Dredging Conservation Assessment for the Thames Estuary

Port of London Authority
19th August 2009
Final Report
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1 INTRODUCTION

1.1 Background

The UK Government considers that where maintenance dredging has the potential to affect a *Natura 2000* site (such as a Special Protection Area (SPA) or Special Area of Conservation (SAC)), maintenance dredging should be considered as a 'plan or project' for the purposes of the EC Habitats Directive (92/43/EEC). Based on this interpretation, maintenance dredging operations would need to be assessed in accordance with Article 6(3) of the Directive. Whilst not endorsing this interpretation, the ports industry has agreed to co-operate with the Government to seek to devise arrangements which allow the effects of maintenance dredging on Natura 2000 sites to be reviewed in a way which does not impose a disproportionate burden on industry, Government, or its agencies.

In order to inform this process, a *Conservation Assessment Protocol on Maintenance Dredging and the Habitats Regulations 1994* (hereafter referred to as the ' Protocol') has been developed to assist port authorities in fulfilling their statutory obligations through the co-operation of the:

- British Ports Association;
- British Marine Federation;
- Cabinet Office;
- Department for Environment, Food and Rural Affairs;
- Department for Transport;
- Natural England; and
- UK Major Ports Group (of which the Port of London Authority is a member)

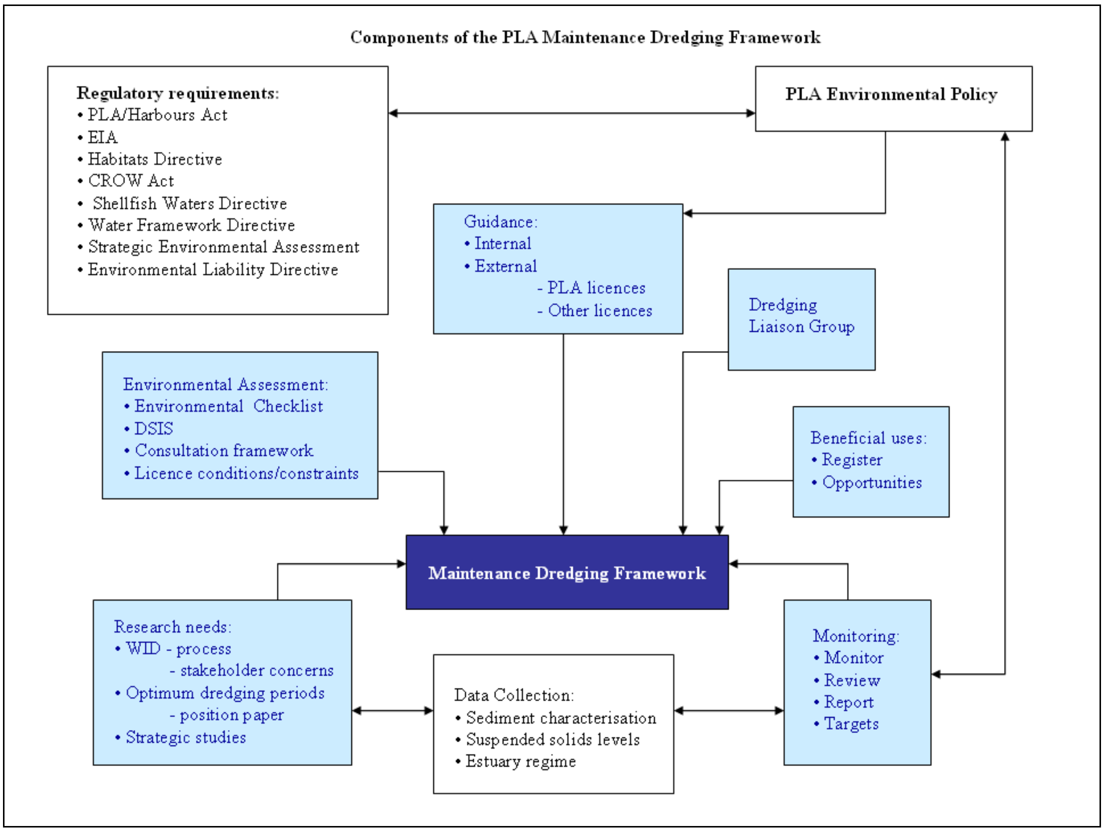
A Draft Protocol was produced in December 2003. Since this date it has been trialled at a number of ports (Humber, Medina and Fal/Helford) and was finalised in 2007. Production of a Baseline Document is voluntary but without it individual maintenance dredge proposals may require more extensive and time-consuming information gathering and consultation. The Protocol recommends that a 'Baseline Document' (hereafter referred to as a Dredging Conservation Assessment (DCA)) is prepared that draws on existing and readily available information to describe current and historic patterns of dredging in relation to the conservation objectives of adjacent European marine sites. This report represents the DCA for the Port of London Authority (PLA). This document therefore contains information relevant to the integrity of the Thames Estuary and Marshes SPA, Benfleet and Southend Marshes SPA and the Holehaven Creek Site of Special Scientific Interest (SSSI).

The Protocol recommends that as the sites change over time, whether as a result of natural or anthropogenic change, the DCA will need to evolve. The DCA has been updated (March 2009) to take account of new baseline data, changes to existing dredging campaigns and new dredging campaigns.

In 2003 the PLA established a Maintenance Dredging Framework for the Thames in partnership with members of the Dredging Liaison Group (a Thames Estuary Partnership Action Group). This framework provides for the co-ordinated assessment and management of dredging operations on the tidal Thames and includes the consideration of any likely impacts on designated conservation sites. Much of the information and data required to inform this DCA has been sourced through the PLA's

Maintenance Dredging Framework, and the document therefore represents a summary of existing environmental management practice in the Thames.

The Framework structure:



The presumption on which the Protocol is based is that maintenance dredging will continue in line with established practice. This DCA has been prepared on the premise that existing practice is part of the functioning of the existing system (i.e. part of the baseline environment).

A key component of the Framework was the development of a Geographical Information System called the Dredging Spatial Information System (DSIS). DSIS brings together stakeholders as partners in the decision-making process for dredging licence applications; facilitates the sharing of information; and produces an excellent baseline of relevant environmental data for the tidal Thames. The partners include, amongst others, the Environment Agency, Natural England, the Royal Society for the Protection of Birds, Kent and Essex Sea Fisheries Committee and four dredging companies, with the Thames Estuary Partnership providing administrative support and a neutral forum for discussion. DSIS is available to members of the Dredging Liaison Group via a secure connection on the PLA's website.

1.2 Context and Scope of the Dredging Conservation Assessment

The PLA and berth operators regularly carry out maintenance dredging works within the River Thames. A proportion of these operations take place on berths or areas of the navigation channel that are in "close proximity" to areas designated under the Conservation (Natural Habitats etc) Regulations 1994. The original Baseline Document was produced in June 2007 and was commissioned by the PLA to help establish a baseline position for the Thames in respect of the specific dredging operations and European sites. As there have been some changes to the maintenance dredging requirements, and there is a potential change to the designated status of one site, this document has been produced to take account of the changes. For the original Baseline Document "close proximity" was defined, with the agreement of Natural England, as being a zone of 5 km radius around the identified dredging operations. The study area for the document was therefore defined by the sites and corresponding buffer areas illustrated in Figure 1.1, extending from Coldharbour Point and the Inner Thames Marshes SSSI at Rainham to the eastern limits of Canvey Island. Other maintenance dredging activities located upstream of the Dartford Crossing were discounted as having no potential to impact on the designated sites, being in excess of 5 km from the nearest boundary. Furthermore, maintenance dredging activity within the Medway River under the administration of the Medway Ports Authority was excluded, despite recognition that impact may arise. This does not prevent such dredging taking place, but places the responsibility of meeting the criteria of the EC Habitats Directive on a case by case basis, or as part of the maintenance dredging baseline prepared to address the Medway specifically.

The original Baseline Document was agreed by Natural England and members of the Dredging Liaison Group (DLG). More details on the DLG are provided in Section 2.1.

In deviation from the protocol, consideration has also been given to the potential impacts on one specific SSSI area, namely Holehaven Creek, in recognition that this may, in future, also be incorporated into the Benfleet and Southend Marshes SPA under the Conservation (Natural Habitats etc) Regulations 1994.

1.3 Additional Information provided in the review

This revised document includes updates to the following dredging campaigns:

1.3.1 Changes to existing dredging campaigns

Customs House Jetty

In recent years HM Revenue and Customs has been granted a licence to dredge up to 4,000m^3 per year using WID (maximum of two campaigns per year), to achieve a maximum depth of 3.0m below Chart Datum. Having reviewed the bathymetric survey data back to early 2007, the PLA revised the actual quantity being dredged as 4,500m^3 per campaign or a maximum of 9,000m^3 per annum. The conclusion of the DLG was that the increase in maintenance requirement would not have an adverse impact on the conservation objectives of the SPAs in the study area.

Oikos Terminal, Holehaven Wharf

Oikos Storage Ltd. has included in their maintenance dredging regime an 'escape channel' from the berth to deep water, to facilitate the removal of silt and sand from the berth for dispersal by the main ebb tide. Presently Oikos is licensed to dredge 65,000m^3 per annum over a maximum of four campaigns using WID to achieve a depth of 12m below Chart Datum. Following the deepening of Oikos's berth a variety of dredging techniques have been trialled to find a suitable method that is both effective and economically viable. As the berth is deeper than the surrounding river bed and the sediment is relatively sandy the usual WID method is no longer able to achieve the required depths. In 2007, the PLA licensed Oikos to dredge an 'escape channel' from the berth to deep water as part of the maintenance dredging campaign. This channel facilitated the removal of silt and sand from the berth for dispersal by the main ebb tide flows in deep water. Oikos has subsequently advised that the dredging was successful. Subsequent maintenance dredging campaigns at the site will include the berth and the escape channel as required.

It has been reported previously that there has been a gradual shallowing of depths at the mouth of Holehaven Creek and that maintenance dredging activities may be the source of the sediment (PLA, 2007). With this in mind the PLA commissioned a study to determine whether maintenance dredging was the source of the sediment. The study concluded that many processes could potentially affect the change in morphology but that the ongoing maintenance dredging is unlikely to be a significant driver (HR Wallingford, 2007).

Further monitoring by bathymetric survey will provide information on the stability of the berth and the performance of the 'escape channel'. The PLA has requested as a condition of the licence that bathymetric monitoring is undertaken comprising monthly surveys, volume calculations and an assessment of the sedimentation rate. The results will be reported to the PLA after each quarterly dredging campaign.

As the site is adjacent to Holehaven Creek SSSI and within 2km from Benfleet and Southend Marshes SPA, consideration was given to the impacts of the escape channel on these sites. Through appropriate mitigation it was agreed that impacts are likely to be minimal. Such mitigation includes dredging on the ebb tide where sediment is moved initially away from the inland designated SPAs towards the Essex Estuaries European Marine Site. The sediment will then become part of the natural sediment load of the estuary and some will eventually be deposited on the mudflats. Assuming that the sediment is uncontaminated then this process can be considered beneficial and representative of the likely fate of the sediment had it not been trapped in the Oikos berth pockets.

1.3.2 New dredging campaigns

Smallgains creek, Canvey Island Essex

Deepening of the entrance channel within Smallgains Creek was undertaken in June 2007, commissioned by Island Yacht Club. The dredged channel is approximately 12m wide and provides access for yachts and fishing vessels into the Creek, which has gradually accreted over recent years. The quantity of material dredged was 4,000m^3 using WID.

As the site lies within the Benfleet and Southend Marshes SPA an Appropriate Assessment was undertaken by the PLA to assess whether the dredge will adversely affect the integrity of the SPA. The SPA is designated in part for supporting overwintering dark bellied brent geese that feed on the seagrass beds next to Two Tree Island situated less that 2km away from the dredge. Through consultation with Natural England, it was determined that key potential impacts of the dredge related to pollution of the intertidal habitat from redistribution of contaminated sediments, disturbance to waterfowl, effect on waterfowl from the direct loss of feeding habitat, interruption in photosynthesis process of the seagrass beds and effects on the designated habitats from any changes to the hydrodynamic regime.

The Appropriate Assessment concluded that the dredge will not have an adverse effect on the integrity of the Benfleet and Southend Marshes SPA, either alone, or in-combination with other plans or projects, subject to compliance with mitigation measures identified in the assessment. The complete Appropriate Assessment can be found in Appendix A.

Lower Wharf in Holehaven Creek

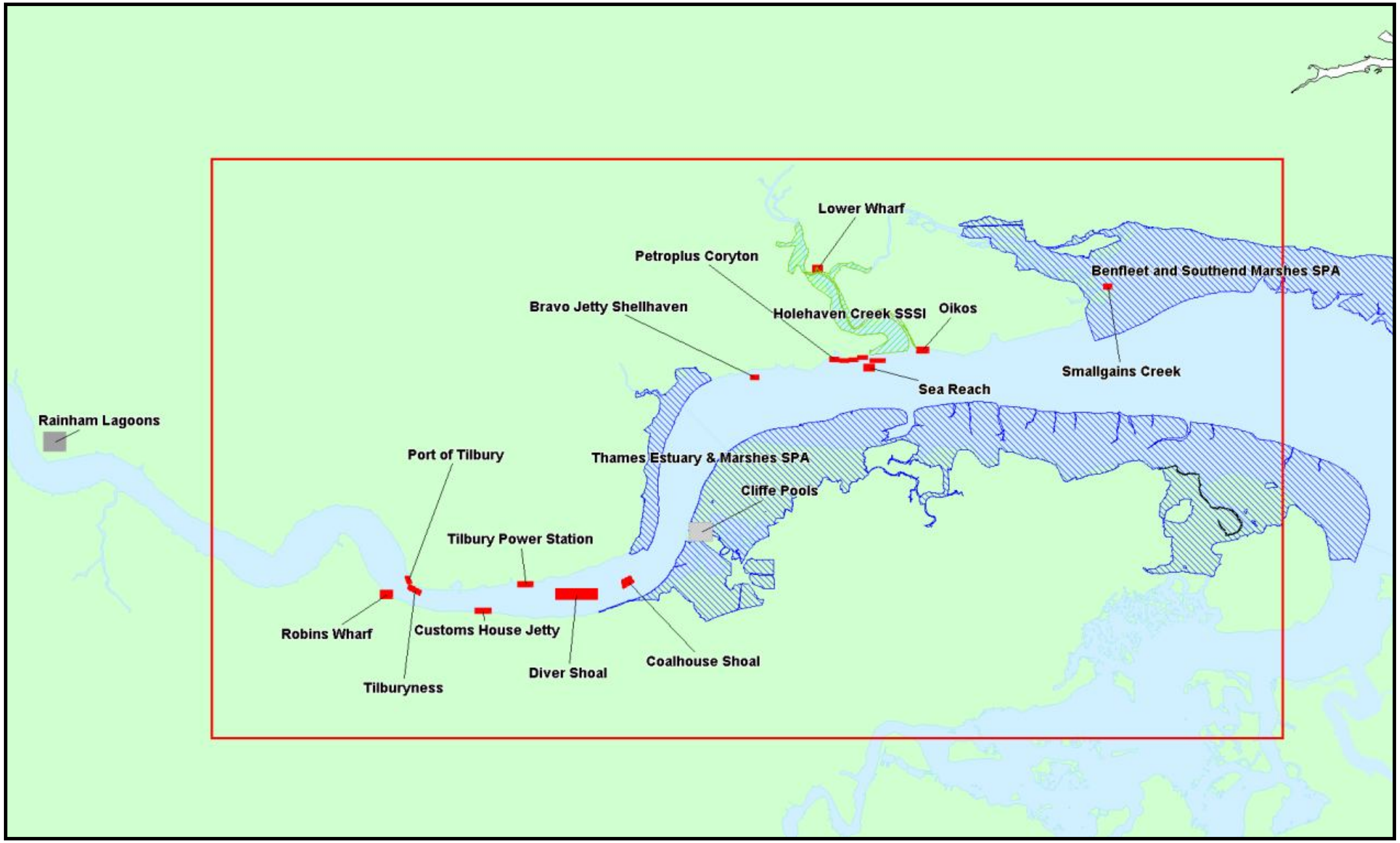
Dredging at Lower Wharf in Holehaven Creek, which historically served Pitsea landfill site (operated by Veolia Environmental Services Ltd.), was carried out in August 2006. Approximately 12,000m^3 of material from the berthing pocket was removed using an excavator, to achieve a depth of 2.66m below Chart Datum. Material was disposed onto the landward wharf, with onward transport via dumper trucks into the landfill site. As high levels of mercury were found in sediment adjacent to the wharf, appropriate constraints were applied to prevent the spread of contaminated material.

As the site lies adjacent to Holehaven Creek SSSI the PLA worked very closely with the RSPB and Natural England to develop a solution that was suitable for all the users.

1.3.3 Baseline conditions

This review also includes additional information that has been gathered to further define the baseline in respect to the parameters discussed in Section 6. New information on sediment quality for all the dredge sites has also been provided by the PLA and is included in the dredging operations summary in Section 2.2.

Figure 1.1 Study area and dredge locations Denotes 5km buffer



1.4 Objectives

The objectives of this DCA are as follows:

- To synthesize relevant existing information about the environmental status of the study area and, in particular, what is known about the potential extent of impacts of previous maintenance dredging activities undertaken by PLA and others;
- To provide the data necessary to allow any maintenance dredging proposals for the River Thames to be assessed in accordance with Article 6(3) of the Habitat Directive and in line with the Conservation Assessment Protocol on Maintenance Dredging and the Habitats Regulations 1994; and
- To assist competent authorities in identifying 'likely significant effect' in respect of future maintenance dredging applications or proposals.

This document will require further updating as more information becomes available and if circumstances and requirements change.

According to the Protocol, baseline documents are to be based on existing and readily available information (e.g. from previous applications and/or EIAs, dredge disposal returns and condition monitoring). Where possible, they are intended to identify:

- the existing need for maintenance dredging in individual areas;
- the existing volumes, frequencies and duration of dredging operations – where this should be based on actual dredge returns rather than volumes applied for in consents;
- the precise locations of dredging and disposal;
- the methods of dredging, transport and disposal, including any restrictions imposed as licence conditions or by physical constraints (e.g. depth, tidal flow, wave or weather conditions);
- material type and chemical status (existing and historical);
- the history of dredging and disposal at particular locations, as well as the variability in material type and volumes due to natural changes;
- any monitoring requirements previously imposed through licences, and the outcomes of such monitoring;
- any beneficial use and sediment cell maintenance schemes, or mitigation and compensation schemes entered into; and
- any other relevant information from past studies or previous applications that have possible direct or indirect links to the maintenance dredging.

They should also include information supplied by Natural England and others (e.g. Defra, CEFAS, Environment Agency) on the condition and characteristics of the *Natura 2000* site, in particular:

- the interest features of the site and their conservation objectives, which could be affected by maintenance dredging; and
- the extent to which the ecological requirements of the site have been achieved, maintained or restored since the requirements of the Birds or Habitats Directive were applied to the site.

The Protocol recommends that a structured and evidence-based approach is adopted to facilitate the consideration of future dredging proposals. This DCA has therefore been prepared with this need in mind.

1.5 Methodology

In preparing (and subsequently updating) the DCA a data gathering exercise was carried out and the following data sources were examined:

- Published literature;
- Unpublished 'grey' literature;
- Consultation with Natural England and Environment Agency; and
- Internet resources, such as the ThamesWeb website (http://www.thamesweb.com) and *MarLIN* (www.marlin.ac.uk).

Much data had already been collated by PLA as part of the PLA's Maintenance Dredging Framework that has been set up for the Thames Estuary.

It should be emphasised that the report is based on a desk study of existing and readily available data only (as specified in the Protocol) and no original survey work has been carried out as part of this exercise. However, through the PLA's Maintenance Dredging Framework, considerable amounts of survey and monitoring data associated with the dredging operations were available and were reviewed in order to produce this DCA.

In addition, the data gathering exercise has deliberately focussed on those environmental parameters that potentially could be affected by maintenance dredging and are of relevance to the integrity of the SPA. These include the following:

- Coastal processes and morphology;
- Sediment quality;
- Water quality;
- Intertidal ecology;
- Ornithology; and
- Noise (where this is limited to potential disturbance of feeding or roosting birds).

The study area for the document is illustrated in Figure 1.1.

1.6 Report structure

Following this introductory section, Section 2 details the history of dredging within the Thames Estuary. An overview of the Benfleet and Southend Marshes SPA and Ramsar Site is presented in Section 3, the Thames Estuary and Marshes SPA and Ramsar Site in Section 4, and the Holehaven Creek SSSI presented in Section 5. The baseline conditions of the estuary relevant to the integrity of the SPA and Ramsar are then considered in Section 6. Section 7 concludes with discussion and recommendations.

2 EXISTING DREDGING REGIME

2.1 Overview of Activity

Maintenance dredging within the outer reaches of the Thames, between Dartford and Southend-on-Sea, is carried out under the management and direction of the PLA, which has a responsibility to maintain depths within the navigation channels. A Maintenance Dredging Framework has been established by PLA in partnership with members of the Dredging Liaison Group (a Thames Estuary Partnership Action Group). This framework provides for the co-ordinated management of dredging operations on the tidal Thames. Berth operators are responsible for the maintenance of their berths and approaches under the regulation of the PLA and in accordance with the Maintenance Dredging Framework, and these dredging requirements have been addressed as part of Section 2.6.

Data on dredging operations in the Thames were obtained through consultation with the PLA, document review and from data received from CEFAS. CEFAS maintain a database of licensed dredging around the UK as part of their Food and Environment Protection Act 1985 (FEPA) disposal licensing responsibilities although they hold only limited information within the Port of London due to the PLA's regulatory regime. Data were obtained from CEFAS for 1989 to 2003 (the most up-to-date available). Data on historical dredging has been collated from the HR Wallingford Report EX4936 Release 2.0, dated March 2007, titled An Overview of the Tidal Thames Estuary - A Historical Review of the Bathymetric and Sedimentary Regimes, together with consultation with PLA and Van Oord UK Limited.

2.1.1 Licensing

Before any dredging work is undertaken on the tidal Thames it is a statutory requirement that a licence for such works is granted under Section 73 of the Port of London Act 1968 (as amended) (Section 73 relates to the control of dredging works). Dredging works are defined as including any operation to cleanse, scour, cut, deepen, widen, dredge or take up or remove material from the bed and banks of the Thames. Bed levelling, ploughing and water injection dredging (WID) fall within this definition.

Dredging licences are normally issued for a period of 12 months. A three year dredging licence may be issued where a dredge site can be shown to be stable in terms of the dredging requirement, dredging methodology and chemical quality and where no adverse environmental effects have been observed.

2.2 Summary of Dredging Techniques

2.2.1 Water Injection Dredging

The majority of dredged sites within the Thames between Gravesend and Southend, by volume and frequency, are undertaken using water injection dredging (WID), rather than more conventional excavation processes. The technique involves the injection of high volumes of water into the recently deposited seabed sediments. This re-fluidises the silts and fine sands, which then flow by gravity or current from the dredge site. The water is injected at low pressures, ensuring the sediment material is re-energised as a density current at the bed, rather than being re-suspended into the full water column. To be effective, the technique requires a flow gradient away from the dredge site, so material is transported to locations from which it is subsequently re-distributed by natural currents. The technique therefore promotes relocation of material based on local dispersion rather than removal to licensed marine or terrestrial disposal grounds. Retention of sediments within the natural estuarine system is widely considered to be a potentially significant environmental benefit of the technique. In order to minimise the environmental effects, dredging is required to be undertaken on an ebb tide to provide maximum dispersion and minimise sedimentation on the designated conservation sites. Where adjacent facilities are dredged (Coryton for example), the sequence in which berths are dredged is managed, when possible, to work downstream, thereby avoiding deposition within recently maintained areas.

Re-deposition rates vary depending on the grading of the dredged materials. Sand material will be re-deposited within close proximity of the dredge site whereas fine silts may remain in suspension for a period of days following dredging.

2.2.2 Trailing Suction Hopper Dredging

Water injection dredging is not suitable for all locations and bed materials. Consequently, some areas are maintained using conventional trailing suction hopper dredging (TSHD) equipment. Material is taken from the seabed and transported to disposal sites in hoppers. There is one established marine disposal site licensed for material arising from the Thames: South Falls. This is located 110km east of Gravesend, within a polygon defined by the following co-ordinates:

CEFAS Site Code	Name	Degrees & Decimal Mins	
		Latitude	Longitude
TH070	SOUTH FALLS	51 35.000 N	01 58.000 E
		51 35.000 N	02 00.000 E
		51 30.000 N	02 00.000 E
		51 30.000 N	01 57.000 E
		51 35.000 N	01 58.000 E

A further sand placement site has been characterised in the North Edinburgh Channel but this is subject to a monitoring regime to validate the environmental assessment.

As a consequence of the costs associated with transporting dredged materials over this distance, it is relatively unusual for sediment dredged from the Thames for maintenance purposes to be placed at sea. In preference, arisings from TSHD operations are typically taken to onshore sites for disposal. Currently, the main onshore placement sites on the Thames Estuary are as follows:

- Rainham Marshes, where the site is owned by the Royal Society for the Protection of Birds (RSPB), licensed to PLA and operated by Westminster Dredging Co. Ltd. The site is managed under procedures agreed jointly by

RSPB (Inner Thames Marshes SSSI) and PLA (Rainham Silt Lagoons Operations Plan);
- Cliffe Pools, where the site is owned by RSPB and managed by Westminster Dredging Co. Ltd.

2.2.3 Plough Dredging

Some plough dredging is undertaken, generally in tandem with other maintenance dredging techniques but also as a stand alone technique.

Ploughing utilises a tug vessel equipped with a plough unit (a steel box suspended on cables/chains). The plough is lowered to predetermined levels and is used to drag sediment along the seabed. Because the vessels are small and manoeuvrable in comparison to, particularly, trailing suction dredgers, ploughing is utilised to move material from areas inaccessible to the main dredging plant. As with WID, ploughing should not lead to significant re-suspension of sediment but if the sediment ploughed is soft it may be sufficiently disturbed to rise into suspension. Ploughing equipment has also been deployed in the Thames to level sand waves in the channel bed, but without significant success. Upstream of the study boundary at least two sites are licensed to use plough dredging on a frequent basis thus remobilising sediment on a little and often principle. Within the study site plough dredging is used on a small scale at Tilbury Power Station to clear material from underneath the jetty.

2.2.4 Backhoe Excavator Dredging

A small number of areas in the study area utilise backhoe dredging. A backhoe dredger is a hydraulic excavator equipped with a half-open shell. This shell is filled as it moves towards the machine. Typically, dredged material is loaded in barges and subsequently disposed of either in landfill or licensed sea disposal sites. This machine is mainly used in harbours and other shallow waters.

The advantages of backhoe dredging are:

- Its ability to dredge a wide range of materials, including those which contain boulders, or debris; difficult materials, such as stiff clays and weak rocks;
- The ability to work in confined spaces;
- Its accurate control of position and depth;
- The minimum disturbance and dilution of the material being dredged.

Within the study area backhoe dredging has been used at Lower Wharf in Holehaven Creek and historically at Oikos.

2.3 Water Injection and Plough Maintenance Dredging Operations

The following subsections identify the locations of WID and plough dredging operations within the study area. The locations of these areas are shown in Figure 1.1. Information is provided on the dredging frequency, estimated quantities, dredge material (where identified) and distances to the SPAs and SSSI. Quantities are calculated based on pre- and post-dredge survey data undertaken for each campaign.

2.3.1 Port of Tilbury Bellmouth

The Bellmouth is located at the entrance to the main lock barrel leading to the Port of Tilbury. Dredging activity for the port is detailed in Table 2.1.

Table 2-1 Summary of WID dredging undertaken for the Port of Tilbury London Limited

Client Organisation	**Port of Tilbury London Limited**
Contractor	Van Oord UK Ltd.
Maintained Depth	-8.5 m CD (with certain areas restricted to -8.0m CD)
Dredging frequency	3 months
Maximum permitted licensed quantity	84,000 m^3
Average quantity removed between 2002-2007	46,000 m^3
Material type	soft silt
Need for Maintenance Dredging activity	To maintain access to the Port of Tilbury through the lock for all vessels at all states of the tide.
Historical context	While the adjacent berths are largely self maintaining, the lock entrance is a natural silt trap. Consequently, dredging has been necessary throughout the operational life of the dock system. WID on the ebb has been implemented over the past decade, with no obvious impact on the adjacent river berths (Northfleet Hope Container Terminal for example). Since 2002 the following volumes have been dredged using WID (DSIS, 2008): • 2002 (26,200m^3) • 2003 (60,000m^3) • 2004 (42,000m^3) • 2005 (61,500m^3) • 2006 (36,200m^3) • 2007 (51,080m^3) • 2008 up to June (34,460m^3) In 2008 the site was granted a three year dredging licence (section 2.1.1).
Contamination testing	Sediments are tested on a two yearly cycle,

Client Organisation	Port of Tilbury London Limited
	with 7 samples tested for TBT in October 2003, and 2 tested for a full suite of metal and organic compounds. TBT has been identified in deeper sediments in an area adjacent to the East Lead-in Jetty (test results dated October 2003). In consequence, and following extensive monitoring and review, the PLA dredging licence is now issued conditional on POTLL/ Van Oord demonstrating that a buffer layer is maintained with the dredge surface in excess of 500mm above the contaminated strata at all stages of the dredge process. The 2003 sampling regime identified no other contamination that precludes dredging and TBT has not been found at elevated levels in subsequent analysis cycles. Sediment samples taken in 2006 indicate elevated levels of lead and mercury, but representative of background levels in this part of the Thames (PLA, 2008). Sediment samples taken in 2008 indicate elevated levels of Cadmium, Lead, Mercury and Zinc, but representative of background levels in this part of the Thames (PLA, 2008).
Distance to Thames Estuary and Marshes SPA	6.4 km
Distance to Benfleet and Southend Marshes SPA	20.4 km
Distance to Holehaven Creek SSSI	14.6 km

2.3.2 Robins Wharf

Table 2-2 Summary of WID and Plough activity undertaken at Robins Wharf for Foster Yeoman

Client Organisation	Foster Yeoman
Contractor	Van Oord UK Ltd.
Maintained Depth	-3.0 m CD
Dredging frequency	1 year
Maximum permitted licensed quantity	2,000 m^3
Average quantity removed between 2001-	2,200 m^3

Client Organisation	Foster Yeoman
2008	
Material type	Silt
Need for Maintenance Dredging activity	Maintenance of the berth pocket to allow receipt and unloading of aggregate vessels at the jetty.
Historical context	A variety of dredging techniques have been used at this site including trailing suction dredging, plough dredging and WID. WID was first used at the site in 1995. In 2007 1700m^3 of material was removed using trailing suction and disposed at Cliffe. Plough campaigns undertaken in 2006, 2007 and 2008 dredged 100m^3, 800m^3, and 250m^3 respectively (DSIS, 2008). WID was last undertaken in 2007 where 2,000m^3 was removed.
Contamination testing	Sediment testing is undertaken on a 2 yearly cycle, with the most recent data from 2007 indicating slightly elevated levels of some heavy metals, but representative of levels in this part of the Thames (PLA, 2007b).
Distance to Thames Estuary and Marshes SPA	7.0 km
Distance to Benfleet and Southend Marshes SPA	21.0 km
Distance to Holehaven Creek SSSI	15.2 km

2.3.3 Customs House Jetty

Table 2-3 Summary of WID activities undertaken at Customs House Jetty for HM Revenue and Customs

Client Organisation	HM Revenue and Customs
Contractor	Van Oord UK Limited
Maintained Depth	-3.0 m CD
Dredging frequency	6 months
Maximum permitted licensed quantity	9,000 m^3
Average quantity removed between 2002-2007	8,000 m^3
Material type	Soft silt
Need for Maintenance Dredging activity	Maintenance of the berth pocket to permit all tide operations for the Customs vessels
Historical context	The jetty has been dredged regularly since construction, with the implementation of WID techniques in early 1990's.

Client Organisation	HM Revenue and Customs
	The following provides a record (where records exist) of all material moved by WID: • 2002 (9,000m^3) • 2003 (9,500m^3) • 2004 (4,500m^3) • 2005 (7,450m^3) • 2006 (1,250 m^3) • 2007 (8,560m^3) • March 2008 campaign (2,495m^3) In recent years Customs House was granted a licence to dredge up to 4,000 m^3 per year using WID (two campaigns per year of 2000m^3). However a review of the bathymetric surveys and volume calculations back to early 2007 revealed that the actual quantity being dredged during each campaign was 4,000m^3 (i.e. 8,000m^3 annually). In view of this a new licence was applied for and granted in 2008 to reflect this change. The licence granted was for three years (see section 2.1.1 for further information).
Contamination testing	Sediment sampling is undertaken on a 2 yearly cycle, with the most recent data from August 2007 revealing slightly elevated levels of mercury and lead (above Cefas Action Level 1) but not to an extent that would prohibit WID (PLA, 2008).
Distance to Thames Estuary and Marshes SPA	3.8 km
Distance to Benfleet and Southend Marshes SPA	18.4 km
Distance to Holehaven Creek SSSI	12.8 km

2.3.4 Bravo Jetty Shellhaven

Table 2-4 Summary of WID activities undertaken at Bravo Jetty Shellhaven for Shell UK Oil Products Ltd.

Client Organisation	**Shell UK Oil Products Ltd.**
Contractor	Van Oord UK Ltd.
Maintained Depth	-14.6 m CD
Dredging frequency	3-4 months
Campaign Duration	15 to 20 hours
Maximum permitted licensed quantity	50,000 m^3
Average quantity removed between 2002-2007	39,300 m^3
Material type	soft silt/ fine sand
Need for Maintenance Dredging activity	Maintenance of the berth pocket to permit all tide operations. The berth is the deepest of the jetties on this portion of the coast.
Historical context	The Shell jetty has been dredged regularly since construction. Frequent dredging is now a necessity to provide appropriate levels of access to the berths. Between 2002 and 2008 the following volumes of material have been dredged by WID (DSIS, 2008): • 2002 (33,300m^3) • 2003 (45,200m^3) • 2004 (40,000m^3) • 2005 (65,950m^3) • 2006 (29,675m^3) • 2007 (21, 635m^3) • 2008 (up to June) (16,815m^3) In addition in 1995 4,000m^3 of material was removed by backhoe.
Contamination Testing	Sediment sampling is undertaken on a 2 yearly cycle, with the most recent data from November 2006 revealing slightly elevated levels of Nickel in one sample, but not to an extent that would prohibit WID (PLA, 2008).
Distance to Thames Estuary and Marshes SPA	1 km
Distance to Benfleet and Southend Marshes SPA	9.8 km

Client Organisation	Shell UK Oil Products Ltd.
Distance to Holehaven Creek SSSI	3.6 km

2.3.5 Petroplus Coryton Refinery

Table 2-5 Summary of WID activities undertaken at Coryton Refinery for Petroplus

Client Organisation	Petroplus
Contractor	Van Oord UK Ltd.
Maintained Depth	Varies: 1 -10.6 m CD 2 -5.1 and -7.0 m CD 3 -13.4 m CD 4 -14.0 m CD 5 -13.1 m CD (Numbers denote jetties 1 -5)
Dredging frequency	3 months
Campaign Duration	Up to 50 hours
Maximum permitted licensed quantity	120,000 m^3
Average quantity removed between 2003-2007	139,000 m^3
Material type	Silt and fine/medium sand
Need for Maintenance Dredging activity	The Coryton facility is of national significance and, without regular dredging, would become unable to accommodate the delivery fleet.
Historical context	The site comprises a range of jetty structures serving differing vessel profiles. All have been dredged regularly since construction. However, analysis of survey data from 1970 to 1999 indicates that the deposition patterns in the area have been changing over the past 25 years. The grading of the sediments at Coryton is understood to be tending to coarser sand fractions. Maintenance of depth is undertaken by WID, but Petroplus undertakes infrequent trailing suction campaigns to remove coarser materials and debris. In 2007, Petroplus applied for a separate licence to dredge an additional area of sandy material adjacent to Jetty No. 1, due to a gradual accumulation of sediment over a number of years. Since 2002 the following volumes of material

Client Organisation	Petroplus
	have been dredged by WID on an annual basis (DSIS, 2008): Jetty 1 Between 14,000 and 47,000m^3 Jetty 2 Between 8,500 and 21,000 m^3 Jetty 3 Between 10,000 and 47,000 m^3 Jetty 4 Between 6,000 and 29,000 m^3 Jetty 5 9,000 and 60,000 m^3
Contamination Testing	Sediment testing is undertaken on a 2 year cycle, with the most recent results dated August 2007. All results were representative of background levels (PLA, 2008).
Distance to Thames Estuary and Marshes SPA	1.4 km
Distance to Benfleet and Southend Marshes SPA	5.8 km
Distance to Holehaven Creek SSSI	400 m

2.3.6 Oikos Terminal (Holehaven Wharf)

Table 2-6 Summary of WID activities undertaken at Holehaven Wharf for Oikos

Client Organisation	Oikos
Contractor	Van Oord UK Ltd.
Maintained Depth	-10.5 m CD
Dredging frequency	3 months
Campaign Duration	Approx 15 hours
Maximum permitted licensed quantity	65,000 m^3
Average quantity removed between 2002-2008	38,800 m^3
Material type	Silt and fine sand
Need for Maintenance Dredging activity	Maintenance of the berth pocket to permit all tide operations. The rate of accretion at the jetty appears to be accelerating, reflecting changing sedimentation patterns in the area.
Historical context	The Oikos jetty has been dredged regularly

Client Organisation	Oikos
	since construction. A variety of dredging techniques have been used including WID, trailing suction and backhoe as detailed below (DSIS, 2008). Trailing suction • 1991 (unknown) • 1994 (2,110m^3 placed at Rainham) • 1998 (9,000m^3 unknown placement site) • 2002 (24, 000m^3 placed at Cliffe) • 2006 (15, 000m^3 placed at Rainham) • 2007 (9,500m^3 placed at Cliffe) Backhoe dredging • 1996 (11,223m^3 unknown placement site) • 2002 (10,845m^3 unknown placement site) Between 2002 and 2008 the following amounts of material have been moved by WID on an annual basis (DSIS, 2008): • 2002 (29, 750m^3) • 2003 (66,500m^3) • 2004 (34,950m^3) • 2005 (36, 925m^3) • 2006 (35, 830m^3) • 2007 (31, 895m^3) • 2008 (35, 610m^3) During the last maintenance dredging campaign PLA licensed Oikos to dredge an 'escape channel' from the berth to deep water. This channel facilitated the removal of silt and sand from the berth for dispersal by the main ebb tide flows in deep water. Subsequent campaigns are likely to involve dredging the berth and also maintaining the escape channel as required. See section 1.3.2 for more discussion on the predicted impacts of the escape dredge.

Client Organisation	Oikos
Contamination Testing	Sediment testing is undertaken on a 2 yearly cycle, with the most recent data from June 2007 and October 2007. No abnormalities have been recorded.
Distance to Thames Estuary and Marshes SPA	1.5 km
Distance to Benfleet and Southend Marshes SPA	5.0 km
Distance to Holehaven Creek SSSI	200 m

2.3.7 Island Yacht Club, Smallgains Creek

Table 2-7 Summary of WID and plough activities undertaken in Smallgains Creek for Island Yacht Club

Client Organisation	Island Yacht Club
Contractor	Van Oord UK Ltd.
Dredging frequency	1 year
Maximum permitted licensed quantity	4,000m^3
Quantity removed in 2007	No data available
Material type	Silt
Need for Maintenance Dredging activity	Deepening of the entrance channel within Smallgains Creek is required to provide access for yachts and fishing vessels into the creek which has gradually accreted over the years.
Historical context	In 2007 4,000m^3 of material was removed using WID under a one year licence. Due to the proximity of the SPA an Appropriate Assessment was undertaken by the PLA. See section 1.3.2 for more discussion on the predicted impacts of the dredge.
Contamination testing	Sediment samples analysed by IYC in 2006 suggested that mercury levels were elevated above the level that would be considered acceptable for sediment dispersion. However all the other contaminants were very low as might be expected of a location in the outer estuary. A further five samples were analysed and the results showed the material to be chemically clean with acceptable levels of mercury. The initial elevated levels are likely to be a result of an

Client Organisation	Island Yacht Club
	error in the laboratory analysis of mercury (PLA, 2007b)
Distance to Thames Estuary and Marshes SPA	3.5km
Distance to Benfleet and Southend Marshes SPA	0km
Distance to Holehaven Creek SSSI	6.5km

2.3.8 Tilburyness Shoal

Tilburyness is located approximately 400 metres seaward of Tilbury Lock entrance.

Table 2-8 Summary of WID and Plough dredging undertaken at Tilburyness Shoal for the PLA

Client Organisation	Port of London Authority
Contractor	Van Oord UK Ltd. Westminster Dredging Co. Ltd.
Ruling Depth	-9.1 m CD
Dredging frequency	3 years
Maximum permitted licensed quantity	2,000 m^3
Average quantity removed between 2003-2008	1, 900 m^3
Material type	Sand
Need for Maintenance Dredging activity	The shoal impinges on the deepwater channel, reducing the all tide ruling depth for the docks and jetties to the west.
Historical context	Dredging quantities are variable, and are influenced by the presence of sand waves. Trailing suction is also used at this site (section 2.4.1). Since 2002 the following volumes of material have been dredged by WID (DSIS, 2008): • 2003 (300m^3) • 2004 (1000m^3) • 2005 (3000m^3) • 2007 (4,000m^3) • 2008 (1,200m^3) In 2008 plough dredging was also used to dredge 1000m^3 of material (DSIS, 2008).
Contamination testing	Sediment sampling is undertaken on a 2

Client Organisation	Port of London Authority
	yearly cycle, with the most recent data collected in January 2008 indicating that contaminant levels are representative of background levels in the Thames, with the exception of Copper which is slightly elevated above background levels, but not to an extent that would prohibit WID (PLA, 2008).
Distance to Thames Estuary and Marshes SPA	5.6 km
Distance to Benfleet and Southend Marshes SPA	19.6 km
Distance to Holehaven Creek SSSI	13.8 km

2.3.9 Diver Shoal

Table 2-9 Summary of WID activities undertaken at Diver Shoal for the PLA

Client Organisation	Port of London Authority
Contractor	Van Oord UK Ltd. Westminster Dredging Co. Ltd.
Maintained Depth	-9.5 m CD
Dredging frequency	3 months
Maximum permitted licensed quantity	950 m^3
Average quantity removed between 2003-2008	1780 m^3
Material type	Fine sand and silt, rare gravel – some debris
Need for Maintenance Dredging activity	The shoal impinges on the deepwater channel, reducing the all tide ruling depth for the docks and jetties to the west. Maintenance of depth is undertaken by WID, but the PLA undertakes less frequent trailing suction campaigns to remove coarser materials and debris.
Historical context	Located upstream of Coalhouse Point, Diver Shoal has historically provided the limiting depth for the river. Training works implemented on the northern side of the channel in 1995 successfully generated higher currents in the channel itself, while allowing accretion on the northern foreshore. This has considerably reduced, although not eliminated, the shoal's maintenance dredging requirements.

Client Organisation	Port of London Authority
	A combination of ploughing and WID has been used at this site. Since 2003 the following amounts of material have been moved by WID (DSIS, 2008): • 2003 (2000m^3) • 2004 (1800m^3) • 2006 (2370m^3) • 2008 (950m^3)
Contamination Testing	Sediment sampling is undertaken on a 2 yearly cycle, with the most recent data from February 2008 revealing slightly elevated levels of cadmium, lead and mercury in one sample, but not to an extent that would prohibit WID (PLA, 2008).
Distance to Thames Estuary and Marshes SPA	1.0 km
Distance to Benfleet and Southend Marshes SPA	15.6 km
Distance to Holehaven Creek SSSI	10.2 km

2.4 Other Dredging Operations

The following describes other dredge techniques that are licensed within the study area, namely Trailing Suction Hopper Dredging and Backhoe dredging.

2.4.1 Tilbury Power Station

This site also uses plough dredging to move material which accumulates under the jetty.

Table 2-10 Summary of Trailing suction Dredging activities undertaken at Tilbury Power Station for RWE NPower

Client Organisation	RWE NPower
Contractor	Westminster Dredging
Maintained Depth	-13.8 m CD
Dredging frequency	6 months
Maximum permitted licensed quantity	20,000 m^3
Average quantity removed between 2005-2007	11, 100 m^3
Disposal Site	Cliffe Pools
Material type	Sandy silt
Need for Maintenance Dredging activity	Maintenance of the berth pocket to permit all

Client Organisation	RWE NPower
	tide operations for the importation of coal for the power station
Historical context	Previously maintenance dredging was carried out on the older B Jetty. However since construction of a new berth (approximately 4 years ago), maintenance dredging has only been carried out on the new jetty and the older jetty has not been dredged. This site utilises a combined methodology: trailer suction hopper dredging in the berth box; and ploughing the section under the jetty.. Between 2005 and 2008 the following amounts of material have been dredged by trailing suction (DSIS, 2008): • 2005 (8,000m^3 placed at Cliffe) • 2006 (13,000m^3 placed at Rainham) • 2007 (12,410m^3 placed at Cliffe)
Contamination testing	Sediment testing is undertaken on a 2 yearly cycle, with the most recent set dated January 2007. Slightly elevated concentrations cadmium and mercury were recorded at two sites (above Cefas Action Level 1) Elevated concentrations of lead were also recorded in one sample.
Distance to Thames Estuary and Marshes SPA	3.0 km
Distance to Benfleet and Southend Marshes SPA	18.4 km
Distance to Holehaven Creek SSSI	11.4 km

2.4.2 Tilburyness Shoal

Tilburyness is located approximately 400 metres seaward of Tilbury Lock entrance.

Table 2-11 Summary of Trailing suction Dredging activities undertaken at Tilburyness Shoal for the PLA

Client Organisation	Port of London Authority
Contractor	Westminster Dredging Co. Ltd.
Ruling Depth	-9.1 m CD
Dredging frequency	3 years
Maximum permitted licensed quantity	700 m^3
Disposal Site	Rainham or Cliffe Pools

Client Organisation	Port of London Authority
Material type	Sand
Need for Maintenance Dredging activity	The shoal impinges on the deepwater channel, reducing the all tide ruling depth for the docks and jetties to the west.
Historical context	Dredging quantities are variable, and are influenced by the presence of sand waves. Ploughing and WID are also used in this area (section 2.3.2). Trailing suction dredging has been undertaken at this site periodically as per the dates below: • 2001 (20,000m^3 unknown disposal location) • 2006 (2, 569m^3 disposed at Rainham)
Contamination testing	The sand sediment was tested for TBT, metals and organic compounds in October 2003. No abnormalities were found. Sediment samples collected in January 2008 indicate that contaminant levels are representative of background levels in the Thames with the exception of Copper which is elevated above background levels.
Distance to Thames Estuary and Marshes SPA	5.6 km
Distance to Benfleet and Southend Marshes SPA	19.6 km
Distance to Holehaven Creek SSSI	13.8 km

2.4.3 Diver Shoal

Table 2-12 Summary of Trailing suction Dredging activities undertaken at Diver Shoal for the PLA

Client Organisation	Port of London Authority
Contractor	Westminster Dredging Co. Ltd.
Ruling Depth	-9.1 m CD
Dredging frequency	3 years, for trailing suction campaign
Maximum permitted licensed quantity	6,000 m^3 for all dredging at the location (see also WID).
Disposal Site	Rainham or Cliffe Pools

Client Organisation	Port of London Authority
Material type	Fine sand and silt
Need for Maintenance Dredging activity	The shoal impinges on the deepwater channel, reducing the all tide ruling depth for the docks and jetties to the west.
Historical context	Located upstream of Coalhouse Point, Diver Shoal has historically provided the limiting depth for the river. Training works implemented on the northern side of the channel in 1995 successfully generated higher currents in the channel itself, while allowing accretion on the northern foreshore. This has reduced, although not eliminated, the shoal's maintenance dredging requirements. The shoal is regularly dredged by WID. However, it is found that debris accumulates in the bed and this is removed by mechanical plant. The excavated material comprises gravels, but with additional waste materials (tyres and steel debris). In 2006 1185m^3 of material was removed and placed at Rainham (DSIS, 2008).
Contamination testing	The material was tested for metals and organic compounds in February 2008. The samples revealed slightly elevated levels of cadmium, lead and mercury at one site (above Cefas Action Level 1).
Distance to Thames Estuary and Marshes SPA	1.0 km
Distance to Benfleet and Southend Marshes SPA	15.6 km
Distance to Holehaven Creek SSSI	10.2 km

2.4.4 Coalhouse Shoal

Table 2-13 Summary of Trailing suction Dredging activities undertaken at Coalhouse Shoal for the PLA

Client Organisation	Port of London Authority
Contractor	Westminster Dredging Co. Ltd.
Ruling Depth	-9.0 m CD
Dredging frequency	3 years
Maximum permitted licensed quantity	1,000 m^3
Disposal Site	Cliffe Pools

Client Organisation	Port of London Authority
Material type	Sand and gravel
Need for Maintenance Dredging activity	The shoal impinges on the deepwater channel, reducing the all tide ruling depth for the docks and jetties to the west.
Historical context	Minor accretion of coarse sediments and debris has required infrequent maintenance, in tandem with works upstream at Diver Shoal. Records for dredging adjacent to this site (Coalhouse Shoal south and Coalhouse Shoal north) begin in 2001 where 20,000m^3 of material was removed using trailing dredging (coalhouse south). This material was later used beneficially for sea defences. In 2006 130m^3 of material was dredged from Coalhouse north using a plough (DSIS, 2008).
Distance to Thames Estuary and Marshes SPA	26.0 m
Distance to Benfleet and Southend Marshes SPA	14.6 km
Distance to Holehaven Creek SSSI	9.2 km

2.4.5 Sea Reach

Table 2-14 Summary of Trailing suction Dredging activities undertaken at Sea Reach for PLA

Client Organisation	Port of London Authority
Contractor	Westminster Dredging Co. Ltd.
Ruling Depth	-10.2 m CD
Maximum permitted licensed quantity	3 months
Average annual dredge quantity	4,000 m^3
Material type	Sand
Need for Maintenance Dredging activity	The shoal impinges on the deepwater channel, reducing the all tide ruling depth for the docks and jetties to the west.
Historical context	Dredging takes place on the northern side of the main navigation channel. Dredging quantities are variable.
Distance to Thames Estuary and Marshes SPA	1.0 km
Distance to Benfleet and Southend Marshes SPA	6.0 km
Distance to Holehaven Creek SSSI	600 m

2.5 Backhoe Maintenance Dredge Operations

2.5.1 Lower wharf, Pitsea

Table 2-15 Summary of backhoe dredging activities undertaken at Lower Wharf in Holehaven Creek

Client Organisation	**Veolia Environmental Services Ltd**
Contractor	Land & Water Services Ltd.
Maintained Depth	-2.66m
Dredging frequency	1 year
Maximum permitted licensed quantity	12,000 m^3
Amount removed in 2007	10, 750 m^3
Material type	Silt
Need for Maintenance Dredging activity	The dredging was required to allow tugs and barges to transport non-hazardous material to Pitsea landfill site via Lower Wharf, to cover the landfill site in preparation for its closure in 2017. Further maintenance dredging may be required depending on the rate of infill at the berth.
Historical context	In 2007 10,750m3 of material was dredged using a backhoe (DSIS, 2008). All dredgings were disposed of into the landfill site.
Contamination testing	Sampling undertaken in 2006 found high levels of mercury in the sediment. Appropriate constraints were applied to prevent the spread of contaminated material. Dredging was carried out during dry conditions with a silt curtain in place to prevent contaminated material entering the water column.
Distance to Thames Estuary and Marshes SPA	5km
Distance to Benfleet and Southend Marshes SPA	9km
Distance to Holehaven Creek SSSI	0km

There are a small number of other operators and facilities undertaking or proposing to undertake maintenance dredging within the study area, including Denton Wharf and Gravesend Canal Basin, but such new projects will be assessed separately and are presently excluded from this issue of the DCA.

2.6 Historic dredging

The Thames River and estuary has provided a national gateway port since the Roman Period. Encroachment through reclamation and construction of wharfage ensured access was maintained, although by the early C19th some dredging works had commenced principally to lower shoals on the main channels and to provide a source of ballast. From 1857, when the Thames Conservators were reconstituted, dredging activity in the Thames increased to maintain and improve the main navigation, ensuring passage of new classes of commercial shipping, which were both wider and deeper drafted. Significant dredging works were undertaken between 1895 and 1900. Further works were undertaken during a second capital dredging campaign concluded by 1928, during which some 37 million cu yards were excavated.

Since 1928, dredging in the Thames has been primarily associated with maintaining depths. The main navigation channel created by 1928 was largely self maintaining, but annual dredging returns for the River and docks for the periods 1928 to 1956 are fairly consistent, averaging 2,660,000 hopper tonnes per annum [1,860,000 m^3] (extracted from An Overview of tidal Thames Estuary, HR Wallingford Report EX 4936, Rev 2.0, Table 4.1, and corroborated in The Thames Estuary Coastal Processes and Conservation, Institute of Estuarine and Coastal Studies, October 1993 – Section 6.1). Much of this material was disposed of in the outer estuary (Black Deep and Barrow Deep). Approximately 50% of this dredging originated in the Mud, Gravesend and other Reaches.

Following a review of the dredging requirements of the River in the 1950s, the PLA implemented a significant change of policy for the dredging objectives and disposal practice. This resulted, from 1967, in a considerable annual reduction in the dredging commitment particularly within the Mud Reaches (HR Wallingford EX 4936, Table 4.2). This included a significant reduction in maintenance dredging from Gravesend Reach/Diver Shoal from 1965 and does not appear to have impacted significantly on the navigable depth in the River. It should also be noted that in the preceding years (1962 to 1966), significant capital dredging had been undertaken including the relocation of the navigation channel in Lower Gravesend Reach (relocated 500 feet south - 1964/1965) and Knock John Channel (Deterioration of North Edinburgh Channel, new channel through Black Deep - 1966) in response to recommendations by the then Hydraulics Research Station.

Historically, arisings have been placed at sea at sites to seaward of Southend. However, two onshore placement sites operate at Rainham and Cliffe. Rainham was operational pre-1949 but was further developed following the Inglis and Allen dredging review of 1957. Initially comprising two large lagoons, the site was extended with the addition of 7 new lagoons, commencing operations in January 1968. The original two lagoons have since been incorporated into the household waste landfill operations facility.

Rainham now comprises a series of 9 linked lagoons, and currently has a capacity of approximately 1.5 million m^3. The site is owned by the RSPB, who manage the Inner

Thames Marshes SSSI. The disposal lagoons are licensed to the PLA and operated by Westminster Dredging Co. Ltd.

Cliffe was originally licensed to receive dredge materials (having formerly operated as clay pits) in 1960. With Rainham originally anticipated to be full by 1982, Westminster Dredging expanded their interest in the Cliffe disposal site in 1972 to provide capacity for 20 years of maintenance operations. The site received its Waste Management Licence in 1977, and this has been maintained. The site was acquired by RSPB in 2001, to provide a habitat for overwintering waders. Nevertheless, it continues to receive dredged material.

2.7 Placement activities

In recognition of potential secondary impacts arising from maintenance dredging operations, consideration has been given to the potential impacts arising from discharge from the two lagoon disposal facilities within the study area, namely Rainham and Cliffe Pools (Figure 1.1).

Since the late 1980s, an increasing proportion of maintenance dredging has been undertaken using water injection equipment, and this has led to a corresponding reduction in the quantities being taken for disposal to the two onshore sites.

2.7.1 Rainham Pump Ashore Facility

This site is a receptor for material arising from maintenance dredging operations, as well being a habitat within the Inner Thames Marshes SSSI, particularly for owls, birds of prey, invertebrates and – when pumping operations are in progress – significant numbers of wildfowl. An Operational Plan was prepared in 2006 to provide an agreed procedure for the operational disposal of dredged material to the Silt Lagoons. The plan has been produced in consultation with the PLA, Westminster Dredging, the RSPB, Natural England and the Environment Agency. The Plan supports the ongoing operation of the site to minimise disturbance to wildlife and maximize opportunities for creating productive habitats during pumping operations.

The Waste Management Licence allows for a maximum annual reception capacity of 350,000 tonnes of deposited material (solids), excluding the water used to carry the material to the lagoons. The dredged material deposited at Rainham is used beneficially to create and maintain the habitats within the silt lagoons.

The ongoing operation of the site is an intrinsic element of the maintenance dredging strategy for the Thames, as well as continuing the management regime of the SSSI itself. The operations do not directly impact on the European sites and the discharge from the lagoons occurs outside the study area. No further examination of direct environmental impact has therefore been undertaken.

2.7.2 Cliffe Pools Pump Ashore Facility

Cliffe Pools has operated as a dredging disposal site since 1960. It is located to the east of Gravesend, in Kent, and forms the western end of the Thames Estuary and

Marshes SPA. Since 2001, the site has been owned by RSPB. In 2002, RSPB entered into a management contract for the lagoons with Westminster Dredging, and this arrangement is ongoing.

The site is a receptor for selected material arising from maintenance dredging operations in the Thames. The deposited materials are used to manage and enhance the existing saline lagoon areas to reduce depths, provide beaches, and create islands which function as breeding and roosting sites.

A Management Plan has been produced for the site which covers the period 2008-2013 (RSPB, 2008). The Plan includes an objective to enhance the existing saline lagoons and brackish pools. This will be achieved primarily through prioritised disposal of dredgings to reduce water depth and create islands to increase numbers of breeding, wintering and passage water birds and maintain their current non-avian value and maintain favourable SSSI and SPA status.

In 2004, Westminster Dredging obtained a Pollution Prevention Control Licence for the site (although Government has since removed the requirement for PPC at such sites). As part of that process, the applicant undertook a habitats risk assessment for the lagoons carried out under the Habitats Regulations. The evaluation considered:

- Toxic Contamination
- Nutrient Enrichment
- Habitat Loss
- Siltation
- Smothering
- Disturbance
- Predation

The assessment concluded that the ongoing operation of the lagoons, undertaken in accordance with the lagoon dredging plan established by RSPB and Westminster Dredging, with agreement of Natural England, as appended to the site management plan, does not adversely affect the integrity of the Thames Estuary and Marshes SPA.

The site has a potential capacity of 850,000 m^3, with an annual ceiling of 150,000 m^3. The site operates in support of dredging activity in the Thames, equating to quarterly periods of approximately 3 weeks duration. During these periods, the site is operational for up to 24 hours each day, with a daily ceiling of 10,000 m^3 excluding the water used to flush material into the site from the discharging vessel. Water, from dredging and precipitation, is discharged from the site via a series of sluices leading to Cliffe Creek. These are operated by Westminster Dredging during operational periods and by RSPB during non-operational phases. The PLA are not aware of any water quality issues associated with this activity.

The RSPB, as landowner, is working in partnership with Westminster Dredging Plc to create a flagship nature reserve at Cliffe Pools which would be the focus for visitors to the RSPB's North Kent Marshes reserves. Westminster Dredging Co. Ltd., in consultation with the RSPB is currently developing a restoration plan for Cliffe Pools, which considers opportunities for enhancement of the saline lagoons by infilling with dredged materials.

3 BENFLEET AND SOUTHEND MARSHES SPA AND RAMSAR SITE

3.1 Overview

The Benfleet and Southend Marshes site was classified on the 14th February 1994 as an SPA. It comprises a series of saltmarsh, mudflat and grassland habitats located on the north bank of the Thames Estuary (Figure 1.1).

The Benfleet and Southend Marshes site qualifies under Article 4.2 of the EU Birds Directive as a designated SPA as it supports internationally important populations of regularly occurring migratory species. This includes dark-bellied brent geese (*Branta bernicla bernicla),* knot (*Calidris cantu),* and grey plover (*Pluvialis squantarola)..* This area also supports internationally important assemblages of waterfowl also covered under Article 4.2 of the Directive.

The Benfleet and Southend Marshes site qualified as a Ramsar site under Ramsar Criterion 5 as it supports assemblages of internationally important waterfowl. It is also notified under Criterion 6 as species occurring at internationally important levels are recorded within the area.

3.2 Conservation objectives

The conservation objectives for the site are detailed in the Regulation 33 advice for the Benfleet and Southend Marshes Marine Site (English Nature, 2001). The conservation objectives for the nationally and internationally important populations of the regularly occurring migratory species are:

Subject to natural change, maintain in favourable condition the habitats for the internationally important populations of regularly occurring migratory species, under the Birds Directive, in particular:

- *Shell banks;*
- *Saltmarsh;*
- *Intertidal Sandflat and Mudflat communities; and*
- *Eelgrass beds.*

And;

Subject to natural change, maintain in favourable condition the habitats for the internationally important assemblages of waterfowl, under the Birds Directive, in particular:

- *Shell banks;*
- *Saltmarsh;*
- *Intertidal Sandflat and Mudflat communities; and*
- *Eelgrass beds.*

Numbers of bird species using these habitats within the Benfleet and Southend Marshes SPA are given in Table 3.1 (average peak counts for the five year period 1991/92 to 1995/96).

It should be noted that the SPA conservation objectives focus on habitat condition (rather than bird numbers) in recognition of the fact that bird populations may change as a reflection of national or international trends or events. However, annual counts for qualifying species will be used by Natural England, in the context of five year peak means, together with available information on UK population and distribution trends, to assess whether the SPA is continuing to make an appropriate contribution to the favourable conservation status of the SPAs across Europe.

Table 3-1 Numbers of Bird Species using habitats within the Benfleet and Southend Marshes site (JNCC, 2001) Data is for five year period 1991/92 – 1995/96

Internationally important populations of regularly occurring migratory species	
Species	Population (5yr Peak mean)
Dark-bellied brent goose	3,819 birds (1.3 % of Siberian/European population)
Knot	8,850 birds (2.5% of East Atlantic flyway)
Grey Plover	3,789,birds (2.5% of East Atlantic flyway)
Nationally important populations of regularly occurring migratory species	
Importance	Population (5yr Peak mean)
Benfleet and Southend Marshes supports large populations of wintering waterfowl	34,789 individual birds.
Nationally important populations of regularly occurring migratory species within the internationally important assemblage of waterfowl	
Ringed Plover	800 birds (1.6% of British Population)
Dunlin	11,100 birds (2.1 % of British population)

The Regulation 33 advice provides favourable condition tables for the Benfleet and Southend Marshes European Marine Sites. The relevant favourable condition targets for the Benfleet and Southend Marshes SPA are presented in Appendix B.

3.3 Current conservation status

The UK Government has a duty to report to the European Union at 6 yearly intervals on the condition of SPAs in the UK. As part of this reporting, the Government is required to carry out monitoring of the features listed in the favourable conditions tables (see Appendix B).

The condition assessment for the Benfleet and Southend Marshes Site of Special Scientific Interest (SSSI) has recently been carried out by Natural England (26th January 2009). The Benfleet and Southend Marshes SSSI is made up of five management units. For each of these units Natural England has assessed their condition according to a number of criteria, and assigned the terms presented in Box 3.1 to the area.

Box 3-1 Definition of SSSI condition assessment terms (from www.naturalengland.org.uk)

Favourable	SSSI is being adequately conserved and is meeting its 'conservation objectives', however there is scope for enhancement of these sites.
Unfavourable recovering	SSSI units are not yet fully conserved but all the necessary management measures are in place. Provided that the recovery work is sustained, the SSSI will reach favourable condition in time.
Unfavourable no change	SSSI unit is not being conserved and will not reach favourable condition unless there are changes to the site management or external pressures. The longer the SSSI unit remains in this poor condition, the more difficult it will be, in general, to achieve recovery.
Unfavourable declining	SSSI unit is not being conserved and will not reach favourable condition unless there are changes to the site management or external pressures. The site condition is becoming progressively worse.
Part destroyed	Part destroyed means that lasting damage has occurred to part of the special conservation interest of a SSSI unit such that it has been irretrievably lost and will never recover. Conservation work may be needed on the residual interest of the land
Destroyed	Lasting damage has occurred to all the special conservation interest of the SSSI unit such that it has been irretrievably lost. This land will never recover.

The full results of the condition assessments for the units of the SSSI are presented in Appendix C, and a summary of the site as a whole is presented in Table 3.2.

Table 3-2 Benfleet and Southend Marshes SSSI condition summary (1st February 2009)

% area meeting PSA target	% area favourable	% area unfavourable recovering	% area unfavourable no change	% area unfavourable declining	% area destroyed/ part destroyed
6.13%	0.87%	5.26%	86.13%	7.74%	0.00%

In general, this area is in an unfavourable condition and not recovering (93.87%), and an area of only 6.13% is reaching the required management targets (Table 3.2). The main issues potentially affecting the condition of the site were coastal squeeze against the sea defences, public access/disturbance, water pollution and discharge. For example, management area 1 within this site was confirmed as having eroding saltmarsh and a foreshore subject to coastal squeeze, though this is being addressed strategically through the Thames CHaMP and Essex Estuaries Shoreline Management Plans and other national policy interventions.

4 THAMES ESTUARY AND MARSHES SPA AND RAMSAR SITE

4.1 Overview

The Thames Estuary and Marshes SPA is shown in Figure 1.1. It includes both marine and terrestrial habitats. The marine area is also termed a European Marine Site. The marshes extend for around 15 km along the south side of the estuary, and also include some intertidal areas found on the north bank[1]. It encompasses brackish, floodplain grazing marsh ditches and saline lagoons as well as intertidal saltmarsh and mudflat. This site was classified as both an SPA and a Ramsar Site (which covers approximately 5500 hectares) on the 31 March 2000.

The Thames Estuary and Marshes SPA qualifies under Article 4.1 of the EU Birds Directive as it supports internationally important populations of the following regularly occurring Annex 1 species;

- the avocet *Recurvirostra avocetta,* and;
- the hen harrier *Circus cyaneus.*

This Site also qualifies as an SPA under Article 4.2 of the EU Birds Directive as it supports internationally important populations of regularly occurring migratory species including;

- ringed plover *Charadrius hiaticula;*
- grey plover *Pluvialis quatarola;*
- dunlin *Caldris alpine alpine;*
- Knot; *Calidris canutus islandica.*
- black-tailed godwit *Limosa limosa,* and
- redshank *Tringa tetanus tetanus.*

This SPA site also supports an internationally important assemblage of waterfowl as stated in Section 4.2 of the Directive, which include the following species;

- gadwall *Anus strepera;*
- shoveler; *Anus clypeata;*
- tufted duck *Aythya fuligula;* and
- pochard. *Aythya farina.*

The Thames Estuary and Marshes Ramsar site qualifies under Criterion 2 as it supports 1 nationally rare and 14 nationally scarce plant species, as well as 1 endangered, 10 vulnerable and 12 rare invertebrate species. It also qualifies under Criterion 5 for its internationally important assemblage of waterfowl, and Criterion 6 for its internationally important numbers of over-wintering waterfowl.

[1] http://www.jncc.gov.uk/default.aspx?page=2042

4.2 Conservation objectives

The conservation objectives for the site are detailed in the Regulation 33 advice for the Thames Estuary and Marshes Marine Site (English Nature, 2001). The conservation objectives for the nationally and internationally important populations of the regularly occurring migratory species are:

Subject to natural change, maintain in favourable condition the habitats for the internationally important population of the regularly occurring Annex 1 bird species, under the Birds Directive, in particular:

- *Saltmarsh;*
- *Intertidal Mudflats; and*
- *Intertidal shingle.*

And;

Subject to natural change, maintain in favourable condition the habitats for the internationally important assemblage of waterfowl, under the Birds Directive, in particular:

- *Saltmarsh;*
- *Intertidal Mudflats; and*
- *Intertidal shingle.*

Numbers of bird species using these habitats within the Thames Estuary and Marshes SPA are given in Table 4.1 (average peak counts for the five year period 1998/99 to 2002/03). More recent data (2002/03 -2006/07) is presented in Table 6-16.

Table 4-1 Numbers of bird species using habitats within the Thames Estuary and Marshes SPA Site. Data is for five year period 1998/9 – 2002/3

Species	**1% thresholds for national and international importance**		**Thames Estuary & Marshes SPA (5-year mean peak 1998/99-2002/03)**	**Mucking Flats SSSI (5-year mean peak 1998/99-2002/03)**
	Great Britain	**International**		
Shelduck	750	3000	1207.2	298.4
Black-tailed Godwit	70	700	1513	206.2
Redshank	1100	1500	1059.2	332.2
Avocet	10	700	634.4	579
Ringed Plover	290	500	534	102.6
Grey Plover	430	1500	1308	449.8
Knot	2900	3500	4695.4	24.8
Dunlin	5300	14000	12951	5875
Lapwing	20,000 (5,000)[1]	20,000	3699	747.8
Total Waterfowl Assemblage	n/a	n/a	34634.4	6479.4

Source BTO 2004

The Regulation 33 advice provides favourable condition tables for the Thames Estuary and Marshes European Marine Sites. The relevant favourable condition targets for the Thames Estuary and Marshes SPA are presented in Appendix B.

4.3 Current conservation status

Condition assessments for the corresponding SSSI sites found within the SPA were available (compiled in 1st February 2009 but carried out between 5 to 10 years before). The SSSI sites that correspond with this SPA and Ramsar site and lie within the study area are the South Thames Estuary and Marshes SSSI for the area south of the river, and Mucking Flats and Marshes SSSI for the area north of the river. Mucking Flats and Marshes SSSI comprises an extensive stretch on the left bank of the Thames mudflats and saltmarsh, together with sea wall grassland. The South Thames Estuary and Marshes SSSI stretches from Gravesend to the eastern end of the Isle of Grain on the right bank and supports a wide range of habitats including saltmarsh, mudflat, grazing marsh and shingle.

These SSSIs were assessed using the same conditions as shown previously in Box 3.1. South Thames Estuary and Marshes is composed of 58 management units, while Mucking Flats and Marshes has only 4 units. The full condition assessments of these areas can be found in Appendix B, while a summary of the findings for both sites are presented in Table 4.2 and 4.3. In general, the area north of the river within the Mucking Flats and Marshes SSSI fell within the ‘area favourable’ assessment, while the area south of the river within the South Thames Estuary and Marshes SSSI is mostly in favourable condition (87%). Only 3.1% of the site is now in unfavourable condition (unfavourable declining and unfavourable no change).

The main issues affecting the site north of the river (Mucking Flats and Marshes SSSI) were inappropriate weed control and public access/disturbance. Such issues were only seen in Unit one, where tall herb ruderals dominated creating a less than ideal high tide roost, coupled with the disturbance from a nearby footpath. South of the river, in the South Thames Estuary and Marshes SSSI, the two major units in unfavourable condition are units 100 and 101, which are both experiencing saltmarsh erosion as a result of coastal squeeze.

Table 4-2 South Thames Estuary and Marshes SSSI condition summary (Compiled 1 February 2009)

% area meeting PSA target	% area favourable	% area unfavourable recovering	% area unfavourable no change	% area unfavourable declining	% area destroyed/ part destroyed
96.87%	86.74%	10.13%	1.34%	1.79%	0.00%

Table 4-3 Mucking Flats and Marshes SSSI condition summary (Compiled 1 February 2009)

% area meeting PSA target	% area favourable	% area unfavourable recovering	% area unfavourable no change	% area unfavourable declining	% area destroyed/ part destroyed
94.13%	94.13%	0.0%	5.87%	0.00%	0.00%

5 HOLEHAVEN CREEK SITE OF SPECIAL SCIENTIFIC INTEREST

5.1 Overview

Although Holehaven Creek is not designated as a SPA or SAC under the Conservation (Natural Habitats &c.) Regulations 1994, it has been included within this assessment due to its status as a Site of Special Scientific Interest (SSSI) (Figure 1.1), and the fact that it may also be included within the boundaries for one of the SPA sites in the near future. Other SSSIs within the study area, such as West Thurrock Lagoons and Marshes, have not been considered within this DCA. Although they lie within the study area, they do not lie within the boundaries of a Natura 2000 site, and are not currently being considered for notification. As such, they are not mentioned further within this document.

The intertidal mudflats and saltmarsh habitats of Holehaven Creek SSSI support a nationally important number of black-tailed godwit. This species also regularly occurs in numbers of international importance. The Creek provides suitable conditions for black-tailed godwit, including an abundance of food in the mudflats (polychaete worms and bivalve molluscs), large areas of saltmarsh (e.g. Lower Horse) for high tide roosts and minimal levels of disturbance. These sheltered inner estuary conditions are rare within the Thames Estuary.

In addition to this, there are a number of features that are important within the context of the Thames Estuary. For example, the site regularly supports an assemblage of over 8,000 waterfowl during the winter, with curlew and dunlin occasionally occurring in nationally important numbers. Furthermore, Holehaven Creek SSSI supports two of the three basic saltmarsh communities characteristic of south-east and east England. These are formerly grazed saltmarshes with saltmarsh-grass and sea aster often in extensive pioneer mid-marsh zones, and ungrazed or lightly grazed saltmarshes, typically with sea-purslane being dominant.

5.2 Current Conservation Status

A condition survey of this area was carried out in May 2008 with the results compiled in February 2009. There are nine management units within this designated site, and each was surveyed and allocated a status as shown previously in Box 3.1. This site was recorded as having an area of 100% falling within the ‘favourable’ assessment. The condition assessment indicates that Wetland Bird Survey (WeBS) counts 5 year peak means for black-tailed godwits are above nationally and internationally important numbers for all nine units. The full condition assessment is available in Appendix C.

6 DESCRIPTION OF BASELINE CONDITIONS

6.1 Coastal and estuarine processes and morphology

6.1.1 Methodology

Work has been previously undertaken to identify past and existing morphological processes and likely future change to inform dredging, coastal erosion, flood risk and habitat management studies for the Thames Estuary. In particular, the following key information sources have been used for this baseline review:

- Thames Barrier Studies (1960s and 1970s);
- London Gateway Port studies (2002/2003);
- Scoping studies for the Thames Estuary 2100 project (2003);
- Monitoring of dredging undertaken by PLA;
- Studies forming part of the Thames Estuary 2100 project (2004); and
- A recent historic review of the bathymetric and sedimentary regimes of the Thames Estuary by HR Wallingford (2007)

As part of the update a request was made to Natural England and Environment Agency to obtain a copy of the draft Thames CHaMP, however, at the time of writing this was not available. When it does become available (in early 2009) it will provide a framework for managing European and Ramsar sites that are located on or adjacent to the estuary. It will also provide a way of fulfilling the UK Governments obligations under the Habitats and Birds Directives and the Ramsar Convention, to avoid damage and deterioration to Natura 2000 and Ramsar sites; particularly when developing Shoreline Management Plans (SMPs) and flood and coastal defence strategies, and planning maintenance and capital works. The CHaMP will be available for the next update of the DCA.

This section of the report summarises the baseline morphological conditions; coastal evolution and historical change; sediment budget (source, transport and storage, of sediment), and likely future change.

6.1.2 Coastal Evolution

Geological Evolution

The Thames Estuary lies towards the southern edge of the London Basin bounded by upland areas to the south (North Downs) and north (Chiltern Hills) composed of Cretaceous Chalk. It was not until the Late Cretaceous (around 65 million years ago) that a major rise in sea level across Europe led to a significant deepening of the sea and without the influence of sediments brought in from nearby landmasses a very pure marine limestone was deposited in the warm sea: This is the Chalk, which may constitute up to 98% calcium carbonate. The Chalk forms the sub-crop of sections of the middle part of the Inner Thames (Erith downstream to Tilbury and parts of Woolwich and Gallions Reaches) (Sumbler, 1996). Elsewhere the Chalk is covered by Tertiary muds and sands (Balson and D'Olier, 1989; British Geological Survey, 1997).

A fall in sea level allowed the emergence of large areas of land and a considerable thickness of Chalk was eroded away. However, around 60 million years ago, sea level rose again and a shallow sea invaded the area depositing a series of Tertiary muds and sands reflecting changes in sea level and the transgression and regression of this sea (Sumbler, 1996). The oldest Tertiary sediments beneath the Thames Estuary belong to the Thanet Sand Formation and Lambeth Group. The bulk of the Thanet Sand consists of shallow marine silty sand with the main outcrops in south-east London (e.g. Howland, 1991) and north Kent. The Lambeth Group comprises sands (the Upnor Formation) deposited in a shallow sea and the overlying Woolwich Formation, comprising a varied assortment of sediments including clays and sands deposited in brackish, estuarine or coastal lagoon environments.

Following a rise in sea level, shallow marine conditions were again established in the Thames area, and the Harwich Formation was deposited, made up of several distinct units of mud and sand. Sea level continued to rise during the Eocene (55-35 million years ago) leading to the deposition of the thick bluish-brown London Clay which is the most widespread and best known of the Tertiary deposits of the London Basin and underlies much of Greater London and the Thames.

The Tertiary units are overlain by a complex suite of sediments deposited during the glacial and interglacial phases of the Quaternary, including those of the Holocene (last 10,000 years). Between the Anglian glaciation and the Devensian glaciation (the last Ice Age) the River Thames and its tributaries became established in their modern valleys and formed wide expanses of river terrace sands and gravels (Bridgland, 1994). These are mainly remnants of floodplains, representing phases in the gradual downcutting of the river during the Pleistocene; the highest terrace being the oldest and the lowest the youngest. This gently terraced landform is now almost completely obscured by urban development. The last major phase of terrace formation was during the Devensian glaciation when the River Thames was graded to a level at least 25 m below present sea level. The Late Devensian River Thames appears to have followed a braided course, crossing a wide floodplain until the early Holocene when it gradually developed into a single channel river (Wilkinson and Sidell, 2000). The deposits are now covered by estuarine alluvium, deposited as sea level rose during the Holocene interglacial (10,000 years ago to present).

Following the melting of the ice sheet at the end of the Devensian glaciation there has been a significant rise in sea level. The Thames Estuary was flooded around 8000 years ago and complex sequences of marine/brackish sediments intercalated with freshwater peats were deposited on the youngest terrace sands and gravels (Devoy, 1977, 1979, 2000; Marsland, 1986). The Holocene sediments cover the floodplain approximating to the area that has been flooded by high water spring tides, including that presently protected by flood defences; they occur on both sides of the estuary and occupy an overall width of 3-10 km (Royal Haskoning, 2004).

The width of the Thames Estuary floodplain deposits is partially controlled by the position and strength of the Cretaceous and Tertiary sub-crops. The most significant change occurs at Tilbury where relatively soft Tertiary deposits downstream are replaced by relatively hard Chalk upstream, resulting in greater confinement of the river upstream. As a consequence the width of the floodplain deposits narrows rapidly from 10 km in the Coryton area to 3 km at Tilbury-Gravesend. The thickness of the deposits increases downstream, reaching a maximum of about 35 m at the eastern end of Canvey Island (Marsland, 1986).

Holocene Evolution
Devoy (1977, 1979) proposed two Holocene relative sea-level curves from the estuary, one for Tilbury and one from sites to the west of Tilbury. Although the curves from both areas followed the same trend, the Tilbury curve plotted c. 1.5 to 3 m below the west of Tilbury curve. Various reasons have been put forward for this anomaly, including the possibility of differential subsidence on an east-west axis (Devoy, 1979). However, a re-interpretation of the data (Haggart, 1995; Long, 1995), removed the need for eastward trending subsidence.

The most recent model proposed for the Holocene evolution of the Thames Estuary (Long, 2000; Long et al., 2000) describes sedimentation within a three-stage sequence based on estuarine development:

- **Stage 1** - The early Holocene rapid rise in relative sea level and flooding of the estuary between 8000 and c. 6000 years ago (Wilkinson and Sidell, 2000) leading to the widespread deposition of the silt and clay.
- **Stage 2** – A major expansion of peat-forming communities between c. 6000 and 3500 years ago: Beginning in the lower estuary, the initial formation replaced estuarine mudflat and saltmarsh sedimentation. Further west in London the rising water table allowed peats to form on top of Devensian terrace sands and gravels. Peat accumulation had a significant impact on the geometry of the estuary, reducing the spatial extent of intertidal environments. At Cross Ness, the intertidal area narrowed by 4 km. It is likely that the reason for initiation of peat formation at this time is a reduction in the rate of relative sea-level rise between c. 6000 and 4000 years ago. In the Thames Estuary the slow down in sea level rise would have encouraged the expansion of saltmarsh and then freshwater communities across areas of former intertidal mudflat.
- **Stage 3** - Between 4000 and 3000 years ago the peats of the lower estuary were inundated with later inundation of middle and upper estuary areas (2500 years ago at Silvertown, Wilkinson et al., 2000). By c. 2500 to 2000 years ago almost all of the once extensive peat forming communities throughout the estuary downstream of Woolwich had been replaced by intertidal conditions. Hence, the tidal Thames expanded and was once again flanked by extensive mudflats and saltmarshes that continued to develop, with only occasional still-stand phases until c. 150 years ago when much of the previously intertidal area was land-claimed for docks and associated installations.

Historic Relative Sea-Level Change and Ground Motion
The most recent relative sea-level curve (Wilkinson and Sidell, 2000) shows that there is a general rise of sea level through time, with an initial rapid rise of 3.5 mm per year, slowing down around c. 6000 years ago to 0.7 mm per year. This is supported by a wider analysis of land-level and sea-level change around Britain (Shennan and Horton, 2002), which calculated a late Holocene (last 4000 years) relative sea-level rise of 0.74

mm per year for the Thames, 0.85 mm per year for Essex and 0.67 mm per year for Kent. This can be compared with those for 20th century sea-level changes published by Woodworth et al. (1999) using tide gauges. They showed relative sea-level rises of 1.22+/-0.24 mm per year at Southend-on-Sea, 1.58+/-0.91 mm per year at Tilbury and 2.14+/-0.15 mm per year at Sheerness. Overall, these figures suggest an additional rate of relative sea level change in the 20th century of around 1 mm per year, as compared to the Late Holocene. This is in general agreement with the view that global sea levels have increased by 100-200 mm over the last century.

Shennan and Horton (2002) suggest, however, that some deficiencies may be inherent in the 20th century dataset. These include the unequal distribution of measurements and the considerable amount of interannual (typically decadal) variability present in all tide gauge records. Littlewood and Crossman (2003) also questioned the degree of accuracy of the tide gauge data based on concerns that they may not have remained at the same level relative to Ordnance Datum throughout their period of deployment. They indicated that the gauges were levelled to Ordnance Datum over 40 years ago, and since that time differential ground subsidence may have caused their perceived level to be different to their actual level. Monitoring using GPS at the tide gauge locations at Richmond, Tower Pier, Silvertown, Erith, Tilbury and Southend-on-Sea has shown that between March 1997 and July 1999, the movement of ground levels at these locations was statistically insignificant.

6.1.3 Anthropogenic Influences

The human race has placed considerable demands on the Thames Estuary. Little control and poor recording of these activities have meant that it is difficult to relate changes in the morphology of the estuary to any particular impact (Royal Haskoning, 2004). Since the 1960s/1970s the large capital or maintenance dredging programmes, the discharge of pollutants and the construction of riverside developments have been subject to increasing legislation to ensure their impact on the hydrodynamic and morphological regimes of the estuary are acceptable.

Land-Claim and Industrial Development

The area covered by the floodplain deposits of the Thames Estuary has been progressively protected and developed since the 12th century. The Industrial Revolution led to the construction of major docks and a rapid expansion of industrial development. The closure of the London docks since the late 1950s and the transfer of these facilities downstream to Tilbury led to further extension of industrial developments on saltmarshes previously used for agriculture. A large proportion of the saltmarshes have been land-claimed behind embankments which stretch along most of the estuary shore.

The progressive land-claim of saltmarsh has meant that most of the enclosed areas now lie below the level of high water. This is due to the consolidation of the saltmarsh sediments after they were drained. The enclosed marshes cannot accrete as their supply of sediment has been cut off.

Land-claim and development have had significant impacts on the coastal processes and morphodynamics of the Thames Estuary by changing the geographical distribution of sediment sources and sinks. New source areas may be activated and existing areas starved due to lack of replenishment. A few examples of how previous developments have impacted on the process regime are described below (Kendrick, 1984; HR Wallingford, 2002f).

Construction of West Thurrock Oil Jetty

Kendrick (1984) examined the impact on the estuary of the construction of West Thurrock oil jetty. A first jetty in place in 1873 caused a local 80 m seaward movement of the low water mark. A second jetty built in 1966 further downstream caused further deposition and the low tide mark at the new jetty advanced around 50 m due to reduced tidal current velocities near the bank. Prior to construction, sediment brought into the area on the flood tide was deposited around high water slack, but then re-entrained into the flow on the ebb tide, maintaining a balance. Once jetty construction was completed the reduction in current velocities provided a longer period for deposition, and the ebb current was less efficient in re-entraining sediment.

Construction of Woolwich Ferry Terminals

Kendrick (1984) found that cofferdams used in the construction of the Woolwich ferry terminals (starting 1964) created eddies in the current flow, particularly on the north bank, reducing current velocities leading to increased sediment deposition. Bed levels during construction were raised by over 3 m in places. Former bed levels were not re-established following the removal of the cofferdams because during construction, the silt had become compacted and post–construction the large number of piles supporting the terminals continued to impede flow. The zone of deposition extended beyond the terminals along the adjacent banks. This was attributed by Kendrick to a secular increase in tidal penetration causing the gradual upstream movement of the zone of main deposition (the Mud Reaches), which increased the quantity of suspended sediment in the area as a whole. There is a possibility that the process may have been enhanced by the cessation of dredging in the downstream Barking Reach between 1963 and 1966, allowing more suspended sediment to arrive in Woolwich Reach on the flood tide.

Construction of Rainham Creek Dam

To prevent tidal surges flooding the low lying Hornchurch and Rainham Marshes flanking Rainham Creek, a sheet pile dam was constructed in 1978/79 spanning the mouth of the creek (about 100 m wide) (Kendrick, 1984). An alternative outlet for the creek (Ingrebourne River) was provided by sluices further up-river. The result was extensive siltation in to the previous location of the low water channel in front of the dam.

Diver Shoal Groynes

HR Wallingford (2002a, f) compared 1970 and 1998 bathymetric charts and found large amounts of accretion (of the order of 1 x 106 m^3) in the area now occupied by the Diver Shoal groynes along the northern shore of Gravesend Reach. They concluded that, as anticipated, the accumulation was almost completely due to this scheme which took place in 1995 and occurred over a 3-year period (1995-1998).

Dredging and Disposal

The Port of London Authority has a statutory duty to provide and maintain designated depths of water in the navigable channels, jetties and berths of the Thames Estuary. As a result of sedimentation it is therefore necessary to periodically undertake maintenance dredging. The importance of London as a port has resulted in a history of dredging, although, as elsewhere, few accurate records of dates of dredging and quantities removed exist. The records that do exist are difficult to use in a quantitative fashion because the units are not always compatible. They may also be approximations such as nominal values (provided as hopper tonnes, in situ volumes, paid volumes etc) assigned to barge loads.

The historic major dredging events in the river are: (adapted from HR Wallingford (2008):

1878-1908	6,000,000 yd^3 of solid material dredged from the tideway by the Thames Conservancy to improve navigation.
1908 (approx)	Capital dredging to develop the Yantlet Channel as the main shipping channel in Lower Sea Reach, the dredged material being deposited in the adjacent Leigh Channel.
1920's	Capital dredging of the navigation channel between Tilbury and Gallions Reach to a depth of 30 feet below chart datum.
1920's	Capital dredging of the navigation channel between Gallions Reach and Upper Pool to 19-20 feet below chart datum.
Mid 1960's	The cessation of the almost continuous maintenance dredging (approximately 1920-1963) programme in the Mud Reaches (Gallions, Barking and Halfway Reaches).
1963/4	Dredging to move the navigation channel in Lower Gravesend Reach towards the southern bank.
1965	Dredging to deepen the Yantlet Channel.
1995	Construction of the groynes at Divers Shoal

Dredging can potentially have two effects on the processes of sediment exchange in the estuary. First, deepening may increase the proportion of total tidal discharge which takes place through the main channel reducing velocities adjacent to the channel. Second, dredging may create an artificial sink for sediment which may modify the fine sediment regime reducing supply to other nearby areas (Royal Haskoning, 2004). Inglis and Allen (1957) described dredging activities in the estuary between 1928 and 1956. The average annual dredged volume taken from the estuary as a whole during this period was 1.86 x 10^6 m^3 (Institute of Estuarine and Coastal Studies, 1993). Most of this sediment along with sewage sludge from London's main sewage works at Barking and

Cross Ness was disposed of in Black Deep in the Outer Estuary. Some was disposed of in Lower Hope Reach in front of north Mucking Flats. HR Wallingford (2002f) reported that a total of around 0.58 x 10^6 m^3 per year of material is estimated to have been disposed of in Lower Hope Reach between 1941 and 1967.

Inglis and Allen (1957) suggested that the disposed sediment at Black Deep was re-entrained and transported back into the estuary, adding to the rate of deposition in primary sources (Thorn and Burt, 1978). Following these results the disposal site was changed in 1961 (and still ongoing) to Rainham Marshes mid-way between London Docklands and Tilbury. This had the effect of removing the dredged sediment from the system. The route of transport of sediment back into the estuary from Black Deep may not be as direct a path as suggested by Inglis and Allen; it may be a more indirect contribution to the general sediment pool in the outer Thames Estuary.

In addition to the change of disposal site, the practice of regular maintenance dredging in the Mud Reaches and at Diver Shoal in Gravesend Reach was discontinued in the 1960s. Since this time dredging of the subtidal channel has been limited to local activities related to new jetties or deepening of existing riverside facilities (Kendrick, 1984) and the annual volume of sediment dredged appears to have fallen dramatically. The Port of London Authority estimates that the present annual requirement for maintenance dredging in the Thames Estuary, removed by conventional dredging methods, is 50,000-150,000 m^3 (HR Wallingford, 2002e) with this material being placed at Rainham Marshes and Cliffe Pools. Most of the dredging on the Thames Estuary is now undertaken using water injection dredging techniques. This agitation technique, which retains fine sediment in the estuary, is currently licensed to remove a maximum of 235,000 m^3 per year at the berths at Shell Bravo, Coryton and Oikos, together with approximately 84,000m^3 per year from the Port of Tilbury Bellmouth. In practice the average amount removed between 2002 and 2007 at the former terminals is 217,000 m^3 and 46,000m^3 from the Port of Tilbury (DSIS, 2008).

Operation of the Thames Barrier

The operation of the Thames Barrier can influence hydrodynamics and sediment transport along the length of the estuary, although the type and magnitude of the influence is presently unclear. For example, Prandle (1975) simulated deployment of the Thames Barrier during the 1953 storm surge, and found that the amplitude of the reflected wave at Southend-on-Sea was negligible. However, Littlewood and Crossman (2003) showed that closure of the Thames Barrier for prevention of fluvial flooding (without a surge component) could result in a reflected wave that may raise high water levels downstream of the barrier by around 0.5 m, depending upon the time of closure. A small negative wave (depression of water level) is generally recorded propagating upriver. It is likely that barrier operations will increase in the future in response to climate change, and thus the influence on morphology will increase (Royal Haskoning, 2004). Due to a lack of data, the impacts of the Barrier on the Greater Thames Estuary (e.g. the Medway), are not currently fully understood.

6.1.4 Salinity, Mixing and the Turbidity Maximum

The relationship between tidal range and river discharge enables all estuaries to be classified between highly stratified estuaries at one end and well mixed estuaries at the other. The Thames Estuary is generally a well mixed estuary; this means that river flow is small compared with the volume of the tide, and the whole water mass migrates up and down the estuary with the flood and ebb tides. A longitudinal salinity gradient also exists and mixing takes place at the interface between the river water and sea water; saline water is mixed upwards (being denser and thus freshwater moves above the saline water) and freshwater is mixed downwards. This mixing causes a weak density current to flow (in addition to the tidal currents), which is a natural mechanism for maintaining a balance of fresh and saline water. This current flows upstream and is an important agent for the transportation of suspended sediment into the Thames Estuary. The near bed residual flows result in the formation of a null point where there is no net movement of water at the bed in either direction. During summer freshwater discharges, the null point is generally located along the Gallions, Barking and Halfway Reaches but variations such as freshwater input will cause the location of the null point to move up- or down- estuary (Royal Haskoning, 2004).

6.1.5 Tides and Tidal Range

The Thames Estuary is macrotidal with a mean spring tide range of 5.2 m at Sheerness gradually increasing upstream to 5.9 m at Tilbury and 6.6 m at London Bridge (United Kingdom Hydrographic Office, 2003). The increasing tidal range upstream is due to the funnelling effect of the estuary, which has gradually been magnified by the formation and subsequent land-claim of extensive areas of saltmarsh.

The Thames Estuary has historically experienced an increase in the elevation of high water levels. Rossiter (1969) showed that between 1934 and 1966 there were increases in mean high water (MHW) and mean low water (MLW) at both Southend-on-Sea and Tower Bridge. He found that superimposed on the 18.6 year (lunar) oscillation were other water level increases (Table 6.1).

Table 6-1 Rate of increase of mean high water (MHW) and mean low water (MLW) or Southend-on-Sea and Tower Bridge between 1934 and 1966/69.

Source	Water level	Southend-on-Sea mm/yr	Tower Bridge mm/yr
Rossiter, 1969	MHW	3.63	7.75
	MLW	2.49	0.92
Bowen, 1972	MHW	3.51	6.80
	MLW	2.50	0.43

Overall, the data shows that an increase in tidal range has taken place, which itself increased steadily with distance upstream from Southend-on-Sea. An increase in tidal range of around 1-1.1 mm per year is described for Southend-on- Sea and 6.4-6.8 mm per year for Tower Bridge, between 1934 and 1969. The increase in tidal range is probably due to a combination of anthropogenic and natural causes (Royal Haskoning, 2004). Bowen (1972) considered that a large part of the observed increase in tidal range is likely to be due to the effects of embanking the estuary. Before construction of flood defences much of the water entering the Thames spread laterally to cover mudflats and saltmarshes. Flood defences have caused a loss of this water storage volume at high tide levels, thus increasing the height of high water contained within the banks through morphological effects. Other contributory artificial causes may include the historic dredging of deeper shipping channels, the damming of tidal creeks and changes to estuary morphology caused by waterside developments. Natural causes also have an influence on tidal range, but the main drivers are difficult to ascertain. The predominant causes of the observed increase in tidal range appear to be (although not definitively) anthropogenic in nature; for this reason a simple extrapolation of the observed rates into the future would not be appropriate (Littlewood and Crossman, 2003) and further analytical work is required in order to (Littlewood et al., 2003):

- Determine the causes of the rise in water levels at Tower Bridge and their relative importance; and
- Examine whether a rise at Tower Bridge will continue into the future and if so whether it will continue to be greater than the rise at Southend-on-Sea.

6.1.6 Storm Surges

The primary driver of flood risk along most of the Thames Estuary is tidal water level enhanced by a storm surge component. The incidence and magnitude of these surges depend on the air pressure and the severity of winds in the North Sea. Positive storm surges in the North Sea are generated by low air pressure combined with strong northerly winds. If the surge component peaks at the same time as high water (particularly spring tides) there will be a high risk of flooding unless the flood defences are able to cope with the increased elevation. Rossiter (1961) compiled surge data for Southend-on-Sea between 1928 and 1938 and showed a tendency for surges to be amplified by around 25% on the rising tide (over those at any other state), irrespective of whether the surges were negative or positive. Rossiter (1961) suggested that the propagation of the tide up the Thames Estuary is retarded (shifted back in time) by the presence of a negative surge and advanced (shifted forward in time) by a positive surge as a result of:

- The rate of progression is reduced by a reduction in water depth during a negative surge but increased by an increase in water depth during a positive surge.
- Bottom friction has the effect of retarding a wave, and as bottom friction is proportional to water depth a negative surge will increase frictional effects and a positive surge will decrease frictional effects.

Predicted tide levels in the Thames Estuary have been raised by as much as 2.5 m at high water, and up to 4 m on the rising tide by storm surges (Trafford, 1981; Horner, 1984). On the 1st February 1953, the storm surge increased the rising tide by 2.9 m and the high tide level at Tower Bridge by 1.9 m (Trafford, 1981).

6.1.7 Tidal Currents and Residual Currents

Tidal currents in the Thames Estuary show an increasing degree of asymmetry in an upstream direction. With the exception of Sheerness and Southend-on-Sea, the tidal wave becomes increasingly flood-dominated in an upstream direction. Between Sheerness and Gravesend, maximum ebb current velocities are in excess of the flood, whereas upstream of Gravesend the flood current velocities are in excess of the ebb (Thorn and Burt, 1978). The switch of tidal dominance coincides with the narrowing of the channel into Long Reach; The Institute of Estuarine and Coastal Studies (1993) suggested that the ebb dominance at Sheerness was due to the exit of the large tidal prism held in the Medway Estuary, confluencing with the Thames Estuary through a constricted mouth at Sheerness.

Thorn and Burt (1978), using historical measured current velocity variation with depth in Halfway Reach (1968 and 1969), found that the velocities at all depths rose sharply after low water slack after which they decreased steadily to a smaller peak just before high water. During both the flood and the ebb tides, velocities generally increased with height above the bed.

The tidal current ebb- or flood-dominance has important implications for sediment transport in the Thames Estuary. Other things being equal, flood-dominance will tend to favour net movement of sediment into the estuary, whereas ebb-dominance will favour net export of sediment. However, this general scenario is complicated by the presence of upstream-directed density currents (see Section 6.1.4) which enhance the flood tidal currents, and if increased river flows occur, they will enhance the ebb tidal currents (especially in the upper reaches). In addition, it has been shown by HR Wallingford (2002e) that the flow regime of the Thames Estuary downstream of Gravesend Reach has three-dimensionality. 3D modelling demonstrates that, although secondary currents are weak in comparison to the main tidal current flows, the flow field has a complex vertical structure in both lateral and longitudinal directions (HR Wallingford, 2002d). Greater detail is now available from ADCP measurements carried out in parts of the estuary by the Port of London Authority to support the investigation of various developments in the Thames Estuary. These datasets provide full river-width current velocity distributions at intervals through the tidal cycle and support this view of a complex flow field (Littlewood and Crossman, 2003).

6.1.8 Waves

HR Wallingford (2002b) modelled the wave regime of the Thames Estuary in Lower Gravesend Reach, Lower Hope Reach and Sea Reach. They found that wind action is the main wave generation process in this part of the Thames Estuary as waves generated offshore were dissipated over the Outer Estuary banks and wide intertidal flats. They modelled waves generated by winds from the east and those from 205^{o} representing waves generated locally from the south across Lower Hope Reach. They found relatively short wave periods and since the fetch is longest for winds from the south-east and east, these winds generally result in the highest wave conditions in this part of the Thames Estuary. However, a lot of energy is dissipated by the extensive offshore bank and channel system before the waves reach Sea Reach leading to relatively small overall wave heights (HR Wallingford, 2004). Significant wave heights were predicted to be slightly greater than 1.5 m at Coryton for 1 in 50 year winds from all directions and under 0.7 m for 10 times a year winds (at all water levels). Another method of wave generation in the estuary is that created by the passage of vessels. Although individually of less energy than wind-generated waves, they may be the largest waves in areas that are protected from wind waves and the passage of large vessels may also influence flow direction and turbulence and hence sediment mobilisation and net direction of transport.

6.1.9 Freshwater Input to the Estuary

The main freshwater input to the Thames Estuary is at Teddington; this has an average flow rate of 90 m^3s^{-1} (Institute of Estuarine and Coastal Studies, 1993). A long record of flow exists with the highest flow estimated at 1059 m3s-1 in 1894. Other major fluvial events occurred in 1947 (714 m^3s^{-1}) and 2003 (461 m^3s^{-1}) (Littlewood and Crossman, 2003). Tributary inputs are relatively small (10-15% of the total flow) compared to the main input at Teddington. Average freshwater inputs are very small compared to tidal discharge in the estuary (Inglis and Allen, 1957). Using ADCP measurements in July 2001, HR Wallingford (2002d) reported tidal discharges of up to 15,000 m^3s^{-1} on both flood and ebb tides (in Lower Hope Reach).

Freshwater input also partly influences morphology through the salinity regime in terms of the position of the null point for sedimentation. Crooks (1994) analysed water level records over the last 100 years for locks upstream of Teddington, and found that there was a greater number of above average peaks before 1940 than after 1940. This work concluded that channel dredging in the upper parts of the Thames and flood prevention schemes have resulted in localised decline in peak flood levels and event duration (particularly since dredging of the main fresh watercourses took place in the 1930s and 1940s); this may have influenced sediment supply to the estuarine parts of the system.

6.1.10 Sediment Sources

Sediment Provenance

It is likely that the sediment is derived from multiple sources (Royal Haskoning, 2004). During the Holocene the estuary has partially filled with marine, estuarine and freshwater sediments derived from 'natural' sources such as the underlying bedrock and reworking of the Holocene sediments themselves. The modern sources of sediment include these sources together with other anthropogenic (industrial) sources not available to the system prior to human influence (HR Wallingford, 2004). Prentice (1972) suggested that the dominant source of muddy sediment during the Holocene was the London Clay under the lower reaches of the estuary. Other sources may include the London Clay cliffs of the Isle of Sheppey (Nicholls et al., 2000) and sediment transported down the East Anglian coast and from the Essex cliffs (Marsland, 1986). It may be that far-field sources supply suspended sediment into the western North Sea where it accumulates in the 'Thames Embayment' immediately offshore of the estuary (east of a line between Walton-on-the-Naze and North Foreland). This sediment slowly enters the estuary where it becomes trapped in the tidal oscillations. The origin of bedload (fine to medium-grained sand) is believed to be mainly from reworking of earlier Thames/Medway Pleistocene fluvial sediments, from cliff erosion in Kent, Essex and Suffolk and from Tertiary sea bed exposures.

Nature of Bed Sediments

The characteristics of the bed sediments of the Inner Thames Estuary vary across and along the estuary. British Geological Survey (1997) and HR Wallingford, 2002d, e, 2004) showed that between Erith and Canvey Island the main subtidal channel generally comprises sand and gravel. To the east of Canvey Island, these sediments are replaced by mainly sand. The Outer Thames Estuary intertidal flats are characterised by sediment with high sand content due to the winnowing action of waves generated locally and those that propagate into the estuary from the North Sea. Mean sediment particle size becomes markedly smaller up-river into the Inner Thames Estuary. Mucking Flats are typified by mud whereas Blyth Sands/Yantlet Flats are muddy towards the high water mark becoming sandy towards the low water mark with a transition zone between the two (British Geological Survey, 1997; HR Wallingford, 2002d, e). A thin strip of coarser sediment (gravel and conglomerates) is generally found at the base of the flood defences backing the intertidal flats. Information on bed characteristics upstream of Erith is limited.

6.1.11 Sediment Transport

Influence of Turbidity Maximum

Littlewood and Crossman (2003) divided the Inner Thames Estuary into four suspended sediment zones on spring tides (they suggested that little sediment is in suspension on neap tides). From Teddington to Lower Pool the suspended load is low, there is little deposition on the bed and banks of the river, and much of the sediment passes through downstream. The second zone, downstream to Erith Reach, includes the turbidity maximum which forms around the null point in Gallions, Barking and Halfway Reaches. This is a zone where large concentrations of suspended sediment accumulate (collectively known as the 'Mud Reaches') which coincides with the limit of saline water intrusion (Inglis and Allen, 1957). Turbulence and the high concentrations of sediment in this zone encourage flocculation, and deposition occurs. The exact position of the turbidity maximum is sensitive to tidal range, changes of sea level, and the seasonal variability of the freshwater flow and saline tidal flow (Kendrick, 1972; Littlewood and Crossman, 2003). During periods of higher river discharge (winter flows), the saline water is pushed seawards and sediments are flushed out of the Mud Reaches and stored downriver in the Gravesend Reach area. During periods of lower river discharge (summer flows), there is a gradual upriver migration of the saline water, modifying residual flows and sediments gather and settle back in the Mud Reaches. Littlewood and Crossman (2003) suggested that the upriver migration of sediment is a slow process (months) because the forces are weak. However, the first freshwater flow of sufficient strength will rapidly move the 'summer' load back to the position it occupied before. They suggested that the downriver movement takes the form of a high suspended sediment concentration close to the bed and in the deeper parts of the channel, with only a small percentage at higher levels in the water column. Inglis and

Allen (1957) observed that a sustained increase in river flow of around 1-2 weeks caused the Barking Reaches channel to deepen by over 0.5 m in the shoal areas. They suggested three reasons for the change:

- The silt-laden water in the Mud Reaches is pushed downstream and replaced by relatively clear water which encourages re-suspension of the bed and hence scour.
- The high river flow appreciably increases the ebb discharge and thus physically scour the bed.
- The almost fresh upland water acts as a dispersing or deflocculating agent on the uppermost layers of consolidated mud thus reducing the effective particle size and bonding of particles and making them more readily transportable.

Suspended Sediment Transport
Once the suspended sediment enters the Inner Estuary system, material movement and accumulation is complex. Using measurements taken in 1953, Inglis and Allen (1957) showed a striking drop in suspended sediment concentration upstream of the Mud Reaches with concentrations in Upper Pool and Bugsby's Reach consistently below 200 ppm. The concentrations rise to a peak near the upper end of the Mud Reaches and gradually decrease seawards. They also described higher concentrations of suspended sediment on the ebb than on the flood. This may be a result of the differential re-suspension of sediment after low water slack and high water slack. On low water slack sediment settles out to form a high concentration (100,000- 150,000 ppm) fluid mud layer close to the bed. Some of the sediment at the base of this mud layer consolidates under its own weight raising the bed level, effectively removing it from re-suspension. At high water slack some suspended sediment again settles out but it is brought back into suspension by the ebb current. More thorough mixing takes place during the ebb, with consequently higher concentrations in the middle to surface layers.

As a result of suspended sediment monitoring, Thorn and Burt (1978) were able to propose several longitudinal areas of the estuary which act as temporary sediment stores releasing and accumulating sediment on a semi-diurnal and spring tide cycle. On the flood tide, sediment deposited on the previous low slack water is re-entrained and moved upstream in a series of 'jumps' corresponding to the 16 km tidal excursion and is then re-deposited at high slack water. On the following ebb tide almost all of this sediment is re-entrained and moved downstream once more where it is deposited close to the original source area at low slack water. Thus the temporary storage areas in the lower estuary supply sediment only on the flood and receive it again only on the ebb, whereas storage areas in the middle estuary, between Gravesend Reach and Blackwall Reach, both receive and supply during flood and ebb. In contrast, the most landward temporary store, in the Syon Reach, receives only on the flood and supplies only on the ebb.

A programme of water sampling at discrete points in the estuary downstream of Gravesend Reach was undertaken in July 2001 by HR Wallingford (2002e). They found a marked concentration gradient with spring tide near-bed levels up to 2000 mg/l in Lower Hope Reach decreasing to 1000 mg/l at Coryton to less than 100 mg/l at Southend-on-Sea. A similar pattern emerged from the neap tide measurements with highs of up to 500 mg/l in Lower Hope Reach and lows of less than 100 mg/l at Southend-on-Sea. They also showed vertical layers on both spring and neap tides; at high water bed concentrations were an order of magnitude greater than mid-depth concentrations and at other states of the tide were several times higher.

HR Wallingford (2002c) modelled fine sand transport (median diameter 0.1 mm) in the estuary downstream of Gravesend and found a net spring and neap tide sediment flux out of the estuary (i.e. export of sediment). Tidal currents transported a majority of the sediment with negligible wave influence. These results support the general conclusions that the estuary is ebb-dominated downstream of Gravesend and wave heights are relatively small and have less influence on the sediment movements.

More recently, it has been recognised that single point measurements in the estuary may not provide information on the full complexity of suspended sediment distribution. For example, the presence of wide meanders influences suspended sediment transport. The interaction of these meanders (and the secondary currents set up by them) with the adjacent intertidal mudflats gives rise to a complex suspended sediment regime with large fluxes of sediment moving on and off the mudflats, with subsequent morphological change (HR Wallingford, 2004, Royal Haskoning, 2004). Bed sediments can also change across the section from the outer to inner part of the meander: For example, the meander separating Gravesend Reach and Lower Hope Reach results in secondary currents that move near-bed sediment towards the inside of the meander increasing suspended sediment concentrations relative to the outside of the meander (HR Wallingford, 2002e).

Sediment Transport as Bedload

On the south shore of the Outer Thames Estuary, longshore sediment transport is inclined to the west under the action of north-easterly waves although this is largely interrupted at the Isle of Sheppey by the River Swale and at the Isle of Grain by the outflow of the River Medway (Welsby and Motyka, 1987). The net transport of sediment decreases in magnitude upstream in the estuary and is generally less than 5000 m^3 per year (Scott Wilson, 1998). Scott Wilson (1998) argued that Kentish Flats and Whitstable Flats (intertidal areas) attenuate the wave energy that would otherwise reach the Isle of Sheppey, and they may therefore influence the relatively low rates of sediment transport along this shoreline.

These results indicate that movement of sediment as bedload is very small in comparison to the loads of suspended sediment that are carried into and out of the estuary.

6.1.12 Response of Intertidal Areas to Historic Sea-Level Rise

The data suggest that vertical accretion on the intertidal areas of Blyth Sands/Yantlet Flats and Mucking Flats and the saltmarshes downstream of Gravesend has exceeded sea level rise over the past 30 years (Royal Haskoning, 2004). However, some areas of intertidal flat along the northern shore (e.g. Southend Flat) appear to have eroded over this time period. Overall, Blyth Sands/Yantlet Flats have vertically accreted at a rate of 4-5 mm per year between 1970 and 1998 (HR Wallingford, 2002a). Similarly, Mucking

Flats has accreted by around 11 mm per year during the same time period (HR Wallingford, 2002e). Vertical accretion rates on saltmarsh surfaces have been measured up to 3.9 mm per year at Higham and 3.4 mm per year at Benfleet. Historic relative sea-level rise has varied between 1.22 and 2.14 mm per year (Woodworth et al., 1999) and as such, sediment availability to the estuary downstream of Gravesend is adequate to meet demand under current environmental conditions.

6.1.13 Sediment Budget

The definition of sediment budgets for estuaries are challenging, particularly for large estuaries such as the Thames, with many (and generally difficult to quantify) anthropogenic (particularly historic dredging and disposal) forcing factors. Only one sediment budget has been published for the Thames Estuary (Institute of Estuarine and Coastal Studies, 1993). This budget suggests that the estuary exists in a balance between sediment deposition and erosion over a number of tidal cycles or seasons, and there is neither loss nor gain of sediment from the estuary. This assertion, if proven, suggests the system is in dynamic equilibrium and this would include the influence of dredging activities. It should be recognised that such equilibrium may be disrupted by new anthropogenic factors, or by accelerated sea-level rise, or by change in components of the budget such as discharge of sewage effluent (HR Wallingford, 2004, Royal Haskoning, 2004).

One of the main difficulties in being definitive about the sediment budget is the small amount of net sediment movement during a tidal cycle compared to the very large volumes of water and sediment moved (Institute of Estuarine and Coastal Studies, 1993): For example, at Southend-on-Sea, the instantaneous discharge on a spring tide is around 42,500 m^3s^{-1} and the background suspended sediment concentration is around 50 ppm (Thorn and Burt, 1978). Therefore, around 2 tonnes of sediment are transported across a given section of the estuary every second, which equates to 46,000 tonnes on a typical spring tide. Of this amount, it is estimated (using the budget in Table 6.2) that less than 300 tonnes (less than 0.7%) is retained in the estuary on the flood tide, the rest is returned to the sea on the ebb tide.

Table 6-2 A proposed sediment budget for the Thames Estuary using data from 1940 to 1988 (figures in m^3 per year) (Institute of Estuarine and Coastal Studies, 1993).

Location	Source	Sink
Saltmarsh	65,000	
Mudflat	50,000	98,600
Subtidal (dredged)		250,000
Fluvial	27,000	
Marine Source	206,100	
Total	348,600	348,600

Subtidal Channel

The average annual volume of sediment dredged from the estuary channel since 1961 is around 225,000 m^3. Assuming a dry density for this sediment in the hoppers and barges is around 500 kgm^{-3} (bulk density of 1300 kgm^{-3}) then the approximate mass of sediment presently extracted from the estuary (sink) is 113,000 tonnes per year and hence this is re-supplied to the system from the various sediment sources.

Blyth Sands and Yantlet Flats
HR Wallingford (2002a) showed that the volume of sediment on the intertidal flats of Blyth Sands and Yantlet Flats increased by 2.39 x 10^6 m^3 between 1970 and 1998. Using a dry density of 1000 kgm^{-3} for soft silts, this equates to an annual mass increase (sink) of 86,000 tonnes per year.

Mucking Flats
HR Wallingford (2002a) showed that the volume of sediment on the intertidal flats of Mucking Flats increased by 8.55 x 10^5 m^3 between 1970 and 1998. This equates to an annual volume increase (sink) of 31,000 m^3 or approximately 31,000 tonnes per year.

Saltmarsh
Burd (1992) calculated that between 1973 and 1988, 0.98 x 10^6 m^2 of saltmarsh were eroded in the Inner Thames Estuary (between Higham Marshes and Shoebury Ness). Assuming that the surface of the saltmarsh is elevated 1 m above the level of the mudflat, and the erosion rate has continued to the present day then 65,000 m^3 (65,000 tonnes) of eroded saltmarsh is yielded every year. In terms of a sediment sink, if it is assumed that accretion of sediment on the saltmarsh surface averages around 3.0 mm per year (1.9-3.9 mm per year at Higham and 3.4 mm per year at Benfleet) then using the 1988 area of saltmarsh of 3.2 x 10^6 m^2 equates to a maximum sink of 9600 m^3 per year or approximately 9600 tonnes per year.

Fluvial
Institute of Estuarine and Coastal Studies (1993) estimated an annual fluvial input of suspended solids of 28,000 m^3. Using a dry density of 1000 kgm^{-3} for the sediment, this equates to a mass of 28,000 tonnes per year.

The Environment Agency and its predecessors have dredged the River Thames upstream of the tidal limit at Teddington for many years with records going back to the 1930s. These schemes now present the Agency with an ongoing liability to maintain the design channel profiles and this means that over the last 10 years, on average, about 40,000 tonnes are dredged annually (Kirby, 2000). Dredgings are currently disposed of at a licensed waste site known as Penton Hook Pit, a former gravel pit adjacent to the Thames and thus are removed from being available to the system.

Response of Estuary to Accelerated Sea-Level Rise
An important question with respect to the future morphological development of the Thames Estuary is whether accretion on the intertidal areas will be able to keep pace with potential accelerated sea-level rise. This is presently a difficult question to answer in the absence of a definitive sediment budget, although several attempts, using different methods, have been made to look at the estuary response based on the available data.

The Institute of Estuarine and Coastal Studies (1993) suggested that under an accelerated rate of sea-level rise, a net loss of intertidal surface area would be likely, although vertical accretion may continue on some intertidal surfaces. They envisaged that this net loss would result in a narrowing of the foreshore, leading to reduced attenuation of wave and tidal energy. It was also suggested that the response of the Thames Estuary to sea-level rise over the next 100 years would be to roll-over in a landward direction. This means that the entire estuary sediment system would transgress landward with sea-level rise causing the pattern of sediment entrainment, transport and deposition to also migrate upstream. To achieve this transgressive movement the estuary must redistribute sediment landward but must also receive sediment inputs from marine sources equivalent to the rate of sea-level rise as the system elevates with the tidal frame. Posford Haskoning (2002a) predicted that for the Thames Estuary this landward migration rate would be around 12.5 m per year assuming an accelerated sea-level rise of 6 mm per year (medium-high scenario).

A combination of process based modelling and historical trend analysis (HR Wallingford, 2002a-f) showed that long term changes observed between 1970 and 1998 could be accounted for by the intertidal processes of accretion at high water and erosion under wave and tidal action as predicted by the sediment transport models. They found that on average Mucking Flats increased in volume by about 30,000 m^3 per year but slightly reduced in area (less than 1000 m2 per year) (HR Wallingford, 2002a). Mucking Flats was observed to be rising at average rates of between 7 mm and 26 mm per year. They also found that (western) Blyth Sands reduced in volume by about 40,000 m3 per year but increased in area by about 9,000 m2 per year. The upper parts of the intertidal area were lowering by about 12 mm per year. Overall, in the period 1970-1998 these intertidal areas underwent net accretion of about 400,000m^3 and the elevations adjacent to the mudflats accreted or eroded at rates substantially greater than observed rates of sea level rise (around 2 mm per year).

If in the medium term, the intertidal areas downstream of Gravesend continued to respond in the same way they have been observed to change between 1970 and 1998, then in ten years time Mucking Flats would be expected to rise in level by between 70 and 260 mm but reduce in area by about 10,000 m^2. The upper parts of Blyth Sands would reduce in level by 120 mm and the lower parts would accrete by 80 mm because of an increase in area due to a lower intertidal accretion of about 90,000 m^3. HR Wallingford (2002a-f) did not propose extrapolation of these rates of change beyond a ten year period and they found no evidence of net erosion of the intertidal areas of the estuary between Gravesend and Canvey Island (which is implied in the Institute of Estuarine and Coastal Studies, 1993 and Haskoning, 2002a predictive studies).

The HR Wallingford results may simply reflect the change in the system from one where (historically) dynamic equilibrium has been reached to one of transition in relation to rising sea levels were the roll-over of the estuary inland to be commencing. However, the roll-over method operates on the basis of potential sediment movement allowing the estuary to adjust to the new tidal frame. The difficulty with applying roll-over to the Thames Estuary is the likelihood that sediment movement will be laterally constrained by flood defences and other developments and the transgression may have ‘nowhere to go' upstream because this boundary of the estuary is constrained by Teddington Weir and development.

The findings of HR Wallingford (2002a) are based upon historical trend analysis and are in broad agreement with process model predictions. Their predictions do not apply to the entire estuary and there is limited historical data on the changes in the downstream intertidal areas. Collectively these studies provide a basis for prediction that needs to be proven or disproven once better information on sediment and historical trend analysis data becomes available.

6.1.14 Summary of Morphological Characteristics

Historic morphological change in the Thames Estuary can be divided into two periods. The first, from the middle of the 19th century until around 1970, was a period when many natural morphological changes were masked by extensive anthropogenic activity, such as flood defences, dredging programmes, waterside schemes and developments. The second period, from 1970 to the present day, corresponds with the implementation of legislation to control waterside activities enabling the estuary to (commence a process to) establish a more natural regime (HR Wallingford, 2003, 2004, Royal Haskoning, 2004). Morphological change in the estuary post-1970 is therefore more representative as a baseline to future development than the long term development (pre- and post-1970s combined), which must be set within the context of large artificial changes to the estuary.

Subtidal Channel

Estuarine channels experience natural periodic shifts in position, due to gradual meander migration or more sudden changes during periods of high river flow, extreme tides or strong winds. A lateral shift in the position of the subtidal channel may over time produce a change in the slope of the intertidal profile and may alter the wave and tidal energy impinging on the shoreline. Historic changes in the position and depth of the Thames Estuary subtidal channel are difficult to ascertain because of the influence of dredging and disposal activities. This is exemplified by two examples:

- A major programme of capital dredging took place between 1909 and 1928 to improve navigation in the Yantlet Dredged Channel. It was further deepened in 1965 and much of the dredged sediment was deposited in Leigh Channel to the north to encourage flow in the Yantlet Channel (HR Wallingford, 2002a).
- The navigation channel in Lower Gravesend Reach migrated to the south after dredging was undertaken in 1963/64. The dredged sediment may have been used to close the previous (more northerly) alignment of the navigation channel.

However, in broad terms, and from both natural and anthropogenic influences, between 1820 and 1988 the subtidal channel increased in width between Lower Hope Reach and the eastern tip of Canvey Island, and narrowed between Canvey Island and the Isle of Grain (Institute of Estuarine and Coastal Studies, 1993). These changes were due to advance or retreat of the adjacent intertidal areas. During a similar period (1834 to 1957/59), HR Wallingford (2003) found that in Lower Hope Reach and Upper Sea Reach, the deep water channel deepened. Between 1920 and 1957/59, this deepening was accompanied by a shallowing of the subtidal areas fronting Mucking Flats and Blyth Sands. These changes are also influenced by the large-scale historic ballast winning and disposal activities in Lower Hope Reach. A more complex pattern of change occurred between 1957/59 and 1970/71, related to realignment of the navigation channel in Lower Gravesend Reach in the 1960s. Overall, between 1920 and 2002, the deep water channel has deepened significantly in Lower Hope Reach and Upper Sea Reach and the subtidal areas adjacent to the intertidal flats have shallowed (HR Wallingford, 2003, 2004).

Intertidal Flats

Institute of Estuarine and Coastal Studies (1993) showed that between 1820 and 1940 (using a comparison of the low water mark on Ordnance Survey maps) the area of intertidal flat downstream of Gravesend increased by 4.86 x 10^6 m^2, but decreased by 1.26 x 10^6 m^2 between 1940 and 1988 (Table 6.3). The decrease occurred mainly because a decrease on the north side of the Thames was greater than a continued increase on the south side. The increase mainly occurred at the low water mark (the low tide boundary of the mudflats encroaching into the subtidal channel) rather than at the boundary with the adjacent saltmarshes. The decrease on the north bank may be due to the increased land-claim and industrialisation that took place here during the mid 20th century.

Table 6-3 Areas of intertidal flat in the Thames Estuary downstream of Gravesend in 1820, 1940 and 1988 (from Institute of Estuarine and Coastal Studies, 1993)

Location	Area (10^6m^2) in 1820	Area (10^6m^2) in 1940	Area(10^6m^2) in 1988
North Bank	23.14	24.94	22.43
South Bank	20.36	23.40	24.65
Total	43.48	48.34	47.08

The extensive intertidal flats downstream of Gravesend can be divided into shorter sections for a more detailed appraisal of change. It should be recognised that these areas exhibit dynamic change on a short term basis but also some assessments have been made of longer term processes. The areas are: on the south bank,

- Blyth Sands.
- Yantlet Flats/Grain Spit

and on the north bank,

- Mucking Flats
- Canvey Island (Chapman Sands, Marsh End Sand, Leigh Sand)
- Southend Flat.

Blyth Sands – According to Institute of Estuarine and Coastal Studies (1993) the northern edge of Blyth Sands fronting Cliffe and Halstow Marshes generally retreated between 1820 and 1940. Between 1940 and 1988 the edge generally advanced seaward, possibly responding to loss of mudflat at Coryton on the opposite bank (dredging of the channel close inshore, deepening the berths at the oil refinery jetties), allowing the main channel to maintain a constant width. This scenario is supported by the results of HR Wallingford (2002a) who showed more deep water adjacent to Coryton in 1970 compared to 1834. HR Wallingford (2002a, c) also showed that the surface of Blyth Sands lowered by up to 1 m over the period 1970-1998 (an average vertical erosion of 12 mm per year), even though accretion (up to 4 m, an average of around 100 mm per year) had taken place around the low water mark . These changes equate to an increase in area of around 4% (5.93 x 106 m^2 to 6.19 x 106 m^2) but a volume decrease of more than 11% (9.5 x 10^6 m^3 to 8.4 x 106 m^3). HR Wallingford (2002f) showed a continuation of general lowering of the Blyth Sands surface between 1998 and 2002, but at a higher rate. They also found a lower rate of general accretion around the lower water mark during this 4-year period compared to 1970-1998.

Yantlet Flats/Grain Spit - There has been significant general accretion along the low water mark of Yantlet Flats fronting St Mary's and Allhallows Marshes between 1820 and 1988 (Institute of Estuarine and Coastal Studies, 1993; HR Wallingford, 2002a). HR Wallingford (2002a) also demonstrated that the main body of the flats has accreted vertically by around 0.5 m between 1970 and 1998, and the flats around the low water mark by up to 8 m. These changes equate to an increase in area of around 16% (11.22 x 10^6 m^2 to 12.98 x 10^6 m^2) and a volume increase of around 15% (22.9 x 10^6 m^3 to 26.4 x 10^6 m^3).

Mucking Flats – Between 1820 and 1988, the southern part of the mudflats at Mucking (opposite East Tilbury) generally advanced into the subtidal channel whilst the northern portion (Mucking) generally retreated, with most of the movement taking place between 1940 and 1988 (Institute of Estuarine and Coastal Studies, 1993). HR Wallingford (2002a) showed a similar trend around the low water mark between 1959 and 1998 and a general vertical accretion (0.5-2 m) of the main body of the flats over the same period. They found that the change had been fairly continuous over the period and was not influenced significantly by the anthropogenic activities that took place in the area in the 1960s. HR Wallingford (2002e) described an average vertical accretion rate of 11 mm per year for the entire intertidal area, between 1970 and 1998, although rates of 20-40 mm per year occured at the northern end (HR Wallingford, 2002f) and some erosion took place at the southern end (towards low water mark). Area and volume comparisons of Mucking Flats between 1970 and 1998 revealed an overall decrease in area above Chart Datum of less than 1% (2.74 x 10^6 m^2 to 2.72 x 10^6 m^2) but a general volume increase of 12% (7.2 x 10^6 m^3 to 8.1 x 10^6 m^3) (HR Wallingford, 2002a). However, HR Wallingford (2002e, d) demonstrated that between 1998 and 2002, Mucking Flats generally lost volume. They postulated two reasons for this change, and the concurrent changes occurring on Blyth Sands (see above):

- Increased wind speeds (and hence increased wave activity) in the 1998-2002 period relative to those experienced 1970-1998.
- Unusually high freshwater flow experienced in winter 2000/2001 causing a change in salinity, tidal flows and hence suspended sediment concentrations.

The 1998-2002 bed level changes could be a short-term perturbation, and hence they may demonstrate the natural variation of change that can occur, within the longer-term trend described by the 1970-1998 data (HR Wallingford, 2002f). Alternatively this could be a more significant change in the processes that future measurement may be able to confirm.

Canvey Island – The intertidal flats in front of Canvey Island have generally retreated between 1820 and 1988 (Institute of Estuarine and Coastal Studies, 1993). Prior to 1909, Chapman Sands and Marsh End Sand to the east of Canvey Island were receding westwards, but since 1909 they have generally extended eastwards. The movement of Marsh End Sand has resulted in a northward shift of Ray Gut and erosion of the mudflats (Leigh Sand) to its north-east.

Southend Flat – Southend Flat has suffered erosion to the west of Southend-on-Sea Pier (due to the northward movement of Ray Gut), while the creek systems draining the flats have enlarged and migrated (Institute of Estuarine and Coastal Studies, 1993). HR Wallingford (2002a) also showed a general loss of intertidal flat volume at Canvey Island and Southend-on-Sea between 1970 and 1998.

Saltmarsh

Maps of 1820 show that large areas of saltmarsh had already been enclosed (Institute of Estuarine and Coastal Studies, 1993). It is likely that early (14th-16th century) land-claims were piecemeal with construction of walls by landowners to protect their property. However, out of this piecemeal approach a fairly uniform sea wall fronting the Thames Estuary developed. Burd (1992) showed that between 1973 and 1988, 4.44 x 10^6 m^2 of saltmarsh identified between Higham Marshes and Shoebury Ness in 1973 had been reduced to 3.21 x 10^6 m^2 by 1988, a loss of 28%. Of the 1.23 x 10^6 m^2 lost (1.06 on the north bank and 0.17 on the south bank), 0.98 x 10^6 m^2 were lost through erosion and 0.25 x 10^6 m^2 through land-claim.

The main mechanism of saltmarsh erosion over the last 30 years is considered to be increased wave energy at the seaward edge (Pye, 2000; Van der Wal and Pye, 2004). The periods 1970-73, 1976-79 and 1985-88 in particular, are characterised by stormy conditions with sustained periods of strong winds and waves from the south-east and east. The erosion is concentrated along the seaward edge of the saltmarshes which are exposed to wave action (e.g. Leigh Marsh and Canvey Point, Cooper *et al*., 2000), whereas the more sheltered saltmarshes, in Benfleet and Holehaven Creeks, have not experienced a retreat of their seaward edges.

6.2 Water quality

6.2.1 Methodology

The following section describes the water quality of the study area and the wider Thames Estuary. Water quality is an important parameter to benthic infauna which comprise the main feeding resource for waterfowl and can be affected by dredging activities. Changes to water quality can affect the health of the infauna and certain pollutants can bioaccumulate through food pathways.

Water quality data is predominantly collected by the Environment Agency in response to legislative requirements. Data is then compared against environmental quality standards (EQS), which are designed to protect the environment and human health. In the Thames estuary study area there are a number of applicable EC Directives which trigger a requirement for monitoring. Applicable legislation is listed below:

- EC Bathing Waters Directive;
- EC Shellfish Waters Directive;
- EC Shellfish Hygiene Directive; and
- EC Dangerous Substances Directive.

The water quality data for the Thames Estuary has been largely derived from monitoring carried out by the Environment Agency. The exception is the information provided by the Food Standards Agency for data collected under the Shellfish Hygiene Directive.

6.2.2 Bathing water quality

There are nine designated bathing waters located in the outer estuary, some of which are located directly on the boundary of the study area and some outside. These bathing waters are shown as individual locations on Figure 6.1 and reflect the Environment Agency's monitoring points.

Bathing water quality is assessed by standards listed in the EC Bathing Waters Directive. The Directive was adopted by the Council of the European Communities in 1975 and transposed into law for England and Wales to form the Bathing Waters (Classification) Regulations 1991. The Directive is concerned with the quality of bathing waters for the purpose of protecting public health and requires monitoring of microbiological parameters and a small number of physical parameters e.g. visible oil.

Figure 6.1 Locations and quality of Environment Agency bathing waters within the study area

There are two types of microbiological standards set out in the Directive, namely the mandatory standards and the more stringent guideline standards.

The imperative (mandatory) standards are:

- 10,000 total coliforms per 100 ml of water; and
- 2,000 faecal coliforms per 100 ml of water.

For a bathing water to comply with the Directive, 95% of samples collected within a bathing season (15th May to 30th September) must meet these and the other physical criteria.

The guideline standards should be achieved where possible and are:

- 500 total coliforms per 100 ml of water (in 80% samples);
- 100 faecal coliforms per 100 ml of water (in 80% samples); and
- 100 faecal streptococci per 100 ml of water (in 90% samples).

Bathing water quality at each of the bathing waters for the period 2002 to 2007 is illustrated in Table 6.4. Water quality is classified as 'excellent', 'good' or 'poor'.

‘Excellent’ relates to the achievement of the more stringent guideline standards and ‘good’ relates to the achievement of the mandatory standards. Bathing waters classified as ‘poor’, fail to meet the Directive’s minimum mandatory standard. The majority of the bathing waters in the area have exhibited either good or excellent quality for at least the last five years. Where designation of the bathing water has occurred within the five years, bathing waters have exhibited either good or excellent quality for at least the last three years.

Table 6-4 Bathing water quality at the designated bathing waters located in or close to the boundary of the study area.

Bathing Water	2002	2003	2004	2005	2006	2007
Sheerness	E	E	G	E	E	E
Leysdown	G	E	G	E	E	E
Shoebury East	E	E	E	E	E	E
Southend Thorpe Bay	E	G	G	G	E	G
Southend Jubilee	-	G	E	E	G	E
Southend Three Shells[1]	E	G	G	E	E	G
Southend Westcliff Bay	E	G	E	E	E	E
Southend Chalkwell[1]	-	G	G	G	E	G
Leigh Bell Wharf[1]	-	E	G	E	G	G

Bathing Waters Classifications: E = Excellent, G = Good, P = Poor

[1] Bathing waters were newly designated in 2002/03.

A new Bathing Water Directive came into force in 2006 (2006/7/EC) which updates the way in which water quality is measured, focusing on fewer microbiological indicators and setting different standards for inland and coastal bathing sites. The updated requirements include:

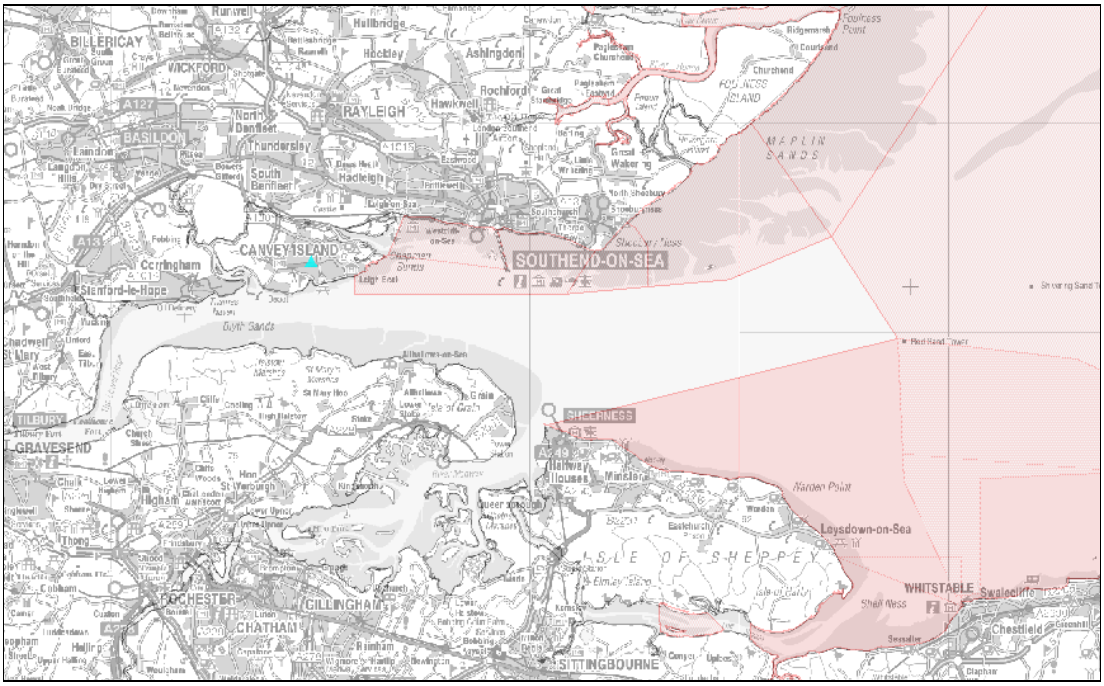
- tighter microbiological standards - to be met by 2015
- two microbiological parameters - Intestinal enterococci and *Escherichia coli*
- water quality classification based on 3 or 4 years monitoring data
- four new classification categories:
    - excellent - approximately twice as stringent as the current guideline standard
    - good - similar to the current guideline standard
    - sufficient - tighter than the current mandatory standard
    - poor - normally non-compliant waters

Defra and the Environment Agency have used the new standards and four years of water quality monitoring data (2005 to 2008) to assess the compliance rate that might be expected in England and Wales under the revised Bathing Water Directive.

The new directive was transposed into domestic UK legislation in March 2008 and will take effect from 2015.

6.2.3 Shellfish Water Quality

There are six designated shellfish waters located in or close to the study area. The location of these shellfish waters can be seen in Figure 6.2.



NB: Any land above the Mean High Water Mark is excluded from the designation e.g., islands that fall within these areas.

Figure 6.2 Designated shellfish harvest areas in the Thames Estuary

The Shellfish Waters Directive (79/923/EEC), repealed by the codified Shellfish Waters Directive (2006/113/EC) adopted on 12 December 2006, is designed to protect the aquatic habitat of bivalve and gastropod molluscan species of shellfish. Species covered include oysters, mussels, cockles, scallops and clams but not crustaceans such as crabs, crayfish and lobsters. The Shellfish Waters Directive is implemented in the UK under the Shellfish Waters (Shellfish) (Classifications) Regulations 1997.

Shellfish waters are monitored for various parameters based on water quality standards established by the Directive. These parameters include suspended solids, salinity, dissolved oxygen (DO), organo-halogenated substances (e.g. PCBs, organochlorine pesticides), metals and guideline values for coliforms in shellfish flesh. For each substance, the Directive specifies the minimum number of samples to be taken, the water quality standards to be met and the percentage of samples that must meet these standards. The standards are either a numeric limit or a descriptive standard (see Table 6.5). The water quality standards have been met if the following percentage of the samples analysed do not exceed the limit values:

- 100% for metals and organo-halogen compounds;
- 95% for salinity and dissolved oxygen (DO);
- 75% for other substances; and
- No evidence of harm to the shellfish from organo-halogenated compounds.

Table 6-5 Selected imperative standards for shellfish waters

Parameter	Units	Standard
Suspended solids	mg/l	A discharge affecting shellfish waters must not cause the suspended solid content of the waters to exceed by more than 30% the content of waters not affected.
Salinity	Parts per thousand (i.e. g/l)	≤40 parts per thousand A discharge affecting shellfish waters must not cause the salinity to exceed by more than 10% the salinity of the waters not affected.
Dissolved oxygen	% saturation	Average of individual values >70% and an individual measurement may not indicate a value lower than 60% unless there are no harmful consequences for the development of shellfish colonies.
Organo-halogenated substances	-	The concentration of each substance in the shellfish waters or in the shellfish flesh must not reach or exceed a level, which has harmful effects on the shellfish and their larvae.
Metals (Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn)	mg/l	The concentration of each substance in the shellfish waters or in the shellfish flesh must not reach or exceed a level, which has harmful effects on the shellfish and their larvae. The synergic effects of these metals must be taken into consideration.

Table 6.6 summarises the Environment Agency's shellfish water quality monitoring data for the designated shellfish waters for the period 1999 to 2001. Samples are taken at designated points within each of the shellfish water selected to be representative of the quality of the whole area of shellfish water.

Table 6-6 Summary of shellfish waters quality (mean concentrations of physicochemical parameters) for 1999 to 2001. (Source Environment Agency)

Parameter	Units	Southend	Outer Thames	Foulness	Sheppey
Suspended solids	**mg.l^{-1}**	31	27	No data	33
Salinity	**g.l^{-1}**	28	31	No data	31
Dissolved oxygen	**% saturation**	94	103	103	100
Organo-halogenated substances	**µg.l^{-1}**	All reported as "<" values. All values <0.005 µg.l^{-1} (or less)	All reported as "<" values. All values <0.005 µg.l^{-1} (or less)	All reported as "<" values. All values <0.005 µg.l^{-1} (or less)	Many reported as "<" values. All values <10 µg.l^{-1} (or less). Variations include total values of DDT, HCH and 'drins, for which no data has been recorded since December 2000
Metals (dissolved)	**µg.l^{-1}**				
As		1.92	1.48	1.41	1.7
Cd		0.06	0.12	0.18	<0.25
Cr		0.26	0.52	0.70	0.55
Cu		4.17	3.20	1.55	2.23
Hg		0.03	0.02	0.02	<0.01
Ni		1.63	1.11	0.93	<3
Pb		0.33	0.19	1.2	<2.5
Zn		9.78	5.12	9.87	7.90

More recent data is available for the Outer Thames and Southend Shellfish Water (Environment Agency, 2008a and Environment Agency, 2008b). The Outer Thames Shellfish Water has met mandatory standards during the period 2003 to 2007, except for the copper standard in 2003 and 2005, the mercury standard in 2003 & 2004 and the hydrocarbon standard in 2003. The Shellfish Water passed guideline standards for salinity and dissolved oxygen every year from 2003 to 2007 except 2004, when the dissolved oxygen standard was failed. The Shellfish Water achieved compliance with the guideline standard for Faecal coliforms in flesh in 2004, 2005, 2006, and 2007.

The failure of the mandatory copper standard in 2004 and 2005 has been the subject of extensive investigation, and is thought to be the result of contaminated sampling equipment which has now been replaced (Environment Agency, 2008a). The failure to achieve the mandatory standard for mercury in 2003 and 2004 was due to single high results out of line with the normal levels. The cause is currently unknown but likely to be a laboratory error (Environment Agency, pers. comm.).

The Outer Thames Shellfish Water will benefit from further remedial action targeted at adjacent Shellfish Waters. However, the Environment Agency has no plans for any remedial action targeted specifically at this Shellfish Water, as it currently achieves all guideline standards.

The Southend Shellfish Water achieved the guideline standard for Faecal coliforms in shellfish flesh in four of the last five years, including 2007. It has consistently achieved compliance with all other guideline standards. Improvements to nine intermittent sewage discharges in the vicinity of Southend were completed at the beginning of 2005.

The Environment Agency will continue to review its monitoring data annually and seek to identify sources of pollution that may lead to failure of guideline standards for all Shellfish Waters.

6.2.4 Shellfish quality

The Shellfish Hygiene Directive, although not a Directive directly protecting water quality, stipulates the level of treatment required depending on numbers of bacteria in the shellfish flesh. This Directive is designed to protect human health. Since shellfish are grown in the natural environment, it is a commonly held view that the concentration of bacteria in the flesh directly relates to the quality of the surrounding water in which they grow. The monitoring undertaken as a consequence of this Directive can therefore be used as an indicator of water quality.

Under the Shellfish Hygiene Directive, standards are set in terms of concentrations of coliform bacteria and salmonella. Shellfish are classed in categories ‘A’, ‘B’, ‘C’ and ‘P’ where ‘A’ is the highest quality and can be collected direct for human consumption. ‘P’ is the poorest quality and shellfish are prohibited from collection. Monitoring for the Shellfish Hygiene Directive is carried out by the local authorities and the data is collated by the Food Standards Agency. Table 6.7 lists the designated bivalve mollusc production areas in the study area and their individual classifications.

Table 6-7 Designated bivalve mollusc production areas in the Thames estuary and North Kent Coast from 1 September 2008. (Source: Food Standards Agency, 2008)

Bed Name	Species	Common Name	Class
Thames Estuary			
Mid and NE Maplin Sands	*Cardium edule*	Common edible cockle	A
Mid Maplin Sands	*Cardium edule*	Common edible cockle	B
Foulness Sands	*Cardium edule*	Common edible cockle	A
Leigh Foreshore	*Cardium edule*	Common edible cockle	B

Bed Name	Species	Common Name	Class
Leigh Foreshore	*Mytilus edulis*	Blue Mussel	B
Southend Flats	*Mytilus edulis*	Blue Mussel	B
Southend Flats	*Cardium edule*	Common edible cockle	B
West of Southend Pier	*Crassostrea gigas*	Pacific Oyster	B
Phoenix	*Cardium edule*	Common edible cockle	B – LT*
Shoebury Island	*Cardium edule*	Common edible cockle	B
Scrapsgate	*Cardium edule*	Common edible cockle	B - LT
Sheppey	*Mytilus edulis*	Blue Mussel	B - LT
North Kent Coast			
The South Oaze	*Mytilus edulis*	Blue Mussel	B – LT
Whitstable	*Mytilus edulis*	Blue Mussel	B - LT
Whitstable Bay	*Crassostrea gigas*	Pacific oyster	B
Whitstable Bay	*Ostrea edulis*	Native or flat oyster	B
Herne Hampton	*Mytilus edulis*	Blue Mussel	B – LT
Beltinge Bay	*Mytilus edulis*	Blue Mussel	B – LT
Herne	*Mytilus edulis*	Blue Mussel	B – LT
Reculver	*Mytilus edulis*	Blue Mussel	B –LT
Swalecliffe	*Mytilus edulis*	Blue Mussel	B – LT
Pollard	*Crassostrea gigas*	Pacific oyster	B – LT
Pollard	*Venerupis philippinarus*	Manila Clam	B – LT
Pollard	*Cardium edule*	Common edible cockle	B – LT
East Last Bank	*Ostrea edulis*	Native or flat oyster	B – LT
East Last Bank	*Mytilus edulis*	Blue Mussel	B – LT
Clite Hole	*Ostrea edulis*	Native or flat oyster	B – LT
Clite Hole	*Mytilus edulis*	Blue Mussel	B – LT
The Street	*Ostrea edulis*	Native or flat oyster	A
The Street	*Mytilus edulis*	Blue Mussel	B – LT
Kentish Flats	*Ostrea edulis*	Native or flat oyster	A
Kentish Flats	*Cardium edule*	Common edible cockle	B – LT
North of Hook	*Cardium edule*	Common edible cockle	B – LT
South of Hook	*Cardium edule*	Common edible cockle	B – LT
Margate Sands	*Cardium edule*	Common edible cockle	B – LT
Minnis Bay	*Cardium edule*	Common edible cockle	B – LT

*LT denotes Long Term classification applies. The Food Standards Agency's Long Term Classification (LTC) system allows immediate investigation into all classification sample results to control shellfish harvesting in areas where high level microbiological results occur.

6.2.5 Dangerous Substances

The Environment Agency monitors for dangerous substances at a variety of sites within the study area for the purposes of ensuring that the Thames Estuary is compliant with the EC Dangerous Substances Directive.

The EC Dangerous Substances Directive was adopted in 1976 to control pollution caused by certain dangerous substances on the aquatic environment. The Directive established List I substances, which are regarded as particularly dangerous because of their toxicity, persistence and bioaccumulation. Pollution by these substances must be eliminated. Pollution by List II substances regarded as less dangerous but which have a deleterious effect on the aquatic environment must be reduced.

The Dangerous Substances Directive stipulates uniform emission standards (UESs, also known as limit values) and environmental quality standards (EQSs) as approaches for the control of List I substances. For List II substances, all member states are required to establish EQSs on a national level. EQSs for List II substances have been implemented in the UK by the Surface Waters (Dangerous Substances) (Classification) Regulations 1997 and 1998.

The EQSs for selected List I substances are shown in Table 6.8. The table is based on the information presented in “Guidelines for managing water quality impacts within UK European marine sites” (Cole *et al*., 1999).

Table 6-8 Selected List I dangerous substances*

Substance**	EQS Type	Marine EQS (annual average, $\mu g.l^{-1}$)	Estuarine EQS*** (annual average, $\mu g.l^{-1}$
Mercury (dissolved)	Annual average	0.3	0.5
Cadmium (dissolved)	Annual average	2.5	5
HCH (Lindane) ****	Annual average	0.02	0.02
Total DDT	Annual average	0.025	0.025
ppDDT	Annual average	0.01	0.01
Pentachorophenol	Annual average	2	2
Aldrin	Annual average	0.01	0.01
Dieldrin	Annual average	0.01	0.01
Endrin	Annual average	0.005	0.005
Isodrin	Annual average	0.005	0.005
Total 'Drins'	Annual average	0.03	0.03
Hexachlorobenzene	Annual average	0.03	0.03
Hexachlorobutadiene	Annual average	0.1	0.1
Carbon tetrachloride	Annual average	12	12
Chloroform	Annual average	12	12
1,2-dichloroethane	Annual average	10	10
Trichloroethyleme	Annual average	10	10
Perchloroethylene	Annual average	10	10

Substance**	EQS Type	Marine EQS (annual average, µg.l^{-1})	Estuarine EQS*** (annual average, µg.l^{-1}
Trichlorobenzene	Annual average	0.4	0.4

*EQS List I taken from www.environment-agency.gov.uk

**total concentration (i.e. without filtration) unless specified

*** in the UK, standards for estuaries are the same as for marine EQSs, as established under the Surface Waters (Dangerous Substances) (Classification) Regulations 1989

**** all HCH isomers, including Lindane

EQSs for List II substances have been implemented in the UK by the Surface Waters (Dangerous Substances) (Classification) Regulations 1997 and 1998. The EQSs for selected List II substances are shown in Table 6.9.

Table 6-9 Selected List II dangerous substances*

Substance	EQS Type	Marine and Estuarine EQS (annual average, µg.l^{-1})
Arsenic (dissolved)	Annual average	25
Chromium (dissolved)	Annual average	15
Copper (dissolved)	Annual average	5
Lead (dissolved)	Annual average	25
Nickel (dissolved)	Annual average	30
Tributyl tin	Maximum concentration	0.002
Zinc (total)	Annual average	40

*The full EQS List II is available on www.environment-agency.gov.uk

Water quality monitoring data for the years 1990 to 2000 has been provided by the Environment Agency and is presented in Table 6.10 below. The Environment Agency undertakes routine monitoring of water quality for dangerous substances at a number of sites along the length of the Thames Estuary (Richmond to North Oaze). These sites are sampled 12 times per annum. Comments are also provided concerning compliance with the environmental quality standards.

Table 6-10 Summary of Dangerous substances provided by the Environment Agency for the period 1990 to 2000.

Substance	Mucking (µg.l^{-1})	Chapman (µg.l^{-1})	Southend (µg.l^{-1})	Sea Reach (µg.l^{-1})	Comments
Mercury (dissolved)	0.018	0.184	0.041	0.04	All data well below EQS, except one 1991 datum at Chapman (3 µg.l^{-1})
Cadmium (dissolved)	0.159	0.111	0.078	0.124	All data below EQS and concentrations generally decreasing

Substance	Mucking ($\mu g.l^{-1}$)	Chapman ($\mu g.l^{-1}$)	Southend ($\mu g.l^{-1}$)	Sea Reach ($\mu g.l^{-1}$)	Comments
HCH (Lindane)	0.006	0.006	0.005	0.006	All data at or below EQS, except one 1990 datum at Sea Reach ($0.1\mu g.l^{-1}$)
Total DDT	0.021	0.021	0.019	0.021	All data below EQS since early 1990s
PpDDT	<0.005	<0.005	<0.005	<0.005	All data below EQS since early 1990s, all concentrations at or <0.005 $\mu g.l^{-1}$
Pentachorophenol	0.106	0.109	No data	0.113	All data below EQS and concentrations generally decreasing since early 1990s and stabilising around $0.1\mu g.l^{-1}$ by mid 1990s
Aldrin	0.005	0.005	0.005	0.005	Virtually all data below EQS in early 1990s and all data below EQS since mid 1990s
Dieldrin	0.005	0.005	0.005	0.005	Virtually all data below EQS in early 1990s and all data below EQS since mid 1990s
Endrin	0.005	0.005	0.005	0.005	All data below EQS since mid 1990s
Total 'Drins'	0.02	0.02	0.018	0.019	All data below EQS since early 1990s; sampling at Southend started in 1999
Hexachlorobenzene	0.005	0.005	0.005	0.005	All data well below EQS
Hexachlorobutadiene	0.014	0.015	0.005	0.015	All data well below EQS
Tetrachloromethane	0.264	0.27	No data	0.261	All data well below EQS
Trichloromethane	0.441	0.386	No data	0.386	All data well below EQS
Dichloroethene	1.056	1.019	No data	1.025	All data well below EQS
Trichloroethane	0.29	0.306	No data	0.297	All data well below EQS
Tetrachloroethene	0.259	0.257	No data	0.249	All data well below EQS
Trichlorobenzene	0.045	0.046	No data	0.046	All data well below EQS since early 1990s
Arsenic (dissolved)	2.448	2.159	2.027	1.86	All data well below EQS
Chromium (dissolved)	0.88	0.662	0.285	0.85	All data below EQS with all concentrations <2 $\mu g.l^{-1}$ since early 1990s
Copper (dissolved)	Although in 2000, all concentrations of copper at all sites fell below the EQS level of 5 $\mu g.l^{-1}$, concentrations of dissolved copper at all sites have on average, exceeded the EQS levels. Concentrations dropped in the early 1990s, but a trend toward increasing concentrations occurred from the mid 1990s to the late 1990s, with a reverse in this trend after 1998.				

Substance	Mucking ($\mu g.l^{-1}$)	Chapman ($\mu g.l^{-1}$)	Southend ($\mu g.l^{-1}$)	Sea Reach ($\mu g.l^{-1}$)	Comments
Lead (dissolved)	0.807	0.697	0.342	0.567	All data below EQS, with concentrations falling in early 1990s
Nickel (dissolved)	4.074	2.984	1.775	2.061	Virtually all data below EQS, with concentrations falling in early 1990s
Tributyl tin	0.004	0.003	0.002	0.001	Most data above EQS except for 1999 and 2000, which may reflect sensitivity of analytical equipment since most data for 1999 and 2000 are recorded as "less than" concentrations.
Zinc (total)	Although in 2000, all concentrations of zinc at all sites fell below the EQS level of 40 $\mu g.l^{-1}$, concentrations of total zinc at Mucking, Chapman and Southern have been recorded around the EQS level, whilst at Sea Reach they have mostly fallen below the level. In the last 4 years there is an apparent trend of declining concentrations.				

More recent data for 2007 was also provided by the Environment Agency. All dangerous substances were below EQS except copper, the results of which are presented in Table 6.11.

Table 6-11 Levels of Copper (µg/l) measured at Mucking, Chapman Buoy and Southend between January and November 2007. Text denoted in red refers to occasions when the EQS of 5 µg/l was exceeded

Date	Site Name	Conc.	Site Name	Conc.	Site Name	Conc.
22/01/2007	Mucking	4.2	Chapman Buoy	5.99	Southend	3.39
07/03/2007	Mucking	3.5	Chapman Buoy	3.83	Southend	3.76
11/04/2007	Mucking	4.85	Chapman Buoy	4.71	Southend	4.26
24/04/2007	Mucking	5.65	Chapman Buoy	5.07	Southend	4.64
09/05/2007	Mucking	6.93	Chapman Buoy	5.02	Southend	6.22
15/06/2007	Mucking	5.85	Chapman Buoy	5.64	Southend	5.78
01/08/2007	Mucking	6.56	Chapman Buoy	7.18	Southend	7.04
01/08/2007	Mucking	3.27	Chapman Buoy	3.33	Southend	N/A
02/08/2007	Mucking	3.49	Chapman Buoy	3.67	Southend	N/A
03/08/2007	Mucking	3.49	Chapman Buoy	3.19	Southend	N/A
06/08/2007	Mucking	3.22	Chapman Buoy	3.97	Southend	N/A
31/08/2007	Mucking	6.04	Chapman Buoy	N/A	Southend	N/A
31/08/2007	Mucking	3.55	Chapman Buoy	2.24	Southend	2.46
20/09/2007	Mucking	3.82	Chapman Buoy	3.12	Southend	2.84

20/09/2007	Mucking	3.13	Chapman Buoy	3.47	Southend	N/A
16/11/2007	Mucking	2.83	Chapman Buoy	2.2	Southend	1.15
30/11/2007	Mucking	4.04	Chapman Buoy	2.95	Southend	2.45

Consultation with the Environment Agency suggests that the high levels of dissolved copper observed in the outer estuary are thought to be the result of sampling artefact and have not been confirmed by detailed surveys.

6.2.6 Water Framework Directive

The Water Framework Directive (WFD) introduces a new, integrated approach to water protection, improvement and sustainable use. As a requirement of the WFD the Environment Agency has identified a number of River Basin Districts (RBD) throughout England and Wales. The Thames estuary is located in the Thames River Basin District and has been designated as a transitional waterbody and as a candidate Heavily Modified Water Body (HMWB) due to its flood defences and port infrastructure. Under the requirements of the directive HMWBs must meet Good Ecological Potential (GEP). Unlike Good Ecological Status (GES) GEP can be achieved if suitable mitigation measures are implemented. If this mitigation is in place, then the water body is classified as achieving good or better ecological potential. If this level of mitigation is not in place, then the water body will be classed as moderate or worse ecological potential.

The main water quality concerns for the tidal Thames centre around the impacts of the combined sewer overflow discharges. These discharges to the Thames frequently result in reductions in dissolved oxygen, aesthetic pollution, risk to human health and fish kills. The impact of effluent discharges to the Thames from the five major sewage treatment works which serve London (Mogden, Beckton, Crossness, Riverside and Longreach) are also of concern (Environment Agency, 2008).

The actual WFD based management obligations relating to the Thames are defined in the Thames River Basin Management Plan, which was published as a draft consultation document by the Environment Agency in 2008. Management of the estuary insofar as it relates to water quality and the protection of the estuary's aquatic ecology will be informed by this document.

6.3 Sediment Quality

6.3.1 Methodology

This section describes the chemical and physical characteristics of sediments within the study area. Data on sediment quality within the estuary have been obtained from the PLA and CEFAS. The PLA require sediment at dredging areas to be analysed on a two to three year cycle as part of the dredging licensing process. CEFAS also undertake analysis of sediments within the estuary as part of the FEPA licensing process, albeit only when disposal of sediments are required offshore. When a FEPA application is received by DEFRA, CEFAS carry out analysis of the sediments in order to assess the nature and degree of any chemical contamination present.

The chemical characteristics of the sediments are described in terms of a range of chemical parameters that can be associated with sediment due to their low solubilties in water. The following lists the chemical parameters:

- Heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc) and other metals (aluminium, boron, iron, manganese, selenium, silver and vanadium);
- Organotins (Tributyl tin (TBT) and dibutyl tin (DBT));
- Total petroleum hydrocarbons (TPH);
- Polyaromatic hydrocarbons (PAHs) (USEPA 16);
- Polychlorinated biphenyls (PCBs) including 25 congeners;
- Ammonia; and
- Sulphide.

Unlike water quality, there are no quantified UK environmental quality standards (EQSs) for *in situ* sediment quality. The only guidance for sediment quality is defined as "standstill (no deterioration)" and is required for most of the EC Dangerous Substances List 1 parameters.

In the absence of any quantified UK standards, the sediment quality data has been compared against other guidelines to provide a basic indication about the degree of contamination and its potential suitability for disposal. The two sets of standards are:

- CEFAS guideline action levels for the disposal of dredged material; and
- Canadian Sediment Quality Guidelines for the protection of aquatic life.

CEFAS's guideline action levels for the disposal of dredged material are not statutory contaminant concentrations for dredged material but as used as part of a weight of evidence approach to decision-making on the disposal of dredged material to sea. The action levels are presented in Table 6.12.

Table 6-12 CEFAS guideline action levels for dredged material (CEFAS, 2005)

Contaminant / Compound	Action Level 1	Action Level 2
	mg/kg Dry Weight (ppm)	mg/kg Dry Weight (ppm)
Arsenic	20	100
Mercury	0.3	3
Cadmium	0.4	5
Chromium	40	400
Copper	40	400
Nickel	20	200
Lead	50	500
Zinc	130	800
Organotins; TBT DBT MBT	0.1	1

Contaminant /	Action Level 1	Action Level 2
PCB's, sum of ICES 7	0.01	none
PCB's, sum of 25 congeners	0.02	0.2
***DDT**	*0.001	
***Dieldrin**	*0.005	

*these levels were set in 1994

These values are used in conjunction with a range of other assessment methods, for example, bioassays, as well as historical data and knowledge regarding the dredging site, the material's physical characteristics, the disposal site characteristics and other relevant data, to make management decisions regarding the fate of dredged material. The action levels are therefore not 'pass/fail' criteria but triggers for further assessment. 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. Dredged material with contaminant levels between action levels 1 and 2 requires further consideration and testing before a decision can be made.

The Canadian Sediment quality guidelines were developed by the Canadian Council of Ministers of the Environment as broadly protective tools to support the functioning of healthy aquatic ecoystems (CCME, 2001). They are based on field research programmes that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms.

Comparison of measured concentrations of various contaminants within the sediments with these guideline values will, therefore, provide a basic indication on the degree of contamination and likely impact on ecology.

The guidelines consist of threshold effect levels (TELs) and probable effect levels (PELs). The TELs and PELs are used to identify the following three ranges of chemical concentrations with regard to biological effects. It is likely that the TELs will be adopted as the ISQGs (CCME, 2001):

- Below the TEL; the minimal effect range within which adverse effects rarely occur.
- Between the TEL and PEL; the possible effect range within which adverse effects occasionally occur
- Above the PEL; the probable effect range within which adverse effects frequently occur.

Table 6.13 lists the existing sediment quality guidelines for some of the parameters that have been monitored.

Table 6-13 Interim marine sediment quality guidelines (ISQGs)/threshold effect levels (TELs), probable effect levels (PELs) (dry weights) and incidence (%) of adverse biological effects in concentrations ranges defined by these values

Substance	Units	ISQG/TEL	PEL	Incidence (%≤ISQG)	Incidence (ISQG<%<PEL)	Incidence (%≥PEL)
Metals						
Arsenic	mg.kg-1	7.24	41.6	3	13	47
Cadmium	mg.kg-1	0.7	4.2	6	20	71
Chromium	mg.kg-1	52.3	160	4	15	53
Copper	mg.kg-1	18.7	108	9	22	56
Lead	mg.kg-1	30.2	112	6	26	58
Mercury	mg.kg-1	0.13	0.7	8	24	37
Zinc	mg.kg-1	124	271	4	27	65
Polychlorinated byphenyls (PCB)						
PCBs: total PCBs	µg.kg-1	21.5	189	16	37	55
Polyaromatic hydrocarbons (PAH)						
Acenaphthene	µg.kg-1	6.71	88.9	8	29	57
Acenaphthylene	µg.kg-1	5.87	128	7	14	51
Anthracene	µg.kg-1	46.9	245	9	20	75
Benz(a)anthracene	µg.kg-1	74.8	693	9	16	78
Benzo(a)pyrene	µg.kg-1	88.8	763	8	22	71
Chrysene	µg.kg-1	108	846	9	19	72
Dibenz(a,h)anthracene	µg.kg-1	6.22	135	16	12	65
Fluoranthene	µg.kg-1	113	1494	10	20	80
Fluorene	µg.kg-1	21.2	144	12	20	70
2-Methylnaphthalene	µg.kg-1	20.2	201	0	23	82
Naphthalene	µg.kg-1	34.6	391	3	19	71
Phenanthrene	µg.kg-1	86.7	544	8	23	78
Pyrene	µg.kg-1	153	1398	7	19	83

6.3.2 Overview of sediment quality within the study area

Sediment quality data for a number of locations within the study between 2002 and 2005 are presented in tables 1 to 3 of Appendix D. A summary of sediment quality in the estuary is provided below.

Metals and organotins

The data collated indicates that the vast majority of concentrations of metals within the study area all fall below the CEFAS action level 2. There is only one exception in the Tilbury area which recorded TBT concentrations above the CEFAS action level 2.

For the Shellhaven and Tilbury areas, a number of samples exceed the CEFAS action level 1. These are mainly concentrations of TBT, chromium, copper, mercury, nickel, lead and zinc.

Concerning the sediment quality guidelines, the majority of samples either fall below the lower interim sediment quality guideline or record values in between the TEL and PEL values. There are only three samples which exceed the higher probable effect level (PEL) value and these are for lead and mercury in the Denton and Shellhaven areas.

Polychlorinated Biphenols (PCBs)
The majority of samples did not detect PCB contamination. Where PCB concentrations were recorded, in two of the three samples at Custom Quarry Gravesend, levels marginally exceeded the higher PEL value.

Poly Aromatic Hydrocarbons (PAHs)
CEFAS action levels do not contain values for individual PAHs. The action levels are therefore based on total PAHs. All samples, where analysis was undertaken for total PAHs, did not detect PAH contamination.

Canadian sediment guidelines however contain individual values for specific substances. Where values were recorded, the majority indicated substance concentrations between the interim sediment quality guideline and the higher PEL.

Summary
The sediment quality throughout the study area exhibits a varied degree of contamination from a variety of substances**.** Contamination levels however remain predominantly below the higher CEFAS action levels and the higher sediment quality guideline levels.

6.4 Intertidal ecology

6.4.1 Methodology

A large amount of marine biological data is available for the Thames Estuary. The main data sources used for the study were marine ecological surveys carried out to inform the London Gateway Port Environmental Impact Assessment (Table 6.14). These provide a comprehensive coverage of the study area. A number of other data sources on the estuary also exist such as the Environment Agency Thames Benthic Monitoring Programme, established in 1989.

Table 6-14 Data sources used to produce this section

Publication Date	Reference
2001	Newell R.C., Seiderer L.J., Robinson J.E. & Simpson N.M (2001) London Gateway Port Project benthic biological resource survey of the lower Thames Estuary, July-September 2001. Marine Ecological Surveys Limited, Cornwall.
2002	Newell R.C., Seiderer L.J., Robinson J.E. & Simpson N.M (2002) London Gateway Port Project benthic intertidal biology of the lower Thames Estuary, July 2002. Marine Ecological Surveys Limited, Cornwall.
2002	The (London Gateway Port) Harbour Empowerment Order 2002 Environmental Statement, Chapter 19. Royal Haskoning.
2005	Royal Haskoning (2005). Frost *et al*., East Tilbury Jetty Environmental Statement.
2007	Port of London Authority (2007a) Benthic Ecology of the Thames Estuary.

6.4.2 Overview of the intertidal ecology of the Thames Estuary

The intertidal areas of the Thames Estuary are characterised by large expanses of mud and sandflats backed by seawalls with some small areas of saltmarsh. There are two main areas on the northern shore of the Thames within the study area: Mucking Flats and Holehaven Creek. Mucking Flats comprises a large area of intertidal mudflats backed by seawall with occasional patches of saltmarsh. The mudflats are largely uniform and homogeneous in terms of sediment composition and stretch from Tilbury to Stanford-le-Hope covering approximately 312 hectares, and extend approximately 0.5km offshore. Holehaven Creek is a sheltered inlet containing many sandbanks that dry at low tide. The west bank of Holehaven Creek comprises a seawall with a rubble foreshore, and at the mouth of the creek is an island. Lower Horse Island is an area of saltmarsh which is surrounded by intertidal sandy mud with cockle beds on the western edge.

On the southern shore of the Thames is a large area of intertidal called Blyth Sands extending up to 1km offshore. Western Blyth Sands, from Egypt Bay to Cliffe Creek, comprises a large expanse of sandflat backed by a seawall fronted by a strip of rocks. Occasional strips of saltmarsh occur which are generally between 10 to 15 m wide. Patches of cobbles are also occasionally present. Eastern Blyth Sands is similar to the western half in that it is backed by seawall with a narrow strip of stones at its base. However, at the eastern end of Blyth Sands, off Allhallows-on-sea, localised patches of other communities, such as seagrass beds and mussels are present. Occasional patches of sandy substrate are also present within Egypt and St Mary's Bays.

Seagrass beds are also present in the estuary. Significant stands are known to occur at Maplin sands (c. 300ha) and at Leigh-on-sea in Essex (c. 95ha). The Maplin sands site, which occurs beyond the study area, is thought to represent the largest surviving continuous population of seagrass in Europe (Environment and Heritage Service, 2003). Within the study area seagrass beds are found adjacent to Two Tree Island near Benfleet Creek which is an important feeding site for overwintering dark-bellied brent geese.

Data on the intertidal communities of the study area are available from an intertidal biotope survey carried out by Royal Haskoning in 2001 and from grab surveys carried out by Newell *et al* in 2001 and 2002. The PLA has also recently commissioned a study looking at benthic ecology of the Thames Estuary (PLA, 2007). These surveys have found that the mud and sandflats are dominated by large populations of *Corophium volutator, Macoma balthica* and a variety of polychaetes, forming two main biotopes: '*Hediste diversicolor* and *Macoma balthica* in sandy mud shores' and '*H.diversicolor* and *Scrobicularia plana* in reduced salinity mud shores' (Royal Haskoning, 2002). The seawalls backing these intertidal flats are colonised by the algae *Fucus vesiculosus* and *Ascophyllum nodosum* along their base. Newell *et al* (2001) found that the infaunal community of intertidal mudflats within the inner Thames Estuary is dominated by *Tubificoides benedii, Aphelochaeta marioni, Corophium volutator* and *Streblospio shrubsolii*. Large population densities of *T. benedii* were recorded mainly on the higher shore at the western end of Blyth Sands, on Mucking Flats and at Holehaven. Significant populations of *Hediste diversicolor* are also located in these areas. Analysis of PLA data has also shown spatial variability in species diversity. High species diversity was typically observed from the Swale Estuary, along the Kentish Flats and off the Canvey Island/Vange Creek area, while low diversity was typically observed off Gravesend.

Relatively high biomass values for molluscs were also recorded along the upper intertidal mudflats of Blyth Sands and Mucking Flats reflecting the presence of a number of bivalves including *Macoma balthica*, *Scrobicularia plana* and the snail *Hydrobia ulvae* (MES, 2002). Much of the muddy intertidal flats in these areas and Holehaven are therefore of potential importance as feeding areas for birds capable of exploiting *Macoma balthica* and other species as a food resource.

Benthic algae within the Thames Estuary are mainly restricted to river walls, mussel, shingle and shell banks, saltmarsh and floating structures. Fucoid seaweeds are common as are *Ectocarpus silliculosus* and *Chaetomorpha capillaria*. The upstream limit of some algal species has moved in recent years. This is a reflection of decreasing water quality and reduced salinity associated with decreased freshwater flow (Newell *et al.,* 2001). The increasing prevalence of hard defences around the estuary has led to an increase in fucoid seaweeds which rapidly colonise hard substrates to the exclusion of soft-sediment species.

Saltmarsh within the Thames Estuary is dominated by *Spartina maritima* at the pioneer level and *Puccinellia maritima* and *Salicornia* on the lower marsh. The rare golden samphire *Inula crithmoides* is also common within the Thames (Newell *et al*., 2001).

Overall the benthic infauna in the estuary is diverse although no nationally rare species have been recorded by the various surveys. It is noted that the mixed sands and muds of Blyth Sands, Mucking Flats and the sheltered creeks of the inner estuary support much higher population densities and species diversity of benthic macrofauna than the subtidal deposits. The intertidal areas of the inner estuary also support a much higher biomass of benthic invertebrates than those of the outer estuary. The communities of shallower water areas and mudflats demonstrate increased dominance by few species which is a reflection of a natural reduction in habitat complexity in the more uniform sediments within these locations (rather than human-induced stress). Generally surveys have underlined the importance of the intertidal mixed sands and muds in supporting a high species diversity, population density and biomass of benthic invertebrates. Some of these are of economic significance whilst others form an important potential food resource for wading birds.

6.4.3 Overview of the subtidal ecology of the Thames Estuary

The subtidal regions of the study area consist of the main shipping channel that runs down the centre of the tidal Thames and the shallower areas either side of the dredged channel. The infaunal communities within the subtidal are dominated by two main community types. Deposits in the central channel support a community including *Balanus crenatus*, juvenile Mytilidae, *Polydora caeca, Tubificoides benedii, Hediste diversicolor, Lanice conchilega* and *Streblospio shrubsolii*. The sediment either side of the channel, along the shallow subtidal areas of Blyth Sands and off Holehaven, support a different range of species including *Nephtys hombergii, Tubificoides benedii* and *Aphelochaeta marioni*. Another community is also present in the subtidal, albeit only in isolated patches. This assemblage comprises juvenile Mytilidae, the polychaete *Aphelochaeta marioni* and barnacles *Balanus crenatus*.

Macroinvertebrates in the outer estuary are dominated by the brown shrimp *Crangon crangon*, the swimming crab (*Liocarcinus holsatus*) and the prawn (*Pandalus montagui*). Prevalent fish species include the goby (*Pomatoschistus* spp.), whiting, dab and poor cod. The inner estuary is dominated by large numbers of fewer species. *C. crangon* and *P. montagui* are still prevalent, as are goby and whiting. Swimming crabs are replaced by shore crabs (*Carcinus maenus*) in the upper estuary, a reflection of reduced salinity.

Analysis of trawl data held by the PLA has also demonstrated a trend from marine species occurring in the outer estuary to brackish water species and freshwater species tolerant of increased salinity occurring in the mid and inner estuary (PLA, 2007a). Typical epibenthic species recorded in the trawls include the brown shrimp *Crangon crangon*, swimming crabs *Liocarcinus spp* and the sea urchin *Psammechinus miliaris*.

The Thames Estuary supports a number of commercially important species. The central part of the inner estuary supports a high biomass of brown shrimp *Crangon crangon*. This area is also an important nursery area for juvenile and post juvenile fish. The whole estuary is important for dover sole *Solea solea* with highest abundances being present in the areas of high brown shrimp biomass. Gut content analysis has showed that brown shrimp forms the major food source for dover sole (Newell *et al*., 2001). Other commercially important species include bib *Trisopterus luscus*, whiting *Merlangius merlangus* and herring *Clupea harengus*,

Another community is present within the southern part of the outer estuary in areas dominated by the colonial bryozoan *Alcyonidium diaphanum,* which provides shelter and habitat for a dense community of fish and invertebrates with higher diversity and abundance than elsewhere in the estuary. Dominant species include *Gammarus* spp., *P. montagui, C. crangon, L. holsatus,* starfish (*Asterias rubens*) and gobies.

In the Chapman Buoy area of the main shipping channel to the south of Canvey, the substratum is highly heterogeneous and comprises muddy sand, clay, stones, shells and sodden wood. This combined with good water quality, results in the invertebrate community here being the most species rich and diverse in the whole estuary. The tubeworm *Sabellaria spinulosa,* has also been found in patchy densities associated with coarse sediment offshore of Canvey Island. Present evidence suggests that the distribution of *Sabellaria* is probably patchy over a general area of coarser seabed between Canvey and to at least 2.5km towards Chapman Buoy (Calor Gas, 2006). The site also consistently records high biomass due to the presence of many large species, the most important being the sea anemone *Sagartia troglodytes*, the fan worm *Sabella pavonina* and the shore crab *Carcinus maenus*. The clay walls of the channel contain a large number of boring piddocks (*Petricola pholadiformis* and *Barnea candida*). The community in the shipping channel was characterised by a wide range of species, some of which were only recorded from this site. This high diversity has been attributed to the high stability of the sediment and good water quality surrounding the site.

In the Chapman Buoy area, the shallow subtidal area to the south of the channel has a very different community from that of the north. The substratum is fairly mobile muddy sand, and the fauna associated with this area (e.g. Blyth Sands, Grain Flats) is lacking in diversity and biomass in comparison to other intertidal and subtidal areas of the outer estuary. The fauna seawards of Blyth and Grain Flats is very similar, and characterised by a low biomass and a variable community structure. This low faunal diversity may be due to large amounts of decaying plant material, such as seagrass, that accumulate on the southern side of the outer estuary.

Overall, whilst not as diverse as the intertidal areas within the Thames Estuary, the subtidal supports communities containing some species that are important potential food resources for commercial fish e.g. sole Solea solea feeds upon brown shrimp. *C. crangon*.

6.5 Ornithology

6.5.1 Methodology

Bird count data have been collected for the Thames Estuary for a number of years as part of the Wetland Bird Survey (WeBS). WeBS is a joint scheme of the British Trust for Ornithology, the Wildfowl and Wetlands Trust, Royal Society for the Protection of Birds and the Joint Nature Conservation Committee. The scheme aims to provide a scientific basis for the conservation of waterbird populations. The counts form two types: Core Counts which are undertaken once a month on pre-selected dates around the winter period (normally) at high tide. Low tide counts are conducted at low tide on most estuaries around once every six years, with up to four counts being made throughout the winter period.

Core Counts

Core Count data was provided by the RSPB for the period 2002/03 - 2006/07. Data was summarised from the sectors shown in Table 6.15.

Table 6-15 Count sectors used to calculate mean peaks

Count Sector	ID Number	Corresponding SPA / SSSI
Reedham Mead	22811	Thames Estuary and Marshes SPA
Cliffe and Cooling	22812	Thames Estuary and Marshes SPA
St Marys Marsh	22902	Thames Estuary and Marshes SPA
North Grain Offshore	22903	Thames Estuary and Marshes SPA
Coombe Bay Offshore	22904	Thames Estuary and Marshes SPA
Higham Bight	22905	Thames Estuary and Marshes SPA
Yantlet and Allhallows	22906	Thames Estuary and Marshes SPA
Yantlet Beach	22907	Thames Estuary and Marshes SPA
Yantlet Saltmarsh	22908	Thames Estuary and Marshes SPA
Cliffe Creek and Offshore	22909	Thames Estuary and Marshes SPA
Lower Hope point Offshore	22910	Thames Estuary and Marshes SPA
Cliffe and Cooling Offshore	22912	Thames Estuary and Marshes SPA
Tilbury to Mucking	25902	Thames Estuary and Marshes SPA
Canvey Point	25411	Benfleet and Southend Marshes SPA
Leigh Marsh and Two Tree Island	25412	Benfleet and Southend Marshes SPA
Southend and Seafront	25415	Benfleet and Southend Marshes SPA
Benfleet Creek	25416	Benfleet and Southend Marshes SPA
Vange and Holehaven	25414	Holehaven SSSI

This represents the most recent information available on bird numbers across the study area. Core Count data is provided for each sector (a specific geographical survey area), and is reported on for mean peak figures for each species over a five year period (in this case 2002/03 – 2006/07). To provide population estimates for the entire SPA, the Core Counts for each sector which fall within the boundaries of the SPA were combined to give an overall figure.

Information on bird usage of the study area has also been collated from other sources such as the "*Thames Estuary Partnership: Tidal Thames Habitat and Species Audit*" and the latest wetland bird survey report published in July 2008. (BTO, 2008).The focus of this section is on the intertidal areas of the study area rather than the inland habitats, as it is the intertidal which has the most potential to be affected by maintenance dredging.

Low water counts

Unlike Core Count data which is collected every year low water counts are only undertaken every 6 years. The most recent data for the Thames Estuary was supplied by the RSPB for the overwintering period 2002—2003. Data is described for the whole Thames estuary including sectors that are not present within the protected areas.

6.5.2 Overview of ornithological interest of the study area

The biological richness and productivity of the Thames Estuary is reflected in the number of waterbirds, particularly waders and wildfowl, which it supports. The estuary contains a variety of habitats, which increase the diversity of species that use it. For example, waders and ducks are dependent on feeding on the benthic invertebrates of mudflats and shallow waters; dark- belied brent geese feed on eelgrass and algae; and an array of diving birds depend on small fish, crustaceans and molluscs sought in the channels at low water and over the mudflats at high water.

The importance of the Estuary for waterbirds is reflected in its SPA designations under the Birds Directive (see Sections 3 and 4). The estuary is designated as the Thames Estuary and Marshes SPA from Tilbury to Mucking on the north shore of the estuary, and Cliffe to Grain on the south shore of the estuary. Adjacent to this site on the north shore of the estuary is the Benfleet and Southend Marshes SPA.

Both sites are of European importance for a number of waterfowl species. Avocet, an Annex 1 species, qualifies under Article 4.1 (79/409/EEC) on the Thames Estuary and Marshes SPA, by occurring in levels of European importance during the winter months.

Non Annex 1 species occurring in levels of European importance at one or both of the designated sites during the winter months are dunlin, knot and grey plover (both sites) black tailed godwit and redshank (Thames Estuary and Marshes SPA only) and ringed plover and brent goose (Benfleet and Southend Marshes SPA only). Ringed plover occur in levels of European importance and qualify under Article 4.2 (79/409/EEC) on the Thames Estuary and Marshes SPA during spring and autumn passage periods.

Both sites are recognised as supporting internationally important assemblages of birds, with over 75,000 waterfowl regularly recorded on the Thames Estuary and Marshes SPA and over 34,000 waterfowl regularly recorded on the Benfleet and Southend Marshes SPA.

Another Annex 1 species, hen harrier, (a non-waterfowl species - a raptor, which is unlikely to be impacted upon by dredging operations), also occurs in the Thames Estuary and Marshes SPA and is a qualifying species for this designation under Article 4.1 (79/409/EEC).

Other Annex 1 species that regularly occur on the Thames Estuary and Marshes SPA in non-qualifying numbers are breeding common tern, and passage and wintering bewick's swan, golden plover, ruff, short-eared owl and kingfisher.

In addition to the SPA designations, the Thames Estuary and Benfleet and Southend Marshes have been recognised as internationally important wetlands through their designation as Ramsar sites.

6.5.3 Analysis of waterbird assemblage

Table 6.16 summarises the overall waterbird assemblage of the Thames Estuary and Marshes SPA for the period 2002/03 - 2006/07 and shows the 5 year mean peak for these years. Table 6.17 shows the same information for Benfleet and Southend Marshes SPA. Data for Tilbury to Mucking has also been included to show the importance of Mucking Flats SSSI as a feeding and roosting site within the Thames Estuary and Marshes SPA. Similarly Vange to Holehaven sector has been included in Table 6.17 to illustrate the importance of Holehaven Creek SSSI, although to date this site has not been included in the Benfleet and Southend Marshes SPA.

The data presented is only representative of the SPAs and not the wider area that this review covers. Historical trends in species populations based on the WeBs Core Counts data are presented in Appendix E and discussed in section 6.5.4

Table 6-16 WeBS Core Counts, 2002/03 – 2006/07 for Thames Estuary and Marshes SPA and Tilbury to Mucking count sector

Species	1% thresholds for national and international importance		Thames SPA Autumn 5 Year mean of peaks 2002/03 - 2006/07	Thames SPA Winter 5 Year mean of peaks 2002/03 - 2006/07	Tilbury to Mucking Sector Autumn 5 Year mean of peaks 2002/03 - 2006/07	Tilbury to Mucking Sector Winter 5 Year mean of peaks 2002/03 - 2006/07
	GB	Inter.				
Avocet	10	70	481	626	463	570
Bar-tailed godwit	530	1000	47	88	17	1
Black-tailed godwit	70	700	2025	657	273	385
Curlew	1200	3500	1458	1455	31	47
Dark-bellied brent goose	1000	3000	230	1442	10	7
Dunlin	5300	14000	3007	14485	2218	7745
White fronted goose	58	10, 000	0	21	0	0
Gadwall	171	600	6	103	0	0
Golden plover	2500	18000	28	376	1	18
Great crested grebe	159	3, 600	0	8	0	0
Greenshank	50	3000	28	1	7	0
Grey plover	430	1500	630	1051	186	393
Knot	2900	5000	191	3487	38	9
Lapwing	20, 000[2]	20, 000	552	2365	131	541
Oystercatcher	3600	9000	2073	1497	4	11
Pink-footed goose	2,400	2,700	0	6	0	0
Pintail	280	600	26	54	3	1
Redshank	1100	1500	810	1127	199	423
Ringed plover	290	500	949	326	110	92
Shelduck	750	3000	359	935	223	196
Shoveler	100	400	2	54	0	0
Teal	1400	4000	295	620	0	0
Turnstone	640	700	268	271	1	5
Whimbrel	50	6500	40	0	4	0
Wigeon	2800	12500	799	4630	102	28

1% Thresholds obtained from BTO (2008)

[2] a site regularly holding more than 20,000 waterbirds (excluding non-native species) qualifies as internationally important by virtue of absolute numbers

Table 6-17 WeBS Core Counts, 2002/03 – 2006/07 for Benfleet and Southend Marsh SPA and Vange to Holehaven count sector

Species	1% thresholds for national and international importance		Benfleet SPA (Autumn 5 Year mean of peaks 2002/03 - 2006/07	Benfleet SPA (Winter 5 Year mean of peaks 2002/03 - 2006/07	Vange – Holehaven Creek Sector Autumn 5 Year mean of peaks 2002/03 - 2006/07	Vange – Holehaven Creek Sector (Winter 5 Year mean of peaks 2002/03 - 2006/07
	GB	Inter.				
Avocet	10	70	68	120	1	16
Bar-tailed godwit	530	1000	26	942	1	1
Black-tailed godwit	70	700	1945	562	1131	1070
Curlew	1200	3500	741	809	1139	743
Dark-bellied brent goose	1000	3000	3017	2386	0	2
Dunlin	5300	14000	4562	18459	74	4448
Golden plover	2500	18000	405	1161	0	0
Greenshank	50	3000	50	5	0	0
Grey plover	430	1500	669	1792	1	1
Knot	2900	5000	2074	7380	0	11
Lapwing	20,000[3]	20,000	297	1144	222	3874
Oystercatcher	3600	9000	1433	3393	7	14
Redshank	1100	1500	1128	1029	706	923
Ringed plover	290	500	866	822	0	0
Shelduck	750	3000	18	121	38	309
Teal	1400	4000	122	451	13	289
Turnstone	640	700	408	465	0	0
Wigeon	2800	12500	1678	771	22	252

1% Thresholds obtained from BTO (2008)

[3] a site regularly holding more than 20,000 waterbirds (excluding non-native species) qualifies as internationally important by virtue of absolute numbers

6.5.4 Trends and Alerts

The BTO monitor changes in waterbird numbers through a system of alerts based on WeBS data detailed in Appendix E. The alerts system provides a standardised method of identifying the direction and magnitude of changes in numbers at a variety of spatial and temporal scales for a range of waterbird species for which sufficient WeBS data are available. Species that have undergone major changes in numbers can then be flagged by issuing an alert. Alerts are intended to be advisory and, subject to interpretation, should be used as a basis on which to direct research and subsequent conservation efforts if required (Maclean *et al,* 2005).

Appendix E present the alerts for the Thames Estuary and Marshes SPA and Benfleet and Southend Marshes SPA respectively. The summaries of the alerts include the following key points:

Thames Estuary and Marshes SPA
Of the 14 species evaluated, four species have had alerts triggered, including one that occurs in internationally important numbers. Some of these species have not undergone either national or regional declines of the same magnitude and there is thus some cause for concern, such as European white-fronted goose. More details on these alerts are presented in the following species accounts.

Maclean (*et al,* 2005) identified that threats to the SPA include considerable infrastructure development (such as the Channel Tunnel rail link and road development), sea-level rise that may result in erosion and flooding, agricultural intensification and expansion, dredging proposals, a lack of management, water quality issues and water shortages for wetland enhancements.

Benfleet and Southend Marshes SPA
This SPA lies at the eastern end of the study area, east of Canvey Island, along the north shore of the estuary. Alerts have been triggered for all five species evaluated (ringed plover was not evaluated). This gives some cause for concern, particularly as some of the species for which alerts have triggered have not declined in either Great Britain or England as a whole.

Maclean (*et al,* 2005) identified that threats to the SPA include changing water levels, sea level rise, erosion, reclamation, dredging, shell-fisheries, intensive recreational activities and development proposals.

Key Species on the Thames Estuary

For the purposes of this assessment, key species are defined as being under one of three selection stages (the stage at which the SPA was cited for a given species).

- **Selection Stage 1.1**: species for which the site qualifies by supporting populations of European importance listed in Annex 1 of the Directive (79/409/EEC);

- **Selection Stage 1.2**: species for which the site qualifies by supporting populations of European importance not listed in Annex 1 of the Directive (79/409/EEC); and
- **Selection Stage 1.3**: species for which the site qualifies by making the site a wetland of international importance.

The following species met one of the above criteria for one or both of the two designated sites in question.

Avocet
(Thames Estuary and Marshes SPA)
Avocet is the only Annex 1 waterfowl species for which the Thames Estuary and Marshes SPA is designated and is present in internationally important numbers, so it can arguably be considered to be its single most important component. Within the Thames Estuary, avocet are largely restricted to the lower marine reaches of the river; the mudflats at Higham Bight and Mucking Flats are particularly important for this species and small numbers also breed amongst the saline lagoons at Cliffe (Tidal Thames Habitat Action Plan, 2002). During the five winters between 1995/6 and 1999/2000, the Thames was ranked as the third most important estuary for wintering avocets within the UK (Musgrove *et al*. 2001). In winter 2001/2002, avocets were recorded in nationally and internationally important numbers on two occasions. In March 2002, a record number of 1395 birds were seen (Shaw, 2002). Avocets feed on insects, crustaceans and occasionally small fish and the most recent high water WeBS counts show that over 90% of the SPA population overwinters on Mucking Flats (Table 6.15). No WeBS alerts have been triggered for this species. High increases in the WeBS data have been observed over the short–term (5 year) and long-term (25 years) within the Thames Estuary and Marshes SPA, with percentage increases being +50% and +2675% respectively (BTO, 2008).

Black-tailed godwit
(Thames Estuary and Marshes SPA)
Black-tailed godwits prefer muddy estuaries where they feed chiefly on intertidal invertebrates, with food located by sight and touch. A wide range of invertebrates are taken, including molluscs, ragworms, crustaceans and earthworms. A peak of 629 was recorded by Shaw (2002) in November 2001 and WeBS high water counts indicate that around 14% of the SPA population use Mucking Flats (Table 6.15). Internationally important numbers of black-tailed godwit also occur within Holehaven Creek, Essex (Tidal Thames Habitat Action Plan, 2002). High increases in the WeBS data have been observed over the short–term (5 year) and long-term (25 years) within the Thames Estuary and Marshes SPA, with percentage increases being +136% and +318% respectively (BTO, 2008).

Dark-bellied brent goose
(Benfleet and Southend Marshes SPA)
The dark-bellied brent goose winters in Britain in internationally important numbers. It breeds in western Siberia and winters in Western Europe, with about half the population in Britain. The species feeds on eelgrass and green algae (especially *Enteromorpha* and *Ulva*) which grow on mudflats. Once these food sources are depleted, the birds

move inland to feed on coastal arable farmland and pasture. The birds roost on sheltered coastal and estuarine waters (Batten *et al.*, 1990). Benfleet and Southend Marshes SPA is designated for holding 3,819 birds (5 year peak mean 1991/92 – 1995/96) and significant numbers overwinter on the Thames Estuary and Marshes SPA, although the species is not a qualifying species for this SPA. On Benfleet and Southend Marshes SPA high increases in the WeBS counts (+86%) have been recorded over the medium term (10 years) but medium level decreases (-24%) have been recorded over the long term (25 years) (BTO, 2008).

Dunlin
(Thames Estuary and Marshes SPA and Benfleet and Southend Marshes SPA)
Dunlin feed principally in extensive muddy areas of estuaries on a wide range of invertebrate prey, including polychaete worms, gastropod snails, bivalves, crustaceans and occasionally small fish. They are the second most widespread wintering estuarine species in the UK, occurring throughout Britain and Ireland. They are also by far the most numerous species on the Thames Estuary and Marshes SPA, comprising between 37% of the total assemblage. Both this site and Benfleet and Southend Marshes regularly support over 11,000 wintering dunlin (Tidal Thames Habitat and Species Audit, 2004). WeBS alerts have been triggered for this species on both SPAs. On the Thames Estuary and Marshes SPA medium level short term and medium term alerts have been triggered due to a decline of 33% over both periods. These declines are considered to be of no immediate concern as this species is prone to fluctuations (Maclean *et al*. 2005), and the data is incomplete. On the Benfleet and Southend Marshes SPA, a medium level medium term alert has been triggered due to a decline of 34% in numbers over 10 years, in line with other wader species at the site (BTO, 2008). However, as with other species, the data since the early 1990s is incomplete and it is therefore difficult to validate the data.

European white-fronted goose
(Thames Estuary and Marshes SPA)
The European white-fronted goose winters in Britain in nationally important numbers. It breeds in western Siberia and winters in Western Europe, with about half the population in Britain. They overwinter in significant numbers on the Thames Estuary and Marshes SPA, and although not a designated species for this site, form part of the internationally important wildfowl assemblage (Table 6.15). White-fronted geese forage on farmland for grass, clover, grain and winter wheat, and are found around the Isle of Grain in small numbers (larger numbers are present around the Swale Estuary). The number of European White-fronted Geese over-wintering on the Thames Estuary SPA have decreased slightly over the long term (a fall of 7% over 25 years). The trend contrasts with that of the region, which has fluctuated, but generally increased, but is inline with the national trend, with little evidence of a decrease in the proportion of the national WeBS total hosted by this site. Over the short term period (5 years), numbers have increased significantly (+728%) although numbers appear to be highly variable within the designated site (BTO, 2008).

Gadwall
(Thames Estuary and Marshes SPA)
The gadwall winters in Britain in internationally and nationally important numbers, predominantly on inshore waters (Batten *et al*, 1990). The Greater Thames Estuary Natural Area supports at least 5% of the wintering British population (English Nature, 1997). The Lee Valley and Southwest London Waterbodies SPAs, (approximately 20km upstream from the current study site) are designated for their high numbers of wintering gadwall. Within the study area the species occurs in nationally important numbers at Cliffe Pools (RSPB website), and although not a qualifying species for the Thames Estuary and Marshes SPA, the species is part of the internationally important waterfowl assemblage within the site. No WeBS alerts have been triggered for this species, and the species has exhibited an increase over both the short term (5 years) and long term (25 years) periods of 7% and 444% respectively (BTO, 2008).

Grey Plover
(Thames Estuary and Marshes SPA and Benfleet and Southend Marshes SPA)
This is another widespread species within the Thames Estuary and around 34% of the SPA population overwinter on Mucking Flats. Their diet comprises chiefly polychaete worms, molluscs and crustaceans. Nationally important numbers were recorded within the Thames Estuary and Marshes SPA in November 2001, March 2002 and November 2002 (Shaw, 2002). A medium level WeBS alert has been triggered for this species on the Benfleet and Southend Marshes SPA over the medium term (10 years), as similar to other wader species at the site, grey plover has undergone a gradual decline since the mid 1980s (-28% over 10 years). However, as with other wader species, the data is incomplete since the early 1990s so the validity of the downward trend is hard to assess. On the Thames Estuary and Marshes SPA, a small downward trend has been detected in the short and medium term (-8% and -3% over 5 and 10 years respectively) although a long term (25 years) increase of 206% is recorded (BTO, 2008).

Knot
(Thames Estuary and Marshes SPA and Benfleet and Southend Marshes SPA)
This is the third most numerous estuarine British wader with an average wintering population of 220,000. The mudflats of the Thames estuary are important wintering sites for this species (Batten *et al*, 1990). Knot are specialist feeders on marine bivalves, particularly *Macoma balthica*, *Mytilus edulis* and *Cerastoderma* sp in the length range 3 – 15 mm. WeBS alerts have been triggered for this species on both designated sites. A medium level short term alert has been triggered on the Thames Estuary due to a decline of 34% over the past 5 years (BTO, 2008). A medium level, medium term alert has been triggered at Benfleet and Southend Marshes SPA due to a decline of 32% over the past 10 years. Both sites exhibit long term increases however, and the declines are thought to be of no immediate concern on the Thames estuary and Marshes SPA, as this species is prone to fluctuations in numbers (Maclean *et al*., 2005). The decline on the Benfleet and Southend Marshes SPA is difficult to validate due to the incomplete data set since the early 1990s.

Lapwing
(Thames Estuary and Marshes SPA)
Lapwing are one of the most numerous estuarine British waders, and forage on saltmarsh for a variety of invertebrates. The highest known winter concentrations of lapwings are found at the Somerset Levels, Humber and Ribble estuaries, Breydon Water/Berney Marshes, the Wash, and Morecambe Bay. Within the Thames Estuary there is widespread suitable habitat for lapwing in the lower Thames Estuary (UK BAP website), this species occurs in significant numbers throughout the Greater Thames Natural Area (English Nature, 1997). No alerts have been triggered for this species at the site, with a short term increase over 5 years of 3% and a long term increase over 25 years of 395% on the site (BTO, 2008).

Little Grebe
(Thames Estuary and Marshes SPA)
Little grebe chiefly overwinters on inland freshwater sites (Davidson *et al* 1991), although approximately 10% over winter on estuaries and coastal habitats, with the Thames estuary providing an important wintering site (RSPB website). No alerts have been triggered for this species at the site, with a short term increase over 5 years of 39% and a long term increase over 25 years of 147% on the site (BTO, 2008).

Oystercatcher
(Benfleet and Southend Marshes SPA)
Wintering oystercatchers are associated with a variety of intertidal habitats, particularly sandy estuaries and beds of cockles and mussels. They are widespread throughout Britain with large numbers present on the Thames Estuary. The Greater Thames Estuary Natural Area supports at least 5% of the wintering British population (English Nature, 1997). A medium-level WeBS alert has been triggered for this species over the medium-term (10 year) on the Benfleet and Southend Marshes SPA, following a decline of 29% over the time period (BTO, 2008). Over the long term, counts have increased and due to incomplete data since the early 1990s the validity of the medium term decline is hard to assess. Oystercatcher is not a qualifying species for the Thames Estuary and Marshes SPA (although part of the internationally important assemblage).

Pintail
(Thames Estuary and Marshes SPA)
The Icelandic population of pintail spend the winter in Britain, favouring coastal marshes and estuaries, flooded grassland, lakes and reservoirs. They eat a variety of plants and invertebrates. The Greater Thames Estuary Natural Area supports at least 5% of the wintering British population (English Nature, 1997). Within the study site Cliffe Pools support nationally important numbers of pintail (RSPB website). No alerts have been triggered for this species at the site, with a short term increase over 5 years of 69% and a long term increase over 25 years of 214% within the site (BTO, 2008).

Redshank
(Thames Estuary and Marshes SPA)
Redshank overwinters in nationally important numbers on the saltmarsh within the Thames Estuary on both of the SPA sites, although only the Thames Estuary and Marshes SPA is actually designated for this species. Additionally, small numbers also

breed on the wetter grazing marsh areas adjacent to the Thames in the lower reaches of the estuary (Tidal Thames Habitat Action Plan, 2002). They are known to feed on a variety of invertebrates but typically feed on crustaceans, molluscs and polychaete worms on estuaries. Redshank is mainly a winter and passage-migrant within the Thames Estuary because suitable breeding habitat conditions are limited. No alerts have been triggered for this species at the site, with a short term increase over 5 years of 5% and a long term increase over 25 years of 44% within the site (BTO, 2008).

Ringed Plover
(Thames Estuary and Marshes SPA and Benfleet and Southend Marshes SPA)
Ringed plover are widely distributed along the lower reaches of the river in numbers of international importance. The Thames Estuary and Marshes SPA and Benfleet and Southend Marshes SPA represent nearly 3% of the UK's passage population of ringed plover (Tidal Thames Habitat and Species Audit, 2004). They feed on invertebrates in a variety of intertidal habitats and roost communally, close to feeding sites along the shoreline, on sandbanks or bare arable fields and in low vegetation. Due to uncharacteristically high numbers recorded on the Thames Estuary and Marshes SPA during two winters in the early-1990s, ringed plover have declined sufficiently to trigger a medium-term high-alert within the Thames Estuary and Marshes SPA (-56% over 10 years). However, apart from these two winters, numbers have remained relatively stable despite regional and national declines (Maclean *et al*. 2005). Furthermore, count data in recent years has been incomplete making declines hard to assess. On the Benfleet and Southend Marshes SPA, a medium level long-term alert has been triggered due to a decline of 33% over 25 years. However, due to incomplete data the validity of this decline is hard to assess (BTO, 2008).

Shelduck
(Thames Estuary and Marshes SPA)
Shelduck has a coastal distribution in Britain, with intertidal sands and mudflats forming the main foraging areas. Their diet includes a variety of invertebrates but predominantly the snail *Hydrobia*. Breeding shelduck are widely distributed within the tidal Thames where suitable habitat occurs. The Thames Estuary and Marshes SPA supports significant numbers of wintering shelduck (Table 6.15).

Since the early-1990s, shelduck numbers on the Thames Estuary and Marshes SPA have decreased sufficiently to trigger medium level medium and long term alerts (-35% and -25% respectively) (BTO, 2008). The regional and national WeBS totals have undergone similar declines, with little evidence of consistent decreases in the proportions of the regional and national WeBS totals hosted by this site. This would suggest that large-scale processes are responsible for the downturn in numbers on this SPA (Maclean *et al*. 2005).

Shoveler
(Thames Estuary and Marshes SPA)
This species winters in Britain on shallow freshwater areas with plentiful marginal reeds or emergent vegetation (Batten *et al*, 1990). The Thames Estuary is an important area for this species with an average of 300 birds wintering annually, particularly on Cliffe Pools (RSPB Website). No negative WeBS alerts have been triggered for this species,

and shoveler counts have increased by 15% and 41% over the short term and long term periods respectively.

6.5.5 Low water counts

The Thames Estuary, for the purposes of the low water counts, is usually taken to include the coast between the Rivers Medway and Crouch. The coverage achieved during counts in 2002/03 was partial and concentrated on the southern shoreline between Shorne Marshes (Gravesend) and the Isle of Grain power station. No counts were made along the northern shore of the Thames, nor within the inner part of the estuary. Low water counts for the estuary are provided in Table 6.18 with a summary of the data provided below.

Table 6-18 Low water counts for the Thames Estuary for 2002 - 2003

Species	Nov	Dec	Jan	Feb	Maximum count
Great Crested Grebe	.	.	.	1	1
Cormorant	67	13	60	51	67
Little Egret	9	6	1	1	9
Grey Heron	7	.	1	2	7
Mute Swan	.	.	4	.	4
Bewick's Swan	5	.	.	.	5
Dark-bellied Brent Goose	47	48	26	.	48
Shelduck	82	118	455	603	603
Wigeon	307	113	7029	1428	7029
Gadwall	2	.	80	63	80
Teal	.	6	565	127	565
Mallard	51	20	66	123	123
Pintail	335	.	263	37	335
Shoveler	.	3	.	3	3
Eider	.	5	1	.	5
Oystercatcher	482	901	576	404	901
Avocet	.	6	.	3	6
Ringed Plover	39	50	29	50	50
Golden Plover	80	70	30	185	185
Grey Plover	860	1222	534	1109	1222
Lapwing	1473	403	1145	43	1473
Knot	6200	3571	1107	11103	11103
Dunlin	14690	16535	20212	28880	28880
Black-tailed Godwit	953	153	.	785	953
Bar-tailed Godwit	28	.	161	16	161
Curlew	785	738	599	591	785
Spotted Redshank	.	.	.	1	1
Redshank	508	438	312	554	554
Turnstone	15	21	23	5	23
Re-established Greylag Goose	.	.	59	63	63

Cormorant were generally distributed within the main channel, whilst most of the little egret were recorded from Cliffe Pools. Relatively small numbers of dark-bellied brent geese occurred between Lower Hope Point and Allhallows. The greatest densities of shelduck were noted between Lower Hope Point and Egypt Bay, with smaller numbers along the coast to Grain.

The peak count of over 600 shelduck was made in February. Wigeon numbers peaked at more than 7,000 birds in January and were mostly found between Lower Hope Point and Allhallows, with a small concentration also present at Higham Bight. Most of the gadwall recorded also favoured the area around Higham Bight, whilst over 500 teal were concentrated between Lower Hope Point and the Bight.

Mallard were widely scattered along the shoreline, whilst pintail exceeded the threshold for national importance in both November and January. There is likely to be some interchange of many species, including pintail, between adjacent estuaries such as the Medway and Swale. Pintail were concentrated off Coombe Bay and between Egypt Bay and Lower Hope Point further to the west.

Most oystercatcher were found towards the mouth of the estuary, particularly around the Isle of Grain, between Allhallows and Grain. Ringed plover were scattered along all of the shoreline covered, whilst golden plover were mostly concentrated around Cliffe Pools. Conversely, the greatest concentration of grey plover occurred in Egypt and St Mary's Bays, with the highest count of 1,222 birds in December.

The counts of lapwing showed marked fluctuations during the winter, the majority distributed from Allhallows westwards. The maximum count of over 11,000 Knot occurred on the shoreline between Egypt Bay to Grain in February. dunlin were ubiquitous throughout, albeit in lower densities between Lower Hope Point and Cliffe Pools. The peak count of 28,880 occurred in February, and this figure represented just over half of the Core Count peak for the whole estuary.

Of the two species of godwit recorded, bar-tailed godwit was the scarcer, with a maximum count of 161 individuals. In contrast, black-tailed godwit peaked at 953 birds in November. The majority of the black-tailed godwit were found on the flats from Egypt Bay to St Mary's Marshes. Both curlew and redshank were widely distributed, including within the Cliffe Pools complex. A single spotted redshank was recorded in February. Small numbers of turnstone were mostly confined to the shore between Allhallows and Grain. A total of nine species of gull were noted, with black-headed gull the most abundant, peaking at over 4,100 individuals in December. Great back-backed gull (peak of 1,236 individuals) and Herring gull (peak of 808 individuals) were the next most numerous species. Common and lesser black-backed gulls were also present in good numbers.

6.5.6 Overall waterfowl assemblage

Broadly speaking, the extensive mudflats and saltmarsh present within the study area provide some of the most important feeding grounds within the Thames Estuary as a whole. It is likely that the distribution of waterfowl is linked to the presence of productive mudflats in these areas which provide key prey items for waterfowl. In particular, the distribution of dark-bellied brent geese is probably governed by the distribution of eelgrass and green algae. Relatively few alerts have been triggered for the key waterfowl species within the Thames Estuary and Marshes SPA indicating that the site is likely to be in good condition overall. However, a greater number of alerts have been triggered for the Benfleet and Southend Marshes SPA, with all five of the species assessed for this site recording alerts, suggesting that the site may not be in good condition, as wader counts have fallen for all species over the medium term in particular.

6.6 Noise

6.6.1 Methodology

Noise may cause disturbance to SPA species and needs to be considered to establish the baseline against which to compare dredging operations. Limited information was retrieved on current noise levels experienced by the waterfowl populations of the Thames Estuary, and no regular noise monitoring programmes were identified for this area. It has not, therefore, been possible to provide an in depth baseline description of noise levels along this stretch of the Thames. As a result, this assessment examines the likely noise levels that would be generated by the maintenance dredging regime, and therefore the levels likely to be experienced by the waterfowl assemblages of the Thames Estuary and Marshes SPA, Benfleet and Southend Marshes SPA, and Holehaven SSSI.

6.6.2 Baseline Conditions

Background noise is likely to be derived from a variety of sources which include:

- Traffic noise (e.g. A2, A13, A1014 and A1089 which run near by to the designated sites);
- Trains;
- Industry and dockyards (e.g. Port of Tilbury, Shell Bravo, etc);
- Temporary construction noise (i.e. new container and roro facilities at the London Gateway Port site); and
- Water-borne noise from vessels and people.

One of the main sources of noise for the birds of the SPA will be a result of the passage of boat traffic. The Port of London is one of the busiest ports within England; with more than 80 terminals, it is a gateway to London and the south-east of England. The PLA has various by-laws in place regarding the control of noise levels within this area. This includes by-law 47(1):

> *No person shall use or knowingly cause or permit to be used a vessel with an internal combustion engine unless the engine is fitted with a silencer, expansion chamber or other contrivance suitable and sufficient for reducing so far as may be reasonable the noise caused by the escape of exhaust gasses from the engine; Provided that the engine may be fitted with a device for cutting out the silencer expansion chamber or other contrivance so long as the device is used only to enable the engine to be started and for no other purpose.*

Such by-laws limit the disturbing effect of noise for both the users and residents of this waterway, but will also reduce the possible impacts on the wildlife communities as well.

6.6.3 Noise from vessels and maintenance dredging

The main source of noise from a vessel originates from the engine, and may travel via the atmosphere or be transmitted through the structure of the craft. The volume of sound generated and transmitted into the air or water depends on the size, design and location of the engine, and the crafts size and construction. Vessel-based ornithological surveys have previously found that the birds are initially disturbed by the presence of a boat, however, dredgers are generally quieter than such survey vessels (PLA, Princes Channel Environmental Assessment Report, 2004).

Most birds are present within the designated areas of interest during low tide in the winter months. The dredging activities mostly occur around times of high water, and so these birds are not generally present during this time (PLA, 2004) although they may be roosting on nearby saltmarshes.

The dredging activities within this stretch of river are primarily undertaken by water injection dredgers anything up to 4 times a year. The areas being dredged are the jetties and the main navigation channels which are heavily used by many types of vessels, but mainly by the larger ships. These are short-term, infrequent events which will take place during the normal operation of the estuary, and so will be in addition to the noise produced by the passage of the vessel traffic. The birds of the SPA will already be accustomed to such background noise, and the noise levels from the dredging, particularly water injection methods, are comparable to, and often lower than, the ongoing noise from routine ship operations (PLA, 2004).

It is more likely that disturbance to the waterfowl will be caused by the movement and visual presence of such a vessel rather than the noise associated with it (Bureau Veritas-Acoustic Technology, 2003). However, given the slow-moving nature of dredgers (i.e. the lack of fast and sudden movements), it is likely that disturbance arising from their movement and presence would also be low. In light of the above, it is considered that maintenance dredging is unlikely to be causing significant disturbance to waterfowl given the background levels of disturbance and the relative infrequency of dredging activities.

7 DISCUSSION AND RECOMMENDATIONS

7.1 The influence of dredging activity on the SPA and Ramsar sites

The aim of this document is to summarise the baseline conditions prevalent within the study area that are relevant to the conservation status of the European marine sites. The results of this document will then be used alongside the existing maintenance dredging framework procedures when licensing maintenance dredging to determine whether the maintenance dredging is likely to have a significant effect on the European sites. In order to aid these decisions, presented below is a brief discussion of the effects that maintenance dredging may currently be having on the European marine sites.

Theoretically, maintenance dredging has the potential to affect the SPA and Ramsar sites through the following routes:

7.1.1 Changes in the morphology of the estuary through the removal or redistribution of sediment within the system.

Removal of sediment from the system can create an artificial sink for sediment which may modify the fine sediment regime reducing supply to other nearby areas (Royal Haskoning, 2004). In the Thames Estuary this has the potential to occur where material is disposed of onshore. However, over half of the maintenance dredging on the Thames Estuary is now undertaken using WID techniques. This agitation technique, which retains fine sediment in the estuary, is licensed to dredge a maximum of 235,000 m^3 per annum from the berths at Bravo Jetty, Coryton and Oikos and 84,000 m^3 per year at Tilbury Docks. Although, as discussed in Section 6.1.3, between 2002 and 2007 an average of 217,000 m^3 has been dredged from the former berths and 46,000m^3 at Tilbury Docks.

The quantity removed by conventional dredging methods, is up to 50,000m^3 per year (HR Wallingford, 2002e) with this material being placed at Rainham Marshes and Cliffe Pools. It is worth noting that the sediment budget that has been published for the Thames Estuary (Institute of Estuarine and Coastal Studies, 1993) suggested that there was a net sediment shortfall in the budget of some 200,000m^3 per annum, met through material entering the system from the sea. Since 1998, the volume of material taken out of the system to land (Cliffe and Rainham) has reduced, and there is currently some 200,000m^3 per annum of dredging undertaken by WID. Based on the earlier assertion by IECS, the change in dredging practice over the past 15 years balances the budget and suggests the system is in dynamic equilibrium, including the influence of dredging activities. Therefore it is regarded that the annual removal of 50,000-150,000 m^3 of sediment from the estuary is already accounted for in the sediment budget and hence morphology of the study area.

The North Kent CHaMP identifies that under various sea level rise scenarios (2mm and 6mm rises); sediment budgets within the estuaries of the embayment could become increasingly depleted over the next 50 years and go into deficit over the next 50-100 years. It is possible that additional fluvial sediment input may arise, but this is unlikely to amount to a significant additional contribution to make up for shortfalls. There is therefore a clear need to ensure that mudflat and saltmarsh health are monitored and an ongoing evaluation of sediment input is maintained. If the effects of shortfalls are identified, there will be a need to find additional ways of retaining sediment within the system through techniques such as WID and sediment placement at suitable locations. It is anticipated that the DCA will evolve over time to incorporate and respond to new information on sediment regimes as it becomes available (i.e. through key projects and initiatives such as TE2100 and the forthcoming Greater Thames CHaMP), as described in Section 7.3.1.

There is some evidence for change in bathymetry within the entrance to Holehaven Creek and to Mucking Flats, indicating changing morphologic conditions. The redistribution of sediment within the system as a result of WID, has been considered in studies by HR Wallingford EX4936, March 2007) and Environmental Tracing Systems (RE40981, November 2003). HR Wallingford concluded that the material arising from WID should not cause significant damaging changes to either the general estuary regime or the maintenance dredging commitments of local river users, and that the impact was no different to that arising from a cessation of dredging at the location of the WID exercise. HR Wallingford also concluded that WID should not be used in higher reaches of the estuary (above Tilbury). However, as noted above, the annual remobilised volume relative to the sediment budget in the outer estuary is not significant. The current trend for accretion has been identified from survey data predating the implementation of WID techniques. The current deposition pattern, while additionally influenced by particular climatic events in noted years, does not appear to have significantly accelerated or altered this underlying trend. The Institute of Esturine and Coastal Studies analysis of Coastal Processes and Conservation in the Thames Estuary (October 1993) concluded that *the estuary has reached dynamic equilibrium and that dredging at the rate practiced over the 100 years does not appear to have any deleterious effect on the intertidal morphology of the estuary. Dredge spoil dumping within the estuary system until 1961 merely resulted in a rapid return of the sediment to the dredge sites. Mudflats within the estuary appear to have responded not only to sea level changes, but to have kept pace with the increase in the rate of such sea level rise which appears to have taken place over the past 40 years.*

7.1.2 Mobilisation of contaminants during maintenance dredging operations.

This could potentially affect the SPAs/Ramsar by remobilising and redistributing contaminated sediments within the estuary which could then affect prey species for birds. The provision of sediment samples is a requirement of all new dredging applications and samples must be provided once every two years for ongoing maintenance dredging operations. The PLA has developed guidelines on the number of samples required which is dependent upon the quantity of sediment to be dredged. This provides a mechanism for modifying or preventing dredging if the sediments are significantly contaminated. In some areas of the estuary, contaminants are present at deeper levels within the sediments, and a buffer layer is maintained to prevent dredging of the contaminated sediments. However, it is understood that in no locations has contamination been identified which precludes dredging but it does influence the type of dredging that is permitted. For example, if contamination levels are sufficiently high then dispersal dredging methods such as WID may not be acceptable. In this case methods such as backhoe which minimise dispersion of sediment may be preferred. It is therefore considered unlikely that maintenance dredging has to date had an adverse effect on the integrity of the European Marine Sites through remobilisation of contaminated sediments. Furthermore, assuming the existing Maintenance Dredging Framework testing regime stays in place, it is unlikely that an impact would be allowed to occur in the future.

7.1.3 Increased levels of suspended sediment

Increased levels of suspended sediment associated with maintenance dredging has the potential to smother sedentary invertebrate species such as bivalves and polychaetes, marine macroalgae and seagrass. Depending on the scale of the dredge and the proximity to sensitive habitats suspended sediment modelling may be required to predict the extent of the plume and where deposition may occur.

As part of the Smallgains Creek dredge application the PLA required the applicant, Island Yacht Club, to undertake sediment modelling to assess whether the proposed dredge would impact upon the sensitive seagrass beds in Benfleet Creek. Modelling showed that peak levels of up to 200 mg l^{-1} above background levels may occur with a duration of 10-20 minutes before gradually decaying to normal background levels. The sediment dispersion modelling was designed to identify the dredging solution with the least impact on the sensitive seagrass beds within the SPA, an important feeding habitat for brent geese. The modelling indicated that approximately 25% of the seagrass beds may be affected by an increase in suspended sediment levels of up to 0.1g l^{-1}. It was shown that these increases in suspended sediment will be short-lived and will decay to normal background levels within a period of approximately twenty minutes.

In addition it was shown that if dredging occurred on an ebb tide the seagrass beds will only be subject to the increased levels for a twenty minute period during each twelve hour tidal cycle. The potential peak increase of 0.1g l^{-1} from the proposed dredging works is likely to be comparable to the maximum levels experienced at the site during the range of normal conditions, for example, storm events.

A number of mitigation measures were required under the terms of the dredging licence for Smallgains Creek, and other licences as required. As such it is considered unlikely that maintenance dredging has to date had an adverse effect on the integrity of the European Marine Sites through increases in suspended sediment.

In addition as part of Natural England's advice given under Regulation 33 for the Thames Estuary and Marshes SPA they recognise that given the natural background levels of suspended sediments in the estuary exposure to damage by siltation is rated as low to moderate and the habitats and qualifying species of the Thames European marine site are not currently vulnerable to physical damage through siltation (English Nature, 1994). However they do note that the role of dredging and the continued disturbance of the channel geometry may result in changes to the natural process of sediment exchange. Increased demand for capital and/or maintenance dredging in association with developments elsewhere in the Thames may therefore influence sediment exchange and local siltation. They recommend that further studies such as CHaMPs will add to current understanding (English Nature, 1994).

7.1.4 Loss of benthic organisms within the footprint of the dredged area.

Maintenance dredging is only carried out in the subtidal and, therefore, is unlikely to significantly affect the SPAs/Ramsar sites (which are largely intertidal) in this way. Species within the over-wintering waterfowl assemblage do feed within the shallow sub-tidal, however the core feeding areas for the principal warterfowl are within the intertidal habitats of the SPA and Ramsar sites.

7.1.5 Increased disturbance.

The visual presence of the dredging plant and increase in noise levels potentially could affect bird populations. It is more likely that disturbance to the waterfowl will be caused by the movement and visual presence of dredgers rather than the noise associated with it (Bureau Veritas-Acoustic Technology, 2003). However, given the slow-moving nature of dredgers (i.e. the lack of fast and sudden movements), it is likely that disturbance arising from their movement and presence would also be low. In light of the above, it is considered that maintenance dredging is unlikely to be causing significant disturbance to waterfowl given the background levels of disturbance and the relative infrequency of dredging activities.

However, as discussed in Section 6.6, dredging is only likely to cause low levels of disturbance over relatively short periods of time which are not predicted to adversely affect bird populations. It is recognised however that there are circumstances which can make the impacts more significant, e.g. sensitivity of location and weather conditions. Furthermore, other plans or projects, may increase the significance of the feeding areas, which needs to be borne in mind when considering ‘in combination’ effects.

7.1.6 Operation of the placement facilities at Cliffe Pools

Under the approved management procedures agreed by Natural England, the ongoing operation has, on balance, an ongoing beneficial impact on the condition of this area of saline habitat. The placement of arisings to Cliffe Pools therefore should be continued for the foreseeable future. Placements at Rainham are not relevant in this context due to its position upstream (>20 km) from the protected sites (Figure 1.1).

7.1.7 Overall impact on the SPA network in the study area

The condition assessment of the SSSIs has been recently updated by Natural England (February 2009), The vast majority of the Benfleet and Southend Marshes SSSI (which only covers a small proportion of the study area) is in unfavourable condition. Unit 3, which lies within the study area, is cited as being in unfavourable condition due to coastal squeeze, public access/disturbance, sea fisheries, water pollution discharge. The assessment comment notes, however, that Smallgains Creek is silting up rapidly and therefore the area of mudflats is likely to be increasing. This process is regarded as being small with respect to the ongoing changes in the SPA and Ramsar site. Within the

Thames Estuary and Marshes SSSI, Mucking Flats is generally in favourable condition. For the area south of the river within the South Thames Estuary and Marshes SSSI some of the saltmarsh units are in unfavourable condition. The reasons cited for this are saltmarsh erosion due to coastal squeeze against the seawall. It is considered that this is likely to be due to sea level rise (and potential morphological roll-over of the estuary to the west) and hence maintenance dredging is not causing this coastal squeeze. This view is supported by the high availability of sediment within the system.

Overall it is considered that within the context of the estuarine system, the existing level of maintenance dredging activity is not having a significant effect of the SPAs or Ramsar sites, when the scale of the operations is compared to the high availability of sediment within the system, and when the management procedures already in place to monitor the activities are considered.

It should be noted that there are other activities currently impacting on the European sites under evaluation. In particular, the Mucking Flats SSSI area currently is influenced by the operation of the waste facilities within the site. It should be noted that the cessation of these operations might impact on the value of the site due to changes in nutrient levels derived from outfalls and discharges. However operations at this site are due to finish in 2010 which may reduce current disturbance levels.

7.2 Data availability

A very large body of information exists for the Thames Estuary on the coastal and estuarine processes of the estuary, including an assessment of Sediment Budget undertaken by IECS in 1993 and a recent summary of historical sedimentary and bathymetric change in a report by HR Wallingford (2008).

Water quality monitoring comprises largely of monitoring by the EA under the various relevant EC Directives. The EA regularly monitor water quality at defined sampling points along the estuary. Water quality data from 1993-2003 and 2007 has been provided to the PLA by the EA and uploaded onto the DSIS website.

New information gathered from real time monitoring buoys stationed in the estuary as part of the London Gateway development will also contribute to a better understanding of suspended sediment patterns particularly in relation to maintenance dredging.

Similarly, sediment quality data have largely been collected as part of the London Gateway Port Environmental Statement, PLA dredging licence applications and, on occasion, FEPA disposal licence applications. Data is therefore available for both the subtidal and selected intertidal areas of the estuary.

There is a good coverage of data available for the Thames Estuary on marine ecology. Comprehensive surveys of the study area have been carried out within the last few years which have involved intensive grab surveys and large scale biotope mapping. It is therefore considered that the marine ecology of the estuary is well characterised from these sources. In addition more recent marine ecological surveying has been undertaken as part of London Gateway Port but is not yet publicly available.

With regard to ornithology, data collected as part of the WeBS scheme provides an excellent coverage of bird data for the intertidal areas of the estuaries. Counts are undertaken every year between September and April at high water and every 6 years at low water. These counts allow systematic monitoring of bird numbers in the estuary, and provide a scientific basis for analysing trends. The WeBS data is also analysed annually by the BTO to analyse trends and detect downwards movements in counts and pick-up alerts. This provides means of monitoring whether there is cause for concern to do with bird numbers within the study area. Data also exists from selected studies such as the London Gateway Environmental Statement. It is considered that the existing level of bird count data is at present sufficient for detecting any declining trends in bird numbers on the SPA. However any declines in bird populations cannot necessarily be ascribed to maintenance dredging activities as downward trends could be attributable to a number of activities or natural phenomena.

In addition WeBS survey information is largely undertaken by volunteers, coverage for some surveys is not always annual, leaving incomplete data sets. With this in mind, the adequacy of bird monitoring data should be monitored as part of the cross-cutting functions of the DLG, the adequacy reviewed as part of the ongoing update of the DCA and additional surveys should be undertaken where regarded appropriate.

Further understanding of coastal processes will be provided in the forthcoming Greater Thames CHaMP.

7.3 Recommendations

7.3.1 Use and Currency of Document

In accordance with the Protocol, it is recommended that this DCA is developed over time to incorporate new information as it becomes available (e.g. from the Regulation 33 Package for the SPAs). It is also intended to be used in consultation with other operators within the estuary who undertake, or plan to undertake, dredging activity.

It is anticipated that the document should not require substantial revision unless major changes are proposed (e.g. capital works or substantial change to existing maintenance dredging methods or quantities) or significant new information comes to light. It will be important to ensure that future proposals are assessed against the updated position and latest information. For example the next update should include data gathered from London Gateway Port and the Greater Thames CHaMP.

7.3.2 London Gateway Port

In this context, a major capital dredge is proposed as part of the London Gateway Port project. The London Gateway Port proposals involve amongst others, a 95ha land claim on the north bank of the Thames and dredging of approximately 30 million m^3. A public inquiry into the proposals was completed in September 2003. In 2007 Government planning approval was finally given for the development with construction due to start in 2009. It is recommended that once the project is complete, this document is revised to take account of the new channel morphology and changes to the maintenance dredging regime.

7.3.3 SPA Condition Assessment

The document should also be reviewed once the six-yearly condition assessment of the SPA has been undertaken by Natural England amd reported to JNCC; where this information will be critical to determining whether existing activities within the estuary are affecting the integrity of the European designated site.

7.3.4 Water Framework Directive

The implementation of the Water Framework Directive is anticipated to have implications on the management of the wider marine resource within the Estuary. Characterisation is now complete and a number of Environmental Objectives have been set for the estuary which has been designated under the directive as a ‘Transitional Waterbody’. The implications of dredging operations as a result of this new directive is still in development and should be included in the next update of the DCA. It is likely however that given the current management structure adopted in the Thames that maintenance dredging activities are sufficiently regulated to comply with the WFD but this is still yet to be agreed. Further information on the implications of the WFD on the Thames estuary can be found at: www.pla.co.uk/pdfs/pe/Water_Framework_Directive.pdf

7.3.5 Further Evaluation of WID

It is recommended that further evaluation be undertaken to monitor bed level changes in the subtidal and intertidal areas adjacent to selected WID sites themselves, including time-step surveys over a period commencing prior to and concluding a reasonable period after dredging campaign to identify any specific deposition trends arising from the technique and to supplement work previously undertaken by HR Wallingford and Environmental Tracing Systems.

Investigation into benthic ecology close to the WID sites could also provide useful information on impacts of smothering of sedentary species.

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