11 Geology, Ground Conditions, Groundwater and Coastal Processes

11.1 Introduction

1 This chapter considers the potential effects of the proposed Onshore Works on the superficial and bedrock geology, ground conditions, groundwater and coastal processes.

2 The chapter presents a description of the baseline geology of the area affected by the proposed Onshore Works for the Neart na Gaoithe Offshore Wind Farm. Detailed consideration is given to the bedrock and Quaternary to recent geological make-up of the proposed Landfall for the cable, the route for the onshore cable, and area of the substation within Crystal Rig Wind Farm.

3 The chapter assesses any potential effects of the construction and operational phases of Onshore Works on the geological and hydrogeological environment, in particular near surface effects on groundwater, ground conditions and erosion potential.

4 The geological and groundwater assessment was undertaken by Border Geo-Science for Kaya Consulting on behalf of LUC. The chapter is supported by two technical appendices, a Peat Stability Assessment (prepared by URS) and a Geotechnical and Geo-environmental Desk Study (prepared by Arup).

5 The chapter also considers the effect of the Onshore Works on coastal processes at Thorntonloch.

6 This assessment is based upon data obtained from publicly accessible archives, as described in the Data Sources below, and a walkover survey.

11.2 Effects Assessed in Full

7 The Scoping Report identified a number of potential effects to be considered within the Geology Chapter. Some of these effects are now dealt within in other chapters in the EIA (as these chapters are more logically placed to respond to these effects). This is explained below :

- effects of localised heating from the cable on ground conditions are considered in this chapter and also discussed in **Chapter 13: Soils, Agriculture and Land Use**;
- soil erosion is considered in **Chapter 12: Hydrology, Flood Risk, Water Resources and Surface Water Quality** and **Chapter 13: Soils, Agriculture and Land Use**;
- effects related to losses of carbon storage are considered partially in **Chapter 13: Soils, Agriculture and Land Use** and also considered in the Peat Stability Assessment which forms **Appendix 11.1** to this Chapter ;
- effects of erosion and washing out of back filled material over time, with particular reference to sand-rich deposits have been scoped out as outlined below;
- pollution/contamination of soils (e.g., from chemical spills and soil erosion) are considered in **Chapter 12: Hydrology, Flood Risk, Water Resources and Surface Water Quality**;
- physical damage to soil having an effect on the soil's ability to perform its functions has been considered in **Chapter 13: Soils, Agriculture and Land Use**.

8 In this chapter, the following effects are considered:

- ground movements and instability for proposed buildings and cable route;
- slope instability along the cable route;
- disruption to the hydrogeological system;
- effects on coastal processes including coastal erosion.

11.3 Effects Scoped Out

9 There are no statutory or non-statutory designated sites with an earth science interest within the area of interest affected by the Onshore Works.

10 The Barns Ness Site of Special Scientific Interest (SSSI) is designated for earth science features related to British Carboniferous stratigraphy. This coastal site lies to the north-west of the Torness Power Station. This is also designated as a Local Geodiversity Site (formerly known as Regionally Important Geological Site (RIGS)).

11 The Rammer Cleugh SSSI lies to the west of the Application Boundary between Woodhall and Weatherly. The site is designated for Quaternary features, both erosional and depositional, as a consequence of the action of glacial meltwaters. The Cable Corridor traverses similar features that are contiguous with the SSSI, but are not designated conservation sites and hence do not present an issue.

12 Therefore, on the basis of the desk based and survey work undertaken, the professional judgment of the EIA team, experience from other relevant projects and policy guidance, or standards, the following topic areas have been 'scoped out':

- direct effects on statutory and non-statutory sites designated for their geological interest through partial/full removal, defacement, or obscuring of rock outcrops/landforms, changes to relic or active river landforms, or sediment input;
- effects on subsurface coal deposits, landfill or other waste disposal facilities; and,
- ground instability and seismic activity.

13 In addition to the effects noted in the Scoping Report, the effect of erosion and washing out of back filled material over time has also been scoped out following the baseline assessment and a review of the proposed construction methods (i.e., construction activities to be reclaimed progressively).

11.4 Guidance and Legislation

14 There is neither a quantitative nor qualitative assessment methodology for geology and earth heritage (e.g., SSSI designated due to geology of the site or geo-diversity) prescribed within the EIA (Scotland) Regulations 1999, although Schedule 4 Section 3 alludes to geodiversity but only within the context of Landscape.

15 The sources noted below, however, provide broad outline guidance:

- Planning Advice Note (PAN) 60: *Planning for Natural Heritage* (Scottish Executive, 2000); and
- Handbook on Environmental Impact Assessment (Scottish Natural Heritage (SNH), 2009).

16 Whilst PAN 60 acknowledges the importance of earth heritage as an important element in our natural heritage, it does not provide statutory guidelines. This document suggests that planning authorities may contribute to the earth heritage conservation by:

- protecting important earth heritage interests within nationally designated areas;
- considering the effects of development proposals on geomorphological processes, landforms and soils and actively seeking measures to avoid, reduce, mitigate or compensate for any adverse effects;
- identifying opportunities to create or enhance earth heritage interests through development; and
- supporting the role of regionally important geological/geomorphological sites (RIGS) with respect to interpretation, education and the conservation of local diversity.

11.5 Data Sources

17 The following data sources and organisations were consulted in the preparation of this chapter:

- The British Geological Survey (BGS). For the following geological maps:
  - Sheet 33E (Dunbar) – Solid Edition. 1:50 000 Series. Published 1978
  - Sheet 33E (Dunbar) – Drift Edition. 1:50 000 Series. Published 1980
  - BGS 1:10 560 Geological Maps for NT 66NW, 66NE, 67SW, 67SE, 77SW & 77SE
- Other BGS data sources include:
  - BGS Borehole Records Index
  - BGS Mineral Assessment Report 147. Published in 1986
  - BGS Seismic Records
  - BGS Geochemical Database (G-Base)

- SNH
  - For SSSI, GCR and other designated sites.
- Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) archives.
  - For aerial photographs.
- East Lothian Council (ELC).
  - For East Lothian Local Plan (East Lothian Council, 2008), and minerals planning.
- Neart na Gaoithe Substation and Cable Corridor Peat Stability Assessment (URS, August 2012).
- Neart na Gaoithe Geotechnical and Geo-Environmental Desk Study (Arup, 17 August 2012).

11.6 Consultation

18 Consultation responses with respect to geology, ground conditions, groundwater and coastal processes are outlined in **Table 11.1**.

Consultee	Scoping/other Consultation	Issue Raised	Response/Action Taken
Scottish Environment Protection Agency (SEPA)	Scoping response	Existing groundwater abstractions and private water supplies Consideration of groundwater abstractions within 100 m radius from roads and 250 m radius from borrow pits and foundations. Coastal Processes Both of the cable landing methods, preferred method (directional drilling) and alternative method (excavation, burying and backfilling), can influence the coastal geomorphology. Effects of construction on coastal geomorphology should be considered. Coastal processes should be assessed along the cable route at the beach. Also, the assessment needs to consider the potential of cable exposure and potential effects of the development on coastal processes.	SEPA, Scottish Water and East Lothian Council were consulted with respect to any relevant information held by them related to private water supplies. One licensed drinking water abstraction site at Woodhall Farm (369004, 672566) and a private water supply at Weatherly (367828, 671727) were identified by SEPA close to the cable route. Mitigation measures for activities that could affect groundwater are provided in this chapter. Effects on coastal processes are considered in this chapter.
SEPA	Engagement response	SEPA was asked for relevant information related to licensed drinking water abstractions. One licensed drinking water abstraction site at Woodhall Farm (369004, 672566) and a private water supply at Weatherly (367828, 671727) were identified.	SEPA data was used in the baseline studies.
Scottish Water	Engagement response	Scottish Water was asked for information on their network within the study area. They were also asked if they had information on private water supplies in the study area. Scottish Water responded by providing plans of public water infrastructure, which did not identify any groundwater sources. They did not identify any private water supplies.	Scottish Water data was used in this assessment.
ELC	Engagement response	ELC was asked for information on private water supplies.	ELC indicated that they have no records of private drinking water supplies in the area.
BGS	Engagement response	The BGS was consulted on sources of information on the geology of the study area and boreholes.	BGS data was used in the baseline studies

Table 11.1: Scoping Responses

11.7 Assessment Methodology

11.7.1 Assessing Significance

19 The assessment is based on a desk top study of all of the available information (detailed in the baseline assessment). A site walkover survey was conducted on the 14 June 2011.

20 In the absence of specific guidelines, the methodology applied in the assessment is a qualitative risk assessment, in which the probability of an effect occurring and the magnitude of the effect, if it were to occur, are considered. This approach provides a mechanism for identifying the areas where mitigation measures are required, and for identifying mitigation measures appropriate to the risk presented by the proposed Onshore Works. This approach allows effort to be focused on mitigating the greatest risks identified on site.

21 The sensitivity of features considered in this chapter is outlined in **Table 11.2**.

22 The magnitude of change has been assessed based on the criteria presented in **Table 11.3.**

23 The predicted significance of effects was determined through a standard method of assessment based on professional judgement, considering both sensitivity and magnitude of change as per **Table 11.4**.

24 Major and moderate effects are considered significant in the context of the Town and Country Planning (EIA) (Scotland) Regulations 2011 (EIA Regulations).

Sensitivity	Geology	Ground Conditions	Groundwater	Coastal Processes
High	Geo World Heritage Sites, Site of Special Scientific Interest (SSSI), Geological Conservation Review site (GCR), or National Scenic Areas	Steep slopes, where major slope instabilities, landslides or slumping[1] is likely. Poorly consolidated to unconsolidated ground.	Groundwater levels either in superficial deposits or bedrock close to or at surface.	Shoreline or beach with long-shore processes or part of a coastal cell where local changes can have widespread effects on erosion and deposition in nearby beaches. Site designated as SSSI for coastal processes or coastal landforms
Medium	Regional Parks	Moderately sloping ground, where local instabilities or slumping is possible.	Groundwater levels either perched in superficial deposits or within bedrock at depths of potential impingement.	Shoreline or beach with limited long-shore sediment transport. Site with locally important coastal processes or coastal landforms including sand dunes.
Low	Local Geoconservation Sites (RIGS) - Non-statutory Special Landscape Areas – used by local authorities to guide development in the countryside Sites with no designation	Flat to gently inclined topography with well consolidated superficial deposits or bedrock with no recognisable instabilities.	Groundwater levels either in superficial deposits or bedrock at significant depth.	Shoreline or beach with no long-shore sediment transport. Rocky coastline with no beach, important coastal processes or coastal landforms.

Table 11.2: Sensitivity Criteria

[1] Slumping is a term used for a form of mass movement event that occurs when poorly consolidated materials, most commonly superficial deposits, move a short distance down a slope.

Magnitude	Geology	Ground Conditions	Groundwater	Coastal Processes
Major	Permanent degradation and total loss of important geological sites or landscape features (e.g. extensive loss or damage to sites of geological interest, identified either as geologically designated/sensitive sites).	Catastrophic slope failure or instability which results in loss of life and/or property.	Significant impingement of groundwater aquifer within either bedrock or superficial deposit aquifers, leading to long term or permanent disruption to groundwater flow, aquifer recharge, and contamination	Change that has a measurable effect on regional coastal processes (on scale of full coastal cell in SNH (1997)) and sediment transport. Change that could affect long-term patterns of sediment erosion and deposition along the coast.
Moderate	Damage to important earth heritage features (e.g. loss or damage to the geological environment or geo-diversity).	Slope failure or instability which may cause foundation problems.	Impingement of groundwater aquifer within either bedrock or superficial deposit aquifers, leading to medium term disruption to groundwater flow, aquifer recharge, and some contamination	Change that has measurable effect on local coastal processes that goes beyond what could be expected to be caused by a storm or other infrequent event. Potential for effects along the coast beyond shoreline adjacent to development.
Minor	Damage to locally important earth heritage features (e.g. loss or damage to the geological environment or geo-diversity).	Some loss or disturbance of ground, but which has no long term effects.	Impingement of groundwater aquifer within either bedrock or superficial deposit aquifers, leading to short term disruption to groundwater flow, aquifer recharge, and/or contamination, which has no long term effects	Changes which are similar to those produced by storm or other infrequent event. No effects outside of shoreline adjacent to development.
Negligible	No effect on or alteration to the existing geological environment or important soil settings (e.g. valuable agricultural land).	No effect on or alteration to the existing geological environment or important soil settings (e.g. valuable agricultural land).	No effect or alteration to existing groundwater aquifers	Changes that are within normal range of coastal processes or whose effects will be removed following action of normal coastal processes. No effects outside of shoreline adjacent to the development.

Table 11.3: Criteria to Assess Magnitude of Predicted Effect

Sensitivity	Magnitude			
	Major	Moderate	Minor	Negligible
High	Major	Major	Moderate	Minor
Medium	Major	Moderate	Minor	Negligible
Low	Moderate	Minor	Negligible	Negligible

Table 11.4: Significance Criteria

11.7.2 Study Area

25 The study area for this assessment includes all of the ground both along and adjacent to the corridor of the proposed route of the Onshore Works. This extends from the Landfall at Thorntonloch on the East Lothian coastline, to the site of a new Substation Site within Crystal Rig II Wind Farm, which lies within the north-eastern parts of the Lammermuir Hills.

26 The route encompasses Thorntonloch Beach and the surrounding coast. The coastal fringe is a low lying, gently undulating topography in part formed from erosion during end-glacial retreat. Rock exposures here are largely restricted to the beds and flanks of incised water courses, such as the Dry Burn and Thornton Burn that reflect routes of former of meltwater channels. Within the upland areas flanking Bransley Hill, bedrock is close to or at surface and accessible for study.

11.8 Existing Conditions

11.8.1 Geology and Ground Conditions

11.8.1.1 Overview of the Bedrock Geology

27 The bedrock geology of the study area is represented by three distinctive stratigraphical rock successions whose history spans two significant earth moving events that affected this part of the Earth's crust (**Figure 11.1**). Bedrock exposure within the area is restricted due to an extensive cover of superficial deposits. Coastal outcrops occur to the north-west and south-east of Thorntonloch, largely as wave-cut platforms. Most other exposures are confined to within water courses, chiefly the Dry Burn, Thurston Mains Burn (tributary of Thornton Burn), and Woodhall Burn. Upland exposures are localised rather than extensive.

28 The oldest part of the geological sequence (Refer to **Figure 11.1 Bedrock Geology**) in this area are Lower Palaeozoic (Silurian) age sedimentary rocks deposited between 440 and 430 million years ago (Ma), on the margins of the former continent of Laurentia. At about 415 to 400 Ma, these rocks were subjected to heat and pressure as the oceanic crust on which they formed was progressively drawn down (subducted) beneath the margin of the Laurentian land mass during the closure of this Iapetus Ocean, which culminated in Caledonian mountain building. These rocks are now part of a north-east to south-west trending belt that forms much of the Southern Uplands of Scotland. The rock succession seen here forms part of the Gala Group (**Figure 11.1**). This comprises dark grey thick bedded to massive pebbly greywacke, thinner greywacke units and laminated siltstones. Pebbly clasts in the greywacke comprise a range in compositions including coarse and fine-grained granitic rocks, quartzite, vein quartz, spilitic basalt, older sedimentary rocks, and some of metamorphic provenance.

29 The mountain building was coupled with rapid erosion of the landmass, in a manner seen today in the modern Himalayas, with the formation of deeply incised river valleys. This gave rise to the deposition of the second geological sequence, the Devonian (c. 350 Ma) age 'Lower Old Red Sandstone' rocks (**Figure 11.1**). The outcrop of these rocks stretches 25 km south-westwards from Dunbar to Duns (**Figure 11.1**), and they sit uncomfortably on the underlying Silurian rocks. The unconformity between these rock sequences is well seen at Siccar Point near Coldingham. This internationally famous site, and SSSI, was where in 1788, James Hutton found proof for his theory that boundaries between geological sequences represent large intervals in time; here some 80 million years. The Old Red Sandstone outcrop in this area is bounded to the east by the Innerwick Fault, which brings them against younger rocks. These deposits largely infilled the palaeo- river valleys formed by river systems that flowed north-westwards into the area are now represented by the Midland Valley. The Devonian rocks here are mostly of red to purple-red conglomerate with rounded to sub-rounded pebbles and cobbles set in a sparse fine sandy to pea-gravel matrix. Clasts (rock fragments) are largely held together by mainly ferruginous or less commonly calcareous, cement. Clasts are predominantly of greywacke, with some pebbles of leucocratic porphyritic microdiorite, quartzite, jasper and chert. Most of the lithology is poorly sorted, although there are some fine-grained beds of sandstone that show some internal horizontal stratification and crude grading.

30 The third geological unit, impersistently exposed to the east of the Innerwick Fault (**Figure 11.1**), comprises rocks of the Ballagan Formation (formerly referred to as the 'Calciferous Sandstone Measures'), which forms part of the Tournasian-age (342-348 Ma) Inverclyde Group, within the stratigraphically lowest part of the Carboniferous succession. Deposition of these sedimentary rocks occurred when the UK was at low latitudes south of the contemporary equator. The lower part of the formation (formerly the 'Cementstone Group') consists mainly of interbedded black/dark grey calcareous mudstones, grey silty mudstones, grey siltstones, with grey to buff nodules and massive, structureless beds of ferroan dolomite (cementstones), and sandy siltstones. They are cut through by buff to off-white channel sandstones, up to 5 m thick. The upper part of the formation (formerly the 'Lower Oil Shale Group') is a sequence predominantly of massive, pale sandstones with dark grey mudstones and shales. Two discrete limestone units and fossil-bearing calcareous shales form much of the top of the succession, while the lower part contains two distinct shale bands containing marine fossils. Deposition of the Carboniferous rocks occurred on the margins of a larger sedimentary basin, now represented by the rocks within much of the Midland Valley. The environment was in part marine, either shallow coastal or a deltaic setting, traversed by distributary channels, with the development of brackish or freshwater lagoons and bays. Shallow water conditions gave rise to the formation of dolomitic muds, while the occurrence of marine bands and limestone beds in the upper part of the sequence mark the onset of marine conditions either as a consequence of rising sea levels or sinking of the land surface - a feature common in modern large deltaic environments such as the Mississippi.

31 Much of the folding and faulting that affects the Carboniferous rocks is likely associated with earth movements that gave rise to the Variscan fold belt at about 300 Ma. The main structure that developed here is the north-west to south-east trending Innerwick Fault (**Figure 11.1**), which has uplifted and allowed the erosion of much younger Carboniferous age sedimentary rocks that would originally have covered much of the area.

11.8.1.2 Overview of the Superficial Deposits – Quaternary Geology

32 As with much of northern Britain, this part of the Southern Uplands was subject to glaciation in the Late Devensian from around 20,000 years before present (bp). During this time an ice sheet up to several hundred metres thick covered the ground. Subsequent melting and retreat of the ice sheets in northern latitudes instigated a rise in sea level and also differential isostatic uplift of the land mass. During periods of relative standstill raised beach features and wave cut platforms formed. Relative fluctuations have resulted in these features being preserved at different heights above Ordnance Datum (OD).

33 Ice sheet deposits in the form of diamictons (e.g. tills and boulder clay) extensively blanket bedrock between Innerwick and the Crystal Rig Wind Farm (Refer to **Figure 11.2 Superficial Deposits**). These deposits range in thickness from less than a metre to up to 5 and 10 m (or more) in scoured depressions in the bedrock surface. Deposits comprise sandy (Refer to **Figure 11.3a Photographic Images, Image 1**) and clay-rich stony (Refer to **Figure 11.3a, Image 2**), and boulder diamictons. The colour and composition of the matrix and the dominant clast types reflect the underlying bedrock substrate to the former ice sheet. Hence, tills derived from the Lower Palaeozoic sedimentary rocks are commonly grey and composed of a hard clay matrix with sub-angular to sub-rounded greywacke and siltstone clasts. A gritty sandy diamicton often predominates over the 'Old Red Sandstone' bedrock, where the clay matrix has a reddish colour, often imparted to the overlying soils. Ice-smoothed and striated pebbles are common within the tills.

34 With the retreat of the ice sheet to the north at approximately 15,500 before present (bp), glacial melt waters emanating from the decaying ice gave rise to the deposition of ice-contact and sub-glacial glacio-fluvial sand and gravel in the form of mounds, ridges and kame terraced deposits (**Figure 11.2**). These are well seen in a narrow east-west zone from Thurston Mains [NT 710 730] to the Cauld Burn at [NT 635 720]. The deposits range from poor to well-sorted (where grains or clasts are all of similar size and shape). The deposits consist of fine- to medium-grained sand with gravel. Coarse gravel is a minor component, although cobbles up to 10 cm in diameter do occur. The fine-grained fraction is significant. Sand-rich deposits are commonly 'clayey', with disseminated silt and clay. Lenses and laminae of silty clay are common. Gravel clasts are mainly rock fragments of sandstone, greywacke,

siltstone, and a range of igneous rock types. These deposits are often reddened, with a ferruginous cement partially lithifying (making rock-like) the sandy matrix, e.g. at [NT 69182 72407] (Refer to **Figure 11.3a, Image 3**).

35 An extensive spread of moundy and flattish spreads of sand and gravel occur between Thurston Farm [NT 704 745] and Thorntonloch [NT 753 739] (**Figure 11.2**). These are outwash deposits laid down by meltwaters from the receding ice sheets on the northern side of the Lammermuir Hills. Such sub-glacial meltwater streams cut down into bedrock forming over-deepened valleys, which now contain water courses such as the Dry Burn. The outwash deposits range widely in thickness, in places up to 15 m thick. The moundy nature of the deposits in the north-west of the study area suggests that dead ice was locally abundant, giving rise to a kettled topography. The variability of the palaeo land and till surfaces also have some control over the form of the sand and gravel deposits, giving rise to local rapid variations in thickness. The deposits are either well- sorted or stratified sand and gravel, with a range of grain sizes from fine-grained sand to coarse gravel. However, their 'clayey' nature, indicates a significant 'fines' component in the form of disseminated clay or more significant layers of silty clays that probably represent glacio-lacustrine deposits. Numerous overflow channels that cut through both the glacio-fluvial deposits, till and bedrock are testament to the high volume of meltwater that emanated from the decaying and retreating ice.

11.8.1.3 Natural Resources and Metalliferous Minerals

36 The sand and gravel resources of part of the area, through which the Onshore Works are proposed to be routed, were investigated by the Institute of Geological Sciences (now the British Geological Survey) Industrial Minerals Assessment Unit during the 1980's (Aitken & Ross, 1986). The survey provided information at an indicative level of potential tonnages and grading of the deposits through a bulk sampling programme that obtained data from boreholes, shallow pits, and natural sections. The results indicate that the coastal outwash spreads do provide a large potential resource. However, the opportunities for development are restricted. The mounds, ridges, and kame terraces in the Woodhall Farm area are of significant thickness, but are limited in extent, and hence are of only local significance.

37 In Scottish Planning Policy (Scottish Government, 2010) it is stated that an "*adequate and steady supply of minerals is essential to support sustainable economic growth*". To ensure continuity of supply, "*planning authorities should ensure a land bank of permitted reserves for construction aggregates of a minimum 10 years extraction is available at all times in all market areas*". Sand and gravel extraction has been ongoing since 1975 at Longyester Quarry, to the south of Gifford, some 13 km to the south-east of the southernmost part of the Onshore Works, with permission for a new extension phase granted in November 2011. To ensure a continuity of supply to meet demand, East Lothian Council has allowed the development of a small sand and gravel extraction site at Skateraw Farm (permission granted in 2010), to the east of Dunbar, although to date there has been no development and extraction of sand and gravel from this site. Under Policy MIN2 of the East Lothian Local Plan (East Lothian Council, 2008), the preferred area of search for sand and gravel working is presently restricted to an area south of Longyester Quarry. However, framework documents for the as yet unpublished East Lothian Development Plan, suggest a need to broaden the scope of the minerals search area.

38 The existing BGS records indicate that there are no occurrences of metalliferous or precious metal mineralisation within the area of the proposed development. Hence, there is no Crown Licence issues for precious metal exploration.

39 Ballagan Formation rocks are being quarried to the north-west of the Application Boundary, at Lafarge's Dunbar quarry as a supply for the adjacent cement works. Although similar rocks occur beneath part of the proposed development, working of this resource is unlikely due to local factors, e.g. the route of the A1(T).

11.8.1.4 Geo-hazards

40 The bedrocks are cut by a significant fault zone, the Innerwick Fault (refer to **Figure 11.1 Bedrock Geology**). No seismic events are recorded in the BGS archives either by modern instruments or historically within the north-eastern Southern Uplands. Thus, both the Innerwick Fault and much larger Lammermuir Fault, to the north-west, may be regarded as stable and not a geo-hazard at this time.

41 At [NT 6827 7179] and [NT 6793 7160] the likely cable route is mapped to cut across several alluvial debris cones. Both are north-west trending down slope features. The latter site represents the larger deposit. There is a potential landslip risk at these sites. Formation of the existing track has cut through the toe of each of the cone deposits. These groundworks do not appear to have induced any visible evidence of slope instabilities.

11.8.1.5 General Description of the Route with Respect to Ground Conditions and Geology

42 The proposed Onshore Works extend from a Landfall to the south of Thorntonloch at [NT 7537 7397] to a point within the Crystal Rig II Wind Farm close to [NT 6650 6955]. At Thorntonloch, the offshore cable will make Landfall on the shore face before heading inland along a line that runs parallel to the Thornton Burn. From here, the onshore cable follows a route parallel to the A1(T) to a point to the east of the Innerwick junction at [NT 7258 7491]. The proposed route then strikes south-westwards across country to intersect a C-Class road to the west of Innerwick close to [NT 7165 7390], and then on to intersect the C-class road to Thurston Mains to the south of Ogle Lodge at [NT 7104 7340]. The route then strikes across country westwards to Birky Bog at [NT 6972 7333] where it intersects and runs mostly parallel to the C-class road to Woodhall Farm to a point at [NT 6922 7236]. From here, the route follows the access track to Crystal Rig.

11.8.1.5.1 Transition Pit

43 The proposed egress point and transition pit lies on the south side of the Thornton Burn close to [NT 7528 7420]. Here, the transition pit would be located in raised beach deposits (Refer to **Figure 11.3a Image 4**). These deposits are thought to be of similar character to those exposed in section further to the south at Thornly, e.g. [NT 75374 7399]. The raised beach feature is degraded, but the shore-face cliff indicates a palaeo sea level standstill at about 2.5 m above the present Ordnance Datum (OD). These coarse deposits consist of well-rounded but flat cobbles, with a matrix of coarse sand (Refer to **Figure 11.3a, Image 5**). Clasts comprise a range of rock types including porphyritic dolerite, ferroan dolomite ('cementstone'), sandstone, and basaltic andesite that typically contain apophyses infilled by agate. These, in part, overlie glacio-fluvial outwash deposits. Exposures close by at [NT 75025 74184] show the deposit comprises coarse well-bedded sand with silty laminations (Refer to **Figure 11.3a Image 6**). The upper parts of the deposits here have been reworked and overlain by alluvium consisting mostly of fine to medium-grained silty sand. The thickness of the superficial deposit here is not known, but may be in excess of 3 m, resting on bedrock of Carboniferous age Ballagan Formation.

44 To the south of Thorntonloch, the coastal foreshore is part of a localised coastal embayment flanked by bedrock exposures to the north and south. The development of a near shore bar and lagoonal complex at Thortonloch, near the mouth of Thornton Burn indicates the interaction between coastal and river processes. There is some erosion of the Devensian and Flandrian geology, e.g. glacio-fluvial outwash fans and raised shoreline features. This is most marked at Thornly, where there is significant cut back of the Flandrian shoreline. However, the presence of a coarse cobble gravel storm beach (Refer to **Figure 11.3a, Image 4**), would suggest that at present such erosion is limited to storm fetch conditions.

11.8.1.5.2 Cable Route from Transition Pit to the A1(T)

45 From the egress transition pit to the A1(T), the proposed cable route is located entirely within glacio-fluvial outwash deposits contiguous with those described above. Thicknesses are variable but borehole information derived from the BGS archives indicates that these range up to 10 m thick.

11.8.1.5.3 Cable Route from Thorntonloch to A1(T) Innerwick Junction

46 In this section, the proposed cable route crosses the route of the A1(T) close to the Thorntonloch junction at [NT 7230 7475]. From here, the route tracks to the south of, but immediately adjacent to, the A1 (T) along a route to 0.75 km east of Innerwick road junction at [NT 7259 7491]. This section of the cable route is (at surface) within deposits of glacio-fluvial outwash. Numerous boreholes were drilled along this section of the cable route as part of a study undertaken during the 1980s of potential re-alignment routes for upgrading of the A1(T) between Cockburnspath and Dunbar. Many of these borehole records held within the BGS archives are not on open access, although available information indicates that most are shallow site investigation boreholes. Some deep borehole records from this study are within the public domain. Two site investigation boreholes located close to Skateraw, e.g. at [NT 73271 74972] & [NT 73325 74968], record a thickness of 10m to the glacio-fluvial deposits. These overlie 2-3 m of till, which rests on bedrock of Ballagan Formation. This confirmed data from a borehole sunk close by in 1925, at [NT 73074 74767], as part of a mineral exploration programme for limestone in the bedrock. A further site investigation borehole located to the west of the Innerwick junction, e.g. at [NT 71755 75082], records a similar thickness of glacio-fluvial sand and gravel deposits, overlying till.

47 Till here is a diamicton in which the upper part of the deposits (1-2 m) consists of a clast supported very sandy stony silt, in which the gravel component is fine to coarse with a significant cobble component. This is commonly underlain by a red-brown to grey thick (2-5 m), stiff silty stony clay. Horizons of silty and sandy laminae of probable glacio-lacustrine origin occur at a depth of approximately 11 m, which indicates the occurrence of an intra-glacial lake.

48 Most borehole logs indicate that groundwater was either not encountered within the sand glacio-fluvial deposits or at depths below 9 m. That said, groundwater is recorded at a depth of 1.8 m from a borehole immediately west of the Innerwick junction. The disparity with the other site investigation boreholes suggests that groundwater in this area may locally be 'perched' above clay-rich glacio-lacustrine deposits that are acting as an aquaclude, i.e. a lithology impervious to groundwater flow and hence acts as a barrier.

11.8.1.5.4 *Cable route from the A1(T) to Woodhall Farm*

49 In this section, the proposed cable route follows a line, mostly across country from close to the junction with the A1(T) at [NT 7259 7491] to Woodhall Farm at [NT 6922 7236]. There are no site investigation borehole or trial pit records available within the public domain for this tract of ground. Two boreholes close to Woodhall Farm were drilled in 1985 by the British Geological Survey as part of the Mineral Assessment Programme of sand and gravel resources of the Humbie and East Linton.

50 From [NT 7259 7491] to [NT 7200 7420] to where the proposed route crosses the C-class road to Innerwick the route is underlain by glacio-fluvial outwash sand and gravel deposits of a similar nature to those along the A1(T) section of the route. The deposits are marginal to the outwash plain, and hence likely to be of significantly reduced thickness. Outcrops of Devonian conglomeratic bedrock within the course of a small spring fed burn to the west of Thurston Farm, e.g. at [NT 7136 7446], suggests that the glacio-fluvial deposits might be less than 2 m thick and underlain by a thin layer of till.

51 From [NT 7200 7240], the proposed route, continues across country to intersect the C-class road from Smithy Row [NT 7170 7385] to Innerwick, at a point close to [NT 7165 7390]. Much of the route is underlain by glacial till deposits. These deposits are likely to be relatively thin, possibly as little or less than 1 m thick, particularly where the route traverses a more elevated terrain. Here, bedrock is likely to be close to surface. This is corroborated by the occurrence of a spring at Smithy Row, and exposure of Devonian conglomeratic bedrock within the small burn fed water source, close to where the proposed cable route intersects with this minor road. Other springs occur at Ogle Lodge [NT 7106 7347]. Here also, bedrock is likely to be close to surface.

52 From Ogle Lodge [NT 7104 7340] the route is underlain by glacial till that forms a fairly smooth terrain (Refer to **Figure 11.3b, Image 7**), but cut through by glacial meltwater channels. The deposit is a brownish-grey sandy clayey diamicton, with small (<4 cm diameter) sub-rounded to sub angular matrix supported clasts of rock. Hand augering at [NT 7069 7367] and [NT 7072 7372] indicates that the deposit is greater than 1 m thick.

53 Within the Birky Bog Plantation [NT 6972 7333] the occurrence of both sinks and groundwater springs suggests that the palaeo-bedrock topography is locally irregular. Exposure of sections in drainage ditches reveal a till, consisting of reddish brown, sandy clay diamicton, with thickness in excess of 1.5 m (Refer to **Figure 11.3b, Image 8**).

54 A sand and gravel resource borehole (Aitken & Ross, 1986) drilled in Whittley Strip at [NT 6927 7288] proved a till thickness of 4.8 m overlying bedrock of Devonian conglomerate. Here, the till is overlain 6.2 m of glacial sand and gravel, with 0.3 m of overburden (soil). This represents a maximum thickness to the mineral within this moundy deposit. The thickness of sand and gravel over till where the cable route crosses the deposit is likely to be less than 1 m, and the underlying till is likely to be similar thickness. A similar thickness of sand and gravel and till is recorded from another resource borehole drilled at Woodhall [NT 6877 7219]. The borehole logs indicate that groundwater was neither encountered in the fluvio-glacial deposits, the underlying till, nor bedrock.

55 From Whittley Strip, the route is mostly in till, avoiding a small area of alluvium associated with a glacial overflow channel, now occupied by a small spring fed burn. A small deposit of sand and gravel is likely to be encountered at [NT 6918 7241]. This deposit comprises poorly sorted, imbricated, cobble gravel, with sub-rounded clasts that range in size from 1 cm to 20 cm, supported in a matrix of coarse sand. The deposit is partly lithified (made rock-like) by a red-brown ferruginous cement. This overlies till, which significantly decreases in thickness as the route reaches higher elevations towards Finlay How, where bedrock is close to or at surface, e.g. [NT 6944 7214].

11.8.1.5.5 *Finley How to Crystal Rig*

56 The route from the C-class road at [NT 6933 7237], north-west of Finlay How, follows the access track to the Crystal Rig Wind Farm, and is underlain by sandy diamicton. This is seen in 0.5 m high section exposed at [NT 678921 72090], (Refer to **Figure 11.3b, Image 9**). This is underlain by bedrock of Devonian conglomerate, either exposed, or close to surface, on the upper slopes of Falseley Hill, e.g. at [NT 6915 7200]. Hence, the till deposits along this section of the route are likely to be relatively thin, probably less than 1.5 m thick.

57 From [NT 6843 7189], the cable route runs to the north of, but parallel to, the site access track, (Refer to **Figure 11.3b, Image 10**), to a point where it crosses the Weatherly Burn at [NT 6773 7158]. This is underlain by glacial till in the form of a sandy clay diamicton. At [NT 67716 71531], close to the Weatherly Burn, 2 m high sections in the deposit indicate that it is heterogeneous, containing pockets of gravelly sand (Refer to **Figure 11.3b, Image 11**). These probably represent small kame terrace glacio-fluvial outwash deposits, associated with meltwater channels. Till deposits are quite thin, less than 1.5 m, with bedrock exposed extensively in the Weatherly Burn and its tributaries, e.g. at [NT 6767 7135]. Pockets of a hard lodgement till (**Refer to Figure 11,3a, Image 2**) were noted at [NT 67620 71466], where they underlie the sandy clayey diamicton.

58 Along the cable route from [NT 6745 7136] to a point where the route crosses the Thorter Cleugh at [NT 6698 7082], bedrock of Devonian-age conglomerate is exposed locally at surface e.g. at [NT 6711 7075], but mostly consists of a red-brown regolith of deeply weathered bedrock. From the Thorter Cleugh to the site of the proposed substation, the underlying bedrock is of Silurian-age Gala Group greywacke. Here also there is a thin regolith of less than 0.4 m, of locally soliflucted head deposits, formed from deep weathering of the bedrock. The unconformity between the Gala Group rock and overlying Devonian conglomerates is not seen. Peat was identified at localised sites along the Cable Corridor (less than 15% of sites sampled as part of a peat survey of the study area, (refer to **Appendix 11.1 Peat Stability Assessment**).

59 A peat survey of the substation site was undertaken (**Appendix 11.1**) and highlighted thin peat accumulations across the area. The majority of peat probe surveys identified peat accumulations of less than 0.5 m, although there were isolated pockets of peat that were between 0.5 and 1 m deep and a single site with depths of 2 m. The superficial deposits in the substation site area are considered to be infill accumulations within small depressions of the bedrock surface. The assessment indicated that there was insignificant risk of hazard resulting from peat stability under baseline conditions at the substation site or the Cable Corridor.

11.8.2 Groundwater

60 The walkover survey and information from publicly accessible borehole records has established that within all of the superficial deposits there is no risk attached to any possible interaction with groundwater within the deposits. Where routed through glacio-fluvial and fluvioglacial sand and gravel deposits, borehole information indicates that groundwater is either absent or lies substantially below the level to which the cable is likely to be laid down. The ground works would therefore be unlikely to disrupt groundwater flow through these deposits.

61 There is little borehole information in respect of the glacial till deposits. Those site investigation boreholes that encountered till were dry. In general the tills and diamictons are impermeable, and hence do not transmit groundwater. Although not established in the survey or information review, it is possible that parts of these deposits might contain elevated sand content or host glacio-fluvial channel deposits. In these cases there is the possibility of limited, perched groundwater, and flow through that part of the deposit.

62 The walkover survey noted a number of areas where the proposed route(s) for the onshore cable might pose a risk to groundwater flow, particularly close to the till-bedrock interface close to Thurston Home Farm, and in the areas Smithy Row and Ogle Lodge, where springs were noted.

63 The presence and thickness of peat within the development boundary has been established through a detailed peat assessment (refer to **Appendix 11.1 Peat Stability Assessment**) in the upland area around the substation. Within the upland area to the south west of Weatherly, e.g. from [NT 674 713], the cable will be routed essentially through bedrock or head deposits formed from weathered bedrock. Much of the bedrock is likely to be relatively permeable, with groundwater flow mostly through fractures. There is little porosity in any of these rocks. Thus groundwater migration is mostly likely through fracture flow, which here includes the pronounced finely spaced

bedding, jointing, faulted zones, and cleavage foliation in shaley mudstones. The ground works would therefore be unlikely to disrupt groundwater flow through these deposits.

11.8.3 Coastal Processes

64 Scottish Natural Heritage (1997) divides the coastline of Scotland into 11 coastal cell units. The proposed cable landing point at Thorntonloch is within coastal sub-cell 1a that includes the coastline between St Abb's Head and North Berwick. The coastline at Thorntonloch can experience severe weather conditions (high tides and wave action) generated in the North Sea.

65 The Thorntonloch beach system has developed from re-working of locally exposed glacial sands and gravels and is constrained between rock outcrops north and south of the beach. In addition, man-made hard defences north of the beach provide protection for the Torness Power Station.

66 The foreshore of Thorntonloch is predominantly sand, but with a shingle storm ridge. There is little evidence of net longshore transport of beach material due to the rock outcrops bounding the beach system; however, there is evidence of a bar and lagoon near the mouth of Thornton Burn, indicating interactions between coastal and river processes. All the beach systems within the sub-cell 1a are largely self-contained in terms of sediment movements and the interaction and movement of beach sediment along the coast is small. Fresh beach material is received from the reworking of hinterland glacial deposits. There is little input from other sources.

67 It was noted during a site visit that there is evidence of erosion at the back of the beach at Thorntonloch with coastal protection work (gabions and rock wall at some locations) adjacent to the caravan park and at the mouth of Thornton Burn, suggesting that local erosion may be an issue within these areas, although most likely as a result of storm damage and undercutting at the mouth of Thornton Burn.

11.8.4 Geotechnical and Geo-environmental Desk Study

68 A Geotechnical and Geo-environmental Desk Study has been prepared to accompany this application (refer to **Appendix 11.2** of this Chapter).

69 A review of the historical plans for the Cable Corridor has indicated that the site remained undeveloped by industry, and that the majority of land is used for arable and pastoral agriculture. Small sections of the surrounding area have had industrial uses including mills, quarries, Torness nuclear power station and a laundry.

11.9 The Do Nothing Scenario

70 If the Onshore Works for the NnG offshore Wind Farm were not developed, it is expected that the land use practices will remain as the status quo (although it is recognised that developments such as other onshore wind farms may be developed within the study area in the future). As noted in Section 11.8.1.5, the north-eastern route of the proposed Cable Corridor passes through extensive and thick deposits of glacio-fluvial sand and gravel. Although not currently within the preferred area of mineral search outlined within the current East Lothian Local Plan (East Lothian Council, 2008), the need for maintaining or increasing the land bank to ensure the 10 year supply, might see this, and the area around Woodhall Farm included in a future assessment of resources. Ongoing effects of climate change and variations in weather patterns might have future effects on the bedrock and superficial deposit groundwater aquifers. In the absence of major abstraction of groundwater within the study area, the current pattern is likely to remain in the 'Do Nothing' scenario. Ongoing coastal erosion/deposition will continue in the 'Do Nothing' scenario, with concomitant loss of geo-diversity. Recent monitoring of the Dunbar Geological Conservation Review site, to the north, by SNH noted accelerated erosion of both hard rock and Quaternary features. Future changes in tidal and coastal processes patterns, or an increase in sea level as a consequence of climate change may have a bearing on future vulnerability of this coastal area.

11.10 Routeing and Design Considerations

71 There are no specific considerations for inclusion in this Chapter.

11.11 Assessment of Effects

11.12 Construction Effects of the Onshore Works

72 Potential effects on the geology, ground conditions, groundwater and coastal processes lie largely with disturbance during ground breaking associated with construction of the Onshore Works.

73 The details of the proposed development are described within the **Chapter 5 Project Description**. The main features of the proposed Onshore Works that have been considered in this assessment include:

- construction of the Landfall including transition pits;
- installation of underground cables to new substation adjacent to Crystal Rig II Wind Farm;
- construction of a new substation.

74 To the east of the access track to the Crystal Rig II Wind Farm from Woodhall Farm, the route of the proposed Onshore Works takes in mostly open fields, while to the west it traverses rough upland grazing and open moorland. A construction corridor formed during the development phase will typically have a maximum width of 20 m (although it is wider in certain locations), comprising 2 m wide trench, 5 m heavy vehicle access, 5 m for equipment laydown and spoil, 3 m small vehicle access track, 2 m buffer between trench and roads and 3 m for fencing, parking and turning. . In addition to the construction corridor, the development boundary includes for the provision of equipment laydown points and bridging of watercourses. Temporary access tracks will be constructed between public roads and the construction corridor at selected locations. Both the onshore substation at Crystal Rig II and transition pits at Thorntonloch will have their own construction footprints. It is envisaged that construction will be phased and remediation undertaken at each stage, thus ensuring that the effects of the construction work is minimised. Post development, the temporary structures both within, and servicing the construction corridor are to be removed and the ground re-instated. The only permanent structures will be the substation at Crystal Rig and the transition pit near Thorntonloch; the latter being buried with the ground above to be reinstated to the current profile.

11.12.1 Geology and Ground Conditions

11.12.1.1 Potential Effects

75 Excavation works related to the digging of the cable trench as well as the construction of access roads have the potential to create slope instabilities. The probability of the risk of slope instability along the cable route is considered to be low, based on the subdued terrain along much of the route. There may be the potential for slope instability within the upland area of the cable route and hence mitigation measures will be incorporated into the design. The magnitude of the pre-mitigated effect is considered to be moderate as the potential collapse of a side slope next to any roads requiring cut-off drains would only be expected to have a local effect.

76 There is the potential for ground movement or instability during the construction of the Onshore Works, including the transition pit and substation. The magnitude of the un-mitigated effect is considered moderate.

77 The peat stability assessment undertaken for this study indicated that there was insignificant risk of hazard resulting from peat stability during construction of the Substation Site or the Cable Corridor (within the study area considered in the peat stability assessment, which was the area between the substation to Croft Angry). Based on the Scottish Executive Best Practice Guide (Scottish Executive 2007), areas with insignificant peat slip hazard may proceed, with monitoring and standard construction control measures.

78 There are no designated sites of earth heritage interest or geological features of note within the proposed Application Boundary. The underlying superficial and bedrock geology is not deemed to be particularly unusual in terms of the regional environment. Similarly, the quaternary landscape features are not of significance in terms of their geo-conservation and geo-diversity value. The effect on the bedrock geology is also considered to be negligible.

79 The sand and gravel deposits are limited in their value as a natural resource, and in this area have nowhere seen a history of extraction either in terms of significant winning and working, or local use from borrow pits.

80 The BGS Geochemical Atlas and G-base records do not indicate any potential metalliferous or precious metal deposits within this region. Thus, the development will not sterilise any future minerals development or have Crown Licence issues.

81 The BGS records suggest that the region has no history of seismicity. Thus, mitigation measures are not required in the design of the Onshore Works.

11.12.1.2 Proposed Mitigation

82 Detailed site investigation will be undertaken prior to construction of building foundations forming part of the Onshore Works, to ensure that the materials beneath these discrete locations are adequate to support any concrete bases and/or foundations, and do not have the potential for instability.

83 Detailed construction plans will be required in areas where the cable route passes through areas of potential instability and appropriate water management controls will be required to maintain the integrity of these areas.

84 It is likely that even with good design and site investigation work, issues related to ground conditions and slope stability will be encountered on site due to local conditions. Hence, there will be a need for good construction design management to minimise potential risks on site.

11.12.1.3 Summary of Effects and Residual Effects

85 Following mitigation, the effects of the development on ground movements and slope instability are considered to be **minor**.

11.12.2 Groundwater

11.12.2.1 Potential Effects

86 The probability of risk to groundwater and the hydrogeological environment over much of the Onshore Works is considered to be low. Along much of the cable route, ground disturbance will be considerably above the water table in the case of where the route traverses sand and gravel deposits. Where till, glacial diamicton and bedrock is encountered, these mediums are likely to be largely non-transmissible in terms of ground water movement. Hence, for most areas within the Onshore Works, the magnitude of any effects on groundwater is considered Minor. Areas of concern have been highlighted at Smithy Row, Ogle Lodge and Birky Bog where the route lies close to issues of groundwater, where the magnitude of effects may be regarded as Moderate.

87 The potential for pollution of shallow groundwater by spills of fuel oils or other chemicals during construction are discussed in **Chapter 12** pertaining to surface water quality. Given the shallow nature of the excavations and limited footprint of the development, the potential risk to deep groundwater aquifers and water quality is thought to be negligible.

88 The effect of the Onshore Works on groundwater, pre-mitigation, is considered overall as minor, although with localised exceptions as noted above.

11.12.2.2 Proposed Mitigation

89 During detailed design, an assessment will be made to ensure that the cable trenches do not act as conduits for the transport of groundwater. Mitigation measures in terms of micro-management of the route will be incorporated into the construction design. For example, this includes protocols for back filling the trenches to minimise the development of voids that might be exploited by water flow, and micro management of the fill materials.

11.12.2.3 Summary of Effects and Residual Effects

90 Following mitigation, the effects of the development on groundwater are considered to be **negligible**.

11.12.3 Coastal Processes

11.12.3.1 Potential Effects

91 The offshore cable from Neart na Gaoithe offshore Wind Farm will reach land on the beach at Thorntonloch. Works associated with the installation of the cable on the beach (if open cut trenching is utilised) and construction of the transition pit to the rear of the beach have the potential to disturb the beach and sand dunes at the back of the beach. The beach system is constrained between hard rock outcrops, while to the north there are hard defences associated with the Torness power station. The baseline studies and published accounts (Ramsay & Brampton, 2000) indicate that coastal processes on the beach at Thorntonloch are largely local and confined to the beach. There is little evidence of net long-shore transport of sediment on this coastline. The beach at Thorntonloch has been created through the re-working of local glacial sands and gravels and comprises mainly sand with a shingle storm ridge. As a result, sediment movements on the beach are likely in response to local tidal and wave processes. There is no evidence of any major long-term erosion or accretion caused by long-shore drift. That said, the dune edge is locally being actively eroded, which has resulted in a rock wall sea defence being constructed to protect the caravan site at Thorntonloch. Thus, in terms of beach processes and beach form, any excavations on the beach would not be expected to impact large scale coastal processes and sediment transport along the shore. The magnitude of effects on coastal process of the Onshore Works is considered Minor and the significance of the pre-mitigation effects are considered minor.

92 The cable route will pass through sand and gravel deposits located at the back of the beach. Coastal erosion has been identified as an issue close to the transition pit. If the construction activities cut through or damage the superficial deposits here, this could create a weak point that could focus and increase future erosion along the beach front. The key area of concern would be where vegetated dunes meet the shingle storm ridge and where removal of vegetation could result in exposure of poorly consolidated sand that could be eroded by wind or due to wave action during the next storm. However, it is noted that although there is evidence of erosion at the back of the beach near Thornton Burn, there is currently no evidence of erosion, or exposed sand at the proposed landing point for the cable.

93 The magnitude of effects on coastal erosion of the Onshore Works is considered moderate and the significance of the pre-mitigation effects is considered moderate.

11.12.3.2 Proposed Mitigation

94 Any excavations on the beach should be limited in time and the beach profile returned to its pre-excavation form once the cable has been installed. Work should be avoided during storm conditions (as far as possible) and should be supervised by an environmental clerk of works (or similar).

95 Damage to the coastal landforms should be avoided, potentially by installing cable by drilling beneath the shingle storm ridge and the vegetated edge of sand dunes at the back of the beach. However, if the landforms need to be excavated, shoring will be provided to prevent slumping of sand into the trench, thereby limiting the footprint of the effects on the dunes and shingle beach. Once the cable has been installed, the beach profiles will be returned to its pre-development form and any grasses planted to re-vegetate dunes affected by trenching. Once the remedial work has been completed, it will be checked by an appropriate professional and further mitigation measures proposed, if required.

96 The cable burial depth at the beach will depend on which of the two intertidal cable installation methods being considered are chosen. If HDD is chosen, the cable will follow a close to parabolic profile under the beach and generally be at least 8 m below the surface with no risk of erosion exposure. If open trenching is chosen, the burial depth at the beach will generally be in the region of 1-2 m. A detailed geotechnical investigation and cable exposure risk assessment will be carried out before design completion. Design burial depths will be adjusted where necessary in areas of loose sand with erosion potential or in areas where shallower burial is appropriate due to outcropping rock.

11.12.3.3 Summary of Effects and Residual Effects

97 Following mitigation, the effect of the development on coastal processes is considered to be n**egligible** and the effect on coastal erosion (dunes) is considered **minor**.

11.12.4 Geotechnical and Geo-environmental Issues

98 As mentioned earlier, a Geotechnical and Geo-environmental Desk Study has been prepared to accompany the application (refer to **Appendix 11.2**).

99 The initial risk assessment has identified a low potential for contamination to be present on site from agricultural use or through migration from surrounding land uses (including two landfill sites, Torness nuclear power station,

the A1 trunk road and the East Coast Railway Line). The report recommends that further intrusive investigations be undertaken pre-construction (full details can be found in **Appendix 11.2**).

11.13 Operational Effects of the Onshore Works

11.13.1 Geology and Ground Conditions

11.13.1.1 Potential Effects

100 There are expected to be limited effects on geology and ground conditions processes during operation of the Onshore Works. Unless there is a need to excavate sections of the cable route for maintenance, there is not expected to be a requirement for ground movements during operations. Any maintenance work will be localised in nature and will be limited in time.

101 Due to its relatively low thermal diffusivity, soil and superficial deposits provide thermal insulation to heat-emitting systems in contact with the ground. This insulation is a shortcoming if the buried system requires to be cooled. Thus, for buried high voltage cables, the temperature elevation must be limited. In high voltage cables, the maximum temperatures depend on the operating tension. The load capability of the cable is strongly restricted by the thermal behaviour of the soil and its ability to dissipate the generated heat. Expansive soils and clay-rich superficial deposits are likely to undergo large volume variations upon wetting, i.e. swelling, or drying, i.e. shrinkage. Such behaviours are related to a combination of factors such as the modification of the internal stress state (through the suction change) and physio-chemical phenomena at the scale of the particles that modify the distance between clay platelets. One potential effect could result from shrinkage of clay-rich superficial deposits due to heat flow from the cable, resulting in possible trench instability along sections of the cable route where buried in diamicton. At present there are, however, no published studies to quantify such effects. The likelihood of this occurring is considered Low and for most of the route the magnitude of the effect is considered minor. However, in areas where the cable traverses areas of either clays, till or diamicton, for example from the area around [NT 7200 7240] to Thorter Cleugh, the magnitude of the effect is regarded as moderate to minor. Hence the significance of the effect is considered moderate in locations along the cable route.

11.13.1.2 Proposed Mitigation

102 Mitigation measures for areas of clays, till or diamicton will be incorporated into the design to limit the risk of shrinkage of superficial deposits. This might include insulation of the cable within the trenches in areas where cable traverses deposits likely to be vulnerable with a back fill of low shrinkage materials, such as sand and gravel.

11.13.1.3 Summary of Effects and Residual Effects

103 Following mitigation the effects of the development on geology and ground conditions are considered to be **negligible**.

11.13.2 Groundwater

11.13.2.1 Potential Effects

104 There are expected to be minimal effects on groundwater during operations of the Onshore Works. If sections of the cable need to be re-excavated for maintenance, the effects on groundwater would be localised and temporary.

11.13.2.2 Proposed Mitigation

105 During any excavations for maintenance, environmental management measures similar to those in place during construction of the Onshore Works will be put in place.

11.13.2.3 Summary of Effects and Residual Effects

106 Following mitigation, the effects of the development on groundwater are considered to be **negligible**.

11.13.3 Coastal Processes

11.13.3.1 Potential Effects

107 If construction work has caused damage or weakness to the dunes on the coastline, there is a risk of increased dune erosion over time. However, if there has been damage, remediation measures will have been put in place at the end of the construction period.

108 There is a risk of exposure of the cable on the beach if the cable is not lain at depth. Storms could cause local erosion events on the beach and Thornton Burn discharges onto the beach, so a flood event in the river could cause local erosion of sand on the beach. These effects would be local as baseline studies indicated that there is limited long-shore transport so any effects on the beach at Thorntonloch would not be expected to affect coastal processes remote from the beach.

11.13.3.2 Proposed Mitigation

109 Inspections of the beach and shoreline will be undertaken following storms to assess whether there has been erosion at the cable landing point or exposure of the cable on the beach. Walkover inspections of the beach and shoreline should also take place on an annual basis. If the cable is exposed the cable will be re-buried and the beach profile re-graded. If there is erosion of dunes or coastal landforms at the cable landing point following a storm, appropriate remedial action would be undertaken.

11.13.3.3 Summary of Effects and Residual Effects

110 Following mitigation the effect of the development on coastal processes and dune erosion is considered **negligible**.

11.13.4 Summary of all effects predicted during construction and operation

111 A summary of all effects predicted during construction and operation is provided in **Tables 11.5** and **11.6** below.

Receptors	Sensitivity of Receptor	Magnitude of Effect	Significance of Effect	Likelihood of Effect Occurring	Mitigation Measures Proposed	Residual Effects
Geology and Ground Conditions						
Slope instability	*Medium*	*Moderate*	*Minor*	*Low*	Cut through of alluvial and debris cones incorporated into design. Site investigation. Standard control measures for construction in peat	**Minor**
Ground movement/ instability for onshore buildings and cable route	Medium	Moderate	Minor/ Negligible	Low	Appropriate design and site investigation	**Minor**
Risk of hazard resulting from peat stability during construction of substation	See separate Peat Assessment for detailed assessment					

Receptors	Sensitivity of Receptor	Magnitude of Effect	Significance of Effect	Likelihood of Effect Occurring	Mitigation Measures Proposed	Residual Effects
Underlying superficial and bedrock geology	Low	Negligible	Negligible	Negligible	None	**Negligible**
Sand and gravel and potential metalliferous or precious metal deposits	Low	Negligible	Negligible	Negligible	None	**Negligible**
Groundwater						
Disruption to hydrogeological and groundwater system Minor at all locations with the exception of Smithy Row, Ogle Lodge and Birky Bog which would be moderate	Low	Moderate-Minor	Minor	Low	Micro management of cable route and trench design (e.g. protocols for backfilling the trenches to minimise the development of voids and micro management of fill materials)	**Negligible**
Coastal Processes						
Coastal Processes	Medium	Minor	Minor	Likely	Limited period of works on shoreline and return of beach profile to pre-construction form. Avoidance of working during storm conditions. Works undertaken under supervision. Cable exposure risk assessment to be completed.	**Negligible**
Coastal Erosion	Medium	Moderate	Moderate	Low	Avoidance of damage to dunes system and protection through shoring if required. Reinstatement post-construction to pre-development form. Assessment on completion of works by suitably qualified professional Cable exposure risk assessment to be completed.	**Minor**

Table 11.5: Summary of Potential Effects during Construction

Receptor	Sensitivity of Receptor	Magnitude of Effect	Significance of Effect	Likelihood of Effect Occurring	Mitigation Measures Proposed	Residual Effects
Geology and Ground Conditions						
Potential for ground movements if sections of cable are excavated for maintenance	Medium	Moderate	Minor/ Negligible	Low	Appropriate design and site investigation	**Minor**
Shrinkage of clay-rich superficial deposits	Medium/ Low	Moderate-Minor	Moderate-Minor	Low over most of the route Moderate over part of cable route which traverses areas of clay/till or diamicton	Design and insulation of trench with sand and gravel.	**Negligible**
Groundwater						
Disruption to hydrogeological and groundwater system during maintenance	Low	Moderate-Minor	Minor	Low	Micro management of cable route and trench design protocols for backfilling the trenches to minimise the development of voids and micro management of fill materials	**Negligible**

Receptor	Sensitivity of Receptor	Magnitude of Effect	Significance of Effect	Likelihood of Effect Occurring	Mitigation Measures Proposed	Residual Effects
Coastal Processes						
Coastal Processes	Medium	Minor	Minor	Likely	During re-excavation of cable for maintenance, similar mitigation measures will be in place as during construction activities.	**Negligible**
Exposure of Cable on Beach	Medium	Minor	Minor	Potential	Inspection of beach following storms, with any exposed cable to be covered with beach profile returned to natural form	**Negligible**
Coastal Erosion	Medium	Moderate	Moderate	Potential	Inspection following storms, with site-specific mitigation measures proposed by suitably qualified professional if there is ongoing erosion at the cable landing point.	**Negligible**

Table 11.6: Summary of Potential Effects during Operation

11.14 Monitoring

112 A strategy to monitor construction activities with respect to slope stability, ground conditions, coastal erosion and potential pollution of groundwater will be agreed with SEPA before works commence.

11.15 Decommissioning of the Cable, Transition Pits and Other Related Components

113 Potential effects during decommissioning of the cable, transition pits and other related components are likely to be similar to those predicted during construction and would include:

- disturbance to the beach and sand dunes through re-excavation of transition pits and removal of cables at the landfall increasing the potential for erosion;
- potential for slope instability/ground movement through re-excavation of trenches to remove the cables;
- localised effects on groundwater (e.g. pollution) through disturbance of land to remove the cables.

114 Mitigation would be similar to that proposed during construction and would include:

- avoiding work at the beach during storm conditions;
- returning the beach profile to its pre-excavation form once the cable has been safely removed, to include replanting of dune grasses;
- restoring excavated areas to pre-excavated condition and ensuring there are no voids/weak points once the cables have been removed and the trenches back-filled.

11.16 Decommissioning of Substation Site

115 Decommissioning of the substation would be supported by updated information on peat slide risk and geotechnical conditions to ensure that no new risks to ground stability or from contamination are encountered and safe removal can be ensured.

11.16.1 Geology and Ground Conditions

11.16.1.1 Potential Effects

116 The above ground infrastructure and impermeable hardstanding will be removed and the site re-profiled close to its former condition. The decommissioning effects on geology and ground conditions are considered negligible given the limited area of the substation site and the low slope gradients in this area.

11.16.1.2 Mitigation Measures

117 The substation site re-profiling will be done using appropriate materials (including local soils) to the level existing prior to construction. The decommissioned material will be reused or recycled where possible. Remaining material will be disposed off-site to a licensed waste disposal site.

118 In addition, comparable mitigation measures to those proposed for the construction period will be applied.

11.16.1.3 Summary of Effects and Residual Effects

119 Prior to, and following, mitigation, the effects of the development on geology and ground conditions are considered to be **negligible**.

11.16.2 Ground Water

11.16.2.1 Potential Effects

120 Given the location of the substation within poorly drained upland soils, any effects of decommissioning on ground water is expected to be restricted to shallow ground water in upper soil or superficial deposit layers. The main risk of contamination of shallow ground water is likely from spillages from machinery or the remobilisation of any contaminants (e.g. soils) spilled onto the gravel surface of the substation during operation. However, any effects would be expected to be minor and local in effect prior to mitigation.

121 Overall, the removal of hardstanding areas and the return of land at the substation site to natural conditions would be expected to have a positive effect on local ground water levels, returning infiltration rates and ground water levels to pre-development conditions.

11.16.2.2 Mitigation Measures

122 Mitigation measures comparable to those proposed for the construction period will be applied during decommissioning. In addition, care will be taken to identify any areas of the substation which were contaminated by spills during operation. Any contaminants identified would need to be removed with care.

11.16.2.3 Summary of Effects and Residual Effects

123 Following mitigation, the effects of the development on groundwater are considered to be **negligible**.

11.16.3 Coastal Processes

11.16.3.1 Potential Effects

124 The substation is not located on the coast. As a result, there will be no effect of decommissioning of the substation on coastal processes.

11.16.3.2 Mitigation Measures

125 None proposed.

11.16.3.3 Summary of Effects and Residual Effects

126 The decommissioning of the Substation Site will have **negligible (no) effect** on coastal processes, including dune erosion.

11.17 Assessment of In Combination Effects

127 In combination effects on coastal processes and erosion from 'The Project' are most likely to occur where the on and offshore cables connect. This chapter provides an assessment of the likely effects on coastal processes and erosion from the Onshore Works. Residual effects are predicted to be of no more than minor significance.

128 Taking account of safeguards proposed as part of both the Onshore Works (including re-instating beach profile following works; providing additional protection through shoring if necessary and annual inspections to identify any exposed areas of cable) and Offshore Works (inspections of areas of buried cable below Mean Low Water Spring), the significance of in combination effects are not predicted to any more than those predicted for Onshore Works alone.

11.18 Assessment of Cumulative Effects

129 At present, there are no other known schemes within the route corridor that are at the planning stage and scheduled to be constructed at the same time as the Onshore Works. However, there are three known nearby planned developments:

- Aikengall II Wind Farm and substation;
- Crystal Rig III Wind Farm Extension;
- SPT NnG Scheme to connect the Onshore Works to the national grid.

11.18.1 Potential Effects

130 Effects of development on geology and ground conditions are by their nature local to the development. Hence, as the other known planned developments are outside of the footprint of the Onshore Works, or overlap between the developments is very small (e.g., part of SPT development), no cumulative effects are anticipated.

131 None of the proposed onshore developments are expected to affect coastal processes at Thorntonloch Beach.

132 The proposed developments are not expected to have any cumulative effect with respect to groundwater.

133 Pre-mitigation cumulative effects of the development on geology, ground conditions, groundwater and coastal processes are considered to be negligible.

11.18.2 Proposed Mitigation

134 No additional mitigation is proposed to address cumulative effects.

11.18.3 Summary of Effects and Residual Effects

135 Cumulative effects of the development on geology, ground conditions, groundwater, and coastal processes are considered to be **negligible**.

11.19 Summary

136 **Table 11.7** summarises the predicted significant effects of the development on geology, ground conditions, groundwater and coastal processes.

Predicted Effects	Significance	Mitigation	Significance of Residual Effects
Construction			
Geology and Ground Conditions			
No significant effects identified			
Groundwater			
No significant effects identified			
Coastal Processes			
Coastal Erosion	Moderate	Avoidance of damage to dunes system and protection through shoring if required. Reinstatement post-construction to pre-development form. Assessment on completion of works by suitably qualified professional.	**Minor**
Operation			
Geology and Ground Conditions			
Shrinkage of superficial deposits	Moderate-Minor	Design and insulation of trench with sand and gravel	**Negligible**
Coastal Processes			
Coastal Erosion	Moderate	Inspection following storms, with site-specific mitigation measures proposed by suitably qualified professional if there is ongoing erosion at the cable landing point	**Negligible**
Decommissioning of Substation Site			
No significant effects identified			
Cumulative Effects			
No significant effects identified			

Table 11.7: Summary of Predicted Significant Effects

11.20 References

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