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Supplementary Environmental Information

Impact of Dredging and Dredged Material Disposal on 1) Subtidal and Intertidal Features and 2) Aquatic Ecology

Explanatory Note EX 10.4

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1 EXPLANATORY NOTE: IMPACT OF DREDGING AND DREDGED MATERIAL DISPOSAL ON 1) SUBTIDAL AND INTERTIDAL FEATURES AND 2) AQUATIC ECOLOGY

1.1 INTRODUCTION

1.1.1 The purpose of this explanatory note is to consider the impacts of dredging and dredged material disposal on subtidal and intertidal features and aquatic ecology. This note discusses both the impacts from the AMEP site and the compensation provided by the Compensation Site (ie it considers the AMEP Project); there will be no dredging at the Compensation Site. This note is specific to the impacts from dredging and dredged material disposal; it does not include potential impacts from the presence of the quay or the drainage channel through the intertidal area, unless otherwise stated. Impacts other than those directly or indirectly caused by dredging and dredged material disposal are not discussed. For the full assessment of impacts on geomorphology and aquatic ecology see the AMEP Environmental Statement (ES).

1.1.2 Information in this note is predominantly taken from the ES, including supporting annexes, which have been submitted to the IPC. In addition, and after submission of the ES, a biotope analysis of the benthic survey was produced (1). The analysis found no rare, or conservation priority biotopes, and as such has not affected the discussion of impacts. HR Wallingford has also conducted further investigation into changes in the estuary bed morphology surrounding AMEP and maintenance dredging requirements. The findings have been included in the discussions below, although again the outcomes of the original assessment are not affected (2) (3) (4).

1.1.3 This note presents the discussion of impacts on subtidal and intertidal features and aquatic ecology from dredging and dredged material disposal. It should be noted that impacts from several activities have

(1) IECS (2012) Biotopes of the Intertidal and Subtidal Sediments around the AMEP Site Report to the Able UK Ltd.
(2) HR Wallingford (2012) Able Marine Energy Park. Assessment of Maintenance Dredging Requirements. Techinical Note DDR4808-04.
(3) HR Wallingford (2012) Able MArine Energy Park 3D Mud modelling. Morphological assessment of changes south-east of development. Technical Note DDR4808-02.
(4) HR Wallingford (2012) Able Marine Energy Park. Assessment of changes to morphology (particularly intertidal) between the Humber International Terminal (HIT) and Humber Sea Terminal (HST). Technical Note DDR4808-03.

been assessed together in the ES (as is the appropriate practice) and direct comparisons between the significance of impacts from dredging and dredged material disposal reported in this note should not be made with the significance reported in the ES. In addition assessing the significance of impacts from dredging and dredged material disposal does not reflect the actual impact of the Project as a whole.

The potential effects from dredging can be broadly divided into the follows:

1. removal of sediment (ie footprint) and the loss of component marine habitats, species etc, noting that this effect will be 'shared' with the quay footprint;
2. removal of sediment changing bathymetry, again acting with the quay, to lead to potential physical changes in the estuary (flows, sediment transport and deposition etc);
3. mobilisation of sediment from the seabed during dredging with potential effects on ecological receptors away from the immediate dredging area due to elevated suspended sediment levels and deposition/smothering;
4. release and transport of sediment during disposal at the licensed disposal sites with potential effects on ecological receptors due to elevated suspended sediment levels and deposition/smothering; and
5. other effects to aquatic ecology from noise, vessel movements etc.

The following sections draw information from the ES in regard to the physical changes that are predicted to result from dredging and the effects these changes may then have on ecological receptors and resources in terms of points 1 – 5 above.

1.2 DREDGING AND DREDGED MATERIAL DISPOSAL

1.2.4 A full description of the dredging and dredged material disposal for the Project can be found in *Annex 7.6* of the ES. In summary dredging and dredged material disposal will be as follows:

Capital Dredging

- Dredging will be required in four areas (as shown in *Figure 1.1*):
- Turning Area (132 000 m^3);
- Approach Channel (682 000 m^3);

- Berthing Pocket (827 000 m^3); and
- Reclamation Area (294 500 m^3).

Dredged Sediment Disposal Sites (as shown in *Figure 1.2*):

- Erodible dredged sediment will be disposed of at the Middle Shoal deposit ground, Humber 1A (HU080); and
- Non-erodible material will be disposed of at sites HU082

Maintenance Dredging:

- Maintenance dredge volumes within the Humber Estuary vary considerably from year to year;
- It has been estimated that there will be a maximum annual maintenance dredge requirement for AMEP of 429 000 dry tonnes per year;
- Maintenance dredging is expected to be required in the berth pockets, however, the turning area and approach channel are predicted to be largely maintenance free;
- All of the maintenance dredge material will be re-deposited within the estuary.

Figure 1.1 Dredging Areas

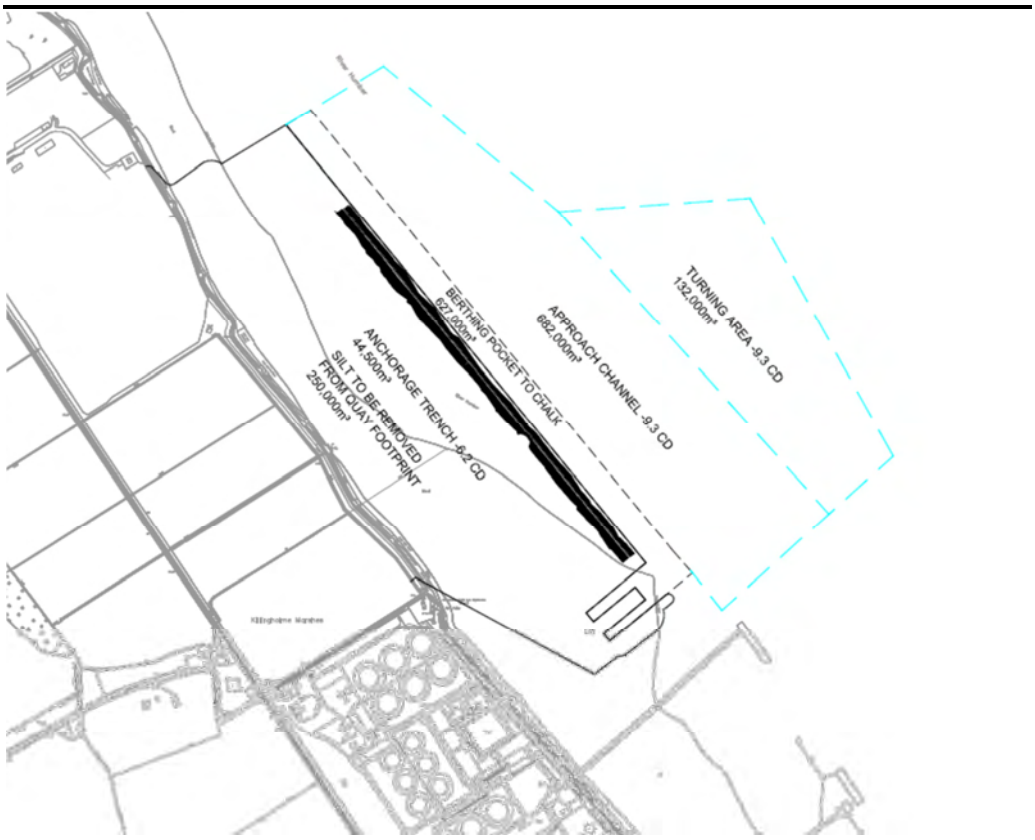
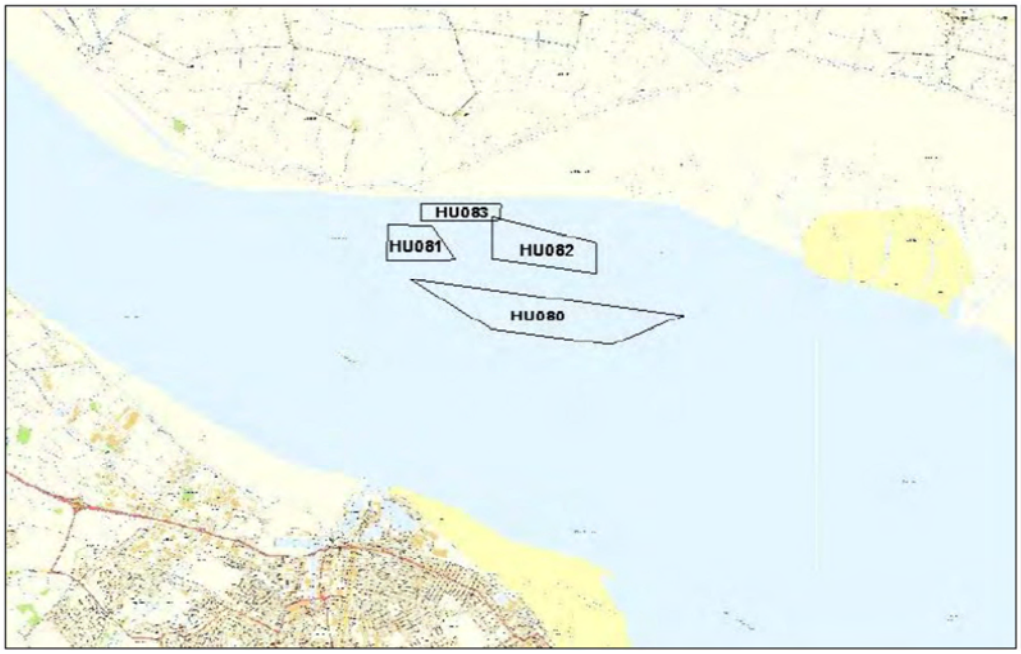


Figure 1.2 Disposal Sites



1.3 IMPACTS TO SUBTIDAL AND INTERTIDAL FEATURES

1.3.5 The dredging and dredge material disposal required for the AMEP Project could impact subtidal and intertidal features through:

- direct loss or change to the feature from sediment removal (including aggregate placement in the berthing pocket);
- changes to the sediment particle size from dispersion of dredged sediment;
- secondary changes to subtidal and intertidal features from project-induced changes in hydrodynamic and morphodynamic regimes.

1.3.6 As many of the impacts from capital and maintenance dredging are the same, they are discussed below together where necessary.

Direct Loss or Change

1.3.7 Direct loss of subtidal and / or intertidal habitat will occur due to dredging for the AMEP (including maintenance dredging) and disposal of the dredged material at the disposal sites. In addition removal of the substrate or placement of aggregate in the berthing pocket may also alter the sediment type by dredging to a depth where different sediments occur or placement of alternative substrata once dredging is complete (eg at the berthing pocket). The total subtidal project footprint at the AMEP site is estimated at 13.5 ha, which is <0.1 percent

of the overall subtidal estuarine habitat of 16 800 ha. Similarly, 31.5 ha of intertidal habitat will be lost under the quay footprint, although not all of this area will require dredging. As discussed above and shown in***Error! Reference source not found.*** and *Figure 1.1* dredging can be divided into four areas plus the dredged material disposal site.

1.3.8 The turning area and approach channel are both currently part of the subtidal area of the estuary. Once dredged, these areas will remain part of the subtidal features of the estuary but will be of a different depth and a change of sediment type may occur.

1.3.9 The berthing pocket will be dredged to rockhead and a suitable aggregate deposited to create a stable footing for use by jackup vessels. The berthing pocket area will remain part of the subtidal features of the estuary but a change in depth and sediment type will occur. On completion, the new sediment type will be a hard rocky substrata due to the aggregate placement.

1.3.10 All dredged sediments will be relocated to the licensed disposal sites. As such these disposal areas will be subject to both depth and sediment type changes, although they will remain subtidal.

1.3.11 The reclamation area will be dredged but then built on to form the quay, which represents a permanent loss of some subtidal and intertidal area. A Compensation Site located on the north shore of the Humber has been designed to compensate for the loss of intertidal habitat due to the AMEP. Over time the Compensation Site will develop into a combination of saltmarsh and mudflat. A small proportion of subtidal habitat will be lost to the quay, however the permanent and intermittently submerged elements of the quay structure will provide additional hard substrate habitat in the estuary (see *Chapter 10* in the ES for details).

Changes to the Sediment Particle Size from Dispersion

1.3.12 Dispersion of sediment from the capital and maintenance dredging plume and the plume from dredged sediment disposal may change the sediment type within the plume footprint as it settles onto the bed. Both subtidal and intertidal areas may be affected.

1.3.13 Sediment plumes will also occur at the dredge site (ie at and in the vicinity of the AMEP) through the action of the draghead on the seabed and overspill from the hopper. However, the plume resulting from dredging is likely to be relatively small compared to the dredge disposal plume due to the much smaller quantity of sediment

suspended. This material will tend not to be mobilised far from the location of dredging, especially in comparison with the dispersion of erodible material deposited at disposal sites. The disposal of erodible material therefore has the main potential for transport and wider effects in the estuary.

1.3.14 The unerodible glacial till to be excavated will produce large lumps of stiff clay. These will be disposed of at the sites to the north of the Sunk Dredged Channel. The disposal of the stiff glacial till clay at these sites is highly unlikely to add significantly to background suspended sediment concentration due to the strongly cohesive nature of the material and will therefore not affect the sediment particle size outside of the disposal areas.

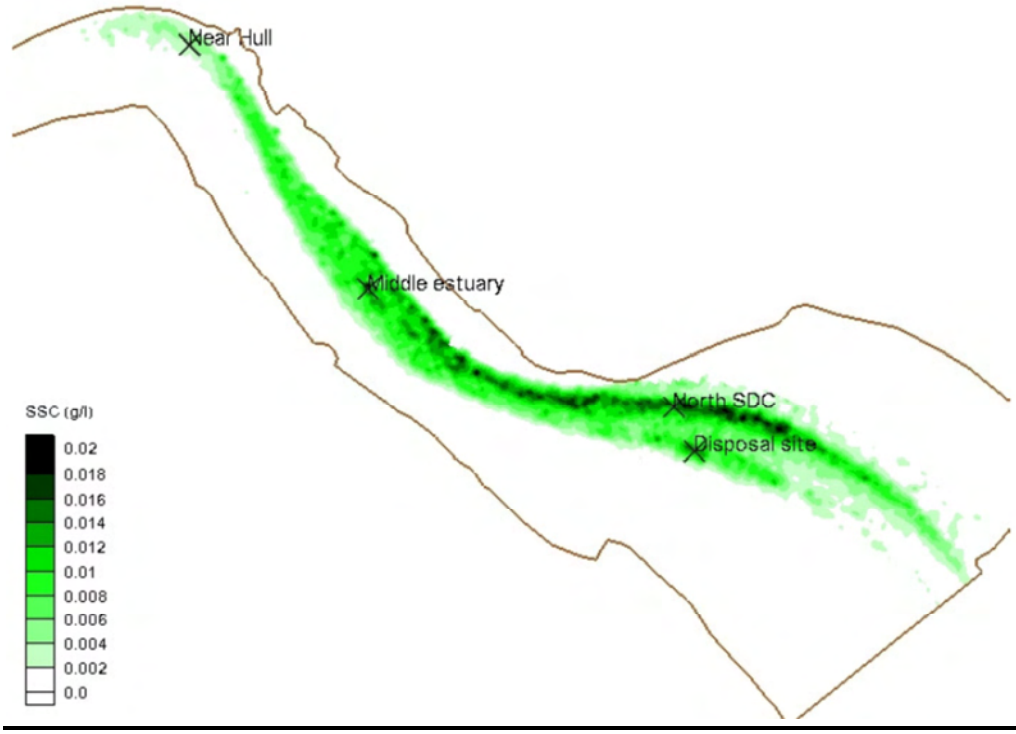
1.3.15 The erodible material will, however, create a plume of sediment (mainly generated during the disposal activity) that could affect sediment particle size distribution in the estuary. The majority of erodible material will be contained within the dynamic plume and settle on the bed of the estuary (ie virtually all coarse material, such as sand and gravels) immediately around the disposal site (approximately within a radius of 100 m). However, a proportion of the finer material will be entrained into the passive plume and will disperse away from the disposal site with the currents. This material will add to background suspended sediment concentrations and may affect sediment particle size as it settles out of the water column onto the bed.

1.3.16 The disposal of erodible sediment excavated during the capital dredge programme may lead to short-term increases in suspended sediment concentrations in the tidal channels within the estuary of up to 80-100 mg/l by the end of the disposal programme, although short lived peaks of 250 mg/l may occur at the disposal site. Increases in suspended sediment concentration at the disposal sites will quickly be dwarfed by background levels, which range between 200 and 1 600 mg/l at the Humber Sea Terminal (to the north of the AMEP) (IECS, 2010). Upon cessation of sediment release suspended sediment concentrations quickly decrease as the sediment disperses within the estuary, or leaves the estuary on successive outgoing tides. Modelling of the effects of sediment disposal at the Middle Shoal Disposal Site, has shown dispersion of the erodible material is likely to extend along the coastline from the Humber Bridge to past the estuary mouth (see *Figure 1.3*). This large area of dispersion means that any accumulation of the disposed sediment on intertidal areas will be negligible compared with accumulation due to natural processes, and ongoing maintenance dredging activities that are effectively part of the background. Changes in subtidal sediment composition may occur and will be greatest in the

areas subject to highest deposition rates (Ware *et al*., 2010), which includes the area affected by the dynamic plume as described above.

1.3.17 Subtidal sandbanks, notably the Middle Shoal, located a short distance away from the disposal site (HU080) are unlikely to be affected long term by any deposition of fine grained sediments as a result of sediment disposal. These banks are not located within the main path of the sediment plume and prevailing tidal currents and wave action in these areas are strong enough to suspend freshly deposited fine sediments, which are then carried away by the currents. As a result any change in sediment composition will be short lived.

Figure 1.3 ***Average Suspended Sediment Concentration during the Last Day of a 14-day Period of Intermittent Sediment Release at the Middle Shoal Disposal Site***



Secondary Changes

1.3.18 Changes to intertidal and subtidal features may occur as a result of changes to the hydrodynamic and morphodynamic regimes. Further details on changes to hydrodynamic and morphodynamic regimes from the Project can be found in Chapter 8 of the ES and the subsequent supporting studies.

It is worth noting the Project will not result in a significant net loss of sediment from the estuary system. All dredged sediment will be retained in the Humber Estuary system through disposal at the

designated sites with the exception of a small fraction of resuspended finer sediments that will leave the estuary on successive tides.

1.3.19 Changes to the hydrodynamic and morphodynamic regimes at both the quay site and disposal site may result in changes to the amount and distribution of intertidal habitat, such as saltmarsh and mudflats. Modelling studies have been conducted to determine where changes to the hydrodynamic and/or morphodynamic regime may result in short to medium term changes to the intertidal habitat in the vicinity of the quay (ie within a few years). However, the model runs take into consideration the new bathymetry due to the dredged areas as well as the presence of the quay. Hence it is not possible to identify the predicted effects of dredging alone on the long term geomorphology of the estuary from this modelling, and the discussion below also includes effects from the quay.

1.3.20 The results of the hydrodynamic modelling suggest that away from the proposed quay the combined impact of the development on intertidal and subtidal areas will be negligible in comparison with natural variation ie no major morphologic change is likely in the wider estuary and the character of mudflat and saltmarsh areas will be maintained following the development of the Project. In addition no change to the submerged gravel areas in the channel off Killingholme is predicted by the model. Overall estuarine morphology and morphodynamics will continue to be controlled by wider natural estuary processes. It can therefore be concluded that wider hydrodynamic impacts to the estuary from the dredged footprint will be negligible and that there will be no secondary effects in terms of sediment transport, sediment deposition and particle size distribution that could in turn affect ecological populations.

1.3.21 However, locally to the quay a dynamic change can be expected to occur that may cause a local shift in morphologic pattern.

1.3.22 Development of intertidal mudflat and saltmarsh is expected to occur adjacent to the development at the expense of other intertidal and subtidal habitat due to the significantly reduced tidal-flow regime. It is very likely that any short-term erosion caused by extreme wave events will be reversed as the following calm tidal conditions act to build up the area affected. Mudflat development is likely to dominate initially but low energy zones will be conducive to saltmarsh development. Evidence of intertidal morphologic development associated with man-made structures elsewhere in the estuary suggest that this will be a slow process with saltmarsh establishing over decadal timescales.

1.3.23 *Figure 1.4* presents the results of the 3D mud transport modelling using the proposed quay design and shows the predicted patterns of changes to potential erosion and deposition of fine sediments, including the areas that may develop into intertidal saltmarsh and mudflat. The area marked with a pink oval highlights the area of increased intertidal levels (approximately 1.5 m) due to the Humber International Terminal (HIT) reclamation. Similar effects are expected to the north of the AMEP, as shown in *Figure 1.4*. As with HIT a stable form northwest of AMEP would likely not be reached for many years.

Figure 1.4 Predicted Increases to Deposition or Erosion after a Spring-neap Cycle (14-15 days, AMEP minus baseline)

1.3.24 The Humber is a large and dynamic estuary and over the same decadal time scales of likely project induced changes, similar changes (in terms of habitats being 'lost', 'created', evolving or being 'replaced' by others) are likely to be occurring naturally elsewhere in the wider estuary. In this context the long term local effects of the Project on the intertidal area due to the presence of the dredged channel and turning area can be regarded as being not significant . Given the long term local loss of subtidal area to intertidal area and the conservation objectives of the estuary the impact to subtidal area is considered to be significant.

Summary of Impacts

1.3.25 Dredging and dredged material disposal will cause changes to the subtidal and intertidal features of the estuary. Much of the dredged area will remain subtidal, although the depth and sediment type will change, especially in the berthing pocket where a layer of aggregate will be placed to transfer load to lower strata. The dredged material disposal site will also remain subtidal although depth and sediment particle size changes will occur. The subtidal sediment type along the plume path may also change, although the subtidal sandbanks, notably the Middle Shoal, are unlikely to be affected long term by any deposition of fine grained sediments as a result of sediment disposal due to the action of waves and currents. A small proportion of subtidal habitat will be lost to the quay, which in itself provides additional hard substrata habitat in the estuary (see *Chapter 10* in the ES for details).

1.3.26 The reclamation area for the quay will also cause a loss of some intertidal area. A Compensation Site located on the north shore of the Humber has been designed to compensate for the loss of estuarine habitat due to the AMEP. Over time the Compensation Site will develop into a combination of saltmarsh and mudflat. Development of intertidal mudflat and saltmarsh is also expected to occur adjacent to the development due to the significantly reduced tidal-flow regime, but this would be at the expense of other intertidal and subtidal habitat.

1.4 IMPACTS TO AQUATIC ECOLOGY

1.4.27 *Section 1.1* lists the five main areas in which physical changes caused by dredging may lead to effects on ecological receptors. These are discussed below taking into consideration the physical changes described in *Sections 1.2* and *1.3* above.

1.4.28 Maintenance dredging and other relevant operational activities are included below as appropriate.

Loss of Subtidal Habitat and Benthic Communities

1.4.29 Loss of benthic habitat will occur as a result of dredging and dredged material disposal. Loss of subtidal area due to dredging and dredged material disposal has been described in *Section 1.3: Impacts to Subtidal and Intertidal Features* above. Impacts on benthic communities and the subtidal area as a habitat are discussed below.

1.4.30 Dredging will cause a direct change to subtidal habitat through substrate removal and depth changes as well as altering the habitat type

due to changes in sediment particle size distribution. Benthic communities in the direct footprint of the dredged areas will be lost. Recovery of benthic communities following dredging and dredged material disposal may occur, however, it will depend on the nature of the new sediment as well as sources and types of re-colonising animals. Full recovery of macrobenthic invertebrates from dredging activities in soft subtidal habitats has been recorded to take between two and three years (Borja *et al*., 2010), however, given the predicted sedimentation at the AMEP regular (possibly annual) maintenance dredging will be required and benthic communities will not fully recover. Full recovery at the disposal sites is also unlikely given the regular use of the sites by this and other projects and a recovery time of more than 1.5 years (Borja *et al*., 2010). The disturbed areas are therefore likely to become dominated by opportunistic species. Loss of the current benthic community as a result of habitat loss will be a permanent effect. It was assessed in the ES, along with the footprint effects of the quay as being significant and is also assessed as significant in its own right.

1.4.31 The subtidal habitat (predominantly mud) is widespread in the vicinity of the AMEP and in the estuary, however, the type of habitat may locally differ due to sediment particle size changes and there will be a reduction of shallow subtidal area. Changes to the wider ecosystem structure and functioning in terms of intertidal and subtidal habitat availability and complexity may occur. However, no loss of benthic species diversity or benthic species of conservation concern is expected. In addition, the Compensation Site at Cherry Cobb Sands will provide an additional area of intertidal habitat to compensate for the loss caused by the Project.

Habitat and Benthic Communities Disturbance from the Sediment Plume and Sediment Deposition

1.4.32 Habitat disturbance will occur as a result of sediment plumes from dredging and dredged material disposal. Habitats that may be affected are the intertidal, subtidal and water column habitats.

1.4.33 The construction of AMEP requires a significant capital dredging operation. As previously described in *Section 1.3*, disposal of the stiff glacial till clay is unlikely to affect habitats as it is not expected to add significantly to background suspended sediment concentrations or disperse outside the dumping ground due to the strongly cohesive nature of the material.

1.4.34 The disposal of erodible material may affect the water column habitats and smother benthos as both dynamic and passive plumes are likely to

develop. Sediment plumes from dredging disperse both vertically and horizontally in the water column and the extent and area over which they disperse are dependent on several factors, including the strength and direction of currents and winds and the sediment particle size (Posford Duvivier Environment and Hill, 2001). Although the majority of erodible material will be contained within the dynamic plume and settle on the bed of the estuary immediately around the disposal site (approximately within a radius of 100 m), a proportion of the finer material will be entrained into the passive plume and will disperse away from the disposal site with the currents and affect the water column habitat.

1.4.35 *Section 1.3* describes the increase in suspended sediment concentration due to the project as well as the already high background levels. In summary there is high natural variation and range in suspended sediment concentrations in the Humber Estuary. Therefore increases in sediment concentration due to disposal and the likely concentrations during dredging are within the general range of suspended sediment concentrations found in the Humber. The water column habitat is unlikely to be affected by increased suspended sediment concentration caused by the plume.

1.4.36 The Humber Estuary supports high macrobenthic biomass but low diversity and few rare species (Mieszkowska, 2010). Benthic communities from habitats with high natural turbidity, such as the Humber, are generally less sensitive and more resilient to disturbance by increased levels of turbidity (Eggleton *et al.*, 2011). However, some changes in benthic communities (ie a reduction in density and diversity) may occur as a result of smothering and/or changes in sediment composition; these changes will be greatest in the areas subject to highest deposition rates (Ware *et al.*, 2010). Disposal sites within the Humber are frequently used and benthic communities in these areas are likely to already be disturbed and/or have modified their structures to the ambient conditions. Disposal sites for non-erodible material are separate to those for erodible material and are used less frequently. Some individuals may be lost at the dredged material disposal site, or in areas of high deposition through smothering and/or the clogging filter feeding apparatus. However, many benthic organisms found in the Humber, such as the cockle *Cerastoderma edule* and the ragworm *Hediste diversicolor* (Fujii, 2007), are relatively tolerant to physical disturbance and smothering, and are able to either survive a thin covering by sediments, or to move away, burrow up or extend siphons into the water column. Recovery of benthic communities is also expected within three years, as described above, although given the likely requirement for regular maintenance

dredging, the communities may not fully recover and may be dominated by opportunistic species.

1.4.37 Overall, the high natural variability of suspended sediments in the Humber Estuary, natural levels of sediment deposition and resuspension, the general dynamism of the benthic environment and the natural recoverability of benthic communities indicates that the benthic communities role in ecosystem functioning will not be affected due to habitat disturbance from the sediment plume. Impacts due to sediment mobilisation and deposition will be not significant.

Disturbance to Fish and Marine Mammals from Dredging Noise

1.4.38 Direct impacts to fish and marine mammals may occur as a result of construction noise and vibration. Noise and vibration will occur during dredging of the approach channel, turning circle and quay location as well as during the piling required for quay construction. Underwater noise and vibration can affect fish distributions and marine mammal behaviour.

1.4.39 Dredging emits continuous broadband sound during operations, mostly in the lower frequencies. Source levels range from 160 to 180 dB re 1 µPa at 1 m (maximum ~ 100 Hz) (Götz *et al*., 2009). Most energy has been found to be below 500 Hz. Dredging noise is expected to occur for relatively long periods, however, given that the estuary is busy and dredging noise is within the range of the general shipping noise that is likely to exist in the estuary it is considered unlikely to affect the distributions of fish or marine mammals. Likewise, vessel movements as part of operation of the AMEP are unlikely to significantly affect the availability of fish foraging areas or migration routes given existing levels of underwater noise and although increases in traffic are likely to be long term, vessel movements for the AMEP site will be intermittent. As such the impact of noise from dredging on fish and marine mammals is not discussed further. *Chapter 10* in the ES assesses impacts from piling.

Secondary Changes to Habitats

1.4.40 Changes to intertidal and subtidal habitats may occur as a result of changes to the hydrodynamic and morphodynamic regimes. Changes to the hydrodynamic and morphodynamic regimes at both the quay site and disposal site may result in changes to the amount and distribution of intertidal habitat, such as saltmarsh and mudflats. Indirect changes to intertidal and subtidal areas are discussed above in

Section 1.3: Impacts to Subtidal and Intertidal Features. These changes will not result in significant effects on ecological populations.

Disturbance to Fish and Fish Eggs/Larvae from Habitat Loss and Disturbance

1.4.41 Indirect impacts to fish may occur as a result of loss of habitat under the footprint of the project and habitat disturbance from dredging and dredge disposal. A number of UK BAP species may occur in the vicinity of AMEP. These include twaite and allis shad, European eel, sea and river lamprey, smelt, Atlantic salmon and cod. The impacts to fish from habitat loss and disturbance may result in behavioural changes, for example temporary avoidance of areas with low water quality due to increased turbidity.

1.4.42 Habitat disturbance from dredging and dredge disposal operations is unlikely to have long-term impacts on fish. Fish are mobile and will avoid any area affected by disturbance, and are able to return once the disturbance has ceased (Posford Duvivier Environment and Hill, 2001). The Humber Estuary is one of the most turbid estuaries in Europe, however, the fish assemblage within the Humber is not influenced by turbidity (Marshall and Elliott, 1998). Turbidity levels above 14 g/l have been found to have a physiological effect on fish (eg clogging of the gills with suspended solids) (Marshall and Elliott, 1998). This value is more than double the maximum concentrations found naturally within the Humber and significantly higher than concentrations predicted by the sediment plume (see above). Fish eggs and larvae are more sensitive to suspended sediment impacts than older life stages and concentrations of suspended material have to be on the scale of milligram per litre (mg/l) to be lethal to fish eggs and larvae (compared to g/l for adult fish) (Engell-Sorensen and Skyt, 2003). However, given the naturally high suspended sediment concentrations found in the Humber it is unlikely dredging operations will have an impact on fish populations.

1.4.43 Dissolved oxygen concentrations in the water column may be temporarily reduced as a result of dredging or dredged material disposal, which can affect fish growth and cause mortality. Oxygen demand following dredge disposal has been shown to rapidly increase for 5-10 minutes, followed by a five to ten times slower rate of dissolved oxygen consumption (Jabusch *et al*., 2008), allowing enough time for fish to avoid the area if dissolved oxygen levels are reduced significantly. However, given the current good dissolved oxygen concentrations and strong tidal currents in the middle section of the Humber Estuary oxygen levels are unlikely to be reduced to potentially

adverse levels. Reduced dissolved oxygen concentration due to sediment resuspension is expected to be localised and short term only (Jabusch *et al*., 2008).

1.4.44 Secondary impacts to fish, as described above, are considered temporary and localised. Although some behavioural changes may occur the area affected is not considered likely to affect the life cycle or migration routes of these fish populations given the total available area of the estuary for foraging and the potential for avoiding disturbed areas during spawning runs.

1.4.45 Loss of nursery area for commercial fish species is, however, a permanent impact. Intertidal and shallow subtidal mudflat areas act as a nursery area to commercial fish species caught in the North Sea, such as common sole and whiting. In total approximately 45 ha of intertidal and subtidal area will be lost due to AMEP from a total of 26,180 ha of the available intertidal and subtidal area in the outer and middle estuary (ie less than 0.2%). A recruitment loss to commercial fish stocks and marine and coastal fisheries may occur as the intertidal and shallow subtidal area is an important influence on juvenile growth and recruitment. A theoretical impact on the nursery function of the estuary could be expected, however, the Compensation Site will provide additional intertidal habitat and will provide a nursery area as the habitat develops. The actual number of adult fish potentially lost as a result of loss of nursery area is not easily quantifiable. However the area is small and against a background of natural predation of juveniles the effect on the adult population will be indistinguishable from natural variations.

Summary of Impacts

1.4.46 Dredging and dredged material disposal will cause some impacts on aquatic ecology. A loss of and change in the benthic communities in the dredging area and dredged material disposal site will be a permanent effect due to changes in depth, changes in sediment composition (including aggregate placement in the berthing pocket) and maintenance dredging preventing full recovery of the original communities. Changes to the wider ecosystem structure and functioning in terms of intertidal and subtidal habitat availability and complexity may occur. However, no loss of benthic species diversity or benthic species of conservation concern is expected. A loss of nursery area for commercial fish species may also occur due to habitat loss and disturbance. However, the subtidal habitat (predominantly mud) is widespread in the vicinity of the AMEP and in the wider estuary and

the Compensation Site will provide additional intertidal habitat to compensate for the loss caused by the Project.

1.4.47 No impacts are expected to fish from increased turbidity due to the naturally high levels in the estuary. Dredging noise is not expected to affect fish or marine mammals as the estuary is busy and dredging is generally within the range of normal shipping.

1.4.48 Other than the loss of subtidal habitat and benthic communities to the dredging footprint for the berth and turning area, none of the above impacts are assessed as significant.

1.5 MITIGATION

1.5.49 Mitigation measures for dredging and dredged sediment disposal as presented in the ES are outlined below:

- Reduce the dredged area to as small as reasonably practicable for the quay and for safe manoeuvring of vessels.
- Reduce the percentage of solids in the overspill to be as low as possible using suitably qualified and experienced contractors.
- Inspection and monitoring of dredging activities to evaluate the effectiveness of impact prevention strategies, and adjust where necessary.
- Optimise the trailing velocity of the dredger to minimise raising suspended sediments during dredging operations.
- Minimise the need for overflowing during dredge operations by recirculation of jetting water.
- Minimise the need for maintenance dredging.

1.6 REFERENCES

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