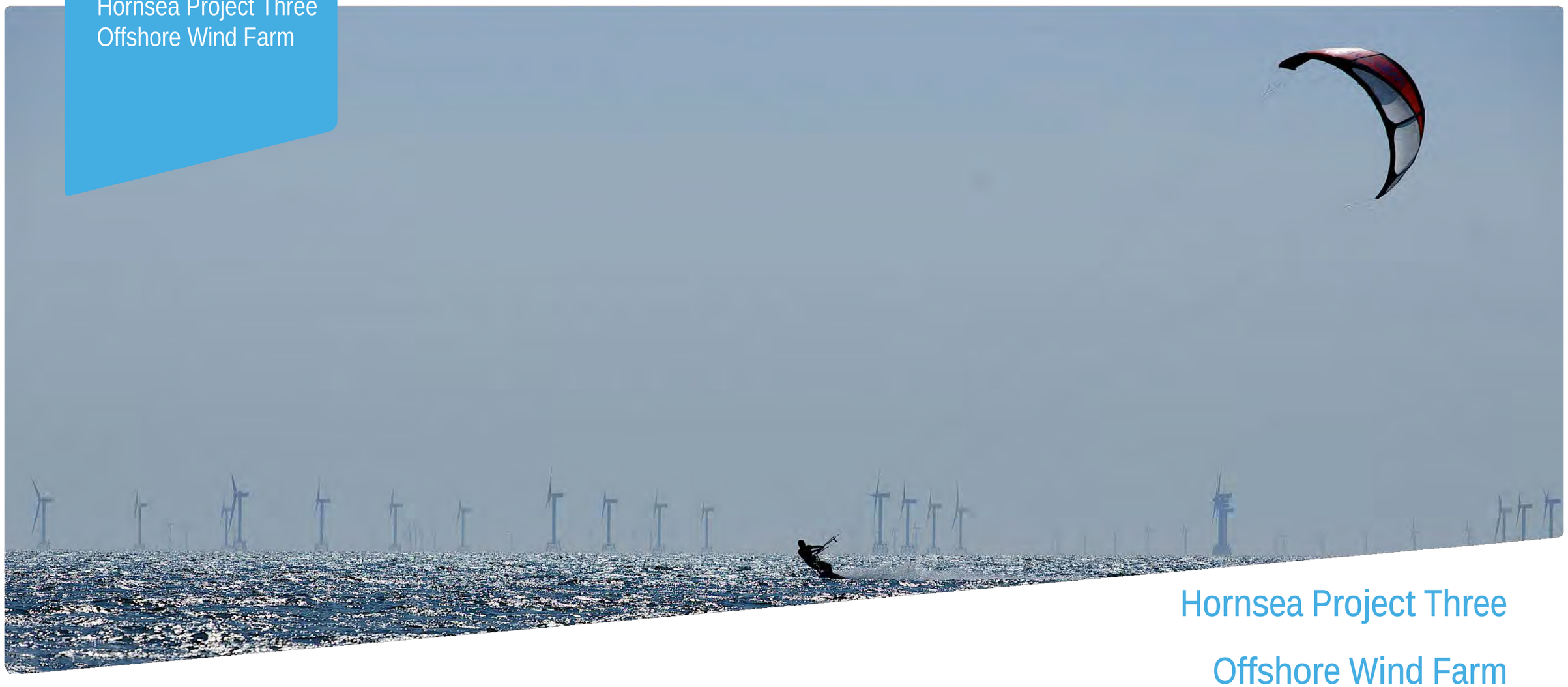
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Preliminary Environmental Information Report:
Chapter 1 – Geology and Ground Conditions (Part 2)

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 3

Chapter 1: Geology and Ground Conditions

Liability

This report has been prepared by RPS, with all reasonable skill, care and diligence within the terms of their contracts with DONG Energy Power (UK) Ltd.

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Front cover picture: Kite surfer near one of DONG Energy's UK offshore wind farms © DONG Energy Hornsea Project Three (UK) Ltd., 2016.

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1.9 Impact assessment criteria

1.9.1.1 The criteria for determining the significance of effects is a two stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts. The terms used to define sensitivity and magnitude are based on those used in the Design Manual for Roads and Bridges (Highways Agency, 2009) methodology, which is described in further detail in volume 1, chapter 5: Environmental Impact Assessment Methodology.

1.9.1.2 The criteria for defining sensitivity in this chapter are outlined in Table 1.10 below.

Table 1.10: Definition of terms relating to the sensitivity of the receptor.

Sensitivity	Definition used in this chapter
Very High	Receptor is very high value or critical importance to local, regional or national economy. Receptor is highly vulnerable to impacts that may arise from the project and recoverability is long term or not possible.
High	Receptor is of high value with reasonable contribution to local, regional or national economy. Receptor is generally vulnerable to impacts that may arise from the project and recoverability is slow and/or costly.
Medium	Receptor is of medium value with small levels of contribution to local, regional or nation economy. Receptor is somewhat vulnerable to impacts that may arise from the project and has moderate to high levels of recoverability.
Low (or lower)	Receptor is of low value with little contribution to local, regional or national economy. Receptor is not generally vulnerable to impacts that may arise from the project and/or has high recoverability.
Negligible	Receptor is of negligible value with no contribution to local, regional or national economy. Receptor is not vulnerable to impacts that may arise from the project and/or has high recoverability.

1.9.1.3 The criteria for defining magnitude in this chapter are outlined in Table 1.11 below.

Table 1.11: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition used in this chapter
Major	Total loss of ability to carry on activities. Impact is of extended temporal or physical extent and of long term duration (i.e. approximately 50 years duration).
Moderate	Loss or alteration to significant portions of key components of current activity. Loss of resource but not affecting integrity of resource. Impact is of moderate temporal or physical extent and of medium term duration (i.e. less than 20 years).
Minor	Some measurable change in attributes, quality or vulnerability. Minor shift away from baseline conditions, leading to a reduction in level of activity that may be undertaken. Impact is of limited temporal or physical extent and of short term duration (i.e. less than 2 years).
Negligible	Very slight change from baseline conditions. Physical extent of impact is negligible and of short term duration (i.e. less than 2 years).
No change	No change from baseline conditions.

1.9.1.4 The significance of the effect upon geology and ground conditions is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The method employed for this assessment is presented in Table 1.12. Where a range of significance of effect is presented in Table 1.12 the final assessment for each effect is based upon expert judgement.

1.9.1.5 For the purposes of this assessment, any effects with a significance level of minor or less have been concluded to be not significant in terms of the EIA Regulations.

Table 1.12: Matrix used for the assessment of the significance of the effect.

		Magnitude of impact				
		No change	*Negligible*	*Minor*	*Moderate*	*Major*
Sensitivity of receptor	*Negligible*	Negligible	Negligible	Negligible or minor	Negligible or minor	Minor
	Low	Negligible	Negligible or minor	Negligible or minor	Minor	Minor or moderate
	Medium	Negligible	Negligible or minor	Minor	Moderate	Moderate or major
	High	Negligible	Minor	Minor or moderate	Moderate or major	Major or substantial
	Very high	Negligible	Minor	Moderate or major	Major or substantial	Substantial

1.10 Assessment of significance

1.10.1 Measures adopted as part of Hornsea Three

1.10.1.1 As part of the project design process, several designed-in measures have been proposed to reduce the potential for impacts on geology and ground conditions (see Table 1.13). This approach has been employed in order to demonstrate commitment to measures by including them in the design of Hornsea Three and have therefore been considered in the assessment presented in section 1.10 below. These measures are considered standard industry practice for this type of development. Assessment of sensitivity, magnitude and therefore, significance includes implementation of these measures. The construction measures set out below would be contained within a Code of Construction Practice which will accompany the Environmental Statement.

Table 1.13: Designed-in measures adopted as part of Hornsea Three.

Measures adopted as part of Hornsea Three	Justification
Construction Phase	
Consultation with Norfolk County Council to further minimise the impacts on the Mineral Safeguarded Areas located along the onshore export cable corridor and the HVAC booster station site.	To minimise the area of mineral resource affected by the project.
Implement measures to protect groundwater during construction, including good environmental practices based on legal responsibilities and guidance on good environmental management in: guidance in: CIRIA C532 Control of Water Pollution from Construction Sites – Guidance for Consultants and Contractors (Masters-Williams, 2001); and CIRIA C648 Control of Water Pollution from Linear Construction Projects (Murnane, Heap, and Swain, 2006).	To help avoid pollution incidents occurring.
A written scheme dealing with contamination of any land and groundwater will be submitted and approved by the Local Authority before any part of the development commences. The scheme will include preliminary risk assessment where appropriate.	To help to deal with potentially contaminated land or groundwater.
Minimise where practicable production of silt and contaminated water by minimising for example: • Disturbance of river bed and bank; • Dewatering and pumping of excavations and subsequent disposal of water; • Runoff from exposed ground and stockpiles; • Plant and wheel washing; • Site roads and river crossings; • Fuel spillages; and • Waste storage and disposal. Mitigation in accordance with CIRIA C650 (Charles and Connolly, 2005).	To reduce the potential for construction and maintenance activities in or near water to cause serious pollution or impact on the bed and banks of a watercourse and on the quality and quantity of the water.
Cable trenching across the SPZ1 areas requires measures to ensure that the principal aquifer is unaffected either directly or indirectly. Appropriate measures will be identified following consultation with the Environment Agency and will be reported within the Environmental Statement. The measures may include agreeing a minimum standoff above the principal aquifer. The depth of superficial deposits would be confirmed via a site investigation to ensure works do not directly impact on the chalk aquifer. Hydrogeological risk assessment meeting the requirements of Groundwater Protection Principles and Practice (GP3) (Environment Agency, 2013), will be undertaken at each trenchless conduit crossing location within a SPZ. Direct Current cabling to be thermally insulated.	To prevent chemical or thermal pollution of a public water supply.
Cable trenching across areas with secondary A or B perched aquifers requires measures to ensure the groundwater quality is not adversely affected and that groundwater does not use the trenches as a conduit to convey groundwater elsewhere. Direct Current cabling to be thermally insulated. Appropriate measures will be identified following consultation with the Environment Agency and will be reported within the Environmental Statement.	To prevent chemical or thermal pollution of secondary aquifers.
Trenchless conduits for onshore watercourse cable crossing points to be a minimum 2 m below the hard bed of the watercourse subject to site investigation confirming a suitable standoff above the chalk principal aquifer. A minimum standoff of 2 m above the chalk aquifer is suggested. Hydrogeological risk assessment meeting the requirements of Groundwater Protection Principles and Practice (GP3) (Environment Agency, 2013), will be undertaken at each trenchless conduit crossing location of a watercourse.	To minimise impacts to principal aquifers.
Site investigations will be undertaken at each proposed HDD location during the detailed design stage to confirm local geological conditions.	To confirm suitability of geology for HDD techniques.
Deep trenchless excavations and deep excavations for pile foundations to be mitigated by casing off perched groundwater units during construction works and sealing off once the casing is removed. Based on guidance in: Piling and Penetrative Ground Improvement Methods on land Affected by Contamination: Guidance on Pollution Prevention (Environment Agency, 2001).	To prevent contamination of groundwater and mixing of different groundwater units.
Implement measures to prevent and control spillage of oil, chemicals and other potentially harmful liquids. Ensure appropriate storage and handling of materials and products to include for example: • Avoidance of oil storage within 50 m of a spring, well or borehole; • Within 10 m of a watercourse • Where oil could run over hard ground into a watercourse; • Secondary containment system that can hold at least 110% of the oil volume stored; and • Avoidance of storage of oil in areas at risk of flooding. In accordance with The Control of Pollution (Oil Storage) (England) Regulations 2001. Refuelling of machinery would be undertaken within designated areas where spillages can be easily contained. Machinery would be routinely checked to ensure it is in good working condition; and any tanks and associated pipe work containing oils and fuels would be double skinned and be provided with intermediate leak detection equipment.	To minimise ground contamination and contaminated runoff to surface water or groundwater.
Used oils will be disposed of properly in accordance with Environmental Permitting (England and Wales) Regulations 2016.	To reduce the risk of soil, surface water and groundwater pollution.

Measures adopted as part of Hornsea Three	Justification
Operational Phase	
Operational practices to incorporate measures to prevent pollution of ground, geology and groundwater, to include emergency spill response procedures, clean up and remediation of contaminated soils.	To reduce the risk of soil, surface water and groundwater pollution.
Decommissioning Phase	
Decommissioning practices to incorporate measures to prevent pollution of geology and ground conditions, to include emergency spill response procedures, and clean up and remediation of contaminated soils. The measures will follow a similar approach to those set out for the construction phase.	To reduce the risk of soil, surface water and groundwater pollution to protect geology and groundwater based on guidance that will be appropriate at the time of decommissioning.

1.10.1.2 In some cases there may be additional mitigation measures required that are not "built in" to the project design ahead of the assessment. These are to be discussed in the sections on Further Mitigation and Future Monitoring sections below.

1.10.2 Construction Phase

1.10.2.1 The impacts of the onshore construction of Hornsea Three have been assessed on geology and ground conditions. The potential environmental impacts arising from the construction of Hornsea Three are listed in Table 1.9 above along with the maximum design scenario against which each construction phase impact has been assessed.

1.10.2.2 A description of the potential effect on geology and ground conditions receptors caused by each identified impact is given below.

Impacts of construction may affect designated geological sites

Magnitude of impact

Weybourne Town Pit SSSI

1.10.2.3 Weybourne Town Pit SSSI, as shown on Figure 1.2, is located outside the onshore cable corridor search area and would not be affected during construction. The impact of magnitude would be **no change**.

Weybourne Cliffs SSSI

1.10.2.4 The eastern section of the Hornsea Three landfall is located within the Weybourne Cliffs SSSI accounting for approximately 4.40% of the total SSSI area.

1.10.2.5 The construction of the Hornea Three landfall using open cut methods at Weybourne Cliffs would lead to direct damage to the geological deposits and also disrupt the natural processes of coastal erosion, with the potential to result in accelerated erosion of previously unexposed deposits. Open cut techniques also would result in the destruction of fossils present in the immediate area of construction and also result in the loss or damage to non-exposed fossils. The predicted impact would be of local extent, medium term duration, continuous and irreversible. The magnitude is therefore considered to be **moderate**.

Kelling Heath SSSI

1.10.2.6 The eastern edge of Kelling Heath SSSI falls within the onshore cable corridor search area. The construction of the onshore export cable corridor would directly disrupt and damage the glacial outwash deposits as a result of soil stripping and storage, compaction from construction vehicles, runoff and potential contamination. The predicted impact would be of local extent, medium term duration, continuous and irreversible. The magnitude is therefore considered to be **moderate**.

Sensitivity of receptor

Weybourne Town Pit SSSI

1.10.2.7 Weybourne Town SSSI is considered to be of national importance due to its glacial till and other glacigenic deposits. The sensitivity of the site is considered to be **very high**.

Weybourne Cliffs SSSI

1.10.2.8 Coastal geological sites form an important part of England's geological resource. Weybourne Cliffs SSSI is designated due to the surface exposure of unusual geological sequences and marine mollusc fossils of the Pastonian and pre-Pastonian age and with potential to also contain fossils of vertebrate. As such the sensitivity to construction activities is considered to be **very high**.

Kelling Heath SSSI

1.10.2.9 Kelling Heath SSSI is considered to be of national importance due to the quality of the glacial outwash plains. It is the shallow and surface materials that are vulnerable to construction works and as such the sensitivity to construction activities is considered to be **very high**.

Significance of the effect

Weybourne Town Pit SSSI

1.10.2.10 The construction of the onshore export cable corridor would not impact Weybourne Town Pit SSSI and therefore, the significance of the effect is considered to be **negligible**, which is not significant in EIA terms.

Weybourne Cliffs SSSI

1.10.2.11 The overall significance of the effect from construction of the Hornsea Three landfall (eastern section) using open cut methods would be **major adverse**, which is significant in EIA terms.

Kelling Heath SSSI

1.10.2.12 The overall significance of the effect from the construction of the onshore export cable route using open cut methods would be **major adverse**, which is significant in EIA terms. If the onshore export cable corridor is micro-routed to be outside the Kelling Heath SSSI boundary, the significance of the effect is considered to be **negligible**. However, if the cable route runs through Kelling Heath SSSI, the significance of the effect is considered to be **major adverse**.

Further mitigation

1.10.2.13 As part of the iterative design process, measures would be considered following the submission of the PEIR to mitigate the potential impacts to designated geological sites. These measures are summarised below.

1.10.2.14 If the western section of the Hornsea Three landfall was constructed as an alternative to the eastern section, the Weybourne Cliffs SSSI would be avoided, the magnitude of impact would be **no change** and the significance of the residual effect would be considered to be **negligible**. Alternatively, the use of HDD at the eastern section of the Hornsea Three landfall would reduce the potential damage to Weybourne Cliffs SSSI. The magnitude of impact would be **negligible** and the significance of the residual effect would be considered to be **minor adverse**, which is not significant in EIA terms.

1.10.2.15 Micro-routing of the onshore export cable route to the east (i.e. outside of the Kelling Heath SSSI boundary) would avoid direct damage to the SSSI. As a result of the micro-routing the magnitude of impact would be **no change**. The residual effect would be of **negligible** significance, which is not significant in EIA terms.

Impacts of construction may result in the loss of mineral resources within Mineral Safeguarded Areas.

Magnitude of impact

1.10.2.16 A review of the Norfolk County Council Mineral Safeguarding Area for sand and gravel shows that approximately 3% of the Mineral Safeguarded Area would be occupied by the onshore elements of Hornsea Three (as defined in 1.1.1.1). The Mineral Safeguarded Area plans are primarily derived from the BGS Mineral and resources map (Harrison *et al.*, 2004), and guidance from Norfolk County Council (2014) recognises that the mineral deposits in Norfolk are highly variable and that the data used to define the Mineral Safeguarded Areas is general in nature. Given the relatively small proportion of the Mineral Safeguarded Area that would be occupied by Hornsea Three (as shown in Figure 1.3) the impact is predicted to be of limited physical extent but would lead to a reduction in the level of activity that could be undertaken (i.e. potential use of the mineral resource). The magnitude is therefore, considered to be **minor**. This assumes that a viable mineral resource is present, but is not extracted prior to construction.

Sensitivity of receptor

1.10.2.17 Sand and gravel resources are relatively abundant throughout Norfolk, however the resource is considered to be of regional value, therefore the sensitivity of these Mineral Safeguard Areas is considered to be **medium**.

Significance of the effect

1.10.2.18 The overall significance of the effect on mineral resources within the Mineral Safeguarded Areas assuming that the resource is not extracted prior to construction is deemed to be **minor**.

1.10.2.19 The effect will, therefore be of **minor adverse** significance, which is not significant in EIA terms.

Further mitigation

1.10.2.20 The area of the Mineral Safeguarded Area occupied by Hornsea Three is likely to reduce following the refinement of the onshore export cable. The Applicant will continue to work with Norfolk County Council regarding the Mineral Safeguarded Area to agree how to minimise the impacts on mineral resources as the project progresses.

Impacts of construction may cause disturbance or contamination of secondary aquifers. The WFD status of the groundwater may also be affected.

Magnitude of impact

1.10.2.21 Direct impacts may occur to the secondary aquifers underlying the onshore cable corridor search area (and onshore HVAC booster station and onshore HVDC converter/HVAC substation) due to the intrusive nature of trenching and piling. The nature of the impact would include potential disruption to groundwater flow and reduction in groundwater quality. The magnitude of impact would depend on the nature and depth of the superficial deposits (and aquifer unit) in relation to the proposed depth of excavation.

1.10.2.22 As the secondary aquifers are likely to be at relatively shallow depth (based on the BGS logs), the impact is predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

1.10.2.23 The secondary aquifers, which form part of the superficial deposits are deemed to be of medium vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of the effect

1.10.2.24 The overall significance of the effect on disturbance or contamination of secondary groundwater aquifers based on the situation which includes the integration of measures adopted in Table 1.13 is deemed to be minor.

1.10.2.25 The effect will, therefore, be of **minor adverse** significance which is not significant in EIA terms.

Impacts of open cut trench construction may affect the groundwater quality of the principal aquifer including at SPZs. The WFD status of the groundwater might also be affected.

1.10.2.26 There are eight SPZs located within the geology and ground conditions study area, six of which are in the onshore cable corridor search area including one SPZ1. The SPZs relate to the underlying chalk aquifer which is covered by superficial deposits with the exception of a number of small chalk exposures; however none of the chalk exposures correspond with the location of SPZs. The majority of the geology and ground conditions study area is underlain by superficial deposits.

Magnitude of impact

1.10.2.27 Given the relatively shallow depth of the cable trench (i.e. up to 2 m deep), the open cut trench construction would generally occur within the superficial deposits and would not directly disturb the groundwater within the principal aquifer. However there is the potential for impacts to occur from vertical hydraulic connections between shallow perched groundwater and principal aquifer groundwater during piling, or during open cut trench construction, particularly in locations where the superficial deposits are shallow.

1.10.2.28 The impacts are predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor indirectly. The magnitude of impact on the groundwater quality within the principal aquifer (including the SPZ2 and SPZ3) and the WFD status of the groundwater is therefore, considered to be **minor**.

1.10.2.29 The impacts on the abstraction borehole from construction of the cable trench across the single SPZ1 footprint (which is underlain by of glacial sand and gravels and till clays, as identified in BGS borehole TG10NW14, and presented in volume 6, annex 1.1: Borehole Logs) is considered to be **minor**. This is due to the presence and depth of superficial deposits overlying the principal aquifer in this location which would provide a degree of attenuation.

Sensitivity of receptor

1.10.2.30 The majority of the principal aquifer in the geology and ground conditions study area is overlain by superficial deposits. The nature of these deposits is variable and includes lower permeability glacial till clays and also more permeable deposits (alluvium, river terrace gravels and sand and gravels). The aquifer has a slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be **high**.

1.10.2.31 Where the SPZ2 and SPZ3 cross the geology and ground conditions study area, the sensitivity is considered to be **high**.

1.10.2.32 Where the SPZ1 crosses the onshore cable corridor search area, the sensitivity can be considered to be **very high**.

Significance of the effect

1.10.2.33 The overall significance of the effect on disturbance or contamination of the principal groundwater aquifer (and SPZ2 and SPZ3), based on the situation which includes the integration of measures adopted in Table 1.13, which will be incorporated into a CoCP post PEIR, is deemed to be **minor**. Where the SPZ1 crosses the onshore cable corridor search area, the significance is deemed to be **moderate**.

1.10.2.34 The effect will, therefore, be of **minor adverse** significance which is not significant in EIA terms. The exception is in the SPZ1 where the effect will be of **moderate adverse** significance which is significant in EIA terms.

1.10.2.35 The proposed mitigation measures (see Table 1.13) will be discussed in detail with the Environment Agency following the submission of the PEIR to identify opportunities to minimise the magnitude of impact at the SPZ1.

Impacts of trenchless conduit construction and piling works (potentially required for the construction of the onshore HVAC booster station or onshore HVDC converter/HVAC substation) may affect the groundwater quality of the principal aquifer, including conduit construction within any SPZs. The WFD status of the groundwater might also be affected.

Magnitude of impact

1.10.2.36 Direct impacts to the principal aquifer may occur from deeper ground workings related to horizontal drilling operations for cable installation beneath surface watercourses or infrastructure. The Environment Agency will be consulted on an appropriate standoff between the trenchless conduit and the chalk which will be confirmed following a site investigation and hydrogeological risk assessment. A similar approach may be followed where piling is required to provide foundation for the onshore HVAC booster station and onshore HVDC converter/HVAC substation.

1.10.2.37 The impacts are predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude of impact on the principal aquifer (including the SPZ2 and SPZ3) and the WFD status of the groundwater is therefore, considered to be **minor**.

1.10.2.38 The impacts on the abstraction borehole from cable trench across the one SPZ1 footprint which is underlain by glacial sand and gravels and till clays (as identified in BGS borehole TG10NW14 and presented in volume 6, annex 1.3: Geology and Ground Conditions) is considered to be **minor**.

Sensitivity of receptor

1.10.2.39 The principal aquifer, which underlies the superficial deposits beneath the onshore cable corridor search area, the onshore HVAC booster station and onshore HVDC converter/HVAC substation, is deemed to be of high vulnerability where it is overlain by low permeability glacial till clays. Where the principal aquifer is overlain by more permeable deposits (alluvium, river terrace gravels and sand and gravels); the aquifer has a slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be **high**. Where the SPZ1 crosses the onshore cable corridor search area, the aquifer sensitivity can be considered to be **very high**.

Significance of the effect

1.10.2.40 The overall significance of the effect of disturbance or contamination of the principal groundwater aquifer based on the situation which includes the integration of measures adopted in Table 1.13 is deemed to be **minor**. Where the SPZ1 crosses the onshore cable corridor search area, the significance is deemed to be **moderate**.

1.10.2.41 The effect will, therefore, be of **minor adverse** significance which is not significant in EIA terms. The exception is in the SPZ1 where the effect will be of **moderate adverse** significance which is significant in EIA terms.

1.10.2.42 The proposed mitigation measures (see Table 1.13) will be discussed in detail with the Environment Agency following the submission of the PEIR to identify opportunities to minimise the magnitude of impact at the SPZ1.

Impacts of construction may affect the quantity and quality of surface waters fed by groundwater. The groundwater WFD status might also be affected.

Magnitude of impact

1.10.2.43 Indirect impacts may occur from hydraulic connections between shallow perched groundwater affected by trenching or piling construction.

1.10.2.44 The impact is predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

1.10.2.45 Surface water courses in hydraulic connection with secondary aquifer units which form part of the superficial deposits beneath the whole of the site are deemed to be of moderate vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of the effect

1.10.2.46 The overall significance of the effect of indirect disturbance or contamination of surface watercourses based on the situation which includes the integration of measures adopted in Table 1.13 is considered to be **minor**.

1.10.2.47 The effect will, therefore, be of **minor adverse** significance which is not significant in EIA terms.

Future monitoring

1.10.2.48 With the exception of the impact on designated sites and groundwater quality in the principal aquifer at SPZ1, the effects of construction are at worst minor adverse and it is not proposed to undertake any future monitoring.

1.10.2.49 The need for monitoring during construction at SPZ1 will be discussed with the Environment Agency following the submission of the PEIR.

1.10.3 Operational and maintenance phase

1.10.3.1 The impacts of the onshore operation and maintenance of Hornsea Three have been assessed on geology and ground conditions. The environmental impacts arising from the operation and maintenance of Hornsea Three are listed in Table 1.9 along with the maximum adverse scenario against which each operation and maintenance phase impact has been assessed.

1.10.3.2 A description of the potential effect on geology and ground conditions receptors caused by each identified impact is given below.

Impacts of operations and maintenance may affect the water quality of secondary aquifers and any associated surface waters together with the principal aquifer. The WFD status might also be affected.

Magnitude of impact

1.10.3.3 Indirect impacts may occur to the secondary aquifers (and any associated surface waters) together with the principal aquifer underlying the onshore HVAC booster station and onshore HVDC converter/HVAC substation from spilled chemicals (e.g. oils, greases, lubricants and other chemicals) used during the routine maintenance. The magnitude of the impact is dependent on the depth of the aquifer unit in relation to the proposed depth of excavation.

1.10.3.4 The impact is predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

1.10.3.5 The secondary aquifers, which form part of the superficial deposits are deemed to be of medium vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

1.10.3.6 Surface water courses in hydraulic connection with affected secondary aquifer units are deemed to be of medium vulnerability, but of high recoverability and medium value. The sensitivity of this receptor is therefore considered to be medium.

1.10.3.7 The principal aquifer, which underlies the superficial deposits beneath the whole of the site, is deemed to be of high vulnerability beneath low permeability glacial till clays, and of very high vulnerability beneath more permeable alluvium, river terrace gravels and sand and gravels; and of slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be high.

Significance of the effect

1.10.3.8 The overall significance of the effect on disturbance or contamination of principal and secondary groundwater aquifers based on the situation which includes the integration of measures adopted in Table 1.13 is deemed to be minor.

1.10.3.9 The effect will, therefore, be of minor adverse significance which is not significant in EIA terms.

Impacts of operation may affect groundwater quality from thermal effects of underground power cables. The WFD status of the groundwater might also be affected.

1.10.3.10 Soil thermal resistivity is important in dissipating the heat generated by electricity flow through the transmission cable (conductor). A resistance to heat flow between the cable and the ambient environment causes the cable temperature to rise. Catastrophic failure can occur when cable temperatures rise to beyond their operating limits. In the case of underground cables the soil is in the heat flow path between the cable and the ambient environment, and therefore forms part of the thermal resistance. Hence soil thermal properties are an important part of the overall design, and may account for over 50% of the total thermal resistance (Campbell and Bristow, 2014).

1.10.3.11 Clearly whilst it is important to keep the cables within safe operating temperatures there is an effect on the surrounding ambient environment caused by the heat transfer. Assuming no forced cooling, underground cable systems have to dissipate the heat associated with losses via the surrounding soil. A cross-linked polyethylene (XLPE) cable system operated at nominal capacity and with a conductor temperature close to 90°C dissipates about 50 $W.m^{-1}$ to 100 $W.m^{-1}$ (Watts per linear metre).

1.10.3.12 Even assuming stationary full load conditions, the impact on soil temperature has been found to be strictly local and very limited, with temperature rises at the surface directly above a cable not exceeding 1 to 2 degrees Kelvin (K) (Campbell and Bristow, 2014). Makhkamova (2011) investigated the effects of dynamic changes in the surrounding environmental conditions of conductors using Computational Fluid Dynamic Methods. The computer models specifically considered the effects of changes in soil moisture, seasonal (winter/summer) temperatures and wind speed on buried underground cables in various arrangements using a 1600 mm x 1600 mm computational domain for single cables and 2500 mm x 2500 mm domain for grouped cables – three single cables buried in flat formation and three cables buried in trefoil formation. The soil temperature increase in response to heat loss by electrical flow through the conductor temperature decreased rapidly with increasing distance from the cables and the heating effect was undetectable beyond 1200 mm either side of the cables in both the horizontal and vertical planes.

1.10.3.13 Nevertheless, in a region of about 0.5 m around a highly loaded cable, soil can dry out due to the generated heat which results in a reduced heat transfer capability and is therefore undesired. For that reason cables are often backfilled with a thermally stabilised layer consisting of concrete or sand blends that guarantee a specific heat resistance of less than 1.0 $W.m^{-1}$. This approach would be adopted for Hornsea Three.

1.10.3.14 The thermal effects of properly installed cables in a thermally stabilised layer will be undetectable more than 1200 mm from the cables in both horizontal and vertical planes. Installation using trenchless technology within 2 m of the chalk would have at worst a minor effect on local superficial deposit temperatures and would probably be undetectable at rock head.

Magnitude of impact

1.10.3.15 As a result of the review of the thermal effects of underground cables above, the thermal impact is predicted to be of local spatial extent within the immediate vicinity of each cable within the ground and any aquifer unit, but of long term duration, of continual occurrence and high reversibility. It is predicted that the impact will affect the receptors indirectly. The magnitude is therefore, considered to be minor. The downstream impact on any groundwater dependent watercourses is considered to be minor.

Sensitivity of receptors

1.10.3.16 The secondary groundwater aquifers which form part of the superficial deposits are deemed to be of medium vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

1.10.3.17 Surface watercourses in hydraulic connection with affected secondary aquifer units are deemed to be of medium vulnerability, but of high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

1.10.3.18 The principal aquifer which underlies the superficial deposits beneath the onshore cable corridor search area, onshore HVAC booster station and onshore HVDC converter/HVAC substation is deemed to be of high to very high vulnerability and of slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be high.

Significance of effect

1.10.3.19 The significance of the effect of thermal pollution on secondary groundwater aquifers and groundwater dependent surface watercourses based on the situation which includes the integration of measures adopted in Table 1.13 is considered to be minor.

1.10.3.20 The overall significance of the effect of thermal pollution on the principal groundwater aquifer based on the situation which includes the integration of measures adopted in Table 1.13 is deemed to be minor.

1.10.3.21 The effect will, therefore, be of minor adverse significance which is not significant in EIA terms.

Future monitoring

1.10.3.22 As the effects of operation and maintenance are at worst minor adverse it is not proposed to undertake any future monitoring.

1.10.4 Decommissioning phase

1.10.4.1 The impacts of the onshore decommissioning of Hornsea Three have been assessed on geology and ground conditions. The environmental effects arising from the decommissioning of Hornsea Three are listed in Table 1.9, along with the maximum adverse scenario against which each decommissioning phase impact has been assessed.

1.10.4.2 A description of the potential effect on geology and ground conditions receptors caused by each identified impact is given below.

Impacts of decommissioning may cause disturbance or contamination of secondary aquifers and associated surface waters together with the principal aquifer and may affect the WFD status.

Magnitude of impact

1.10.4.3 Direct and indirect impacts may occur to the secondary aquifers (and associated surface waters) and principal aquifer underlying the onshore HVAC booster station and onshore HVDC converter/HVAC substation due to the intrusive nature of works required to remove the above and below ground structures.

1.10.4.4 The impact is predicted to be of local spatial extent within each aquifer unit, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be minor.

1.10.4.5 Minimal disturbance is likely to occur from the decommissioning of the onshore export cable as this will be cut, sealed and left in situ. However the structure of the jointing pits and link boxes may be removed where feasible. The magnitude of impact as a result of this localised disturbance is considered to be minor.

Sensitivity of receptor

1.10.4.6 The secondary aquifers, which form part of the superficial deposits are deemed to be of medium vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

1.10.4.7 Surface water courses in hydraulic connection with affected secondary aquifer units are deemed to be of medium vulnerability, but of high recoverability and medium value. The sensitivity of this receptor is therefore considered to be medium.

1.10.4.8 The principal aquifer, which underlies the superficial deposits beneath the whole of the site, is deemed to be of high vulnerability beneath low permeability glacial till clays, and of very high vulnerability beneath more permeable alluvium, river terrace gravels and sand and gravels; and of slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be high.

Significance of effect

1.10.4.9 The overall significance of the effect of disturbance or contamination of secondary groundwater aquifers as a result of the decommissioning of the onshore HVAC booster station and onshore HVDC converter/HVAC substation which includes the integration of measures set out in Table 1.13 is deemed to be minor.

1.10.4.10 The effect will, therefore be of minor adverse significance which is not significant in EIA terms.

Future monitoring

1.10.4.11 As the effects of decommissioning are at worst minor adverse it is not proposed to undertake any future monitoring.

1.11 Cumulative Effect Assessment Methodology

1.11.1 *Screening of other projects and plans into the Cumulative Effect Assessment*

1.11.1.1 The Cumulative Effect Assessment (CEA) takes into account the impacts associated with Hornsea Three together with other projects and plans. The projects and plans selected as relevant to the CEA presented within this chapter are based upon the results of a screening exercise undertaken as part of the 'CEA long list' of projects (see annex 4.5: Cumulative Effects Screening Matrix and Location of Schemes). Each project on the CEA long list has been considered on a case by case basis for scoping in or out of this chapter's assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

1.11.1.2 In undertaking the CEA for Hornsea Three, it is important to bear in mind that other projects and plans under consideration will have differing potential for proceeding to an operational stage and hence a differing potential to ultimately contribute to a cumulative impact alongside Hornsea Three. For example, relevant projects and plans that are already under construction are likely to contribute to cumulative impact with Hornsea Three (providing effect or spatial pathways exist), whereas projects and plans not yet approved or not yet submitted are less certain to contribute to such an impact, as some may not achieve approval or may not ultimately be built due to other factors. For this reason, all relevant projects and plans considered cumulatively alongside Hornsea Three have been allocated into 'Tiers', reflecting their current stage within the planning and development process. This allows the CEA to present several future development scenarios, each with a differing potential for being ultimately built out. Appropriate weight may therefore be given to each Tier in the decision making process when considering the potential cumulative impact associated with Hornsea Three (e.g. it may be considered that greater weight can be placed on the Tier 1 assessment relative to Tier 2). An explanation of each tier is included below:

- Tier 1: Hornsea Three considered alongside other project/plans currently under construction and/or those consented but not yet implemented, and/or those submitted but not yet determined and/or those currently operational that were not operational when baseline data was collected, and/or those that are operational but have an on-going impact;
- Tier 2: All projects/plans considered in Tier 1, as well as those on relevant plans and programmes likely to come forward but have not yet submitted an application for consent (the PINS programme of projects is the most relevant source of information, along with the planning register held by the relevant local planning authorities). Specifically, this Tier includes all projects where the developer has submitted a Scoping Report; and
- Tier 3: All projects/plans considered in Tier 2, as well as those on relevant plans and programmes likely to come forward but have not yet submitted an application for consent (the PINS programme of projects is the most relevant source of information). Specifically, this Tier includes all projects where the developer has advised PINS in writing that they intend to submit an application in the future but have not submitted a Scoping Report.

1.11.1.3 The specific projects scoped into this CEA and the Tiers into which they have been allocated, are outlined in Table 1.14. The distance to Hornsea Three relates to the distance from the onshore elements of Hornsea Three (as defined in 1.1.1.1). The projects included as operational in this assessment have been commissioned since the baseline studies for this project were undertaken and as such were excluded from the baseline assessment.

Table 1.14: List of other projects and plans considered within the CEA.

Tier	Phase	Project/Plan	Distance from Hornsea Three	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
1	*Residential development*						
	Construction/Operation and Maintenance/Decommissioning	PF/12/1263	<1 km	Change of use of land from agriculture to 53 units tent-only campsite and formation of vehicular access.	N/A	No	Yes
	Construction/Operation and Maintenance/Decommissioning	PF/15/1223	<1 km	Erection of twenty two residential units (Class C3) with associated highway and landscape works.	2020 to 2022	Yes	Yes
	Construction/Operation and Maintenance/Decommissioning	2014/2611	<1 km	The erection of 890 dwellings; the creation of a village heart to feature an extended primary school, a new village hall, a retail store and areas of public open space; the relocation and increased capacity of the allotments; and associated infrastructure including public open space and highway works.	2018 to 2028	Yes	Yes
	Quarrying						
	Construction/Operation and Maintenance/Decommissioning	C/7/2014/7030	<1 km	(I) For a southern extension to Mangreen Quarry and ancillary works with progressive restoration to agriculture and nature conservation by the importation of inert restoration materials; (II) Retention of existing consented facilities at Mangreen Quarry; (III) Establishment of crossing point over Mangreen Lane; and (IV) Proposed variation to approved restoration scheme at Mangreen Quarry.	2017 to 2024	Yes	Yes
	Offshore wind farm – on shore cables routes						
	Construction/Operation and Maintenance/Decommissioning	PF/14/0177	<1 km	Installation of landfall transition pit and buried electrical cable system (revisions to previously approved scheme) and changes to the construction configuration at the landfall.	2018 to 2019	No	Yes
2	*Residential development*						
	Construction/Operation and Maintenance/Decommissioning	2013/0092	<1 km	Outline application for up to 20 residential units and associated highways works with all matters reserved.	2020 to 2021	Yes	Yes
	Offshore wind farm – on shore cables routes						
	Construction/Operation and Maintenance/Decommissioning	EN010079"	<1 km	Norfolk Vanguard is a proposed offshore wind farm with an approximate capacity of 1800MW off the coast of Norfolk.	2020 to 2024	Yes	Yes
3	*No Tier 3 Projects*						

1.11.2 Maximum design scenario

1.11.2.1 The maximum design scenarios identified in Table 1.15 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. The cumulative impact presented and assessed in this section have been selected from the details provided in the Hornsea Three project description (volume 1, chapter 3: Project Description), as well as the information available on other projects and plans, in order to inform a 'maximum design scenario'. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project Design Envelope to that assessed here be taken forward in the final design scheme.

Table 1.15: Maximum design scenario considered for the assessment of potential cumulative impacts on geology and ground conditions.

Potential impact	Maximum design scenario	Justification
Construction phase		
Impacts of construction may result in the loss of mineral resources within Mineral Safeguarded Areas	Tier 1 C/7/2014/7030.Tier 2 – 2013/0092 and EN010079 Tier 3 N/A	Outcome of the CEA will be the greatest when most development occurs within Mineral Safeguarded Areas.
Impacts of construction may cause disturbance or contamination of secondary aquifers. The WFD status of the groundwater might also be affected.	Tier 1 C/7/2014/7030.Tier 2 – 2013/0092 and EN010079 Tier 3 N/A	Outcome of the CEA will be greatest when the greatest disturbance to the ground occurs in secondary aquifers.
Impacts of open cut trench construction may affect the groundwater quality of the principal aquifer including at SPZ. The WFD status of the groundwater might also be affected.	Tier 1 C/7/2014/7030.Tier 2 – 2013/0092 and EN010079 Tier 3 N/A	Outcome of the CEA will be greatest when the greatest disturbance to the ground occurs in principle aquifer or SPZ's.
Impacts of trenchless conduit construction and piling works (potentially required for the construction of the onshore HVAC booster station or onshore HVDC converter/HVAC substation) may affect the groundwater quality of the principal aquifer, including conduit construction within any SPZs. The WFD status of the groundwater might also be affected.	Tier 1 C/7/2014/7030.Tier 2 – 2013/0092 and EN010079 Tier 3 N/A	Outcome of the CEA will be greatest when the greatest disturbance to the ground occurs.
Impacts of construction may affect the quantity and quality of surface waters fed by groundwater. The groundwater WFD status might also be affected.	Tier 1 C/7/2014/7030.Tier 2 – 2013/0092 and EN010079 Tier 3 N/A	Outcome of the CEA will be greatest when the greatest disturbance to the ground occurs.
Impacts of operations and maintenance may affect the water quality of secondary aquifers and any associated surface waters together with the principal aquifer. The WFD status might also be affected.	Tier 1 C/7/2014/7030.Tier 2 – 2013/0092 and EN010079 Tier 3 N/A	Outcome of the CEA will be greatest when the greatest disturbance to the ground occurs.
Impacts of operation may affect groundwater quality from thermal effects of underground power cables. The WFD status of the groundwater might also be affected.	Tier 1 C/7/2014/7030.Tier 2 – 2013/0092 and EN010079 Tier 3 N/A	Outcome of the CEA will be greatest when the greatest disturbance when other thermal effects may exist.
Decommissioning phase		
Impacts of decommissioning may cause disturbance or contamination of secondary aquifers and any associated surface waters together with the principal aquifer may affect the WFD status.	Tier 1 C/7/2014/7030.Tier 2 – 2013/0092 and EN010079 Tier 3 N/A	Outcome of the CEA will be greatest when the greatest disturbance to the ground occurs.

1.12 Cumulative Effect Assessment

1.12.1.1 A description of the significance of cumulative effects upon geology and ground conditions receptors arising from each identified impact is given below.

1.12.2 Construction phase

Temporary loss/disturbance to designated geological sites

1.12.2.1 None of the 'other development' impact designated geological sites. Thus, it is likely that there would be no significant cumulative impact with regard to temporary loss/disturbance to designated geological sites.

Impacts of construction may result in the loss of mineral resources within the Mineral Safeguarded Areas.

Tier 1/Tier 2

1.12.2.2 A review of the cumulative schemes within the hydrology and flood risk study area has identified that several schemes are located within the Mineral Safeguarded Areas. Where viable sand and gravel resources are present it is assumed that extraction will not take place prior to construction. Therefore, there is potential for a cumulative impact to occur as a result of multiple areas of viable sand and gravel resources not being utilised and lost under development for at least the lifetime.

Magnitude of impact

1.12.2.3 The impact is predicted to be direct and of local spatial extent. The magnitude is therefore, considered to be **moderate**.

Sensitivity of receptor

1.12.2.4 The sand and gravel resources within the Mineral Safeguarded Areas are deemed to be of medium value and contribute to the regional economy. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of effect

1.12.2.5 The overall significance of the effect on mineral resources within the Mineral Safeguarded Areas based on the situation is deemed to be **moderate**.

1.12.2.6 Overall, it is predicted that the sensitivity of the receptor is considered to be medium and the magnitude is deemed to be moderate. The effect will, therefore, be of **moderate adverse** significance, which is significant in EIA terms.

Tier 3

1.12.2.7 As per Table 1.14 no Tier 3 other developments have been assessed as part of the CEA.

Impacts of construction may cause disturbance or contamination of secondary aquifers. The WFD status of the groundwater might also be affected.

Tier 1/Tier 2

Magnitude of impact

1.12.2.8 The impact is predicted to be of local spatial extent, short term duration, intermittent and reversible. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

1.12.2.9 The secondary aquifers, which form part of the superficial deposits are deemed to be of medium vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of Effect

1.12.2.10 The overall significance of the effect on disturbance or contamination of secondary groundwater aquifers based on the situation which includes the integration of measures adopted in Table 1.13 is deemed to be **minor**.

1.12.2.11 Overall, it is predicted that the sensitivity of the receptor is considered to be medium and the magnitude is deemed to be minor. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Tier 3

1.12.2.12 As per Table 1.14 no Tier 3 other developments have been assessed as part of the CEA.

Impacts of open cut trench construction may affect the groundwater quality of the principal aquifer including at SPZs. The WFD status of the groundwater might also be affected.

Tier 1/Tier 2

Magnitude of impact

1.12.2.13 Direct impacts may occur from vertical hydraulic connections between shallow perched groundwater and principal aquifer groundwater during piling, or during open cut trench construction. Cumulative impact would only occur where excavations coincide.

1.12.2.14 The impacts are predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor indirectly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

1.12.2.15 The principal aquifer, which underlies the superficial deposits beneath the whole of the site, is deemed to be of high vulnerability beneath low permeability glacial till clays, and of very high vulnerability beneath more permeable alluvium, river terrace gravels and sand and gravels; and of slow/costly recoverability and high value. The sensitivity of the principal aquifer (including SPZ2 and SPZ3) is therefore, considered to be **high**. Where the SPZ1 crosses the onshore cable corridor search area, the sensitivity can be considered to be **very high**.

Significance of effect

1.12.2.16 The overall significance of the effect on disturbance or contamination of the principal groundwater aquifer (and SPZ2 and SPZ3) based on the situation which includes the integration of measures adopted in Table 1.13, is deemed to be **minor**. Where the SPZ1 crosses the onshore cable corridor search area, the significance is deemed to be **moderate**.

1.12.2.17 The effect will, therefore, be of **minor adverse** significance which is not significant in EIA terms. The exception is in the SPZ1 where the effect will be of **moderate adverse** significance which is significant in EIA terms.

Tier 3

1.12.2.18 As per Table 1.14 no Tier 3 other developments have been assessed as part of the CEA.

Impacts of trenchless conduit construction and piling works (potentially required for the construction of the onshore HVAC booster station or onshore HVDC converter/HVAC substation) may affect the groundwater quality of the principal aquifer, including conduit construction within any SPZs. The WFD status of the groundwater might also be affected.

Tier 1/Tier 2

1.12.2.19 None of the cumulative sites screened in for the CEA for the geology and ground conditions chapter are located near the onshore HVAC booster station or onshore HVDC converter/HVAC substation).

1.12.2.20 HDD techniques may be used to cross major rivers and other key infrastructure. A crossing schedule will be prepared following the submission of the PEIR which will confirm the location of the HDD crossings. A review of the schemes within the geology and ground conditions study area has indicated that several schemes are in the vicinity of potential HDD crossings.

Magnitude of impact

1.12.2.21 The impacts are predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude of impact on the principal aquifer (including the SPZ2 and SPZ3) and the WFD status of the groundwater is therefore, considered to be **minor**.

1.12.2.22 The impacts on the abstraction borehole from cable trench across the one SPZ1 footprint which is underlain by of glacial sand and gravels and till clays (as identified in BGS borehole TG10NW14 and presented in volume 6, annex 1.3: Geology and Ground Conditions) is considered to be **minor**.

Sensitivity of receptor

1.12.2.23 The principal aquifer, which underlies the superficial deposits beneath the onshore cable corridor search area, the onshore HVAC booster station and onshore HVDC converter/HVAC substation, is deemed to be of high vulnerability where it is overlain by low permeability glacial till clays. Where the principal aquifer is overlain by more permeable deposits (alluvium, river terrace gravels and sand and gravels); the aquifer has a slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be **high**. Where the SPZ1 crosses the onshore cable corridor search area, the aquifer sensitivity can be considered to be **very high**.

Significance of the effect

1.12.2.24 The overall significance of the effect of disturbance or contamination of the principal groundwater aquifer based on the situation which includes the integration of measures adopted in Table 1.13 is deemed to be **minor**. Where the SPZ1 crosses the onshore cable corridor search area, the significance is deemed to be **moderate**.

1.12.2.25 The effect will, therefore, be of **minor adverse** significance which is not significant in EIA terms. The exception is in the SPZ1 where the effect will be of **moderate adverse** significance which is significant in EIA terms.

Impacts of construction may affect the quantity and quality of surface waters fed by groundwater. The groundwater WFD status might also be affected.

Tier 1/Tier 2

Magnitude of impact

1.12.2.26 Indirect impacts may occur from hydraulic connections between shallow perched groundwater affected by trenching or piling construction.

1.12.2.27 The impact is predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

1.12.2.28 Surface water courses in hydraulic connection with secondary aquifer units which form part of the superficial deposits beneath the whole of the site are deemed to be of moderate vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of Effect

1.12.2.29 The overall significance of the effect of indirect disturbance or contamination of surface watercourses based on the situation which includes the integration of measures adopted in Table 1.13 is considered to be **minor**.

1.12.2.30 The effect will, therefore, be of **minor adverse** significance which is not significant in EIA terms.

Tier 3

1.12.2.31 As per Table 1.14 no Tier 3 other developments have been assessed as part of the CEA.

Future monitoring

1.12.2.32 The need for groundwater monitoring at the SPZ1 will be discussed with the Environment Agency and reported in the Environmental Statement.

1.12.3 Operation and maintenance phase

Impacts of operations and maintenance may affect the water quality of secondary aquifers and any associated surface waters together with the principal aquifer. The WFD status might also be affected.

Tier 1/Tier 2

Magnitude of impact

1.12.3.1 Direct impacts may occur to the superficial deposits present along the route due to the operation and maintenance activities dependent on the depth of the aquifer unit in relation to the proposed depth of excavation. Cumulative impact would therefore only occur where excavations coincide.

1.12.3.2 The impact is predicted to be of local spatial extent, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

1.12.3.3 The secondary aquifers, which form part of the superficial deposits are deemed to be of medium vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be **medium**.

1.12.3.4 The principal aquifer, which underlies the superficial deposits beneath the whole of the site, is deemed to be of high vulnerability beneath low permeability glacial till clays, and of very high vulnerability beneath more permeable alluvium, river terrace gravels and sand and gravels; and of slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be **high**.

Significance of the effect

1.12.3.5 The overall significance of the effect on disturbance or contamination of principal and secondary groundwater aquifers based on the situation which includes the integration of measures adopted in Table 1.13 is deemed to be **minor**.

1.12.3.6 Overall, the effect will therefore be of **minor adverse** significance which is not significant in EIA terms.

Impacts of operation may affect groundwater quality from thermal effects of underground power cables. The WFD status of the groundwater might also be affected.

Tier 1/Tier 2

Magnitude of impact

1.12.3.7 Direct impacts which may occur to groundwater along the route due to the thermal effects of the underground power cables would be dependent on the depth of the aquifer unit in relation to the proposed depth of excavation. Cumulative impact would only occur where cable routes cross.

1.12.3.8 The impact is predicted to be of local spatial extent, of long term duration and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

1.12.3.9 The secondary aquifers, which form part of the superficial deposits are deemed to be of medium vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore considered to be **medium**.

1.12.3.10 The principal aquifer, which underlies the superficial deposits where the cable routes cross, is deemed to be of high vulnerability beneath low permeability glacial till clays, and of slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be **high**.

Significance of Effect

1.12.3.11 The overall significance of the effect on disturbance or contamination of principal and secondary groundwater aquifers based on the situation which includes the integration of measures adopted in Table 1.13 is deemed to be **minor**.

1.12.3.12 Overall the effect will, therefore, be of **minor adverse** significance which is not significant in EIA terms.

Tier 3

1.12.3.13 As per Table 1.14 no Tier 3 other developments have been assessed as part of the CEA.

Future monitoring

1.12.3.14 As the in combination cumulative effects of operation and maintenance are at worst minor adverse no future monitoring is proposed.

1.12.4 Decommissioning phase

Impacts of decommissioning may cause disturbance or contamination of secondary aquifers and any associated waters together with the principal aquifer and may affect the WFD status.

Magnitude of impact

1.12.4.1 Direct impacts may occur to the secondary aquifers underlying the onshore HVAC booster station and onshore HVDC converter/HVAC substation due to the intrusive nature of works required to remove the above and below ground structures.

1.12.4.2 The impact is predicted to be of local spatial extent within each aquifer unit, of short term duration, of intermittent occurrence and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **minor**.

1.12.4.3 Minimal disturbance is likely to occur from the decommissioning of the onshore export cable as this will be cut, sealed and left in situ.

Sensitivity of receptor

1.12.4.4 The secondary aquifers, which form part of the superficial deposits are deemed to be of medium vulnerability, but of moderate to high recoverability and medium value. The sensitivity of the receptor is therefore, considered to be **medium**.

1.12.4.5 Surface water courses in hydraulic connection with affected secondary aquifer units are deemed to be of medium vulnerability, but of high recoverability and medium value. The sensitivity of this receptor is therefore considered to be **medium**.

1.12.4.6 The principal aquifer, which underlies the superficial deposits beneath the whole of the site, is deemed to be of high vulnerability beneath low permeability glacial till clays, and of very high vulnerability beneath more permeable alluvium, river terrace gravels and sand and gravels; and of slow/costly recoverability and high value. The sensitivity of the receptor is therefore, considered to be **high**.

Significance of effect

1.12.4.7 The overall significance of the effect of disturbance or contamination of secondary groundwater aquifers as a result of the decommissioning of the onshore HVAC booster station and onshore HVDC converter/HVAC substation which includes the integration of measures set out in Table 1.13 is deemed to be **minor**.

1.12.4.8 The effect will, therefore be of **minor adverse** significance which is not significant in EIA terms.

Future monitoring

1.12.4.9 As the in combination cumulative effects of decommissioning are at worst **minor adverse** no future monitoring is proposed.

1.13 Transboundary effects

1.13.1.1 A screening of transboundary impacts has been carried out and is presented in annex 5.5: Transboundary Impacts Screening Note. This screening exercise identified that there was no potential for significant transboundary effects with regard to geology and ground conditions from Hornsea Three upon the interests of other EEA States.

1.14 Inter-related effects

1.14.1.1 Inter-relationships are considered to be the impacts and associated effects of different aspects of the proposal on the same receptor. These are considered to be:

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the project (construction, operational and maintenance, and decommissioning), to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages (e.g. construction noise, operational noise and noise during decommissioning and dismantling of the onshore HVDC converter/HVAC substation); and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on geology and ground conditions, such as disturbance or contamination of secondary aquifers, loss of mineral resources, direct impacts on designated geological sites may interact to produce a different, or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects might be short term, temporary or transient effects, or incorporate longer term effects.

1.14.1.2 A description of the likely inter-related effects arising from Hornsea Three on geology and ground conditions is provided in volume 3, chapter 12: Inter-Related Effects (Onshore).

1.15 Conclusion and summary

1.15.1.1 The geology and ground conditions study area contains three designated geological sites, two of which fall within the Hornsea Three landfall and onshore cable corridor search area (i.e. Weybourne Cliffs SSSI and Kelling Heath SSSI). Open cut construction would damage the designating features of these sites and result in major adverse effects. Design measures (i.e. micro-routing and HDD) will be considered following the submission of the PEIR to avoid or minimise the potential impacts.

1.15.1.2 The geology and ground conditions study area is predominantly underlain by chalk bedrock, which is classified as a principal aquifer. There are eight SPZs within the geology and ground conditions study area, six of which are located within the onshore cable corridor search area, including an SPZ1 which is considered to be very highly sensitive. The principle aquifer and the other SPZs are considered to be highly sensitive. Potential impacts to the SPZs and the principal aquifer are predicted to be minor adverse assuming mitigation measures are in place (see Table 1.13). Mitigation measures would be discussed and agreed with the Environment Agency to reduce potential impacts from open cut trenching and HDD methods.

1.15.1.3 The majority of the principal aquifer is overlain by superficial deposits. The deposits include glacial deposits, brickearth, alluvium, and sand and gravel. The superficial deposits are variable in nature but provide a barrier to contaminant migration. However, the risk of pathways being created as a result of disturbance of the deposits during construction cannot be ruled out.

During operation it has been assumed that oils and lubricants will be used in the maintenance of the onshore HVAC booster station and onshore HVDC converter/HVAC substation. The effect of spills and leaks occurring and affecting underlying groundwater resources is considered to be minor adverse, assuming appropriate mitigation measures are in place (see Table 1.13). The thermal effectof underground cables of groundwater during the operation and maintance phase is considered to be minro adverse assuming that stabilisef backfill material is used in the construction of the onshore cable trenches.

1.15.1.4 The effect of decommissioning on secondary and principal aquifers is considered to be minor adverse assuming that appropriate mitigation is in place (see Table 1.13).

1.15.1.5 A summary of the findings of the EIA that have been completed to date and which relate to geology and ground conditions are presented in Table 1.16.

1.16 Next Steps

1.16.1.1 The next steps in producing the Environmental Statement are summarised below:

- As part of the iterative design process, micro-routing and HDD measures would be considered following the submission of the PEIR to mitigate the potential impacts to designated geological sites;
- Liaison with Norfolk County Council as the Minerals Planning Authority to agree how to further minimise the impacts on minerals resources where onshore elements of Hornsea Three are located in the sand and gravel Mineral Safeguarded Area;
- Following the refinement of the onshore cable corridor search area, records on the depth and condition of the peat deposits within the onshore export cable route would be obtained via a desk study or survey if required;
- Any proposed mitigation measures (see Table 1.13) would be discussed in detail with the Environment Agency following the submission of the PEIR to identify opportunities to minimise the impact at the SPZ1, the principal aquifer and secondary aquifers; and
- Measures to manage the impacts of construction would be set out within a Code of Construction Practice.

Table 1.16: Summary of potential environment effects, mitigation and monitoring.

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Construction Phase							
Impacts of construction may affect designated geological sites	See additional measures.	No change – Weybourne Town Pit SSSI Moderate – Weybourne Cliffs SSSI and Kelling Heath SSSI	Very high	No change (not significant in EIA terms) – Weybourne Town Pit SSSI Major (significant in EIA terms) – Weybourne Cliffs SSSI and Kelling heath SSSI	Micro-routing or HDD (Weybourne Cliffs SSSI and Kelling Heath SSSI)	Weybourne Cliffs SSSI – negligible or minor adverse Kelling Heath SSSI -negligible	None
Impacts of construction may result in the loss of mineral resources within the Mineral Safeguarded Areas.	Mineral assessment (see Table 1.13).	Minor	Medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Impacts of construction may cause disturbance or contamination of secondary aquifers. The WFD status of the groundwater may also be affected.	Good environmental practice, storage and handling of materials and waste management (see Table 1.13).	Minor	Medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Impacts of open cut trench construction may affect the groundwater quality of the principal aquifer including at SPZs. The WFD status of the groundwater might also be affected.	Good environmental practice, storage and handling of materials and waste management (see Table 1.13).	Minor	High Very high (SPZ1)	Minor adverse (not significant in EIA terms). Moderate adverse – SPZ1 (significant in EIA terms)	None	N/A	The need for monitoring groundwater at the SPZ1 will be discussed with the Environment Agency.
Impacts of trenchless conduit construction and piling works (potentially required for the construction of the onshore HVAC booster station or onshore HVDC converter/HVAC substation) may affect the groundwater quality of the principal aquifer, including conduit construction within SPZs. The WFD status of the groundwater might also be affected.	Good environmental practice (see Table 1.13).	Minor	High Very high (SPZ1)	Minor adverse (not significant in EIA terms). Moderate adverse – SPZ1 (significant in EIA terms)	None	N/A	
Impacts of construction may affect the quantity and quality of surface waters fed by groundwater. The groundwater WFD status might also be affected.	Good environmental practice (see Table 1.13).	Minor	Medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Operation Phase							
Impacts of operation and maintenance may affect the water quality of secondary aquifers and any associated surface waters. The WFD status might also be affected.	Operational measures (see Table 1.13).	Minor	Medium (secondary aquifers and surface waters) High (principal aquifer)	Minor adverse (not significant in EIA terms)	None	N/A	None

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Impacts of operation and maintenance may affect the groundwater quality from thermal effects of the power cables. The WFD status of the groundwater might also be affected.	Operational measures (see Table 1.13).	Minor	Medium (secondary aquifers) High (principal aquifer)	Minor adverse (not significant in EIA terms)	None	N/A	None
Decommissioning Phase							
Impacts of decommissioning may cause disturbance or contamination of secondary aquifers (and associated surface waters) together with principal aquifer and may affect the WFD status.	Decommissioning measures (see Table 1.13).	Minor	Medium (secondary aquifers and surface waters) High (principal aquifer)	Minor adverse (not significant in EIA terms)	None	N/A	None

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