dredging since 1991 in a small part of the Licence Area shown in Figures 1.5a and 1.5c. The anchor-dredging zone was extended northeast in 1994 and subsequently further to the northeast using trailer-dredging techniques (see Figure 1.5c). Elsewhere in the east of the survey area the deposits are dominated by sands with relatively low gravel content to the east of the Nab Tower.

Deposits in the west of the survey area comprised gravels with variable quantities of sand and mud, with reefs in the shallower waters off Bembridge in the southeast of the Isle of Wight. Good samples were obtained at most of the stations sampled with the Hamon grab, with the exception of outcrops of reefs. The percentage stones (>37.5 mm particle diameter), gravel (>3.35 mm particle diameter) and sand (>0.075 mm particle diameter) is summarised in Appendix Table 1.

The volume of sediment obtained at each of the sampling stations is summarised in Appendix Table 1. An average volume of 10.6 litres of sediment was obtained for 130 samples of 0.2 m^2 used for biological analysis. A specific gravity of seabed deposits may be approximated as 1.8kg/m^3, thus the average weight of seabed material from which the fauna was extracted can be calculated as 19.1 kg per sample. This value was used to estimate the quantity of benthic invertebrate material that is likely to be 'processed' by a dredger during the normal loading operation.

Figure 5.1a shows the representative particle size of 151 grab samples that were analysed for full particle size distribution. This information was then used to investigate both the possibility that there was tendency for samples downstream of the dredge site to show a fining of size (due to the plume) and test the relationship of particle size to benthic community relationships.

Analysis of the particle size distribution in the deposits of the survey area is best carried out by non-parametric multivariate techniques. These identify differences and similarities between the sediments that could not be identified by mere inspection of the data. Similar methods have been used to analyse the particle size composition of coastal sediments in the southern North Sea off Orford Ness by Seiderer and Newell (1999), in the eastern English Channel off Hastings, Kent by Kenny (1998) and off Folkestone, Kent by Newell *et al*. (2001).

Both the percentage similarity of the sediments and the corresponding two-dimensional multidimensional scaling (MDS) ordination based on the percentage particle size distribution at each of the stations sampled are shown in Figure 5.1c.

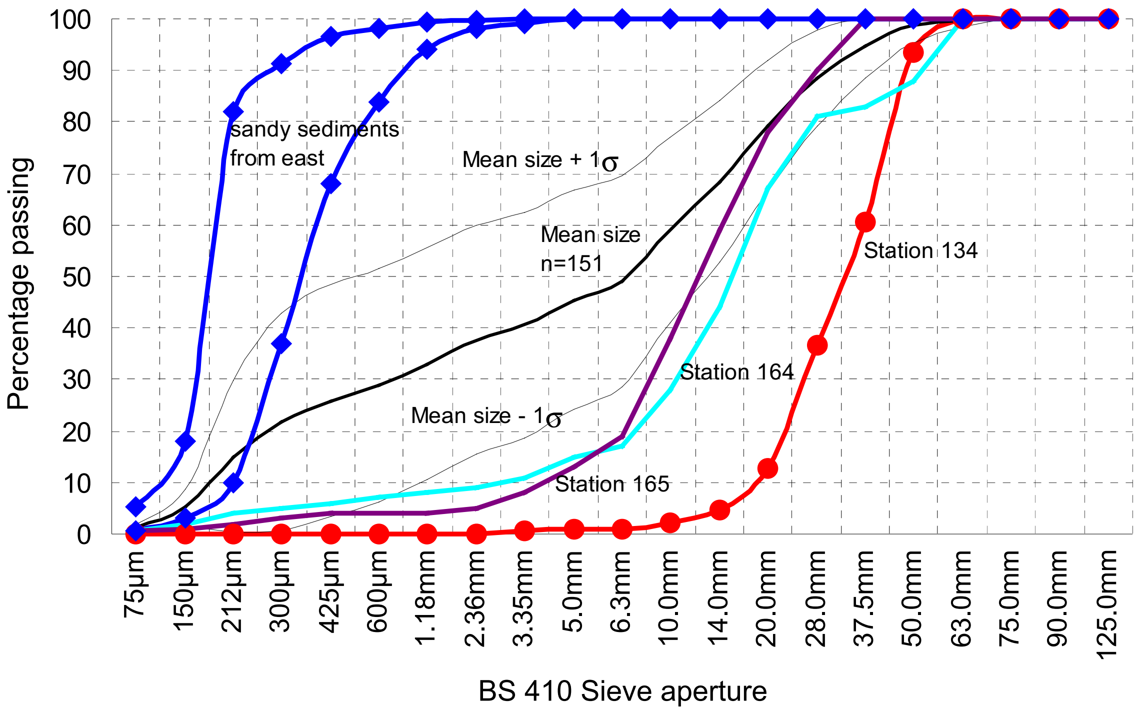

Figure 5.1a Representative particle size distribution of 151 grab samples from the North Nab study site with specific samples selected that are referred to in the text.

Figure 5.1b shows the percentage composition of the deposits in the North Nab survey area, graphically, based on the data shown in Appendix Tables 1 and 2 and summarised in size curves of Figure 5.1a.

It is clear that the deposits in the central part of the survey area comprise >60% gravel. At the east of the survey area, the percentage gravel falls to less than 10% where sands dominate the seabed deposits. At the western end of the survey area, the percentage gravel falls to below 40% mainly due to the increased proportion of sands and muds noted in our site survey records.

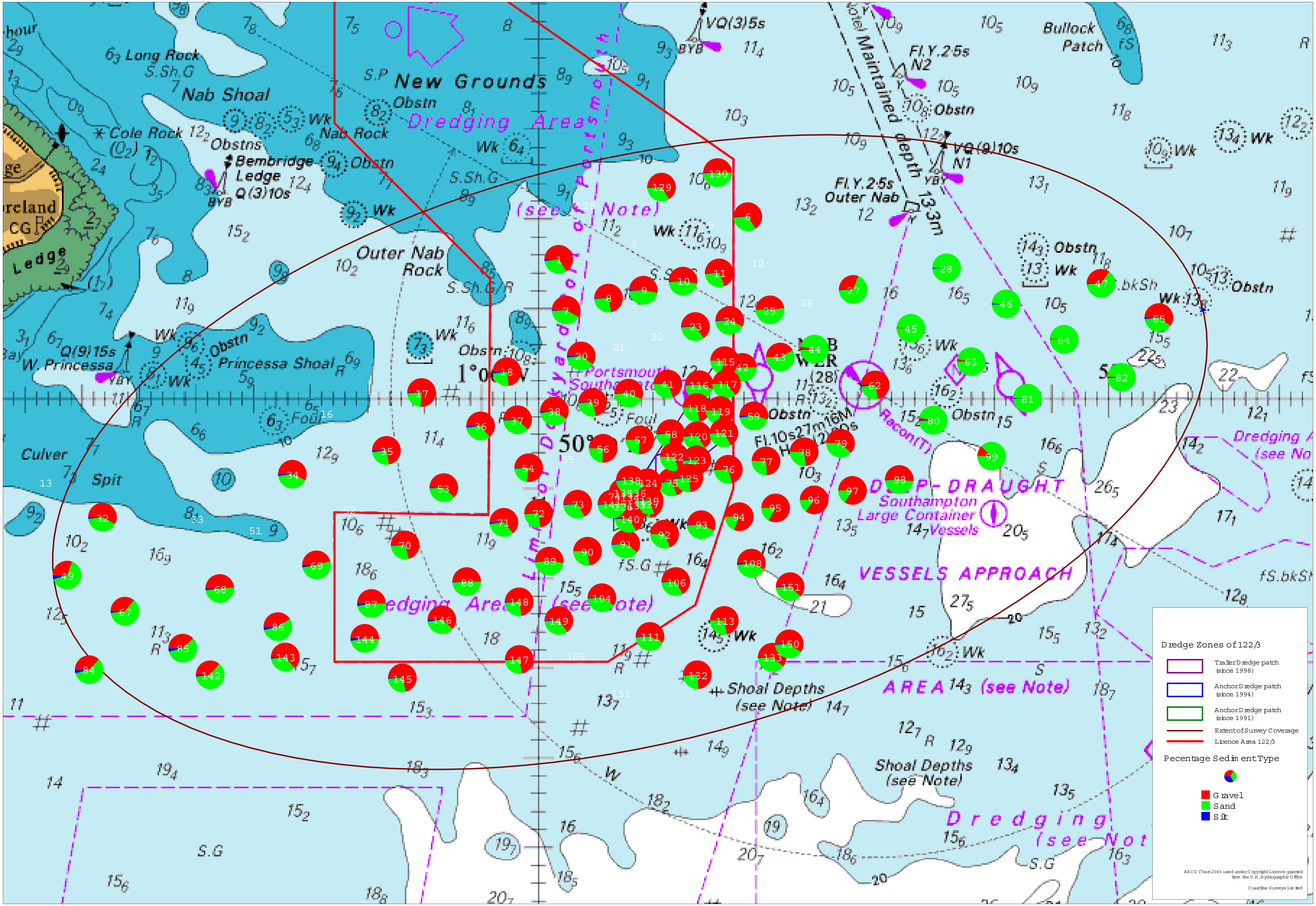

Figure 5.1b: Map of the North Nab survey area showing the relative proportions of silt (<0.063mm), sand (0.063mm - 3.35mm) and gravel (>3.35mm)

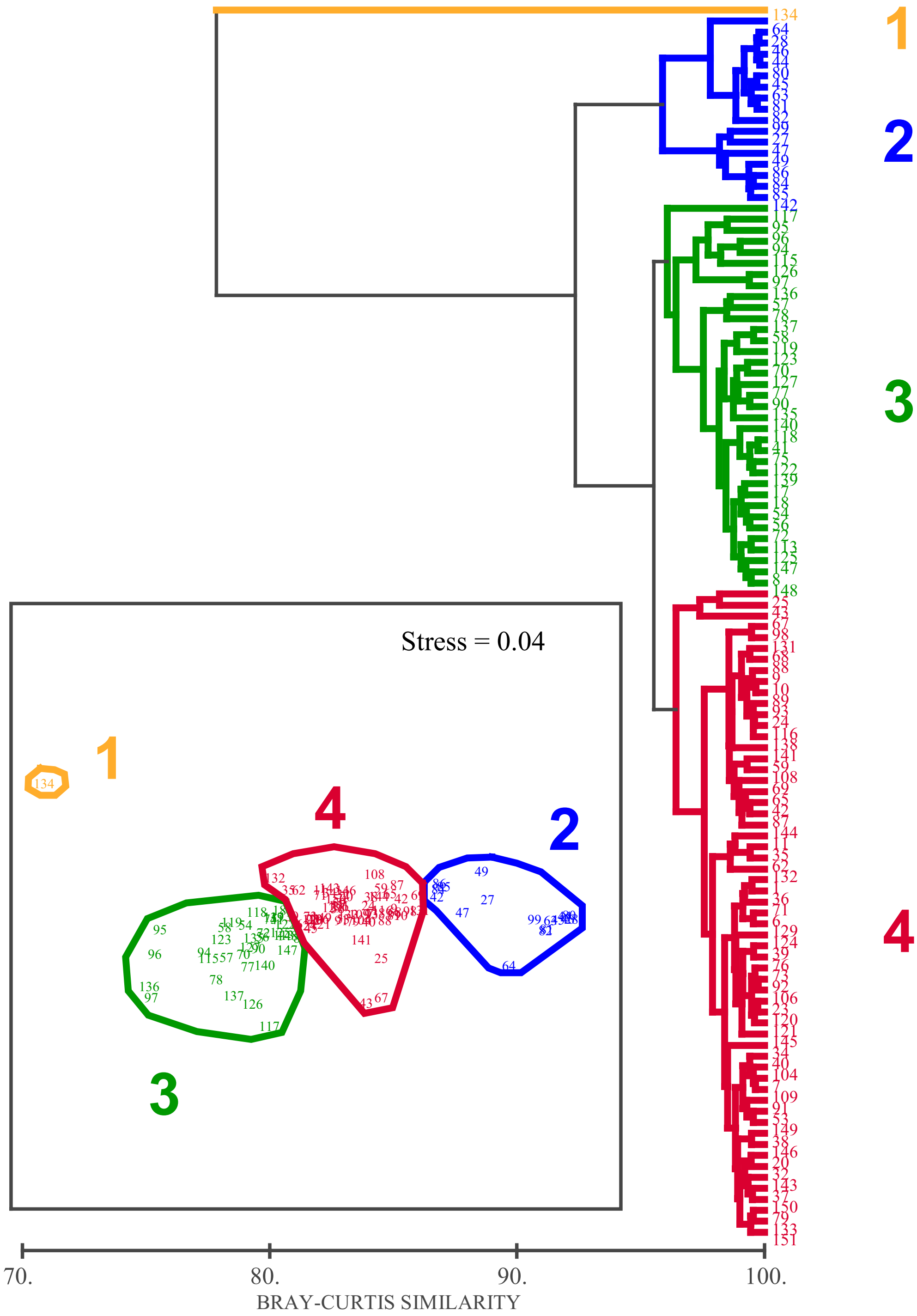

Figure 5.1c. Group average sorting dendrogram and corresponding two-dimensional multidimensional scaling (MDS) ordination based on the particle size composition of sediments from the North Nab survey area in March 1999.

Sediments in the survey area are evidently best regarded as comprising four main types. These are an isolated Group 1 sediment type that occurs only at Station 134; this may reflect an impact of dredging at that site. A second Group 2 (coded blue in Figure 5.1c) comprises mainly sands and muddy sands with a low proportion of gravel. A third Group 3 (coded green in Figure 5.1c) comprises mainly gravels. A final Group 4 (coded red in Figure 5.1c) comprises gravels with varying proportions of sand and mud.

The results for Station 134 are of particular interest. This site corresponds with the centre of an anchor-dredge pit recorded in May 1999. Inspection of Figures 5.1a and 5.1c shows that the sediments at Station 134 are quite distinct from all others in the survey area. The deposits at this site are exceptionally coarse (see Appendix Tables 1 and 2) and may reflect a removal of fine material during the dredging process. Elsewhere the deposits closely resemble those outside the boundaries of the exploited area, so any impact of dredging on particle size composition appears to be confined to the immediate vicinity of a dredge site currently under exploitation. The distribution of these groups of sediments is shown in Figures 5.1d and 5.1e.

The Group 1 sediment type occurs only at Station 134, close within the zone of intensive anchor dredging. The Group 2 sediments (coded blue in Figure 5.1d) represent the sands and muddy deposits that occur at the eastern and western extremities of the survey area. The Group 3 sediments (coded green) are mainly confined to the high-grade gravel deposits close to the intensively worked area within the boundaries of the main Production Licence Area 122/3 (see Figure 5.1e). Finally the Group 4 sediments (coded red) represent the sandy gravels that occur over much of the central part of the survey area.

The sediments within each Group are evidently related to one another with a high degree of internal similarity and are relatively uniform over much of the central part of the survey area. A similar high level of internal similarity has been recorded for other coastal sediments both in the southern North Sea (Seiderer and Newell, 1999) and in the eastern English Channel (Kenny, 1998, Newell *et al*., 2001).

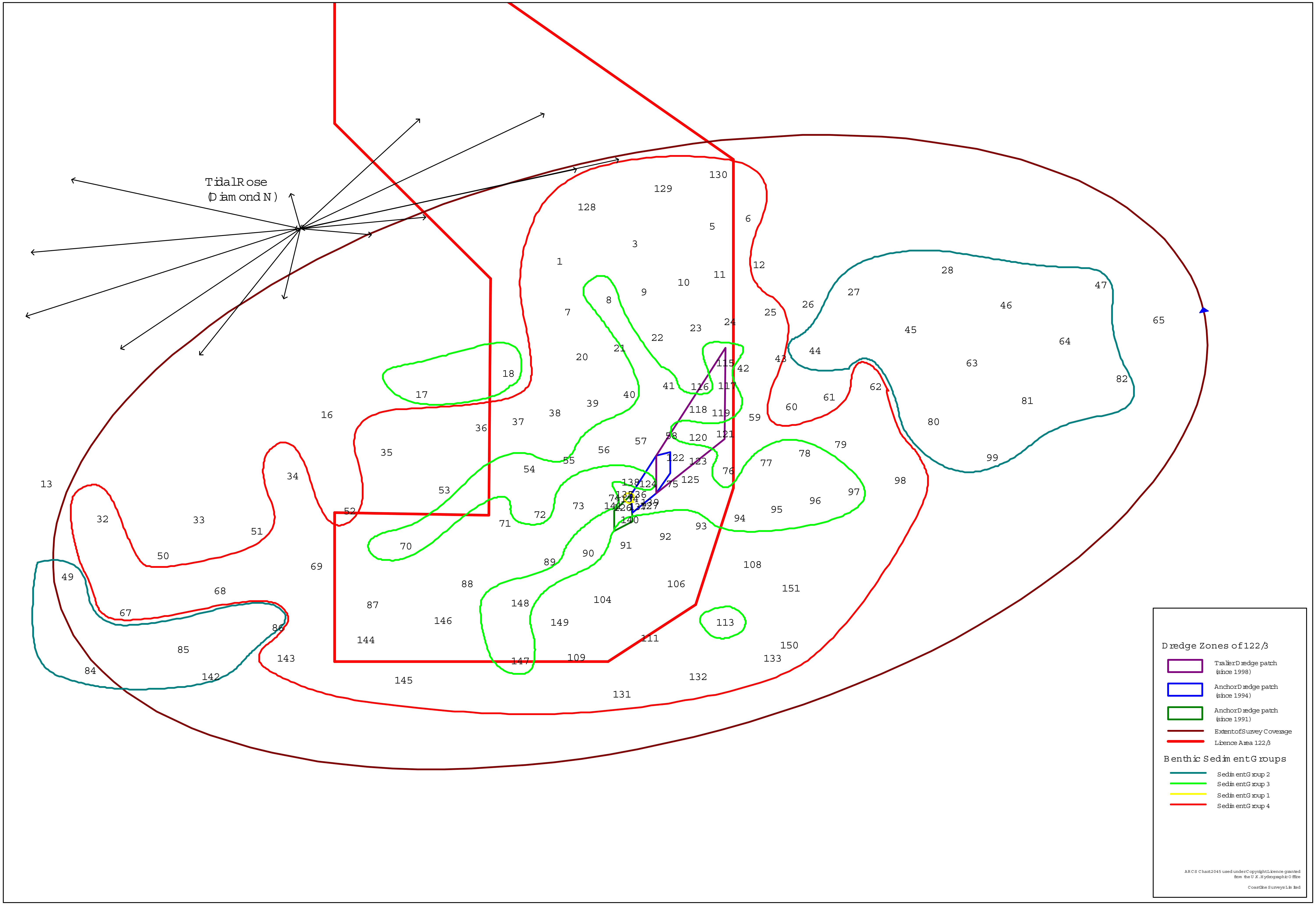

Figure 5.1d: Map of the North Nab survey area showing the distribution of sediment types identified by non-parametric multivariate analysis

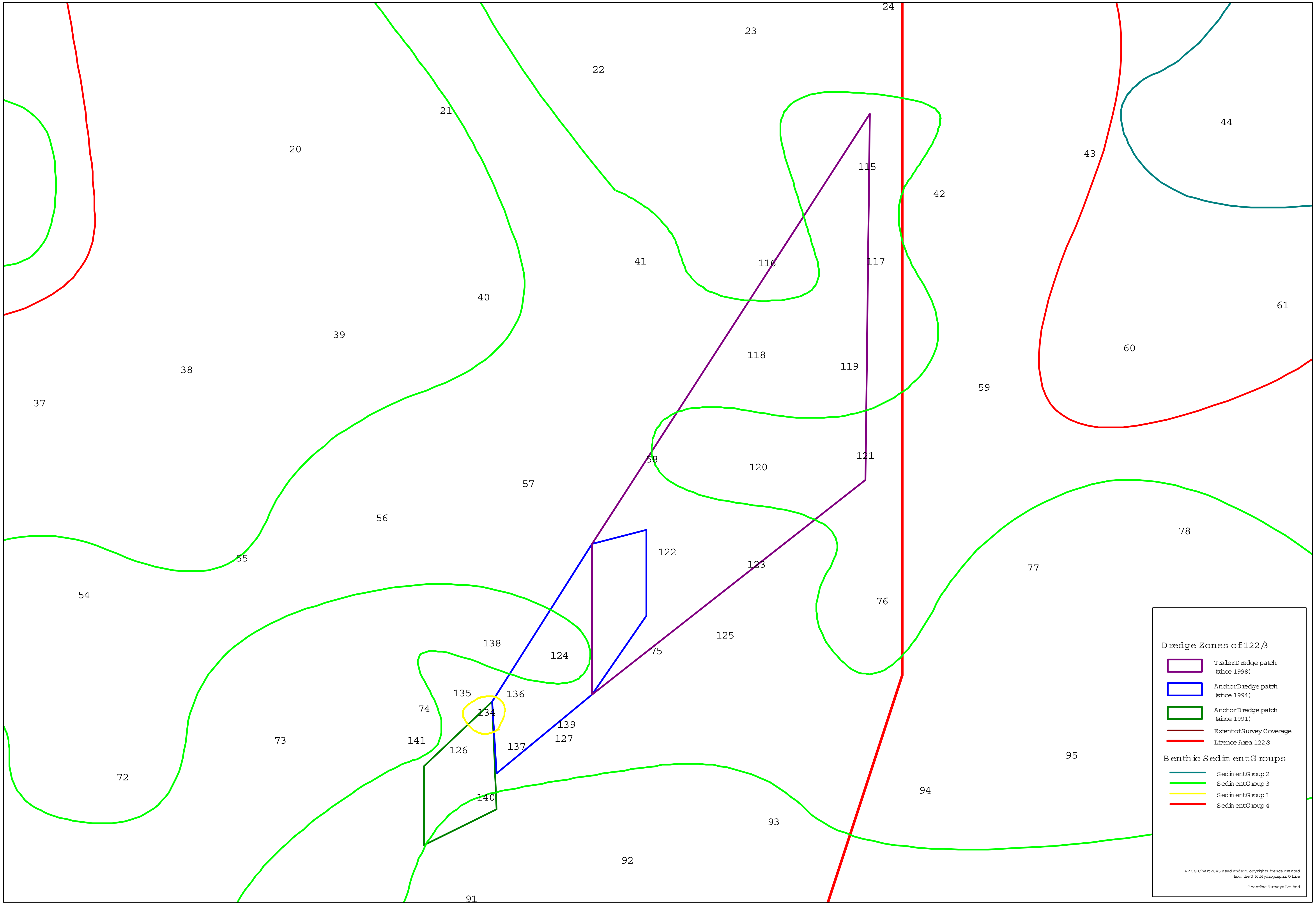

Figure 5.1e: Detail of the North Nab survey area showing the distribution of sediment types identified by non-parametric multivariate analysis in previous figure

Although the sediments at Station 134 are quite distinct from those in the surrounding deposits and may reflect a local impact of dredging on sediment composition, the similarity of sediment composition at other sites within the exploited area that are known to have been worked in the months prior to the survey shows that neither anchor dredging nor trailer dredging at the North Nab site has resulted in a detectable alteration in sediment composition compared with the surrounding deposits. This is to be expected in a Production Licence area where there is no discharge of screened material.

5.2 Sidescan Sonar Mosaics of the Survey Area

The principal sidescan sonar mosaic that has provided most information is generated from the data collected in 1999. Subsequent surveys collected data very close into the dredging operation, within the actively dredged pits area, but this seabed is so uneven the sidescan sonar can reveal little information.

Inspection of the sidescan sonar mosaic presented in Figure 5.2a clearly shows the differing acoustic contrasts of the seabed in the principal sediment provinces. To the east, the lighter tone reflects the distribution of predominantly sandy size sediments. The remainder of the survey area is typically a uniform dark grey, characteristic of even, coarser sediments. The distribution of coarse sediments on the sonargraphs is again quite clearly depicted by the licence boundaries. Other than a very small zone, some 500m^2, on the extreme northwest boundary of the survey zone, there are no bedforms such as ripples or megaripples. This localised development is near a small shelf of local solid rock control. Around the actively dredged area there is no evidence of development of sand ripples or other microtopographical features indicative of a localised sand transport path, as may be expected to develop during overboard release of sediments. We know that screening does not occur on this licence, so the potential quantity of remobilised fine sediments is small.

Also shown on Figure 5.2a are the boundaries of the principal sediment provinces based on multivariate analysis of the sediment classes, overlain onto the regional sidescan sonar mosaic of the region collected in 1999. The major sediment provinces are well indicated by the production licence area that closely follows the distribution of gravelly sediments. This supports the resource management Code of Practice to restrict licensed areas of the seabed to the minimum required. These techniques enable a detailed assessment of the sediment distribution, and importantly reveal small groups of gravelly sediments that show an elevated sand content, distributed around the actively dredged area, not discernible by other geostatistical techniques. The ribbons of sandier gravels extend some 1500-2000m away from the dredge location and correspond well with the predominant tidal axes away from the active dredge zone.

From Figure 5.1a, the distinct sample stations 134, 164 and 165 are located within the dredge pit, and reflect a very well sorted coarse gravelly deposit, which is the target resource.

Anchor dredge activity can clearly be located on the sidescan sonar. Single dredge pits caused during isolated dredging operations are also clear around the main dredge area. There is also isolated evidence of trailer dredging activities in the designated zone, but these trails are poorly distinguished. Loading whilst trailing is not commonly undertaken. Anecdotal evidence from the vessels suggest that the method performs poorly in this locale, due possibly to presence of a lag gravel deposit through which the dredge head does not penetrate easily. Measurements from the sonargraphs indicate that the trailer dredge tracks are shallow, some 10-20 centimetres deep. Width is poorly distinguished.

Figure 5.2c clearly show the distribution of sediments (as discussed above) and faunal communities. For a detailed analysis of the benthic resources and the implications of the community distributions, see the following chapter. Importantly, however, we may briefly consider the lack of correlation between the change in sediment type downstream of the dredging activity (the enhanced ‘sandiness’ of the gravels) (from Figure 5.2a) and the faunal community.

This suggests that either the type of community structure present is unaffected by the change in sediment composition or, more likely, is tolerant of the level of change that the community has been exposed to. However, an increased or prolonged exposure may cause a negative impact, or the existing exposure may cause a level of stress to the community that reduces its tolerance to other impacts.

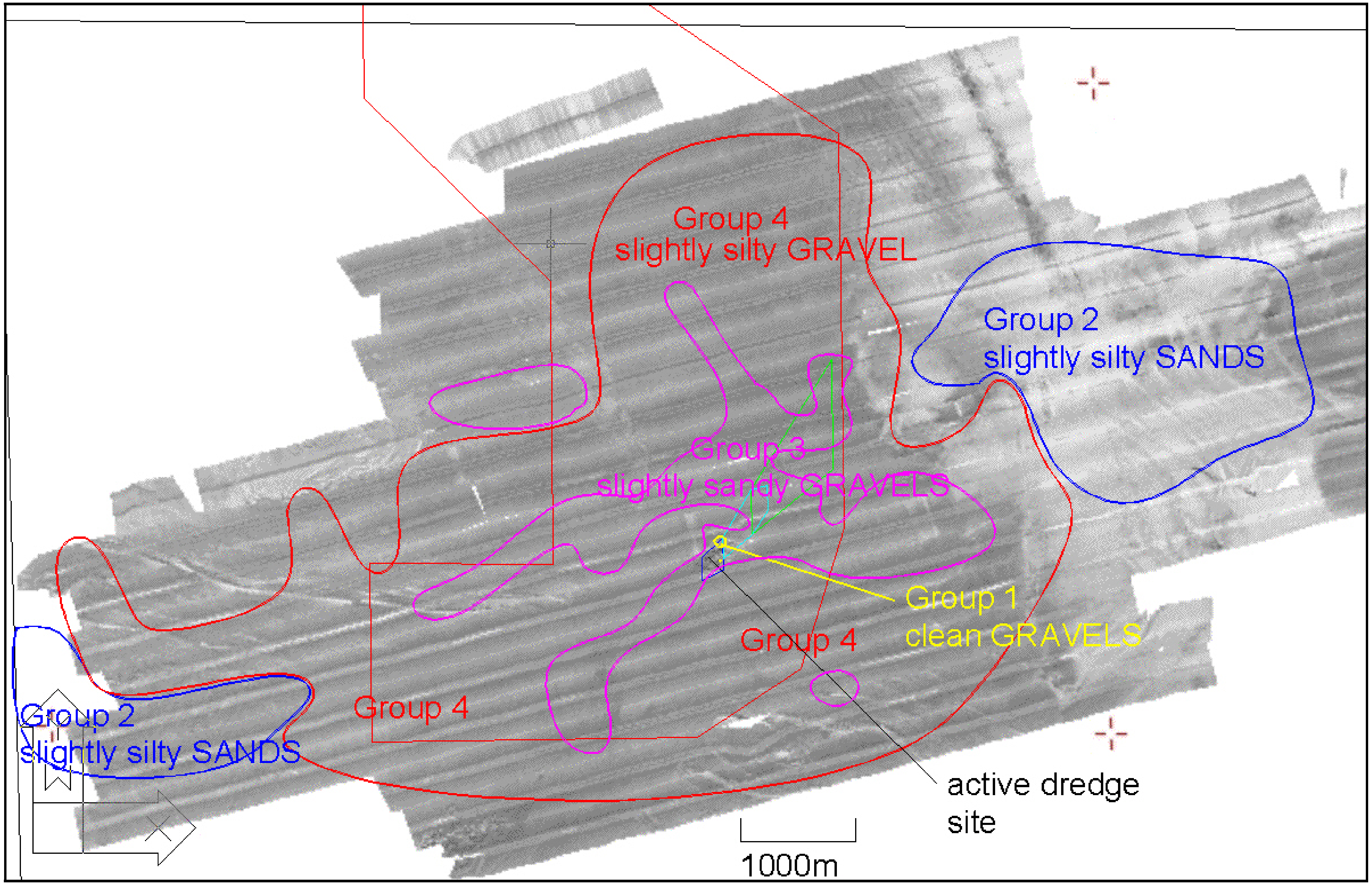

Figure 5.2a Sidescan sonar mosaic formed from the 1999 data collection. The principal sedimentary provinces determined by the statistical analysis of the grab samples has been superimposed on the sonargraph. The correlation between sandy sediments and low reflectivity is clear to the east of the mosaic. Other than the exposed sub-bottom sediments of Group 1 (clean gravels), almost the entire licence area is of slightly silty gravels. Note the elongated changes in sedimentary composition (Group 3) adjacent to the dredge zone aligned with the principal tidal vectors, to the South West, West, North and East.

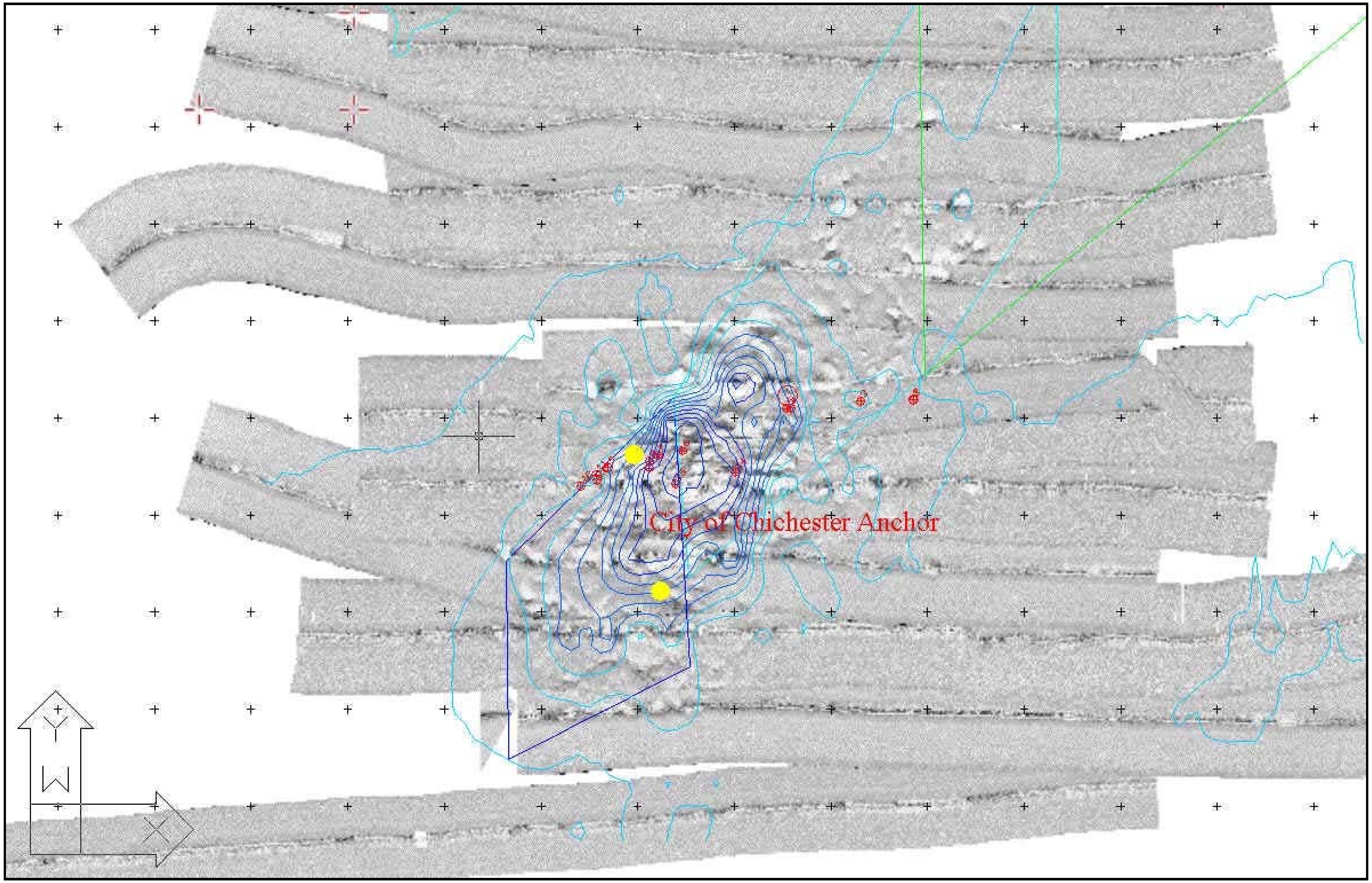

Figure 5.2b Sidescan sonar mosaic formed from the 2000 data collection. The bathymetry is superimposed, reduced to chart datum.
The dredging activity can be seen to be slowly working towards the north, when compared with data collected in 1999.
There is a good correlation between the location of the pits from the sidescan and the hollows recorded on the bathymetry.

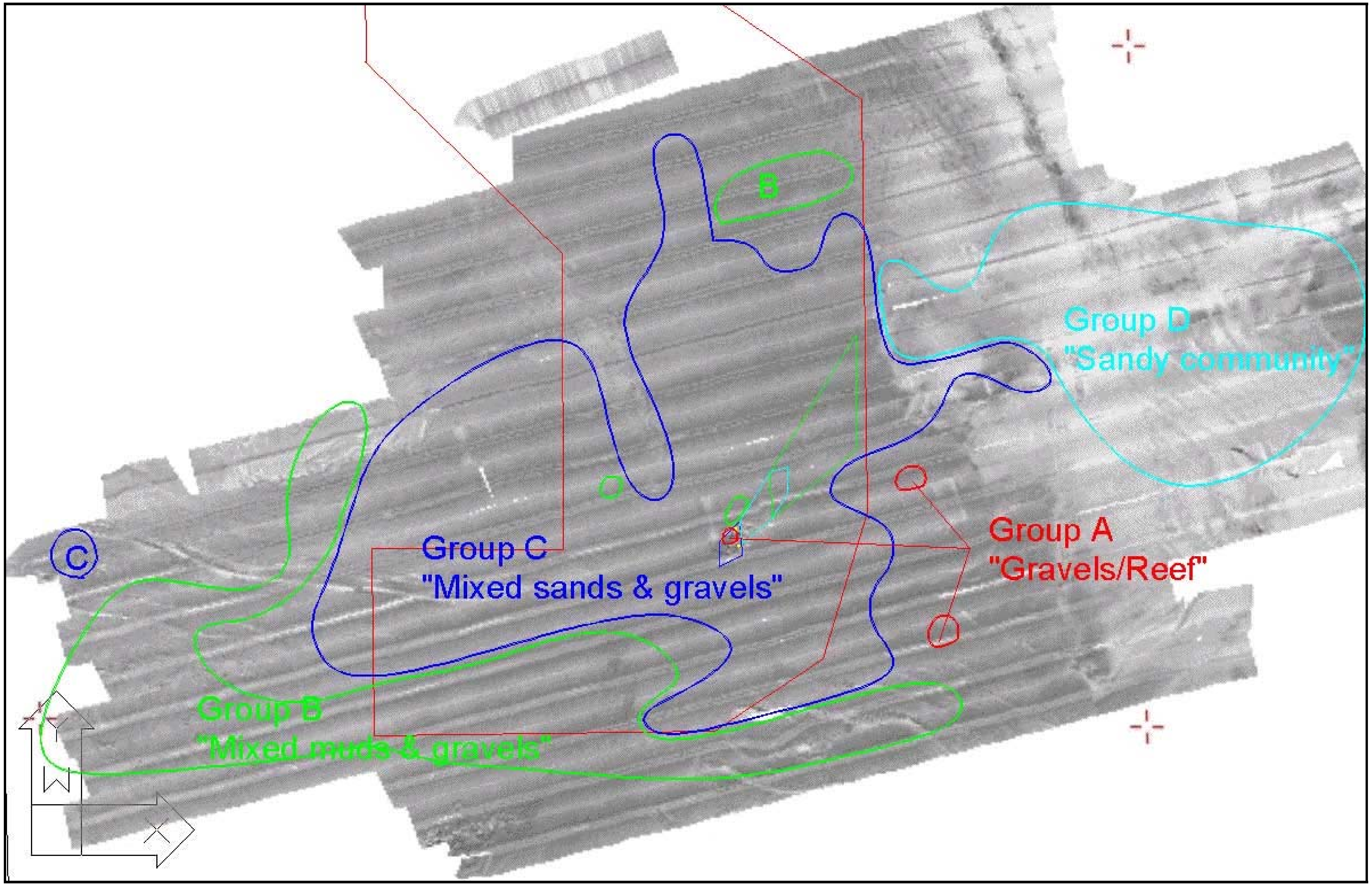

Figure 5.2c. Superimposing the benthic community types on the sidescan mosaic and comparing with Figure 5.2a, we can see that there is no correlating change in community type similar to the recorded changes in sediment province. Community Groups B and C pass over the tongues of sandy material downstream of the dredge zone (this does not appear to be an artefact caused by data density). See Section 6 for full analysis of the community types and implications of these observations.

5.3 Plume Morphology

A composite image of the continuous backscatter profiling (CBP) of the plume developed by the 2300 tonne capacity *City of Chichester* during loading of an all-in cargo is shown in Figure 5.3a. The screen-dump images show a series of transects downstream of the dredger at varying distances. Data collection at the far-field extremes of the survey, necessary to prove return distances to background levels, was curtailed by the presence of numerous small vessels at anchor. Nevertheless, the transects and samples obtained give a good indication of the near-field density current dynamic phase plume morphology. High intensity backscatter values are coloured red, reducing through yellow, white and to pale blue approaching background levels of backscatter. Close to the dredger, the plume can be visualised falling immediately below the vessel (45 metre image). The sequence 45 metres to 200 metres shows the dense plume falling to the seabed, and spreading laterally downstream of the operation. Scale of the transects changes such that the 45 metre transect is some 200 metres long, whilst the 200 metre transect is some 500 metres long.

Suspended sediment samples obtained by subsurface pumps immediately astern of the dredger are presented in Table 5.3a along with corresponding depths and distances downstream of the dredger. Pre-dredging background levels are 5-10 mg/l in settled conditions. Maximum values reached are approximately 5.5 g/l reducing to 450 mg/l further away from the vessel at the limit of the survey. Considerably more samples are needed for future works to resolve the fine scale eddies and internal structures that are developed during the overspill process. Included in Table 5.3a are corresponding results of a previous study on an adjacent site, using a similar methodology. In this instance, generally much lower concentrations of suspended sediments were recorded. Although the vessels are similar in size and operation, this may be due to different tidal conditions in the earlier study leading to much quicker dispersion of the plume. Van der Veer *et al*. (1985) measured overflow concentrations of suspended sediment from a small dredger to be 6300 mg/l, within range of the results obtained here. Background concentrations were found to average 60 mg/l.

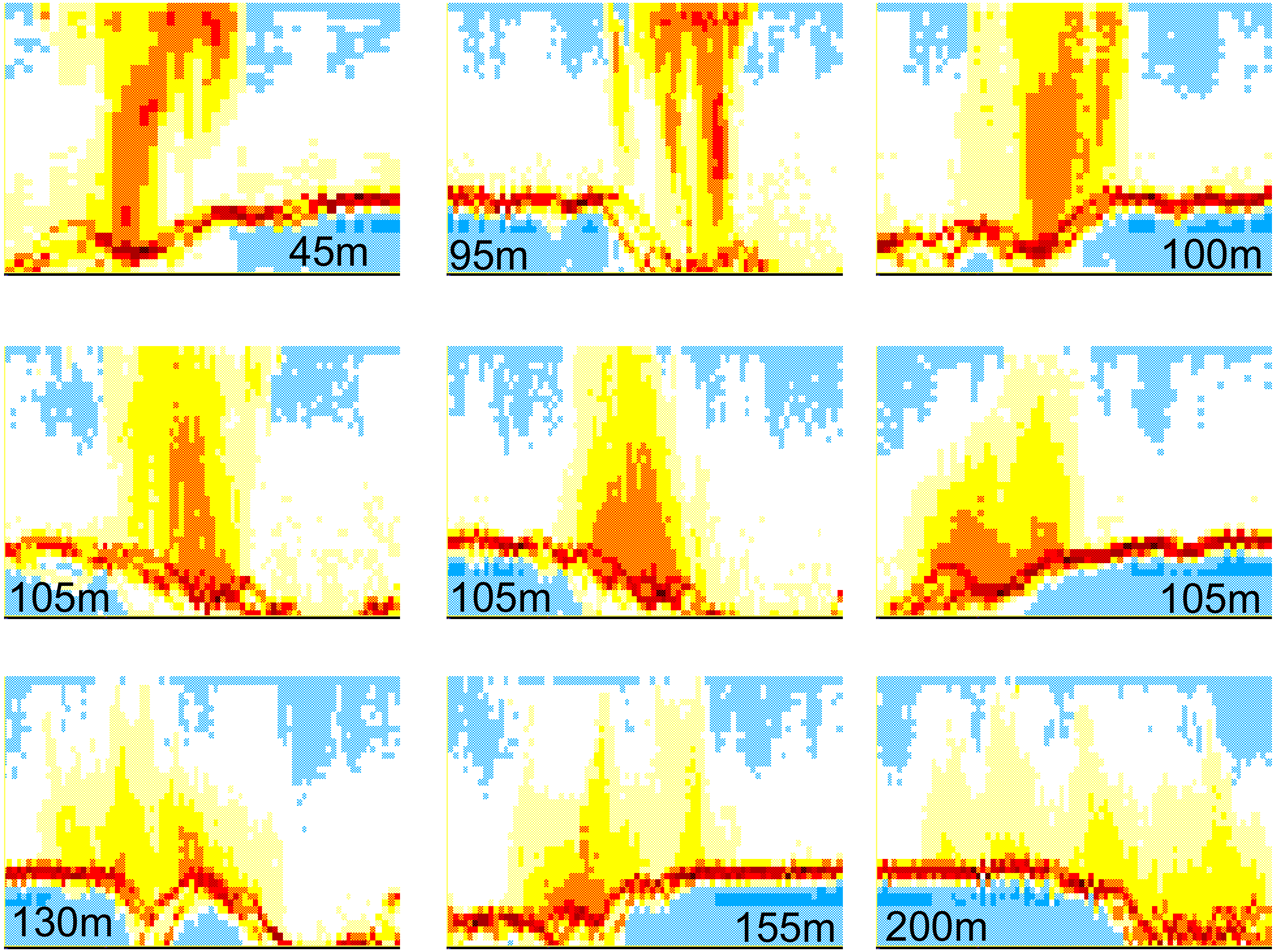

Figure 5.3a. Series of Acoustic Doppler Current Profiles obtained with a 1200kHz RDI BroadBand system astern of the small 2300 tonne capacity suction dredger *City of Chichester* whilst loading at anchor without screening. Profiles show high intensity backscatter (red) close to and immediately astern of the dredger (range 45m), reducing quickly to levels approaching background away from the dredger (range 200m). Transect lengths range from 200m close to dredger, slowly increasing to 500m at maximum range from dredger. Water depth 25m.

Sampling data from the 1995 research (Hitchcock and Dearnaley, 1995) indicated that at distances less than 100 metres from the dredger, total suspended solids concentrations ranged 480-611 mg/l in the lower water column, and 80-340 mg/l in the upper water column. Most of the sand had settled out reaching background levels within 250 metres, implying a forced settling rate of 32 mm/s in the water depths and current speed encountered, whilst the silt content reached background within 480 metres implying a settling velocity of 17 mm/s. This study provides suspended solids concentrations an order of magnitude higher, in the range 0.5-5.5 g/l.

Figure 5.3b records two longitudinal profiles downstream of the dredging operation to the limits that were possible on the day. The first profile (45 metres to 820 metres) shows a reduction in backscatter with two distinct phases. At about 300 metres, there is a rapid reduction in suspended solids backscatter. It is not clear whether this is a phenomenon of irregular loading and hence discharge rates (the dredge density and rate varies by the minute), or may represent observations similar to previous work, with a major reduction in the plume density roughly 300 metres to 500 metres from the dredge site (Newell *et al.* 1998, Hitchcock and Drucker 1996).

Sample Number	Distance (metres)	Depth (metres)	Volume (litres)	Suspended Solids (mg/l)
Nab14	84	18	9.049	1259.808
Nab15	152	15	8.926	728.2097
Nab16	210	10	8.651	947.8673
Nab17	337	2	4.965	2819.738
Nab18	65	2	8.54	1030.445
Nab19	133	5	9.298	1312.11
Nab20	192	10	8.595	1407.795
Nab21	258	15	8.694	1702.323
Nab22	331	18	8.363	442.425
Nab23	66	5	7.594	5517.514
Nab24	98	2	7.367	1615.312
Nab25	195	10	7.724	1993.786
Nab26	262	18	7.785	3301.22
Nab27	474	5	7.899	696.2907
Nab28	612	10	7.277	3091.933
Nab29	674	15	8.288	711.8726
Nab30	776	2	8.126	615.3089
Nab31	109	2	6.9	695.6522
Nab32	183	5	7.439	927.544
Nab33	272	10	8.021	411.42
Nab34	350	15	9.171	621.5244
OWERS01	138	12		1170
OWERS02	156	16		1171
OWERS03	178	18		1346
OWERS04	194	18		1225
OWERS05	585	8		26
OWERS06	573	12		18
OWERS07	561	16		18
OWERS08	534	18		18
OWERS09	549	18		22
OWERS10	491	1		46
OWERS11	675	4		10
OWERS12	691	8		13
OWERS13	707	12		13
OWERS14	724	18		25
OWERS15	740	18		38
OWERS16	201	4		47
OWERS17	227	8		304
OWERS18	248	12		582
OWERS19	259	18		613
OWERS20	94	4		723
OWERS21	111	8		103

Table 5.3a Table showing the total suspended sediment concentrations in waters downstream of aggregate dredging operations on two adjacent sites (Nab and OWERS). Ten litre samples obtained using sub-surface pumps.

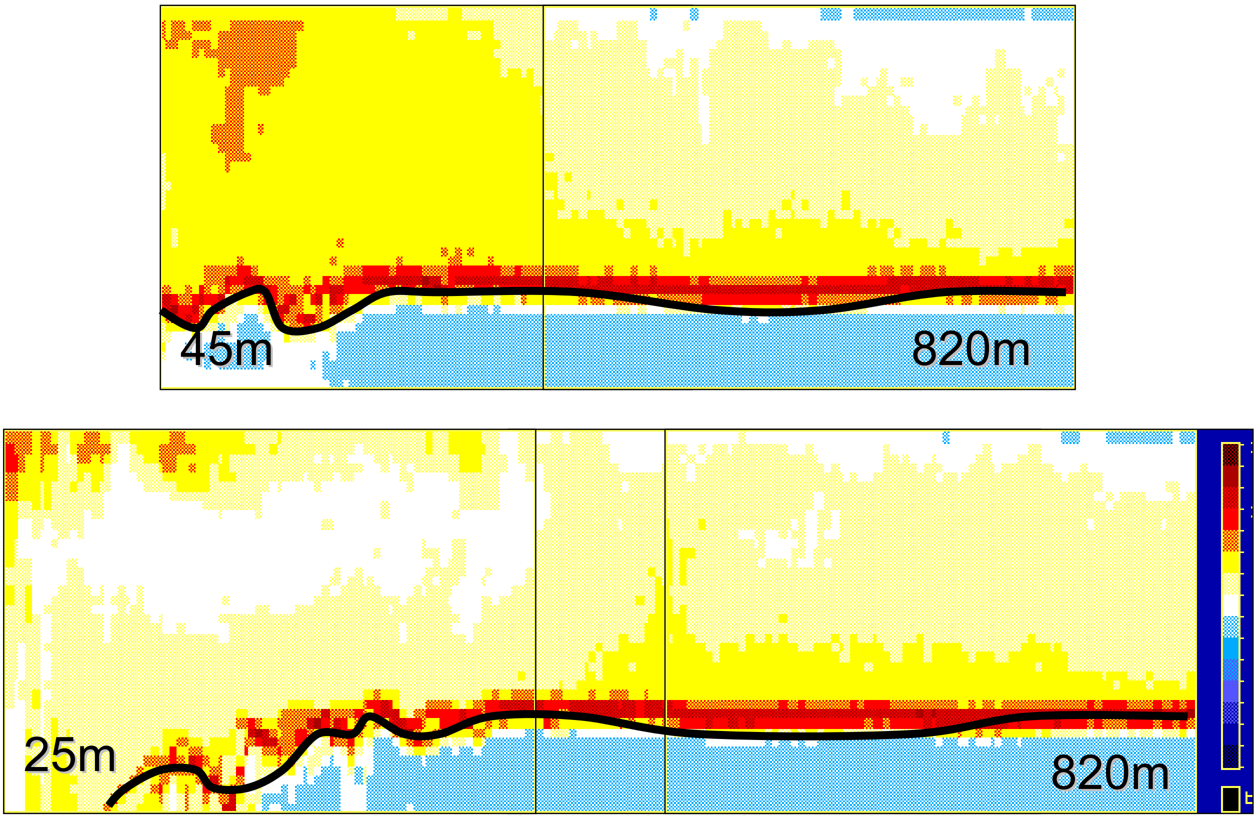

Figure 5.3b Longitudinal Backscatter profiles obtained downstream of the 2300 tonne capacity suction dredger *City of Chichester* showing the persistence of a nearbed sediment plume to the end of the monitoring area. Water depth 25m. Figures are ranges astern and downtide of the dredger.

Interestingly the second profile shows a near bed extension to the dense plume, extending beyond 800 metres, some 3-4 metres high in the water column off the seabed. This is important because it gives us, for the first time, some indication of a near bed extension to the benthic plume that has been observed by others (Dickson and Rees, 1998) and is discussed further in the following sections.

5.4 Impacts Outside The Dredge Boundary on Physical Resources

New software has enabled us to re-process data collected in previous research and presented elsewhere (Hitchcock and Drucker, 1996). Figures 5.4a and 5.4b present a 3D image of the same plume data as 5.4c. This re-processing has enabled us to identify a near bed extension to the dense dynamic phase of the plume that extends beyond the zone of monitoring, and hence well beyond the zone of previous detected impacts outside the dredge boundary. In water depths of 21 metres and currents of up $1.5ms^{-1}$, extraction of sand and gravels with screening would appear to generate a near-bed plume, some 2-4 metres thick, that extends downstream beyond 4.5 kilometres from the dredge site. The fate of the material is presently unknown since data does not exist beyond this zone.

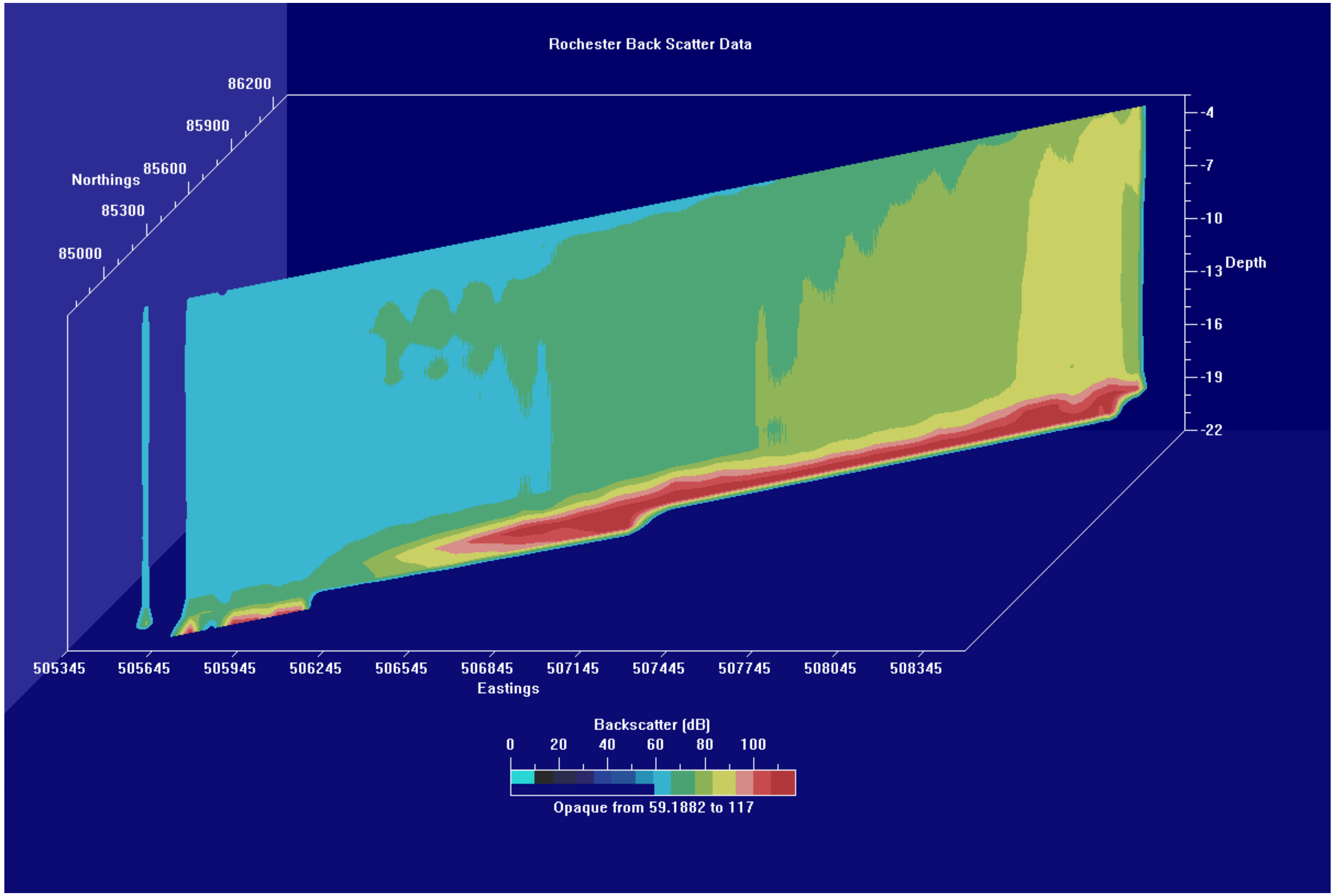

Figure 5.4a. Backscatter profiles obtained in 1995 on a similar aggregate dredging site located nearby have been reprocessed with newly developed software and reveal the presence of a well developed nearbed sediment plume extending well beyond the initial zones of impact.

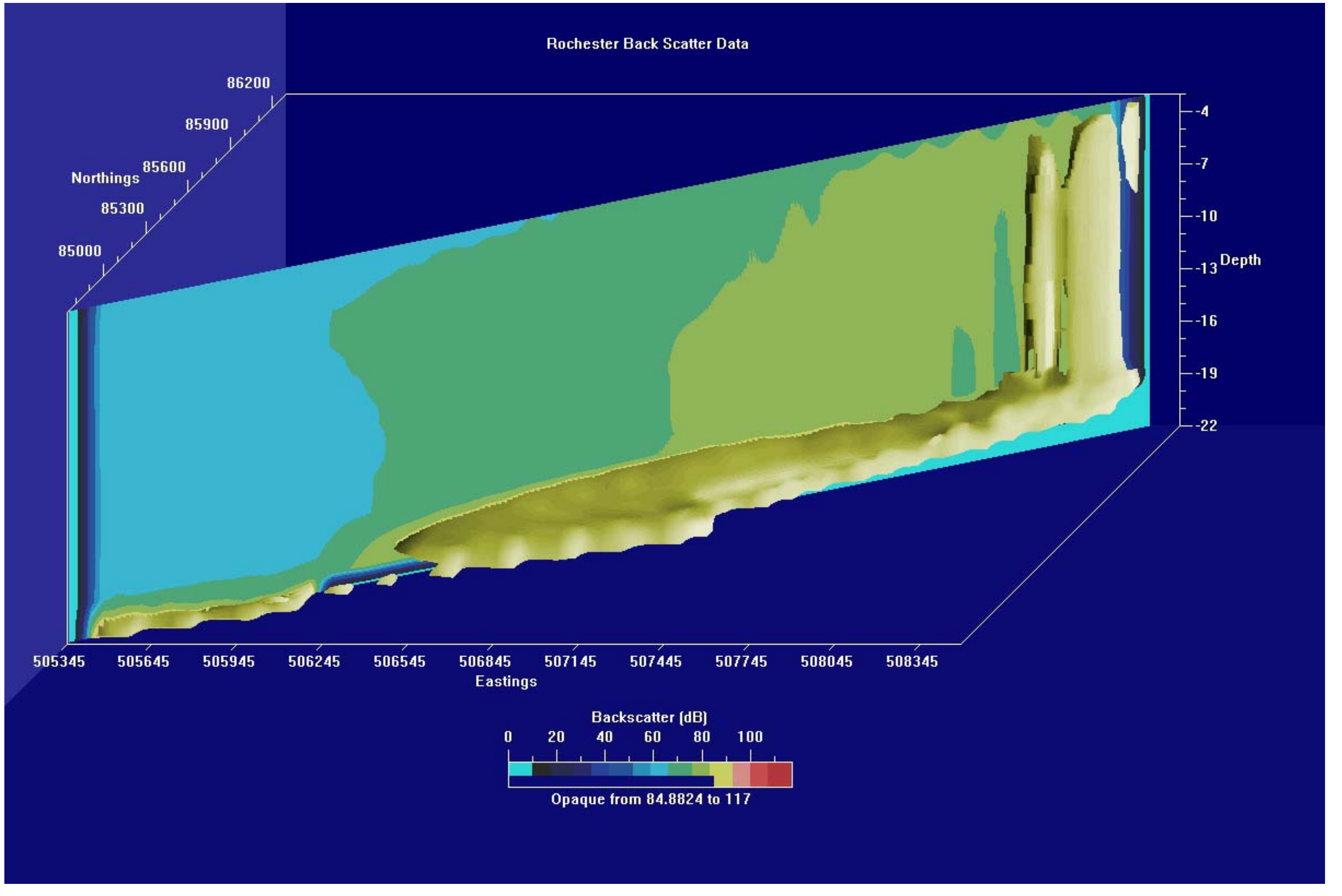

Figure 5.4b. The thickness of the nearbed plume can be gauged from this image of well-developed nearbed sediment plume. This extends well beyond the initial zones of impact.

However, the recent study by Dickson and Rees (1998) does suggest that 'benthic landers' (seabed monitoring apparatus designed by CEFAS) have monitored the progress of a near bed plume of sediments some 8 kilometres from a dredge site in the southern North Sea. This is important for two reasons: (i) using different technologies, independent studies have corroborated the presence of a near bed plume extending some way beyond the dredge site; and (ii) the extension of the near bed plume beyond the dredge zones gives credence to a mechanism for faunal community enhancement that has been observed in various studies (Newell *et al*. 1998, Poiner and Kennedy, 1984).

Following figure 5.4c, sequences of figures illustrate the new processing technique and clearly show the common presence of a near bed plume of sediments travelling beyond our zones of measurements. Others have recorded this phenomenon in the southern North Sea.

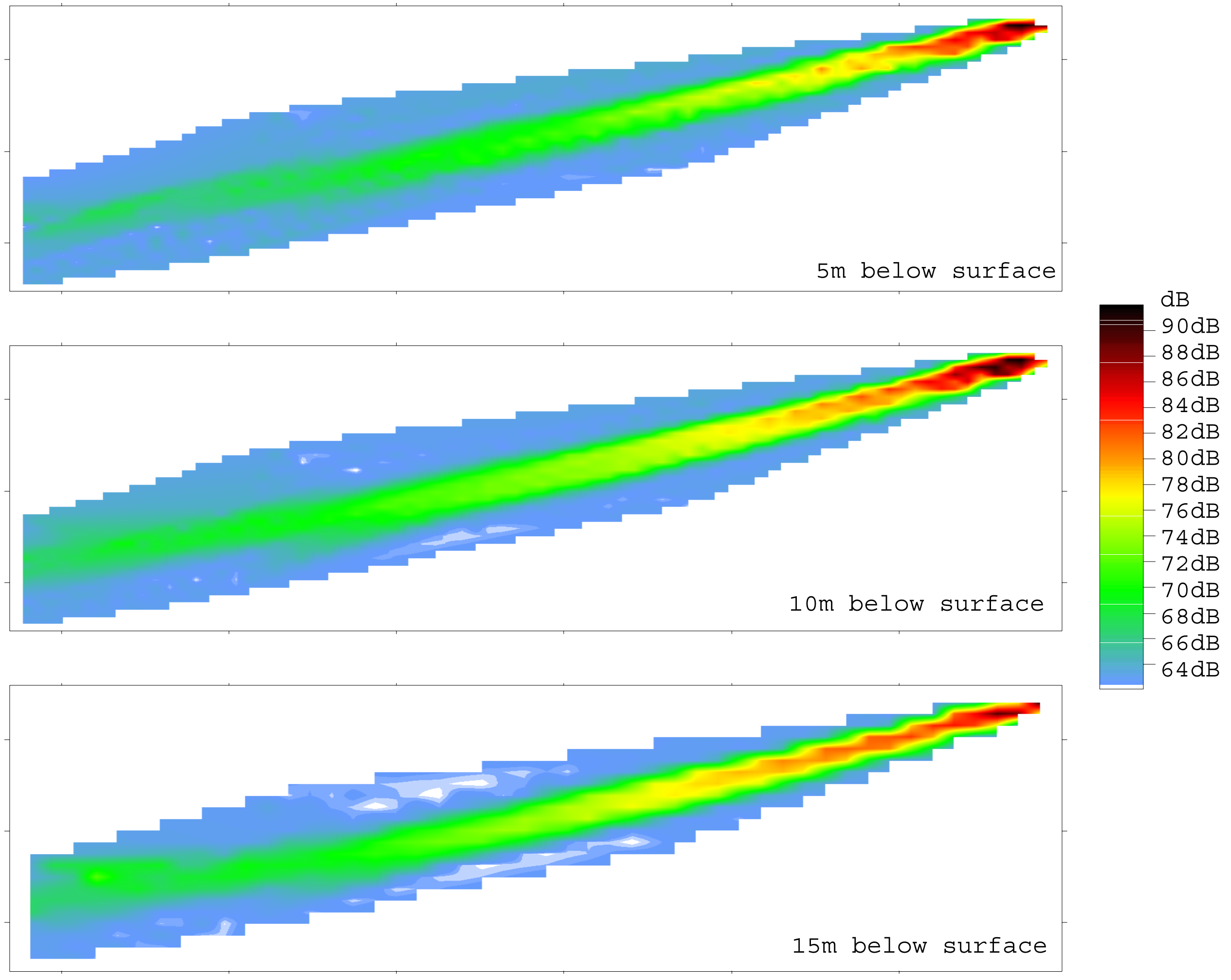

Figure 5.4c. Representation of the plume from the City of Rochester in 1995. This can be compared with Figures 5.4a and 5.4b, which were produced using new image processing techniques. The raw data has not been altered. The near bed plume is not visible from these types of image, even at the near bed sections.

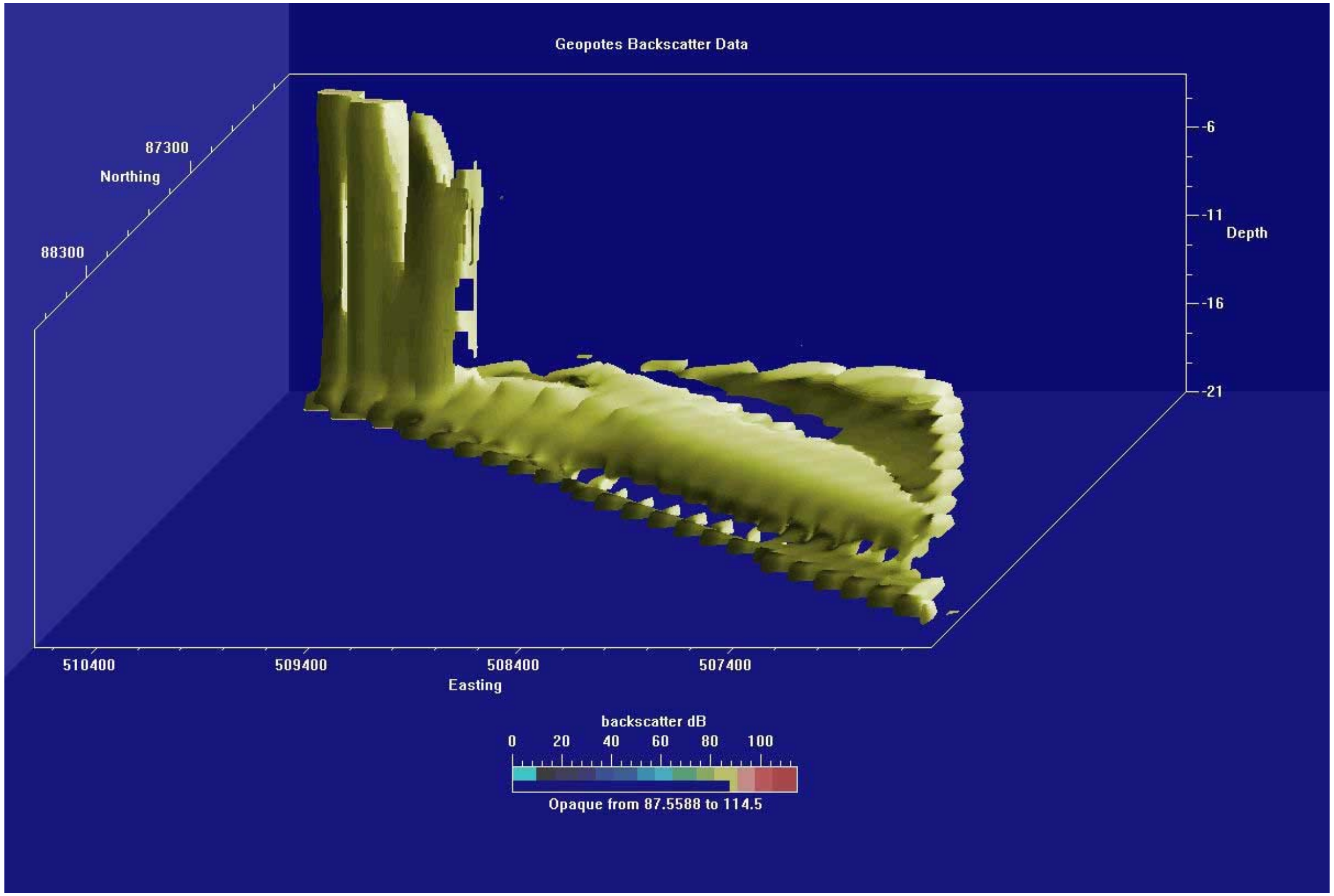

Figure 5.4d. Reprocessed representation of the 1995 data collection for the Geopotes, a large Dutch dredger temporarily working in the UK for beach recharge purposes. The near bed plume extends for some 5km to the end of the survey zone, although is much thinner. This may be due to the highly dense overspill formed by the Geopotes, which has a single central spillway discharging below the vessel.

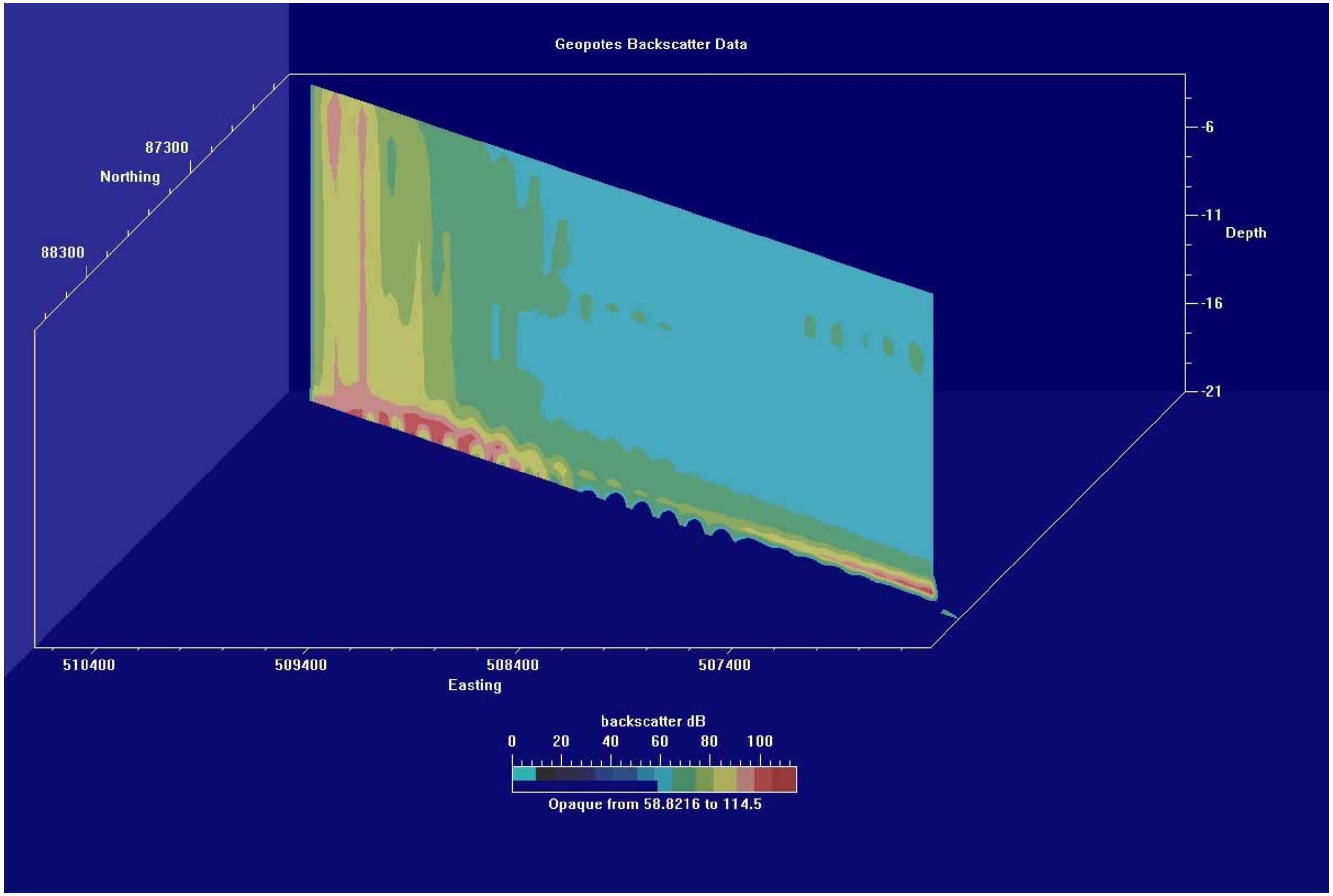

Figure 5.4e. Reprocessed representation of the 1995 data collection for the Geopotes, a large Dutch dredger temporarily working in the UK for beach recharge purposes. The near bed plume extends for some 5km to the end of the survey zone, although is much thinner. This may be due to the highly dense overspill formed by the Geopotes, which has a single central spillway discharging below the vessel.

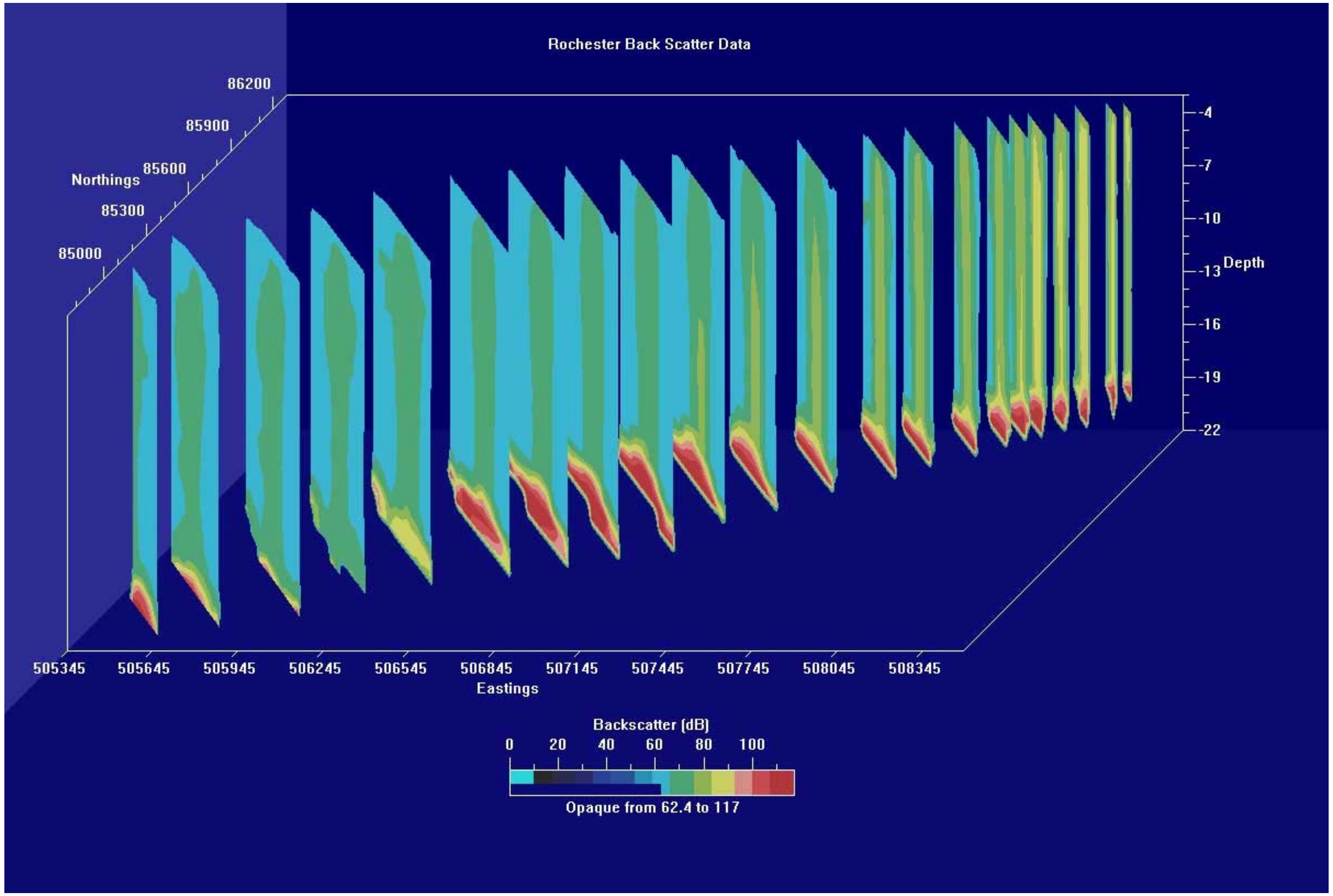

Figure 5.4f. Reprocessed representation of the 1995 data collection for the Rochester, a small English anchor dredger. The near bed plume extends for some 3km to the end of the survey zone. Note the thickness of the plume in the near bed zone. The width is approximately 700m at its maximum.

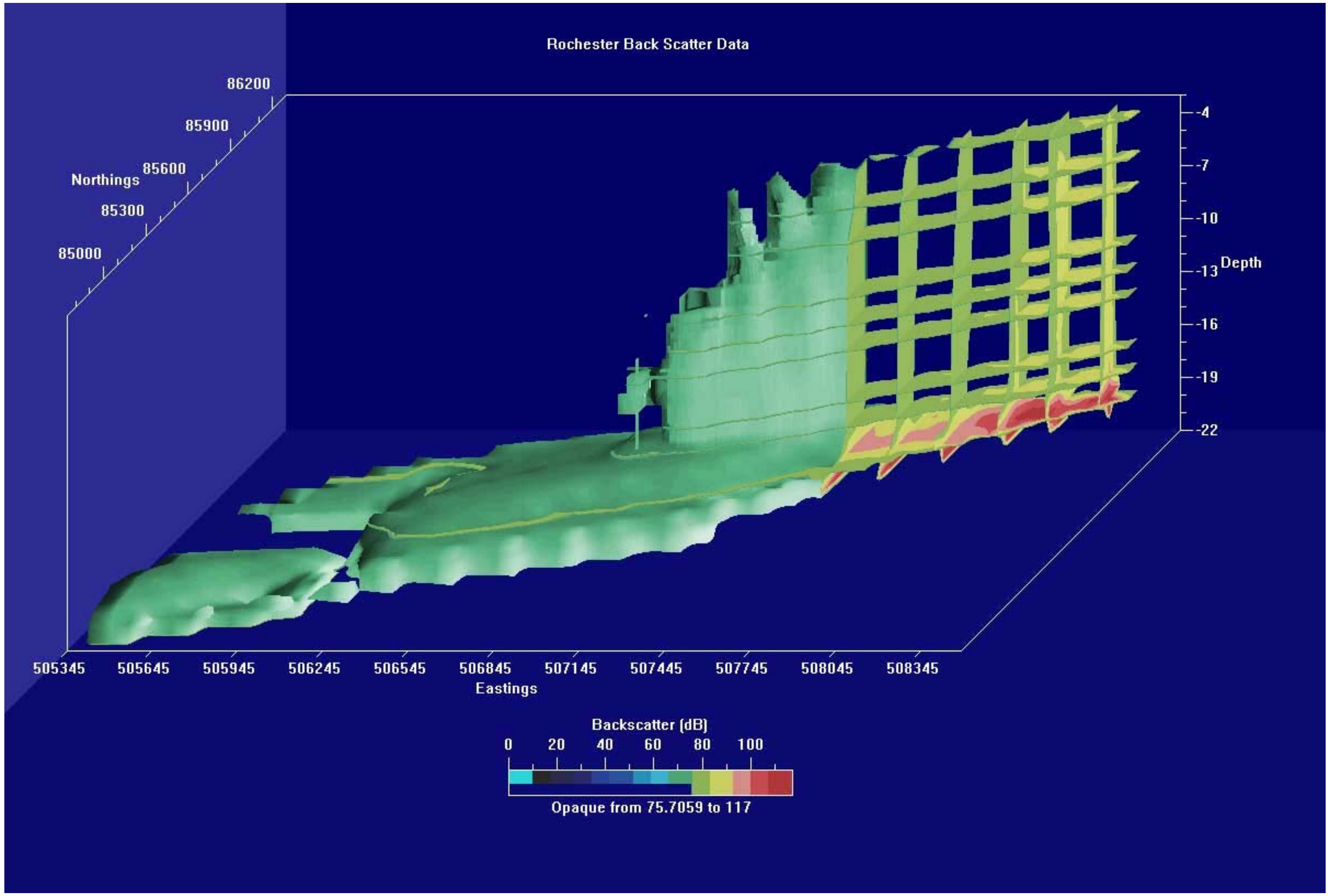

Figure 5.4g. Reprocessed representation of the 1995 data collection for the Rochester, a small English anchor dredger. The near bed plume extends for some 3km to the end of the survey zone. Note the thickness of the plume in the near bed zone. The width is approximately 700m at its maximum.

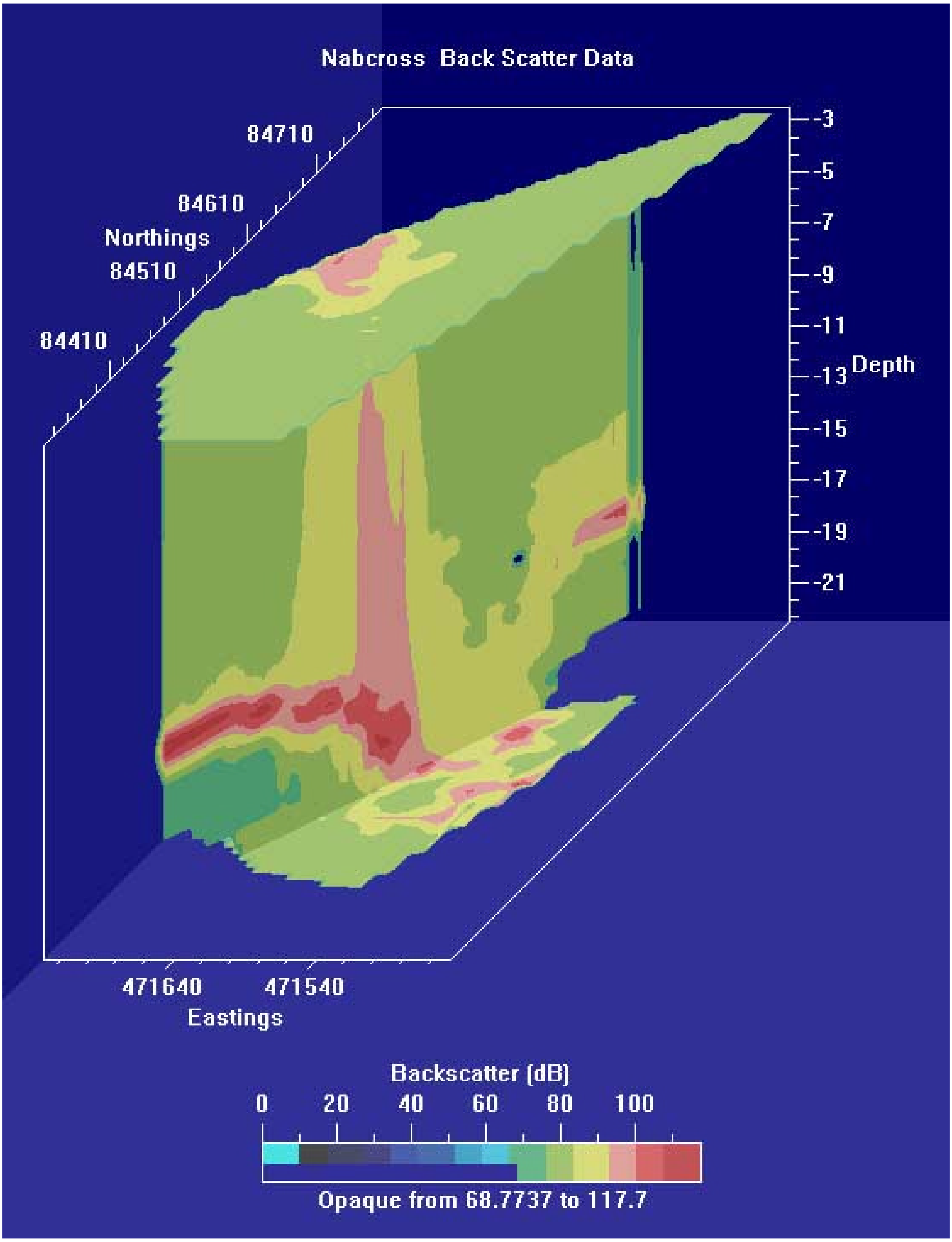

Figure 5.4h: 2001 data collected at the Nab study site. AVI video data has been prepared from these shots showing the generation and 3D representation.

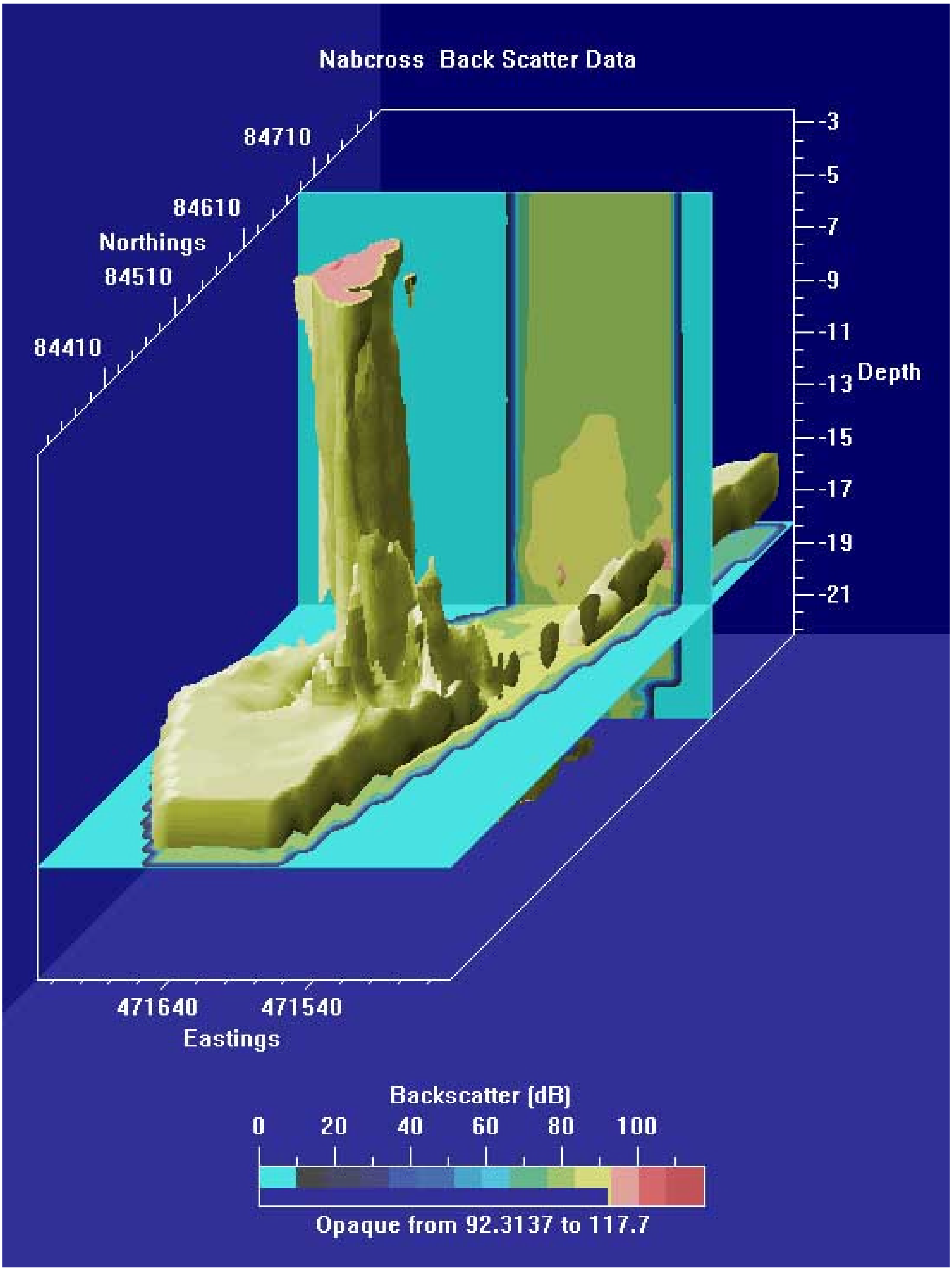

Figure 5.4i: 2001 data collected at the Nab study site. AVI video data has been prepared from these shots showing the generation and 3D representation.

It has often been assumed for the purposes of simulation models for British coastal waters that the dispersion of material rejected via the reject chute and spillways during the dredging process is controlled by Gaussian diffusion principles. Consequently, tidal currents could carry suspended material as much as 20 kilometres each side from a point source of discharge. Indeed, in water depths up to 25 metres and peak spring tide velocities of 1.75 ms-1, very fine sand may potentially travel up to 11 kilometres from the dredging site, fine sand up to 5 kilometres, medium sand up to 1 kilometre and coarse sand less than 50 metres. In current regimes with a lower peak velocity of some 0.9 ms-1, similar sized material may only travel up to 6.5 kilometres from the point of release (HR Wallingford, 1993). Worst-case estimates have suggested that sediment plumes may persist for up to 4-5 tidal cycles.

Interestingly, detailed and extensive monitoring campaigns associated with the construction of the Størebælt Link have detected suspended sediment related to a specific dredging operation up to 35 kilometres from the source. However simulations have shown that 6 kilometres from the operations, the ‘monthly average surplus suspended solids concentrations’ caused by some of the most intensive dredging operations were at the same level as the background concentration (2 mg/l).

Investigations in Hong Kong were undertaken at an early stage when marine dredging for aggregate was considered (Holmes, 1988). The concern for plume impingement on sensitive spawning grounds necessitated monitoring of water quality during dredging operations. The investigations concluded that within the water column the practical effects of enhanced suspended solids concentrations are difficult, if not impossible to assess. The effects were observed to be short lived and have limited areal extent and therefore concluded that suspended sediment impacts within the water column were negligible, and away from spawning and mariculture zones.

Further, and probably related to the sampling methodology and dredging technique, suspended solids concentrations in the hopper surface waters were only 10000-30000 mg/l, reducing rapidly to 5000 mg/l adjacent to the dredge vessel in the sea. A rapid dilution is therefore observed. Indeed, Holmes (1988) observed that (i) the sand fraction settled quickly within a few hundred metres of the dredger (at a rate of 46mm/s for 320 µm particles); and (ii) the pelitic fines content will settle much slower at 0.1-1 mm/s and will therefore disperse over a wider area, observed up to 4 kilometres.

Similarly, Kiørboe and Møhlenberg (1981) monitored the operation of a sand suction dredge in the Øresund, Denmark and concluded that any suspended solids concentrations likely to be detrimental were not present more than 150 metres downstream of the dredge. Levels adjacent to the dredge were up to 5000 mg/l, rapidly decreasing to 100mg/l at 150 metres. Background levels were regained at 1000 metres downstream.

A plume dispersion model developed by Whiteside *et al*. (1995) for the surface layer (the upper 8 metres of the water column) for up to 40 minutes after discharge compares well with plume decay measurements in the vicinity of the dredger. The contours for sediment deposition evidently remain as a narrow band extending for approximately 100 metres on each side of the track of the dredging vessel, much as recorded by Gajewski and Uscinowicz (1993) for Baltic waters and observed here.

5.5 Impact Within The Dredge Boundary on Physical Resources

Processing of the Nab ADCP data has produced an image of the plume that confirms the presence of the near bed plume extension. This plume has the capacity to egress the 10 metre deep hole dredged below the level of the surrounding seabed. The limits of the plume extension may however, be limited by the flux of sediment available to contribute to the plume and also the limited time available for the plume excursion. An important operational feature of the Nab licence is that exploitation commonly takes place for around an hour either side of low water, this being the expedient time for the vessel to return to port to discharge in the tidal berths found locally.

5.5.1 Impact of Dredging on Seabed Sediment Principal Components

Figures 5.2a and 5.2c clearly show the distribution of sediments (as discussed above) and faunal communities. Importantly, the lack of correlation between the change in sediment type downstream of the dredging activity (the enhanced 'sandiness' of the gravels) and the faunal community suggests that either the type of community structure present is unaffected by the change in sediment composition or, more likely, is tolerant of the level of change that the community has been exposed to. However, an increased or prolonged exposure may cause a negative impact, or the existing exposure may cause a level of stress to the community that reduces its tolerance to other impacts.

Changes in composition of the seabed sediments may cause changes to the benthic community structure. Désprez and Duhamel (1993) noted that following intense dredging activity off Dieppe, the predominantly sandy gravel surface sediments were reduced to predominantly sandy sediments (possibly existing as a thin veneer of mobile sands deposited by the settling overboard returns). Further, they recorded dominance of several new species characteristic of finer sediments with establishment of communities of the *Polychaetes Ophelia acuminata, Nephtys sp.* and *Spiophanes bombyx* and the Echinoderm *Echinocardium cordatum*. These species were also observed in the sandy sediments present on the Klaverbank (Sips and Waardenburg, 1989) although in this case extensive rather than intensive dredging did not lead to distinguishable changes in predominant sediment grain size. A detailed assessment of the implications to benthic communities of dredging intensity is given in Section 6.

5.5.2 Impact of Dredging on Bathymetry

The most striking changes within the dredge boundary are produced by the dredging activity itself (Table 5.5.2). Anchor dredging produces the largest single features, with seabed pits reported by Dickson and Lee (1973) some 4 metres deep by 50 metres diameter. This study reports here bed levels up to 10 metres below the surrounding deposits, the base of the depression having dimensions of 300 metres x 100 metres (see Figures 5a, 5b and 5c).

The fisheries concerns against this type of dredging methodology centre on the risk of snagging towed gear within the depression, and general unsuitability for beam trawling. Such deep pits are considered to pose the risk of formation of an anoxic bottom layer of water with reduction of water circulation and accretion of fine sediments.

However, deployment of an underwater camera in the depressions formed at Nab 122/3 showed little difference to water turbidity of the surrounding natural bed levels, whilst a similar number of individual fish and other benthic invertebrates were observed, as may be expected in high energy well mixed coastal waters

Type of dredging	Advantages	Disadvantages
Deep isolated pits	impact on small area reduced or little modification of wave and current patterns	entrapment of bed load irregular, hummocky terrain increased possibility of disturbance of underlying strata e.g. clays seabed topography unsuitable for trawling stratification of water within deep pits possibility of anaerobic conditions in deepest pits reduced chances of faunal recovery
Shallow extensive furrows	reduced alteration of topography improved conditions for faunal recovery reduced possibility of exposure of underlying strata suitability for modern dredgers	may effect current and wave patterns extensive area impacted

Table 5.5.2 Summary of the principal pros and cons of intensive and localised anchor dredging forming large pits and extensive trailer dredging over wide areas

5.5.3 Impact of dredging on microtopographical seabed structures

Trailer dredging produces a 'furrowed' topography and has been observed by Dickson and Lee (1973), and more recently analysed in extensive detail by Davies and Hitchcock (1992). Different types of dredge imprint are reported in the latter work. The dredge imprint will vary according to the type of draghead used, but some features more generally associated with one particular type of draghead can occasionally be found on others. Importantly, however, the furrow width is generally less than approximately 1 metre greater than the width of the draghead. Narrower dragheads produce deeper furrows, approximately 2.5 metres width by 0.5 metres deep. Wider dragheads such as the 'California Type' produce shallower and wider furrows 0.35 metres deep by 3.5 metres wide.

Recently, some companies using the simple 'Fixed Visor' type of draghead have replaced them with California Type dragheads with significant improvements in the quality of cargoes loaded and simultaneous reduction in the loading times. Désprez and Duhamel (1993) report sidescan sonar observations of dredge furrows on the Klaverbank being 3 metres wide and approximately 0.5 metres deep. Kenny and Rees (1996) observed furrows 0.3-0.5 metres deep but only 1-2 metres wide: however it is known that the furrows were made with a 'California Type' draghead of some 2.6 metres wide. One year after dredging, the furrows were no longer distinguishable by underwater camera, whilst after 2 years the furrows were barely detectable by sidescan sonar. ICES (1975) concede that trailer dredging does not greatly affect the action of seabed trawls. There has been little data put forward since to change this statement.

Davies and Hitchcock (1992) noted that many furrows were characterised by the formation of lateral levées, resulting from the draghead digging deeper into the seabed than the pumps could remove. This is an inefficiency in the system, and it is apparent that the wider dragheads do not suffer from such losses as much as the narrower types. There is thus less potential for interference with trawling activities.