8 Water Environment

Introduction

8.1 This chapter presents a preliminary assessment of the OMSSD project on the Water (marine) Environment – specifically the effects generated by the proposed dredging of the berth pocket at the existing Jetty 2 and the potential disposal of the dredged material at a marine disposal site – which at this stage of the project definition remains an option alongside land based disposal. In addition, a preliminary assessment has been undertaken of a marine option for the supply and discharge of water from a new potential firewater system for the site. The location of the berth pocket and disposal sites are shown on Figures 8.1 and 8.2. This chapter has been prepared by ABPmer.

8.2 These preliminary assessments have been informed by modelling studies undertaken on the Thames Estuary flows (hydrodynamics) (ABPmer, 2016a – see Table 8.1)[62]. These studies were carried out for the purposes of previous development at Jetty 2 of the Oikos facility. The dredging assessment has also been informed by consultation feedback received in respect of a separate previous (but now withdrawn) application made by Oikos to the Marine Management Organisation (MMO) for a marine licence to undertake a capital dredge at the Jetty 2 berth, the OMSSD Scoping Opinion responses and consultation with key stakeholders (which is ongoing). In addition, modelling of the proposed berth pocket has been undertaken to determine the potential changes in hydrodynamics and sediment regime.

8.3 This chapter focusses on the effects of the proposed dredging works required as part of the OMSSD project on the marine/estuary characteristics and physical processes (flows, water levels, waves and sediments) occurring locally within the Thames Estuary. The firewater system is assessed based on the worst case potential intake and discharge volumes with respect to the local hydrodynamics, potential scour of the bed and potential to affect the mooring at Jetty 1.

8.4 The final dredge method has not yet been confirmed and could be different for the capital and maintenance dredging works. However, in order to consider a worst-case scenario at this preliminary stage of the project, it has been assumed that the capital dredge arisings will be deposited at an existing licensed marine disposal site.

8.5 As already indicated, it is not yet possible at this preliminary stage to confirm how the capital dredge arisings will be disposed of. Both land based and marine based options are being considered. For completeness, therefore, the preliminary assessment contained within this chapter of the PEIR considers the potential impacts arising from the disposal of the material in the marine environment. If, by the time the final DCO application is ready for submission,

[62] ABPmer (2016a) Oikos Deepwater Jetty: Hydrodynamic Modelling. ABPmer Report R2497 Rev A, January 2016.

the land based disposal option has been chosen then the Water Environment Chapter of the Environmental Statement will not need to consider marine based disposal options.

8.6 In respect of marine disposal options, the only presently open licensed marine disposal sites in the local area are understood to be in the Outer Thames Estuary. The closest location is the North Edinburgh Channel site (TH080) and for the purposes of this PEIR it is this site which has been assumed to be the disposal location (if marine disposal is required). This assumption along with the dredge method of Trailer Suction Hopper Dredging (TSHD) provides a worst-case scenario in respect of the marine water environment for the possible dredge and disposal methodologies for the capital works.

8.7 Although Water Injection Dredging (WID) is considered not to be viable for much of the capital dredged material (due to the relatively high proportion of gravel within the dredged material), it is considered likely to be the optimal method for any maintenance dredging during operation of the Jetty 2 berth pocket. This method has been assessed for the operational phase as WID is considered a realistic worst case given the intensity and form of sediment disturbance. WID will not require the disposal of any dredge arisings and, therefore, the potential impacts at the marine disposal site (as outlined above) have only been assessed for the capital dredge during construction.

Definition of the Study Area

8.8 The study area for this assessment is the area over which potential direct and indirect effects of the OMSSD project are predicted to occur during the construction (including preparation) and operational periods. The direct effects on the water environment are those confined to within the footprint of the proposed capital dredge, i.e., the berth pocket, and the disposal location. Indirect effects are those that may arise outside the dredge or sediment disposal area due to changes in the Thames Estuary flow and sedimentary regime and any change to the Thames Estuary morphology as a result of the works. This could include for example, disturbance of sediment to create a sediment plume that may occur during construction and subsequent maintenance dredging, both from the dredge site and any disposal locations.

8.9 Previous modelling undertaken in respect of previous works at Jetty 2 of the Oikos facility indicates that effects, particularly from the dredge dispersal plume, could extend up and down the Thames Estuary, assuming the dredging occurs on both the flood and ebb tides. The modelling indicates the study area associated with the dredge is the Thames Estuary between Stanford-le-hope (approximately 8 km west of the Oikos Facility) and Southend-on-Sea (approximately 11 km to the east of the Oikos Facility) (see Figure 8.2). The effects from the potential marine firewater system will be contained well within the above defined area.

8.10 Similar dispersal effects will also occur up and down flow from the disposal location (assumed to be the North Edinburgh Channel (TH080)) should marine disposal be required. This disposal site was characterised for the disposal of predominantly sand for the deepening of the Princes Channel prior to the London Gateway Dredge in 2004. Numerical modelling at the time indicated that there was not likely to be a potential for direct or indirect physical changes beyond 5 km distance of the site (PLA, 2004)[63]. On this basis the detailed study area is approximately 5 km surrounding the centre of the channel.

8.11 It should be re-iterated that the final overall study area is still not possible to define as this will only finally be known once the method of dredging and disposal for the OMSSD Project is confirmed. However, the preliminary study areas referred to above enable a worst case assessment to be undertaken at this preliminary stage.

Assessment Methodology

Data and Information Sources

8.12 The key data sources used to gather the baseline information on the water environment receptors and inform the PEIR are included in Table 8.1.

Table 8.1: Data Sources

Data	Source
Oikos Storage Limited (OSL) Deepwater Jetty, Environmental Statement – Volume 2 (Oikos Storage Ltd.), January 2016.[64]	OSL, 2016
Oikos Deep Water Jetty: Hydrodynamic Modelling. ABPmer Report R.2497 (Rev. A), January 2016.	ABPmer, 2016a
Bathymetric Analysis: Oikos No. 1 Jetty. ABPmer Report R.2488, October 2015.[65]	ABPmer, 2015
Sedimentation Assessment: Approaches to Oikos No. 1 Jetty. ABPmer Report R.2625TN, April 2016.[66]	ABPmer, 2016b
Thames Estuary Channel Management – Habitats Regulations Assessment.[67]	PLA, 2016a
Thames Estuary Channel Management – Waste Hierarchy Assessment.[68]	PLA, 2016b
British Geological Survey: Thames Estuary, Sheet 51N 00; Seabed sediments and quaternary, scale 1:250,000.[69]	BGS, 1990
UKHO Admiralty Tide Tables.[70]	UKHO, 2020

[63] PLA (2004) Princes Channel Development. Placement of Dredged Sand in the North Edinburgh Channel. Environmental Characterisation Report.

[64] Oikos Storage Limited (OSL) (2016) OSL Deepwater Jetty, Environmental Statement – Volume 2 (Oikos Storage Ltd.), January 2016.

[65] ABPmer (2015) Bathymetric Analysis: Oikos No. 1 Jetty. ABPmer Report R.2488, October 2015.

[66] ABPmer (2016b) Sedimentation Assessment: Approaches to Oikos No. 1 Jetty. ABPmer Report R.2625TN, April 2016.

[67] PLA (2016) Thames Estuary Channel Management – Habitats Regulations Assessment.

[68] PLA (2016) Thames Estuary Channel Management - Waste Hierarchy Assessment.

[69] British Geological Survey: Thames Estuary, Sheet 51N 00; Seabed sediments and quaternary (1990). Available at: https://webapps.bgs.ac.uk/data/maps/maps.cfc?method=viewRecord&mapId=11242

[70] UKHO (2020) Tide Tables.

Data	Source
Port of London Authority: Maintenance Dredge Protocol and Water Framework Directive Baseline Document.[71]	PLA, 2014
Port of London Authority: Maintenance Dredge Protocol Baseline Document Update.[72]	PLA, 2020
Thames Estuary 2100: Geomorphological Review and Conceptual Model.[73]	Posford Haskoning, 2004
Natura 2000 standard data forms or information sheets for each designation: Information on the species and habitats listed in the original citations.[74]	JNCC, 2020
Oikos Marine & South Side Development – Environmental Statement – Scoping Report March 2020.[75]	Adams Hendry Consulting Ltd, 2020
Scoping Opinion: Proposed Oikos Marine and South Side Development Case Reference: TR030004.[76]	Planning Inspectorate, May 2020

Determining Significance of Effects

8.13 In order to assess the likely effects upon the marine physical environment relative to the existing baseline, a combination of analytical methods have been used. These include qualitative and quantitative assessments of data from the OMSSD project and surrounding areas; consideration of the existing evidence base of natural change, empirical evaluation and previous numerical modelling studies.

8.14 The assessment methodology has followed the source-pathway-receptor model. Receptors include the coast and offshore morphological features both locally and within the extent of influence that are likely to result from the sediment dispersal plumes from the OMSSD project site, the potential marine disposal location and the local estuary deepening at the Jetty 2 berth. The receptor can only be exposed to a change if a pathway exists through which an impact can be transmitted between the source activity and the receptor.

8.15 Although waves and tides may be altered by the deepened pocket, they largely represent ‘pathways’ as opposed to ‘receptors’. They are also the mechanisms that control local and

[71] PLA (2014) Port of London Authority: Maintenance Dredge Protocol and Water Framework Directive Baseline Document. ABP Marine Environmental Research Ltd, Report No. R.2238a.

[72] PLA (2020) Planning Policy. Available at: http://www.pla.co.uk/About-Us/Planning-Policy

[73] Posford Haskoning (2004) Thames Estuary 2100: Geomorphological Review and Conceptual Model. Report for Environment Agency, 20th August 2004. Ref: P4702/R/DBRE/PBor.

[74] JNCC (2020) Natura 2000 standard data forms or information sheets for marine desginated sites https://jncc.gov.uk/our-work/about-marine-protected-areas/?page=4524

[75] Adams Hendry Consulting Ltd (2020) Oikos Marine & South Side Development – Environmental Statement – Scoping Report

[76] Planning Inspectorate (2020) Scoping Opinion: Proposed Oikos Marine and South Side Development Case Reference: TR030004.

regional patterns of sediment transport, erosion and deposition, and these in turn, directly influence short and long-term net morphological change on the seabed and intertidal areas.

8.16 Designated sites within the Thames Estuary are included in the list of physical process receptors along with the other maritime infrastructure because modification of the hydrodynamics and sediment processes could potentially affect the reasons for the designation of these sites or the operability of the marine structures.

8.17 The hydrodynamic and sediment process effects are often the primary cause of effects in other topic areas, such as benthic habitats, water quality, navigation etc. which are considered separately in other chapters - such as Marine Ecology and Commercial and Recreational Navigation – of this PEIR.

8.18 Potential water environment impacts from the dredging are predominantly related to sediment disturbance. e.g. from the dredger activity and disposal effects for both the capital dredge and any further maintenance dredging. The magnitude of these impacts is controlled by the existing:

- Current regime;
- Wave regime; and
- Sediment transport regime.

8.19 Changes as a result of the proposed dredging on these regimes and parameters have been assessed with the aid of trend analysis of historic data, numerical modelling, empirical calculations and interpretation, as well as expert opinion.

8.20 To facilitate the impact assessment process and ensure consistency in the terminology of significance, a standard assessment methodology has been applied. This framework, which is presented in the following sections, has been developed from a range of sources, including relevant EIA Regulations, the EIA Directive (2014/52/EU)[77], statutory and non-statutory guidance, consultations and ABPmer's previous (extensive) EIA project experience. The assessment also follows the principles of relevant guidance, including IEMA guidelines (e.g. IEMA, 2016[78]), and the latest CIEEM guidelines for ecological impact assessment in the UK and Ireland (which combine advice for terrestrial, freshwater and coastal environments) (CIEEM, 2018)[79].

[77] EIA Directive (2014/52/EU).

[78] IEMA (2016). Environmental Impact Assessment Guide to: Delivering Quality Development. Available at: https://www.iema.net/assets/newbuild/documents/Delivering%20Quality%20Development.pdf (accessed February 2021).

[79] Charted Institute of Ecology and Environmental Management (CIEEM) (2018). Guidelines for Ecological Impact Assessment in the UK and Ireland (Terrestrial, Freshwater, Coastal and Marine). Available at: https://www.cieem.net/data/files/ECIA%20Guidelines.pdf (accessed August 2019).

Magnitude of impacts

8.21 Whether a receiving environment can be exposed to an impact or change depends on there being a route or pathway. The magnitude of the impact and its ability to affect a receptor also depends on a range of other factors, primarily:

- *Scale of change* – the scale of change above and beyond the baseline conditions and natural variability;
- *Spatial extent* – the spatial extent of a change is referred to using the terms 'near field' and 'far-field; and
- *Frequency and Duration* – The ability for a change to be repeated along with the length of time a change can be considered to operate over and is described as either a short or long-term period. 'Short-term' changes are more likely to occur as a result of activities during the construction phase (which are temporary in nature), whilst 'long-term' is more likely to be relevant to the operational period.

8.22 Table 8.2 sets out the basic criteria used to determine the magnitude of the impact / change on the coastal and estuarine processes and receptors for the purposes of the assessment of development effects. Whilst these are basic criteria, not all changes can be 'neatly' defined. To take account of this the assessment needs to be 'moderated' taking account of a holistic understanding of the Thames Estuary to ensure consistency throughout the assessment.

Table 8.2: Definition of magnitude of exposure to change for marine physical processes

Magnitude of Exposure	Definition
Large	Continuous change, over the whole development area and beyond (i.e. offsite extending into the far-field), of a scale that will change key characteristics or features of the particular environmental aspect's character or distinctiveness.
Medium	Noticeable, temporary (during the project duration) or infrequent change, over the far-field, of a scale that will partially change key characteristics or features of the particular environmental aspect's character or distinctiveness; or continuous change to the near-field environment of a scale that will change key characteristics.
Small	Noticeable, temporary (for part of the project duration) change, or barely discernible change for any length of time, over a small area, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Negligible	Changes which are not discernible from background conditions.

Sensitivity of receptors

8.23 An impact can only occur if the receptor is exposed to a change to which it is sensitive. Hence it is necessary to understand the sensitivity of the receptor to that change. Sensitivity can be described as the tolerance of a receptor to readily accept the levels of predicted change to which they are exposed.

8.24 The assessment of receptor sensitivity to the impact / change (Table 8.3), therefore, considers the adaptability of the environment to its former state following exposure to the impact. In this assessment sensitivity is considered as the degree of perturbation a receiving environment can tolerate in response to the predicted changes to which they are exposed along with its ability to recover from that change.

Table 8.3: Definition of receptor sensitivity for marine physical processes

Sensitivity	Definition
High	No capacity to accommodate the proposed form of change.
Moderate	Low to Moderate capacity to accommodate the proposed form of Change.
Low	Moderate to High capacity to accommodate the proposed form of change.
Negligible	High capacity to accommodate the proposed form of change.

8.25 The vulnerability of a receiving environment is essentially the comparison of the anticipated magnitude of exposure with the specific sensitivity or response characteristics of the receptor. Where the exposure and sensitivity characteristics overlap then vulnerability exists, and an impact may occur. Where an exposure or change occurs for which the receptor is not sensitive then no impact will occur. Table 8.4 sets out how the level of vulnerability is determined.

Table 8.4: Vulnerability based upon receptor sensitivity and magnitude of exposure to change

Sensitivity of Receptor (Table 8.3)	Magnitude of Exposure to change (Table 8.2)			
	Large	Medium	Small	Negligible
High	High	High	Moderate	None
Moderate	High	Moderate	Low	None
Low	Moderate	Low	Low	None
Negligible	None	None	None	None

8.26 Prior to assessing significance, the importance of the receptor needs to be identified. This is likely to relate primarily to any statutory designations or socio-economic factors. The definition of receptor importance is provided in Table 8.5 and is then combined with the vulnerability of the receptor to determine significance as outlined in Table 8.6.

Table 8.5: Definition of receptor importance

Receptor Importance	Definition
High	Receptor of international importance. Likely to be rare with minimal potential for substitution. May also be of high or very high socio-economic importance.
Moderate	Receptor designated and/ or of national importance. Likely to be relatively rare. May also be of high socioeconomic importance.
Low	Receptor not designated but of local to regional importance.

Receptor Importance	Definition
Negligible	Receptor of local importance.

Significance criteria

8.27 Table 8.6 summarises the process of estimating an overall significance of effect based on vulnerability and importance of the interest feature.

8.28 The overall level of significance statement provides a summation of the evaluation process and considers both adverse and beneficial effects, which may be categorised as being insignificant, minor, moderate or major.

Table 8.6: Relative level of significance derived from vulnerability and importance

Importance of Receptor (Table 8.5)	Vulnerability of Feature to Impact (Table 8.4)			
	High	Moderate	Low	None
High	Major	Moderate	Minor	Insignificant
Moderate	Moderate	Minor	Insignificant	Insignificant
Low	Minor	Insignificant	Insignificant	Insignificant
Negligible	Insignificant	Insignificant	Insignificant	Insignificant

8.29 In summary therefore, effects can be beneficial or adverse effects and can be described as follows:

- Insignificant - change not having a discernible effect;
- Minor - effects that are discernible but tolerable;
- Moderate - effects that are of a local to regional nature, of medium to long-term duration and/or where effects are anticipated to potentially be above accepted guidelines/standards. Where these changes are adverse, they will usually require some impact reduction or mitigation measure where feasible; or
- Major - acute effect on a national or international scale, of long-term or permanent duration, and clearly above accepted guidelines or standards (or indeed against best practice policy, or even illegal in nature). Where these changes are adverse, they will generally require extensive impact reduction or mitigation where feasible.

8.30 Within this assessment, effects are only considered to be significant in respect of the requirements of EIA legislation if they are of major or moderate significance.

Receptor Identification

8.31 The receptors listed in Table 8.7 have been identified as potentially sensitive to the anticipated type, magnitude and extent of effects from the OMSSD dredge.

8.32 Designated areas of seabed are also included in the list of physical process receptors. Importantly, the assessment of potential impacts to nearby designated sites (see Marine Ecology Chapter 9, Figure 9.1) focuses upon the potential for significant modification of the naturally occurring physical processes that could indirectly impact the specific designated features, or the habitats they support.

8.33 Also included in Table 8.7 is the nearby coastal and maritime infrastructure, in particular the adjacent jetties at Canvey Island and Coryton to the west. The receptors belong to the human, rather than the physical environment but are included as they are sensitive to changes in the physical environment.

Table 8.7: List of identified physical processes receptors

Receptor Type	Receptor Name and Description	Approximate Distance to Dredge Area
Navigation Channels	Thames Navigation Channel	60 m
Coastal Infrastructure	Oikos Jetty 1	350 m
	Oikos Jetty 3	300 m
	Chainrock Jetty	1 km
	Coryton O&G	2.0 km
	Calor Jetty	500 m
	London Gateway Port	4 km
Non Designated Intertidal	South coast of Canvey Island (intertidal)	200 - 300 m
Designated Sites (around dredge location)	Thames Estuary and Marshes Ramsar, SPA	Minimum 1.3 km
	South Thames Estuary SSSI	Minimum 1.3 km
	Holehaven Creek SSSI	Minimum 800 m
	Benfleet and Southend Marshes Ramsar, SPA	Minimum 4.5 km
	Mucking Flats and Marshes SSSI	Minimum 6.3 km
	Medway MCZ	13 km
Designated Sites (around North Edinburgh Channel disposal site)	Outer Thames Estuary SPA	Within and surrounds
	Margate and Long Sands SAC	Within and surrounds

Consultation

8.34 Consultation with regard to whether there are any likely significant water environment effects of the OMSSD project has been undertaken with the Port of London Authority (PLA), the Marine Management Organisation (MMO) and the Environment Agency (EA).

8.35 Consultation has already occurred with respect to a previous application – now withdrawn – by Oikos for a Marine Licence to dredge the berth of Jetty 2. The responses received to that application have also been used along with the OMSSD Scoping Opinion.

8.36 Table 8.8 provides a summary of the Inspectorate's comments on the water environment section of the OMSSD project Scoping Report (Adams Hendry, 2020) and how those comments are being addressed. In addition, Table 8.8 summarises other elements of specific consultation that have been undertaken.

Table 8.8: Summary of consultation to date

Consultee	Date	Summary of Response	How comments have been addressed in this Chapter
Planning Inspectorate	May 2020	Potential for impact was identified as extending to other designated areas.	Mucking Flats and Marshes (SSSI) and Benfleet and Southend Marshes (SSSI/SPA) have been included as potential receptors for assessment of effects from the dredge location.
Planning Inspectorate	May 2020	Zone of Influence (ZOI) from the potential dredge disposal not Identified.	ZOI for possible marine disposal location at North Edinburgh Channel (TH080) has now been identified with zone of possible likely significant effects. Outer Thames Estuary SPA and Margate and Long Sands SAC added to potential receptors for assessment of effects from the possible disposal location.
Planning Inspectorate	May 2020	Tidal influence and saline intrusion not considered for assessment.	Included with respect to potential effects on estuary physical processes.
Planning Inspectorate	May 2020	Inspectorate recommends determination of ZOI by modelling.	Hydrodynamic modelling of the deepening and plume dispersion assessment from existing modelling and bespoke modelling have informed this assessment.
Planning Inspectorate/MMO	May 2020	No assessment of effects of upgrades and additions to Sewerage Infrastructure	No sewerage works are proposed to be undertaken in the marine environment. Further details of the proposed works are included in the flooding and drainage chapter of this PEIR.
Planning Inspectorate	May 2020	Modelling of Extreme Water Levels out of date.	Data has been updated according to latest 2018 EA and UKCIP guidance.
Planning Inspectorate	May 2020	Dredge and disposal method/location not identified.	The final dredge and disposal method has not yet been confirmed. Worst case scenario of potential options has been assessed for PEIR. This will be confirmed in the ES.
Planning Inspectorate	May 2020	No assessment of potential effects of amendment to the River Works License.	This is a matter that will be addressed within the DCO itself. The impact of the works on navigation and other activities within the River Thames are

Consultee	Date	Summary of Response	How comments have been addressed in this Chapter
			considered within other ES chapters.
MMO	June 2020	Confirmation required concerning construction works from the Estuary at the Jetty.	Information is included in the description of works. Changes during the construction phase have been assessed.
Environment Agency	February 2020	Concern that the dredge may affect the WFD.	Assessment and evaluation of the physical and chemical effects has been undertaken in this chapter to inform the WFD. An initial draft WFD compliance assessment is included in Appendix 8.1.
MMO	Meeting, 2 October	MMO highlighted that any new dredge disposal site (if required) needs to be characterised in the assessment.	No new dredge disposal site is currently considered to be necessary. Should beneficial re-use of dredge material not be possible at land disposal sites, the material is proposed to be disposed of at the existing marine disposal site in the Outer Thames Estuary. The closest location is the North Edinburgh Channel site (TH080) and for the purposes of this PEIR it is this site which has been assumed to be the disposal location (if required).

Implications of Legislation, Policy and Guidance

8.37 The coastal and estuarine impacts of the OMSSD project is considered having regard to relevant policy, legislation and guidance including:

- Planning Act 2008;[80]
- Port of London Act 1968 (as amended)[81];
- Marine and Coastal Access Act 2009 (MCAA)[82] introduced a new planning system for marine environmental management and a new requirement to obtain Marine Licences for works at sea. The MCAA inserted a new section (Section 149A) into the Planning Act 2008 which enables an applicant for a Development Consent Order (DCO) to apply for 'deemed Marine Licences' as part of the DCO process. The MMO is the responsible authority in England and works with the Planning Inspectorate (PINS) to ensure that the deemed Marine Licences are transposed into the DCO. The MMO

[80] Planning Act (2008)

[81] Port of London Act (as amended) (1968)

[82] Marine and Coastal Access Act (2009)

remains the monitoring and enforcement body in respect of the conditions and restrictions set out in the deemed Marine Licences.

- The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017, which came into force on 16 May 2017;[83]
- The Conservation of Habitats and Species Regulations 2017[84] (Habitats Regs)[85] as amended by the Conservation of Habitats and Species and Planning (Various Amendments) (England and Wales) Regulations 2018[86], which together implement the EU Habitats Directive (92/45/EEC)[87] and Birds Directive (2009/147/EC)[88];
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017[89] (WFD Regs)[90], which implement the European Water Framework Directive (WFD) (2000/60/EC)[91];
- National Policy Statement for Ports (NPSfP) (DfT, 2012)[92];
- Overarching National Policy Statement for Energy (DECC 2011)[93];
- UK Marine Policy Statement (MPS) (HM Government, 2011), which provides a framework for marine plans and decision making in the marine environment as required by Section 44 of the Marine and Coastal Access Act 2009;[94] and
- Any relevant local policy – for example contained within the adopted and emerging development plan and the Thames Estuary 2100 Plan[95].

8.38 The NPSfP requires the generic impacts of any port development on biodiversity and geological conservation to be assessed. This includes both direct and indirect effects of

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[83] Infrastructure Planning (Environmental Impact Assessment) Regulations (2017)

[84] Conservation of Habitats and Species Regulations (2017)

[85] Following the UK leaving the EU, these have been modified by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019. Available at: https://www.legislation.gov.uk/uksi/2019/579/contents/made (accessed January 2021)

[86] Conservation of Habitats and Species and Planning (Various Amendments) (England and Wales) Regulations (2018)

[87] European Union (1992) Directive 92/45/EEC

[88] European Union (2009) Directive 2009/147/EC

[89] Water Environment (Water Framework Directive) (England and Wales) Regulations (2017).

[90] Following the UK leaving the EU, the main provisions of the WFD have been retained in English law through the Floods and Water (Amendment etc.) (EU Exit) Regulations 2019. Available at: https://www.legislation.gov.uk/uksi/2019/558/contents/made (accessed January 2021)

[91] European Union (2000) Directive 2000/60/EC

[92] DfT (2012) National Policy Statement for Ports

[93] Department of Energy and Climate Change (2011) Overarching National Policy Statement for Energy (EN-1)

[94] HM Government (2011) UK Marine Policy Statement

[95] Environment Agency (2021) Thames Estuary TE2100 Plan (Updated February 2021). Available at: https://www.gov.uk/government/publications/thames-estuary-2100-te2100/thames-estuary-2100-te2100

infrastructure and operations along with capital and maintenance dredging in accordance with relevant legislation. In addition, effects of climate change, on-going coastal evolution and flood risk issues need consideration to ensure future sustainability.

8.39 The objective of the MPS is to provide an appropriate, consistent approach to marine planning in UK waters to ensure sustainable marine resources and strategic management of all marine activities. The aim is to achieve clean, healthy, safe, productive and biologically diverse oceans and seas.

8.40 The Thames Estuary 2100 Plan (Environment Agency, 2021) sets out recommendations for flood risk management for London and the Thames Estuary through to the end of the century. This PEIR document includes an assessment of flooding issues in Chapter 16.

8.41 Port of London Act 1968 (as amended). The Port of London Authority (PLA) is the harbour authority, licensing authority and landowner with the duty to administer, preserve and improve the Port of London. The Act was established for the purpose of preserving and improving the conservancy of the river and estuary.

8.42 With respect to its policies the PLA seeks to translate general UK governmental support for sustainable transport of freight to the specific context and policy environment existing within the Port of London.

Preliminary Description of the Existing Environment

Surrounding Area

8.43 The proposed OMSSD project is located on the south coast of Canvey Island, near Holehaven Creek, within an existing active fuel and bulk liquid import and storage facility in a highly industrialised area. The surrounding area was, in the past, developed for use by oil refineries, and is still in use for fuel and gas import and storage today. The dredging that would impact on the marine environment is located at the end of Jetty 2. The location and proposed extent of the dredge is shown in Figure 8.1.

8.44 The Thames Estuary is one of the largest estuaries on the east coast of England, a classic macrotidal funnel-shaped estuary that has been heavily reclaimed and modified over time by anthropogenic influences. The Thames Estuary is approximately 82.5 km in length to the normal tidal limit at Teddington Weir, narrowing in width from around 2.1 km at the mouth to *circa* 85 m.

8.45 The Oikos jetty (Jetty 2) extends approximately 390 m from the coastline in the River Thames Sea Reach. At the head of the jetty, the current berth provides an alongside minimum depth of approximately -15 m below Chart Datum (CD), approximately 250 m north of the edge of the Yantlet Navigation Channel.

8.46 The physical parameters of the estuary are summarised in Table 8.9.

Table 8.9: Physical parameters of the Thames Estuary

Parameter	Unit	Thames Estuary
Total Area	(ha)	20,000
Intertidal Area	(ha)	13,510
Shoreline	(km)	232
Channel Length	(km)	82.5
Mean River Flow	(cumec)	92.5
Maximum River Flow	(cumec)	572.7
Cross Sectional Area	(m2)	58,062
Mouth Width	(m)	2,100

Source: Defra, 2002[96]

Geology and Sediments

8.47 The floodplain and intertidal areas of the Thames Estuary are underlain by Holocene deposits resulting from interglacial conditions following the Devensian/Weichselian glacial maximum (18,500 before present day), where significant sea-level rise following the melting of the ice sheet led to flooding in the Thames Estuary. The sequence of sediments at Canvey Island (Lake *et al.,* 1986)[97] reveals the history of marine transgression through the Holocene Epoch, identifying distinct layers of estuarine and marine sediments (ABPmer, 2007)[98]. These layers include lower silty clays, silty sands and upper silty clays and clayey silts.

8.48 The dredge will be into the post-Pleistocene gravels, sands and mud, predominantly from the Holocene Epoch laid down over the last 10,000 years.

8.49 The bed material of the Thames Estuary therefore consists of a complete mixture of sediments ranging from coarse non-cohesive gravels, through sands and shell in the subtidal areas, to fine cohesive muds within the intertidal areas depending on the energy levels in any individual location. The dredge area for the OMSSD project consists of predominantly sand that could have a component of black mud (P&O, 2004)[99]. Boreholes undertaken for the construction of Jetty 2 (OSL, 2016) at the Oikos Facility show that the Thames Estuary bed in the area to be dredged is predominantly non-cohesive medium sand (median grain diameter of 350 μm), near the surface, changing to gravel with pebbles (mean diameter 5 cm) at 3 m, beyond the proposed dredge depth. Geotechnical analysis of samples from the boreholes taken at the northern edge of the dredge indicate that around 90% of the

[96] DEFRA (2002) The Futurecoast Project. Project code FD2002

[97] Lake, R.D., Ellison, R.A., Henson, M.R. and Conway, B.W. (1986) Geology of the country around Southend and Foulness. Mem. Br. Geol. Surv., Sheets 258 and 259

[98] ABPmer (2007) Thames Estuary 2100: Greater Thames CHaMP – Scoping Document. Report No. R.1281

[99] P&O (2004) The (London Gateway Port) Harbour Empowerment Order 2002. Environmental Statement, Chapter 11: Marine and Coastal Processes.

material to be dredged will be sand and some silt (less than 1 mm in diameter), the rest will be gravel from the existing deeper depths (Fugro, 2015)[100].

8.50 Surface sampling undertaken from the berth pocket in October 2020 shows that the majority of sediment to be dredged from the western third of the pocket (where the greatest dredging is required) will comprise up to 50% mud (<63 μm) and over 50% medium to fine sand, with an overall median grain size (D_{50}) of 67 – 83 μm. The eastern section of the dredge will consist predominantly of gravel with a D_{50} of 11 – 18 mm.

8.51 Sediment samples within the proposed dredge area collected in December 2020 confirm the material is relatively coarse. Sediments are predominantly sand (>70%) in the western part of the proposed dredge area, with the remaining fraction comprised of silt/mud (no gravel component). In the centre and to the east of the proposed dredge area, a significant gravel fraction is observed (>60%), with comparatively small sand (>15%) and silt (<10%) fractions. Further details are provided in Appendix 8.1.

8.52 Surface samples from within the North Edinburgh Channel disposal location (EMU, 2004)[101] had a sand content of greater than 90%, the majority of which is less than 350 μm and aD_{50} of 80 – 150 μm. Most of the seabed and much of the surrounding area is described as heterogeneous, poorly sorted, mixed sediments with variable levels of silt and gravel fraction (EMU, 2004). At the western edge of the disposal site the seabed is more homogeneous moderate to well sorted sands.

8.53 There are no formal quantitative Environmental Quality Standards (EQS) for the concentration of contaminants in sediments, although the WFD has introduced optional standards for a small number of priority (hazardous) substances. Cefas has prepared a series of Guideline Action Levels to assist in the assessment of dredged material (and its suitability for disposal to sea). In general, contaminant levels in dredged material below Guideline Action Level 1 (AL1) are of no concern and are unlikely to influence the licensing decision. However, dredged material with contaminant levels above Guideline Action Level 2 (AL2) is generally considered unsuitable for disposal at sea. Dredged material with contaminant levels between AL1 and AL2 may require further consideration before a decision can be made. The Cefas Guideline Action Levels should not be viewed as pass/fail thresholds. However, these guidelines provide an appropriate context for consideration of contaminant levels in sediments and are used as part of a ‘weight of evidence’ approach to assessing dredged material.

8.54 Chemical analysis for metals, organotins, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), were undertaken for the construction of Jetty 2 (EA-NLS, 2015)[102]. The results for metals showed levels slightly above AL1 for cadmium, chromium

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[100] Fugro Seacore Ltd (2015) Draft Factual Report Oikos, Deep Water Delivery Berth. Fugro Project Ref.:C1719 / N152006U

[101] EMU Ltd. (2004).Edinburgh Cannel Development: marine Biological Survey. Report No. 04/J/1/03/0609/052

[102] Environment Agency-National Laboratory Service (EA-NLS) (2015) Sediment Samples – Canvey Island, Analysis Report ID – 20079829-1

and mercury at the surface and at depth (1.50m and 3.0m depth samples) in only one sample (BH05) located adjacent to Jetty 2. The total sum of PAHs above AL1 occurred in 12 out of the 20 samples analysed, with individual PAHs congeners above AL1 in four locations, in surface and depth samples. Despite these exceedances of AL1, the sediments were considered acceptable for marine disposal.

8.55 Further sampling and analysis from the area now to be dredged was undertaken in 2019. Four locations were tested for heavy metals, organotins, PAHs, PCBs and particle size analysis (PSA). All analytes of organotins and PCBs were below AL1. Most metals were below AL1, except for mercury (one sample) and arsenic (three samples), which were marginally above AL1 (Cefas, 2019)[103].

8.56 Just over half of the results for PAHs were elevated above AL1, including Fluoranthene, which had the highest value (2.13 mg/kg, AL1=0.1 mg/kg). Cefas applied the Gorham-Test (1999)[104] method of analysis to the sample results. The results showed two sample were below the observed low range effects and all were below the median number of observed effects. The results indicated that the levels of PAHs, PCBs, metals and organotins in the sediment did not present significant risk to the marine environment and as such, disposal of the dredge material at sea was considered acceptable at that time.

8.57 To support the DCO application, Oikos submitted a sample plan request to the PLA, as the Statutory Harbour Authority for the Thames, and the MMO. In September 2020, a sample plan was provided by the PLA, followed by the MMO in October 2020 (SAM/2020/00058) (which was prepared in consultation with Cefas). Based on a review of the existing bathymetry, surface sampling was required at six stations within the berth pocket and at depth sampling (mid and full depth) at one of the stations.

8.58 Sampling has been undertaken in accordance with the agreed PLA/MMO sample plan (SAM/2020/00058). The results of this analysis (Socotec, 2020)[105] show that all trace metal, organotin and PCB determinands were well below the respective AL1 (Appendix 8.1). The maximum in each case was recorded at depth towards the north west corner of the berth pocket. PAH values were below AL1 for all locations except for the north west corner of the pocket where some small exceedance of AL1 occurred at 1-2 m depth, particularly for Chrysene, Pyrene, Flouranthene, Phenanthrene and the Benzo determinands. All samples were lower in contaminant content than the 2019 analysis. Based on these data and the historic analysis, there is no reason to indicate that the sediment will be unsuitable for disposal in the marine environment. At the time of writing, the polybrominated diphenyl ethers (PBDE) results from Cefas were not available. This data will be considered within the ES.

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[103] Cefas, (2019) Marine and Coastal Access Act (2009). Consultation by OIKOS STORAGE LIMITED for The OSL Jetty 2 Capital and Maintenance Dredge Licence in the River Thames, Canvey Island, Essex. Reference Number: MLA/2019/00250

[104] C. Gorham-Test, T. Wade, V. Engle, K. Summers, E. Hornig (1999) Regional environmental monitoring and assessment program — Galveston Bay 1993

[105] Socotec (2020). Certificate of Analysis. Project No: 20121112 - Project Reference: MAR00877

8.59 Chemical sampling was undertaken for the original characterisation of the North Edinburgh Channel (TH080) disposal site in 2004 (PLA, 2004). This analysis showed that the seabed material was predominantly fine sand. For the most part, the analysis showed that for a large majority of the 16 samples analysed, metals, organotins, pesticides, organic compounds and microbiological parameters were below the limits of detection and/or below the respective AL1. Mean concentrations of arsenic, however, were greater than AL1, albeit the maximum concentration (75 mg/kg dry weight) was still less than AL2 (100 mg/kg).

8.60 Further chemical sampling in the North Edinburgh Channel took place in 2008 (PLA, 2016) at 22 locations following most of the disposal from the Princes Channel. The results obtained showed similar results to the earlier sampling undertaken for the characterisation of the disposal site in 2004, again with only arsenic having concentrations above AL1 at a number of sites. The maximum concentrations observed in 2008, however, were lower at 54 mg/kg. Isolated low magnitude exceedances of AL1 occurred for nickel and zinc. One location recorded tributyl-tin (TBT) at 4.9 mg/kg, well above AL2 but this was not characteristic of the rest of the samples. For the most part, the majority of the PAH contaminant determinands were well below limits of detection.

8.61 The PLA undertook a Waste Hierarchy Assessment (WHA) for maintenance dredging of the Outer Thames channels in 2016 (PLA, 2016b). The sediment proposed to be deposited at the time was of similar physical and chemical characteristics to the 2008 disposal site sampling, and therefore was considered to cause little change to the environmental character of the disposal site. To date, the Defra Disposal at Sea Database (DAS) indicates that disposal to this site has not yet taken place.

8.62 These analyses indicate that the currently proposed dredge material from the OMSSD dredge will have very similar characteristics to those that occur at the potential marine disposal location (TH080).

Morphology

8.63 The OMSSD project is located in 'Sea Reach', within the Inner Thames Estuary. In this area, tidal processes dominate the hydrodynamics and sediment movement. The morphology in this area is generally more stable in the short term than in the Outer Thames Estuary (to the east where the potential marine disposal location is sited), where tidal and meteorological conditions of the southern North Sea dominate the hydrodynamics (HR Wallingford, 2002b)[106].

8.64 The morphological regime of the Thames Estuary has been subject to much change over the past few centuries influenced by considerable historical reclamation, channel deepening and the construction of flood defences along its banks. Complementary changes in morphology of the upper and lower Thames Estuary since 1900, have broadly balanced the sediment

[106] HR Wallingford (2002b) London Gateway Development Studies – Review and assessment of morphological changes. Report EX 4486

budget of the wider system (Baugh et al., 2013)[107]. Results from morphological analysis undertaken by HR Wallingford (2002c)[108] showed that the area between Gravesend Reach and Canvey Island has been, and remains, morphologically active since at least 1970.

8.65 Canvey Island is part of a complex and extensive creek system comprising Holehaven, Vange, East Haven and Benfleet creeks that, for the most part, is presently accreting. Accretion within Holehaven Creek occurs when sediment transported on the flood tide falls out of suspension and is not eroded on the following ebb tide (HR Wallingford, 2002d)[109].

8.66 Due to this sedimentation, control sluices have become buried and areas of saltmarsh within parts of the creek system have converted to grassland (ABPmer, 2006)[110]. However, similar to much of the estuary, the width of the creek system is generally highly constrained by coastal defences and is likely to be subject to 'coastal squeeze' in the future as sea levels rise.

8.67 The Outer Thames Estuary is a dynamic environment with highly mobile sandbanks intersected by deep channels. Numerous studies that have been carried out on the movement of the sandbanks and historical charts show clearly how the banks and channels have moved over time. The main channels are generally oriented in the direction of the prevailing currents (with speeds of in excess of 1 m/s) and are relatively stable in location. There are also many "swatchways" which run across the prevailing currents which are very unstable in location and depth. These "swatchways" are formed, in part, by the complex interaction of tides from both the North Sea and the English Channel (PLA, 2004).

8.68 It is well known that these channels (Princes, Fishermen's Gat, the Edinburghs etc.) change depth fairly regularly, as do the sand banks that separate and surround them (D'Olier, 1998)[111]. The seabed in this area is, thus, known to be mobile.

Dredge Location Bathymetry Change

8.69 The bathymetry in the area of the OMSSD project is characterised by a main channel, flanked by shallow subtidal and intertidal areas of varying heights and widths. Along the south of Canvey Island, is a relatively narrow intertidal area, extending around 150 m from the coastline. From here, the bed slopes relatively steeply to the depth of the main channel

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107 Baugh, J., Feates, N., Littlewood, M. and Spearman, J. (2013) 'The fine sediment regime of the Thames Estuary – A clearer understanding'. Ocean and Coastal Management, 79(July 2013), pp. 10-19

108 HR Wallingford (2002c) London Gateway Development Studies. Technical Report: Results and implications of further flow, sediment transport and morphological studies. Appendix C – Review and assessment of morphological change. Report EX 4633.

109 HR Wallingford (2002d) London Gateway Development Studies. Technical Report: Results and implications of further flow, sediment transport and morphological studies. Appendix B –Sediment transport and morphological studies. Report EX 4632

110 ABPmer (2006) Proposed Pipeline Route Corridor Investigation: Marine Study – Isle of Grain. Report No. R.1238

111 D'Olier B. (1998) Report on Princes Channel Geophysical & Borehole Survey with analysis of Hydrographic Charts 1775-1996

at around -16 m CD. The main channel is around 650 m in width at this location, before sloping upwards at a somewhat shallower angle to the south of the Outer Thames Estuary. Here, the wide intertidal area of Blyth Sands extends around 1.3 km from the Medway coast.

8.70 Sediment is transferred via bed-load transport (sand) and via suspended load transport (very fine sand and silts). The main source of sediment to the west side of Canvey Island is the Thames Estuary, which carries sediment from eroding saltmarshes down-estuary. The area of development, however, is a sink for this sediment, causing accretion of saltmarshes and mudflats in Blyth Sands and Holehaven Creek, as recorded and documented (HR Wallingford, 2002 a[112], c, d and e[113]; PLA, 2014; ABPmer, 2009)[114].

8.71 The pattern of accretion in the Creek System is also evident either side of the site of Jetty 2. Analysed bathymetric datasets between 1970 and 1999 showed accretion in bed depths in the vicinity of the Jetties, at the entrance to Holehaven Creek and the subtidal waters fronting the creek, by at least 6 m. The area of proposed dredging, however, is near the edge of the main navigation channel, where depths fluctuate in the order of 2 m, with no overall trend of erosion or accretion.

8.72 The London Gateway Port reclamation and capital dredging works (completed 2014) was predicted to increase maintenance dredging requirements at the existing jetties of West Canvey Island by 20% (Royal Haskoning, 2002) and the sediment supply to Holehaven Creek by 6% (HR Wallingford, 2002 a, c, d and e).

8.73 Further bathymetric analysis at Jetty 1 between 1988 and 2015 showed that the previously identified sedimentation across the frontage to the Oikos Facility continues at the present day, with notable increases around 1993, 1999 and 2012.

8.74 The causes of increase are believed to be associated with the main Thames flows and those to and from Holehaven Creek, which interact with the Coryton and Chainrock Jetties up estuary and Calor Jetty down estuary of the frontage to the Oikos Facility. This interaction causes eddies and slack water zones in the area of, and offshore of, the Oikos Jetty 1 and towards the area of the proposed deepened berth for the OMSSD project (Jetty 2).

8.75 Some of the sediment released from Holehaven Creek during ebb tides appears to be trapped by the eddies and circulation patterns, particularly forming a potential supply of sediment, which accumulates off the existing Jetty 2 in the area immediately behind the head of Jetty 2. Two sedimentation areas are identified to be migrating through the study area: one frontage is originated from the head of the Chainrock Jetty and progresses down estuary creating a "submerged bank", whilst the second is attached to the shoreline at the location of the existing (old) Jetty 2 and progresses up estuary. Within these areas, sedimentation rates

[112] HR Wallingford (2002a) London Gateway Development Studies – Tidal Flow studies. Report EX 4487.

[113] HR Wallingford (2002e) London Gateway Development Studies – Impact of development on sediment transport and estuary morphology. Report EX 4490.

[114] ABPmer (2009) Bowers Marsh Managed Realignment: Modelling and Coastal Process Report. ABP Marine Environmental Research Ltd, Report No. R.1592.

up to around 1 m/yr have been occurring since 2012 and are likely to reduce in the future as an equilibrium level develops.

8.76 These hydrodynamic and sedimentary patterns are continuing to evolve and, at present, it is hypothesised that the "submerged" bank has taken over as the primary influence on flow and sediment regime.

8.77 Time series analysis has revealed patterns of sediment accumulation which are illustrated in Table 8.10 below and Figure 8.3 illustrates the locations of the time-series. Bathymetric analysis was undertaken of over 100 datasets pre and post dredging campaigns in the area of Jetty 1 and Jetty 2 and shows relative stable depths at the location of the head of Jetty 2 up to 2012, when a rapid increase in sedimentation took place, possibly due to capital dredging at Jetty 1. After 2014, however, an erosional pattern occurred at the Jetty 2 berth area (current proposed dredge area) and depths were predicted to stabilise once an equilibrium had been achieved. These patterns of change are discussed below.

8.78 Time-series analysed at the location of Jetty 2 indicates a perturbation occurred between 2012 and 2014 causing accretion, which is evident throughout the frontage of the Oikos Facility with rates averaging about 0.5 m/yr. However, there is also evidence that this accretion pattern reversed with erosion in the east of this area, which is less apparent towards the west. This suggests that erosion has been occurring from east to west at the jetty head. There is little evidence to suggest that erosion could occur inshore of the 12 m contour in the future.

8.79 Likewise, transects throughout the Jetty 2 area show that migration of a shallower seabed 'sand bank' feature in the deep water area was evident in 2014, whereas inshore the migration of the 'front' appeared to have stopped. Since 2010, the 14 m CD contour moved about 100 m down estuary towards Jetty 2. This appears to have occurred 'sporadically' and was not continuous. Also, of note is the sudden temporary reduction in depth that occurred in May 1988 (*circa* 5m) and again in June 2008 (*circa* 3 m) in the area of Jetty 2. There is no apparent reason for such changes, however, these accumulations were not dredged and subsequently re-eroded. It is possible such changes of this type would occur sporadically in the future and would require enhanced rates of maintenance dredging to keep the new berth pocket operational.

8.80 Water Injection Maintenance dredging (WID) at Jetty 1 (undertaken during ebb tides) also adds to the sediment supply in the local area, therefore, a proportion of the dredged material is re-cycled and not carried to the main channel and away from the local sediment cell. This material could increase sedimentation at the deepened berth pocket.

8.81 The 2012 sudden increase in sedimentation rates (noted in para 8.73) at the Jetty 2 berth location is likely to have been partially caused by capital dredging from the deepening of the berthing pocket at Jetty 1. This considerably increased Suspended Sediment Concentrations (SSC) available to interact with eddies, causing increased deposition rates throughout the area of Jetty 1 and the site of Jetty 2.

8.82 In combination with the effects of the dredging (and reclamation) works associated with the construction of the London Gateway port development, these local effects have all contributed to an ongoing cycle of sediment accumulation.

8.83 Due to the evidence of local change from previous structures it is likely that Jetty 2 will have had some impacts which would have influenced the current sedimentation patterns. The structure has a more ‘open’ form compared with the older jetties and will have caused a small change to the local flow regime, as shown by the hydrodynamic modelling for the initial Jetty 2 development.

Table 8.10: Summary table of averaged sedimentation rates (m/year) between 1988 and 2015

<table>
<tr><th colspan="2" rowspan="2">TS</th><th colspan="5">Sedimentation rate (m/yr)</th></tr>
<tr><th>L</th><th>M</th><th>N</th><th>O</th><th>P</th></tr>
<tr><td rowspan="56">Year</td><td rowspan="2">1988</td><td rowspan="11">-0.06</td><td rowspan="11">-0.03</td><td rowspan="22">-0.12</td><td rowspan="22">-0.01</td><td rowspan="22">-0.05</td></tr>
<tr></tr>
<tr><td rowspan="2">1989</td></tr>
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<tr><td rowspan="2">1990</td></tr>
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<tr><td rowspan="2">1991</td></tr>
<tr></tr>
<tr><td rowspan="2">1992</td></tr>
<tr></tr>
<tr><td rowspan="2">1993</td></tr>
<tr><td rowspan="11">0.35</td><td rowspan="28">0.40</td></tr>
<tr><td rowspan="2">1994</td></tr>
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<tr><td rowspan="2">1998</td></tr>
<tr></tr>
<tr><td rowspan="2">1999</td><td rowspan="17">0.06</td><td rowspan="17">-0.02</td><td rowspan="17">0.00</td><td rowspan="17">-0.01</td></tr>
<tr></tr>
<tr><td rowspan="2">2000</td></tr>
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<tr><td rowspan="2">2006</td></tr>
<tr></tr>
<tr><td rowspan="2">2007</td></tr>
<tr><td rowspan="8">-0.09</td><td rowspan="8">0.09</td><td rowspan="8">0.02</td><td rowspan="8">0.00</td><td rowspan="8">-0.03</td></tr>
<tr><td rowspan="2">2008</td></tr>
<tr></tr>
<tr><td rowspan="2">2009</td></tr>
<tr></tr>
<tr><td rowspan="2">2010</td></tr>
<tr></tr>
<tr><td rowspan="2">2011</td></tr>
<tr><td rowspan="2">1.11</td><td rowspan="9">0.62</td><td rowspan="6">0.50</td><td rowspan="6">0.15</td><td rowspan="6">0.51</td></tr>
<tr><td rowspan="2">2012</td></tr>
<tr><td rowspan="7">0.64</td></tr>
<tr><td rowspan="2">2013</td></tr>
<tr></tr>
<tr><td rowspan="2">2014</td></tr>
<tr><td rowspan="3">-0.31</td><td rowspan="3">-0.04</td><td rowspan="3">-1.02</td></tr>
<tr><td rowspan="2">2015</td></tr>
<tr></tr>
</table>

Key			
Sedimentation (m/year)		Erosion (m/year)	
0 - 0.1	(pale yellow)	-0.1 - 0	(pale blue)
0.1 - 0.3	(light orange)	-0.3 - -0.1	(light blue)
0.3 - 0.5	(orange-yellow)	-0.5 - -0.3	(mid blue)
> 0.5	(orange)	< -0.5	(dark blue)
(green)	Values during capital dredging		

Note: Locations L, M, N, O and P are shown on Figure 8.3

North Edinburgh Channel Disposal Site (TH080)

8.84 The disposal site (TH080) is located in the north-western part of the North Edinburgh Channel, as shown on Figure 8.2. The channel is in one of a number of dynamic channels in a complex sandbank system of the Outer Thames Estuary and borders the large sandbank known as Long Sand. Seabed sediments comprise mobile sands with low levels of fine sediment with biological communities representative of seabed disturbance (EMU, 2004). The PLA characterisation report (PLA, 2004) for the disposal site provides a hypothesis on the seabed dynamics of the Outer Estuary sandbanks and channels. It is thought that sand enters the outer estuary as sand ribbons and waves moving from the north east and joins the north western tip of the Long Sand. This sandbank feature is considered to control water movement in the outer estuary and thus the movement of sand (pers. comm. B D'Olier, 2004). The interaction of the tidal currents from the North Sea and the English Channel result in the sand being moved westwards through a series of deposition zones to the eventual deposition site on the Maplin Sands (pers. comm. B D'Olier, 2004). The PLA characterisation report (PLA, 2004) considered it reasonable to assume that the Outer Thames Estuary forms a single sedimentary system and the Princes Channel and the North Edinburgh Channel, being a few km apart, are part of this system. Studies of historical charts demonstrate that the forms of the various sandbanks have changed over time and the PLA's ongoing hydrographic surveys continue to find changes in depth and form. Within the context of these large-scale movements, smaller scale changes are observed such as those in the North Edinburgh Channel.

8.85 An analysis of bathymetry undertaken by Cefas (2018)[115] indicates that the North Edinburgh Channel has been subject to significant bathymetric change over the last 20 years. This has been predominantly through distinct shifts to the north-eastwards of the main channel, over periods of ten years. Between 2015 and 2017, however, small shifts southwards of the main channel contours occurred. At the same time the channel deepened over a wider area below the 15 m below CD contour.

Hydrodynamic Regime

8.86 The Thames Estuary is characterised as a macrotidal estuary (>4m range), with extensive intertidal areas. The general hydrodynamics of the Lower Thames and around Canvey Island are a result of the interaction between the tidal dynamics of the North Sea, the fluvial inputs from Holehaven Creek and Benfleet Creek, and meteorological forcing effects, i.e., surges, winds and wave climate.

8.87 The Outer Estuary consists of a highly dynamic complex of channels and sandbanks that vary on a short time scale reacting to the interaction of wave and tidal forcing.

Tidal Water Levels

8.88 Tidal water levels are currently monitored at a number of locations within the Thames Estuary, but the closest stations to the OMSSD project site and the North Edinburgh Channel are at Coryton, Sheerness and Southend-on-Sea. Overall, there is general consistency in the pattern of the tide both in phase and amplitude, with a moderate increase in range moving upstream (due to the funnelling effect of the Thames Estuary), which has gradually been magnified by the extent of intertidal reclamation and the presence of flood defences (Posford Haskoning, 2004). There are also localised increases in tidal range along the coastline due to the shallow water effects at the mouths of major estuaries, triggering

[115] Cefas (2018) Dredged Material Disposal Site Monitoring Round the Coast of England: Results of Sampling (2017-18).

significant deformation of the tidal wave and producing ebb dominant estuarine systems (Motyka and Welsby, 1987)[116].

8.89 The closest tide station to the OMSSD project is at Coryton, which shows a mean tidal range of 5.6m and 3.5m during spring and neap tides, respectively, with a Highest Astronomical Tide (HAT) level of 6.8m above Chart Datum (3.75m above ODN). The characteristic tidal data near to the OMSSD project site is shown in Table 8.11.

Table 8.11: Characteristic tidal data - Coryton

Tidal level	Coryton	
	m CD	m ODN
Highest Astronomical Tide (HAT)	6.8	3.75
Mean High Water Spring (MHWS)	6.2	3.15
Mean High Water Neap (MHWN)	5.0	1.95
Mean Sea Level (MSL)	3.20	0.15
Mean Low Water Neap (MLWN)	1.5	-1.55
Mean Low Water Spring (MLWS)	0.6	-2.45
Lowest Astronomical Tide (LAT)	-0.1	-3.15
Astronomic tide range (HAT-LAT) (m)	6.9	
Spring tide range (MHWS-MLWS) (m)	5.6	
Neap tide range (MHWN-MLWN) (m)	3.5	

Source: UKHO Tide Tables, 2020

Extreme Water Levels

8.90 The primary driver of extreme water levels (and associated increased flood risk) along most of the Thames Estuary is the enhancement of the tidal water level by a non-tidal (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 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 an increased risk of flooding, unless the flood defences are able to cope with the increased elevation of water.

8.91 A rise in water levels of approximately 0.3 m by the surge component is not uncommon, and may be greatly exceeded (ABPmer, 2009). The significant surge event that occurred on 5 December 2013 reached a maximum water level of 4.03 mODN (6.93 mCD), with a skew-surge of 1.33 m above predicted harmonic tidal levels. Environment Agency 2018 modelled water levels in the River Thames show a maximum water level of 4.83 mODN for a 1 in 100-year return period event at a location near Jetty 2.

[116] Motyka, J.M. and Welsby, J. (1987). A Macro-Review of the Coastline of England and Wales Volume 3: The Wash to the Thames. HR Wallingford Report SR 135.

8.92 Conventional flood defences along the creeks surrounding Canvey Island, including the frontage to the Oikos Facility, provide protection to approximately 6.82 m ODN, but in the event of a storm tide, flood barriers along the creeks become operational.

8.93 The Thames Barrier is an invaluable flood defence for London and is now being used to protect against fluvial flooding as well as surge levels. However, when closed to protect from fluvial flooding, depending upon the time of closure, it could result in a reflected wave that may raise water levels downstream by around 0.5 m (Littlewood and Crossman, 2003;[117] ABPmer, 2014)[118].

8.94 Table 8.12 provides the Environment Agency (Environment Agency, 2018)[119] present day extreme water levels (considering surge and tide, no waves).

Table 8.12: Extreme water levels for Jetty 2, Southend-On-Sea and Sheerness (present date rates)

Return Period (Years)	**Extreme water levels (m ODN) (Present day 2020)**		
	Jetty 2 (Chainage _3.33_i)	**Southend-On-Sea (Chainage _4312)**	**Sheerness (Chainage _4318_5)**
1	4.03	3.72	3.74
2	4.17	3.83	3.88
5	4.27	3.98	4.05
10	4.44	4.10	4.19
20	4.58	4.23	4.34
50	4.72	4.39	4.49
100	4.83	4.53	4.63
200	4.98	4.67	4.77
500	5.14	4.87	4.98
1000	5.25	5.04	5.14
10000	5.66	5.61	5.65

Source: Environment Agency (2018)

8.95 Key climate change factors are taken here as changes that might occur to the baseline which relate to mean sea level, freshwater flow (precipitation), winds and waves (i.e. storminess). The primary source of climate change information is the UK Climate Change Impacts Programme (UKCIP) and the most recent predictions are from UKCP18 (Palmer et

[117] Littlewood, M.A. and Crossman, M. (2003) Planning for Flood Risk management in the Thames Estuary Technical Scoping. Report to the Environment Agency, March 2003.

[118] ABPmer, 2014. Inner Thames Estuary Airport Option: Impact Appraisal. ABP Marine Environmental Research Ltd, Report No. R. 2254.

[119] Environment Agency (2018) Coastal flood boundary conditions for the UK: update 2018. Project: SC060064/TR7: User guide.

al., 2018)[120]. To determine future sea level rise, the industry recognised climate change scenario for planning purposes is what is termed the 'Representative Concentration Pathways (RCPs) 8.5, 95%ile likelihood'. The associated sea level rise predictions for Canvey Island are provided in Table 8.13.

Table 8.13: Predicted relative sea level rise

Year	SLR Based on RCP8.5 95% Scenario (m)
2020	0.00
2040	0.16
2070	0.52
2120	1.37
[1] Value extrapolated based on UCKP18 predictions.	

Source: Palmer *et al.* (2018)

Flows

8.96 The Thames Estuary presents a complex tidal current system, with a location-specific variation between ebb and flood dominance. Generally, between Southend-on-Sea and Gravesend, maximum ebb current velocities are typically greater than the flood (PLA, 2014), giving rise to an ebb dominance with respect to flows. Tidal asymmetry has important implications for the net sediment transport flux in and out of the Thames Estuary with flood dominance indicative of a net import of sediment and ebb dominance of a net export of sediment. Within the Thames Estuary the movement of coarse sediment is likely controlled by flood dominance, and the movement of fine sediment by ebb dominance (ABPmer, 2007).

Local to Dredge site

8.97 Tidal diamond flow data just down-estuary of Canvey Island (UKHO, 2020) show mean flood tide flows of up to 0.9 m/s and 0.6 m/s on spring and neap tides, respectively. Associated peak flows on the ebb tide are shown to be 1.3 m/s and 0.9 m/s, respectively, with directions following the alignment of the river channel. Data obtained from the modelling undertaken for the construction of the Oikos Deep Water Jetty 2 (ABPmer, 2016a) showed ebb flows are generally slightly faster than flood speeds, with peak velocities reaching approximately 1.1 m/s and 0.8 m/s during spring and neap tides, respectively, off the head of the jetty, in the area to be dredged under the current proposal.

8.98 The area inshore of the Jetty 2 head is complex with respect to flows. Mudflats located in the vicinity of the coastal defences of Holehaven Wharf and Holehaven Point dry out during low water (LW). However, the sudden increase in depth at the berth pockets and within the clearance channel, along with the interaction with the complicated bathymetry and jetty

[120] Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts C. and Wolf J. (2018) UK Climate Projections Science Report: UKCP18 Marine report. Met Office Hadley Centre: Exeter.

structures, cause continually varying flow patterns at different stages of the tide (OSL, 2016; ABPmer, 2016a).

Local to North Edinburgh Channel Disposal Site

8.99 The North Edinburgh Channel is characterised by a dynamic mobile sandy environment and the channel is migrating eastwards. A survey of tidal currents was carried out in the North Edinburgh channel in February 2004 and a vessel-mounted ADCP was used to collect water velocity data along four transects. In the deeper water in the centre of the Channel and towards the northern side of the Channel, peak water speeds were approximately 1 m/s while in the shallow water speeds were in the range of 0.5 m/s to 0.9 m/s. At one location in the deep water in the centre of the Channel the current speed reached 1.5 m/s but this isolated reading is not considered representative (PLA, 2004).

Waves

8.100 The highest waves in the inner part of the Outer Thames are generated from the southeast and east, in the direction of the longest available fetch; however, wave periods are generally short (2-3 seconds). Wave energy is dissipated by the extensive offshore bank and channel system before the waves reach Sea Reach, to the east of the OMSSD project site, leading to relatively small overall wave heights (P&O, 2004). Significant wave heights were predicted to be approximately 1.5 m at Coryton for 1 in 50-year omnidirectional winds and under 0.7 m for 10 in 1-year winds (at all water levels). As a result of increased sheltering effects, the wave climate typically decreases in an upstream direction (PLA, 2014).

8.101 As part of the London Gateway Port Environmental Statement, the wave regime of the estuary was modelled between Gravesend Reach and Sea Reach (HR Wallingford, 2002f)[121] including the OMSSD project site. This study showed that wind directions of greatest importance in the development area are those between 75°N and 105°N (east-northeast to east-southeast), due to the longer fetch, and between 165°N and 225°N (south-southeast to southwest), due to the direct incidence of wind-generated waves from these directions.

8.102 Similar results were obtained by HINDWAVE modelling (Environment Agency, 2012), as part of the development of extreme wave conditions for the Thames Estuary. Table 8.14 shows extreme wave conditions for Holehaven Creek, based on different stages of tides, calculated for 10 in 1 year and 1 in 100 year event. The 100 year joint probability for wave conditions is presented in Table 8.15, which shows significant wave heights of 0.98 m and extreme water levels of 4.0 m ODN (7.05 m CD) for a 1 in 10 year event.

[121] HR Wallingford (2002f) London Gateway Development Studies – Wave Studies. Report EX 4488.

Table 8.14: Extreme wave conditions for Holehaven Creek. Table shows the sensitivity to tidal currents

Return Period (Years)	Waves from the Outer Estuary								
	No Current			Ebb Current			Flood Current		
	Hs (m)	T(s)	Dir (ºN)	Hs (m)	T(s)	Dir (ºN)	Hs (m)	T(s)	Dir (ºN)
0.1	0.62	2.16	106	0.53	2.45	103	0.38	1.34	125
100	1.02	2.45	112	0.96	2.84	109	0.81	2.00	125

Source: HR Wallingford (2005)[122]

Table 8.15: 100 year joint probability wave condition

Return Period of wind speed (years)	Extreme Water level		Waves from the Outer Estuary		
	Approx. Return Period (years)	Level (m ODN)	Hs(m)	T(s)	Dir (ºN)
1	50	4.3	0.88	2.50	106
10	10	4.0	0.98	2.43	108
100	MHWS	2.9	1.02	2.45	112

Source: HR Wallingford (2005)

Sediment Transport and Suspended Sediment

8.103 The Inner Thames Estuary has previously been divided into four suspended sediment zones on spring tides (with little suspended sediment apparent on neap tides), as documented by Littlewood and Crossman 2003 (cited in ABPmer 2014). There is a central null point in Gallions Reach, which creates a zone collectively known as the Mud Reaches. At times of high river discharge, the sediment is flushed downstream to the area of Gravesend Reach. During summer low flow periods, this sediment is slowly moved back to the Mud Reaches. Littlewood and Crossman suggest that the downriver movement takes the form of a high SSC close to the bed and in the deeper parts of the channel, with reduced concentrations at higher levels in the water column.

8.104 More locally, the main sediment source into the creek system around Canvey Island is from the Thames Estuary with sediment entering the channels on the flood tide and falling out of suspension at high water slack. Not all of this sediment is subsequently re-mobilised on the following ebb tide. Additional sources of sediment include the erosion of mudflats and saltmarshes within the Thames Estuary, particularly the eastern saltmarshes on Canvey Island.

[122] HR Wallingford, 2005. Thames Estuary 2100 – Wave Studies. Report EX 5243.

8.105 On a typical spring tide (during calm conditions) approximately 60,000 tonnes of sediment is in suspension over a cross section of the river in the vicinity of Canvey Island (HR Wallingford, 2002g)[123]. This sediment has been modelled to show that tidal currents transport the majority of the sand (median diameter 100 μm), with negligible wave influence. These results support the general conclusions that the Thames Estuary is ebb-dominated downstream of Gravesend and wave heights have a negligible influence on sediment movement. The modelling (HR Wallingford, 2002g) found a net export of sediment from the Thames Estuary.

8.106 The Environment Agency measured sediment concentration at transects along the Thames from 1972 to 2008. Higher suspended sediment concentrations occur in more seaward locations. At Gravesend Reach (approximately 10 km upstream from Canvey Island) the total sediment flux during neap tides is 21,300 tonnes per tidal phase and during spring tides this is 65,900 tonnes per tidal phase (HR Wallingford, 2013)[124]. Measurements were taken near the surface and as a result would be expected to show a lower suspended sediment concentration than would be found near the river bed.

8.107 The main pathway for sediments is the water body itself, which transports fine sediment in suspension. As part of a monitoring programme for historic dredging at Jetty 1, SSC were recorded at two locations (Holehaven Pier and Jetty 3) for seven weeks during one of the maintenance dredging campaigns in February/March 2006 (HR Wallingford, 2006)[125]. The sensors were installed 1 m above the seabed. The average background concentrations pre dredging varied between 25 and 200 mg/l, depending on the tidal range, with peak concentrations occurring during the first stages of flood tide, at around 400 mg/l.

8.108 The dredging methodology historically used for works at Jetty 1 is WID, which occurs on the ebb tide to produce a sediment density current flow out of the clearance channel and into the main channel near the western end of current proposed capital dredge area. Monitoring of SSC during dredging showed that, when the method of dredging applied a standard pressure of 1 Bar, no changes were observed in SSC (1 m above the bed). However, when a high pressure method was used (7 Bar) to remove harder material found at the east end of the berth pocket, an increase of about 50 mg/l was identified, which corresponds to a 50% increase in background concentrations at both locations at the time of observation. After the end of the dredging activities, no evidence of change in SSC was observed.

8.109 SSCs were also monitored between January and December 2009 as part of the London Gateway port surveys (prior to the capital dredging and reclamation works). The monitoring identified a clear reduction in near-bed concentrations in a seaward direction during both summer and winter months, with peak spring SSCs of *circa* 1,400 mg/l within the main Yantlet Channel, opposite the development area; neap tide concentrations show a similar

[123] HR Wallingford (2002g) Proposed dredging at Oikos jetty, Canvey Island, River Thames.

[124] HR Wallingford (2013) Sediment fluxes in the Tidal Thames #100-RG-MDL-WALLI-0051_AA. Report to Thames Tideway Tunnel Delivery Team, Report No. RT006.

[125] HR Wallingford (2006) Monitoring of dredging at the Oikos No. 1 Jetty, Sea Reach, Thames Estuary. Final Report. Report EX 5329.

pattern but of lesser magnitude. Subsequent monitoring (2010 to 2014) during the London Gateway port capital dredge measured near surface SSC typically between 200 and 1,000 mg/l, with near bed concentrations varying between 500 and 3,000 mg/l. SSC concentrations reduce seaward of Sea Reach (ABPmer, 2014).

Dredging

8.110 Dredging in the Thames Estuary has taken place for over 150 years, changing navigation depths within the river since 1857. A significant dredge, changing the channel system occurred in the mid-1960's, with dredging of the navigation channel in Lower Gravesend Reach in 1964/1965, and Knock John Channel in 1966 (PLA, 2014). Subsequently, further activity took place for the deepening of the Outer Thames approaches (*circa* 26 million m^3) and *circa* 2.7 million m^3 for the berths and immediate approaches to the London Gateway port development.

8.111 Maintenance dredging for the river and docks between 1928 and 1956 was relatively consistent, averaging about 1.86 million m^3/yr (HR Wallingford, 2007;[126] IECS, 1993[127]). Since 1961 amounts reduced to approximately 225,000 m^3/yr (IECS, 1995;[128] Posford Haskoning, 2004); with a significant reduction, particularly at Diver Shoal and Gravesend Reach from 1965 (ABPmer, 2014). Historically, much of the maintenance dredge arisings were deposited offshore, seaward of Southend-on-Sea but research suggested that deposited sediment was transported back into the Thames Estuary, adding to the rate of deposition. More recently, material has been deposited on land at Rainham Marshes and Cliffe. The majority of the maintenance dredging is now undertaken using WID.

8.112 Jetty 1 was built in the early 1930's, jetties 2 and 3 in the early 1950's and jetty 2 extended in the last five years and maintenance dredging has been occurring since construction to permit all tide operations (PLA, 2014). Between 2004 to date the majority of dredging was achieved using WID except for smaller TSHD campaigns of 13,000m^3 in 2006 and 13,000m^3 in 2007. A further 5,000m^3 was excavated in 2007 using a Grab Barge Dredger. In 2012, capital dredging was undertaken, deepening the Jetty 1 berth pocket by 1.5 m, from -11.0 m to -12.5 m CD. Behind the jetty, depth is maintained at 4 m below CD and within the approach channel, -13.5 m CD. Table 8.16 shows the dredge volumes per year (based on volumetric calculations provided by Oikos) within the Jetty 1 berth pocket, behind the jetty and clearance channel. Maintenance dredging occurs every three months at Jetty 1 and campaigns have a duration of approximately 15 hours.

[126] HR Wallingford (2007) An overview of the tidal Thames Estuary. A historic review of the bathymetric and sedimentary regimes. Report EX 4936.

[127] Institute of Estuarine and Coastal Studies (IECS) (1993) The Thames Estuary: Coastal Processes and Conservation. Report to EN.

[128] IECS (1995) Institute of Estuarine and Coastal Studies. The Thames Estuary: Coastal Processes and Conservation. Report to English Nature by the Institute of Estuarine and Coastal Studies (IECS). Report number: Z035-95-F (a).

Table 8.16: Dredging volumes (m³) for Jetty 1, including capital and maintenance (2004 -2020)

Oikos Terminal (Main Berth Pocket, Behind Jetty 1 and Escape Channel)					
2004	**2005**	**2006**	**2007**	**2008**	**2009**
21,469	18,907	41,699	49,358	65,100	39,528
2010	**2011**	**2012**	**2013**	**2014**	**2015 (until March)**
44,318	10,294	115,511	86,458	127,624	30,348
2015 - 2016	**2016 - 2017**	**2017 - 2018**	**2018 – 2019**	**2019 - 2020**	
105,019	150,218	128,915	62,147	80,156	

Local Morphology

Dredge Location

8.113 Bathymetric analysis for available charts between 1970 and present day in conjunction with an evaluation of the flow regime around the Canvey Island shoreline and entrance to Holehaven Creek has identified mechanisms at work which have, and are, interacting to cause the ongoing evolution of the seabed in the study area.

8.114 The flow and sediment regime is a complex product of the flow retardation and diversion effects, creating jet flows and eddies, resulting from the construction of the various jetties along the Coryton and Canvey Island frontages, in particular the most offshore structures, e.g. Chainrock Jetty, the Coryton Offshore Jetty and the Calor Jetty down estuary of Jetty 1. These effects are complicated further due to the flows as a result of the tidal exchange to and from Holehaven Creek, which pass immediately adjacent to the Jetty 1.

8.115 The effects caused by flow interaction with the various jetties and the tidal-generated flows from Holehaven Creek vary from flood to ebb and at different water levels. As a consequence, the effects on the estuary flows have created a net sedimentary regime, which, as the bed level evolves, causes further changes to the flow patterns creating continually evolving bed levels around the Oikos Facility frontage. These changes are continuing today.

8.116 The main mechanisms for bed level change are a function of the flow patterns during ebb and flood tides.

8.117 At high water levels, flows are generally ‘strong’ (*circa* 0.8 m/s) running approximately parallel to the shoreline, behind the heads of Chainrock and Coryton offshore jetties and through the Oikos frontage. At these water levels, the estuary flows tend to dominate over those from Holehaven Creek. Unpublished studies have identified average SSCs in the order 100-150 mg/l, 1 m above the bed.

8.118 As the water levels fall, flows are ‘squeezed’ from up estuary between the jetty heads and the shoreline due to the jetty head blockage (resistance). At the same time, flows are retarded in a ‘sheltered’ area down estuary of the heads. Over time, a submerged bank has developed in this sheltered area behind the head of Chainrock Jetty towards the approaches of Jetty 1, as flows are reduced. This sheltering has added to the jetty effects and caused sedimentation inshore. Since about the 1970s, the area of ongoing sedimentation has moved down estuary, with reduced depths of up to about 6 m in places. Inshore of the main area of sedimentation, the 'squeezed' flow interacts with the draining flow from Holehaven Creek, which becomes more dominant at lower water levels. The combined effect is to deflect the sedimentation emanating from the Chainrock Jetty head in a more offshore direction, whilst creating a counter-clockwise eddy centred close to the Jetty 1 and extending down estuary. This eddy is initially relatively fast and traps sediment from both inshore areas, up estuary and Holehaven Creek. During the lower half of the tide, sediment (predominantly fine sand) is moved in the eddy from east to west through the Jetty 1 berth pocket before flows reduce to near slack. This then allows sedimentation due to settling of sediment from the water column.

8.119 On the first half of the flood tide, flows tend to pass approximately parallel to the Canvey Island foreshore, behind the head of the Calor Jetty, down estuary. Initially, around the Oikos Facility frontage, flows are moved offshore by a combination of the submerged bank and strong draining flow from Holehaven Creek. As the tide rises, these dual influences reduce and relatively fast flows (in excess of 0.45 m/s) pass directly through the Jetty 1 berth pocket before being drawn inshore at the west end to form the flow into Holehaven Creek. These flows are high enough to move sediment near the bed from the down estuary shallow areas. This increased sediment is illustrated by higher SSCs than the rest of the tide (200-300 mg/l) (unpublished study). These sediments then tend to deposit in the east end of the Jetty 1 berth pocket as flows suddenly reduce as they enter the significantly deeper area.

8.120 During the upper half of the flood tide, flows are drawn over Chapman Sand at the east of Canvey Island (approximately 5 km) and then drawn off closer to Jetty 2, concentrating near Scar's Elbow (approximately 1.2 km to the east) where the aspect of the shoreline changes by *circa* 45^0. These flows are added to the main estuary flows and directions are diverted offshore around the head of the Calor Gas Jetty. The combination of the flow direction, relatively high flow rates and shallower water inshore create a clockwise eddy centred just to the east the Jetty 1 berthing pocket. During this period, the flow speeds in the eddy are considerably lower, giving rise to the potential for sediment settling from the water column. This sediment is likely to be finer than that which moves in the berth pocket at the beginning of the flood tide and is likely to be re-suspended during higher flows. Therefore, this probably contributes little to the net sedimentation occurring in the area, predominantly just adding to the general background SSC, which creates the main supply of sediment to Holehaven Creek.

8.121 The majority of these changes occur inshore of the Jetty 2 berthing face and the area currently proposed to be dredged. As a result, sedimentation in the existing berth is relatively low in the short term, but depths have varied by *circa* 2 m with time. Following deepening the WID maintenance dredging principally from Jetty 1 is likely to increase the supply of sediment available for redeposition within the newly dredged berth pocket.

Disposal Area Morphology

8.122 Bathymetric data relating to the North Edinburgh Channel can be found on PLA Chart 203MS, which was last subject to a full main survey in 1997. More recently a survey was carried out by PLA in 2004. These data show the channel to have moved some 220 m eastwards between the two surveys as well as becoming considerably shallower overall. Rough computations, using the approximate channel geometries, indicate that a total of around 24 Mm^3 of sand would have eroded from a 4 km strip on the east side of the channel to allow this to happen. It has been estimated that a net average in excess of 6 Mm^3 of sand is moving annually to make these geomorphological changes. In practice, the gross amount of material moved in any direction would probably be an order of magnitude higher (PLA, 2004).

Environmental Change Without the OMSSD Project

8.123 In the absence of the OMSSD project, the current marine physical processes would remain the same as described above and the Oikos Facility would continue to operate in its current capacity with product being delivered to the facility via Jetties 1 and 2. There are unlikely to be any short-term changes in the physical processes and the existing variance in depths at Jetty 1 and Jetty 2. Regular maintenance dredging will continue at Jetty 1 with no consistent maintenance dredge requirement at Jetty 2.

8.124 Initially the effects of climate change, particularly increased mean sea level will not be noticeable for the next 15 – 20 years due to the natural variation in the lunar nodal cycle affecting the tidal levels. Any changes will be small and unlikely to cause a variation in the existing pattern of change. Longer-term, sea level rise will become more noticeable, which could potentially slow the tidal flows at the jetties. These flow reductions, however, are unlikely to cause any significant change to the sediment regime. Large changes would only result if there was to be a substantial change in sediment supply from elsewhere in the Thames Estuary.

8.125 Sedimentation in shore of the jetty head is likely to continue but will slow as a new equilibrium is established in the area, however, bathymetric analysis (ABPmer, 2015) does not suggest this to be imminent. The sedimentation is likely to increase the potential for maintenance dredging at the inshore berths. As this dredging is undertaken by WID there could be an increased sediment supply through the proposed berth area. The flows are, however, likely to remain high enough to remove this sediment from the berth frontage. The Thames Estuary depths will continue to shallow towards the head of Jetty 2 until the new equilibrium results.

8.126 At the North Edinburgh Channel disposal site (TH080) there will be no change beyond the existing natural variability of the site.

Preliminary Consideration of Likely Impacts and Effects

8.127 This section identifies, at this preliminary stage, the potential likely effects on the water (marine) environment receptors as a result of the construction (dredge and disposal) and subsequent operation of the OMSSD project along with the potential effects of a possible marine firewater system. As noted above, effects on the physical processes are often the primary cause of effects in other topic areas, such as benthic habitats, water quality, navigation etc. which are considered separately within other specific chapters of this PEIR.

Dredging and Disposal

8.128 The dredging works (*circa* 25,000 m³) that could affect the water environment is small relative to the size of the Thames Estuary and the current Thames Estuary maintenance dredging practice. The average depth to be removed is in the order of 1 m over the area of the berth pocket (range 0 – 3 m depth change).

8.129 As noted earlier in this chapter, the method of dredging has not been finalised. This PEIR assessment has, therefore, considered the overall realistic worst case from the potential methods available, i.e. TSHD dredging with proposed disposal at the North Edinburgh Channel licensed disposal site (TH080) for the capital works. WID, however, is the most likely worst-case method to be used for the maintenance dredging thereafter, therefore this method is assessed for the operational phase of the OMSSD project.

8.130 The rate of dredging associated with a TSHD is governed by the dredger size and the disposal site location. The most likely size of TSHD to be used is of medium size with a capacity of *circa* 2,000 – 2,500 m³ *in situ* per load (i.e. 10 to 13 loads for the complete dredge). Given the particle size of the sand and gravel to be dredged, 3 to 4 hours is likely to be required to load the dredger with the use of overflow to bulk the load.

8.131 The North Edinburgh Channel disposal site is about 50 km (27 nautical miles) from Jetty 2, therefore the dredger round trip including disposal time would take between 5.5 to 7 hours depending on the tides. Depths at the berth and on route to the disposal site do not limit the time the dredger could operate, therefore 24/7 operation for the dredge is anticipated. This suggests that the dredge production rate would be in the order of one dredger load per tide and, therefore, the whole capital dredge could be completed in about a week.

8.132 To minimise dispersal effects towards up estuary infrastructure, the current WID maintenance dredging that predominantly takes place at Jetty 1 is only undertaken on the ebb tide. Given the round trip required to the disposal site, the capital dredge is likely to also be able to be undertaken on the ebb tide, to minimise the potential effects of the dispersion from the dredge, without significant impact on production.

8.133 If the future maintenance dredging is undertaken by TSHD, the overall environmental effects would be similar to the capital works although the material dredged would be marginally finer and there would potentially be less of it.

8.134 If the future maintenance dredging is undertaken by WID, typical production rates are likely to range between 15 and 150 m³/hr/m width of injection head (Van Rijn, 2019a)[129] in mud. Rates in sand, however, are lower therefore maximum rates of dredging by this method are likely to be less than 100 to 150 m³/hr.

8.135 Based on the above understanding of the scale of the dredging works, together with the environmental baseline and stakeholder comments from the Scoping Opinion, the likely effects that have been identified as potential occurring during the construction phase and the operation of the OMSSD project are included in Table 8.17.

Table 8.17: Potential impacts of marine works comprising the OMSSD Project

Phase of Development	Potential Impact Pathways
Construction	Changes in suspended sediment concentrations (SSC) over the extent of the disturbance plume as a result of the OMSSD capital dredging works.
	Changes in seabed bathymetry and composition as a result of the deposition of dredged/disposal material within the area of the respective (dredge and disposal) plumes.
	Changes in SSC as a result of the potential disposal of capital dredge material at a licensed offshore disposal site, the North Edinburgh Cannel (TH080).
	Changes in water quality as a result of increased SSC and potential contaminants in the sediment.
Operation	Local changes in the hydrodynamic regime (flow speed and direction) within the Jetty 2 dredge pocket, as a result of the marginally increased water depths within the berth.
	Local changes in the wave regime within the Jetty 2 dredge pocket, as a result of the marginally increased water depths within the berth.
	Changes in the sediment transport pathways, as a result of the localised changes to the driving hydrodynamic (and wave) forcing.
	Increased SSC and potential sedimentation in the area of the dispersal plume as a result of maintenance dredging (by WID) of the Jetty 2 berth pocket.

Firewater System

8.136 There are currently two options being considered for the firewater system; one involves the use of water stored in tanks, which will have no effects on the water environment. The second is a marine option. This second option is proposed to comprise an intake pipe

[129] Van Rijn, L. C. (2019a) Water Injection Dredging.

situated near the estuary bed at a location along the Jetty 1 approach. The outlet (discharge) will be a pipe attached to one of the piles of the jetty head (platform). Diffusers will be attached to the pipes which will reduce/spread the flows at the intake and outfall. At the time of this assessment, exact locations or specifications have not been confirmed. The proposed water circulation through the system will be at a rate of 2,100 m³ per hour when required for a fire emergency. The system will, however, be tested weekly for approximately an hour – each pump running for a 20 minute period. The potential impact pathways from the firewater system are included in Table 8.18.

Table 8.18: Potential impacts from the marine firewater system option

Phase of Development	Potential Impact Pathways
Construction	Change to seabed and disturbance of sediment resulting in an increase in SSC in the water column from marine plant during installation of the intake and outfall structures.
Operation	Potential scour of the seabed and release of sediment into the water column due to acceleration of flows in front of the intake and from the outlet. This has the potential to create plumes and sedimentation in the Jetty 1 berth pocket, and in turn increasing the existing maintenance dredging requirement.
	Potential increase in the local flows around Jetty 1 which may impact on vessels manoeuvring and moored at the berth,

Other Pathways

8.137 In addition to the above potential impact pathways, cumulative impacts on the marine environment could arise as a result of other coastal and marine developments and activities in the Thames Estuary. These will be considered as necessary as part of the cumulative impacts and in-combination effects assessment that will be provided within the Environmental Statement. The cumulative and in-combination effects chapter of this PEIR (Chapter 22) sets out the approach proposed to be adopted in this respect.

Construction

Dredge and Disposal Impacts

Changes in SSC from dispersal plumes due to dredging

<u>Understanding of potential impact</u>

8.138 Dredging by TSHD into the sand and gravel substrate will cause disturbance of the seabed sediment from the draghead and from overflow through the dredger hull during the process of 'bulking' the load. This material will advect and disperse with the ambient flows and be further disturbed by the dredger propellers. As a result, the SSC of the surrounding marine environment will be increased above background levels during the period of filling the dredger.

8.139 The suction dredging is likely to be undertaken in a series of 'runs' along the length of the berth followed by the dredger backing up whereby no suction activity takes place. Each load of the dredger will cause a series of 'pulses' of increased SSC in the water column lasting *circa* 5 to 7 minutes then with a gap of a similar period of time throughout the 3 to 4 hour loading period. During approximately the first hour of loading all the disturbance will be from the draghead (near the seabed), whilst the remaining period will be a combined effect from the draghead and the overflow.

8.140 Based on the above dredge scenario 9,850 kg of dry sand/silt will be disturbed into the water column over the *circa* 375 m of dredged pocket for each of the *circa* 16 individual 'runs' required to fill the dredger, thus creating a series of sediment 'pulses' during the *circa* 3 to 4 hour dredger loading phase. This material, if it all remains in suspension, would be dispersed in the estuary flows which peak at about 0.9 m/s on the flood and 1.1 m/s on the ebb of spring tides causing the greatest dispersion of sediment. Initial SSC beneath the dredger are likely to be around 200 mg/l above background, reducing to an average of around 100 mg/l over the area of the dredge.

8.141 The material to be dredged is considered to range predominantly from silt and fine sand through to gravel, with on average 30 % less than 125 μm and 20% less than 63 μm in size. As a result, a large proportion of the disturbed material (estimated as much as 80 %) is likely to return to the bed beneath the dredger and remain in the locality of the pocket to be re-dredged. SSC dispersing beyond the dredge area, on average are unlikely to be in excess of 40 to 50 mg/l and will predominantly be in the lower water column. The very finest sediments disturbed are unlikely to travel more than about 1.75 km up or down estuary. At that distance the SSC are likely to be below 10 mg/l. The plume is only likely to be evident during the 3 to 4 hour period of each dredge load and for an additional period of about 0.5 hours following the completion of each dredge load. Most of the sediment will have settled to the bed and merged with the background concentrations within 500 m of each end of the dredge pocket (east-west aligned) with a maximum plume width of about 100 m (north-south aligned). The flow regime indicates the plume will be predominantly confined to the shallow subtidal area.

8.142 These estimates of the increased SSC from the proposed dredge are generally low when compared with existing background levels of near bed SSC. Measurements within the main navigation channel are highly variable, between 500 and 3,000 mg/l, whilst background near bed SSC measured inshore of Jetty 2 can naturally reach 400 mg/l.

8.143 Comparing these background concentrations with the estimates that are predicted in this assessment, it is possible to conclude that any increase in SSC due to capital dredging by TSHD will be within the natural variability of the system, very localised (with the majority of effects less than 500 m down flow of the dredger) and are unlikely to be evident about 30 minutes following the cessation of dredging each load.

Assessment of level of significance without mitigation

8.144 The level of significance on water environment receptors has been assessed based on the outcomes of the analysis of the dredge effects set out above and are summarised in Table

8.19. Given the maximum extent of the sediment plume of approximately 1.75 km up and down estuary, a number of the identified receptors are potentially exposed to the changes in SSC during dredging.

8.145 The assessment indicates the exposure to the impact for the majority of the receptors is, however, negligible to small due to their tolerance to change and recoverability. The sensitivity of the receptors is also negligible to low due to the dynamic nature of the estuary environment. Jetty 1 is considered to have a moderate sensitivity to take account of the implications of any resulting potential requirement for maintenance dredging. The assessment has been undertaken on the basis that the dredge could be undertaken on either the flood or ebb tide, whilst also taking account of maximum flow rates, and thus provides an assessment of the worst-case potential for sediment dispersion.

8.146 For all receptors, the resulting level of significance of this impact pathway is assessed as insignificant.

Table 8.19: Assessment of the level of significance associated with changes in SSC on relevant receptors

Receptor	Magnitude of Exposure to Impact	Sensitivity of Receptor	Vulnerability of receptor	Importance of Receptor	Significance of Effect
Thames Navigation Channel	Small	Low	Low	Moderate	Insignificant
Jetty 1	Small	Moderate	Low	Moderate	Insignificant
Jetty 3	Small	Low	Low	Low	Insignificant
Chainrock Jetty	Small	Negligible	None	Low	Insignificant
Coryton O&G	Negligible	Low	None	Moderate	Insignificant
Calor Jetty	Negligible	Low	None	Moderate	Insignificant
London Gateway	Negligible	Low	None	Moderate	Insignificant
South coast of Canvey Island (intertidal)	Small	Low	Low	Low	Insignificant
Thames Estuary and Marshes Ramsar/SPA/SSSI	Negligible	Low	None	High	Insignificant
South Thames Estuary SSSI	Negligible	Low	None	Moderate	Insignificant
Holehaven Creek SSSI	Small	Low	Low	Moderate	Insignificant
Mucking Flats and Marshes (SSSI)	Negligible	Low	None	Moderate	Insignificant
Benfleet and Southend Marshes (SSSI/SPA)	Negligible	Low	None	High	Insignificant

Changes in seabed bathymetry and processes - dredge location

Understanding of potential impact

8.147 The dredged pocket at Jetty 2 is being deepened to 16.5 m below CD. This involves dredging up to 3 m of silt, sand and some gravel from the north west corner of the pocket but little change in areas towards the east side. A hydrodynamic model (Delft3D Flow) was developed for the previous ES that was undertaken for the construction of Jetty 2 in 2015 (OSL, 2016). This model has been used to predict the physical processes changes that would result from the proposed dredge at Jetty 2 and complement the conceptual understanding from analysis of previous studies. Figures 8.4 to Figure 8.5 show the worst-case effects on the estuary dynamics at the time of peak flood and ebb spring tide flows (top plot in these figures are the baseline flows and the bottom figure is the change in flows with the scheme in place). Figure 8.6 shows the time series throughout the tide near the location of greatest change at the north west corner of the dredge pocket.

8.148 Figure 8.4 and Figure 8.5 indicate that all changes are small, generally less than 0.1 m/s (< 10%) of the ambient flows and are confined to a relatively small area within, around and behind the berth pocket. Within the berth, reductions in flow are confined to the western 100 m of the pocket. Behind the jetty, flow speed reductions are between 0.025 and 0.05 m/s and extend *circa* 280 m to the outer edge of the intertidal area. This area is predominantly confined to up estuary of the jetty head approach on the ebb but behind the whole length of the pocket on the flood. Small areas of increased flow by up to 0.05 m/s occur outside each end of the berth pocket on both the flood and ebb as additional flow is drawn through the deepened berth pocket.

8.149 Figure 8.6 shows that the small reduction in flow speed is evident throughout the tide with a very small reorientation in the flow direction (< 5 °). The plot also indicates the maximum change in the bed shear stress (BSS) resulting from the deepening. On the flood, the reduction in BSS was about 0.05 N/m² and 0.07 N/m² on the ebb, representing *circa* 10% of the existing BSS. This change has a negligible effect on the ability of the flows to transport the sand/silts in motion within estuary. As a result, sedimentation within the berth area is unlikely to change from the natural estuary sediment regime. The new configuration of the pocket will, however, provide increased potential for some initial sedimentation as a result of the increased supply of sand arising from the existing maintenance dredging of Jetty 1. Most of the material is expected to disperse on subsequent tides although some may accumulate at the base of the western end slope in the north west corner of the berth.

8.150 The modelling indicates that maintenance dredging at the Jetty 2 berth under the current flow regime is likely to be minimal with only small amounts requiring to be removed infrequently.

8.151 The areas of reduced flow behind the Jetty 2 berth are in areas where sedimentation is already occurring back to an equilibrium level. The small reduction in flow is likely to cause a marginal increase to the sedimentation rate until the ongoing sedimentation reaches a natural equilibrium for the current hydrodynamic regime.

8.152 The small changes to the bathymetry and their local effect on physical processes mean there will be no measurable changes to estuary dynamics including tidal propagation, water levels or effects on saline intrusion.

Assessment of level of significance without mitigation

8.153 The only receptors that the changes in seabed bathymetry and estuary processes have the potential to affect are Jetties 1 and 3, and the South Coast of Canvey Island (intertidal). All other receptors will not be affected (i.e. no impact).

8.154 Applying the assessment methodology indicates a small to very small potential for sedimentation behind the dredged Jetty 2 berth pocket. As summarised in Table 8.20, these effects are assessed as insignificant on relevant receptors with respect to the existing baseline.

Table 8.20: Assessment of the level of significance associated with changes in bathymetry and estuary processes on relevant receptors

Receptor	Magnitude of Exposure to Impact	Sensitivity of Receptor	Vulnerability of receptor	Importance of Receptor	Significance of Effect
Jetty 1	Small	Moderate	Low	Moderate	Insignificant
Jetty 3	Small	Moderate	Low	Low	Insignificant
South coast of Canvey Island (intertidal)	Small	Low	Low	Low	Insignificant

Changes in seabed bathymetry - disposal location

Understanding of potential impact

8.155 A total of about 25,000 m³ *in situ* will be deposited at the North Edinburgh Channel disposal site from up to 13 dredger loads at a rate of one load per tide. At least 80% to 90% of the material will settle directly to the bed and cause a mound beneath the dredger, which could initially be three to four metres high, but would flatten out with the channel flows.

8.156 Existing depths at the disposal site are for the most part in excess of -14 mCD with deeper pockets. Good practice will be followed by distributing each load throughout the site thus minimising the initial reduction in depth. By following this practice, the maximum reduction in depth at any one location would be about 3 to 4 m; a maximum percentage reduction of around 30% at any location. This will result in an increase in flow around each mound and subsequent erosion and redistribution will take place particularly for the sand material. The mounds are therefore likely to be a temporary feature evident for *circa* a few months.

8.157 Analysis of previous dredge disposal data indicates that the site has previously accommodated disposal rates of up to 1.2 million m³ per month (i.e. a 48 times greater disposal rate than currently proposed) without significant long-term changes to the channel depths. Bathymetric survey analysis indicates the total to be deposited is also less than 0.5 % of the sand estimated to be in motion naturally through the dredge area in a year.

8.158 The dredge deposits will be initially discernible on the seabed before being flattened and dispersed. The maximum reduction in depth would still leave *circa* 10 m of water at LW and therefore will not significantly affect navigation through the channel.

8.159 Effects of the disposal are unlikely to be evident against the background variability after an estimated three months.

Assessment of level of significance without mitigation

8.160 The disposal site is situated in a deep highly mobile channel within both the Outer Thames Estuary SPA and the Margate and Long Sands SAC. All effects are unlikely to be discernible from background variability within *circa* 3 months after the end of the disposal activity providing good practice is carried out by spreading the individual loads throughout the deposit area. As a result, any bathymetric changes above the natural variability will be of a temporary nature. Table 8.21 sets out the results of the assessment of the level of significance.

8.161 The effects of bathymetric change are assessed as minor significant on the Outer Thames Estuary SPA and Margate and Long Sands SAC due to the effects, albeit temporary in nature, being located directly within these internationally nature conservation sites.

Table 8.21: Assessment of the level of significance associated with changes in bathymetry at the disposal site on relevant receptors

Receptor	Magnitude of Exposure to Impact	Sensitivity of Receptor	Vulnerability of receptor	Importance of Receptor	Significance of Effect
Outer Thames Estuary SPA	Small	Low	Low	High	Minor
Margate and Long Sands SAC	Small	Low	Low	High	Minor

Changes in SSC distribution at the Disposal Site

Understanding of potential impact

8.162 The proposed capital dredge of the OMSSD project is likely to be undertaken by a TSHD with a capacity of up to about 2,500 m of *in situ* material. The complete dredge will therefore be undertaken in 10 to 13 loads. The distance between the dredge area at Jetty 2 and the North Edinburgh Channel disposal site means the frequency of disposal will be restricted to one load per tide. The water depths at the site and in the navigation channels to the site mean disposal can take place at any state of the tide, both on springs and neaps. The material to be disposed of will comprise predominantly silt, sand with some gravel which will be non-cohesive in nature. The dredged sediment has up to 50 % of fines (less than 63 μm) some of which will be 'winnowed' out during the dredge process. The sediment will be deposited from the hull of the dredger and will take up to about 10 minutes to dispose.

8.163 The worst case with respect to the dispersal SSC would arise from the disposal occurring on spring tides and at the time of peak flows. On the basis that each load contains 2,500 m³ of *in situ* material, about 3,158 dry weight tonnes of silt, sand and gravel will be deposited at the site per load, at a rate of the order of 5.62 t/s. On the assumption that the disposal takes place at the shallowest location, at about 10 m below CD at mean tide level, and the dredger has a 6 m laden draught then the initial average concentration passing through the water column beneath the dredger would be of the order of 65,000 mg/l.

8.164 At least 80 % to 90 % of the material will settle directly to the bed and cause a mound beneath the dredger, which could initially be three to four metres high, but would flatten out with the channel flows. Some of the finest sediment will be immediately dispersed on spring tide flows which would redistribute the finer fractions of the disposal. The sediment remaining in the water column, within the passive plume, is likely to have initial concentrations in excess of 650 mg/l but would be settling to the bed at up to 0.045 m/s. Most of this suspended sediment would result from the physical impact disturbance with the bed and therefore would be in the lower half of the water column. On this basis the majority of sediment would settle out within about 200 m down flow of the disposal location.

8.165 Given the existing flow speeds, a small proportion of the sediment could reach about 1.5 km from the disposal site but concentrations are likely to be less than 10 mg/l above the background at these greater distances from the site.

Assessment of level of significance without mitigation

8.166 The level of significance on the two receptors that have the potential to be affected has been assessed according to the defined assessment method and is presented in Table 8.22. The maximum worst-case extent of the potential dispersion from the disposal site is estimated to be about 1.5 km down flow of each disposal load and would be predominantly confined to the orientation of the channel. This ZOI remains within both the Outer Thames Estuary SPA and the Margate and Long Sands SAC.

8.167 Up to *circa* 90% of the material is likely to initially remain within 200 m of each disposal load location, before being further redistributed over time by the natural variability of physical processes occurring at that location. Changes in SSC would not be discernible from background SSC within around 15 to 30 minutes of each dredger load that is disposed.

8.168 Peak SSC away from immediately under the dredger could exceed 650 mg/l for a short period (few minutes) but would rapidly settle out. The North Edinburgh Channel disposal site was initially characterised to accommodate greater than an order of magnitude of more material than the 25,000 m³ currently proposed to be disposed and was reassessed in 2016. Dredge disposal returns indicate the site has previously accommodated up to 1.18 million wet tonnes of similar material in a month. Bathymetric calculations in a period without dredging also indicate the natural variability of volumetric change at the site is in the order of over 6 million m³ in a year.

8.169 The overall magnitude of exposure to impact in terms of SSC at the disposal site is assessed as small only lasting for a period of up to 30 minutes on the 10 to 13 consecutive tides required for the disposal. The SSC effects are assessed as not significant for the Outer

Thames Estuary SPA and Margate and Long Sands SAC due to these effects occurring within these internationally important sites.

Table 8.22: Assessment of the level of significance associated with changes in SSC at the disposal site on relevant receptors

Receptor	Magnitude of Exposure to Impact	Sensitivity of Receptor	Vulnerability of receptor	Importance of Receptor	Significance of Effect
Outer Thames Estuary SPA	Small	Low	Low	High	Minor
Margate and Long Sand SAC	Small	Low	Low	High	Minor

Changes in water quality as a result of increased SSC and potential contaminants in the sediment

<u>*Understanding of potential impact*</u>

8.170 The changes in water quality have been assessed within the preliminary WFD compliance assessment. An initial draft of this assessment for the purposes of the PEIR and based on current scheme assumptions is included in Appendix 8.1.

8.171 The proposed development has the potential to remobilise any contaminants that may be trapped within the sediments. The likelihood of mobilising sediments and contaminated sediments and the magnitude of any effect is dependent upon the level of contamination and the volume of material being removed; the proximity of the activity to the feature; the type of activity occurring; the manner in which that activity is pursued (including the extent and duration); the particle size of the disturbed sediments (contaminants tend to be associated with finer particles) and the hydrodynamic conditions.

8.172 An overview of existing chemical sediment data, including sampling that has been undertaken in accordance with the agreed PLA/MMO sample plan (SAM/2020/00058) is included in earlier parts of this chapter). The results confirm that the sediments to be dredged are considered acceptable for disposal in the marine environment from a chemical perspective. It should be noted that at the time of writing, however, the polybrominated diphenyl ethers (PBDE) results from Cefas were not available. This data will be considered within the ES.

<u>*Assessment of level of significance without mitigation*</u>

8.173 Based on all available information, the overall level of contamination in the proposed dredge area is low and the extent of sediment dispersal as a result of the dredge is considered to be spatially limited. Significant elevations in the water column contamination are not anticipated (see analysis presented in the WFD Compliance Assessment; Appendix 8.1). During disposal, sediment will be rapidly dispersed in the water column. Therefore, the already low levels of contaminants in the dredged sediments will be dispersed further.

8.174 The conclusions of this assessment are that the proposed dredge and disposal of dredge material at the North Edinburgh Channel disposal site are not expected to lead to a significant deterioration in water quality. Overall, the changes in water quality are assessed as insignificant.

Firewater System Impacts

Change to the seabed and SSC due to marine plant

Understanding of potential impact

8.175 At the present time, the method for the construction of the intake and outlet pipework has not been defined in detail. The worst case change in the seabed and SSC would result from the use of a jack-up barge with its legs resting on the seabed. Should this be the case, the legs will create 'pock marks' in the bed and scour of fine sediments would occur in close proximity to the legs.

8.176 Modelling of flows throughout the tide (ABPmer, 2016a) show that tidal flows in the area of the jetty approach (the site of the intake) are always below 0.2 m/s on spring tides and will be essentially slack during neaps. At the rear of the jetty head (location of the outlet) peak flow speeds are also less than 0.2 m/s on the flood but can reach 0.4 m/s for about 2 hours on the early ebb tide, with directions approximately aligned with the Jetty in the down estuary direction.

8.177 These flows are low and given the small scale nature of the works and, therefore, the time a jack-up barge will be on station would be small (matter of days), the potential for scour will be small and local to the legs, probably contained within 2 diameters of the legs. The depth of change would depend on the density of the bed and the material type but would be expected to be no more than about 0.2 m around each leg. The volume of sediment released would be small and would redeposit close by as a result of the low estuary flows.

Assessment of level of significance without mitigation

8.178 The main effects from the construction are likely to arise from the interaction of the legs of the jack-up barge with the seabed adjacent to Jetty 1. Previous modelling has shown the flow speed in the work areas to be low (ABPmer, 2016a). As a result of the small scale nature of the works, with plant on site no more than a few days, the potential for scour is considered to be small to negligible at the intake location and slightly more (small) at the outlet. Such effects will not occur if the works are undertaken from the existing structure or floating plant.

8.179 All effects during construction of the marine firewater system are assessed as being either small or negligible in magnitude and, therefore, the impact is assessed as insignificant.

Operation

8.180 Table 8.17 indicates that there are four potential impact pathways during the operational phase of the OMSSD project resulting from the change to physical processes and maintenance dredging. These potential impacts for the most part stem from the changes that the dredge causes to the ongoing hydrodynamic and sediment regime of the estuary. Consequently, these potential impacts have been discussed together using evidence from the hydrodynamic modelling that has been undertaken and is discussed above and presented in Figures 8.4 to 8.6. Operational effects will potentially also result, from the weekly testing of the marine firewater system and during a fire emergency should this occur. The pathways for potential impact are included in Table 8.18 and assessed below.

Dredge and Disposal Impacts

Changes in physical processes during operation

<u>*Understanding of potential impact*</u>

8.181 Figures 8.4 and 8.5 show that flow speeds through the Jetty 2 berth will be marginally slower by up to 0.1 m/s at the time of peak flows, predominantly at the west end of the berth, where the deepening will be greatest. Figure 8.6 indicates that this effect is consistent throughout the tide and there is a small rotation in flow direction (<5 °) realigning the flow even closer to the alignment of the berthing face.

8.182 Initially there will be a small increase in flow up to 0.05 m/s just outside either end of the Jetty 2 berth. This, however, is expected to be reduced once slight erosion by winnowing of the finest sediment occurs.

8.183 In general flow speeds will be reduced by 0.025 to 0.05 m/s in the shallow subtidal area behind the jetty. This is currently an area of sedimentation and changing flows and the changes associated with the OMSSD project are less than 10 % (many below 5 %) of the ambient flows.

8.184 The Bed Shear Stress (BSS), although reduced by up to *circa* 10 % throughout the berth pocket, will still be well above the thresholds for movement of the estuary sediments. There will be no change to the overall natural supply of sediment through the area and the berth is expected to remain predominantly self-maintaining from the natural sedimentary regime.

8.185 As noted earlier in the chapter, the maintenance dredging of Jetty 1 by WID moves material through the north west corner of the Jetty 2 berth. This increased supply could initially cause some sedimentation at the western end of the berth, particularly near the base of the steep end slope, which may need to be maintenance dredged.

8.186 The hydrodynamic and sedimentary changes resulting from the deepened berth at Jetty 2 are expected to result in a small requirement for maintenance dredging at the berth (estimated at less than 10,000 m^3 per annum, on an *ad hoc* basis). This maintenance dredge could be undertaken as an extension of the existing Jetty 1 maintenance dredge campaign, which is a considerably larger quantity and which already disturbs sediment to the berth area. The additional dredging requirement at Jetty 2 is therefore a small change. The quantity is likely to be similar to the existing variability in the maintenance dredge campaign and therefore any effects from maintaining the new berth will be small and possibly only noticeable as a slight increase in the overall time that plumes exist. The overall SSC in the water column and settlement over the bed is unlikely to be measurable.

8.187 The increased depths at the Jetty 2 berth will allow a slightly higher wave activity to take place at the western end of the berth than at present. This will be, however, no different to what already occurs at the eastern end of the berth. The distance offshore means the small localised increase in energy will be dissipated by the shallower subtidal depths inshore and will not have any measurable effects on the intertidal.

8.188 Any wave effects on local receptors will, therefore, be negligible in magnitude.

Assessment of level of significance without mitigation

8.189 During the operational phase all effects of the deepened Jetty 2 berth on the hydrodynamic and sedimentary regime will be local to the jetty and berth and of small to negligible magnitude compared to the baseline conditions.

8.190 The modelling suggests the berth will be predominantly self-maintaining against the natural estuary regime. The greatest potential for sedimentation arises from the disturbance and dispersal of sediment from the existing maintenance dredging by WID of Jetty 1. The amounts, however, that are anticipated to accumulate at Jetty 2 and require re-dredging are small. This additional maintenance dredge requirement at Jetty 2 is likely to be within the existing natural variability of the Jetty 1 maintenance dredge requirement, and therefore unlikely to cause a significant effect.

8.191 Table 8.23 sets out the results of the assessment of operational effects on all potentially relevant receptors. All effects are assessed as being either small or negligible in magnitude. For all receptors. the changes during operation are therefore assessed as insignificant.

Table 8.23: Assessment of the level of significance associated with changes during operation on relevant receptors

Receptor	Magnitude of Exposure to Impact	Sensitivity of Receptor	Vulnerability of receptor	Importance of Receptor	Significance of Effect
Thames Navigation Channel	Small	Low	Low	Moderate	Insignificant
Jetty 1	Small	Moderate	Low	Moderate	Insignificant
Jetty 3	Small	Low	Low	Low	Insignificant
Thames Navigation Channel	Small	Low	Low	Moderate	Insignificant
Jetty 1	Small	Moderate	Low	Moderate	Insignificant
Jetty 3	Small	Low	Low	Low	Insignificant
Chainrock Jetty	Negligible	Negligible	None	Low	Insignificant
Coryton O&G	Negligible	Low	None	Moderate	Insignificant
Calor Jetty	Negligible	Low	None	Moderate	Insignificant

Receptor	Magnitude of Exposure to Impact	Sensitivity of Receptor	Vulnerability of receptor	Importance of Receptor	Significance of Effect
London Gateway	Negligible	Low	None	Moderate	Insignificant
South coast of Canvey Island (intertidal)	Small	Low	Low	Low	Insignificant
Thames Estuary and Marshes Ramsar/SPA/SSSI	Negligible	Low	None	High	Insignificant
South Thames Estuary SSSI	Negligible	Low	None	Moderate	Insignificant

Firewater System Impacts

Change to seabed and sediment release from intake and outlet flows

Understanding of potential impact

8.192 As noted earlier, flow speeds in and around the potential locations of the intake and outlets are low, for the most part with peak flows on spring tides less than 0.2 m/s. Localised change in flow patterns around the structures are, therefore, likely to result during the weekly testing of the systems and if ever required during an emergency.

8.193 In the worst case (without diffusers), maximum intake and outlet velocities at the end of the pipe will be about 2 m/s and 4.5 m/s respectively, i.e. considerably faster than the natural flows. These flows will, however, reduce quickly with distance from the pipe or diffuser. Whilst in operation there is potential for scour of the bed close to the structures which will release sediment to the water column. The distance of travel of this plume, however, will be small due to the low flows and the silty/sand nature of the sediment.

8.194 Erosion will occur predominantly in the first few tests of the system, however, an equilibrium scour 'hole' is likely to form, with sediment settling in the 'hole' between test operations. As a consequence, once an equilibrium morphology has formed, the release of material is likely to be limited to the amount of sedimentation that has occurred between successive tests.

8.195 During the initial erosion period, given the small predicted transport distance it is quite likely that the eroded sediment would accumulate within the Jetty 1 berth pocket, therefore, temporarily increasing the maintenance dredge requirement for the berth. The assessment below suggests this volume will be a relatively small increase compared to the volumes already required to be dredged from natural sedimentation (see Table 8.16).

8.196 On the assumption that the intake and outlet flows are drawn or discharged into still water and the velocity disperses and diffuses at a rate 1:10 (lateral: longitudinal), then average velocities are likely to reduce to *circa* 0.3 m/s within 5 to 6 m from the end of each pipe.

Using Van Rijn (2019b)[130], assuming the flow interacts with the bed and the particle size is about 100 μm, then erosion is likely to be confined within these distances. Allowing for variation in sediment type and the small background flow, it is estimated that the equilibrium morphology will develop within about 10 m of both the intake and outlet in the direction of the 'jet'. Initially, sediment would be drawn through the system due to the bed erosion. It is, therefore, likely that the intake will be located above the bed but below the lowest water level. Should this be the case then erosion at the intake is likely to be smaller than assessed above.

Assessment of level of significance without mitigation

8.197 The likely changes to the seabed resulting from the water being drawn into the intake and released as a jet from the outlet, include the potential to cause erosion within about 10 m of the respective pipes. This erosion will occur relatively quickly, over a few weeks and an equilibrium morphology will develop, reducing further erosion rates. The impact will only occur at worst for one hour every week. The overall effect is, therefore, considered to be small initially reducing to a negligible impact within a few weeks. Given the slow ambient flow and the sediment size, any sediment plumes will be short- lived and sediment will be quickly returned to the seabed. Plumes with high suspended load are not expected to disperse beyond the Oikos frontage, particularly once an equilibrium morphology has developed.

8.198 The overall magnitude of changes caused by the flows through the marine firewater system are assessed as at worst small initially, reducing to negligible after a few weeks. In addition, given the short and intermittent nature, the significance of the impact is assessed as insignificant.

Change to hydrodynamics affecting vessels at the Jetty 1

Understanding of potential impact

8.199 As noted above, velocities from the outlet are expected to decay to around background levels within about 10 m of the outlet. The current potential design specification indicates that diffusers would be part of the design so flow speeds are likely to be even lower. Any effects on vessels would, therefore, only be noticeable if the jet were directed out perpendicular to the jetty from the outside edge of the jetty head. Should a vessel be moored then the flow could 'push' the vessel away from the jetty, increasing the mooring force for the short period of the test.

Assessment of level of significance without mitigation

8.200 In theory there could be a small increase in mooring loads on a moored vessel, however, the short timescale of potential effect allows the time of the test to be varied to avoid any

[130] Van Rijn, L. C. (2019b) Simple general formulae for sand transport in rivers, estuaries and coastal waters. (www.leovanrijn-sediment.com)

potential effect on the vessels. Even without such management practice, the impact is considered small in magnitude and the significance assessed as insignificant.

Human health

8.201 All physical processes effects arising from the construction (dredging and disposal) and operation of Jetty 2 are confined to the marine water environment. These effects, with the possible exception of sediment contamination do not directly impact on human health. Sediment contamination sampling through the depth of the proposed dredge has been undertaken to the agreed PLA/MMO sample plan. At the time of writing, the polybrominated diphenyl ethers (PBDE) results from Cefas were not available. This data will be considered within the ES. All other contaminants were lower in content than the 2019 analysis. Based on these data and the historic analysis, there is no reason to indicate that the sediment will be unsuitable for disposal in the marine environment. The levels of contamination are therefore not expected to have a significant human or ecological effect.

Climate change

8.202 The bathymetric and hydrodynamic changes resulting from the dredging and disposal activities are very small in the estuary wide context. The magnitude of these changes are insufficient to cause morphological change that would significantly affect tidal propagation, saline intrusion or wave activity. As a result, the works will have no impact on the predicted ongoing effects of climate change in the marine environment. Equally the effects of climate change in the future would make an insignificant change to the physical processes effects that have been assessed as a result of the OMSSD project.

Cumulative effects

8.203 Inter-related (cumulative) effects of the marine works comprising the OMSSD project are at worst of small or very small magnitude and remain relatively local to the dredge and disposal locations and are temporary in effect (a week to three months). The potential for inter-related effects is therefore considered to be low.

8.204 A potential cumulative effect between the maintenance dredging of the new berth pocket at Jetty 2 and Jetty 1 has been identified, however, the significance of the combined effect is likely to remain insignificant.

8.205 A cumulative effect would arise at the disposal site if the Outer Thames Approach channels maintenance dredging as proposed in the WHA undertaken by PLA (2016) were to take place at the same time as the capital dredge. The total dredge quantities could be an order of magnitude higher than for the proposed dredge at Jetty 2. This combined total has been accommodated previously at the disposal site. Should the Outer Thames Approach channel maintenance dredging take place at the same time as the disposal for the OMSSD project then a localised shallowing and an initial change to the bedform characteristics is likely to occur at the North Edinburgh Channel disposal site before being restored by the existing flow regime which is unlikely to be affected. During disposal most material will be placed near to the bed and will remain within 5 km of the disposal location. For a short time during the dredging operation, dredge plumes will be evident within the water column. The chemical status of the bed material is unlikely to change markedly from that which has previously been characterised. Overall, therefore, the significance of a cumulative effect during disposal is likely to remain minor significant at worst.

Mitigation Measures

8.206 The highest level of significance identified within the water environment assessment was minor significant and related to the potential effects of disposal operations during construction on the Outer Thames Estuary SPA and Margate and Long Sands SAC. The magnitude of these effects, however, were small with the significance assessed as minor primarily due to the internationally designated status (i.e. high importance) of the sites. The significance of all other potential impacts on other relevant receptors was assessed as insignificant.

8.207 In accordance with the defined impact assessment methodology, mitigation measures are only considered necessary if the level of significance is assessed as moderate or above. Based on the assessment outcomes, there is considered to be no requirement for secondary mitigation measures as defined by IEMA (2016).

8.208 Good practice, which is considered to be an in built mitigation measure, will be followed for the potential disposal activity at the North Edinburgh Channel disposal site (TH080) by distributing each load throughout the site. This will minimise the initial reduction in water depth and any environmental changes at this site. Although this is not likely to alter the assessment conclusions, it is considered to be standard good practice.

Limitations

8.209 This assessment has been undertaken based on the following assumptions:

- Dredging is undertaken by TSHD with disposal at the North Edinburgh Channel (TH080) disposal site (if required);
- Any maintenance dredging requirement will be undertaken by WID;
- Hydrodynamic modelling has not been undertaken for the purposes of the PEIR. Once the methodologies for the proposed dredge and disposal (if required) have been confirmed, the need for additional plume modelling will be considered for the ES;
- Assessment of sediment release terms is based on theoretical analysis and expert opinion gained from previous dredge analyses; and
- The potential effects of the marine firewater system option has been assessed using a simple conceptual approach.

8.210 Whilst these are limitations, the assessment within this PEIR has been undertaken considering the anticipated worst-case scenario in respect of the marine water environment at both the dredge and disposal locations and for the firewater system. The assessment will be updated in the ES once the dredge and disposal (if required) methodologies have been confirmed and the design of the firewater system finalised.

Preliminary Conclusions on Residual Effects

8.211 No specific mitigation has been identified as being necessary within the marine environment arising from the physical effects of dredging the berth pocket at Jetty 2 and the disposal of the arisings. Overall, it is considered that the residual effects will remain the same as the assessment of significance in advance of mitigation above.

8.212 The assessment concludes that there is no potential for significant effects. The main effects predominantly remain local to the individual dredging and disposal locations, as well as the potential marine firewater intake and outlet pipes. Apart from one exception, all impact pathways are assessed as insignificant. The exception was a minor adverse (not significant) impact arising from changes in the bathymetry at the disposal site, which overlaps with two international designated sites (Outer Thames Estuary SPA and Margate and Long Sands SAC). This minor effect, however, is only likely to be evident for an estimated period of *circa* 3 months following the disposal activity.