REPORT

Boston Alternative Energy Facility - Preliminary Environmental Information Report

Chapter 16 Estuarine Processes

Client: Alternative Use Boston Projects Ltd

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Non-Technical Summary

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

Expert geomorphological assessment has been used to assess the potential effects of the Facility. Considerations of these effects on the wave, tidal current and sediment transport regimes have been made followed by the potential impacts on two receptor groups which contain valuable designated features. These are The Wash Ramsar / Site of Special Scientific Interest (SSSI) and the Havenside Local Nature Reserve (LNR). The impacts have been assessed using the worst-case characteristics of the proposed Facility as provided by the project and presented in **Chapter 5 Project Description**.

In all cases for construction and operation, the impact of the worst-case scenario for the Facility on estuarine processes for the identified receptor groups is no impact. The table below describes the impact significance for the environmental factors related to estuarine processes during construction and operation of the Facility.

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

Cumulative effects with the Boston Tidal Barrier have been considered with respect to sediment plume interaction during simultaneous capital or maintenance dredging campaigns. It is concluded that the cumulative impact 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 Preliminary Environmental Information Report (PEIR) describes the existing environment in relation to estuarine processes and details the assessment of the potential impacts during construction, operation and decommissioning of the Boston Alternative Energy Facility (the Facility). 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 impacts provided where significant impacts were identified.

16.2 Legislation, Policy and Guidance

Legislation

16.2.1 The European Union (EU) Water Framework Directive (WFD) considers the potential impact of a project on the surrounding waters' biological, hydrological, geomorphological and physico-chemical characteristics. Within the WFD classification, The Haven 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) and changes to the hydrology and geomorphology by the Facility may affect its ability 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:

- overarching NPS for Energy (EN-1) (July 2011); and
- NPS for Renewable Energy Infrastructure (EN-3) (July 2011).

16.2.3 The relevant aspects of EN-1 and EN-3 are presented in **Table 16.1**. This chapter of the PEIR 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	PEIR 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 PEIR 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 the conceptual model. It would be disproportionate to run a numerical model of The Haven system. Also, estuarine processes data was reported for 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 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) and any relevant Marine Plans (Objective 10 of the East Inshore and East Offshore Marine Plans is "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 SMPs)… and capital	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 **Section 16.7**. The Facility has been designed so that it is not vulnerable to coastal change taking account of climate change.

NPS Requirement	NPS Reference	PEIR Reference
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.'		
'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 group (SAC, SPA, SSSI, NNR) and Havenside LNR. The potential to affect their integrity is assessed with respect to changes in tidal currents, wave climate (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 2.6.193 and 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. 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, 2017) 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 consultation of relevance to estuarine processes is detailed in **Table 16.2**.

Table 16.2 Consultation and Responses

Consultee and Date	Response	Section in the Assessment
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 group of receptors (SAC, SPA, SSSI, NNR).
The Planning Inspectorate July 2018	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 is defined in **Section 16.5**.
The Planning Inspectorate July 2018	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	**Section 16.7** quantifies potential timescales of effects for construction and operation.

Consultee and Date	Response	Section in the Assessment
	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.	
The Planning Inspectorate July 2018	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**.
The Planning Inspectorate July 2018	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 PEIR 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 the conceptual model. It would be disproportionate to run a numerical model of The Haven system. Also, estuarine processes data was reported for Boston Tidal Barrier including numerical modelling of hydrodynamics.
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	Baseline information on the tidal regime including asymmetry is presented in

Consultee and Date	Response	Section in the Assessment
	Estuaries database the Witham is flood dominant; understanding this will help to address sedimentation issues.	**Section 16.6**.
Environment Agency 3rd July 2018	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**.
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.
MMO July 2018	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.
MMO July 2018	The Scoping Report proposes to scope out impacts on the Inner Wash (6.10.17), based on the understanding that no dredging will 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.	**Section 16.7** assesses the potential effects on The Wash group of receptors (SAC, SPA, SSSI, NNR) of capital and maintenance dredging.
MMO July 2018	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 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).
MMO July 2018	Section 6.10.6 states that the Port of Boston has confirmed that no ongoing maintenance dredging	The anticipated maintenance dredging

Consultee and Date	Response	Section in the Assessment
	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.	requirement and the assessment of its effects are described in **Section 16.7**.
MMO July 2018	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. Hence, it is not included in this PEIR. The anticipated dredging requirements and the assessment of their effects are described in **Section 16.7**.
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 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.	The anticipated capital dredging requirement and the assessment of its effects are described in **Section 16.7**.
Port of Boston 5th July 2018	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 capital dredge will be disposed to sea. The maintenance dredge material 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**.
Port of Boston 5th July 2018	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 material. Hence, it is not included in this PEIR.
Port of Boston 5th July 2018	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	The maintenance dredge material can be used within the Facility in the aggregate production

Consultee and Date	Response	Section in the Assessment
	therefore be scoped in to the assessment.	process. There is no anticipated sea disposal. Hence, it is not included in this PEIR. The anticipated dredging requirements and the assessment of their effects are described in **Section 16.7**
Port of Boston 5th July 2018	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**.
Port of Boston 5th July 2018	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 material. Hence, it is not included in this PEIR.

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 composition and elevation of the bed (receptor).

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 waves, tidal currents 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 PEIR 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 morphological 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 impacts on them is assessed within the relevant chapters of this PEIR.

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 Natura 2000 site, including The Wash Special Protection Area (SPA), Ramsar site and Site of Special Scientific Interest (SSSI), The Wash and North Norfolk Coast Special Area of Conservation (SAC), and The Wash Natural Nature Reserve.

16.4.9 The nearest point of The Wash group of 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 Local Nature Reserve (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 and includes coastal grazing marsh, marsh, 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 proposed project cumulatively or in combination with other developments and other nearby estuary activities. Although a screening process has been carried out in conjunction with Boston Borough Council to define which projects will be considered in the Cumulative Impact Assessment, it is considered likely that only the Boston Tidal Barrier project is relevant to the Facility to act cumulatively in terms of estuarine processes. Information to support the Cumulative Impact Assessment will draw from findings of the Boston Tidal Barrier Environmental Impact Assessment (EIA) (Environment Agency 2016a, b, c).

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 impacts 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 and bathymetry: Lidar data of the intertidal and supratidal areas	Environment Agency GeoStore web-based data portal
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 and numerous boreholes for the Boston Tidal Barrier EIA	Lincs Laboratory (2011), T.L.P. Ground Investigations (2012) and Mott MacDonald (2015)
Predicted water levels	Admiralty Tide Tables (2018)
Tidal currents: hydraulic modelling for the Boston Tidal Barrier EIA	Mott MacDonald (2016)
Relative sea-level rise	Shennan et al. (2012) and Church et al. (2013)
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)
Deeper sediment particle size: 32 samples recovered from vibrocores for the Boston Tidal Barrier EIA in 2017	Environment Agency (2017a)
Turbidity: 11 water samples recovered for the Boston Tidal Barrier EIA in 2017	Environment Agency (2017a)

16.5.3 The assessment uses available literature and data, including the Environmental Statement 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 solely based 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) (**Figure 16.1**). 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 and bathymetry data was obtained from the Environment Agency. A mosaic of Lidar data captured over several years (dataset which uses the best data from a range of years) by the Environment Agency was combined with a multibeam echosounder survey in 2016 along the lower intertidal and subtidal areas of the Haven (Briggs Marine Contractors, 2016).

16.6.6 Both 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 Lidar data, then the echosounder data was used to avoid errors associated with the water surface. To create the surface the Lidar data was 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 OD and 3.8 m below OD (**Figure 16.2** and **Plate 16.1**). The mudflats slope landwards 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**.

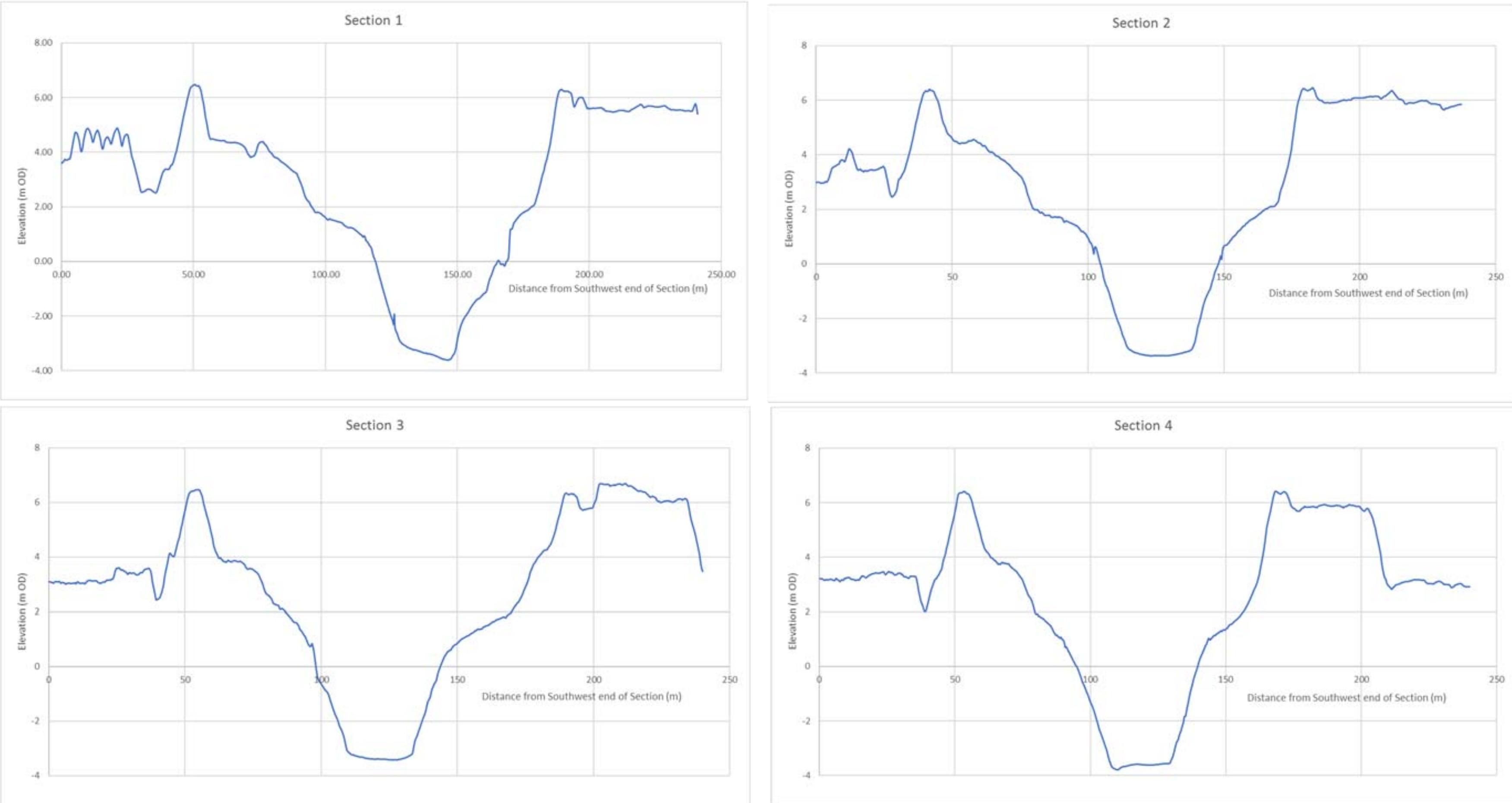


Plate 16.1 Sections Across the Bathymetry and Topography at and Adjacent to the Facility. Locations of the Sections are Shown on Figure 16.2.

Plate 16.2 Intertidal Mudflats and Subtidal Channel at the Facility. Photographs Taken 8th October 2018 From the West Bank (Top) and 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 southwest bank and N1-N3 on the north 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 West Bank Looking up Estuary (Left) and 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.

16.6.13 The Holocene sediments at Boston are about 4-8 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 and south 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 Ordnance Datum (OD) (typically -3 m OD) on the north bank and -2.4 m to -2.6 m OD (typically -2.6 m OD) on the south bank, underlain by diamicton. Bedrock is at about -20 m to -21 m OD (at the location of the Boston Tidal Barrier).

Astronomical Water Levels

16.6.18 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, 2018) (**Table 16.5**). High water occurs first at the estuary mouth (Tabs Head) and then progressively up the estuary as the tidal wave propagates upstream.

Table 16.5 Tidal Levels at Boston (Admiralty Tide Tables, 2018)

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

Tidal Prism

16.6.19 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

16.6.20 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

16.6.21 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 north of the

Facility at the proposed location of Boston Tidal Barrier, current velocities on the ebb tide can be faster than those on the flood tide. This occurs when the river flow is released from upstream sluices as the tide ebbs under non-flood conditions.

16.6.22 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

16.6.23 The narrow entrance to The Haven at Tabs Head excludes much of the externally generated higher wave energy. Local waves are generated from commercial vessels (ship wash) entering and exiting The Haven. No data on significant wave heights is available, but expert geomorphological assessment suggests that naturally generated wind-waves would have heights less than 0.1 m in the Haven.

Future Relative Sea-level Rise

16.6.24 Using the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment of Climate Change (Church et al. 2013) and Shennan et al. (2012), the estimated rises in relative sea level at Boston are 0.12 m, 0.26 m and 0.72 m after 10, 20 and 50 years relative to a baseline of 2018, respectively (**Table 16.7**). The derivation of these projections is described in **Appendix 16.1 Supplementary Information to Estuarine Processes**.

Table 16.7 Projected Changes in Sea Level at the Facility Relative to a Baseline of 2018

Year	Median Global Sea-level Rise (RCP*8.5) (m) (Church et al. 2013)	Vertical Land Motion (m) (Shennan et al. 2012)	Estimated Relative Sea-level Rise (m)
2018	0	0	0
2023	0.02	0.04	0.06
2028	0.04	0.08	0.12
2033	0.07	0.12	0.19
2038	0.10	0.16	0.26
2068	0.32	0.40	0.72

*Representative Concentration Pathway = projection of global sea-level rise for an emissions scenario of future climate change (Church et al. 2013)

Estuary Bed Sediment Distribution

16.6.25 Environment Agency (2017a) collected water samples, estuary bed grab samples and short vibrocores from three areas (**Figure 16.6**):

- 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.

16.6.26 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 positions of samples for 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

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

16.6.27 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. 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%.

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

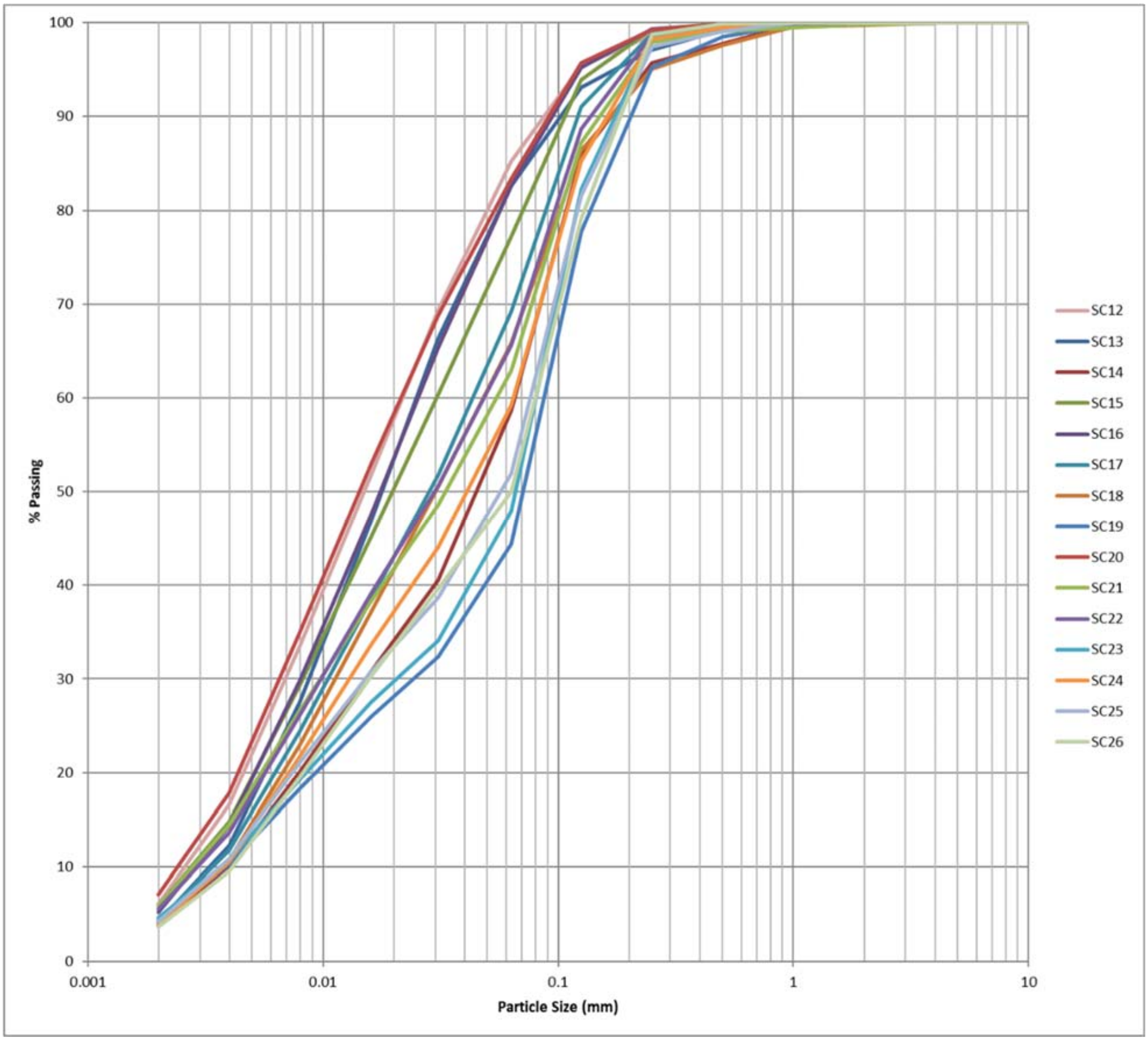


Plate 16.4 Cumulative Particle Size Distributions of Bed Sediment Samples Collected in 2017. Locations are Shown on Figure 16.6.

16.6.28 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.

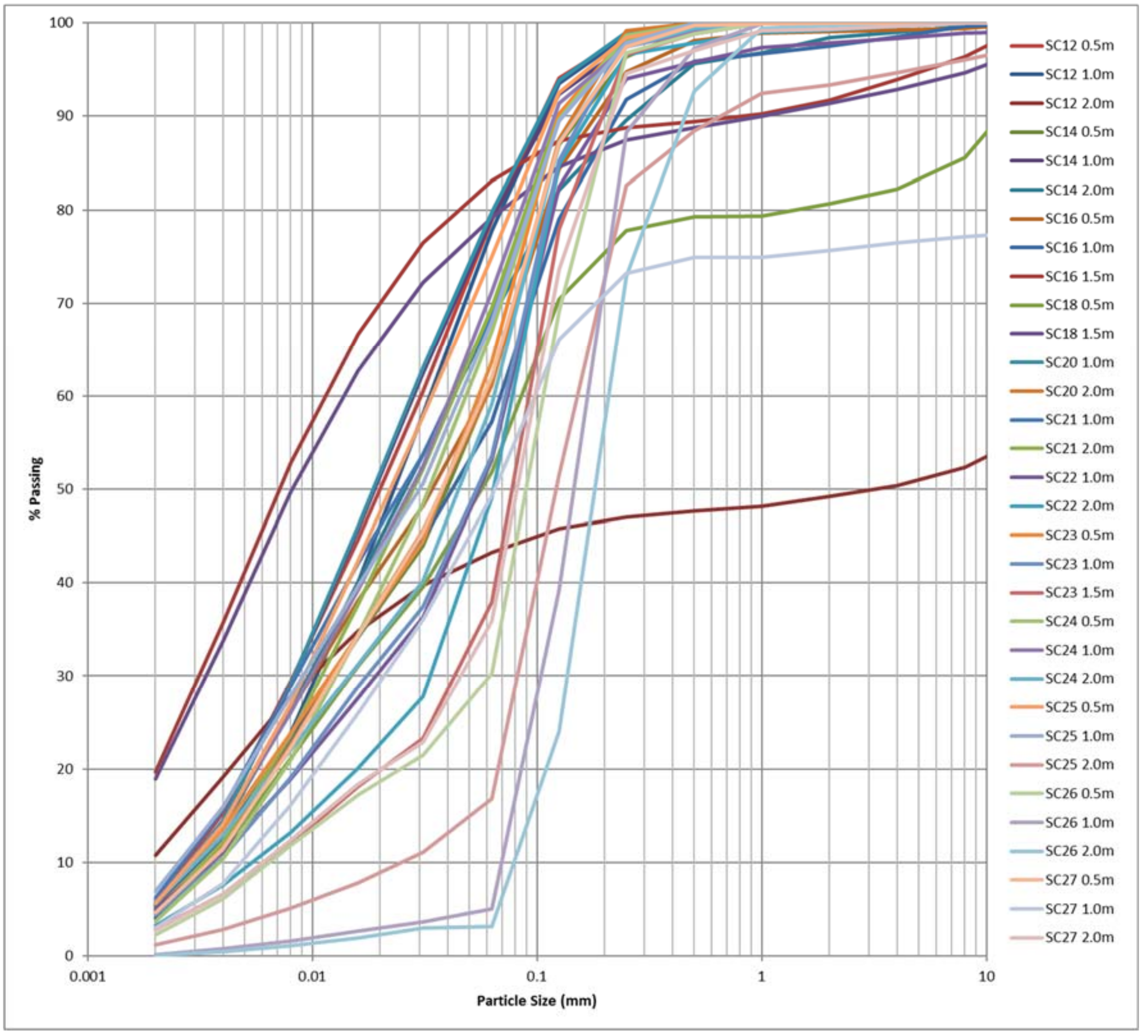
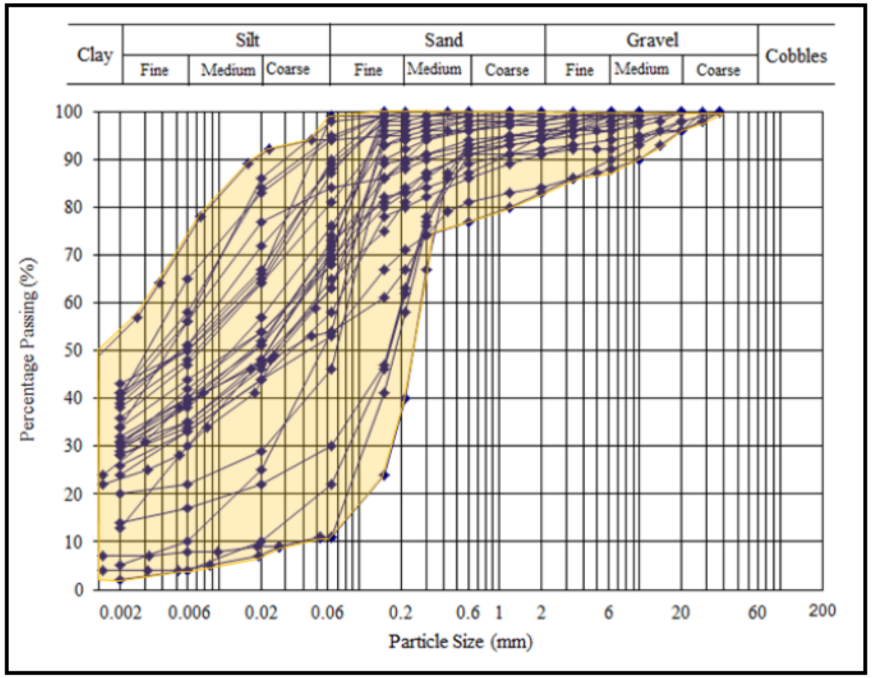


Plate 16.5 Cumulative Particle Size Distributions of Vibrocore Sediment Samples Collected in 2017. Locations are Shown on Figure 16.6.

16.6.29 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.

16.6.30 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.



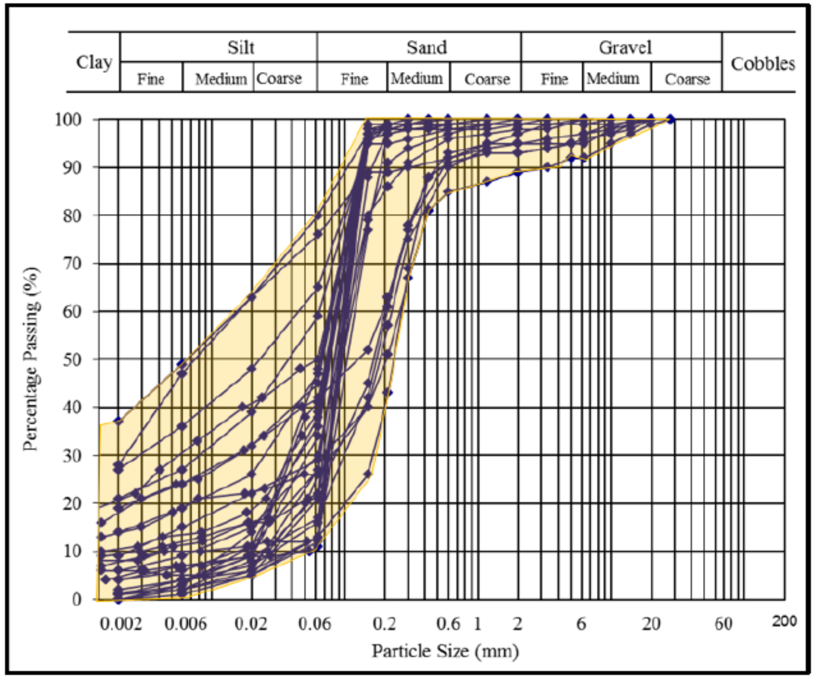


Plate 16.6 Cumulative Particle Size Distribution Curves for Clayey Silt (Left) and Very Fine Sand (Right) Samples Recovered From Vibrocores Upstream of the Facility (Mott MacDonald 2015).

Suspended Sediment Transport and Deposition

16.6.31 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.

16.6.32 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.

16.6.33 The muddy shoreline of The Haven is located where tidal current velocities are too weak to re-suspend completely 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.

16.6.34 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 was measured in Nephelometric Turbidity Units (NTU). 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 16.6 (Environment Agency, 2017a)

16.6.35 There is a general increase in turbidity from near the estuary bed into the higher parts of the water column (**Table 16.9**). With respect to the effect of turbidity on fish assemblages, Environment Agency (2016c) used a general scale to define the water quality characteristics based on NTU values:

- Clear water: less than 10 NTU;
- Intermediate turbidity: 10–80 NTU; and
- Turbid water: greater than 50 NTU.

16.6.36 Environment Agency (2016c) also 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**).

Table 16.9 Turbidity Characteristics Along the Haven in August 2017

Height above 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

Anticipated Evolution of the Baseline Condition

16.6.37 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 sea 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 impacts on the tidal current and/or wave and/or sediment transport regimes on The Wash group and Havenside 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/impacts or reduce effects/impacts as far as possible. Three main embedded mitigation measures have been proposed to reduce potential impacts 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 impacts in The Haven water column; and
- dispose of capital dredged sediment on land rather than at sea.

Worst Case Scenarios

16.7.3 Full details of the range of design options being considered are provided in **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 16.7**. The preferred structure is a suspended deck on piles over a sloping revetment (1 in 2 slope) with a fronting quay wall. The suspended deck would be up to 400 m long and 20 m wide and constructed on top of about 300 driven piles. Excavation of about 140,000 m^3 of sediment would be required to create sufficient water depth in the berthing areas in front of the quay wall. The construction of the wharf is anticipated to take between 15 to 18 months.

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 60 m from the centre of the channel.

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

- excavation of the slope for the revetment; and
- capital dredging in front of the quay wall to create the berthing areas.

16.7.7 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 can enter the water column as suspended load.

16.7.9 The 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 60 m distance from the quay wall to the subtidal channel means that it could still be necessary to use floating plant. It is estimated that approximately one third of the sediment would be dredged by land-based plant and two thirds by floating plant. This estimate is based on the expectation that the land-based plant could only reach approximately 15 m estuary-ward from the end of the suspended deck.

16.7.10 The dredged sediment would comprise a mix of recent intertidal mud and older Holocene mud with possible peat layers. The boundary between these two 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 and Holocene 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 sediment is 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.

Wharf Operation

16.7.13 Three elements of the wharf operation have the potential to influence estuarine processes:

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

16.7.14 The creation of the berthing areas and the position of the quay wall would result in local changes to the channel geometry. The setting back of the quay wall and the removal of a wedge of sediment in front of it would result in an increase in spring tidal prism of 85,250 m^3 at this location, from 178,650 m^3 to 263,900 m^3.

16.7.15 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 low suspended sediment concentrations (less than 100 mg/l) and major density current effects, like The Haven, the observed rates were 0.1 m/year to 0.3 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, and the larger tidal prism at the wharf. Hence, a worst case estimate of 0.05 m/year (5cm/year) is used here.

16.7.16 Using this as a baseline sedimentation rate in the berthing areas over an area of 32,850 m^2 (dredged footprint of the berthing areas) would lead to accumulation of mud of approximately 1,643 m^3/year.

16.7.17 The number of vessels using The Haven would increase from 400 each year to 960 each year. This has the potential to increase the frequency of ship wash encroaching on the intertidal areas of The Haven, which could potentially lead to erosion.

Wharf Decommissioning

16.7.18 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 would replace a section of the current primary flood defence bank and form a permanent structure that is not anticipated to be decommissioned. Hence, decommissioning impacts are not covered in this assessment as the management of the wharf beyond the life of the Facility would be negotiated and discussed in a Decommissioning Plan.

Design Parameters that potentially influence Estuarine Processes

16.7.19 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 for the Estuarine Processes Assessment

Impact	Parameter
Construction	
Impact 1: Changes in suspended sediment concentrations due to capital dredging of the berthing areas	Sediment plume created by capital dredging

Impact	Parameter
Impact 2: Changes in estuary-bed level due to capital dredging of the berthing areas	Sediment deposited from the plume created by capital dredging
Operation	
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
Impact 2: Changes to the wave regime (ship wash) due to the increase in vessel traffic	Waves
Impact 3: Changes in suspended sediment concentrations due to maintenance dredging of the berthing areas	Sediment plume created by maintenance dredging
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

Impact 1: Changes in suspended sediment concentrations due to capital dredging of the berthing areas

16.7.20 To allow access for vessels to the berths, capital dredging of approximately 140,000 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 suspended sediment concentrations. The dredging method would be excavators operating from both the land and marine sides of the dredging area. The worst-case scenario assumes that sediment would be dredged and then disposed or recovered on land.

16.7.21 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.

16.7.22 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 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).

16.7.23 Due to the small volume of sediment released and the predominantly fine size of the particles (very fine sand, silt and clay, **Plate 16.4, Plate 16.5** and **Plate 16.6**), the plume is likely to be rapidly dispersed. The plume would contain measurable but modest suspended sediment concentrations (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 suspended sediment concentrations 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 Impact Significance

16.7.24 The worst-case changes in suspended sediment concentrations 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 Suspended Sediment Concentrations Under the Worst-Case Scenario 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.

16.7.25 The effects on suspended sediment concentrations 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 group and Havenside LNR are related to processes operating on the estuary/sea bed and not in the water column. Hence, there is **no impact** on the identified receptors groups associated with the suspended sediment generated by the Facility.

Impact 2: Changes in estuary-bed level due to capital dredging of the berthing areas

16.7.26 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.

16.7.27 Given the low suspended sediment concentrations in the plume compared to the ambient concentrations in The Haven, the deposited sediment layer across the wider estuary bed would be very thin (less than one millimetre) 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.

<u>Assessment of the Magnitude of Effect and/or Impact Significance</u>

16.7.28 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 Worst-Case Scenario 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.

16.7.29 The overall impact of capital dredging activities on estuary-bed level changes under a worst-case scenario for the identified morphological receptor groups (The Wash group and Havenside LNR) is **no impact**. 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.

Potential Impacts during Operation

Impact 1: Changes to the tidal current regime and erosion/accretion patterns due to the presence of the wharf and berthing areas

16.7.30 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.

16.7.31 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.

16.7.32 The tidal prism at the wharf would increase from 178,650 m^3 to 263,900 m^3 once dredging of 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 only 1.8 %. This very 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 very small.

Assessment of the Magnitude of Effect and/or Impact Significance

16.7.33 The changes to the tidal current regime and erosion/accretion patterns under the worst-case scenario 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 Worst-Case Scenario 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.

16.7.34 The overall impact of the locally increased tidal prism on the tidal current regime and erosion/accretion patterns under a worst-case scenario for the identified morphological receptor groups (The Wash group and Havenside LNR) is **no impact**. This is because the predicted change to tidal currents and hence erosion and accretion would be very small both local to the Facility at Havenside LNR and at The Wash (a distance of 3.5 km from the Facility) and within the natural range of change resulting from the neap and spring tidal cycle.

Impact 2: Changes to the wave regime (ship wash) due to the increase in vessel traffic

16.7.35 The number of vessels arriving and leaving along the Haven would increase from 400 each year to 960 each year due to operation of the Facility; an increase of about 150%. There is the potential for the additional waves created by ship wash to affect the adjacent intertidal areas through increased erosion.

16.7.36 As a worst-case scenario, it is assumed that the height of a wave created by an individual vessel in the Haven is 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 the potential for erosion. The key to understanding the potential effect is to determine if the increase in annual wave energy caused by the increase in traffic is large enough to significantly increase erosion of the intertidal areas over and above that already occurring through the combined effect of wind-waves and existing traffic volumes.

16.7.37 More than a doubling of the vessel traffic would lead to more than a doubling of the number of waves created by ship wash that would impinge on the intertidal mudflats. The natural wind-wave conditions would not change. A ship movement would create a wave lasting about 30 seconds at a single location (based on observation). The contribution of wind waves in terms of frequency is much higher; there is the potential for creation of natural waves all year round, although they have a lower significant wave height than ship wash.

16.7.38 Given the increase in time that ship wash would be active on the intertidal mudflats (30 seconds, from 400 to 960 more times a year) compared to the time that wind-waves are active, albeit with lower significant wave heights, it is considered that annually the effect of wind waves would significantly exceed that of ship waves. It is concluded that the increase in vessel traffic is unlikely to affect the intertidal mudflats and saltmarsh as the contribution to the overall erosion of these areas by locally-generated wind waves would significantly exceed the contribution from ship waves.

Assessment of the Magnitude of Effect and/or Impact Significance

16.7.39 The increase in ship wash due to the increase in vessel traffic and its effect on intertidal mudflat and saltmarsh erosion under the worst-case scenario is likely to have the magnitude of effect shown in **Table 16.14Table *16.14***.

Table 16.14 Magnitude of Effect on Waves Generated as Ship Wash Under the Worst-Case Scenario for Operation

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

16.7.40 The overall impact of increased ship wash under a worst-case scenario for the identified morphological receptor groups (The Wash group and Havenside LNR) is **no impact**. This is because the predicted change to waves generated by extra ship wash is very small compared to the effect of natural wind-waves.

Impact 3: Changes in suspended sediment concentrations due to maintenance dredging of the berthing areas

16.7.41 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 1,643 m^3.

16.7.42 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 Impact Significance

16.7.43 The worst-case changes in suspended sediment concentrations 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 Suspended Sediment Concentrations Under the Worst-Case Scenario 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.

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

Impact 4: Changes in estuary-bed level due to maintenance dredging of the berthing areas

16.7.45 The suspended sediment in the water column associated with operational impact 3 has the potential to deposit sediment 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.

16.7.46 Given the suspended sediment concentrations 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 Impact Significance

16.7.47 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 Worst-Case Scenario 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.

16.7.48 The overall impact of maintenance dredging of the berthing areas on estuary-bed level changes under a worst-case scenario for the identified morphological receptor groups (The Wash group and Havenside LNR) is **no impact**, 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 proposed Facility indicates that in all cases, the effects that have been evaluated would result in **no impact** to the identified morphological 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.

16.8.3 Also, alternative approaches to the capital dredge process would be explored to minimise any requirement of dredging using floating platform. For example, working in a linear fashion in parallel to the river and dredged (or cut) working backwards from the land in front of the flood defence bank, means that almost all of the berthing pocket could be created from land.

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 impact to The Wash group 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**).

Table 16.17 Potential Projects that could Cumulatively Interact with the Facility

Project	Status	Development period	Distance from the Facility (km)	Project definition	Project data status	Included in CIA	Rationale
Boston Tidal Barrier	Transport and Works Act Order consented	2017 - ongoing	Boston Tidal Barrier at closest point to the Facility is 500 m	Environmental Statement	Complete/ high	Yes	Estuary-based and close enough for cumulative dredging activities and operation
Triton Knoll Offshore Wind Farm	DCO consented	2008 - ongoing	Onshore cable corridor and construction compound at Langrick 9.7 km from the Facility	Environmental Statement	Complete/ high	No	Land-based so no interaction with estuarine processes
Viking Link Interconnector B/17/0340	Application approved	2014 - 2023	Bicker Fen substation 14.4 km from the Facility	Environmental Statement	Incomplete	No	Land-based so no interaction with estuarine processes
Battery Energy Storage Plant (Marsh Lane) B/17/0467	Application approved	2017 - ongoing	Beeston Farm less than 10 m from the Facility	Detailed application	Incomplete	No	Land-based so no interaction with estuarine processes
The Quadrant Mixed-use development of 502 dwellings and commercial/ leisure uses B/14/0165	Application approved Construction started	2014 - ongoing	Quadrant 1 - 1.2 km from the Facility	Details within Environmental Statement	Quadrant 1 – Complete/ high Quadrant 2 - Incomplete/ low	No	Land-based so no interaction with estuarine processes
Land to the west of Stephenson Close Residential Development of up to 85 dwellings B/17/0515	Application not yet determined	2017 - ongoing	From the most eastern part of the Scheme to the Facility is 550 m	Outline only	Incomplete/ low	No	Land-based so no interaction with estuarine processes

16.9.2 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.

16.9.3 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.

16.9.4 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	

16.9.5 The impacts of the capital dredging activities on the identified receptors were identified to be of no impact for the Facility alone.

16.9.6 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. The worst-case scenario 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 suspended sediment concentrations and estuary-bed level could have a greater spatial extent and be greater in a vertical sense than each individual project.

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

16.9.8 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		
1: Changes in suspended sediment concentrations due to capital dredging of the berthing areas	**-**	**Yes**		
2: Changes in estuary-bed level due to capital	**Yes**	**-**		

dredging of the berthing areas				
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) 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) 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**	**-**

16.12 Summary

16.12.1 The assessment of the construction and operational phases of the proposed 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 group and Havenside LNR. In all cases, the effects that have been assessed resulted in **no impact** 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 Impact
Construction						
Impact 1: Changes in suspended sediment concentrations due to capital dredging of the berthing areas	The Wash group and Havenside LNR	N/A	N/A	No impact	N/A	No impact
Impact 2: Changes in estuary-bed level due to capital dredging of the berthing areas	The Wash group and Havenside LNR	N/A	N/A	No impact	N/A	No impact
Operation						
Impact 1: Changes to the tidal current regime and erosion/accretion patterns due to the presence of the wharf and berthing areas	The Wash group and Havenside LNR	N/A	N/A	No impact	N/A	No impact
Impact 2: Changes to the wave regime (ship wash) due to the increase in vessel traffic	The Wash group and Havenside LNR	N/A	N/A	No impact	N/A	No impact
Impact 3: Changes in suspended sediment concentrations due to maintenance dredging of the berthing areas	The Wash group and Havenside LNR	N/A	N/A	No impact	N/A	No impact
Impact 4: Changes in estuary-bed level due to maintenance dredging of the berthing areas	The Wash group and Havenside LNR	N/A	N/A	No impact	N/A	No impact

16.13 References

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