IMMINGHAM EASTERN RO-RO TERMINAL

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Chapter 7: Physical Processes
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Immingham Eastern Ro-Ro Terminal

Environmental Statement: Volume 1
Chapter 7: Physical Processes

December 2022

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7.1 Introduction

7.1.1 This chapter provides an assessment of the potential significant effects of the proposed Immingham Eastern Ro-Ro Terminal (IERRT) on physical processes in the marine environment, namely flows, waves and sediments and how they may impact the proposed development site and the wider study area. The key elements of the proposed development in the Humber Estuary are shown on Figure 1.2 in Volume 2 of this Environmental Statement (ES) (Application Document Reference number 8.3). The marine infrastructure works, specifically the capital dredge of the berth pocket, the associated dredge disposal, and the proposed floating pontoons and pile structures have formed the basis of this physical processes assessment. This chapter has been prepared by ABPmer.

7.1.2 The following receptors have been considered as part of the assessment:

- Hydrodynamics;
- Sediment transport;
- Plume dispersion; and
- Waves.

7.1.3 Where predicted impacts to these receptors have the potential to subsequently impact specific features of interest (such as existing marine infrastructure, or estuary banks and channels), these have been identified and considered within the assessment in Section 7.8.

7.1.4 A number of figures support the description of the existing environment (baseline) and are provided in Volume 2 of this ES document (Application Document Reference number 8.3). Figures 1.1 and 1.2 show the location of the study area in relation to the marine elements of the proposed IERRT, whilst Figure 7.1 shows the proposed site in the context of the regional setting and the wider Physical Processes study area. Current and wave roses from the immediate vicinity of the marine works (as collected in the project specific survey campaign, see ABPmer, 2020) are provided in Figure 7.2 to this ES, and maps of baseline flows and waves are provided throughout the assessment figures, to provide context to the predicted changes. The results of baseline sediment sampling, defining Particle Size Distribution (PSD) of bed material across the study area, are provided in Figures 7.3 and 7.4 to this ES.

7.1.5 This assessment has enabled a consideration of effects on physical features or sites of interest, including those across the wider study area and adjacent berth pockets to be undertaken. It has also informed the Water and Sediment Quality assessment (Chapter 8), the Nature Conservation and Marine Ecology assessment (Chapter 9), the Commercial and Recreational Navigation assessment (Chapter 10), the Coastal Protection, Flood Defence and Drainage assessment (Chapter 11) and the Cultural Heritage and Marine Archaeology assessment (Chapter 15).

7.1.6 This physical processes assessment has also assisted in informing the Habitats Regulations Assessment (HRA) (Application Document Reference number 9.6), the Water Framework Directive (WFD) Compliance Assessment and the Waste Hierarchy Assessment (WHA). The latter two documents are included as Appendix 8.1 and Appendix 2.1 respectively to Volume 3 of the ES (Application Document Reference number 8.4).

7.2 Definition of the study area

7.2.1 The study area for this assessment is the area over which potential direct and indirect effects of the IERRT project are predicted to occur during the construction and operational periods.

7.2.2 The direct effects on physical processes are those confined to the areas within the footprint of the proposed development, i.e., the piers, pontoons, dredged berth pocket and disposal of dredge material at the proposed disposal sites.

7.2.3 Indirect effects are those that may arise due to wider changes in the estuary flow and sedimentary regime and any associated change to the estuary morphology as a result of the proposed development.

7.2.4 As a consequence, the study area for the physical processes topic comprises the proposed development site and the adjacent Immingham coastline, the existing jetties across the near-field and the central part of the Humber Estuary, the area generally between Sunk Dredged Channel (SDC) and Halton Middle and the proposed spoil grounds HU056 and HU060. Within the far-field region, the study area includes the wider Humber Estuary from the mouth to up-estuary of the Hull Bend (Figure 7.1).

7.3 Assessment methodology

Data and information sources

7.3.1 Current baseline conditions have been determined by a desk-based review of available information. A series of project-specific surveys have also been undertaken to characterise the local hydrodynamic and wave regime and the sediment composition within (and around) the proposed dredged berth pocket and across the proposed disposal sites.

7.3.2 Survey, modelling and conceptual analysis of the physical processes of the Humber Estuary has been undertaken by ABPmer for several decades. Due to this vast knowledge and experience, it has been possible to draw upon more historical data and past work than would normally be the case for an assessment of this kind. The main desk-based sources of information that have been reviewed to inform the current baseline description within the vicinity of the proposed development include:

- Various ABPmer reports covering project work for ABP in and around the Immingham region (including those related to the Immingham Oil Terminal (IOT), the Humber International Terminal (HIT), Immingham Outer Harbour and associated maintenance dredging and disposal studies; and
- Guidance documents relevant to the study, including Environment Agency Coastal Flood Boundary datasets for extreme events and UK Climate Projections (Met Office, 2018; Palmer, *et al*, 2018) for influence of future climate change.

7.3.3 Site specific surveys that have been undertaken to underpin the assessments include:

- Combined bathymetric and topographic (LiDAR) survey data over the proposed study area, providing elevation data over the planned dredge berth pocket and surrounding area;
- Geophysical seismic survey of the site, providing a full spread of multibeam bathymetry, sub-bottom profiling, side-scan sonar and magnetometer data (provided in Appendix 7.2 of this ES). These data have been used as inputs to the numerical model and also used to inform the assessments as well as for determining the required dredge depths (and volumes);
- Hydrodynamic and wave data collected by ABPmer during 2020, including a 6-month deployment of 1 MHz Acoustic Wave and Current Profiler (AWAC) (waves at 1-hour intervals, currents at 10-minute intervals) and water quality sensors (Conductivity-Temperature Depth (CTD) and Turbidity at 10-minute intervals) between 15 November 2019 and 05 June 2020 at the proposed development site and a subsequent 3-month deployment at HIT between 05 June 2020 and 13 September 2020; and
- Site specific marine sediment samples collected in 2021 within the boundaries of the IERRT and the proposed disposal sites for particle size analysis (PSA).

Determining significance of effects

7.3.4 The methods adopted for the assessment of the changes to physical processes – flows, waves, dredge plumes and sediments – are different to those adopted for other environmental topics. This is because whilst the proposed development has the potential to cause changes to hydrodynamic and sedimentary processes, these are not, in themselves, generally recognised as environmental features/receptors and, therefore, the changes do not equate to ‘impacts’. The impacts will instead be the consequence of these changes on other environmental features or receptors. For example, ‘changes’ in the transport and deposition of sediment may ‘impact’ on the structure and function of marine habitats and their associated species.

7.3.5 It should be noted, therefore, that the assessment undertaken in relation to physical processes, has applied a standard impact assessment methodology to assess the potential 'exposure to change' resulting from the impact pathways that have been scoped into the assessment, but not the significance of any effects. The consequent significance of effects resulting from changes to physical processes on other environmental features/receptors have been assessed in other topic-specific chapters of this ES, namely Water and Sediment Quality (Chapter 8), Nature Conservation and Marine Ecology (Chapter 9), Commercial and Recreational Navigation (Chapter 10) and Coastal Protection, Flood Defence and Drainage (Chapter 11).

7.3.6 The scale of potential physical processes changes that are likely to occur as a result of the IERRT are considered to be small. This is because the magnitude of the physical changes brought about by the proposed development is very small in the context of the scale of ongoing natural changes both in the local and far field study areas (Figure 7.1). This ongoing background variability both in the short and long term is discussed and illustrated in Section 7.6. Project-specific numerical modelling to inform the physical processes assessment has been undertaken to provide predictions of likely changes to hydrodynamics, suspended sediment concentrations (SSC), and potential sedimentation (erosion/accretion) patterns across the Immingham frontage and the wider study area. Analyses of the likely fate of sediment plumes from marine construction (i.e. capital dredging and disposal) and operational activities (i.e. maintenance dredging and disposal) have also been undertaken.

7.3.7 The assessment methodology which has been applied and which is presented in the following sections, is designed to incorporate the key criteria and considerations without being overly prescriptive.

Stage 1 – Identify pathways and changes

7.3.8 The first stage identifies the potential environmental changes resulting from the proposed activity and the processes that are likely to be affected (which are together referred to as the impact pathway). The potential impact pathways that are considered relevant to this Environmental Impact Assessment (EIA) are set out in Section 7.8.

Stage 2 – Understand change

7.3.9 The second stage involves understanding the nature of the environmental changes to provide a benchmark against which the changes and levels of exposure can be compared. The scale of the impacts (via the impact pathways) depends upon a range of factors, including the following:

- Magnitude (local/strategic):
  - Spatial extent
    - small scale – limited in extent to the development areas itself and areas immediately adjacent;

        - large scale – extent of effect spread over a wider area, including up- and down-estuary regions;
    - Duration
        - temporary – impacts likely to persist for as long as an activity is being undertaken, before ceasing once activities stop;
        - short/intermediate – impacts likely to occur for months to years;
        - long-term – impacts likely to be evident for decades;
    - Frequency
        - routine – activities likely to occur frequently (at least three or four times per year) throughout the lifetime of the project
        - intermittent/occasional – activities leading to impacts likely to occur annually (or less frequently)
        - rare activities leading to impacts that may occur only once or twice during the lifetime of the project;
    - Reversibility;
- Probability of occurrence;
- The baseline conditions of the system;
- Existing long-term trends and natural variability; and
- Confidence, or certainty, in the impact prediction.

7.3.10 Table 7.1 has been applied to define the estimate of 'exposure to change' for each impact pathway. Magnitude of change is considered in spatial and temporal terms (including duration, frequency and seasonality), and against the background environmental conditions in a study area. Once a magnitude has been assessed, this is then combined with the probability of occurrence to arrive at an exposure score. For example, an impact pathway with a medium magnitude of change and a high probability of occurrence would result in a medium exposure to change.

Table 7.1. Assessment of exposure to change, combining magnitude and probability of occurrence

Probability of occurrence	Magnitude of change			
	Large	Medium	Small	Negligible
High	High	Medium	Low	Negligible
Medium	Medium	Medium/Low	Low /Negligible	Negligible
Low	Low	Low /Negligible	Negligible	Negligible
Negligible	Negligible	Negligible	Negligible	Negligible

Stage 3 – Mitigation

7.3.11 The final stage is to identify exposure to change and determine whether any impacts require mitigation measures to reduce residual impacts, as far as possible, to environmentally acceptable levels. Within the assessment procedure the use of mitigation measures will alter the risk of exposure to change.

7.3.12 Mitigation measures considered throughout the EIA process can take three forms (IEMA, 2016):

- Primary (inherent) – modifications to the location or design of the development made during the pre-application phase that are an inherent (or embedded) part of the project. These are captured and taken into account in the initial impact assessment;
- Secondary (foreseeable) – actions that will require further activity in order to achieve the anticipated outcome (identified as necessary through the assessment process). Within the impact assessment process, the use of secondary mitigation measures will alter the risk of exposure to change and, hence, will require significance to be re-assessed and thus the residual impact (i.e. with mitigation) identified; and
- Tertiary (inexorable) – actions that would occur with or without input from an environmental impact assessment process, including actions that will be undertaken to meet other existing legislative requirements, or actions considered to be standard practices to manage commonly occurring environmental effects. These are captured and taken account of in the initial impact assessment.

7.4 Consultation

7.4.1 Consultation on whether there are any likely physical processes changes as a result of the construction and operation of the of the IERRT project has been undertaken as appropriate, including with the Environment Agency and the Marine Management Organisation (MMO). The outcomes of the formal scoping process, as well as any feedback received in response to the statutory consultation and the publication of the Preliminary Environmental Information Report (PEIR) and supplementary statutory consultation and the publication of the Supplementary Consultation Report, have also been taken into account to inform the assessment.

7.4.2 The outcome of the consultation that has been undertaken, along with how it has influenced the physical processes assessment, is presented in Table 7.2.

Table 7.2. Summary of consultation

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
Planning Inspectorate (PINS) Environment Agency	Scoping Opinion, October 2021 (ABPmer, 2021) Table ID 4.1.2 Appendix 2 Environment Agency response Environment Agency Pre-application meeting, 29 November 2021	The ES must clearly describe the receptors to be considered in the assessment and explain how/why they were identified. The assessment should consider effects on the existing jetties near the Proposed Development site, the existing Immingham tidal level gauge and any other telemetry devices in the area of Immingham Docks.	Identified receptors (including adjacent jetties and existing telemetry devices) have been listed in Section 7.1 of this chapter of the ES with further detail on the assessment undertaken for each receptor provided within the relevant parts of Section 7.8.
PINS Marine Management Organisation (MMO)	Scoping Opinion, October 2021 Table ID 4.1.3 Appendix 2 MMO response	The assessments in the ES should address the potential effects on physical processes as a result of vessel movement and vessel wash in the shallow nearshore area.	Sensitivity testing of the presence of vessels on-berth has been included in the assessment, as described in Section 7.8 of this chapter of the ES.
PINS	Scoping Opinion, October 2021 Table ID 4.1.4	The Applicant should seek to agree the methodology used to assess changes in coastal processes, suspended sediment concentrations (SSC) and erosion and accretion patterns and waves with the MMO and other relevant stakeholders as far as possible.	The approach to the assessment has been discussed with the MMO and the Environment Agency and is described in Section 7.8 of this chapter of the ES.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
PINS	Scoping Opinion, October 2021 Table ID 4.1.5	It is not clear from the Scoping Report if any ground investigations are planned as part of the assessment. The ES must explain how the baseline data is derived and (in the event that no further ground investigations are undertaken) provide a justification as to why the data is adequate for the assessment of effects from the Proposed Development	Geophysical data collected in January 2022 has informed this assessment in the ES (Appendix 7.2 of this ES).
Environment Agency	Scoping Opinion, October 2021 Appendix 2 Environment Agency response Environment Agency Pre-application meeting, 29 November 2021	The dredge disposal impact assessment should include any impact on physical processes (e.g. erosion/deposition) and any change on channel morphology, even if expected to be temporary.	This has been assessed in Section 7.8 of this chapter of the ES.
Environment Agency	Scoping Opinion, October 2021 Appendix 2 Environment Agency response Environment Agency Pre-application	The Environment Agency is supportive of the proposed assessment methodology, and data/models to be used within that assessment. We are also pleased to see, and are in agreement with, paragraph 6.2.38 in that *"at the current stage there is considered to be insufficient evidence to*	Noted.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
	meeting, 29 November 2021	*exclude any potential pathways from further assessment within the EIA".*	
MMO	Scoping Opinion, October 2021 Appendix 2 MMO response	It is important that the assessment of sediment disposal is framed in terms of sediment budget and temporal variation in sediment flux i.e., not just a blanket annual figure. The MMO view disposal within the sediment system of the estuary an acceptable measure in the absence of other forms of beneficial reuse. It would be useful however to illustrate the temporal variability of this relative to the licensed disposal volumes and past quantities, i.e., whether the cycling of dredge and disposal is a significant contribution to short or long-term sediment flux.	The sediment budget has been described in Section 7.6 of this chapter of the ES and the assessment of impact of dredge and disposal activities has been included in Section 7.8.
MMO	Scoping Opinion, October 2021 Appendix 2 MMO response	The MMO consider that the definition of processes as a receptor is possible if the assessor simply chooses to define it as one. The MMO consider this a good idea in cases where the overall importance of a physical process in affecting the state of another receptor is not fully understood i.e., where the effect of a change in the process cannot be quantified. If the opposite approach is taken, the MMO would expect the ES to demonstrate that the effect of process changes is well understood	The impact of the scheme on the identified physical processes has been assessed in Section 7.8 of this chapter of the ES. The potential effect on the defined impact pathways has been assessed in terms of exposure to change, combining magnitude and likelihood of predicted effect.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
		which is likely to be possible in the present case.	
MMO	Scoping Opinion, October 2021 Appendix 2 MMO response	Section 6.2.5 gives extensive verbal description of the setting and zone of interest but lacks reference to any image or mapping of the named features which would greatly aid interpretation.	Figure 7.1 to this ES provides a general location map and includes locations of features named within this ES chapter.
Associated Petroleum Terminals (APT) (PI30)	Statutory Consultation – 19 Jan – 23 Feb 2022	The IOT Operators are concerned that the area will suffer from siltation or scouring during the construction [and operation] phase of the IERRT Development and need to be satisfied that changes to the physical processes of the port area during the construction [and operation] phase of the IERRT Development will not affect the IOT jetty or impede its ability to operate its business. The IOT Operators therefore seek further information from ABP on the data used to inform the studies relied upon by ABP.	The potential impact of the IERRT project on the IOT terminals has been assessed within this ES chapter, with the findings described in Section 7.8 for both Construction and Operation Phases. The list of data sources used to inform this assessment is provided in Section 7.3 of this chapter.
Environment Agency (PI34)	Statutory Consultation – 19 Jan – 23 Feb 2022	The physical processes assessment should consider the nature and likelihood of impacts upon the existing Immingham tide level gauge, which is situated on the eastern jetty near the dock walls.	The potential impacts on the existing Immingham tide gauge have been included in the physical processes assessment, with the findings described in Section 7.8 of this chapter.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
Marine Management Organisation (MMO) (PI35)	Statutory Consultation – 19 Jan – 23 Feb 2022	Some named features within the wider Chapter are not included on map/figures. This would be useful to provide context to location described.	Figure 7.1 to this ES provides a general location map and includes locations of features named within this ES chapter.
Marine Management Organisation (MMO) (PI35)	Statutory Consultation – 19 Jan – 23 Feb 2022	Construction traffic impacts from ship wash/vessel propulsion to be included.	The assessment of potential impacts from construction vessel ship wash/vessel propulsion has been included, with the findings provided in Section 7.8 of this chapter.
Marine Management Organisation (MMO) (PI35)	Statutory Consultation – 19 Jan – 23 Feb 2022	Net sediment budget estimates have been included (Table 7.5) but reference to these values do not appear in the assessments.	The assessment section of this physical processes chapter of the ES (Section 7.8) includes discussion of potential impacts in the context of (and with reference to) the wider estuary sediment budget.
Marine Management Organisation (MMO) (PI35)	Statutory Consultation – 19 Jan – 23 Feb 2022	In comparison with the mixed presentation of wave and tide, suspended sediment concentration (SSC) data are described in the text, but the data are not plotted. It would be instructive to understand the temporal distribution and duration of different SSC levels.	Additional timeseries plots of predicted excess SSC (and associated sedimentation) have been included at Figure 7.7 to this ES, informing an updated description of SSC provided in the text in Section 7.8 of this ES chapter.
Marine Management Organisation (MMO) (PI35)	Statutory Consultation – 19 Jan – 23 Feb 2022	The MMO, in consultation with Cefas, consider that the required dredges are all additional interventions in coastal processes so should be presented as a percentage increase to the existing levels of disturbance.	The physical processes assessment in Section 7.8 of this chapter of the ES includes percentage increases in dredge volume against annual average existing (baseline) levels.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
Marine Management Organisation (MMO) (PI35)	Statutory Consultation – 19 Jan – 23 Feb 2022	The chapter refers frequently to impacts and mitigation (dependent on significance), and also described effects on impact pathways; it is an assessment of impact significance in all but name.	The impact of the scheme on the identified physical processes has been assessed in Section 7.8 of this chapter of the ES. The potential effect on the defined impact pathways has been assessed in terms of exposure to change, combining magnitude and likelihood of predicted effect.
North Lincolnshire Council (NLC) (PI38)	Statutory Consultation – 19 Jan – 23 Feb 2022	NLC do not wish to raise any objection to the principle of the proposed scheme, although it should be noted that NLC do not have expertise in this area.	Noted.
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	Advise that your assessment consider the potential impact of the proposed development on estuarine geomorphology, including the adjacent intertidal profile, banks and channel morphology.	The physical processes assessment in Section 7.8 of this chapter of the ES includes consideration of potential impacts of the proposed development on local and regional features, including estuary banks and channels.
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	The list of receptors does not include significant morphological features within the Zone of Influence (ZoI), such as intertidal banks, channel systems and navigation channels. These features should be identified and considered in the impact assessment. It would be useful to provide a figure showing the ZoI of the proposed development.	The physical processes assessment in Section 7.8 of this chapter of the ES includes consideration of potential impacts on local and regional features, including estuary banks and channels. ZoI for each of the different physical process elements is provided on the respective map plots for hydrodynamics, sediment transport

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			and plume dispersion as shown in Figures 7.5 to 7.24 to the ES.
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	The impact pathways set out in section 7.3.9 should be refined. For example, spatial extent should consider national, regional, local and site-specific scales. Duration should also be more specific; it is not clear what is meant by short, intermediate and long-term. Similarly for frequency, it is not clear what is meant by routine, intermittent, occasional, rare.	Descriptions of the various impact pathway elements for spatial, temporal, duration, frequency have been provided in order to give additional context and refinement in Section 7.3 of this chapter to the ES.
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	We recommend the assessment consider the influence of long-term tidal cycles on patterns of sedimentation and channel migration within the ZoI as well as the tidal prism in this location.	The longer-term morphological trends across the wider area are described in Section 7.6 of this chapter to the ES. The physical processes assessment in Section 7.8 of this chapter has been updated to include consideration of potential impacts on longer-term tidal cycles and tidal prism.
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	No sub-surface data has been presented in Chapter 7. Natural England advises that these data are important for informing understanding of any geological constraints, the potential seabed mobility, and the nature of sub-surface material that may be disturbed during the project construction.	Summary results from the recent geophysical survey (including sub-bottom profiling) have been included within the physical processes assessment at Section 7.6 of this chapter to the ES.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	Deposits at HU060 have been assessed. However, it is not clear what the sedimentary character at this, or other, potential disposal sites is, and this should be provided.	The baseline description of the sediments in and around the proposed disposal sites has been provided in Section 7.6 of this chapter, Table 7.6 to this chapter and Figures 7.3 and 7.4 to this ES.
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	The modelled period with continuous dredging operations and disposal every 4 hours equates to around 35% of the total required berth dredge volume. The maximum SSC and sedimentation from dredge and disposal across the study area should be modelled for 100% of the total required berth dredge volume.	The final scheme design requires a smaller dredge volume than was assessed at the time of the PEIR, meaning the assessment now covers approximately 73% of the total required berth dredge volume. The assessment in Section 7.8 of this chapter has also been updated (with inclusion of timeseries plots of SSC and sedimentation at Figure 7.7 to this ES) to enhance the description of the temporal nature of the impacts and provide consideration of the potential for successive dredge/disposal operations to result in a cumulative impact.
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	It is not clear how bed shear stress, sediment erosion and/or deposition potential and water column properties would be affected within and adjacent to the disposal site(s) due to disposal of material. Nor is it clear if bed levels at the disposal site would be monitored.	The physical processes assessment in Section 7.8 of this chapter includes consideration of potential impacts from disposal at the disposal site(s) along with consideration of the continuation of ongoing bed level monitoring.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
Natural England (PI40)	Statutory Consultation – 19 Jan – 23 Feb 2022	Changes to bed shear stress as a result of the proposed development, and the implications of this for sediment accumulation and/or erosion within and adjacent to the proposed development, particularly around the dredged area, should be considered within the assessment.	The physical processes assessment in Section 7.8 of this chapter includes consideration of changes to bed shear stress (including map and timeseries outputs at Figures 7.10 to 7.16 and Figure 7.20 of this ES) along with associated changes to sediment transport (including map outputs of bed level change at Figure 7.19 of this ES) due to accretion/erosion as a result of the IERRT development.
Anglian Water (PI43)	Statutory Consultation – 19 Jan – 23 Feb 2022	Request that the assessment of construction dredging on the Immingham Sea Outfall is provided to Anglian Water and agreement reached on the design and mitigation steps required to safeguard its continued operation.	The Immingham Sea Outfall has been included as a receptor within this physical processes chapter of the ES and the potential impacts from IERRT are described in Section 7.8. There is not predicted to be an increase in bed sedimentation along the foreshore as a result of the dredging (and disposal) activity and therefore no mitigation is required.
North East Lindsey Drainage Board (c/o Witham Internal Drainage Board) (PI44)	Statutory Consultation – 19 Jan – 23 Feb 2022	North East Lindsey Internal Drainage Board (IDB) want reassurance that the new structures won't cause accretion/restrictions to flow at the Habrough Marsh Drain outfall.	The North East Lindsey IDB Habrough Marsh Drain outfall has been included as a receptor within this physical processes chapter of the ES and the potential impacts from IERRT are described in Section 7.8.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
Q1	Statutory Consultation – 19 Jan – 23 Feb 2022	Perception that the existing dredging practices are not removing material from the system and are, subsequently, leading to siltation around the wider estuary.	Description of the wider sediment budget (which includes the existing dredging practices) and the potential impacts arising from the proposed IERRT are described in Sections 7.6 and 7.8 of this chapter of the ES.
Q16	Statutory Consultation – 19 Jan – 23 Feb 2022	The only concern about the construction of the development is the effect it will have further down the coast on the beaches at Cleethorpes and Humberston.	The physical processes assessment in this chapter of the ES includes the wider far-field study area across the whole Humber Estuary and its Approaches. The consideration of impacts from IERRT across the wider study area, including on hydrodynamics and sediment transport, area is described in Section 7.8 of this chapter of the ES.
EX21	Statutory Consultation – 19 Jan – 23 Feb 2022	General concern regarding sediment accretion in main channels and perceived lack of dredging by ABP.	Baseline description at Section 7.6 of this chapter of the ES includes consideration of average existing levels of dredging undertaken at the existing Immingham berths and the associated disposal volumes at the identified disposal sites.
Q65	Statutory Consultation – 19 Jan – 23 Feb 2022	Concern about the impacts of the amount of maintenance dredging that is required was raised.	The potential impacts arising from the maintenance dredging required for the IERRT project are described in 7.8 of this chapter of the ES.
MMO and Cefas	Pre-application meeting, 6 April 2022	Discussion was had around the MMO's response to the statutory consultation on the PEIR, and preliminary outcomes	The specific responses to the MMO's comments on the PEIR are noted in this table in the rows above.

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
		of the assessment of changes to physical processes. The MMO did not have major concerns regarding impacts to physical processes or the assessment that has been presented in the PEIR. The MMO and Cefas reaffirmed that there were no major concerns with the assessment presented in the PEIR	
Environment Agency	Pre-application meeting, 20 May 2022	Discussion was had around the Environment Agency's response to the statutory consultation on the PEIR, and preliminary outcomes of the assessment of changes to physical processes. The Environment Agency did not have major concerns regarding impacts to physical processes or the assessment that has been presented in the PEIR. The Environment Agency had no further comments to make in relation to the physical processes assessment or to the proposed approach to responding to the comments made on the PEIR.	The specific responses to the Environment Agency's comments on the PEIR are noted in this table in the rows above.
MMO (PI 10)	Supplementary Statutory Consultation – 28 Oct – 27 Nov 2022	Previous comments raised relating to coastal processes on 23 February 2022 remain unchanged.	Noted.
		The MMO consider it would be useful to see the assessment of impact of additional material considering the	The assessment of dredge disposal detailed in Section 7.8 of this chapter includes consideration of the

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
		volume and the physical and chemical nature of the material at the disposal sites in combination with other disposal events.	increased volume arising from the newly dredged berth pocket and also provides assessment of the potential for relative changes to future maintenance dredging.
Environment Agency (PI 11)	Supplementary Statutory Consultation – 28 Oct – 27 Nov 2022	This consultation has alerted us to the potential for additional impacts on siltation to the Harborough Marsh Drain outfall and that these impacts were not specifically assessed as a separate impact pathway in the original Preliminary Environmental Impact Report (Table 1, Page 42). It is our view that these potential impacts should be assessed for both the construction phase and the future operation of the terminal. If the assessment concludes that the development will (or may) have a detrimental impact on the operation of the existing outfall then details of appropriate monitoring and mitigation measures, and the mechanism for securing these, should be included in the Environmental Statement.	Impacts on the existing infrastructure (including the Habrough Marsh Drain) have been considered (for both construction and operation phases) within Section 7.8 of this chapter.
North East Lindsey Internal Drainage Board (c/o Witham Internal Drainage Board) (PI 12)	Supplementary Statutory Consultation – 28 Oct – 27 Nov 2022	The Board is still concerned of the effects of the new infrastructure in the Humber over and near to the gravity outfall of Habrough Marsh Drain, there is concern that this will result in siltation which will impede the discharge. The	Siltation (and longer-term morphological) impacts on the existing infrastructure (including the Habrough Marsh Drain) have been considered (for both construction and

Consultee	Reference, Date	Summary of Response	How Comments have been Addressed in this Chapter
		Flood Risk Assessment and Drainage Strategy should address this and put in place measures to mitigate it.	operation phases) within Section 7.8 of this chapter.
Natural England (PI 22)	Supplementary Statutory Consultation – 28 Oct – 27 Nov 2022	As stated in our previous response Natural England broadly agrees with the scope of the assessment and we welcome any changes to design whereby impacts on any physical process are reduced. Natural England advise that our previous response sets out clearly the potential impacts and any clarification that should be made when finalising your ES prior to Development Consent Order (DCO) submission.	Noted.
BDB Pitmans LLP on behalf of Able Marine Energy Park (PI 29)	Supplementary Statutory Consultation – 28 Oct – 27 Nov 2022	Able is concerned that the effects of the IERRT may cause siltation or scouring at Able's Marine Energy Park once constructed, and would wish to see this assessed and an undertaking from ABP for financial compensation for any additional dredging or other works required to mitigate such effects.	The potential impact of the IERRT project on siltation and scouring has been assessed within this ES chapter, with the findings described in Section 7.8 for both Construction and Operation phases. Changes to physical processes are anticipated to be small in both magnitude and extent, and are not anticipated to affect the Able Marine Energy Park once constructed.

7.5 Implications of policy legislation and guidance

7.5.1 This section of the chapter sets out key aspects and implications of policy and guidance that are relevant to the assessment of likely impacts on physical processes. It builds upon the overarching chapter covering Legislation, Policy and Consenting Framework (Chapter 5 of this ES).

7.5.2 Although the UK has left the EU, some parts of EU legislation which applied directly or indirectly to the UK before 11.00 p.m. on 31 December 2020 has been retained in UK law as a form of domestic legislation known as 'retained EU legislation' by virtue of sections 2 and 3 of the European Union (Withdrawal) Act 2018 (as amended).

Legislation

The Marine and Coastal Access Act 2009 (MCAA)

7.5.3 The MCAA provides the legal mechanism to help ensure clean, healthy, safe, productive and biologically diverse oceans and seas by putting in place a new system for improved management and protection of the marine and coastal environment.

The Planning Act 2008

7.5.4 Whilst the MCAA regulates marine licensing for works at sea, section 149A of the Planning Act 2008 enables an applicant for a Development Consent Order (DCO) to include within the Order a Marine Licence which is deemed to be granted under the provisions of the MCAA.

The Habitats Regulations

7.5.5 The Conservation of Habitats and Species Regulations 2017 (as amended), known as the "Habitats Regulations", transposed the Habitats Directive (Directive 92/43/EEC) (European Union, 1992) and the Birds Directive (2009/147/EC) (European Union, 2009) into English law. The Conservation of Habitats and Species Regulations 2017 (as amended), remain part of domestic legislation following the UK's departure from the European Union.

7.5.6 The Habitats Regulations provide for the designation and protection of 'European sites', the protection of 'European protected species' and the adaptation of planning and other controls for the protection of European sites. The Regulations also require the compilation and maintenance of a register of European sites in England, to include Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) (classified under the Birds Directive). These sites form the Natura 2000 network. In addition, Natural England (2017) advice suggests that these regulations apply to Ramsar sites (designated under the 1971 Ramsar Convention for their internationally important wetlands), candidate SACs (cSAC), potential Special Protection Areas (pSPA), and proposed and existing European offshore marine sites.

7.5.7 Where a development project is located close to, or within, a European/Ramsar Site, the Habitats Regulations apply. This requires the Competent Authority to determine whether the proposed works have the potential to create a likely significant effect (LSE) on the interest features and/or supporting habitat of a European/Ramsar site either alone or in-combination with other plans, projects and activities and, if so, to undertake an Appropriate Assessment (AA) of the implications of the proposals in light of the site's conservation objectives.

7.5.8 An HRA has been undertaken given the direct overlap of the marine elements of the proposed development with the Humber Estuary SAC, SPA and Ramsar site (as shown in Figure 9.3 to this ES) and is provided at Application Document Reference number 9.6.

7.5.9 The outcomes of the physical processes assessment reported within this chapter have informed the HRA (see Chapter 5 Legislation, Policy and Consenting Framework, Section 5.12), in particular with respect to the following key potential impact pathways:

- Physical damage through disturbance and/or smothering of supporting habitats and associated prey resources for interest features;
- Physical damage through alterations in physical processes of supporting habitat for interest features; and
- Non-toxic contamination through elevated SSC resulting in effects on interest features, or their prey resources.

The Water Framework Regulations

7.5.10 The Water Framework Directive (WFD) (2000/60/EEC) establishes a framework for the management and protection of Europe's water resources. It is implemented in England and Wales through the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (as amended), known as the "Water Framework Regulations".

7.5.11 The overall objectives of the WFD as implemented by the Water Framework Regulations is to achieve "good ecological and good chemical status" in all inland and coastal waters by 2021 unless alternative objectives are set or there are grounds for time limited derogation. For example, where pressures preclude the achievement of good status (e.g. navigation, coastal defence) in heavily modified water bodies (HMWBs), the WFD provides that an alternative objective of "Good ecological potential" is set.

7.5.12 In terms of physical processes, "Good ecological status/potential" has regard to hydromorphological elements. The Good ecological status/potential assessment also considers biological and physicochemical quality elements, and specific pollutants. "Good chemical status" has regard to a series of priority substances and priority hazardous substances.

7.5.13 A WFD Compliance Assessment has been undertaken to determine whether the proposed development complies with the objectives of the WFD (see

Chapter 5 Legislation, Policy and Consenting Framework, Section 5.12) and is provided in Appendix 8.1 to this ES. This includes consideration of the potential risks for several key receptors, including hydromorphology. The WFD Compliance Assessment has been informed by the outcomes of the physical processes assessment reported within this chapter.

The Waste Regulations

7.5.14 Waste policy and, consequently, the Waste Hierarchy Assessment (WHA) are strongly governed by the waste hierarchy set out in Article 4 of the Waste Framework Directive (2008/98/EC). This Directive was transposed in England and Wales through the Waste (England and Wales) Regulations 2011. The waste hierarchy ranks waste management options according to what is best for the environment.

7.5.15 The waste hierarchy places emphasis on waste prevention or minimisation of waste, followed where possible by re-use of the material. For any dredging project, the *in situ* characteristics of the material (physical and chemical), the method and frequency of dredging (and any subsequent processing), determines its characteristics in the context of securing a consent that is in compliance with the waste hierarchy. This understanding is central to the consideration of management options for dealing with dredged material in light of the requirements of the WHA.

7.5.16 Where prevention of the dredging is not possible, then the volume to be dredged should be minimised, and options for the re-use of the material, recycling and other methods of recovery must be considered in the first instance. In the context of re-use and recycling of dredge material this could include engineering uses, agricultural and product uses, environmental enhancement or post treatment of the dredge material to change its character with a view to determining a potential use. Should no practical and cost-effective solutions be identified, only then can options for the disposal of the dredged material be considered. These include marine disposal in licensed deposit sites or land-based disposal in terrestrial landfill.

7.5.17 A WHA for the IERRT project has been undertaken to determine the Best Practical Environmental Option (BPEO) for dealing with the dredge arisings (see Chapter 5 Legislation, Policy and Consenting Framework, Section 5.12) and is provided in Appendix 2.1 to this ES. The WHA has been informed by the outcomes of this physical processes assessment. On the basis that the WHA has not identified a beneficial use for the dredged arisings (see Appendix 2.1 to this ES), the option of disposal in the estuary has been assessed as part of this physical processes assessment and is described in Section 7.8 of this chapter.

National policy

National Policy Statement for Ports (NPSfP)

7.5.18 The NPSfP (DfT, 2012) provides the policy framework for nationally significant infrastructure port and harbour related proposals which fall within the Planning Act 2008 thresholds. It advises that in order to meet the requirements of the Government's policies on sustainable development, new port infrastructure should, amongst other things, assess the impact on coastal processes, be adapted and resilient to the impacts of climate change and provide high standards of protection for the natural environment.

7.5.19 It also advises that applicants should assess the impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development has an impact on coastal processes, the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast.

7.5.20 The policy advice extends to the need also to assess the vulnerability of the proposed development to coastal change in the context of climate change during the project's operational life and any decommissioning period (Section 5.3 of the NPSfP).

UK Marine Policy Statement (MPS)

7.5.21 The MPS is the framework for preparing marine plans and taking decisions affecting the marine environment. The MPS also sets out the general environmental, social and economic considerations that need to be taken into account in marine planning and provides guidance on the pressures and impacts that decision makers need to consider when planning for and permitting development in the UK marine areas.

7.5.22 Section 2.6.8 of the MPS is relevant to the physical processes assessment. In particular, paragraph 2.6.8.4 states, amongst other things, that - *"Marine plan authorities should be satisfied that activities and developments will themselves be resilient to risks of coastal change and flooding and will not have an unacceptable impact on coastal change...".* In addition, paragraph 2.6.8.6 notes that the impacts of climate change throughout the operational life of a development should be taken into account in assessments, and that any geomorphological changes that an activity or development has on coastal processes, including sediment movement, should be minimised and mitigated.

UK Marine Strategy

7.5.23 The aim of the UK Marine Strategy is effectively to protect the marine environment across the UK. The Strategy sets out a comprehensive framework for assessing, monitoring and taking action to achieve the UK's shared vision for clean, healthy, safe, productive and biologically diverse seas (Defra, 2019). It aims to achieve good environmental status of marine waters by 2020 (followed by a six-year review) and to protect the resource base upon which marine-related economic and social activities depend. The Strategy constitutes the vital environmental component of future maritime policy, designed to achieve the full economic potential of oceans and seas in harmony with the marine environment.

7.5.24 The UK Marine Strategy applies to the landward boundary of coastal waters as defined under the WFD (i.e., from mean high-water springs (MHWS)) to the outer limit of the UK Exclusive Economic Zone (EEZ), as well as the area of UK continental shelf beyond the EEZ. Reporting against the Strategy is a cyclical process, and updated assessments and Marine Strategy documents are anticipated in due course. The anticipated pressures exerted on the marine environment by the IERRT project are considered to be of sufficiently small magnitude, in the context of UK Marine Regions, that they are unlikely to be a significant issue. The Strategy is, therefore, not considered further in this ES with regards to the physical processes assessment.

East Inshore and East Offshore Marine Plans

7.5.25 The first Marine Plans include the East Inshore and East Offshore Marine Plans, which are collectively referred to as 'the East Marine Plans'. These were formally adopted on 2 April 2014. The East Inshore Marine Plan area covers 6,000 km² of sea, from MHWS out to the 12 nautical mile limit from Flamborough Head in the north to Felixstowe in the south. The East Offshore Marine Plan covers 49,000 km² of area from the 12 nautical mile limit to the border with The Netherlands, Belgium and France.

7.5.26 There are no policies within the East Marine Plans related specifically to coastal processes. Policy CC1, however, states that:

7.5.27 "*Proposals should take account of:*

- *how they may be impacted upon by, and respond to, climate change over their lifetime; and*
- *how they may impact upon any climate change adaptation measures elsewhere during their lifetime. Where detrimental impacts on climate change adaptation measures are identified, evidence should be provided as to how the proposal will reduce such impacts*."

7.5.28 With respect to this physical processes assessment, the future baseline is discussed in Section 7.7 of this chapter to the ES, to provide context to the predicted changes (as a result of the proposed development) described in Section 7.8.

7.6 Description of the existing environment

Bathymetry and morphology

7.6.1 In plan shape, the Humber Estuary has a meandering funnel shape widening towards the mouth, where a southerly orientated spit has formed in response to littoral drift processes and antecedent geological controls. The funnel shape is demonstrated by the exponential decrease in estuary area, width, and depth from the mouth to the head. Regions defined and locations identified in the following paragraphs are shown on Figure 7.1, for ease of reference.

7.6.2 The estuary can be divided into three regions:

- The Inner Humber (Trent Falls to Humber Bridge);
- The Middle Humber (Humber Bridge to Grimsby); and
- The Outer Humber (Grimsby to Spurn Point).

7.6.3 In the Inner Humber, downstream of Trent Falls, where the Rivers Trent and Ouse merge, the estuary is characterised by a number of extensive intertidal banks composed of sand/silt. These banks include Winteringham Middle Sand, Redcliff Middle Sand, Hessle Sand and Barton Ness Sand.

7.6.4 The Middle Humber is similar in its characteristics to the Inner Humber, having a number of banks and channels which have a preferred configuration. In the northernmost section, the main channel lies close to the Hull Waterfront, but westwards, where it meets Hessle Sand, a secondary channel develops along the southern shore. Down-estuary this reach is dominated by Skitter and Foul Holme Sands.

7.6.5 The Outer Humber is dominated by a three-channel system at the mouth (offshore of Spurn Head), a large, submerged sandbank (the Middle Shoal, located approximately in the middle of the estuary offshore of Grimsby), and a single deep channel leading to the Middle Humber. The three channels are Haile Channel (to the south of the mouth of the Humber), Hawke Channel (to the northern side of the mouth, located off the tip of Spurn Head) and Bull Channel (in between the two). Up-estuary, Hawke Channel is extensively dredged and the resulting channel, known as SDC, provides shipping access to the ports of Immingham and Hull. The presence of boulder clay deposits in the Outer Humber provides a geological constraint that influences the position of some of the sand banks, intertidal areas and Spurn Point itself. The Outer Humber contains a number of disposal grounds.

7.6.6 The Humber Estuary has a macro tidal range, fast flows and a high background suspended sediment content. This means the bed of the estuary is very dynamic in its morphology, both in the short term and on longer time scales, particularly in areas where there are no constraints, either geological or man-made. This dynamism manifests itself in cyclical variations in the positions of channels and banks throughout different regions of the estuary, with many of these regions showing an interconnectivity of process. The dominant influences on morphological change are tides, waves and freshwater flows, tidal surges and biological activity.

7.6.7 These influences produce changes in SSC, deposition rates, bed composition and ultimately channel/bank configurations. The dynamic nature of the Humber is illustrated by the interactions existing between the various bank systems in the Inner and Middle Humber. Channel migration in the Inner Humber releases sand, which forms banks off Barton and New Holland in the Upper Middle Humber. Furthermore, there is a sediment exchange between Barton Ness Sand and Skitter Sand lower down the

Humber, which ultimately helps determine the shape and levels across Halton Flats. This variability in the banks and channels has been particularly noticeable around the Hull Bend during the last *circa* 20 - 25 years, with large changes to the intertidal banks and secondary channels in the areas of Hull Middle, Skitter Sand and Halton Flats.

7.6.8 Further down-estuary, between Immingham and Grimsby, the estuary is at its deepest, and relatively speaking, this is its most stable location. The main channel varies between 10 and 20 m below Chart Datum (CD) and is bounded by steep ‘hard sides’ thought to comprise boulder clay, which are relatively in-erodible to present-day hydrodynamics. On the south side of the channel a relatively wide and gently sloping shallow subtidal ‘ledge’ exists, predominantly associated with the construction of the Grimsby Dock System. To the north, near Hawkins Point, the intertidal area is narrow compared to the areas up and down the estuary. This is due to human intervention through the reclamation of Sunk Island in this area.

7.6.9 Across the proposed development site, the near field bathymetry is influenced by the deeper approaches to the Port of Immingham and the relatively shallower subtidal region behind the existing jetties (Figure 7.1 to this ES). Bed elevation within the approaches to Immingham, the SDC and on the berths at IOT varies in the approximate range of -8 to -20 mCD. Across the proposed development site, bed levels range from around -10 mCD offshore, sloping up towards the land along the Immingham foreshore. The intertidal area adjacent to the proposed development is around 230 m in width, narrowing slightly to the south, to around 160 m at the landward end of the IOT jetty.

7.6.10 A review of historical bathymetric charts extending both up and down estuary of the proposed development shows that in the 1930s, the channel up estuary was considerably deeper than present day, with depths of the order of -16 mCD centred about 1 km from the shoreline. The channel has consistently in-filled until about 1990, resulting in a depth of around -7 mCD. During the last 15 years, depths have been relatively stable, although variations between -6 m and -7 mCD have occurred in Whitebooth Road (Figure 7.1). Around the proposed development site (including Stalingborough Flats and the wider Immingham frontage), bed levels have remained relatively stable over time.

Tides and water levels

7.6.11 The Humber Estuary is macro tidal with a mean spring tidal range of 5.7 m at Spurn increasing to 7.4 m at Saltend then decreasing to 6.9 m at Hessle which is 45 km inland. Tides are semi diurnal with a slight diurnal inequality, amounting to a 0.2 m difference in high water spring tides at Immingham. Standard tidal levels at Immingham are provided in Table 7.3.

Table 7.3. Standard tide levels for Immingham

Tidal Level		Immingham mCD	Immingham mODN
Highest Astronomical Tide	HAT	8.00	4.10
Mean High Water Springs	MHWS	7.30	3.40
Mean High Water Neaps	MHWN	5.80	1.90
Mean Sea Level	MSL	4.18	0.28
Mean Low Water Neaps	MLWN	2.60	-1.30
Mean Low Water Springs	MLWS	0.90	-3.00
Lowest Astronomical Tide	LAT	0.20	-3.70
Mean Spring Tidal Range (MHWS – MLWS)		6.40 m	
Mean Neap Tidal Range (MHWN – MLWN)		3.20 m	
Note: Conversion from mCD to mODN at Immingham = -3.90 m.			

Source: UK Hydrographic Office (UKHO) 2022

7.6.12 The Humber tides are driven by the amphidromic system centred off the west coast of Denmark in the central North Sea. As the tide passes south of North Shields, it enters shallow water conditions which amplify the tidal range. This amplified tidal range drives the Humber tidal system so that the macro tidal range within the estuary is a product of the general morphology of the east coast as well as the estuary itself.

Extreme water levels

7.6.13 Current extreme predictions determined by the Environment Agency for Immingham are the most up-to-date and appropriate for this review (Environment Agency, 2018). These are provided in Table 7.4 for a baseline year of 2017.

Table 7.4. Predicted extreme water levels for the Port of Immingham

Return Period (Years)	Annual Exceedance Probability (%)	Extreme Water Level (mODN)
1	100	4.15
2	50	4.25
5	20	4.40
10	10	4.51
20	5	4.62
25	4	4.66
50	2	4.77
75	1.3	4.85
100	1	4.90
150	0.67	4.97
200	0.5	5.03
250	0.4	5.06
300	0.33	5.10
500	0.2	5.20
1,000	0.1	5.34
10,000	0.01	5.85

Source: Environment Agency, 2018

7.6.14 The maximum water level currently recorded at Immingham occurred on 5 December 2013 at 19:00 hours with a level of 5.216 m Ordnance Datum Newlyn (ODN) compared to the predicted 3.689 m ODN, therefore, the meteorological surge effect was 1.527 m.

Sea level rise

7.6.15 The above data do not allow for sea level rise in the future. In order to take into account future sea level rises, and given an assumed engineering design standard of 50 years from 2023, the latest UKCP18 relative sea level research and assuming a Representative Concentration Pathway (RCP) 8.5 95%ile scenario will add 0.52 m to the water levels provided in Table 7.4 to this chapter.

Flows

7.6.16 Flow speed data has been collected in proximity to the proposed development site between November 2019 and June 2020. Figure 7.2 to this ES shows a current rose of the data collected by the AWAC bed frame over the full deployment period.

7.6.17 The data reveals the flow regime fronting Immingham is generally rectilinear, with flows aligned approximately east-southeast on the ebb to west-northwest on the flood. Peak flows above 1.8 m/s were recorded during the ebb tide, with notably slower flows on the flood phase of the tide, resulting from the relative effects of the shallow 'shelf' of Stalingborough Flats and the drag effects from IOT.

Waves

7.6.18 The wave climate across the proposed development site is generally protected from large waves approaching from the North Sea by a combination of sheltering effects (from Spurn Head, the various banks and channels within the outer parts of the Humber Estuary, and by the local jetties at Immingham).

7.6.19 Measured data from an AWAC bed frame deployment in the vicinity of the proposed site was collected between November 2019 and June 2020. The data from this survey was used to provide the wave rose shown in Figure 7.2 to this ES. This reveals that the wave regime at the proposed site is dominated by waves approaching from the northwest and the southeast (coincident with the longest fetch lengths at the proposed site). Waves with significant wave height (Hs) of above 0.7 m are observed from both of these main approach directions, with a peak Hs value during the deployment period, of 0.84 m.

Geology and sediments

7.6.20 The Humber lies in a complex of solid and superficial geology which can be simplified into three groups: the pre-Quaternary, the glacial (or Quaternary) and Post Glacial (or Holocene).

7.6.21 The estuary upstream of the Humber Bridge represents an older estuary system formed in the last interglacial (120,000 to 80,000 years BP) with the estuary mouth at this time being located near the current Humber Bridge. Downstream of this point, the estuary is more recent in geological terms, the channel having formed in immediate post glacial times as melt water cut down through glacial till deposits. During the post glacial period of SLR, the former river channel underwent marine transgression and became subject to estuarine sedimentation.

7.6.22 The sediment budget of the Humber Estuary has previously been informed by historic analysis of data between 1946 and 2000 (comprising approximately three complete nodal tidal cycles) (ABPmer, 2004). It is noted that there is a high degree of variability in the underlying data, so regression coefficients calculated during the analysis are poor (although the relationships are statistically significantly different from 'no trend'). The three main sediment sources for the Humber Estuary are its tributaries, the North Sea (in the form of background suspended sediment) and the eroding Holderness coast. The exchange between the rivers and the sea is an order of magnitude smaller than the flux of sediment through the mouth on each tide and the inputs and outputs on each tide are very much smaller than the volume of sediment held in suspension and continually moving within the Estuary. A summary of the sediment budget is provided in Table 7.5.

Table 7.5. Net sediment budget model for the Humber Estuary

System Element	Sediment load and rate of exchange with the Estuary (+ve indicates an input; -ve indicates a removal) (tonnes per tide)
Humber Estuary	1.2×10^6 tonnes
River inputs	+335
Intertidal accretion	-4
Subtidal erosion	+145
Cliff erosion	+7
Saltmarsh deposition	-11
Met marine exchange	-472
Average tidal flux	$\pm 1.2 \times 10^5$

Source: ABPmer, 2004 (based on analysis of data between 1946 and 2000)

7.6.23 The bed sediments within the vicinity of the study area are understood to be a mixture of muds and sands. Previous sampling in the Immingham area has also identified the potential for chalk outcrops at depth. The benthic sampling, undertaken during September 2021 as part of the IERRT study, collected 20 sediment samples within, and adjacent to, the proposed berth dredge (see Figure 7.3 of this ES for locations). The bed samples were subsequently analysed for PSD, in order to characterise the bed material across the proposed berth dredge site. The majority (16 of the 20 samples) are classified as sandy Mud (after Folk, 1954), with the remainder comprising Sand and Mud (see Figure 7.4 to this ES for the PSD of the proposed berth dredge site and Table 7.6 to this chapter for summary PSD information). The same survey also collected grab samples across the two disposal sites (HU56 and HU60). PSD information for these samples (see Figure 7.3 for locations) are also provided in Figure 7.4 and Table 7.6 to this chapter, revealing a mixture of sediment type, with varying proportions of sand, mud and gravel.

7.6.24 Across the 20 sediment samples collected as part of the IERRT study, the average bed composition is 78% mud, 22% sand and no gravel material. Within the proposed dredge pocket, these average values shift slightly towards the finer particles with 80% mud and 20% sand. As noted above, the majority of locations are categorised as 'sandy Mud' (after Folk, 1954), with locations 1, 11 and 19 defined as 'Mud' and location 20 (located further offshore, towards the main channel, just behind the western arm of the IOT jetty) classed as 'Sand'.

7.6.25 Measurements of SSC in the Immingham area, collected between November 2019 and June 2020 in the vicinity of the proposed development, show that during ebb tides peak SSC can vary from a few hundred mg/l to over 1,000 mg/l, during larger spring tides. The SSC levels are also generally higher on spring tides (approximately double the concentrations observed on neap tides) and during the winter months, compared to summer months.

Table 7.6. Particle size distribution across the IERRT and disposal sites

Sample	Percentage Composition (%)			Sediment Description*	Mean Grain Size (d50) (µm)
	Mud	Sand	Gravel		
1	90.7	9.3	0.0	Mud	12.8
2	87.5	12.5	0.0	Sandy Mud	18.0
3	77.5	22.5	0.0	Sandy Mud	30.8
4	77.3	22.7	0.0	Sandy Mud	25.2
5	74.0	26.0	0.0	Sandy Mud	31.1
6	80.8	19.2	0.0	Sandy Mud	25.8
7	80.3	19.7	0.0	Sandy Mud	24.3
8	69.7	30.3	0.0	Sandy Mud	35.6
9	80.4	19.6	0.0	Sandy Mud	21.0
10	80.0	20.0	0.0	Sandy Mud	18.7
11	91.0	9.0	0.0	Mud	9.6
12	82.5	17.5	0.0	Sandy Mud	12.8
13	70.5	29.5	0.0	Sandy Mud	27.9
14	80.5	19.5	0.0	Sandy Mud	16.7
15	84.1	15.9	0.0	Sandy Mud	15.4
16	85.1	14.9	0.0	Sandy Mud	15.6
17	86.9	13.1	0.0	Sandy Mud	10.9
18	83.8	16.2	0.0	Sandy Mud	12.8
19	91.1	8.9	0.0	Mud	10.6
20	6.9	93.1	0.0	Sand	155.6
HU56_01	0.0	100.0	0.0	Sand	159.0
HU56_02	1.6	84.0	14.4	Slightly Gravelly Muddy Sand	186.1

Sample	Percentage Composition (%)			Sediment Description*	Mean Grain Size (d50) (µm)
	Mud	Sand	Gravel		
HU56_03	37.1	16.2	46.6	Muddy Gravel	83.8
HU56_04	16.3	12.1	71.5	Gravelly Mud	17.7
HU56_05	18.7	80.1	1.2	Gravelly Sand	707.9
HU56_06	35.0	17.0	48.0	Muddy Gravel	73.7
HU60_01	0.0	100.0	0.0	Sand	230.7
HU60_02	0.0	100.0	0.0	Sand	227.7
HU60_03	0.4	61.7	37.9	Slightly Gravelly Muddy Sand	148.1
HU60_04	0.0	100.0	0.0	Sand	232.7
HU60_05	0.0	100.0	0.0	Sand	202.1
HU60_06	0.0	100.0	0.0	Sand	223.6

* Sediment description after Folk, 1954

7.6.26 In addition to the bed sampling described above, a full-spread geophysical survey has also been carried out across the proposed IERRT development site (Appendix 7.2). In addition to multibeam bathymetry, this survey campaign also collected sub-bottom profiler (SBP), sidescan sonar (SSS) and magnetometer (MAG) datasets of the proposed site. Vibrocores were also collected in October 2021 for sediment contamination analysis (see Water and Sediment Quality chapter (Chapter 8) of this ES) and were analysed as part of the geophysical survey in Appendix 7.2. A summary of the interpreted geophysical datasets is provided below.

7.6.27 Three seabed sediment classifications have been identified from the SSS and Multibeam Echo Sounder (MBES) data: silt/mud, muddy sand, and firm clay. Silt/mud is the dominant sediment type. Muddy sand is present on the northern edge of the site and also hosts an area of mobile bedforms. Firm clay is present in the south-eastern corner of the site and presents as positive relief exposure at the seabed.

7.6.28 Four main types of sub surface units have been identified, also with sub-units. The geological model has been informed by background site information and geotechnical work carried out previously at, or near to, the survey area. The uppermost unit is comprised of alluvium deposits that can be further subdivided into surficial sediments composed of soft silt/mud with a depth range between 0 to 3.0 m below seabed (BSB).

7.6.29 The alluvium is composed of a mix of fluvial sediments comprised of sands, gravels, and clays. The unit presents a complex structure of channelisation and subsequent sediment fill. The base of the alluvium sediments (as a whole) range between 0.8 and 9.1 m BSB.

7.6.30 A bright reflector was identified in the upper sub-surface of much of the survey site. This reflector has been interpreted as a layer of organic sediment due to severe acoustic attenuation of the seismic data and by reference to historical borehole logs. All subsequent horizon interpretations have been limited by the presence of the organic sediment layer that attenuates the underlying reflectors making them uninterpretable across certain areas of the survey site.

7.6.31 A layer of boulder clay underlies the alluvium which has been interpreted as the “upper boulder clay” unit. The upper boulder clay ranges between 0 and 20.0 m BSB. Beneath the boulder clay lies a horizon interpreted from geotechnical data as inter-glacial clays. This horizon ranges between 4.0 and 25.6 m BSB. A second layer of boulder clay has been interpreted as the “lower boulder clay” unit and is intermittently interpreted between 8.7 and 37.5 m BSB. The bedrock has been identified as chalk (from geotechnical data) and has been intermittently observed in the seismic data at depths between 15.4 and 41.5 m BSB. The bedrock level appears to be dipping downwards towards the north-western edge of the study area.

7.7 Future baseline environment

7.7.1 Hydrodynamic and sedimentary processes will continue to be influenced by natural and human-induced variability, ongoing cyclic patterns and trends (e.g., ongoing maintenance dredging and disposal) with or without the proposed development.

7.7.2 The future baseline will also be influenced by climate change and, in particular, increased rates of mean sea level rise. Projections of change for Immingham up to 2100 are 0.99 m (based on UKCP18 RCP 8.5 95%ile climate change scenario, (Met Office, 2018)). Water levels in the future, as now, will also be affected by unpredictable surge and weather-related events.

7.8 Consideration of likely impacts and effects

7.8.1 This section identifies the potential likely effects on the physical processes receptors as a result of the construction and subsequent operation of the IERRT project, which have been identified.

7.8.2 Cumulative impacts on physical processes that could arise as a result of other developments and activities in the Humber Estuary are considered as necessary as part of the cumulative impacts and in-combination effects assessment (Chapter 20 of this ES).

Construction phase

7.8.3 This section contains an assessment of the potential impacts of the construction phase of the IERRT project. The following construction activities and impacts have been assessed:

- Capital dredge and disposal and piling works:
  - Increased SSC and potential sedimentation over the extent of the disturbance plume as a result of the construction of the new piers, jetty and possible vessel impact protection (piling) and capital dredging works;

  - Increased SSC and potential sedimentation as a result of the deposit of capital dredge material at a licensed offshore disposal site;
  - Changes in seabed bathymetry and composition as a result of deposition of dredged/disposal material within the area of the respective plumes; and
- Changes in local flow speeds (and potential impact on local sediment dynamics) as a result of construction vessel activity (ship wash, vessel propulsion etc.).

7.8.4 The construction of the IERRT project may be completed in a single stage, or it may be sequenced such that construction of the southernmost pier takes place at the same time as operation of the northernmost pier (see Chapter 3 of this ES). In the case of a sequenced construction, the duration of construction activity will be extended but it will not increase the scale of construction activity. However, all capital dredging (and associated disposal activity) will be undertaken together at one time, before operation of the northernmost pier commences. The assessment of capital dredging works as a continuous operation (as described below) represents the worst case for construction. Consequently, the below impact pathway assessment is considered the worst case and will not be altered by a sequenced construction period.

Capital dredge and disposal and piling - potential impact on SSC and sedimentation

7.8.5 The disposal of dredged material at sea associated with the proposed development will be fulfilled at licensed disposal sites HU056 and HU060 (see Chapters 2 and 3 of this ES).

7.8.6 The potential impact of dredge arisings (and spoil from removal to licensed disposal sites) on SSC and sedimentation has been assessed. The approach has used the dredge volumes provided by the project engineers and expert knowledge of the likely dredging process and of the availability of open disposal sites. The assessment has been informed through application of the calibrated numerical hydrodynamic modelling tool, which has been used to drive a Danish Hydraulic Institute (DHI) particle tracking module (Appendix 7.1 to this ES).

7.8.7 It is anticipated that most of the dredging for the berth pocket will be carried out by a backhoe dredger and will be supported by split barges on a continuous cycle to the disposal grounds. This dredging method has been assessed here as a worst-case for potential impact on SSC (resulting from release of material throughout the water column during both dredging and disposal – further detail of assumptions is provided below). The number of barges will be determined by the barge loading time and the time of transit to and from the disposal grounds so that the backhoe dredger is never stood idle, meaning the works will be a 24/7 operation until dredging is complete. This assessment has assumed that barge access to the disposal sites can be achieved throughout the full tidal cycle (this is considered to be a conservative, worst-case assumption for dredging and disposal operations and the subsequent plume development). Current dredge volume estimates (based on the latest available site-specific geotechnical and geophysical information) are for 40,000 m³ of boulder/glacial clay, alongside 150,000 m³ of sand/silt (alluvium), *in situ*. The inerodible boulder/glacial clay will be disposed of at site HU056, whilst HU060 is to be used to dispose of the sand/silt (alluvium) material.

Dredging of the proposed berth and associated disposal at HU060

7.8.8 Based on previous experience, the following assumptions have been made in relation to the berth dredge:

- Backhoe bucket size of 8 m³;
- Average bucket cycle time of 2 minutes;
- Working capacity of barge = 950 m³;
- A continuous barge operation would provide maximum production and greatest potential for magnitude in plume; and
- Typical rates, vessel speeds and distance to disposal site have been used to calculate typical dredge cycle times.

7.8.9 In addition, the following details have also been applied to the plume assessment, based on an understanding of the method and equipment to be used:

- Distance from dredge to disposal site is approximately 1.1 nautical miles and the assumed load service speed is 8 knots;
- Barge deposit time is 10 minutes;
- Characteristic sediment distribution is informed by the bed sampling (detailed in Table 7.6 to this chapter, with a mean grain diameter of around 20 µm, and the model inputs are summarised in Table 7.7 to this chapter;
- Inputs to the plume modelling from the dredge are applied both at the bed and also uniformly through the water column, arising from bucket lowering, bed ripping, water column wash and slewing (breaking the water surface);
- Inputs to the plume modelling from the deposit at the disposal site are applied both at the bed (from the deposit) and also just below the surface (from the initial release, based on the loaded draught of the barge); and
- At the disposal site, the sediment predominantly falls to bed as a density current and is then available for onward advection through bed erosion processes.

7.8.10 Using the above assumptions, the model assesses the repeating cycle of dredging at the planned berth pocket and subsequent disposal at HU060. Consequently, the basis of the assessment includes continuous dredging (throughout the modelled period) at the proposed berth location and a disposal (over a 10-minute period) at HU060 every four hours.

7.8.11 The composition of the dredged material (and that of the subsequent disposal) has been informed by the sediment sample analysis, carried out for the project (see Water and Sediment Quality chapter (Chapter 8) of the ES, ABPmer, 2020 and Appendix 7.2). Table 7.7 provides the derived composition information used in the plume dispersal modelling.

Table 7.7. Plume dispersion module - Sediment properties

Sediment description	Grain diameter (µm)	Settling velocity (m/s)	Percentage bed composition (%)
Fine sand	93	6×10^{-3}	20
Coarse silt	20	3×10^{-4}	56
Fine silt	4	1×10^{-5}	24

7.8.12 A list of five dredging/disposal scenarios have been defined to provide a range of sediment disturbance locations and tidal states that cover the potential dredge and disposal operations likely to be required for the development. These are described further in Table 7.8 to this chapter. The deposits at HU060 have been assessed, as this site is likely to receive the vast majority of the more unconsolidated dredged material. If required, HU056 will be used for the disposal of the inerodible boulder clay, which is considered likely to remain on the bed, without resulting in a significant plume of material. As a consequence, disposal activities at HU056 have not been modelled as the impacts are considered to be well within the magnitude and extent of the envelope of impact defined by the assessment of material at the HU060 disposal site (included in this assessment).

7.8.13 The assessed scenarios include modelling of a continuous dredge and associated disposal at HU060 (Scenario 1). In addition, a number of individual dredge and disposal operations have also been assessed, taking place at the time of peak ebb and peak flood tidal flows (Scenarios 2 to 5).

Table 7.8. Plume dispersion model scenarios

Scenario	Tidal state	Plume input location(s)	Description
1	Spring/neap cycle	Continuous cycle of berth dredge and disposal Site HU060	Backhoe from dredge pocket with barge disposal at disposal site HU060
2	Spring flood	Disposal Site HU060	Maximum initial disposal dispersion at HU060 Flood Tide - split hopper barge
3	Spring ebb		Maximum initial disposal dispersion at HU060 Ebb Tide - split hopper barge
4	Spring flood	Berth (dredge pocket)	Maximum initial Dredge Pocket Dispersion Flood Tide - Backhoe Dredger
5	Spring ebb		Maximum initial Dredge Pocket Dispersion Ebb Tide - Backhoe Dredger

Spatial dispersion of dredge plume and sedimentation

7.8.14 Following the repeating schematic dredge cycle (Scenario 1 in Table 7.8) the particle tracking model has been run with sequential dredge > disposal > dredge > … etc. cycles. The initial dredge commences during a mean spring tide and the cycle repeats for the remainder of the model run period (accounting for assessment of around 73% of the full required dredge volume). Dredge locations within the berth are switched between either end of the pocket, whilst disposal inputs are to the centre of the HU060 disposal site.

7.8.15 Figure 7.5 to this ES shows the maximum spatial extent of the combined dredge/ disposal SSC plume over peak flood and peak ebb tidal flows (on a spring tide).

7.8.16 For dredge arisings disposed at the HU060 site, it is anticipated that material will initially remain in suspension (when deposited during flood or ebb tidal flows), before settling to the bed during slack water around high water (HW) and low water (LW) periods. Once deposited to the bed, the material will return to the background sedimentary system for subsequent transport under flood or ebb tidal flows. Maximum SSC levels are associated with the disposal activities (with relatively small increases in SSC arising from the dredge itself). Peak excess SSC levels resulting from the disposal activities are around 600-800 mg/l at the spoil ground, reducing to typically 100-200 mg/l with distance from the source. Upstream of Hull, maximum SSC levels are lower; generally, between 20 and 100 mg/l, as the tidal excursion from the disposal site limits the extent of the resultant plume.

7.8.17 In practice, due to the high magnitude of (and wide envelope of variability in) background SSC levels (see Section 7.6 of this chapter), the predicted increase in concentrations resulting from the disposal activities is likely to become immeasurable (against background) within approximately 1 km of the disposal site. Furthermore, the effects of the proposed dredge and disposal operations are considered to be no different to those arising from the ongoing maintenance dredge/disposal activities that are carried out at the adjacent Immingham berths. The measurable plume from each disposal operation is only likely to persist for a single tidal cycle (less than 6 hours from disposal). After this time, the dispersion under the peak flood or ebb tidal flows means concentrations will have reverted to background levels. Increased concentrations arising from the dredge operations are of lower magnitude and persist over a shorter distance (and time) than that from the disposal.

7.8.18 Across the whole modelled period with continuous dredging operations and a disposal every four hours (amounting to disposal of around 73% of the total required berth dredge volume), the maximum SSC (throughout the full modelled period) is shown in Figure 7.6. Associated sedimentation (Figure 7.7 to this ES) to the bed extends up- and down-estuary from the disposal site. Peak sedimentation depths are around 4-6 mm within a distance of around 4 km from the disposal site. At the dredge location, increased sedimentation above 3 mm is predicted within around 500 m (aligned to the flow vectors) up- and down-stream of the dredged pocket. Outside of these areas, the majority of deposition levels across the study site are less than 1 mm. Once on the bed, the deposited material returns to the background system to be put back into suspension on subsequent peak flood or ebb tide to be further dispersed.

7.8.19 Example timeseries plots of predicted excess SSC and associated sedimentation (from the combined dredge/disposal operations) is provided in Figure 7.7 for two locations – one just up-estuary and one just down-estuary of the HU060 disposal site. In each case, peak SSC and sedimentation values are predicted at the disposal site whilst, at locations approximately 1.5 km up- and down-estuary, the timeseries plots show the temporal nature of the excess material. Each disposal results in peak SSC of around 100-200 mg/l at the selected locations (approximately 1.5 km from the disposal source). Each peak in SSC generally persists for a single timestep before the tidal forcing transports the plume further up/down estuary on the prevailing flood/ebb tide, respectively. Due to the timing of successive disposal events, there is no evidence of cumulative increases in SSC (i.e. the impact from each disposal is dispersed sufficiently before the next disposal, such that there is no predicted positive trend in excess SSC with sequential disposal events). As a result, the assessment of 73% of the total required dredge volume provides the maximum spatial extent and magnitude of impact. Extending the assessment for the full 100% of the dredged volume simply extends the period of time over which the predicted impacts are likely to occur (i.e. for the duration of the dredging and disposal operations, before ceasing and conditions returning to the existing baseline).

7.8.20 Associated with this, each disposal operation results in sedimentation of around 1-2 mm at locations around 1.5 km from source. Once deposited, this material remains on the bed during slack water periods, before being put back into suspension on the subsequent flood or ebb tide. Thus, material is returned to the existing (baseline) sediment regime, retained within the wider Humber Estuary system following disposal at HU060.

7.8.21 In addition to the impacts described above, it is noted that the dredging activity will take place at the berth pocket location, adjacent to the Immingham foreshore. Potential impacts arising from this activity along this stretch of coastline (which includes existing port infrastructure and drainage outfalls (Immingham Sea Outfall and Habrough Marsh Drain) have been considered. The predicted increase in SSC (and subsequent sedimentation) is generally confined to the dredge area and the immediate vicinity. Dispersal plumes are taken from the dredge site up- and down-estuary aligned with the dominant flood and ebb tidal streams. Consequently, the effect along the adjacent foreshore is generally small in magnitude and limited in extent both spatially and temporally. An increase in bed sedimentation along the foreshore as a result of the dredging (and disposal) activity is not predicted. Potential impacts on existing infrastructure, arising during the operational phase, are considered in subsequent sections of this chapter.

7.8.22 It should be noted that the map plots in Figure 7.5 and Figure 7.6 do not show the instantaneous SSC and sedimentation levels at any given point in time, rather they show the maximum SSC and sedimentation value at any location during the complete model run time. As a result, the plots show the extent of overall effect from the dredge and the disposal within the wider Humber Estuary, without reference to how soon after commencement of operations they occur, nor how long these values persist at any given location.

Assessment of exposure to change

7.8.23 The greatest increase in SSC from the piling, dredging and disposal activities will occur during the barge depositing material at the licensed disposal site. Material within the passive plume will be dispersed throughout the water column as the load drops to the bed, with the potential to be transported up- and down-estuary through the full tidal excursion (dependent on tidal state at the point of release). Initial SSC values within the dynamic plume will be very high but, given the very high natural levels within the estuary, excess levels are likely to be reduced to below natural storm disturbance conditions very quickly (and before the next disposal operation commences four hours later). This is typically the same scenario that occurs for the existing maintenance dredging of the local Immingham berths, which has been undertaken frequently (multiple times during the year) since the berths were first implemented.

7.8.24 At the disposal site, the effect of deposition of capital dredge arisings will be similar to that which already occurs as a result of ongoing maintenance dredging and disposal. Local changes to the bathymetry (as a result of material disposal to the bed) within the disposal site will be small in the context of the existing depths. As is currently the practice, disposal activity will be targeted to the deeper areas within the site, ensuring that bed level changes are not excessive in any one area, thus minimising the overall change. As a result, associated changes to the local hydrodynamics (and sediment transport pathways) will be negligible. Ongoing monitoring of depths within the disposal site (an activity already undertaken to assess bed level changes as a result of existing dredge disposal activities) will continue into the future. Consequently, the impact of the disposal from both capital and future maintenance dredging of the proposed IERRT berth will be monitored.

7.8.25 The local hydrodynamics, the existing (background) SSC levels within the wider Humber Estuary and the proposed dredge and disposal works have all been considered within this assessment. The increase in SSC and potential sedimentation in the marine environment is likely to be the same as that which already occurs from existing maintenance dredging in the area (which has been occurring for many years). Moreover, peak increases will remain within the envelope of natural variability in background SSC. As a result, the probability of occurrence is considered high although the magnitude of change is assessed as small, resulting in an overall **low** exposure to change.

Construction vessel activity – impacts on local hydrodynamics and sediment transport arising from ship wash and vessel propulsion

7.8.26 As described in Chapter 3 of the ES, the piling and decking for the approach jetty and piers are being constructed using land-based plant and equipment, and by quasi-stationary floating and jack-up barges. Consequently, the only vessels associated with the construction phase are the dredgers and barges for the capital works and slow-moving jack-ups that, once in position, effectively remain stationary whilst carrying out the works. The majority (if not all) of the material will be removed with a backhoe dredger to a hopper (for subsequent disposal). Whilst the optimal size of the dredging plant will need to be determined by the specialist dredging contractor, the backhoe method effectively uses stationary plant to dredge a defined area, with the plant moving across the dredge site until all the required material has been removed. In this way, the construction vessel movements are generally limited in frequency to the movements across the dredge area, rather than being continuous throughout dredge operations. Due to water depths across the adjacent intertidal area, it is further considered likely that dredging plant will access the berth pocket from offshore, meaning that any ship wash and vessel propulsion effects on local flow speeds are anticipated to occur away from the adjacent foreshore.

7.8.27 Some material may also be removed by trailer suction hopper dredger (TSHD) depending on the sediment conditions and the availability of TSHD dredgers. Should this be the case, then deeper water depths will be required for the vessel to operate in. As described above, this will lead to potential ship wash and vessel propulsion impacts (to local flow speeds) being limited in extent to the deeper offshore areas on the estuary-side of the proposed IERRT berth.

Assessment of exposure to change

7.8.28 There is predicted to be a generally limited temporal impact from the construction vessel movements (with infrequent movements across the berth pocket), coupled with the likely extent of effect being limited to the deeper, offshore side of the IERRT site. As a result, it is unlikely that there would be any notable impact on local flows across the adjacent intertidal area and, by association, no likely impact on local accretion or erosion processes. Consequently, the probability of occurrence is considered medium although the magnitude of change is assessed as small, resulting in an overall **low/negligible** exposure to change.

Operational phase

7.8.29 This section contains an assessment of the potential impacts as a result of the operational phase of the IERRT project. The following operational elements and impacts have been assessed:

- Marine facilities (Ro-Ro berth and dredge pocket):
  - Local changes to hydrodynamic regime (flow speed and direction) as a result of the new piers, jetty and possible vessel impact protection

  (piling) and the deepening from the capital dredging required to develop new berth pocket;
  - Local changes to the wave regime, as a result of the new piers, jetty and possible vessel impact protection (piling) and capital dredging required to develop the new berth pocket;
  - Associated local changes to the sediment transport pathways, as a result of localised changes to the driving hydrodynamic (and wave) forcing;
  - Potential impacts on existing features, including existing marine infrastructure, outfalls and estuary banks and channels;
- Maintenance dredging - potential impact on SSC and sedimentation
  - Increased SSC and potential sedimentation in the area of dispersal plume as a result of maintenance dredging;
  - Increased SSC and potential sedimentation as a result of deposition of maintenance dredge material at a licensed disposal site;
  - Changes in seabed bathymetry and composition as a result of deposition of dredged/disposed maintenance dredge material.

7.8.30 The pathways of change as a result of the operational phase of the proposed development, including changes to flow regime with a vessel at the berth, and changes to the sediment transport regime to determine potential effects on sedimentation rates (and hence the potential for maintenance dredging) are summarised in the following sections.

Marine facilities (Ro-Ro berth and dredge pocket) - potential impact on hydrodynamics

7.8.31 Impacts on hydrodynamics have been assessed using numerical modelling tools and conceptual analysis. The modelling has been completed using an updated version of the existing ABPmer calibrated and validated MIKE Hydrodynamic (HD) Flexible Mesh (FM) model of the Humber Estuary. The updated model mesh has been refined around the study area and adjacent coastline.

7.8.32 The bathymetric datasets used in the creation of the model mesh consist of a combination of survey data collected for the IERRT project, existing data provided by ABP in and around Immingham, along with topographic LiDAR data from the Environment Agency Open Data portal.

7.8.33 The updated model has been subject to new calibration and validation using survey data for the local area. Calibration and validation have been carried out over a spring and neap tide. Full details of the model setup, calibration and validation are provided in Appendix 7.1 to this ES.

7.8.34 Although not specifically shown on a figure within this assessment, it should be noted that the assessment of the proposed scheme on local hydrodynamics reveals no impact on water levels across the near- or far-field area. Consequently, water levels across the existing berths are not predicted to change as a result of the IERRT scheme. In addition, there is no predicted impact on the existing tide gauge situated on the Immingham Eastern Jetty.

7.8.35 The predicted impacts on the local flow regime, obtained through hydrodynamic modelling of the area, are summarised both spatially, in the immediate vicinity of the Ro-Ro facility and dredge pocket, and temporally at a series of point locations identified as strategic locations and areas of greatest impact.

7.8.36 The spatial hydrodynamic effects on the marine facilities (Ro-Ro berth and dredge pocket) are shown in Figure 7.8 and Figure 7.9 to this chapter for the approximate time of peak flood and ebb spring flows, respectively. The results of the hydrodynamic modelling show that the new marine facilities cause generally small impacts, confined predominantly to the vicinity of the structure.

7.8.37 During the flood tide, a reduction in flows of up to 0.30 m/s is seen within 200 m to the south of the dredge pocket. Flow reductions of up to 0.2 m/s extend approximately 400 m to the southeast of the dredge pocket. A reduction in flows of up to 0.1 m/s extends no further than 500 m from the southeast of the berth pocket. Around the dredge pocket, there are small areas of increased flow speeds of up to 0.2 m/s, extending no further than 250 m from the edge of the berth pocket in an easterly, north easterly and south westerly direction.

7.8.38 Within the dredge area itself, flows are reduced by up to 0.3 m/s in some areas, although generally flow reductions are less than 0.15 m/s.

7.8.39 These changes in flow speed on the flood tide are relatively small with regards to the baseline flow speeds. Baseline flows are between 0.8 m/s and 1 m/s in the area of interest. As a result, maximum predicted changes in flow speed as a result of the Ro-Ro facility tend to be limited in extent to the dredge pocket itself and are around ±25 to 30% of baseline flow speeds. Further afield, changes remain constrained to the area adjacent to the marine facilities, with flow speed changes generally around ±5 to 25%.

7.8.40 On the ebb tide, the assessment shows a slightly different pattern of change compared to the flood tide. Here, the change is more aligned with the direction of flow, and extends further downstream of the marine facilities, up to 2 km down estuary of the eastern end of the berth pocket. At this point, reductions of less than 0.2 m/s are seen. Within the berth pocket, the area of change is limited to the southeast end of the dredge pocket, where decreases in flow speeds of less than 0.4 m/s are predicted. A small area of flow speed increase of around 0.1 m/s takes place around the middle of the dredge pocket (DP1). Slightly larger areas of flow speed increase are also seen between the dredge pocket and the port frontage, along the intertidal (Figure 7.9). Here, flow speed increases of up to 0.35 m/s occur.

7.8.41 These changes in flow speed on the ebb tide are slightly larger than those predicted on the flood, with regards to the baseline flow speeds. Baseline flows vary from approximately 1.1 m/s along the southern edge of the dredge pocket, to approximately 1.43 m/s along the northern edge. As a result, predicted maximum reductions in ebb flow speed within the dredge pocket generally tend to be around 30% of baseline flow speeds. Outside of the berth pocket, reductions in flow speed are notably less (less than 5% of baseline).

7.8.42 Timeseries plots have been provided to illustrate a predicted temporal change throughout the spring tide at key locations. These are provided in Figure 7.10 to Figure 7.16 to this ES. The locations of each of these points is provided in the top image of Figure 7.8 to this ES.

7.8.43 Within the dredge pocket (locations DP1 to DP4), a general decrease in flow speeds is predicted (Figure 7.10 and Figure 7.11 to this ES). This is particularly evident at DP3 and DP4. At DP3, flow speeds are reduced by up to 0.3 m/s on both the flood and ebb tides, whilst at DP4 flow speeds are reduced by up to 0.2 m/s on the flood and 0.5 m/s on the ebb. At DP1, there is minimal decrease in flow speeds on the flood tide, and a very small increase in the peak of the ebb tide. At DP2, the changes in flow speed are negligible.

7.8.44 At P1, located inshore of the dredge pocket, there is a negligible predicted change in flow speeds on the flood tide, and a slight increase in flow speeds of approximately 0.25 m/s on the ebb tide. (Figure 7.12). At P2, northwest of the dredge pocket, there is negligible changes to flow speeds (Figure 7.12), whilst at P3 (east of the dredge pocket) and P4 (downstream of the IOT jetty, adjacent to the shore) changes in flow speeds are also negligible (Figure 7.13). At P5, behind Immingham Eastern Jetty, there is a slight increase in flow speeds of approximately 0.1 m/s on the ebb tide. (Figure 7.14). At P6 (Figure 7.14), there is a slight predicted increase of <0.1 m/s on the flood tide, and up to 0.5 m/s on the ebb. At P7 (Figure 7.15), fronting the North East Lindsey IDB outfall at Habrough Marsh Drain, there is negligible change in the hydrodynamics.

7.8.45 At IOT and Humber Sea Terminal (HST) (and at the site of the consented ABLE Marine Energy Park), there is no predicted impact on flow speeds on either the flood or ebb tide (Figure 7.15 and Figure 7.16). With specific regard to IOT, this is true for both the main deep-water berths and the inshore finger jetty. Overall, this suggests that the IERRT will have no impact on the existing (baseline) hydrodynamics of these terminals (Figure 7.8 and Figure 7.9). Further afield, across the wider Humber Estuary (including the offshore banks and channels, the foreshore along the northern side of the estuary and the coastline up- and down-estuary of Immingham), there is no predicted changes to the existing (baseline) hydrodynamics as a result of the proposed IERRT marine elements.

Inclusion of vessels on-berth

7.8.46 Assessment of hydrodynamic impacts during the operational phase of the development has considered the effect of three vessels berthed at the pontoons, in addition to the pontoon structures themselves and dredged pocket - i.e., equivalent to the maximum development case.

7.8.47 The assessment has included a sensitivity test, which has considered three vessels on-berth with a Length Overall (LOA) of 240 m; breadth of 35 m and draught of up to 8.0 m (most likely 7.5 m but 8.0 m assessed here as worst-case).

7.8.48 The spatial hydrodynamic effects on the operation of the proposed development (Ro-Ro facility and dredge pocket) are shown in Figure 7.17 and Figure 7.18 to this ES for the approximate time of peak flood and ebb spring flows, respectively. Results of the hydrodynamic modelling show that with vessels alongside, the new Ro-Ro facility and dredge pocket cause relatively small impacts, confined to within approximately 2.5 km of the facility.

7.8.49 On the flood tide with the vessels *in situ* (Figure 7.17 to this ES), a reduction in flow speed of up to 0.18 m/s (20%) is seen within the dredge pocket, extending approximately 2 km from the Immingham Eastern Jetty to the eastern end of the HIT.

7.8.50 To the northeast of the HIT, an area of flow speed increase of up to 0.07 m/s (6%) is seen over a distance of approximately 1 km. A small area of increase in flow speed of up to 0.11 m/s (18%) is also seen along the southern edge of the dredge pocket, between the port frontage and dredge pocket (Figure 7.17).

7.8.51 On the ebb tide (Figure 7.18), a decrease in flow speeds of up to 0.15 m/s (10%) extends southeast of the dredge pocket for a distance of approximately 1.5 km a decrease of up to 0.08 m/s extends for a further 1 km beyond that. Towards the north-western edge of the dredge pocket, an area of decreased flows of less than 0.25 m/s is also predicted and extends slightly out of the dredge pocket towards Immingham Eastern Jetty.

7.8.52 An area of increased flow speed of less than 0.5 m/s (90%) is seen extending around 500 m along the port frontage between the dredge pocket and port frontage.

Assessment of exposure to change

7.8.53 Marginal changes to hydrodynamics (local flow speed) are likely to result from the IERRT within, and adjacent to, the proposed berth pocket. Slight changes in flow speed are predicted to extend up-estuary to IOH and down-estuary past the IOT jetty. The largest predicted magnitude of change is anticipated within the berth pocket itself (particularly towards the landward edge, as a result of the larger proposed dredge depths). Given the relatively stable nature of the estuary morphology across the near-field study area (Section 7.6 of this chapter), it is further considered that the changes arising from IERRT will not vary with the longer-term cyclic patterns in the estuary banks and channels. The probability of occurrence is, therefore, considered high, although the magnitude of change is assessed as small, giving rise to an overall **low** exposure to change.

Marine facilities (Ro-Ro berth and dredge pocket) – potential impact on sediment transport

7.8.54 Changes to the local hydrodynamics, as a result of the proposed IERRT project (as described above) have the potential to affect local sediment transport (i.e., faster flows may increase bed erosion, and lower flows may encourage sedimentation).

7.8.55 To investigate the potential impact of the marine facilities on sediment transport the movement of fine-grained material (as identified across the project grab sampling survey) has been investigated using the MIKE Mud Transport (MT) module. The model is driven by the hydrodynamic model described above and has been verified against local dredge records and SSC measurements. The model setup and validation are described in Appendix 7.1 to this ES.

7.8.56 The modelling tool has been applied to model the existing baseline and the proposed IERRT, and the difference in bed thickness over a 15-day mean spring neap cycle has been calculated.

7.8.57 Figure 7.19 to this ES shows the predicted change in bed thickness of fine material, as a result of the proposed development, over a mean spring/neap tidal cycle. It is predicted that the changes in accretion and erosion patterns are generally small in both magnitude and extent. The reduction in flow speeds within the dredged berth and across the leeward side slopes result in associated change to bed shear stress (BSS) (Figure 7.20 to this ES), allowing for increased settlement over the baseline condition. A very small increase in accretion rate, is also seen along the rear of the IOT jetty, and along the intertidal area to the southeast, with a small reduction, just up-estuary (northwest) of the berth pocket, towards the Immingham Eastern Jetty (Figure 7.19 to this ES).

7.8.58 The difference to baseline in the settling rate over the 15-day modelled period is up to 50 cm beneath the newly proposed jetty piles, along the southern and eastern edges of the berth pocket, reducing to around 2 cm across the deeper, offshore parts of the berth. In contrast, slight increases to flow speeds up-estuary of the berth result in a very small area of reduced accretion, by around 1 to 2 cm over the 2-week period. The average accretion across the whole dredged area (including side slopes) was 19 cm over the 2-week modelled period. The implications of this accretion, on potential future maintenance dredging of the berth pocket, are considered in subsequent sections of this chapter.

7.8.59 In addition to the predicted increased accretion within parts of the proposed berth pocket, slight increases in local peak ebb current speed landward of the berth pocket (Figure 7.18 to this ES) result in associated increases to BSS (Figure 7.20 to this ES). These increases lead to a limited amount of predicted erosion of the bed along part of the lower intertidal (at the elevation of MLWS) beneath the landward end of the proposed jetty (Figure 7.19 shows the difference in bed thickness change against the baseline, with negative values indicating areas of either increased erosion or of reduced accretion). Over a mean spring neap cycle, the predicted erosion is less than 0.05 m, resulting in a potential indirect loss in intertidal area of approximately 0.01 ha. The assessment indicates that once this part of the softer upper layer is removed, the harder, more consolidated, underlayer of bed material is unlikely to erode further. This calculation represents a worst-case assessment of potential elevation changes and has been considered on a precautionary basis. The level of predicted change is at the limit of the accuracy of the modelled data and, in real terms, is likely to be immeasurable against the context of natural variability (as a result of storm events, for example).

7.8.60 The results above reflect the predicted changes over the modelled spring neap period. As bed levels change through accretion and erosion processes, so the flow regime over the local area will also become affected, and the associated sedimentation and erosion rates will respond. In this way, extrapolating rates of local bed level change is not necessarily a linear process, as the bed will seek to achieve some level of equilibrium over the longer-term. This notwithstanding, scaling up the 15-day model run over an annual period (which is considered to provide a conservative, worst case estimate of accretion rates), the annual average sedimentation rate within the berth pocket increases by 4.9 m beneath the jetty piles towards the southern and eastern edges of the berth. This anticipated increase in rate remains generally consistent with the historic rates of accretion within local dredged areas (Table 7.9 of this chapter), which provide averaged annual accretion rates of 7.2 m within Immingham Outer Harbour and around 3.7 m at the HIT.

7.8.61 During operation, the movement of vessels on and off berth will also help to remobilise some of the newly deposited material within the pocket. In addition, over time, the deposited material will consolidate, causing the *in-situ* sediment thickness to reduce. The rates associated with the existing berths will already take these effects into account (Table 7.9 of this ES). Consequently, the actual rate of infill for the IERRT berth pocket is likely to be lower than the conservative, worst case estimate described above. Given the proposed location, the likely frequency of use and the characteristics of the pocket, a siltation rate closer to that already experienced at the Bellmouth (around 2.3 m/yr, on average), is considered more realistic.

7.8.62 To provide context to the predicted impacts on siltation, the baseline modelled rates of accretion in and around the Immingham frontage are shown in Figure 7.21, over a mean spring neap tidal cycle. This shows the general siltation across the existing dredged berths (which are included in the model baseline as dredged berth pockets), including HIT, IOH, East and West Jetties and Immingham Bellmouth. Within the proposed IERRT pocket, the baseline model indicates a generally stable bed with only small levels of siltation (around 0.02 m) along a thin strip of the shallow subtidal, which is in line with the bathymetric observations.

Table 7.9. Typical accretion rates in the vicinity of the study area

Location	Accretion Rate (m/yr)*		
	Minimum	Maximum	Average
Immingham Outer Harbour (IOH)	3.5	11.9	**7.2**
West Jetty Extension	0.1	2.8	**0.5**
Immingham Gas Terminal (IGT)	0.6	3.5	**1.0**
Immingham Bellmouth	1.4	3.5	**2.3**
Humber International Terminal (HIT)	1.8	7.2	**3.7**

* Accretion rates defined by reported dredge load information between 2004 and 2020 and based on an assumed bed density of 1,300 kg/m³

7.8.63 Across the wider study area (including the existing berths at IOT, the rest of the intertidal area along the Immingham frontage, the Habrough Drain and Immingham Sea outfalls, the offshore banks and channels and the wider estuary up- and down-stream), the proposed IERRT marine facilities have no impact on the existing (baseline) accretion and erosion rates (Figure 7.19 to this ES). Overall, there is predicted to be limited magnitude and extent of predicted change, resulting from the IERRT development (in terms of both hydrodynamics across the range of tidal states and the associated negligible impact on estuary tidal prism and far-field sediment transport pathways). This, coupled with the in-estuary disposal of capital and maintenance dredge material (thus maintaining the sediment as part of the wider estuary sediment budget), indicates that the proposed scheme will not result in long-term changes to the wider estuary morphology.

Assessment of exposure to change

7.8.64 Hydrodynamic forcing within (and adjacent to) the proposed IERRT will only be marginally altered and, therefore, changes in the sediment pathways will be small. Predicted changes to future sediment transport are greatest within the proposed dredge pocket itself, which will require future maintenance dredging to ensure sufficient underkeel clearance for vessels on berth. The rate of infill is likely to be similar to that already experienced within the existing Immingham berths. Outside the proposed berth pocket, the proposed scheme has limited impact on the baseline sedimentation and erosion rates.

7.8.65 As a result, the probability of occurrence is considered to be high, and the magnitude of change is assessed as small, resulting in an overall **low** exposure to change.

Marine facilities (Ro-Ro berth and dredge pocket) - potential impact on waves

7.8.66 Impacts on waves have been assessed using numerical modelling tools and conceptual analysis. The modelling has been completed using the existing ABPmer calibrated and validated MIKE Spectral Wave (SW) model of the Humber Estuary. The model has subsequently been used to examine how waves conditions will be affected during extreme and more frequently occurring events.

7.8.67 The model utilises the same bathymetric data as the hydrodynamic model (as described above and detailed in Appendix 7.1 to this ES); however, the model mesh has been edited slightly around the marine facilities to provide a minimum spatial resolution of approximately 40 m.

7.8.68 The updated model has been subject to performance checks by simulating wave conditions at the site, over a short period during which waves were recorded at the site during the IERRT AWAC deployment. Full details of the model setup and verification are provided in Appendix 7.1 to this ES.

7.8.69 The assessment of potential wave impacts from the proposed IERRT has defined a set of wave conditions (including Hs, peak wave period (Tp) and wind speed (WS)), for a range of return periods and for a number of approach directions (described in Appendix 7.1 to this ES and summarised in Table 7.10). These wave events have then been applied to the numerical model under existing (baseline) and scheme scenarios. The predicted difference in modelled wave heights, as a result of the berth pocket dredge, have then been calculated.

Table 7.10. Extreme Boundary Wave Conditions for the Humber Spectral Wave Model

Return period (yr)		North-easterly	Easterly	South-easterly
		All Year	All Year	All Year
0.5	Hs (m)	3.4	2.4	2.4
	Tp (s)	9.0	6.7	5.6
	WS (m/s)	15.0	13.0	15.0
50	Hs (m)	5.2	4.1	4.8
	Tp (s)	11.1	8.7	7.9
	WS (m/s)	23.0	21.0	25.0

7.8.70 The spatial wave effects of the construction of the IERRT marine facilities are shown in Figure 7.22 to Figure 7.24 to this ES for each of the events modelled in Table 7.10. Results of the wave modelling show that the new Ro-Ro facility and dredge pocket cause generally small impacts, confined predominantly to the area in the vicinity of the structure.

7.8.71 The effect on wave height for the 0.5-yr, north easterly event is negligible, with a very small (less than 100 m) area of reduced wave heights of less than 0.04 m, just south of the dredge pocket. (Figure 7.22 to this ES). Baseline wave heights for this event tend to be in the region of 1 to 1.2 m around the marine facilities. The maximum predicted change in wave height is therefore around -4%. This change is limited in extent to the area immediately around the dredge pocket.

7.8.72 For the 0.5-yr, easterly event, it is anticipated that the impacts will extend slightly further than those of the north easterly event (Figure 7.22 to this ES). A slight decrease in wave height of up to 0.04 m is seen along the southern edge of the dredge pocket towards the frontage. The baseline wave heights for this event are between 1 and 1.2 m; hence a predicted decrease of 0.04 m represents a change of around -4%.

7.8.73 The 0.5-yr, south easterly event shows a similar pattern of impact on wave height as the easterly event, however a slightly larger reduction in wave heights of up to 0.06 m is predicted (Figure 7.23 to this ES). With the maximum baseline wave heights for this event being approximately 1.6 m, the potential changes described above are around -4% of the baseline condition.

7.8.74 For the 50-yr, north easterly event, the impact of the marine facilities on wave height is again likely to be small and generally confined to the area between the berth pocket and adjacent coastline (Figure 7.23 to this ES). There are a few small areas of increased wave height within the dredge pocket of <0.04 m (approximately 2% relative to the baseline). Meanwhile, a small area of decreased wave height of approximately 0.06 m (3% relative to baseline) is predicted between the dredge pocket and the Immingham frontage.

7.8.75 The 50-yr easterly event sees a slightly larger area of impact compared to the north easterly event (Figure 7.24 to this ES). Here, an area of increased wave heights extends northwest of the dredge pocket, with an increase of up to 0.04 m (4% relative to baseline) for approximately 400 m, stopping just before Bellmouth. A small area of increased wave heights of up to 0.04 m (1% relative to baseline) is also seen extending from the southeast corner of the dredge pocket towards the coastline. An area of decreased wave height of up to 0.13 m (8% relative to baseline) is seen extending from the southern edge of the dredge pocket towards the adjacent coastline.

7.8.76 Similarly to the easterly wave (above), the 50-yr south easterly event sees an increase in wave height of up to 0.1 m over a small area within the dredge pocket. This reduces quickly to approximately 0.06 m over a 500 m distance, whilst an area of increased wave heights of up to 0.04 m extends out of the dredge pocket and across Bellmouth (Figure 7.24 to this ES). An area of decreased wave height of up to 0.16 m (-7% compared to baseline) extends from the southern edge of the dredge pocket towards the adjacent coastline.

Assessment of exposure to change

7.8.77 Marginal changes to Hs are likely to result from the IERRT marine facilities within, and adjacent to, the proposed berth pocket. For the various wave events assessed, slight changes in wave height (typically less than ±5% of baseline values) are predicted to extend up-estuary as far as the Immingham Western Jetty (for a wave event approaching from the southeast) (Figure 7.24). The largest predicted magnitude of change is anticipated in close proximity to the berth pocket itself.

7.8.78 The probability of occurrence is considered high, although the magnitude of change is assessed as small giving rise to an overall **low** exposure to change.

Marine facilities (Ro-Ro berth and dredge pocket) - potential impact on existing features, including marine infrastructure, outfalls and estuary banks and channels

7.8.79 Identified changes to the existing (baseline) hydrodynamics, waves and associated sediment transport pathways have the potential to impact existing features. Such features, which include existing marine infrastructure, land drainage outfalls and estuary banks and channels, have been identified in the relevant sections above and the potential impact from the IERRT marine facilities is summarised here.

7.8.80 Changes to flows, waves and sediment transport pathways are predicted to be generally limited in extent to the proposed IERRT marine facilities and immediate vicinity. The predicted impacts at the existing marine terminals (including IOT, HST, Immingham Eastern and Western Jetties, IOH and IGT) are (where predicted) generally small in magnitude. This is also the case for the areas fronting the North East Lindsey IDB Habrough Marsh Drain and the Anglian Water Immingham Sea outfalls. With distance from the proposed development, the predicted impacts reduce further and are not predicted to occur over the far-field region. Changes to local and regional sediment transport pathways are only predicted in close proximity to the IERRT marine facilities, meaning the existing banks and channels of the wider Humber Estuary are not predicted to be impacted by the development.

Assessment of exposure to change

7.8.81 Changes to flows and waves (and associated sediment transport pathways) are likely to result from the IERRT marine facilities within, and adjacent to, the proposed berth pocket and jetty infrastructure. These changes are predicted to be greatest in closest proximity to the development, reducing in magnitude with distance. In addition, given the relatively stable nature of the estuary morphology across the near-field study area (Section 7.6 to this chapter), it is further considered that the predicted changes arising from IERRT will not affect the existing, longer-term cyclic patterns in the estuary banks and channels.

7.8.82 Across the near-field, the probability of occurrence is considered high, although the magnitude of change is assessed as small giving rise to an overall **low** exposure to change. Across the far-field, the probability of occurrence is considered low, and the magnitude of change is assessed as negligible, giving rise to an overall **negligible** exposure to change.

Maintenance dredging - potential impact on SSC and sedimentation

7.8.83 Given the average predicted accretion of 19 cm within the southern and eastern parts of the berth pocket over a 15-day spring – neap cycle, the estimated annual siltation volume is around 120,000 m³. This volume is considered to be a conservative estimate as it assumes that the modelled siltation rate is maintained throughout the year and assumes also that the accretion occurs entirely within the berth pockets themselves. In reality, the siltation rate could be expected to reduce as the berth pocket shallows and as the side slopes adjust to the new layout. Furthermore, part of the accretion is predicted to occur beneath the proposed piers and jetties (between the support piles), in areas where it will not directly affect depths within the vessel berths themselves. However, since it will be important for the berth dredge depth to be maintained, the conservative value of 120,000 m³ has been taken as the worst-case annual infill rate. This conservative value would represent an increase of 6% on the existing average annual maintenance dredge (between 2004 and 2020) rate across the existing Immingham berths and an increase of around 4% on the average annual disposal volume at the HU060 disposal site since 2004.

7.8.84 The actual requirements for the level and frequency of potential future maintenance dredging of the Ro-Ro berth will be dependent on a number of commercial factors (including vessel type, size and berthing requirements). However, assuming a similar level of use (and by similar drafted vessels) and given the predicted infill rates within the IERRT berth pockets, it would be reasonable to assume that the proposed new berths would require a slightly lower level of maintenance to that which is presently afforded to the Immingham berths (including IGT, HIT, Bellmouth and East and West Jetty). Based on the predicted rates of infill from the numerical modelling, depths within the southern ends of the berth pockets might be expected to shallow by around 0.5 m in approximately 14 weeks. Consequently, a maintenance dredge campaign within the IERRT berths might be required around 3 to 4 times per year (although, as noted above, this will be dependent on a range of factors).

7.8.85 Outside of the proposed Ro-Ro berth, and particularly within the existing Immingham berths, the predicted changes to accretion and erosion are negligible. Consequently, it is considered unlikely that the proposed works for IERRT would have any noticeable impact on existing maintenance dredge requirements along the remainder of the Immingham frontage. This is particularly true considering the range of natural variability in the annual maintenance requirements within the existing berths (Table 7.9 of this chapter).

7.8.86 As noted above, as dredged areas infill, the rate of further infill will reduce as flow speeds over the area increase and a level of equilibrium is approached. Furthermore, scour from vessel movements, and from increased flows whilst a vessel is at berth will also act to help mobilise freshly deposited material and consolidation of settled material will reduce the bed thickness; these aspects are not included in the modelling, thus the estimated dredge volumes provided above represent a very worst case in accretion rate. For some context, on the assumption that the actual infill rate of the proposed berth pocket is more similar to the rate already experienced at the Bellmouth (2.3 m/yr, on average), the annual siltation volume would be approximately 56,000 m³ (which would represent an increase of 3% on the existing average annual maintenance dredge (between 2004 and 2020) rate across the existing Immingham berths (or 2% increase on the average annual disposal volume at the HU060 disposal site since 2004).

7.8.87 Volumes of material from maintenance dredging (up to 120,000 m³ annually, to be dredged as required) of the IERRT berth pocket will be lower than those from the original proposed capital dredge (190,000 m³ in total, described in Chapter 2 of this ES). Furthermore, the density of the newly settled material will be less than that from the consolidated bed dredged during the capital campaign and, rather than a sustained dredge campaign of the full amount, the future maintenance dredge will be from a larger number of smaller individual dredging events (as required for operational requirements of the terminal). As a result, maintenance dredge arisings and disposal will have a notably lower magnitude and will be more dispersive than the impacts described above for the capital works.

7.8.88 Consequently, the impact of maintenance dredging and disposal is considered to be considerably less than that described from the capital dredge in Section 7.8, with lower excess SSC values, and less frequent intermittent sedimentation on the bed. Placement of the dredged material (both capital and maintenance) at the proposed HU056 and HU060 disposal sites (within the main channel off of Immingham) will help maintain the overall sediment budget of the wider Humber Estuary system. In this way, material remains distributed throughout the wider region, rather than being removed (either placed outside of the estuary or used, for example, as infill for reclaim). The overall distribution of the sediment over the wider Humber Estuary, as a result of any maintenance dredging and disposal activity, will be similar to that shown in Figures 7.6 to this ES for the capital works.

Assessment of exposure to change

7.8.89 As a result of a less intensive dredge programme (and an overall lower predicted dredge volume), future maintenance dredging will result in smaller changes in SSC and sedimentation (within the dredge plumes and at the disposal site) compared to the capital dredge (as described above). Furthermore, the predicted impacts from future maintenance dredging will be similar to that which already arises from the ongoing maintenance of the existing Immingham berths. As a result, the probability of occurrence is considered high although the magnitude of change is assessed as small, resulting in an overall **low** exposure to change.

7.9 Mitigation measures

Secondary mitigation

7.9.1 None of the impact pathways identified for physical processes are expected to give rise to a measurable exposure to change and, therefore, no secondary mitigation measures are proposed to minimise and/or avoid the potential for significant adverse effects.

Tertiary mitigation

7.9.2 Tertiary mitigation measures will be undertaken to manage commonly occurring environmental effects. Although these are not likely to alter the assessment conclusions, they are considered to be standard good practice and are taken account of in the initial impact assessment. In terms of physical processes, the following tertiary mitigation measure will be undertaken:

- **Even disposal deposition**: The targeting of disposal loads in the central/deeper areas of the disposal sites (HU056 and HU060) will be undertaken to reduce depth reductions. This will minimise the initial reduction in water depth and any environmental changes at these disposal sites.

7.10 Limitations and assumptions

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

- The proposed IERRT scheme is implemented as proposed and described in Chapter 2 of this ES (with regards berth pocket location, depths, jetty and pontoon pile locations and dimensions);
- Capital dredging works are mainly undertaken using backhoe equipment with hopper barges used for subsequent transit and disposal at existing licensed disposal sites HU056 and HU060 (as described in Section 7.8 of this chapter); and
- Following construction of the proposed IERRT development, vessels operating from the newly constructed berths are assumed with dimensions described in Section 7.8 of this chapter.

7.10.2 Whilst these are assumptions, the assessment within this ES has been undertaken considering the anticipated worst-case scenario in respect of physical processes receptors across the wider study area, including at the dredge, piling and disposal locations.

7.11 Residual effects and conclusions

7.11.1 A summary of the impact pathways that have been assessed, the identified residual impacts and level of confidence are presented in Table 7.11 of this chapter based on the current understanding. This assessment has focussed on the potential ‘exposure to change’ resulting from the impact pathways that have been scoped into the assessment.

7.11.2 Overall, the physical processes changes brought about by the construction and operation of the IERRT project are currently considered small in both magnitude and extent and the resultant exposure to change assessed as low.

Table 7.11. Summary of potential exposure to change in physical processes and significance of impacts on physical receptors

Impact pathway	Exposure to change	Impact Significance	Confidence
Construction Phase			
Capital dredge and disposal and piling			
Increased SSC and potential sedimentation over the extent of the disturbance plume as a result of the construction of the new piers, jetty and possible vessel impact protection (piling) and capital dredging works	Low	Not Applicable (NA)	Medium
Increased SSC and potential sedimentation as a result of the deposit of capital dredge material at a licensed offshore disposal site	Low	NA	Medium
Changes in seabed bathymetry and composition as a result of deposition of dredged/disposal material within the area of the respective plumes	Low	NA	Medium
Construction vessel activity – impacts on local hydrodynamics and sediment transport arising from ship wash and vessel propulsion	Low/negligible	NA	Medium
Operational Phase			
Marine facilities (Ro-Ro berth and dredge pocket)			
Local changes to hydrodynamic regime (flow speed and direction) as a result of the new piers, jetty and possible vessel impact protection (piling) and capital dredging	Low	NA	Medium

Impact pathway	Exposure to change	Impact Significance	Confidence
Local changes to the wave regime, as a result of the new piers, jetty and possible vessel impact protection (piling) and capital dredging	Low	NA	Medium
Associated local changes to the sediment transport pathways, as a result of localised changes to the driving hydrodynamic (and wave) forcing	Low	NA	Medium
Potential impact on existing features, including marine infrastructure, outfalls and estuary banks and channels	Low/negligible	NA	Medium
Maintenance dredging - potential impact on SSC and sedimentation			
Increased SSC and potential sedimentation in the area of dispersal plume as a result of maintenance dredging	Low	NA	Medium
Increased SSC and potential sedimentation as a result of deposition of maintenance dredge material at a licensed disposal site	Low	NA	Medium
Changes in seabed bathymetry and composition as a result of deposition of dredged/disposed maintenance dredge material	Low	NA	Medium

7.12 References

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7.13 Abbreviations/Acronyms

Acronym	Definition
AA	Appropriate Assessment
ABP	Associated British Ports
APT	Associated Petroleum Terminals
AWAC	Acoustic Wave and Current
BP	Before Present
BPEO	Best Practical Environmental Option
BSB	Below Seabed
BSS	Bed Shear Stress
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
cSAC	Candidate Special Area of Conservation
CTD	Conductivity-Temperature Depth
d50	50^{th} percentile grain diameter
DCO	Development Consent Order
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
DHI	Danish Hydraulic Institute
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ES	Environmental Statement
EU	European Union
FM	Flexible Mesh
HAT	Highest Astronomical Tide
HD	Hydrodynamic
HIT	Humber International Terminal
HMWBs	Heavily Modified Water Bodies
HRA	Habitats Regulations Assessment
Hs	Significant Wave Height
HST	Humber Sea Terminal
HW	High Water
IDB	Internal Drainage Board
IEMA	Institute of Environmental Management and Assessment
IERRT	Immingham Eastern Ro-Ro Terminal
IGT	Immingham Gas Terminal

IOH	Immingham Outer Harbour
IOT	Immingham Oil Terminal
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LOA	Length Overall
LSE	Likely Significant Effect
LW	Low Water
MAG	Magnetometer
MBES	Multibeam Echo Sounder
MCAA	Marine and Coastal Access Act
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MMO	Marine Management Organisation
MPS	Marine Policy Statement
MSL	Mean Sea Level
MT	Mud Transport
NA	Not Applicable
NLC	North Lincolnshire Council
NPSfP	National Policy Statement for Ports
ODN	Ordnance Datum Newlyn
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PSA	Particle Size Analysis
PSD	Particle Size Distribution
pSPA	Potential Special Protection Area
RCP	Representative Concentration Pathway
SAC	Special Area of Conservation
SBP	Sub-Bottom Profiler
SDC	Sunk Dredged Channel
SLR	Sea Level Rise
SPA	Special Protection Area
SSC	Suspended Sediment Concentrations
SSS	Sidescan Sonar
SW	Spectral Waves
Tp	Peak Wave Period

TSHD	Trailer Suction Hopper Dredgers
UK	United Kingdom
UKCP	UK Climate Projections
UKHO	UK Hydrographic Office
WFD	Water Framework Directive
WHA	Waste Hierarchy Assessment
WS	Wind Speed
ZoI	Zone of Influence

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

7.14 Glossary

Term	Definition
Advance the Line	New defences are built further out in the sea in an attempt to reduce the stress on current defences and possibly extend the coastline slightly
Bathymetry	The measurement of depth of the water
Benthic habitats	Habitats associated with the bottom of a body of water
Best Practical Environmental Option	Procedures adopted with the goal of managing waste and other environmental concerns which emphasise the protection and conservation of the environment across land, air and water
Chart Datum	Usually close to the lowest tide level that can occur under normal meteorological conditions and is the level to which tidal levels and predictions are measured
Diurnal inequality	The variation in height that is often observed between adjacent high waters and low waters
Glacial Till	Unsorted and unstratified material deposited by glacial ice
Interglacial	Warmer period between two glaciations
Intertidal	The area between high and low tide also known as the foreshore or seashore
Littoral drift processes	The longshore transport of material (e.g. sand) under the action of waves and currents (movement occurring along or near the foreshore)
No Active Intervention	A policy decision not to invest in the provision or maintenance of any defences
Ramsar	Wetlands of international importance designated under the Ramsar Convention
Rectilinear	Contained by, consisting of, or moving in a straight line or lines
Representative Concentration Pathway	A greenhouse gas concentration (not emissions) trajectory adopted by the Intergovernmental Panel on Climate Change
Risk	The likelihood of a specified level of harm occurring within a specified period of time
Special Area of Conservation	A designated area protecting one or more habitats or species listed in the Habitats Directive
Sedimentary regime	The size, quantity, sorting, and distribution of sediments
Special Area of Conservation	A designated area protecting habitats and species identified in Annexes I and II of the Habitats Directive

Special Protection Area	A designated area protecting one or more rare, threatened or vulnerable bird species listed in Annex I of the Birds Directive
Subtidal	The area where the seabed is below the low tide water mark
Turbidity	Turbidity is the measure of relative clarity of a liquid and is a measurement of the amount of light that is scattered by the material in the water
UK Climate Projections	Future climate projections and observed (historical) climate data for UK regions. UKCP18 provides the most up-to-date assessment of how the UK climate may change in the future.

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