Immingham Green Energy Terminal

TR030008

Volume 6

6.2 Environmental Statement

Chapter 16: Physical Processes

Planning Act 2008

Regulation 5(2)(a)

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 (as amended)

September 2023

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 (as amended)

Immingham Green Energy Terminal

Development Consent Order 2023

6.2 Environmental Statement

Chapter 16: Physical Processes

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16.1 Introduction

16.1.1 This chapter presents the findings of the assessment of likely significant effects of the Project on marine Physical Processes. For more details about the Project, including construction methodology, layout and life span, refer to **Chapter 2: The Project [TR030008/APP/6.2]** of this Environmental Statement ("ES").

16.1.2 This assessment identifies the potential environmental changes likely to result from the proposed activity and the physical processes that are likely to be affected. The elements of the Project with the potential to impact physical processes of the existing system are the marine piling and marine works, capital and maintenance dredging and associated construction and operational vessel movements. The physical processes under consideration are together referred to as the impact pathways, which have the potential to affect identified receptors (within this and other topic chapters). The following impact pathways have been considered as part of the assessment:

a. Hydrodynamics

b. Sediment transport

c. Plume dispersion

d. Waves

16.1.3 Where predicted impacts to these pathways have the potential to subsequently impact specific features of interest (such as the local coastline, nearshore sandbank and channel system, existing berth and jetty infrastructure), these have been identified and considered within the assessment in **Section 16.8**.

16.1.4 There may be interrelationships related to the potential effects on Physical Processes and other disciplines and, where this is the case, the findings of the physical processes assessment have been used to inform other topic chapters. Therefore, also refer to the following chapters **[TR030008/APP/6.2]**:

a. **Chapter 9: Nature Conservation (Marine Ecology)**

b. **Chapter 10: Ornithology**

c. **Chapter 15: Historic Environment (Marine)**

d. **Chapter 17: Marine Water and Sediment Quality**

e. **Chapter 18: Water Quality, Coastal Protection, Flood Risk and Drainage**

f. **Chapter 19: Climate Change**.

16.1.5 This chapter is also supported by the following figures **[TR030008/APP/6.3]**:

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16.1.6 A numerical model calibration report (covering each of the different modules) is provided in **Appendix 16.A [TR030008/APP/6.4]**. A geophysical survey report is provided at **Appendix 16.B [TR030008/APP/6.4]** and a hydrodynamic survey report is provided at **Appendix 16.C [TR030008/APP/6.4]**.

16.1.7 Numerical modelling tools and conceptual analyses have been used to predict coastal processes and hydrodynamic effects by comparing the baseline and future environmental conditions created by the Project. This includes predicting the changes to tidal water levels, currents, and waves. It also includes modelling of sediment transport pathways (including assessment of potential changes to erosion and accretion patterns) and the fate of sediment plumes from marine construction and maintenance dredging and disposal activities.

16.1.8 Changes in hydrodynamic (and sedimentary) processes are considered in the context of climate change (specifically sea level rise) over the engineering design period of the Project by assessing the effects under projected future sea levels. As further sampling data are acquired this information will be analysed to optimise the construction and dredging methods and minimise changes in physical processes during construction and operation. Some existing ground investigation data does exist, which has been used to inform the sediment transport and dredge plume modelling. Additionally, this data has been used to inform the specifications of the Project specific ground investigation (“GI”) works.

16.1.9 Modelling has been completed using existing models of the Humber Estuary, with updates to ensure mesh resolution and model performance across the primary study area remains suitable. The modelling utilises the state of the art Mike suite of modelling software from the Danish Hydraulics Institute (“DHI”). These modelling tools have previously been developed specifically for oceanographic, coastal and estuarine applications within the Humber region. The selected modelling tools have been updated with the latest available bathymetric and topographic data and have undergone a further verification stage using local measurements collected for the Project (see **Appendix 16.A [TR030008/APP/6.4]**).

16.1.10 Following the refinement of the models to replicate the baseline conditions, the models have then been updated to include a representation of the marine elements of the Project, namely the jetty, the dredge footprint and the dredge disposal site(s). The models also include a representation of any other coastal and marine developments that may overlap or interact with the Project to allow the potential for cumulative effects to be assessed.

16.2 Consultation and Engagement

16.2.1 A scoping exercise was undertaken in August 2022 to establish the form and nature of the Physical Processes assessment, and the approach and methods to be followed. The Scoping Report (**Appendix 1.A [TR030008/APP/6.4]**) records the findings of the scoping exercise and details the technical guidance, standards, best practice and criteria being applied in the assessment to identify and evaluate the likely significant effects of the Project on Physical Processes. A Scoping Opinion was adopted by the Secretary of State on 10 October 2022 (**Appendix 1.B [TR030008/APP/6.4]**).

16.2.2 Statutory Consultation took place between 9 January and 20 February 2023 in accordance with the Planning Act 2008 (“2008 Act”). The Applicant prepared a Preliminary Environmental Information Report (“PEI Report”), which was publicised at the consultation stage.

16.2.3 As a result of consideration of the responses to the first Statutory Consultation, the developing environmental assessments and through ongoing design-development and assessment, a series of changes within the Project were identified. A second Statutory Consultation took place between 24 May and 20 July in accordance with the 2008 Act and a PEI Report Addendum was publicised to support the consultation.

16.2.4 The consultation undertaken with statutory consultees to inform this chapter, including a summary of comments raised via the formal scoping opinion (**Appendix 1.A [TR030008/APP/6.4]**) and in response to the formal consultation and other pre-application engagement is summarised in **Table 16-1**. The full responses to consultation comments are included within the Summary of Consultation Responses document **[TR030008/APP/5.1]**.

Table 16-1: Scoping Opinion Comments on Physical Processes

Reference, Date	Consultee	Summary of Response	How comments have been addressed in this chapter
Scoping Opinion, 10 October 2022	Planning Inspectorate	The Scoping Report refers to physical environmental receptors "such as the local coastline and the nearshore sandbank and channel system, along with existing berth and jetty infrastructure". The ES must clearly describe the receptors to be considered in the assessment and explain how/why they were identified. The ES should consider whether the changes to physical processes would impact on sea defences through changes to wave patterns or sedimentation, and the likelihood of impacts on any telemetry devices in the area of Immingham docks.	Receptor pathways have been identified as, sediment transport, plume dispersion and waves. For each of these receptor pathways, the potential impacts on the local coastline (including existing defences), nearshore sandbank and channel system, existing berth and jetty infrastructure have been assessed in **Section 16.8**.
Scoping Opinion, 10 October 2022		The Scoping Report states that for impacts on physical receptors (i.e. local coastline, sandbank and channel system, existing infrastructure) an assessment of effect significance would be undertaken following the methodology presented in section 4.6 of Chapter 4 The EIA Process. The ES should explain and justify how the evaluation of the importance/ value and sensitivity of relevant physical processes receptors has been undertaken, and how the magnitude of impact has been defined for this aspect.	The approach to the assessment for physical processes is outlined in **Section 16.4**. Where applicable, the assessment for physical processes receptors is carried out in line with the Environmental Impact Assessment ("EIA") methodology in **Chapter 5: EIA Approach [TR030008/APP/6.2]**.
Scoping Opinion, 10 October 2022		Item J mentions relevant local policy and we would highlight the need to consider the relevant Shoreline Management Plan and Humber Estuary schemes/plans in relation to this topic.	Reference is made to local planning policy and plans including the River Basin Management Plan and Shoreline Management Plan and information has been provided as to the relevance of these plans to the Project in relation to physical processes (**Table 16-2** in **Section 16.3**).

Reference, Date	Consultee	Summary of Response	How comments have been addressed in this chapter
Scoping Opinion, 10 October 2022	Environment Agency	This Chapter sets out what will be done to assess the changes to physical processes and what these impacts will be. We are pleased that at this stage no issues have been scoped out. However, we would like the assessment to also specifically consider whether the changes to physical processes would have an impact on sea defences through changes to wave patterns or sedimentation. Paragraph 15.4.8 states that the jetty will not be decommissioned and is likely to remain part of the port estate. An engineering standard of 50 years has been given for the development. If the jetty is to remain in place longer than 50 years, the assessments need to reflect this in an appropriate design life for the marine element of the proposed development. Paragraph 15.6.9 summarises the relevant legislation, policy and technical guidance, which will be cross-referenced as appropriate. Item J mentions relevant local policy and we would highlight the need to consider the relevant Shoreline Management Plan and Humber Estuary schemes/plans in relation to this topic.	Modelling of wave patterns and sediment transport has been carried out and the assessment is presented in **Section 16.8**. The Shoreline Management Plan and other plans relevant to the Humber Estuary have been considered and are detailed in **Table 16-2**.
Statutory Consultation (PEI Report) January – February 2023	Marine Management Organisation	Section 9.7.28 indicates that the development would be a very minor intervention in the sediment cycling within the estuary volumes and Table A10 (Appendix 16A) suggests that the mud transport model reproduces the essential features of the sediment system. However, Plate A21 (Appendix 16A) shows that the suspended sediment concentrations (SSC) model yields a good overall pattern but a (very) large number of observations of SSC are well in excess of the modelled curve, i.e. the actual total suspended sediment is very often substantially underestimated by the model. The PEI Report should	Additional review and description of the model performance against the measured data has been included in the ES **Appendix 16.A [TR030008/APP/6.4]**.

Reference, Date	Consultee	Summary of Response	How comments have been addressed in this chapter
		comment on how the model (under-)estimates used might (or not) have affected the impact assessment.	
Statutory Consultation (PEI Report) January – February 2023		Calibration/validation of hydrodynamics models is presented in Appendix 16A (volume IV), where it is shown that target accuracies for the current modelling are achieved, but that the wave model appears to underestimate wave heights/periods, (frequently by 50%) in a range of conditions at the calibration location. More comment should be provided on how this performance affects the results of the discrete/extreme events used to derive the results used in the PEIR. For instance, it should be explained why, as per Appendix 16A 1.5.9, “Overall, the performance of the model is considered sufficient for use in the subsequent assessment of potential impact on defined wave events”. For example, can it be assumed that the modelled wave height and period at the jetty (impact) location could be <50% of the wave that could really occur in this scenario; and, would the impact of the structure be greater if the waves were actually 100% larger than the modelled case, and if so, is it possible to estimate by how much?	Model performance has been updated to include the newly collected hydrodynamic survey data, along with explanation of model performance against observed events (see **Appendix 16.A [TR030008/APP/6.4]**).
Statutory Consultation (PEI Report) January – February 2023		In section 16.6.28, it is indicated that additional SSC data will be collected. When presenting this data, focus should be on the extent and duration of natural ‘excess SSC events’ such as storms. Rather than absolute (discrete) values as already presented (showing excess SSC associated with dredge of up to 600-800 mg/L versus a	Additional data has been included from survey within **Appendix 16.A [TR030008/APP/6.4]**, to include focus on natural excess SSC events’ in order to provide context to the predicted dredge/disposal impacts.

Reference, Date	Consultee	Summary of Response	How comments have been addressed in this chapter
		typical tidal range of 100-1000 mg/L, i.e. order 100% increase) the assessment of the impacts should focus on the temporal dimension – the typical duration of natural excess vs dredge-associated excess SSC (i.e., is a dredge event unusually long and atypical of normal behaviour?)	
Statutory Consultation (PEI Report) January – February 2023		The PEIR indicates that the applied physical process mitigation (16.7.1) includes Embedded Mitigation (minimising dredge requirements by design and location of the jetty) and Standard Mitigation (disposal (if required) evenly to reduce mounds). The MMO suggests that adding beneficial reuse of dredge sediment as a possible 'net gain' mitigation for development impacts more widely should be considered.	The options for beneficial use of dredged material have been considered within **Appendix 2.A[TR030008/APP/6.4]**.
Statutory Consultation (PEI Report) January – February 2023		"The MMO consider that a small number of figures could be amended for readability: · Plate 2-1 is not marked to help locating Figures 2.1/2.2 (and Figure 2.2 is just a less detailed version of 2.1, therefore it should be considered whether both are required) and locations only become clear on Figure 3.3. · The spatial scale is not explicit on Fig 16-9 (hydrodynamic impact extents)."	Figures have been reviewed and updated (as necessary) in the ES.
Statutory Consultation (PEI Report) January – February 2023	Natural England	"Chapters 16 and 17: Physical Processes and Marine Water and Sediment Quality Based on our current understanding, Natural England broadly agrees with the scope of the assessment set out in Chapters 16 and 17 of the PEIR, however, we note that the sediment sampling and physical process modelling is	Noted. The wider Humber Estuary system (including relevant designated features) are included within the assessment in **Section 16.8**.

Reference, Date	Consultee	Summary of Response	How comments have been addressed in this chapter
		currently incomplete and therefore we may provide additional comments. We note that the Humber Estuary SSSI should be included in the assessment."	
Pre-application meeting, 20 April 2023	Marine Management Organisation and Cefas	The meeting provided an update on the Project and focused on discussing comments received from the MMO and Cefas on the PEIR with respect to physical processes and water and sediment quality	The scope of the environmental assessments has been completed taking on board consultee comments from this meeting.
Second Statutory Consultation May 2023 – July 2023	Natural England	Natural England acknowledges the efforts made to reduce the project footprint, specifically the re-design of the jetty structure, which will see the number of berths decrease from two to just a single berth. Although we welcome these changes and anticipate that the downscaling of infrastructure may have a beneficial effect in terms of reducing the environmental impact on the site, Natural England would need to review the new maximum parameters for all aspects of the new design along with the activities in the construction phase, i.e., updated changes in total dredge volume and number of piles required, so that the correct worst case scenario can be assessed. In addition, we note that the updated layout will be assessed using hydrodynamic modelling to predict the magnitude and extent of changes in the Environmental Statement.	The full Project details are provided in the parameters section of **Chapter 2: The Project [TR030008/APP/6.2]**. The worst case parameters have been included within the numerical modelling assessment.
Second Statutory Consultation May 2023 – July 2023	Marine Management Organisation	The MMO has no additional comments to make at this stage regarding Coastal Processes, however, our previous comments from the last round of consultation, dated 16 February 2023, remain outstanding despite this PEIR addendum submission.	Noted. All comments received from the Marine Management Organisation ("MMO") have been captured within the physical processes assessments.

Reference, Date	Consultee	Summary of Response	How comments have been addressed in this chapter
Second Statutory Consultation May 2023 – July 2023	Lincolnshire Wildlife Trust	**Capital Dredging and Maintenance Dredging** LWT is pleased to see that the level of dredging required for the Project has now reduced with the decision to implement one berth instead of two. However, the details of dredging works remain vague at this time, and LWT will continue to monitor this as more information is given. Our concerns regarding capital dredging and maintenance dredging were not addressed in the updated documents for this Second Statutory Consultation. Therefore, we have included our previously stated views in an appendix (Appendix A) to this letter.	The potential effects arising from the capital and maintenance dredging (if required) have been fully assessed within this chapter. This has included numerical modelling to inform the assessments.

16.3 Legislation, Policy and Guidance

16.3.1 **Table 16-2** presents the legislation, policy and guidance relevant to physical processes assessment and details how their requirements have been met.

Table 16-2: Relevant legislation, policy and guidance regarding Physical Processes

Legislation/Policy/Guidance	Consideration within the ES
The Marine and Coastal Access Act 2009 ("MCAA") (Ref 16-1)	
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 MCAA established the Marine Management Organisation ("MMO") as the organisation responsible for marine planning and licensing. The Project will require a Marine Licence for the elements of the works below Mean High Water Springs including dredging, disposal and placing or removing objects on or from the seabed. For Nationally Significant Infrastructure Projects ("NSIPs") the Development Consent Order ("DCO") where granted may include provision deeming a marine licence to have been issued under Part 4 of the Marine and Coastal Access Act 2009. The MMO is responsible for enforcing, post-consent monitoring, varying, suspending, and revoking any deemed marine licence(s) as part of the DCO.	Information relevant to the marine licensing process is provided in the ES including characterisation of the physical processes baseline (**Section 16.6**) and an assessment of the exposure to change and potential impacts (**Section 16.8**).
The Planning Act 2008 (2008 Act) (Ref 16-2)	
Whilst the MCAA regulates marine licensing for works at sea, section 149A of the 2008 Act enables an applicant for a DCO to include within the Order a Marine Licence which is deemed to be granted under the provisions of the MCAA.	Information relevant to the marine licensing process is provided in the ES including characterisation of the physical processes baseline (**Section 16.6**) and an assessment of the exposure to change and potential impacts (**Section 16.8**).
The Water Environment ("WFD") (England and Wales) Regulations 2017 (Ref 16-3)	
The Water Framework Directive (2000/60/EEC) is transposed into UK law through the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 as	The WFD surface water bodies are described in **Chapter 17: Marine Water and Sediment Quality [TR030008/APP/6.2]**. A WFD Compliance Assessment has been prepared to support the DCO application. This includes consideration of the potential risks for several key receptors, including hydromorphology. The WFD Compliance Assessment

Legislation/Policy/Guidance	Consideration within the ES
amended, known as the Water Framework Regulations[1]. In terms of water and sediment quality, *"Good ecological status/potential"* has regard to physico-chemical quality elements, and specific pollutants. The Good ecological status/potential assessment also considers biological and hydromorphological elements. "Good chemical status" has regard to a series of priority substances and priority hazardous substances.	has been informed by the outcomes of the physical processes assessment reported within this chapter.
The Conservation of Habitats and Species Regulations 2017 (Ref 16-4)	
The Habitats Directive and Birds Directive are transposed into UK law through the Conservation of Habitats and Species Regulations 2017 as amended, known as the "Habitats Regulations"[2]. 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, to include Special Areas for Conservation ("SACs") (classified under the Habitats Directive) and Special Protection Areas ("SPAs") (classified under the Birds Directive). These sites form the Natura 2000 network. These regulations also 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.	**Section 16.6** characterises the baseline for physical processes. An assessment of the exposure to change and potential impacts is described in **Section 16.8** which has informed the assessment of impacts on protected habitats and species presented in **Chapter 9: Nature Conservation (Marine Ecology)** and **Chapter 10: Ornithology [TR030008/APP/6.2]**. In particular information is provided with respect to the following 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. • Non-toxic contamination through elevated SSC resulting in effects on interest features, or their prey resources. A Shadow Habitats Regulations Assessment ("Shadow HRA") has been prepared to inform the Appropriate Assessment ("AA") and is provided in **[TR030008/APP/7.6]** as part of the Habitats Regulations Assessment ("HRA"). This report will inform the consultation process and will aid the Competent Authority in determining whether the Project has the potential for 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, will inform the requirement to undertake an

1 Following the UK leaving the EU, the main provisions of the WFD have been retained in English law through The Floods and Water (Amendment etc.) (EU Exit) Regulations 2019.

2 Following the UK leaving the EU, the Conservation of Habitats and Species Regulations 2017 have been modified by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019.

Legislation/Policy/Guidance	Consideration within the ES
	AA of the implications of the proposals in light of the site's conservation objectives and will inform the stage 2 AA of whether the Project will have an adverse effect on integrity of the protected sites.
The Waste (England and Wales) Regulations 2011 (as amended) (Ref 16-5)	
The Regulations set out the measures required for the prevention of, production and management of waste. This describes the purpose of a waste prevention program with waste prevention measures and makes reference to monitoring by appropriate authorities using qualitative or quantitative benchmarks. It also outlines the waste hierarchy which ranks waste management options according to what is best for the environment. It gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery, and last of all disposal (e.g. landfill). 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 Regulations. 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.	**Section 16.6** provides baseline information on sediment characteristics. This information has informed a Waste Hierarchy Assessment ("WHA") for the Project to determine the Best Practical Environmental Option ("BPEO") for dealing with the dredge arisings (see **Appendix 2.A [TR030008/APP/6.4]**). The WHA has been informed by the outcomes of this physical processes assessment. The option of disposal in the estuary has been assessed as part of this physical processes assessment and is described in **Section 16.8**.

Legislation/Policy/Guidance	Consideration within the ES
National Planning Policy Statement for Ports ("NPSfP") (Ref 16-6)	
The NPSfP provides the policy framework for nationally significant infrastructure projects involving new port development (Department for Transport, 2012). In order to meet the requirements of the Government's policies on sustainable development, the NPSfP requires that new port infrastructure should also, 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. It also advises in Paragraph 5.3.5 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. Paragraph 5.3.5 of the NPSfP advises that applicants 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. Paragraph 5.3.8 states that the decision-maker should be satisfied that the proposed development will be resilient to coastal change, taking account of climate change, during the project's operational life and any de-commissioning period.	A physical processes chapter has been prepared for the ES. An assessment of the exposure to change and potential impacts on physical processes is described in **Section 16.8**.
UK Marine Policy Statement ("MPS") (Ref 16-7)	
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 consenting development in the UK marine areas. Section 2.6.8 of the MPS is relevant to the Physical Processes assessment. In particular,	A physical processes chapter has been prepared for the ES. An assessment of the exposure to change and potential impacts on physical processes is described in **Section 16.8**. Where relevant mitigation has been considered in **Section 16.7**.

Legislation/Policy/Guidance	Consideration within the ES
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 (Ref 16-8)	
The aim of the UK Marine Strategy is to protect the UK's marine environment. 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. It aims to achieve good environmental status of marine waters by 2020 (followed by a six-year review) and then to protect the resource base upon which marine-related economic and social activities depend. The Strategy constitutes a vital environmental component of future maritime policy, designed to achieve the full economic potential of oceans and seas in harmony with the marine environment. 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. Government reporting against the Strategy is a cyclical process, and the most recent assessments and Marine Strategy documents were updated in 2019.	The anticipated pressures exerted on the marine environment by the 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 (Ref 16-9)	
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.	With respect to this physical processes assessment, the future baseline is discussed in **Section 16.6**, to provide context to the predicted changes (as a result of the Project) which are described in **Section 16.8**.

Legislation/Policy/Guidance	Consideration within the ES
There are no policies within the East Marine Plans related specifically to coastal processes. Policy CC1, however, states that: *"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."*	
Flamborough Head to Gibraltar Point Shoreline Management Plan ("SMP") (Ref 16-10)	
The Flamborough Head to Gibraltar Point SMP identifies the most sustainable approach for managing the risk from coastal flooding and erosion over the short, medium and long-term. It covers the Humber Estuary coastline up to Immingham.	The ES recognises that the Project lies adjacent to Policy Unit L 'East Immingham to Cleethorpes' where the policy in the short, medium and long term is 'Hold the Line', which will influence current and future baseline conditions (**Section 16.6**).
North East Lincolnshire Local Plan 2013 to 2032 (Ref 16-11)	
The North East Lincolnshire Local Plan was adopted in 2018 and covers the period 2013 to 2032. Within its Spatial Portrait, the Local Plan highlights the importance of the 'Estuary Zone' of the local authority area, which includes the 'nationally important port' of Immingham. When considering the detail of how the economy of the area will be developed, the Plan specifically identifies at the outset that there are good expectations of growth within the ports and logistics sector. On the policies map which accompanies the Local Plan, the Site of the Project is shown as being located within an area identified as 'Employment – Operational Port'. In addition, Policy 34 of the plan makes clear that: *"Water management* *1. Development proposals that have the potential to impact on surface and ground water should consider the objectives and*	The Project is located largely within the administrative area of North East Lincolnshire, although elements of the marine infrastructure fall beyond the local Council's administrative boundary. Consideration of impacts on physical processes is provided in **Section 16.8**. This has also been assessed in **Appendix 17.A [TR030008/APP/6.4]** which will be submitted with the DCO application and considers WFD objectives as outlined in the Humber River Basin Management Plan.

Legislation/Policy/Guidance	Consideration within the ES
programme of measures set out in the Humber River Basin Management Plan." The Humber River Basin Management Plan provides a framework for protecting and enhancing the benefits provided by the water environment within the Humber River Basin District and informs decisions on land-use planning. The Humber River Basin District covers an area of 26,100 km² and extends from the West Midlands in the south, northwards to North Yorkshire and from Staffordshire in the west to part of Lincolnshire and the Humber Estuary in the east	
PINS Advice Note Eighteen: The Water Framework Directive (Ref 16-12)	
Advice Note Eighteen explains the information that the Inspectorate considers an applicant must provide with their NSIP application in order to clearly demonstrate that the WFD and the Water Environment ("WFD") (England and Wales) Regulations 2017 have been appropriately considered. The Advice Note also refers to Environment Agency guidance (as described above) in terms of the WFD process and the information required. Furthermore, the guidance describes the relevant bodies to be consulted in the pre-application process, and the presentation of information.	The WFD Compliance Assessment for the Project (**Appendix 17.A [TR030008/APP/6.4]** contains the information specified in this guidance as appropriate. The WFD Compliance Assessment has been informed by the outcomes of the physical processes assessment in **Section 16.8**.

16.4 Assessment Method

16.4.1 The physical processes assessment applies the same principles as the impact assessment methodology as described in **Chapter 5: EIA Approach [TR030008/APP/6.2]** and assesses the potential 'exposure to change' resulting from the impact pathways that have been scoped into the assessment. However, in most instances the methods adopted for the assessment of the physical processes changes differs slightly to those adopted for other environmental topics. This is because whilst the Project has the potential to cause changes to hydrodynamic and sedimentary processes, these changes are not, in themselves, generally recognised as environmental features/ receptors and, therefore, do not equate to 'effects'. The effects would instead be the consequence of these changes on other environmental features. For example, 'changes' in the transport and deposition of sediment may 'effect' the structure and function of marine habitats and their associated species.

16.4.2 The consequent significance of effects resulting from changes in physical processes on other environmental features/receptors have been assessed in other topic-specific ES chapters, including **Chapter 9: Nature Conservation (Marine Ecology)**; **Chapter 10: Ornithology**; **Chapter 15: Historic Environment (Marine)**; **Chapter 17: Marine Water and Sediment Quality**; and **Chapter 18: Water Quality, Coastal Protection, Flood Risk and Drainage [TR030008/APP/6.2]**.

16.4.3 Where changes in physical processes may potentially impact on physical environmental receptors, such as the local coastline and the nearshore sandbank and channel system, along with existing berth and jetty infrastructure, an assessment of effect significance is undertaken following the methodology presented in **Chapter 5: EIA Approach [TR030008/APP/6.2]**. In accordance with published guidance and an established approach that has been used in numerous previous EIAs, the assessment includes an evaluation of the importance/value and sensitivity of relevant physical processes receptors.

Data and Information Sources

16.4.4 The description of the existing baseline draws on available information from new and existing surveys, reports, dredging records and publicly available data. Additional, project-specific surveys have also been undertaken and used to inform this baseline characterisation. The following data key data sources have been used:

a. Hydrodynamic data collected by ABPmer between 12 August 2022 and 03 March 2023 at the location of the Project (**Appendix 16.C [TR030008/APP/6.4]**).

b. Available hydrodynamic data across the wider study area, including within the vicinity of the Port.

c. Bathymetric survey data collected by ABPmer in the vicinity of the proposed marine works in July 2022, along with a repeat bathymetric survey conducted by ABP in 2023 (**Appendix 16.B [TR030008/APP/6.4]**).

d. Site-specific marine sediment samples collected in 2022 and 2023 within the boundaries of the Project marine infrastructure works area for particle size analysis (“PSA”).

e. Historic marine surface sediment samples (2001) collected in the area of Immingham Outer Harbour (“IOH”) for PSA analysis.

f. Numerical modelling tools developed specifically for the Project and covering the assessment of hydrodynamic, wave and sediment transport impacts for the proposed works (jetty construction and potential for dredging and disposal).

g. Various ABPmer reports covering project work for ABP in and around the Immingham region.

h. Guidance documents relevant to the study, including Environment Agency Coastal Flood Boundary datasets for extreme events; UK Climate Projections ("UKCP18") for influence of future climate change.

Limitations and Assumptions

16.4.5 The information presented in this assessment reflects the proposed parameters and design for the Project as described in the parameters section of **Chapter 2: The Project [TR030008/APP/6.2]**.

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

a. The Project is implemented as described in **Chapter 2: The Project [TR030008/APP/6.2]** (with regards berth pocket location, depths, jetty and pontoon pile locations and dimensions).

b. Numerical modelling is based on a scenario with all elements of infrastructure in place and is considered a 'worst-case' scenario.

c. Capital dredging would be undertaken by backhoe dredger (e.g., Mannu Pekka or similar) with disposal at the Clay Huts disposal site (HU060) or the Holme Channel (HU056) disposal site. Maintenance dredging (if required at all) would be undertaken by Trailing Suction Hopper Dredger ("TSHD") with disposal at the Clay Huts disposal site (HU060). Dredge operations would be continuous and operate 24 hours a day and seven days a week until the full dredge volume has been removed (estimated to be 12 days).

d. Following construction of the Project, vessels operating from the newly constructed berth are assumed with dimensions described in **Chapter 2: The Project [TR030008/APP/6.2]**. Where a range of vessel sizes is possible, the largest dimensions have been used in this assessment as representative of a realistic worst case scenario.

e. 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).

f. The capital dredge volumes assumed are a total of approximately 4,000m^3.

16.4.7 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, marine piling and disposal locations. Specific assumptions (and associated methodology) for each assessment are detailed in the relative sections of **Section 16.8**.

16.5 Study Area

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

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

16.5.3 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 Project.

16.5.4 As a consequence, the study area for the physical processes topic comprises the 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 (see **Figure 16.1 [TR030008/APP/6.3]** for locations).

16.6 Baseline Conditions

Current Baseline

Bathymetry and morphology

16.6.1 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.

16.6.2 The estuary can be divided into three regions (see **Figure 16.1 [TR030008/APP/6.3]** for locations):

a. The Inner Humber (Trent Falls to Humber Bridge);

b. The Middle Humber (Humber Bridge to Grimsby); and

c. The Outer Humber (Grimsby to Spurn Point).

16.6.3 In the Inner Humber, downstream of Trent Falls, where the River Trent and River 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.

16.6.4 The Middle Humber, where the Project is located, 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.

16.6.5 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.

16.6.6 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.

16.6.7 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 to 25 years, with large changes to the intertidal banks and secondary channels in the areas of Hull Middle, Skitter Sand and Halton Flats.

16.6.8 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 10m and 20m 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.

16.6.9 Across the Project, the near field bathymetry is influenced by the deeper approaches to the Port of Immingham (“The Port”) and the relatively shallower subtidal region behind the existing jetties (**Figure 16.2 [TR030008/APP/6.3]**. Bed elevation within the approaches to Immingham, the SDC and on the berths at Immingham Oil Terminal (“IOT”) varies in the approximate range of -8m to -20mCD. Across the Site, bed levels range from around -16mCD offshore, sloping up towards the land along the Immingham foreshore. The intertidal area adjacent to the Project is around 100m in width, narrowing slightly to the south, to around 80m south of the landward end of the jetty(s).

16.6.10 A review of historical bathymetric charts extending both up and down estuary of the Project shows that in the 1930s, the channel up estuary was considerably deeper than present day, with depths of the order of -16mCD centred about 1km from the shoreline. The channel has consistently in-filled until about 1990, resulting in a depth of around -7mCD. During the last 15 years, depths have been relatively stable, although variations between -6m and -7m CD have occurred in Whitebooth Road (**Figure 16.1 [TR030008/APP/6.3]**. Around the Site (including Stallingborough Flats and the wider Immingham frontage), bed levels have remained relatively stable over time.

Tides and water levels

16.6.11 The Humber Estuary is macro tidal with a mean spring tidal range of 5.7m at Spurn increasing to 7.4m at Saltend then decreasing to 6.9m at Hessle, which is 45km inland. Tides are semi diurnal with a slight diurnal inequality (one slightly higher high water followed by a slightly lower one), amounting to a 0.2m difference in high water spring tides at Immingham. Standard tidal levels at Immingham are provided in **Table 16-3**.

Table 16-3: Standard tide levels for Immingham

Tidal Level		Immingham	
		mCD	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	0.10	-3.80
Mean Spring Tidal Range	(MHWS – MLWS)	6.40m	
Mean Neap Tidal Range	(MHWN – MLWN)	3.20m	
Note: Conversion from mCD to mODN at Immingham = -3.90m.			

Source: Ref 16-13

16.6.12 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 of the estuary itself.

Extreme water levels

16.6.13 Current extreme predictions determined by the Environment Agency for Immingham are the most up-to-date and appropriate for this review (Ref 16-14), as recommended by current guidance. These are provided in **Table 16-4** for a baseline year of 2017.

Table 16-4: Predicted extreme water levels for the Port of Immingham (Ref 16-14)

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

16.6.14 The maximum water level currently recorded at Immingham occurred on 5 December 2013 at 19:00 hours with a level of 5.22m Ordnance Datum Newlyn (“ODN”) compared to the predicted 3.69m ODN; therefore, the meteorological surge effect during the recorded event was 1.53m.

Sea level rise

16.6.15 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 (Ref 16-18) relative sea level research and assuming a Representative Concentration Pathway (“RCP”) 8.5 (95%ile) scenario will add 0.52m to the water levels provided in **Table 16-4**.

Flows

16.6.16 Flow speed data has been obtained from the United Kingdom Hydrographic Office (“UKHO”) Admiralty Tidal Diamond, located within the main channel, approximately 2km up-estuary of the Project. The variation in the tidal flow conditions is provided in **Table 16-5**.

16.6.17 Bespoke, site-specific hydrodynamic information has also been collected. During this sevenmonth period, depth averaged current speed values peaked at *circa* 1.5m/s on the ebb tide and *circa* 1.3m/s on the flood tide on the spring tide phase. During a neap tide phase, peak values were *circa* 0.8m/s (ebb) and *circa* 0.4m/s (flood).

16.6.18 Current directions were generally aligned with the orientation of the estuary throughout a tidal cycle, remaining consistent throughout the duration of the flood with WNW flow (between 290°N and 295°N). During the ebb, flows were also generally uniform, with initially ESE flows (*circa* 120°N) becoming more E (*circa* 100°N) approaching LW. A current rose, showing the collected survey data, is provided in **Figure 16.3 [TR030008/APP/6.3]**.

Table 16-5: Tidal flow conditions from the closest Admiralty Tidal Diamond (Ref 16-13)

Time (hours)	Direction (going to °N)	Spring rate (m/s)	Neap rate (m/s)
-6	132	1.30	0.41
-5	239	0.10	0.10
-4	303	1.10	0.57
-3	305	1.70	0.87
-2	314	1.60	0.87
-1	315	1.50	0.57
HW	319	0.67	0.15

Time (hours)	Direction (going to °N)	Spring rate (m/s)	Neap rate (m/s)
1	122	0.67	0.36
2	133	1.70	0.72
3	129	2.10	1.20
4	132	2.30	1.40
5	126	1.80	1.30
6	132	1.50	0.82

16.6.19 The predicted flow data from further up-estuary reveals that the flow regime in this area remains generally rectilinear, with flows aligned approximately east-southeast on the ebb to west-northwest on the flood. Peak flows here of around 2.1m/s are predicted 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 Stallingborough Flats and the drag effects from IOT.

Waves

16.6.20 From available data, the wave climate across the Site is generally protected from large waves approaching from the North Sea by a combination of sheltering effects (from Spurn Head and the various banks and channels within the outer parts of the Humber Estuary).

16.6.21 Measured data from the Project oceanographic survey campaign has also been used to provide a more detailed description of the local wave climate.

16.6.22 This measured data, from the Project AWAC deployment (**Appendix 16.C [TR030008/APP/6.4]**), reveals wave heights were generally less than 0.8m and showed a semi-diurnal relationship with water level (highest heights over HW periods and lowest heights around LW), indicating most were locally wind generated. A maximum wave height H_{max} of 1.19m was observed on 3 September 2022, with an elongated period of higher wave heights between 16-18 September 2022 resulting from predominantly northerly wind conditions.

16.6.23 Peak wave period (T_p) generally remained between 2s and 5s, with mean wave period (T_z) between 1s and 3s. Similar to wave height, a semi-diurnal relationship of wave period and water level can be established, indicating most waves are locally wind generated. Occasionally larger T_p between 6s and 10s were isolated values with little or no respective increase in T_z values. These are likely a result of vessel wakes from commercial shipping approaching/exiting IOT and Immingham Dock. Although these are correctly derived values by the AWAC instrument, a large proportion have been flagged during the data Quality Assurance process and should be treated with caution.

16.6.24 Wave direction was generally variable, although with a slight bias from E and NE sectors between 45°N and 110°N which reflects the deployment location in relation to the estuary. Between 16 to 18 September 2022, waves were concentrated from a N direction (315°N-360°N). This period resulted in a small increase in wave heights above routine values. A wave rose, showing the collected survey data, is provided in **Figure 16.3 [TR030008/APP/6.3]**.

Geology and sediments

16.6.25 The underlying solid geology of the Humber is Upper Cretaceous Chalk. Locally there are two formations: Flamborough Chalk and Burnham Chalk. The younger Flamborough Chalk has identifiable bedding surfaces, distinct marl bands and is without flint. The underlying Burnham Chalk, which subcrops along the eastern part of the Site, is thinly bedded and laminated and contains continuous flint bands. The Port is located at a point where the Burnham Chalk Formation is not covered by the Flamborough Chalk Formation (Ref 16-15).

16.6.26 The chalk surface is characterised by a highly fractured zone created by glacial and periglacial processes, and overlain by Pleistocene deposits of Glacial Till. These glacial and post-glacial sequences are subsequently overlain by fine-grained (Clay and Silt) Tidal Flat Deposits.

16.6.27 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).

16.6.28 The estuary upstream of the Humber Bridge represents an older estuary system formed in the last interglacial (120,000 to 80,000 years Before Present) 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 Sea Level Rise ("SLR"), the former river channel underwent marine transgression and became subject to estuarine sedimentation.

16.6.29 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) (Ref 16-16). 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 16-6**.

Table 16-6: Net sediment budget model for the Humber Estuary (Ref 16-16) (based on analysis of data between 1946 and 2000)

System Element	Sediment load and rate of exchange with the Estuary (+ve indicates an input; -ve indicates a removal) (tonnes per tide)
Humber Estuary	$1.2x10^6$ tonnes
River inputs	+335
Intertidal accretion	-4
Subtidal erosion	+145
Cliff erosion	+7
Saltmarsh deposition	-11
Met marine exchange	-472
Average tidal flux	$\pm1.2x10^5$

16.6.30 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 July 2022 as part of the Project study, collected eight sediment samples within, and adjacent to, the proposed berth dredge (see **Figure 16.4 [TR030008/APP/6.3]** for locations). The bed samples were subsequently analysed for PSD, in order to characterise the bed material across the Site. The majority (five of the eight samples) are classified as 'sandy Mud' (Ref 16-17), with the remainder comprising 'Mud' (see **Figure 16.4 [TR030008/APP/6.3]** for the PSD of the Site and **Table 16-7** for summary PSD information). Previous sampling has also collected grab samples across the two disposal sites (HU056 and HU060). PSD information for these samples (see **Figure 16.4 [TR030008/APP/6.3]** for locations) are also provided in **Table 16-7**, revealing a mixture of sediment type, with varying proportions of sand, mud and gravel.

16.6.31 Across the eight sediment samples collected as part of the baseline studies carried out for the Project, the average bed composition is 76% mud, 24% sand and no gravel material. Within the proposed dredge pocket, these average values shift slightly towards the coarser particles with 69% mud and 31% sand. As noted above, the majority of locations (all within the proposed dredge pocket) are categorised as 'sandy Mud' (Ref 16-17), with locations 01, 02 and 03 (inshore of the dredge pocket) defined as 'Mud'.

16.6.32 Measurements of SSC previously collected from the Immingham area, 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. The Project oceanographic survey has collected information on suspended sediments, which has been used to detail the local characteristics.

16.6.33 Additional Vibrocore samples (further information provided in Section 17.6 of **Chapter 17: Marine Water and Sediment Quality** of the ES **[TR030008/APP/6.2]**), collected in March 2023 in and around the dredge pocket and at varying depths, show the predominant sediment compositions to be 'muddy Gravel' (39%), 'gravelly Mud' (23%) and 'sandy Mud' (16%). The average percentage composition of the sediments collected and sampled were:

a. Mud – 57.36%

b. Sand – 15.84%

c. Gravel – 26.80%

Table 16-7: Particle size distribution across the Project and disposal sites

Sample	Percentage composition (%)			Sediment description*	Mean grain size (d50) (µm)
	Mud	Sand	Gravel		
1	96.69	3.31	0.0	Mud	7.8
2	94.11	5.89	0.0	Mud	8.2
3	96.32	3.68	0.0	Mud	7.0
4	71.10	28.90	0.0	Sandy Mud	20.1
5	57.35	42.65	0.0	Sandy Mud	27.7
6	63.76	36.24	0.0	Sandy Mud	23.6
7	71.51	28.49	0.0	Sandy Mud	17.9
8	55.43	44.57	0.0	Sandy Mud	30.6
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
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

Sample	Percentage composition (%)			Sediment description*	Mean grain size (d50) (µm)
	Mud	Sand	Gravel		
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 Ref 16-17					

16.6.34 In addition to the bed sampling described above, a full-spread geophysical survey has also been carried out across the Site to provide a general description of the sub-bottom geology, provided below.

16.6.35 Results from a combination of Side Scan Sonar and Multibeam Echo Sounder data show five seabed sediment classifications: Mixed Sediment, muddy SAND, firm CLAY, soft MUD and rock protection. Firm CLAY has been marked tentatively as an increase in soil strength is only supported by an increase in reflectivity, rather than having been verified by ground truthing. Bespoke Ground Investigation (“GI”) works are currently underway.

16.6.36 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 3.0m below seabed.

16.6.37 The uppermost unit is comprised of surficial alluvium deposits composed of soft SILT/CLAY and SAND with a depth range between 0.0m – 4.8m below seabed. A layer of interpreted boulder clay underlies the alluvium which has been interpreted as the Upper Boulder Clay unit. The Upper Boulder Clay ranges between 0.0m – 10.6m below seabed and is largely observed to exist in tandem with the underlying Lower Boulder Clay which appears to completely erode away towards the north. The Lower Boulder Clay unit is observed to exist between 0.0m – 15.0m below seabed in the survey area. Discontinuous lenses of SAND/GRAVEL are also noted within this unit. The bedrock has been identified as CHALK from geotechnical data. The surface of the CHALK has been observed in the seismic data at depths between 0.0m – 15.0m below seabed. The bedrock level below seabed shoals to the north where it is observed at or close to the riverbed.

16.6.38 Two small, isolated regions of acoustic attenuation are observed, likely caused by moderate accumulation of organic matter within the surficial sediments.

16.6.39 There is good confidence in the geophysical interpretation in the deeper waters (proposed berth area) at the northeast of the survey area due to the chalk horizon being clearly observed reaching the seabed and correlating with results of the recent sediment sampling (vibrocore) campaign.

Future Baseline

16.6.40 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 Project.

16.6.41 The future baseline would 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 0.99m (based on UKCP18 RCP 8.5 95%ile climate change scenario). Water levels in the future, as now, would also be affected by unpredictable surge and weather-related events. These parameters have been factored into the assessment of potential changes to physical processes introduced via the Project.

16.7 Design, Mitigation and Enhancement Measures

Embedded Mitigation Measures

16.7.1 The Project has been designed, as far as possible, to avoid and minimise impacts and effects on physical processes through the process of design development, and by embedding mitigation measures into the design, such as minimising the dredge requirements as far as possible in the context of the existing bathymetry.

Standard Mitigation Measures

16.7.2 Standard mitigation measures would be implemented 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 standard mitigation measure would be implemented:

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

16.8 Potential Impacts and Effects

16.8.1 This section identifies the potential likely effects on the physical processes receptors as a result of the construction and subsequent operation of Project **Figure 16.5 [TR030008/APP/6.3]**.

16.8.2 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 25: Cumulative and In-Combination Effects [TR030008/APP/6.2]**).

Construction

16.8.3 This section contains an assessment of the potential impacts of the construction phase of the Project. Numerical modelling is based on a scenario with all elements of infrastructure in place including the berth and is considered a 'worst-case' scenario in terms of potential impacts on hydrodynamics.

16.8.4 The following construction activities and impacts have been identified and considered:

a. Capital dredge and disposal and marine piling works:

   i Increased SSC and potential sedimentation over the extent of the disturbance plume as a result of the construction of the new jetty (piling) and capital dredging works.

   ii Increased SSC and potential sedimentation as a result of the deposit of capital dredge material at a licensed offshore disposal site(s).

   iii Changes in seabed bathymetry and composition as a result of deposition of dredged/disposal material within the area of the respective plumes.

b. Changes in local flow speeds (and potential impact on local sediment dynamics) as a result of construction vessel activity (ship wash, vessel propulsion etc.).

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

16.8.5 The disposal of dredged material at sea associated with the Project would be fulfilled at licensed disposal sites HU056 (for any inerodible boulder/glacial clay) and HU060 (for any sand/silt (alluvium) material) (see **Chapter 2: The Project [TR030008/APP/6.2]**).

16.8.6 The potential impact of dredge arisings (and spoil from removal to licensed disposal sites) on SSC and sedimentation has been assessed. However, the disposal activity is considered to result in a larger extent and magnitude of impact than that arising from the dredge (as a result of the relative volumes and methods). The approach uses 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 is informed by application of the calibrated numerical hydrodynamic modelling tool, which drives a Danish Hydraulic Institute ("DHI") particle tracking module.

16.8.7 It is anticipated that the dredging for the berth pocket would be undertaken by a backhoe dredger and would 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 – see assumptions in **Section 16.4**). The number of barges would 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 would be a 24/7 operation until dredging is complete. The assessment is based on barge access to the disposal sites being achieved throughout the full tidal cycle (see **Paragraph 16.4.6**). Current dredge volume estimates (based on the latest available site-specific geotechnical and geophysical information) are for a total of approximately 4,000m^3 of material.

Dredging of the proposed berth(s) and associated disposal at HU060

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

a. Backhoe bucket size of 8m^3.

b. Average bucket cycle time of 2 minutes.

c. Working capacity of barge = 950m^3.

d. A continuous barge operation would provide maximum production and greatest potential for magnitude in plume.

e. Typical rates, vessel speeds and distance to disposal site have been used to calculate typical dredge cycle times.

16.8.9 In addition, the following details have also been assumed in respect of the plume assessment, based on an understanding of the method and equipment to be used:

a. Distance from dredge to disposal site is approximately 1.1 nautical miles and the assumed load service speed is eight knots.

b. Barge deposit time is ten minutes.

c. Characteristic sediment distribution is informed by the bed sampling (detailed in **Table 16-7** to this chapter, with a mean grain diameter of around 20µm.

d. 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).

e. 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).

f. 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.

16.8.10 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 assumes continuous dredging (of the full dredge volume) at the proposed berth location(s) and a disposal (over a ten minute period) at HU060 every four hours.

16.8.11 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 would be used for the disposal of any 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).

Spatial dispersion of dredge plume and sedimentation

16.8.12 Following the repeating schematic dredge cycle the particle tracking model has been run with sequential dredge, disposal, dredge, cycles. The initial dredge commences during a mean spring tide and the cycle repeats until the full dredge volume (4,000m^3) has been deposited. Dredge locations within the berth pocket are switched between either end of the berth pocket, whilst disposal inputs are to the centre of the HU060 disposal site.

16.8.13 **Figure 16.6 [TR030008/APP/6.3]** shows the maximum spatial extent of the disposal SSC plume at HU060 over the full dredge and disposal campaign (covering both peak flood and peak ebb tidal flows (on a spring tide). The output, therefore, shows the maximum extent of excess SSC and sedimentation resulting from the assessed repeating ‘dredge > disposal…’ cycle (**Figure 16.6 [TR030008/APP/6.3]**).

16.8.14 For dredge arisings disposed at the HU060 site, it is anticipated that material would 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 would 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.

16.8.15 In practice, due to the high magnitude of (and wide envelope of variability in) background SSC levels, the predicted increase in concentrations resulting from the disposal activities is likely to become immeasurable (against background) within approximately 1km of the disposal site. Furthermore, the effects of the proposed 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 would 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.

16.8.16 Associated sedimentation **Figure 16.6 [TR030008/APP/6.3]** to the bed extends up- and down-estuary from the disposal site. Peak sedimentation depths are around 1-2mm within a distance of around 1km from the disposal site. At the dredge location, increased sedimentation above 0.5mm is predicted within around 500m (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 negligible. 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.

16.8.17 Example timeseries plots of predicted excess SSC and associated sedimentation (from the combined dredge/disposal operations) are provided in **Figure 16.7 [TR030008/APP/6.3]** 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 1.5km 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 1.5km 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).

16.8.18 Associated with this, each disposal operation results in sedimentation of around 1-2mm at locations around 1km 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.

16.8.19 It should be noted that the map plots in **Figure 16.6 [TR030008/APP/6.3]** 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 estuary, without reference to how soon after commencement of operations they occur, nor how long these values persist at any given location. In contrast, the successive temporal plots provided in **Figure 16.8 [TR030008/APP/6.3]** show the instantaneous extent and magnitude of excess SSC (and associated sedimentation) following a number of consecutive disposal events.

Assessment of exposure to change

16.8.20 The greatest increase in SSC from the marine piling, dredging and disposal activities would occur during the barge depositing material at the licensed disposal site. Material within the passive plume would 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 would 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.

16.8.21 At the disposal site, the effect of deposition of capital dredge arisings would 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 would be small in the context of the existing depths. As is currently the practice, disposal activity would 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) would be negligible.

16.8.22 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. Overall, 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 would 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

16.8.23 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 of the material would be removed with a backhoe dredger to a hopper (for subsequent disposal). Whilst the optimal size of the dredging plant would 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 wider area, it is further considered likely that dredging plant would 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.

Assessment of exposure to change

16.8.24 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 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.

Operation

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

a. Marine facilities (approach jetty and dredge pocket):
   - i Local changes to hydrodynamic regime (flow speed and direction) as a result of the piers (piling) and the implementation of the new berth pocket.
   - ii Associated local changes to the sediment transport pathways, as a result of localised changes to the driving hydrodynamic (and wave) forcing.
   - iii Local changes to the wave regime, as a result of the piers (piling) and the implementation of the new berth pocket.
   - iv Potential impacts on existing features, including existing marine infrastructure, outfalls and estuary banks and channels.

b. Maintenance dredging - potential impact on SSC and sedimentation:
   - i Increased SSC and potential sedimentation in the area of dispersal plume as a result of maintenance dredging.
   - ii Increased SSC and potential sedimentation as a result of deposition of maintenance dredge material at a licensed disposal site.
   - iii Changes in seabed bathymetry and composition as a result of deposition of dredged/disposed maintenance dredge material.

Marine facilities (approach jetty, jetty head and dredge pocket) - potential impact on hydrodynamics

16.8.26 An assessment of impacts on hydrodynamics has been carried out using numerical modelling tools and conceptual analysis (see **Paragraph 16.1.7**). The modelling has been completed using an updated version of the existing calibrated and validated MIKE FM HD model of the Humber Estuary. The updated model mesh has been refined around the study area and adjacent coastline.

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

16.8.28 The updated model has been subject to new calibration and validation using survey data for the local area. Calibration and validation have been undertaken over a spring and neap tide. Full details of the model setup, calibration and validation are provided in **Appendix 16.A [TR030008/APP/6.4]** .

16.8.29 Although not specifically shown on a figure within this assessment, it should be noted that the assessment of the Project 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 Project.

16.8.30 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 approach jetty, jetty head and dredge pocket, and temporally at a series of point locations identified as strategic locations and areas of greatest importance.

16.8.31 The spatial hydrodynamic effects of the marine facilities (approach jetty, jetty head and berth pocket) are shown in **Figure 16.9 [TR030008/APP/6.3]** for the approximate time of peak flood and ebb spring flows. Initial results of the hydrodynamic modelling show that the Project causes generally small impacts, confined predominantly to the vicinity of the structure and adjacent IOT.

16.8.32 During the flood tide (**Figure 16.9 [TR030008/APP/6.3]**), the extent of effect as a result of the Project is approximately 2km up estuary from the west edge of the berth pocket, across IOT and Humber International Terminal (“HIT”). Along IOT, flow speeds are reduced by < 0.3m/s on the eastern end of the jetty, and by <0.2m/s at the western end. By the time flows reach HIT, the flow speed reductions are < 0.1m/s. At the western edge of the berth pocket, flows are reduced by up to 0.31m/s. Small increases in flow speeds are seen just to the north of the jetty head, and to the south along the shore frontage; the magnitude of these changes is < 0.1m/s.

16.8.33 These changes in flow speed on the flood tide are relatively small with regards to the baseline flow speeds. Baseline flows are between 1.2 and 1.3m/s in the area of interest. As a result, maximum predicted changes in flow speed as a result of the Project generally tend to be limited in extent to the dredge pocket itself and are around -20% of baseline flow speeds. Further afield, changes remain constrained to the area adjacent to the berth, with relative flow speed changes generally around -5%.

16.8.34 On the ebb tide (**Figure 16.9 [TR030008/APP/6.3]**), the assessment shows a similar pattern of change to the flood tide, however, the reduction in flow speed occurs for approximately 2.5km down estuary from the eastern end of the jetty head. Here, there are flow speed reductions of < 0.6m/s. However, this quickly reduces to around a 0.4 and 0.3 m/s reduction 500m and 1km downstream, respectively. In the berth pocket itself, flow speeds are reduced by up to 0.2m/s. South of the Project, flow speeds are slightly increased, by around 0.1m/s moving towards the shoreline.

16.8.35 As with the flood tide, these changes in flows speed are relatively small in relation to the baseline flows speeds. Baseline flows vary from approximately 1.6m/s to approximately 1.7m/s in the area of interest. As a result, predicted reductions in ebb flow speed within the dredge pocket generally tend to be up to around -18% of baseline flow speeds. To the east of the jetty head, flow speeds reduce by up to 30% of the baseline, reducing to -5% 1km downstream of the Project.

16.8.36 Timeseries plots have been provided to illustrate a predicted temporal change throughout the spring tide at key locations. These are provided in **Figure 16.10** to **Figure 16.12 [TR030008/APP/6.3]**.

16.8.37 At P1 (**Figure 16.10 [TR030008/APP/6.3]**, approximately 3km downstream of the Project, changes in flow speeds on the flood tide would be negligible, and on the ebb tide, flow speeds would be reduced by approximately 0.05m/s.

16.8.38 At P2 and P3 (**Figure 16.10 [TR030008/APP/6.3]**, within 500m of the eastern end of the jetty head, changes in flow speed on the flood tide would again be negligible. On the ebb tide, flow speeds at both P2 and P3 are reduced by up to 0.25m/s.

16.8.39 Within the dredge pocket (locations P4 and P5), a general decrease in flow speeds is predicted (**Figure 16.10** and **Figure 16.11 [TR030008/APP/6.3])** on the flood tide at both locations, flow speeds are reduced by up to 0.4m/s. On the ebb tide, flows speeds at P4 are reduced by approximately 0.3m/s, whilst at P5, reduction in flow speeds are negligible.

16.8.40 At P7 and P8 (**Figure 16.11 [TR030008/APP/6.3])**, in front of IOT, and P9 (**Figure 16.11 [TR030008/APP/6.3])** (500m northwest of IOT) flow speeds are reduced by up to 0.25m/s on the later stage of the flood tide. On the ebb tide, changes in flow speeds are negligible.

16.8.41 At P10 (**Figure 16.12 [TR030008/APP/6.3]**), approximately 3.5km upstream of the Project in front of the Humber International Terminal, flow speeds on the flood tide are reduced by less than 0.05m/s, whilst changes in flow speed on the ebb tide are negligible.

16.8.42 At P6, P11 and P12 (**Figure 16.12 [TR030008/APP/6.3]**), south of the Project, just in front of the foreshore, flow speeds are slightly increased by up to 0.05m/s on both the flood and ebb tides, although changes in flow speeds on the ebb tide at P12 are negligible. At each of these locations, associated changes to bed shear stress are typically negligible in the context of the thresholds of motion for the typical bed material. The potential for changes to sediment transport pathways is considered further in the sections below.

Inclusion of vessels on-berth

16.8.43 Assessment of the hydrodynamic impacts during the operational phase of the development has considered the effect of one vessel berthed at the jetty, in addition to the pontoon structures themselves and dredged pocket – i.e., equivalent to maximum development case.

16.8.44 The assessment has also conducted a sensitivity test, which has considered one vessel on berth with a Length Overall of 250m; breadth of 37m and draught of 12.8m.

16.8.45 The spatial hydrodynamic effects of the operation of the Project with a vessel on-berth are shown in **Figure 16.13 [TR030008/APP/6.3]** for the approximate time of peak flood and ebb spring flows. Results of the hydrodynamic modelling show that with a vessel alongside, the Project causes relatively small impacts, which are confined to within 2km of the facility.

16.8.46 Along IOT, flow speeds are reduced by up to 0.3m/s (24% of baseline flows) on the eastern end of the jetty, and by < 0.2m/s (12%) at the western end. By the time flows reach HIT, the flow speed reductions are < 0.1m/s (5%). At the western edge of the berth pocket, flows are reduced by up to 0.5m/s (38%). Small increases in flow speeds are seen just to the north of the jetty head, and to the south along the shore frontage of < 0.1m/s.

16.8.47 On the ebb tide (**Figure 16.13 [TR030008/APP/6.3]**), the assessment shows a similar pattern of change to the flood tide, however, the reduction in flow speed occurs for approximately 3km down estuary from the eastern end of the jetty head. Here, there are flow speed reductions of up to 0.6m/s. However, this quickly reduces to a 0.4 and 0.2 m/s reduction 500m and 1km downstream, respectively. South of the Project, flow speeds are slightly increased by around 0.1m/s moving towards the shoreline. These results are typically the same as those described above for the ‘scheme without vessel’ scenario.

Assessment of exposure to change

16.8.48 Marginal changes to hydrodynamics (local flow speed) are likely to result from the Project within, and adjacent to, the proposed berth pocket. Slight changes in flow speed are predicted to extend up-estuary to Immingham Outer Harbour and IOT and down-estuary. The largest predicted magnitude of change is anticipated within the berth pocket itself and the eastern and western end of the jetty head. 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 (approach jetty, jetty head and dredge pocket) – potential impact on sediment transport

16.8.49 Changes to the local hydrodynamics, as a result of the 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).

16.8.50 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 outputs of the hydrodynamic model described above and verified against local dredge records and SSC measurements. The model setup and validation are described in **Appendix 16.A [TR030008/APP/6.4]**.

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

16.8.52 **Figure 16.14 [TR030008/APP/6.3]** shows the predicted difference (to baseline) in bed thickness change, as a result of the Project, 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 slight reduction in flow speeds within (and adjacent to) the dredged berth pocket and across the leeward side slopes result in a very small associated change to bed shear stress ("BSS"), allowing for slightly reduced erosion over the baseline condition (i.e. the dominant process within the berth pocket is still for erosion, but at a slightly reduced potential). The predicted change is very small in magnitude (resulting change in bed level of less than 0.1m) and limited in extent to part of the Site underneath the piled jetty head. This indicates that the berth pocket, once dredged, would remain swept clear of deposited material by the flood and ebb tidal flows (in much the same way as the existing IOT berths are). Consequently, the need for future maintenance dredging within the new berth pocket is expected to be very limited (if required at all).

16.8.53 In addition to the predicted reduced erosion along parts of the proposed berth pocket side slopes, local increases in peak flood and ebb current speed at the landward end of the proposed I approach jetty (**Figure 16.9 [TR030008/APP/6.3]**), result in associated slight increases to BSS. These lead to a slight increase in predicted erosion of the bed at the elevation of MLWS, beneath the landward end of the proposed jetty. **Figure 16.14 [TR030008/APP/6.3]** 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 0.1m, resulting in a potential indirect loss in intertidal area of up to 0.03ha. 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).

16.8.54 Across the wider study area (including the existing berths at IOT, the rest of the intertidal area along the Immingham frontage, the Habrough Marsh Drain and Immingham Sea outfalls, the offshore banks and channels and the wider estuary up- and down-stream), the Project marine facilities have no impact on the existing (baseline) accretion and erosion rates (**Figure 16.14 [TR030008/APP/6.3]**). Overall, there is predicted to be limited magnitude and extent of predicted change, resulting from the Project (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 Project would not result in long-term changes to the wider estuary morphology.

Assessment of exposure to change

16.8.55 Hydrodynamic forcing within (and adjacent to) the Project would only be marginally altered and, therefore, changes in the sediment pathways would be small. Predicted changes to future sediment transport are small in magnitude and limited in extent to the berth pocket and the landward end of the approach jetty. Outside the proposed berth pocket, the Project has limited impact on the baseline sedimentation and erosion rates.

16.8.56 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. With specific reference to the identified physical processes receptors (the existing infrastructure, the coastline along the Immingham frontage, existing outfalls and the local banks and channels), the exposure to change is assessed as **low** over the near-field and **negligible** over the far-field, resulting in and overall impact assessment of **insignificant**.

Marine facilities (approach jetty, jetty head and dredge pocket) - potential impact on waves)

16.8.57 Impacts on waves have been assessed using numerical modelling tools and conceptual analysis. The modelling has been completed using the existing (updated, as described) calibrated and validated MIKE SW model of the Humber Estuary. The model examines how wave conditions would be affected during extreme and more frequently occurring events.

16.8.58 The model utilises the same bathymetric data as the hydrodynamic model (as described above).

16.8.59 The updated model has been subject to performance checks by simulating wave conditions at the Site, over a short period during which waves have been recorded at the Site during the Project AWAC deployment (for discrete periods between 2020 and 2022). Full details of the model setup and verification are provided in **Appendix 16.A [TR030008/APP/6.4]**.

16.8.60 The assessment of potential wave impacts from the Project 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 further in **Appendix 16.A [TR030008/APP/6.4]**. These wave events have then been applied to the numerical model under existing (baseline) and Project scenarios. The predicted differences in modelled wave heights, as a result of the berth pocket dredge, have then been calculated.

Table 16-8: 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

16.8.61 The spatial wave effects of the construction of the Project are shown in **Figure 16.15** to **Figure 16.17 [TR030008/APP/6.3]** for each of the events modelled in **Table 16-8**. The results of the wave modelling show that the Project results in generally small impacts, confined predominantly to the area in the vicinity of the structures.

16.8.62 The greatest effect on wave height for the 0.5-yr, north easterly event is seen along the jetty head, with reductions in wave height of up to 0.25m on the western end and 0.2m on the eastern end (**Figure 16.15 [TR030008/APP/6.3]**). Along the approach jetty, a decrease in wave height of up to 0.13m is seen, extending back from the berth pocket towards the foreshore. This reduction in wave heights continues south of the jetty head, towards the foreshore. At the foreshore, wave height reductions are less than 0.1m. A slight reduction in wave height of < 0.1m also extends to the eastern end of IOT. There is also a small, predicted reduction in wave height (also < 0.1m) in the southwest corner of the berth pocket. Baseline wave heights for this event tend to be in the region of 1.1m around the Project. The maximum predicted change in wave height is therefore around -25%. This change is limited in extent to the area immediately around the jetty platform.

16.8.63 For the 0.5-yr, easterly and south easterly event, it is shown that the impacts extend slightly further than those of the north easterly event (**Figure 16.15** and **Figure 16.16 [TR030008/APP/6.3]**. As with the north easterly event, the biggest impact is seen along the jetty head, with decreases in wave heights of up to 0.3m. The sheltering effect of the Project extends further west, across the IOT and towards Bellmouth. At this point however, wave height reductions are small (<0.1m). By the time it has reached the most eastern part of IOT, changes to baseline wave heights are negligible. The baseline wave heights for this event are approximately 1.2m, with a maximum decrease of 0.3m, which represents a change of around -25 % at the jetty head. Reductions in wave heights elsewhere represent a change of around -6%.

16.8.64 As with the 0.5-yr event, the greatest effect on wave height for the 50-yr, north easterly event is along the jetty head, with reductions in wave height of up to 0.35m (31% decrease from the baseline (**Figure 16.16 [TR030008/APP/6.3]**). A reduction in wave height of up to 0.16m continues south of the jetty head along the approach jetty, towards the foreshore. However, this quickly reduces to less than 0.1m within 50m east and west of the approach jetty.

16.8.65 For the 50-yr, easterly event, it is anticipated that the impacts would extend slightly further than those of the north easterly event (**Figure 16.17 [TR030008/APP/6.3]**). As with the north easterly event, the biggest impact is seen along the jetty head, with decreases in wave heights of up to 0.4m. The sheltering effect of the Project extends further west, across the IOT and towards Bellmouth. At this point, however, wave height reductions are negligible. Along the most western part of IOT, wave heights are reduced by less than 0.05m (2%). Within the western end of the berth pocket, wave heights are reduced by around 0.15m (7%).

16.8.66 The 50-yr south easterly event is similar in pattern and magnitude of effects on wave height as the easterly event, particularly along the jetty head (**Figure 16.17 [TR030008/APP/6.3]**). However, due to the higher baseline wave heights for this event, the relative (percentage) decrease in wave height is less than that for the easterly event. At the jetty head, wave heights are expected to decrease by up to 14%, whilst at IOT and towards the adjacent foreshore, wave heights are expected to decrease by less than 3% compared to the baseline.

Assessment of exposure to change

16.8.67 Marginal changes to significant wave height (Hs) are likely to result from the Project within, and adjacent to, the proposed berth pocket. For the various wave events assessed, slight changes in wave height (typically less than -6% of baseline values) are predicted to extend up-estuary as far as Bellmouth (for a wave event approaching from the southeast). The largest predicted magnitude of change is anticipated in the immediate vicinity of the jetty head.

16.8.68 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 at this stage of the assessment.

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

16.8.69 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 Project is summarised here.

16.8.70 Changes to flows and waves are predicted to be generally limited in extent to around the Project marine facilities and in the immediate vicinity. The predicted impacts at the existing marine terminals (including IOT, Humber Sea Terminal, Immingham Eastern and Western Jetties, Immingham Outer Harbour and Immingham Gas Terminal) are (where predicted) generally small in magnitude. This is also the case for the adjacent foreshore areas fronting the Site, which include a number of outfalls. With distance from the Project, the predicted impacts reduce further and are not predicted to occur over the far-field region. Changes to local and regional sediment transport pathways have been modelled and are only predicted in close proximity to the marine elements of the Project, 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

16.8.71 Changes to flows and waves are likely to result from the Project 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 Project, reducing in magnitude with distance. Due to the small extent and low magnitude of effect on the driving hydrodynamics, coupled with the relatively stable nature of the estuary morphology across the near-field study area, it is considered that the changes arising from the Project would not affect the existing, longer-term cyclic patterns in the estuary banks and channels.

16.8.72 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

16.8.73 The assessment of impacts on local and regional sediment transport pathways has been undertaken to inform the potential requirement for future maintenance dredging. The modelling indicates that the berth pocket, once dredged, would remain swept clear of deposited material by the flood and ebb tidal flows (in much the same way as the existing IOT berths are). Consequently, the need for future maintenance dredging within the new berth pocket is expected to be very limited (if required at all).

16.8.74 Outside of the berth(s), and particularly within the existing Immingham berths, the predicted changes to flow speed and wave height are generally negligible, and therefore it is considered unlikely that the proposed works for the Project 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.

Assessment of exposure to change

16.8.75 It is considered that any future maintenance dredging (if required) would result in negligible changes in SSC and sedimentation. Furthermore, the predicted impacts from future maintenance dredging (if required) would be similar to that which already arises from the ongoing maintenance of the existing Immingham berths. As a result, the probability of occurrence is presently considered low and the magnitude of change is assessed as small, resulting in an overall **negligible** exposure to change.

16.9 Mitigation and Enhancement Measures

16.9.1 The exposure to change of all physical processes receptors as a result of the construction and subsequent operation of Project are considered to be Low at worst, and therefore, no additional mitigation measures are required.

16.10 Assessment of Residual Effects

Construction

16.10.1 None of the impact pathways identified for physical processes are expected to give rise to a measurable exposure to change. All potential effects during construction have been assessed as **not significant**.

Operation

16.10.2 All potential effects on impact pathways identified for physical processes during operation have been assessed as **not significant**.

Decommissioning

16.10.3 The DCO will not make any provision for the decommissioning of the main elements of the marine infrastructure above and below water level. This is because the jetty, jetty head, loading platforms, access ramps and jetty access road would, once constructed, become part of the fabric of the Port estate and would, in simple terms, continue to be maintained so that it can be used for port related activities to meet a long-term need. It is anticipated that plant and equipment on the jetty topside would be decommissioned in parallel with the decommissioning of the related landside elements. On this basis, potential effects on physical processes from decommissioning have been scoped out.

16.11 Summary of Assessment

16.11.1 A summary of the impact pathways that have been assessed, the identified residual effects and level of confidence are presented in **Table 16-9** to 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.

16.11.2 Overall, the physical processes changes brought about by the construction and operation of the Project are currently considered small in both magnitude and extent and the resultant exposure to change assessed as low. These assessments have been informed through application of numerical modelling tools and consideration of predicted impacts against existing (baseline) characteristics. The confidence associated with the assessment is considered 'Medium' as it is based on site specific data, and conceptual understanding of the study area combined with numerical modelling. The numerical model is fully calibrated, however, it is recognised that such models represent a number of complex parameters within dynamic environments and as such there will always be a limit to the level of accuracy that can be achieved.

Table 16-9: Summary of potential impact, mitigation measures and residual effects

Receptor	Impact Pathway	Exposure to change	Mitigation Measure	Residual Effect	Confidence
Construction Phase					
Physical processes	Increased SSC and potential sedimentation over the extent of the disturbance plume as a result of the construction of the new piers (piling) and capital dredging works	Low	N/A	Low	Medium
	Increased SSC and potential sedimentation as a result of the deposit of capital dredge material at a licensed offshore disposal site	Low	N/A	Low	Medium
	Changes in seabed bathymetry and composition as a result of deposition of dredged/disposal material within the area of the respective plumes	Low	N/A	Low	Medium
	Construction vessel activity – impacts on local hydrodynamics and sediment transport arising from ship wash and vessel propulsion	Low/negligible	N/A	Low/negligible	Medium
Operational Phase					
Physical processes	Local changes to hydrodynamic regime (flow speed and direction) as a result of the piers (piling) and capital dredging	Low	N/A	Low	Medium
	Local changes to the wave regime, as a result of the piers (piling) and capital dredging	Low	N/A	Low	Medium

Receptor	Impact Pathway	Exposure to change	Mitigation Measure	Residual Effect	Confidence
	Associated local changes to the sediment transport pathways, as a result of localised changes to the driving hydrodynamic (and wave) forcing	Low	N/A	Low	Medium
	Potential impact on existing features, including marine infrastructure, outfalls and estuary banks and channels	Hydrodynamics: Low Sediment transport: Low	 N/A N/A	 Low Low	 Medium Medium
	Increased SSC and potential sedimentation in the area of dispersal plume as a result of maintenance dredging	Negligible	N/A	Low	Medium
	Increased SSC and potential sedimentation as a result of deposition of maintenance dredge material at a licensed disposal site	Negligible	N/A	Low	Medium
	Changes in seabed bathymetry and composition as a result of deposition of dredged/disposed maintenance dredge material	Negligible	N/A	Low	Medium

16.12 References

Ref 16-1 The Stationery Office Limited (2009). Marine and Coastal Access Act 2009.

Ref 16-2 The Stationery Office Limited (2008). Planning Act 2008.

Ref 16-3 The Stationery Office (2017a). Statutory Instrument 2017 No. 407. The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017.

Ref 16-4 The Stationery Office (2017b). Statutory Instrument 2017. No. 1012. The Conservation of Habitats and Species Regulations 2017.

Ref 16-5 The Stationery Office Limited (2011). Statutory Instrument 2011. No. 988. The Waste (England and Wales) Regulations 2011.

Ref 16-6 Department for Transport (2012). The National Planning Policy Statement for Ports. HMSO, London.

Ref 16-7 The Stationery Office Limited (2011). UK Marine Policy Statement.

Ref 16-8 Department for Environment, Food and Rural Affairs (Defra) (2019). UK Marine Strategy.

Ref 16-9 HM Government (2014). East Inshore and East Offshore Marine Plans.

Ref 16-10 Environment Agency (2010). SMP3: Flamborough Head to Gibraltar Point Shoreline Management Plan.

Ref 16-11 North East Lincolnshire Council (2018). North East Lincolnshire Local Plan.

Ref 16-12 Planning Inspectorate (2017). Advice Note Eighteen: The Water Framework Directive.

Ref 16-13 UK Hydrographic Office (2022) Admiralty Tide Tables.

Ref 16-14 Environment Agency. (2018). Coastal flood boundary conditions for the UK: update 2018. Technical summary report. SC060064/TR6

Ref 16-15 British Geological Society (BGS) (2022). Geology Viewer.

Ref 16-16 ABPmer. (2004). Humber SMP2: Additional verification of morphological modelling, ABPmer Report No. R.1138. A report produced by ABPmer for Black & Veatch (on behalf of the Environment Agency), September 2004.

Ref 16-17 Folk, R.L. (1954). The Distinction between Grain Size and Mineral Composition in Sedimentary-Rock Nomenclature. Journal of Geology, 62, 344-359.

Ref 16-18 Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts C., Wolf J. (2018). UK Climate Projections Science Report: UKCP18 Marine report. Met Office Hadley Centre: Exeter.