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Dredged Material Disposal Site Monitoring Around the Coast of England: Results of Sampling (2010)

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Executive Summary

- This report presents the scientific findings and monitoring implications of dredged material disposal site monitoring under SLAB5 around the coast of England during 2010.
- The main aims of this report are to aid the dissemination of the monitoring results, to assess whether observed changes are in line with those expected, to compare the results with those of previous years (where possible) and to facilitate our improved understanding of the impacts of dredged material disposal at both a site-specific and a national (i.e., non site-specific) level.
- Parameters monitored varied between sites (governed by site-specific concerns) but included multibeam and sidescan sonar acoustic techniques, sediment particle size assessments, sediment organic carbon and nitrogen, macrofaunal communities, sediment profile imaging (SPI), and the assessment of a range of sediment contaminants including tri-butyl tin (TBT), polycyclic aromatic hydrocarbons (PAHs), organohalogens (e.g., pesticides, flame retardants) and trace metals.
- While biological impacts (where assessed) were generally similar across all disposal sites (i.e., an altered community structure within, and in the immediate vicinity of, the disposal site), elevations in the concentrations of the various contaminant types were somewhat site-specific.
- The implications of these findings for each site are discussed with respect to the need for subsequent monitoring under SLAB5. However, these data do not represent the sole basis of such final decisions regarding monitoring; in addition, up-to-date intelligence regarding potential changes to the disposal regime and/or concerns raised from any stakeholder are all embraced within the selection process for disposal site monitoring under this project.

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1. INTRODUCTION

1.1 Regulation of disposal activity in England

For the year 2010, the deposit of substances and articles in the sea, principally the disposal of dredged material, was controlled by a system of licences issued under Part II of FEPA. Note that the responsibility for the licensing function in England and Wales transferred on 1st April 2010 from the Marine and Fisheries Agency to the Marine Management Organisation (MMO) for England and to the Welsh Government for Wales. The marine licensing provisions of the Marine and Coastal Access Act 2009 that came into force on 1st April 2011 have now taken over from Part II of FEPA for the licensing function in England and Wales.

In licensing the disposal of dredged material at sea, numerous conditions associated with the relevant national and international agreements (e.g., the London Convention 1972 (LC72) and London Protocol of 1996 (LP96), the OSPAR Convention, the Environmental Impact Assessment Directive (97/11/EEC), the Habitats and Species Directive (92/43/EEC), the Wild Birds Directive (79/409/EEC), and the Water Framework Directive (WFD, 2000/60/EC)), must be considered to determine whether likely impacts arising from the dredging and disposal are acceptable (MEMG, 2003). Criteria considered under the various conventions and directives include the presence and levels of contaminants in the materials to be disposed of, along with perceived impacts on any sites of conservation value in the vicinity of disposal. Additional potential beneficial usage of the materials must be considered prior to a disposal consent being issued (MEMG, 2003).

One of the roles of Cefas is to provide scientific advice to the MMO on the suitability of the material for sea disposal at the application stage and, once a licence is granted, to check that licence conditions are met and that no unexpected effects occur. Advice on the licensing of dredged material disposal at sea is provided by Cefas' Regulatory Assessment Team (RAT), work conducted under SLAB5 helps underpin the scientific rationale for such advice (see Section 1.3).

1.2 Disposal sites around England

There are approximately 150 sites designated for dredgings disposal around the coast of England, not all of which are used in any one year. While the majority of these are located on the coast of the mainland, generally within a few miles of a major port or estuary entrance, a significant number are positioned within estuaries (e.g., Humber) or on intertidal mudflats as part of beneficial use schemes (Bolam et al., 2006).

In total, approximately 40 million wet tonnes are annually disposed of to coastal sites around England, although this can vary from 26 to 57 million wet tonnes. Individual quantities licensed may range from a few hundred to several million tonnes, and the nature may vary from soft silts to boulders or even crushed rock according to origin, although the majority consists of finer material (Bolam et al., 2006).

1.3 Overview of Cefas/MMO MoU contract No. SLAB5 'Monitoring of dredged material disposal sites'

In England, SLAB5 was one of several contracts funded by the MMO under a non-R&D MoU. The project provides field evaluations ('baseline', monitoring and 'trouble-shooting' surveys) at dredged material disposal sites round the coast of England. A major component of the project is, therefore, the commissioning of sea-going surveys at targeted disposal sites. Such field evaluations under SLAB5 are designed to ensure that:

- environmental conditions at newly designated sites are suitable for the commencement of disposal activities;
- predictions for established sites concerning limitations of effects continue to be met; and,
- disposal operations conform with licence conditions.

The outcomes of such surveys contribute directly to the licensing/enforcement process by ensuring that any evidence of unacceptable changes or practices is rapidly communicated and acted upon. As such, there are inherently strong links and ongoing discussions between the approaches and findings of this project with the work carried out by Cefas' RAT. One of the key roles of the latter is to advise the licensing authority (i.e., the MMO) of the appropriateness of current licences and the suitability of any new licence applications. The scientific outcomes of work undertaken within SLAB5 are circulated to the Cefas RAT *via* a number of routes including peer-reviewed publications (including both activity-specific and site-specific findings), internal documents, direct discussions and internal and external presentations. The production of this report, within which a summary of the annual findings is presented (Section 2), forms an important element of such scientific communication. It is not the purpose of this report to present a detailed appraisal of the processes giving rise to impacts at a particular site (this is more the role of, for example, peer-review outcomes) but to encapsulate the essence of the impacts associated with this activity in its entirety round the coast of England (see Section 1.5).

1.4 Sites monitored

To aid with determining which disposal sites should be selected for sampling in any one year, Cefas has derived a tier-based approach that classifies a number of possible issues or environmental concerns that may be associated with dredged material disposal into a risk-based framework (Bolam et al., 2009; Birchenough et al., 2010). The issues that pertain to a particular disposal site, and where these lie within the tiering system (i.e., their perceived environmental risk) depict where that site lies within the tiered system. This ultimately determines whether that site is considered for sampling during a particular year. It is intended that this approach should increase the transparency of the decision-making process regarding disposal site selection for SLAB5 monitoring, i.e., it establishes a model for site-specific decisions regarding sampling.

A tiered survey design and site assessment system, therefore, facilitates the prioritisation of dredge material disposal sites in terms of the need for, and the scale of, monitoring required at each site. In practice, this method will provide a scientifically valid rationale for the assessment of risks associated with relinquished, current and proposed disposal sites to the surrounding environment and amenities.

The disposal sites targeted for Cefas monitoring during 2010 are listed in Table 1.1. These sites were identified following consultation between Cefas case officers within the RAT and scientists in a number of key disciplines (e.g., benthic ecology, sediment contaminants). Additionally, these sites have been selected based on information from dredged material licence applications, consultation with the MMO and through concerns identified by stakeholders including conservation agencies and the general public.

	Geographical location off English coast	**Code**	**Prioritisation assessment: Tier**
North Tyne	Northeast	TY070	1
Souter Point	Northeast	TY081	1
Tees Bay A	Northeast	TY160	2
Tees Bay C	Northeast	TY150	2
Goole Reach	East	HU041	1
Inner Gabbard East	Southeast	TH056	2
Eastbourne	Southeast	DV040	1
Swanage	South	WI110	2
Site Z, Liverpool Bay	Northwest	IS140	1

Table 1.1. Dredged material disposal sites targeted for monitoring under SLAB5 during 2010.

1.5 Aims and structure of this report

This report does not aim to present a critique of the processes leading to observed changes at dredged material disposal sites around the coast of England. Such appraisals are conducted *via* other reporting routes, either *via* discussions with Cefas case officers, presentations and subsequent publications at national and international conferences, and *via* papers in peer-reviewed journals (e.g., Bolam and Whomersley, 2005; Bolam et al., 2006; Birchenough et al., 2006; Bolam et al., 2011). The aims of this report are:

- To present the findings of the results of sampling undertaken during 2010 under SLAB5, thereby aiding the dissemination of the findings under this project;
- To indicate whether the results obtained are in line with those expected, or whether subsequent investigations should be conducted;
- Where possible, to assess the 2010 results in line with those of previous years to provide a temporal assessment (see Bolam et al., 2009 and Bolam et al., 2011 for reports of previous years' monitoring);
- To facilitate our improved understanding of the impacts of dredged material disposal at both a site-specific level and a national level; and,
- To promote the development of scientific (or other) outputs under SLAB5.

This report represents a revised structure from its predecessors (i.e., Bolam et al., 2009; Bolam et al., 2011) with the aim of making the key findings regarding each site more explicit to the reader. Previously, an appraisal of the findings of each data component (e.g., acoustics, sediment granulometry, macrofauna, contaminants) for each site was presented followed by a summary of the implications of such information for subsequent monitoring under SLAB5. Due to the inherent length of the former, the key outcomes of the report were perhaps not sufficiently prominent to the reader. Thus, in this report, the concluding section for each site has been made more explicit by placing all such conclusions within a new section within the report (i.e., Section 2, below); the presentation of all the scientific data has remained as previous but deferred to an appendix (Appendix 2). For background information and impact hypotheses regarding each disposal site monitored during 2010, the reader is directed towards this appendix. Appendix 1 contains, as per the previous reports, information regarding the analytical and numerical methods used during the assessments of sediment contaminants (the reader may need to consult these whilst appraising Section 2).

2. CONCLUSIONS AND IMPLICATIONS FOR FURTHER MONITORING

The main findings of the monitoring data for each site are presented within this section (see Appendix 2 for more detail), together with their implications regarding the need for subsequent monitoring under SLAB5. However, it should be noted that these data do not represent the sole basis of such final decisions regarding monitoring; up-to-date intelligence regarding potential changes to the disposal regime and/or concerns raised from any stakeholder are all embraced within the selection process for disposal site monitoring under this project. Thus, the recommendations for monitoring presented here for each site, although representing a major component of the decision-making process, may or may not be altered by other site-specific factors.

2.1 North Tyne

Monitoring at the North Tyne dredged material disposal site has been conducted under SLAB5 for a number of consecutive years. As such, a good understanding of the spatial variation in the biology, sediments and contaminants following disposal activity at this site has been acquired. The 2010 monitoring data show that infaunal communities within the licensed boundary of the disposal site display decreased number of species and abundance yet slightly enhanced biomass, and exhibit distinctly altered community structures. However, these changes appear to be restricted to within the disposal site: all stations outside appear to have similar (unimpacted) benthic community assemblages.

TBT concentrations were below Limit of Detection (LOD) apart from NT4 (inside the disposal site) where detectable concentrations of 0.08 mg/kg were found. This concentration, below Cefas AL1, shows a decline from 2009 (0.1 mg/kg) and is somewhat lower than those reported a number of years back (e.g., 1999). PAH concentrations at North Tyne are high, with the Effects Range Low (ERL) for Low Molecular Weight (LMW) PAHs being exceeded at all station sampled, even those furthest from the disposal site. Increased concentrations in 2010 were observed relative to those in 2009 for three stations, although some stations show a decreased concentration. Organohalogen concentrations at North Tyne do not appear to present a concern. For example, although chlorinated biphenyls (CBs) and brominated diphenylethers (BDEs) were detected at almost all stations sampled in 2010, nearly all stations were below Cefas AL1. The exceptions were NT4 (above Cefas AL1 for CBs, dieldrin and DDTs) and NT5 (above Cefas AL1 for CBs). These contaminants are showing some decline since 2009, except at NT4 and NT5 which have shown increases.

Although some trace metals were enriched relative to OSPAR Background Assessment Concentrations (BACs) due to the metal mineralisation in the catchment and the results of mining activity, metals in general are not showing any trend of increasing or decreasing at North Tyne. When assessing these levels against regional baseline values, enrichment is still generally observed, albeit to a reduced level relative to those against OSPAR BACs.

These data indicate that monitoring at the North Tyne should be conducted in 2011 with special attention to ensuring that concentrations of certain contaminant groups, TBT, PAHs and organohalogens in particular, do not show increasing levels outside the disposal site boundary. The nature of subsequent monitoring at North Tyne should also be based on additional insights regarding changes to the amount, frequency and nature (e.g., contaminant loading) of the material licensed for disposal. Details of the latter issues will be discussed and used within the tier-based approach for disposal site monitoring site selection.

2.2 Souter Point

Monitoring at Souter Point dredged material disposal site has been conducted annually for a number of years, aiming primarily to determine the physical integrity of the cap over the contaminated sediment (See section 2.2.1 of Appendix 2 for further information) and ensure that impacts of ongoing disposals are limited to within the vicinity of the disposal site. A number of complementary approaches (e.g., grabbing, coring, acoustics, SPI) have been adopted at this site to achieve these aims. The 2010 data indicate that accumulations of deposited material have, relative to 2005, migrated further west and occupy a larger footprint on the bed. This is in agreement with previous findings suggesting that this is likely to continue in subsequent years.

Macrofaunal communities inside the disposal site show signs of decreased abundances, species richness and altered community structure relative to those outside the licensed boundary. Macrofaunal biomass was generally spatially variable, with some stations furthest away from the disposal site displaying lower biomass than those inside the capping area.

TBT concentrations from the grab stations were all low (only CAP4 showed levels above LOD). PAH concentrations, however, are generally high at this site; all stations breached the ERL for LMW PAHs and the ERL for HMW PAHs was breached by stations within or close to the disposal site. Organohalogens were spatially variable, with low values being found south of the site and higher values within (although not always) and north of the disposal site. However, CB concentrations were below Cefas ALs for all stations (except SPI5 which was above AL1 but below AL2).

The approaches used to provide data regarding the vertical profiling of sediments gave additional insights, particularly in relation to cap thickness. The contaminated dredged material (CDM) layer below the cap could only be tentatively discerned at CAP2 (22 – 27cm depth). TBT concentrations at various sediment depths, when compared with those from 2009, indicated that there may have been some net sediment deposition at stations CAP5 within the last 12 months. Comparable data regarding the organohalogens were inconclusive as different groups of organohalogens exhibited peak concentrations at different depths.

Future monitoring at Souter Point needs to be conducted under SLAB5, the details of which must be drafted following an appraisal of the various data already obtained for this site. Monitoring at this site has, and must continue to have, two aims; to ensure spatial impacts of ongoing disposal events are in line with expectations, and to ensure cap integrity. Under the former, the spatial assessment of contaminant levels should be a priority. Due to the somewhat limited depth penetration of the Nioz corer (between 20 – 25 cm depth), assessments regarding cap integrity would clearly benefit from additional techniques to improve depth and spatial coverage. It is recommended that acoustic sub-bottom profiling (or similar) techniques with appropriate coring devices for layer-truthing be considered.

At the time of writing, a multidisciplinary monitoring team have initiated a comprehensive analysis of the various data types acquired regarding Souter Point under SLAB5 with the aim of producing a paper for peer-review. The work undertaken as part of this will undoubtedly improve our understanding of the processes leading to the observed spatial and temporal changes thus far at this site, and will facilitate decisions regarding appropriate monitoring approaches during subsequent years.

2.3 Tees (Inner and Outer)

Analogous to the situation for North Tyne and Souter Point, monitoring at the Tees disposal sites has been conducted annually for a number of years and, as such, we have a good temporal dataset to draw upon when making contemporary assessments. While there have been no deposits at Outer Tees during the year subsequent to the 2010 survey, ongoing deposits at Inner Tees have been conducted using a sequencing approach whereupon deposits are placed at varying locations within the licensed boundary.

In accordance with the outcomes of previous years, the macrofaunal communities within both disposal sites appear altered (relative to those outside), but show little sign of reductions in total abundance. TBT concentrations at these two sites remain very low; below LOD for all stations. Contrastingly, PAHs remain very high within this region with all stations (bar IND5 and IT2) within the Inner Tees survey exceeding the ERM for LMW PAHs; the ERL for HMW PAHs was also exceeded at all stations with the exception of IND5 and IT2. Organohalogens, while present at most sampling stations, are found at somewhat low concentrations; concentrations of CBs at all stations were below Cefas ALs, while concentrations of DDTs were above AL1 at ten stations sampled. A number of metals are enriched (generally by a factor of between 2 and 5) relative to OSPAR BACs (particularly at the Inner site), however, for many metals (e.g., Pb, Zn) these enrichments decline when assessed using the regional baseline approach as it takes into account the natural mineralisation of the area. Notable enrichment is still observed against the regional baseline around the Inner Tees area for a number of metals however (e.g., Cu, Cd).

These data imply that subsequent monitoring at Tees should continue, but effort should focus predominantly at determining the spatial extent of increased concentrations of PAHs and organohalogens. While it might be prudent to continue to sample for the macrofaunal communities, decisions regarding the processing of such samples should perhaps rest upon the outcomes of the contaminant assessments. Naturally, decisions regarding the precise nature of subsequent monitoring must embrace all intelligence relating to any specific changes to the nature and type of the disposal activity at these two sites.

2.4 Goole

The monitoring conducted along the River Ouse which spans from the west of Goole Reach to the east of Whitgift Bight has again demonstrated that there are significantly elevated concentrations of PAHs within this region, especially upstream of the Goole Reach disposal site. Concentrations are slightly lower for most stations relative to those observed in 2008, although the highest concentration in 2010 (at G2) is much higher than previously observed.

Regarding organohalogens, concentrations of CBs were generally below Cefas ALs (except at G2); DDTs were generally above Cefas AL1 and concentrations of dieldrin were above Cefas AL1 at three stations. No temporal trends since 2008 are apparent for these groups, except for a slight general increase for BDE209. No linear spatial gradient in metals concentrations (as indicated by enrichment relative to regional baseline concentrations) could be seen; Hg and Cd appear notably enriched (especially the latter) along this stretch of the River Ouse.

While monitoring around the Goole Reach disposal site area, along the River Ouse, has highlighted high levels of certain contaminants in sediments both during 2008 and 2010, pin-pointing the source of such contamination is inherently problematic. This is a highly dispersive site and sediment-bound contaminants are likely to be dispersed over this region, with higher concentrations being ultimately observed at relatively depositional stretches of the River (higher concentrations were generally observed at those stations in sediment group Go1; the highest-silt/clay group). Continued monitoring at this site is recommended based on the present data, although implicitly the final decision must be made in association with contemporary information regarding the nature of recent and future deposits.

2.5 Inner Gabbard East

The acoustic-based monitoring conducted at the Inner Gabbard East site in 2009 and 2010 has provided important data from which assessments regarding granulometric and bathymetric changes can be made and, consequently, indications regarding the fate of material deposited. The data to date support notions that the material has been deposited within, and remains within, the licensed boundary. Importantly, there is no indication that material is being transported beyond the northerly and southerly limits of the boundary.

Future acoustic monitoring at this site must inherently depend on the likelihood of subsequent disposal activity. If material is destined for this site subsequent to the 2010 survey then further monitoring, using the same methods as current, is recommended to allow assessments regarding the ability of this site to received and contain deposited material. This would be particularly necessary if the amount of material to be placed at this site in future represents an increase from preceding years.

2.6 Eastbourne

The 2010 survey at Eastbourne represented the first time this site has been monitored under SLAB5. The survey design followed that undertaken by the port's own monitoring and aimed primarily to test whether the elevated concentrations of certain metals observed was also supported by independent monitoring. TBT, PAHs and organohalogens were all at low levels and present no concern regarding the disposal activity.

When assessed by comparison with regional baseline concentrations, enrichment was somewhat minimal. The highest enrichment observed was below a factor of two and no particular spatial trend could be discerned, i.e., enrichment factors were somewhat consistent across all stations as opposed to being restricted to either stations near the disposal site or either reference area (with possible exception of Hg where slight enrichment was only observed at, and immediately south of, the disposal site). Of particular importance, these data do not indicate that there is a noticeable issue regarding the concentrations of either Ni or Cr, either in the vicinity of the disposal area nor the western control site, as was indicated as part of the monitoring undertaken on behalf of the operator. Based on these data, further monitoring at Eastbourne under SLAB5 is not recommended.

2.7 Swanage Bay

The monitoring survey conducted under the auspices of SLAB5 at Swanage Bay primarily aimed to provide data to assess whether the material being disposed of to this site is showing any indication of observable impacts towards the Poole Bay to Lyme Bay Reefs draft SAC. The approach consisted of five stations from within, and along a westerly transect from, the disposal site. Although previous monitoring has been conducted at this site under SLAB5 (i.e., during 2006 and 2007), such monitoring aimed at assessing the sedimentary and bathymetric conditions towards the east of the disposal site and are, as such, of limited utility for comparisons with the data acquired in 2010.

All five stations displayed low silt/clay contents (< 5%) and the video data indicated little observable change in biotope types along the transect. Although the westernmost station displayed a different biotope (infralittoral mobile clean sand with sparse fauna) this is likely to be a response to the shallower depth as opposed to disposal activity.

Metals enrichment relative to regional baseline concentrations was not observed for most metals, except for Hg where moderate to high enrichment was apparent.

The data acquired by this survey in 2010 have provided some indication of the sedimentary conditions apparent from within the disposal site and along a westerly transect. The data reveal that there is no indication of a change along this transect nor of an impact associated with the disposal activity. Based on this information, there is little need for subsequent monitoring under SLAB5.

2.8 Site Z, Liverpool Bay

Compared to previous SLAB5 surveys at Site Z, the 2010 survey is more spatially-comprehensive, so as to acquire data from additional stations primarily to the east of, and within, the disposal site than previously obtained.

The macrofaunal communities within the disposal site, as in previous years, are altered in terms of multivariate structure and exhibit significantly reduced number of taxa and biomass. TBT concentrations were low, below LOD for all but one station. Similarly, PAH concentrations were also low, below ERL and ERM threshold values except for two stations to the south of the disposal site (nearest the entrance to the Mersey Estuary). These two latter stations also displayed the highest concentrations of various organohalogens which were otherwise found at concentrations which do not pose a concern. Organohalogens in 2010, in general, show a decline in concentrations when compared with those of previous years. Enrichment of metals relative to regional baseline concentrations are generally slight (enrichment between a factor of 1 and 2); however, moderate enrichment is observed for Hg and Pb.

The results attained from monitoring Site Z in 2010 under SLAB5 indicate that there has been no significant change in either the impacts on the macrofaunal communities or to any of the sediment contaminants from what has been concluded from previous surveys. It is not recommended that monitoring should be undertaken at this site every year, unless a significant change to either the nature (physically or chemically) or the amount of material being disposed is expected.

3. Acknowledgements

A large number of Cefas staff has helped contribute to the work which has been conducted to produce this report. Such staff have been involved in all aspects of the work from an early stage, e.g., during discussions of the specific issues regarding dredged material disposal sites around the England coast (Cefas' RATs), through to the field sampling and the laboratory processing of the various components. In particular, staff within Cefas' Chemistry Function i.e., Mariusz Huk, Joanna Uzyczak and Penny Bruce-Vanderpuije (organohalogens); Kerry Potter, Anna Sypniewska-Huk and Phil Mellor (PAHs); and Paul Nelson, Lee Warford, Bobby Thomas and David James (metals), and Sedimentology Function, i.e., Briony Silburn and Louise Webster, are gratefully thanked for processing the large numbers of samples that are required under SLAB5 and form the core of this report. The structure and content of this report have been significantly improved following comments provided by Dr. Chris Vivian at various stages along its production.

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APPENDICES

Appendix 1. Assessment methods for sediment contaminants

1.1 TBT

1.1.1 Methodology

The sediment samples were collected in hexane-rinsed glass jars and were frozen immediately after collection. The samples were collected for organics analyses, mainly organotins (TBT and DBT), organohalogens and hydrocarbons analyses. The whole (wet) sediment sample is homogenised then sub-sampled for the determination of the total solid content and for organotins analysis.

Sample extraction is initially carried out by alkaline saponification, the organotins compounds are then converted into their hydrides forms with the addition of sodium borohydride. The organotins hydrides are finally extracted back in hexane by liquid-liquid extraction. Analysis is undertaken using a Gas Chromatography-Flame Photometric Detector (GC-FPD) and quantification is done using external calibration. A certified reference material is run within each sample batch for quality control. Results are reported in mg kg^{-1} (ppm) dw.

1.1.2 Method used for assessment

In this report, since the method is similar to that used for the dredged materials analysis, direct comparison can be made and therefore we assess the organotins data against the actions levels used by the Regulatory Assessment Team (Table A1.1.1). In general, contaminant levels in dredged material below Action Level 1 are of no concern and are unlikely to influence the licensing decision. However, dredged material with contaminant levels above Action Level 2 is generally considered unsuitable for sea disposal. The latter situation most often applies only to a part of a proposed dredging area and so that area can be excluded from disposal at sea and disposed of by other routes e.g. landfill. Dredged material with contaminant levels between Action Levels 1 and 2 requires further consideration and testing before a decision can be made.

ACTION LEVELS	Action Level 1 (mg/kg)	Action Level 2 (mg/kg)
Organotins; TBT/ DBT/ MBT	0.1	1

Table A1.1.1. Actions levels for organotins compounds.

1.2 PAHs

1.2.1 Methodology

Sediment samples, collected in glass jars, were frozen immediately after collection and not defrosted until required for analysis. Each homogenised wet sediment sample was extracted using alkaline saponification followed by liquid/liquid extraction. A sample of sediment was taken for a total solids determination as all results are reported on a dw basis. The sample extract was then passed through an alumina chromatography column in order to remove polar compounds, concentrated to 1 ml and sealed in a vial. A suite of alkylated and parent PAH were then determined using coupled gas chromatography/mass spectrometry (GC/MS). Quantification was by means of deuterated internal standards added prior to digestion, with analytical quality control samples being run within each sample batch. Full details can be found in Kelly *et al*. (2000).

1.2.2 Method used for assessment

Cefas currently has action level limits for contaminants such as trace elements and PCBs but none currently exist for PAHs. Reviews of what has been investigated in other countries has indicated that the most promising of the currently available co-occurrence methods is the Effects Range Low/Effects Range Median (ERL/ERM) methodology which is founded on a large database of sediment toxicity and benthic community information (Long *et al*., 1998).

The ERL/ERM methodology derives SQGs representing, respectively, the 10th and 50th percentiles of the effects dataset and can be derived for individual PAH compounds. In a regulatory context, where SQGs are to be used as informal (non-regulatory) benchmarks to aid in the interpretation of sediment chemistry (Long *et al*., 1998), this becomes complicated where a large number for individual PAH are determined, as is usually the case. This has led to separate ERL/ERM derived SQGs being set for “Low molecular weight PAHs” and “High molecular weight PAHs”. In this context;

LMW PAHs include 2- and 3-ring PAH compounds;

- Naphthalene
- monomethyl naphthalenes
- acenaphthene
- acenaphthylene
- fluorine
- phenanthrene
- anthracene

HMW PAHs include the 4- and 5-ring PAH compounds;

- fluoranthene
- pyrene
- benz[*a*]anthracene

- chrysene
- benzo[*a*]pyrene
- dibenz[*a,h*]anthracene

Although a wider suite of PAH is determined routinely for both licensing and monitoring purposes, these can be considered as toxicity markers for the PAH as a whole. The ERL and ERM concentrations applied are given in Table A1.2.1.

PAH compounds	**ERL** (µg kg^{-1} dw)	**ERM** (µg kg^{-1} dw)
LMW PAH	552	3,160
HMW PAH	1,700	9,600

Table A1.2.1. ERL and ERM concentrations for LMW and HMW PAHs in sediments.The limits for LMW PAH are lower than those for HMW PAH as they carry a higher acute toxicity.

1.3 Organohalogens

Full details of the analytical methodology are given in Allchin *et al*. (1989) and de Boer *et al*. (2001).

1.3.1 Sample extraction

Sediment samples were air dried and sieved (<2mm) in a controlled environment. 10 g of dried sediment were mixed with sodium sulphate, transferred to a glass Soxhlet thimble and topped with 1 cm of sodium sulphate. ^{13}C-labelled BDE209 was added as internal standard to all samples prior to the extraction step. Samples were extracted over a 6 h period using 50:50 hexane:acetone, with an average of 9 - 10 cycles h^{-1}. Sulphur residues were removed at this stage with copper filings.

1.3.2 Sample extract clean-up

An aliquot of the Soxhlet extract was cleaned up and fractionated using alumina (5% deactivated) and silica (3% deactivated) columns, respectively. The silica column fractionation results in two fractions, the first fraction containing polychlorinated biphenyls (PCBs) and BDE209, the second fraction containing polybrominated diphenylethers (PBDEs), with organochlorine pesticides (OCs) split across the two fractions

1.3.3 Analysis of PCBs and OCs by GC-ECD

After addition of internal standard CB53, PCB and OC concentrations were determined with an Agilent 6890 GC with µECD, with separate injections for PCBs and OCs. The separation of analytes was performed on a 50.0 m × 200 µm, 0.33-µm-film-thickness DB-5 capillary column (J&W). The carrier and ECD make-up gas were hydrogen (32.2 psi constant pressure, initial velocity 50 cm/s) and argon/methane (95:5), respectively. The initial oven temperature was 90°C, held for 2.00min, then increased to 165°C at 15°C/min, to 285°C at 2°C/min, and finally held for 23 min. The injector temperature and detector temperature was 270°C and 300°C, respectively. A 1-µl extract was injected in splitless mode with a purge time of 2 min.

1.3.4 Analysis of PBDEs by GC-MS

After addition of internal standard CB200, PBDE concentrations were determined with an Agilent 6890 GC with 5973 MS in negative chemical ionisation (NCI) mode. The separation of analytes was performed on a 50.0 m × 250 µm, 0.25-µm-film-thickness DB-5 capillary column (J&W). The carrier gas was helium (30 psi constant pressure, average velocity 40 cm/s) and the reagent gas was methane (40 psi). The initial oven temperature was 90°C, held for 2.00min, then increased to 200°C at 30°C/min, to 295°C at 2.5°C/min, and finally held for 31.33 min. The injector temperature and detector temperature was 270°C and 200°C, respectively. A 2-µl extract was injected in splitless mode with a purge time of 2 min.

1.3.5 Analysis of BDE209 by GC-MS

BDE209 concentrations were determined with an Agilent 6890 GC with 5973 MS in NCI mode. The separation of analytes was performed on a 15.0 m x 250 µm, 0.1-µm-film-thickness DB-1 capillary column (J&W). The carrier gas was helium (1.3ml/min constant flow, average velocity 59 cm/s) and the reagent gas was methane (40 psi). The initial oven temperature was 90°C, held for 1.00min, then increased to 200°C at 25°C/min, to 295°C at 10°C/min, and finally held for 20 min. The injector temperature and detector temperature was 250°C and 200°C, respectively. A 2-µl extract was injected in pulsed splitless mode with a 20psi pulse until 1 min and a purge time of 2 min.

1.3.6 Quantitation methods

The identification of PCBs and OCs was based on the retention time of individual standards in the calibration mixtures. Quantitation was performed using internal standards and 7 calibration levels (range 0.5 – 100 ng/ml). The PCB standard solutions contained the following 27 compounds in iso-octane (IUPAC designations): Hexachlorobenzene; *p,p'*-DDE; CB101; CB105; CB110; CB118; CB128; CB138; CB141; CB149; CB151; CB153; CB156; CB158; CB170; CB18; CB180; CB183; CB187; CB194; CB28; CB31; CB44; CB47; CB49; CB52; CB66. The OC standard solutions contained the following 6 compounds in iso-octane: alpha-HCH; beta-HCH; gamma-HCH; dieldrin; *p,p'*-TDE; *p,p'*-DDT.

Quantitation for PBDEs was performed using internal standards and 8 calibration levels (range 0.1 – 50 ng/ml). The PBDE standard solutions contained the following 11 compounds

(IUPAC designations) in iso-octane: BDE17; BDE28; BDE47; BDE66; BDE100; BDE99; BDE85; BDE154; BDE153; BDE138; BDE183; together with the internal standard CB200.

Quantitation of BDE209 was performed using an internal standard and 7 calibration levels (range 0.5 – 500 ng/ml). The BDE209 standard solutions contained IUPAC BDE209 in iso-octane, together with the internal standard $^{13}C_{12}$- labelled IUPAC BDE209.

1.3.7 Quality assurance/ quality control procedures

AQC procedures included reagents purification, method blanks, and use of control charts created from repeated analysis of the SETOC 770 Certified Reference Material (CRM).

PCB and OCP concentrations were determined in the sediments and reported on a dry weight (dw) basis. The ∑ICES 7 CBs (CB28, CB52, CB118, CB153, CB138, CB 170, CB183), and the sum of all 25 measured CBs (∑CBs) were calculated. Where individual congener concentrations were below the limit of detection (LOD) of 0.2 µg/kg, a value of half the LOD was inserted for calculation of summed concentrations. The CB congener distribution was calculated from the proportion of the sum of ∑CBs that contained 3 chlorines (CB18, CB28, CB31), 4 chlorines (CB44, CB47, CB49, CB52, CB66), 5 chlorines (CB105, CB110, CB101, CB118), 6 chlorines (CB128, CB158, CB141, CB149, CB153, CB138, CB151, CB156), 7 chlorines (CB170, CB180, CB183, CB187), and 8 chlorines (CB194), respectively. Congener profiles at different stations were compared to identify stations with different sources.

The Total Organic Carbon (TOC) content in the <2 mm fraction determined at a number of representative sampling stations was used to additionally calculate the contaminant concentration normalised to 2.5% TOC content. The TOC data from the representative stations was used to estimate the TOC content at adjacent stations for which this value was lacking.

Concentrations of PCBs in the sediment were compared with various action limits, to investigate whether any adverse effects in benthic biota were likely to be expected as a consequence of their presence. The current Cefas ALs for dredge disposal are: AL1 if ∑ICES7 CBs > 10 µg/kg, ∑CBs > 20 µg/kg, and AL2 if ∑CBs > 200 µg/kg. Concentrations are expressed on a dw basis. According to the work of McDonald *et al.*; (2000), consensus-based TECs (Threshold effect concentrations), i.e. below which harmful effects are unlikely to be observed, are: ∑CBs <59.8 µg/kg; and consensus-based PECs (Predicted effect concentrations), i.e. above which harmful effects are likely to be observed (∑CBs >277 µg/kg). Concentrations are expressed on a dw basis. OSPAR have set criteria for Background Assessment Concentrations (BAC) and Environmental Assessment Concentrations (EAC) for the ICES7 CBs in sediments (see Table A1.3.1). Concentrations are expressed in µg/kg dw normalised to 2.5% organic carbon. Concentrations below BACs would be considered to have high environmental status. Concentrations significantly below EACs could be considered to have good environmental status and those above, bad environmental status. The station is deemed to have ‘bad’ environmental status if ‘bad’ status occurs for more than one ICES7 CB congener.

Sediment (μg/kg dw, normalised to 2.5% TOC)

Compound	BAC	EAC
CB28	0.22	1.7
CB52	0.12	2.7
CB101	0.14	3.0
CB118	0.17	0.6
CB138	0.15	7.9
CB153	0.19	40
CB180	0.10	12

Table A1.3.1. OSPAR assessment criteria for CBs in sediment from CP2.

1.4 Trace Metals

1.4.1 Methodology

The sediment samples were collected in plastic bags and were frozen immediately after collection. The samples were collected for PSA and metal analyses on the <63μm fraction. Details on obtaining the <63μm sediment fraction can be found in the Particle Size Analysis technical report.

The sample is digested in a mixture of hydrofluoric, hydrochloric and nitric acids using enclosed vessel microwave, the digest is made up in 1% nitric acid and further diluted prior to analysis by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma-Mass Spectroscopy (ICP-AES). Quantification of Al, As, Cd, Cr, Cu, Fe, Li, Mn, Ni, Pb, Rb and Zn is done using external calibration with Indium as internal standard. A certified reference material is run within each sample batch for quality control. Results are reported in mg kg^{-1} (ppm).

Some samples contained insufficient silt/clay (<63μm) for trace metals determination. Values lower than the detection limits were omitted from the dataset. This is because several detection limits were higher than real values, causing spurious elevations.

1.4.2 Numerical assessments

1.4.2.1 Raw data

Two approaches were carried out on the raw data:

1. Data comparison between the stations located inside the disposal sites and those that are situated outside the disposal site. The average concentration is obtained over a number of years and sites to allow data comparison. This data is averaged and so might not reflect the true observed trend for individual stations.
2. Temporal trend is also assessed for stations within the disposal sites and outside the disposal site. The average concentration is calculated for each year to carry out temporal trend analysis.

1.4.2.2 Enrichment factors

In order to assess relative level of trace metal contamination for a sampled station, enrichment to a baseline is required. This report presents two assessment methods; (i) comparisons with OSPAR Background Assessment Concentrations (BACs) as in previous reports, and (ii) comparisons with regional baseline concentrations.

Enrichment ratio is defined as: $$\frac{\text{Metal raw value}}{\text{OSPAR BAC or proposed baseline value}}$$

Enrichment is arbitrary defined in 4 levels:

0-1: no enrichment

1-2: slight enrichment

2-5: moderate enrichment

>5: high enrichment

The two assessment methods are detailed below (but refer to Cefas (2011) for a fuller explanation).

1.4.2.2.1 OSPAR BACs

OSPAR (BACs) are defined for Clean Seas Environment Monitoring Programme (CSEMP) assessment to determine temporal trends in concentrations (OSPAR, 2008). They are derived from Background Concentrations (BCs) which are based on concentrations recorded in ‘pristine’ areas.

Normalisation of metal concentrations is required to account for differences caused by different sediment types present in the area surveyed. Normalisation of the metal concentrations to 5% aluminium using a pivot point is completed to derive the OSPAR BACs, using pivot point data defined in the assessment manual for contaminants in sediment and biota (OSPAR, 2008). Aluminium and lithium are both commonly used to normalise metal concentrations. Correlations between all trace metals, at each site, were completed to determine the best normaliser to use.

For most sites, there were no clear correlations between the trace metals and correlations values of aluminium and lithium indicate that the relationship between the normaliser and trace metals was not strong enough to endorse the use of Al or Li for normalisation.

As trace metal concentrations used for in this study were measured on the fine fraction of sediment (<63µm), normalisation to some extent has already been completed, therefore all enrichment calculation were based on the raw data.

1.4.2.2.2 Regional baselines

The above-mentioned Background Concentrations (BCs) are based on concentrations recorded in ‘pristine’ areas. There is only one set of values assigned by OSPAR for the whole North Atlantic (http://www.ospar.org). However, trace metal concentrations are known to show regional variation in the UK, largely related to the variable geology around the coast and historical industrial activity in the early 19th Century which has caused localised elevated levels (Ridgeway *et al*, 2003; Rowlatt and Lovell, 1994; Cefas, 2005). Therefore, for assessing enrichments at disposal sites, Cefas have developed regional baselines utilising various spatial datasets around England and Wales. Recently, an extensive study was carried out on 8 regions defined in the Clean Seas and Environment Programme (CSEMP) (Figure A1.4.1) and the proposed metals baselines concentration derived from this study have additionally been used in this report as a validation tool to i/ compare with OSPAR BACs values and ii/ to assess the credibility of using those proposed baselines values instead of the OSPAR BACs values when studying for metals enrichment. The proposed baselines for the areas are given in Table A1.4.1, along with the corresponding OSPAR BACs values for each metal (OSPAR, 2006).

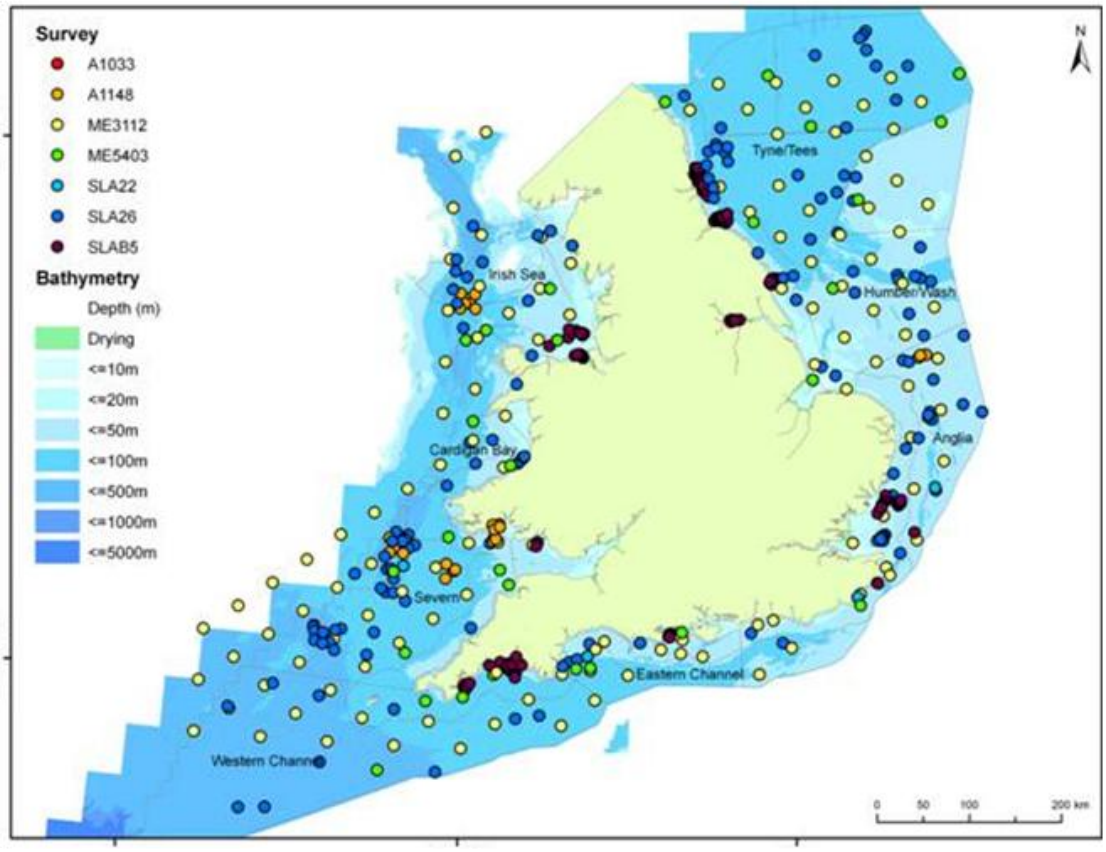


Figure A1.4.1. Location of stations sampled to provide metals data as part of the regional baseline approach.

	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Anglia	33	0.2	115	40	0.16	56	46	130
Cardigan Bay	26	0.29	103	26	0.12	44	73	145
Eastern Channel	23	0.18	90	26	0.12	31	45	107
Humber Wash	30	0.17	109	31	0.21	44	67	129
Irish Sea	21	0.29	115	38	0.43	47	77	240
Severn	21	0.2	81	27	0.1	36	47	135
Tyne/Tees	27	0.31	135	29	0.35	55	131	171
West Channel	34	0.19	105	72	0.77	50	108	153
OSPAC BAC	25	0.31	81	27	0.07	36	38	122

Table A1.4.1. OSPAR BACs (in red) with proposed baselines for regions covered in disposal site assessment in 2010.

Appendix 2. Results

2.1 North Tyne (TY070)

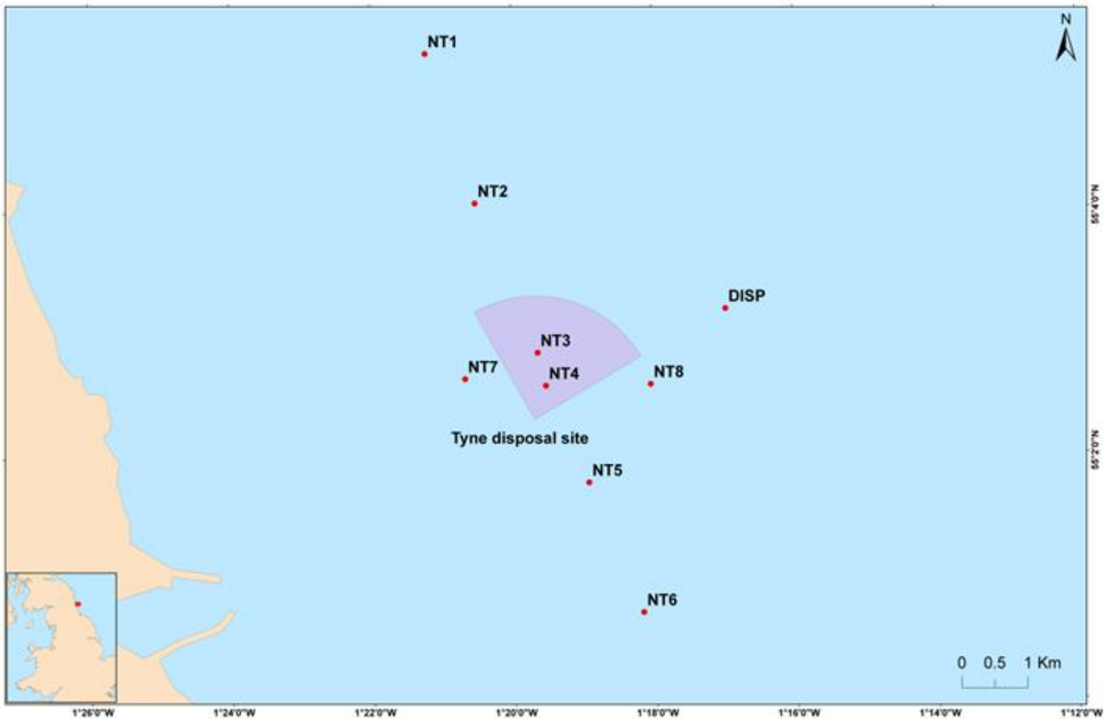


Figure A2.1.1. Locations of monitoring stations at North Tyne disposal site during 2010.

2.1.1 Background

Material disposed of to North Tyne is made up of predominantly silt and sand. In the past the site was used for capital and maintenance dredgings, rock mine-tailings and fly-ash from power stations. An application for the disposal of significant quantities of capital material (up to 1.3 million tonnes) from the Tyne navigational channel and deepening of berths has been recently licensed with disposal activity scheduled for early 2011. Some material under this application was excluded from sea disposal; some used for land reclamation while the portion accepted for sea disposal can be used to top up the cap at Souter Point. The total licensed for sea disposal is approximately 1 million tonnes which will be apportioned to North Tyne and Souter Point. The applicant is to provide a dredged disposal management plan detailing a grid system for disposal to avoid shoaling and interference with the capping region at Souter Point.

The relatively contaminated nature of the dredge material potentially destined for the North Tyne site is a result of the region’s industrial background. For example, the mining industry has resulted in elevated levels of heavy metals and hydrocarbons. Additionally, the historical ship-building industry on the Tyne, and large volumes of shipping traffic in and out of the wharve, has contributed to a legacy of TBT contamination.

RAT prioritisation assessment: Tier 1

- Where a significant increase in the quantity of material disposed of has occurred.
- Where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas AL 1 and 2 in proposed dredged sediments) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries).

2.1.2 Impact hypotheses

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits
- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

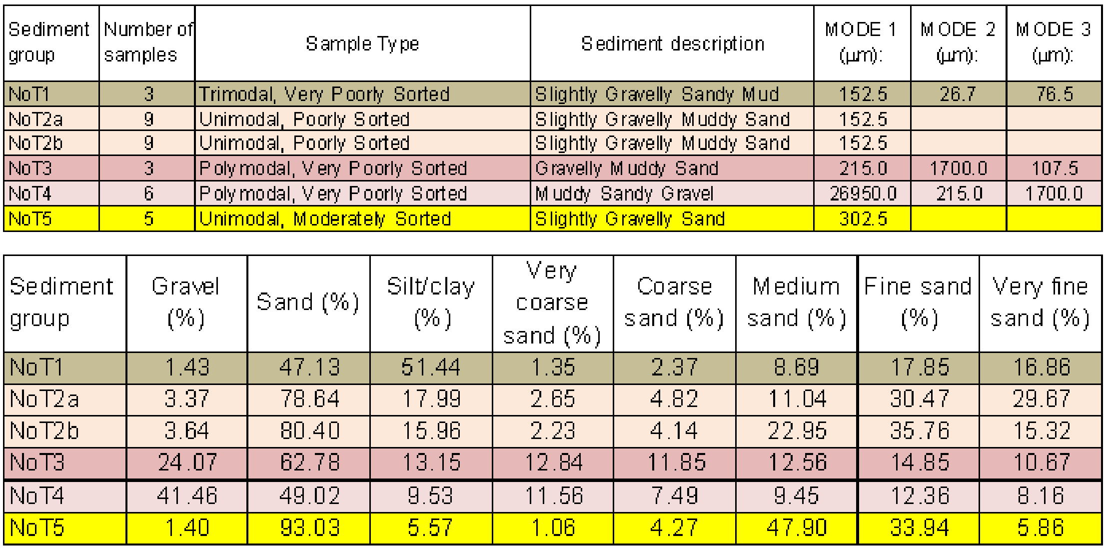
2.1.3 Parameters monitored

Sediment particle size distribution
Sediment organic carbon and nitrogen
Macrofaunal communities
Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

2.1.4 Results

2.1.4.1 Sediment particle size

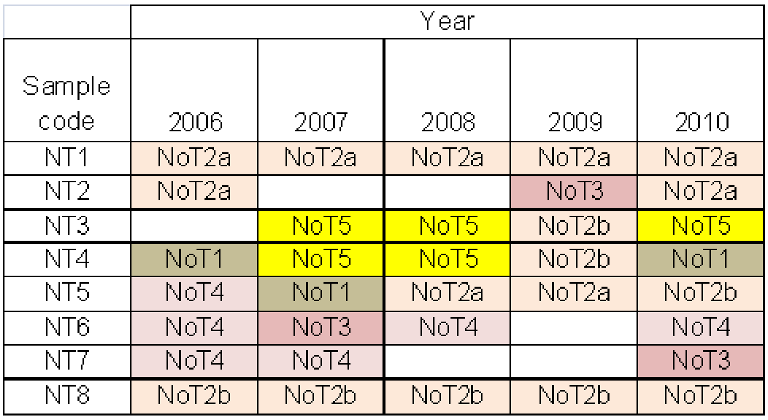
North Tyne sediments are predominantly muddy sands, with some unimodal sands and some gravels and muds (Table A2.1.1). The temporal changes in sediment groups for sampling stations since 2006 are minimal, with a maximum of two step group changes at most sampling stations, except within the disposal site at NT4 and to a lesser extent at NT3, as well as south of the site at NT5 (Table A2.1.2). The greater temporal variation in sediment granulometry at stations within the disposal site may perhaps reflect changes in the nature of sediments being disposed, or variations caused by the differences in the proximity of samples to recent disposal events.



Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
NoT1	3	Trimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud	152.5	26.7	76.5
NoT2a	9	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	152.5		
NoT2b	9	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	152.5		
NoT3	3	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand	215.0	1700.0	107.5
NoT4	6	Polymodal, Very Poorly Sorted	Muddy Sandy Gravel	26950.0	215.0	1700.0
NoT5	5	Unimodal, Moderately Sorted	Slightly Gravelly Sand	302.5		

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
NoT1	1.43	47.13	51.44	1.35	2.37	8.69	17.85	16.86
NoT2a	3.37	78.64	17.99	2.65	4.82	11.04	30.47	29.67
NoT2b	3.64	80.40	15.96	2.23	4.14	22.95	35.76	15.32
NoT3	24.07	62.78	13.15	12.84	11.85	12.56	14.85	10.67
NoT4	41.46	49.02	9.53	11.56	7.49	9.45	12.36	8.16
NoT5	1.40	93.03	5.57	1.06	4.27	47.90	33.94	5.86

Table A2.1.1 Average sediment descriptions and statistics for each sediment group at North Tyne.



	Year				
Sample code	2006	2007	2008	2009	2010
NT1	NoT2a	NoT2a	NoT2a	NoT2a	NoT2a
NT2	NoT2a			NoT3	NoT2a
NT3		NoT5	NoT5	NoT2b	NoT5
NT4	NoT1	NoT5	NoT5	NoT2b	NoT1
NT5	NoT4	NoT1	NoT2a	NoT2a	NoT2b
NT6	NoT4	NoT3	NoT4		NoT4
NT7	NoT4	NoT4			NoT3
NT8	NoT2b	NoT2b	NoT2b	NoT2b	NoT2b

Table A2.1.2 Sediment groups for each sample code between 2006 and 2010 inclusive at North Tyne.

The spatial variation in the proportional representation of gravel, sand and silt/clay for each sampling station in 2010 is shown in Figure A2.1.2 and the percentages of silt/clay content in Figure A2.1.3. NT4 (within the disposal site) has the highest silt/clay content (68%); this may be linked to a recent disposal event (a feature that may be confirmed if there are concomitant elevations in contaminant concentrations). Silt/clay contents at all the other sampling stations are much lower (next highest is an average of 17.99% at NT2) while gravel was only present in notable proportions to the west of, and the extreme south of, the disposal site (Figure A2.1.2).

Silt/clay content in a subset of dredge sediments for licensing applications to dispose of at North Tyne was 61% +/-10. All the monitoring samples contained less silt/clay than this, except those in sediment group NoT1 (i.e., at NT4). This may support the notion that silt/clay is dispersing away from the site.

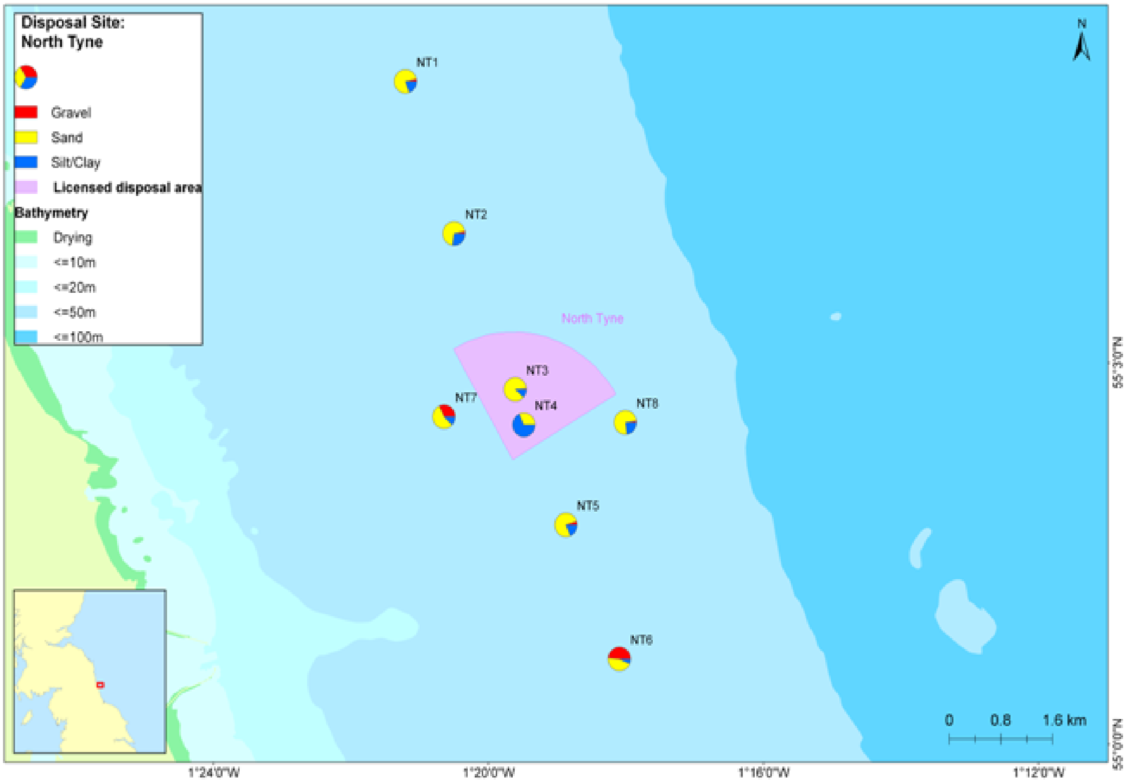


Figure A2.1.2 Pie charts of gravel, sand and silt/clay at North Tyne in 2010.

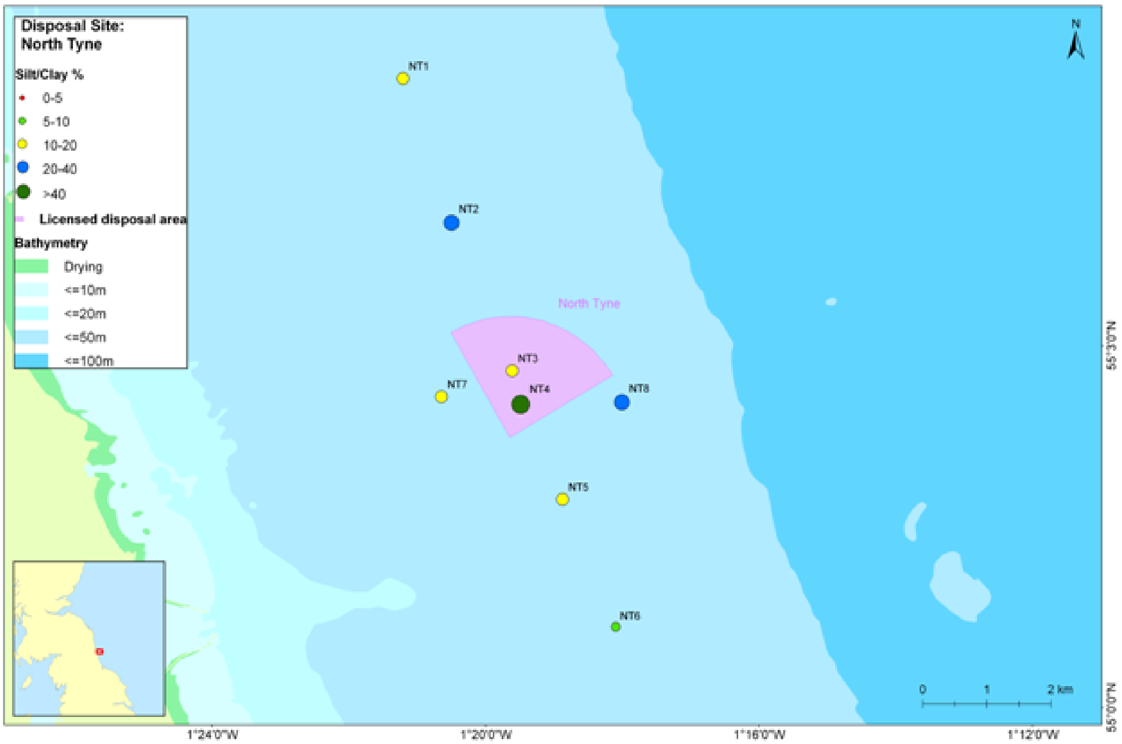


Figure A2.1.3 Silt/clay content (%) of sediments sampled at North Tyne in 2010.

2.1.4.2 Sediment organic carbon & nitrogen

Organic carbon values (in the <63µm sediment fraction) range from 3.04 to 5.53 %m/m and 0.27 to 0.31 %m/m for organic nitrogen. These are similar to those observed between 2006 and 2009 (Bolam et al., 2009, 2011). Figure A2.1.4 indicates that the higher organic carbon contents were exclusively found at stations within the licensed boundary of the disposal site (i.e., at NT3 and NT4).

As was the case in 2009, several samples have higher levels of organic carbon present in the <2mm fraction than the <63µm fraction; some of the organic carbon for this area is present in coarser sediment, possibly as coal (which is supported by data from the PSA).

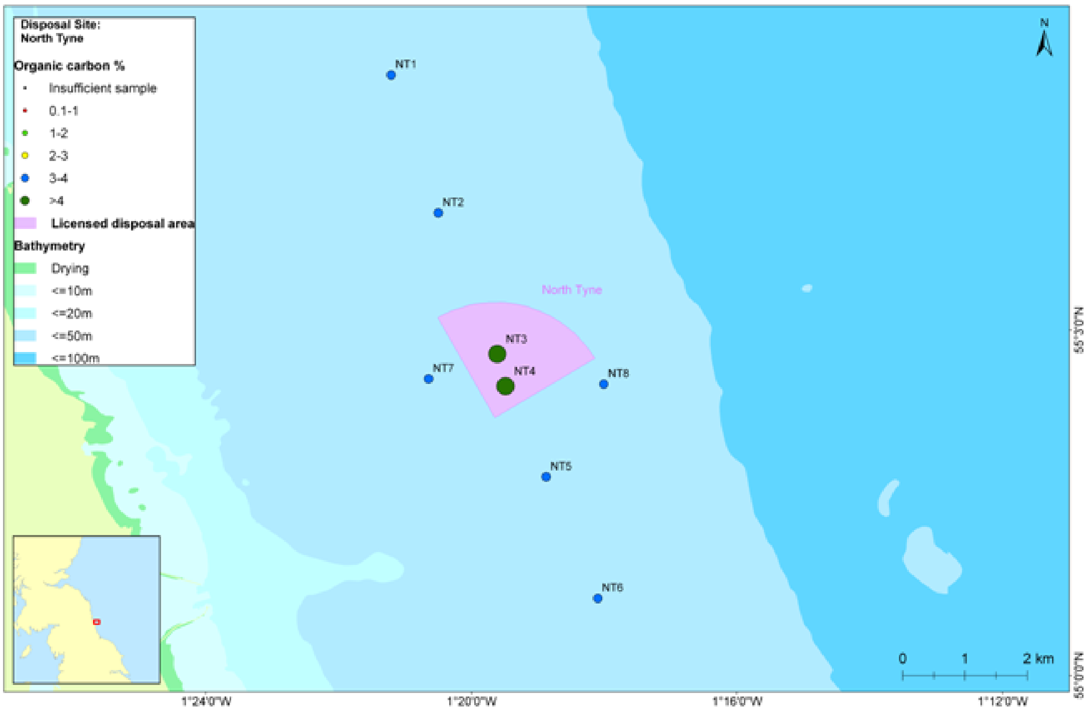


Figure A2.1.4. Organic carbon (%m/m) in the silt/clay fraction (<63µm) at North Tyne in 2010.

2.1.4.3 Macrofaunal communities

A total of 8374 individuals from 268 taxa were identified from 32 samples collected from within and outside the designated disposal area (i.e., eight stations each with 4 replicates). The main taxonomic groups sampled across the whole survey (with their percentage contribution of total abundance), are shown in Figure A2.1.5. This reveals that annelids (worms) numerically dominate the faunal communities across the survey area, with arthropods and molluscs also present in significant proportions. The average number of individuals at each site ranged from between 83 to 543 0.1 m^{-2} (Figure A2.1.6a) and the average number of taxonomic groups sampled at each station ranged from 31 to 71 m^{-2} (Figure A2.1.6b). Thirty-two percent of the taxonomic groups recorded occurred in only one sample while three taxonomic groups (*Lumbrineris gracilis*, *Nemertea* and *Galathowenia oculata*) occurred in over 80 % of samples. Total biomass in each sample ranged from 1.0 to 15.2 g 0.1 m^{-2} (Figure A2.1.6c). The relatively high-biomassed urchin *Echinocardium cordatum* was present in 63 % of the samples taken from inside the disposal ground and only found in one of the remaining samples from outside the disposal ground.

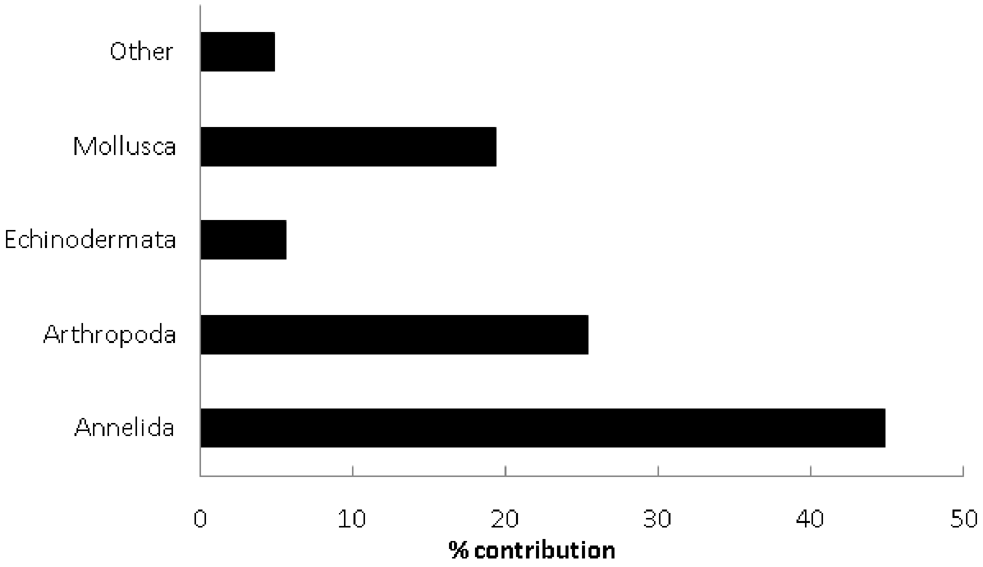


Figure A2.1.5. Percentage (numerical) contribution of the major phyla sampled in all stations at North Tyne 2010.

One way analysis of variance (ANOVA) revealed significant differences in the number of individuals and taxonomic groups present between stations ($p<0.0001$; $p<0.0001$, respectively). There was, however, no significant difference in biomass between stations ($p= 0.27$). An independent samples t-test was carried out in order to identify any significant differences in the number of individuals, number of taxonomic groups and biomass between replicates inside and outside the disposal ground. Samples inside the disposal ground were found to have significantly less individuals, fewer taxonomic groups present and higher biomass than those samples outside the disposal ground ($p< 0.001$; $p< 0.001$; $p< 0.05$, respectively). These findings support the results graphically shown in Figure A2.1.6(a-c).

Multivariate analyses were carried out using Primer version 6.1.5 (Clarke & Gorley, 2006). Non-parametric multi-dimensional scaling analysis (MDS) was carried out on the square root-transformed abundance data in order to identify any variation in benthic community between and within sampling stations. Hierarchical CLUSTER and SIMPROF analyses were carried out to determine grouping of replicates within a station, and the relationships between stations located within and outside the disposal area. SIMPROF revealed 11 significantly different clusters, labelled a-j ($p< 0.05$), (Figure A2.1.7). Sample replicates of NT2 & NT8 split into 4 separate clusters (e, f, g & h) while all other stations' replicates clustered together ($p< 0.05$). At 30% similarity, the invertebrate community structure was characterised by two separate clusters on the 2-d MDS plot; stations inside the disposal ground and outside the disposal ground were distinctly separated (Figure A2.1.8a). At 40 % similarity, NT6 and NT7 (both outside the disposal ground), formed a third cluster (Figure A2.1.8b).

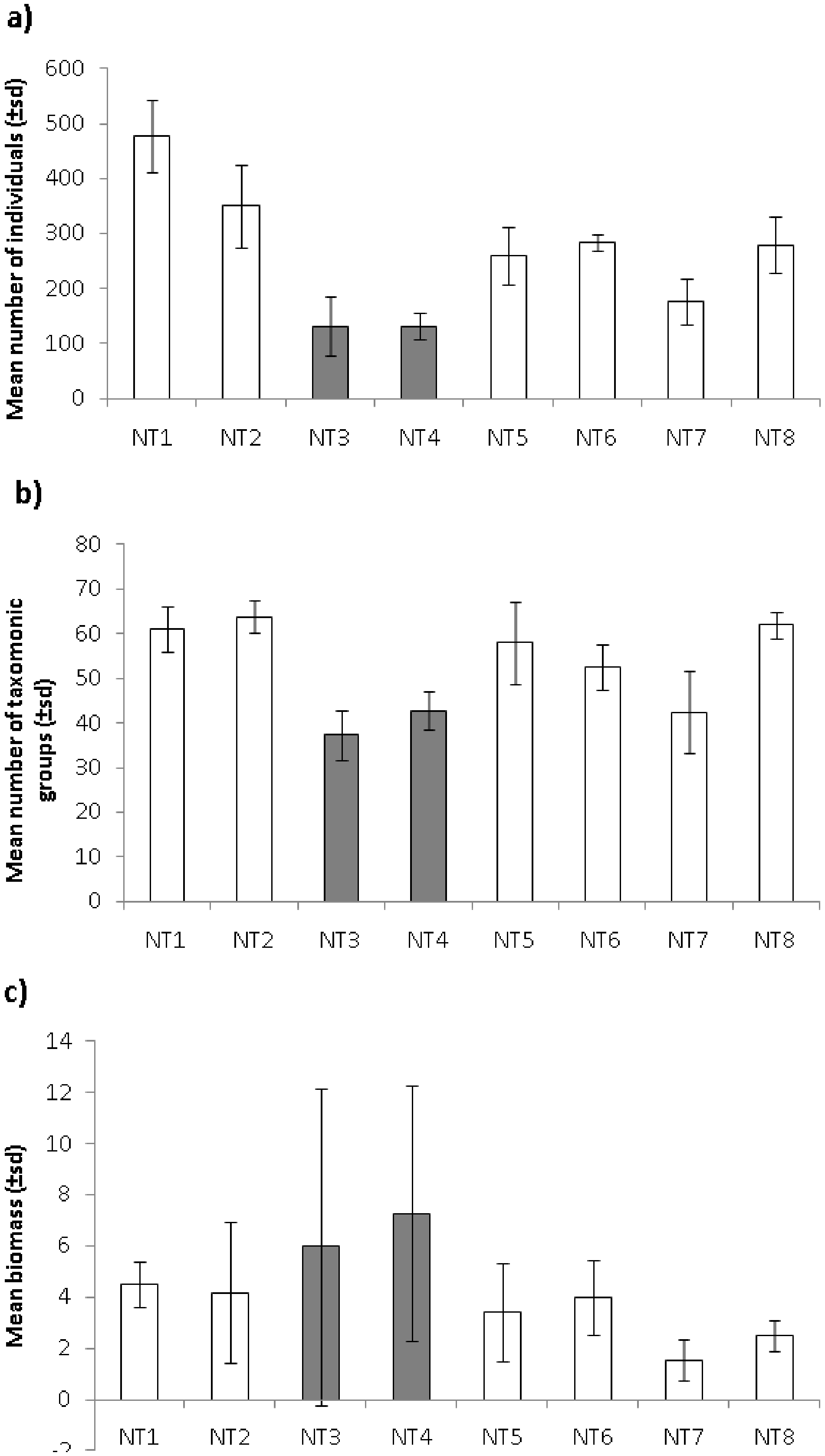


Figure A2.1.6(a-c). Mean values per 0.1 m^{-2} (± sd) for a) number of individuals, b) number of taxonomic groups and c) wet biomass for each of the stations. Stations outside the disposal area are presented in white and those inside are shaded.

A one-way ANOSIM test was then performed to determine any significant differences in benthic community structure between samples taken inside and outside the disposal ground. The test revealed that communities inside the disposal site were indeed statistically different from those outside the site (R = 0.73; p<0.001; ANOSIM) which supports the conclusion reached following inspection of the MDS plot (Figure A2.1.8).

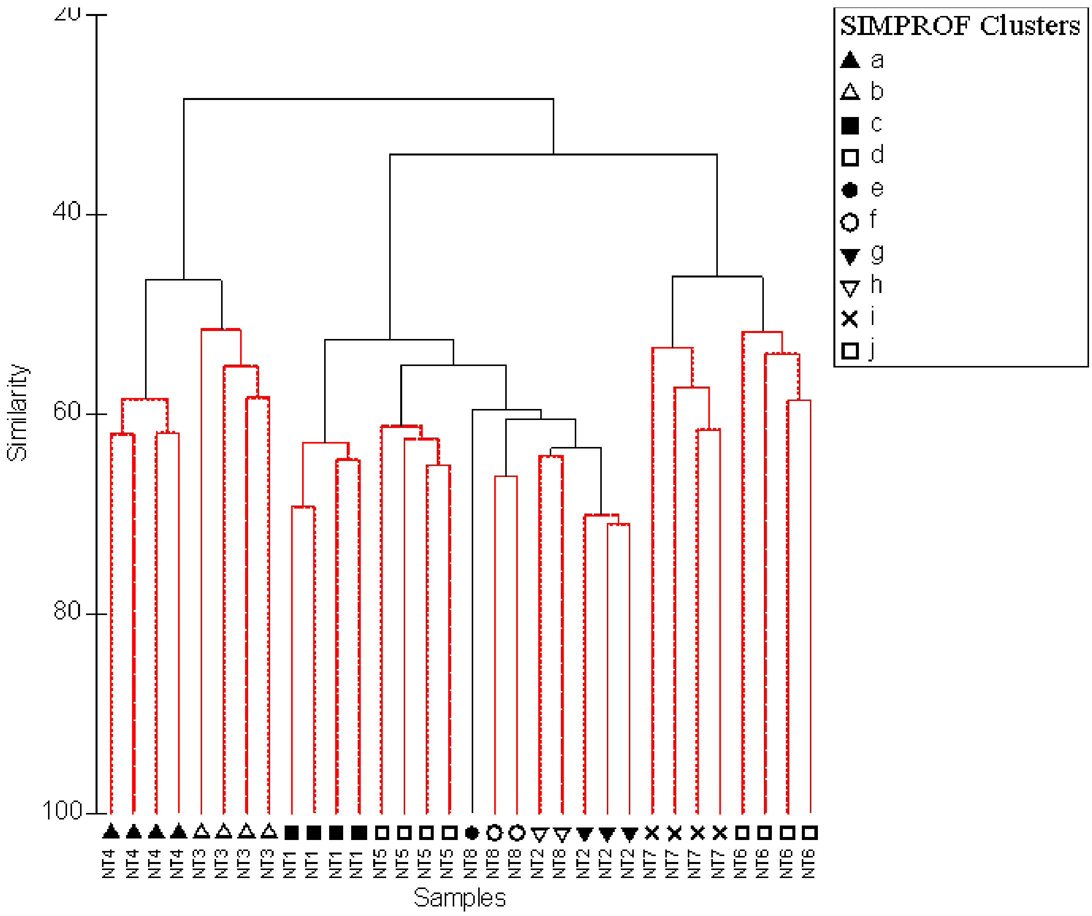


Figure A2.1.7. Dendrogram produced by hierarchical agglomerative clustering based on a Bray-Curtis similarity matrix of square root-transformed abundance data of the North Tyne stations, 2010. The majority of station replicates clustered within station except for NT2 & NT8 which formed 4 clusters (e, f, g, & h). Significant clustering is indicated by groups with dashed, red lines.

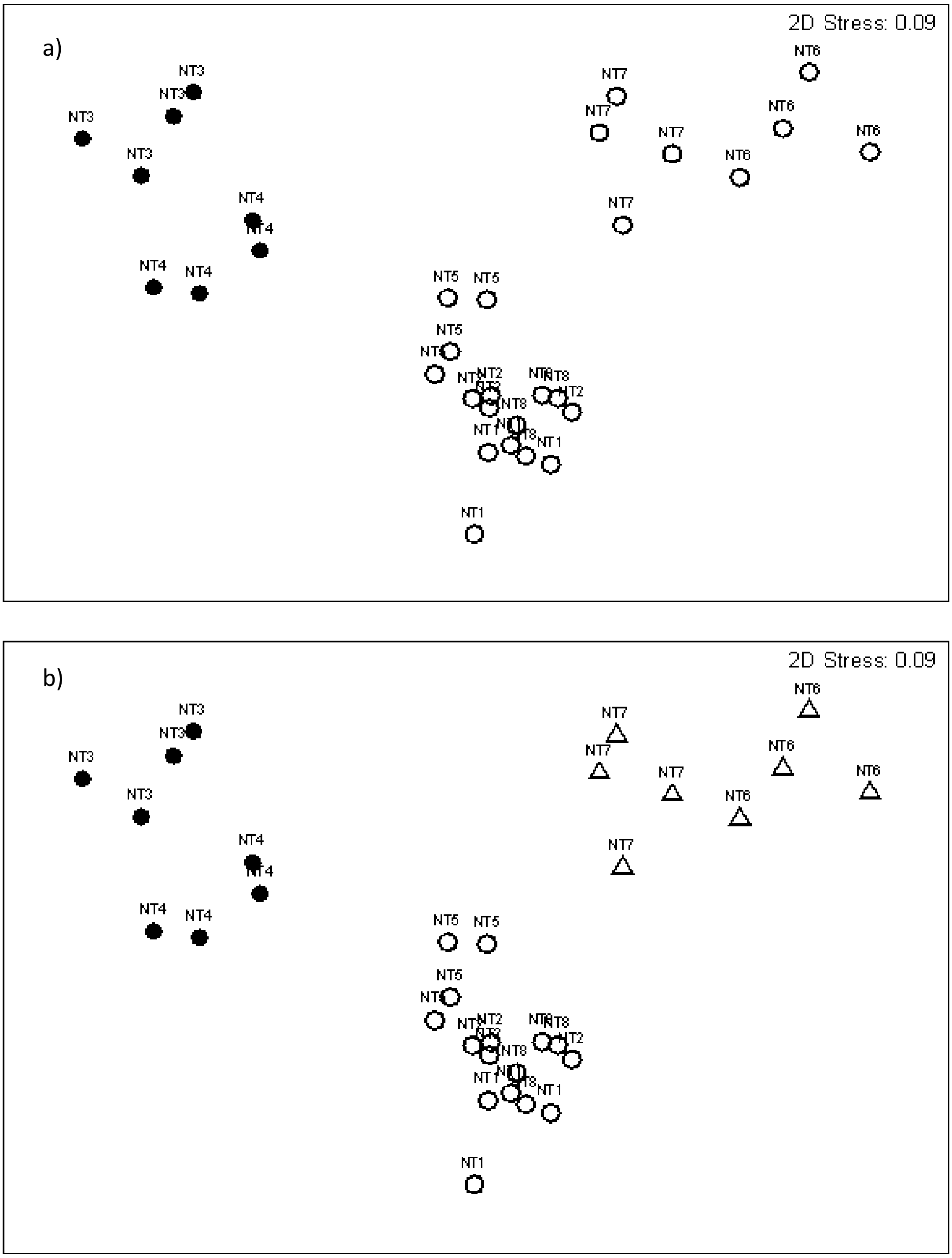


Figure A2.1.8(a&b). MDS ordinations (based on root-transformed abundance data) of all 32 samples collected during the 2010 North Tyne Dredging survey, a) showing the stations clustering at 30% similarity and b) showing clustering at 40% similarity. Stations inside the disposal site are shown in black.

2.1.4.4 Sediment contaminants

2.1.4.4.1 TBT

All 8 stations sampled at North Tyne were assessed for sediment TBT concentration. TBT was detected only at NT4; a slight decrease in level was observed at this station compared to that observed in 2009 (0.08mg/kg recorded in 2010 compared to 0.11mg/kg in 2009). This concentration remains below Cefas AL1.

Levels of TBT and DBT were below the method limit of detection (0.002mg/kg) for stations outside the disposal site (NT1, NT2, NT5, NT6, NT7 and NT8). Both NT1 and NT8 were consistently below the method LOD for the last 4 years and levels of TBT at station NT5 have been continually decreasing since 2007. The total loading of TBT (either from capital or maintenance dredging) remained constant over the last 2 years.

Overall, there were small decreases in DBT and TBT concentrations, however, the findings are very similar to previous year's in terms of their general concentrations.

2.1.4.4.2 PAHs

The highest summed PAH concentration of the 2010 survey was 92,500 µg kg^{-1} dw found at NT5, situated on the south-eastern transect from the disposal site (Figure A2.1.9). This is comparable to the higher concentrations found there in 2007 and 2008. The second highest concentration in 2010 was found further along this SE transect at NT6 which again is where the highest concentrations were found in 2007 and 2008. The lowest summed PAH concentration in 2010 was 14,200 µg kg^{-1} dw; found within the disposal site at NT3 (Figure A2.1.9). To the north and east of the disposal site, concentrations between 15,000 and 25,000 µg kg^{-1} dw were observed; again, these are consistent with concentrations seen in previous years.

Looking at the particle size analysis (PSA) data from 2009 compared to 2010, there was a small increase in percentage sand content at NT3 (Tables 2.1.1 and 2.1.2), which may account for the decrease in PAH concentration. Similarly, at NT4 and NT5, the decrease in the proportion of sand in the sediments could account for an increase in concentrations over the period 2009-2010.

All sediment samples collected in 2010 exceeded the ERL for low molecular weight (LMW) PAHs in this survey. Sediments from stations NT4, NT5, NT6 and NT7 also exceeded the ERM for the LMW PAHs. These stations, along with NT2, also exceeded the ERL for the high molecular weight (HMW) PAHs, but no station exceeded the ERM for the HMW PAHs. Evaluation of the PAH data indicate that the source in all the sediment samples was predominantly petrogenic, generally with > 80% of the PAH content arising from oil sources.

The phenanthrene/anthracene ratio (P/A) was greater than 10 at NT6 and the fluoranthene/pyrene ratio (Fl/Py) was less than 1, both supporting the notion that the source of the PAH at this disposal site is predominantly petrogenic. The PAH ratios seen at NT7 and NT5 were particularly close to the indicator values, with P/A ratios of 9.2 and 8, respectively, and Fl/Py ratios of 0.9 and 1.0, respectively, which indicates a more oil-derived than combustion-derived source.

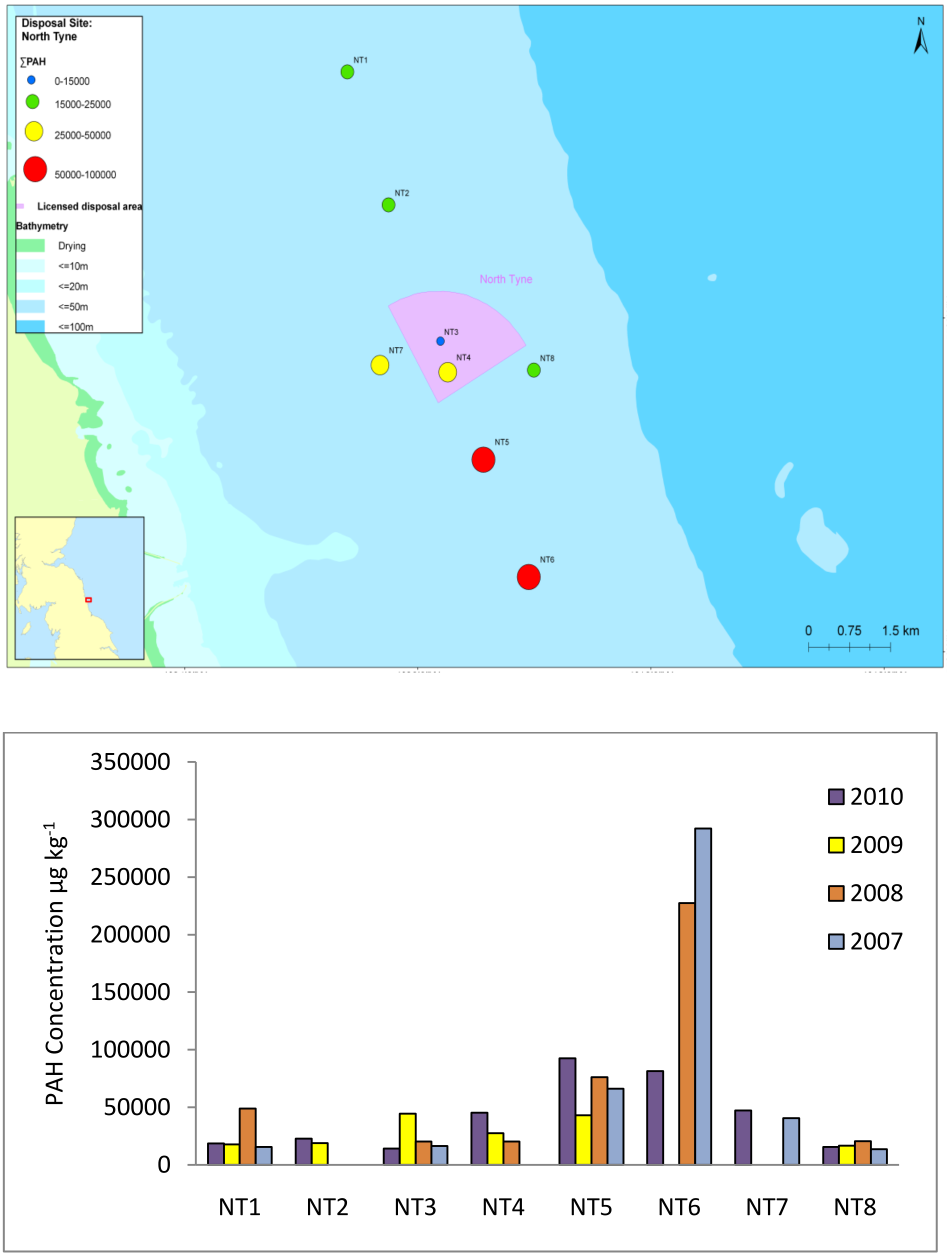


Figure A2.1.9. Summed PAH concentrations (µg kg^{-1}dw) for stations sampled in 2010 at North Tyne (top) and concentrations observed during 2007, 2008 2009 and 2010 (bottom).

2.1.4.4.3 Organohalogens

CBs were detected at all stations sampled at North Tyne (∑ICES7 CBs range 0.98-11.9 µg/kg dw). Concentrations of CBs were lowest to the north of the disposal site, generally close to the limits of detection (LODs), with low concentrations also at stations to the east and west of the disposal area (Figure A2.1.10). The highest CB concentration was found at NT5 south of the disposal site (∑ICES7 CBs 11.9 µg/kg dw) with similar concentrations also found at NT4 within the licensed disposal site boundary (∑ICES7 CBs 11.0 µg/kg dw).

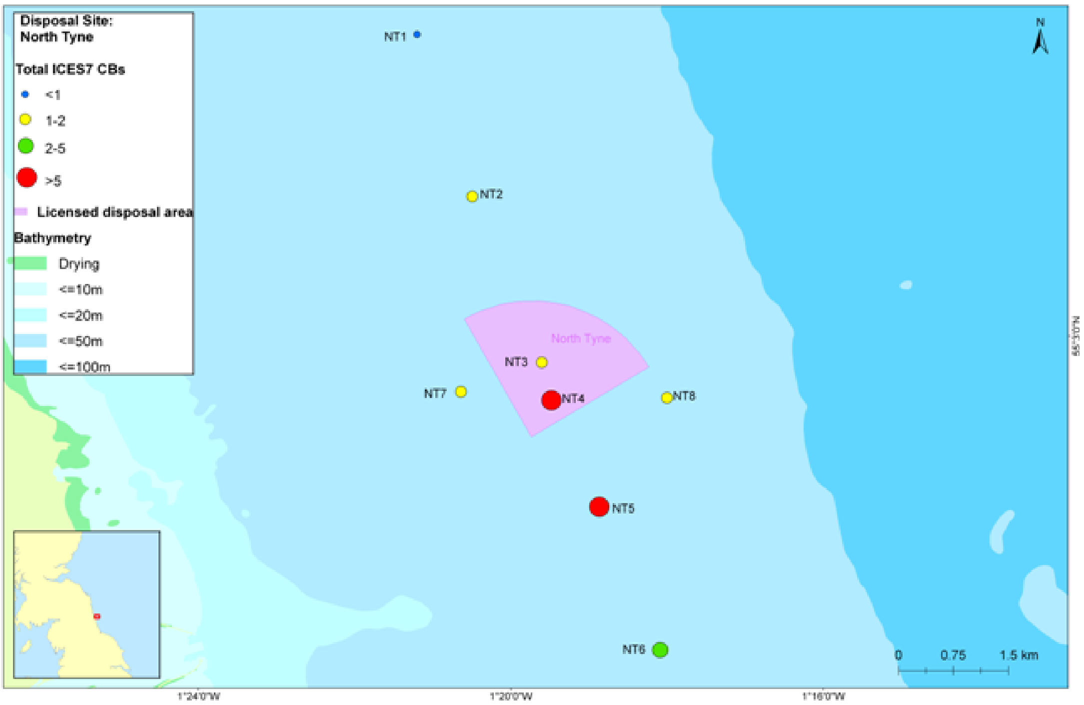


Figure A2.1.10. ∑ ICES7 CB concentrations for the North Tyne Stations, 2010.

Mapping such concentrations over a wider area, including Souter Point and Tyne Sewage reference stations, we see that the highest concentrations are limited to within the disposal sites and a station in between them (offshore from the mouth of the River Tyne) (Figure A2.1.11). The other stations between the disposal sites do not show such elevated levels.

BDEs were detected at all stations (∑11 BDEs range 0.84-4.2 µg/kg dw). The highest concentration (4.2 µg/kg dw) was found at NT4 inside the disposal area (Figure A2.1.12). BDE47 and BDE99 are the dominant congeners present, indicative of the pentaBDE technical mixture, but BDE183 was also detected, suggesting that the octaBDE or decaBDE technical mixture was also in use. Penta and octa technical mixtures are no longer in use, having been banned in the EU since 2004. Looking at levels across a wider area, the North Tyne disposal site displays higher BDE concentrations than the Souter Point disposal site (Figure A2.1.13).

Figure A2.1.11. ∑ ICES7 CB concentrations for North Tyne, Souter Point and Tyne Sewage Stations, 2010.

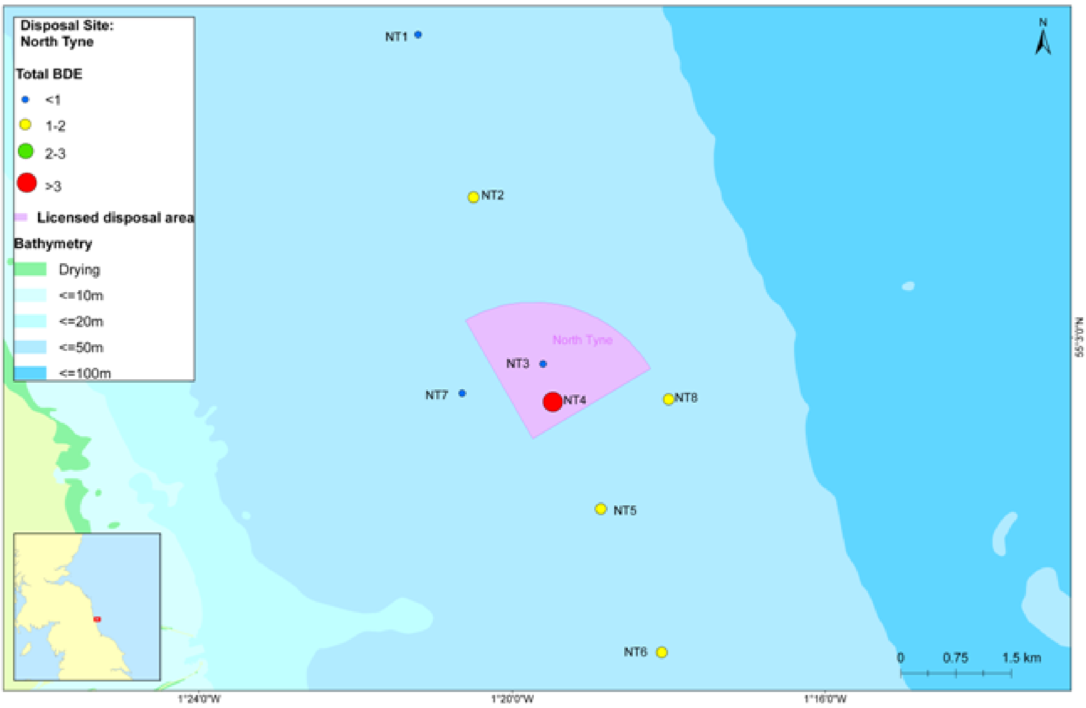


Figure A2.1.12. ∑ 11 BDEs concentrations for North Tyne, 2010.

Figure A2.1.13. ∑ 11 BDEs concentrations for North Tyne, Souter Point and Tyne Sewage Stations, 2010.

BDE209 was detected at all stations and displayed higher concentrations than the other measured organohalogens (range 3.9-95 µg/kg dw). When included with the other BDEs, BDE209 made up >80% of the BDEs present (range 81-96%). BDE209 is indicative of the decaBDE technical mixture, which has been in use more recently than the other technical mixtures, although it's use has been restricted in the EU since 2008. The highest concentration (95 µg/kg dw) was detected at NT4 within the disposal site (Figure A2.1.14). Concentrations of 18 and 20 µg/kg dw were present at stations NT7 and NT8, west and east of the disposal site, respectively. Other stations were all <10 µg/kg dw, with the exception of NT2, with a concentration of 12 µg/kg dw.

Over the wider Tyne area, concentrations in the Tyne disposal site were approximately three times higher than those found in the Souter Point disposal site (Figure A2.1.15).

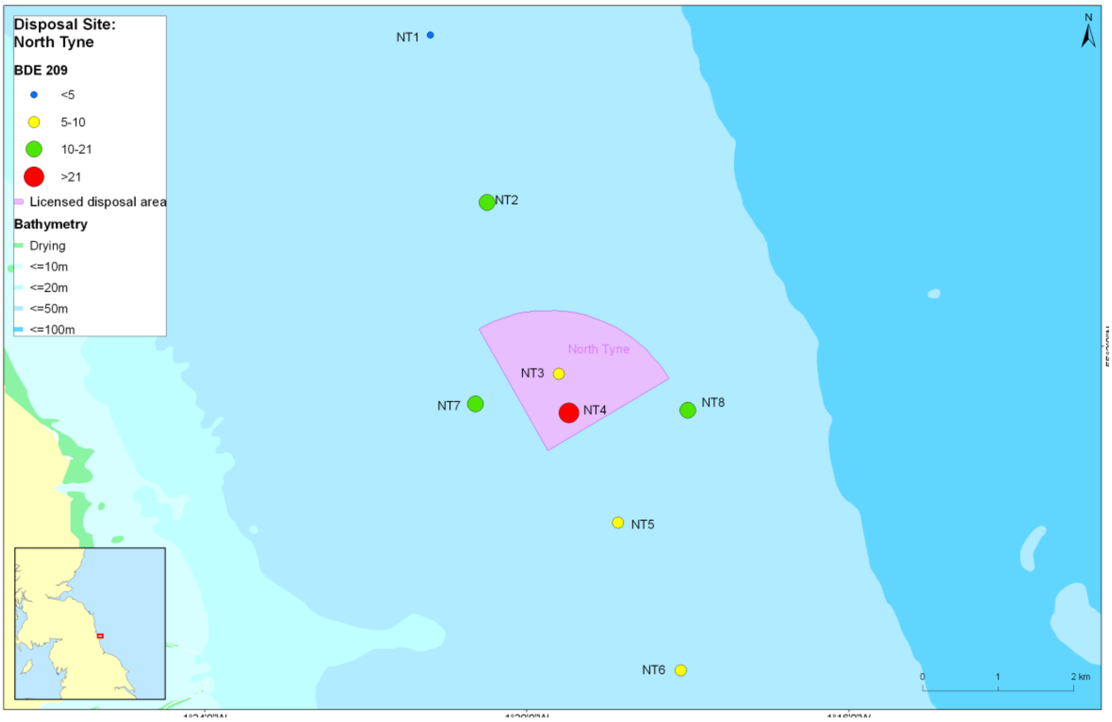


Figure A2.1.14. BDE209 concentrations for North Tyne, 2010.

Figure A2.1.15. BDE209 concentrations for the North Tyne, Souter Point and Tyne Sewage Stations, 2010.

Levels of organochlorine pesticides were < 1 ug/kg dw at all stations except for NT4, within the disposal site. Here, concentrations for HCB, dieldrin, *p,p'*-DDE and *p,p'*-TDE were 3.3, 1.4, 3.9 and 3.0 ug/kg dw, respectively (Figure A2.1.16 and 2.1.17). *p,p'*-DDT concentrations were below or close to LODs at all stations, meaning that metabolites made up the majority of total DDT and there was no evidence of any recent usage of DDT. HCHs were below LODs at all stations.

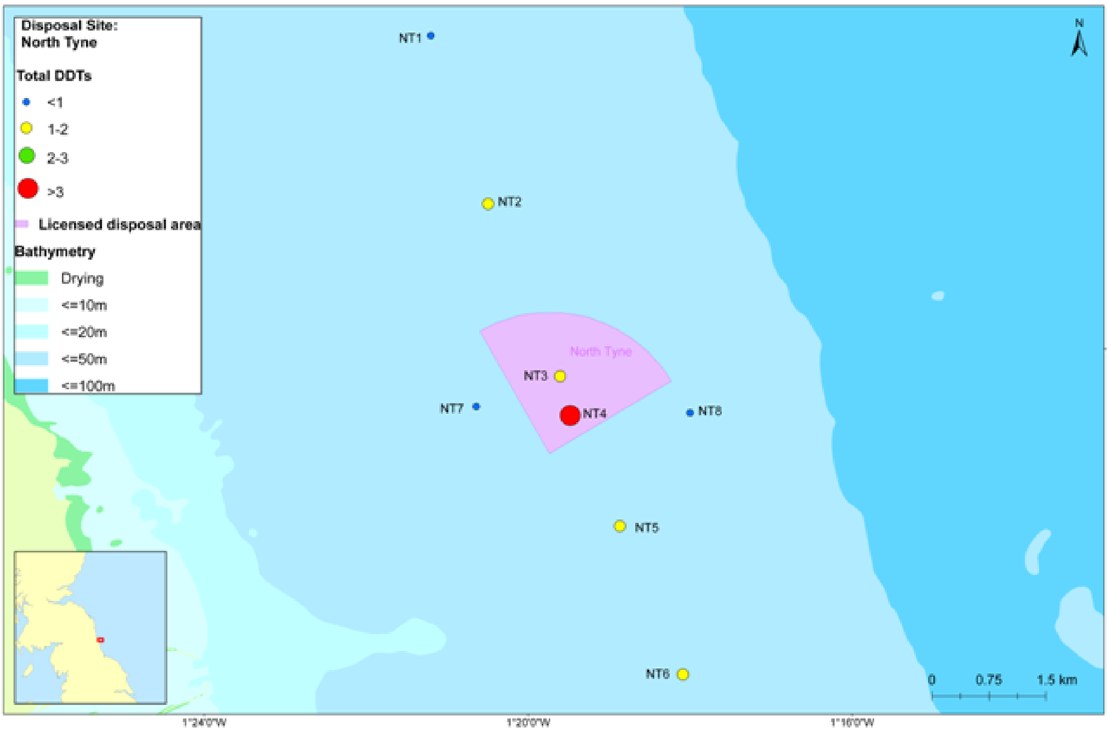


Figure A2.1.16. ∑ DDTs concentrations for North Tyne, 2010.

Concentrations of CBs and OCPs at most stations were below Cefas ALs. Exceptions were NT4 which was above AL1 for CBs, dieldrin and DDTs, and NT5 which was above AL2 for CBs. No Cefas ALs exist for BDEs including BDE209. According to the OSPAR guidelines, most stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. NT4 had 'bad' environmental status for CB118 but 'good' status overall. No OSPAR guidelines exist for BDEs or OCPs at present.

There are data available to look at temporal trends of contaminants from 2006 to 2010. For CBs (where all but one station in 2010 was below Cefas AL1), there are no clear trends overall with some stations showing increases and other showing decreases (Table A2.1.3). Levels of CBs at stations NT1, NT2, NT8 and NT7 are very similar to previous years, and levels at NT3 and NT6 have halved since last measurements were made. However, levels at NT4 and NT5 are the highest they have been over this period and show 3 fold increases since 2009. Trends for BDEs were similar (Table A2.1.4), except for NT5 where concentrations have declined.

Figure A2.1.17. ∑ DDTs concentrations for the North Tyne, Souter Point and Tyne Sewage Stations, 2010.

Station code	**∑ICES 7 CBs concentration (in µg/kg dw)**				
	2006	**2007**	**2008**	**2009**	**2010**
NT1	1.54	0.97	2.11	0.93	0.98
NT2				1.69	1.63
NT3	1.48	2	1.79	4.12	1.63
NT4	7.21		*0.7*	4.58	11.0
NT8	5.21	2	0.81	*0.7*	1.12
NT5	2.7	7.59	6.05	3.24	11.9
NT6	2.44	2.54	3.88		2.09
NT7		1.55			1.76

Table A2.1.3. Temporal trends (2006-2010) of ∑ICES 7 CBs concentration (in µg/kg dw) at North Tyne in the stations sampled during 2010. Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs.

Station code	∑11 BDEs concentration (in µg/kg dw)				
	2006	2007	2008	2009	2010
NT1	1.56	1.68	1.27	0.95	0.93
NT2	5.28			1.27	1.84
NT3	1.72	1.54	0.49	2.55	0.52
NT4	13.2		0.28	1.27	4.18
NT8	1.86	2.84	1.42	0.74	1.65
NT5	2.18	4.49	0.96	5.89	1.31
NT6	7.69	4.12	1.18		1.34
NT7		1.77			0.84

Table A2.1.4. Temporal trends (2006-2010) of ∑11 BDEs concentration (in µg/kg dw) at North Tyne in the stations sampled during 2010. Note, limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower from 2008 onwards, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs.

In addition to the analysis of 2010 samples for BDE209, sample extracts from 2008 and 2009 were retrospectively analysed, giving some temporal information. There are no clear trends overall, with some stations showing increases and other showing decreases (Table A2.1.5). Increases were detected at stations NT4 and NT8, whereas decreases were observed at NT1 and NT5.

Station code	BDE209 concentration (in µg/kg dw)		
	2008	2009	2010
NT1	104.2	11.46	3.93
NT2		12.23	12.2
NT3	2.72	48.54	7.91
NT4	0.78	36.11	95.5
NT5	6.21	11.94	6.64
NT6	6.15		8.69
NT7			17.5
NT8	8.03	8.95	20.1

Table A2.1.5. Temporal trends (2008-2010) of BDE209 concentration (in µg/kg dw) at North Tyne in the stations sampled during 2010.

Total DDT concentrations generally declined over the period 2006-2010 (Table A2.1.6), as would be expected for a chemical which has not been approved for use in the UK since 1984. Levels increased at station NT4 within the disposal site, possibly due to more contaminated material being disposed of at the site since the last survey.

Station code	∑DDTs concentration (in µg/kg dw)			
	2006	2007	2008	2010
NT1	0.97	1.54	1.44	0.83
NT2	1.56			1.38
NT3	0.89	1.83	3.17	1.27
NT4	7.2		1.12	6.92
NT8	0.84	1.59	0.88	1.36
NT5	1.12	3.41	3.48	1.25
NT6	1.25	2.25	1.84	0.91
NT7	1.12	1.66		0.95

Table A2.1.6. Temporal trends (2006-2010) of ∑DDTs concentration (in µg/kg dw) at North Tyne in the stations sampled during 2010.

2.1.4.4.4 Trace metals

When comparing the average concentration between stations within the disposal site with those located outside the disposal site (Figure A2.1.18) no significant difference was observed for any metal over the past five years. This observation may be due to the dispersive nature of the site or high regional background levels.

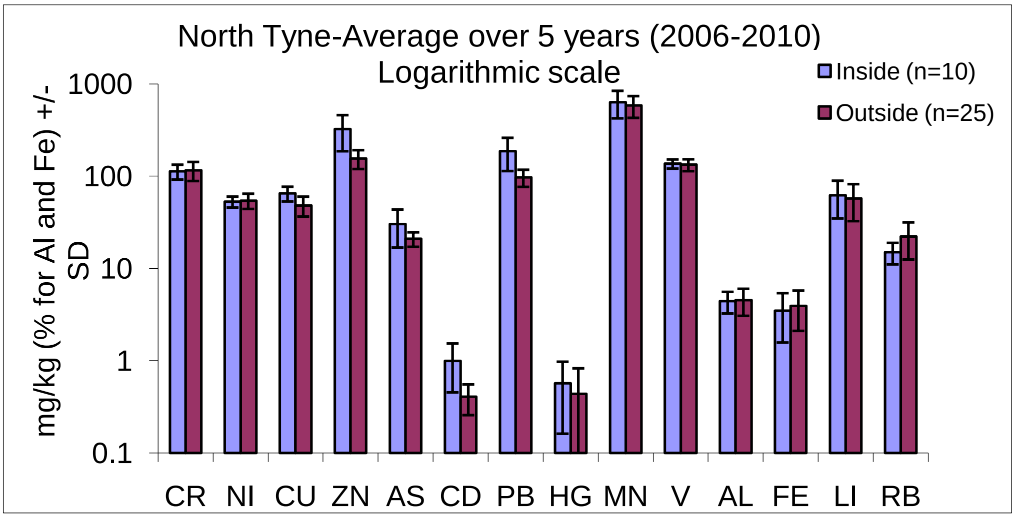


Figure A2.1.18. Average metal concentrations at North Tyne inside and outside between 2006 and 2010 inclusive.

Figures 2.1.19 and 2.1.20 show temporal variation of metals for stations within and outside the disposal site respectively. No temporal trends are apparent over this five year period for either case, although the average concentration of Hg both inside and outside the disposal site noticeably increased in 2010.

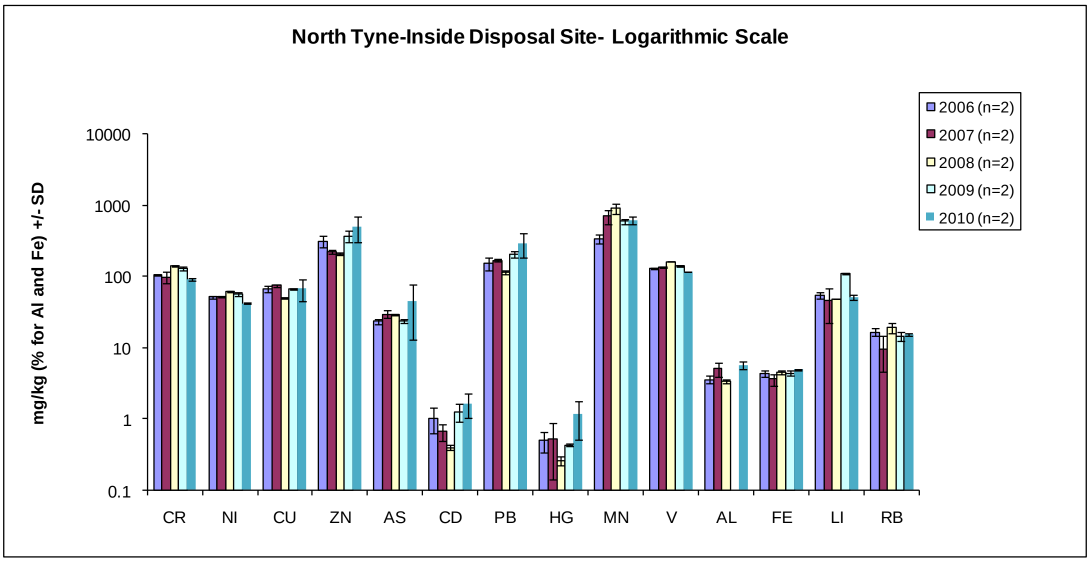


Figure A2.1.19. Average metal concentrations inside the North Tyne disposal site from 2006-2010

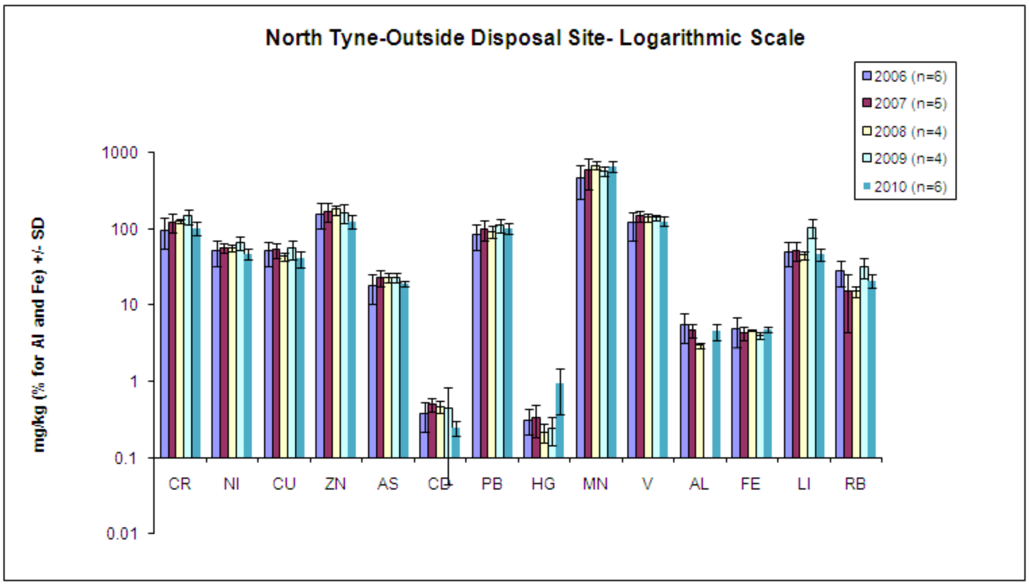


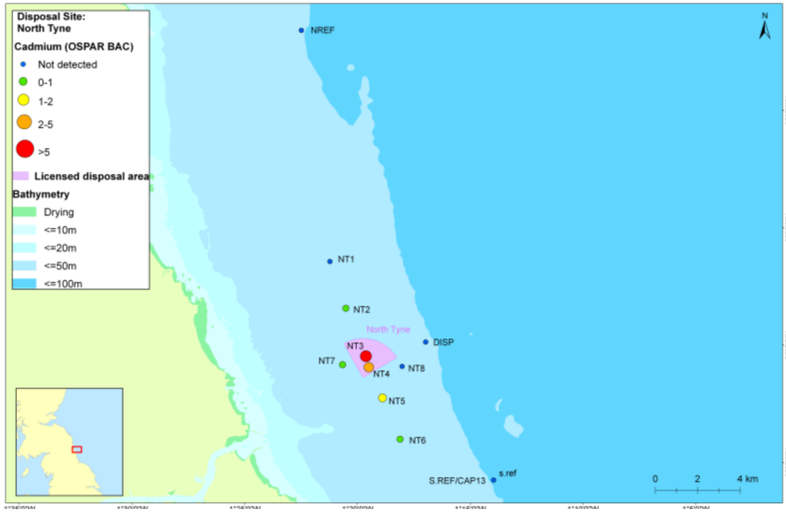
Figure A2.1.20. Average metal concentrations outside the North Tyne disposal site from 2006-2010.

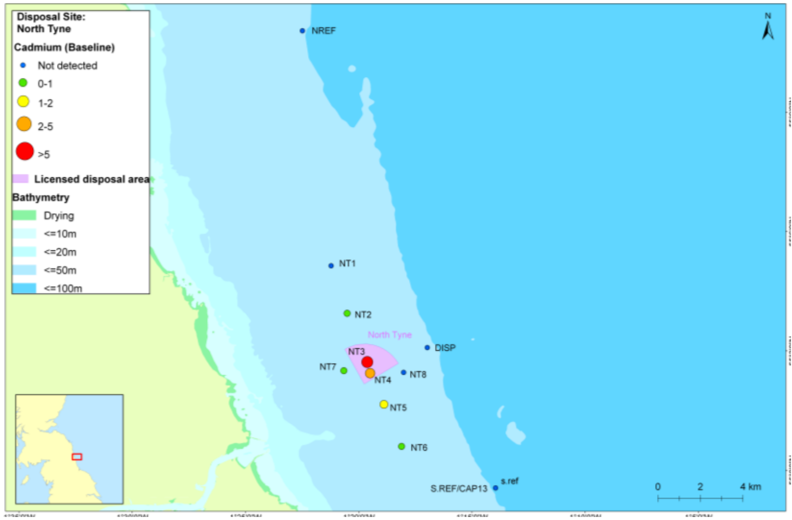
Assessment of metals enrichment shows that enrichment is observed for As within the disposal site (NT3). No enrichment is recorded elsewhere. Both methods using OSPAR BAC and baseline values show similar observations. A transect showing a gradient of Cd enrichment starting from stations within the disposal site (NT3 and NT4) towards the south west of the disposal site, indicating a dilution of Cd levels possibly due to the effect of tidal currents (Figure A2.1.21).

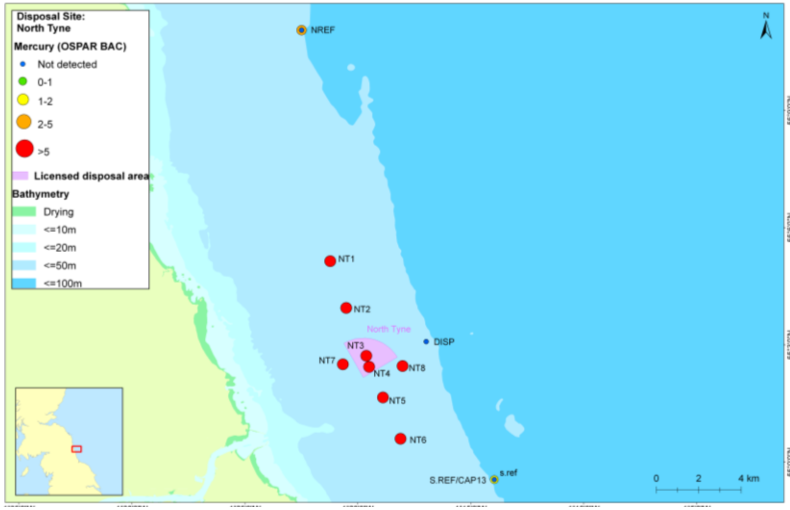
Ni and Cr are slightly enriched with the OSPAR assessment but since the baseline values for this region are higher that the OSPAR BAC values no enrichment is observed when using the baseline approach. Hg is highly enriched relative to OSPAR background assessment concentrations and remains enriched (but to a lesser extent) using the baseline approach, especially to the south of the disposal site (Figure A2.1.21).

Enrichment is observed for Pb (Figure A2.1.21) and Zn at most stations using the OSPAR approach while the baseline approach only depicts enrichment at stations within the disposal site. Cu is slightly enriched and both assessment methods indicate a vertical transect of enrichment from north of the disposal (NT1) to south of the disposal site (NT6).

In conclusion, the metals concentrations tend to be much higher than the OSPAR BAC values especially for Hg, Pb and Zn. This is generally due to the legacy from the historical and current industrial activities of the area (Cefas, 2011). When assessing those concentrations against the proposed baseline values, which account for regional variability, enrichment is still generally observed, albeit to a reduced level.


Disposal Site:
North Tyne
Cadmium (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
NREF
NT1
NT2
North Tyne
DISP
NT3
NT7
NT4
NT8
NT5
NT6
s.ref
S.REF/CAP13
0
2
4 km


Disposal Site:
North Tyne
Cadmium (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
NREF
NT1
NT2
North Tyne
DISP
NT3
NT7
NT4
NT8
NT5
NT6
s.ref
S.REF/CAP13
0
2
4 km


Disposal Site:
North Tyne
Mercury (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
NREF
NT1
NT2
North Tyne
DISP
NT3
NT7
NT4
NT8
NT5
NT6
s.ref
S.REF/CAP13
0
2
4 km


Disposal Site:
North Tyne
Mercury (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
NREF
NT1
NT2
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NT6
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S.REF/CAP13
0
2
4 km

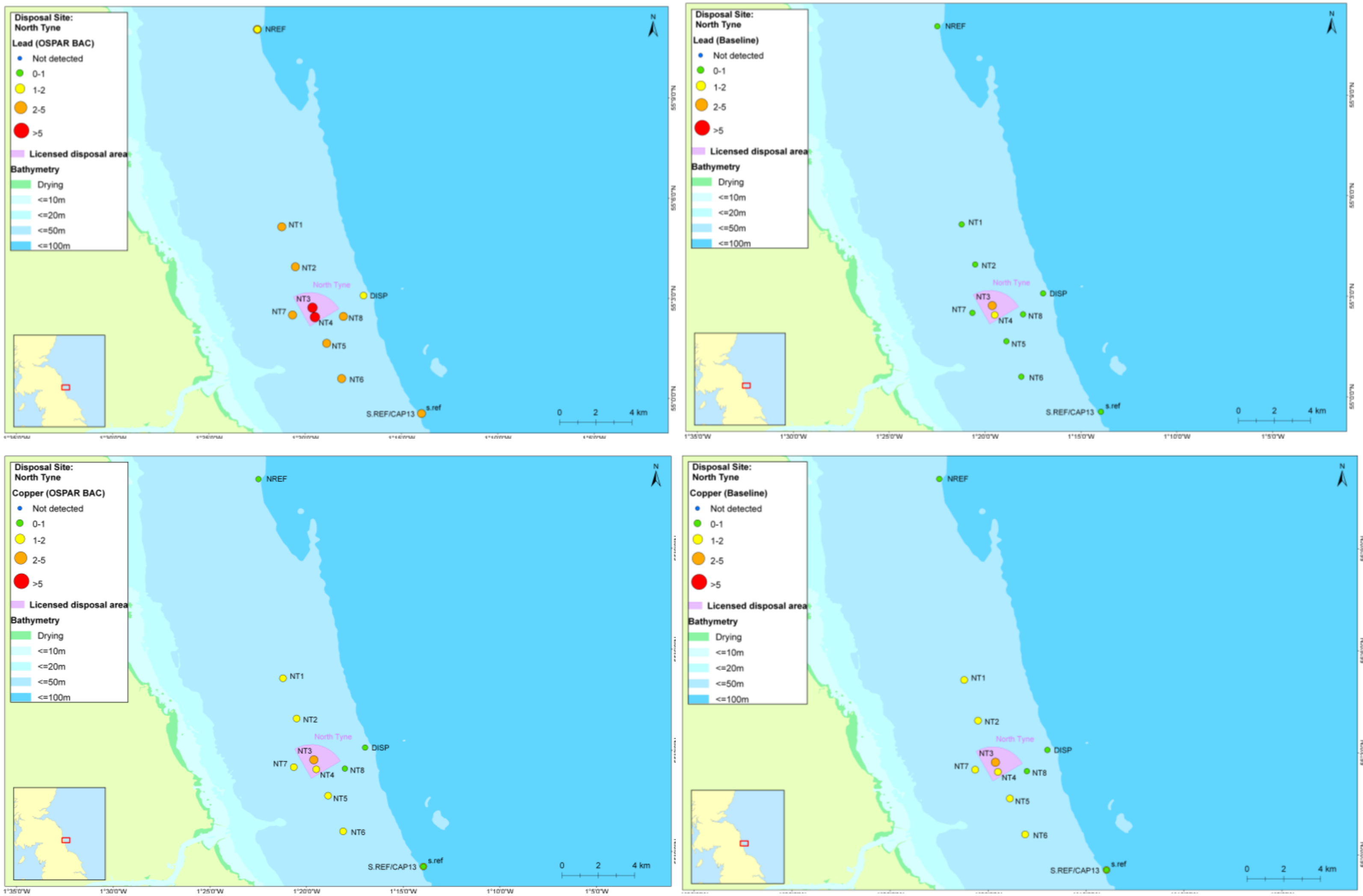


Figure A2.1.21. Enrichment to OSPAR BACs and Baseline values at North Tyne, 2010.

2.2 Souter Point (TY081)

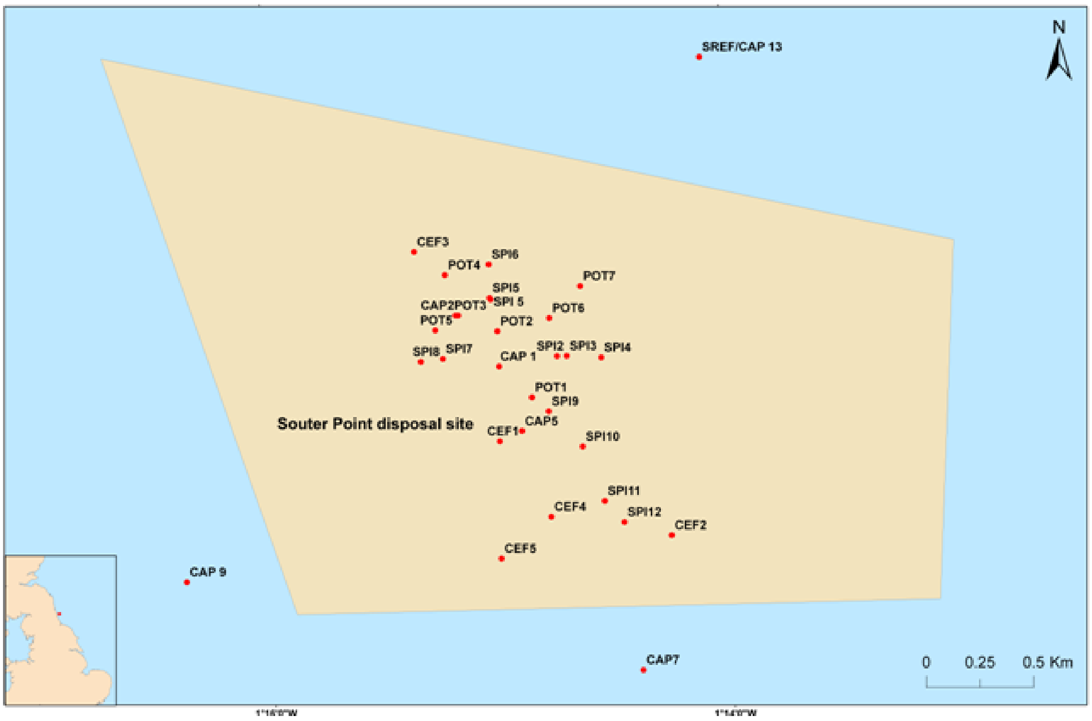


Figure A2.2.1. Location of sampling stations at Souter Point, 2010.

2.2.1 Background

The sediments within the vicinity of Souter Point are muddy sands. However, sediments may vary to a large extent from this following dredged material disposal and in response to its history of solid industrial wastes discharged inshore. The disposal site is located at a depth of approx. 40m, but this shallows by up to 5 m at the inshore end due to historical accumulations of minestone and fly-ash concretions. Tidal currents in the vicinity of the disposal site are moderate in strength and run generally parallel with the coastline with a net residual drift southwards, at least in surface waters.

In December 2004-April 2005 a trial level bottom-capping project was undertaken within the centre of the site. The Port of Tyne disposed 60,000 m^3 of contaminated dredged material (CDM), which was to be covered with 100,000 m^3 of silt and around 60,000 m^3 of sand. On placement of the silt around 80% was siphoned off, thus, to leave a 1.5m cap, 90,000 m^3 of sand was later placed. Further material was deposited in 2006 and 2007 to attempt to ensure isolation of the CDM. During this time the maintenance dredged material from the Tyne was disposed of to the North Tyne TY070. As detailed briefly in Section 2.1.1 regarding North Tyne, material dredged from the Tyne under a new three-year licence is expected at Souter Point during early 2011; a phased management plan will be devised to minimise the potential of this material interfering with the cap.

RAT prioritisation assessment: Tier 1

- where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas action levels of 1 and 2 in proposed dredge sediments) (Appendix 1) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries).
- that have been observed or pose an increased risk to the surrounding area and receptors.
- identified as ‘sites of local concern’ by public, pressure groups, NGO’s etc.

Concerns:

Following the trial capping project undertaken at this site (see above), there are current concerns regarding the integrity of the cap, specifically related to cap thickness.

2.2.2 Impact hypotheses

- No migration of cap material outside original disposal footprint, measurable using acoustic data (SSS,SPI Multibeam) to show no long-term movement of the cap
- Cap integrity is maintained with no leakage of CDM to surrounding area
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

2.2.3 Parameters monitored

Sidescan sonar (SSS) and multibeam (MB)
Sediment particle size distribution
Sediment organic carbon and nitrogen
Macrofaunal communities
Sediment Profiling Imaging (SPI)
Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

2.2.4 Results

2.2.4.1 Sidescan and multibeam

The Souter Point acoustic survey was conducted using a Kongsberg EM3002D multibeam system and an Edgetech 4200FS sidescan sonar on 16-17th June 2010. The site is predominantly characterised by muddy sands with a centralised cap of fine sand. Figure A2.2.2 presents the multibeam results with the disposal site boundary highlighted in purple. The seabed reaches a depth of approximately 50m with moderate tidal currents in the area running parallel to the coastline.

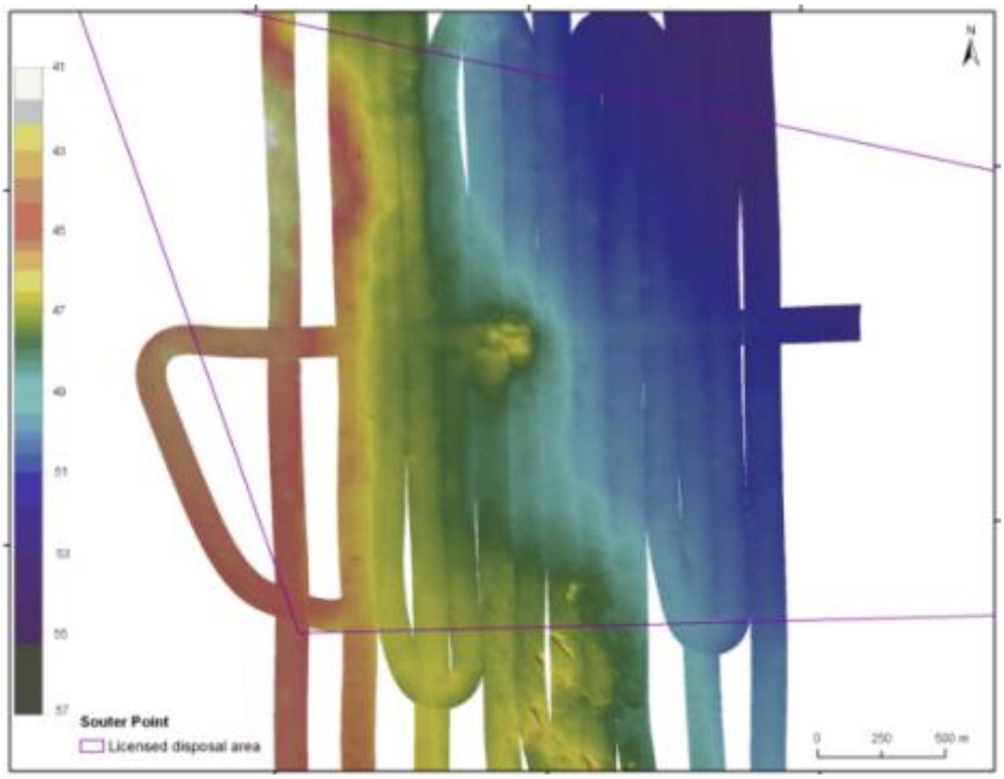


Figure A2.2.2. Multibeam bathymetry collected at Souter Point, 2010.

Particle size analysis (PSA) was obtained from samples collected using a Day grab to support the interpretation of the acoustic data. Ten samples were collected in total, of which only five were located directly within the licensed disposal area (Figure A2.2.3). The multibeam backscatter has a stronger return directly on top of the capping area (Figure A2.2.3). The sediments directly surrounding the sandy cap have a weaker return suggesting an increase in the mud and gravel content. The disposal cap itself is clearly defined from the backscatter and can be easily distinguished from the surrounding, non-cap sediments.

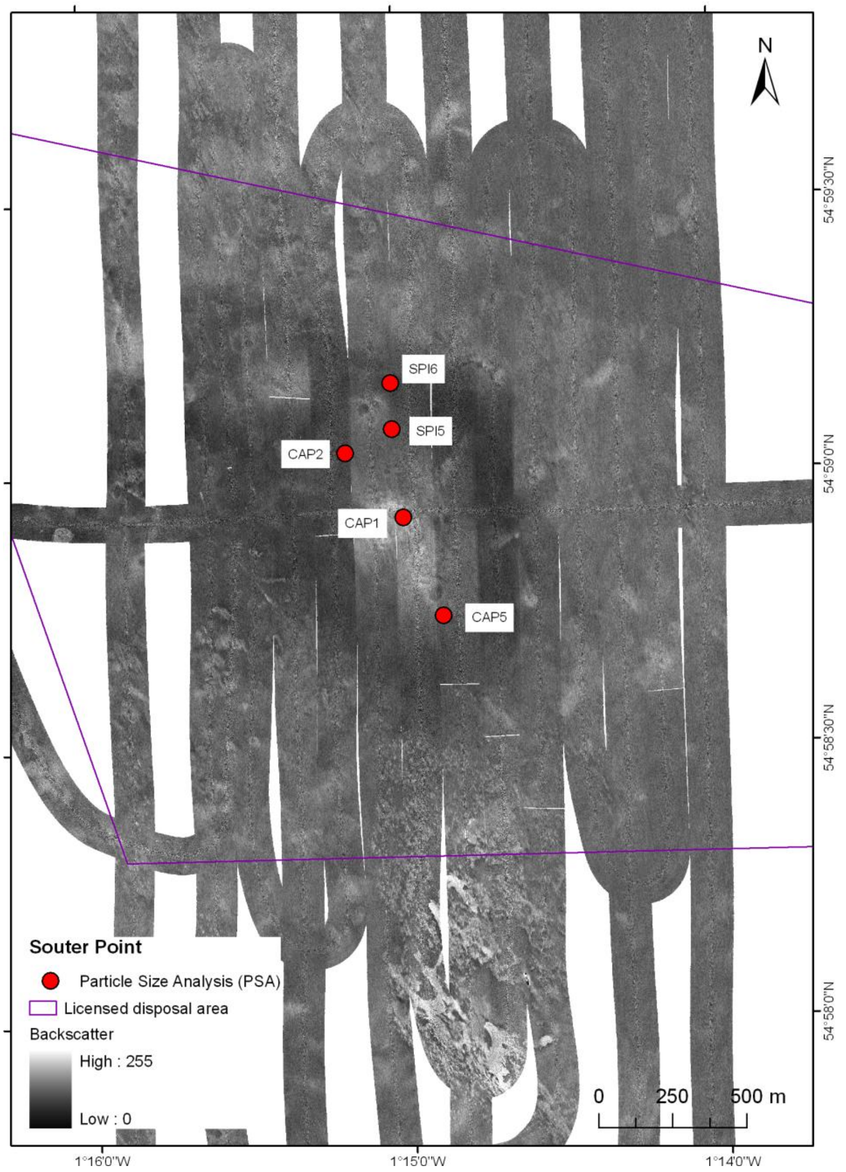


Figure A2.2.3. Multibeam backscatter from the Souter Point 2010 survey with PSA sample positions overlaid.

A map produced following interpretation of the acquired acoustic data is shown in Figure A2.2.4. The central disposal area has a much stronger backscatter return and can therefore be associated with the sandy cap, with its peaked dome, identifiable in the multibeam bathymetry and backscatter. The area surrounding the cap contains sandy muds and to the south linear raised features consisting of muddy gravelly sands can be seen. The seabed to the northwest and directly east of the disposal cap appears to have a higher backscatter return indicating coarser or harder substrates, likely to be associated with increased gravel content.

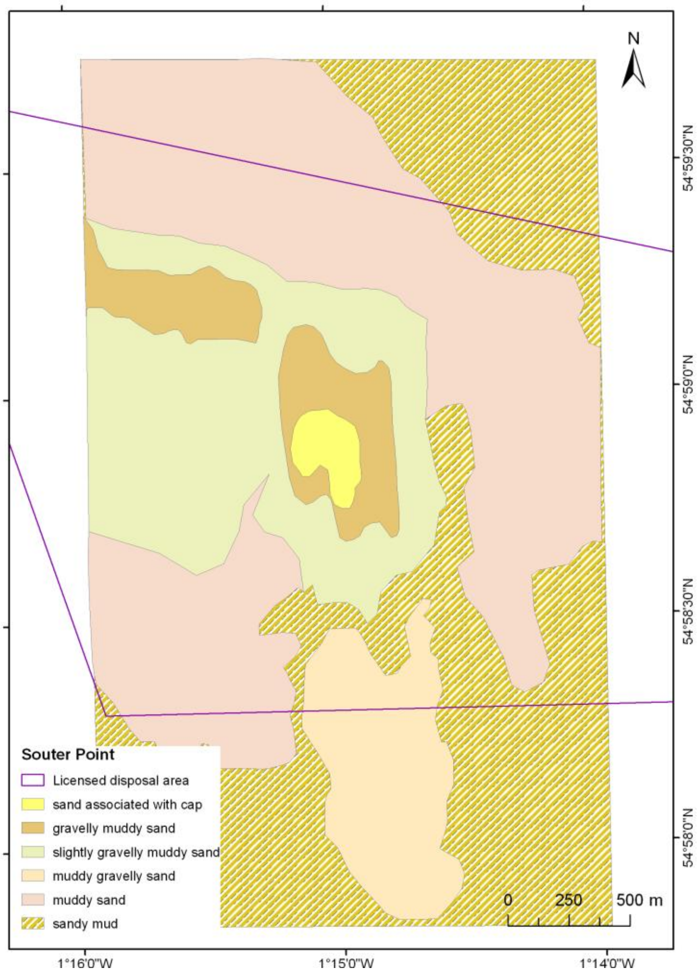


Figure A2.2.4. Interpretation of the multibeam backscatter and sidescan sonar at Souter Point, 2010.

A time-series of acoustic data have now been acquired *via* monitoring under the auspices of SLAB5. However, direct comparisons with previous acoustic results can be slightly subjective as survey conditions can change from year to year. Nevertheless, when taking this into account, the cap appears to have changed shape and reduced in size; the cap limit appears to have migrated somewhat to the northwest and has merged with the surrounding sediments (Figure A2.2.5). This latter feature can make it difficult to define a firm boundary around the cap itself.

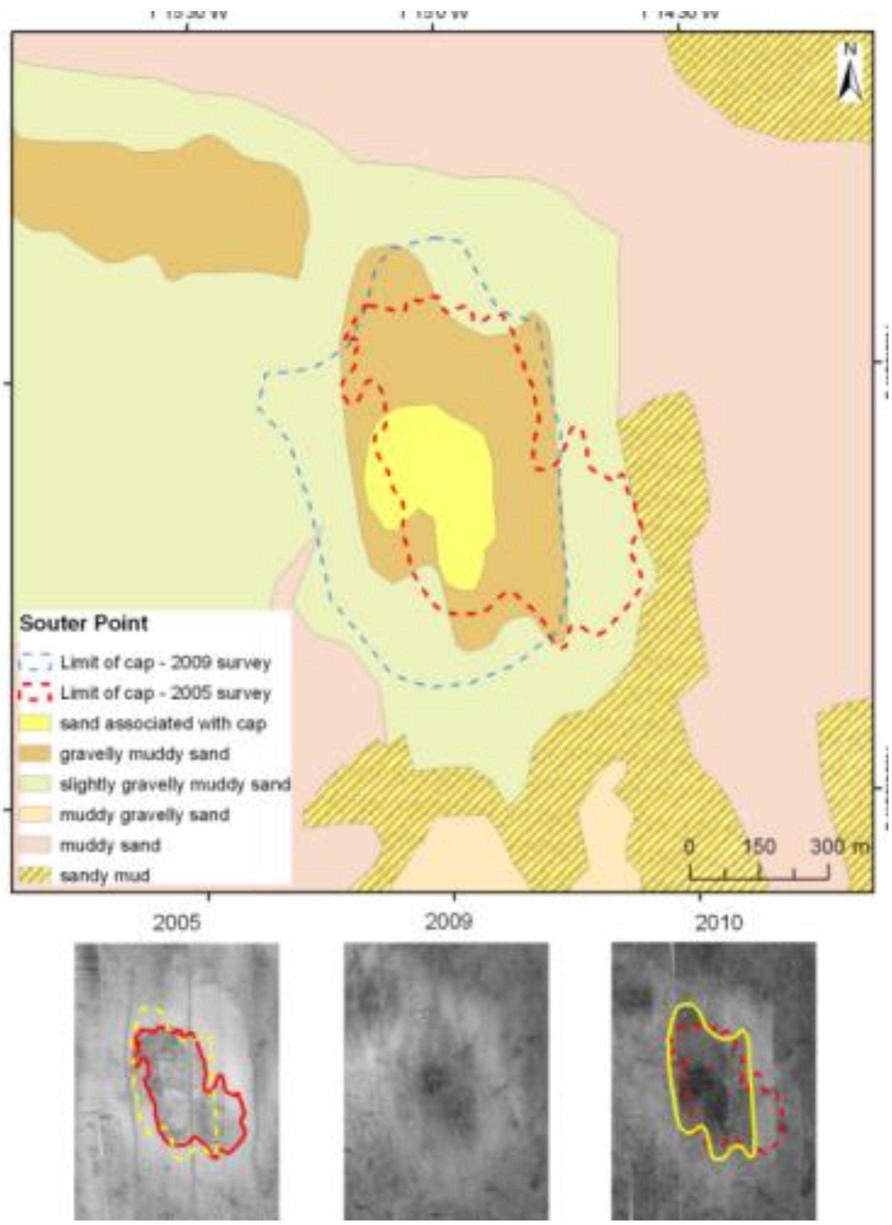
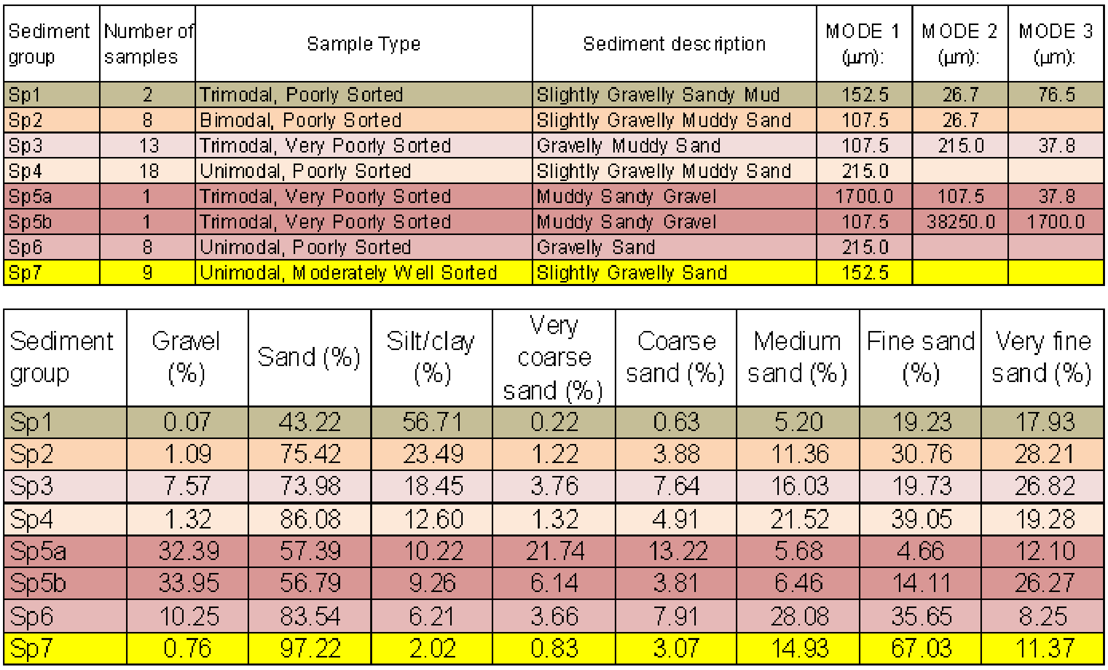


Figure A2.2.5. Interpretation of the acoustics collected in 2010 (top) with results from 2005 (red outline) and 2009 (blue outline) and backscatter results for 2005, 2009 and 2010 surveys (bottom).

The newly-laid cap in 2005 was of a similar size to what is observed in 2010 but with a higher proportion of the cap residing to the east than currently. The 2009 data indicated a shift to the west of the site and an expansion of the overall footprint of the cap. This appears to still be the case, however, the main impacted area with a predominantly sandy cap has remained in the same location with the surrounding sediments consisting of slightly gravelly muddy sand shifting to the west. Future surveys will help to ascertain whether sediment distribution at the disposal site continues to follow this pattern.

2.2.4.2 Sediment particle size

Souter Point sediments are predominantly muddy sands, with some gravelly sands, unimodal sands and muds (Table A2.2.1). Changes in sediment group are shown in Table A2.2.2 for each station between 2005 and 2010 inclusive, showing the changes that have occurred at the site since the capping trial (December 2004 – April 2005). Pie charts of gravel, sand and silt/clay are shown for 2010 data in Figure A2.2.6 and silt/clay content in Figure A2.2.7. Sediment group Sp7 (slightly gravely sand) is expected to represent the sand cap, and this sediment group is exclusively found at CAP1, CAP2, CAP5 and NEWCAP; all within the capping area. In 2007 and subsequent years, sediment at CAP1 and CAP5 are more mixed with a higher gravel content, possibly reflecting the addition of further capping material. Silt/clay content increased from <5% (prior to 2009) to >10% in 2010. In 2009, sediment at CAP2 has higher silt/clay content (30%) which may relate to either a recent disposal event or possible loss of sand cap material. In 2010, the silt/clay content is lower (10%) than in 2009. Sediment groups are more temporally variable within and to a lesser extent outside the site edges (CAP4, CAP7 and CAP9) than at the reference sites (TC2, TC3 and TC4) (Table A2.2.2).



Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
Sp1	2	Trimodal, Poorly Sorted	Slightly Gravelly Sandy Mud	152.5	26.7	76.5
Sp2	8	Bimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	107.5	26.7	
Sp3	13	Trimodal, Very Poorly Sorted	Gravelly Muddy Sand	107.5	215.0	37.8
Sp4	18	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	215.0		
Sp5a	1	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel	1700.0	107.5	37.8
Sp5b	1	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel	107.5	38250.0	1700.0
Sp6	8	Unimodal, Poorly Sorted	Gravelly Sand	215.0		
Sp7	9	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand	152.5		

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
Sp1	0.07	43.22	56.71	0.22	0.63	5.20	19.23	17.93
Sp2	1.09	75.42	23.49	1.22	3.88	11.36	30.76	28.21
Sp3	7.57	73.98	18.45	3.76	7.64	16.03	19.73	26.82
Sp4	1.32	86.08	12.60	1.32	4.91	21.52	39.05	19.28
Sp5a	32.39	57.39	10.22	21.74	13.22	5.68	4.66	12.10
Sp5b	33.95	56.79	9.26	6.14	3.81	6.46	14.11	26.27
Sp6	10.25	83.54	6.21	3.66	7.91	28.08	35.65	8.25
Sp7	0.76	97.22	2.02	0.83	3.07	14.93	67.03	11.37

Table A2.2.1 Average sediment descriptions and statistics for each sediment group at Souter Point.

	Year					
Sample code	2005	2006	2007	2008	2009	2010
CAP1	Sp7	Sp7	Sp6	Sp6	Sp6	Sp6
CAP2	Sp7	Sp7	Sp7	Sp7	Sp2	Sp4
CAP4	Sp4	Sp4	Sp4	Sp6	Sp3	Sp4
CAP5	Sp7	Sp7	Sp6	Sp6	Sp4	Sp6
CAP7	Sp4	Sp4	Sp2	Sp3	Sp4	
CAP9	Sp2	Sp2	Sp2	Sp5a	Sp2	Sp5b
NEWCAP	Sp7					
POT6				Sp2		
SPI10				Sp2		
SPI5						Sp4
SPI6						Sp4
TC2	Sp3	Sp3	Sp3		Sp3	Sp3
TC3	Sp4	Sp4	Sp4	Sp4	Sp4	Sp4
TC4	Sp3	Sp3	Sp3	Sp3	Sp3	Sp3

Table A2.2.2 Sediment groups for each sample code between 2005 and 2010 inclusive at Souter Point.

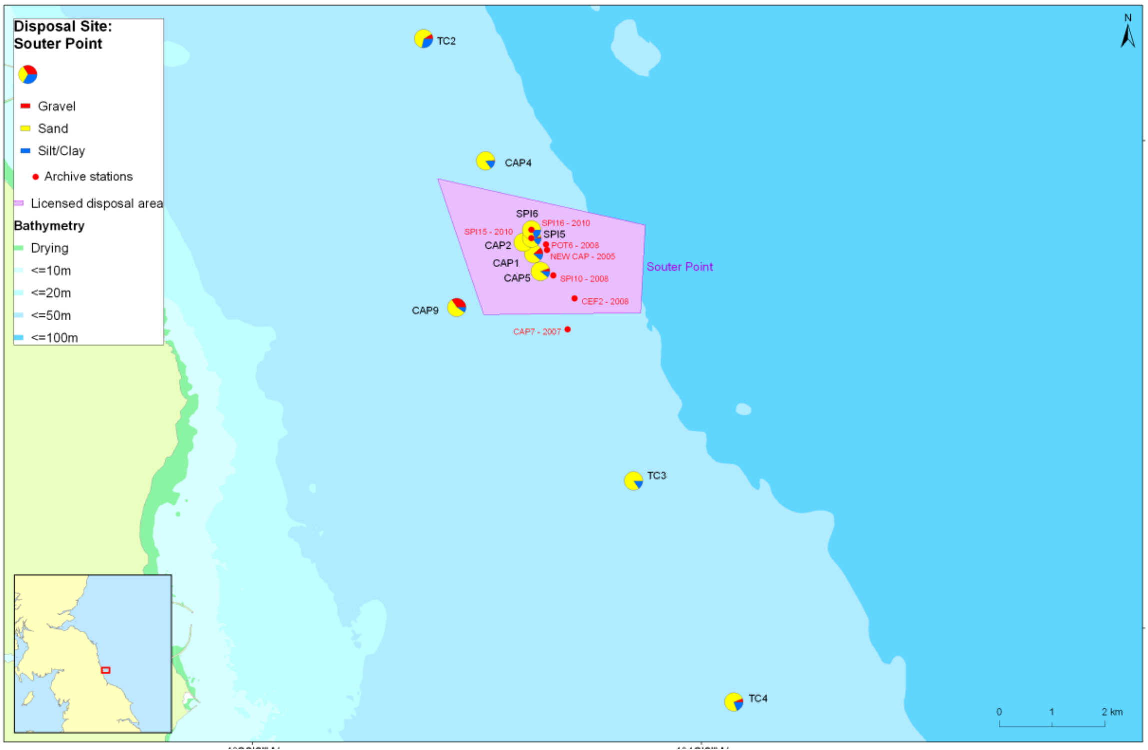


Figure A2.2.6. Pie charts of gravel, sand and silt/clay at Souter Point, 2010.

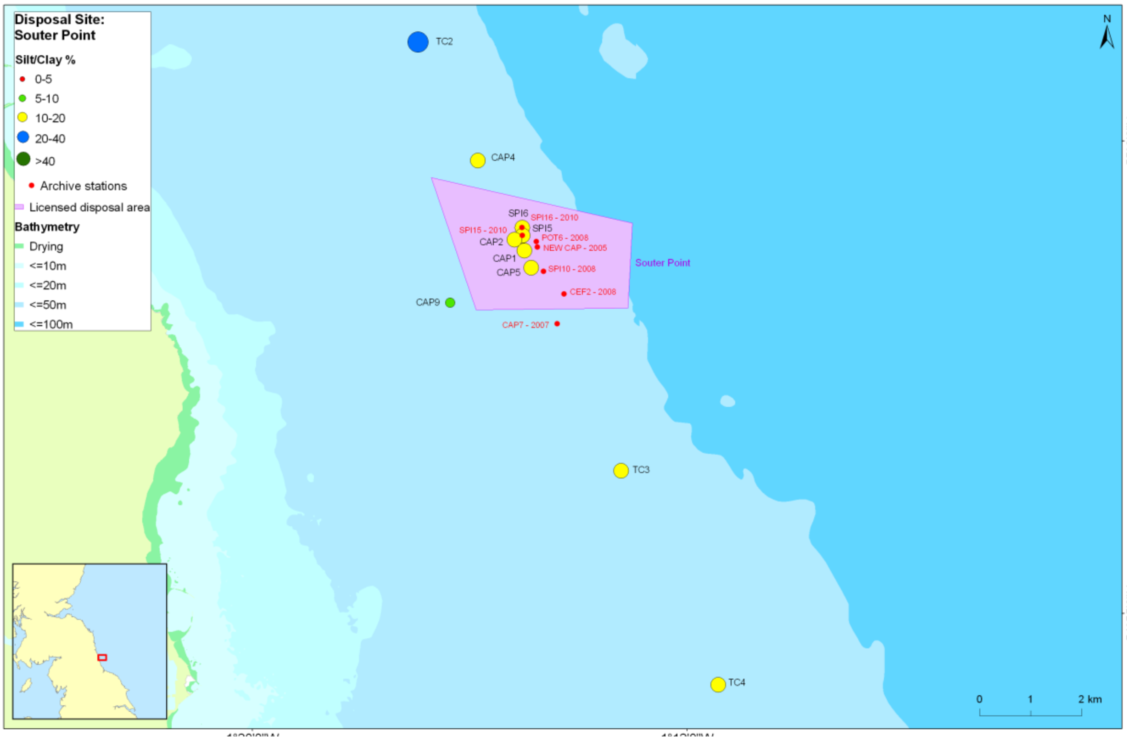


Figure A2.2.7. Silt/clay (%) at Souter Point, 2010.

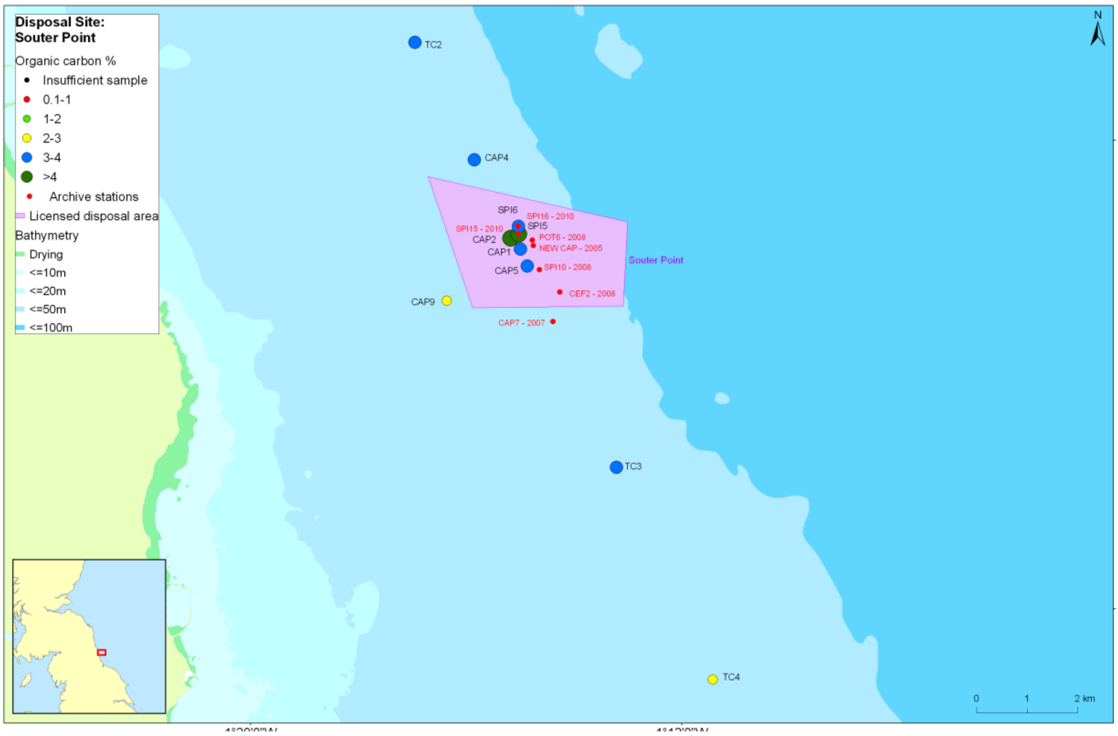


Figure A2.2.8. Organic carbon (%m/m) in the silt/clay fraction (<63µm) at Souter Point, 2010.

2.2.4.3 Sediment organic carbon and nitrogen

Sediment organic carbon values (in the <63µm sediment fraction) in 2010 range from 2.6 to 4.2% m/m (Figure A2.2.8) and 0.2 to 0.3% m/m for nitrogen. These are similar to those obtained between 2006 and 2009 (Bolam et al., 2009; 2011). CAP9, outside and to the west of the disposal site, has higher levels of organic carbon (7.3% m/m compared with 2.6% m/m) present in the <2mm fraction than the <63µm fraction, showing that a significant proportion of the organic carbon for this area is present in coarser sediment, possibly as coal.

2.2.4.4 Macrofaunal communities

Macrofaunal analysis identified a total of 2489 individuals and 61 taxa at Souter Point from the samples taken during 2010. The main taxonomic groups were represented by Annelida (59%), Mollusca (21%), Miscellanea (7%), Echinodermata (8%), and Crustaceans (5%) (Figure A2.2.9).

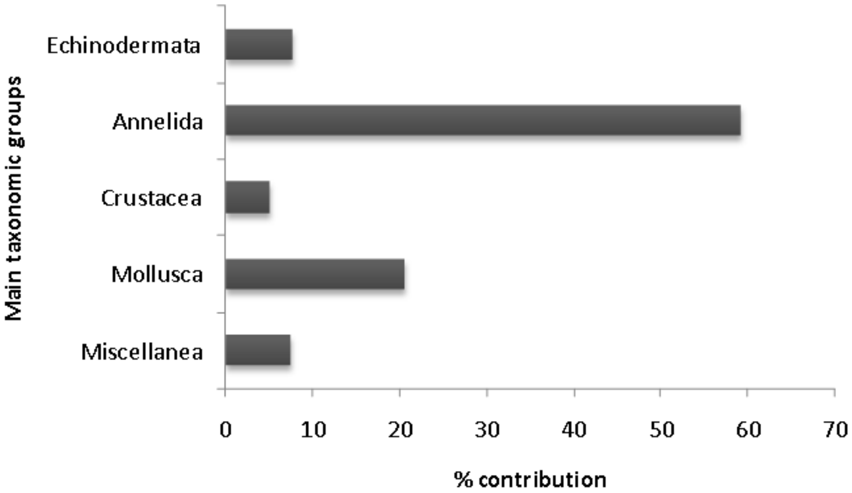


Figure A2.2.9. Percentage numerical contributions of the main taxonomic groups sampled at Souter Point, 2010.

The total abundance of individuals fluctuated from 151 to 262 per 0.1 m^2 across the study area in 2010. Although some stations (e.g., CAP4, TC02, CAP9) showed significantly higher total abundances than some other stations, many stations from within and outside the disposal site exhibited comparable numbers of individuals, between 150 and 180 per 0.1m^{-2} (Figure A2.2.10a). Although total number of species was higher at CAP04, most stations possessed comparable numbers of species (Figure A2.2.10b). Total biomass was observed to be in the order of 2 to 13 g / 0.1 m^2 (ww) in the area. Higher biomass values were recorded at stations SPI05, Cap2 and TC4 (13.4, 10.0 and 9.2 g / 0.1 m^2 (ww) respectively) (Figure

A2.2.10c). The species responsible for the higher biomass were *Echinocardium cordatum, Turritella communis, Chamelea striatula and Atelecyclus rotundatus.*

Multivariate analyses showed some separation of stations located in the centre of the disposal site (Cap1, Cap2, Cap5 and SPI05), immediately outside the disposal site (Cap4, Cap9 and TC3) and the north and some of the south reference stations (TC2 and TC4) (Figure A2.2.11). This general observation regarding the spatial variability in macrofaunal community structure is comparable to that reached based on the 2009 macrofaunal data (see Figure A2.2.10 in Bolam et al., 2011).

SIMPER analysis also evidenced the species that were causing the dissimilarity over the disposal site and reference stations during 2010. The average dissimilarity between the disposal site and northern reference accounted for 54.43 %, from which the species responsible were *Peresiella clymenoides*, *Thyasira polygona*, *Ampharete falcata, Maera loveni*, *Magelona alleni, Amphictene auricoma* and *Rhodine gracilior* (these species contributed to 11.34 % of overall group dissimilarity).

Comparisons between the dissimilarity observed between the disposal site and south reference showed the highest group dissimilarity with 51.68%, the species responsible were: *Peresiella clymenoides*, *Terebellides stroemi*, *Trichobranchus roseus*, *Turritella communis*, *Cylichna cylindracea*, *Kurtiella bidentata*, Ophiuridae (juv.), *Gari fervensis* (juv.) and *Rhodine gracilior* (these species contributed to 10.48% of the overall group dissimilarity).

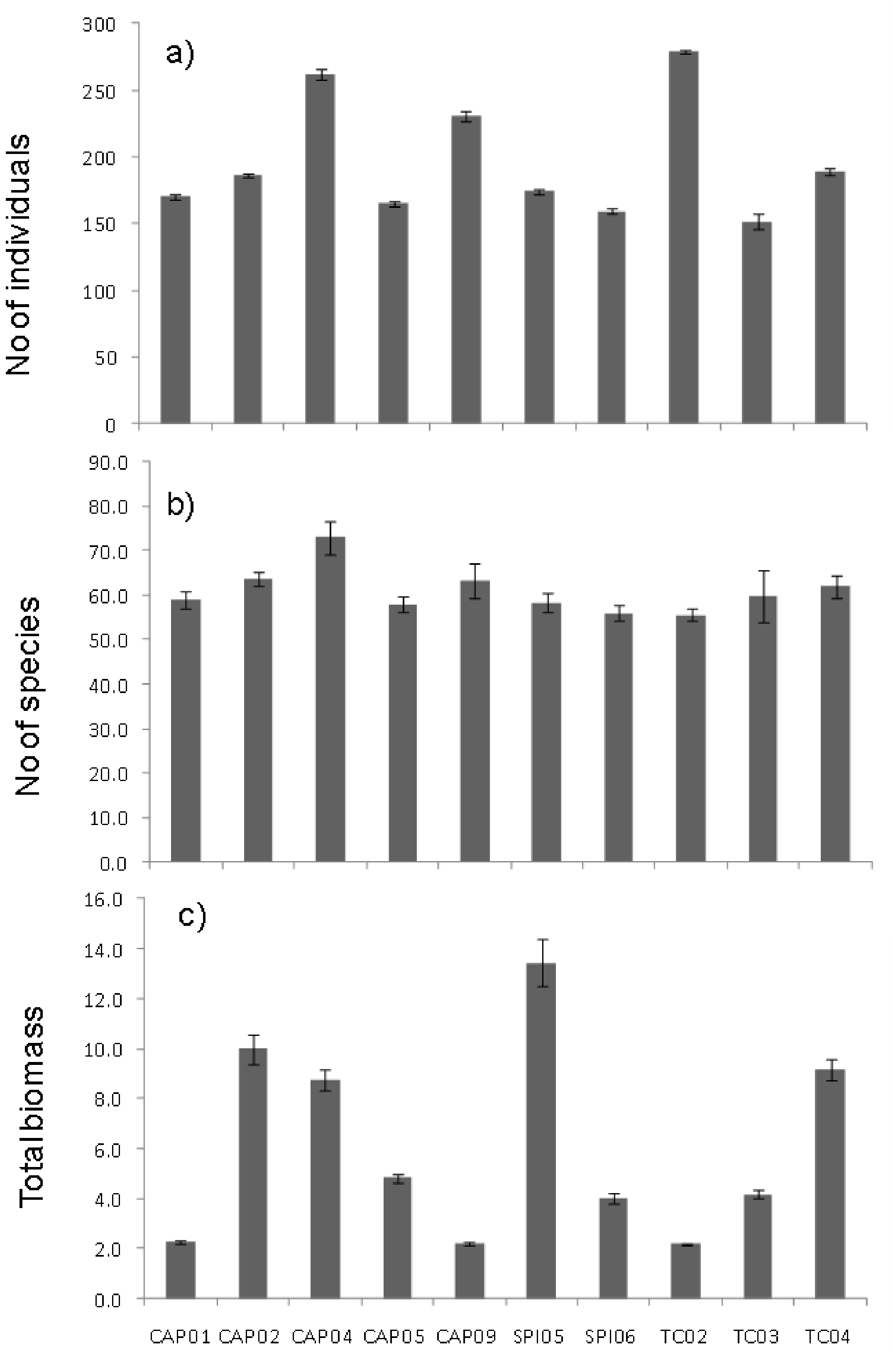


Figure A2.2.10(a-c). Mean values (n=3) per 0.1 m^2 for a) total number of individuals, b) total number of taxa and c) total biomass for Souter Point, 2010.

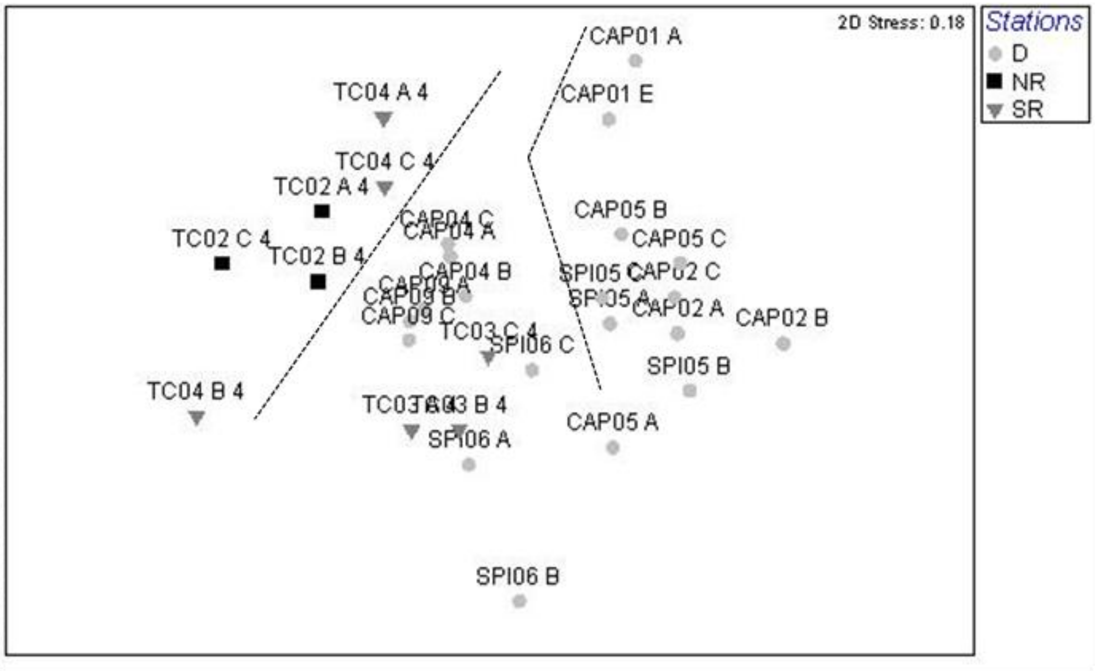


Figure A2.2.11. Multidimensional scaling ordination (based on Bray-Curtis similarity of abundance data following a fourth-root transformation) for macrofauna at Souter Point, 2010.

2.2.4.5 Sediment Profiling Imaging (SPI)

The SPI images obtained during the May 2010 survey confirmed the presence of fauna present at the stations located in the centre of the disposal site (Figure A2.2.12a-b). The SPI penetration at station Cap1 was limited due to the compacted nature of the sediment layers. In contrast, at Cap2 and SPI5 (also in the centre of the disposal site) there was also an indication of a layer of dredged material with a very thin layer of silt and sand (Figure A2.2.12b). There was clear evidence of the presence of benthic organisms at stations in the centre of the disposal site (e.g. Cap1, Cap2 and SPI5), these stations showed signs of initial colonisation. Surface infauna (e.g. polychaete tubes), infauna and burrows were observed in the SPI images collected (Figure A2.2.12a-c).

Data collected at northern stations further away from the centre (TC2) showed the presence of fine sediments, surface fauna, burrow and feeding voids (Figure A2.2.12d). Stations located further south from the disposal site (e.g. TC3 and TC4, Figure A2.2.12e-f) showed the presence of surface fauna, feeding voids, burrows and broken shells, which are indicative of infaunal activity at these stations. The aRPD measured at these stations ranged between were 3.5 and 4.5 cm, and showed signs of biological activity. At the stations located further south the presence of deep burrowing polychaetes and feeding voids represented a mature benthic community (stage II - III) (Rhoads & Germano, 1990).

The overall aRPD calculation ranged from 3.3 to 4.8 cm over the sampling time (Figure A2.2.12a-f), which demonstrated some biological activity and much shallower aRPD layers in the disposal site when compared to deeper aRPD layers and active fauna at the stations located north and south of the disposal area.

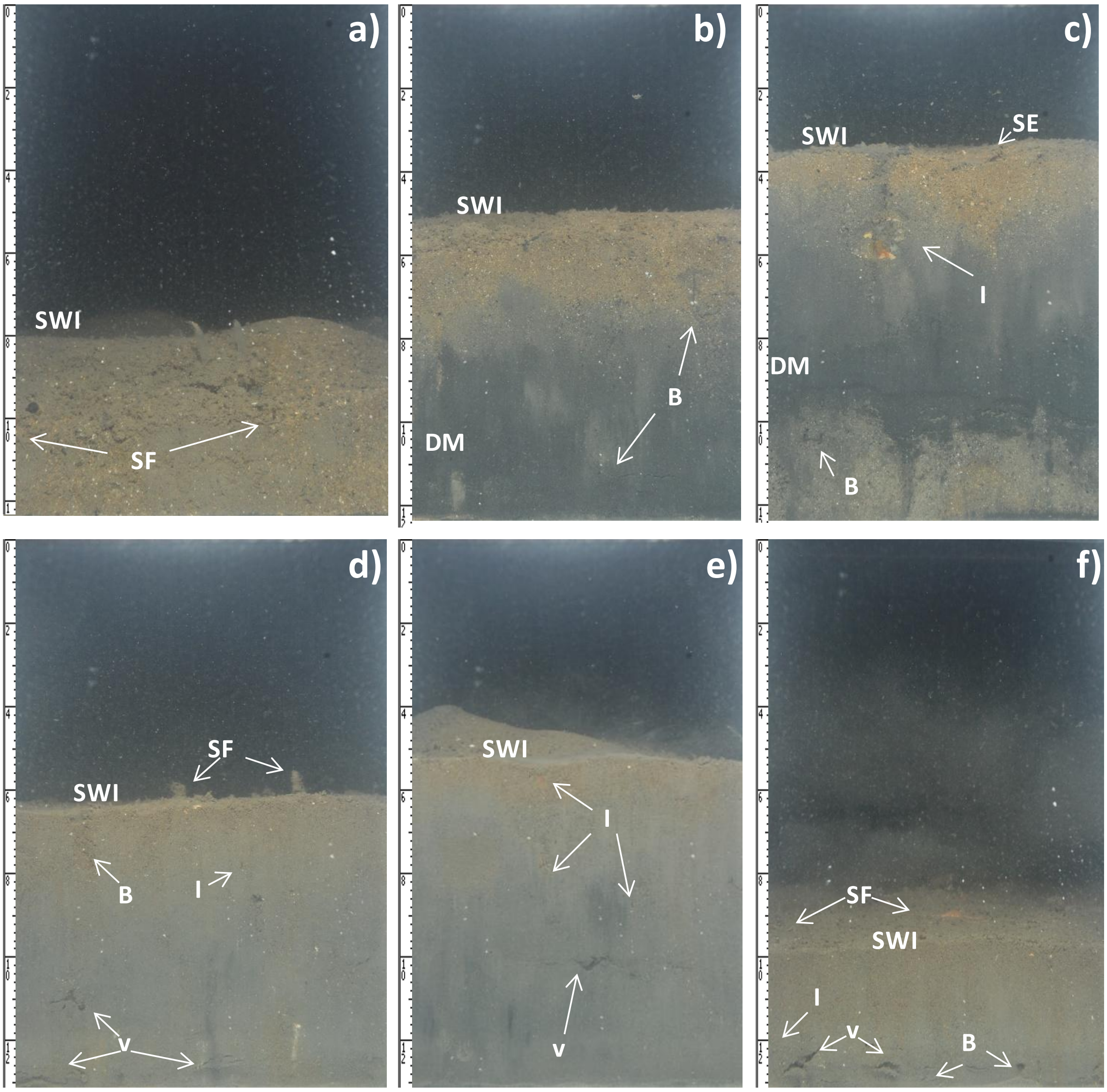


Figure A2.2.12a-f. Sediment profile images (SPI) collected at Souter point disposal site, stations; a) Cap1, b) Cap2, c) SPI5, d) TC2, e) TC3 and f) TC4. SWI=sediment water interface, DM=contaminated dredged material, SF=surface fauna, I=infaunal polychaete, ARPD=apparent redox discontinuity layer, v=void and B= burrows. Scales on left-hand side are 2 cm intervals.

2.2.4.6 Sediment contaminants

2.2.4.6.1 TBT

Samples were collected at 10 stations at the Souter point disposal site, as well as individual depth slices from the NIOZ cores for TBT depth profiling. Of the surficial samples derived from the grabs, only Cap 4 exhibited a detectable level of TBT in 2010 (0.04 mg/kg), a slight increase from 2009 (Bolam et al., 2011). However, a similar level of TBT was detected in the 2008 survey (0.06mg/kg) (Bolam et al., 2009); both these are below Cefas AL1. Both TBT and DBT were <LOD at Cap 1 and Cap 2 in 2010, a slight decrease at both stations from 2009. The organotins results were <LOD (hence below AL1) for all other stations that were sampled and analysed in the 2010 survey.

Temporal trends show consistent results below LOD for Cap 5, Cap 9, TC2, TC3 and TC4 from 2005 to 2010 at the surface samples. The total loading of TBT (either from capital or maintenance dredging) has remained constant over the last 2 years.

Overall, there was a small decrease in DBT and TBT concentrations, however, the findings are very similar to previous year's in terms of their general concentrations.

In addition to the (above) grab survey data, NIOZ cores were used to ascertain the depth profiles of TBT at a number of stations within and outside the capping area. Core photos and TBT core profiles for CAP 2 and CAP 5 over the 3 year period (2008-2010) are displayed in Figures 2.2.13 and 2.2.14 respectively. Although a detailed study of particle size analysis of those cores is yet to be completed, we can observe from the preliminary photos that the visually-discernable layers of the cores tend to correspond with the TBT depth profile, i.e., lower TBT at coarser layer and more elevated TBT for fined-sediment layer. This was also found to be the case in previous years (Bolam et al., 2011).

At CAP2, concentrations throughout the core profile increased with depth, exhibiting a TBT concentration of 0.27mg/kg for the bottom layer (22-27cm). The concentration is above AL1 but remains below AL2. Compared with 2008 and 2009, this shows an increase in TBT at a comparable depth.

At CAP5, when comparing with the previous year's data, a clear decline in TBT concentrations is observed, particularly in the lower layer of the core. All TBT results for CAP5 profile are below AL1, with the bottom layer (20-23cm) recording a concentration of 0.085mg/kg of TBT. The low TBT concentration from the core suggests that the contaminated dredged material (CDM) was not present at 20cm depth, which might indicate that the thickness of the cap could be greater than 20cm. Visual observation of the core profile depicts differences in sedimentology/granulometry between 2009 and 2010 cores. While the 2009 core layers at CAP5 were reasonably well delineated with alternated coarse and muddy layers, the 2010 core have less well defined layers, especially in the top 15 cm which appears to be mostly coarse grained sediment. This could explain the low levels of TBT that were recorded for the 2010 core.

In 2010, sediment profile samples were taken at SPI5 and SPI6 for the first time; the results are presented in Figures 2.2.15 and 2.2.16 respectively. The TBT profile at SPI5 peaked (just above 0.1 mg/kg) around 5cm depth to a level just above AL1 (Figure A2.2.15). As for CAP2, SPI5 shows layers of different granulometry which can be due to a number of factors (dymamics, storms, remobilisation and possible dredged material disposal etc). Similar to observations regarding CAP5, the low maxima of TBT concentration at SPI5 implies that the cap thickness is greater than 20cm.

In contrast, the core taken at SPI6 exhibits a more continuous/homogeneous granulometry with sediment depth; the majority being coarse-grained sediment (Figure A2.2.16). This might depict the top part of the cap (which is mostly sandy) resulting in the very low levels in TBT observed.

Acoustic data have shown that the cap has slightly moved north-westwards (see Section 2.2.4.1), the sandy sediments of the cap may have, therefore, been deposited around CAP5, making the cap sediment layer thicker here than previously (in 2009, the CDM was suspected to be present at 25cm depth due to very elevated TBT levels; see Bolam et al., 2011).

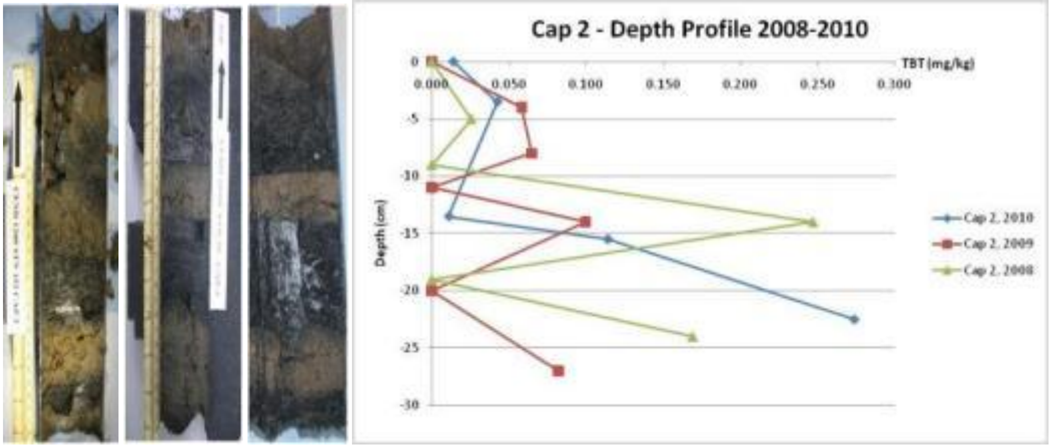


Figure A2.2.13. Cap 2. Core photos (2008-2010 left to right) and TBT depth profile.

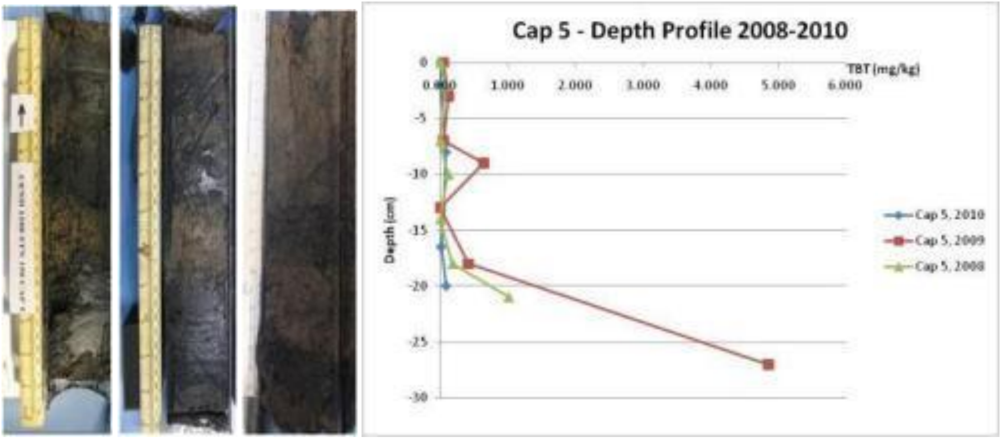


Figure A2.2.14. Cap 5. Core photos (2008-2010 left to right) and TBT depth profile.

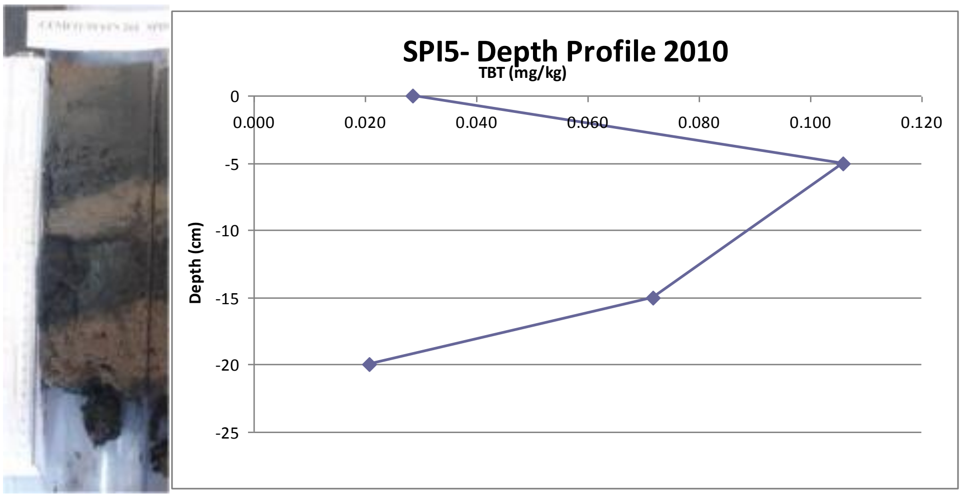


Figure A2.2.15. SPI5. Core photo and TBT depth profile in 2010.

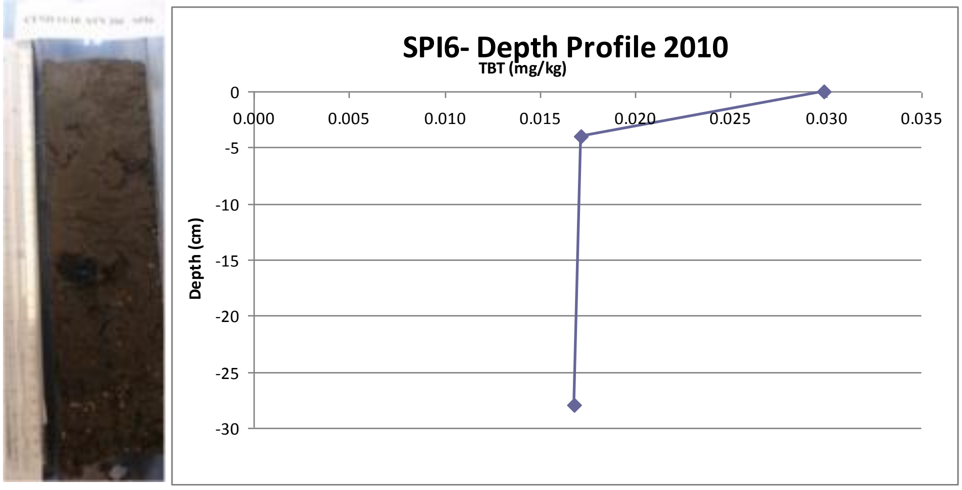


Figure A2.2.16. SPI6. Core photo and TBT depth profile in 2010.

2.2.4.6.2 PAHs

The highest summed PAH concentrations found during the Souter Point survey were found at CAP9 (50,600 µg kg^{-1} dw); just outside the southwest boundary of the disposal site (Figure A2.2.17). This was similar to the concentration observed here 2009 (54,300 µg kg^{-1} dw; Bolam et al., 2011). In 2009, the highest concentrations were found at CAP5 (67,200 µg kg^{-1} dw) and at CAP1 (62,000 µg kg^{-1} dw), both of which are located within the disposal ground. In 2010, PAH concentrations at these two stations were significantly lower (4,190 and 23,400 µg kg^{-1} dw respectively). One possible explanation for the marked change in concentration found this year could be a change in sediment granulometry; these stations show a decrease in silt/clay content in 2010 which may explain the decreased concentrations of PAHs. Summed PAH concentrations have remained generally similar to the previous year at the other sampling stations, with the lowest values found at TC3 (south reference station), southeast of the disposal ground (8,000 µg kg^{-1} dw).

All sampling stations were found to exceed the ERL for LMW PAHs with the ERM for LMW PAHs being exceeded at CAP4, CAP5 and CAP9. The ERL for the HMW PAH was breached at CAP2, CAP4, SP15 and CAP9, which are all situated on or close to the disposal site. No station exceeded the ERM for the HMW PAHs; in 2009 this was breached at CAP5. The Tyne Estuary was shown to have high levels of PAH in its sediments during an earlier survey (Woodhead et al., 1999). Evaluation of the PAH data indicate that the source in all of the sediment samples was predominantly petrogenic, generally with > 80% of the PAH content arising from oil sources.

Trends in summed PAH concentrations with depth in sediment cores varies with location. At CAP2 and SP15, just to the north of the centre of the disposal site, the concentration of summed PAHs increases with depth to approximately 20cm, below which there is a decrease in concentration. At CAP1, in the centre of the disposal site, the surface concentration is low, with higher and similar concentrations at 5-11 cm and 11-16 cm depth (Figure A2.2.18). At SP16, also within the disposal site, concentrations increase with depth. Evaluation of the PAH data indicate that the sources in all the core sediment samples were predominantly petrogenic, generally with > 80% of the PAH content being oil-derived.

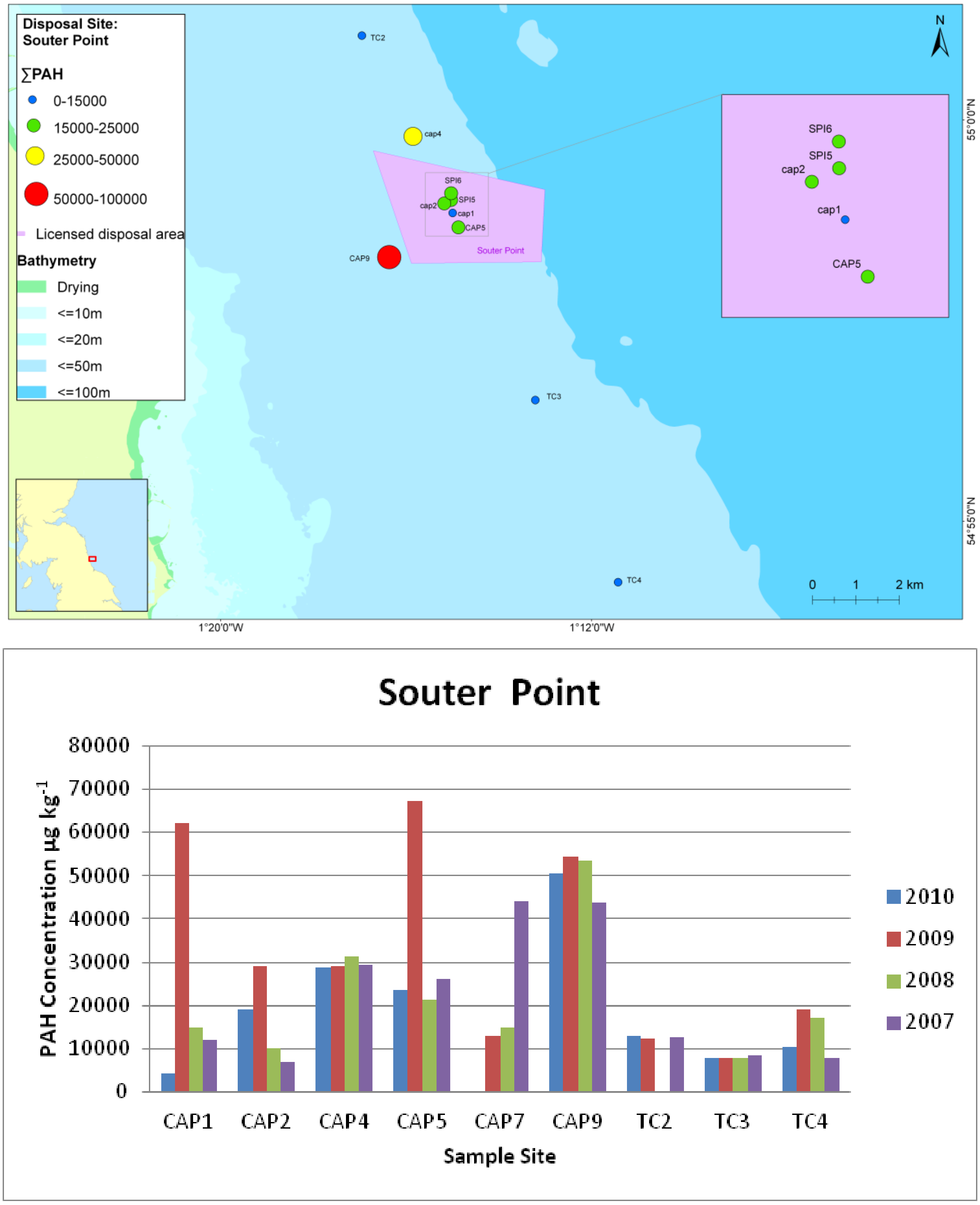


Figure A2.2.17. Summed PAH concentrations (µg kg-1) for stations sampled in 2010 at Souter Point (top) and concentrations observed during 2007, 2008 2009 and 2010 (bottom).

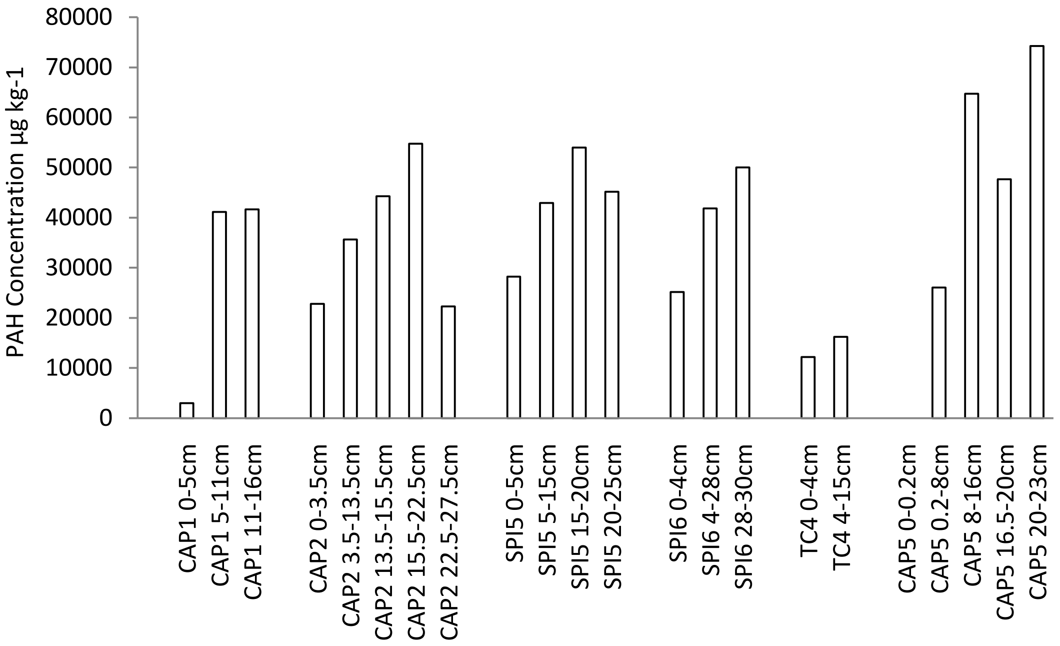


Figure A2.2.18. Total PAH concentrations at various sediment depths for stations sampled with the NIOZ core, Souter Point, 2010.

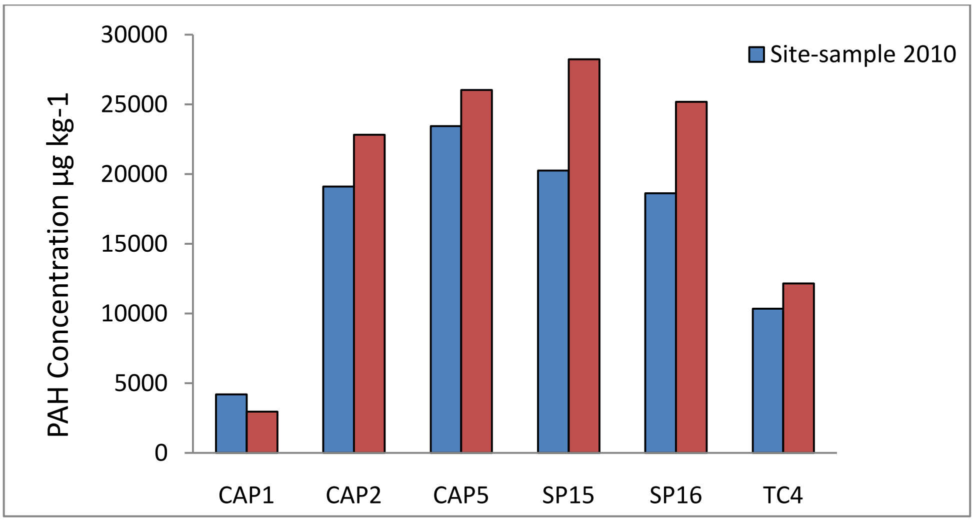


Figure A2.2.19. Comparisons of total PAH concentration from samples obtained by grabs and those surface slices obtained from NIOZ cores, Souter Point, 2010.

Concentrations obtained from the grab samples are generally found to be slightly lower than those observed in the surface slices from the cores, with the exception of CAP1 (Figure A2.2.19). Surface sediment samples from grabs are taken to a depth of approximately 2 cm, whilst the depth of the core surface slices varies from 0.2 to 5 cm, so the two sets of samples are not directly comparable. Furthermore, unlike the latter, samples from the grabs represent the top 2 cm of sediment regardless of the presence (or lack) of any discernible layers that may be present. Consequently, these two sample types are unlikely to give comparable values as grab samples may represent a combination of different depth concentrations.

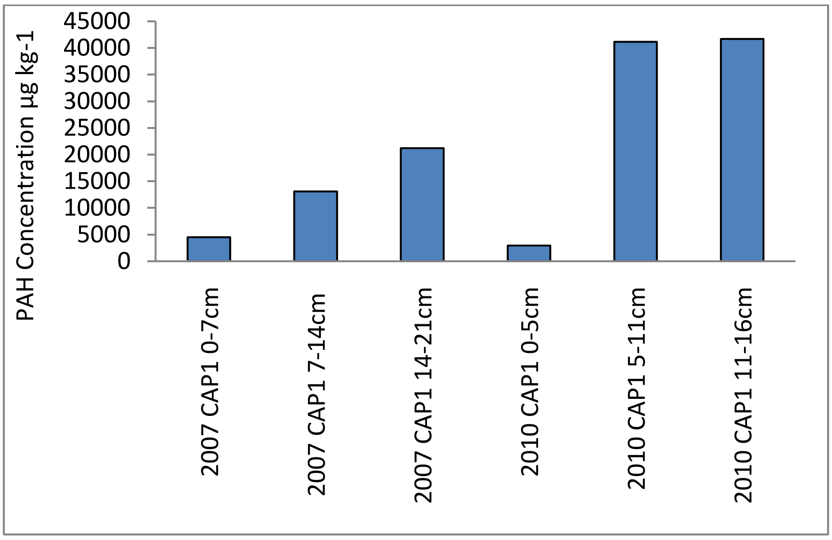


Figure A2.2.20. Concentrations of total PAHs at depth for CAP1 in 2007 and 2010, Souter Point.

CAP1 showed the lowest surface sediment concentrations found in the cores (Figure A2.2.18). In 2007, surface concentrations for summed PAHs were 4,470 µg kg^{-1} dw, whilst in 2010 a slightly lower concentration of 2,970 µg kg^{-1} was observed (Figure A2.2.20). This could be an indication that there has been no breach of the cap. Concentrations found in the deeper portions of the cores were found to be much higher in 2010, ca 40,000 µg kg^{-1} dw in slices from both 5-11cm and 11-16cm, whereas in 2007 the concentrations were more directly correlated with depth.

In 2007, the summed PAH concentrations in the surface slices of the core at CAP2 was 26,800 µg kg^{-1} dw, similar to that seen in 2010 (22,800 µg kg^{-1} dw) (Figure A2.2.21). This may also suggest that there has been no breach of the cap. The cores were sliced at slightly different intervals making it difficult for direct comparisons to be made. However, the maximum observed concentrations remained very similar, with summed PAH concentrations in 2007 at 11.5-17.5cm found to be 57,900 µg kg^{-1} dw and in 2010 at 15.5-22.5cm found to be 54,800 µg kg^{-1} dw. The lowest concentrations in the 2010 core were found both at the surface (0-3.5 cm) and at the base of the core sample (22.5-27.5 cm), both ca 20,000 µgkg^{-1} dw. No sample was collected below 21.5 cm depth in 2007.

At CAP5 the cores were sliced at slightly different intervals making it difficult for direct comparison. Surface concentrations in the 2010 core sample were lower than in 2007, with a summed PAH concentration of 26,000 µg kg^{-1} dw in 2010 compared to 48,200 µg kg^{-1} dw in

2007. Again, this may suggest that there has been no breach of the cap. The maximum observed PAH concentrations remain very similar, with a summed PAH concentrations at the bottom of the core in 2007 of 71,800 µg kg^{-1} dw, and of 74,200 µg kg^{-1} dw at 20-23 cm depth in 2010.

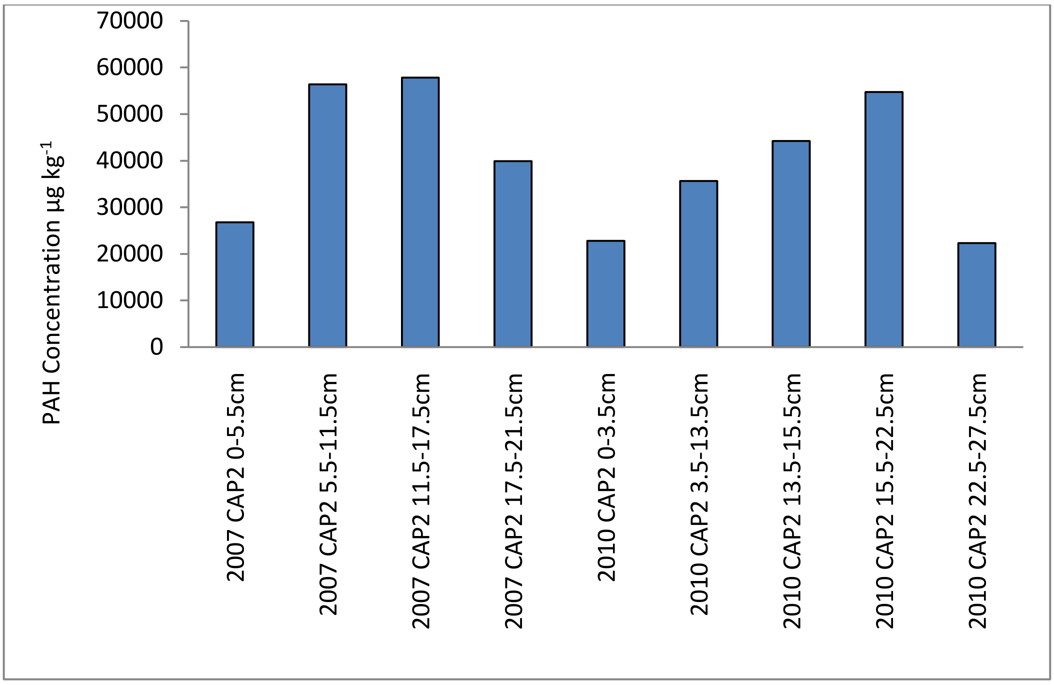


Figure A2.2.21.. Concentrations of total PAHs at depth for CAP2 in 2007 and 2010, Souter Point.

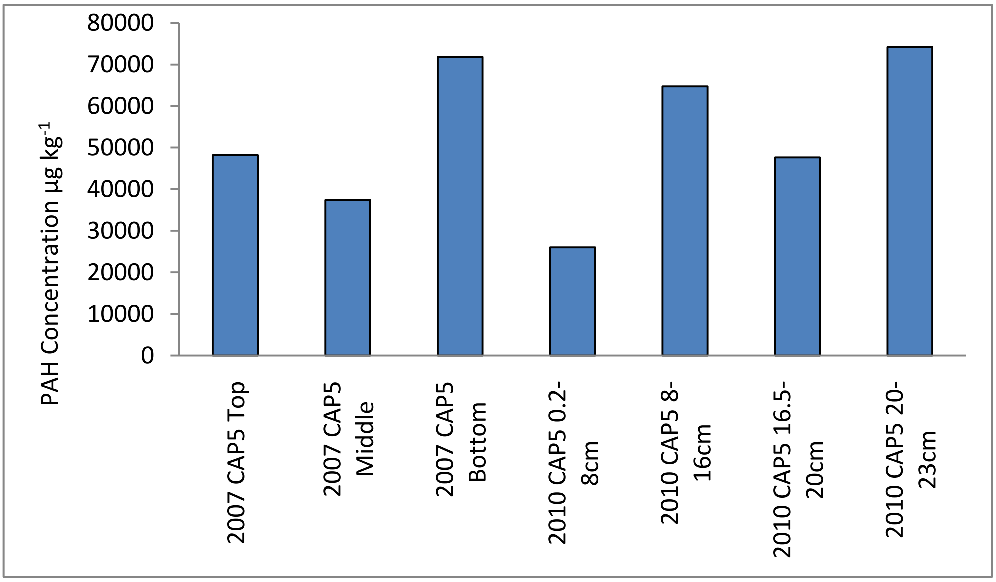


Figure A2.2.22. Concentrations of total PAHs at depth for CAP5 in 2007 and 2010, Souter Point.

2.2.4.6.3 Organohalogens

CBs were detected at all stations sampled at Souter Point except for CAP1 and TC3 (∑ICES7 CBs range <0.7-56 µg/kg dw) (Figure A2.2.23). Concentrations of CBs were generally lower to the south of the disposal site and at CAP1 and CAP5 within the disposal site. Slightly higher ∑ICES 7 concentrations of 1.5 and 3.1 µg/kg dw were found at CAP4 and CAP9 to the north and west of the disposal site respectively. The highest ∑ICES 7 CBs concentrations were found within the disposal site, with 3.0 µg/kg dw found at CAP2 and 56.0 and 3.6 µg/kg dw at the newly-sampled SPI15 and SPI16, respectively. The high concentration at SPI15 was much greater than that observed by all other samples taken from within the Tyne area.

BDEs were detected at all stations (∑11 BDEs range 0.28-2.8 µg/kg dw) (Figure A2.2.24). The highest concentration was found at SPI16 within the disposal site. Similarly to CBs, concentrations of BDEs were also lowest at stations CAP1 and CAP5 within the disposal site, with concentrations of 0.28 and 0.88 µg/kg dw, respectively. Thus, there appears to be a high degree of spatial variability in BDE concentrations in surface sediments within the disposal site boundary. Higher ∑11 BDE concentrations of 1.5 and 1.4 µg/kg dw were found at TC3 and TC4 to the south of the disposal site respectively and of 1.2 and 1.3 µg/kg dw at CAP2 and SPI15 within the disposal site. Slightly higher ∑11 BDE concentrations of 1.9 and 2.2 µg/kg dw were found at CAP9 and TC2 to the west and north of the disposal site. BDE47 and BDE99 are the dominant congeners present, indicative of the pentaBDE technical mixture, but BDE183 was also detected, suggesting that the octaBDE or decaBDE technical mixture had also been in use.

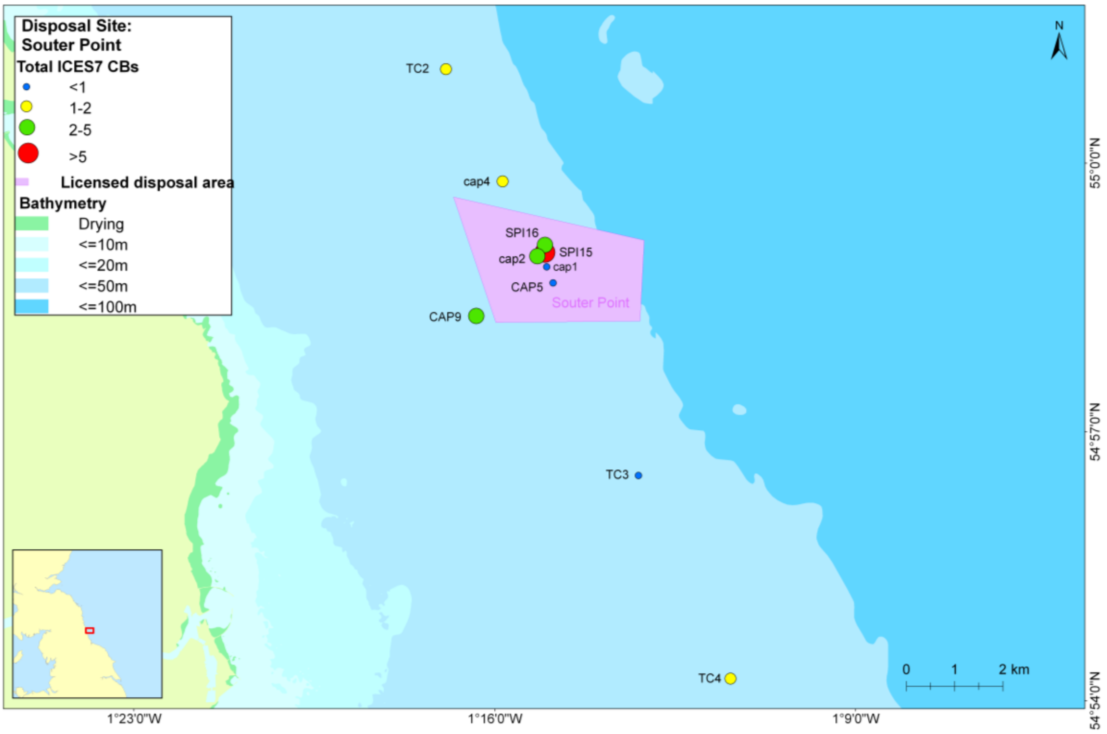


Figure A2.2.23. ∑ ICES7 CB concentrations for the Souter Point Stations, 2010.

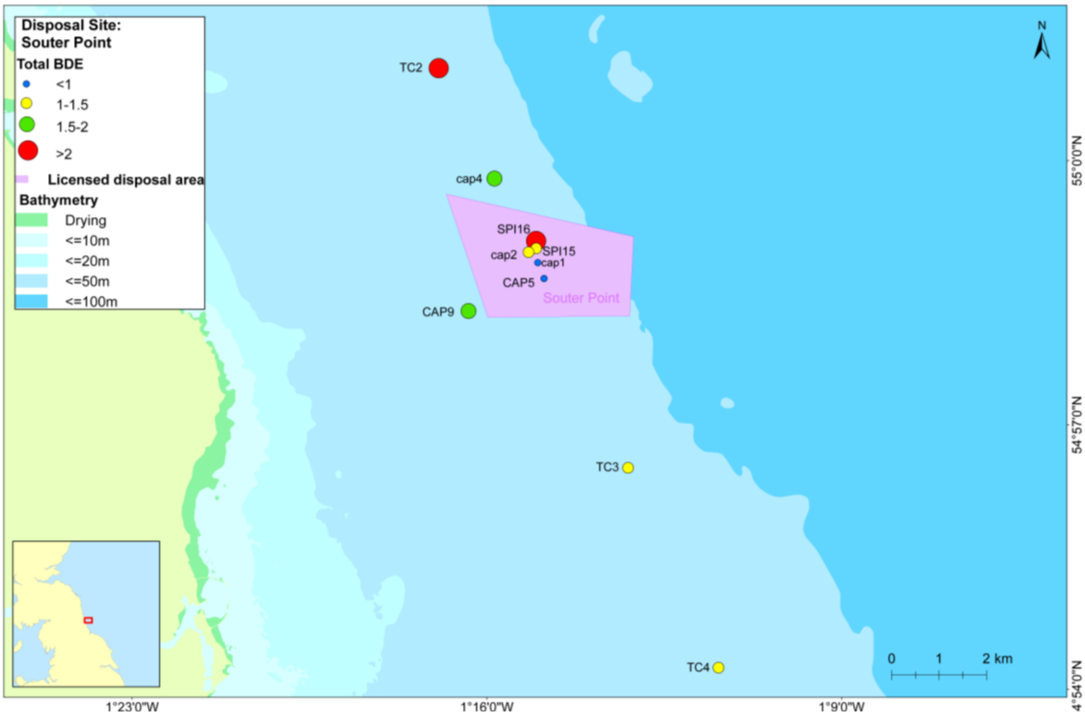


Figure A2.2.24. ∑ 11 BDE concentrations for the Souter Point Stations, 2010.

BDE209 was detected at all stations and was at higher concentrations than the other measured organohalogens (range 0.89-28 µg/kg dw). When included with the other BDEs, BDE209 made up >75% of the BDEs present. BDE209 is indicative of the decaBDE technical mixture, which had been in use more recently than the other technical mixtures, although it's use has been restricted in the EU since 2008. The highest concentration of 28.0 µg/kg dw was detected at SPI16 within the disposal site (Figure A2.2.25). Moderately high concentrations of 13.0 and 18.0 µg/kg dw were present at stations TC4 and CAP2; south of and within the disposal site, respectively. Other stations were all in the range 3.8-7.6 µg/kg dw, with the exception of CAP1, with a concentration of 0.89 µg/kg dw.

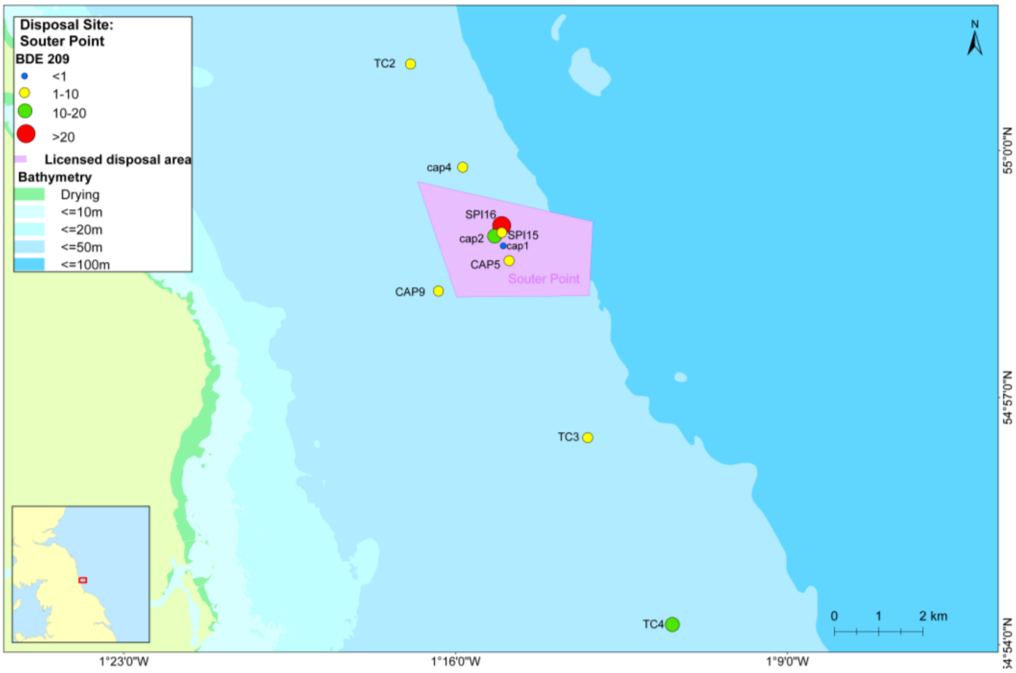


Figure A2.2.25. BDE209 concentrations for the Souter Point Stations, 2010.

OCs were present at low concentrations < 1.0 µg/kg dw when detected. HCHs were below LODs at all stations. Exceptions were DDTs which were higher at CAP2, CAP9 and SPI16 inside or close to the disposal site and TC3 to the south (Figure A2.2.26). ∑ DDT concentrations of 11.0, 4.1, 2.1 and 2.0 µg/kg dw were found at these respective stations. Unlike North Tyne stations, *p,p'*-DDT was detected at the stations inside the Souter Point disposal site, at CAP9 to the west and TC3 to the south, indicating that dredged material with a more recent source of DDT had been disposed.

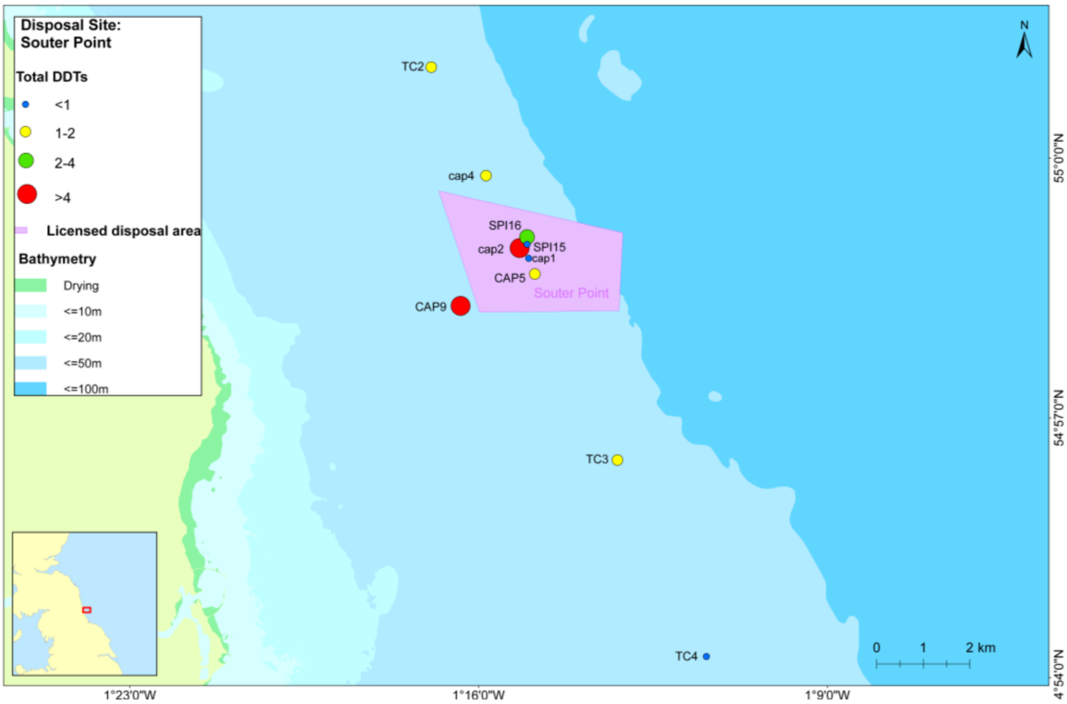


Figure A2.2.26. ∑ DDTs concentrations for the Souter Point Stations, 2010.

Concentrations of CBs at most surface stations were below Cefas AL1, except for SPI15 which was above AL1 but below AL2. Concentrations of CBs in most NIOZ core layers were below Cefas ALs, except for the 8-16.5 cm layer at CAP5 which was above AL1 but below AL2. Concentrations of OCs at CAP2, CAP4, CAP5, CAP9, SPI16, TC2 and TC3 were above Cefas AL1, as were many core slices. There is no Cefas AL2 for DDTs and no Cefas ALs exist for BDEs. According to the OSPAR guidelines, most stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall. Exceptions were SPI16 which had CB118 with ‘bad’ environmental status but with ‘good’ status overall, and SPI15 which had CBs 101, 118 and 153 with ‘bad’ environmental status and therefore ‘bad’ status overall. No OSPAR guidelines exist for BDEs and OCs at present.

The majority of stations sampled for organohalogens in 2010 at Souter Point have been sampled for a number of years under the auspices of SLAB5 monitoring. As such, the available data allow a comprehensive assessment of the temporal changes in resulting concentrations for this region. In 2010, ICES 7 concentrations were either similar to previous years, or display large decreases; by a factor of 2 at CAP4 and a factor of 3 at CAP2, for example (Table A2.2.3).

Station code	**∑ICES 7 CBs concentration (in µg/kg dw)**					
	2005	**2006**	**2007**	**2008**	**2009**	**2010**
TC2		6.2	2.58		1.54	1.47
CAP4	3.7	3.6	2.35	3.39	3.11	1.50
CAP2	0.83	1.01	*0.7*	*0.7*	7.23	2.96
CAP2 (subsurface mud)	8.24	10.1				
CAP2 (0-5.5 cm, sand)			2.67			
CAP2 (5.5-11.5 cm, muddy sand)			5.22			
CAP2 (11.5-17.5 cm, sand)			27.4			
CAP2 (17.5-21.5 cm, black mud)			22.1			
CAP1	1.1	0.84	*0.7*	0.96	1.88	*0.7*
CAP1 (0-7 cm, sand)			*0.7*			
CAP1 (7-14 cm, sand)			11.2			
CAP1 (14-21 cm, sand)			25.3			
CAP5	1.1	0.86	0.7	3.22	1.11	0.8
CAP5 (surface)			5.15			
CAP5 (middle)			2.91			
CAP5 (bottom)			8.82			
CAP9	4.97	2.91	2	2.84	3.25	3.13
CAP7	1.34	1.12	2.23	1.51	1.24	
TC3	0.96	1.19	*0.7*	*0.7*	0.96	*0.7*
TC4	1.17	1.14	*0.7*	2.62	1.3	1.09
SPI15						56.0
SPI16						3.61

Table A2.2.3. Temporal trends (2005-2010) of ∑ICES 7 CBs concentration (in µg/kg dw) at Souter Point in the stations sampled during 2010. Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs.

There were no clear temporal trends for BDEs. Total concentrations of these compounds at TC2, CAP4, CAP5, TC3 and TC4 have increased since 2009 whilst concentrations at CAP2 and CAP1 have decreased. However, levels were lower than the highest values detected in the period 2005-07 (Table A2.2.4).

Station code	**∑11 BDEs concentration (in µg/kg dw)**					
	2005	**2006**	**2007**	**2008**	**2009**	**2010**
TC2	3.95	8.30	2.94		1.36	2.16
CAP4	5.84	2.15	2.57	1.37	1.18	1.95
CAP2	1.11	1.01	0.79	0.41	1.55	1.24
CAP2 (subsurface mud)	9.76	16.7				
CAP2 (0-5.5 cm, sand)			4.18			
CAP2 (5.5-11.5 cm, muddy sand)			7.30			
CAP2 (11.5-17.5 cm, sand)			4.71			
CAP2 (17.5-21.5 cm, black mud)			1.48			
CAP1	0.83	0.80	0.96	0.26	0.62	0.28
CAP1 (0-7 cm, sand)			*0.69*			
CAP1 (7-14 cm, sand)			*0.69*			
CAP1 (14-21 cm, sand)			*0.69*			
CAP5	1.13	1.07	0.91	0.41	0.54	0.88
CAP5 (surface)			4.08			
CAP5 (middle)			59.6			
CAP5 (bottom)			14.1			
CAP9	3.77	12.6	5.92	1.02	1.92	1.95
CAP7	1.94	2.37	3.96	0.85	0.80	
TC3	1.45	5.96	1.36	0.55	0.73	1.45
TC4	1.78	8.59	1.51	0.82	0.86	1.34
SPI15						1.28
SPI16						2.75

Table A2.2.4. Temporal trends (2005-2010) of ∑11 BDEs concentration (in µg/kg dw) at Souter Point in the stations sampled during 2010. Note, concentrations in italic represent estimates of concentrations for samples where all 11 BDE congener concentrations were below LODs. Limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower from 2008 onwards, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs.

In addition to the analysis of 2010 samples for BDE209, sample extracts from 2008 and 2009 were retrospectively analysed, giving some temporal information. Of those stations showing the highest BDE209 concentration in 2009 (e.g., TC2, CAP2, CAP5, CAP9), their concentrations in 2010 were all lower (Table A2.2.5). CAP4, which possessed relatively average concentrations of BDE209 in 2008 and 2009 (3.3 – 3.9 µg/kg dw) showed approximately 100% increases in 2010.

Station code	**BDE209 concentration (in µg/kg dw)**		
	2008	**2009**	**2010**
TC2		9.00	6.68
CAP4	3.37	3.88	7.63
CAP2	0.90	49.2	17.8
CAP1	0.77	7.49	0.89
CAP5	2.75	12.0	3.79
CAP9	4.08	13.6	5.08
CAP7	3.72	3.92	
SPI15			4.08
SPI16			28.4
CEF2	4.48		
SPI10	12.3		
POT6	14.4		

Table A2.2.5. Temporal trends (2008-2010) of BDE209 concentration (in µg/kg dw) at Souter Point in the stations sampled during 2010.

Station code	**∑DDTs concentration (in µg/kg dw)**				
	2005	**2006**	**2007**	**2008**	**2010**
TC2		1.1	1.05		1.03
CAP4	2.17	0.95	0.59	28.62	1.02
CAP2	2.08	0.56	0.63	0.57	10.52
CAP2 (subsurface mud)	9.3	6.1			
CAP2 (0-5.5 cm, sand)			2.03		
CAP2 (5.5-11.5 cm, muddy sand)			3.17		
CAP2 (11.5-17.5 cm, sand)			3.07		
CAP2 (17.5-21.5 cm, black mud)			1.12		
CAP1	1.52	0.49	0.59	0.54	*0.3*
CAP1 (0-7 cm, sand)			0.63		
CAP1 (7-14 cm, sand)			0.73		
CAP1 (14-21 cm, sand)			0.60		
CAP5	1.73	0.87	0.56	1.35	1.01
CAP5 (surface)			4.13		
CAP5 (middle)			1.19		
CAP5 (bottom)			4.7		
CAP9	2.42	1.55	1.69	1.1	4.1
CAP7	2.17	0.82	1.96	0.74	
TC3	2.13	1.18	0.82	*0.53*	1.95
TC4	2.46	1.11	0.77	1.79	0.8
SPI15					0.89
SPI16					2.08

Table A2.2.6. Temporal trends (2005-2010) of ∑DDTs concentration (in µg/kg dw) at Souter Point in the stations sampled during 2010.

Similarly, for DDTs, there were no clear temporal trends at Souter Point. In 2010 CAP2 and CAP9 had the highest concentrations over the whole time period (Table A2.2.6). In contrast, levels at CAP4 were much lower than was observed in 2008. Other stations had similar concentrations to recent years.

NIOZ cores collected at Souter Point stations in 2010 allow assessments of organohalogen sediment depth profiles. Levels at CAP1 were low at all depths for all contaminants, most being below LODs (Table A2.2.7). In all the other core samples, BDE209 was found at higher concentrations than the other contaminants, similar to the situation for surface (grab) samples discussed above. CAP2 had two more contaminated layers at depth, separated by a relatively 'clean' layer. The lower layer at 15.5-22.5cm had the highest concentrations. This pattern was found for all contaminants. Also, CAP5 possessed two more-contaminated layers at depth, separated by a relatively 'clean' layer. In contrast with CAP2, the highest concentration was not in the deeper layer, but at 8-16.5cm. At station SPI15, in the 4 sections of core, highest levels were found in the 3rd layer for BDEs and OCs, but in the 2nd layer for CBs. Concentrations of BDEs and BDE209 in the 3rd layer were the highest measured at Souter Point. At station SPI16, distribution of contaminants did not follow the same patterns. Highest BDE209 concentrations were found in the top layer, highest CB concentrations in the 2nd layer, and highest BDEs and DDTs concentrations in the 3rd layer. The reference station TC4 had higher concentrations of CBs, OCs and BDEs below the surface, apart from BDE209 which had lower concentrations, reflecting greater historical inputs for all but the more recently used BDE209.

To summarise, therefore, the analysis of various organohalogen concentrations with sediment depth provided equivocal conclusions regarding cap thickness as different organohalogen groups displayed different depth profiles at some stations. These results would indicate that none of the slices analysed represented the CDM at the cap site since the lowest layer was generally not the most contaminated for a particular station. This, however, assumes that the CDM placed in 2006 displayed organohalogen concentrations sufficiently elevated relative to both capping material and ongoing maintenance dredged material to allow these contaminants to act as indicators of this layer.

Station	**Core layer**	**Concentration (in µg/kg dw)**			
		∑ICES 7 CBs	**∑11 BDEs**	**BDE209**	**∑DDTs**
CAP2	0-3.5 cm	5.36	1.85	8.42	1.35
	3.5-13.5 cm	7.97	2.89	18.7	3.15
	13.5-15.5 cm	1.31	1.25	5.03	0.71
	15.5-22.5 cm	9.26	9.02	89.4	3.53
	22.5-27.5 cm	1.31	2.80	1.54	0.4
CAP1	0-5 cm	*0.7*	0.16	*0.05*	*0.3*
	5-11 cm	0.92	0.25	*0.05*	*0.3*
	11-16 cm	0.7	0.24	*0.05*	*0.3*
CAP5	0-0.2 cm	N/A	N/A	N/A	N/A
	0.2-8 cm	1.82	1.32	4.00	0.83
	8-16.5 cm	11.55	5.89	55.8	4.31
	16.5-20 cm	1.84	2.73	8.34	1.05
	20-23 cm	7.6	4.92	39.7	1.91
TC4	0-4 cm	1.44	2.13	5.17	0.98
	4-15 cm	2.08	2.57	3.94	1.35
SPI15	0-5 cm	3.72	2.40	12.0	2.49
	5-15 cm	6.82	4.40	32.6	3.09
	15-20 cm	6.55	11.0	125	3.53
	20-25 cm	1.13	0.56	1.45	0.61
SPI16	0-4 cm	2.39	2.74	23.0	1.28
	4-28 cm	4.1	6.44	8.77	2.74
	28-30 cm	3.36	7.20	7.03	5.3

Table A2.2.7. Concentration (in µg/kg dw) of contaminants in the Souter Point Capping Survey NIOZ Core samples collected in 2010. N/A = not enough sample was available for analysis.

2.2.4.6.4 Trace metals

Figure A2.2.27 indicates that there is no significant difference in metals concentration between sediments sampled inside and outside the disposal sites between 2006 and 2010. The direct input of heavy metals from dredged material disposed of at this site may have been masked by the existing elevated concentrations derived from a combination of activities on the Tyne (mining, shipping, smelting) where a legacy of high levels of heavy metals could still be observed. Additionally, it is possible that prior to 1974 (when licensing of dredged material was brought in) material disposed of at this and nearby sites contained much higher trace metals concentrations to what is deemed acceptable under licence conditions.

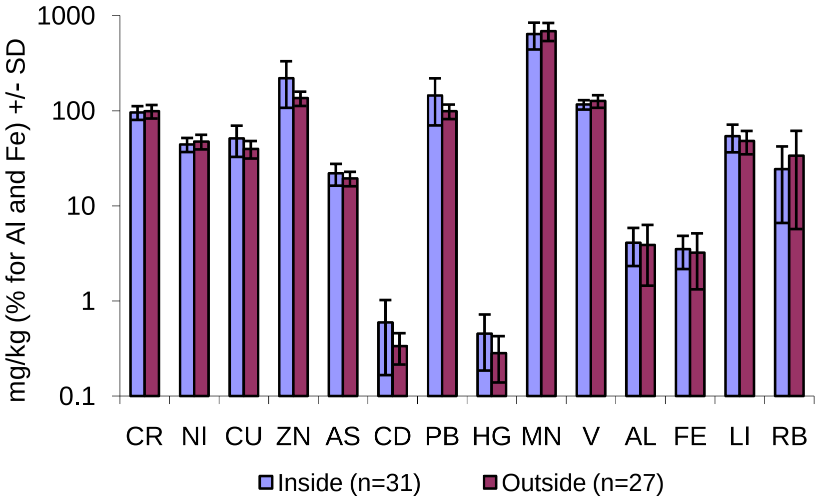


Figure A2.2.27. Average metal concentrations inside and outside for metal concentrations at Souter Point between 2006 and 2010 inclusive

When assessing temporal trends (Figure A2.2.28 and Figure A2.2.29), similar patterns are observed for all elements and no significant trend is discernible for neither stations inside the disposal site nor those outside. This is perhaps a reflection of the dispersive nature of Souter Point, i.e., moderate tidal currents that run generally parallel with the coastline, with a net residual drift southwards (at least in surface waters).

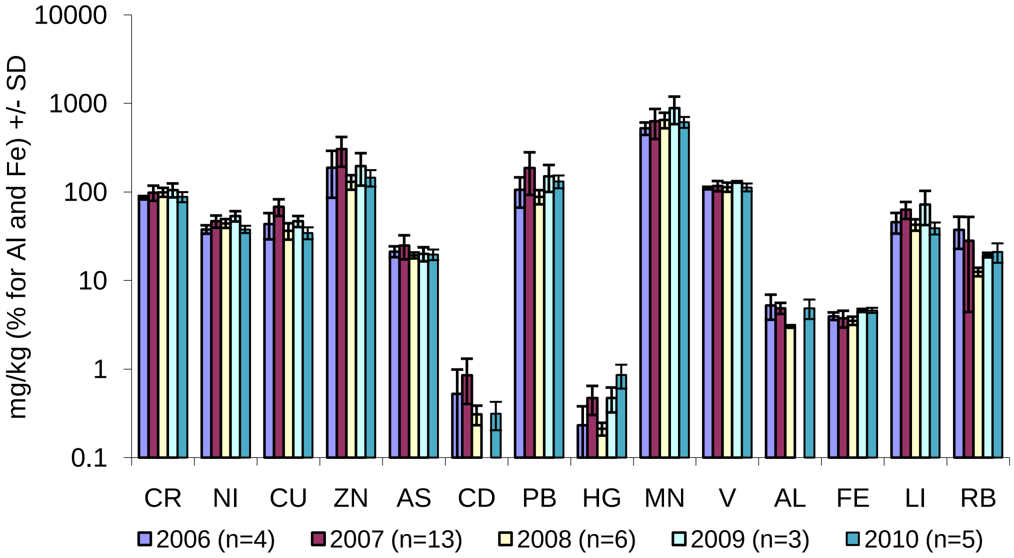


Figure A2.2.28. Average metal concentrations inside the Souter Point disposal site from 2006-2010

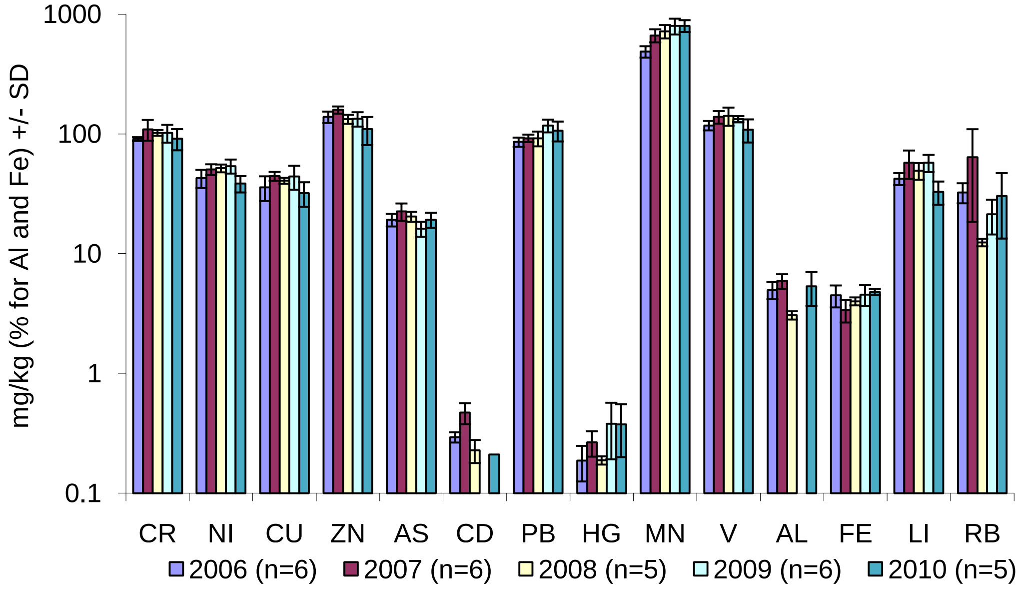
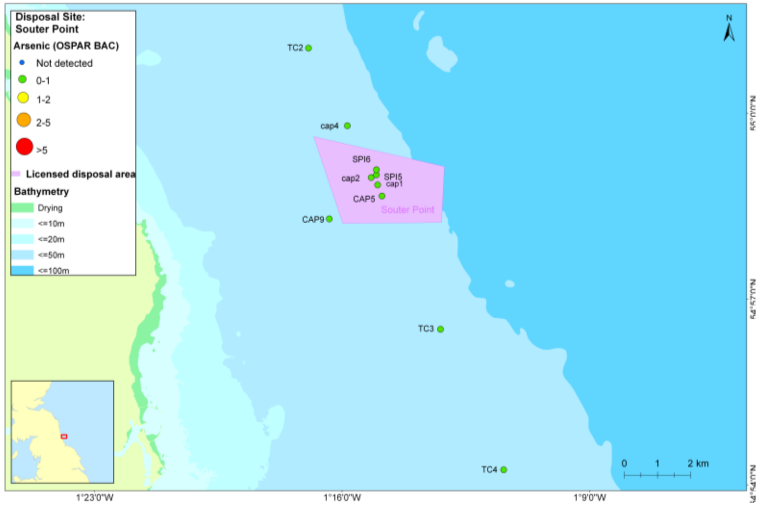


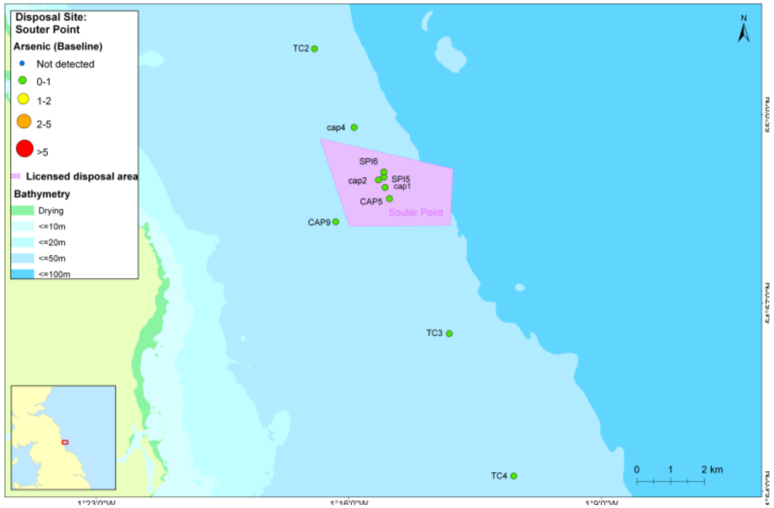
Figure A2.2.29. Average metal concentrations outside the Souter Point disposal site from 2006-2010.

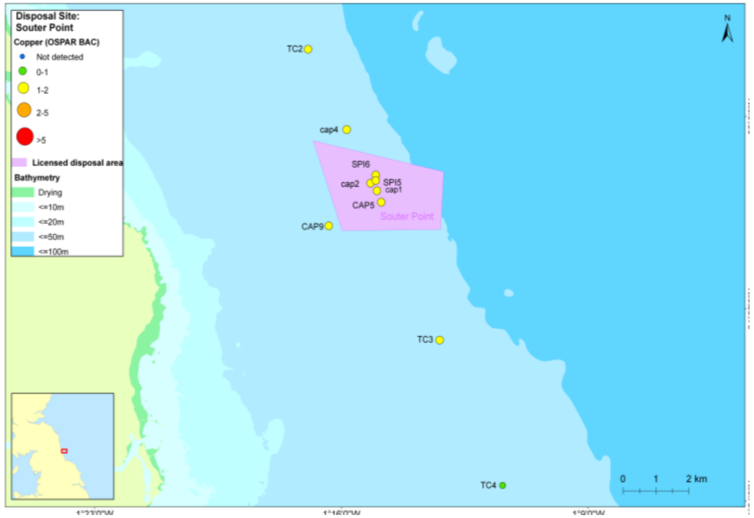
When assessing the level of metal concentrations within the Souter Point area, comparisons with OSPAR BAC and regional background concentrations show no enrichment of As at Souter Point (Figure A2.2.30). Reference stations TC2 (north of disposal site), TC3 and TC4 (both south of disposal sites) and CAP9 (west of disposal site) all displayed concentrations of Cd below the limit of detection. A slight enrichment of Cd at two stations within the disposal site (SPI6 and CAP2) is, however, recorded when using the OSPAR approach, although this was not the case using the regional baseline method. This finding is also similar to that for Cr where a north-south transect of slight enrichment is depicted with the OSPAR approach; no enrichment was observed based on the baseline method. Similarly, slight enrichment for Cu, Ni, Zn and, to a more enriched level, Pb was exhibited, again these were not enriched when the regional baseline method was applied (see Figure A2.2.30 for Cu and Pb).

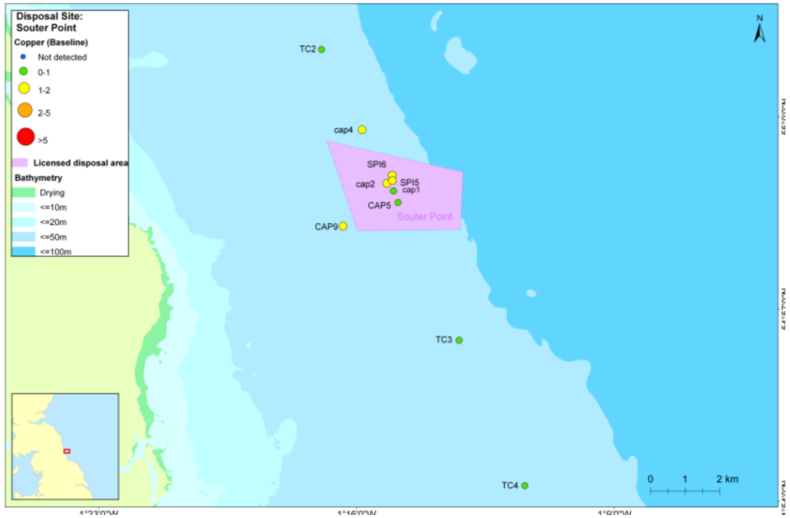
Hg shows the highest enrichment ratio (>5 times above the OSPAR BAC value) across all stations; enrichment is only found to be present (yet to a lesser extent, i.e., 2-5 times) using the regional approach for stations within the disposal sites (Figure A2.2.30). Enrichment for reference stations TC2, TC3 and TC4 change from highly enriched to slightly or not enriched using the baseline approach for Hg.

In conclusion, as for North Tyne, most of the proposed baselines values are higher than the current OSPAR BACs values since the latter did not take into account previous solid industrial wastes or other (unregulated) discharges inshore at Tees (Cefas, 2011) nor the natural mineralisation in the area. Therefore, using OSPAR BACs as a tool to assess metal enrichment could be misleading for some metals, in particular Hg and Pb. The proposed baselines give a more accurate level of enrichment for the Tyne/Tees region.


Disposal Site:
Souter Point
Arsenic (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
TC2
cap4
SPI6
cap2
SPI5
cap1
CAP5
Souter Point
CAP9
TC3
TC4
N
0
1
2 km
1°23'0"W
1°16'0"W
1°9'0"W
55°0'0"N
54°57'0"N
54°54'0"N


Disposal Site:
Souter Point
Arsenic (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
TC2
cap4
SPI6
cap2
SPI5
cap1
CAP5
Souter Point
CAP9
TC3
TC4
N
0
1
2 km


Disposal Site:
Souter Point
Copper (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
TC2
cap4
SPI6
cap2
SPI5
cap1
CAP5
Souter Point
CAP9
TC3
TC4
N
0
1
2 km


Disposal Site:
Souter Point
Copper (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
TC2
cap4
SPI6
cap2
SPI5
cap1
CAP5
Souter Point
CAP9
TC3
TC4
N
0
1
2 km

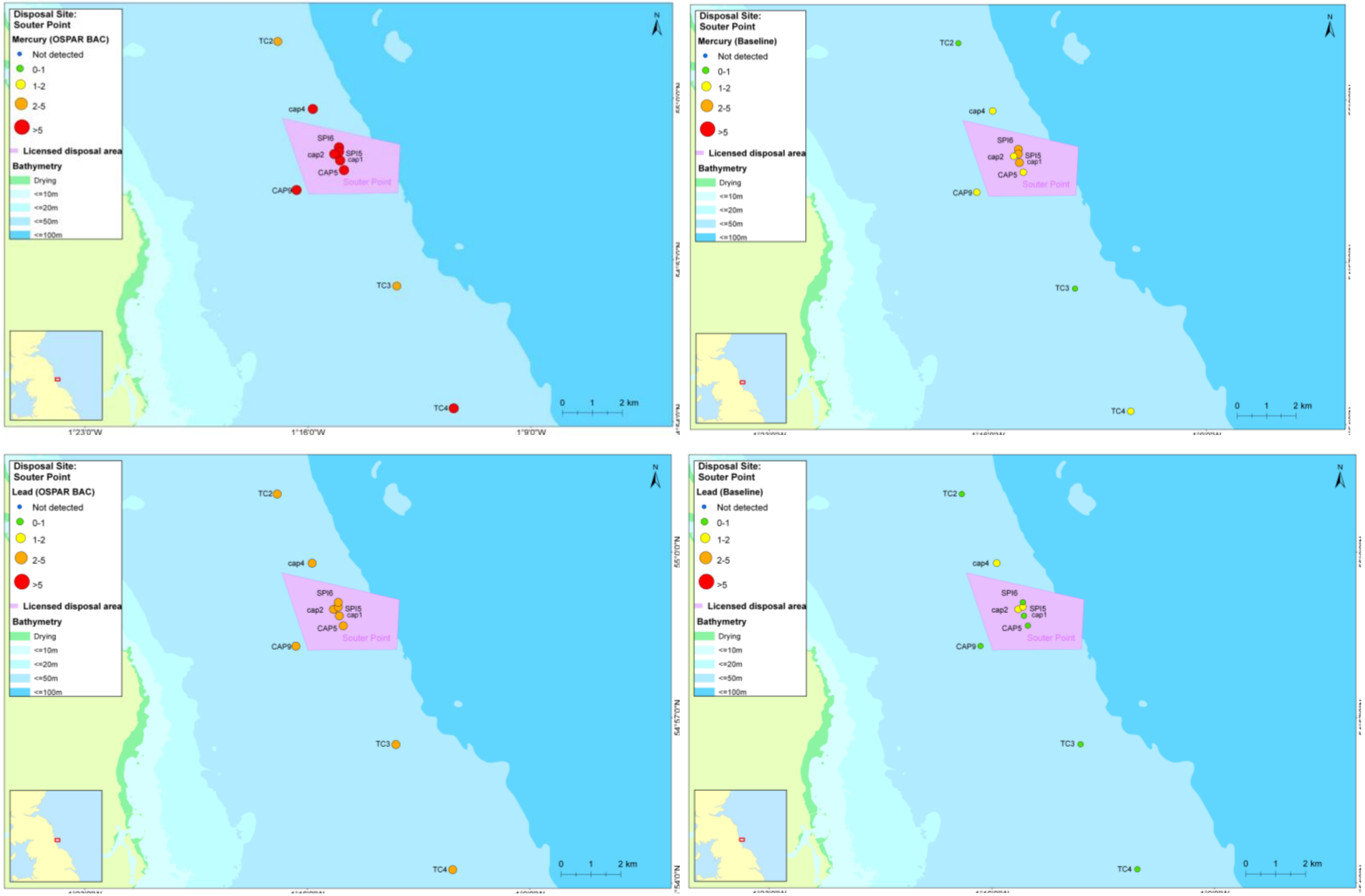


Figure A2.2.30. Enrichment to OSPAR BACs and Baseline values at Souter Point, 2010.

2.3 Tees (inner and outer, TY160 & TY150)

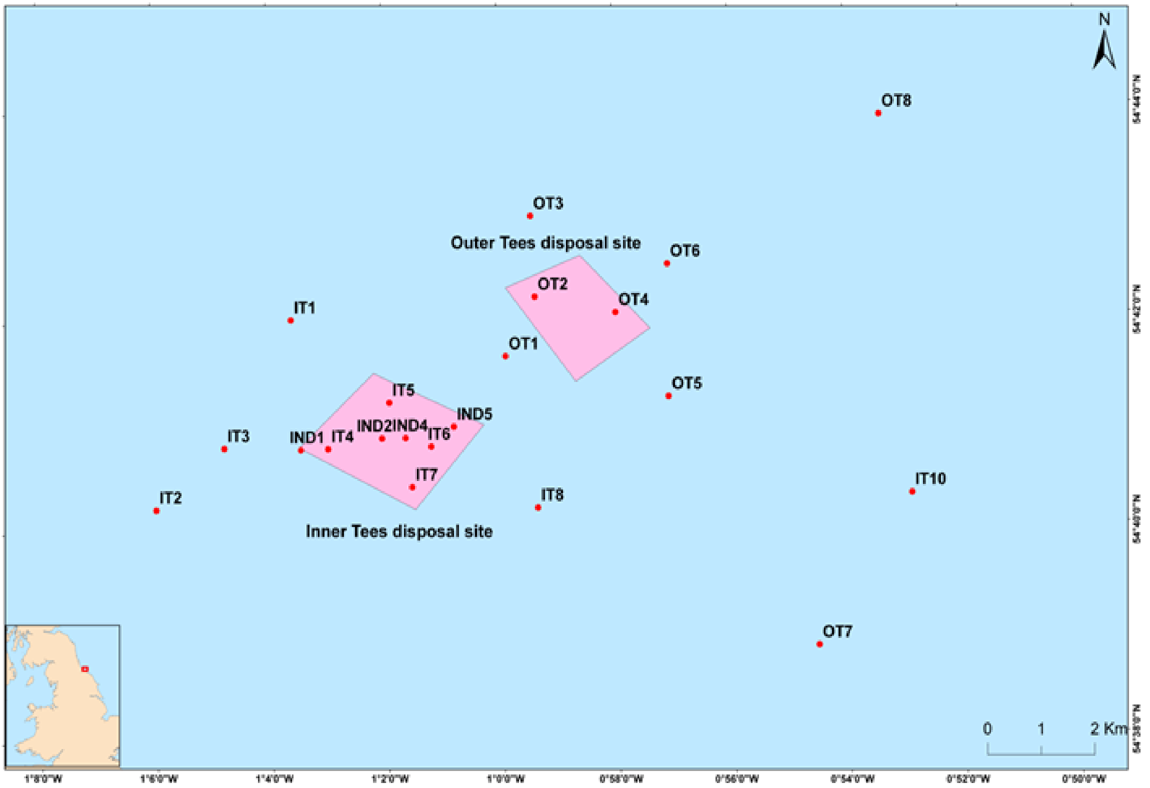


Figure A2.3.1. Location of sample stations at Inner and Outer Tees, 2010.

2.3.1 Background

Previous surveys of Inner Tees disposal site have shown the area to have a very homogeneous substrate of muddy sand. Some of the stations sampled within the disposal area showed evidence of previous spoil disposal with small lumps of black mud and black flecks present which were probably coal particles (Bolam et al., 2009, 2011). This site receives most of the 2,715,000 tonnes of maintenance dredged material per year from the Tees Estuary, the Seaton Channel and Hartlepool. In recent years the material disposed of to this site was seen to shoal at the eastern edge. The operators PD Teesport concluded that the dredgers would dispose at the earliest opportunity to save fuel, resulting in accumulation at that location. Therefore the port offered to divide the disposal area into twelve and dispose to each on a monthly basis. This has been undertaken since 2006.

Material disposed of to Outer Tees is usually comprised of capital dredgings. This is a more mobile site and the port places more consolidated clay dredged material at this site rather than to Inner Tees. This is often at the discretion of the operator based on observations of the material being dredged.

RAT prioritisation assessment: Tier 1

- where a significant increase in the quantity of material disposed of has occurred.
- where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas action levels of 1 and 2 in proposed dredge sediments) (Appendix 1) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries).
- where the material to be disposed of is very different (sediment type) to the receiving environment.
- with agreed increases in quantities of material (including changes in material and contaminant loadings).

Concerns:
There have been a number of high profile construction and disposal at sea applications made under the FEPA with regard to the Tees over recent years. In addition to the 2.7 million tonnes of maintenance dredge material licensed annually for sea disposal there are also several small scale capital projects ongoing although it is anticipated that the nature of the material arising will be largely 'soft' capital which will be disposed of to the Tees Bay Inner (TY160) site.

Permission has also been granted for the Northern Gateway container terminal which will include dredging of turning circles and berth pockets in the Tees resulting in a 2 million tonne dredge. Due to the physical nature of some of the material it is anticipated that this material would be divided between the two Tees disposal sites.

The Tees has a large quantity of chemical industries which have resulted in contaminants within dredged sediments. ICI, TiOxide factories and brominated flame retardant producers have all discharged into the Tees. Within the Tees Estuary there has also historically been a breach in the half-tide embankment allowing erosion of the enclosed mudflat; sediments of which have been contaminated with high levels of lead and zinc. Construction works to repair this breach have subsequently been licensed and are currently near completion. Analysis of dredged material from the Tees has displayed some of the highest levels of hydrocarbons found in UK marine sediments.

2.3.2 Impact hypothesis:

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits

- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

2.3.3 Parameters to be assessed:

Sidescan and multibeam (Inner Tees only)
Sediment particle size
Sediment organic carbon and nitrogen
Macrofaunal communities
Sediment contaminants (TBT, PAHs, organohalogens, trace metals)

Assessments of the status of, and impacts at, the two disposal sites are conducted based on data derived from a single survey that comprises stations within each licensed boundary, together with a number of stations located at varying distance outside each site.

2.3.4 Results

2.3.4.1 Sidescan and multibeam

The acoustic survey conducted at Inner Tees was undertaken on the 16thJune 2010. The survey utilised a Kongsberg EM3002D multibeam system to provide seabed bathymetry and backscatter strength data. Sidescan data were not collected on this survey. The extent of the area surveyed is approx 4.6 square kilometres consisting mostly of muddy sandy sediments. The area has previously had dredged material concentrated in the south western corner of the site, which has resulted in a raised mound approximately 5m higher than the surrounding topography. There is a gentle slope towards the north east and east of the site reaching a maximum depth of around 40m (Figure A2.3.2).

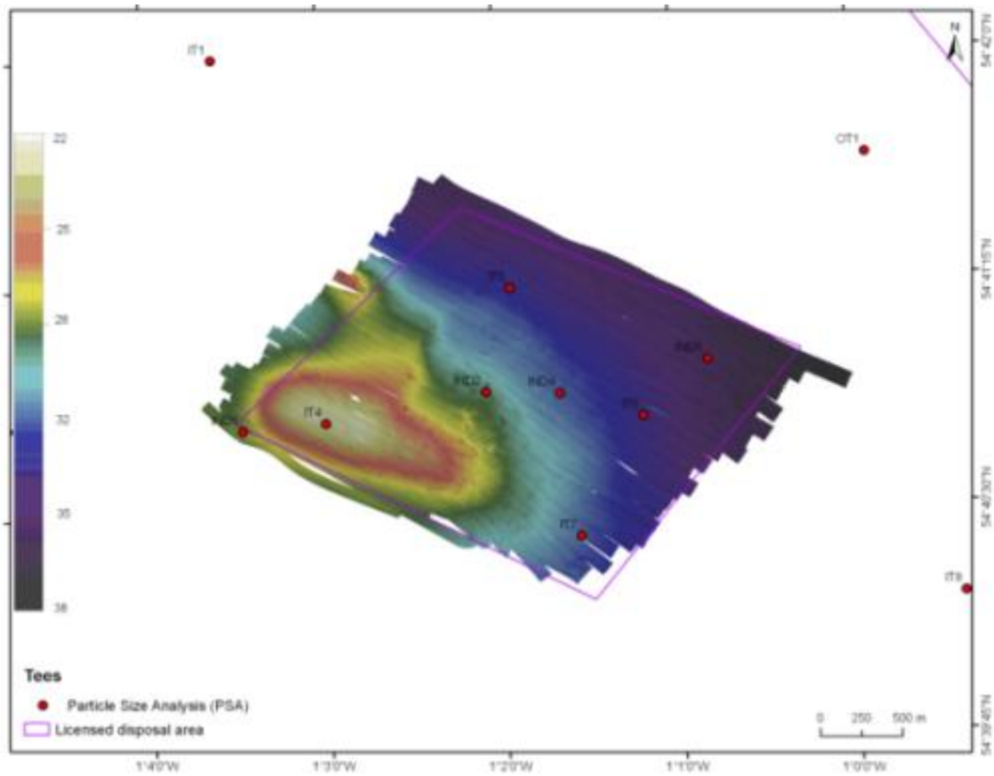


Figure A2.3.2. Inner Tees seabed bathymetry from the 2010 multibeam survey.

Ground-truthing to support the interpretation of the acoustic data was attained from samples collected using Day grabs. Twenty one Particle Size Analysis (PSA) samples were collected around the Tees site, with eight positioned within the acoustic coverage area (Figure A2.3.2). The backscatter results (Figure A2.3.3) reveal large areas with low backscatter return, indicating a relatively uniform seabed surrounding the main impacted disposal area. Higher backscatter readings in the north east and south west of the site suggest coarser or harder substrates; these are likely to be more varied in nature.

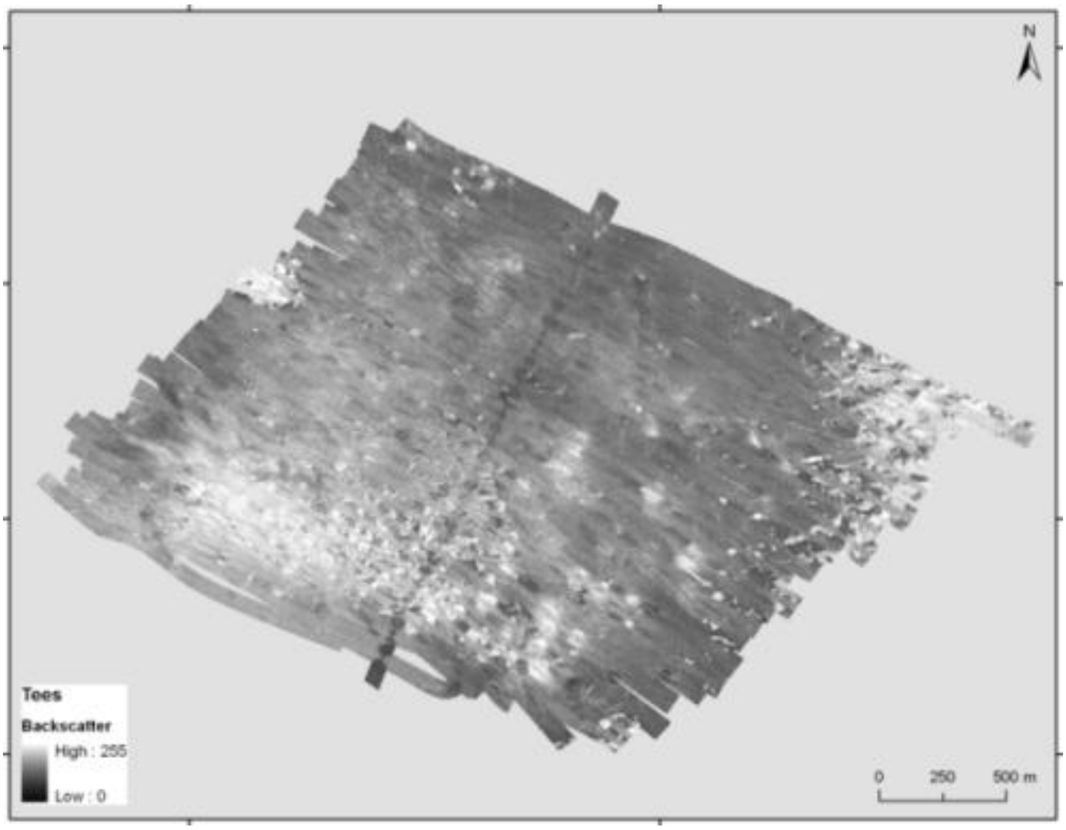


Figure A2.3.3. Inner Tees disposal site multibeam backscatter from 2010 survey.

Figure A2.3.4 presents an interpretation of the acoustic results from the 2010 survey. The figure identifies the extent of the licensed disposal area (highlighted in purple) within the acoustic area. The red dotted line shows the results of the main impacted area from the 2009 survey overlaid on the 2010 interpretation. The main area demonstrating visible impacts from the dredged material disposal activity has not moved in location; however, the overall shape itself has changed to some extent. The majority of the slightly gravelly muddy sand seen to constitute this dredged material disposal area has remained in the same location to the south, with a slight extension to the southwest. This accumulation of material could be the result of historical activity within the site.

The disposal of material to the south has subsequently altered the distribution of the surrounding sediments. The size of the area consisting solely of mud has significantly reduced to the south east of the site and increased to the northwest.

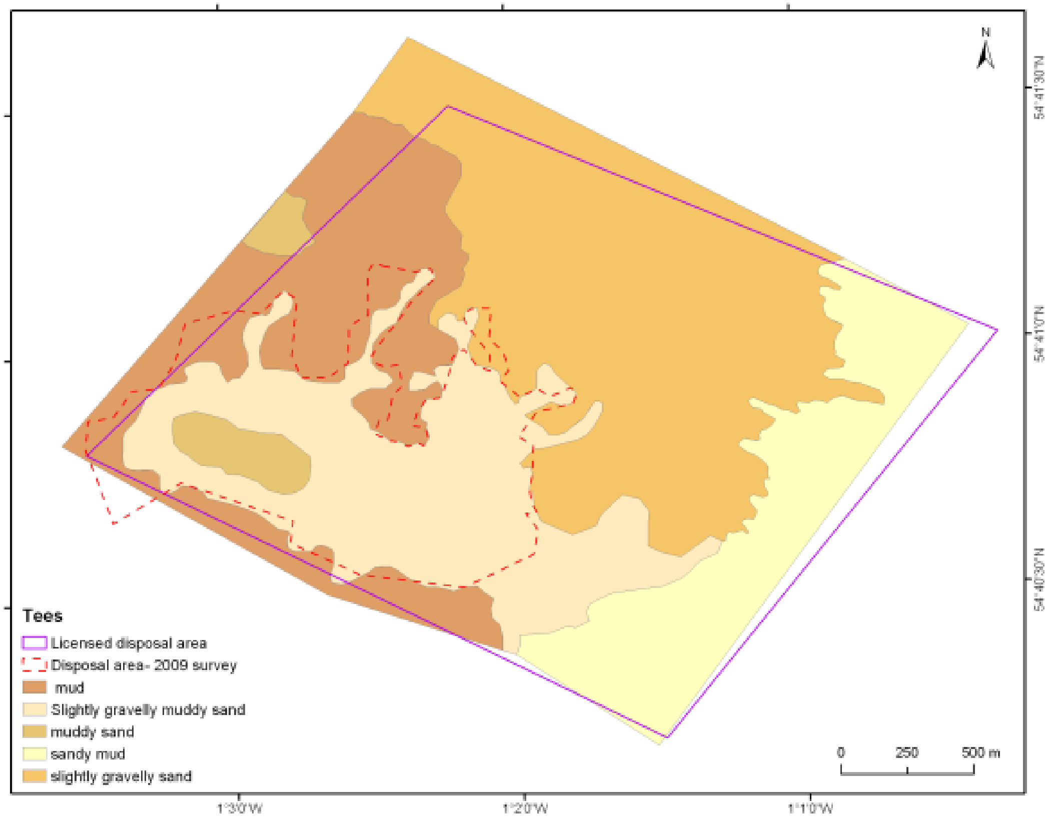


Figure A2.3.4. Interpretation of the Inner Tees 2010 multibeam survey showing the region of disposal from the 2009 acoustic survey superimposed.

When comparing these data with those from previous surveys at the site it is apparent that only a small change has occurred to the sediment distribution in the area. The high intensity backscatter appears to be more widespread and covers a larger area. This could be the result of the disposal activity extending over a greater area, resulting in a wider distribution across the site. This is possibly the result of the agreement to deposit material across the whole disposal site as opposed to close to the southwestern edge as was previously undertaken.

Figure A2.3.5 illustrates the 2010 interpretation, with the backscatter results shown for the 2008, 2009 and 2010 surveys. It must be noted that when comparing previous multibeam backscatter data sets, the settings used to process and clean the raw data from year to year can change. Therefore, although the high and low backscatter returns remain unchanged the colour settings themselves can have variations.

The ability to determine the nature of sediment changes to the seabed at Tees is often limited. Due to the nature of bathymetric acoustic surveys it can be difficult to establish whether the changes noted are natural temporal ones or due to a change in the regime of sediment disposal at the site. With this caution in mind, comparison of the 2010 data with those of 2008 and 2009 suggest that there is an increase in the disposal of material to the south-eastern part of the site, especially near to where the raised feature can be seen. This suggests that there has been a slight change in the bathymetric impacts of the disposal activity in the area.

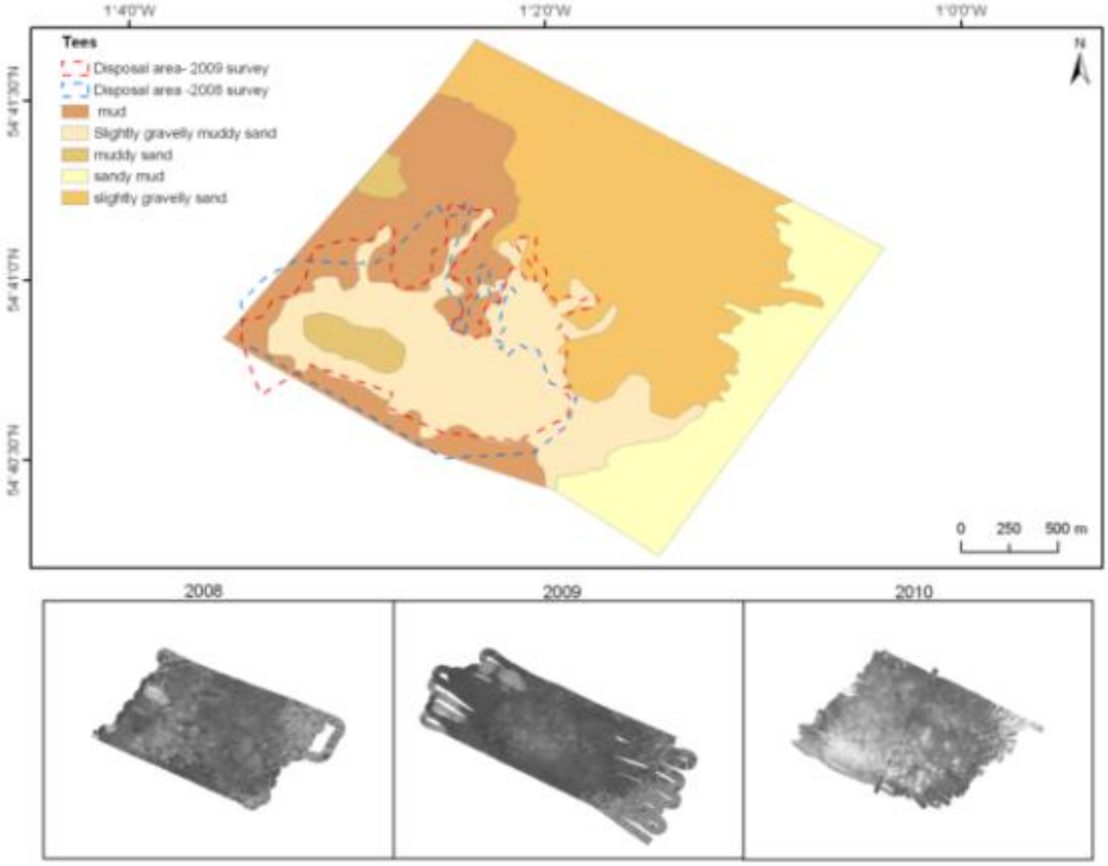


Figure A2.3.5. Interpretation of the 2010 multibeam backscatter data for Inner Tees, with results from the 2008 and 2009 survey showing the limit of cap for 2008 as a blue line and for 2009 as a red line (top), and backscatter results for 2008, 2009 and 2010 surveys (bottom).

2.3.4.2 Sediment particle size

Inner Tees sediments are predominantly muddy sands and unimodal sands, with small but varying amounts of gravel (Table A2.3.1). Temporal changes in sediment group are shown in Table A2.3.2 for each sample code in 2006 to 2010 inclusive. Most stations have shown very little change in sediment group in 2010 compared to 2009, being either in the same or adjacent sediment group. The only exceptions were IND2 (inside the disposal site; InT1 to InT3b) which has increased its sand component, and IT3 to the west of the site (InT3b in 2008 to InT1 in 2010) which has become more muddy in composition.

Figure A2.3.6 demonstrates the predominantly sandy nature of the sediment across this survey area in 2010 with some stations displaying an increased silt/clay component (Figure A2.3.7). Silt/clay content in a subset of dredge sediments for licensing applications to dispose of at Inne Tees was 66% (+/- 8 %, 95% CI). Most monitoring samples contained less silt/clay than this, except sediments in sediment group InT1, tentatively indicating that the finer fractions of the material disposed are being dispersed.

Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
InT1	3	Bimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud	76.5	18.9	
InT2	2	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand	605.0	76.5	1700.0
InT3a	7	Unimodal, Moderately Sorted	Slightly Gravelly Muddy Sand	107.5		
InT3b	9	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	152.5		
InT3c	19	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	107.5		
InT4a	13	Unimodal, Moderately Sorted	Slightly Gravelly Sand	152.5		
InT4b	5	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand	215.0		

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
InT1	0.05	26.15	73.80	0.30	1.22	2.53	5.84	16.25
InT2	15.53	65.34	19.13	10.98	20.62	12.32	7.39	14.04
InT3a	0.64	83.04	16.32	0.54	1.09	2.53	12.08	66.80
InT3b	2.45	82.13	15.43	2.68	6.78	14.45	38.23	19.98
InT3c	0.38	85.10	14.52	0.60	1.88	5.62	33.99	43.00
InT4a	0.45	95.61	3.93	1.03	3.13	10.06	53.63	27.77
InT4b	0.12	98.54	1.34	0.24	1.35	15.87	70.95	10.14

Table A2.3.1 Average sediment descriptions and statistics for each sediment group at Inner Tees.

	Year				
Sample code	2006	2007	2008	2009	2010
IND1	InT3c	InT3c	InT4a	InT3c	InT3c
IND2	InT4a	InT4a	InT4a	InT1	InT3b
IND4		InT4a	InT3c	InT3c	InT4a
IND5		InT4a	InT4b	InT4b	InT4b
IT1	InT3c	InT3c		InT3c	InT3c
IT10	InT3b	InT3b	InT2	InT3b	InT2
IT2				InT4b	InT4b
IT3	InT3b	InT1	InT3b		InT1
IT4	InT3c	InT3c	InT3c	InT3c	InT3c
IT5	InT4a	InT3c	InT3b	InT4a	InT3c
IT6	InT4a	InT3b	InT3b	InT3c	InT4a
IT7	InT4a	InT4a	InT3c	InT3c	InT3c
IT8	InT3a	InT3a	InT3a	InT3a	InT3a

Table A2.3.2 Sediment groups for each sample code between 2006 and 2010 inclusive at Inner Tees.

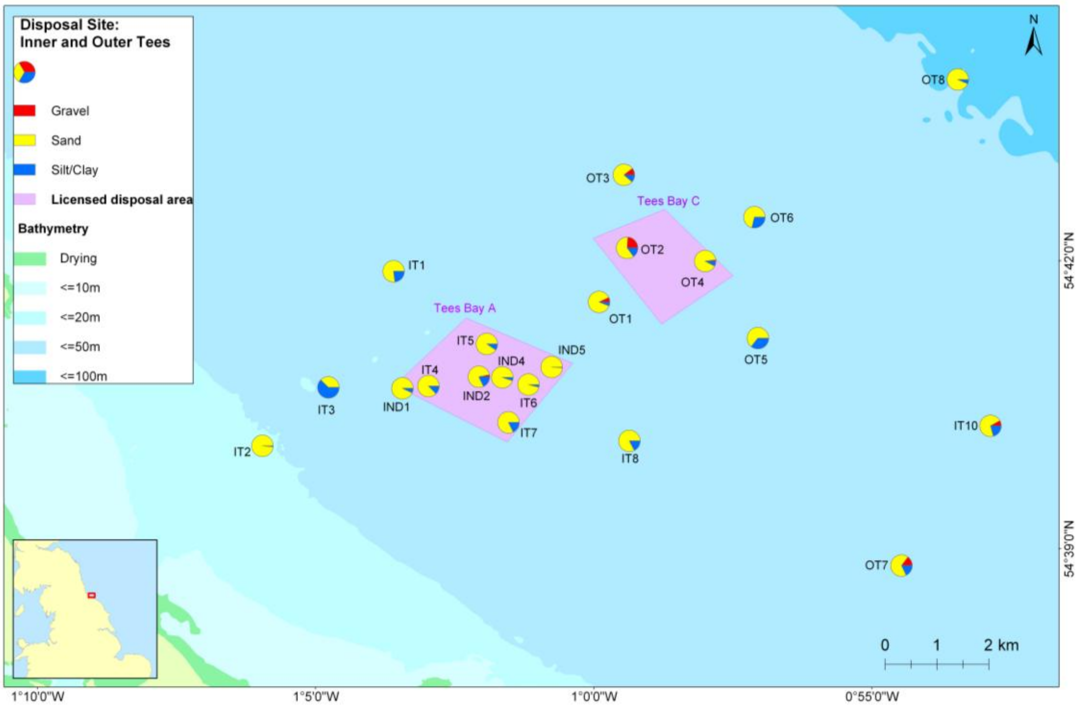


Figure A2.3.6. Pie charts of gravel, sand and silt/clay at Inner Tees (Tees Bay A) and Outer Tees (Tees Bay C) in 2010.

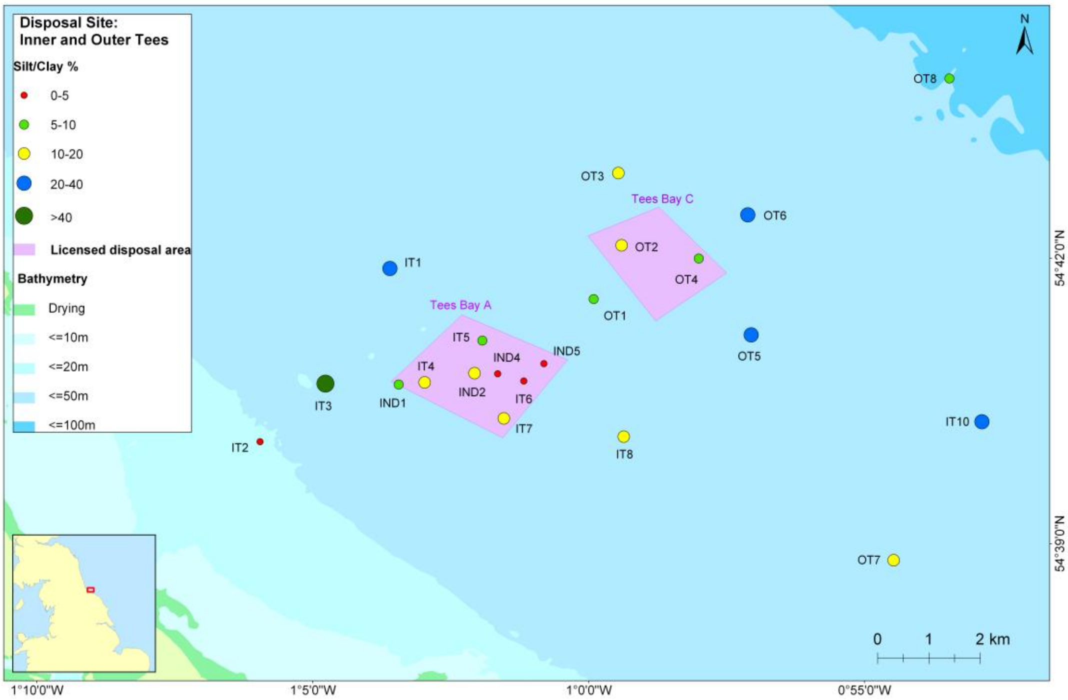
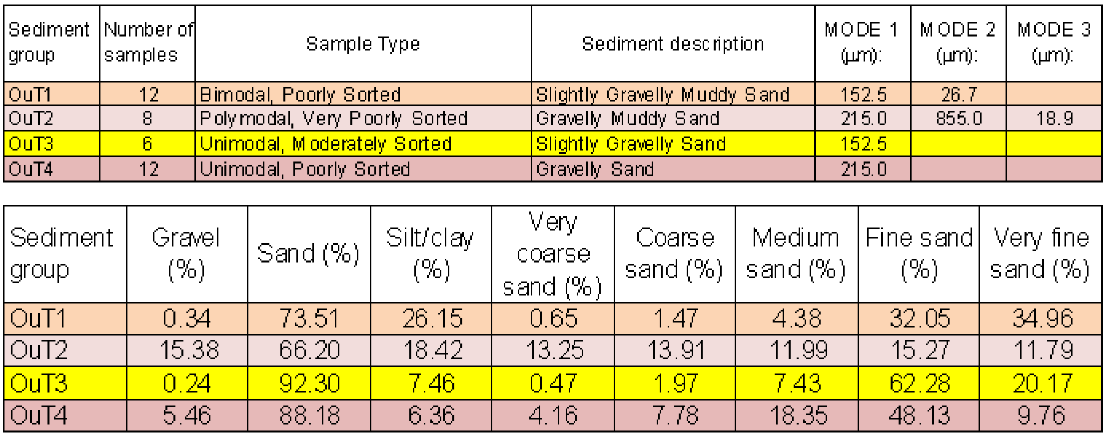


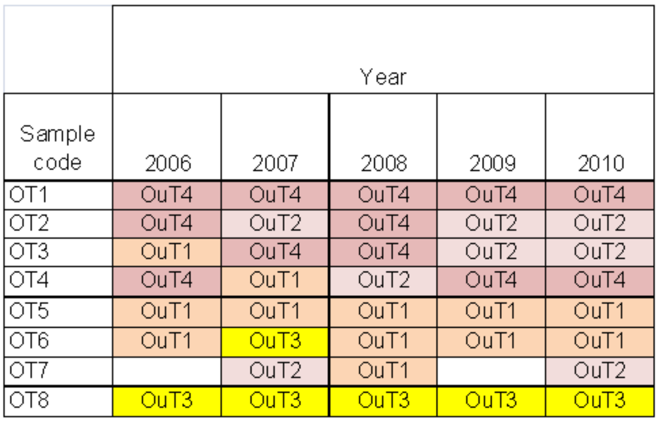
Figure A2.3.7. Silt/clay (%) at Inner Tees (Tees Bay A) and Outer Tees (Tees Bay C) in 2010.



Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
OuT1	12	Bimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	152.5	26.7	
OuT2	8	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand	215.0	855.0	18.9
OuT3	6	Unimodal, Moderately Sorted	Slightly Gravelly Sand	152.5		
OuT4	12	Unimodal, Poorly Sorted	Gravelly Sand	215.0		

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
OuT1	0.34	73.51	26.15	0.65	1.47	4.38	32.05	34.96
OuT2	15.38	66.20	18.42	13.25	13.91	11.99	15.27	11.79
OuT3	0.24	92.30	7.46	0.47	1.97	7.43	62.28	20.17
OuT4	5.46	88.18	6.36	4.16	7.78	18.35	48.13	9.76

Table A2.3.3. Average sediment descriptions and statistics for each sediment group at Outer Tees, 2010.



	Year				
Sample code	2006	2007	2008	2009	2010
OT1	OuT4	OuT4	OuT4	OuT4	OuT4
OT2	OuT4	OuT2	OuT4	OuT2	OuT2
OT3	OuT1	OuT4	OuT4	OuT2	OuT2
OT4	OuT4	OuT1	OuT2	OuT4	OuT4
OT5	OuT1	OuT1	OuT1	OuT1	OuT1
OT6	OuT1	OuT3	OuT1	OuT1	OuT1
OT7		OuT2	OuT1		OuT2
OT8	OuT3	OuT3	OuT3	OuT3	OuT3

Table A2.3.4. Sediment groups for each sample code between 2006 and 2010 inclusive at Outer Tees, 2010.

Outer Tees sediments are predominantly muddy sands, with some gravelly sands and unimodal sands (Table A2.3.3). Table A2.3.4 indicates that there has been no change in sediment groups for any station within the 2010 Outer Tees survey compared to that of the 2009 survey. The lack of disposal activity during this period will have undoubtedly been partly responsible for this finding. Figure A2.3.6 reveals the spatial variability in major sediment size classes (sand. Silt/clay and gravel) for 2010; predominantly sandy with occasionally increased proportions of gravel (e.g., OT2, OT3) or silt/clay (OT5, OT6) sediments are present.

2.3.4.3 Sediment organic carbon and nitrogen

In 2010, organic carbon values (on the <63µm sediment fraction) range from 3.56 to 5.04 %m/m (Figure A2.3.8) and for nitrogen 0.18 to 0.30 %m/m. IND5 had a low silt/clay content (<2% silt/clay) and so it was not possible to measure the organic carbon on this fraction. In general, sediment organic carbon contents were similar to those obtained in 2006, 2007 2008, and 2009 (Bolam et al., 2009, 2011).

For the Outer Tees site, organic carbon values (on the <63µm sediment fraction) ranged from 2.73 to 4.53 %m/m (Figure A2.3.8) and for nitrogen 0.15 to 0.33 %m/m. As for the Inner site, these are similar to those observed in 2006, 2007 2008, and 2009.

As in 2009, several samples from the Inner and Outer Tees survey possessed higher levels of organic carbon in the <2mm fraction than the <63µm fraction, indicating that some organic carbon for this area is present in coarser sediment, possibly as coal (akin to the situation at North Tyne and Souter Point).

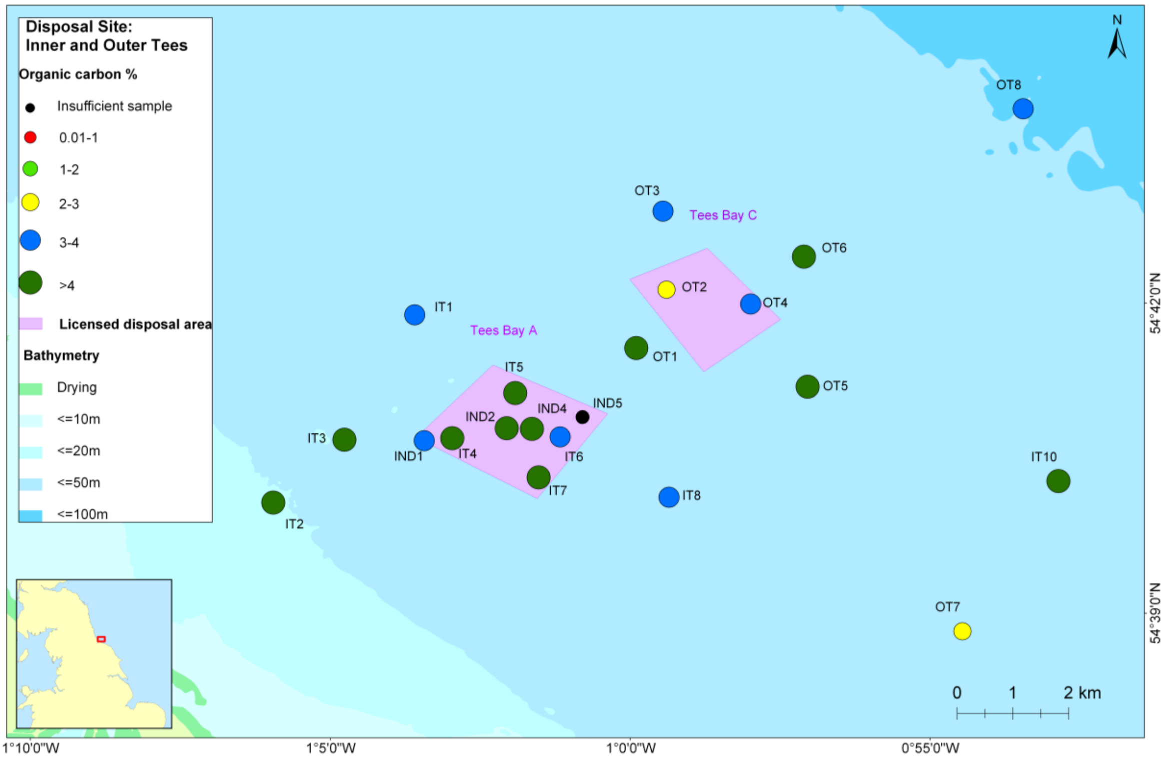


Figure A2.3.8. Organic carbon (%m/m) in the silt/clay fraction (<63µm) at Inner Tees and Outer Tees, 2010.

2.3.4.4 Macrofaunal communities

The total number of taxa sampled from the 8 stations (3 replicates at each) within the Inner Tees disposal sites was 147, while 154 taxa were sampled from the 4 stations outside. The mean number of taxa per grab sample for the former was 36 (maximum = 47), while a mean of 41 taxa (maximum = 60) was sampled from each grab sample at stations outside the disposal site. Figure A2.3.9a indicates that there was a large amount of spatial variability in the number of taxa at the four stations outside the Inner Tees disposal site; while two showed the highest number of taxa, the two other stations displayed approximately the same as the lowest mean number of taxa found within the site. Thus, there appears to be little discernable change in the total number of taxa within the Inner Tees disposal site. This conclusion mirrors the observation in previous years (Bolam et al., 2009, 2011).

The mean total density per grab was 154 and 172 for stations inside and outside the disposal site, respectively (Figure A2.3.9b). As observed regarding total number of taxa, there was a high spatial variability in the total density; mean total density of all (except IND2) the stations sampled from within the disposal site were within the range observed for the stations outside the disposal site. Thus, disposal activity had a negligible impact on total densities. Again, this was the conclusion reached for preceding years (Bolam et al., 2009, 2010).

Although only two sampling stations were located within, and two outside, the Outer Tees disposal site, Figure A2.3.9a&b indicates that disposal activity here had non-significant impacts on both total number of taxa per grab and total number of individuals. Note, the raised number of individuals sampled at OT2, and the large replicate variability at this station, was predominantly caused by the presence of the barnacle *Verruca stroemia* which was found on one or two larger particles of sediment at this station only.

The MDS plots showing the relative (dis)similarity between stations in terms of species identity and abundance (using fourth-root transformed data) are displayed in Figure A2.3.10a and 2.3.10b for Inner and Outer Tees respectively. For Inner Tees, the MDS indicates that there was some significant difference in the multivariate community structure between stations inside and outside the site. While the variation in community structure of the stations inside was relatively small, that of the 4 stations outside was relatively large; each such station had a somewhat unique community structure. For example, IT8 and IT1 appear somewhat similar but dissimilar to all other stations, and, perhaps to a lesser extent, the same applies for IT2 and IT3. The spatial variability in community structure for stations inside the licensed boundary is comparably much less. The ANOSIM test performed on the Inner Tees data produced an R statistic of 0.54; this would indicate that there are significant differences in community structure between stations inside and outside the disposal site, as is perhaps supported by the MDS plot.

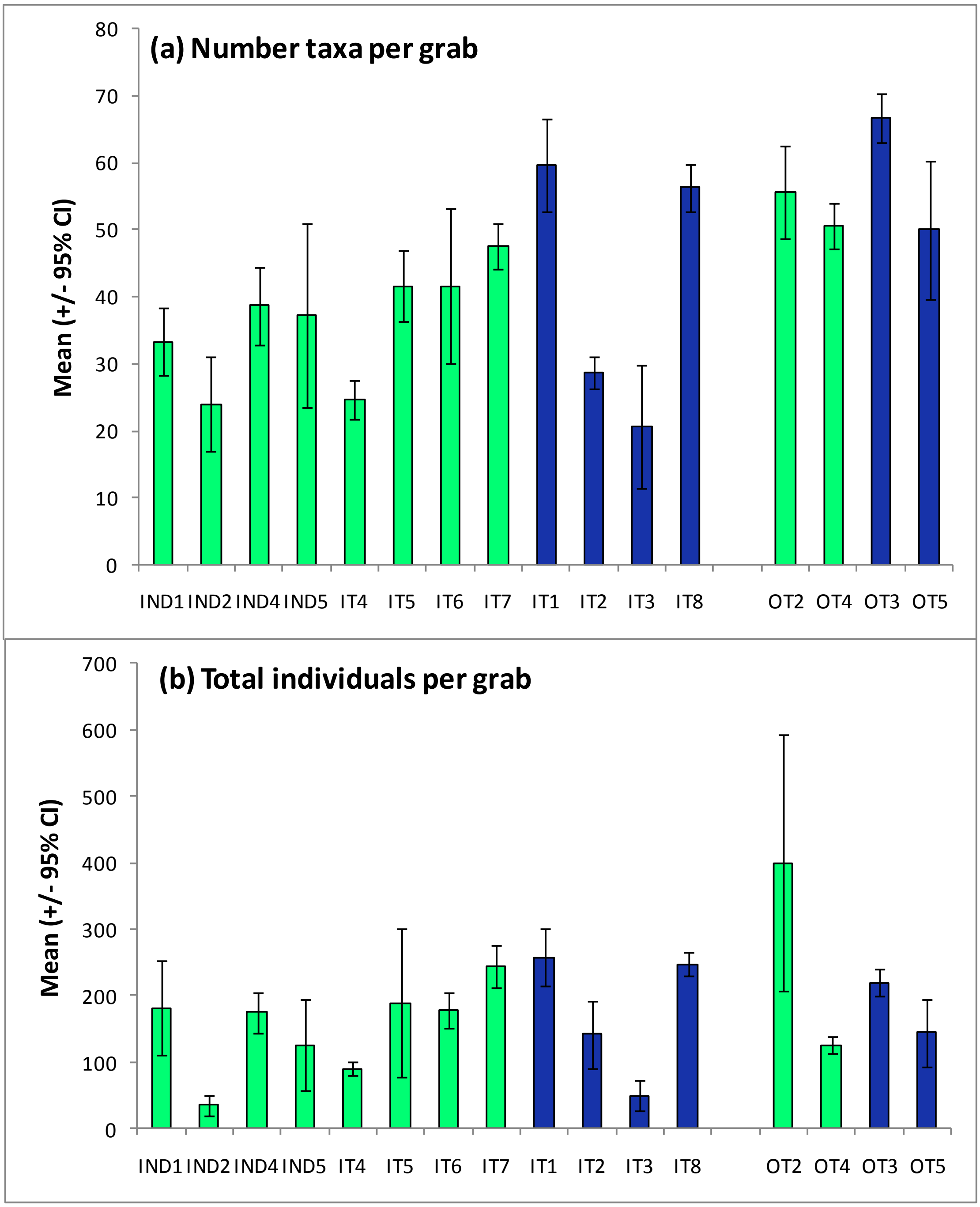


Figure A2.3.9. Mean number of taxa (a) and total individuals (b) sampled at Tees Inner and Tees Outer sampling stations during 2010. Stations located within the licensed boundary of the disposal site are shown in green, those outside are in blue.

The taxa primarily responsible for the differences between these inside and outside stations were investigated using the SIMPER procedure in PRIMER. The results indicate that these differences were not down to changes in species identities (as maximum individual % contributions are low), but due to more subtle differences in species abundances (Table A2.3.5).

A similar multivariate analysis performed on the Outer Tees macrofaunal abundance data indicated that OT2's community structure is somewhat different from that of the other three stations (primarily due to *V. stroemia*). OT4 (inside) and OT3 (outside) display relatively similar community structures while that of OT5 (outside) is both spatially-variable and somewhat different from the others from this survey. This latter observation depicts subtle differences in the dominance of taxa at this station (e.g., relatively higher numbers of *Diplocirrus glaucus* and *Heteromastus filiformis*). ANOSIM R value performed on the macrofaunal data for Outer Tees was 0.274 indicating little evidence of a significant difference between the community structures inside and outside this disposal site (as would, again, perhaps be surmised from the MDS plot).

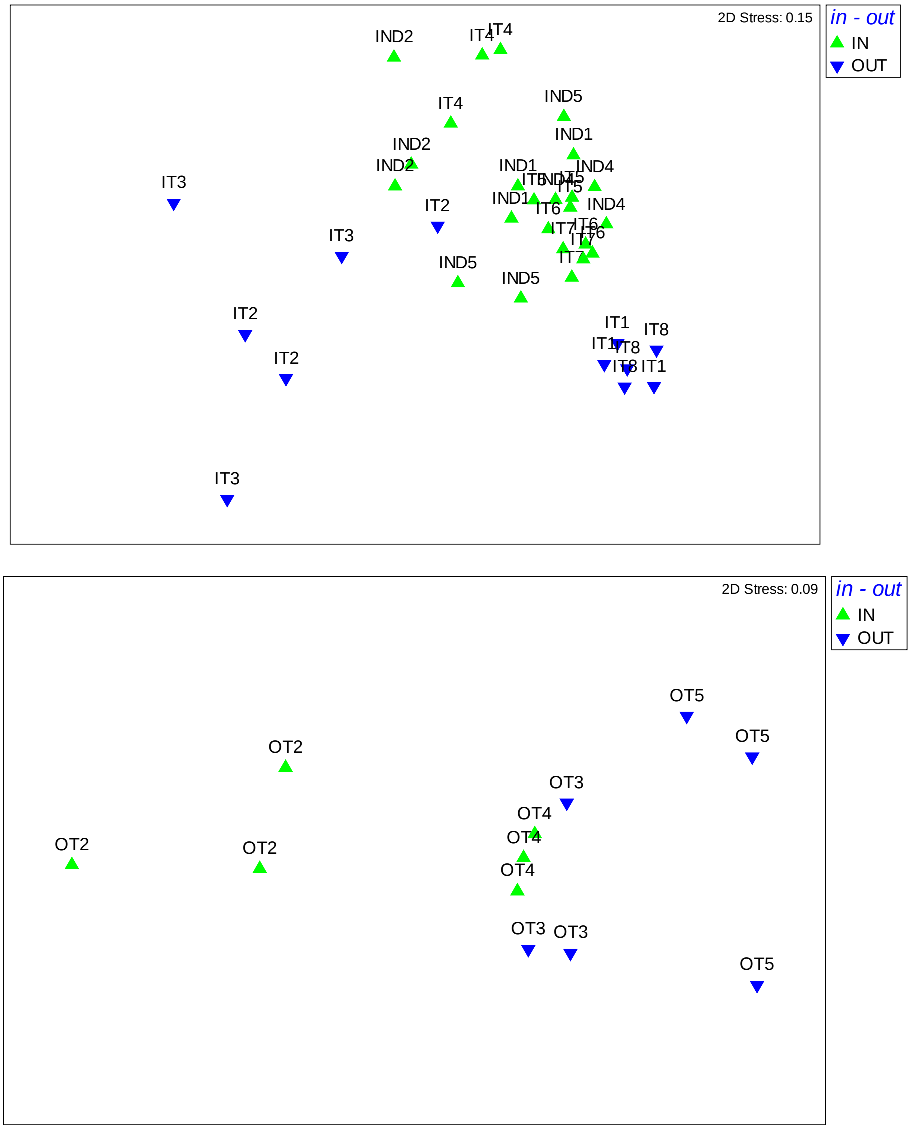


Figure A2.3.10a&b. 2-d MDS plots (based on a Bray Curtis similarity matrix derived from fourth-root transformed abundance data) for Inner Tees (a) and Outer Tees (b) macrofaunal communities.

Taxa	% contrib.	Abund inside (per grab)	Abund outside (per grab)
Nucula nitidosa	3.1	54.1	0.5
Spiophanes bombyx	1.7	5.8	1.3
Abra alba	1.7	4.5	12.3
Chaetozone christiei	1.7	3.4	0.9
Echinocardium cordata	1.6	7.0	0.6
Amphiura filiformis	1.6	2.0	19.1
Kurtiella bidentata	1.5	1.3	9.1
Phoronis	1.5	2.9	7.8
Diastylis rathkei	1.3	0.0	2.6
Abra nitida	1.3	7.2	1.8

Taxa	% contrib.	Abund inside (per grab)	Abund outside (per grab)
Verruca stroemia	2.0	60.3	0.0
Harpinia antennaria	1.5	0.0	1.7
Kurtiella bidentata	1.4	0.0	3.7
Arctica islandica	1.4	1.0	5.5
Serpulidae	1.4	11.3	0.0
Thyasira flexuosa	1.4	1.0	7.5
Ophiuridae	1.3	6.7	0.7
Diplocirrus glaucus	1.3	0.0	3.0
Melinna elisabethae	1.3	8.7	0.2
SPATANGOIDA	1.1	0.3	2.5

Table A2.3.5. Top ten taxa most responsible for defining the differences in community structure of stations sampled inside the site and those outside the disposal site for Inner Tees (top) and Outer Tees (bottom) based on fourth-root transformed abundance data. Average dissimilarity between inside and outside station were 69.8 % and 54.5 % for Inner and Outer Tees respectively.

2.3.4.5 Sediment contaminants

2.3.4.5.1 TBT

All the 13 stations sampled as part of the Inner Tees survey produced TBT results below the detection limit. This represented a slight decrease from the previous year for IND4 which was 0.04mg/kg in 2009 (Bolam et al., 2011).

Similarly, all the 8 stations sampled as part of the Outer Tees survey recorded results below the detection limit. This observation is consistent with that of the last 4 consecutive years (Bolam et al., 2011).

2.3.4.5.2 PAHs

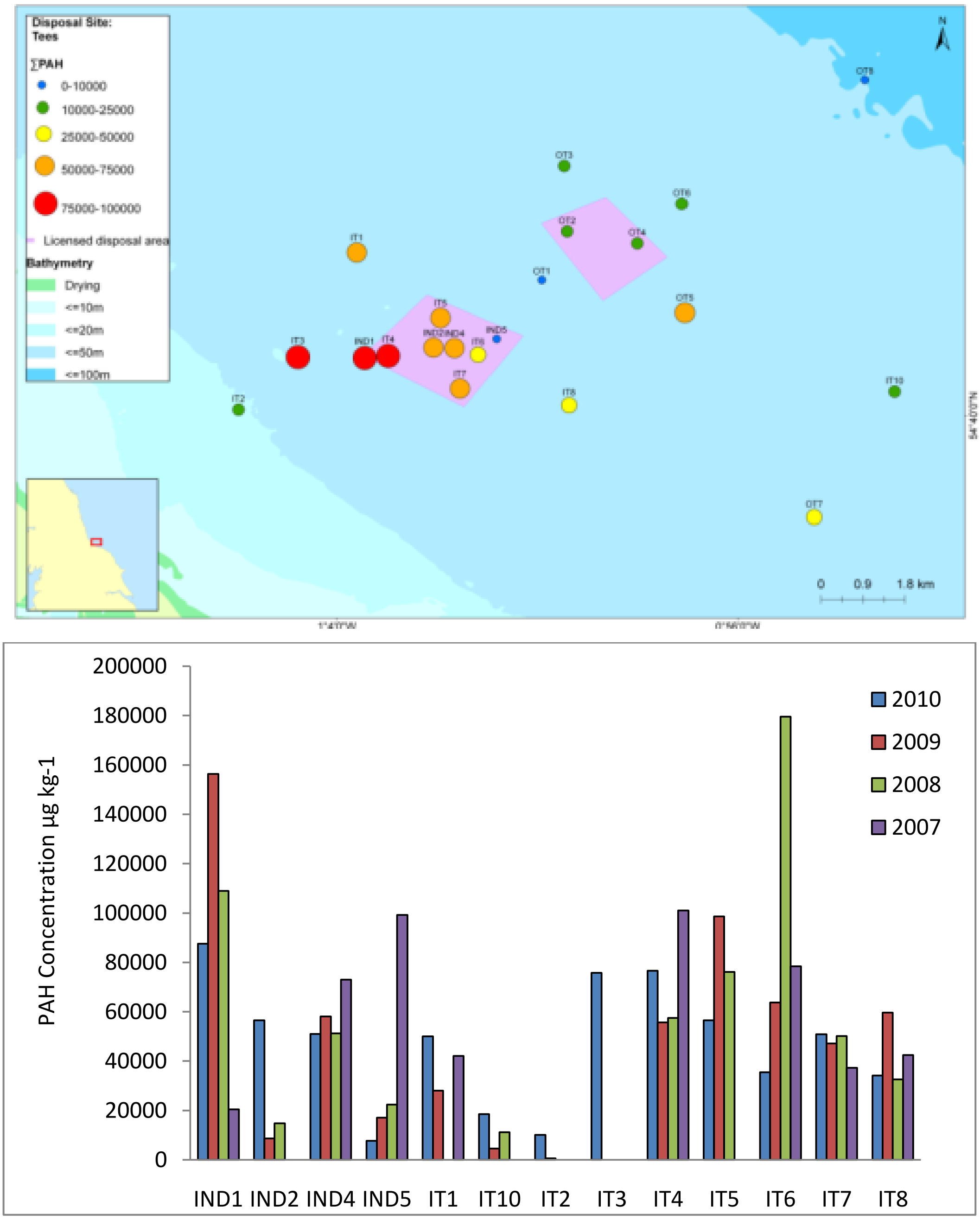


Figure A2.3.11. Summed PAH concentrations (µg kg^{-1}dw) for stations sampled in 2010 around the Tees Inner and Outer disposal sites (top) and concentrations observed during 2007-2010 at the Inner Tees disposal site (bottom).

The highest summed PAH concentrations in 2010 were found in and immediately to the west of the Inner Tees disposal area (Figure A2.3.11). The highest concentration was found at IND1 at the western corner of the disposal site, 87,500 µg kg^{-1} dw; this was, however, much lower than in 2009, where the concentration here was 156,000 µg kg^{-1} dw. High summed PAH concentrations were also found at two nearby sites, IT3 and IT4, whilst the lowest summed PAH concentration was found at the eastern tip of the disposal site at IND5 (7,650 µg kg^{-1} dw) (Figure A2.3.11). All sampling sites were found to exceed the ERL for LMW PAHs, with the ERM for LMW PAHs being exceeded at all sites except IND5 and IT2 on the disposal site. The ERL for the HMW PAH was breached at all sites except IND5 on the disposal ground, at IT2 to the west of the disposal site and at IT10 to the east of the disposal site. No station exceeded the ERM for the HMW PAHs.

A further evaluation of the PAH data indicated that the predominant source in all the sediment samples was petrogenic, generally with > 87% of the PAH content arising from oil sources. The P/A ratio was greater than 10, also indicating a petrogenic source at all sites within the Inner Tees disposal site, except at IND2 where the P/A ratio was 8.7.

The Outer Tees area has often displayed much lower summed PAH concentrations than the Inner Tees area, and the highest summed PAH concentration in 2010 was at OT5 to the southeast of the disposal site (66,900 µg kg^{-1} dw) (Figures 2.3.11 and 2.3.12). Concentrations at all sampling sites were found to exceed the ERL for LMW PAHs, with the ERM for LMW PAHs being exceeded at sites OT2, OT5, OT6 and OT7. The ERL for the HMW PAH was breached at OT5 and OT7. No site exceeded the ERM for the HMW PAHs.

Evaluation of the PAH data indicate that the source in all the sediment samples was predominantly petrogenic, generally with > 80% of the PAH content arising from oil sources; however no samples showed a P/A ratio greater than 7.7. As for the Tyne, the Tees Estuary is known to exhibit elevated PAH concentrations in sediments as a result of historical inputs (Woodhead et al., 1999).

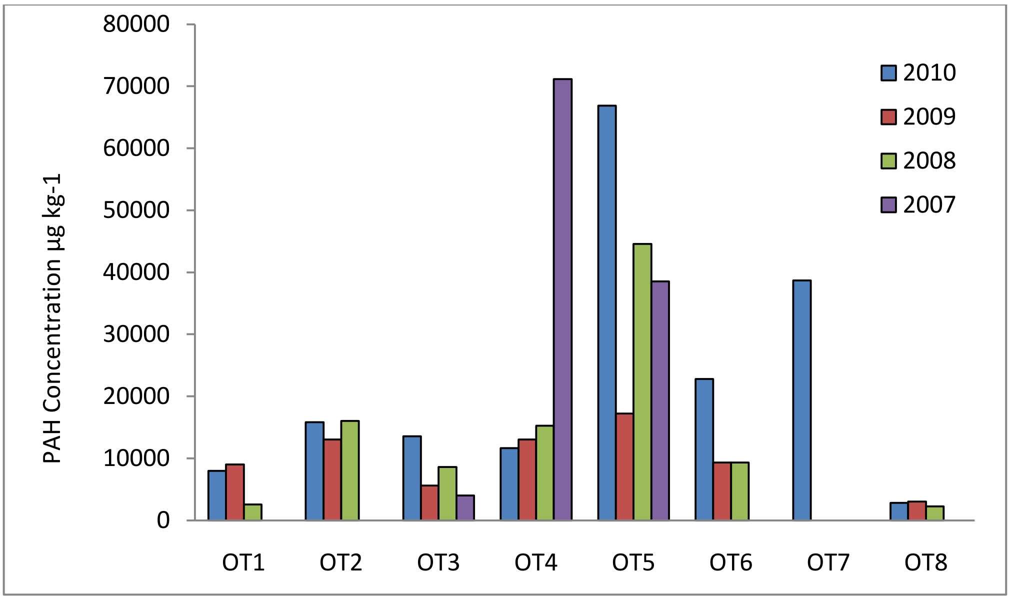


Figure A2.3.12. Concentrations observed during 2007- 2010 at the Outer Tees disposal site sampling stations.

2.3.4.5.3 Organohalogens

At Tees, CBs were detected at 13 of the 20 stations, with the highest concentrations generally in the Inner Tees area (∑ICES7 CBs range <0.7-4.6 µg/kg dw) (Figure A2.3.13). Highest ∑ICES 7 CB concentrations were found at IT3 west of the inner Tees disposal site and OT5, southeast of the Outer Tees disposal site, with concentrations of 4.6 and 4.2 µg/kg dw, respectively. Highest concentrations in the Inner Tees disposal area were 2.7 and 2.0 µg/kg dw for IND2 and IT4 respectively, with 2.0 µg/kg dw also found at IT1 north of the disposal area. ∑ICES 7 CB concentrations were < 1 µg/kg dw in the Outer Tees disposal site, with higher concentrations of 1.2 and 1.8 µg/kg dw at OT3 and OT6 to the north and east. All CBs were below limits of detection at 5 of the Inner Tees stations (IT2, IT6 IND1, IND4 and IND5) and 3 of the Outer Tees stations (OT1, OT2 and OT4) (Figure A2.3.13).

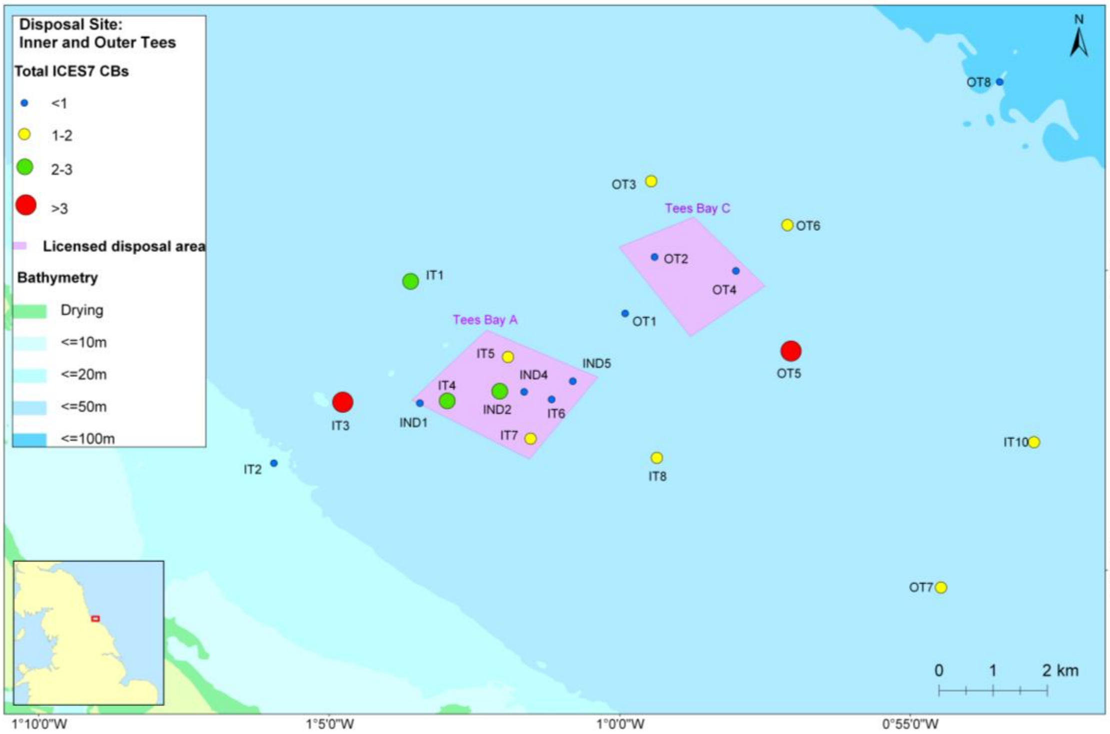


Figure A2.3.13. ∑ ICES7 CB concentrations for the Inner and Outer Tees Stations, 2010.

BDEs were detected at all of the 20 stations (∑11 BDEs range 0.19-29 µg/kg dw), with at least BDEs 47 and 99 detected at all stations. Concentrations were again higher at the Inner Tees area compared to the Outer Tees area (Figure A2.3.14). Highest ∑11 BDEs concentrations in the Inner Tees disposal area were 29 and 6.4 µg/kg dw for IND2 and IT4 respectively, with 7.9 and 5.4 µg/kg dw also found at IT3 and IT2 just west of the disposal area.

Highest ∑11 BDEs concentrations measured for the Outer Tees area were 5.4 µg/kg dw at OT5 and 2.2 µg/kg dw at OT6. Concentrations were <1 µg/kg dw at OT2 and OT4 within the disposal site. Two congeners, BDE99 and BDE47, were responsible for > 50% of the ∑11 BDEs concentrations. BDE183 was detected at 16 of the 20 stations which is indicative of widespread use of the octa or deca PBDE technical mixes.

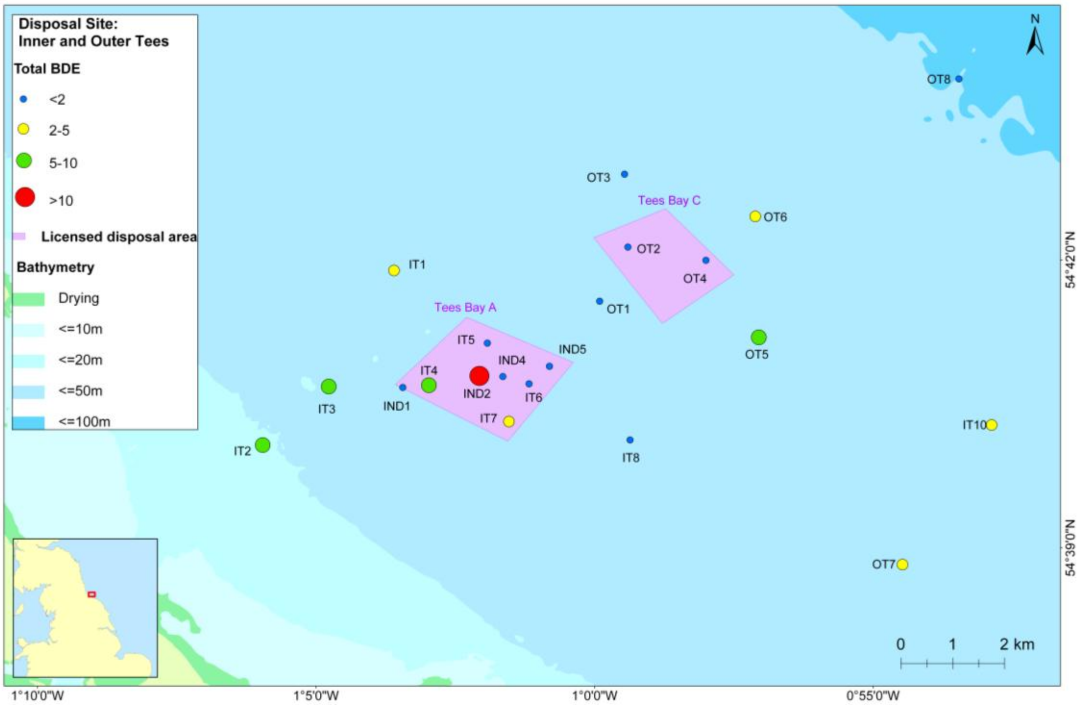


Figure A2.3.14. ∑ 11 BDEs concentrations for the Inner and Outer Tees Stations, 2010.

BDE209 was detected at 19 of the 20 stations (with IND5 the exception) and was at higher concentrations than the other measured organohalogens (range <0.05-32 µg/kg dw). When included with the other BDEs, BDE209 made up >65% of the BDEs present, except for at IND2 and IT2 where it was 52 and 35% of ∑12 BDEs. BDE209 is indicative of the decaBDE technical mixture, which had been in use more recently than the other technical mixtures, although it's use has been restricted in the EU since 2008. The highest concentration of 32 µg/kg dw was detected at IND2 within the inner Tees disposal site, with 31 µg/kg dw at IT3 just west of the disposal site (Figure A2.3.15). For the Inner Tees area, other notable values inside the disposal site were 12 µg/kg dw for IT4 and 10 µg/kg dw for IT5 and IT7. For the Outer Tees disposal site, levels were much lower, <3 µg/kg dw. However, a BDE209 concentration 20 µg/kg dw was found at OT5, to the southwest of the Outer disposal site.

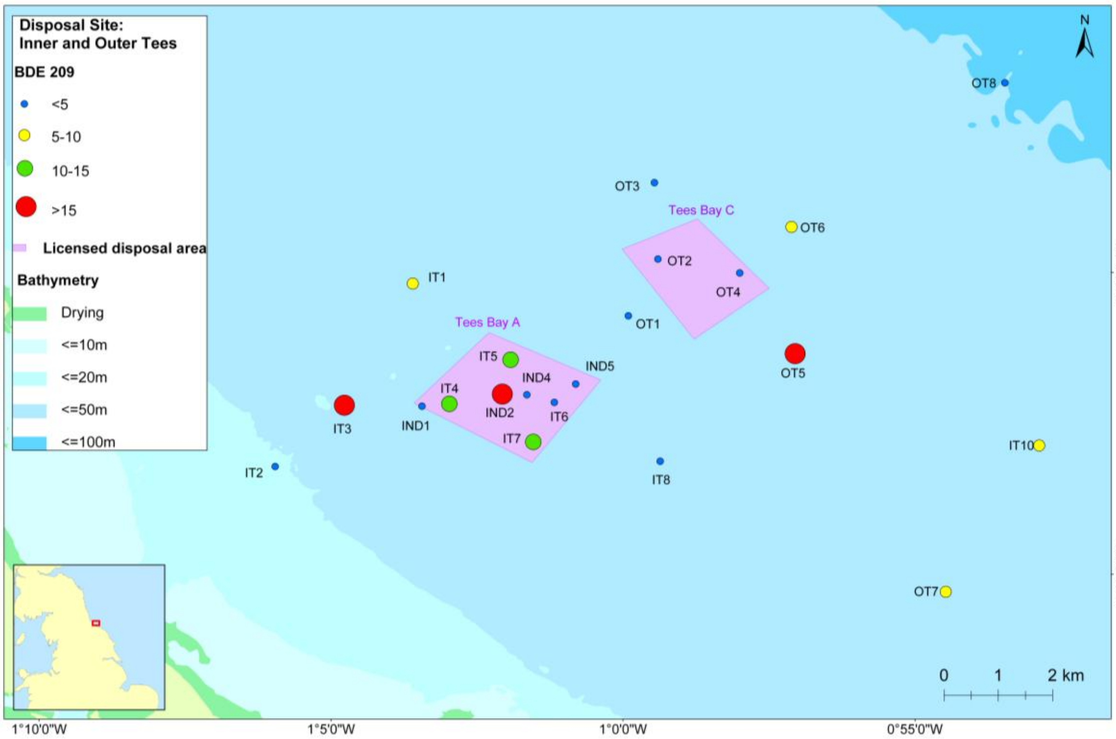


Figure A2.3.15. BDE209 concentrations for the Inner and Outer Tees Stations, 2010.

OCs were present at low concentrations, generally <1 µg/kg dw when detected. Exceptions were DDTs and HCB which were occasionally higher. HCB concentrations of 1.5, 1.1, 1.1 and 1.1 µg/kg dw were found at IT4, IT3, IND2 and OT5, respectively. For the Inner Tees area, IT1, IT3, IT5 and IT7 had ∑ DDT concentrations of 1.0, 2.0, 1.2 and 1.6 µg/kg dw, respectively (Figure A2.3.16), most of which was DDT metabolites. In the Outer Tees area, ∑ DDT concentrations of 2.5, 2.4, 2.1, 2.1, 1.9 and 1.1 µg/kg dw were found for OT5, OT6, OT2, OT3, OT4 and OT1 respectively, and with DDT present at higher concentrations than its metabolites, indicating a more recent source of DDT. HCHs were detected at low concentrations <0.4 µg/kg dw at 10 out of 20 stations, in both Inner and Outer Tees areas.

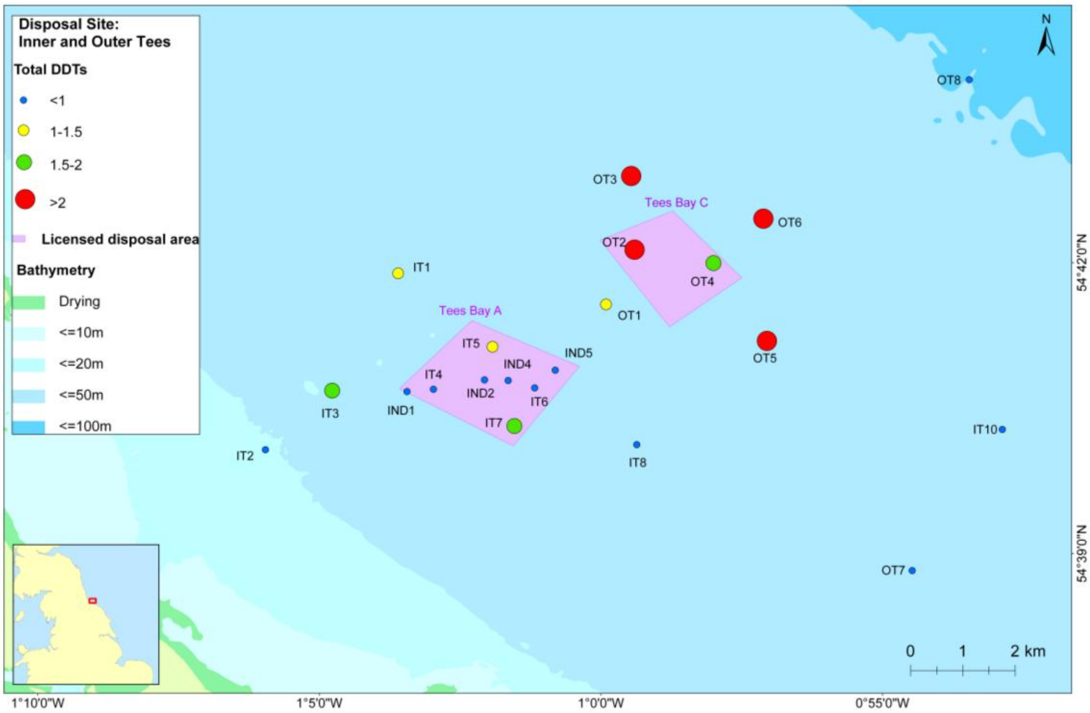


Figure A2.3.16. ∑ DDTs concentrations for the Inner and Outer Tees Stations, 2010.

Concentrations of CBs at all stations were below Cefas ALs. Concentrations of DDTs were above Cefas AL1 at stations OT1, OT2, OT3, OT4, OT5, OT6, IT1, IT3, IT5 and IT7. No AL2 exists for DDTs and no Cefas ALs exist for BDEs including BDE209. According to the OSPAR guidelines, all stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. No OSPAR guidelines exist for BDEs and OCs at present.

Sampling organohalogens under the auspices of SLAB5 has now been conducted at these stations for a number of years. Consequently, there are sufficient data to investigate temporal trends of these contaminants from 2003 to 2010 (Tables 2.3.6 to 2.3.9). At Inner Tees, there is no clear temporal trend for CBs, with some stations increasing and others decreasing (Table A2.3.6). Stations IT3, IND2, IT5 and IT7 all had higher concentrations in 2010 than in 2009, whereas IND1, IT4, IND4, IT6 and IT8 all had lower concentrations. Regarding Outer Tees, there is generally an increasing trend, with OT2, OT3, OT5, OT6 and IT10 all having higher concentrations in 2010 than in 2009 (but not necessarily relative to 2008), and only OT4 having lower concentrations. However, one notable feature is that these values in more recent years do not approach the high levels occasionally found at some stations towards the start of this monitoring period (i.e., 26.4 and 24.1 µg/kg dw at IT4 and IT7 respectively, during 2003).

Station code	**∑ ICES 7 CBs concentration (in µg/kg dw)**							
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
IT2	*0.7*						*0.7*	*0.7*
IT1				0.83	1.54		2.13	2.04
IND1				*0.7*	*0.7*	*0.7*	1.96	*0.7*
IT3	*0.7*			*0.7*	5.09	*0.7*		4.58
IT4	26.4			*0.7*	2.8	*0.7*	2.75	2.03
IND2				*0.7*		*0.7*	*0.7*	*2.72*
IT5	*0.7*			*0.7*		0.92	*0.7*	1.21
IND4					4.62	1.76	2.15	*0.7*
IT7	24.1			*0.7*	1.7	*0.7*	1.04	1.6
IT6	*0.7*			*0.7*	0.82	2.2	2.39	*0.7*
IND 5					0.95	*0.7*	*0.7*	*0.7*
IT8	*0.7*			*0.7*	1.5	1.64	1.79	1.13
OT1				*0.7*		*0.7*	*0.7*	*0.7*
OT2				*0.7*		*0.7*	*0.7*	0.91
OT3				0.9	*0.7*	*0.7*	*0.7*	1.17
OT4				1.28	5.8	1.5	1.61	*0.7*
OT6				0.83		1.81	*0.7*	1.81
OT5				0.83	3.49	4.19	1.25	4.24
IT10	*0.7*					1.08	0.93	1.85
OT7						6.12		1.27
OT8				*0.7*		*0.7*	*0.7*	*0.7*

Table A2.3.6. Temporal trends (2003-2010) of ∑ICES 7 CBs concentration (in µg/kg dw) at Tees in the stations sampled during 2010. Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs.

For BDEs, there are temporal data available from 2006 to 2010 (Table A2.3.7). At Inner Tees, there was no clear trend, with some stations increasing and others decreasing. Stations IT1, IT2, IT3, IT4, IND2 and IT7 all had higher concentrations in 2010 than in 2009, whereas IND1, IND4, IT6 and IT8 all had lower concentrations. IND2 had a large increase from <LOD to 29 µg/kg. Regarding Outer Tees, BDE concentrations were generally increasing, with OT1, OT2, OT3, OT5, OT6, OT8 and IT10 all having higher concentrations in 2010 than in 2009, and only OT4 having lower concentrations.

In addition to the analysis of 2010 samples for BDE209, sample extracts from 2008 and 2009 were retrospectively analysed, giving some temporal trend information. At Inner Tees, there was no clear trend, with some stations increasing and others decreasing. Stations IT1, IT2, IT3, IND2, IT5 and IT7 all had higher concentrations in 2010 than in 2009, whereas IND1, IND4, IT6 and IT8 all had lower concentrations. IND2 displayed a large increase from <LOD to 32 µg/kg. In the Outer Tees disposal site, BDE209 concentrations are generally increasing

with OT1, OT2, OT3, OT5, OT6, OT8 and IT10 all having higher concentrations in 2010 than in 2009, and only OT4 having lower concentrations.

Station code	**∑11 BDEs concentration (in µg/kg dw)**				
	2006	**2007**	**2008**	**2009**	**2010**
IT2				0.30	5.44
IT1	3.75	2.43		1.75	2.73
IND1	2.85	0.92	0.50	2.10	1.27
IT3	1.08	9.55	0.36		7.76
IT4	3.17	6.19	1.99	4.13	6.41
IND2	1.02		0.22	*0.11*	29.4
IT5	1.04		1.84	1.45	1.87
IND4		3.31	2.99	2.57	1.18
IT7	1.32	1.20	0.64	1.40	3.04
IT6	1.61	1.46	2.80	3.67	0.58
IND 5		1.19	0.20	0.20	0.19
IT8	1.22	2.51	0.95	1.66	1.19
OT1	0.84		0.18	0.23	0.53
OT2	1.06		0.38	0.43	1.24
OT3	1.71	1.04	0.73	0.26	1.26
OT4	2.04	9.91	0.82	1.26	0.74
OT6	1.55		0.87	0.63	2.17
OT5	1.56	8.21	3.41	0.89	5.45
IT10			0.60	0.68	2.85
OT7			5.57		2.61
OT8	0.96		0.79	0.35	0.58

Table A2.3.7. Temporal trends (2003-2010) of ∑11 BDEs concentration (in µg/kg dw) at Tees in the stations sampled during 2010. Note, concentrations in italic represent estimates of concentrations for samples where all 11 BDE congener concentrations were below LODs. Limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower from 2008 onwards, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs.

For DDTs, there are currently sufficient data available to determine temporal trends from 2003 to 2010. For Inner Tees, there is no clear trend; some stations increase and others decrease over time. Stations IT3, IND2, IT8and IT7 all had higher concentrations in 2010 than in 2008, whereas IND1, IT5, IND4, IT6 and IND5 all had lower concentrations. Concerning Outer Tees, there is generally an increasing trend with OT1, OT2, OT3, OT4, OT5 and OT6 all having higher concentrations in 2010 than in 2009, and OT7, OT8 only IT10 having lower concentrations.

Station code	BDE209 concentration (in µg/kg dw)		
	2008	2009	2010
IT2		0.87	2.96
IT1		20.9	9.16
IND1	1.46	9.65	3.29
IT3	1.17		31.0
IT4	13.3	26.6	12.3
IND2	<0.1	<0.1	32.4
IT5	7.42	2.16	10.0
IND4		9.95	2.65
IT7	1.76	5.27	10.5
IT6	39.8	37.9	1.75
IND 5		<0.1	<0.1
IT8		5.89	3.54
OT1	0.58	0.70	2.35
OT2	1.27	1.38	2.56
OT3	2.37	0.80	3.57
OT4	3.81	3.13	1.45
OT6	3.42	2.29	7.85
OT5	19.0	3.86	20.0
IT10	2.19	1.97	6.43
OT7	84.3		5.53
OT8	0.75	<0.1	1.53

Table A2.3.8. Temporal trends (2008-2010) of BDE209 concentration (in µg/kg dw) at Tees in the stations sampled during 2010.

2.3.4.5.4 Trace metals

There were no significant differences in metals concentrations over the last five years for those stations within and those outside the disposal site (Figure A2.3.17). This observation may be due to the dispersive nature of the site, therefore diluting all elevated concentrations across the sampling area.

Temporal variations of metals concentrations for stations inside the disposal site (Figure A2.3.18) and outside the disposal site (Figure A2.3.19) show similar patterns for all elements with no definite increase/decrease over time. The highly dispersive area may have masked the increase of this input.

Station code	**∑DDTs concentration (in µg/kg dw)**							
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
IT2	0.60							*0.3*
IT1				1.43	2.01			1.01
IND1				0.85	0.99	1.12		0.47
IT3	0.41			0.64	3.73	0.63		1.95
IT4	0.55			0.88	1.63	0.88		0.89
IND2				0.58		0.45		0.95
IT5	0.41			0.65		1.55		1.15
IND4					2.02	1.17		*0.3*
IT7	3.65			0.60	1.4	0.81		1.58
IT6	*0.3*			0.98	1.62	1.72		0.71
IND 5					1.81	0.41		*0.3*
IT8	0.45			0.65	1.91	0.71		0.91
OT1				0.58		0.64		1.12
OT2				0.81		0.66		2.08
OT3				0.88	1.4	0.73		2.11
OT4				0.93	4.4	0.92		1.87
OT6				1.01		0.85		2.42
OT5				1.05	2.81	2.27		2.45
IT10	*0.3*					0.89		0.84
OT7						2.88		0.71
OT8				0.78		0.65		*0.3*

Table A2.3.9. Temporal trends (2003-2010) of ∑DDTs concentration (in µg/kg dw) at Tees in the stations sampled during 2010.

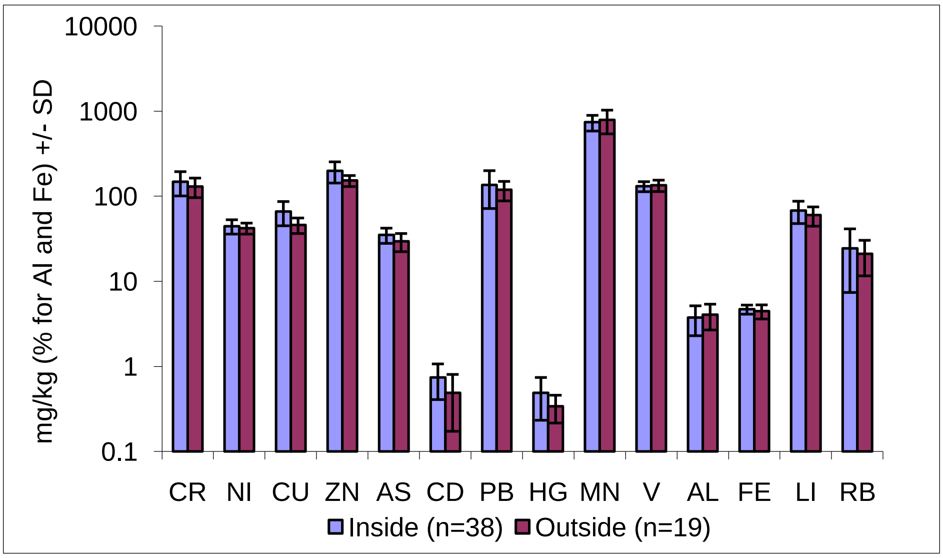


Figure A2.3.17. Average metal concentrations inside and outside for metal concentrations at the Inner Tees between 2006 and 2010 inclusive

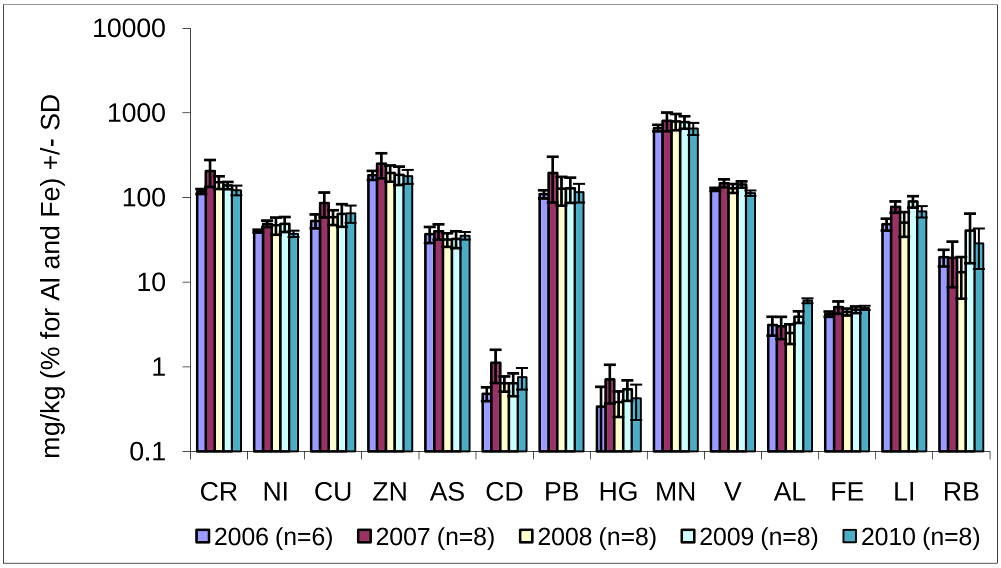


Figure A2.3.18. Average metal concentrations inside the Inner Tees disposal site from 2006-2010

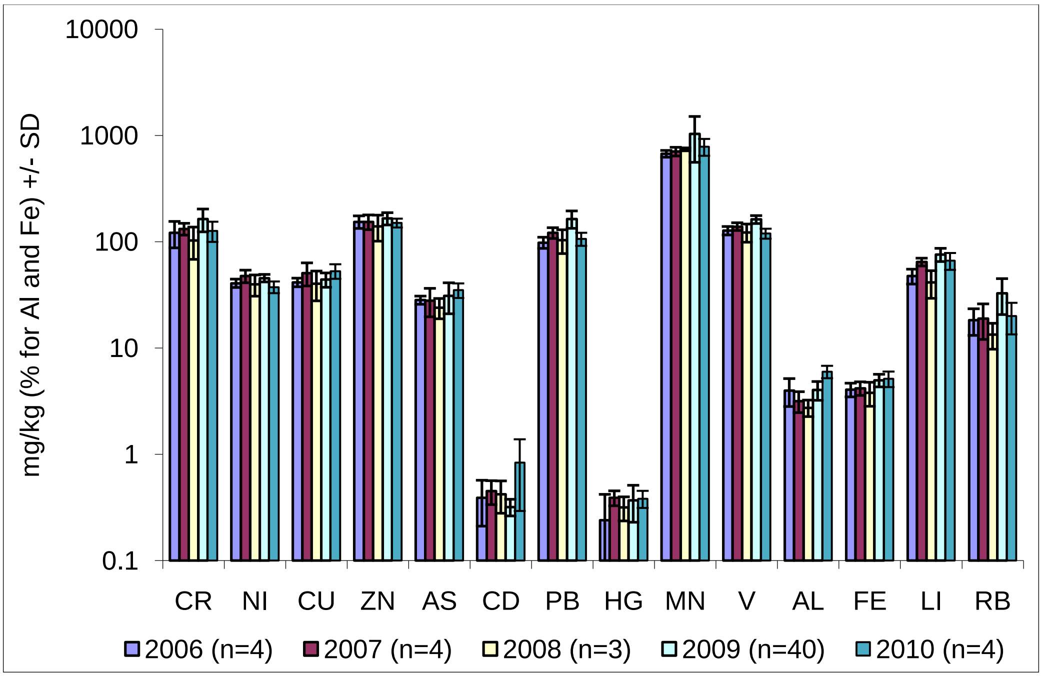


Figure A2.3.19. Average metal concentrations outside the Inner Tees disposal site from 2006-2010.

Stations within and outside the disposal sites show similar levels of metals concentration across the five year period (Figure A2.3.20). The same conclusions reached regarding spatial (inside and outside differences) and temporal variations in metals concentrations for the Inner

Tees site also apply to the findings based on the data acquired for the Outer Tees disposal site (Figures 2.3.20 to 2.3.22). However, unlike the Inner Tees site, there has been no dredged material disposed of to the Outer site, a feature that may partly explain the lack of differences between metals concentrations inside and outside the disposal site.

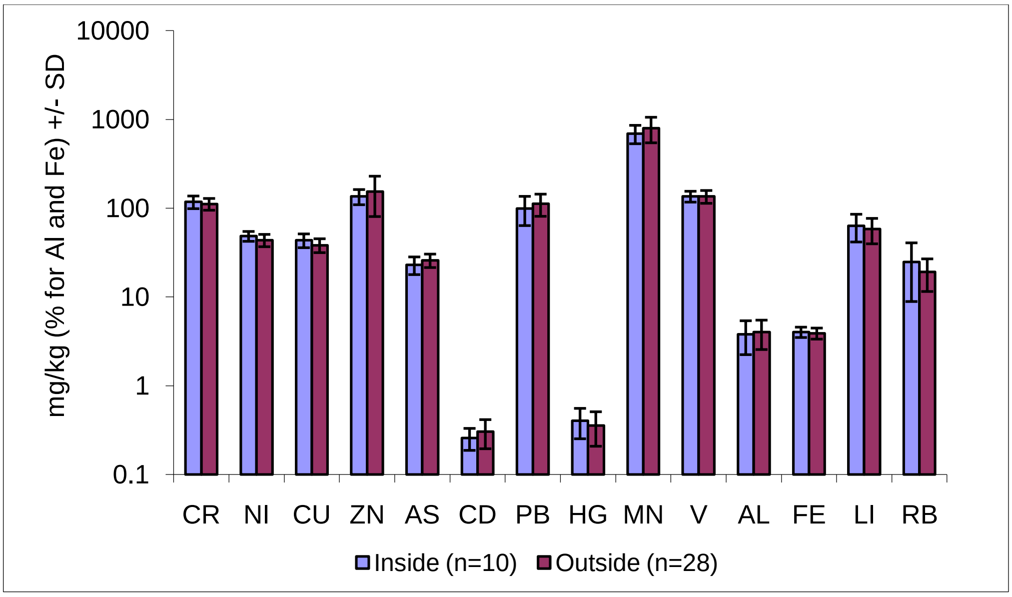


Figure A2.3.20. Average metal concentrations inside and outside for metal concentrations at the Outer Tees between 2006 and 2010 inclusive.

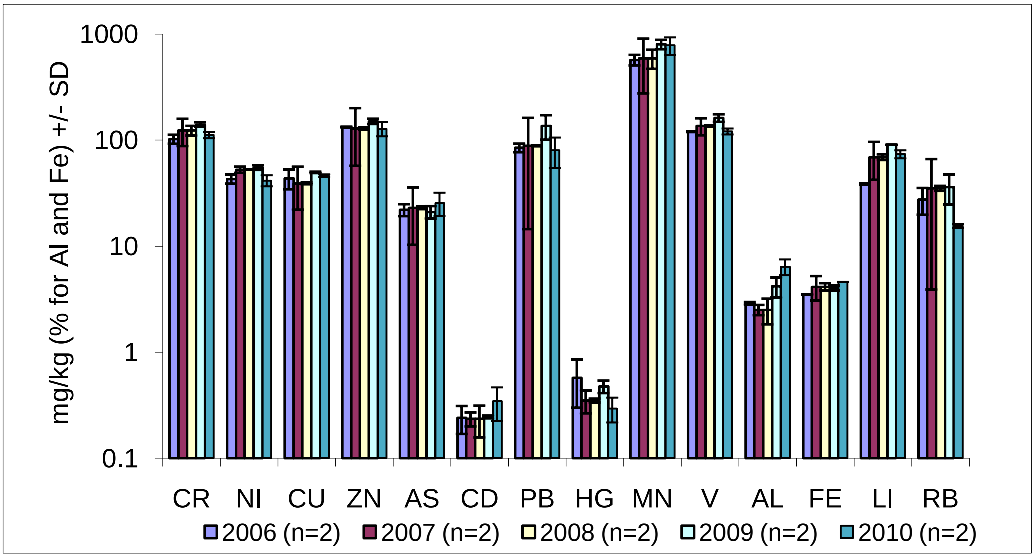


Figure A2.3.21. Average metal concentrations inside the Outer Tees disposal site from 2006-2010.

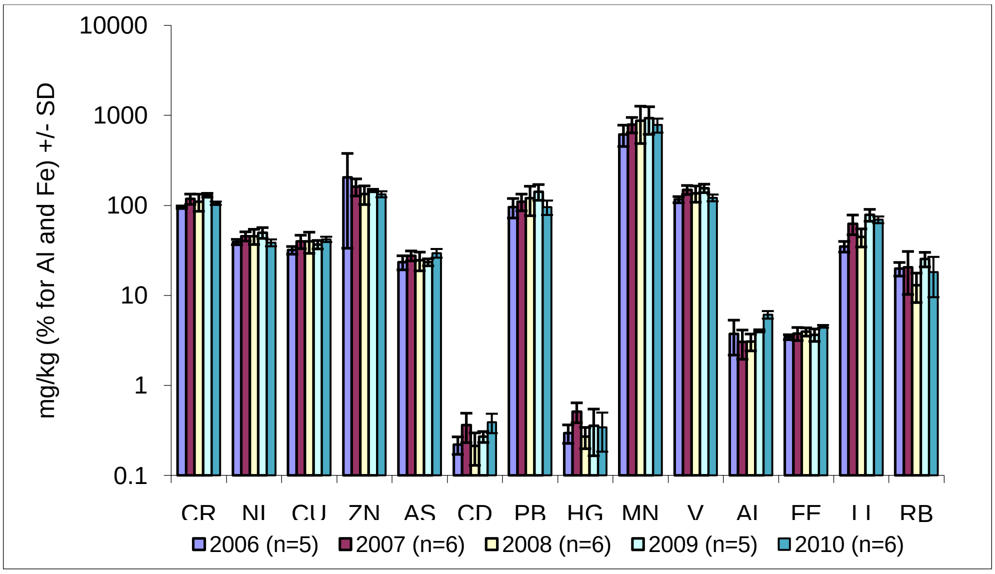


Figure A2.3.22. Average metal concentrations outside the Outer Tees disposal site from 2006-2010.

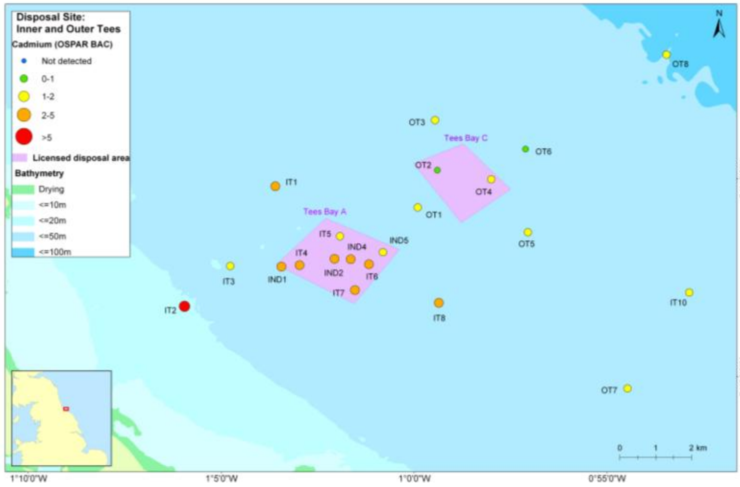
As, Cr, Ni and Zn show similar enrichment factor; a slight enrichment is observed at most sites based on the OSPAR BAC approach. This enrichment is slightly reduced when assessed using the baseline method (see Figure A2.3.23 for Zn). This is due to the fact that the proposed baselines values for the above metals are higher than the OSPAR BAC value, to take into consideration regional variability (Cefas, 2011).

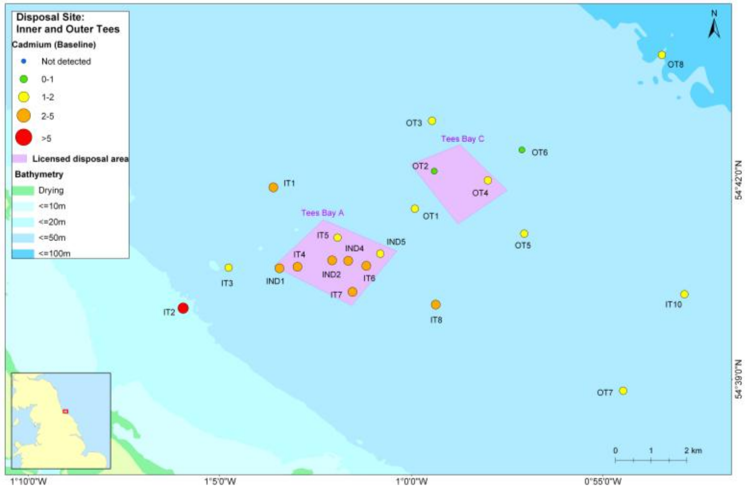
The difference in enrichment factors between the two assessment approaches was perhaps even more pronounced for Pb. For example, Pb shows a moderate enrichment for all stations at Tees disposal sites with the OSPAR numerical approach whereas only one station within the Inner Tees disposal site (IND2) exhibits a slight enrichment according to the regional baseline method (Figure A2.3.23).

Enrichment for Cd and Cu are relatively higher at Inner Tees disposal site than at Outer Tees disposal site; this is maintained when based on both assessment approaches (Figure A2.3.23). This observation may be due, in part, to the fact that no dredged materials have been disposed of at the Outer Tees disposal site for the last 3 years.

Hg is found to be moderately enriched (Outer Tees) to highly enriched (Inner Tees) when compared with the OSPAR BAC. Those levels are lower when assessment was conducted using baseline value, with only one station (located within the disposal site, IND2) exhibiting level of enrichment between 2 and 5.

Despite the fact that the Tees has a large quantity of chemical industries which have resulted in contaminants within dredge sediments (ICI and TiOxide factories have all discharged into the Tees) and there is an eroding mud flat within the Tees Estuary, which is contaminated with high levels of lead and zinc, the findings show that the extent of enrichment of Pb and Zn still remain low.


Disposal Site:
Inner and Outer Tees
Cadmium (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
Tees Bay A
Tees Bay C
OT1
OT2
OT3
OT4
OT5
OT6
OT7
OT8
IT1
IT2
IT3
IT4
IT5
IT6
IT7
IT8
IT10
IND1
IND2
IND4
IND5
N
0
1
2 km
54°42'0"N
54°39'0"N
1°10'0"W
1°5'0"W
1°0'0"W
0°55'0"W


Disposal Site:
Inner and Outer Tees
Cadmium (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
Tees Bay A
Tees Bay C
OT1
OT2
OT3
OT4
OT5
OT6
OT7
OT8
IT1
IT2
IT3
IT4
IT5
IT6
IT7
IT8
IT10
IND1
IND2
IND4
IND5
N
0
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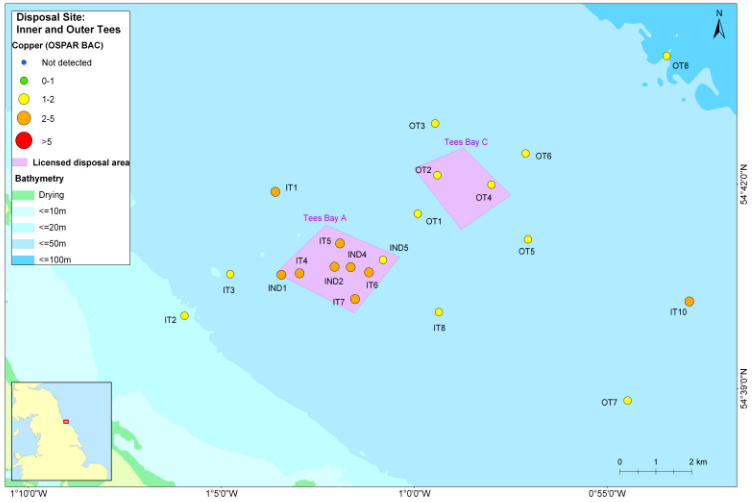
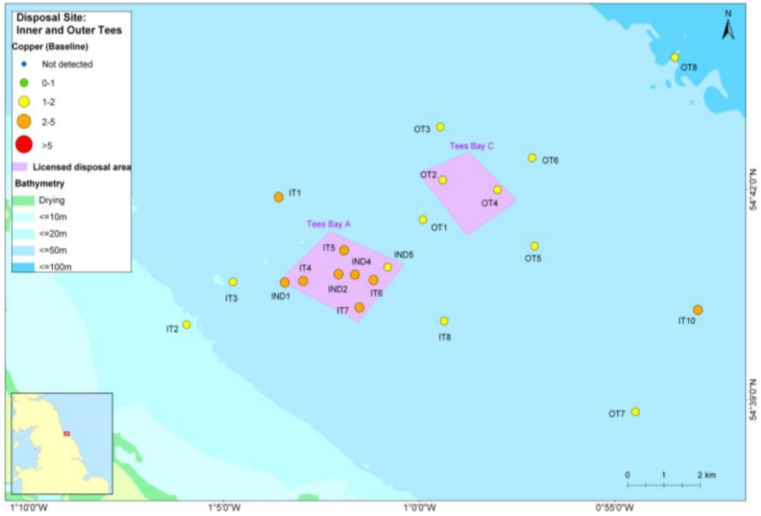
1°5'0"W
1°0'0"W
0°55'0"W


Disposal Site:
Inner and Outer Tees
Copper (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
Tees Bay A
Tees Bay C
OT1
OT2
OT3
OT4
OT5
OT6
OT7
OT8
IT1
IT2
IT3
IT4
IT5
IT6
IT7
IT8
IT10
IND1
IND2
IND4
IND5
N
0
1
2 km
54°42'0"N
54°39'0"N
1°10'0"W
1°5'0"W
1°0'0"W
0°55'0"W


Disposal Site:
Inner and Outer Tees
Copper (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
Tees Bay A
Tees Bay C
OT1
OT2
OT3
OT4
OT5
OT6
OT7
OT8
IT1
IT2
IT3
IT4
IT5
IT6
IT7
IT8
IT10
IND1
IND2
IND4
IND5
N
0
1
2 km
54°42'0"N
54°39'0"N
1°10'0"W
1°5'0"W
1°0'0"W
0°55'0"W

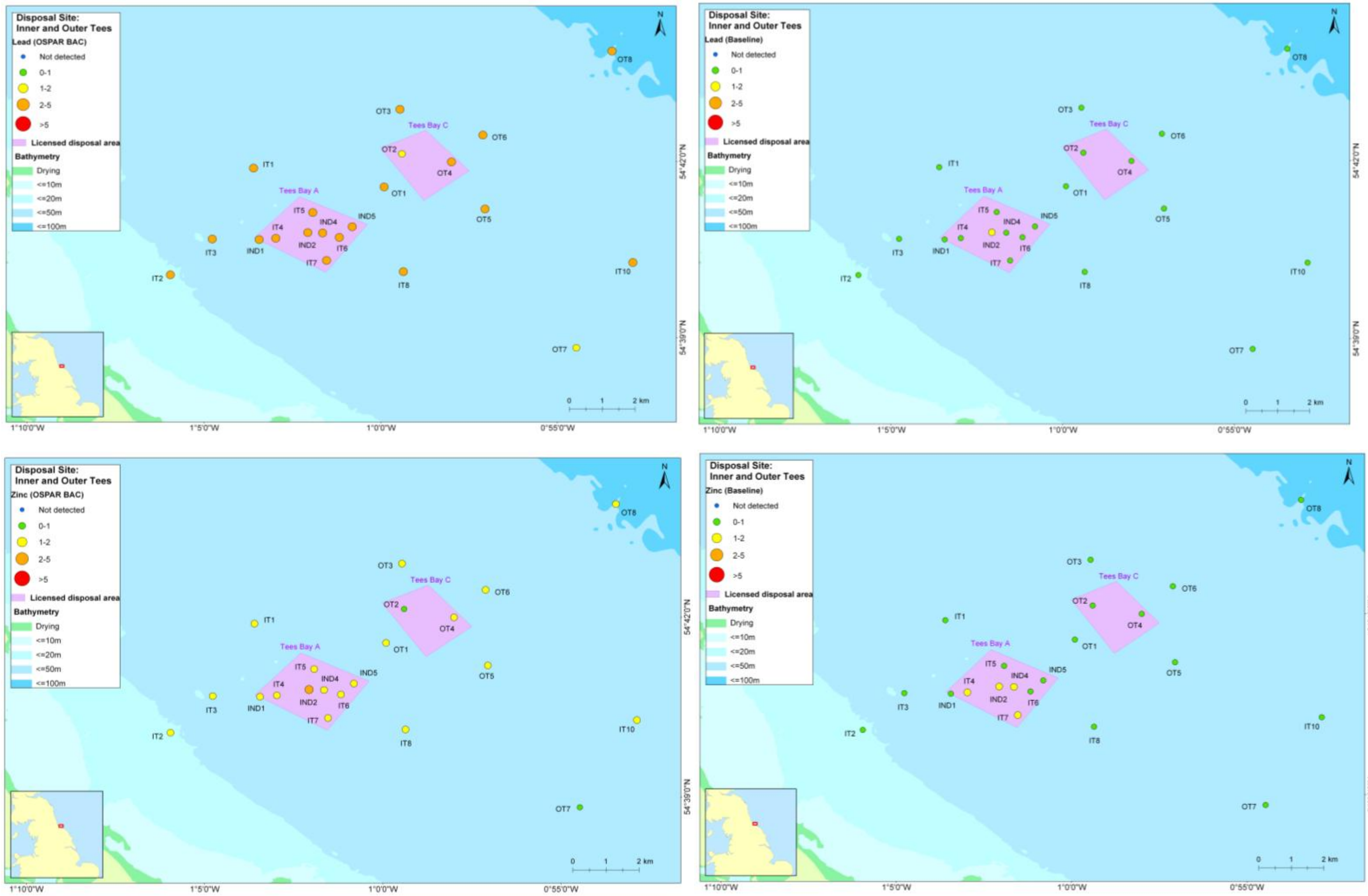


Figure A2.3.23. Enrichment to OSPAR BACs (raw/OSPAR BAC) and regional baselines for Inner and Outer Tees, 2010.

2.4 Goole (HU041)

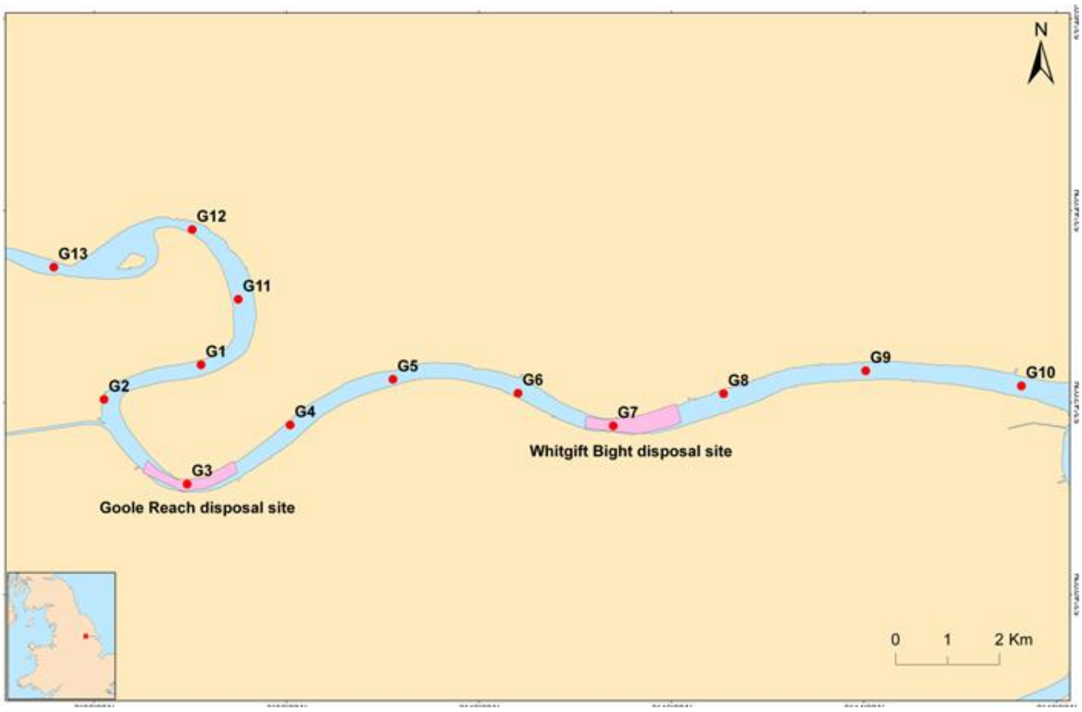


Figure A2.4.1. Location of the sampling stations at Goole, 2010.

2.4.1 Background

Goole Reach (HU041) and Whitgift Bight (HU040) dredged material disposal sites are both located on the River Ouse on the upper reaches of the Humber Estuary. These sites are located within hydrodynamic stretches of the river; material is rapidly dispersed both upstream and downstream (depending on the tidal state at disposal) following disposal.

HU040 was opened in 1982, but no disposal was made until 1984. HU041 was opened in 1990, first disposals in 1990. Only maintenance dredged material from Goole docks is disposed to these sites, and is generally silt/sand material with an approximate specific gravity of 1.3.

Goole Docks have a current FEPA licence for the disposal of 49,000 tonnes (37,690 m^3) of maintenance dredged material. Dredging operations take place prior to high tide with deposition taking place around high water, with the disposal of approximately 1100 tonnes per tide.

RAT prioritisation assessment: Tier 1

- Where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas action levels of 1 and 2 in proposed dredge sediments) arising from historical or current activities at source.

Concern:

These disposal sites have been selected for sampling as material from Goole docks with elevated levels of PAH has been disposed to these sites. Sampling at and adjacent to the disposal sites under SLAB5 during 2008 revealed high levels of DDT: further sampling under this project is needed to improve our understanding of the potential source of this contaminant (i.e., disposal activities or otherwise). The catchment area of this river is predominantly agricultural; high levels of DDT observed in the sediments may be a result of the historical use of DDT in agricultural practices.

2.4.2 Impact hypotheses:

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits

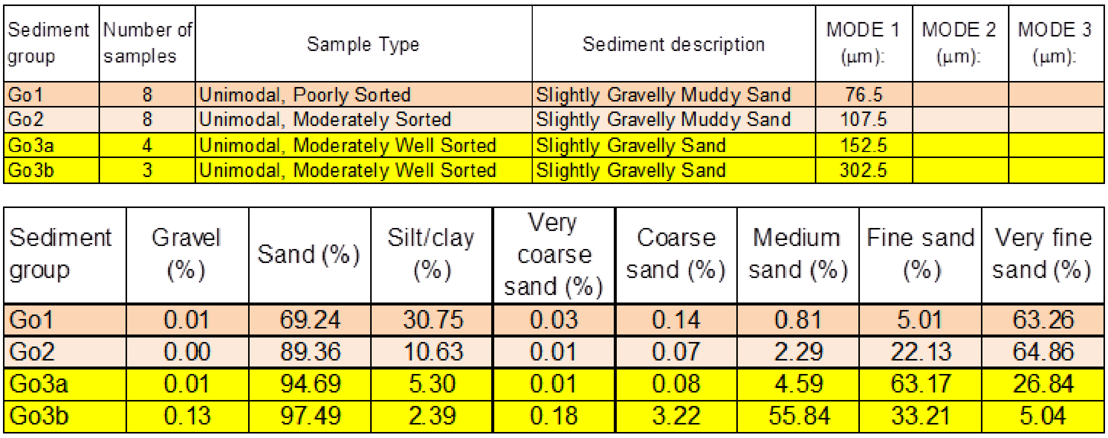
2.4.3 Parameters monitored (via non-Cefas charter vessel):

Sediment particle size
Sediment organic carbon and nitrogen
Sediment contaminants (TBT, PAHs, organohalogens, trace metals)

2.4.4 Results

2.4.4.1 Sediment particle size

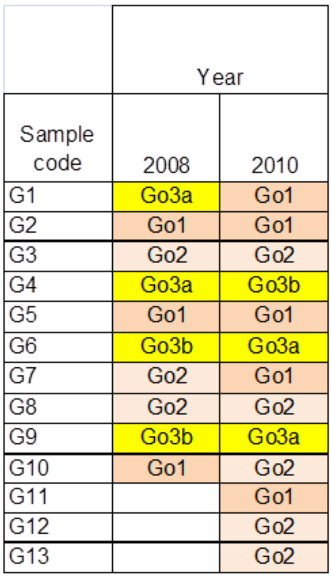
Goole sediments are predominantly muddy sands (Table A2.4.1). Changes in sediment groups from 2008 to 2010 are shown in Table A2.4.2; such changes have been minimal except for an increase of fines at G1 (towards to top of the river), G7 (within the disposal site) and decrease of fines at G10 (at the entrance to the narrow part of the Humber). Pie charts of gravel, sand and silt/clay for 2010 are shown in Figure A2.4.2 and silt/clay content in Figure A2.4.3. These Figures reinforce the above findings of the predominantly sandy nature of the sediments, with increased proportions of silt/clay at several stations (i.e., those in sediment group G01).



Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
Go1	8	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	76.5		
Go2	8	Unimodal, Moderately Sorted	Slightly Gravelly Muddy Sand	107.5		
Go3a	4	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand	152.5		
Go3b	3	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand	302.5		

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
Go1	0.01	69.24	30.75	0.03	0.14	0.81	5.01	63.26
Go2	0.00	89.36	10.63	0.01	0.07	2.29	22.13	64.86
Go3a	0.01	94.69	5.30	0.01	0.08	4.59	63.17	26.84
Go3b	0.13	97.49	2.39	0.18	3.22	55.84	33.21	5.04

Table A2.4.1 Average sediment descriptions and statistics for each sediment group at Goole.



	Year	
Sample code	2008	2010
G1	Go3a	Go1
G2	Go1	Go1
G3	Go2	Go2
G4	Go3a	Go3b
G5	Go1	Go1
G6	Go3b	Go3a
G7	Go2	Go1
G8	Go2	Go2
G9	Go3b	Go3a
G10	Go1	Go2
G11		Go1
G12		Go2
G13		Go2

Table A2.4.2 Sediment groups for each sample code in 2008 and 2010 at Goole.

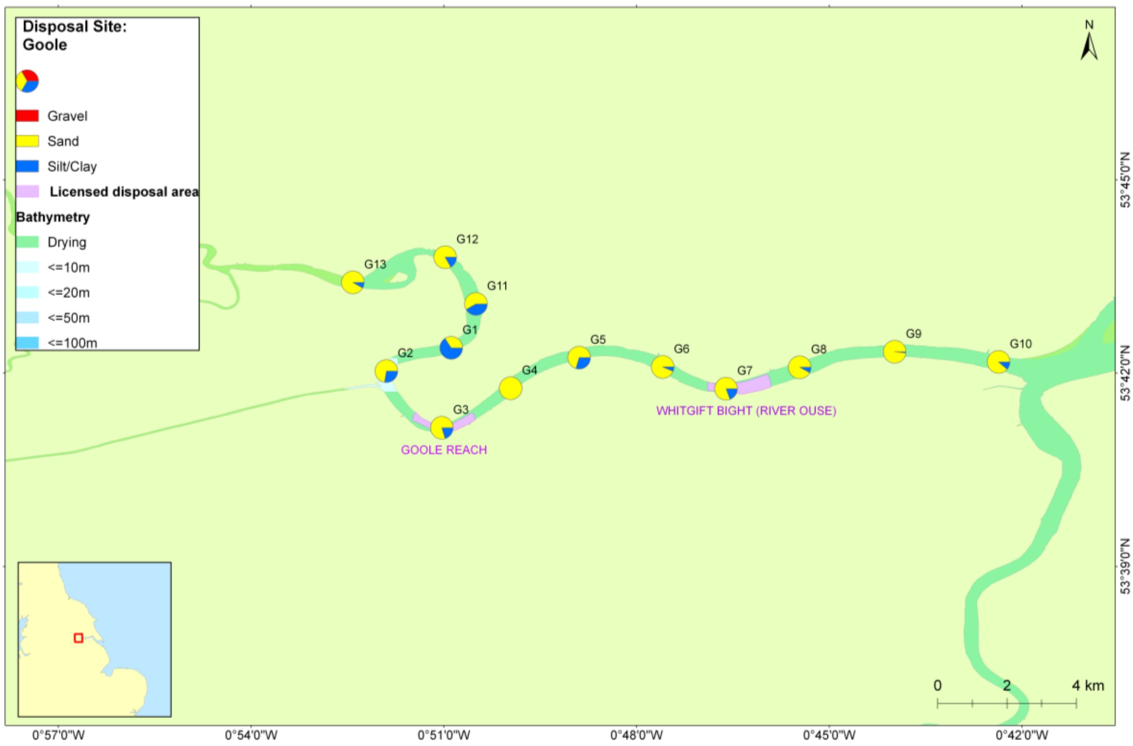


Figure A2.4.2 Pie charts of gravel, sand and silt/clay at Goole in 2010.

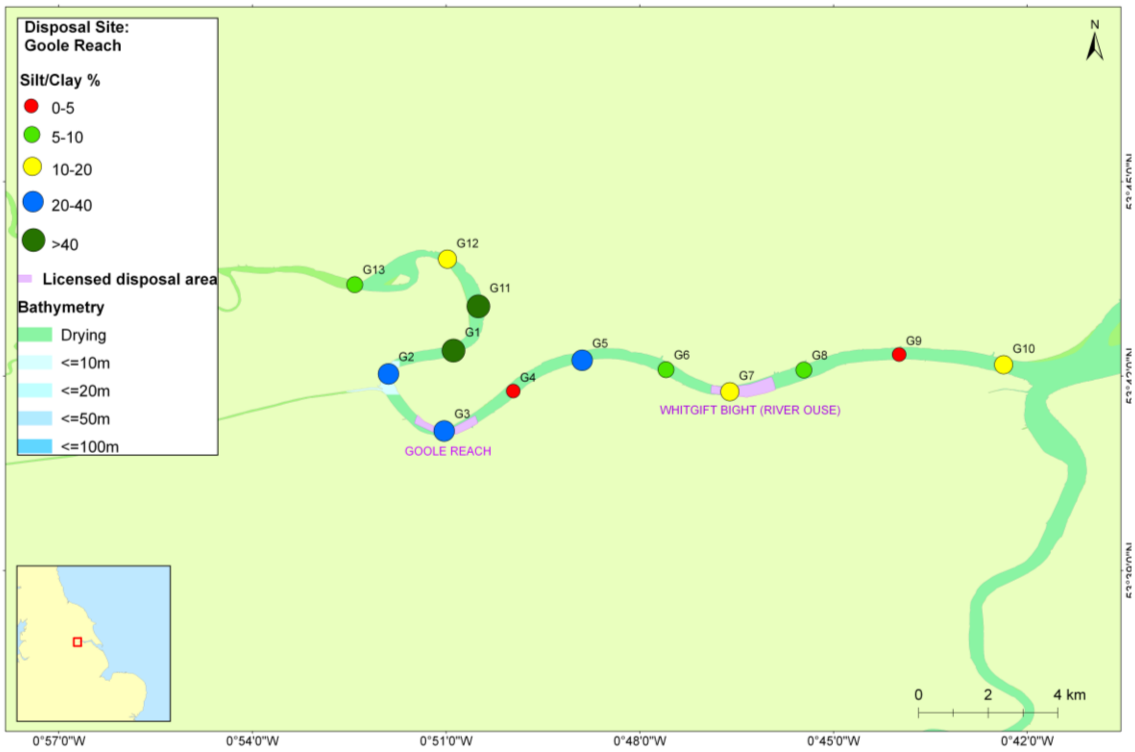


Figure A2.4.3 Silt/clay (%) at Goole in 2010.

2.4.4.2 Sediment organic carbon and nitrogen

In 2010, organic carbon values (in the <63µm sediment fraction) ranged from 0.61 to 2.22 %m/m (Figure A2.4.4) and for organic nitrogen 0.05 to 0.16 %m/m. G04 has low silt/clay content (<2% silt/clay) and so it was not possible to measure the organic carbon in this fraction. These data indicate that organic carbon contents are higher for most sample stations when compared to concentrations measured in 2008 (Bolam et al., 2009).

As in 2008, several samples displayed higher levels of organic carbon present in the <2mm fraction than the <63µm fraction, showing that organic carbon is also present in coarser sediment, probably as coal.

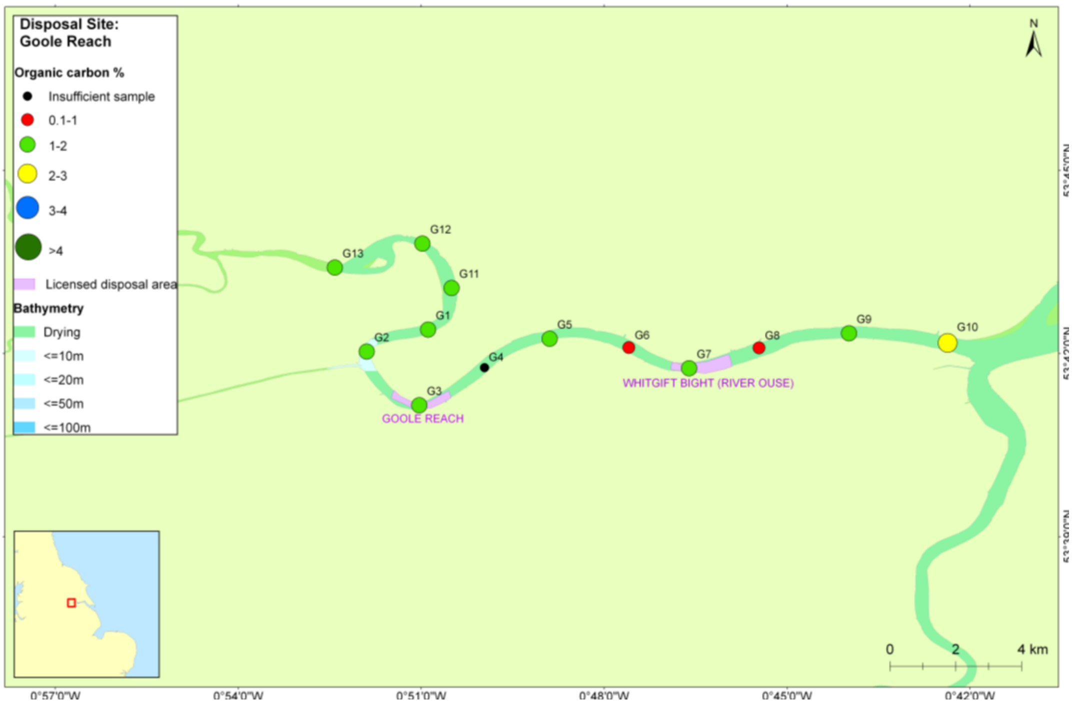


Figure A2.4.4. Organic carbon (%m/m) in the silt/clay fraction (<63µm) at Goole in 2010.

2.4.43 Sediment contaminants

2.4.4.3.1 TBT

Concentrations of TBT and DBT throughout the Goole survey were below LOD except for at stations G1, G2 and G11, all upstream of the disposal site and at station G10, which is downstream of HU040 (Figure A2.4.1). G1, G2 and G11 all exhibited very similar TBT concentrations (0.011, 0.014 and 0.014 mg/kg), while G10 exhibited a slightly lower concentration (0.006mg/kg). All the TBT levels detected at these four stations remain below Cefas AL1. In 2008, all sampling stations exhibited TBT levels <LOD; thus, there has been a slight increase in TBT at some stations in 2010.

2.4.4.3.2 PAHs

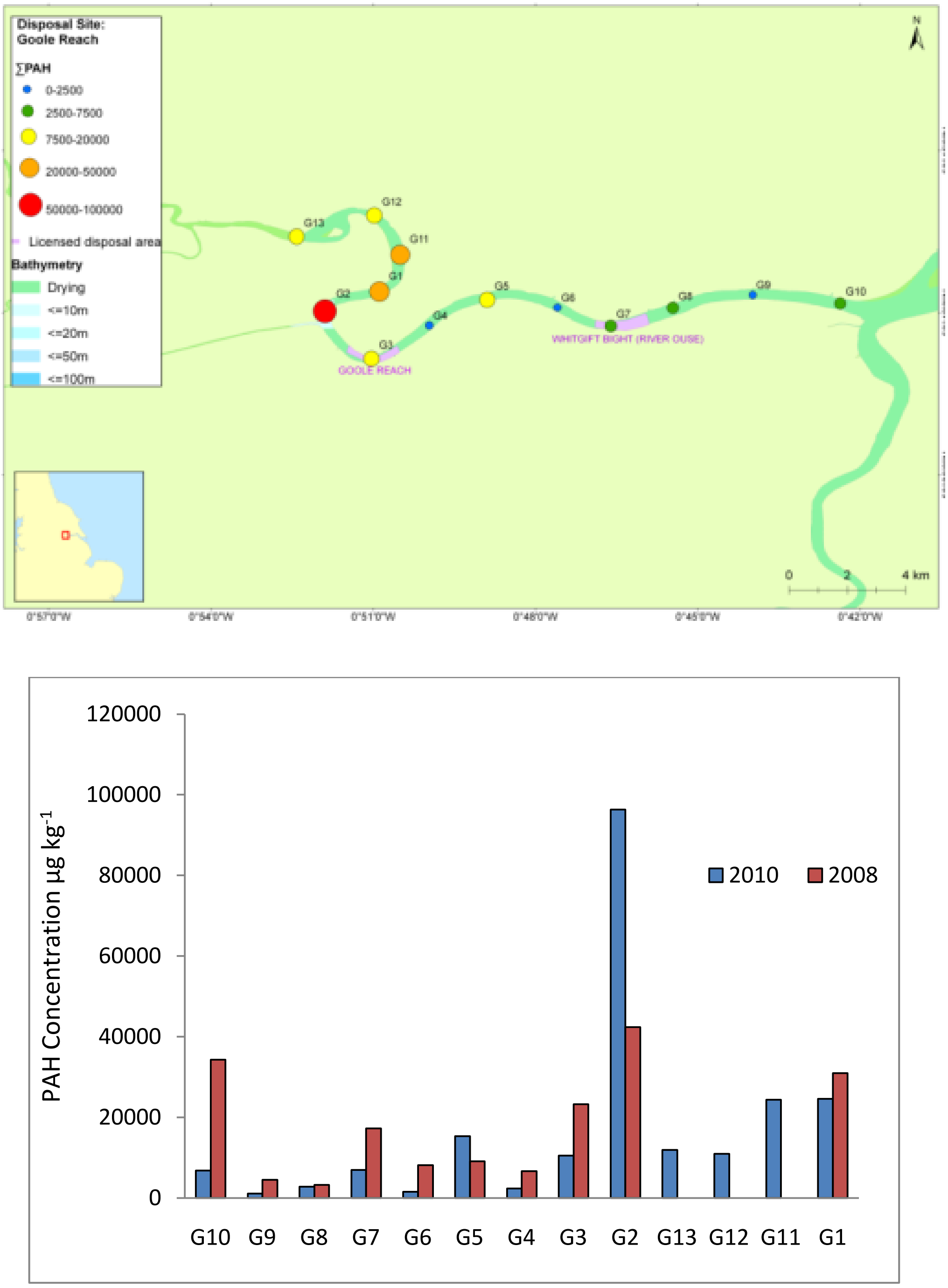


Figure A2.4.5. Summed PAH concentrations (µg kg^{-1} dw) for stations sampled in 2010 at Goole (top) and concentrations observed in 2008 and 2010 (bottom).

The highest summed PAH concentration was, as in 2008, observed at G2 (just upstream of Goole Reach; immediately outside the locks entrance to Goole Docks) (Figure A2.4.5). The summed PAH concentration at this station was much higher than was found in 2008 (i.e., 96,300 µg kg^{-1} dw compared to 21,100 µg kg^{-1} dw in 2010) (Figure A2.4.5). Elevated concentrations were also found at G1 and G11, also upstream of Goole Reach. The ERL for LMW PAHs was exceeded at all stations except G9, G8, G6 and G4. The ERM for LMW PAHs was exceeded at G2, G1 and G11, while the ERL for HMW PAHs was exceeded at G1, G2, G5, G11 and G13. The ERM for HMW PAHs was only breached at G2. The source of PAH was found to be > 70% oil-derived at all sites, except at G4, G8 and G9. Disposal of material to Goole Reach increased in 2009 to 17,000 tonnes, compared to approximately 8,000 tonnes during 2008. At the neighbouring disposal site, Whitgift Bight, the volume of disposal has only increased slightly, from 3,380 tonnes in 2008 to 5,800 tonnes in 2009. Much lower concentrations are generally found in this area compared to those seen further upstream around the Goole Reach disposal site. Because this area is affected by strong tidal currents, concentrations may reflect redistribution of both sea-bed sediments and material from dredgings disposal.

2.4.4.3.3 Organohalogens

CBs were detected at 12 out of the 13 stations sampled, with only station G4 not containing detectable levels of CBs (∑ ICES 7 CBs range <0.7-13 µg/kg dw) (Figure A2.4.6). The highest ∑ ICES 7 CBs value of 13 µg/kg dw was at G2, just upriver of Goole Reach. Note, this was also where the highest levels of PAHs were observed (Figure A2.4.5). The concentration of 2.3 µg/kg dw at G3 within the disposal site however was much lower.

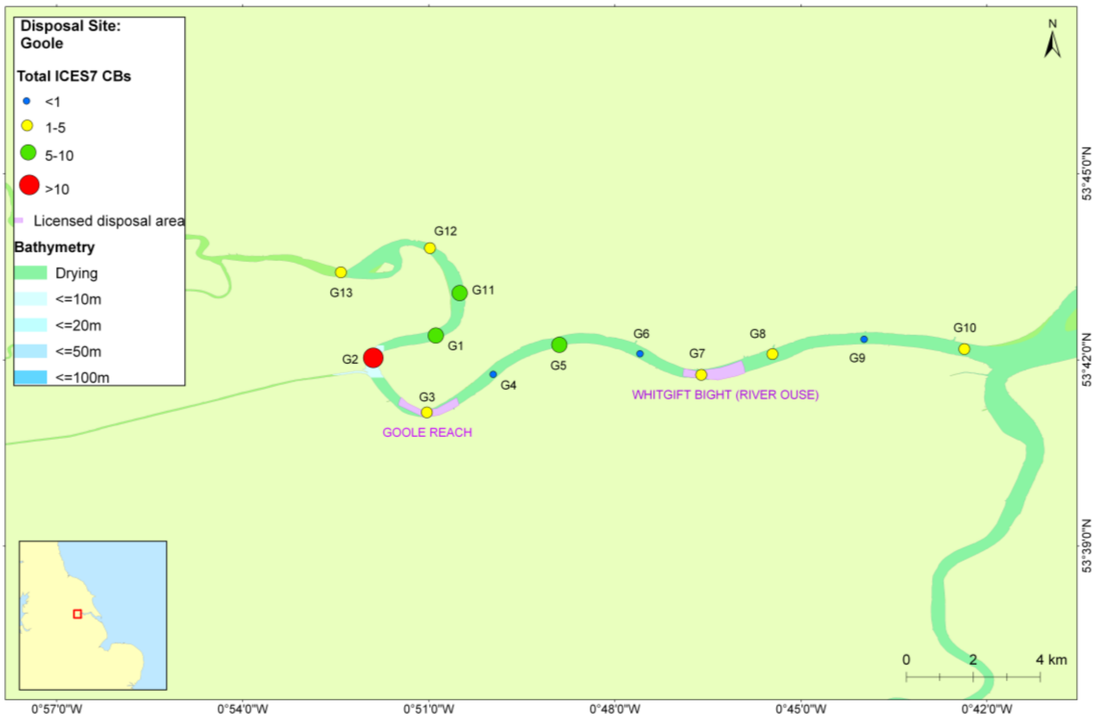


Figure A2.4.6. ∑ ICES7 CB concentrations for the Goole Stations, 2010.

BDEs were detected at all stations in the Goole survey (∑ 11 BDEs range 0.2-20 µg/kg dw). Highest concentrations were upriver of the Goole Reach disposal site, with concentrations of 20, 17 and 8 µg/kg dw at G2, G11 and G1, respectively (Figure A2.4.7). BDE47 and BDE 99 were detected in all stations and were the dominant congeners present. BDE183 was only detected in 4 out of 11 stations, coinciding with high BDE209 values, indicating that the decaBDE technical mixture was its likely source.

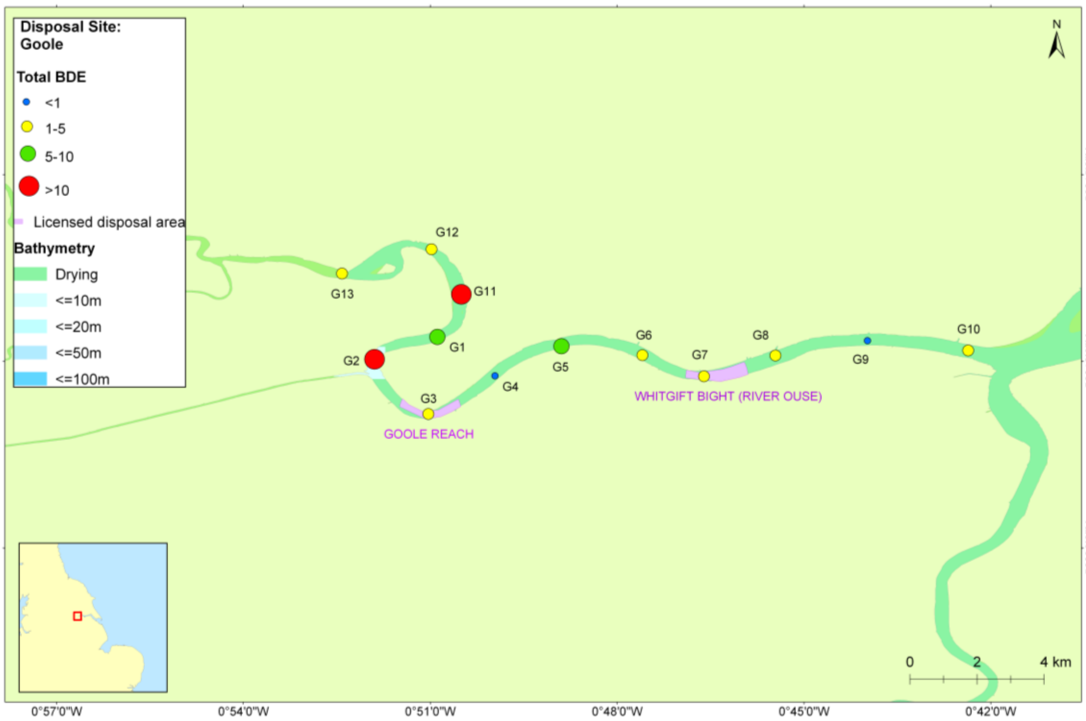


Figure A2.4.7. ∑ 11 BDEs concentrations for the Goole Stations, 2010.

BDE209 was detected at 9 out of the 13 stations sampled in 2010 and was generally at higher concentrations than the other measured organohalogens (range <1 - 310 µg/kg dw). When included with the other BDEs, BDE209 made up >57 % of the BDEs present (range 57 - 95%). BDE209 is indicative of the decaBDE technical mixture, which has been in use more recently than the other technical mixtures, although it's use has been restricted in the EU since 2008. The highest concentration of 310 µg/kg dw was detected at G11 (Figure A2.4.8), with 81, 49 and 38 µg/kg dw at G1, G5 and G2, respectively. Levels within the disposal sites were lower, with 14 and 19 µg/kg dw measured at G3 and G7.

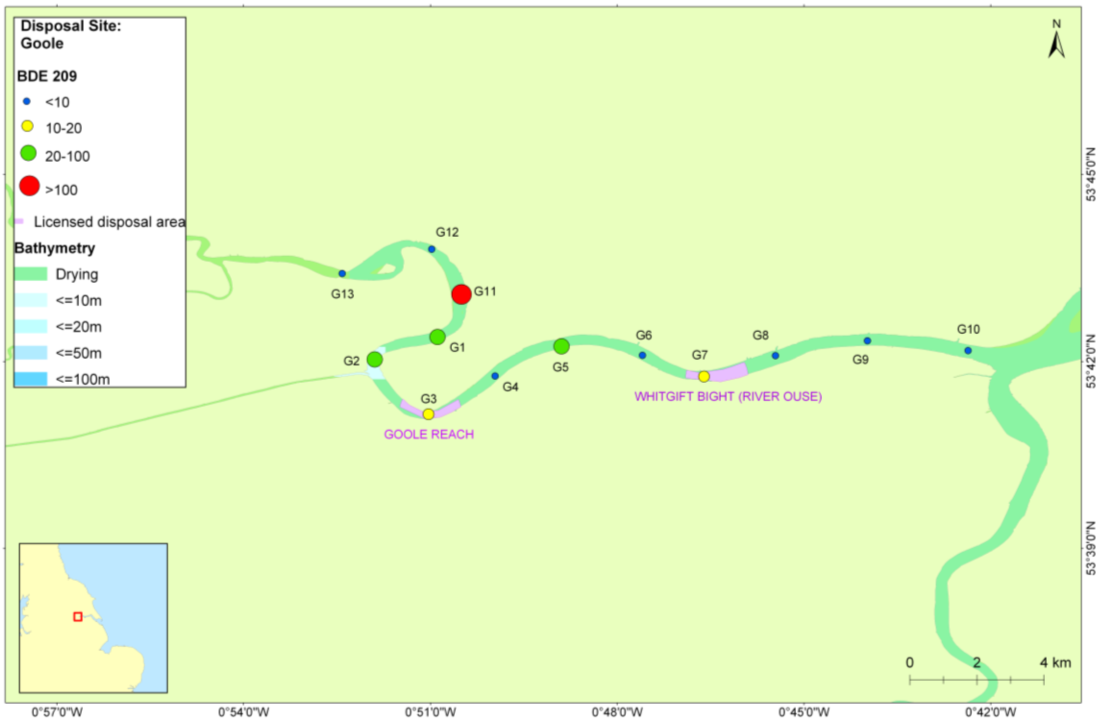


Figure A2.4.8. BDE209 concentrations for the Goole Stations, 2010

p,p'-DDT was detected at 8 out of the 13 stations (range <0.2-7.2 µg/kg dw), with its metabolites detected at all stations in the Goole survey area (range <0.2-19 µg/kg dw). ∑ DDT concentrations were consistently high, with 9 out of 13 stations >5 µg/kg dw (range 0.9 - 22 µg/kg dw) (Figure A2.4.9). Highest concentrations were generally around the Goole Reach disposal site, although levels within the actual site were lower, 5.5 µg/kg dw. The Whitgift Bight disposal site had a higher total DDT concentration of 11 µg/kg dw relative to those concentrations displayed at neighbouring stations (G6, G8 and G9). HCH concentrations were low, with only α-HCH detected at low levels in 4 out of 13 stations. HCB was detected at 10 out of 13 stations, with levels mostly <0.6 µg/kg dw, except at G1, G2 and G11, where concentrations of 1.0, 1.1 and 0.9 µg/kg dw, respectively were recorded. Dieldrin was detected at all stations, with highest levels upriver of the Goole Reach disposal site, where 2.1, 1.4 and 2.0 µg/kg dw was observed at G11, G1 and G2, respectively.

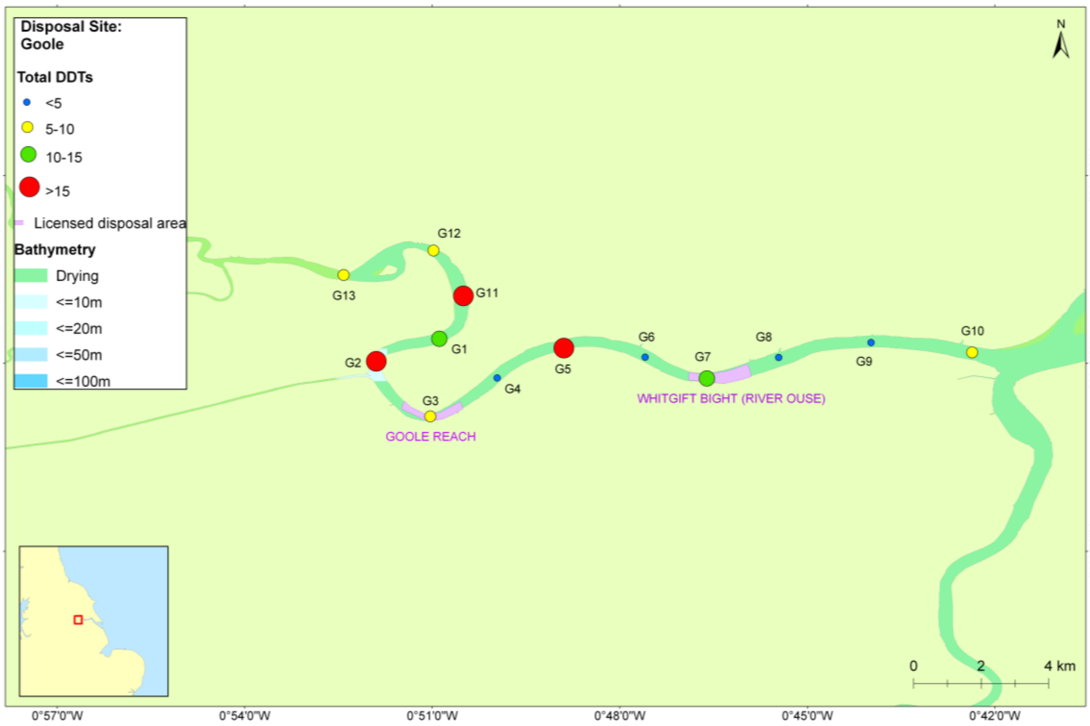


Figure A2.4.9. ∑ DDTs concentrations for the Goole Stations, 2010.

Concentrations of CBs at most stations were below Cefas ALs, with the exception of G2 which was above AL1 but well below AL2. Concentrations of DDTs were above Cefas AL1 at all stations with the exception of G4. No AL2 exists for DDTs. Concentrations of dieldrin were above Cefas AL1 at stations G11, G1 and G2. No Cefas AL2 exists for dieldrin. No ALs exist for BDEs including BDE209. According to the OSPAR guidelines, most stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall. Exceptions with one CB with ‘bad’ environmental status but ‘good’ status overall were G6 and G8 (for CB28) and G5 and G12 (for CB118). Station G10 at the mouth of the river had ‘bad’ environmental status for CB28, CB101 and CB118 and therefore ‘bad’ status overall. No OSPAR guidelines exist for BDEs and OCs at present.

Tables 2.4.3 – 2.4.6 present the current findings with those for 2008 (when only G1 – G10 were sampled) for CBs, BDEs, BDE209 and DDT. For CBs, there was no clear temporal pattern; levels decreased at G3 (within Goole Reach disposal site), G4 and G10 yet increased at G1, G2, G5 and G8 (Table A2.4.3).

Station code	∑ICES 7 CBs concentration (in µg/kg dw)		
	2008	**2009**	**2010**
G1	3.85		*5.58*
G2	4.95		12.7
G3	3.88		2.33
G4	2.07		0.7
G5	1.83		5.35
G6	*0.7*		0.82
G7	2.32		2.46
G8	1.19		1.63
G9	*0.7*		0.83
G10	5.21		3.83
G11			6.83
G12			3.07
G13			2.82

Table A2.4.3. Temporal trends (2008-2010) of ∑ICES 7 CBs concentration (in µg/kg dw) at Goole in the stations sampled during 2010.

Similarly, there was no clear temporal pattern for BDEs. Between 2008 and 2010, concentrations at some stations, including G1, G2, G5 and G8 increased whilst concentrations at some stations, including G3, G6, G7, G9 and G10 decreased. This might represent a weak trend of concentrations upriver increasing and concentrations downriver decreasing.

Station code	∑11 BDEs concentration (in µg/kg dw)		
	2008	**2009**	**2010**
G1	3.68		*8.06*
G2	5.29		20.2
G3	3.78		2.76
G4	1.75		0.18
G5	1.73		6.47
G6	5.45		1.35
G7	4.53		3.56
G8	1.00		1.83
G9	15.6		0.66
G10	7.17		2.00
G11			16.8
G12			3.05
G13			2.51

Table A2.4.4. Temporal trends (2008-2010) of ∑11 BDEs concentration (in µg/kg dw) at Goole in the stations sampled during 2010.

Concentrations of BDE209 generally increased between 2008 and 2010, with G10 the only station where a decrease was observed. Concentrations more than doubled at stations G1, G2, G3 and G5, with G5 and G7 increasing by a factor of approximately 10 (Table A2.4.5).

Station code	**BDE209 concentration (in µg/kg dw)**		
	2008	**2009**	**2010**
G1	*10.2*		*81.3*
G2	7.16		38.2
G3	4.44		14.3
G4	*0.05*		*0.05*
G5	3.36		48.6
G6	5.29		8.24
G7	1.96		18.7
G8	*0.05*		*0.05*
G9	*0.05*		*0.05*
G10	34.2		7.24
G11			310
G12			*0.05*
G13			3.34

Table A2.4.5. Temporal trends (2008-2010) of BDE209s concentration (in µg/kg dw) at Goole in the stations sampled during 2010.

Concentrations of DDTs generally decreased between 2008 and 2010, with G7 the only station where an increase was observed (Table A2.4.6). Concentrations more than halved at stations G1, G3, G4 and G6.

Station code	∑DDTs concentration (in µg/kg dw)		
	2008	**2009**	**2010**
G1	28.46		11.24
G2	22.8		22.2
G3	12.52		5.46
G4	8.87		0.88
G5	19.79		15.39
G6	4.85		1.88
G7	6.39		10.71
G8	5.25		3.62
G9	3.22		2.17
G10	13.34		6.72
G11			21.94
G12			6.70
G13			5.69

Table A2.4.6. Temporal trends (2008-2010) of ∑DDTs concentration (in µg/kg dw) at Goole in the stations sampled during 2010.

2.4.4.3.4 Trace metals

The concentrations of all metals (averaged across all stations) in 2010 were very similar to those observed in 2008 (Figure A2.4.10). Obviously, such averages my mask any smaller-scale changes if they are offset by opposing changes elsewhere within the survey region. Investigating these data further, by averaging values within the disposal sites and averaging those outside, we do see some slight increase in metals concentrations inside the two disposal sites (e.g., for Hg, Al, Pb; Figure A2.4.11).

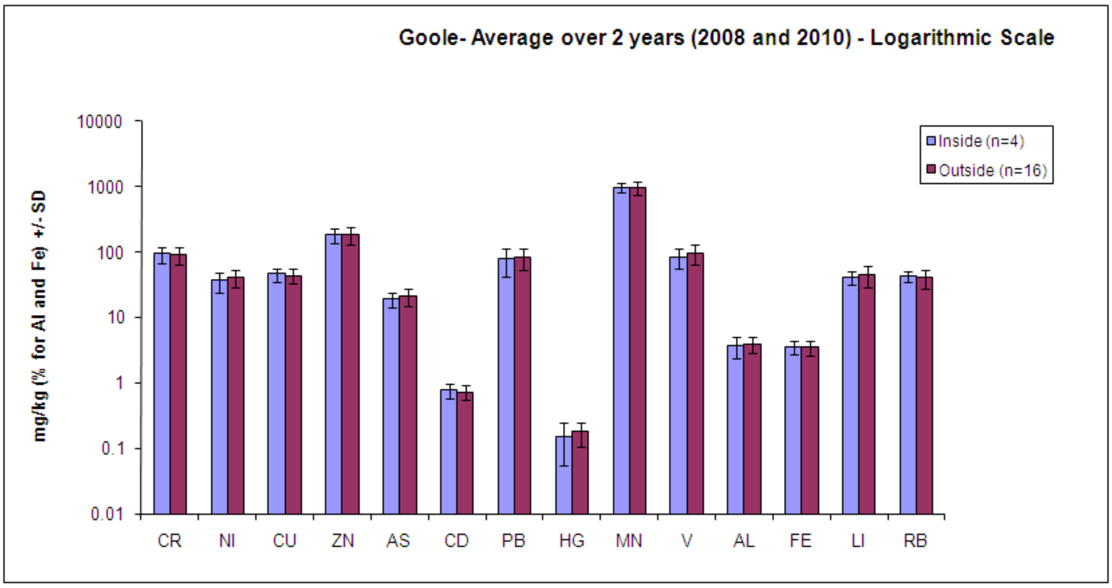


Figure A2.4.10. Average metal concentrations inside and outside for metal concentrations at Goole in 2008 and 2010.

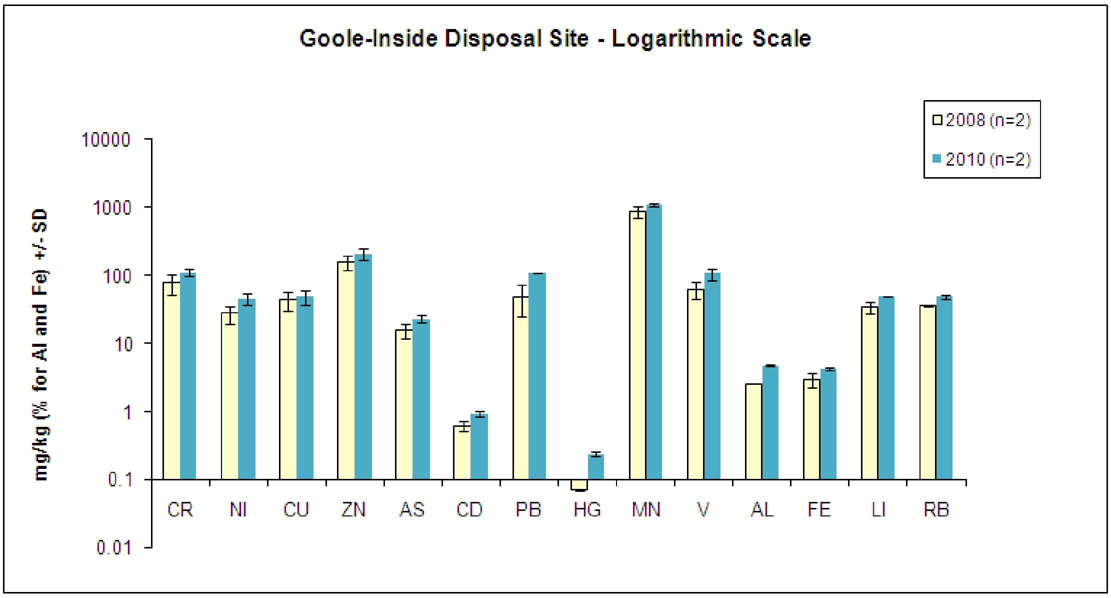


Figure A2.4.11. Average metal concentrations inside the Goole disposal site in 2008 and 2010.

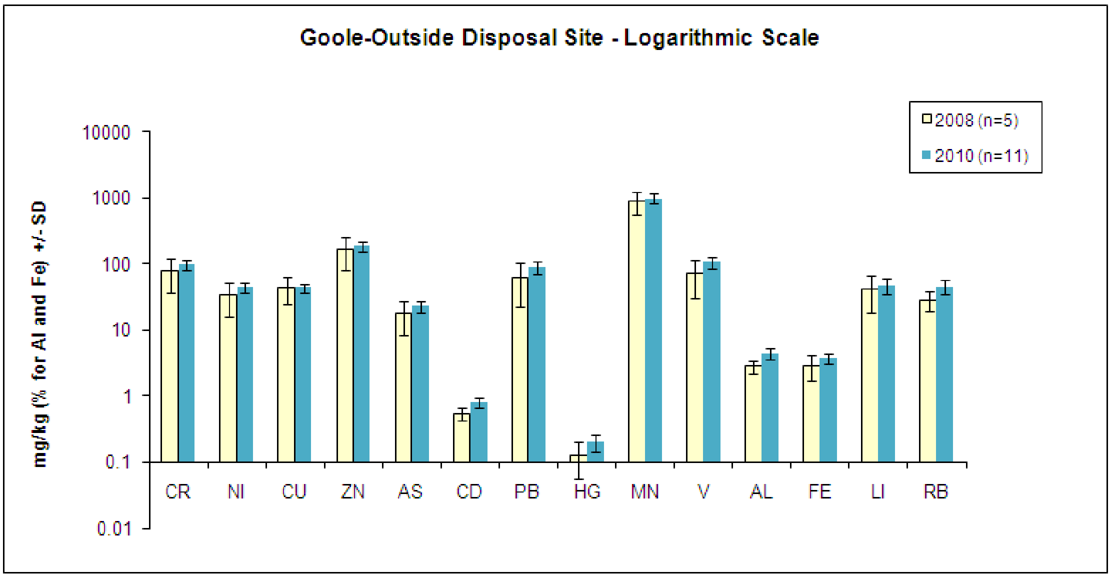
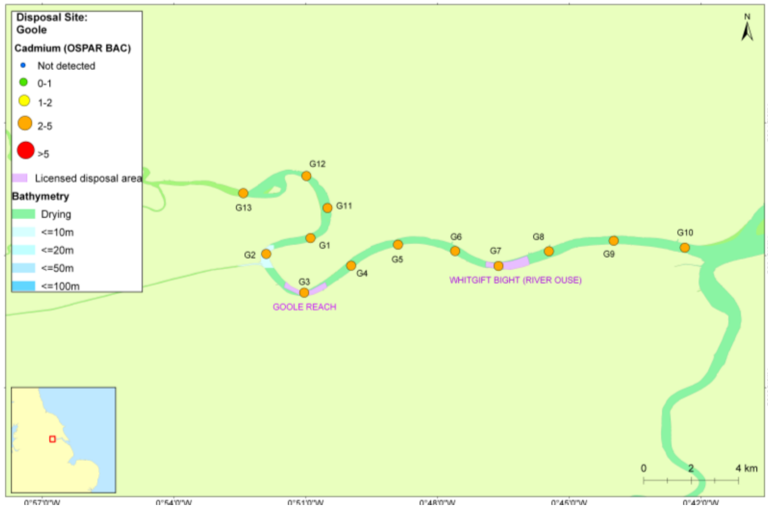


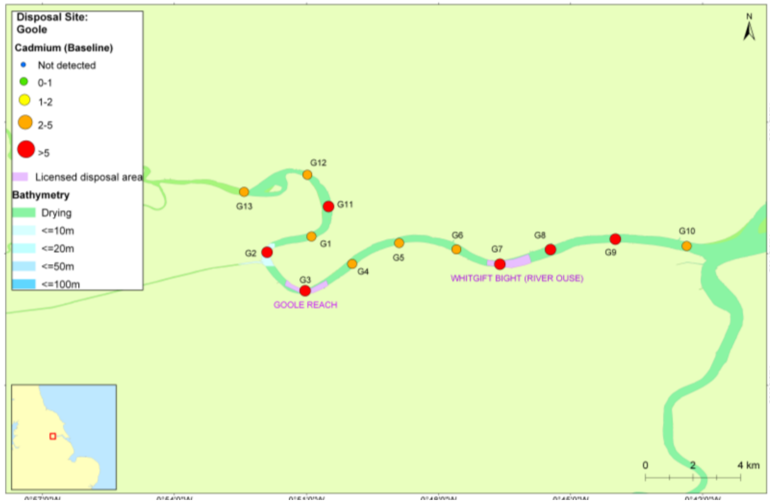
Figure A2.4.12. Average metal concentrations outside the Goole disposal site in 2008 and 2010.

Arsenic levels were comparable to the OSPAR BAC and baseline value, with only 2 stations expressing a slightly higher concentration (G10, at the mouth of the river and G5, in the middle of the river). Cd, however, exhibited a moderate enrichment at all stations. Interestingly, the baseline value for this region is lower than the OSPAR BAC value, making enrichment even higher at some stations, particularly at G3 and G7, both located within the disposal site (Figure A2.4.13). These latter concentrations observed for 2010 are >5 times the regional baseline values.Enrichment is also evident in Cu and Zn (slight enrichment) and in Hg (moderate enrichment; Figure A2.4.13) at most stations from both assessment methods since the OSPAR BAC value is comparable to the baseline value for these metals.

When comparing with the OSPAR BAC value for Cr, Ni and Pb, all stations were found to be either slightly enriched (Cr and Ni) or moderately enriched (Pb) (Figure A2.4.13). Pb remained slightly enriched at those sites when comparing to the baseline value whereas Cr and Ni were found not to be enriched across the majority of the survey region using this assessment method.

The proposed regional baseline values for the Humber region are generally higher than those for the current OSPAR BAC, except for Cd (Cefas, 2011). This suggests that there is regional variability and that the proposed baselines values might be more suitable to use when assessing for metal enrichment.


Disposal Site:
Goole
Cadmium (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
G12
G13
G11
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
GOOLE REACH
WHITGIFT BIGHT (RIVER OUSE)
0
2
4 km
53°45'0"N
53°42'0"N
53°39'0"N
0°57'0"W
0°54'0"W
0°51'0"W
0°48'0"W
0°45'0"W
0°42'0"W


Disposal Site:
Goole
Cadmium (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
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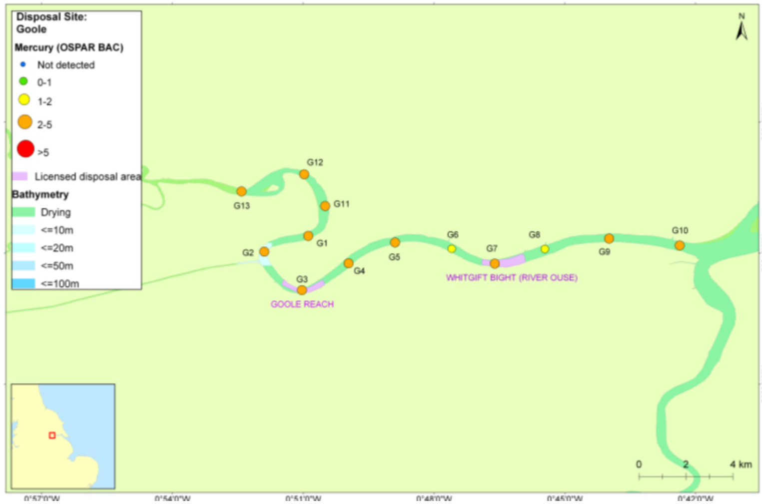
<=20m
<=50m
<=100m
N
G12
G13
G11
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
GOOLE REACH
WHITGIFT BIGHT (RIVER OUSE)
0
2
4 km
53°45'0"N
53°42'0"N
53°39'0"N


Disposal Site:
Goole
Mercury (OSPAR BAC)
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0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
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<=20m
<=50m
<=100m
N
G12
G13
G11
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
GOOLE REACH
WHITGIFT BIGHT (RIVER OUSE)
0
2
4 km
53°45'0"N
53°42'0"N
53°39'0"N
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0°51'0"W
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0°42'0"W

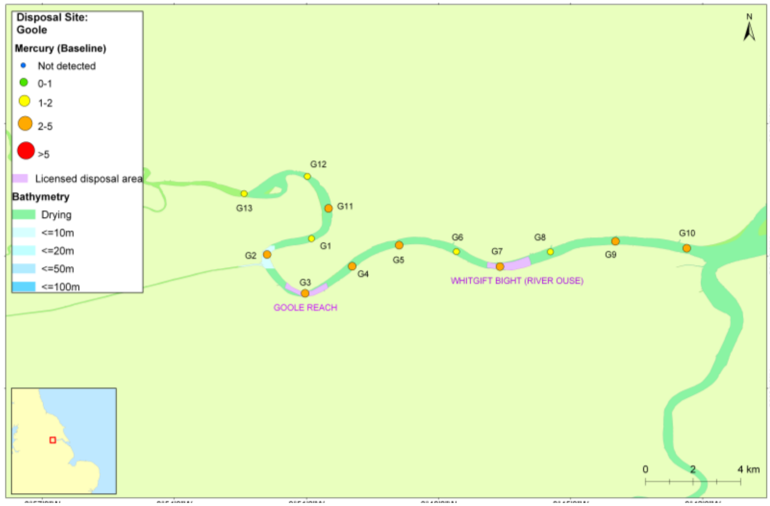

Disposal Site:
Goole
Mercury (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
G12
G13
G11
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
GOOLE REACH
WHITGIFT BIGHT (RIVER OUSE)
0
2
4 km

Figure A2.4.13. Enrichment to OSPAR BACs and Baseline values for Goole, 2010.

2.5 Inner Gabbard East (TH056)

Figure A2.5.1. Map showing the position of the stations sampled for ground-truthing at Inner Gabbard East, 2010.

2.5.1 Background

Inner Gabbard East (TH056) is a relatively new site characterised by Harwich Haven Authority (HHA) to take consolidated capital dredged material from the proposed container port development at Bathside Bay and the now consented Felixstowe South Redevelopment (FSR). The site is broadly similar in terms of wave and tidal flow climates and bed conditions to the existing Inner Gabbard (TH052) disposal site, being characterised as fairly featureless, flat sand and gravel beds. The main difference is depth, TH056 is in an elongated depression in the seabed approximately 55m deep.

As the FSR was the first to be realised the site is now taking material from that project. Dispersion of material from the IGE site was not seen as a major issue, however, it was proposed it could be minimised by making a series of placements at one location, creating localised mounds and effectively trapping material in the lower layers. As the location of the disposal site is in an elongated depression north to south it was also proposed to form bunds to the northern and southern ends at the start of the disposal operations. These ‘bunds’ would consist of more consolidated material and would form less ‘erodable’ ends to the deposit, providing some shelter from the prevailing currents and a measure of constraint to what would be more mixed material (sand/ clay/ stone) subsequently placed. Conditions were imposed on the licence to ensure that the disposal was carried out as described.

However, during the FSR project, it became apparent that more of the dredged material was usable for use in reclamation than previously thought, leading to reduced import of new material to the disposal site. In addition, as a result of changes to the dredging methodology, more of the material destined for the IGE site, and particularly most of that dredged at first, was likely to be finer material, containing a mixture of sands, clays and smaller stone pieces. Therefore it was not possible to form the initial bunds at the ends of the site. As a result, the Marine and Fisheries Agency (MFA; the licensing agency at that time) agreed to amend the licence conditions. The nature of the disposal operation has therefore changed to that originally agreed; material would initially be placed evenly over the site with more consolidated material subsequently deposited at the ends, as described below.

- Material for disposal from trailer dredgers is to be placed by bottom dumping when stationary, located initially no closer than 250 m from the northern or southern limits of the site and no closer than 50 m from the eastern or western limits of the site. (The whole licensed disposal site is approximately 1,250m by 500m.). Material is to be placed evenly over this reduced area using a system of targeted and recorded locations for each disposal
- Rock and stiff clay is to be placed in the areas at the northern and southern ends of the site, in targeted loads to produce an even distribution. Barges, when dumping this material, are to be located no closer than 50 m from the disposal site limits

Concerns:
As a result of these changes, the MMO requires Cefas to identify this disposal site as a priority for monitoring to ensure that the disposal operation has been carried out as agreed, and to determine if the deposited material is remaining in place or being eroded. An acoustic survey of the site was conducted by Cefas under the auspices of SLAB5, during July 2009; the 2010 survey essentially comprises a repeat of this to improve our understanding of the fate of the deposited material.

RAT prioritisation assessment: Tier 1.

- where a significant increase in the quantity of material disposed of has occurred (*new site*)
- where specific concerns have been raised

- that have been observed or pose an increased risk to the surrounding area and receptors

2.5.2 Impact hypothesis

- to ensure deposited material is being maintained within the confines of the licensed disposal site

2.5.3 Parameters monitored: Sediment particle size
Sidescan and multibeam

2.5.4 Results

2.5.4.1 Sidescan and multibeam

The multibeam and sidescan data gathered at Inner Gabbard East were used to interpret the nature of the seabed within the licensed area. A Kongsberg EM3002D multibeam echosounder and Edgetech 4200FS sidescan sonar were employed for this survey, conducted on the 6th June 2010.

Samples for Particle Size Analysis (PSA) were collected during the survey to ground-truth the acoustic data (Figure A2.5.2)). Five locations across the site were chosen for sampling, these were gathered using a Shipek grab and, in addition, a total of fifteen samples (three replicates at each station) were collected utilising a Hamon grab. Results from both grab techniques were analysed and those gathered using the Hamon grab were used to validate the acoustic results as they appeared to be more consistent with the grab results from the previous years PSA data.

The Inner Gabbard East disposal area has a seabed with an average water depth of 50m (Figure A2.5.2). The area has a central trench running in a north-northeast to south-southwest orientation reaching approximately 55m at its deepest. The trench gently slopes to the east levelling out to approximately 48m. The western edge has a sharper incline, increasing from 50m water depth to 40m within a 50m range. The disposal site boundary is clearly evident in the acoustic data with a distinct boundary defined between the site and the surrounding sediment morphology.

The backscatter data (Figure A2.5.3) shows a relatively homogeneous seabed surrounding the disposal site with a central area of lower backscatter return making up the main impacted site. There appears to be pockets of slightly higher returns within this central disposal area. The surrounding sediments have a much stronger acoustic return signifying a seabed consisting of coarser sediments. To the west of the site smaller patches with a lower reading can be identified.

Figure A2.5.4 presents the side scan sonar data collected as part of the acoustic survey at Inner Gabbard East. The imagery clearly shows the disposal site within the acoustic coverage. The boundary of the disposal area (marked in purple) reflects a lower backscatter return whilst the interior concurs with the multibeam backscatter results, suggesting a higher return from coarser sediments.

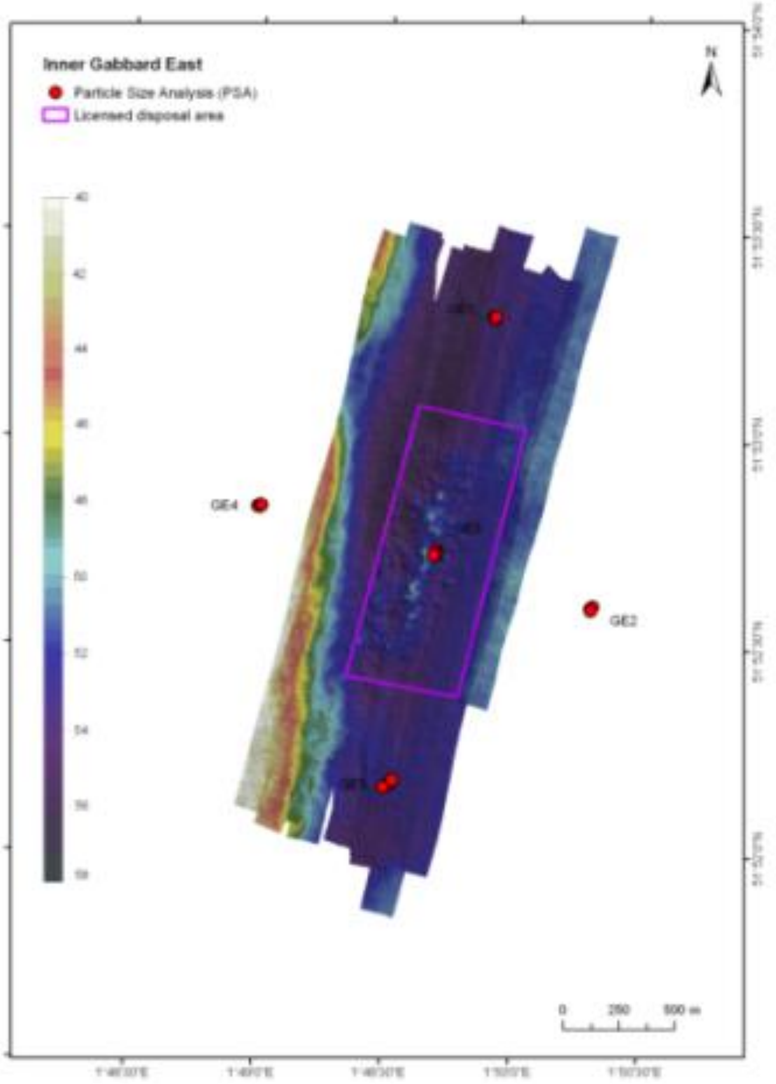


Figure A2.5.2. Inner Gabbard East seabed bathymetry from the 2010 multibeam survey, showing the location of the 5 sediment sampling stations used for ground-truthing.

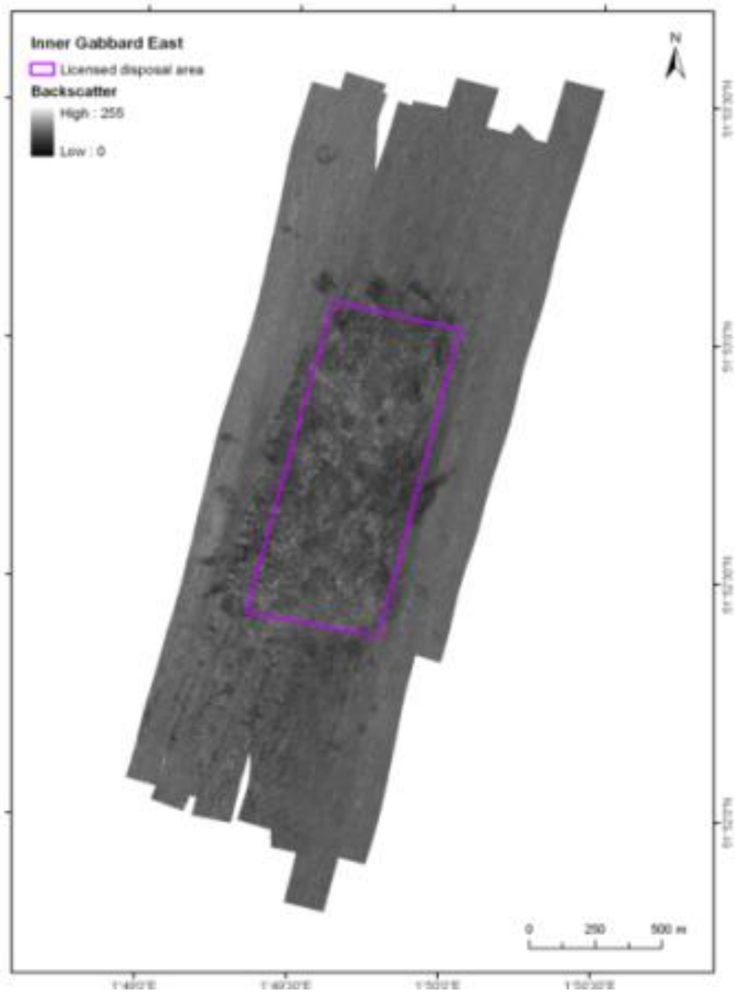


Figure A2.5.3. Multibeam backscatter data collected during the 2010 acoustic survey at Inner Gabbard East

Figure A2.5.5 presents an interpretation of the multibeam backscatter data gathered together with information acquired from the sediment PSA. A distinct boundary can be seen running from the north east to the south west of the site separating the sandier sediments in the west of the site from the muddier ones to the east.

The centre of the site consists predominantly of muddy sand and gravelly muddy sands. This is likely the result of the dredged material disposal activity in this area, as demonstrated by the presence of disposal features on the multibeam bathymetry and a low return from the backscatter data collected in this area. Patches of high backscatter can be identified within the disposal site, possibly indicating concentrations of finer sediments. The surrounding sediments have a much stronger acoustic return signifying a seabed consisting of coarser sediments, typically those containing muddy gravels. There are also small patches of gravelly muddy sand identifiable to the west of the site, outside of the licensed boundary of the disposal site; this is possibly associated with dredged material disposal events.

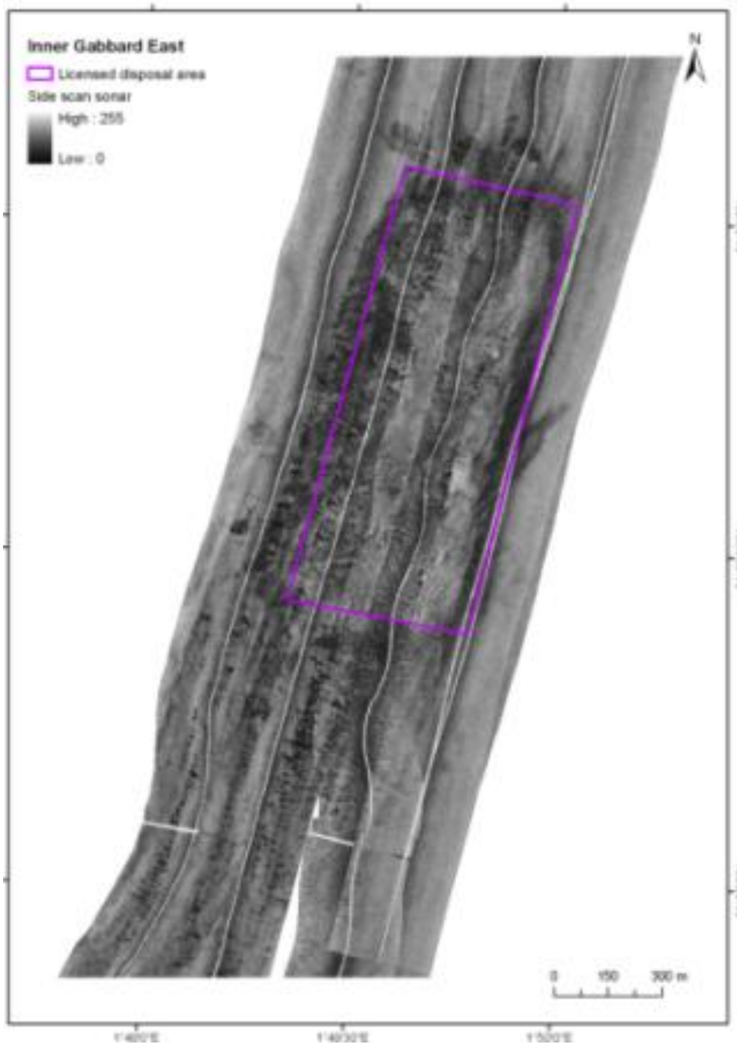


Figure 2.5.4. Sidescan data gathered during the 2010 Inner Gabbard East survey.

Comparison with the previous acoustic survey undertaken in 2009 at Inner Gabbard East indicates that there has been no noticeable change to the sediment distribution at the disposal ground. The main impacted area shows no sign of alteration in shape or extent and material is predominantly contained with the licensed disposal area.

<u>2.5.4.2 Sediment particle size</u>

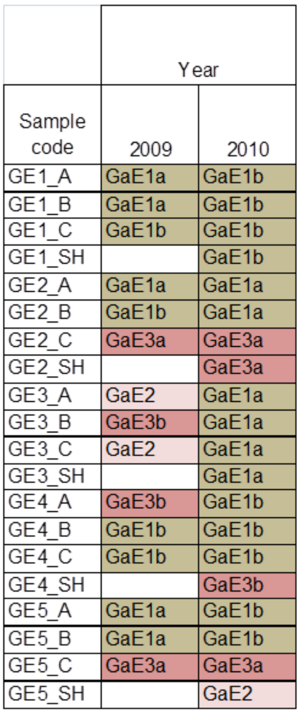
Inner Gabbard East sediments are predominantly muddy gravels/ gravelly muddy sands and gravelly muddy sands (Table A2.5.1). Changes in sediment group between 2009 and 2010 are shown in Table A2.5.2; these data indicate that temporal changes have been minimal except at GE3 (at the centre of the disposal site) which has increased silt/clay content in 2010 (>78%). This may result from a recent disposal operation. Sediments are mixed at sampling stations outside of the disposal site, and are least muddy south of the site at GE5. Pie charts of gravel, sand and silt/clay are shown in Figure A2.5.6 for 2010.

Figure A2.5.5. Interpretation of the multibeam and side scan sonar data collected on the 2010 survey of Inner Gabbard East

Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
GaE1a	10	Polymodal, Very Poorly Sorted	Gravelly Mud	6.7	215.0	9600.0
GaE1b	13	Polymodal, Extremely Poorly Sorted	Gravelly Mud	215.0	605.0	9600.0
GaE2	3	Bimodal, Very Poorly Sorted	Gravelly Muddy Sand	215.0	9.4	
GaE3a	5	Polymodal, Extremely Poorly Sorted	Muddy Sandy Gravel	215.0	605.0	2400.0
GaE3b	3	Polymodal, Very Poorly Sorted	Muddy Sandy Gravel	13600.0	215.0	605.0

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
GaE1a	10.24	13.34	76.41	2.72	3.12	2.26	4.21	1.03
GaE1b	24.42	33.65	41.93	5.90	10.38	6.58	8.92	1.88
GaE2	13.84	55.92	30.24	2.77	3.60	17.28	29.83	2.45
GaE3a	37.28	38.51	24.21	10.00	10.52	5.65	9.32	3.02
GaE3b	44.48	42.04	13.48	5.86	11.81	12.01	10.19	2.16

Table A2.5.1 Average sediment descriptions and statistics for each sediment group at Inner Gabbard East.



	Year	
Sample code	2009	2010
GE1_A	GaE1a	GaE1b
GE1_B	GaE1a	GaE1b
GE1_C	GaE1b	GaE1b
GE1_SH		GaE1b
GE2_A	GaE1a	GaE1a
GE2_B	GaE1b	GaE1a
GE2_C	GaE3a	GaE3a
GE2_SH		GaE3a
GE3_A	GaE2	GaE1a
GE3_B	GaE3b	GaE1a
GE3_C	GaE2	GaE1a
GE3_SH		GaE1a
GE4_A	GaE3b	GaE1b
GE4_B	GaE1b	GaE1b
GE4_C	GaE1b	GaE1b
GE4_SH		GaE3b
GE5_A	GaE1a	GaE1b
GE5_B	GaE1a	GaE1b
GE5_C	GaE3a	GaE3a
GE5_SH		GaE2

Table A2.5.2 Sediment groups for each sample code for 2009 and 2010 at Inner Gabbard East. SH – Shipek grab surface sample, Replicates A,B and C are Hamon grab subsamples – mixed sediment to ~8cm

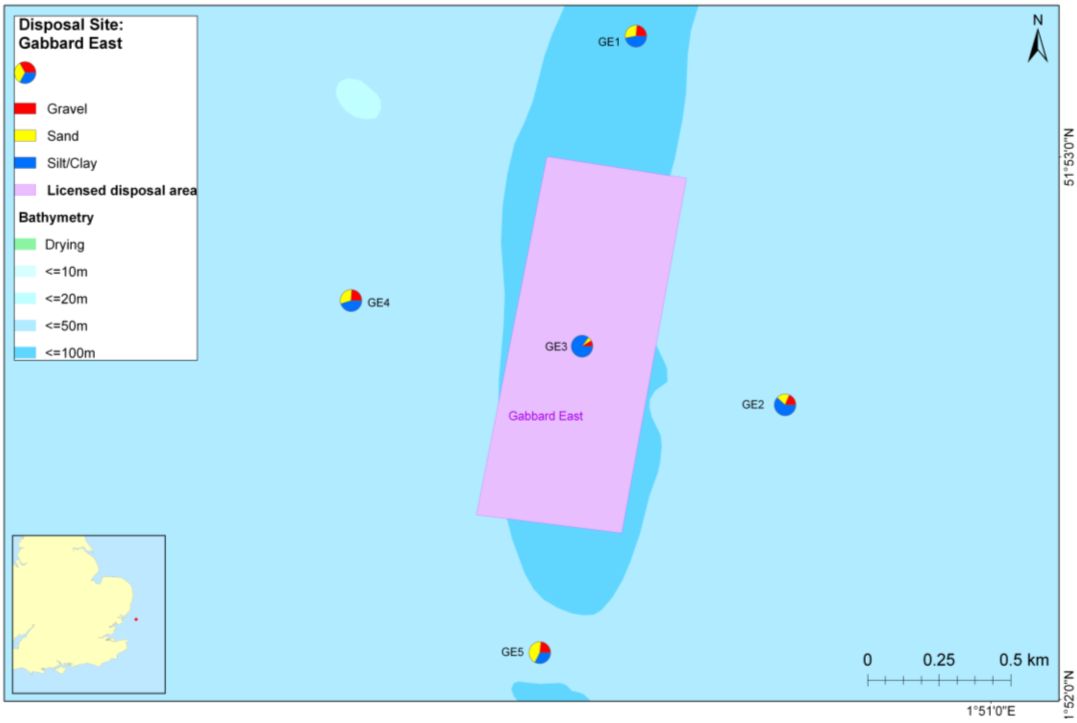


Figure A2.5.6. Pie charts of gravel, sand and silt/clay at Inner Gabbard East in 2010.

2.6 Eastbourne (DV040)

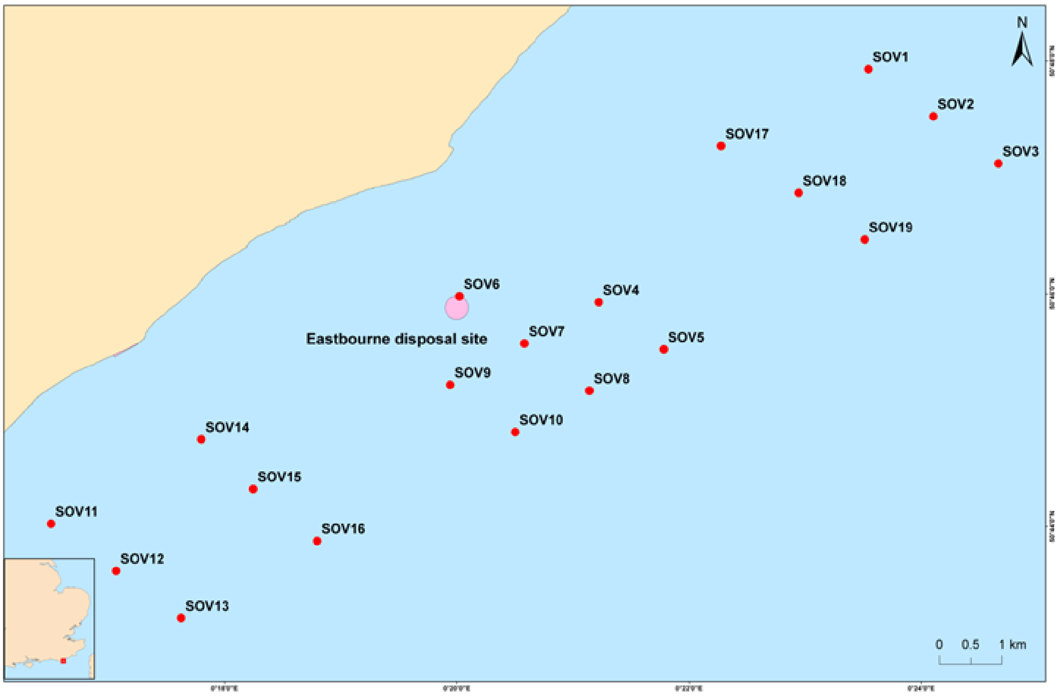


Figure A2.6.1. Eastbourne disposal site, showing the locations of the sampling stations, 2010.

2.6.1 Background

Material disposed of to Eastbourne dredged material disposal site (dredged from Sovereign Harbour and its access channel) is predominantly sand and silt. Since construction in 1992/93 Sovereign Harbour has experienced significant siltation at the entrance channel and Outer Harbour. During 2000 and 2001 silt, sand and gravel accumulated in the entrance channel and restricted access to the Inner Harbour for fishing vessels, leisure craft and the RNLI's lifeboat. Consequently there was an immediate requirement for a dredging campaign to be undertaken to provide full tidal access to Sovereign Harbour. It was proposed that this would be achieved by an initial dredge campaign of approximately 40,000m^3 of material from the entrance channel to achieve the design profile. Since 2000, this material has been disposed of to Eastbourne disposal site, located approximately 3.5km to the south of Sovereign Harbour.

Under the supplementary conditions of the FEPA licence, Premier Marinas (Eastbourne) Limited is required to undertake a Sedimentation Monitoring Programme to monitor the impact of the disposal campaigns on the existing faunal communities within the anticipated disposal plume footprint and the rate of dispersion of deposited spoil. The key issues to be considered within the Sedimentation Monitoring Programme include: FEPA disposal licence conditions, the disposal campaign, particle size analysis, faunal analysis, chemical analysis and bathymetric survey data analysis.

The results of their monitoring programme have indicated that the overall change in particle size distribution across all sites between 2001 and 2008 has been a reduction in gravel content (-5.3%), an increase in sand (+2.5%), and an increase in silt content (+2.8%). The diversity and abundance of macrobenthic communities during this period decreased. There is some evidence (particularly in 2005, 2007 and 2008) suggesting that silt and some heavy metals may have an influence on the distributions of the biological communities at the receptor site. The chemical with the highest correlation with biological distributions seems to change from year to year, in addition the correlations are relatively weak (apart from lead in 2008). This suggests that some caution is needed in the interpretation of the data. Continued monitoring and annual collection of samples for chemical analysis is therefore recommended at these sites to assess any future changes and current trends e.g. decrease in abundance and diversity, which at this stage is difficult to attribute to the disposal programme because the values have fluctuated between 2001 and 2008.

Based on the results of monitoring undertaken on behalf of Premier Marinas, elevated concentrations of nickel and chromium were identified within, and in the vicinity of, the disposal site. According to Halcrow (2008) this indicates either that the source of the elevated concentration is independent of the maintenance dredgings placed at the site in 2007 (seabed material in this area is very mobile and sediments/ heavy metals may have been disturbed and/or mobilised from other sources) or that material deposited at the disposal site is influencing the western control site.

Concerns:
Concentrations of chromium and nickel at several locations within and to the west of the disposal site have been observed. Material disposed of to this site has not exceeded Cefas AL 2 values for these two metals (or any other determinands). It is not known yet what is the cause of the elevated values of chromium and nickel in the disposal and the western control location. There are commercial fisheries interests in the proximity of the disposal site and, since the dredging is likely to continue over time, it needs to be established whether the observed changes in physical and biological parameters in the disposal site area are related to the disposal of material from Sovereign Harbour

RAT prioritisation assessment: Tier 1

- Where specific concerns have been raised.

- Where a significant increase in the quantity of material disposed of has occurred.

- Where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas action levels of 1 and 2 in proposed dredge sediments) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries).

2.6.2 Impact hypotheses

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits
- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

2.6.3 Parameters monitored (via non-Cefas charter vessel):

Sediment particle size distribution
Sediment organic carbon and nitrogen
*Macrofaunal communities
Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

At the start of the survey, it transpired that the winch aboard the charter vessel had developed a problem which prevented safe operation of the Hamon grab. As such, faunal communities could not be sampled during this research cruise. While the assessment of contaminant concentrations (particularly metals) was the main priority of this survey, assessment of faunal communities was also planned. Following consequent discussions with the appropriate Cefas RAT, it was agreed to not undertake a subsequent survey for faunal sampling; the concern regarding impacts associated with benthic communities had been resolved.

2.6.4 Results

2.6.4.1 Sediment particle size

Eastbourne sediments are predominantly sandy gravels/ gravely sands (Table A2.6.1 and 2.6.2), with slightly increased levels of silt/clay found in sediment group Ea1 (i.e., at SOV5, SOV7, SOV8, SIV12 and SOV13). These slightly muddier stations are located just offshore of, and to the west of, the disposal site (Figure A2.6.2 and 2.6.3). SOV5, east of the disposal site and offshore has the highest silt/clay content (13%).

Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
Ea1	5	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel	26950.0	302.5	2400.0
Ea2	6	Bimodal, Very Poorly Sorted	Gravelly Sand	302.5	9600.0	
Ea3a	4	Trimodal, Very Poorly Sorted	Sandy Gravel	9600.0	302.5	2400.0
Ea3b	2	Bimodal, Very Poorly Sorted	Sandy Gravel	38250.0	302.5	

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
Ea1	50.18	42.90	6.92	4.10	4.01	22.32	10.17	2.31
Ea2	21.09	74.64	4.27	4.89	4.58	36.39	25.50	3.28
Ea3a	56.26	41.58	2.16	3.82	3.23	17.98	14.00	2.55
Ea3b	46.30	51.86	1.84	4.32	4.46	25.23	14.59	3.26

Table A2.6.1 Average sediment descriptions and statistics for each sediment group at Eastbourne.

Sample code	Sediment group
SOV2	Ea3b
SOV3	Ea2
SOV4	Ea3b
SOV5	Ea1
SOV6	Ea2
SOV7	Ea1
SOV8	Ea1
SOV9	Ea2
SOV10	Ea2
SOV11	Ea3a
SOV12	Ea1
SOV14	Ea2
SOV15	Ea2
SOV16	Ea3a
SOV17	Ea3b
SOV18	Ea3b
SOV19	Ea1

Table A2.6.2 Sediment groups for each sample code for 2010 at Eastbourne.

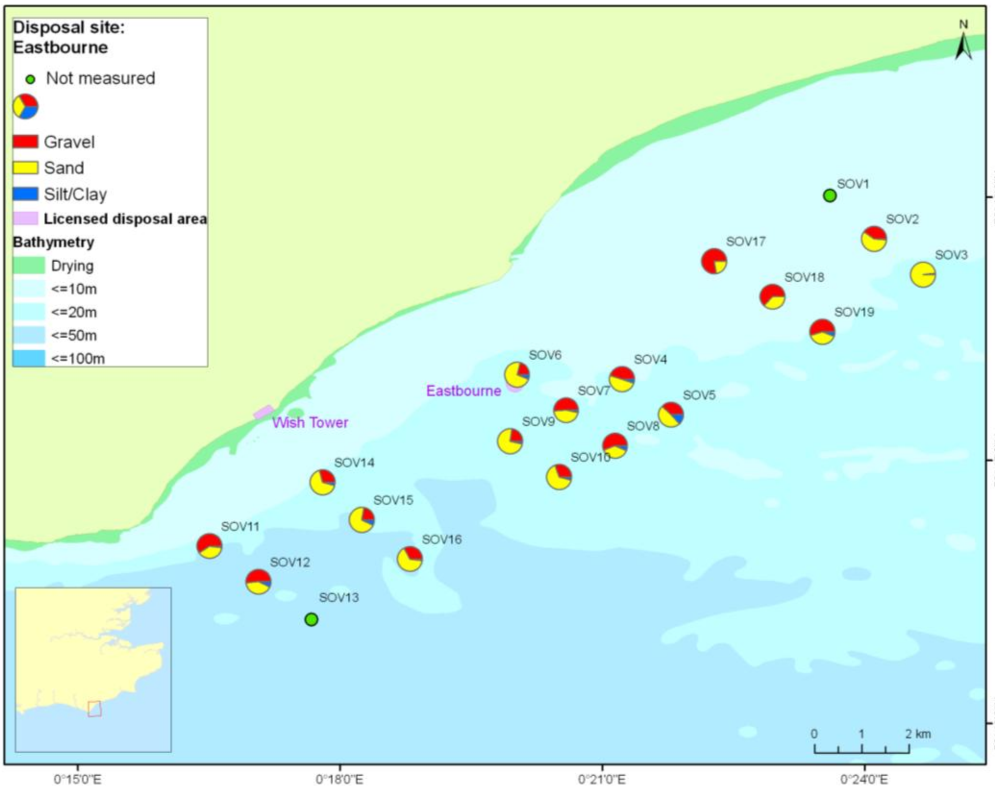


Figure A2.6.2 Pie charts of gravel, sand and silt/clay at Eastbourne in 2010.

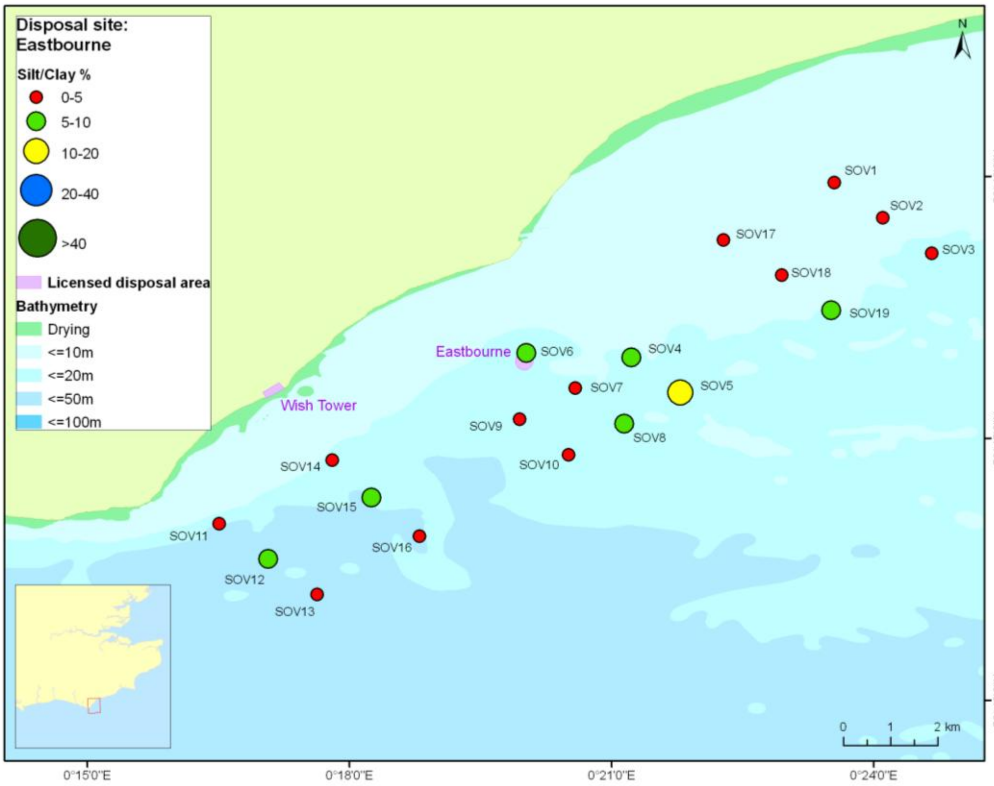


Figure A2.6.3 Silt/clay (%) at Eastbourne in 2010.

2.6.4.2 Sediment organic carbon and nitrogen

In 2010, organic carbon values (on the <63µm sediment fraction) range from 0.62 to 1.52 %m/m (Figure A2.6.4) and for nitrogen 0.09 to 0.27 %m/m. SOV18 has a low silt/clay content (<2% silt/clay) and so it was not possible to measure the organic carbon on this fraction.

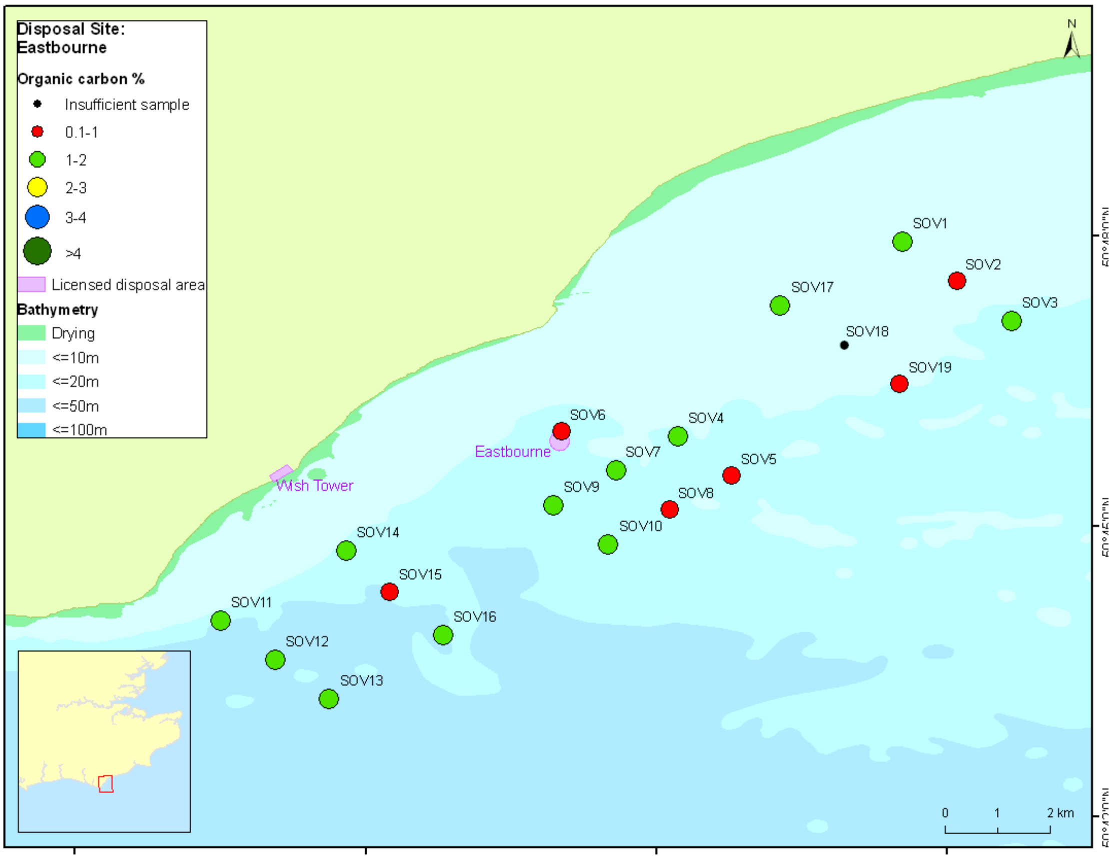


Figure A2.6.4 Organic carbon (%m/m) in the silt/clay fraction (<63µm) at Eastbourne, 2010.

2.6.4.3 Sediment contaminants

2.6.4.3.1 TBT

All the 19 stations sampled as part of the Eastbourne disposal site 2010 survey recorded results below the detection limit. Very little input of TBT was present in the 2009 disposal activities at this site.

2.6.4.3.2 PAHs

Concentrations of summed PAHs found at Eastbourne are the lowest of all the dredged material disposal sites monitored under SLAB5 during 2010. The highest summed PAH concentration was found at SOV6, inshore and to the north-west of the disposal site but, in contrast with the samples from disposal sites off northeast England, this concentration was much lower (211 µg kg^{-1} dw). No stations breached the ERL or ERM for either low or high molecular weight PAHs. From the PAH profiles, there is no clear source information other than at SOV6 which indicates a main (approximately 69%) combustion source - this sample consisted of a mixture of sand, stones and shells). Approximately 61,000 tonnes of material from maintenance dredging has been disposed in this area during 2009, similar to the volumes of previous years, but despite the large volume the source material is very low in PAH concentrations and is of little environmental concern.

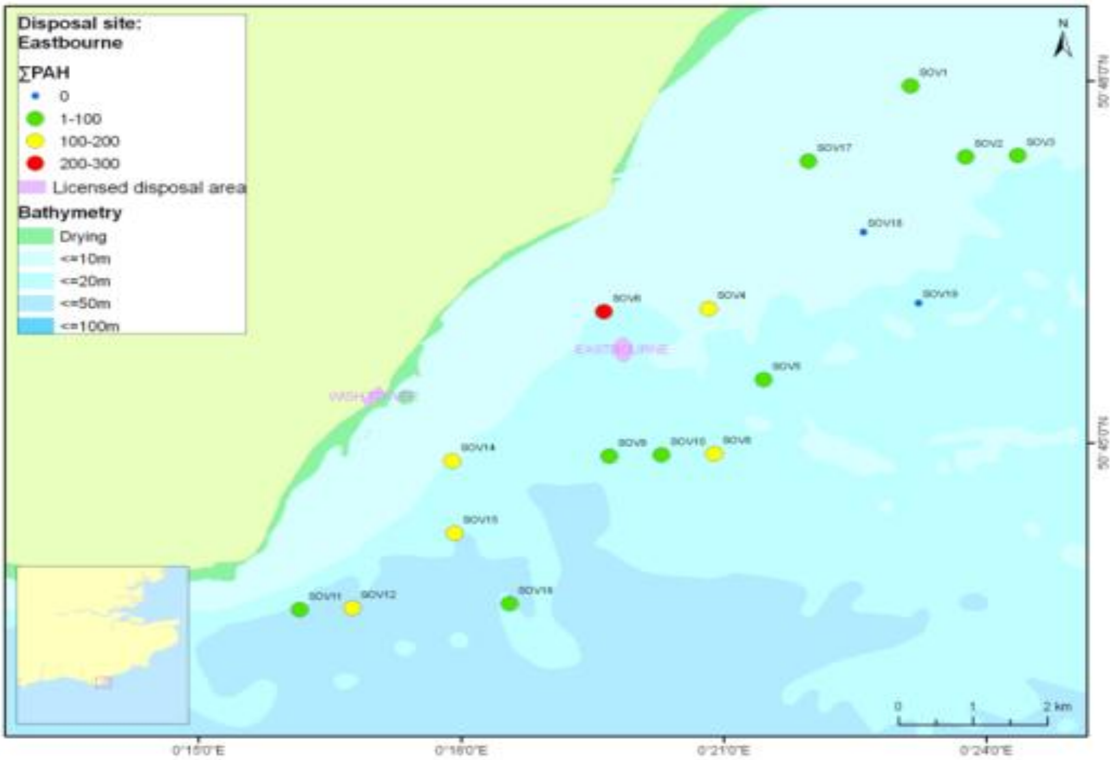


Figure A2.6.5. Summed PAH concentrations (µg kg-^{1}) for stations sampled at Eastbourne, 2010.

2.6.4.3.3 Organohalogens

In line with the conclusions obtained regarding PAHs, levels of organohalogen contaminants at Eastbourne were also low. ICES 7 CBs were all below LODs at all 19 stations, with only a few other CBs detected in 5 stations. OCs were not determined in Eastbourne samples. BDEs were detected at low concentrations in 14 out of 19 stations (∑ 11 BDEs range <0.11-0.17 µg/kg dw; Figure A2.6.6). Only BDE47 and BDE99 were present above limits of detection. BDE209 was detected at low concentrations in 16 out of 19 stations. Levels of BDE209 were <1 µg/kg dw except at SOV11, SOV5 and SOV18, where concentrations of 3.5, 2.1 and 1.5 µg/kg dw were measured (Figure A2.6.7).

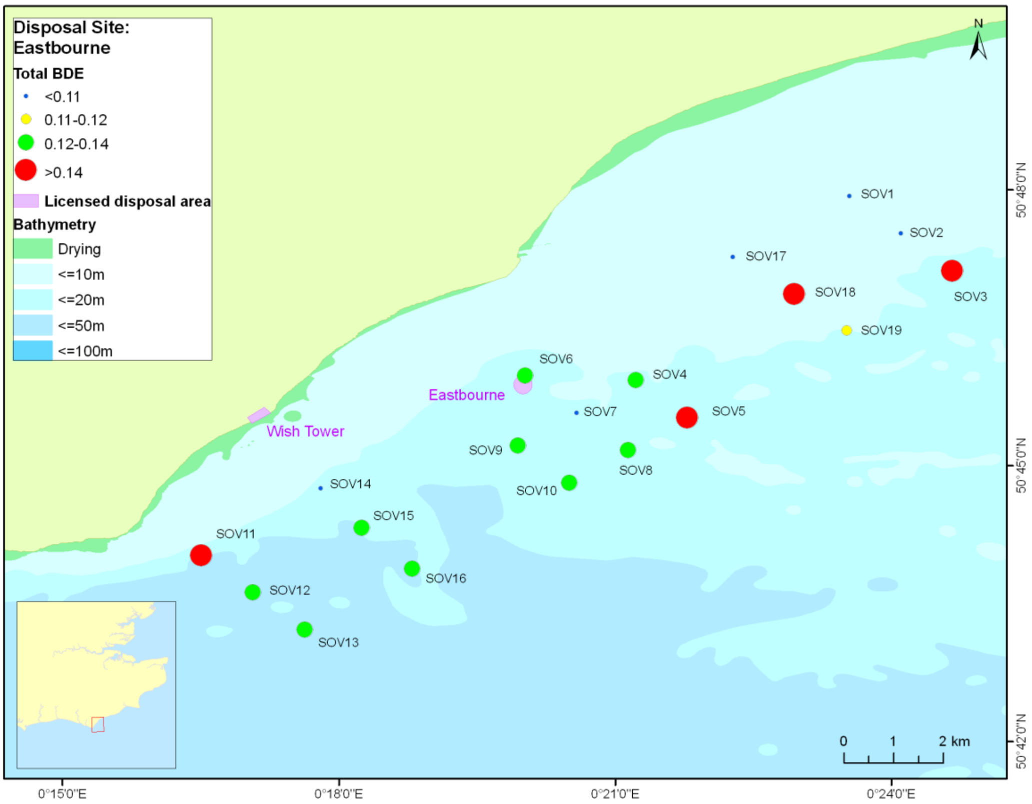


Figure A2.6.6. ∑ 11 BDEs concentrations for the Eastbourne Stations, 2010.

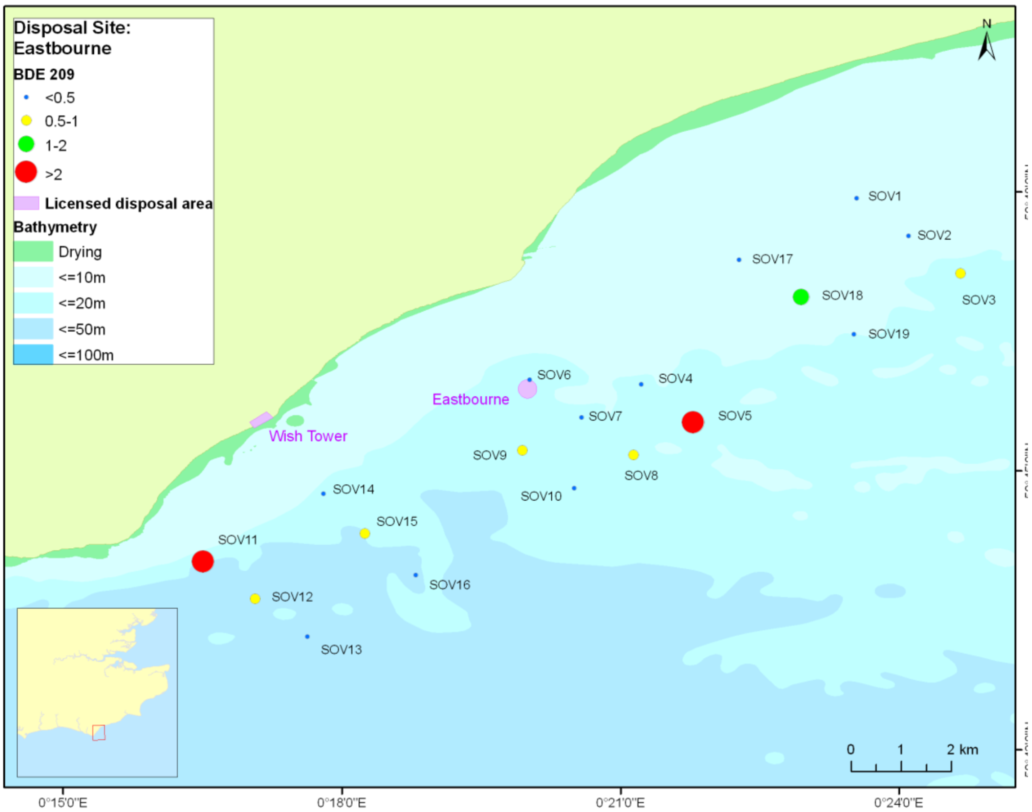


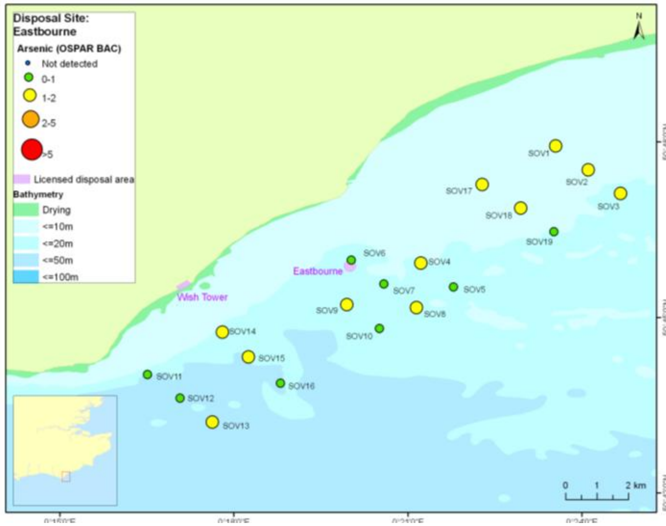
Figure A2.6.7. BDE209 concentrations for the Eastbourne Stations, 2010.

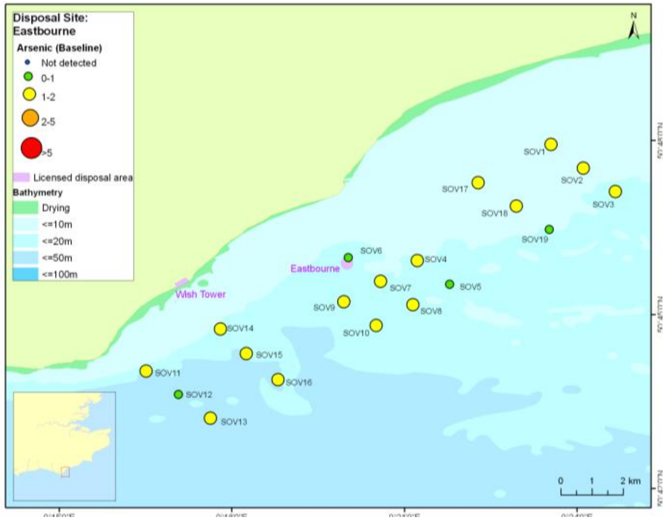
Concentrations of CBs were below Cefas ALs. No Cefas ALs exist for BDEs including BDE209. According to the OSPAR guidelines, all stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall. No OSPAR guidelines exist for BDEs at present.

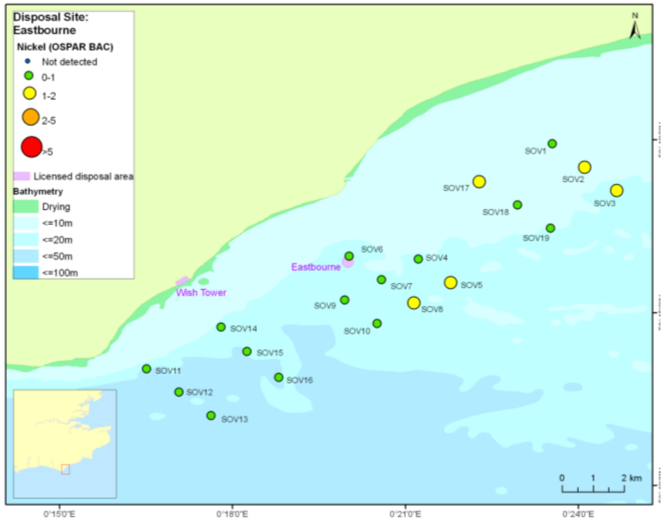
2.6.4.3.4 Trace metals

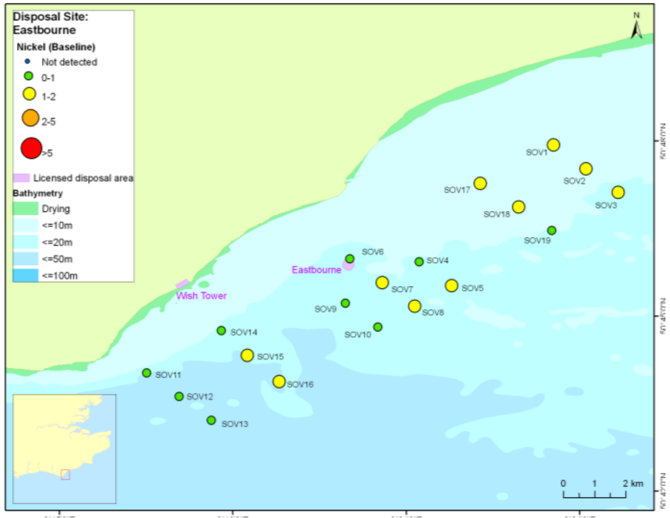
Metals enrichment, either based on OSPAR BACs or regional baselines, were generally low for many metals across the survey region. Enrichment for As, for example, is generally low for both assessment methods. Cd concentrations were below limit of detection for all stations sampled in 2010. Ten stations showed slight enrichment for Ni; these were all between 1 and 2 times enriched (Figure A2.6.8). Enrichment of Cu and Cr are similar spatially (widely spread around the disposal site); enrichment level is low for both approaches for both metals.

Hg exhibits levels of enrichment between 2-5 at SOV6, SOV9 and SOV10 (south of the disposal site) with the OSPAR BAC method; enrichment is still observed when using the baseline approach, but to a lesser extent (i.e. enrichment ratio between 1-2; Figure A2.6.8). All other stations recorded Hg levels below the method limit of detection. Zn show a slight enrichment at most stations, with SOV6 (within the disposal site) remain below both OSPAR BAC and baseline value. No enrichment is observed for Pb, except at the easterly station SOV3 where it is slightly enriched.


Disposal Site: Eastbourne
Arsenic (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
Wish Tower
Eastbourne
SOV1
SOV2
SOV3
SOV4
SOV5
SOV6
SOV7
SOV8
SOV9
SOV10
SOV11
SOV12
SOV13
SOV14
SOV15
SOV16
SOV17
SOV18
SOV19
0 1 2 km


Disposal Site: Eastbourne
Arsenic (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
Wish Tower
Eastbourne
SOV1
SOV2
SOV3
SOV4
SOV5
SOV6
SOV7
SOV8
SOV9
SOV10
SOV11
SOV12
SOV13
SOV14
SOV15
SOV16
SOV17
SOV18
SOV19
0 1 2 km


Disposal Site: Eastbourne
Nickel (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
Wish Tower
Eastbourne
SOV1
SOV2
SOV3
SOV4
SOV5
SOV6
SOV7
SOV8
SOV9
SOV10
SOV11
SOV12
SOV13
SOV14
SOV15
SOV16
SOV17
SOV18
SOV19
0 1 2 km
0°15'0"E
0°18'0"E
0°21'0"E
0°24'0"E


Disposal Site: Eastbourne
Nickel (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
Wish Tower
Eastbourne
SOV1
SOV2
SOV3
SOV4
SOV5
SOV6
SOV7
SOV8
SOV9
SOV10
SOV11
SOV12
SOV13
SOV14
SOV15
SOV16
SOV17
SOV18
SOV19
0 1 2 km

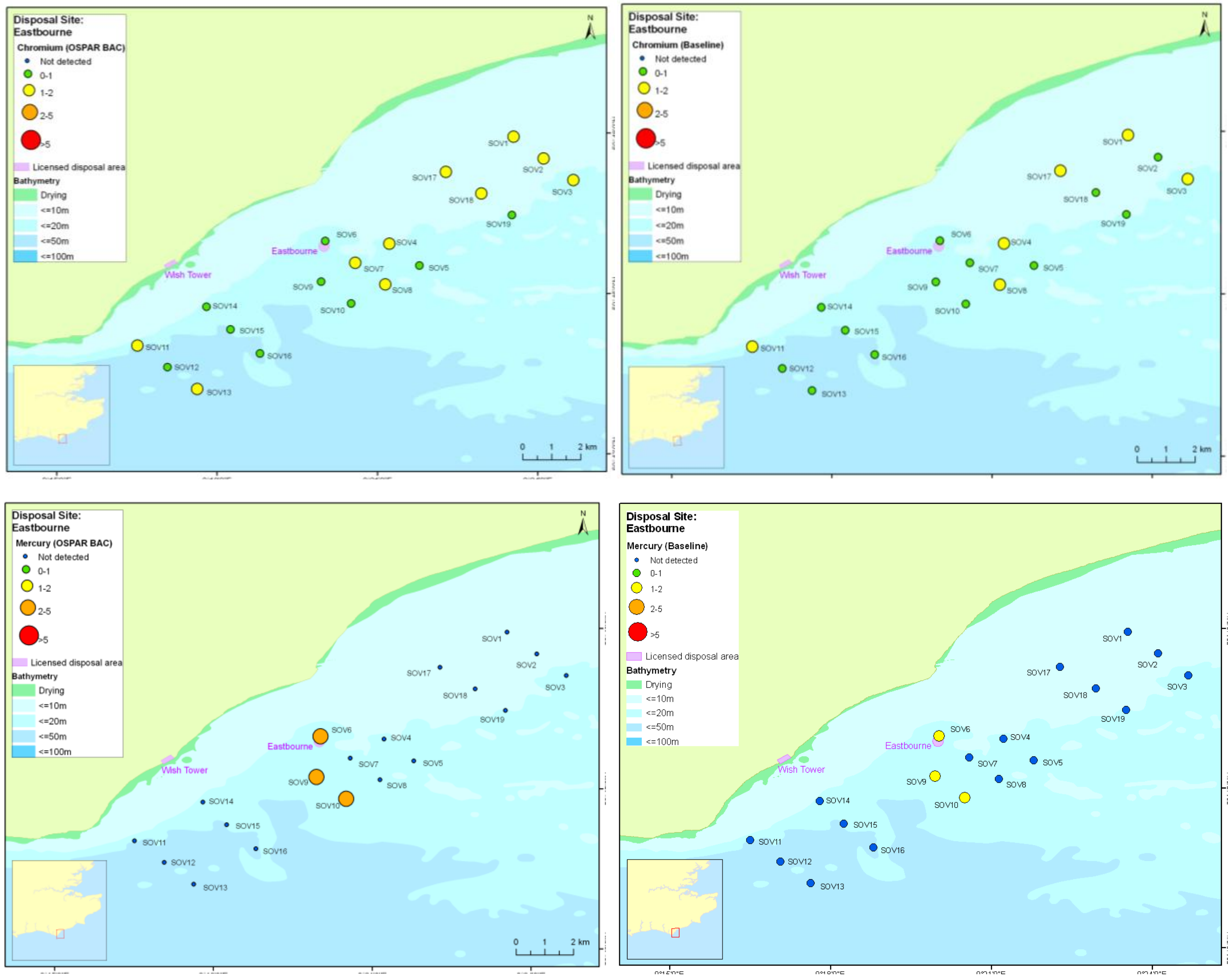


Figure A2.6.8. Enrichment to OSPAR BACs (left) and Regional Baseline values (right) at Eastbourne, 2010 (As, Ni, Cr and Hg).

2.7 Swanage Bay (WI110)

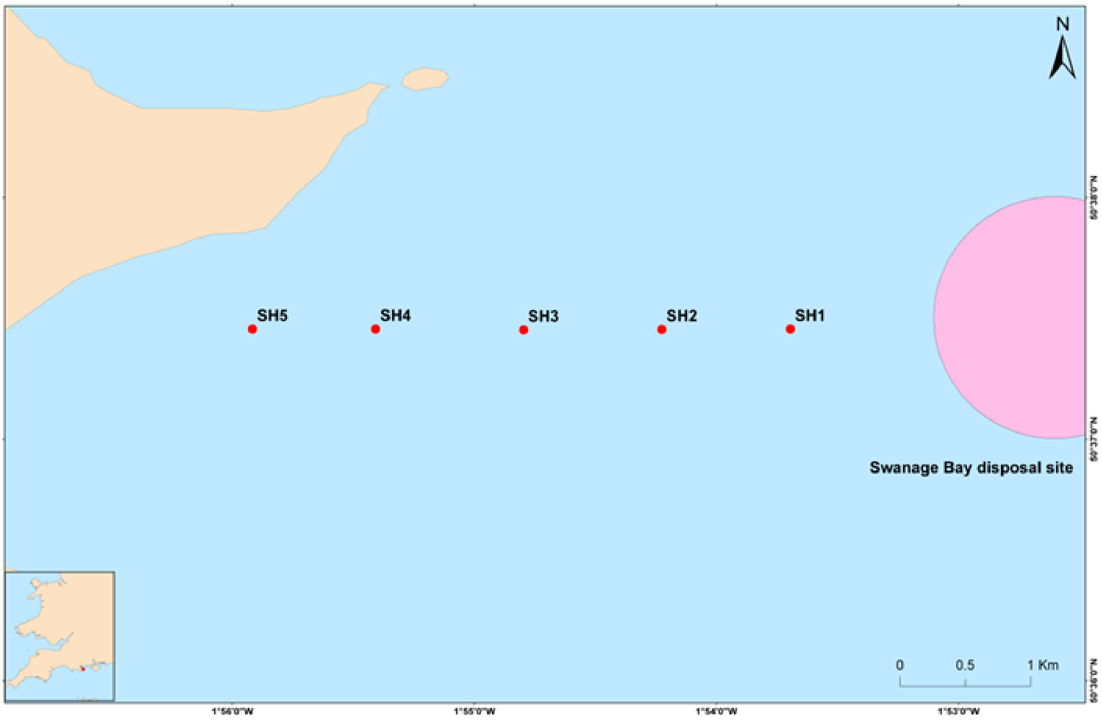


Figure A2.7.1. Location of sampling stations at Swanage Bay, 2010.

2.7.1 Background

Swanage Bay disposal site lies 1.8km southeast of the Poole Bay to Lyme Bay Reefs draft SAC. There has been increased interest from potential applicants in using this site. In 2005 and 2006, disposal at this site was mainly of capital dredgings, in 2007 however, a large maintenance dredged disposal (160,000 tonnes) was conducted. Under the current licence conditions, material is dispersed towards the SAC. Following consultation with MFA and Natural England, it was agreed that a standard set of conditions for the disposal site should exist in order to limit impact on the SAC.

Cefas have previously undertaken survey work at this disposal site under the auspices of SLAB5 (e.g., in 2004). A repeat of the sampling previously undertaken will allow an assessment of the temporal changes in sediments, benthic ecology and bathymetry. The result of this should allow us to improve our understanding of the fate of the material and whether the disposal activity is detrimentally affecting the integrity of benthic communities towards the SAC.

RAT prioritisation assessment: Tier 2

- where the material to be disposed of is of a similar type to the receiving environment

- which contribute to sustaining an appropriate level of spatial coverage of representative sites around England
- pose a moderate/small risk to protected areas e.g. SACS, SSSI. (Conservation Regulations 1994).

2.7.2 Impact hypothesis:

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits
- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

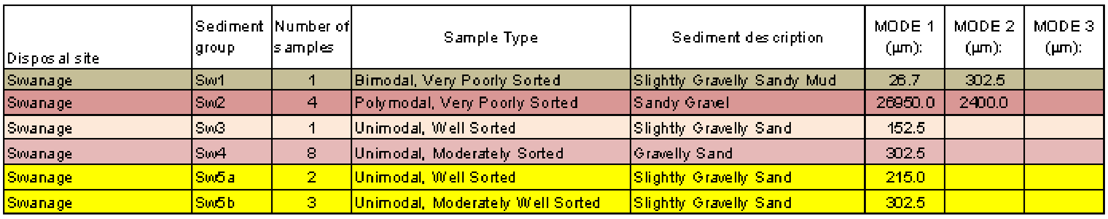
2.7.3 Parameters to be assessed:

Sediment particle size
Sediment organic carbon and nitrogen
Macrofaunal communities
Sediment contaminants (trace metals)

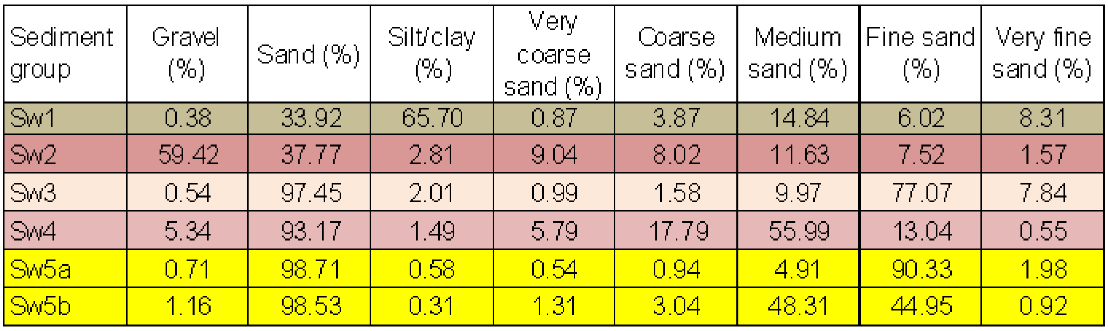
2.7.4 Results

2.7.4.1 Sediment particle size

Swanage Bay sediments are predominantly gravelly sands, with some unimodal sands and gravels (Table A2.7.1). Table A2.7.2 presents the sediment groups for stations sampled in 2006 and 2007, together with those sampled during the current survey in 2010. The stations previously sampled were, however, not within the same region as those in 2010 but centred within, and to the east of, the disposal site (Cefas, 2006) as opposed to the current transect towards the west of the disposal site. While the former stations were predominantly gravelly sand (SW4) those to the west of the site sampled in 2010 are sandy gravel (SW2) with the most westerly station being predominantly sandy (SW3). On the assumption that any potential impacts on the SAC due to disposal activity is manifested via transport of the finer material, all five stations along the current transect exhibit low silt/clay contents (<5 %), especially compared to station HG3 (in the disposal site) sampled in 2007 which exhibited 65.7 % silt/clay content. Pie charts of the gravel, sand and silt/clay fractions for each station sampled in 2010 is displayed in Figure A2.7.2, while a more detailed representation of the relative silt/clay fraction is presented in Figure A2.7.3.

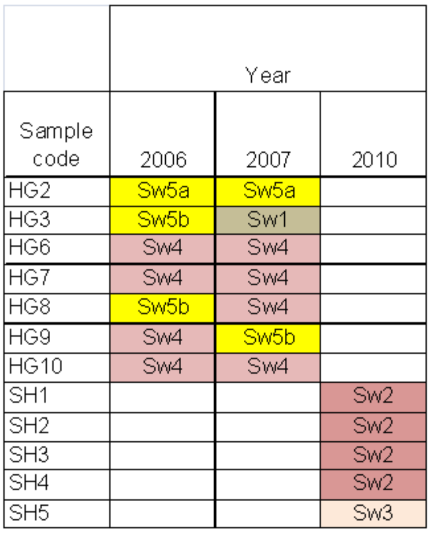


Disposal site	Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
Swanage	Sw1	1	Bimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud	26.7	302.5	
Swanage	Sw2	4	Polymodal, Very Poorly Sorted	Sandy Gravel	26950.0	2400.0	
Swanage	Sw3	1	Unimodal, Well Sorted	Slightly Gravelly Sand	152.5		
Swanage	Sw4	8	Unimodal, Moderately Sorted	Gravelly Sand	302.5		
Swanage	Sw5a	2	Unimodal, Well Sorted	Slightly Gravelly Sand	215.0		
Swanage	Sw5b	3	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand	302.5		



Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
Sw1	0.38	33.92	65.70	0.87	3.87	14.84	6.02	8.31
Sw2	59.42	37.77	2.81	9.04	8.02	11.63	7.52	1.57
Sw3	0.54	97.45	2.01	0.99	1.58	9.97	77.07	7.84
Sw4	5.34	93.17	1.49	5.79	17.79	55.99	13.04	0.55
Sw5a	0.71	98.71	0.58	0.54	0.94	4.91	90.33	1.98
Sw5b	1.16	98.53	0.31	1.31	3.04	48.31	44.95	0.92

Table A2.7.1. Average sediment descriptions and statistics for each sediment group at Swanage, 2010.



	Year		
Sample code	2006	2007	2010
HG2	Sw5a	Sw5a	
HG3	Sw5b	Sw1	
HG6	Sw4	Sw4	
HG7	Sw4	Sw4	
HG8	Sw5b	Sw4	
HG9	Sw4	Sw5b	
HG10	Sw4	Sw4	
SH1			Sw2
SH2			Sw2
SH3			Sw2
SH4			Sw2
SH5			Sw3

Table A2.7.2. Sediment groups for each sample code for 2006, 2007 and 2010 at Swanage.

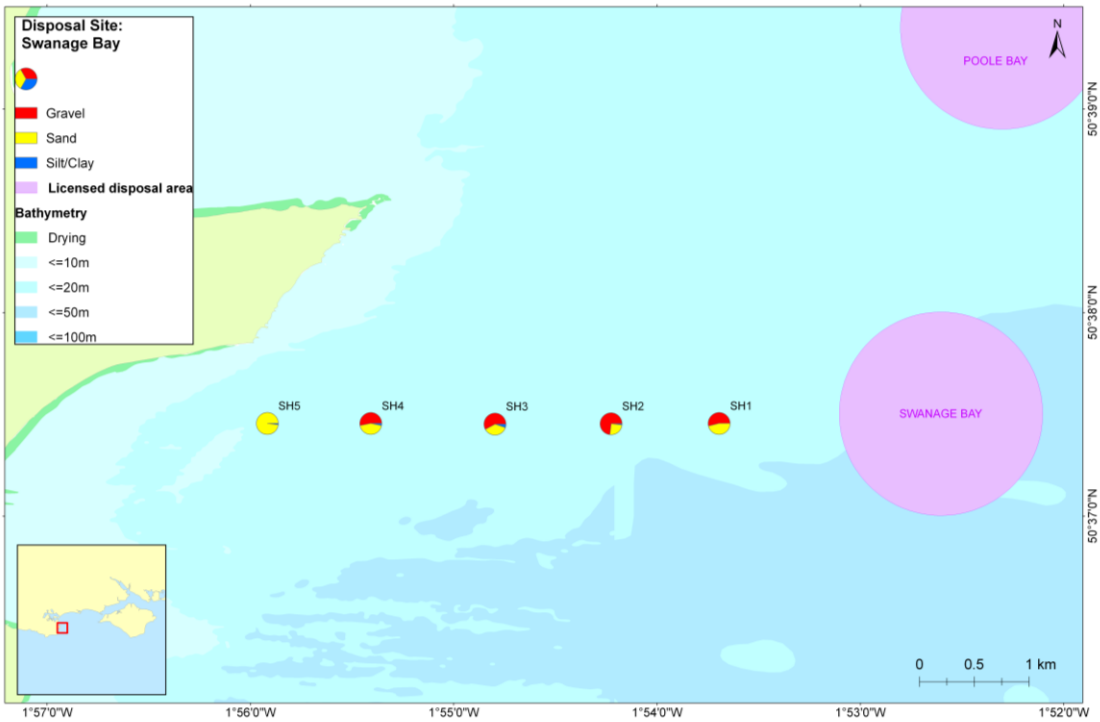


Figure A2.7.2. Pie charts of gravel, sand and silt/clay at Swanage in 2010.

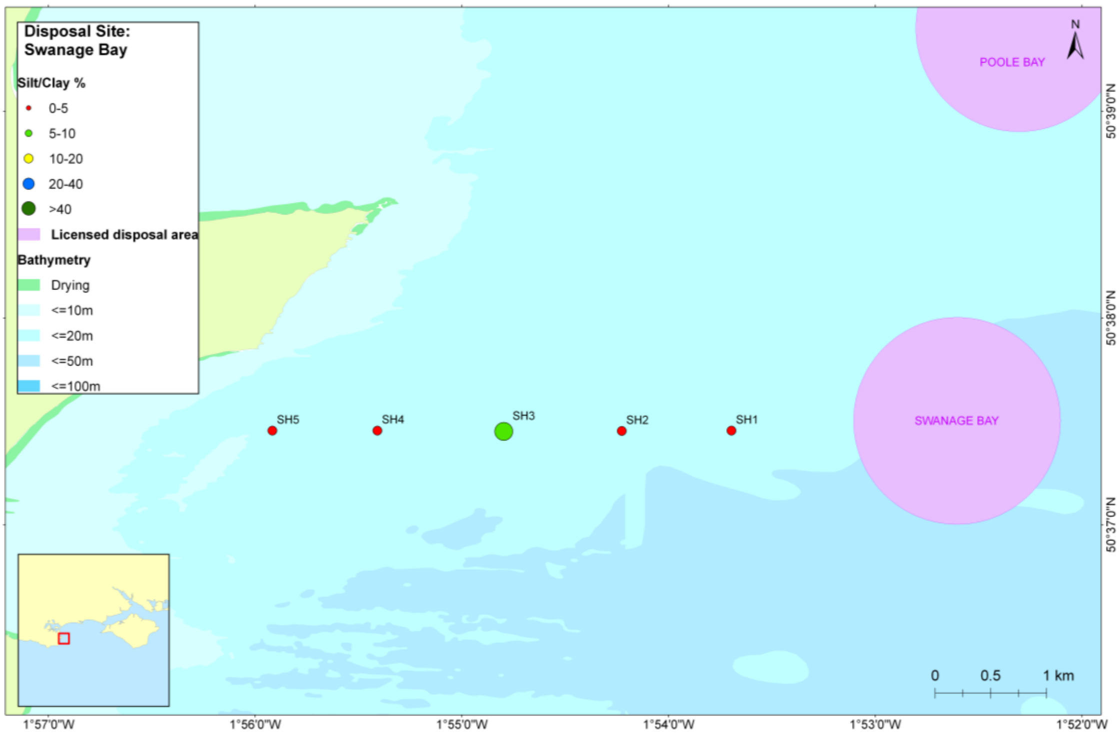


Figure A2.7.3. Silt/clay (%) at Swanage in 2010.

2.7.4.2 Sediment organic carbon and nitrogen content

In 2010, organic carbon values (in the <63µm sediment fraction) are 1.64 and 2.08 %m/m (Figure A2.8.3) and 0.25 and 0.28 %m/m for nitrogen. Three of the five samples (i.e., SH1, SH2, SH5) had low silt/clay contents (<2% silt/clay; Figure A2.7.3) and so it was not possible to measure the organic carbon in these fractions.

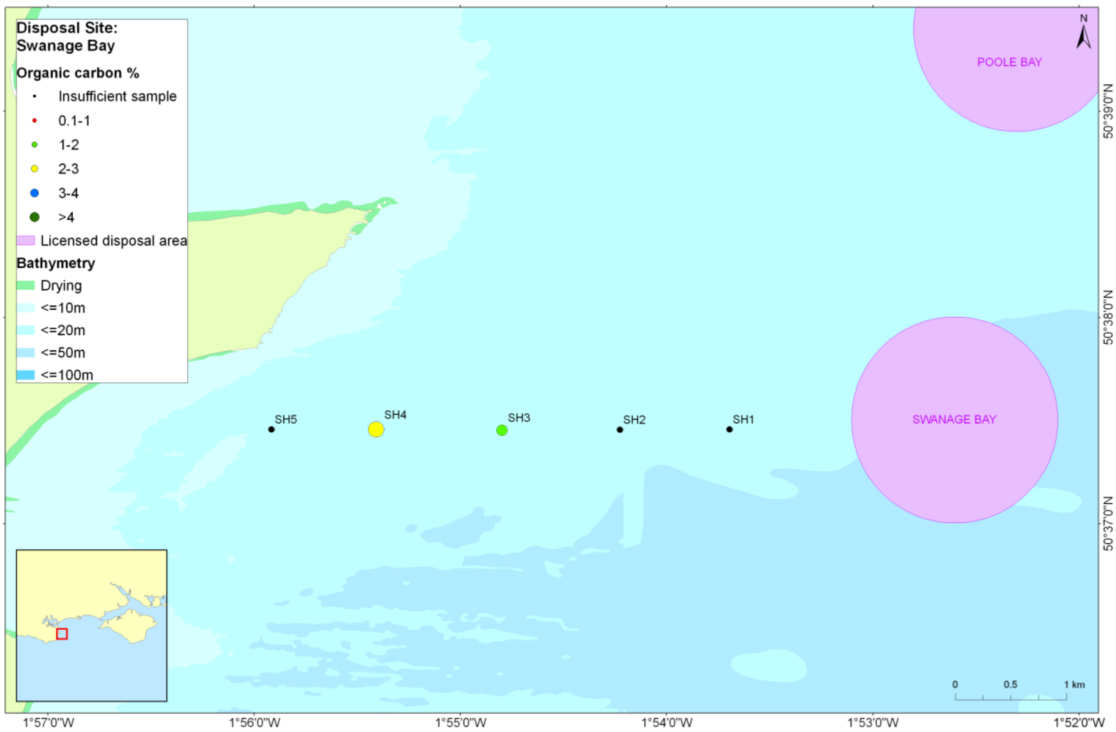


Figure A2.7.4. Organic carbon (%m/m) in the silt/clay fraction (<63µm) at Swanage, 2010.

2.7.4.3 Macrofaunal communities

Swanage Bay was monitored on the 13th July 2010 aboard the RV *Cefas Endeavour*. Two transects (Figure A2.7.5) were surveyed using underwater video to characterise the biological and physical features along these transects with the aim of identifying any potential effects from disposed dredgings moving shoreward from the disposal site towards the SAC.

Video and photographic images were collected using drop-frame camera system. Video data were collected along the length of each transect and stills collected at set intervals, or when something of interest came into view.

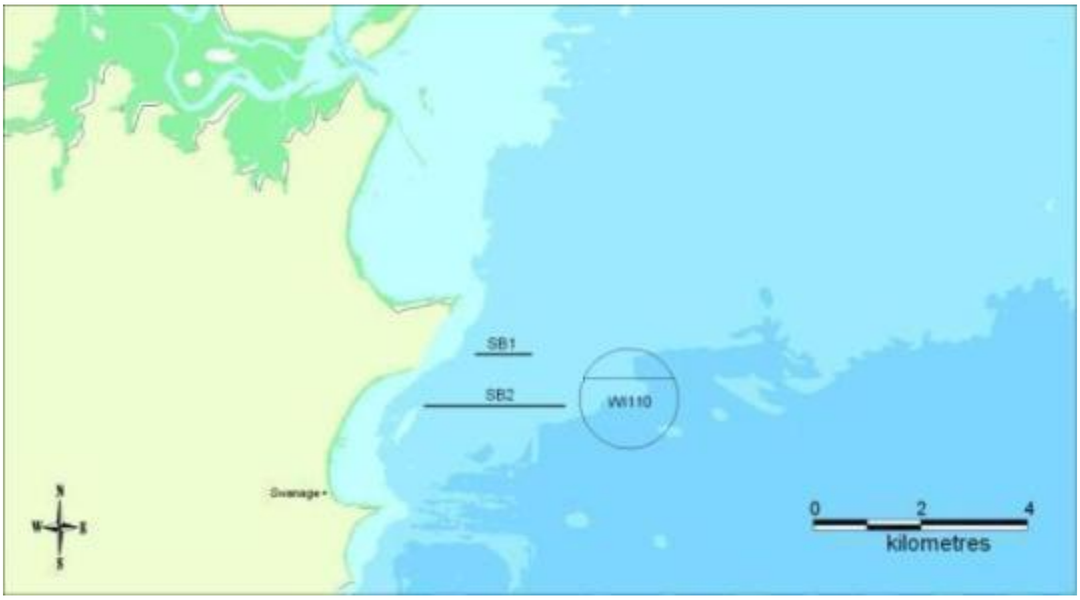


Figure A2.7.5. Location of the two video transects SB1 and SB2, Swanage 2010.

The video and stills taken along transect SB1 showed this area to be mixed sediment dominated by *Crepidula fornicata* and red seaweed (Figure A2.7.6, SB1_A-D). Over the length of the transect the substratum remained mixed with the occasional boulder (Figure A2.7.6, SB1_B). The biotope changed from *Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment (JNCC code: SS.SMx.IMx.CreAsAn, EUNIS code :A5.431; Figure A2.7.6, SB1_B-D) to *Laminaria saccharina* and red seaweeds on infralittoral sediments (JNCC code: SS.SMp.KSwSS.LsacR , EUNIS code: A5.521; Figure ASB1_A) at the western end of the transect.

The video and stills taken along SB2 showed this area to be similar to that seen along SB1 with large swaths of it consisting of the *Crepidula* biotope SS.SMx.IMx.CreAsAn (Figure A2.7.6, SB2_C and E). Between these were patches of *Phymatolithon calcareum* maerl beds in infralittoral clean gravel or coarse sand (JNCC code: SS.SMp.Mrl.Pcal, EUNIS code: A5.511; Figure A2.7.6, SB2_B and D); maerl could also be seen within the *Crepidula* biotope. The western end of the transect graduated from SS.SMx.IMx.CreAsAn to infralittoral mobile clean sand with sparse fauna (JNCC code: SS.SSa.IFiSa.IMoSa, EUNIS code: A5.231; Figure A2.7.6 SB2_A).

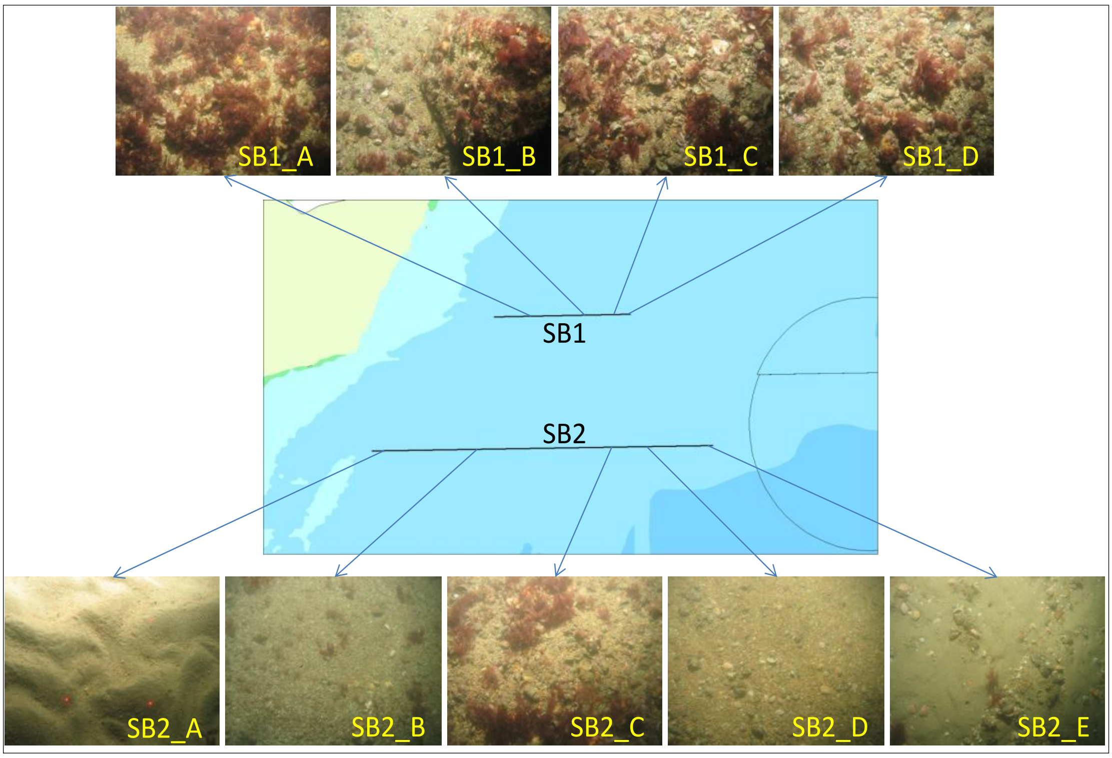


Figure A2.7.6. Video stills taken along the two transects at Swanage, 2010.

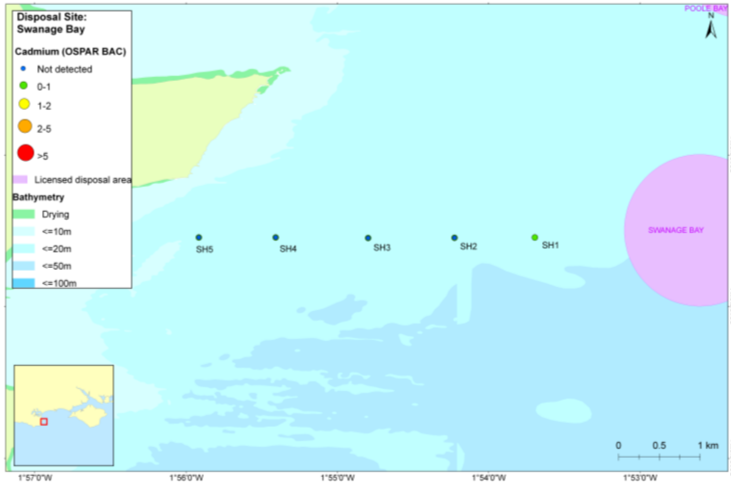
<u>2.7.4.4. Sediment contaminants</u>

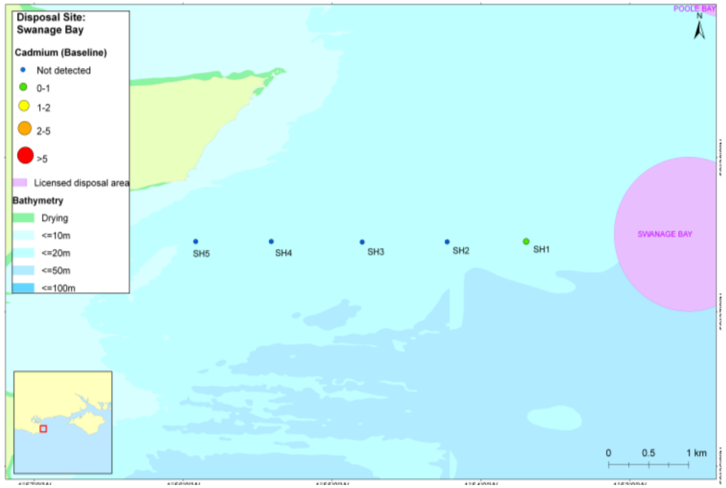
2.7.4.4.1 Trace metals

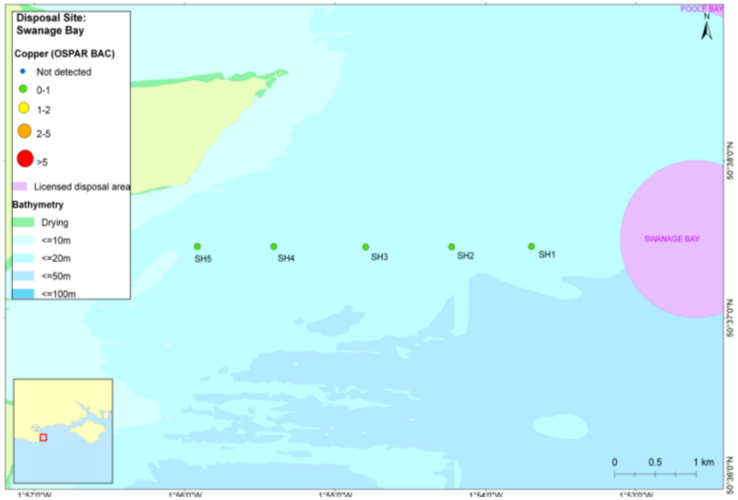
Comparisons of trace metal concentrations between the stations sampled outside the disposal site in 2010 with those sampled in 2006 and 2007 are deemed unsuitable due to their locational differences. Furthermore, temporal comparisons of concentrations observed inside the disposal site cannot be conducted as all stations sampled in 2010 were located outside the licensed boundary. Thus, analyses of the trace metals concentrations for 2010 were restricted to enrichment assessments.

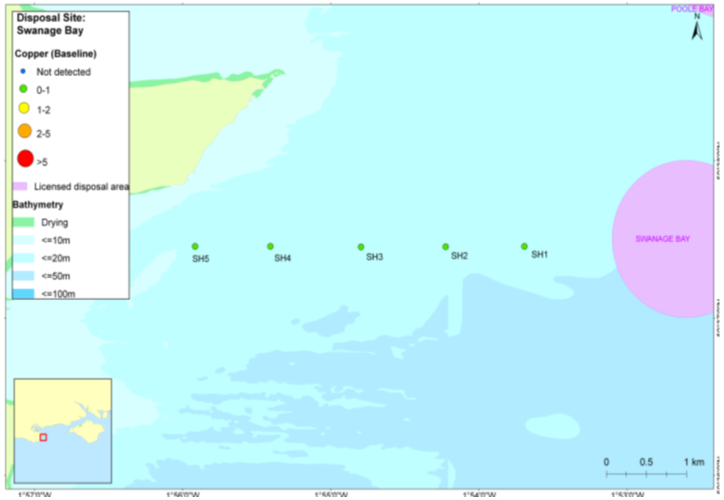
All stations depicted As, Cr, Cu, Ni and Zn concentrations below OSPAR BAC and proposed baseline value, indicating no enrichment of the above metals at this site (Figure A2.7.7 for Cu). Similarly, no enrichment was observed for Cd; most concentrations were below the method limit of detection (Figure A2.7.7). Pb exhibited a slight enrichment at SH5 (west of disposal site), the remaining stations recorded concentrations below both OSPAR BAC and proposed baseline value. Hg, however, is very enriched when comparing with the OSPAR BAC at most stations, the enrichment is less pronounced when using the proposed baseline value, except for SH4 which remains highly enriched (Figure A2.7.7).

The historic mining activities and the regional natural mineralogy of the West Channel result in elevated metal baseline values. Proposed baselines values for Cu, Hg and Pb reflect this observation since the values are higher than the OSPAR BACs, as well as for As, Zn and Ni (but to a lesser extent) (Cefas, 2011). Therefore, enrichment assessment with OSPAR BACs might give misleading high enrichment since the regional variations are not taken into account.


Disposal Site:
Swanage Bay
Cadmium (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
POOLE BAY
N
SH5
SH4
SH3
SH2
SH1
SWANAGE BAY
0
0.5
1 km
1°57'0"W
1°56'0"W
1°55'0"W
1°54'0"W
1°53'0"W


Disposal Site:
Swanage Bay
Cadmium (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
POOLE BAY
N
SH5
SH4
SH3
SH2
SH1
SWANAGE BAY
0
0.5
1 km


Disposal Site:
Swanage Bay
Copper (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
POOLE BAY
N
SH5
SH4
SH3
SH2
SH1
SWANAGE BAY
0
0.5
1 km
50°38'0"N
50°37'0"N
50°36'0"N


Disposal Site:
Swanage Bay
Copper (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
POOLE BAY
N
SH5
SH4
SH3
SH2
SH1
SWANAGE BAY
0
0.5
1 km

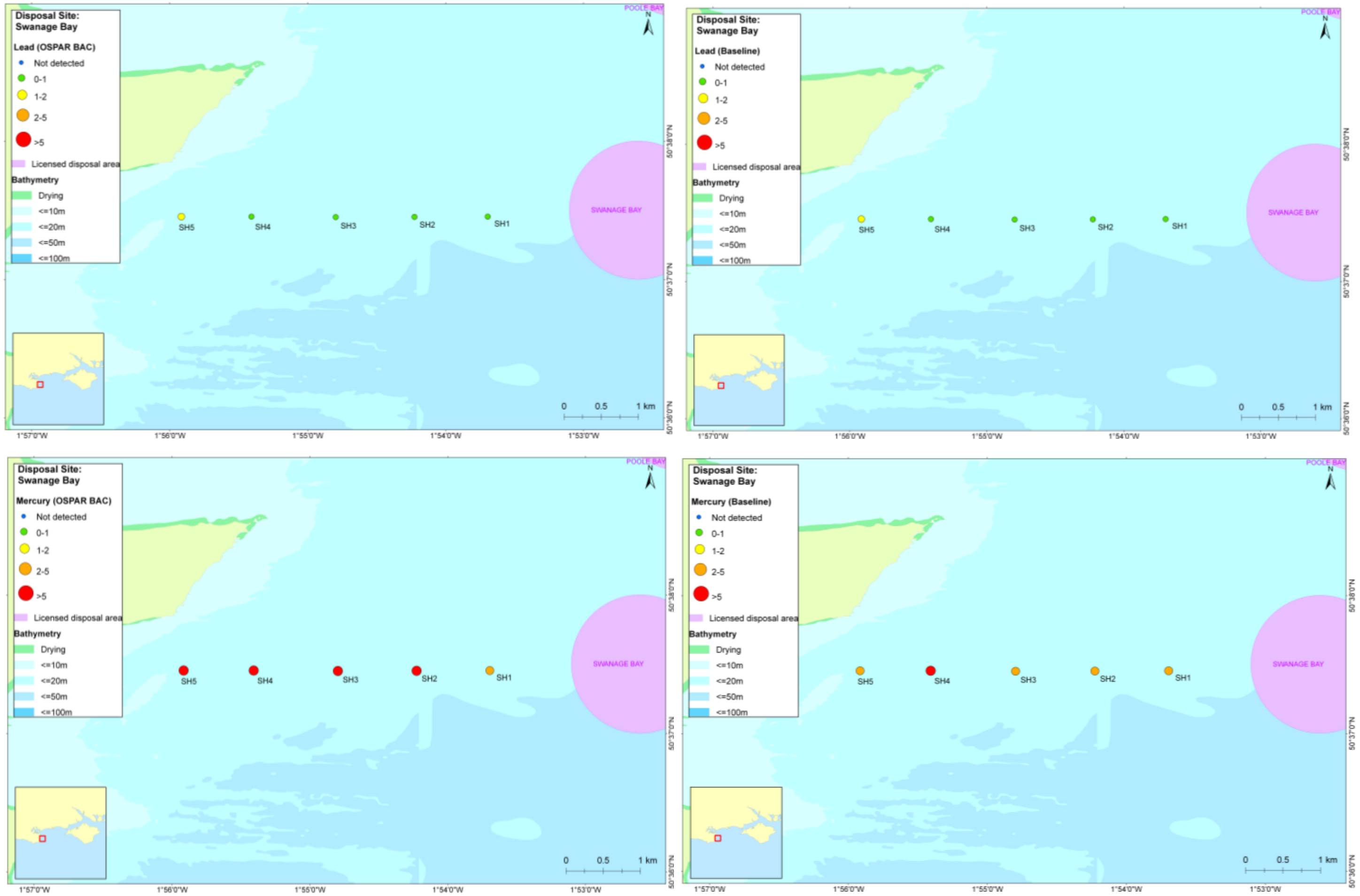


Figure A2.7.7. Enrichment to OSPAR BACs and Regional Baseline values at Swanage Bay, 2010.

2.8 Site Z (IS140), Liverpool Bay

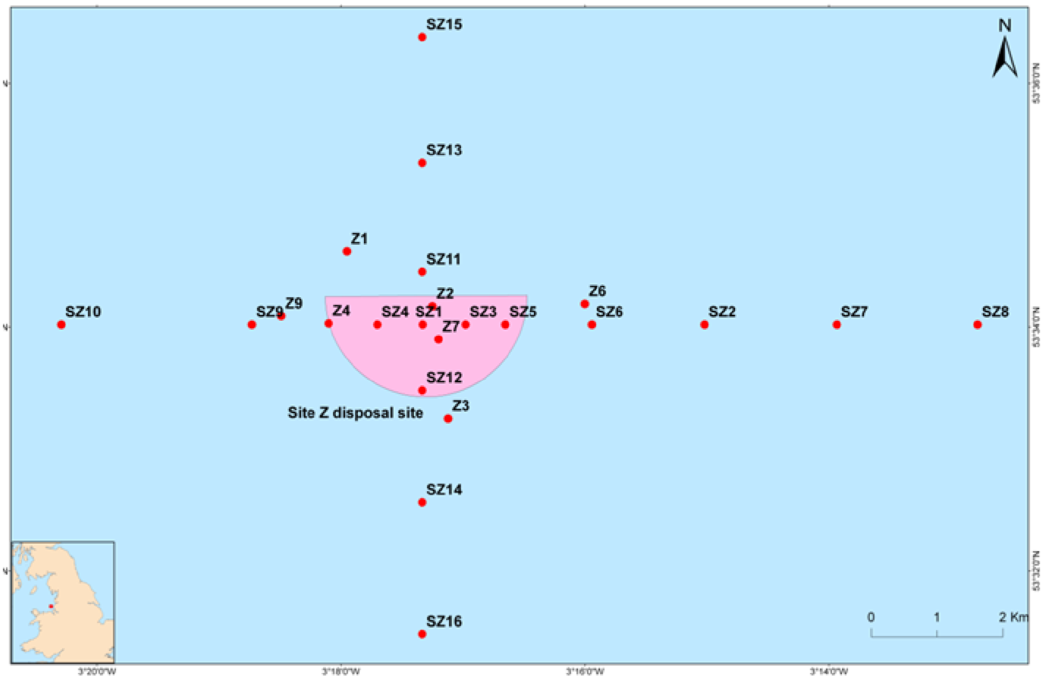


Figure A2.8.1. Location of sampling stations at Site Z, 2010.

2.8.1 Background

Site Z (Liverpool Bay on the west coast of the UK) was first licensed for disposal of dredged material in 1982 following closure of a nearby site owing to shoaling. The disposal site is located in shallow water (10 m) and is exposed to wave action principally from westerly to northerly winds with residual bottom currents flowing in a predominantly landward (eastward) direction. Site Z was extended to the west because of shoaling in the centre of the licensed area. This site receives a comparatively large volume of material; an average of two million wet tonnes per annum. The material disposed of largely originates from maintenance dredging of docks or navigational channels in the Mersey Estuary and its approaches.

Concerns

There has recently been a change in the disposal regime to Site Z. Previously, relatively small amounts of material were deposited on a regular basis; during 2009-10 this changed to two large disposal events during the year. This raises concerns regarding potential shoaling at the site and the fate of the material. Although Cefas have sampled this site annually for a number of years under the auspices of SLAB5, no such monitoring has been undertaken since 2006.

RAT prioritisation assessment: Tier 1.

2.8.2 Impact hypothesis:

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits
- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic

2.8.3 Parameters to be monitored (via non-Cefas charter vessel):

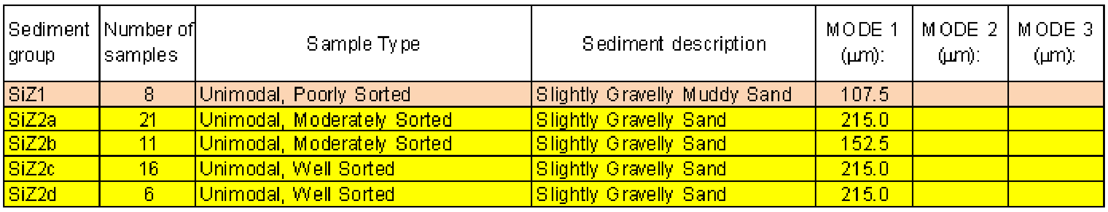
Sediment particle size
Sediment organic carbon and nitrogen
Macrofaunal communities
Sediment contaminants (TBT, PAHs, organohalogens, trace metals)

2.8.4 Results

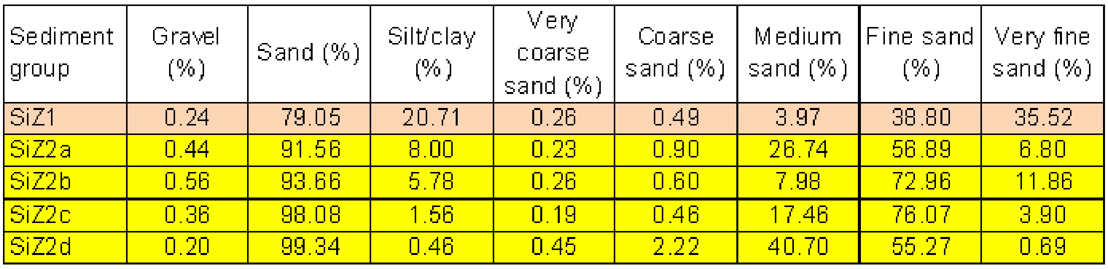
2.8.4.1 Sediment particle size

Sediments around Site Z are predominantly unimodal sands with some sandy muds/muddy sands (Table A2.8.1). The differences in sediment characteristics between the range of sediment groups are not large; all contained <1% gravel, >90% sand (except SiZ1) but slightly vary in their small proportions of silt/clay contents (0.46 % in SiZ2d to 20.71% in SiZ1; Table A2.8.1). Pie charts of gravel, sand and silt/clay are shown in Figure A2.8.2 and silt/clay content in Figure A2.8.3. Silt/clay elevations are most likely linked to bathymetry, with increasing silt/clay found as the seafloor deepens at the west side of the disposal site off shore to the west and south of the site at SZ16.

Temporal changes in the sediment granulometric properties at many of the stations sampled in 2010 cannot be investigated as most were not sampled during previous surveys at Site Z (the 2010 survey represented a more spatially comprehensive survey than its forebears). For those stations which have previously been sampled, there has been little change in the sediment groups since 2002; those stations exhibiting elevated silt/clay contents in 2010 appear to have done so for many years.

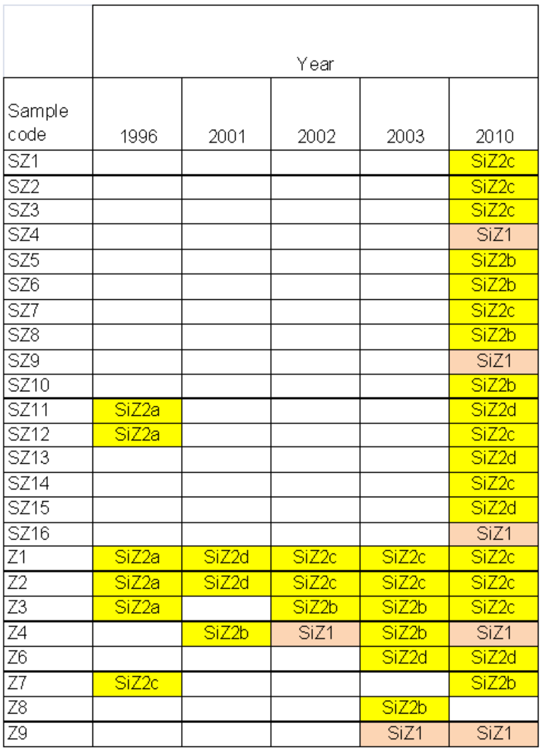


Sediment group	Number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
SiZ1	8	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	107.5		
SiZ2a	21	Unimodal, Moderately Sorted	Slightly Gravelly Sand	215.0		
SiZ2b	11	Unimodal, Moderately Sorted	Slightly Gravelly Sand	152.5		
SiZ2c	16	Unimodal, Well Sorted	Slightly Gravelly Sand	215.0		
SiZ2d	6	Unimodal, Well Sorted	Slightly Gravelly Sand	215.0		



Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
SiZ1	0.24	79.05	20.71	0.26	0.49	3.97	38.80	35.52
SiZ2a	0.44	91.56	8.00	0.23	0.90	26.74	56.89	6.80
SiZ2b	0.56	93.66	5.78	0.26	0.60	7.98	72.96	11.86
SiZ2c	0.36	98.08	1.56	0.19	0.46	17.46	76.07	3.90
SiZ2d	0.20	99.34	0.46	0.45	2.22	40.70	55.27	0.69

Table A2.8.1 Average sediment descriptions and statistics for each sediment group at Site Z, Liverpool Bay.



	Year				
Sample code	1996	2001	2002	2003	2010
SZ1					SiZ2c
SZ2					SiZ2c
SZ3					SiZ2c
SZ4					SiZ1
SZ5					SiZ2b
SZ6					SiZ2b
SZ7					SiZ2c
SZ8					SiZ2b
SZ9					SiZ1
SZ10					SiZ2b
SZ11	SiZ2a				SiZ2d
SZ12	SiZ2a				SiZ2c
SZ13					SiZ2d
SZ14					SiZ2c
SZ15					SiZ2d
SZ16					SiZ1
Z1	SiZ2a	SiZ2d	SiZ2c	SiZ2c	SiZ2c
Z2	SiZ2a	SiZ2d	SiZ2c	SiZ2c	SiZ2c
Z3	SiZ2a		SiZ2b	SiZ2b	SiZ2c
Z4		SiZ2b	SiZ1	SiZ2b	SiZ1
Z6				SiZ2d	SiZ2d
Z7	SiZ2c				SiZ2b
Z8				SiZ2b	
Z9				SiZ1	SiZ1

Table A2.8.2 Sediment groups for each sample code for 1996, 2001, 2002, 2003 and 2010 at Site Z, Liverpool Bay.

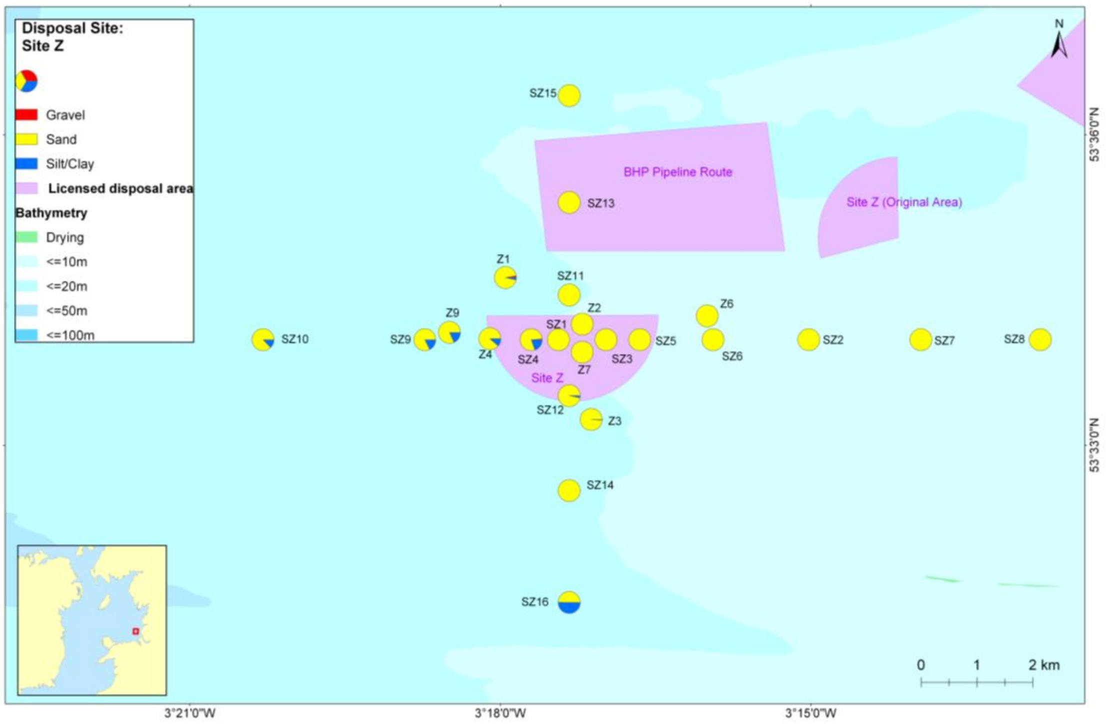


Figure A2.8.2 Pie charts of gravel, sand and silt/clay at Site Z, Liverpool Bay in 2010.

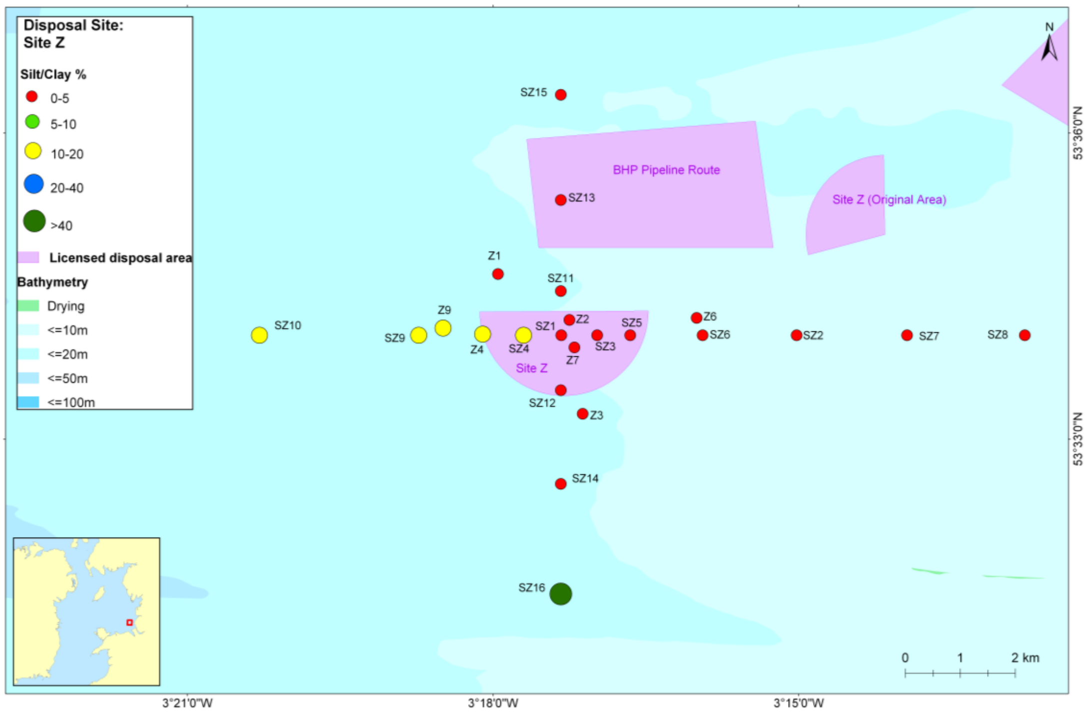


Figure A2.8.3 Silt/clay (%) at Site Z, Liverpool Bay in 2010.

2.8.4.2 Sediment organic carbon and nitrogen

In 2010, organic carbon values (in the <63µm sediment fraction) range from 1.77 to 2.11 %m/m (Figure A2.8.4) and for organic nitrogen 0.22 to 0.27 %m/m. Many samples exhibited low silt/clay content (<2% silt/clay) and so it was not possible to measure the organic carbon in these fractions.

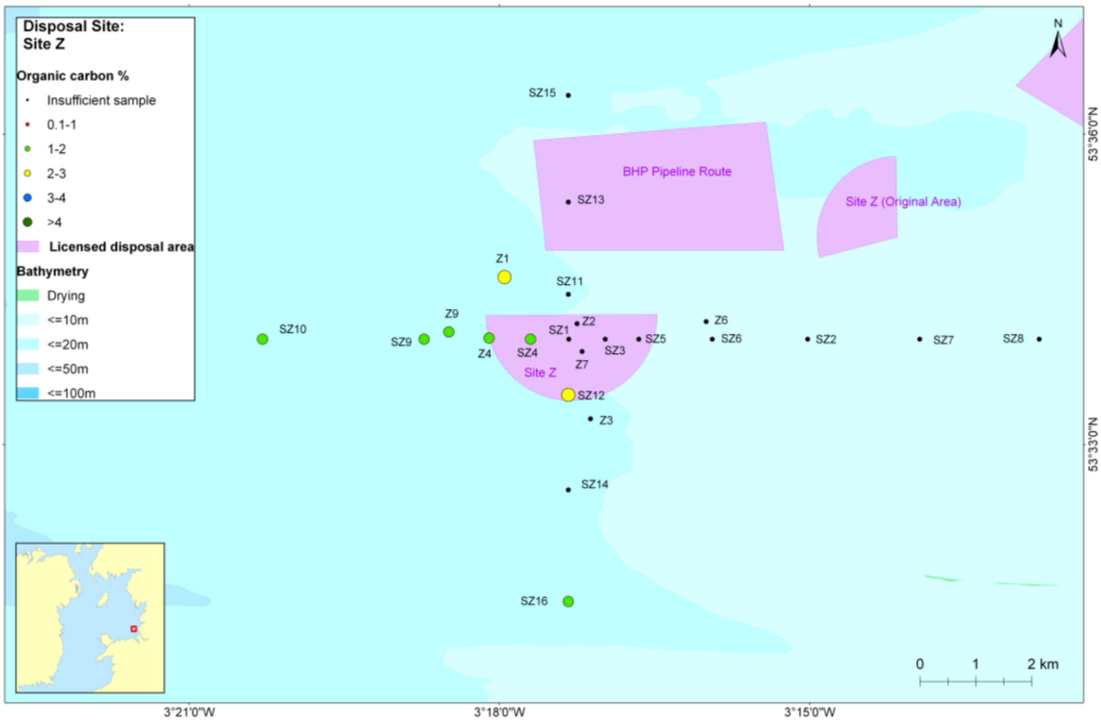


Figure A2.8.4. Organic carbon (%m/m) in the silt/clay fraction (<63µm) at Site Z, Liverpool Bay in 2010.

2.8.4.3 Macrofaunal communities

A total of 6542 individuals from 136 taxonomic categories (excluding colonial and vertebrate species) were identified from the 7 stations (four replicates at each) sampled for macrofauna at Site Z in 2010. The main taxonomic groups and their percentage numerical contribution are shown in Figure A2.8.5. The average number of individuals at each site ranged from between 50 to 786 individuals per 0.1m^{-2} being notably higher at Z9 (to the west of the disposal site) and Z4 (on the western limit of the licensed boundary). The average number of taxonomic groups in each site ranged from 15 to 47 per m^{-2}. 32% of the taxonomic groups recorded occurred in only one sample and four taxonomic groups (*Nemertea*, *Spiophanes bombyx*, *Iphinoe trispinosa* and *Nucula nitidosa*) occurred in over 80% of samples. Total biomass in each sample ranged from 0.2 -165 g^{-1} 0.1 m^{-2} with three species (*Pharus legumen*, *Acanthocardia echinata* and *Echinocardium cordatum*) contributing the highest biomass. *P.*

legumen, *A. echinata* and *E. cordatum* contributed 84% (±3.3 sd) of total biomass at site Z4 and 78% (± 8.4 sd) at site Z9. In general, according to these three univariate indices of community structure and mass, the two stations within the disposal area were relatively impoverished while those just to the west were comparatively richer.

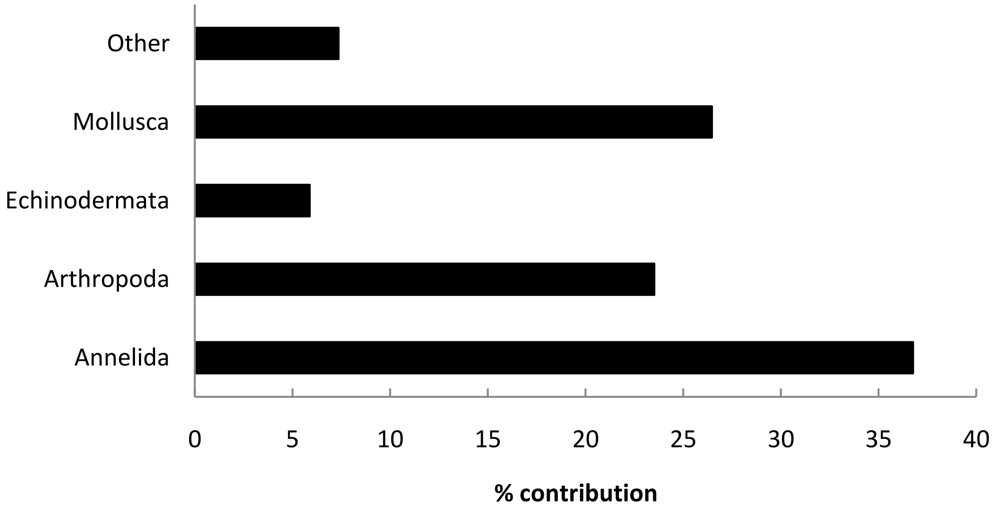


Figure A2.8.5. Percentage contribution of the major phyla sampled at all stations in Site Z 2010.

One way analysis of variance (ANOVA) revealed significant differences in the number of individuals, number of taxonomic groups and biomass between the 7 stations ($F_{IND\ 6,\ 21}$= 154, $p< 0.0001$; $F_{TAX\ 6,\ 21}$= = 13.5, $p< 0.0001$; $F_{BIO\ 6,\ 21}$= 21.4, $p< 0.0001$ respectively). ANOVA was then carried out on the same three variables with position (inside, outside or on the edge of the disposal ground) as the factor. There were significant differences in the number of individuals, number of taxonomic groups and biomass between sites classified as being on the edge, inside and outside of the disposal area ($F_{IND\ 2,\ 25}$= 3.3, $p= 0.05$; $F_{TAX\ 2,\ 25}$= 11.3, $p< 0.001$; $F_{BIO\ 2,\ 25}$= 11, $p< 0.001$ respectively). Results of the Bonferroni post hoc tests are shown below (Table A2.8.3). Mean number of taxonomic groups significantly varied between comparisons of site locations with more taxonomic groups being found outside or on the edge of the disposal area than within (x_{EDGE}= 32 (± 2.1 sd), $x_{OUTSIDE}$= 33 (± 7.5 sd), x_{INSIDE}= 20 (± 4 sd).

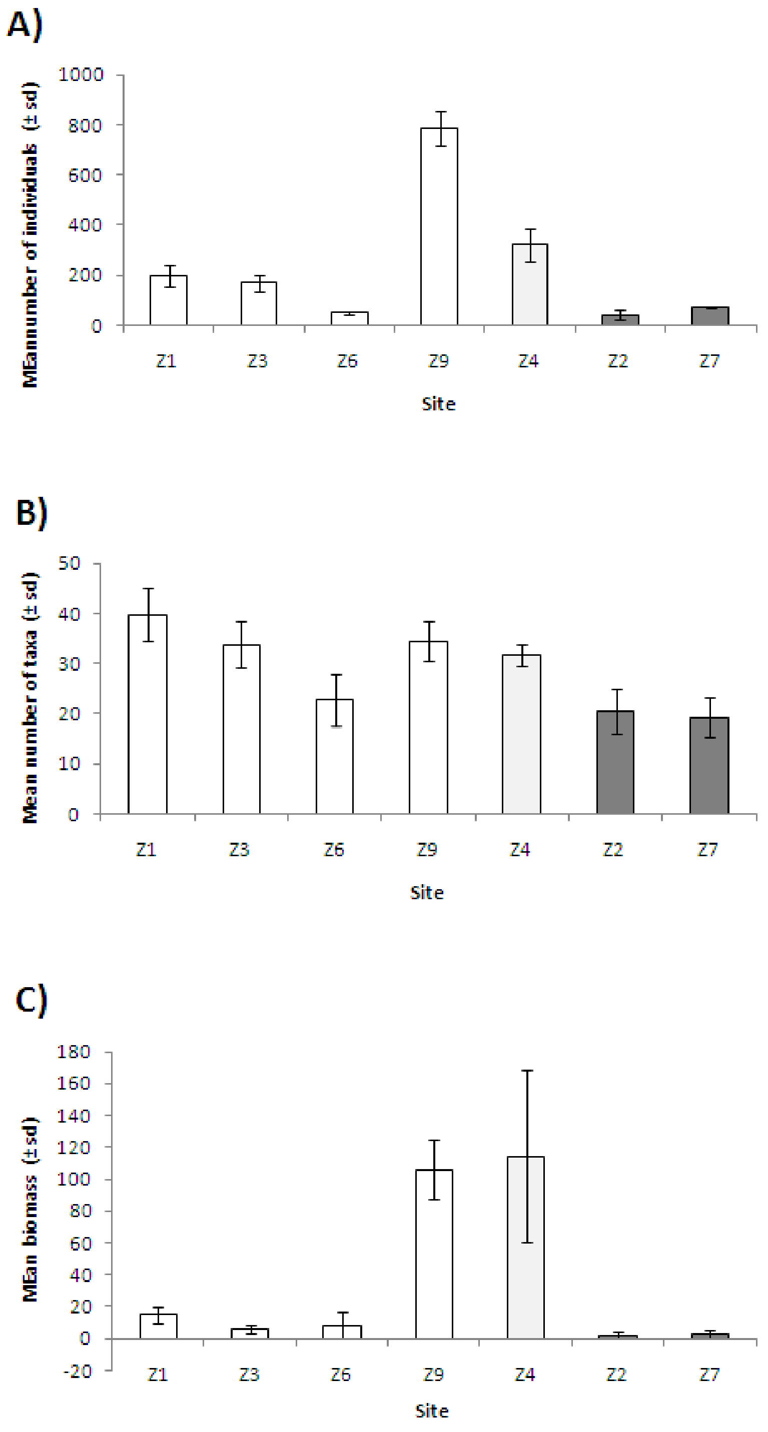


Figure A2.8.6. Mean values (± sd) for A) Number of individuals, B) Number of taxonomic groups and C) Biomass for each of the study sites. Sites Z1,Z3,Z6 & Z9 are outside the disposal area (white), site Z4 is on the edge of the disposal area (grey) and sites Z2, Z7 are inside the disposal area (dark grey).

Variable	**Comparison**	**Bonferroni post hoc p value**
Mean number of individuals	Inside / Outside	0.02
	Edge / Inside	0.07
	Edge / outside	0.87
Mean number of taxonomic groups	Inside / Outside	<0.0001*
	Edge / Inside	0.0054*
	Edge / outside	0.79
Mean biomass	Inside / Outside	0.07
	Edge / Inside	<0.0001*
	Edge / outside	0.0011*

* Comparisons for this Bonferroni post hoc test are not significant unless the corresponding probability value is <0.0167.

*Table A2.8.3. Results of the Bonferroni post hoc analysis. * indicates a significant probability value.*

Multivariate analyses were carried out using Primer version 6.1.5 (Clarke & Gorley, 2006). Nonparametric multi-dimensional scaling analysis (MDS) was carried out on the square root-transformed abundance data in order to identify any variation in benthic community between and within stations (Figure A2.8.7). Hierarchical CLUSTER and SIMPROF analyses were carried out to determine grouping of replicates within a station, and the relationships between stations located within, outside and on the edge of the disposal area. SIMPROF revealed 8 significantly different clusters, labelled a-f ($p < 0.05$), (Figure A2.8.8). Replicates of Z1 split into 3 separate clusters (a, b & c) while the two stations within the disposal area boundary (Z2 & Z7) clustered into a single group (h). All other sample replicates clustered within their station. The cluster analysis was then overlaid onto the MDS to highlight any clustering as a result of location within or outside the disposal area. At 40% similarity, samples from Z4 (closest to the disposal site boundary) clustered with sites located outside the disposal area (Z1, Z3 & Z9). Z6, despite being outside the disposal area, was more similar, at the 30% level, to those sites inside the boundary (Z2 & Z7), (Figure A2.8.9).

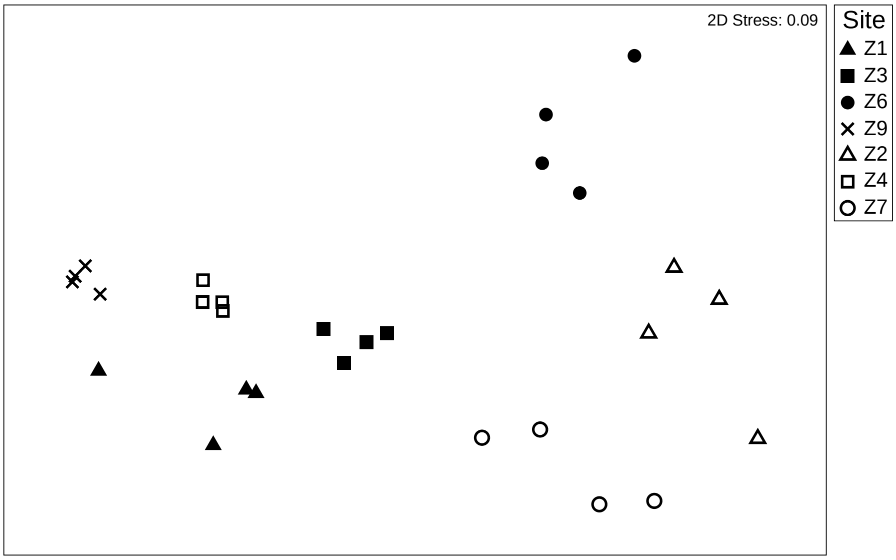


Figure A2.8.7. MDS ordination of square root transformed data based on Bray Curtis similarity for all infauna samples collected during 2010 Site Z survey.

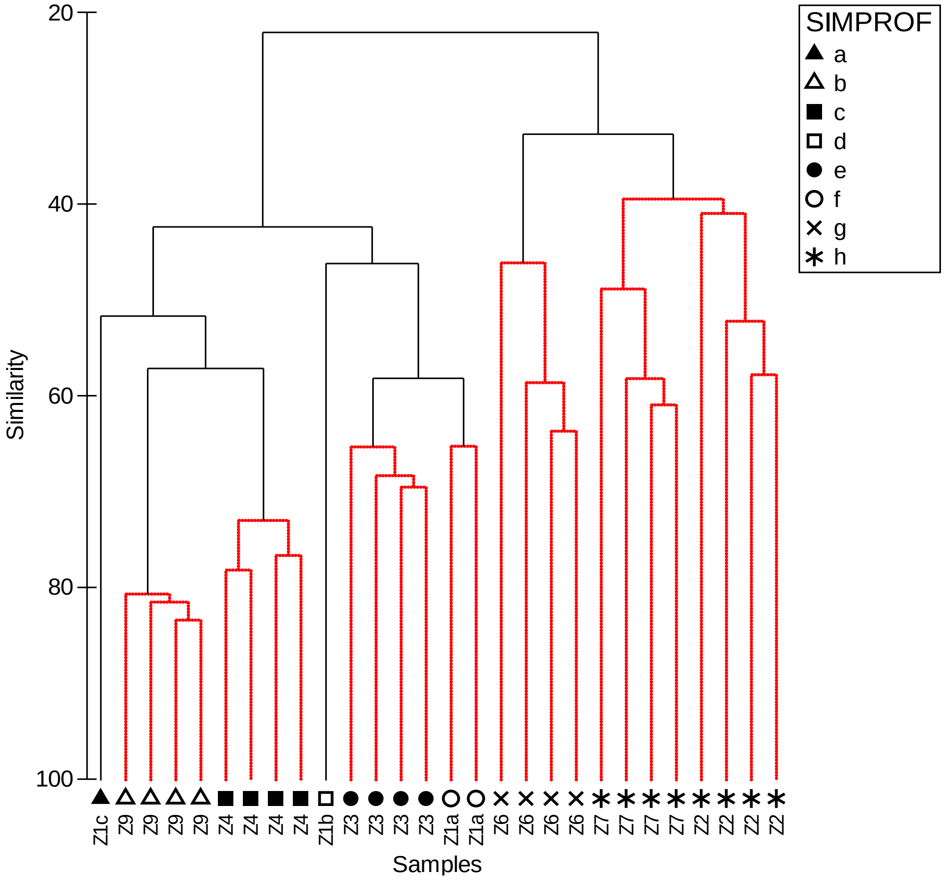


Figure A2.8.8. The majority of replicates clustered within their station, however, Z1 split to form 3 separate clusters (a, b & c) and Z2 & Z7 formed one cluster (h). Significant clustering is indicated by groups with dashed, red lines.

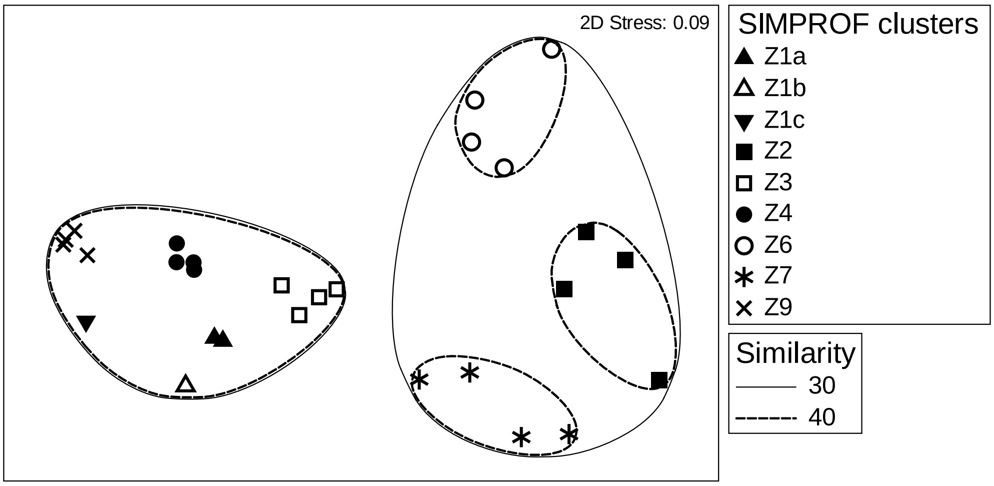


Figure A2.8.9. MDS ordination of all 28 samples collected on the Site Z 2010 survey. SIMPROF clusters (significance level 5%) are represented using symbols. Z4 has a more similar benthic community to those samples outside the disposal area (40% similar) while Z6 is more similar to samples inside the disposal area.

One way ANOSIM was carried out to determine any significant differences in overall community structure between sites inside, outside and on the edge of the disposal ground. There is a small yet significant difference in benthic community structure depending on position (Global R= 0.34, p< 0.01). Pairwise tests between the groups (inside, outside and on the edge) revealed significant differences in benthic community structure between sites inside the disposal ground and those outside or on the edge (R_{I-O}= 0.51, p< 0.001; R_{I-E}= 0.95, p< 0.01). There is no significant difference between samples taken from outside and samples on the edge of the disposal ground (R_{O-E}= -0.21, p= 0.98).

2.8.4.4. Sediment contaminants

2.8.4.4.1.TBT

Concentrations of TBT and DBT were generally below LODs for all 23 stations sampled at Site Z in 2010 except for Z3, south of the disposal site. Comparison with the previous survey data (in 2006) revealed that the TBT and DBT levels generally remain the same, with only a slight in increase of TBT at Z3 (from below LOD to 0.007mg/kg) and a slight decrease of TBT at Z7 (from 0.06mg/kg to below LOD).

2.8.4.4.2. PAHs

The highest summed PAH concentration at Site Z was found to the south of the disposal site at SZ16 (6,990 µg kg^{-1} dw; figure 2.8.10). The lowest concentrations were found in samples from within the disposal area. At SZ3, the summed PAH concentration was 13 µg kg^{-1} dw, with other values < 100 µg kg^{-1} also seen to the north and east of the disposal site. Intermediate PAH concentration levels were found to the west and south of Site Z. The ERL for LMW PAHs was breached at SZ16 and SZ14 to the south of the disposal area, but no station exceeded the ERM for LMW PAHs. The ERL for the HMW PAH was breached only at SZ16; no station exceeded the ERM for HMW PAHs.

The only sample exhibiting a dominant PAH source was from SZ4 on the disposal site, which showed 73% combustion-derived PAH from a sandy sediment. Dredging disposal volume at this disposal site was much higher in 2009 than in the previous year, with 1,550,000 tonnes disposed in 2009 compared to 312,000 tonnes in 2008. This site has not been sampled for PAHs since 2006, when the highest summed PAH concentration was found to be 3,040 µg kg^{-1} dw.

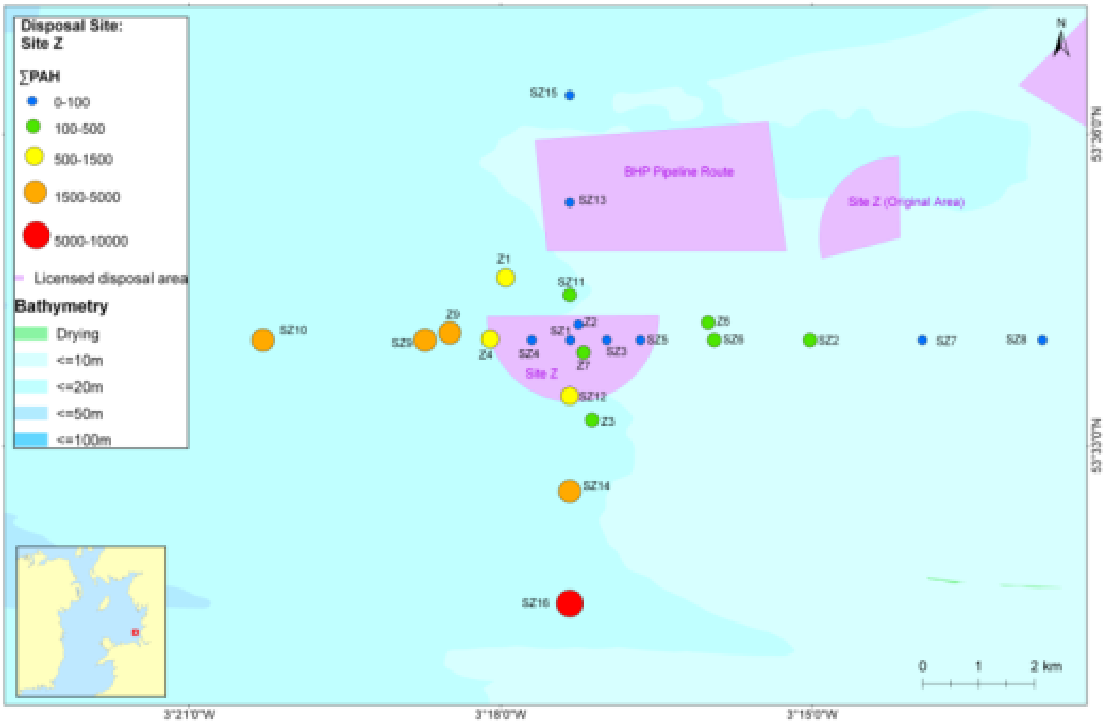


Figure A2.8.10. Summed PAH concentrations (µg kg^{-1} dw) for stations sampled in 2010 around Site Z in Liverpool Bay.

2.8.4.4.3 Organohalogens

ICES 7 CBs were only detected at 8 of the 23 stations (∑ ICES 7 CBs range <0.7-5.2 µg/kg dw). The highest concentration of 5.2 µg/kg dw was at SZ16, which is closest to the mouth of the River Mersey (Figure A2.8.11). ∑ ICES 7 CB concentrations were <1 µg/kg at all other stations apart from SZ9 and Z9 which had levels of 1.4 and 1.1 µg/kg dw, respectively. Levels at all stations within the disposal site were low.

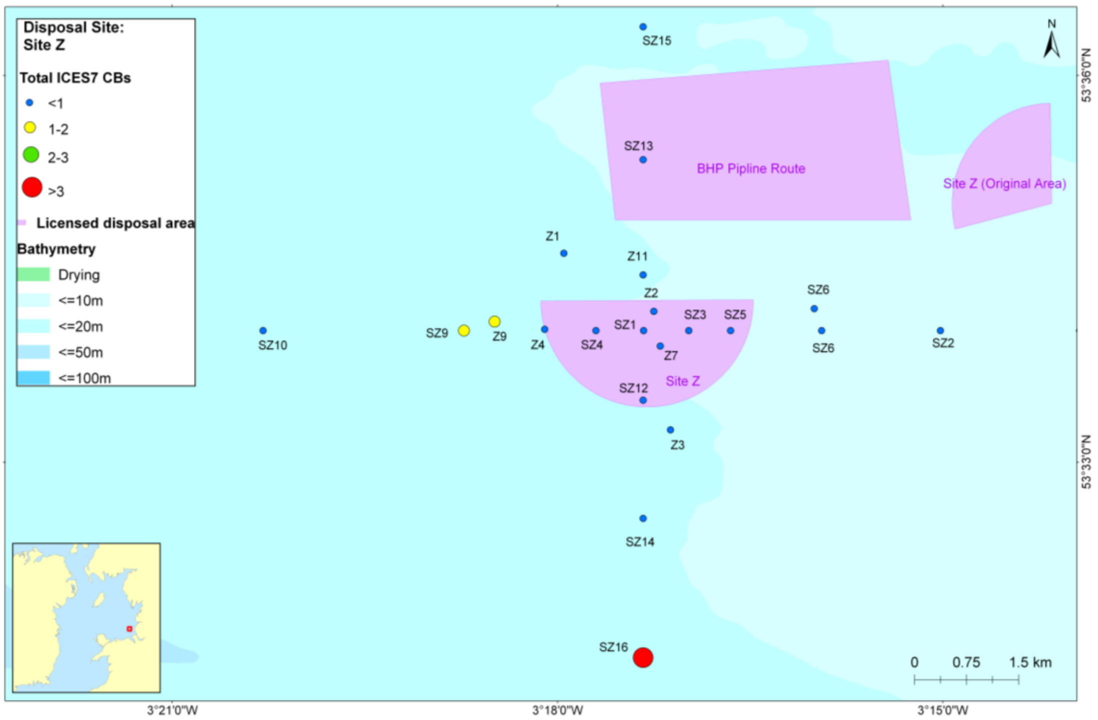


Figure A2.8.11. ∑ ICES7 CB concentrations for the Site Z Stations, 2010.

BDEs were detected at 9 of the 23 stations (∑ 11 BDEs range <0.11-1.9 µg/kg dw). Again, the highest concentration of 1.9 µg/kg dw was at station SZ16 close to the mouth of the River Mersey (Figure A2.8.12). ∑ 11 BDEs concentrations were <0.4 µg/kg dw at all other stations apart from SZ9, SZ10 and SZ12 which had levels of 1.5, 0.7 and 0.9 µg/kg dw, respectively. As for CBs, levels at all stations within the disposal site were low.

BDE209 was detected in 19 out of 23 stations at Site Z, making it the most ubiquitous contaminant analysed (range <1-302 µg/kg dw). BDE209 made up >83% of total 12 BDEs. Highest concentrations were at stations SZ16 and SZ14 with values of 302 and 112 µg/kg dw, again reflecting proximity to the mouth of the Mersey (Figure A2.8.13). High values of 102, 95 and 79 µg/kg dw were also present at stations Z9, SZ9 and SZ10 to the west of the disposal site. Within the disposal site, only SZ12 had BDE209 concentration >10 µg/kg dw.

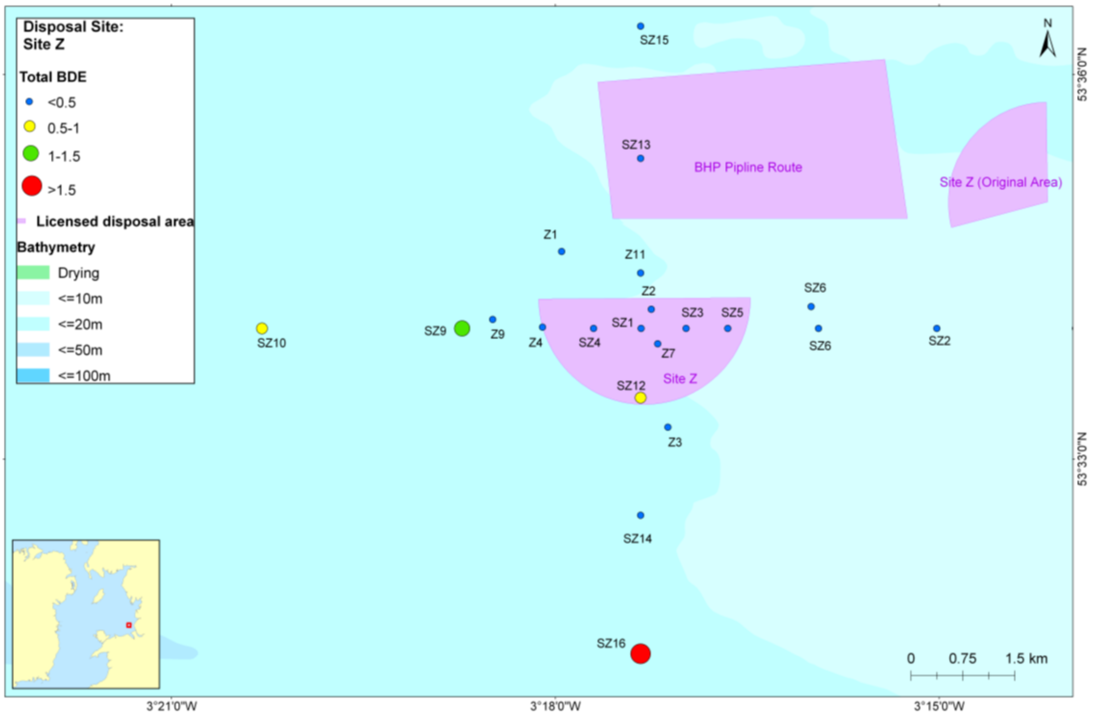


Figure A2.8.12. ∑ ICES7 CB concentrations for the Site Z Stations, 2010.

Levels of organochlorine pesticides in the Site Z area were generally low. HCB and HCHs were below LODs in 22 out of 23 stations and only just quantifiable when present. *p,p'*-DDT was not detected in any stations, but its metabolites *p,p'*-DDE and *p,p'*-TDE were detected in 5 and 16 stations respectively. The highest ∑ DDT concentration of 2.8 µg/kg dw was also at the mouth of the River Mersey at SZ16 (Figure A2.8.14). ∑ DDT levels were <1 µg/kg dw at all other stations except Z9 and SZ14 which were just above. Again, levels in the disposal site were low.

There is limited data available for the stations at Site Z from 2002, 2003 and 2006 with which to compare the CB, BDE and DDT concentrations observed in 2010 (Tables 2.8.4 to 2.8.6). For all contaminants, levels in 2010 are noticeably lower than found in previous years.

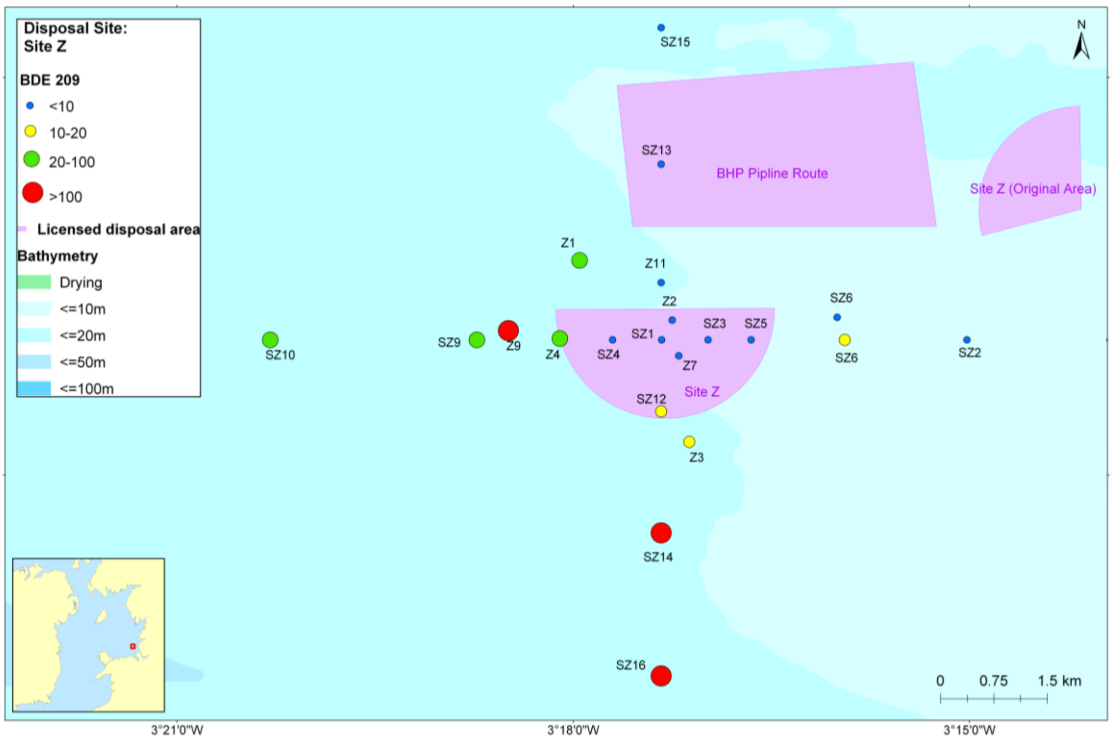


Figure A2.8.13. BDE209 concentrations for the Site Z Stations, 2010.

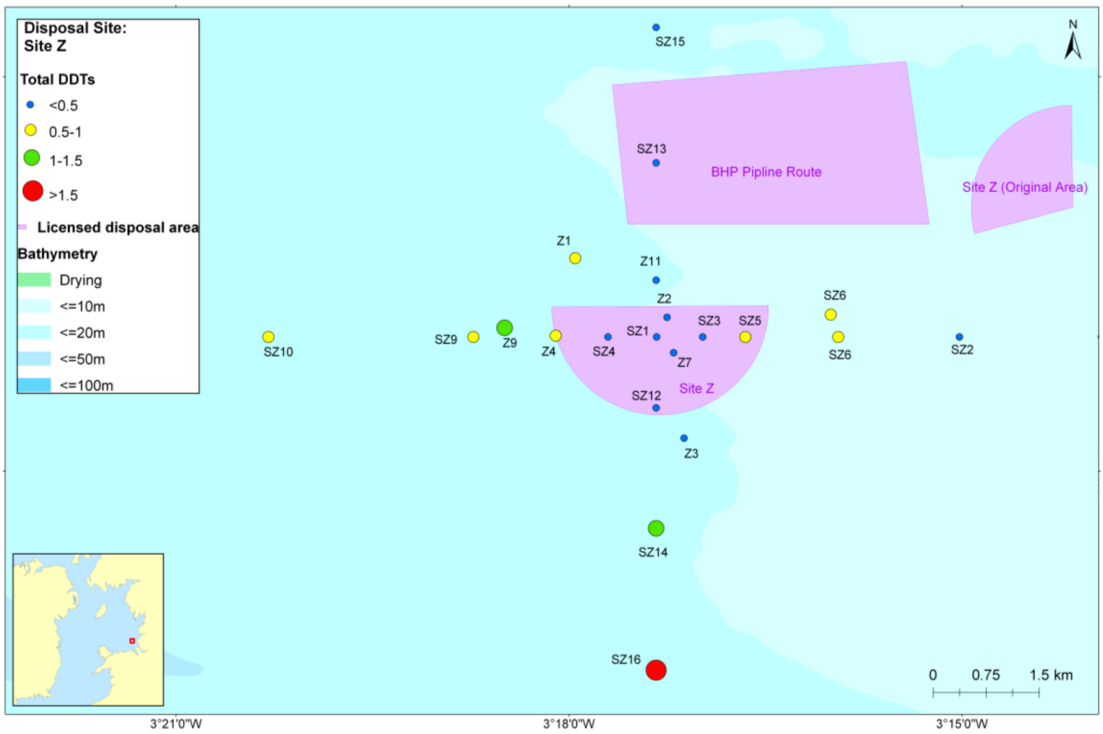


Figure A2.8.14. ∑ DDTs concentrations for the Site Z Stations, 2010.

Station code	**∑ICES 7 CBs concentration (in µg/kg)**								
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
SZ16									5.2
SZ4					1.13				*0.7*
Z3	*0.7*	*0.7*			1.22				*0.7*
SZ12									*0.7*
SZ10									0.91
SZ9									1.44
Z9	2.07	*2.48*			2.57				1.06
Z4	1.56								0.99
SZ15									*0.7*
SZ13									*0.7*
Z1		*0.7*			1.14				*0.7*
SZ11									*0.7*
Z2	*0.7*				0.81				*0.7*
SZ14									0.9
SZ1									0.81
Z7	*0.7*				2.4				0.84
SZ3									*0.7*
SZ5									*0.7*
Z6	*0.7*	*0.7*			0.7				*0.7*
SZ6									*0.7*
SZ2									*0.7*
SZ7									*0.7*
SZ8									*0.7*

Table A2.8.4. Temporal trends (2002-2010) of ∑ICES 7 CBs concentration (in µg/kg) at Site Z in the stations sampled during 2010.

Concentrations of CBs at all stations were below Cefas AL1. Concentrations of DDTs were above Cefas AL1 at stations Z9, SZ14 and SZ16. No Cefas AL2 exists for DDTs and no ALs exist for BDEs including BDE209. According to the OSPAR guidelines, most stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall. Exceptions with one CB with ‘bad’ environmental status but ‘good’ status overall were Z4 and Z9 (for CB28), SZ1 and Z7 (for CB101) and SZ9 and SZ10 (for CB118). Station SZ16 had ‘bad’ environmental status for CB28 and CB118 and therefore ‘bad’ status overall. No OSPAR guidelines exist for BDEs and OCs at present.

Station code	**∑ 11 BDEs concentration (in µg/kg dw)**							
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
SZ16								1.95
SZ4				*0.69*				*0.11*
Z3	0.71			*0.69*				0.18
SZ12								0.93
SZ10								0.75
SZ9								1.49
Z9	0.75			1.58				0.23
Z4								0.20
SZ15								*0.11*
SZ13								*0.11*
Z1	*0.69*			*0.69*				0.13
SZ11								*0.11*
Z2				*0.69*				*0.11*
SZ14								*0.11*
SZ1								0.31
Z7				0.79				*0.11*
SZ3								*0.11*
SZ5								*0.11*
Z6	*0.69*			*0.69*				*0.11*
SZ6								*0.11*
SZ2								*0.11*
SZ7								*0.11*
SZ8								*0.11*

Table A2.8.5. Temporal trends (2002-2010) of ∑11 BDEs concentration (in µg/kg dw) at Site Z in the stations sampled during 2010.

2.8.4.4.5 Trace metals

Figure A2.8.15 indicates that there is no significant difference between inside and outside the disposal sites between 2006 and 2010 surveys.

During the 2006 survey, all the sampling stations were outside the disposal site, thus temporal comparisons with the findings of 2010 cannot be made. For stations outside the disposal site, Figure A2.8.16 shows that there is no significant trend that can be depicted between 2006 and 2010.

Concentrations of As at most stations are lower than the OSPAR BAC, indicating no enrichment. However, with the proposed baseline being lower than the OSPAR BAC, the majority of the stations (including all stations within the disposal site) were found to be slightly enriched for As when comparing with the baseline value (Figure A2.8.17).

Station code	**∑DDTs concentration (in µg/kg dw)**							
	2002	**2003**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
SZ16								2.76
SZ4								*0.3*
Z3	1.63	0.86		0.8				0.49
SZ12								0.48
SZ10								0.76
SZ9								0.9
Z9	2.25	2.34		1.83				1.06
Z4	2.04			0.58				0.77
SZ15								*0.3*
SZ13								0.46
Z1		0.76		0.55				0.6
SZ11								0.46
Z2	0.81			0.40				*0.3*
SZ14								1.03
SZ1								*0.3*
Z7	1.42			1.61				0.47
SZ3								*0.3*
SZ5								0.51
Z6	0.78	0.57		*0.3*				0.54
SZ6								0.54
SZ2								*0.3*
SZ7								*0.3*
SZ8								0.54

Table A2.8.6. Temporal trends (2002-2010) of ∑DDTs concentration (in µg/kg dw) at Site Z in the stations sampled during 2010.

All stations are enriched for Cd, with a higher degree of enrichment in a horizontal transect from westerly to easterly across the disposal site. Stations Z7 and SZ5 (within the disposal site) and station SZ8 (the most easterly station from the disposal site) have enrichment ratios above 5. This general finding is similar for both assessment methods.

Generally, Cu levels seem to be more elevated on the east part of the disposal site and all stations were found to be relatively enriched when using the OSPAR BAC approach. The enrichment is also observed, but to a lesser extent, when comparing the concentrations with the baseline value.

Hg concentrations (Figure A2.8.17) are generally more elevated than the OSPAR BAC making Site Z area very enriched in Hg. Despite having taken into account for regional variability (due to mineralogy, historical mining and industries) when using the regional baseline approach, enrichment is reduced but still remain at a moderate level across the area. Part of this elevation may be a relic of the high Hg inputs in the sewage sludge that was historically disposed of offshore from Site Z. OSPAR BAC value for Ni is very comparable to the proposed baseline for this region, giving an overall slight enrichment of Ni for this area. Pb and Zn enrichment (Figure A2.8.17) is moderate for all stations when assessing against OSPAR BAC, this enrichment is still present to a lesser extent with the baseline value. However, SZ8, west of the disposal site, remains very enriched when using both approaches.

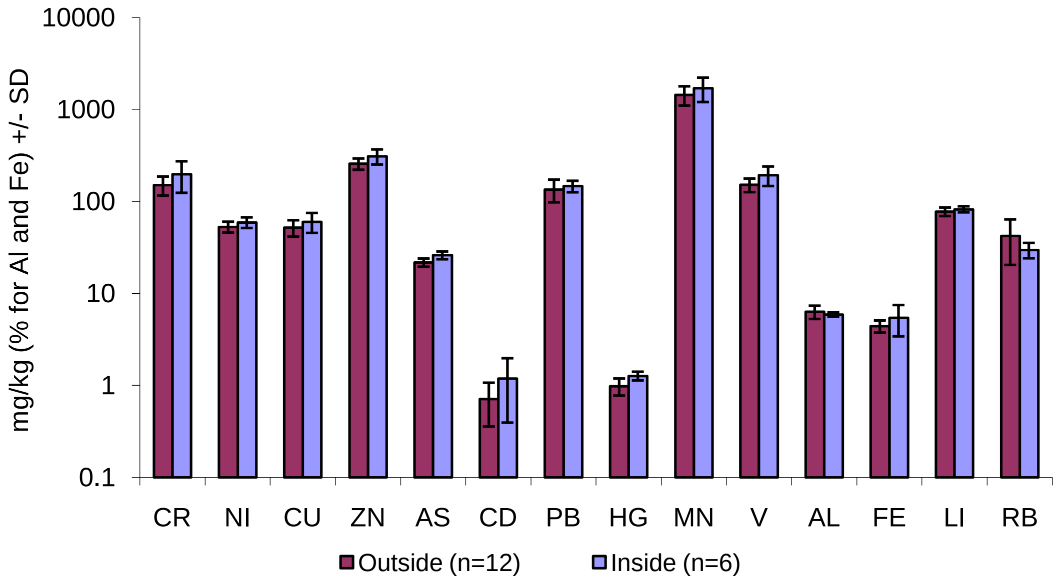


Figure A2.8.15. Average metal concentrations inside and outside for metal concentrations at Site Z in 2006 and 2010.

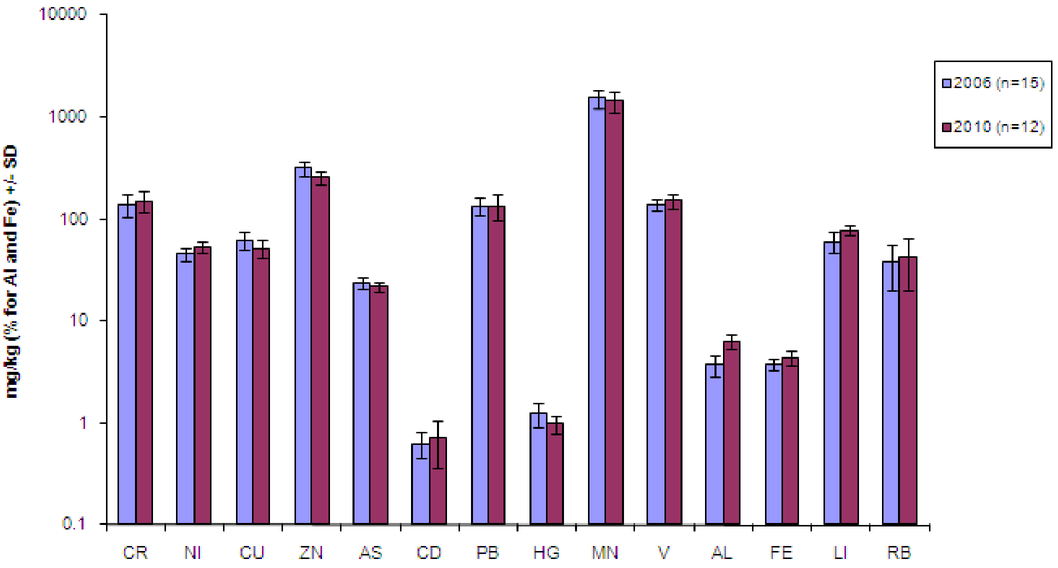
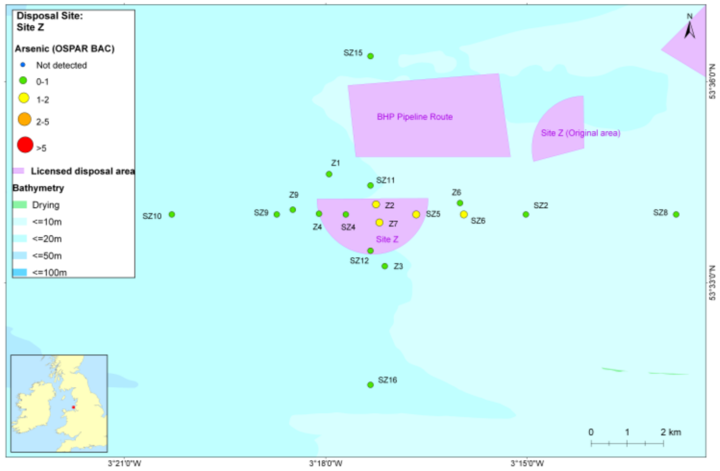
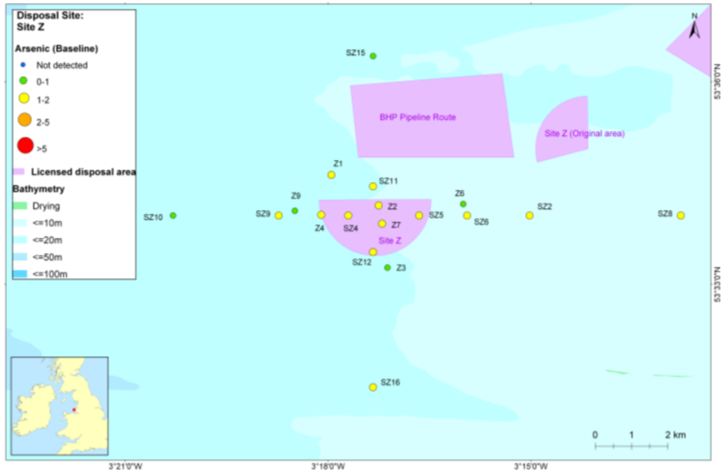
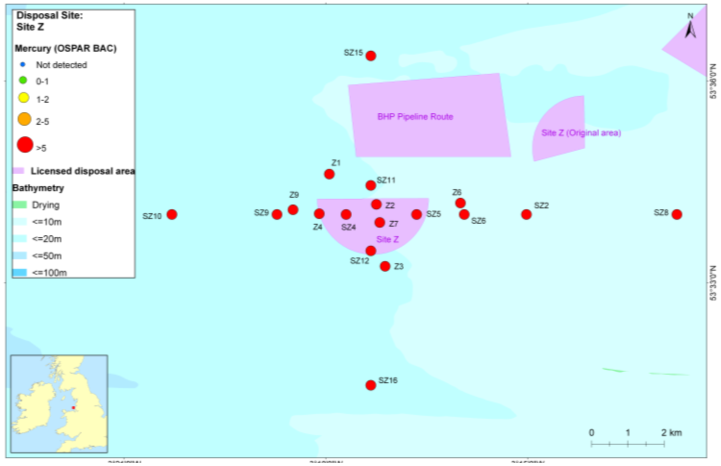
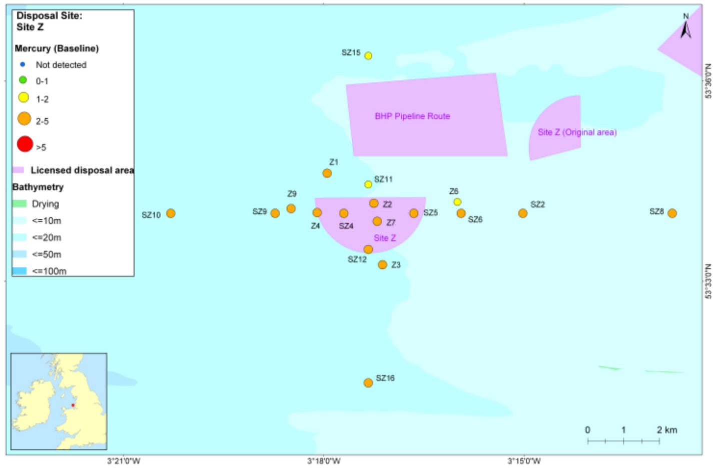


Figure A2.8.16. Average metal concentrations outside the Site Z disposal site in 2006 and 2010.


Disposal Site:
Site Z
Arsenic (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
SZ15
BHP Pipeline Route
Site Z (Original area)
Z1
SZ11
Z9
Z6
SZ10
SZ9
Z2
SZ5
SZ2
SZ8
Z4
SZ4
Z7
SZ6
Site Z
SZ12
Z3
SZ16
0
1
2 km
53°36'0"N
53°33'0"N
3°21'0"W
3°18'0"W
3°15'0"W


Disposal Site:
Site Z
Arsenic (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
SZ15
BHP Pipeline Route
Site Z (Original area)
Z1
SZ11
Z9
Z6
SZ10
SZ9
Z2
SZ5
SZ2
SZ8
Z4
SZ4
Z7
SZ6
Site Z
SZ12
Z3
SZ16
0
1
2 km
53°36'0"N
53°33'0"N
3°21'0"W
3°18'0"W
3°15'0"W


Disposal Site:
Site Z
Mercury (OSPAR BAC)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
SZ15
BHP Pipeline Route
Site Z (Original area)
Z1
SZ11
Z9
Z6
SZ10
SZ9
Z2
SZ5
SZ2
SZ8
Z4
SZ4
Z7
SZ6
Site Z
SZ12
Z3
SZ16
0
1
2 km
53°36'0"N
53°33'0"N


Disposal Site:
Site Z
Mercury (Baseline)
Not detected
0-1
1-2
2-5
>5
Licensed disposal area
Bathymetry
Drying
<=10m
<=20m
<=50m
<=100m
N
SZ15
BHP Pipeline Route
Site Z (Original area)
Z1
SZ11
Z9
Z6
SZ10
SZ9
Z2
SZ5
SZ2
SZ8
Z4
SZ4
Z7
SZ6
Site Z
SZ12
Z3
SZ16
0
1
2 km
53°36'0"N
53°33'0"N
3°21'0"W
3°18'0"W
3°15'0"W

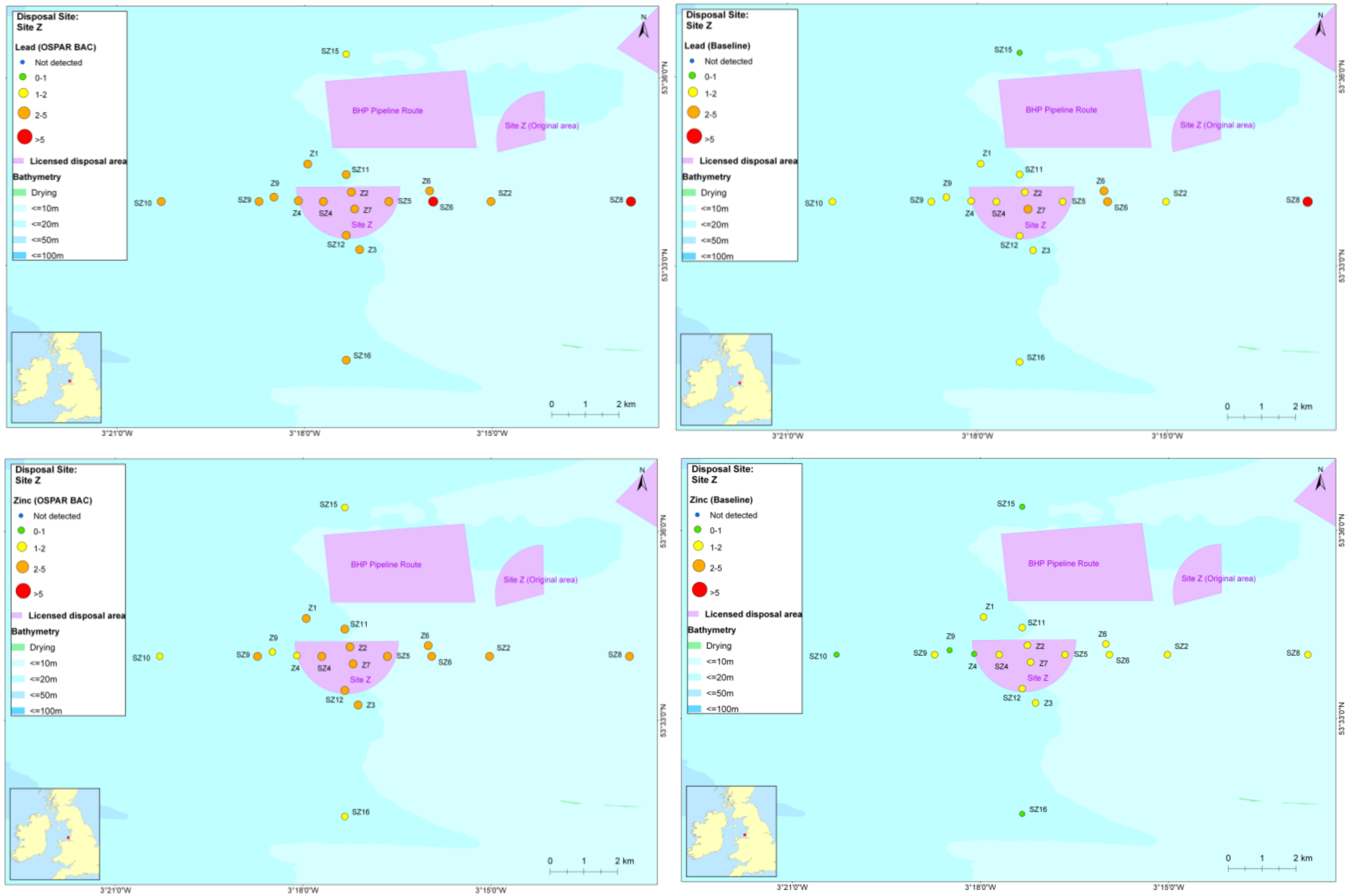


Figure A2.8.17. Enrichment to OSPAR BACs and Regional Baseline values at Site Z, Liverpool Bay, 2010.

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