REPORT

Boston Alternative Energy Facility – Environmental Statement

Chapter 16 Estuarine Processes

Client:	Alternative Use Boston Projects Ltd
Planning Inspectorate Reference:	EN010095
Document Reference:	6.2.16
Pursuant to:	APFP Regulation: 5(2)(a)
Reference:	PB6934-RHD-01-ZZ-RP-N-3016
Status:	0.0/Final
Date:	23 March 2021

baef
Boston Alternative Energy Facility

Royal HaskoningDHV
Enhancing Society Together

HASKONINGDHV UK LTD.

Rightwell House
Rightwell East
Bretton
Peterborough
PE3 8DW
Industry & Buildings
VAT registration number: 792428892

+44 1733 334455 **T**
+44 1733 262243 **F**
email **E**
royalhaskoningdhv.com **W**

Document title:	Boston Alternative Energy Facility – Environmental Statement
Document short title:	Estuarine Processes
Reference:	PB6934-RHD-01-ZZ-RP-N-3016
Status:	0.0/Final
Date:	23 March 2021
Project name:	Boston Alternative Energy Facility
Project number:	PB6934-RHD-01-ZZ-RP-N-3016
Author(s):	David Brew
Drafted by:	David Brew
Checked by:	Gary Bower
Date:	17/09/20 GB
Approved by:	Paul Salmon
Date:	21/03/21 PS

Classification
Project related

Table of Contents

Table of Tables

Table of Plates

Table of Figures

Appendices

Executive Summary

This chapter of the Environmental Statement (ES) considers estuarine processes. As part of the assessment, a detailed description of the current baseline is provided, through a combination of desk-based studies, consultation and on-site surveys. All potential effects of the construction, operation and decommissioning of the Boston Alternative Energy Facility ('the Facility') are identified, and an assessment made on the severity of each potential effect using a standardised approach, by an estuarine processes specialist. The assessment also considers cumulative impacts, where the Facility is considered alongside the predicted effects of the Boston Tidal Barrier.

Expert geomorphological assessment has been used to assess the potential effects of the Facility. Consideration of these effects on tidal currents, waves and sediment transport have been made followed by the potential effects on two receptor groups which contain valuable designated features. These are The Wash European Marine Site (EMS) and the Havenside Local Nature Reserve (LNR). The effects have been assessed using the worst case scenario for the Facility, presented in **Chapter 5 Project Description**.

In all cases for construction and operation, the effect of the worst case scenario (WCS) for the Facility on estuarine processes for the identified receptor groups is either **no effect** or **negligible effect**. The table below summarises the effect significance for the environmental factors related to estuarine processes during construction and operation of the Facility.

Phase	Environmental Factor	Effect Significance
Construction	Changes in suspended sediment concentrations due to capital dredging of the berthing areas	No Effect
	Changes in estuary-bed level due to capital dredging of the berthing areas	Negligible
	Changes to the wave regime (ship wash) and erosion/accretion patterns due to construction vessel movements	Negligible
Operation	Changes to the tidal current regime and erosion/accretion patterns due to the presence of the wharf and berthing areas	Negligible
	Changes to the wave regime (ship wash) and erosion/accretion patterns due to the increase in vessel traffic	Negligible
	Changes in suspended sediment concentrations due to maintenance dredging of the berthing areas	No Effect
	Changes in estuary-bed level due to maintenance dredging of the berthing areas	Negligible

Cumulative impacts with the Boston Tidal Barrier have been considered with respect to sediment plume interaction during potential simultaneous capital or maintenance dredging campaigns. It is concluded that the cumulative effect of suspended sediment concentrations and deposition from the plume of the two projects being dredged at the same time is **negligible**.

16 Estuarine Processes

16.1 Introduction

16.1.1 This chapter of the Environmental Statement (ES) describes the existing environment in relation to estuarine processes and details the assessment of the potential effects during construction, operation and decommissioning of the Boston Alternative Energy Facility ('the Facility').

16.1.2 The chapter assesses changes to tidal currents, waves and suspended sediment transport caused by the Facility, which drive changes in patterns of erosion and deposition along the subtidal and intertidal areas of The Haven and potentially into The Wash. Mitigation measures are provided and a discussion of the residual effects provided where significant effects were identified.

16.2 Legislation, Policy and Guidance

Legislation

16.2.1 The European Union (EU) Water Framework Directive (WFD) (Council Directive 2000/60/EC establishing a framework for community action in the field of water policy) (European Parliament, 2000) considers the potential effect of a project on the surrounding waters' biological, hydrological, geomorphological and physico-chemical characteristics. Within the WFD classification, The Haven is the Tidal River Witham from the Grand Sluice in Boston to the mouth where it empties into The Wash. It is a heavily modified water body: a body of water which is substantially changed in character as a result of physical alterations by human activity (European Environment Agency definition, European Commission, 2003). Changes to the hydrology and geomorphology by the Facility may affect the ability of The Haven to reach good ecological potential, which is the desired objective of the WFD. The intertidal and subtidal areas close to the Facility are sensitive ecological receptors and their health is dependent on estuarine processes within The Haven.

National Planning Policy and Guidance

16.2.2 The assessment of potential effects on estuarine processes has been made with specific reference to the relevant National Policy Statements (NPS), which are the principal decision-making documents for Nationally Significant Infrastructure Projects (NSIP). Those relevant to the Facility that require an assessment of estuarine processes in The Haven are the:

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC), 2011a); and
- NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b).

16.2.3 The relevant aspects of EN-1 and EN-3 are presented in **Table 16-1**. This chapter of the ES either directly addresses these issues or provides information which enables these issues to be addressed in other, more relevant chapters, such as **Chapter 8 Cultural Heritage**, **Chapter 17 Marine and Coastal Ecology**, and **Chapter 18 Navigational Issues**.

Table 16-1 NPS Assessment Requirements

NPS Requirement	NPS Reference	ES Reference
NPS for Energy (EN-1)		
'where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures'	Section 5.5, paragraph 5.5.6	The approach adopted in this ES is conceptual based on expert judgement. A conceptual approach for estuarine processes is preferred over detailed numerical modelling based on the principle of proportionality. For estuarine processes, the environmental sensitivity of the Facility (physically and/or in relation to the importance, risks, or functional consequence) is relatively low and can be assessed through use of professional judgement only, using the outcomes of a geomorphological review. It would therefore be disproportionate to run a numerical model of The Haven system. Also, estuarine processes data was reported for the nearby Boston Tidal Barrier including numerical modelling of hydrodynamics.
'the ES should include an assessment of the effects on the coast. In particular, 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 will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on	Section 5.5, paragraph 5.5.7	The assessment of potential construction and operational impacts are described in **Section 16.7**. The Facility will not affect The Wash Shoreline Management Plan (Gibraltar Point to Old Hunstanton). Embedded mitigation to minimise potential impacts are described in

NPS Requirement	NPS Reference	ES Reference
other parts of the coast. The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs), any relevant Marine Plans and capital programmes for maintaining flood and coastal defences. The vulnerability of the proposed development to coastal change, taking account of climate change, during the project's operational life and any decommissioning period.'		**Section 16.7**. The assessment also adheres to Objective 10 of the East Inshore and East Offshore Marine Plans "*To ensure integration with other plans, and in the regulation and management of key activities and issues, in the East Marine Plans, and adjacent areas*". This therefore refers back to the objectives of the SMP. The Facility has been designed so that it is not vulnerable to coastal change taking account of climate change.
'the applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones, candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential SCIs and Sites of Special Scientific Interest (SSSI).'	Section 5.5, paragraph 5.5.9	The potential receptors to morphological change are The Wash European Marine Site (EMS) comprised of SAC, SPA, SSSI and NNR, and Havenside LNR. The potential to affect their integrity is assessed with respect to changes in tidal currents, waves (ship wash), and deposition of suspended sediment from dredge plumes (**Section 16.7**).
NPS for Renewable Energy Infrastructure (EN-3)		
'The assessment should include predictions of physical effect that will result from the construction and operation of the required infrastructure and include effects such as the scouring that may result from the proposed development.'	Section 2.6, paragraph 2.6.194	Each of the impact assessments in **Section 16.7** cover the potential magnitude and significance of the physical (tidal currents, waves and sediments) effects upon the baseline conditions resulting from the construction and operation of the Facility.

16.2.4 The Marine Policy Statement (MPS, HM Government 2011) provides the high-level approach to marine planning and general principles for decision making that contribute to achieving this vision. It also sets out the framework for environmental, social and economic considerations that need to be considered in marine planning. It has been prepared and adopted for the purposes of section

44 of the Marine and Coastal Access Act 2009. The key reference for estuarine processes is in section 2.6.8.6 of the MPS which states:

"…Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement."

Local Planning Policy and Guidance

16.2.5 The South-East Lincolnshire Local Plan (South-East Lincolnshire Joint Strategic Planning Committee, 2019) was adopted in March 2019. Policy 28: The Natural Environment is (indirectly) relevant to estuarine processes and states that:

"…development proposals that would cause harm to internationally-designated sites (such as The Wash) will not be permitted, except in exceptional circumstances, where imperative reasons of overriding public interest exist, and the loss will be compensated by the creation of sites of equal or greater nature conservation value."

"…development proposals that would directly or indirectly adversely affect nationally or locally-designated sites (including Havenside Local Nature Reserve (LNR)) will not be permitted unless there are no alternative sites that would cause less or no harm, the benefits of the development at the proposed site, clearly outweigh the adverse impacts on the features of the site and the wider network of natural habitats, and suitable prevention, mitigation and compensation measures are provided."

16.2.6 The Local Plan acknowledges that nationally protected wildlife sites will continue to be protected and enhanced, consistent with national legislation and the objectives in their management plans.

16.3 Consultation

16.3.1 Consultation undertaken throughout the pre-application phase informed the approach and the information provided in this chapter. A summary of the Scoping Report and Section 42 consultations of relevance to estuarine processes are detailed in **Table 16-2**.

Table 16-2 Consultation and Responses

Consultee and Date	Response	Section in the Assessment
Scoping Response - The Planning Inspectorate, July 2018	Effects on the geomorphology processes within The Wash The Scoping Report does not provide information relating to the location of dredging and disposal activities. In the absence of this information the Inspectorate is unable to scope out the potential for significant effects on the geomorphology processes within The Wash, and subsequently effects on its status under the WFD and effects to its associated nature conservation designations.	**Section 16.7** assesses the potential effects of dredging on The Wash EMS. The dredged sediment is to be managed on land with no anticipated sea disposal. Hence, assessment of disposal is not included in this ES.
	WFD ecological classification The Applicant should ensure that the ES includes accurate baseline information regarding sensitive receptors. In this regard the Applicant is referred to comments by the EA noting that The Haven has a bad ecological potential, and not a moderate ecological potential as stated within the Scoping Report.	**Section 16.2** has been updated for the WFD classification of The Haven.
	Study Area The ES should clearly define the Study Area applied to the assessment. The Study Area must be established having regard to the extent of impacts and likely significant effects. Assumptions applied when establishing the Study Area should be clearly set out in the ES.	The study area for estuarine processes, and the assumptions used to establish its boundaries, are defined in **Section 16.5**.
	Potential effects The Scoping Report describes impacts as temporary for construction and permanent for the operational phase. The Inspectorate considers that resulting effects may not adhere to the same timescales, for example permanent effects can result from temporary construction activities. The ES should characterise the duration of predicted effects, and define any terms used, e.g. temporary, intermittent, short term, long term etc. in terms of days/months/years.	**Section 16.7** quantifies potential timescales of effects for construction and operation.

Consultee and Date	Response	Section in the Assessment
	Mitigation/monitoring The ES should demonstrate how mitigation and monitoring measures relied upon in the assessment would be secured and how any necessary remedial action would be undertaken. For example, if the proposed in-construction bathymetric surveys indicate that erosion and deposition are exceeding predicted values. The Inspectorate notes the intention to carry out surveys during operation to assess the need for channel maintenance. The Inspectorate advises that the anticipated nature of the maintenance dredging should be set out in the ES, where this information has been relied upon for the assessment of significant effects.	**Section 16.8** covers mitigation and monitoring. The anticipated maintenance dredging requirement and the assessment of its effects are described in **Section 16.7**.
	Methodology The ES should explain how desk-study and modelling data has been used to inform the assessment. The Applicant should make effort to agree the approach with the relevant consultation bodies.	The approach adopted in this ES is a desk-based conceptual study, using expert judgement (**Section 16.4**). A conceptual approach for estuarine processes is preferred over detailed numerical modelling based on the principle of proportionality. For estuarine processes, the environmental sensitivity of the Facility (physically and/or in relation to the importance, risks, or functional consequence) is relatively low and can be assessed through use of professional judgement only, using the outcomes of a geomorphological review. It would be disproportionate to run a numerical model of The Haven system. Also, estuarine processes data was reported for the nearby Boston Tidal Barrier including numerical modelling of hydrodynamics.
Scoping Response - Environment Agency 3rd July 2018	The EIA will need to include further information surrounding the tidal regime i.e. the tidal range and tidal symmetry. According to the UK Estuaries database the Witham is flood dominant; understanding this will help to address sedimentation	Baseline information on the tidal regime including asymmetry is presented in **Section 16.6**.

Consultee and Date	Response	Section in the Assessment
	issues.	
	Sub-section 6.10.3 states incorrect information; according to both our Catchment Data Explorer and Catchment Planning System the Haven (Witham Transitional) waterbody is currently classed as having bad ecological potential (this represents the 2016 classification – the 2015 classification was moderate). The project should consider if there is any scope to offer better mitigation to help achieve good ecological potential?	**Section 16.2** has been updated for the WFD classification of The Haven.
	6.10.8 Refers to a high-level pre-scoping document that looked into the potential environmental effects. It would be helpful to have this document appended or summarised to the EIA. There are many potential impacts; loss of tidal prism and sediment storage due to the wharf along with scour due to navigation, vessel movements and anchoring etc. Given the proposals to dredge a significant area of the bank we have a concern that the application may have underestimated how frequently they will need to dredge the frontage of the wharf to maintain a viable depth – this should be covered in detail in the EIA.	The anticipated maintenance dredging requirement and the assessment of its effects are described in **Section 16.7**.
Scoping Response - MMO, July 2018	The MMO considers that the direct impact of vessels (i.e. wash during manoeuvring in the nearshore) should be explicitly considered, during construction and operation, within the ES.	**Section 16.7** assesses the effects of ship wash.
	Whilst the monitoring measures appear to be sufficient for the likely scale of the proposed project, the ES should identify what further mitigation may be proposed should the proposed monitoring identify changes exceeding the predictions – and, therefore, also indicate what would represent an unacceptable local change.	**Section 16.8** covers mitigation and monitoring.
	The Scoping Report proposes to scope out impacts on the Inner Wash (6.10.17), based on the understanding that no dredging will	**Section 16.7** assesses the potential effects on The Wash EMS of capital and maintenance dredging.

Consultee and Date	Response	Section in the Assessment
	be required in the channel here. Impacts in the Wash will need to be assessed if there is any doubt or change in the presumption regarding channel dredging. Also, if dredging is required within the Haven, the assessment will need to demonstrate that impacts (i.e. the suspended sediment plume) do not extend into the Wash. The decision to scope out these impacts should be (briefly, but quantitatively) justified in the ES by reference to evidence that the impacts caused will not be significant here.	
	The MMO consider that the proposed Expert Geomorphological Assessment (EGA), should clearly separate the specific spatial context of the new wharf and work for previous projects.	This chapter uses the results of the nearby Boston Tidal Barrier EIA up-estuary to support the assessment. Where this has been done it is clearly explained in **Section 16.6** (Existing Environment) and **Section 16.7** (Potential Impacts).
	Section 6.10.6 states that the Port of Boston has confirmed that no ongoing maintenance dredging is carried out in the Haven at the wharf site. Maintenance dredging is carried out immediately upstream of the wharf by the Port of Boston and Boston Barrier and the MMO consider that maintenance dredging at the wharf is likely to be a requirement and should be fully assessed in the ES.	The anticipated maintenance dredging requirement and the assessment of its effects are described in **Section 16.7**.
	Should a new offshore disposal site need to be designated, further impacts at the disposal site (such as increased suspended sediment, changes to sediment properties and their effects on biological receptors) would need to be considered. Should there be an identified need for maintenance dredging, the impacts should also be identified in section 6.9.11 (operational impacts).	The capital and maintenance dredged sediment is to be managed on land with no anticipated sea disposal. No new offshore disposal site is anticipated. Hence, it is not included in this ES. The anticipated dredging requirements and the assessment of their effects are described in **Section 16.7**.
Scoping Response - Port of Boston, 5th July 2018	6.10.10 - A major capital dredging campaign is an essential ingredient in the construction of the new wharf facility, include dredging within and directly adjacent to the main navigation channel. The Port is concerned that the report understates	The anticipated capital dredging requirement and the assessment of its effects are described in **Section 16.7**.

Consultee and Date	Response	Section in the Assessment
	this impact, since in order to facilitate safe access for ships onto the newly created river berths, significant dredging will be needed, including extensive transitions upstream and downstream of the facility.	
	6.10.11 - there is the potential to impact on the sea disposal site due to the likely need to undertake maintenance dredging of the new wharf facility.	There will be no impact on the sea disposal site because none of the maintenance dredge sediment will be disposed to sea. The maintenance dredge sediment can be used within the Facility in the aggregate production process. The anticipated maintenance dredging requirement and the assessment of its effects are described in **Section 16.7**.
	Mitigation might include a similar approach to the Boston Barrier project, which has allowed for disposal of capital dredged materials to land and not to sea so as to mitigate the potential impact on the sea disposal site serving the port.	There will be no anticipated sea disposal of capital dredge sediment. Hence, it is not included in this ES.
	6.10.17 - dredging may not be needed within the approach channel, but sea disposal will be needed of maintenance dredging and/or the capital dredging of the scheme. This should therefore be scoped into the assessment.	The maintenance dredge sediment can be used within the Facility in the aggregate production process. There is no anticipated sea disposal. Hence, it is not included in this ES. The anticipated dredging requirements and the assessment of their effects are described in **Section 16.7**.
	6.10.18 - Since capital dredging of the scheme is an essential ingredient of the scheme, and that this will impact significantly on the profile of the river channel at the Boston Alternative Energy Facility site, the impacts on geomorphology and estuarine processes should be scoped in.	The anticipated capital dredging requirement and the assessment of its effects are described in **Section 16.7**.
	6.10.25 - the Port believes that the impacts on geomorphology in the Wash should be scoped in due to the potential impact on sea disposal of dredged materials.	There is no anticipated sea disposal of dredged sediment. Hence, it is not included in this ES.
Section 42 Consultation Response – Royal	Impact of the planned wharf. Adding a new structure into the mudflat area has the ability to alter the dynamics of	The tidal dynamics of the estuary would be changed by the operation of the wharf.

Consultee and Date	Response	Section in the Assessment
Society for the Protection of Birds (RSPB), August 2019	the river. This could increase erosion in some areas or affect accretion rates. This needs to be fully considered in understanding potential impact on intertidal habitats and mitigation requirements.	However, the assessment shows that the effects on tidal currents are negligible and so the impact on erosion is also **negligible**. This is described in **Section 16.7**.
	Increase in container vessels transiting the Haven and The Wash. Whilst it is stated that the increase in vessel movements will be a minor increase, this does not appear to appreciate the change in vessel type. It is anticipated that many of the movements will be smaller vessels, typically fishing boats, that will be smaller. It is essential that the impact of bigger vessels is clearly assessed. It is assumed that the wash from such vessels would be greater and the overall disturbance potentially greater. The potential impact must be based on vessel type and not simply vessel numbers.	The vessel sizes that will be entering and exiting The Haven will be no larger than the vessels already using the waterway (see **Section 16.7**).
Section 42 Consultation Response – Environment Agency, 6th August 2019	Updated extreme sea level estimates, with a base date of 2018, are expected to be released in late August 2019 and therefore we would expect these to be used in further assessment work. We will be able to supply these to you, upon request, when they are released.	Noted.
	We request that the Environmental Impact Assessment provides additional clarity surrounding the possible role of surges and the risk that they have been excluded due to the emphasis on relative sea level rise using Intergovernmental Panel on Climate Change (IPCC) and Shennan *et al.* rather than the United Kingdom Climate Projections in 2018 (UKCP18) projections.	Information has been added to the baseline on storm surge heights in The Haven (see **Section 16.6**).
	We also request further clarity in respect of the assessment of impacts related to ship wash, which assumes that the effects of wind waves over a year exceeds that of the worst case increase in ship wash over the same duration. This seems like a simplistic approach – would the potential erosion effects not be dictated by the shear stress of individual waves, such that less frequent but more energetic	The assessment of this impact has been modified and described in more detail in **Section 16.7**. The increase in ship wash would result in an increase in erosion but the resultant impact on identified receptors is **negligible**.

Consultee and Date	Response	Section in the Assessment
	ship wash could far exceed the impacts of more frequent wind waves generating lower shear stresses? Further work is required for us to be confident in the assessment of magnitude and significance of the effect.	
	Appendix 16.1 Supplementary Information to Estuarine Processes 6.1.1 The relative sea level (RSL) projections use the IPCC's global mean sea level (GMSL) projections for future sea-level rise combined with Shennan et al.'s (2012) regional estimates of vertical land motion (VLM). It is unlikely that this approach, using the IPCC's GMSL projections, are reflective of the future rates expected in Boston for the following reasons: 1. GMSL is considered 'eustatic' and is the sea-level change that would result by distributing water evenly across a rigid, non-rotating planet. Thus, a globally uniform, eustatic, sea level has been adopted for the Boston sea level projections. This is problematic because sea level is highly variable spatially due to oceanographic, gravitational and rotational processes which cause local changes in the sea-surface topography independent of local VLM processes (e.g. Gehrels and Long, 2008). It is therefore unlikely that any location in the world reflects GMSL (unless by chance the numerous regional/local RSL components cancel one another out). 2. 2. IPCC's projections under the various representative concentration pathway (RCP) scenarios are derived from general circulation models (GCMs) of the global climate using a coarse grid but do not take into account local-scale (subgrid) processes. To connect the global-scale projections and regional climate dynamics requires 'downscaling' of the	The IPCC 5th Assessment global sea-level rise estimates and Shennan are replaced in this chapter by the relative sea-level rise estimates of UKCP18 (**Section 16.6**).

Consultee and Date	Response	Section in the Assessment
	GCMs (e.g. Wolf et al., 20152). 3. 3. A linear rate of RSL has been assumed over the 50 year time period under consideration. However, sea-level theory suggests future climate-related sea-level change is expected to be non-linear.	
	Appendix 16.1 Supplementary Information to Estuarine Processes The latest UKCP18 provides downscaled versions of the global projections which also includes regional mean sea-level, storm surge, extreme water level and wave climate projections and directly include the most recent and most plausible VLM estimates. These provide a more plausible context than the IPPC's global projections and should be used over the IPCC's global projections. Moreover, the impacts that RSL rise pose arise primarily from associated extreme water level events, so consideration of the UKCP18 extreme water level and wave climate projections is recommended. It is also recommended that the full confidence range, rather than just the median values, are considered. Finally, over the relatively short time periods considered for the Facility (50 years) interannual to multidecadal sea-level variability should be considered. The best information currently available on observed coastal sea level variability comes from tide gauge and bottom pressure data records that can be accessed from the Permanent Service for Mean Sea Level (http://www.psmsl.org/).	The assessment of future relative sea-level rise using IPCC 5th Assessment and Shennan has been replaced using UKCP18 data for the grid cell covering Boston and The Haven (see **Section 16.6**). Estimates based on medium emissions 50%ile and high emissions 95%ile are included to cover the worst case scenario and the full high range of confidence. The inclusion of interannual and multi-decadal data is considered disproportionate to the requirements of the assessment and is not included. The full methodology is now included in the main text and has been removed from **Appendix 16.1**. A new figure (**Figure 16.6**) has been added.
Section 42 Consultation Response – MMO, 6th August 2019	The MMO note that the following applications (MLA/2015/00052, MLP/2014/00239 and MLA/2011/00348) have taken samples within 600 metres (m) of the works, however please note that the most recent results are four years old and in line with OSPAR, new samples would be required.	Due to the large amount of data that was collected for the Boston Tidal Barrier EIA, as well as other available data as shown in **Table 16-3**, there is a good understanding of the existing estuarine processes environment at the Facility and its adjacent areas.
	The Preliminary Environmental Impact Report (PEIR) has assessed	The assessment of this impact has been modified and

Consultee and Date	Response	Section in the Assessment
	the impacts of increased vessel traffic (ship wash) on the wave regime and concluded that "*… the increase in vessel traffic is unlikely to affect the intertidal mudflats and saltmarsh as the contribution of the overall erosion of these areas by locally-generated wind waves would significantly exceed the contribution from ship waves*". Whilst the MMO agree that "*The contribution of wind waves in terms of frequency is much higher*", thereby providing a source of persistent pressure, the waves generated by ship wash are considered likely to result in increased erosion. In addition, the PEIR does not explicitly state that the 150% increase in vessel movements is the result of additional vessels of similar size and speed to the existing stock, which would have implications for the energy profile of the additional vessels. The MMO recommend that the impact of ship wash is assessed in greater detail within the Environmental Impact Assessment (EIA) and Environmental Statement (ES). Whilst this is not considered to have a major impact on physical and coastal processes within this already heavily modified site, it may have implications for habitats and/or flood defence.	described in more detail in **Section 16.7**. The increase in ship wash would result in an increase in erosion but the resultant impact on identified receptors is **negligible**. The vessel sizes that will be entering and exiting The Haven will be no larger than the vessels already using the waterway. The implications for habitats and/or flood defence are addressed in the relevant chapters dealing with those receptors.
	The current preferred structure is a suspended concrete deck, constructed on approximately 300 driven piles. The impact of these structures on patterns of erosion and accretion have not been considered in the PEIR and should be quantitatively considered within the EIA and ES.	**Section 16.7** has been amended to cover this concern. The significance of the operational effects on tidal currents and erosion/accretion patterns has not changed.
	There is the potential for an adverse synergistic impact to occur during the operational phase as a result of increased tidal velocities (due to the capital dredge and resultant increase in the tidal prism) and wave energy (due to increased vessel movements). Combined, these pressures have the potential to result in elevated rates of erosion. Whilst this would not be expected to have a	A new Paragraph has been added to **Section 16.11** to assess this potential interaction.

Consultee and Date	Response	Section in the Assessment
	significant adverse impact in what is an already heavily modified system. The MMO recommend that an assessment is included in the final CIA.	
	Within the PEIR paragraphs 16.7.15 and 16.7.16 estimate the maintenance dredge volume at 1,643 cubic metres per year (m^3/yr). However, this is based on suspended sediment concentrations (SSC) of "*less than 100 [milligrams per litre] (mg/l)*", whilst **Table 16-9** presents baseline SSC ranging between 210-1,790 mg/l, with an average of 545 mg/l 1 metre above the bed. Consequently, the maintenance dredge is considered to be an underestimate. The capital and maintenance dredge volumes require clarification. The total capital dredge volume is reported as generating 140,000 to 150,000 m^3 of material (e.g., paragraphs 16.7.4 and 15.7.17 respectively). The MMO advise that evidence of a more robust calculation of both capital and maintenance dredge volumes would be expected within the EIA and ES.	The discrepancy between baseline SSC and the SSC used to calculate maintenance dredge requirements is addressed in **Section 16.7**. The estimate of maintenance dredge volume has been increased in line with the baseline values of SSC. The capital dredge volume has been modified using the wharf dimensions and geometry and the bathymetry captured by the drone survey and echosounder survey.
Section 42 Consultation Response – Natural England, 6th August 2019	Coastal Processes didn't fully consider the impacts from coastal erosion of having the facility there changing habitats and water flow	Water flow would be changed by the operation of the wharf. However, the assessment shows that the effects on tidal currents are negligible and so the impact on erosion and any potential to change habitats is also **negligible**. This is described in **Section 16.7**.
	The non-technical summary and HRA quote increase of 624 vessels but Chapter 15 and 16 state 560.	The proposed number of vessels using The Haven would be 580 per year with the Facility operational.
	Why haven't impacts to functionally liked land and duties under the Wildlife and Countryside Act 1981 (as amended) and the NERC Act 2006 been considered.	Following this response, **Chapter 12 Terrestrial Ecology** and **Chapter 17 Marine and Coastal Ecology** have been updated.
	There are lots of statements within this chapter with limited supporting evidence.	Response has been noted.
	The Wash group is more commonly known as The Wash European	The Wash group has been changed to The Wash EMS

Consultee and Date	Response	Section in the Assessment
	Marine Site (EMS).	throughout the chapter.
	Natural England disagrees that Suspended Sediment Concentrations and Bed levelling will have 'no impact' to the natural environment.	The no impact significance for SSC is assigned to the two receptors specifically related to estuarine processes. With respect to these receptors there is no impact because the designated features are related to sediment on the bed not in the water column. There is an effect (i.e. change) to the concentration of sediment in the water column but this does not manifest itself as an impact from an estuarine processes perspective. Impacts to natural environment receptors defined in other chapters are addressed in **Chapter 15 Marine Water and Sediment Quality** and **Chapter 17 Marine and Coastal Ecology**. The bed level impact has been modified to **negligible** (as identified in **Section 16.7**).
	Operational Impact – there is insufficient evidence provided to demonstrate that the presence of a fixed structure will not change water flows and velocity and impact of surrounding habitats up and down stream. In addition, additional ship wash effects is based on professional judgement and would be useful to have evidence to support that judgement.	Water flow and velocity would be changed by the operation of the wharf. However, the assessment shows that the effects on tidal currents are negligible and so the impact on upstream and downstream habitats is also **negligible**. This is described in **Section 16.7**. The assessment of ship wash impact has been modified and described in more detail in **Section 16.7**. The increase in ship wash would result in an increase in erosion but the resultant impact on identified receptors is **negligible.**
	NE advises that not only is bed level considered but also sediment supply to habitats of conservation importance.	Sediment supply is now referred to in the example Source-Pathway-Receptor conceptual model in **Section 16.4**.
	Information sources are not directly relevant to the specific works and the age of the data is greater than would be considered appropriate for an EIA assessment.	All the data highlighted in **Table 16-3** is relevant to the specific works. The bathymetry and topography are at the site or adjacent to it. The sediment data (surface and sub-surface) is not site specific but was collected

Consultee and Date	Response	Section in the Assessment
		from areas nearby and given the homogeneous nature of the mudflats (spatially and vertically and from a particle size perspective) is relevant for use in this assessment. With respect to age, this is related to sediment quality and is addressed in **Chapter 15 Marine Water and Sediment Quality**.
	Due to the proximity of the tidal barrier the applicant doesn't believe that new surveys are required. However, it is Natural England view that insufficient evidence has been demonstrated to show that the data is fit for purpose for this project. Especially in an estuarine environment that is dynamic.	All the data is fit for purpose. The bathymetry and topography are at the site or adjacent to it. The sediment data (surface and sub-surface) is not site specific but was collected from areas nearby and given the homogeneous nature of the mudflats (spatially and vertically and from a particle size perspective and regardless of dynamism) is relevant for use in this assessment. Hence, no new surveys were recommended as there was a sufficient evidence base.
	Wash heights are important when considering wash. We would like to see the expert geomorphological assessment.	**Section 16.5** provides a statement indicating the method adopted to estimate baseline wave heights (expert geomorphological assessment (EGA)). The actual estimate based on EGA is less than 0.1 m and the method and supporting evidence is discussed further in **Section 16.6**.
	Would be helpful to see evidence supporting the assessment that the natural wave heights are 0.1 m.	Further evidence for significant wave heights less than 0.1 m is provided in **Section 16.6**.
	As previously advised for the Boston Barrier works NE would welcome sediment staying within the system rather than being removed. Consideration there some be given to beneficial use of the sediment and/or disposal.	With respect to estuarine processes impacts the assessment is based on the Facility design (i.e. sediment removed by capital dredging is lost from the estuarine system as it is placed on land; and maintenance dredging material is used in the manufacture of aggregate within the Facility).
	A 68% increase in the tidal prism is not insignificant and the implications on coastal processes and erosion	In terms of a local change to the tidal prism in front of the Facility, the change is relatively large.

Consultee and Date	Response	Section in the Assessment
	need further consideration. Any loss of supporting habitat for SPA features also needs to be reviewed.	However, in terms of an estuary wide change it is very small (less than 2 % of The Haven's tidal prism). So, the downstream effects of such a small change both on discharge and erosion/accretion would be insignificant, as the effect is cumulative from upstream to downstream (Regime Theory). This is explained in **Section 16.7**.
	32,850 m^2 dredge of the berth area is also not insignificant given the width of the Haven.	The driving force behind any changes to discharge and, in turn, erosion/accretion is tidal prism. Hence, the area of the dredged berth area is not relevant to the estuarine processes assessment.
	150% increase in vessel movement in the Haven is also not insignificant and could lead to increased erosion.	The assessment of this impact has been modified and described in more detail in **Section 16.7**. The increase in ship wash would result in an increase in erosion but the resultant impact on identified receptors is **negligible.**
	140,000 m^3 is a large capital dredge especially in this area of the Haven.	In terms of a local change to the geometry and hence the tidal prism in front of the facility, the change is relatively large. However, in terms of an estuary wide change it is very small (less than 2 % of The Haven's tidal prism). So, the downstream effects of such a small change both on discharge and erosion/accretion would be insignificant, as the effect is cumulative from upstream to downstream (Regime Theory). This is explained in **Section 16.7**.
	There is insufficient evidence presented for NE to agree with this section that the impacts are not significant.	The local changes to the tidal prism have been quantified based on the capital dredge requirements and the existing bathymetry. This estimate is then compared to the tidal prism of The Haven This is explained in **Section 16.7**). The quantified result indicates that the change to tidal prism of The Haven is

Consultee and Date	Response	Section in the Assessment
		less 2 %. This means that any resulting downstream changes in discharge will be small and insignificant as will any resulting changes to erosion/accretion patterns. Hence, the conclusion that changes to the tidal current velocities due to the operation of the Facility are **negligible** remains valid.
	Impact 3: Ship Wash – it is stated that the annual wave effect exceeds ship wash. However, the point is that this is in additional to the natural wave impact. It is not sufficient to say the ship wash is less so not an issue.	The assessment of this impact has been modified and described in more detail in **Section 16.7**. The increase in ship wash would result in an increase in erosion but the resultant impact on identified receptors is **negligible.**
	Missing EA maintenance work over the lifetime of the project as well as for construction. Boston Harbour dredge has not been included.	By maintenance work, from an estuarine processes perspective this is maintenance dredging, which has been assessed in **Section 16.7**.
	NE is concerned that two negligible have been found to be negligible without evidence present to demonstrate what is effectively professional judgement.	Justification for this conclusion is provided in **Section 16.9**.
	The proposal must not undermine the Wash nature conservation designation.	The Wash EMS is one of the receptors assessed in this chapter. **Table 16-21** provides a summary of the potential impacts on estuarine processes at the EMS and they are assessed as either no impact or negligible impact.
Section 42 Consultation Response – RSBP, August 2019	Impact of the planned wharf. Adding a new structure into the mudflat area has the ability to alter the dynamics of the river. This could increase erosion in some areas or affect accretion rates. This needs to be fully considered in understand potential impact on intertidal habitats and mitigation requirements. In addition, this will allow vessels to moor in areas they have not previously. This activity could cause disturbance and displace birds from an additional zone around the wharf. It is not clear that this has been adequately assessed at this time.	Hydrodynamic assessment has been undertaken and is reported in **Section 16.7**.

Consultee and Date	Response	Section in the Assessment
	Increase in container vessels transiting the Haven and The Wash. Whilst it is stated that the increase in vessel movements will be a minor increase, this does not appear to appreciate the change in vessel type. It is anticipated that many of the movements will be smaller vessels, typically fishing boats, that will be smaller. It is essential that the impact of bigger vessels is clearly assessed. It is assumed that the wash from such vessels would be greater and the overall disturbance potential greater. The potential impact must be based on vessel type and not simply vessel numbers.	This has been addressed in operational impacts for disturbance to birds and mammals. The larger vessels have the higher impact in terms of presence of vessels. See **Chapter 12 Terrestrial Ecology** and **Chapter 17 Marine and Coastal Ecology**.
Section 42 Consultation Response – Boston Borough Council (BBC), 6th August 2019	The proposal must not undermine the Wash nature conservation designation.	The Wash EMS is one of the receptors assessed in this chapter. **Table 16-21** provides a summary of the potential impacts on estuarine processes at the EMS and they are assessed as either **no effect** or **negligible effect**.

16.4 Assessment Methodology

Impact Assessment Methodology

16.4.1 The assessment of effects on estuarine processes is predicated on a Source-Pathway-Receptor (S-P-R) conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor impacted by the effect, and the receptor is the receiving entity.

16.4.2 An example of the S-P-R conceptual model is provided by dredging which disturbs sediment on the estuary bed (source). This sediment is then transported by tidal currents until it settles back to the bed (pathway). The deposited sediment could then change the supply of sediment to habitats of conservation importance and the composition and elevation of the bed (receptors).

16.4.3 Consideration of the potential effects of the Facility on estuarine processes is carried out over the following spatial scales:

- near-field: the area within the immediate vicinity (tens or hundreds of metres) of the Facility infrastructure; and
- far-field: the wider area that might also be affected indirectly by the Facility (e.g. due to disruption of tidal currents, waves or sediment pathways).

16.4.4 Three main phases of development are considered, in conjunction with the present-day baseline, over the life cycle of the Facility (at least 25 years). These are:

- construction phase;
- operational phase; and
- decommissioning phase.

16.4.5 The assessment of estuarine processes adopted in this ES follows two approaches.

16.4.6 The first type of assessment is impacts on estuarine processes whereby discrete direct receptors are identified. These include receptors which possess their own intrinsic morphological value, such as saltmarsh and intertidal mudflats. The impact assessment incorporates a combination of the sensitivity of the receptor, its value (if applicable) and the magnitude of the change to determine a significance of impact by means of an impact significance matrix. **Chapter 6 Approach to EIA** provides an overview of this approach to the assessment of impacts.

16.4.7 In addition to identifiable estuarine processes receptors, the second type of assessment covers changes to estuarine processes which in themselves are not necessarily impacts to which significance can be ascribed. Rather, these changes (such as a change in the tidal regime or a change in suspended sediment concentrations) represent effects which may manifest themselves as impacts upon other receptors, such as marine and coastal ecology (e.g. in terms of increased suspended sediment concentrations, or erosion, or smothering of habitats on the estuary bed). In this case, the magnitude of effect is determined in a similar manner to the first assessment method but the sensitivity of the other receptors and the significance of effects on them is assessed within the relevant chapters of this ES.

Impact Receptors

16.4.8 For impacts on estuarine processes, two receptor groups are identified, which contain intertidal mudflat and saltmarsh with ascribed inherent value. The location of these is shown in **Figure 16.1**. One group covers The Wash EMS, including The Wash SPA, Ramsar site and SSSI, The Wash and North Norfolk Coast SAC, and The Wash Natural Nature Reserve (NNR).

16.4.9 The nearest point of The Wash EMS receptors is located about 3.5 km from the Facility downstream along The Haven. It is included because of the potential for dispersal of fine sediment towards and into The Wash during capital and maintenance dredging of the berthing areas.

16.4.10 The second receptor is Havenside LNR located opposite the Facility and for about 3 km downstream on the north east bank of The Haven. The Havenside LNR covers about 19 ha (0.19 km^2) and includes coastal grazing marsh, saltmarsh, and reedbed. The wetland is valuable in a local context and of significant value to local bird populations.

16.4.11 Havenside LNR is included as a receptor because of the potential for local changes to tidal currents and erosion/accretion patterns during the operational phase of the Facility and dispersal of suspended sediment from dredging during both phases.

Cumulative Impact Assessment

16.4.12 Cumulative impacts are assessed through consideration of the extent of influence of changes or effects upon estuarine processes arising from the Facility alone and those arising from the Facility cumulatively or in combination with other developments and other nearby estuary activities. Although a screening process has been carried out in conjunction with BBC to define which projects will be considered in the Cumulative Impact Assessment (CIA), only the Boston Tidal Barrier project has the potential to act cumulatively with the Facility in terms of estuarine processes. Information to support the CIA is drawn from the findings of the Boston Tidal Barrier EIA (Environment Agency, 2016a; 2016b; 2016c).

Transboundary Impact Assessment

16.4.13 Transboundary impacts are assessed through consideration of the extent of influence of changes or effects and their potential to impact upon estuarine processes receptor groups that are located within other EU member states. Given the distance of the Facility from international boundaries in the North Sea, it is concluded that transboundary effects on estuarine processes would not occur.

16.5 Scope

Study Area

16.5.1 This chapter addresses the potential effects on estuarine processes along The Haven and into The Wash embayment (**Figure 16.1**). The boundaries of the study area are defined based on expert geomorphological assessment of the potential predicted area of influence of changes to estuarine processes. The judgement on the extent of the estuarine processes study area was also steered by the consultation responses (**Table 16-2**).

Data Sources

16.5.2 The assessment was undertaken using numerous sources, described in **Table 16-3**.

Table 16-3 Key Information Sources

Data	Reference
Bathymetry: multibeam echosounder along the subtidal channel	Briggs Marine Contractors (2016) for the Environment Agency (31st October to 4th November 2016)
Topography: airborne laser and LiDAR data of the intertidal and supratidal areas	Drone survey flown at the end of March 2019 by Future Aerial and a mosaic of LiDAR data captured by the Environment Agency over several years
Habitat: saltmarsh survey in November 2017	Environment Agency (2017b)
Geology: six boreholes at a site about 900 m to the south of the Facility, four boreholes at a site about 500 m to the south of the Facility, three boreholes on the north east bank opposite the Facility and numerous boreholes for the Boston Tidal Barrier EIA	Lincs Laboratory (2011), T.L.P. Ground Investigations (2012), Mott MacDonald (2015) and CH2M (2017)
Predicted water levels	Admiralty Tide Tables (2020)
Tidal currents: hydraulic modelling for the Boston Tidal Barrier EIA	Mott MacDonald (2016)
Relative sea-level rise	UK Climate Projections (UKCP18) user interface for the model grid cell that covers The Haven
Estuary-bed sediment particle size: 16 samples recovered for the Boston Tidal Barrier EIA in 2017 supported by two samples collected in 2000, two samples in 2005 and six samples in 2010	Halcrow Jacobs Alliance (2011) and Environment Agency (2016b, 2017a)
Sediment particle size at shallow depths: 32 samples recovered from vibrocores for the Boston Tidal Barrier in 2017	Environment Agency (2017a)
Turbidity: 11 water samples recovered for the Boston Tidal Barrier in 2017	Environment Agency (2017a)

16.5.3 The assessment uses available literature and data, including the ES which supported the recently approved Boston Tidal Barrier scheme. Estuarine processes data reported and cited in that document provides useful baseline information of relevance to the Facility, including numerical modelling of hydrodynamics. Apart from observations at the Facility during a site visit on 8th October 2018, no new estuarine processes data collection is warranted due to the proximity of the Boston Tidal Barrier to the Facility.

Assumptions and Limitations

16.5.4 Due to the large amount of data that was collected for the Boston Tidal Barrier EIA, as well as other available data (**Table 16-3**), there is a good understanding of the existing estuarine processes environment at the Facility and its adjacent areas.

16.5.5 Data on significant wave heights are not available, and this assessment is founded on expert geomorphological assessment of the likely magnitudes based on the perceived energy conditions.

16.6 Existing Environment

16.6.1 This section provides an overview of the key information from the assessment of the existing estuarine processes environment. The approach taken has been to review existing relevant data and reports from The Haven and formulate a conceptual understanding of the baseline estuarine physical environment using expert-based assessment and judgement.

Lower River Witham and The Haven

16.6.2 The lower valley of the River Witham stretches from Lincoln to the Kyme Eau (canalised River Slea) between Billinghay and Coningsby. Here, the Witham Valley floodplain is up to 10 km wide. South east of the Kyme Eau, the River Witham flows south east across open Fenland to reach The Wash at Tabs Head, south east of Boston.

16.6.3 At Boston, the upstream and downstream parts of the River Witham are divided by the Grand Sluice (built in the 18th century). The River Witham downstream of Grand Sluice is an estuarine environment known as The Haven. It is approximately 11 km long between the upstream tidal extent at Grand Sluice (which is about 3 km upstream of the Facility) and its downstream confluence with The Wash. Grand Sluice forms an artificial barrier and protects upstream areas from tidal influences.

16.6.4 Prior to engineering works, The Haven was a meandering channel. It was straightened and narrowed in the 19th century to improve navigational access to Boston. Hence, The Haven is a canalised estuary, which is restricted in width and less sinuous than it would have been in its natural state.

Bathymetry and Topography

16.6.5 Topography data was obtained from an airborne laser survey of the Facility flown with a drone in March 2019 and a mosaic of LiDAR data captured by the

Environment Agency over several years (dataset which uses the best data from a range of years). The topography data was combined with a multibeam echosounder bathymetric survey in 2016 along the lower intertidal and subtidal areas of The Haven (Briggs Marine Contractors, 2016).

16.6.6 All the datasets required manipulation before being 'stitched' together to create the final surface elevation. If the landward part of the echosounder data overlapped the seaward part of the laser and LiDAR data, then the echosounder data was used to avoid errors associated with the water surface. To create the surface, the laser and LiDAR data were clipped at the boundary of the echosounder data.

16.6.7 The elevation of the thalweg of the subtidal channel of The Haven adjacent to the Facility varies between about 3.4 m below Ordnance Datum (OD) and 3.8 m below OD (**Figure 16.2** and **Plate 16-1**). The mudflats slope landwards and upwards to elevations of about 1.8-2.0 m above OD, before a further rise where the fringing saltmarsh is at elevations between approximately 3.8 m above OD to greater than 4 m above OD. The intertidal mudflats and subtidal channel adjacent to the Facility are shown in **Plate 16-2**.

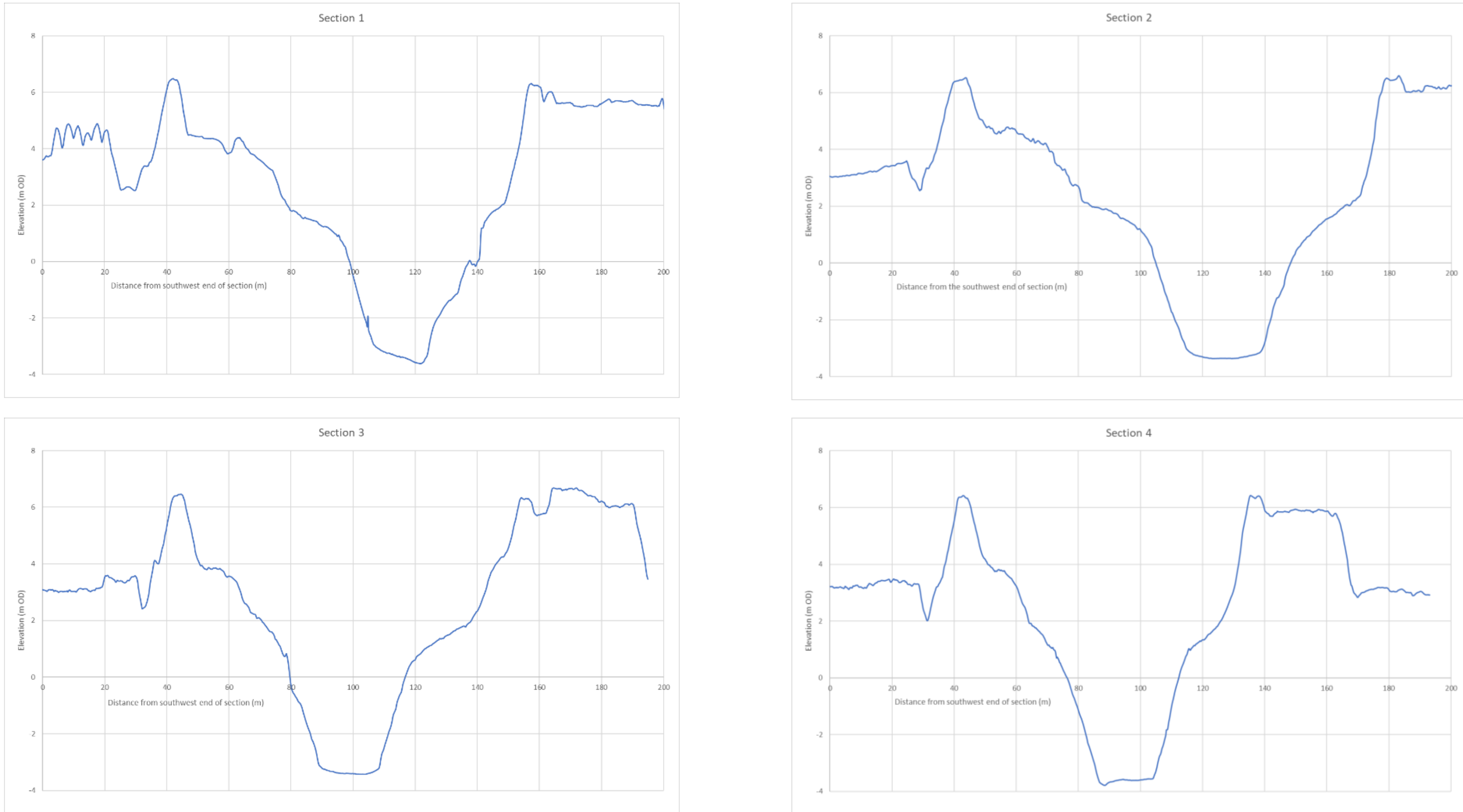


Plate 16-1 Sections Across the Bathymetry and Topography at and Adjacent to the Facility. Locations of the Sections are Shown on Figure 16.2

Plate 16-2 Intertidal Mudflats and Subtidal Channel at the Facility. Photographs Taken 8th October 2018 From the South West Bank (Top) and North East Bank (Bottom)

Saltmarsh

16.6.8 Environment Agency (2017b) completed a saltmarsh survey in November 2017. The transects and quadrats surveyed are shown in **Figure 16.3**. Five of these transects, B1 and B2 on the south west bank and N1-N3 on the north east bank, are close to the Facility.

16.6.9 Along B2, at the Facility, the saltmarsh transitions from high marsh at its landward side (dominated by *Festuca rubra* with subordinate *Elytrigia atherica*) into mid-low marsh (dominated by *Puccinellia maritima* and *Plantago maritima*) then transitional low marsh (*Puccinellia maritima* and *Glaux maritima*) at the boundary with the mudflats. In B1, downstream from the Facility, the results show a dominance of *Puccinellia maritima* with subordinate *Aster tripolium* and *Plantago maritima*. The habitat at this location was described as mid-low marsh. The saltmarsh adjacent to the Facility is shown in **Plate 16-3**.

16.6.10 Along N1 to N3, the saltmarsh varies from high marsh (dominated by *Elytrigia atherica*) to mid-low marsh with *Aster tripolium* and *Triglochin maritima* along N1 and *Puccinellia maritima, Plantago maritima-Armeria maritima* along N3.

Plate 16-3 Saltmarsh at the Facility (Top) and Exposure of Diamicton at the Facility (Bottom). Saltmarsh Photographs Taken 8th October 2018 From the South West Bank Looking up Estuary (Left) and North East Bank Looking Down Estuary (Right)

Geology

16.6.11 Bedrock beneath Boston and the Facility is composed of Upper Jurassic Ampthill Clay Formation (**Table 16-4**). The top of the rock is at depth (greater than 20 m below the ground surface) and overlain by Pleistocene diamicton (glacial till) and glaciofluvial sand and gravel deposits, overlain by Holocene sediments (British Geological Survey, 1995).

Table 16-4 Geological Formations Present Under the Facility

Geological Unit	Age	Lithology
Ampthill Clay	Upper Jurassic	Mudstone
Diamicton and Glaciofluvial Deposits (undifferentiated)	Pleistocene	Firm to very stiff gravelly (chalk and flint) clay and medium to coarse sand and gravel
Barroway Drove/Terrington Beds	Holocene	Soft clayey silt to silty very fine sand

16.6.12 At a broad scale, Brew *et al.* (2000) showed that the Holocene sediments at Boston are either intertidal mud (with the possibility of a basal peat; Barroway

Drove Beds of British Geological Survey 1995) or intertidal and marine sand (Terrington Beds). The Facility is close to the transition between the two facies (CH2M, 2017).

16.6.13 The Holocene sediments at Boston are about 4 to 8 m thick (Brew *et al.*, 2000). However, locally, *in-situ* diamicton appears to be exposed at the ground surface, although it is possible it is artificial ground (**Plate 16-3**).

16.6.14 Shennan *et al.* (1994) described a simple Holocene stratigraphy for the area north and west of Boston comprising a discontinuous basal peat (sandy at base) overlain by a thin transitional clay which passes into a discontinuous silty clay then (clayey, sandy) silt. In many areas the basal peat and silty clay are missing and the silt rests directly on the pre-Holocene surface. Palaeochannels (roddons) infilled with laminated silts and fine sands were also observed.

16.6.15 Several ground investigations have been undertaken close to the Facility. Lincs Laboratory (2011) recovered six boreholes at a site about 900 m to the south. They recovered up to 9.45 m (but mostly 5.8 m to 6.7 m thick) of silt and clay (with occasional silty fine sand layers) on top of glacial diamicton or sand and gravel. The base of the glacial deposits was reached in one borehole at a depth of 23.4 m (thickness of 16.7 m) where Ampthill Clay was recovered. The boreholes were not reduced to a datum so only thicknesses are available.

16.6.16 T.L.P. Ground Investigations (2012) recovered four boreholes about 500 m to the south of the Facility. They found 4.75-4.8 m of silty clay, underlain by 0-0.6 m of peat, underlain by 0.85-1.7 m of medium sand, all resting on diamicton. The base of the diamicton was not reached. The boreholes were not reduced to a datum so only thicknesses are available.

16.6.17 Mott MacDonald (2015) recovered numerous boreholes along the north east and south west banks of The Haven upstream of the Facility. The boreholes encountered made ground at the surface and so the thickness of the Holocene deposits is difficult to determine. However, the depth to the base of the Holocene deposits varies from -2 m to -3.7 m OD (typically -3 m OD) on the north east bank and -2.4 m to -2.6 m OD (typically -2.6 m OD) on the south west bank, underlain by diamicton. Bedrock is at about -20 m to -21 m OD (at the location of the Boston Tidal Barrier).

16.6.18 CH2M (2017) described three boreholes on the north east bank of The Haven directly opposite the Facility. These boreholes recovered made ground (up to 3.8m thick) underlain by 6m of silty fine sand (Terrington Beds) on top of diamicton and glaciofluvial deposits.

Astronomical Water Levels

16.6.19 The tides at Boston are regular and semi-diurnal, with predicted spring and neap tide ranges of 5.3 m and 2.7 m, respectively (Admiralty Tide Tables 2020) (**Table 16-5**). High water occurs first at the estuary mouth (Tabs Head) and then progressively moves up the estuary as the tidal wave propagates upstream.

Table 16-5 Tidal Levels at Boston (Admiralty Tide Tables, 2020)

Tidal Datum	Elevation at Boston (m CD)	Elevation at Boston (m OD)
Highest Astronomical Tide (HAT)	7.6	4.73
Mean High Water Spring Tide (MHWS)	6.6	3.73
Mean High Water Neap Tide (MHWN)	4.6	1.73
Mean Sea Level (MSL)	3.3	0.43
Mean Low Water Neap Tide (MLWN)	1.9	-0.97
Mean Low Water Spring Tide (MLWS)	1.3	-1.57
Lowest Astronomical Tide (LAT)	0.7	-2.17

Storm Surge

16.6.20 The southern North Sea is particularly susceptible to storm surges and water levels in The Haven could become elevated above the predicted astronomical water levels. Predicted extreme water levels can exceed predicted mean high-water spring levels by about 1 m for a 1 in 1-year return period event (extreme tidal level of 4.82 m OD at the mouth) and by around 2 m for a 1 in 100-year return period event (extreme tidal level of 5.78 m OD at the mouth) (Royal Haskoning, 2010).

Tidal Prism

16.6.21 Mott MacDonald (2016) estimated the spring tidal prism (the volume difference between high water spring and low water spring excluding any contribution from freshwater inflow) of The Haven to be approximately 4.8 Mm^3 with a water surface area of 1 km^2 at mean high water spring tide. Using the bathymetry and spring tidal datums, the spring tide volume and tidal prism along the section of The Haven in front of the Facility (**Figure 16.4**) are shown in **Table 16-6**. The contribution to the spring tidal prism of The Haven from in front of the Facility amounts to about 180,000 m^3 (0.18 Mm^3).

Table 16-6 Tidal Volumes and Tidal Prism of The Haven in Front of the Facility

Volume below MHWS (m^3)	Volume below MLWS (m^3)	Spring Tidal Prism (m^3)
205,250	26,600	178,650

Fluvial Flows

16.6.22 Freshwater flow into The Haven is artificially controlled by sluice structures. Freshwater inputs include flows from the Lower Witham (upstream of Grand Sluice), the South Forty Foot Drain (at Black Sluice), Maud Foster Drain and Sluice and Hobhole Drain and Sluice.

Tidal Currents

16.6.23 The tide in The Haven is asymmetrical and produces flood and ebb phases that are not equal. Over its length, current velocities are generally faster on the flood tide than on the ebb tide, resulting in flood tide dominance (Babtie Brown and Root 2004). However, Environment Agency (2016a) indicated that current velocities on the ebb tide can be faster than those on the flood tide north of the Facility at the location of the Boston Tidal Barrier. This occurs when the river flow is released from upstream sluices as the tide ebbs under non-flood conditions.

16.6.24 Mott MacDonald (2016) presented simulated baseline tidal current velocities upstream of the Facility and at its north end, using TUFLOW modelling. At the north end of the Facility, predicted maximum flood velocities were up to 1 m/s decreasing to around 0.5 m/s on the ebb tide (**Figure 16.5**).

Waves

16.6.25 Waves generated in the North Sea propagate south into The Wash through its entrance between Gibraltar Point and Hunstanton. Halcrow (2002) used offshore wave data and a wave transformation model to derive an inshore wave climate for The Wash. The modelled incoming significant wave height was attenuated from 1 m at the entrance to 0.1 m at Butterwick Low, fronting The Haven.

16.6.26 The wave heights diminish as they travel into The Wash and are attenuated as they propagate across the wide shallower intertidal areas along the south west margin. The narrow entrance to The Haven at Tabs Head also excludes much of the externally generated higher wave energy. No data on significant wave heights in The Haven is available, but expert geomorphological assessment suggests that naturally generated wind-waves would have heights less than 0.1 m (less than the wave heights at Butterwick Low). Local waves are generated from commercial vessels (ship wash) entering and exiting The Haven.

Future Relative Sea-level Rise

16.6.27 Historical data shows that the global temperature has risen since the beginning of the 20th century, and predictions are for an accelerated rise, the magnitude of which is dependent on the magnitude of future emissions of greenhouse gases and aerosols. To determine a climate change relative sea-level allowance for Boston in 10-, 20- and 50-years' time, this assessment uses the data of the UKCP18 user interface for the model grid cell that covers The Haven (**Figure 16.6**).

16.6.28 UKCP18 relative sea-level rise estimates use 1990 as their starting year and are based on the IPCC 5th Assessment Report. They are available for low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions scenarios and presented by UKCP18 as central estimates of change (50 % confidence level, 50%ile) in each scenario with an upper 95 % confidence level (95%ile) and a lower 5% confidence level (5%ile).

16.6.29 Relative sea-level rise projections using the 50%ile of the medium (RCP4.5) emissions scenario and the 95% of the high (RCP8.5) emissions scenario from the UKCP18 user interface are used in this assessment. Using 2020 as the baseline for implementation of the Facility, and an assumption that the 30 years of relative sea-level rise between 1990 and 2020 has already taken place, then the projected relative sea-level rises using a 2020 baseline are shown in **Table 16-7**.

16.6.30 For the medium (RCP4.5) emissions 50%ile, the estimated rises in relative sea level at Boston are 0.05 m, 0.10 m and 0.27 m after 10-, 20- and 50-years relative to a baseline of 2020, respectively. For high emissions 95%ile, relative sea level rises in 10-, 20- and 50-years' time are estimated to be approximately 0.07 m, 0.16 m and 0.52 m, respectively.

Table 16-7 Projected Changes in Relative Sea Level at the Facility Under the 50%ile Medium (RCP4.5) and 95%ile High (RCP8.5) Emissions Scenarios Using 2020 as the Starting Year

Year	Medium emissions 50%ile (m)	High emissions 95%ile (m)
2020	0	0
2025	0.023	0.035
2030	0.047	0.073
2035	0.072	0.115
2040	0.099	0.160
2070	0.272	0.519

Estuary Bed Sediment Distribution

16.6.31 Environment Agency (2017a) collected water samples, estuary bed grab samples and short vibrocores from three areas (**Figure 16.7**):

- the proposed location of the Boston Tidal Barrier north of the Facility;
- east of the FCC Environment waste management company landfill site south of the Facility; and
- adjacent to Witham Sailing Club opposite the Facility.

16.6.32 Eleven water samples and 16 grab samples were collected 11-15th August 2017, and 16 vibrocores (up to four at each location) were recovered 30th August to 3rd September 2017. The length of the vibrocores and the vertical positions of samples with particle size analysis are shown in **Table 16-8**. Older estuary bed sampling campaigns from 2000, 2005 and 2010 along The Haven are described in **Appendix 16.1 Supplementary Information to Estuarine Processes**.

Table 16-8 Details of Vibrocore Recovery and Sample Depths for Particle Size Distribution (Environment Agency 2017a). Locations of the Samples are Shown on Figure 16.7

Site	Recovery (m)				Particle Size Sample Depths (m)
	Core 1	Core 2	Core 3	Core 4	
SC12	2.3	2.3			0.5, 1, 2
SC13	3				-
SC14	2.1				0.5, 1, 2
SC15	2.5				
SC16	1.5				0.5, 1, 1.5
SC17	2.5	1.5	2.6		
SC18	1.4				0.5, 1.5
SC19	1.2				
SC20	2.4	2.2			1, 2
SC21	3.2	3.2			1, 2
SC22	2.6				1, 2
SC23	1	1	1.9	1.6	0,5, 1, 1.5
SC24	2.6	2.7			0.5, 1, 2
SC25	2.75	2.6			0.5, 1, 2
SC26	2.7	2.8			0.5, 1, 2
SC27	2.5	2.7			0.5, 1, 2

16.6.33 The particle size analysis results for the grab samples are shown in **Plate 16-4**. They show slightly different characteristics for samples located upstream, opposite and downstream of the Facility.

16.6.34 Upstream of the Facility (SC12 to SC21) the median particle sizes vary from 0.015 mm (silt) to 0.07 mm (very fine sand). Sand content varies from 15 % to 55 %, with mud between 44 % and 85 %.

16.6.35 Downstream of the Facility (SC23-SC27), the bed sediments are slightly coarser with median particle sizes between 0.04 mm (silt) and 0.07 mm (very fine sand). The proportion of sand was 41-52 % with 48-59 % mud.

16.6.36 The single bed sample opposite the Facility (SC22) has a median particle size of 0.03 mm (silt) with 66 % mud and 34 % sand.

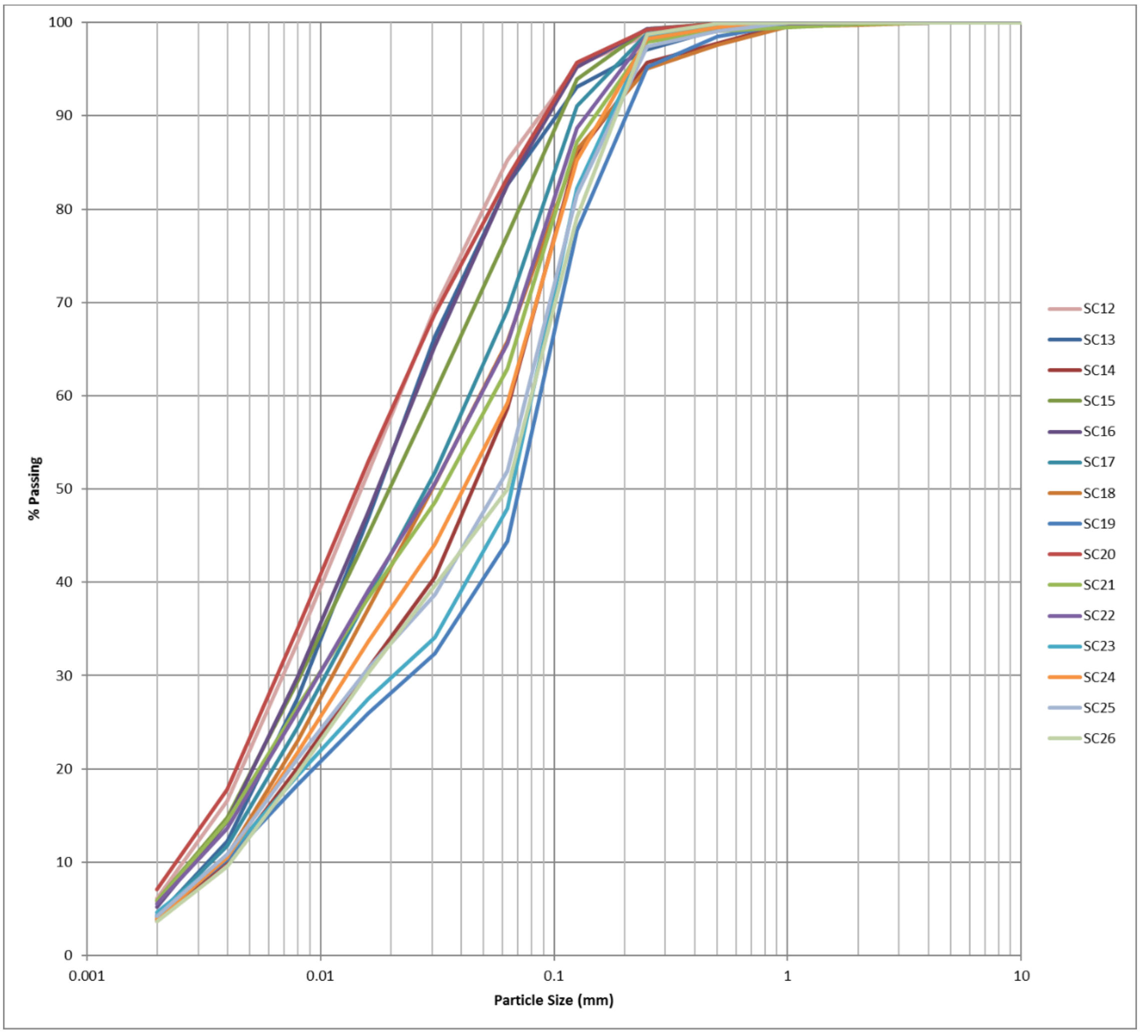


Plate 16-4 Cumulative Particle Size Distributions of Bed Sediment Samples Collected in 2017 (Environment Agency, 2017a). Locations of the Samples are Shown on Figure 16.7

16.6.37 The particle size analysis results for the vibrocore samples are shown in **Plate 16-5**. A similar pattern to the grab samples emerges with generally coarser sediments further downstream. The upstream samples (SC12 to SC21) have median particle sizes between 0.02 mm and 0.06 mm (silt) whereas downstream (SC23-SC27) median particle sizes increase to between 0.02 mm (silt) and 0.2 mm (fine sand). Upstream sand content varies from 6 % to 40 % with mud between 43 % and 83 %, whereas downstream, sand content was 25-97 %, with mud between 3 % and 75 %. Opposite the Facility, two samples recorded median particle sizes of 0.055 mm and 0.065 mm, with 45-50 % sand and 49-53 % mud.

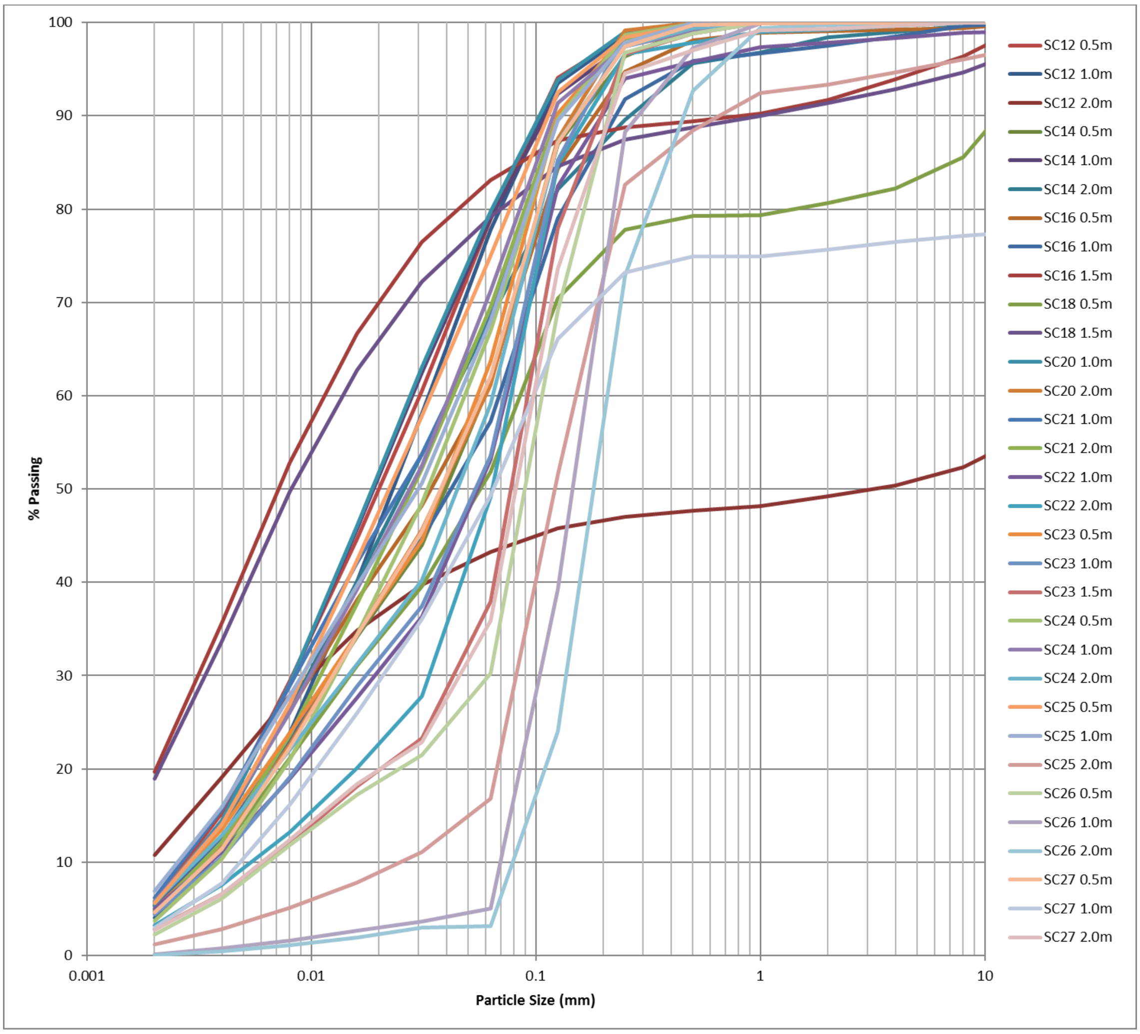
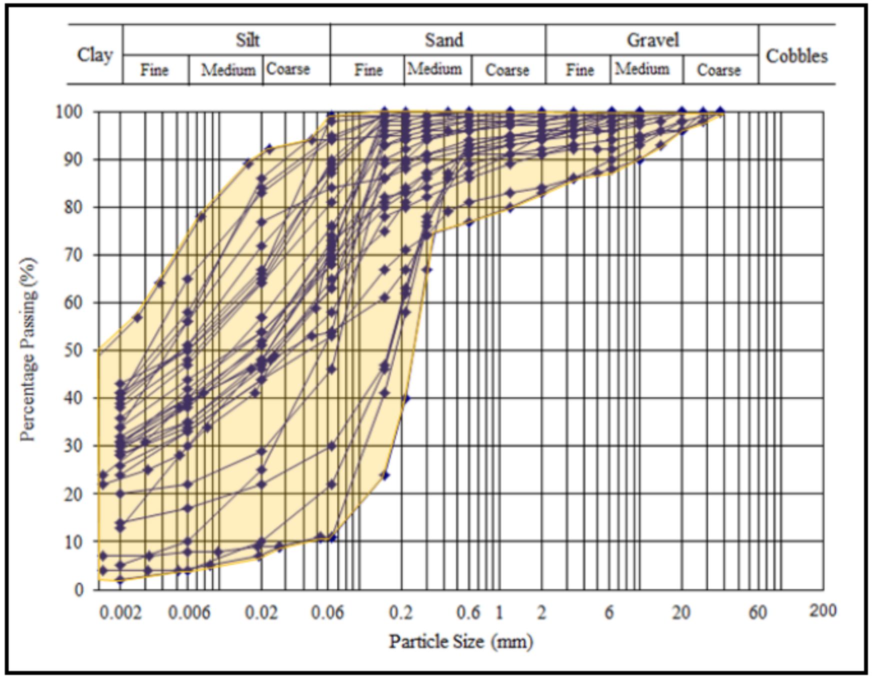


Plate 16-5 Cumulative Particle Size Distributions of Vibrocore Sediment Samples Collected in 2017 (Environment Agency, 2017a). Locations of the Samples are Shown on Figure 16.7

16.6.38 Several samples contain higher proportions of coarse sand and gravel (e.g. SC12 2.0 m, SC27 1.0 m), which may represent glacial deposits closer to the bed, where the Holocene sequence is thinner.

16.6.39 Mott MacDonald (2015) also showed that the Holocene deposits upstream of the Facility are predominantly clayey silt to silty very fine sand (**Plate 16-6**). Discontinuous peat layers were also recognised between 0.1 m and 0.7 m thick.



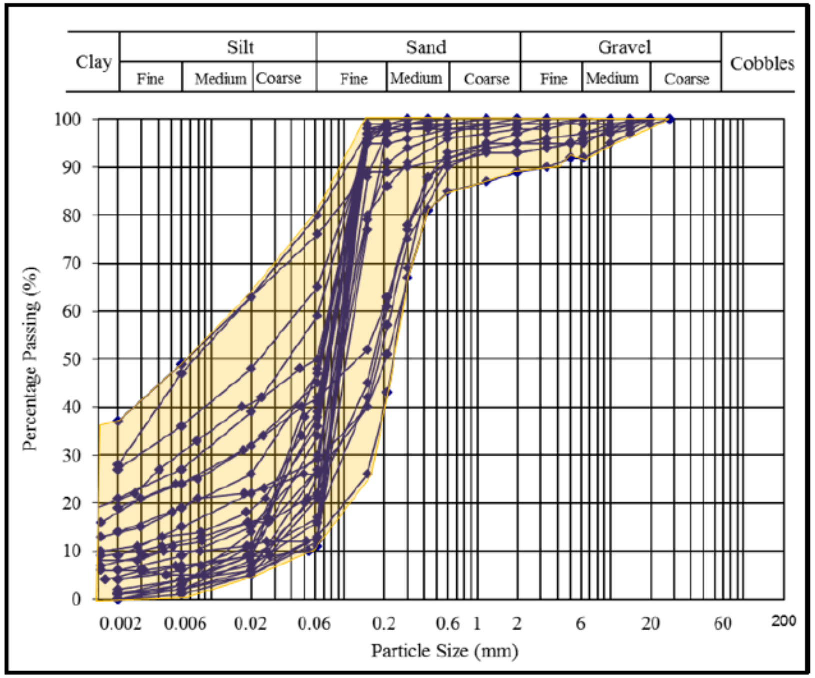


Plate 16-6 Cumulative Particle Size Distribution Curves for Clayey Silt (Left) and Very Fine Sand (Right) Samples Recovered From Vibrocores Upstream of the Facility (Mott MacDonald, 2015)

Suspended Sediment Transport and Deposition

16.6.40 The fluvial flows and sources of sediment from the upstream catchment into The Haven are restricted by the sluice structures, so the main source of sediment is from The Wash. The dominance of the flood tide (Babtie Brown and Root, 2004) results in a net transport of sediment into The Haven and net accretion on the channel margins and estuary bed.

16.6.41 However, The Haven is likely to be self-balancing in terms of sediment accretion and erosion. This is because the opening of the sluice structures during high winter fluvial flows periodically removes sediment accreted on the intertidal areas. Indeed, the Port of Boston Harbour Authority has indicated that there is currently no maintenance dredging carried out in The Haven at the location of the Facility. They do, however, dredge at Hob hole and further downstream.

16.6.42 The muddy shoreline of The Haven is located where tidal current velocities are too weak to completely re-suspend the mud that settles out around the time of high-water slack, thus permitting the net accretion necessary to form the intertidal mudflats. Typically, when the tide turns, the mudflats will be eroded only if the ebb current generates a shear stress large enough to erode the sediment. Muds are cohesive, so they are more difficult to erode after deposition.

16.6.43 Data quantifying the baseline turbidity along The Haven are available from the Boston Tidal Barrier EIA. Environment Agency (2017a) measured turbidity in the water at 11 locations (WS1-11) at 1 m and 3 m above the bed and at the water surface on 13th/14th August 2017. Turbidity is measured in Nephelometric Turbidity Units (NTU) or Formazin Turbidity Units (FTU). Although the two scales measure turbidity differently, using white light (NTU) or infrared light (FTU), they are essentially the same in value. So, 1 NTU = 1 FTU.

16.6.44 The instrument used for measuring turbidity is a nephelometer and an NTU is a measure of the intensity of light scattered at 90^{o} as a beam of light passes through a water sample. Turbidity values range from about 27 NTU (water surface sample in WS04) to 357 NTU (1 m above bed in WS04), with most between 30 NTU and 100 NTU (**Plate 16-7**).

Plate 16-7 Turbidity at the 11 Water Sampling Locations Shown in Figure 16.7 (Environment Agency, 2017a)

16.6.45 There is a general increase in turbidity from near the estuary bed into the higher parts of the water column (**Table 16-9**).

Table 16-9 Turbidity Characteristics Along the Haven in August 2017

Height above estuary bed (m)	Average (NTU)	Average (mg/l)	Maximum (NTU)	Maximum (mg/l)	Minimum (NTU)	Minimum (mg/l)
1 (17 samples)	109	545	358	1,790	42	210
3 (13 samples)	48	240	72	360	36	180
Water surface (17 samples)	45	225	69	345	27	134

16.6.46 BMMJV (2019) published turbidity monitoring data for February 2019 during construction of the Boston Tidal Barrier at two locations, one upstream near the swing bridge on the north east bank and the other downstream attached to a structure extending into The Haven. They reported mean turbidity measurements of 34-43 NTU and median values of 22-23 NTU. The 75%ile values ranged from 35 NTU to 39 NTU.

16.6.47 Environment Agency (2016c) presented a conversion factor of 1 NTU equivalent to 5 mg/l (suspended sediment concentration). Using this conversion, the baseline suspended sediment concentrations in The Haven are high, ranging from 210 mg/l to 1,790 mg/l (average 545 mg/l) near to the bed, to 134-345 mg/l (average 225 mg/l) at the water surface (**Table 16-9**). Mean values during construction of the Boston Tidal Barrier in February 2019 ranged from 170 mg/l to 215 mg/l (BMMJV, 2019).

Anticipated Evolution of the Baseline Condition

16.6.48 In the absence of the Facility in the future, the baseline estuarine processes would evolve naturally. The tidal prism of the estuary would increase slightly due to sea-level rise leading to a small increase in tidal current velocities, but the flood tide dominance is likely to continue. The protection afforded by the narrow entrance would continue and wave heights would remain low. There would be no anticipated changes in vessel traffic and ship wash would continue at the current levels. Given the insignificant changes in the physical processes which drive sedimentary processes, it is anticipated that the estuary bed sediment distribution, and bedload and suspended sediment transport regimes would continue at similar magnitudes to historically.

16.7 Potential Impacts

16.7.1 This section assesses the significance of potential effects on the tidal current and/or wave and/or sediment transport regimes on The Wash EMS and Havenside LNR sensitive receptors.

Embedded Mitigation Relevant to Estuarine Processes

16.7.2 Embedding mitigation into the project design is a type of primary mitigation and is an inherent aspect of the EIA process. The Facility has committed to several techniques and engineering designs/modifications as part of the project, during the pre-application phase, to avoid several effects or reduce effects as far as possible. Three main embedded mitigation measures have been proposed to reduce potential effects on estuarine processes. These are:

- the volume of capital dredging would be minimised by setting the quay wall of the wharf as close to the channel as possible, but without compromising the ability for safe passage of vessels, nor compromising the safety of moored vessels;
- complete as much of the capital dredging and maintenance dredging as possible using land-based equipment to reduce effects in The Haven water column; and

- capital dredged sediment would be disposed of on land rather than at sea and maintenance dredged sediment would be used as a binding agent for aggregate production at the Facility.

Worst Case Scenarios

16.7.3 Full details of the range of design options being considered are provided in **Chapter 4 Site Selection and Alternatives** and **Chapter 5 Project Description**. The principal aspect of the Facility which has the potential to affect estuarine processes is the proposed wharf. A worst case project envelope for wharf construction, operation and decommissioning is considered below.

Wharf Construction

16.7.4 The envisaged layout of the wharf is shown in **Figure 5.2**. The preferred structure is a suspended deck on piles over a sloping revetment with scour protection (1 in 4 slope) with a fronting quay wall. Slope protection would be installed adjacent to the north and south ends of the wharf where the berthing areas surface slopes upwards to the natural surface. The suspended deck would be about 400 m long and about 30 m wide and constructed on top of 300 driven piles. Excavation of about 75,000 m^3 of sediment would be required to enable installation of the revetment. About 150,000 m^3 of sediment would require excavation to create enough water depth in the berthing areas in front of the quay wall. The design of wharf has adopted a Not Always Afloat But Safely Aground (NAABSA) berth with a bed at an elevation of -3.5 m OD formed of a gravel/chalk (or similar) campshed. Construction of the first section of the wharf (to allow for raw materials to be received by ship) is anticipated to take six months, and the remaining section of the wharf will take a further 12 months (approximately) to complete.

16.7.5 The distance from the quay wall to the centre of the channel would be set to minimise the volume of capital dredging (i.e. as close as possible to the channel) and provide a safe clearance between a berthed vessel and other vessels passing along the channel. The quay wall would be about 50 m from the centre of the channel (40 m from the south west edge of the channel).

16.7.6 Two elements of wharf construction could potentially influence estuarine processes:

- excavation of the slope for the revetment (1st Phase Dredging); and
- capital dredging in front of the quay wall to create the berthing areas (2nd Phase Dredging).

16.7.7 The 1st Phase Dredging of the slope for the revetment would be completed using land-based equipment. Long-arm hydraulic excavators (and/or suitable cranes equipped with a grab) would sit on top of the flood defence and excavate the slope. The dredged sediment would be recovered or disposed on land.

16.7.8 This method of excavation for the revetment slope, its position relative to the channel, and disposal on land means that there will be no effect on estuarine processes. This is because none of the sediment that is dredged (75,000 m^3) can enter the water column as suspended load.

16.7.9 The 2nd Phase capital dredging of the berthing areas in front of the quay wall has the potential to temporarily increase suspended sediment concentrations in The Haven. Where possible, the capital dredge would be completed from land, with equipment sitting on the suspended deck. However, the 40 m distance from the quay wall to the subtidal channel means that it would be necessary to use floating plant for part of the excavation.

16.7.10 The dredged sediment would comprise a mix of recent intertidal mud, older Holocene mud with possible peat layers, and diamicton. The boundaries between these three units in the berthing areas is difficult to establish, and so the volumes of the different units that would be dredged are also difficult to quantify.

16.7.11 The distinction between the volumes of recent, Holocene and Pleistocene sediment is important because during the dredging process the recent sediment is more likely to break down into its constituent particles (and be suspended), whereas the Holocene and Pleistocene sediments are more likely to remain as aggregated clasts of mud. If these clasts were released into the water column, they would fall rapidly to the estuary bed (in less than a minute), rather than being disaggregated into their individual fine-grained sediment components.

16.7.12 For the worst case scenario for increase in suspended sediment concentrations due to capital dredging, it is assumed that all the sediment that is released into the water column is broken down into its constituent particles.

16.7.13 The construction phase of the Facility requires delivery of aggregate (and steel/rebar) using vessels along The Haven for approximately two years, from six months after the start of construction, as it is estimated that it will take six months to construct the first section of the wharf to allow raw materials to be received by ship (see **Chapter 5 Project Description**). Approximately 89 shipments (i.e. vessels) would be required during this period, based on an assumed payload of 2,500 tonnes. The vessels used would be no larger than the commercial vessels already using the waterway.

Wharf Operation

16.7.14 Three elements of the suspended deck wharf operation have the potential to influence estuarine processes:

- changes in the geometry of the channel and its hydrodynamics due to the presence of the wharf, piles and berthing areas;
- maintenance dredging to keep the berthing areas navigable; and
- ship wash from increased vessel numbers along The Haven.

16.7.15 The position of the quay wall, creation of the berthing areas, and presence of the piles would result in local changes to the channel geometry and hydrodynamics. The setting back of the quay wall and the removal of a wedge of sediment in front of it (capital dredge for berths) and behind it (excavation for sloping revetment) would result in an increase in spring tidal prism of about 95,000 m^3 at this location, from 180,000 m^3 to 275,000 m^3.

16.7.16 The piles would provide a local obstruction to the passage of ebb and flood tidal currents changing their flow velocity and direction. The scour protection across the sloping revetment, the slope protection to the north and south of the berthing area, and the campshed of the NAABSA berth would prevent erosion of the bed beneath the suspended deck, the sloping sides adjacent to the berthing areas and the berthing area, respectively. This means there would be no release of suspended sediment into the water column by scour around the piles or around the grounded vessels during operation.

16.7.17 Future maintenance dredging of the berthing areas is anticipated as they would be a sink for sediment and there is potential for partial infilling with mud during operation of the wharf. Van Rijn (2016) estimated siltation rates in harbours for a range of scenarios. For situations with relatively high suspended sediment concentrations (200 mg/l to greater than 1,000 mg/l) and major density current effects, like The Haven, the observed rates were about 0.6 m/year to 1.2 m/year. These rates would be conservative for The Haven because of the potential erosional effects of opening the sluice structures during high winter fluvial flows (there is currently no maintenance dredging carried out in The Haven at the proposed location of the Facility) and the larger tidal prism at the wharf. Hence, a worst case estimate of 0.5 m/year (50 cm/year) is used here.

16.7.18 Using this as a baseline sedimentation rate in the berthing areas over an area of 16,000 m^2 (dredged footprint of the berthing areas; 400 m long by 40 m wide) would lead to accumulation of mud of approximately 8,000 m^3/year.

16.7.19 The number of vessels using The Facility during operation is proposed to be 580 each year (in addition to approximately 400 commercial and cargo vessels per annum using the port). This will increase the frequency of ship wash encroaching on the intertidal areas of The Haven, which could potentially lead to erosion. The size of the vessels (length, beam and draft) that are proposed for use at the Facility are anticipated to be the same as the large cargo vessels that already use the waterway. The new vessels would not be larger than the maximum sizes that the port currently handles, as the size of vessels is restricted by the width of the Wet Dock entrance and the size of the turning circle at the Port of Boston (either in the Wet Dock or at the Knuckle Point just outside the Wet Dock) (see **Chapter 18 Navigational Issues**, **Section 18.6**). The speed limit for vessels along The Haven is 4 knots (about 2 m/s) to mitigate damaging the intertidal areas through ship wash.

Wharf Decommissioning

16.7.20 The Facility would be designed to operate for a period of at least 25 years, after which ongoing operation would be reviewed and if it is not appropriate to continue operation, the plant would be decommissioned. The wharf structure is proposed to be constructed to replace a section of the current primary flood defence bank. Hence, it will form a permanent structure that is not anticipated to be decommissioned. Therefore, decommissioning impacts are not covered in this assessment because the management of the wharf beyond the life of the Facility would be negotiated and discussed in a Decommissioning Plan.

Habitat Mitigation Area Construction and Operation

16.7.21 To mitigate the loss of roosting and foraging areas for waders, works will be completed southeast of the wharf (in advance of its construction) to create a Habitat Mitigation Area (see **Chapter 17 Marine and Coastal Ecology**). All works would be undertaken in the dry (i.e. avoiding high water) and such works would include:

- creation of up to 4 shallow pools (maximum 15 cm deep) in the existing saltmarsh habitat;
- re-profiling the edges of existing pools and banks, including flattening and removal of the old embankment in front of parts of the saltmarsh; and
- increasing the volume and height of the line of rocks in the upper intertidal part of the mitigation area by relocating rocks near the wharf to their landward side.

16.7.22 Construction activities to create these features would be relatively minor. Plant and equipment would be limited to a long-reach excavator potentially delivered to the site on a floating barge and a small workforce using hand tools. The works are unlikely to take longer than a week (weather and tide dependent).

16.7.23 Due to the works being undertaken in the dry, extremely limited sediment remobilisation will occur (to a small part of the unconsolidated sediment disturbed by the construction activities as the tide rises). Therefore, the worst-case scenario for increase in suspended sediment concentrations during construction would be the wharf capital dredging described above.

16.7.24 During operation, the tidal prism of The Haven would remain unchanged, the rocks would be placed parallel to the direction of the incoming and outgoing tidal currents so there would be no additional ‘blockage’ effects, and the saltmarsh would continue to be flooded and drained along the tidal creek at the north end of the habitat mitigation area. There may be a small impact on waves by shallowing the gradient of the old embankment (or removing it) and adding height to the line of rocks. There would be less wave reflection off the embankment, but more wave reflection off the rocks. These two effects would balance each other to effect little change to the overall wave climate.

16.7.25 Given these small changes in estuarine processes caused by operation of the habitat mitigation area, the worst-case scenario for operation would be the wharf operation described above.

Design Parameters that Potentially Influence Estuarine Processes

16.7.26 In this chapter, only those design parameters with the potential to influence estuarine processes are identified (**Table 16-10**). Other design parameters are not considered to have a material bearing on the outcome of this assessment.

Table 16-10 Worst Case Scenarios (WCSs) for the Estuarine Processes Assessment

Impact	Parameter
Construction	
Construction Impact 1: Changes in suspended sediment concentrations due to capital dredging of the berthing areas	Sediment plume created by capital dredging
Construction Impact 2: Changes in estuary-bed level due to capital dredging of the berthing areas	Sediment deposited from the plume created by capital dredging
Construction Impact 3: Changes to the wave regime (ship wash) and erosion/accretion patterns due to construction vessel movements	Waves
Operation	
Operational Impact 1: Changes to the tidal current regime and erosion/accretion patterns due to the presence of the wharf and berthing areas	Tidal currents and erosion/accretion patterns
Operational Impact 2: Changes to the wave regime (ship wash) and erosion/accretion patterns due to the increase in vessel traffic	Waves

Impact	Parameter
Operational Impact 3: Changes in suspended sediment concentrations due to maintenance dredging of the berthing areas	Sediment plume created by maintenance dredging
Operational Impact 4: Changes in estuary-bed level due to maintenance dredging of the berthing areas	Sediment deposited from the plume created by maintenance dredging

Potential Impacts during Construction

Construction Impact 1: Changes in Suspended Sediment Concentrations (SSC) due to Capital Dredging of the Berthing Areas

16.7.27 To allow access for vessels to the berths, capital dredging of approximately 150,000 m^3 of sediment from the area in front of the quay wall would be undertaken. There is the potential for the dredging activities to disturb sediment resulting in localised and short-term increases in SSC. The dredging method would be excavators operating from both the land and marine sides of the dredging area. The WCS assumes that sediment would be dredged and then disposed or recovered on land.

16.7.28 Sediment would be released into the water column in two ways:

- the action of the excavator on the estuary bed would disturb the bed sediments and lift them into the water; and
- a small volume of the dredged sediment would be lost from the excavator during the dredging process and enter the water.

16.7.29 Expert-based assessment suggests that a small, low concentration plume of suspended sediment would be created, which would be dispersed by tidal currents (and waves) away from the Application Site, either up-estuary on the flood tide or down-estuary on the ebb tide. Any sand particles would fall rapidly (within minutes) to the estuary bed immediately upon its discharge (within a few tens of metres along the axis of tidal flow).

16.7.30 Due to the small volume of sediment released and the predominantly fine size of the particles (very fine sand, silt and clay, see **Plate 16-4** to **Plate 16-6**), the plume is likely to be rapidly dispersed. The plume would contain measurable but modest SSC (likely to be less than 100 mg/l close to the excavator reducing to less than tens of mg/l within a few 100 m of the excavator). These SSC are much lower than the natural variability in The Haven (134 mg/l to 1,790 mg/l) and would be indistinguishable from background levels.

Assessment of the Magnitude of Effect and/or Effect Significance

16.7.31 The worst case changes in SSC due to capital dredging of the berthing areas are likely to have the magnitudes of effect shown in **Table 16-11**.

Table 16-11 Magnitude of Effect on SSC Under the WCS for Capital Dredging of the Berthing Areas

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Low	Negligible	Negligible	Negligible	Negligible
*The near-field effects are confined to a small area, likely to be several hundred metres up to a kilometre from the dredging location.					

16.7.32 The effects on SSC due to capital dredging do not directly impact upon the identified receptor groups for estuarine processes. This is because the designated features of The Wash EMS and Havenside LNR are related to processes operating on the estuary bed and not in the water column. Hence, there is **no effect** on the identified receptors groups associated with the suspended sediment generated by the Facility.

Construction Impact 2: Changes in Estuary-Bed Level due to Capital Dredging of the Berthing Areas

16.7.33 The suspended sediment in the water column associated with construction impact 1 has the potential to deposit and locally raise the estuary bed elevation slightly. Deposition from the plume is likely to be within The Haven, but there is potential for the very finest sediments to be flushed out into The Wash on an ebb tide. On a flood tide, deposition is likely to be towards Boston.

16.7.34 Given the low SSC in the plume compared to the ambient concentrations in The Haven, the deposited sediment layer across the wider estuary bed would be very thin (<1 mm) and within the range of natural deposition on the mudflats and saltmarsh. This deposited sediment also has the potential to become re-mobilised and would rapidly become incorporated into the mobile estuary bed sediment layer, thus further reducing any potential effect.

Assessment of the Magnitude of Effect and/or Effect Significance

16.7.35 The changes in estuary-bed level due to capital dredging under the worst case sediment dispersal scenario are likely to have the magnitudes of effect shown in **Table 16-12**.

Table 16-12 Magnitude of Effect on Estuary-Bed Level Changes due to Deposition Under the WCS for Sediment Dispersal During Capital Dredging of the Berthing Areas

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Low	Negligible	Negligible	Negligible	Negligible
*The near-field effects are confined to a small area, likely to be several hundred metres up to a kilometre from the dredging location.					

16.7.36 The overall effect of capital dredging activities on estuary-bed level changes under a WCS for the identified estuarine processes receptor groups (The Wash EMS and Havenside LNR) is **negligible effect**. This is because the predicted thickness of sediment depositing on the estuary bed would only amount to a maximum which would be within the range of natural sediment deposition. After this initial deposition, the sediment would be continually re-suspended to reduce the thickness even further to a point where it would be effectively zero.

Construction Impact 3: Changes to the Wave Regime (Ship Wash) and Erosion/Accretion Patterns due to Construction Vessel Movements

16.7.37 Once the first section of the wharf has been constructed (this is anticipated to take six months) and the wharf is able to received raw materials by ship, the number of additional vessels arriving and leaving along The Haven would be 89, over the subsequent two year period of the construction phase to support construction of the Facility. There is the potential for the waves created by ship wash to affect the adjacent intertidal mudflat and saltmarsh areas through increased re-suspension and erosion. The size of the vessels using The Haven during construction would not increase compared to the existing traffic.

16.7.38 Impacts of ship wash during construction over a two-year period would be significantly less than the impacts of ship wash during operation, which involves 580 vessel movements per year over a longer 25-year period. Hence, the worst case impacts of ship wash are caused by operation of the Facility and they are considered in the section below (see Operational Impact 2).

Potential Impacts during Operation

Operational Impact 1: Changes to the Tidal Current Regime and Erosion/Accretion Patterns due to the Presence of the Wharf and Berthing Areas

16.7.39 During operation, the additional space for water created by the berthing areas would increase the tidal prism (the volume difference between high water and low water) in that section of The Haven. This could potentially increase tidal current velocities downstream of the Facility, which may increase erosion pressure on the intertidal and subtidal areas.

16.7.40 There is an empirical relationship between channel cross-sectional area at mean sea (tide) level and upstream spring tidal prism (or discharge). This equation takes the form: $CSA = a.P^b$, where CSA = cross-sectional area (mean sea level), P = upstream spring tidal prism, a = constant coefficient, and b = constant exponent.

16.7.41 The tidal prism at the wharf would increase from 180,000 m^3 to 275,000 m^3 once dredging for the sloping revetment, berthing areas and sloping sides adjacent to the berthing areas has been completed. This would increase the tidal prism of the entire Haven from 4.8 Mm^3 to about 4.9 Mm^3, which represents an increase of 1.8 %. This small change to the tidal prism means that the adjustments of channel cross-sectional area downstream to equilibrate with the new tidal prism would also be small. Changes close to the downstream end of the wharf would be greatest (albeit still small), with gradually less change progressing further downstream until the change would be imperceptible towards The Wash.

16.7.42 Also, during operation, the piles behind the quay wall would have the potential to redirect and change the velocity of current flows around them. Typically, changes in flow speeds are restricted to small 'wakes' around each pile. The piles break up the otherwise linear flow pattern, causing bifurcation of flow around them. This involves acceleration of flow around the edges of each pile, with reductions (shadow) in flow in the lee of each pile. At the Facility, the spatial extent of the wake effect would be confined to small distances beneath the deck and just outside the wharf footprint downstream from the southernmost pile and immediately upstream from the northernmost pile. The changes in velocity and direction would diminish rapidly either side of the wharf structure along the channel.

16.7.43 Baseline flow conditions close to the proposed pile locations would be around 0.3 m/s to 0.4 m/s (**Figure 16.5**). These would be altered locally by the presence of the piles, mostly by less than ±0.05 m/s, although in the immediate wake area the changes could be greater. The limited spatial changes to tidal currents indicate that they would only impinge on the scour protection for the revetment and not on the natural estuary bed downstream and upstream of the wharf. This means that changes to the tidal current regime caused by the piles would have no effect on erosion/accretion patterns in the Haven (both locally and regionally).

Assessment of the Magnitude of Effect and/or Effect Significance

16.7.44 The changes to the tidal current regime and erosion/accretion patterns under the WCS for operation are likely to have the magnitudes of effect shown in **Table 16-13**.

Table 16-13 Magnitude of Effect on Tidal Currents and Erosion/Accretion Patterns Under the WCS for Operation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Low	Negligible	Negligible	Negligible	Negligible
*The near-field effects are confined to a small area, likely to be several hundred metres up to a kilometre from the Facility.					

16.7.45 The overall effect of the locally increased tidal prism and the presence of the piles on the tidal current regime and erosion/accretion patterns under a WCS for the Havenside LNR estuarine processes receptor group is **negligible effect** and for The Wash EMS is **no effect**. This is because the predicted change to tidal currents and hence erosion and accretion would be very small and local to the Facility at Havenside LNR and non-existent at The Wash EMS (a distance of 3.5 km from the Facility). They are likely to be within the natural range of change resulting from the neap and spring tidal cycles.

Operational Impact 2: Changes to the Wave Regime (Ship Wash) and Erosion/Accretion Patterns due to the Increase in Vessel Traffic

16.7.46 The number of vessels arriving and leaving along The Haven would increase from approximately 400 commercial and cargo vessels visiting the Port of Boston each year (a total of 800 movements passing a particular location each year) to 980 each year (a total of 1,960 movements each year) due to operation of the Facility; an increase of about 145 %.

16.7.47 There is the potential for the additional waves created by ship wash to affect the adjacent intertidal mudflat and saltmarsh areas through increased re-suspension and erosion. The size of the vessels using The Haven would not increase compared to the existing traffic.

16.7.48 A 145% increase in vessel traffic would lead to a 145% increase in the number of waves created by ship wash that would impinge on the mudflats and saltmarsh. There are two parts to understanding the potential effects:

- to determine if ship wash is already causing erosion of the intertidal areas; and
- if so, would the increase in erosion caused by the additional ship wash be significant from an estuarine processes perspective.

16.7.49 The natural wind-wave conditions and the potential erosion caused by them would not change.

16.7.50 Ship wash differs from natural wind waves in that it is typically higher (likely to be up to 0.4 m in The Haven) and longer period (potentially up to eight seconds) but short duration. A ship movement would create a wave lasting about 60 seconds at a single location. The first few waves impinging on the intertidal mudflats would be small height (less than 0.1 m), followed by waves of the larger heights (for about 30 seconds), and then a gradually decaying series of smaller waves (**Plate 16-8**).

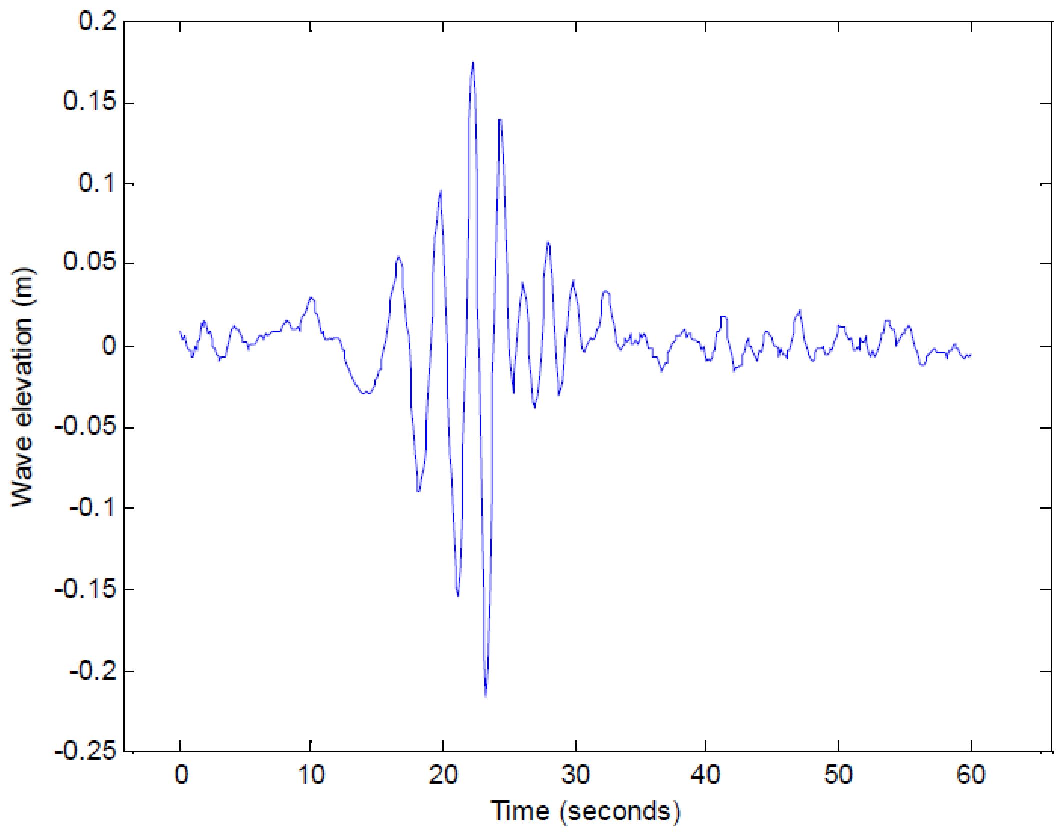


Plate 16-8 Ship Wash Wave Height Development over time as a Vessel Passes a Point

16.7.51 The period when mudflat and saltmarsh erosion is more likely to take place would be the 30 seconds of higher and long period waves through the middle of the wave time series. Bathymetry and shoreline type are site-specific, making it difficult to develop general guidelines and quantify the effect of ship wash on shoreline erosion. However, given the heights and periods of these waves, they potentially exceed the threshold values above which erosion could occur in The Haven.

16.7.52 Hence, as a WCS, it is assumed that the heights and periods of waves created by an individual vessel in The Haven are above the threshold for the erosion of mud from the intertidal areas and that the increase in the shipping traffic would result in an increase in erosion.

16.7.53 The flood-tide dominance of The Haven results in a long-term net transport of suspended sediment into The Haven and net accretion of mud on the channel margins and estuary bed. This accretion has taken place despite the short-term erosional events caused by ship wash of vessels currently using the river. This indicates that the annual net deposition of mud on the intertidal areas during natural wind-wave conditions exceeds the short-term erosion of mud during 800 vessel movements (400 upstream and 400 downstream) along the channel.

16.7.54 The annual erosion of the mudflats and saltmarsh from 800 vessel movements has occurred over a worst case cumulative period of about 13 hours (800 x 60 seconds). This equates to 0.15 % of a year. The increase in vessel movements to 1,960 would lead to a future worst case cumulative period of about 33 hours over which the ship wash would affect the mudflats and saltmarsh. This equates to 0.37 % of a year.

16.7.55 Given the relatively small amount of time that ship wash would be active on the intertidal mudflats (increasing from 0.15 % to 0.37 % of a year) compared to the relatively large amount of time that wind-waves are active (from 99.85 % to 99.62 % of a year), the annual effect on erosion/deposition of wind waves (and tidal currents) would continue to significantly exceed the erosion caused by ship wash. This means that The Haven mudflats and saltmarsh would continue to be accretionary because the proportional increase in erosion through ship wash would be small.

16.7.56 It is concluded that the increase in vessel traffic is unlikely to affect the intertidal mudflats and saltmarsh as the contribution to the overall accretion of these areas by locally-generated wind waves and tidal currents would significantly exceed the contribution to erosion from ship waves.

Assessment of the Magnitude of Effect and/or Effect Significance

16.7.57 The increase in ship wash due to the increase in vessel traffic and its effect on intertidal mudflat and saltmarsh erosion under the WCS is likely to have the magnitude of effect shown in **Table 16-14**.

Table 16-14 Magnitude of Effect on Waves Generated as Ship Wash Under the WCS for Operation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
The Haven	Low	Negligible	Negligible	Negligible	Negligible

16.7.58 The overall effect of increased ship wash under a WCS for the identified estuarine processes receptor groups (The Wash EMS and Havenside LNR) is **negligible effect**. This is because the predicted change to waves generated by extra ship wash is very small compared to the effect of natural wind-waves.

Operational Impact 3: Changes in SSC due to Maintenance Dredging of the Berthing Areas

16.7.59 The berthing areas would potentially create a sink for deposition of fine sediment, and they may require maintenance dredging to maintain depth during the operational phase. The annual volume of sediment that would deposit in the berthing areas is about 8,000 m^3.

16.7.60 The worst case method of dredging would be similar to the capital dredge using excavators from the marine side of the wharf. Disturbance of the estuary bed and loss of sediment from the excavator would be less than the capital dredge, and hence the effects would be lower magnitude.

Assessment of the Magnitude of Effect and/or Effect Significance

16.7.61 The worst case changes in SSC due to maintenance dredging of the berthing areas are likely to have the magnitudes of effect shown in **Table 16-15**.

Table 16-15 Magnitude of Effect on SSC Under the WCS for Maintenance Dredging of the Berthing Areas

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Low	Negligible	Negligible	Negligible	Negligible
*The near-field effects are confined to a small area, likely to be several hundred metres up to a kilometre from the dredging location.					

16.7.62 These effects on suspended sediment concentrations due to maintenance dredging would have **no effect** upon the identified receptors groups for estuarine processes. This is because The Wash EMS and Havenside LNR are dominated by processes that are active along the estuary bed and are not affected by sediment suspended in the water column.

Operational Impact 4: Changes in Estuary-Bed Level due to Maintenance Dredging of the Berthing Areas

16.7.63 The suspended sediment in the water column associated with operational impact 3 has the potential to deposit and raise the estuary bed elevation slightly. The mud released into the water column from the bed and lost from the excavator during the dredging process would form a plume and be dispersed before settling on the estuary bed, in a similar way to the capital dredged plume.

16.7.64 Given the SSC in the plume would be lower than the concentrations created by the capital dredge means that the depositional effects would also be lower magnitude. The deposited sediment layer across the wider estuary bed would be within the range of natural deposition rates of The Haven. In a similar way to the capital dredge, the deposited sediment has the potential to become re-mobilised and be rapidly incorporated into the mobile estuary bed sediment layer.

Assessment of the Magnitude of Effect and/or Effect Significance

16.7.65 The changes in estuary-bed levels due to maintenance dredging under the worst case sediment dispersal scenario are likely to have the magnitudes of effect shown in **Table 16-16**.

Table 16-16 Magnitude of Effect on Estuary-Bed Level Changes due to Deposition Under the WCS for Sediment Dispersal During Maintenance Dredging of the Berthing Areas

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Low	Negligible	Negligible	Negligible	Negligible
*The near-field effects are confined to a small area, likely to be several hundred metres up to a kilometre from the dredging location.					

16.7.66 The overall effect of maintenance dredging of the berthing areas on estuary-bed level changes under a WCS for the identified estuarine processes receptor groups (The Wash EMS and Havenside LNR) is **negligible effect**, for the same reasons highlighted for the capital dredge.

16.8 Mitigation

16.8.1 The assessment of the construction and operational phases of the Facility indicates that in all cases, the effects that have been evaluated would result in **no**

effect or **negligible effect** to the identified estuarine processes receptor groups. Hence, no specific mitigation is required.

16.8.2 However, to monitor the geomorphological evolution of The Haven local to the Facility, bathymetric surveys should be undertaken every six months during the construction period. This would support early warning of erosion and/or deposition exceeding predictions. Bathymetric surveys should also be undertaken during the early operation of the wharf, to monitor sedimentation in the berthing areas and quantify the future requirement for maintenance dredging.

16.9 Cumulative Impacts

16.9.1 The estuarine processes effects that have been assessed for the Facility alone are anticipated to result in **no effect** or **negligible effect** to The Wash EMS and Havenside LNR receptors. However, there may be potential cumulative effects on some of the identified receptor groups arising from interaction of changes to estuarine processes with those changes generated by other plans, projects and activities (**Table 16-17**).

16.9.2 A wider list of potential cumulative developments is available for consideration in other technical chapters of this ES. However, the only relevant developments that have potential to cumulatively impact on estuarine processes are those that will directly affect the river. Hence, **Table 16-17** only considers directly relevant schemes.

Table 16-17 Potential Projects that could Cumulatively Interact with the Facility

Project	Status	Development Period	Distance from the Application Site (km)	Project Definition	Project Data Status	Included in CIA	Rationale
Boston Barrier Flood Defence	Transport and Works Act Order consented	2017 – ongoing (completed August 2021)	Boston Barrier at closest point to the Application Site is 500m	ES	Complete / high	Yes	Will directly affect sediment flow in The Haven

16.9.3 It is likely that only the Boston Tidal Barrier project is estuary-based and close enough to the Facility to act cumulatively. Cumulative effects may arise due to:

- simultaneous capital dredging activities;
- simultaneous operation; and
- simultaneous maintenance dredging activities.

16.9.4 When the Boston Tidal Barrier is built and the banks immediately downstream are raised, Boston will be protected from a tidal surge with a 300-year return period. The barrier will feature a 25 m wide hydraulic-powered gate across The Haven, new flood defence walls on both banks and a replacement gate across the entrance to the existing Port of Boston wet dock. When not in use, the gate will lay flat on the estuary bed to prevent sediment build-up and minimise the impact on navigation. It will be raised to close off the River Witham when flooding is expected, preventing high tides from the North Sea from raising river levels in the town.

16.9.5 A summary of the potential cumulative impacts with the Boston Tidal Barrier is set out in **Table 16-18**.

Table 16-18 Potential Cumulative Impacts with the Boston Tidal Barrier

Impact	Potential for Cumulative Impact	Data Confidence	Rationale
Construction Impact 1: Changes in suspended sediment concentrations due to simultaneous capital dredging	Yes	High	Where the construction windows for the Facility and the Boston Tidal Barrier could overlap there is potential for cumulative impact
Construction Impact 2: Changes in estuary-bed level due to due to simultaneous capital dredging	Yes	High	
Operational Impact 1: Changes in suspended sediment concentrations due to simultaneous maintenance dredging	Yes	High	Where the dredging windows for the Facility and the Boston Tidal Barrier could overlap there is potential for cumulative impact
Operational Impact 2: Changes in estuary-bed level due to due to simultaneous maintenance dredging	Yes	High	

16.9.6 The impacts of the capital dredging activities on the identified receptors were identified to be of **no effect** or **negligible effect** for the Facility alone.

16.9.7 The construction programmes of the Facility and the Boston Tidal Barrier may overlap depending on the final construction programmes and so there is potential for cumulative impacts. However, this is unlikely, given the anticipated programme for the construction of the Barrier. However, a WCS from an estuarine processes perspective would be for both to be dredged at the same time. This would provide the greatest opportunity for interaction of sediment plumes and a larger change in estuary-bed level during their construction. The combined change in SSC and estuary-bed level could have a greater spatial extent and be greater in a vertical sense than each individual project.

16.9.8 The Boston Tidal Barrier EIA (Environment Agency 2016a; 2016b; 2016c) concluded that the impact of increased SSC and deposition from the plume due to capital dredging would both be **negligible** magnitude. The receptor sensitivities would also be negligible. Therefore, it is considered that the cumulative impact of SSC and deposition from the plume of the two projects being dredged in this area at the same time would also be **negligible**.

16.9.9 This assessment assumes that SSC released by construction of the Boston Tidal Barrier would be similar magnitude to those released by capital dredging of the Facility. If these two plumes combined, the resulting SSC (up to 200 mg/l), would still be within (at the low end) the natural variability in The Haven (134 mg/l to 1,790 mg/l) and would be indistinguishable from background levels.

16.9.10 A similar conclusion can be reached for simultaneous maintenance dredging operations, where the release of suspended sediment would be lower in volume.

16.10 Inter-Relationships with Other Topics

16.10.1 The range of effects on estuarine processes of the Facility not only have the potential to directly affect the identified estuarine processes receptors but may also manifest as impacts upon receptors other than those considered within the context of estuarine processes. The assessments of significance of these impacts on other receptors are provided in the chapters listed in **Table 16-19**. This chapter has inter-relationships with **Chapter 8 Cultural Heritage**, **Chapter 17 Marine and Coastal Ecology** and **Chapter 18 Navigational Issues**.

Table 16-19 Chapter Topic Inter-Relationships

Topic and description	Related Chapter	Where addressed in this Chapter
Effects on water column (suspended sediment concentrations)	**Chapter 17 Marine and Coastal Ecology**	**Section 16.7**
Effects on estuary bed (morphology/sediment erosion and deposition)	**Chapter 8 Cultural Heritage** **Chapter 17 Marine and Coastal Ecology** **Chapter 18 Navigational Issues**	**Section 16.7**

16.10.2 These inter-relationships are included for the following reasons:

- The receptors of changes in suspended sediment are fish and marine mammals and therefore these are assessed in **Chapter 17 Marine and Coastal Ecology**.
- Changes to sediment erosion and deposition could affect the exposure of, and therefore impact on archaeological features assessed in **Chapter 8 Cultural Heritage**.
- Changes to estuary bed morphology/sediment erosion and deposition could affect the habitat of benthic and fish receptors (**Chapter 17 Marine and Coastal Ecology**).
- Sediment deposition could potentially affect navigability in The Haven and so this is assessed in **Chapter 18 Navigational Issues**.

16.11 Interactions

16.11.1 The impacts identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic impacts because of that interaction. The worst case impacts assessed within the chapter take these interactions into account and for the impact assessments are considered conservative and robust. For clarity, the areas of interaction between impacts are presented in **Table 16-20**, along with an indication as to whether the interaction may give rise to synergistic impacts.

Table 16-20 Interaction Between Impacts

Potential interaction between impacts			
Construction			
	1: Changes in suspended sediment concentrations due to capital dredging of the berthing areas	2: Changes in estuary-bed level due to capital dredging of the berthing areas	3: Changes to the wave regime (ship wash) and erosion/accretion patterns due to construction vessel movements
1: Changes in suspended sediment concentrations due to capital dredging of the berthing areas	**-**	**Yes**	**No**
2: Changes in estuary-bed level due to capital dredging of the berthing areas	**Yes**	**-**	**No**

Potential interaction between impacts			
3: Changes to the wave regime (ship wash) and erosion/accretion patterns due to construction vessel movements	**No**	**No**	**-**

Operation				
	1: Changes to the tidal current regime and erosion/accretion patterns due to the presence of the wharf and berthing areas	2: Changes to the wave regime (ship wash) and erosion/accretion patterns due to the increase in vessel traffic	3: Changes in suspended sediment concentrations due to maintenance dredging of the berthing areas	4: Changes in estuary-bed level due to maintenance dredging of the berthing areas
1: Changes to the tidal current regime and erosion/accretion patterns due to the presence of the wharf and berthing areas	**-**	**No**	**No**	**No**
2: Changes to the wave regime (ship wash) and erosion/accretion patterns due to the increase in vessel traffic	**No**	**-**	**No**	**No**
3: Changes in suspended sediment concentrations due to maintenance dredging of the berthing areas	**No**	**No**	**-**	**Yes**
4: Changes in estuary-bed level due to maintenance dredging of the berthing areas	**No**	**No**	**Yes**	**-**

16.11.2 The conclusion of no synergistic impact between increased tidal velocities (due to the capital dredging and the resultant increase in the tidal prism) and wave energy (due to increased vessel movements) with respect to erosion requires further explanation.

16.11.3 The potential erosion caused by changes in tidal current velocity would be greatest (albeit with **negligible effect**) close to the downstream end of the wharf diminishing to immeasurable further downstream before The Wash. The potential erosion caused by ship wash would be greatest along the portion of The Haven where the vessels are travelling fastest from the entrance to The Haven to within range of the wharf. On their approach to the berths, the vessels would slow significantly, and consequently, the wash caused by their movement would be less.

16.11.4 The reduction in potential erosion downstream caused by changes in tidal current velocities would be opposite to the reduction in potential erosion upstream caused by ship wash. Hence, there would be an insignificant combined effect caused by the interaction of the two processes.

16.12 Summary

16.12.1 The assessment of the construction and operational phases of the Facility could cause a range of effects on estuarine processes. The magnitude of these effects has been assessed using expert assessment. The receptors that have been specifically identified in relation to estuarine processes are The Wash EMS and Havenside LNR. In all cases, the effects that have been assessed resulted in **no effect** or **negligible effect** to these receptors. A summary of impacts to these receptors are listed in **Table 16-21**.

Table 16-21 Impact Summary

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Effect
Construction						
Construction Impact 1: Changes in suspended sediment concentrations due to capital dredging of the berthing areas	The Wash EMS and Havenside LNR	N/A	N/A	No effect	N/A	No effect
Construction Impact 2: Changes in estuary-bed level due to capital dredging of the berthing areas	The Wash EMS and Havenside LNR	N/A	N/A	Negligible	N/A	Negligible
Construction Impact 3: Changes to the wave regime (ship wash) and erosion/accretion patterns due to construction vessel movements	The Wash EMS and Havenside LNR	N/A	N/A	Negligible	N/A	Negligible
Operation						
Operational Impact 1: Changes to the tidal current regime and erosion/accretion patterns due to the presence of the wharf and berthing areas	The Wash EMS	N/A	N/A	No effect	N/A	No effect
	Havenside LNR	N/A	N/A	Negligible	N/A	Negligible
Operational Impact 2: Changes to the wave regime (ship wash) and erosion/accretion patterns due to the increase in vessel traffic	The Wash EMS and Havenside LNR	N/A	N/A	Negligible	N/A	Negligible
Operational Impact 3: Changes in suspended sediment concentrations due to maintenance dredging of the berthing areas	The Wash EMS and Havenside LNR	N/A	N/A	No effect	N/A	No effect
Impact 4: Changes in estuary-bed level due to maintenance dredging of the berthing areas	The Wash EMS and Havenside LNR	N/A	N/A	Negligible	N/A	Negligible

16.13 References

Babtie Brown and Root (2004). Boston Haven Flood Management Strategy Study: Geomorphological Report. Version A02. Report to the Environment Agency.

BMMJV (Bam Nuttall Mott MacDonald Joint Venture) (2019). Monitoring Report – February 2019. Boston Barrier Design and Build, April 2019.

Brew, D.S., Holt, T., Pye, K. and Newsham, R. (2000). Holocene sedimentary evolution and palaeocoastlines of the Fenland embayment, eastern England. In. Shennan, I. and Andrews, J. (eds) Holocene Land-Ocean Interaction and Environmental Change around the North Sea. Special Publication of the Geological Society, 166, 253-273.

Briggs Marine Contractors (2016). River Witham. Boston, Lincs, Bathymetric Survey. Survey Report to Environment Agency, November 2016.

British Geological Survey (1995). Boston. England and Wales Sheet 128. Solid and Drift Geology. 1:50 000 Provisional Series (Keyworth, Nottingham: British Geological Survey).

CH2M (2017). Boston Haven Banks Geotechnical Report. Report to Ben Purkiss, June 2017.

Department of Energy and Climate Change (DECC) (2011a). Overarching National Policy Statement for Energy (EN-1). London: HMSO.

Department of Energy and Climate Change (DECC) (2011b). National Policy Statement for Renewable Energy Infrastructure (EN-3). London: HMSO.

Environment Agency (2011). Coastal flood boundary conditions for UK mainland and islands. Project: SC060064/TR2: Design sea levels. February 2011.

Environment Agency (2016a). A17/2b - Volume 2b: Technical Report: Estuarine and Geomorphology Processes, August 2016. Available at: https://consult.environment-agency.gov.uk/engagement/bostonbarriertwao/supporting_documents/A17%202B.%20Environmental%20Statement%20Volume%202B%20Estuarine%20and%20Geomorphology%20Processes.pdf

Environment Agency (2016b). A17/2b - Volume 2b: Technical Report: Surface Water and Flood Risk, August 2016. Available at: https://consult.environment-agency.gov.uk/engagement/bostonbarriertwao/supporting_documents/A17%202B.%20E nvironmental%20Statement%20Volume%202B%20Surface%20Water%20and%20Flood%20Risk.pdf

Environment Agency (2016c). A17/2b - Volume 2b: Technical Report: Ecology and Nature Conservation, August 2016. Available at: https://consult.environment-agency.gov.uk/engagement/bostonbarriertwao/supporting_documents/A17%202B.%20Environmental%20Statement%20Volume%202B%20Ecology%20and%20Nature%20Conservation.pdf

Environment Agency (2017a). Boston Barrier Project 2017 Water quality and sediment quality Report, November 2017.

Environment Agency (2017b). Boston Barrier Tidal Project: 2017 Saltmarsh Survey Report, November 2017.

European Commission (2003). Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document no. 4. Identification and Designation of Heavily Modified and Artificial Water Bodies. Available at: https://circabc.europa.eu/sd/a/f9b057f4-4a91-46a3-b69a-e23b4cada8ef/Guidance%20No%204%20-%20heavily%20modified%20water%20bodies%20-%20HMWB%20(WG%202.2).pdf

European Parliament (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for the Community action in the field of water policy. EU Water Framework Directive.

Halcrow (2002). The Wash Wave Modelling Study. Numerical Modelling and Geomorphic Assessment. Report to the Environment Agency.

Halcrow Jacobs Alliance (2011). Boston Barrier and Haven Works. Water Quality and Sediment Chemistry Technical Note. Report to the Environment Agency, March 2011.

HM Government (2011). UK Marine Policy Statement, March 2011.

Lincs Laboratory (2011). Ground Investigation Report for Boston Waste Transfer Station, Slippery Gowt Lane, Riverside Industrial Estate, Lincolnshire. December 2011.

Mott MacDonald (2015). Boston Barrier Ground Investigation Report. Report to the Environment Agency, February 2015.

Mott MacDonald (2016). Boston Barrier TWAO Hydraulic Modelling Report. Report to the Environment Agency, June 2016.

Royal Haskoning (2010). The Wash Shoreline Management Plan 2. Gibraltar Point to Old Hunstanton.

Shennan, I., Waller, M. and Alderton, A. (1994). North-western Fens (Lincs) in. Waller, M. (ed) The Fenland Project, Number 9: Flandrian Environmental Change in Fenland. East Anglian Archaeology Report Number 70: 283-295.

South-East Lincolnshire Joint Strategic Planning Committee (2019). South-East Lincolnshire Local Plan 2011-2036. Adopted March 2019.

T.L.P. Ground Investigations (2012). Ground Investigation Report. Proposed Power Generation Plant, Land off Nursery Road, Boston, Lincolnshire. November 2012.

Van Rijn, L.C. (2016). Harbour siltation and control measures. Report, May 2016.