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Appendix 9.3

Ground Stability Report

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Glossary

Term	Definition
The Applicant	Fred. Olsen Renewables Ltd
Environmental Impact Assessment	Environmental Impact Assessment (EIA) is a means of drawing together by the developer, in a systematic way, a description of the development and information relating to the likely significant environmental effects arising from a proposed development.
Environmental Impact Assessment Report	A document reporting the findings of the EIA and produced in accordance with the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 Regulation 5
The Proposed Development	The Proposed Scawd Law Wind Farm development
The Proposed Development Area/The Site	The development area within the red line site boundary (application area) as shown in Volume 3a Figure 1.2: Site Layout.

List of Abbreviations

Abbreviation	Description
AOD	Above Ordance Datum
BGS	British Geological Survey
CGeol	Chartered Geologist
CMS	Construction Method Statement
CEMP	Construction Environment Management Plan
EIAR	Environmental Impact Assessment Report
FORL	Fred. Olsen Renewables Ltd
FoS	Factor of Safety
Natural Power	Natural Power Consultants Ltd
NGR	National Grid Reference
Pa	Pascal
PGR	Peat Ground Acceleration
PWP	Pore Water Pressures
SEPA	Scottish Environment Protection Agency
T	Turbine

A9.3.1 GROUND STABILITY REPORT

This report presents a peat slide risk assessment following detailed site survey which took place in October 2021.

Terrain across the proposed wind turbine locations was found to meet the criteria for peat slide assessment under current Scottish Government Guidance in respect of T6 and the surrounding area. That is to say for this limited area only, peat is present across terrain of greater than 2° slope angle.

This report therefore provides necessary detailed risk assessment of peat slide associated with any future development at this specific location.

Objectives

A9.3.1.9 Natural Power was appointed by Fred Olsen Renewables to conduct a geotechnical desk study including ground stability report for the Proposed Development. This report compiles existing geological and geotechnical information and provides advice for any future site assessment.

A9.3.1.10 The following key objectives of the report are:

- Present relevant desk study information and ground model information;
- Report on site survey and reconnaissance including relevant geomorphological mapping;
- Identified areas of existing instability and risk of future peat landslide; and
- Provides targeted recommendations for future development and construction.

Reporting Experience

A9.3.1.11 **Report Author:** Sam Fisher is a geotechnical engineer at Natural Power and geologist by training (MSc Engineering Geology) and Fellow of the Geological Society of London with over five years of relevant geotechnical experience. On behalf of Natural Power, Sam has been involved in field work and reporting of multiple peat slide risk assessments for renewable energy projects across Scotland and Northern Ireland.

A9.3.1.12 **Report Approver** - Gavin Germaine is a principal geotechnical engineer at Natural Power and engineering geologist by training (MSc Engineering Geology) with thirteen years of relevant geotechnical experience. Gavin is a Chartered Geologist (CGeol) and a Fellow of the Geological Society of London. Over the last decade has completed multiple peat slide risk assessments for wind energy projects across the UK and Ireland. Gavin has further provided expert technical advice as part of two public inquiries and joined international teams examining new geotechnical investigation techniques for in-situ testing and sampling of peat.

Sources of Information

A9.3.1.13 The main sources of information used in the preparation of this report are:

- British Geological Survey (BGS) geology map data;[1]
- Historical Ordnance Survey Map review[2];
- National Soil Map of Scotland[3]
- Aerial photographic records (various public domain web mapping resources).
- Online archival and news searches
- Scottish Environment Protection Agency (SEPA) flooding and rainfall information[4]

[1] http://mapapps2.bgs.ac.uk/geoindex/home.html

[2] https://maps.nls.uk/

[3] http://soils.environment.gov.scot/maps/

[4] www.sepa.org.uk/rainfall/

- Site specific survey data including soil probe depths, terrain reconnaissance and mapping.

A9.3.1.14 The application is for a wind farm comprising of up to 8No. wind turbines with a blade tip of up to 180 m.

A9.3.1.15 Figures A9.3.1 & A9.3.2 below indicate the final site layout and regional context of the proposed development. Figure A9.3.1 illustrates the relevant elements, including locations for the proposed 8No. turbines, site tracks, crane pads, substation, storage compound areas, any existing anemometry masts and potential borrow pit search area (local temporary source of construction aggregate which are solely for the purpose of the wind farm construction).

Source: Natural Power / Ordnance Survey Crown Copyright © 2021

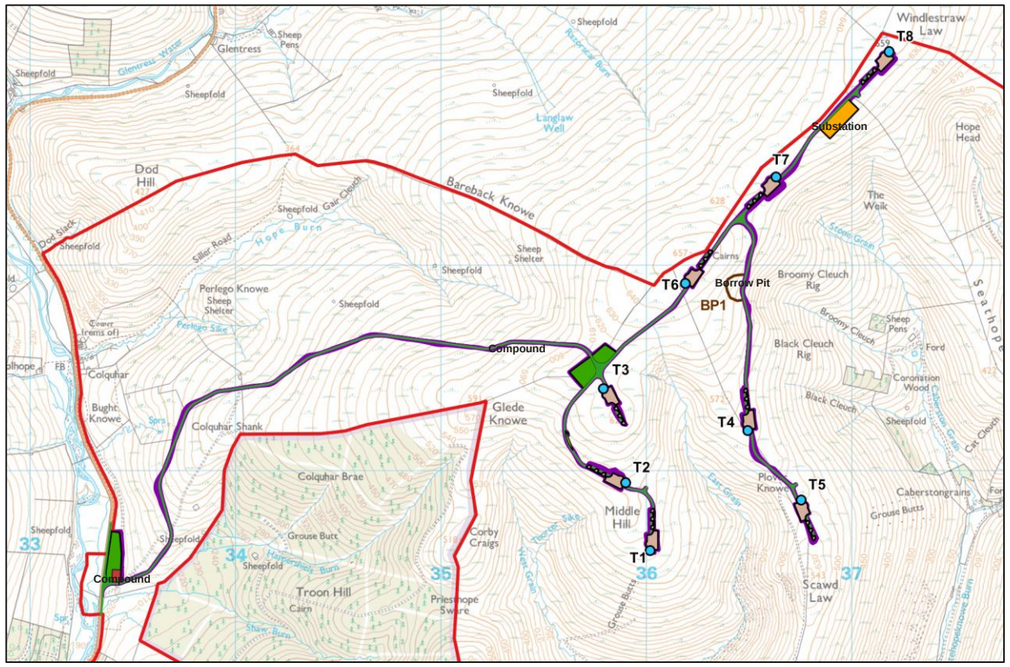

Figure A9.3.1: Scawd Law Wind Farm – Extract Final Site Layout – EIAR Figure 1.2

A9.3.1.16 The centre of the development is approximated to National Grid Reference (NGR) [336013,641679]. The development is located on an area of upland north-east of Innerleithen, Scottish Borders. See Figure A9.3.2.

Source: Natural Power / OpenStreetMap

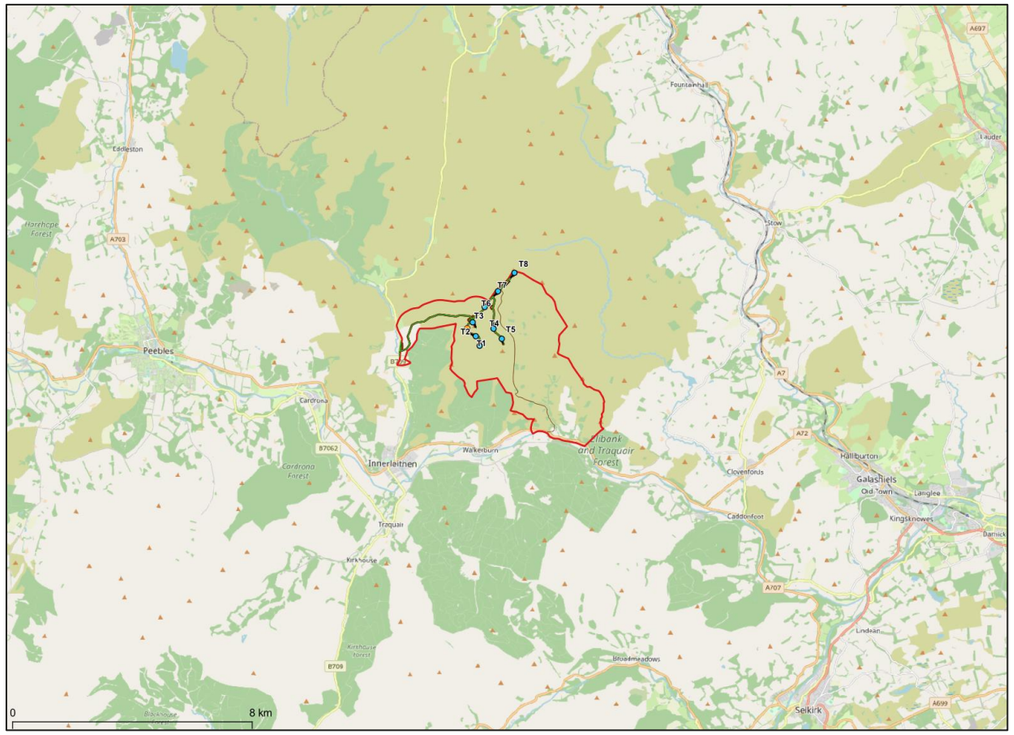

Figure A9.3.2: Scawd Law Wind Farm – Regional Context

A9.3.1.17 The Proposed Development will consist of the erection, operation, and subsequent decommissioning of 8No. wind turbines. This will include associated turbine foundations and external (?) transformers, energy storage, hardstanding areas for erecting cranes at each turbine location, a series of on-site tracks connecting each turbine, underground cables linking the turbines to the grid connection, an on-site substation, a construction compound and one borrow pit.

A9.3.1.18 Wind turbines are likely to be installed on reinforced concrete gravity foundations depending on ground conditions. It is anticipated that construction aggregate will be won on-site.

A9.3.1.19 Each wind turbine requires an area of hard standing ("crane pad") to provide a level and firm base for the cranes at the location of each turbine. Each would be surfaced with coarse aggregate.

A9.3.1.20 There would be a temporary construction compound. The temporary compound would provide a secure area for site office facilities and storage of materials and compounds. This would be constructed adjacent to the site track, with a hardcore base, surrounded by a security fence and locked gates.

A9.3.1.21 Transformers to step-up the voltage exported from each turbine would be placed in a small secure external transformer housing placed next to each wind turbine tower.

A9.3.1.22 Battery energy storge infrastructure located within the substation compound, see EIAR Figure 1.2.

A9.3.1.23 High voltage and control cables would be placed in trenches (dimensions to be determined by the ground conditions, but typically 0.5 m x 1 m deep and routed alongside the access tracks.

A9.3.1.24 A single storey substation building would be built and will house the switchgear and control equipment, in addition to acting as a secure storage space. Parking spaces will be included in the design.

A9.3.1.25 Figures A9.3.3 and A9.3.4 below provide an indication of the terrain type within the site.

Source: Natural Power

Figure A9.3.3: View towards head of East Grain Valley

Source: Natural Power

Figure A9.3.4: Photo view from main area of peat at T6

Geotechnical Classification of Structures

A9.3.1.26 In line with BS EN 1997:1 – 2004 (Eurocode 7 Geotechnical Design), the structures proposed for the development have been classified as detailed in Table 1 below.

Table 1: Geotechnical Structure Category

Construction Element	Geotechnical Category
Wind Turbine Generator and Foundation	3
Control Building/ substation & Battery/Energy Storage	2
Access Tracks / Hardstands / Compound	2

A9.3.1.27 **Geotechnical Category 2** structures: include conventional types of structure and foundations with no exceptional risk or difficult ground or loading conditions. Designs for structures in this category should normally include quantitative geotechnical data and analysis to ensure that the fundamental requirements are satisfied. Routine procedures for field and laboratory testing and for design and execution may be used for Geotechnical Category 2 designs.

A9.3.1.28 **Geotechnical Category 3** structures: are those which fall outside the limits of geotechnical categories 1 and 2. This category has been set for wind turbines due to their large size and exceptional loading conditions which

incorporates, dynamic loading and high overturning forces. Any future phases of ground investigation should be designed for category 2 and 3 structures.

Geology

Superficial Deposits

A9.3.1.29 The Proposed Development exhibits a mix of past and current depositional environments. Residual soils are present on the steeper slopes and hill tops, alluvial deposits in the valley bottoms and patches of till, glaciofluvial deposits and peat. The peat is isolated to a single main extent of peatland focussed around the area of turbine T6 and as shown in Figure A9.3.4.

A9.3.1.30 In general terms: Peat is described as an organic soil composed of semi carbonised organic material. Peat can be very soft to firm, fibrous to amorphous. Deposits may be selectively worked to shallow depth. Foundation conditions are very poor, deposits are very weak and compressible. Specialist very low load or floating foundations may be suitable in some cases, but deposits at surface should be removed or pile foundations from stronger deposits employed. Easy digging, but will require specialist machinery, requires immediate support and dewatering, this will lead to surface lowering and oxidation of peat.

A9.3.1.31 Residual soil composition is controlled by the underlying rock type, this ranges from igneous granite to layered mud and sandstones, as well as a small portion of contact metamorphism products. These are described in more detail in the Solid Geology section below. The residual soil types on steep slopes and hill tops are described as Argillic to Arenaceous, with an intermediate depth. Soil underlain by granitic intrusions will be shallow and composed of a medium grained sandy material. Soils formed from rocks subject to contact metamorphism are varied and require a detailed ground investigation as the nature of the metamorphism is the main control on the soil creation.

A9.3.1.32 Alluvium can be found in the base of most deeply incised valleys within the site boundary; it is composed of different proportions of silt, sand and gravel. This is classified as a fine soil with regards to engineering properties and can be very soft to very stiff in consistency. Desiccation of the few top meters can result in firm to stiff material overlying soft to very soft material at depth. Foundation conditions are variable, dependent on the shear strength and consolidation of the soil, settlement rates can be slow, but can result in high total settlements. Conditions for differential settlement can also be present. Excavation is easy, and will usually require immediate support, water bearing silts and sands will require ground water control measures. Soil may be suitable for selected cohesive fill depending on grading, plasticity, water content and sulphide/sulphate contents if concrete or steel are being used. The site investigation should determine lithological variability as well as the presence, depth and extent of any soft compressible zones. Shrink/swell potential of any clays should be assessed; as well as in situ loading tests are advised.

A9.3.1.33 Till deposits may be encountered on the hill tops and valley forms. They are classified as fine layered till by the BGS; and are composed of firm to very stiff, slightly gravelly sandy CLAY, with interbeds of laminated clay/silt and beds/lenses of sand or gravel. Foundation conditions are generally good, and dependant on shear strength, consolidation characteristics and the presence of water-bearing sand and silt. Differential settlement is possible where foundations overlap coarse and fine material. Excavation is considered easy, with excavations requiring immediate support due to water-bearing layers/lenses. Suitable as general cohesive fill depending on plasticity and water content. Any future site investigation should determine the deposit thickness and lithological variation, it would also be important to confirm the presence of laminated silts and clays as well as water-bearing sand and gravel layers.

A9.3.1.34 Glaciofluvial deposits can be found near the base of the valleys. These are classified primarily as fine soil, which is like the description of Alluvium above, but may also have characteristics like coarse soils. Coarse soils are described as loose to dense fine to coarse-grained sand or sand and gravel with some cobbles. Sandy clay and silt can occur locally. High to very high ground water permeability. Foundation conditions are variable, with near surface frost susceptibility of near surface silt and fine sand lithologies. Digging is usually easy with occasional hard digging. Immediate support will be required and ground water control where deposits are below the water table. Material may be suitable as selected granular fill if composition is appropriate or with separation of desired grades. Any future site investigation (carried out during the pre-construction phase) should determine the lithological variation and deposit geometry, in particular the presence and dimension of buried channels and infilling deposits.

A9.3.1.35 Figure A9.3.5 below depicts for the proposed wind farm infrastructure footprint; the BGS superficial map data. (Note the extent of peat has been refined by detailed site-specific survey carried out as part of the EIAR). EIAR Figure 9.5 provides full details of the Superficial Geology.

Source: British Geological Survey © NERC 2019 / Ordnance Survey Crown Copyright © 2021

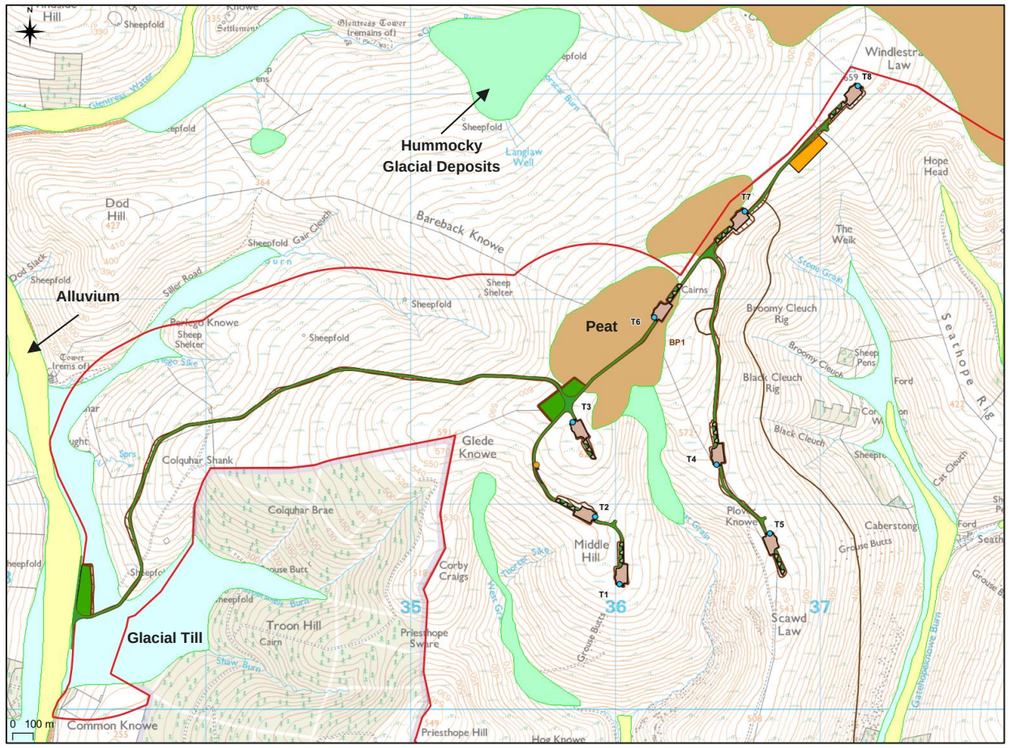

Figure A9.3.5: Extract 1:50,000 scale superficial geology mapping – EIAR Figure 9.5

Geomorphology

A9.3.1.36 Figure A9.3.6 below details the major geomorphological features encountered across the peatland terrain. Further information regarding the baseline conditions across the site are provided in Chapter 9.7 of the EIAR.

A9.3.1.37 Key aspects to note are the sites of soil erosion and instability in the underlying subsoils. These are focussed across the southern aspect slopes where terrain angle increases. There was no existing or historical peat slide failures evident. The area of peat is being routinely traversed by 4x4/ATV vehicles which have left scars and tracks as indicated. No evidence of peat movement was recorded associated with these features.

A9.3.1.38 Reconnaissance and geomorphological mapping was carried out at the development during May 2021. This exercise provided opportunity for surveyors to visualise the terrain, access soil exposures, examine slope systems, ground cover, and record any features impacting peat stability across the vicinity of turbine T6 as shown in Figure A9.3.6 below.

Source: Natural Power Bing Maps

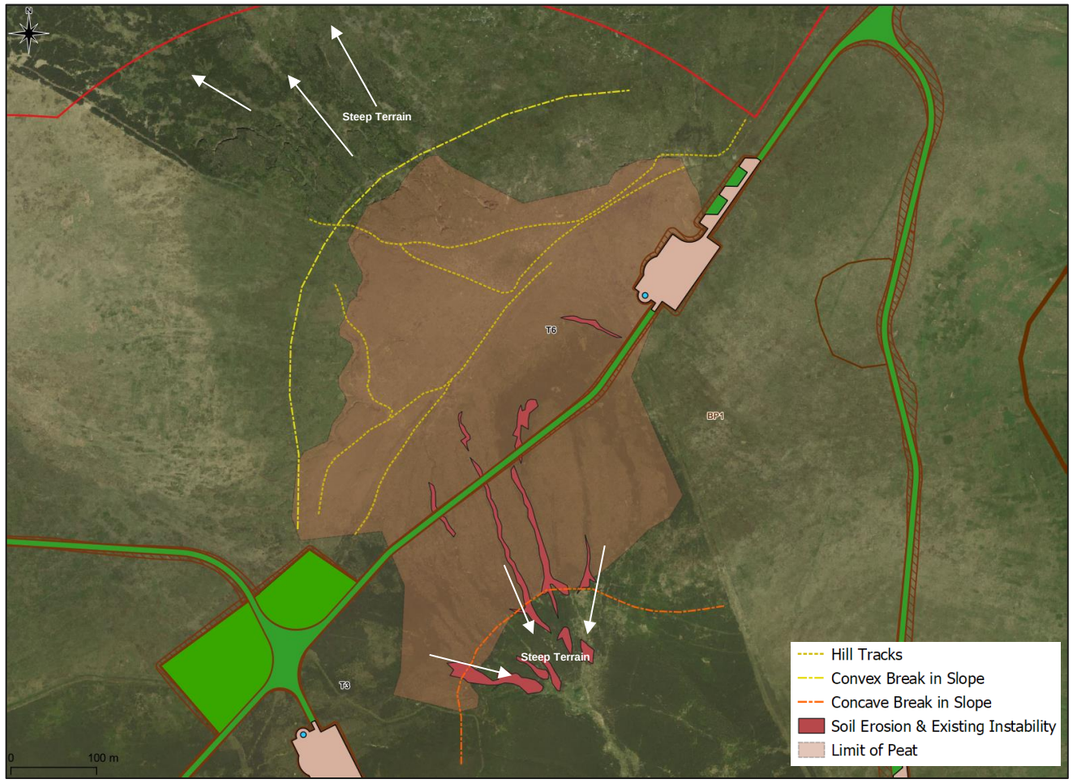

Figure A9.3.6: Geomorphological features across area of Peat

Solid Geology

A9.3.1.39 The site is underlain by the 'Unit 7' greywacke of the Gala Group; with occasional granitic intrusions. One intrusion has created a relatively large metamorphic aureole to the southwest of the development, the resultant changes imparted to the rock mass would require intrusive investigation for further detail. Detailed geotechnical investigation would be undertaken as part of the pre-construction phase of works. Figure A9.3.7 shows the solid geology across the site as provide by the BGS and is an extract of EIAR Figure 9.6.

A9.3.1.40 A reverse fault trending northeast/ southwest is inferred to run to the southeast of the site. The site is located within the hanging wall, thus multiple low angle slip surfaces dipping to the northwest would be envisaged. The frequency and nature of these is unknown as the fault is inferred and therefore the location and nature of the fault zone could vary.

A9.3.1.41 The Gala group is defined as being made up of strong sandstone and slate. Slate is generally strong to very strong with a large range of bed sizes, joint spacing is medium to wide with well-marked cleavage planes. Rock weathers to clayey gravel, ground water flow is low, with flow restricted to discontinuities. Slate is generally good for foundations depending on the nature of the weathered zone. Excavation is generally hard, with fresh rock requiring blasting. Slate is suitable for granular fill if its tabular nature can be dealt with. Future site investigation undertaken as part the pre-construction phase of work would determine the discontinuity spacing and orientation, as well as the nature of the weathered zone within the rock mass.

A9.3.1.42 'Strong Sandstone' is defined as a medium strong to extremely strong sandstone, it may contain slate or mudstone and siltstone beds. Weathers to loose to very dense sand, gravel or silty/clayey sand. Groundwater flow can be through matrix and discontinuities. foundation conditions are usually very good, depending on the nature of the weathered zone. Highly weathered rock may be excavatable by hard digging, but fresher material may require blasting. When excavated as a slope fresh or slightly weathered material may maintain long term stability. Strong sandstone is suitable as selected granular fill if care is taken during abstraction. Future site investigation undertaken as part of the pre-construction phase of work would determine intact rock strength as well as nature of discontinuities and weathered zone.

A9.3.1.43 The igneous intrusions are described as Late Silurian to early Devonian Granite, Microgranite and Felsite, these are generally very strong rocks, resistant to weathering and impermeable. Intrusive features can lead to differential settlement if surrounded by weaker weathered material of another lithology. Fresh rock will require blasting. Figure A9.3.7 depicts the extract of solid bedrock geology beneath the proposed wind farm infrastructure footprint.

Source: British Geological Survey © NERC 2019 / ESRI World Topo

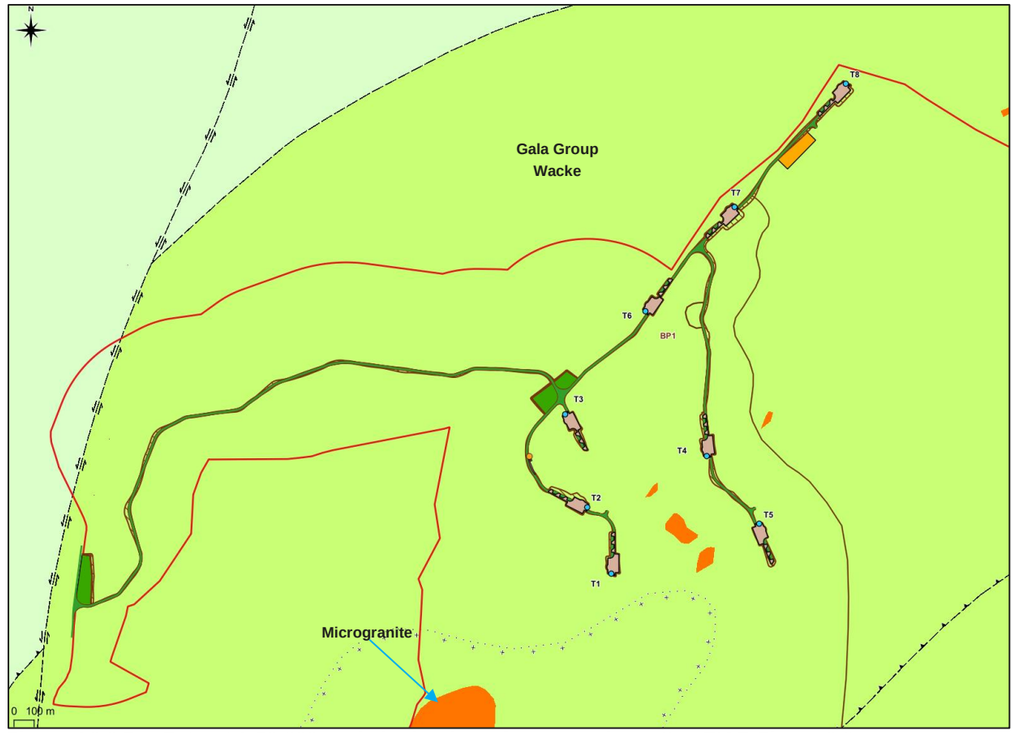

Figure A9.3.7: Extract 1:50,000 scale bedrock geology mapping – See EIAR Figure 9.6

Hydrology

A9.3.1.44 Surface run-off predominantly drains towards the southeast. Sharply incised gulley features initially are formed giving way to more open valley forms. Gatehopeknowe Burn is formed from the confluence of many minor

watercourses and flows into the River Tweed south from the development. Priesthope Burn similarly drains the development flowing south into the River Tweed. Surface water flow to the north is diffuse and thought to be predominantly through the area of peat at T6 and deeper superficial deposits.

Hydrogeology

A9.3.1.45 There are no significant aquifers underlying the site. The Gala Group and the unnamed igneous intrusions are all classified as low productivity by the BGS.

Radon Gas

A9.3.1.46 The entire site is in an area with the lowest radon potential, with less than 1% of homes above the action level.

Natural Ground Hazards

A9.3.1.47 The BGS Onshore Geoindex does not record any mass movement deposits or landslides within 1 km of the development boundary. The risk of mass movement must be considered by any future phase of intrusive geotechnical site investigation.

A9.3.1.48 In general, superficial deposits (peat, residual weathered soils and glacial till deposits) are soils most likely to be at risk of instability. A detailed Peat Slide Risk Assessment has been reported for the section of the site which contains peatland. There are some indications that; where peat is present at key watershed areas these soil masses may be susceptible to natural movement in the long term through erosion, hagging and detachment. The effects of the proposed development on peat stability have been considered further in Section 4.

A9.3.1.49 Geomorphological features indicating minor instability have been identified within approximately 100 m of proposed infrastructure. These take the form of erosional instability on the sides of steeply incised gulley's. At current desk study stage these features appear to be isolated from proposed infrastructure. Thus, there is anticipated to be no immediate risk of ground instability. Field survey and a peat slide risk assessment should form part of any further environmental impact assessment for further confirmation.

A9.3.1.50 Following introduction of Eurocode 8 building regulations there is a requirement to review the potential for seismic hazard for certain developments. The BGS provides guidance and recent seismic hazard maps indicate peat ground acceleration (PGA) for the development to be low. In general, the UK is bracketed as low for seismic hazard.

Peat Slide Risk Assessment

Peat Survey

A9.3.1.51 Natural Power carried out a Stage 1 probe survey implementing a 100 m grid of probes across the development infrastructure areas. Soil depths were recorded using probes inserted into the ground and measuring the depth to refusal. This provides a wide-ranging dataset with the following limitations:

- Probes may record depth to obstructions (e.g., tree roots, rock clasts);
- Probes may over-estimate peat depth where the underlying soil strata is very soft;
- Peat probes can underestimate peat depth in very dry peat deposits due to early refusal of the probe;
- The probe depths do not confirm the presence of peat this was determined following visual reconnaissance, in-situ peat coring and additional detailed probing.

A9.3.1.52 Detailed probing was undertaken across the locations confirmed as peat (visual reconnaissance / coring confirmed the extent of peat). In-situ hand shear vane tests were conducted to provide an estimate of undrained shear strength within the peat.

A9.3.1.53 Supplementary to this, peat cores have been taken at select locations to provide confirmation of peat depth, material classification and morphology.

Source: Natural Power, Ordnance Survey Crown Copyright © 2021

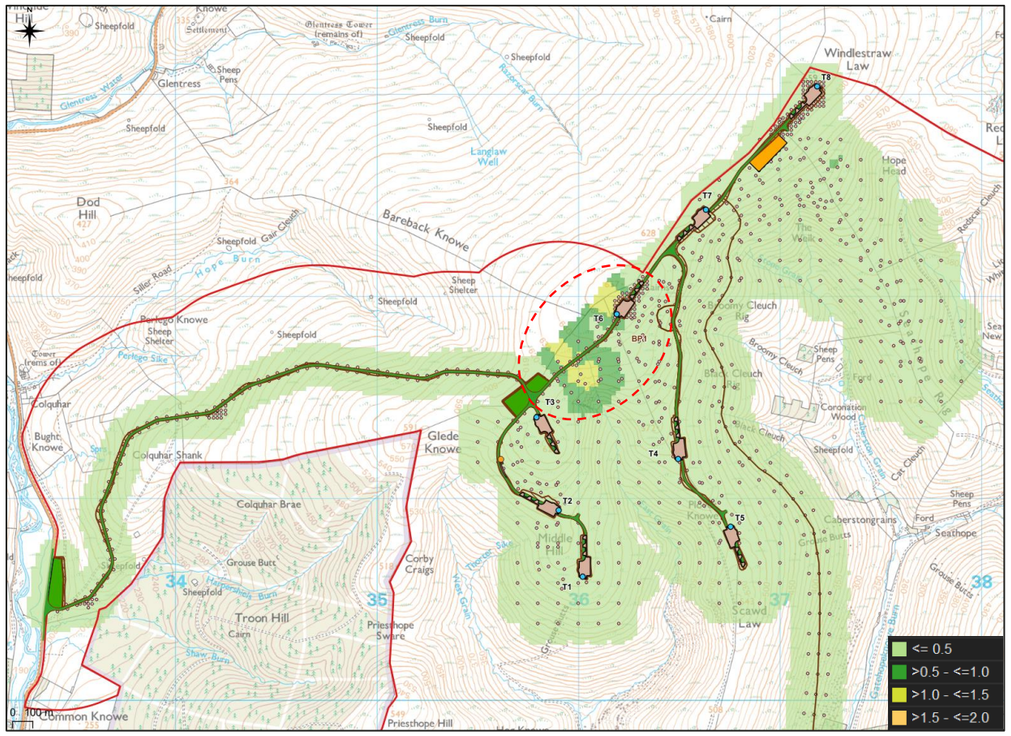

Figure A9.3.8: Peat Depth Extract (Depth Classes in metres (<0.5 is not peat) – EIAR Figure 9.4

A9.3.1.54 Peat depth mapping is shown on Figure A9.3.8 and extracted from EIAR Figure 9.4. To prepare the interpolated peat depth mapping; a spatial interpolation method termed 'Ordinary Kriging' was applied. Areas of <0.5 m probe depth are defined as not peat soils with the single area of peatland identified in the vicinity of T6 (red dashed ellipse).

A9.3.1.55 Terrain slope angle has further been assessed via a digital elevation model dataset with a grid resolution of 5m. The risk assessment has considered terrain slope angle as part of a quantitative slope stability analysis and further used for qualitative screening the site where slope angle is used as a key contributory factor to peat failure. Figure A9.3.9 below shows the predominant shallow slope angles in the area of deepest peatland with steeper valley forms to the north and south. The slope map class has been colour coded with red and amber signifying terrain slope angles most associated with instability. Whilst white and green signify lower propensity for instability in relation to peat landslide.

Source: Natural Power / OS Terrain 5 DTM

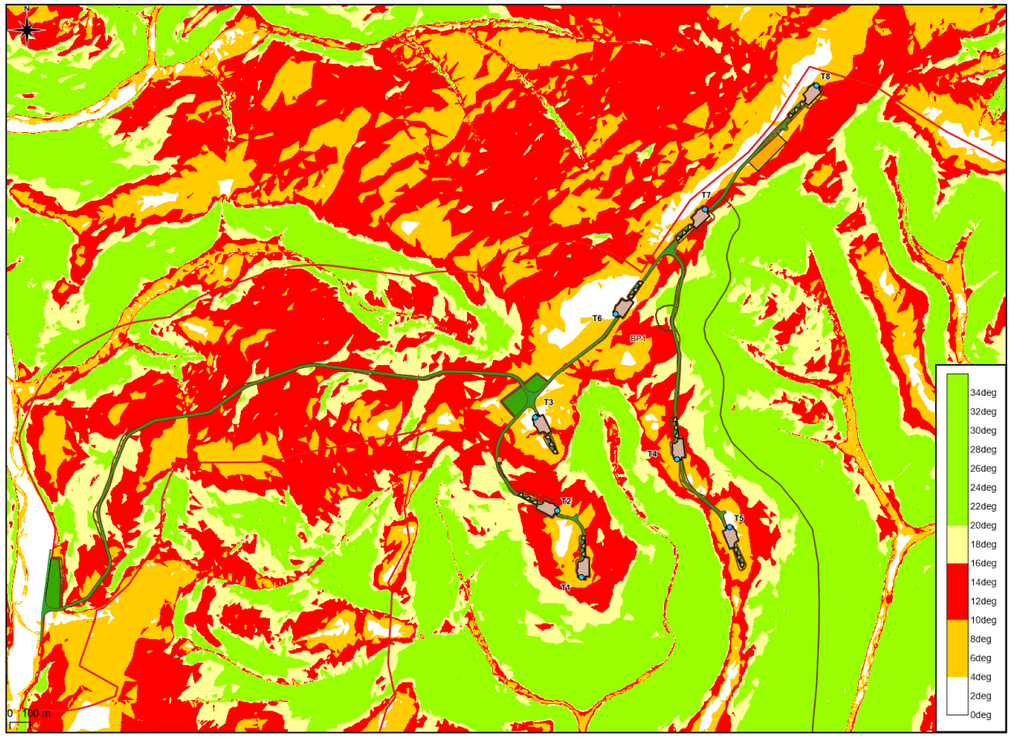

Figure A9.3.9: Terrain Slope Angle Map

Peat Morphology

A9.3.1.56 A hand shear vane was used during the detailed site survey to measure the undrained shear strength of the in-situ peat deposits if present and of sufficient depth. Shear vane testing was undertaken where the peat was present at T6 and along the approaching access route approximately 150 m southwest of T6.

A9.3.1.57 The hand shear vane provides a preliminary and conservative estimate of peak and re-moulded un-drained shear strength. The basal contact of the peat with the underlying mineral subsoil was not able to be sampled. This material is likely to comprise a granular deposit (poorly sorted) of sand, gravel, and clay. This is based on soil exposures examined across the wider development.

A9.3.1.58 The measured peak undrained shear strength ranges from 17-45 kPa with a mean value of 27 kPa. The mean re-moulded shear strength is 19 kPa. The in-situ testing confirms the peat has very low to low shear strength.

A9.3.1.59 The degree of humification has been recorded at the same location as the strength testing. The peat has been characterised according to the Von Post Classification[5]. Peat classification ranges from H3 to H7 with increasing humification with depth. A moisture class of B3 is also recorded.

A9.3.1.60 The peat encountered across the development is typically very soft and fibrous to amorphous in the acrotelmic surface layer. In the deeper deposits, characteristically humification increases with depth at the catotelmic layer. Figure A9.3.10 – 12 below provides photographic record of typical peat core samples. A Russian peat corer was used to obtain these samples.

Source: Natural Power

Figure A9.3.10: T6 – Peat Core 0.0 – 0.5 m

Stockholm

Source: Natural Power

Figure A9.3.11: T6 – Peat Core 0.50 – 1.0 m

Source: Natural Power

Figure A9.3.12: NT 36083 41765 – Peat Core 150 m SW from T6

Peat Slide Risk Assessment

A9.3.1.61 Peat failure in this assessment refers to the mass movement of a body of peat that would have a significant adverse impact on the surrounding environment or infrastructure. This definition excludes localised movement of peat, for example movement that may occur below an access track, creep movement or erosion events and failures in underlying mineral soils.

A9.3.1.62 The potential for peat failure at the development is examined with respect to the activities envisaged during construction and operation of the wind farm. The discrete location of peat deposits and elevated position has

[5] Von Post L, Granlund E (1926) Södra Sveriges torvtillgångar 1. Swedish Geological Survey, Stockholm

indicated peat slide morphology which would comprise: an intact mass of peat moving bodily down slope over comparatively short distances. A slide which intersects an existing surface water channel may evolve into a debris flow and therefore travel further down-slope. The risk of a peat slide is assessed further below.

Numerical Slope Stability Analysis

A9.3.1.63 A slope stability model as defined by Skempton et al, (1957)[6] has been adapted to determine the factor of safety against peat slide for the relevant section of the Development. A minimum factor of safety (FoS) of '1.3' has been set after, BS 6031: 2009[7].

A9.3.1.64 The slope analysis is based on a translational slide. This analysis adopts total stress (measured undrained) conditions in the peat. This state applies to short-term conditions that occur during construction and for a time following construction until construction induced pore water pressures (PWP) dissipate (PWP requires time to dissipate as the hydraulic conductivity can be low in peat deposits). The following assumptions apply:

- The groundwater is resting at ground level;
- Minimum acceptable factor of safety required is 1.3;
- Failure plane assumed at the basal contact of the peat layer;
- Slope angle on base of sliding assumed to be parallel to ground surface and that the depth of the failure plane is small with respect to the length of the slope;
- Thus, the slope is considered as being of infinite length with any end effect ignored;
- The peat is homogeneous;

A9.3.1.65 Undrained shear strength values (Cu) are used throughout this assessment. Effective strength values are not applicable for the case of rapid loading of the peat during short term construction phase of works hence the formula cited above, has been adopted. Figure A9.3.13 maps out the calculated FoS for the peat when applying a conservative 13 kPa as the peak undrained shear strength for peat soils. This mapping includes the calculated FoS when 20 kPa surcharge pressure is applied to the surface.

A9.3.1.66 The numerical slope modelling shows no part of the peatland to fall below a factor of safety of 1.3. It is therefore considered that peat slide is very unlikely. FoS is demonstrated to reduce towards the south and into the steeper slope system south from T6.

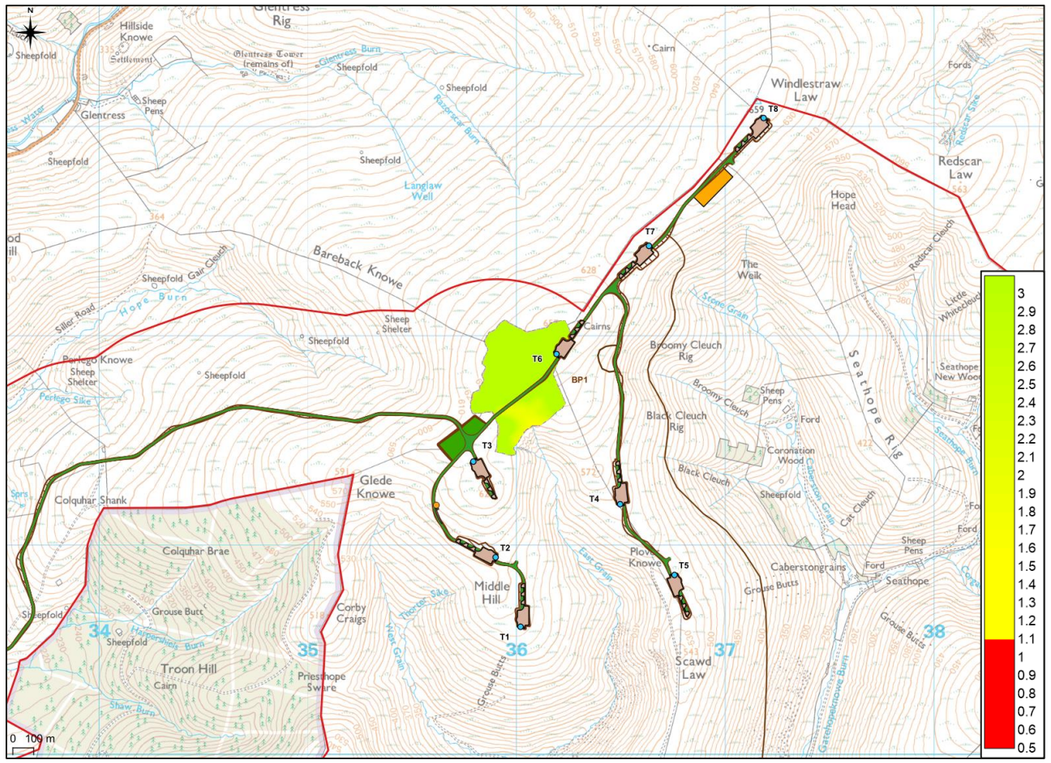

Figure A9.3.13: Slope Stability Model (Factor of Safety) Peat Slide

Source: Natural Power / Ordnance Survey Crown Copyright © 2021

Qualitative Risk Assessment

A9.3.1.67 Assessing the qualitative risk of peat landslide there are multiple contributory factors and potential impacts which have been considered. These contributory factors to peat landslide have comprised:

- Peat Depth – **Score 5**
  - 1.7 m peat depth at maximum depth a depth class with the highest association with peat slide.
- Slope Angle – **Score 3**
  - Worst case 3-9º slope angle class and a likely association with peat slide
- Factor of Safety -**Score 1**
  - FOS >1.3 – no numerical prediction of slope failure.
- Hydrology & Groundwater -**Score 2**
  - Frequent evidence for surface cracking, ephemeral flows and scarps which may focus groundwater flows.
- Previous Instability – **Score 3**
  - Evidence of erosion and soil detachment at head of steep valley system to south of T6
- Land use – **Score 1**
  - Negligible instances of hill tracks

[6] Skempton, A.W., DeLory, F.A., 1957. Stability of natural slopes in London clay. Proceeding's 4th International Conference on Soil Mechanics and Foundation Engineering, vol. 2, pp. 378 – 381.

[7] BS 6031:2009 Code of practice for earthworks

A9.3.1.68 The isolated peat mass recorded within the development has been assessed based on these factors and relevant risk scoring undertaken. For this specific location there has deemed to be a low potential impact (Score 1) due to remote proximity from offsite receptors and there is no proposed infrastructure or sensitive receptors down slope of the peat mass. In the event of a peat slide the most likely scenario would be material entrained within the upper East Grain watercourse. Material in a debris flow and suspended solids would then travel south and be contained to the trajectory of the watercourse. Thus, environmental pollution would be the most likely scenario rather than damage or severing of existing or proposed infrastructure. Release of material to the north is considered less likely due to the flat plateau and shallower slope angles.

A9.3.1.69 Alternative access / egress was also considered in the event that the connecting track between T3 and T6 is disrupted.

A9.3.1.70 Table A9.3.2 below provides further context for the risk ranking based on Natural Power's project experience and the national risk assessment guidance.

Table A9.3.2: Risk Rank Category & Control Levels

Risk Rank Score	Required Control Measures
17 - >25	High: Avoid project development at these locations.
11 – 16 (Scawd Law Wind Farm)	Medium: Project should not proceed unless risk can be avoided or mitigated at peat locations, without significant environmental impact, in order to reduce risk ranking to low or negligible.
5 - 10	Low: Project may proceed pending further investigation to refine risk assessment and mitigate hazard through relocation or re-design at these locations.
1 - 4	Negligible: Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate.

Source: Natural Power

A9.3.1.71 An overall risk score of **13** is determined for the peatland at the development. This has combined the contributory factors where >1 and multiplied by the potential impact score of 1. This is a medium risk category and will require targeted mitigation during construction. This will ensure the residual risk is reduced to a low/negligible level.

Required Control Measures

A9.3.1.72 In order for the project to proceed there will be a requirement to apply the following targeted control measures during the construction phase of development. These measures would be implemented as part of the Construction Environmental Management Plan (CEMP):

- Ensure the wind farm infrastructure design employs low volume and low impact construction techniques. Particularly on the access track section T3 – T6. Where appropriate this should be constructed using 'floating' methods where the excavation of peat is avoided.
- At key locations consider soil reinforcement including provision for soil anchors, geofabric stabilisation and vegetation matting to stabilise eroding peat and underlying sub-soils. This may be particularly important at the head of the East Grain valley form and in the immediate vicinity north of T6. Detailed civil infrastructure design should incorporate slope stability modelling to demonstrate the efficacy of these measures prior to construction.
- Ensure drainage outflows are directed away from the peat mass and diverted to areas of the site where there is no risk of peat slide.
- No stockpiling or storage or excavated materials anywhere on the peatland.
- Monitoring of peat soils should take place during the construction phase and into the operational phase using a system of geodetic monitoring stations to detect any potential long term creep movement in the peat mass.
- Long term maintenance of drainage systems will be required to ensure blockages or deterioration of these systems does not result in unplanned outflows onto the peat body.
- Downstream watercourse protection measures should be in place or able to be deployed as part of a rapid reaction strategy in the event of a peat failure during construction. These may take the form of silt traps; debris fencing or catch walls which may be placed at strategic locations to halt or reduce the volume of peat material which may be entrained into the watercourse.

Conclusions

Development Setting

A9.3.1.73 The Proposed Development is located on an open area of upland banked by steep sided valleys to the south. The proposed development at its highest elevation reaches to 650 m AOD. Sharply incised small gulley's open out into wider valley forms with most steep slope aspects facing towards the south. North from the site a thin plateau of higher ground rises to the summit of Windlestraw Law.

A9.3.1.74 Current land management practices across the development indicate ongoing burning of moorland vegetation. In the long term these practices can be detrimental to soil slope stability. There are limited parcels of forestry plantation, generally downslope and away from proposed infrastructure.

A9.3.1.75 An isolated mass of peat exists in the vicinity of the proposed wind turbine T6. A detailed peat slide risk assessment has been conducted using numerical slope stability and qualitative considerations. The risk of peat slide is currently assessed to be at a medium level without suitable controls. Targeted and routine control measures will be required to reduce the risk of peat slide to a low or negligible level.

Ground Model

A9.3.1.76 Based on the available desk study data the following generalised conceptual geotechnical ground model has been developed for the development:

- Broad plateau areas with an isolated body of peat and otherwise thin residual soils. Steeper valley sides are likely topped with a thin residual soil, or topsoil.
- Thicker deposits of superficial material could be deposited as moraines on hill sides or over hill tops. Deposits of glaciofluvial sediment or alluvium will be present in the valley bottoms, likely thickening as the rivers move down the valley.
- The entire site is underlain by Gala Group greywacke, with occasional igneous dyke and sill intrusion of felsic material, a larger intrusion of microgranite is present to the southwest of the development footprint and associated metamorphic aureole. Bedrock may contain low angle thrust faults.
- Minor zones of instability have been noted generally at the upper reaches of the valley forms in steep gulley's. Soil erosion from overland flows are the likely cause of this instability, which may be exacerbated during periods of high rainfall.

Geotechnical Constraints

A9.3.1.77 The following construction related factors are highlighted for consideration.

- Movement can occur following overloading of peat slopes, e.g., by placement of fill, stockpiling and end-tipping directly onto peat slopes;
- Suitability of drainage measures and the prevailing groundwater conditions are also key factors to consider during construction. Increasing pore water pressures within peat deposits decreases the stability of a slope;

- In extreme events, peat can act as a viscous fluid and travel over very shallow slopes. The re-working or excessive handling of peat can reduce the shear strength to residual levels and hence lead to 'liquid' peat behaviour;
- The rate of construction can have a major influence on the stability of peat land environments. Rapid loading and limited time for excess pore pressure dissipation can also decrease the stability state of peat slopes;
- Excavation across a side slope, a convex slope / break in slope can induce peat failure;

A9.3.1.78 A detailed intrusive ground investigation should be carried out (post-consent) and as part of the pre-construction phase of development. This investigation should seek to further characterise the peat deposits with emphasis on, depth, classification, in-situ shear strength testing and targeted undisturbed sampling and laboratory testing. All peat samples recovered should be classified in accordance with the Von Post system, (Hobbs, 1986) and current British and Eurocode standards for site investigation;

A9.3.1.79 Groundwater level information should be collated as part of any future ground investigation;

A9.3.1.80 The results of a detailed ground investigation should be assessed with respect to refining the peat stability assessment at all infrastructure locations. All pertinent control measures and mitigation measures should be revised, and their implementation supervised following the results of the ground investigation and construction design phase of works;

A9.3.1.81 Continued assessment and monitoring throughout the construction phase of works and at suitable intervals post construction should be implemented to ensure the control measures are suitable and are providing adequate mitigation against peat instability;

A9.3.1.82 Construction practices should be managed through the Construction Method Statement (CMS) and within the wider context of the Construction Environmental Management Plan (CEMP). The CMS should be prepared by the appointed principal contractor and reviewed by a suitably experienced geotechnical engineer who has read and understood this report. The following general recommendations are provided in line with the NatureScot, Good practice during wind farm construction, (4th Edition, 2019) guidance:

- Avoid peat arisings being placed as local concentrated loads on peat slopes without first establishing the stability condition of the ground and slope system. Stockpiling on areas of deep peat and in close proximity to steep slopes should be avoided.
- Avoidance of uncontrolled and concentrated surface water discharge onto peat slopes as this may act as contributory factor to failure. All water discharged from excavations during construction phase should be directed away from all areas identified as susceptible to peat failure and should managed by a suitably designed site drainage management plan.
- All excavations where required should be adequately supported to prevent collapse and the destabilising peat deposits adjacent to excavations.
- A system of daily reporting should be established during construction and utilised to monitor the geotechnical performance of slopes including peat, sub-soil and bedrock. This should be implemented and undertaken by a suitable experienced and qualified geotechnical engineer. Post construction this monitoring procedure should be curtailed to allow for annual or ad-hoc inspection as required.

Floating Track Construction

A9.3.1.83 Floating type construction which leaves the peat deposits in situ may be advantageous with respect to preventing peat failure. This method of construction has a lower impact on the internal groundwater flow within the peat land. However, there are cases where groundwater flow within the peat can be detrimentally affected. The following control measures should be implemented as part of the design and construction of 'floating' access track:

- Prevent the rupture of vegetation surface of the peat by avoiding the use of large sharp rock fill;
- Prevent the overloading and subsequent shearing of the peat throughout construction and use of the 'floating' track;
- Monitoring of the long-term settlement of the 'floating' track is necessary to predict the effects of reducing permeability within the peat and hence increasing groundwater pressures beneath the track construction. Through ongoing monitoring additional drainage relief measures can be implemented when conditions for peat failure are predicted;
- Do not position 'floating' access track on or adjacent to convex side slopes.
- An additional control on the construction and use of 'floating' track is through the strict management of construction traffic loading. This may involve the timing between heavy traffic to be staggered to prevent the effect of cyclic loading over short time periods reducing the shear strength of the peat. In order to assess the maximum loading rate or timing between heavy construction traffic it may be necessary to monitor the vertical deformation of the 'floating' track sections following loading and recording the time taken for recovery of vertical deformation. The use of simple settlement plates and survey pegs can be used to achieve this. The frequency of trafficking for heavy loads must then be timed to allow deformation of the 'floating' road to recover its deformation.
- A robust procedure in place should it become apparent that a peat failure is imminent.

Cut/Fill Track Construction

A9.3.1.84 Across areas of the Proposed Development not affected by peat and on slopes; the construction of proposed access tracks should be considered by excavation and replacement method. Excavated peat is removed and targeted for suitable re-use. Aggregate would be used to form the subgrade and running surface of the track.

A9.3.1.85 In these areas the following control measures are advised:

- Careful excavation of peat deposits by appropriate machine excavator to limit localised peat failures which can occur on the edge of the track excavation. This is in order to prevent a minor failure triggering retrogressive peat failure affecting a larger area of peat adjacent to the track;
- Temporary drainage systems followed by establishment of a permanent drainage network. Silt traps and small retaining structures may be required especially in proximity to water crossings to prevent siltation and blockage of watercourses;
- Ongoing monitoring and on demand maintenance when silt traps require emptying and temporary drainage reinstated if blocking occurs. This will assist in maintaining hydrology baseline conditions;
- The permanent drainage system must direct surface water flow away from the 'cut' track to prevent peat failure within the track bunds;

Earthworks

A9.3.1.86 It has been identified that there is a requirement for the excavation of peat and superficial deposits during construction of the wind farm. Initially the vegetated peat layer and any topsoil should be stripped and temporarily stockpiled away from areas of deep peat and instability risk. The design of this stockpile must be approved by a suitably qualified geotechnical engineer. When working in areas of deep peat (i.e., >1.0 m) no peat or overburden should be stored on such deposits as this may lead to instability. The following options for peat storage may be considered:

- Dedicated peat storage areas designed under the advisement of a suitable qualified geotechnical engineer and conform to up-to-date regulations and waste directives.

- Re-use of peat in dressing-off of batters on access tracks, finishing of cable trenching works, the landscaping of turbine bases. Peat must be re-used to ensure stability and its long terms sustainability i.e., the prevention of drying of desiccation.
- Excavated glacial till and weathered rock may be used as backfill to turbine bases should material be deemed geotechnically suitable. All related works must be carried out in accordance with an agreed CEMP and conform to site restoration plans.

A9.3.1.87 For in-situ and undisturbed peat; site vehicle movements must be minimised across such areas, throughout construction and post construction. Observation and monitoring for settlement, deformation, or signs of failure along access tracks and critical working areas must be implemented. This may be achieved with a network of settlement plates and survey markers which can be periodically re-surveyed, and any differential movements identified. It is recommended that all earthworks are designed in accordance with current national standards.

The following risk mitigation is recommended with regards to peat storage:

- Storage site selection and stockpile design would be undertaken by a suitably qualified and experienced engineer;
- In general, the temporary storage of peat in a single dedicated area shall be avoided;
- Peat storage on areas of negligible peat slide risk only
- Peat storage height shall not exceed 1 m;
- Routine maintenance and inspection of peat storage areas would be undertaken;

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