ARECLOCH WINDFARM EXTENSION

Technical Appendix 10.1: Peat Landslide Hazard and Risk Assessment
Prepared for: ScottishPower Renewables

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1.0 Introduction

SLR Consulting Ltd (SLR) was commissioned by ScottishPower Renewables (SPR) to undertake a peat landslide hazard and risk assessment at the proposed Arecleoch Windfarm Extension. The proposed Development would be located near the village of Barrhill in South Ayrshire, centred on NGR NX 19194 80689. The Site location is identified in Figure 10.1.1.

The purpose of this report is to consider the potential risk of peat slides occurring at the Site such that suitable controls and appropriate methodologies can be employed during the construction and commissioning of the windfarm to mitigate against these risks. This report presents the findings of the peat slide hazard and risk assessment based on the data obtained by peat depth surveys which were peat depth and coring surveys which were undertaken by MacArthur Green in November 2018 and February 2019 (Technical Appendices 10.6 and 10.7).

The work has been undertaken by a team of geologists, with over 15 years’ experience in undertaking peat assessments. The team was led by an Engineering Geologist with 35 years’ experience in geology (B.Sc.) and engineering (M.Sc.) and over 15 years in renewable energy. He has managed and undertaken geotechnical risk registers and peat landslide and hazard risk assessments for windfarms, electricity infrastructure including substations, overhead and buried cabling routes. He has successfully completed over 25 PLHRA’s under the original guidance (2005) and recent guidance 2017.

The methods adopted for the assessment follow the best practice guidance 3 issued by the Scottish Government for investigation, assessment and reporting for windfarms in peat areas.

1.1 Background

The importance of assessing the stability of peat deposits in relation to windfarm developments came to the fore as a result of peat failures during the construction of Derrybrien4 Windfarm in Ireland in 2003. Although no fatalities were associated with these failures, there was a significant environmental impact. Windfarms tend to be constructed in high moorland areas which are primarily associated with significant peat deposits (typically blanket bogs). There is a potential for peat instability to occur, particularly where deposits are in excess of 1 m deep. Peat instability is influenced by many factors, including, but not limited to, peat thickness, hill slope gradient, underlying geology and subsurface hydrology.

1.2 Objectives of Report

The Peat Stability Assessment is primarily concerned with the influence of the peat on the proposed Development.

The main objective is to assess the potential peat stability at the proposed windfarm Site, identify areas of potential concern and identify mitigation measures to ensure the maintenance of peat stability before, during and after construction. All aspects of construction should be based on ensuring minimum disruption to the peat areas.

The objectives have been achieved by completion of the following:

- Review of historic peat depth data provided by SPR (for Arecleoch Windfarm);
- Geomorphological mapping of the Site to identify the prevailing conditions influencing the potential for, or any evidence of, active, incipient or relict peat instability, including identification of the location and photographic record, as appropriate;
- Reporting on evidence of any active, incipient or relict peat instability, and the potential risk of future instability, describing the likely causes and contributory factors;
- Identification of potential controls to be imposed on the Contractors for the Works to minimise the risk of peat instability occurring at the proposed Arecleoch Windfarm Extension site; and
- Provide recommendations for further work or specific construction methodologies to suit the ground conditions at the Site to mitigate any unacceptable risk of potential peat instability;
- A site visit was undertaken in August 2018 by SLR to gain a preliminary understanding of the Site and to verify survey data and review areas of concern, such as watercourse crossings, deep peat where identified, borrow pit and substation locations.
- Probing has been undertaken in two phases, firstly by MacArthur Green (Technical Appendix 10.6) in November 2018 (Technical Appendix 10.7) to a 100 m² grid across the Site and secondly a detailed survey by MacArthur Green in February 2019, targeting key areas of infrastructure around tracks and turbine locations. The results have been used to produce a peat thickness and peat landslide risk and hazard map. Further details are given in subsequent sections of this report.

3 Peat Landslide Hazard and Risk Assessment (Scottish Government, December 2006).
1.3 Site Location and Description

The proposed Arecleoch Windfarm Extension Site is located near the village of Barrhill in South Ayrshire, centred on NGR NX 19194 80689 identified in Figure 10.1.1. The Site is located on the National Forest Estate approximately 3 km south west of Barrhill in South Ayrshire, centred on NGR NX 19194 80689. The majority of the Site is located within the South Ayrshire Council (SAC) area. The entrance to the Site is within the Dumfries and Galloway Council (D&GC) area. Access to the Site for turbine deliveries would be via the existing entrance at Wheeb Bridge on the A714. The Site is characterised by a Plateau Moorland landscape covered mainly by commercial forest and encompasses the western side of Shiel hill (228.4 m AOD). A number of small tributaries run through the Site and feed the Water of Tig, Cross Water and Haw Burn. These three water courses then in turn feed into the Duisk River and River Stinchar.

Site access would be along the A75 to the unclassified road past Newton Stewart where they would join the A714. This route has previously been used during the construction of Arecleoch and Kilgallioch Windfarms.

Photograph 1-1: General View across Arecleoch Windfarm Extension towards Arecleoch Windfarm

Photograph Location: 21900, 581300, Direction of View: North

The proposed Development comprises a 13 turbine (tip height of 200 m) windfarm with associated infrastructure including:

- turbine foundations;
- crane hardstandings;
- transformer/switchgear housings located adjacent to turbines;
- new and upgraded access tracks including watercourse crossings where necessary;
- underground cabling;
- substation compound including control buildings, external equipment and ancillary grid service equipment/battery storage;
- one permanent anemometer mast;
- up to three temporary Power Performance Masts;
- close circuit television mast(s);
- communication mast(s);
- site signage;
• search areas for up to six borrow pits; and
• one temporary construction compound area.

1.4 Scope Report

The scope of the report is primarily concerned with the influence of peat on the design, construction and operation of the proposed Development and secondly to minimise the disturbance of peat, if it is present.

The principle objective was to assess the extent of organic peat (>0.5 m) and peaty soils (<0.5 m) on the Site, with the purpose of identifying instability at the Site, areas of potential concern and any mitigation measures required to ensure the maintenance of peat stability before, during and after construction.

This information should allow development options to be considered so that where possible, there is minimum disruption to peat areas by avoidance of deeper peat through design consideration. The objective was achieved by completion of the following:

• Review of geological, hydrological and topographical information;
• Geomorphological mapping of the Site to identify the prevailing conditions influencing the potential for, or any evidence of, active, incipient or relict peat instability, including a photographic record and identification of their location and report on the potential risk of future instability, describing the likely causes and contributory factors;
• Identifying potential controls to be imposed on the construction contractor to minimise the risk of peat instability occurring at the proposed Development; and
• Provide recommendations for further work or specific construction methodologies to suit the ground conditions at the proposed Development to mitigate any unacceptable risk of potential peat instability.

Probing has been undertaken in two phases, initially to a 100 m$^2$ grid across the Site and secondly by targeting key areas of infrastructure around tracks and turbine locations. The results have been used to produce a peat thickness and peat landslide risk and hazard map. Further details are given in subsequent sections of this report.

1.4.1 Topographic Surveys

All of the surveys were based on 5 m DTM data which was used to determine slopes across the Site and to determine slope coefficient (score) factors at each probe hole location. The Site has been characterised into slope classes and a slope plan produced to identify slope areas where potential gradients are more or less susceptible to slope failure mechanisms.

1.4.2 Aerial Photography Interpretation

The aerial photography reviewed shows changes in vegetation on the ground, and it is also possible to identify stream courses, ditches, and roads/tracks. The aerial photographs were used in conjunction with the Site DTM data to identify the major geomorphological features such as the breaks of slope and landslips (where present).

Interpretation of available aerial photographs was undertaken to assess and identify evidence of historic peat instability. The photographs were examined to highlight features of interest, including:

- possible extension and/or compression features;
- areas of historic failure scars and debris;
- evidence of peat creep;
- areas with apparently poor drainage;
- areas with peat drift recorded on steep slopes;
- areas with concentrations of surface drainage networks; and
- steeply incised stream cuttings within peat deposits; and
- historic peat workings.

From the aerial photograph and topographic survey interpretation no significant features or obvious evidence of concern were identified that indicate evidence of peat instability which warranted further attention, mainly due to extensive forest cover. Only limited aerial photography was available, dating back to 2005, with aerial photographs in 2014 and 2017.

None of these features demonstrate any significant evidence of failure in the vicinity of the proposed Development. A summary of the geomorphology of the Site is included in Figure 10.1.8. Areas of potential peat coverage are highlighted along with areas where bedrock is likely to outcrop at surface.

1.4.3 Peat Landslide Hazard and Risk Assessment

The purpose of a peat landslide hazard and risk assessment (PLHRA) is to identify those parts of the Site that are naturally susceptible to a higher risk of instability so that they can be avoided or accommodated through design consideration. It should be noted that all peat slopes have a risk of instability and the vast majority of peat slope failures occur naturally.
Construction of a windfarm would only increase the risk of peat slope instability if good geotechnical construction practice is ignored and it is a requirement of all windfarm developments to follow a very carefully worded and designed Construction and Environmental Management Plan (CEMP) which uses many of the recommendations of the peat landslide hazard and risk assessment.

Without the guidance contained in a Construction Method Statement or CEMP, the following factors would increase the risk of instability:

- construction of access tracks;
- excavation and stockpiling for foundations;
- construction of hardstanding area; and
- blocking of natural drainage, inappropriate new drainage or drainage discharge.

It is important to note that peat instability and the impacts of any instability are not constrained by artificial site or ownership boundaries but by topographic and geomorphologic boundaries. It is therefore important to ensure that the breadth of scope of any assessment adequately covers the real extent of possible impact.

The risk assessment is based on ground models developed using a Geographical Information System (GIS) specifically for this Site. A numerical analysis was undertaken in which coefficients were allocated for each of the factors influencing peat stability and their impact on possible receptors. This aspect is described in greater detail in Section 5.0.

The conceptual layout of the turbines and access routes, the findings from the peat probing, sampling and analysis were used by the design team to optimise the turbine layout to avoid or mitigate areas of unacceptable peat slide risk. The layout presented in the figures represents the final iteration of the turbine layout.

This system outlined above was developed in accordance with the guidelines on PLHRA by the Scottish Government (SG) for the investigation, assessment, and reporting for windfarms in peat areas. The analysis and interpretation is based upon the results obtained from this process as well as previous experience and the results of case studies elsewhere. Where deviations from this guidance have occurred, this is highlighted and explained in the text.

### 1.5 Geological Setting

#### 1.5.1 Superficial Geology

The principal soil type underlying the Site is peat with areas of peaty gleys and brown soils along many of the watercourse valleys. Rare units of peaty gleyed podzols exist within the application boundary, most notably at the watercourse crossing of Cross Water (WX01). Mineral gleys and Brown soils have been recorded along the existing access track to the A714, west of Barrhill. Along the larger watercourses at lower altitudes (Water of Tig and River Cree) alluvial soils are observed within and along watercourses.

British Geological Survey mapping shows the Site to be almost entirely underlain by peat, with alluvium mapped around the Water of Tig, Pollingowan Burn and River Cree. Hummocky features are identified as glacial till with superficial deposits absent on some hill tops.

The Superficial geology of the Site is detailed in Figure 10.1.2 – Superficial Geology.

#### 1.5.2 Solid Geology

The geology of the Site comprises Ordovician age sedimentary rocks of the Barrhill Group.

The Site is almost entirely underlain by greywacke of the Kirkcolm Formation with narrow bands of the Galdenoch Formation. All of the proposed turbines are underlain by the Kirkcolm Formation. Faulting within the region is generally on a south west - north east trend. There are two minor faults mapped within the application boundary, cross-cutting the proposed access track, the Glen App Fault is present outside the application boundary, to the north west. The fault is defined by a change in lithology, to the younger Dalreoch Formation.

The solid geology of the Site is shown in Figure 10.1.3. Details of the geological units present onsite and immediately adjacent to Site are detailed in Table 1-1.

<table>
<thead>
<tr>
<th>Table 1-1: Solid Geology Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
</tr>
<tr>
<td>Ordovician (458 – 449 Ma)</td>
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</tbody>
</table>
1.5.3 Mining and Quarrying
There have been no historic mining or quarrying activities within the Site, with the exception of the rock extracted on the Site as part of the borrow pits for the original Arecleoch Windfarm site.

1.5.4 Hydrogeology
The solid geology underlying the Site is classified as a low productivity aquifer, where flow is virtually through fractures and discontinuities. Small amounts of groundwater may be present in the near surface weathered zone and within secondary fractures.

2.0 Peat Instability
This section reviews the nature of peat and how current and past activities can influence stability. The factors which are likely to influence the potential for peat instability are:

- significant peat depths over impermeable bedrock or minimal soil;
- the presence of slope gradients greater than 4° (approximately) and general topography;
- natural drainage paths;
- evidence of past failures, including soil creep;
- drainage features at the base of slopes which could lead to undercutting;
- forestry plantations and artificial drainage;
- recent climate patterns.

It should be noted that peat instability is not a recent phenomenon and there is documentary evidence of peat landslides dating back over 500 years. Many landslides that involve peat have no human interference that could be considered as a trigger and this should be borne in mind when considering the susceptibility of a site to potential instability.

2.1 Background Information Regarding Peat
Peat is found in extensive areas in the upland and lowland regions of the UK and is defined as the partly decomposed plant remains that have accumulated in-situ, rather than being deposited by sedimentation. When peat forming plants die, they do not decay completely as their remains become water logged due to regular rainfall. The effect of water logging is to exclude air and hence limit the degree of decomposition. Consequently, instead of decaying to carbon dioxide and water, the partially decomposed material is incorporated into the underlying material and the peat ‘grows’ in-situ.

Peat is characterised by low density, high moisture content, high compressibility and low shear strength, all of which are related to the degree of decomposition and hence residual plant fabric and structure. To some extent, it is this structure that affects the retention or expulsion of water in the system and differentiates one peat from another.

Lindsay defined two main types of peat bog, raised bog and blanket bog, which are prevalent on the west coast of Europe along the Atlantic seaboard. In Britain, the dominant peat land is blanket bog which occurs on the gentle slopes of upland plateaux, ridges and benches and is predominantly supplied with water and nutrients in the form of precipitation. Blanket peat is usually considered to be hydrologically disconnected from the underlying mineral layer.

There are two distinct layers within a peat bog, the upper acrotelm and the lower catotelm. The acrotelm is the fibrous surface to the peat bog, typically less than 0.5 m thick; which exists between the growing bog surface and the lowest position of the water table in dry summers. Below this are various stages of decomposition of the vegetation as it slowly becomes assimilated into the body of the peat.

For geotechnical purposes the degree of decomposition (humification) can be estimated in the field by applying the ‘squeezing test’ proposed by von Post and Grunland (1926). The humification value ranges from H1 (no decomposition) to H10 (highly decomposed). The extended system set out by Hobbs provides a means of correlating the types of peat with their physical, chemical and structural properties.

The relative position of the water table within the peat controls the balance between accumulation and decomposition and therefore its stability, hence artificial adjustment of the water table by drainage requires careful consideration.

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2.1.1 Peat Shear Strength

In geotechnical terms, the shear strength of a soil is the physical characteristic that provides stability and coherence to a body of soil. For mineral soils such as clays or sands, such strength is variously given by an inter-particle friction value and cohesion. Depending whether the mineral soil is predominantly cohesive (clay) or non-cohesive (sand) governs which of the components of strength control the behaviour of the soil.

For peat soils, where the major constituent is organic and there is likely to be little or no mineral component, the geotechnical definition of shear strength does not strictly apply. At present there is no real alternative method for defining the shear strength of peat, therefore the geotechnical definition is generally adopted, in the knowledge that it should be used with great caution.

As noted before, the acrotelm or near surface peat comprises a tangle of fresh and slightly rotted roots and vegetable fibres. These roots and fibres impart a significant tensile shear strength capacity to the material which provides it with a significant load carrying capacity. The acrotelm is, in effect, a fibre reinforced soil.

In the more decomposed catotelm, the tensile shear strength is reduced as the roots and fibres become more rotted. However, the loss in strength due to decomposition is offset to a limited degree, by a gain in strength due to the overburden pressure. In geotechnical engineering there is an established relationship for recently deposited soils, between the shear strength of a sample and the thickness of overburden above it.

Consequently it is almost impossible to predict a shear strength profile in peat and attempts to measure the shear strength using normal geotechnical methods can be misleading. Typical values of shear strength from hand shear vane would be in the range 10-60 kilopascal (kPa) although values over 100 kPa have been recorded in peat elsewhere. The higher strengths are almost certainly the influence of roots or other non-decomposed material. It is believed that the strength of peat should be quoted as a cohesion value as there are few, if any, discrete particles to give the material a significant frictional resistance. It should be noted, however, that any quotation of shear strength for peat should be treated with extreme caution.

2.1.2 Peat Stability – Factors to be Considered

There is considerable observational information relating to debris and peat flows although the actual mechanisms involved in peat instability are not fully understood. The main influences on slope stability are geological, geotechnical, geomorphic, hydrological, topographic, climatic, agricultural and human influences such as drainage and construction activity. Peat is affected to a degree by changes in any of the above list and it is vital to appreciate that changes to the existing equilibrium would affect the level of slope stability during construction and operation of the scheme.

Some of the contributory factors to peat instability are summarised below:

- The geographical limits which could be affected by potential instability are not confined to the artificial boundaries imposed by land ownership; landslip occurring above a site could affect the site and property down slope or downstream of the site for several kilometres;
- Agriculture and grazing has a substantial effect on peat areas and this can be compounded in areas that have been managed to improve grazing. Grazing compacts the peat surface reducing the rainwater infiltration and the additional nutrients change the ecological balance of the original peat bog. Agricultural management can include surface drainage and periodic burning, both of which can leave the surface of the peat bare for a period of time resulting in temporary desiccation of the surface. Subsequent wetting of the peat and resumption of peat accumulation results in the former desiccated and possibly ash covered surface (following burning) being incorporated into the body of the peat which introduces a weak discontinuity in the profile; this in turn becomes another unknown factor in the stability assessment.
- Forestry has a substantial effect on slope stability particularly in the early stages as the creation of a forest involves disruption of the natural equilibrium and drainage of the slopes and the installation of artificial drains by deep ploughing. The construction of access tracks further disrupts the drainage and concentrates groundwater flow into narrow, fast flowing erosive streams. The work by Winter el al16 noted that forest tracks can act to retard or concentrate the down slope flow of water and thus aid its penetration into the slope below. Such a mechanism has been observed at a number of recent landslips that have affected the road network in Scotland.
- Natural Drainage – some of the precipitation falling onto a natural upland peat bog would be absorbed into the low permeability catotelm peat. However, most of the water would run-off as sheet flow through upper, high permeability acrotelm. Thus the water is transmitted to the lower slopes in a reasonably controlled manner through a range of interconnections that operate at different scales and speed. Failure to understand this and to disrupt the transmission process for the groundwater could result in instability.
- Artificial Drainage – where agricultural drainage has been used to improve the quality of the grazing or to promote forestry it reduces the overall volume of water entering the bog and transfers this water to the edges more rapidly. This can result in ditches and streams becoming enlarged, causing increased erosion and a greater silt burden in the stream water.

2.2 Peat Mass Stability

The principal surface indicator of peat slide potential is cracking of the peat land surface and it is the identification of crack patterns in the field and the attendant causes of the cracking that is fundamental to a Peat Stability Assessment.

Sites that have exhibited natural instability in the past are likely to be more susceptible to future instability during and following construction of a windfarm, therefore it is important to identify such instability as part of the Peat Stability Assessment.

2.2.1 Types of Failure

The result of instability in peat is the downslope mass movement of the material; there are a number of definitions of peat instability which are used to characterise the type of failure. A brief description is given below:

- Bog Bursts or Bog Flows – the emergence of a fluid form of well humified, amorphous peat from the surface of a bog, followed by the settling of the residual peat, in-situ\(^1\);
- Peat Slides – the failure of the peat at or below the peat/substratum interface leading to translational sliding of detached blocks of surface vegetation together with the whole underlying peat stratum\(^1\); and
- Bog slide – an intermediate form of instability where failure occurs on a surface within the peat mass with rafts of surface vegetation being carried by the movement of a mass of liquid peat.

2.2.2 Bog Bursts

Accounts of bog bursts are generally associated with very wet climates or areas which have received storm rainfall events. Bog bursts can be associated with particularly wet peat landscapes; therefore it is possible to identify broad regions of a higher susceptibility to these failures. The constraints used to identify the areas of higher susceptibility to bog burst failure are given below:

- Peat thickness in excess of 1.5 m with no upper limit;
- Shallow gradients, generally within the range of 2 to 10\(^o\), peat thicker than 1.5 m is generally not observed on slopes steeper than 10\(^o\), also moisture content is generally reduced on steeper slopes due to drainage;
- Ground which is annually waterlogged to within the upper 1 m below ground level, (the groundwater level may rise above this but rarely falls below)\(^12\);
- Greater humification of the lower catotelm within the waterlogged ground; and
- Lower surface tensile strength of the fibrous peat and vegetation.

The humified mass can be considered as analogous to a heavy liquid and the stability of this mass is maintained by the strength of the surface or acrotelm peat. Should the surface become weakened through erosion or desiccation or the construction of a surface drainage ditch for agricultural or forestry reasons or through turbary (peat cutting), failure is made more likely.

2.2.3 Peat Slides

Peat slides tend to be translational failures with a defined shear surface at or close to the interface with the substrate. The factors generally considered to influence susceptibility to peat slide failures are listed below:

- Peat depth up to 2 m;
- Slope gradients between 5\(^o\) and 15\(^o\);
- Natural or artificial drainage cut into the surrounding peat landscape;
- Greater humification of the lower catotelm within the waterlogged ground; and
- Lower surface tensile strength of the fibrous peat and vegetation.

It is noted that some of the factors causing instability are common to both bog bursts and peat slides. The peat – substrate interface is the primary zone of failure and is enhanced by elevated water content at this boundary and softening or weathering of the lower mineral surface. For this reason, any investigation or probing should try to distinguish the nature of the lower mineral substrate.

2.2.4 Bog Slides

A bog slide is a variation on a peat slide where part of the peat mass is subject to movement, usually on an internal layer of material, which may be more prone to movement, such as an interface between the acrotelmic and catotelmic layer.

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2.2.5 Natural Instability

The stability of a peat mass is maintained by a complex interrelationship of many factors, some of which may not be immediately obvious. Key factors include sloping rock head and proximity to a water body. Rainfall often acts as the trigger after the slope has already been conditioned to fail by natural processes.

It should also be remembered that peat bogs are growing environments and that there would come a time, on sloping ground, where the forces causing instability, i.e. the weight of the bog, can no longer be resisted by the internal strength of the peat and its interface with the underlying mineral surface. At this point, failure would occur.

The weight of the peat bog or any soils mantling steep hill slopes would be increased during periods of very heavy rain and it is common to see landslips occurring following extreme rain events. This may be a concern for future developments where one of the predicted effects of global warming will be a greater frequency of extreme weather, intense storms being one element.

3.0 Site Work

3.1 Peat Depth and Peat Core Survey

A detailed peat depth survey was undertaken in 2 phases within the proposed Development area. Probing was completed across a 100 m grid across the Site and then around infrastructure locations, along existing and proposed track routes.

3.1.1 Phase 1 – MacArthur Green (2018)

An initial peat depth survey was undertaken by MacArthur Green in November 2018 (Technical Appendix 10.6) within the proposed Development area. The area was surveyed on a 100 m² grid with approximately 882 probes sampled.

3.1.2 Phase 2 – MacArthur Green (2019)

A detailed peat depth survey was undertaken by MacArthur Green in February 2019 (Technical Appendix 10.7) within the proposed Development area. Probing was completed across the Site around infrastructure locations, along existing and proposed track routes (881 probes). A peat coring survey to gather data on the nature of the peat deposits present was also undertaken at key areas of proposed infrastructure as detailed in Table 3-1: Peat Core Locations in Table 3-1 below.

<table>
<thead>
<tr>
<th>Sample Core ID</th>
<th>X</th>
<th>Y</th>
<th>Proposed Infrastructure*</th>
</tr>
</thead>
<tbody>
<tr>
<td>B055</td>
<td>220711</td>
<td>580590</td>
<td>Substation</td>
</tr>
<tr>
<td>B093</td>
<td>219904</td>
<td>580841</td>
<td>Borrow Pit 5</td>
</tr>
<tr>
<td>T059</td>
<td>219038</td>
<td>579261</td>
<td>Turbine 11</td>
</tr>
<tr>
<td>T117</td>
<td>219985</td>
<td>580410</td>
<td>Turbine 9</td>
</tr>
<tr>
<td>T204</td>
<td>219774</td>
<td>581117</td>
<td>Turbine 1</td>
</tr>
<tr>
<td>T262</td>
<td>218078</td>
<td>581522</td>
<td>Turbine 5</td>
</tr>
<tr>
<td>T320</td>
<td>218758</td>
<td>581958</td>
<td>Turbine 3</td>
</tr>
</tbody>
</table>

3.1.3 Methodology

The surveys carried out followed best practice guidance for developments on peatland13,14.

---

Peat Depth Analysis

The initial phase of peat probing was completed by MacArthur Green on a 100 m² grid.

The second phase of peat probing (881 probes) carried out by MacArthur Green aimed to supplement the original data by providing a greater resolution of detail around areas of proposed infrastructure.

The following methods were employed during the second phase of probing:

- The lines of proposed new tracks were probed at approximately 50 m intervals along the entire length, with additional probe points where thick peat was identified;
- Turbine, substation, compound and borrow pit search locations were probed on an approximately 10m x 10m grid around the centre of each infrastructure footprint;
- Sample locations were generated using Geographic Information System (GIS) and downloaded onto hand-held Geographic Positioning System (GPS) devices which were used to locate sample points in the field; and
- A fibre glass peat depth probe was used to each sample point to establish peat depth.

The peat depth data was provided to SLR and uploaded into various figures and analysis assessments included within this report.

Peat Coring

Peat coring was undertaken by MacArthur Green in February 2019. The following methods were employed:

- A core was taken at each turbine location, substation, construction compound and potential borrow pit search area using a Russian Auger;
- The full depth of peat was cored at each location in 50 cm sample depth intervals; and
- A photographic record and description of the peat was recorded for each core sample.

A full record of peat core data, including photographs is included within the MacArthur Green report dated April 2019\(^1\) (Technical Appendix 10.7)

4.0 Slope Stability/Ground Conditions

The stability of slopes is dependent upon the shear strength of the soil to resist the disturbing forces due to the weight of the soil, the effects of the groundwater and other disturbing influencing forces.

The level of stability of a slope is normally assessed by reference to the factor of safety which is expressed, numerically, as the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It is commonly expressed as the ratio of the load or action which would cause failure against the actual load or actions likely to be applied during service. This is readily determined for some types of analysis (e.g. limit equilibrium slope stability analyses).

4.1 Shear Strength

The strength of the peat in the upper acrotelm is significantly influenced by the root and fibres that are abundant in this layer. There are many influences on the stability of the peat and observing or measuring high shear strength should not be used to assume a high degree of stability.

4.2 Stability Risk Assessment

It is apparent that the stability of peat is complex and the numerous inter-relationships that affect the stability are not fully understood.

The problem with a quantitative assessment is that it requires a numerical input and the analysis cannot account for the unquantifiable input required for a comprehensive Peat Stability Assessment. For this reason, a purely quantitative assessment should only be considered as a guide and that a qualitative assessment of stability should be used to provide the final recommendations.

A stability risk assessment was undertaken to evaluate the risk of instability occurring associated with the construction of the turbine bases and access tracks at the proposed Arecleoch Extension Windfarm.

The peat found on the proposed Arecleoch Windfarm Extension Site was cored during Phase 2 at seven of the proposed infrastructure locations. There are two distinct layers within a peat bog, as described in Section 2.1.

Acrotelm was recorded at only one sample location, with the remaining six samples locations indicating no discernible acrotelm due to the expanse and effects of commercial conifer plantation. Sample T059 was recorded as having an acrotelm of just 1 cm, with further locations showing disturbed ground from tree felling or a conifer needle layer.

The depth of acrotelm was logged from each core sample with a variable depth between 0.01 and 0.38 m bgl with a mean depth of 0.158 m. Full details are included within Table 4-1. Two distinct layers (detailed in Table 4-2) were observed and range from the following, based on the Von Post \(^*\) classification:

- the fibrous zone which was generally found in the upper 0 – 10.5 cm ranging from H3 – H4;
- the intermediate pseudo fibrous zone ranging from H5 – H6; and
the amorphous zone, was not identified.

### Table 4-1: Depth of Acrotelm in Peat Core Samples

<table>
<thead>
<tr>
<th>Sample Core Location</th>
<th>Depth of Acrotelm (m)</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substation</td>
<td>Not identified – impacted by forestry</td>
<td>Conifer plantation</td>
</tr>
<tr>
<td>Borrow Pit 5</td>
<td>Not identified – impacted by forestry</td>
<td>Conifer plantation</td>
</tr>
<tr>
<td>Turbine 11</td>
<td>0.01</td>
<td>Conifer plantation</td>
</tr>
<tr>
<td>Turbine 9</td>
<td>Not identified – impacted by forestry</td>
<td>Conifer plantation</td>
</tr>
<tr>
<td>Turbine 1</td>
<td>Not identified – impacted by forestry</td>
<td>Conifer plantation</td>
</tr>
<tr>
<td>Turbine 5</td>
<td>Not identified – impacted by forestry</td>
<td>Conifer plantation</td>
</tr>
<tr>
<td>Turbine 3</td>
<td>Not identified – impacted by forestry</td>
<td>Conifer plantation</td>
</tr>
</tbody>
</table>

### Table 4-2: Von Post Classification in Peat Core Samples

<table>
<thead>
<tr>
<th>Sample Core Location</th>
<th>Fibrous Zone</th>
<th>Intermediate Zone</th>
<th>Amorphous Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth (m)</td>
<td>Von Post</td>
<td>Depth (m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Classification</td>
<td></td>
</tr>
<tr>
<td>Substation</td>
<td>0 – 0.15</td>
<td>H3</td>
<td>Not identified</td>
</tr>
<tr>
<td>Borrow Pit 5</td>
<td>0 – 0.26</td>
<td>H3</td>
<td>Not identified</td>
</tr>
<tr>
<td>Turbine 11</td>
<td>0 – 0.34</td>
<td>H3</td>
<td>Not identified</td>
</tr>
<tr>
<td>Turbine 9</td>
<td>0 – 1.0</td>
<td>H4</td>
<td>1.0 – 4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbine 1</td>
<td>0 – 0.36</td>
<td>H4</td>
<td>Not identified</td>
</tr>
</tbody>
</table>
### Results

The results of the probing exercise are detailed in the following sections and the peat depths identified onsite are shown in Figure 10.1.4 – Peat Depth Plan.

#### 4.3.1 Peat/Peaty Soils

The peat was found to vary across the Site in terms of thickness and coverage. The majority of probes (approximately 78%) across both phases of peat probing identified peat (greater than > 0.5 m) and peaty soils less than 1 m thick. Figure 10.1.5 details the peat depth greater than >0.5 m i.e. not peaty soils.

**Northern section**

Five of the proposed turbine locations are situated in this area. Peat deposits are thinnest, with peat averaging <0.72 m with several watercourses including the Water of Tig flowing to the north.

**Central section**

Seven of the proposed turbine locations are situated in this area. Peat deposits are thicker, with peat averaging <1.52 m with several watercourses including the Water of Tig flowing to the north and Cross Water flowing to the east.

**Southern section**

Only one of the proposed turbine locations is situated in the central section. Although peat deposits are thick (~2.06 m), the proposed turbine can be accessed via existing tracks in a thinner peat area. The White Loan drains across the Site towards the east.

The slopes onsite are detailed in Figure 10.1.6 – Slope Plan. When viewed in conjunction with the Peat Depth Plan (Figure 10.1.4), it is evident that the peat is generally concentrated on the flatter expanses that mimic the topographic flat lying areas. Peat deposits are thickest in the flat expanse across the central and southern portions of the Site and limited where the ridge is present and falls to the east of the Site and towards the north. There are several watercourses that drain through the flat expanse in the central area and southern area where the deep peat deposits are present, shown in photograph 4-1.

### Sample Core Location Table

<table>
<thead>
<tr>
<th>Sample Core Location</th>
<th>Fibrous Zone</th>
<th>Intermediate Zone</th>
<th>Amorphous Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Turbine 5</strong></td>
<td>0.0 – 0.5</td>
<td>H4</td>
<td>Not identified within core sample.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Not identified within core sample.</td>
</tr>
<tr>
<td><strong>Turbine 3</strong></td>
<td>0.0 – 0.5</td>
<td>H4</td>
<td>Not identified within core sample.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Not identified within core sample.</td>
</tr>
</tbody>
</table>
A total of 1781 probe holes were undertaken across both survey phases, with the results summarised in Table 4-3 below.

<table>
<thead>
<tr>
<th>Peat Thickness (m)</th>
<th>No. of Probes</th>
<th>Percentage (of total probes undertaken onsite)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (no peat)</td>
<td>14</td>
<td>0.8</td>
</tr>
<tr>
<td>0 – 0.5 (peaty soil)</td>
<td>577</td>
<td>32.4</td>
</tr>
<tr>
<td>0.51 – 1.0 (thin peat)</td>
<td>567</td>
<td>31.8</td>
</tr>
<tr>
<td>1.01 – 1.5 (thin peat)</td>
<td>162</td>
<td>9.1</td>
</tr>
<tr>
<td>1.51 – 2.0 (thick peat)</td>
<td>122</td>
<td>6.9</td>
</tr>
<tr>
<td>2.01 – 2.5 (thick peat)</td>
<td>92</td>
<td>5.2</td>
</tr>
<tr>
<td>2.51 – 3.0 (thick peat)</td>
<td>59</td>
<td>3.3</td>
</tr>
<tr>
<td>3.01 – 4.0 (thick peat)</td>
<td>58</td>
<td>3.3</td>
</tr>
<tr>
<td>4.01 – 5.0 (thick peat)</td>
<td>37</td>
<td>2.1</td>
</tr>
<tr>
<td>&gt;5.01 (thick peat)</td>
<td>38</td>
<td>2.1</td>
</tr>
</tbody>
</table>

In summary the peat depth probing has shown that:

- approximately 65 % of probes intersected peaty soils/peat <1.0 m thick;
- approximately 35 % of peat probes undertaken across the entire Site found peat in excess of 1 m thick;
- peat is generally limited to topographically flat lying areas with peat generally limited on steeper slopes.

The underlying soil/peat thickness at each location was recorded and the data used to draw the interpreted peat thickness map, presented as Figure 10.1.4.
4.3.2 Substrate

The assessment of the underlying substrate from the probing data was interpreted as predominately glacial soils and weathered bedrock. Bedrock was identified in outcrop and close to surface on many of the topographically high areas. Photograph 4-2 shows the typical bedrock outcrop onsite (Kirkholm Formation).

Photograph 4-2: Bedrock outcropping
Photograph Location: 238000, 587000, Direction of View: north west

4.4 Description of Ground Conditions at Turbine Locations

Table 4-4 outlines the ground conditions found at each proposed turbine location.

Table 4-4: Ground Conditions at Proposed Turbine Locations

<table>
<thead>
<tr>
<th>Turbine No.</th>
<th>Peat Thickness (m)</th>
<th>Peat Conditions</th>
<th>Slope (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.51</td>
<td>Thin Peat</td>
<td>4.3</td>
</tr>
<tr>
<td>2</td>
<td>0.47</td>
<td>Peaty Soil</td>
<td>3.3</td>
</tr>
<tr>
<td>3</td>
<td>0.70</td>
<td>Thin Peat</td>
<td>10.0</td>
</tr>
<tr>
<td>4</td>
<td>0.21</td>
<td>Peaty Soil</td>
<td>5.0</td>
</tr>
<tr>
<td>5</td>
<td>0.92</td>
<td>Thin Peat</td>
<td>3.2</td>
</tr>
<tr>
<td>6</td>
<td>0.50</td>
<td>Thin Peat</td>
<td>3.5</td>
</tr>
<tr>
<td>7</td>
<td>0.67</td>
<td>Thin Peat</td>
<td>1.2</td>
</tr>
<tr>
<td>8</td>
<td>0.80</td>
<td>Thin Peat</td>
<td>1.9</td>
</tr>
<tr>
<td>9</td>
<td>0.63</td>
<td>Thin Peat</td>
<td>3.5</td>
</tr>
<tr>
<td>10</td>
<td>0.62</td>
<td>Thin Peat</td>
<td>2.6</td>
</tr>
</tbody>
</table>
### 5.0 Peat Landslide Hazard and Risk Assessment

A preliminary peat risk assessment has been undertaken for the Site. Following 2 phases of peat probing, a Site visit by an experienced SLR windfarm geotechnical engineer, and appraisal of the data, the potential for a peat slide occurring at the Site was initially assessed as low. This was based on the fact that:

- although there are significant thicknesses of peat present onsite, the windfarm’s infrastructure has generally avoided the thickest areas and there are no areas with thick peat on significant slopes (>4°);
- no evidence of historical or current peat slide activity at the Site (having reviewed historical dating back to 2004, with photos in 2007, 2012 and current photographs (2016);
- shallow to moderate gradients (<4°) for 9 No. turbines 4-6° (3 No. turbines) and 1 No. in excess of 10° where turbines overlying peat are proposed;
- conclusions of a detailed Site walkover and results from Site probing;
- avoidance of the vast majority of very deep peat with a depth of >2 m by most of the proposed Development’s infrastructure (e.g. tracks, turbines, Site compound etc.); and
- floating roads have been proposed in the limited areas where peat is >1 m thick.

To further quantify this initial assessment, analysis of the terrain at Site utilising GIS has been undertaken to analyse slopes and gradients, Figure 10.1.6 shows that the majority of slopes within key infrastructure areas are generally <8°. The site specific slope data has been combined with site specific peat depth data and using Scottish Government guidance for the assessment of the risk of instability in peat, an assessment of peat slide risk has been completed.

The method of risk and hazard assessment has been developed with reference to the Scottish Guidance. Key factors which may have an effect on the stability of the peat deposits have been identified leading to an assessment of the RISK of instability. The potential impact of any instability, the HAZARD, was then considered for identified potential receptors. Scores were attributed to the key factors that have the greatest influence on peat stability. Risk scores were determined, which, when combined with an assessment of vulnerability of potential targets, were developed into an assessment of the hazard.

In order to differentiate between risk and hazard, the following nomenclature has been adopted (Table 5-1).

<table>
<thead>
<tr>
<th>Turbine No.</th>
<th>Peat Thickness (m)</th>
<th>Peat Conditions</th>
<th>Slope (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>0.55</td>
<td>Thin Peat</td>
<td>1.5</td>
</tr>
<tr>
<td>12</td>
<td>0.06</td>
<td>No Peat</td>
<td>2.9</td>
</tr>
<tr>
<td>13</td>
<td>0.77</td>
<td>Thin Peat</td>
<td>4.3</td>
</tr>
</tbody>
</table>

#### Table 5-1: Risk versus Hazard

<table>
<thead>
<tr>
<th>Risk</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Low</td>
<td>Significant</td>
</tr>
<tr>
<td>Medium</td>
<td>Substantial</td>
</tr>
<tr>
<td>High</td>
<td>Serious</td>
</tr>
</tbody>
</table>

This section outlines the approach taken and the scores allocated for various factors relevant to peat stability.

At this stage in the proposed Development, the objective is to determine the peat areas that would have an effect on the proposed Development and to set out the mitigation that could be adopted and incorporated into the overall development plan to ensure that due cognisance is taken in this regard.

The level of slope is normally assessed by reference to the factor of safety which is expressed, numerically, as the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It is commonly expressed as the ratio of the load or action which would cause failure against the actual load or actions likely to be applied during service. This is readily determined for some types of analysis (e.g. limit equilibrium slope stability analyses). The following sections present a brief discussion on some of the issues relating to stability and risk assessment.
The stability of peat is a complex subject and there are numerous inter-relationships that affect the stability.

A quantitative assessment requires a numerical input and such an analysis cannot account for the unquantifiable input required for a comprehensive Peat Stability Assessment. For this reason a purely quantitative assessment should only be considered as a guide and a qualitative assessment of stability should be used to inform the final recommendations.

The characteristics of the peat failure phenomena have been incorporated in a stability risk assessment to evaluate the risk of instability occurring within the peat areas. The main factors controlling the stability of the peat mass are the surface gradients, the depth and condition of the peat at each location and the type of substrate.

The natural moisture content and undrained shear strength of the peat are important; however, it is generally accepted that where present, the peat would be saturated and have a very low strength. It is believed to be unrealistic to rely on specific values of shear strength to maintain stability when back analysis of failed slopes indicates that there is often a significant discrepancy between measured strength in peat and stability. Therefore shear strength has been assumed to be constant and worst case, throughout this assessment. It has also been assumed, as a worst case, that the groundwater level is coincident with the ground surface.

The key factors identified as being critical to stability and the development of a risk rating system is:

- A – Slope gradient;
- B – Peat thickness;
- C – Substrate type or condition; and
- D – Historic instability.

The risk scores are multiplied together to generate a risk rating which is a measure of the likelihood of peat instability.

### 5.1 Slope Gradients

The slope gradients were assessed by reference to the mapping and particularly the DTM which was used to generate a gradient map (Figure 10.1.6), from which the gradient at each probe location could be determined and input into the risk rating spread sheet (Annex A). The gradient quoted at each location was based on the average gradient over a 5 m grid. Significant effort has gone into reducing slopes along routes and at turbine bases and positioning infrastructure on flat areas, it is evident from the Slope Plan that the majority of the tracks close to turbines and at turbines are on areas with moderate gradients (<8°). Some areas of the track to the north and at turbine T3 are located on slightly steeper gradients (>12°).

<table>
<thead>
<tr>
<th>Slope Angle (°)</th>
<th>Slope Angle Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2°</td>
<td>1</td>
</tr>
<tr>
<td>2° - &lt;4°</td>
<td>2</td>
</tr>
<tr>
<td>4° - &lt;8°</td>
<td>4</td>
</tr>
<tr>
<td>8° - &lt;12°</td>
<td>6</td>
</tr>
<tr>
<td>&gt;12° Slope</td>
<td>8</td>
</tr>
</tbody>
</table>

Coefficients for slope gradient have been assigned to ensure the potential for both peat slides (gradients of 4-15°) and bog slides (gradients of 2-10°) are addressed.

By simple inspection it is clear that steeper slopes pose a greater risk of instability than shallow gradients. Therefore, a graduated gradient scale from 0° to >12° (the practical maximum gradient on which peat is commonly observed) has been applied.

### 5.2 Peat Thickness and Ground Conditions

The ground conditions were assessed by using peat depths recorded during peat probing. Thin peat was classed as being 0.5 m to 1.5 m thick, with deposits in excess of this being classed as thick. The thickness ranges used are intended to reflect the risk of instability associated with both peat slides (in thin peat) and bog slides. Where the probing recorded peat less than 0.5 m thick, this has been considered to be an organic soil rather than peat. Table 5-2 gives the coefficients applied to the various ground conditions.

In addition to peat thickness, the presence of existing landslip debris or indicators of meta-stable conditions such as tension cracks or slumping in the peat suggest the material is likely to become even less stable should the existing ground conditions change. Where evidence of historical slips, collapses, creep or flows is seen, a separate coefficient is applied, however there is no evidence of any slips, collapses, creep or flows on the Site therefore we have not attributed a value for this during the assessment.
Table 5-2: Coefficients for Peat Thickness and Ground Conditions

<table>
<thead>
<tr>
<th>Ground Conditions</th>
<th>Ground Condition Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peaty or organic soil (&lt;0.5 m)</td>
<td>1</td>
</tr>
<tr>
<td>Thin Peat (0.5 – 1.5 m)</td>
<td>2</td>
</tr>
<tr>
<td>Thick Peat (&gt;1.5 m)</td>
<td>3*</td>
</tr>
<tr>
<td>Slips /collapses / creep / flows</td>
<td>8</td>
</tr>
</tbody>
</table>

*Note that thicker peat generally occurs in areas of shallow gradients and records indicate that thick peat does not generally occur on the steeper gradients.

5.3 Substrate

As noted above, most failures in thin peat layers occur at the interface with the underlying substrate; the nature of the substrate has a very large influence on the probable level of stability.

Where sand and/or gravel (derived from glacial till) form the substrate, the effective strength of the interface can be considered to be good with comparatively high friction values. Under these conditions, failure is likely to occur in a zone within the peat, just above the interface. Further factors are necessary to cause a failure of this nature (increased pore pressures within the peat) and occurrence of such events is rare.

Where clay forms the interface, there is likely to be a significant zone of softening in the clay (due to saturation at low normal stresses, poor or nonexistent vertical drainage and the effect of organic acids), resulting in either very low undrained shear strength or low effective shear strength parameters. The result is that potential shearing could occur either in the peat, on the interface or in the clay; all three possibilities have been documented in the past.

A rock substrate provides a high strength stratum, however, the rock surface can be smooth, and, depending on the dip orientation of the strata, it can provide a very weak interface. For these reasons, at this stage, a rock interface has been given the same risk rating as clay.

Table 5-3: Coefficients for Substrate

<table>
<thead>
<tr>
<th>Substrate Conditions</th>
<th>Substrate Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/gravel</td>
<td>1</td>
</tr>
<tr>
<td>Clay</td>
<td>2</td>
</tr>
<tr>
<td>Rock</td>
<td>2</td>
</tr>
<tr>
<td>Not proven</td>
<td>3</td>
</tr>
<tr>
<td>Slip material</td>
<td>5</td>
</tr>
</tbody>
</table>

If the overall thickness of the peat had not been proven, the risk associated with the significant thickness and the unknown substrate would have been given a high rating to accommodate the unknown factors.

5.4 Risk Rating

The risk rating coefficient (score) was derived by multiplying the coefficients for the four key factors (historic instability is discounted as there is no evidence of it onsite) identified in the above sections together to produce a risk rating which is a measure of the likelihood of peat instability, and this enables potential areas of concern to be highlighted.

For example, a thin peat (2) x sand/gravel (granular) (1) x slope 6° (4) = 8 (low risk).

For the stability risk assessment, the following Potential Stability Risk classes were applied as shown in Table 5-4.

Table 5-4: Risk Rating

<table>
<thead>
<tr>
<th>Risk Rating Coefficient</th>
<th>Potential Stability Risk (Pre-Mitigation)</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>Negligible</td>
<td>No mitigation action required</td>
</tr>
</tbody>
</table>
ScottishPower Renewables
Arecleoch Windfarm Extension
Filename: Peat Landslide and Hazard Risk Assessment

SLR Ref No: 405.00481.00049
June 2019

<table>
<thead>
<tr>
<th>Risk Rating Coefficient</th>
<th>Potential Stability Risk (Pre-Mitigation)</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - &lt;15</td>
<td>Low</td>
<td>As for negligible condition plus development of a site specific construction and management plan for peat areas</td>
</tr>
<tr>
<td>15 - &lt;31</td>
<td>Medium</td>
<td>As for Low condition plus may require mitigation to improve site conditions.</td>
</tr>
<tr>
<td>&gt;31</td>
<td>High</td>
<td>Unacceptable level of risk, the area should be avoided. If unavoidable, detailed investigation and quantitative assessment required to determine stability and sensitivity to minor changes in strength and groundwater regime combined with long term monitoring.</td>
</tr>
</tbody>
</table>

The rating system outlined above differs slightly from that proposed in the SE Guidance as the system adopted here incorporates three inputs compared to two in the guidance, with the potential impact of substrate is added in this section.

The table of results; included in Annex A shows that 1781 probe locations were identified within the extent of the Digital Terrain Model, peat/peaty soil was present at 1174 locations. The stability risk rating identified the following:
- negligible risk at 1245 (70 %) probe locations;
- low risk at 515 (29 %) locations;
- medium risk at 3 (1 %) locations;
- no High risk (0 %) location; and
- no peat was recorded at 14 locations, hence no risk.

Figure 10.1.7 presents the interpreted risk of peat instability based on the multiplication of the risk coefficients discussed above in Table 5-1 to Table 5-3 and using the detailed mitigation in Table 5-4. The Peat Stability Risk Rating for each proposed turbine is summarised in Table 5-5.

### Table 5-5: Stability Risk Rating at Each Turbine

<table>
<thead>
<tr>
<th>Turbine No.</th>
<th>Stability Risk Rating</th>
<th>Peat Depth (m)</th>
<th>Slope (°)</th>
<th>Acceptable Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>0.51</td>
<td>4.3</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Negligible</td>
<td>0.47</td>
<td>3.3</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>0.70</td>
<td>10.0</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Negligible</td>
<td>0.21</td>
<td>5.0</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Negligible</td>
<td>0.92</td>
<td>3.2</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Low</td>
<td>0.50</td>
<td>3.5</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Low</td>
<td>0.67</td>
<td>1.2</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Negligible</td>
<td>0.80</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Negligible</td>
<td>0.63</td>
<td>3.5</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>Negligible</td>
<td>0.62</td>
<td>2.6</td>
<td>Yes</td>
</tr>
<tr>
<td>11</td>
<td>Negligible</td>
<td>0.55</td>
<td>1.5</td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
<td>Negligible</td>
<td>0.06</td>
<td>2.9</td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>Low</td>
<td>0.77</td>
<td>4.3</td>
<td>Yes</td>
</tr>
</tbody>
</table>

As can be seen from Table 5-5, all of the proposed turbine positions fall within the ‘negligible’ or ‘low’ risk classification. Most of the turbines are sited on shallow to moderate slopes (< 6°), with the exception of T3 at 10°.
The proposed access track also falls mainly within the ‘negligible’ or ‘low’ classification. There is one area where the risk of instability along the track has been classed as ‘medium’ and, as such, warrants further consideration.

5.5 Turbine Sites (Including Hard Standings)

The table of results shows that the following potential stability risks exist at the turbine locations:

- negligible risk at eight locations;
- low risk at five locations;
- no medium risk locations were identified; and
- no high risk locations were identified.

The construction compound and substation are located on areas with no or limited peat with negligible – low risk of instability.

5.6 Access Track

The table of results shows that the following potential stability risks exist across the Site at all probing locations along the areas of new access track:

- three medium risk areas have been identified to the west of T5, on track to T5 and south of T3.

5.7 Hazard Score Development

A further assessment of the medium risk locations, at the track (to the west of T5, on track to T5 and south of T3,) has been undertaken. It should be noted that the impact assessment is primarily concerned with impacts that affect the environment, ecology, public or infrastructure associated with the proposed Development, both onsite and potentially off-site. These assessments do not consider the detailed ecological impact of construction induced peat instability; however, the majority of the sensitive onsite receptors are the watercourses and thus the inferred ecological and environmental issues are addressed. The proposed mitigation measures in Section Error! Reference source not found. would limit the potential for any slope failures into water courses and drainage features hence limit such impacts.

The effect a slope failure may have on the construction site and infrastructure can be easily identified. However the effect of an instability event on features impacted by an event not associated with the proposed Development is harder to predict.

In order to address this effect, it is not considered appropriate to assess the effect at every potential receptor location close to a site; but rather to assess the effect a particular infrastructure feature (track, turbine, substation, etc.) would have on the structures or features surrounding it. By adopting such an approach, the assessment of infrastructure features where a risk ranking of ‘negligible’ or ‘low’ (assessed in the stability risk assessments described above) is discounted from further assessment.

5.8 Receptor Ranking

Now the infrastructure features with a ‘medium’ or higher risk rating for instability have been identified it is necessary to identify potential impact receptors. These are nearby structures or features that may be affected by peat movements caused during or following construction. Generally, only receptors immediately down gradient of the infrastructure feature could be affected by peat instability therefore the first phase of feature ranking requires topographic ridges and valleys to be identified across the Site and surrounding area. From this, receptors at risk from particular infrastructure features can be identified. However, should instability occur on a steep slope, there is the risk of the back scarp of the instability migrating up-slope, there-by affecting areas previously considered not to be at risk.

Following identification of receptors at risk, these are ranked according to their size and sensitivity. Table 5-6 presents the coefficients placed on particular receptor types.

At the Site, only watercourses are deemed significant receptors at risk from peat slides. Communities have been discounted due to distance from infrastructure, the impact therefore, should a slide occur is directly to water courses.

<table>
<thead>
<tr>
<th>Nature of Feature</th>
<th>Feature Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-critical infrastructure (minor/private roads, tracks)</td>
<td>1</td>
</tr>
<tr>
<td>Watercourses and critical infrastructure (pipelines, motorways, dwellings and business properties etc.)</td>
<td>3</td>
</tr>
<tr>
<td>Sub-Community (settlement 1-10 residents)</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 5-6: Coefficients for Impact Receptor Ranking
5.9 Receptor Proximity

The proximity of an impact receptor is also critical in assessing the likely level of disruption it may suffer following an instability event. Based on this, two further coefficients – distance from infrastructure feature and relative elevation differences between the infrastructure feature and impact receptor - are applied in deriving an impact ranking. Table 5-7 and Table 5-8 present the coefficients derived for distance and elevation of impact receptors.

<table>
<thead>
<tr>
<th>Nature of Feature</th>
<th>Feature Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community (settlement of &gt;10 residents)</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 5-7: Coefficient for Impact Feature Distance

<table>
<thead>
<tr>
<th>Distance from Coefficient Feature</th>
<th>Distance Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1km</td>
<td>1</td>
</tr>
<tr>
<td>100 m – 1 km</td>
<td>2</td>
</tr>
<tr>
<td>10 – 100 m</td>
<td>3</td>
</tr>
<tr>
<td>0 – 10 m</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5-8: Coefficient for Impact Feature Elevation

<table>
<thead>
<tr>
<th>Relative Elevation of Feature</th>
<th>Elevation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 m</td>
<td>1</td>
</tr>
<tr>
<td>10 – 50 m</td>
<td>2</td>
</tr>
<tr>
<td>50 – 100 m</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 100 m</td>
<td>4</td>
</tr>
</tbody>
</table>

5.9.1 Impact Rating

The impact rating coefficient (score) is derived by multiplying the receptor ranking coefficient (score) by the distance coefficient (score) and the elevation coefficient (score) for each impact receptor associated with a particular infrastructure feature.

Based on distance to impact receptors, in this instance we have identified watercourses (which are the most sensitive receptor near the Site). The other receptors have been discounted, either they are not present or distance to receptor mitigates risk. Watercourses are the principal receptor as they are at risk of not only direct impact from a peat slide but potentially the water course creates a pathway to impact other receptors indirectly, either ecological or potential water users downstream. Based on Table 5-6 the watercourses would have an impact receptor coefficient (score) of 3 and then considering the distance to the receptor and the relative elevation differences on site of receptors, a potential impact can be derived.

For example, a watercourse (score 3) x 479m from the risk area (score 2) x an elevation difference of 25m (score 2) = 12 (3x2x2) (low risk).

5.10 Hazard Ranking

The SE guidance recommends that the hazard ranking is assessed using the following formula:

- Hazard Ranking = Hazard x Exposure

This philosophy can be applied to the assessment carried out so far in the following approach:

- Hazard Ranking = Risk Rating x Impact Rating

In order to achieve a meaningful and manageable result from the hazard ranking, the results of the Stability Risk Assessment and Impact Assessment have been normalised to a standard numerical scale (below).
The method of assessing risk, impact and hazard developed by SLR Consulting incorporates additional critical elements such as the substrate interface and coefficients for the receptor position, distance and elevation and as such is considered to be more rigorous than the assessment scheme proposed by the SE. Whilst the scales used in the SLR method deviate from the SE Guidance (with risk and impact rating scales from 1-4 rather than 1-5), the ultimate Hazard Ranking scale does equate to the SE scale, with hazard rankings divided over four zones. A simple multiplication of these coefficients would result in potentially large and unwieldy risk and impact rating numbers. We have therefore opted to normalise these values to bring them in line with the values used in the SE Guidance, as illustrated in Table 5-9 above.

<table>
<thead>
<tr>
<th>Hazard Ranking</th>
<th>Hazard Ranking Zone</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>Insignificant</td>
<td>No mitigation action required although slide management and monitoring shall be employed. Slide management shall include the development of a site specific construction plan for peat areas.</td>
</tr>
<tr>
<td>5 - 10</td>
<td>Significant</td>
<td>As for Insignificant condition plus further investigation to refine the assessment combined with detailed quantitative risk assessment to determine appropriate mitigation through relocation or re-design.</td>
</tr>
<tr>
<td>11 - 16</td>
<td>Substantial</td>
<td>Consideration of avoiding project development in these areas should be made unless hazard mitigation can be put in place without significant environmental effect.</td>
</tr>
<tr>
<td>17-25</td>
<td>Serious</td>
<td>Unacceptable level of hazard; development within the area should be avoided.</td>
</tr>
</tbody>
</table>

5.11 Results

The stability risk assessment has demonstrated that the majority of the Arecleoch Windfarm Extension Site lies within an area of negligible to low risk with regards to stability based on Figure 10.1.7. Those areas that have been identified as being at medium risk of instability but do not impact the Site layout have not been considered in a hazard impact assessment. There are no communities of any description within the application area or within 1 km of any down slope regions of the Site where a peat slide would be likely to migrate to.

There are two watercourses present onsite – Water of Tig flowing to the north and Cross Water flowing to the east. Only the Water of Tig is at risk from a peat slide.

The stability risk assessment results are presented in Table 5-11 shows the calculated hazard ranking associated with every location where there is a stability risk of medium or above, at or close to windfarm infrastructure. The particular mitigation measures to reduce the risk of instability occurring are dependent upon location and the type of proposed structure. Proposed mitigation measures and actions already undertaken to reduce the risk of peat instability occurring are also identified in Table 5-11, together with the associated, revised hazard ranking. A more detailed discussion of the possible mitigation measures are presented in Section 6.

There are three medium risk area of peat instability within influencing distance of a proposed turbine (T3 and T5) with three locations of medium risk of peat instability, one the proposed access track (close to T5). A total of 3 medium risk probe locations have been identified across the Site, mostly in localised areas; following review, the majority of these locations are not considered to have either a potential impact on the windfarm infrastructure, due to locality, either well away from influencing windfarm infrastructure, in a down gradient position or have no impact on the local watercourses.
5.12 Hazard Rated Locations

As noted in Figure 10.1.7 where the risk assessment has identified a negligible or low risk of peat instability, no specific mitigation measures are necessary. However, in order to ensure best practise is employed, there would be a need for careful monitoring and the construction management must include careful design of both the permanent and temporary works appropriate for peat soils; these are discussed further in Section 6.

The areas of the infrastructure that were rated as medium risk, or above, were subjected to a hazard assessment; a number of areas were discounted as they were located off the proposed access track and do not fall within influencing distance of any of the key proposed Site infrastructure.

The procedure adopted was to review Figure 10.1.7 and identify those areas with a medium risk or greater, that were in close proximity or influencing distance of any of the proposed infrastructure or watercourses. Those risk areas where there is no development would not affect the natural stability of the peat.

The assessment carried out in Table 5-11 was completed as described in the sections above. For example, location 1 has a risk rating of 3 (derived from Table 5-5 and Table 5-10) with an impact rating of 2 (derived from the process described in Section 5.9.1 and normalised in Table 5-10). These ratings are multiplied (2 x 3) to give a hazard ranking of 6 (significant), as detailed in Table 5-11.

Although the potential hazards identified in Table 5-11 can be mitigated to ‘insignificant’ it is believed that hazards should be subject to further post consent investigation and on-going monitoring during construction. Further details of mitigation during construction are described in Section 6.

<table>
<thead>
<tr>
<th>Location</th>
<th>Coordinates</th>
<th>Risk Rating</th>
<th>Impact Rating</th>
<th>Hazard Ranking</th>
<th>Mitigation</th>
<th>Revised Hazard Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>218711, 581746</td>
<td>Medium (3)</td>
<td>Low Impact (2)</td>
<td>Significant (3x2)</td>
<td>Not located near any infrastructure</td>
<td>Insignificant</td>
</tr>
<tr>
<td>2</td>
<td>218211, 581646</td>
<td>Medium (3)</td>
<td>Low Impact (2)</td>
<td>Significant (3x2)</td>
<td>Access Track crossing peat area, micro siting slightly west would reduce risk</td>
<td>Insignificant</td>
</tr>
<tr>
<td>3</td>
<td>217911, 581546</td>
<td>Medium (3)</td>
<td>Low Impact (2)</td>
<td>Significant (3x2)</td>
<td>Not located near any infrastructure</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

6.0 Construction Issues and Mitigation Measures

It has been shown that excavation, drainage and general construction activities can have a destabilising influence on peat and that design should allow for the delicate and susceptible condition of the peat. There is no extensive evidence for past peat instability onsite, however appropriate good practice measures and mitigation should be employed to minimise the risk of adverse effects on peat and hydrological receptors.

The following sections highlight the construction issues that should be considered for each general area of construction. Many of the issues raised should be incorporated into the CEMP and construction method statement for the Site.

The following is a list of controls that should be considered for incorporation into the development of construction methodologies for the works in all areas of peat during detailed design stage:

- appropriately experienced and qualified engineering geologist/geotechnical engineer is appointed during the construction phase, to provide advice during the setting out, micro-siting and construction phases of the works;
- geotechnical Risk Register is developed and maintained by the appointed geotechnical engineer;
- a minimisation of “undercutting” of peat slopes, but where this cannot be avoided, a more detailed assessment of the area of concern by the geotechnical engineer would be required;
- careful micro-siting of turbine bases, crane hardstanding’s and access track alignments to minimise effects on the prevailing hydrology;
- although the risk of a peat slide is considered to be low for the majority of the proposed Development, it is recommended that methodologies should be developed as a contingency to minimise the effects to watercourses in the unlikely event of peat instability; and
- use of floating track across areas of deep peat.

Notwithstanding any of the above comments, detailed design and construction practices would need to take into account the particular ground conditions and the specific works at each location throughout the construction period.

Good practice measures are provided in Section 6 to minimise the risk of potentially inducing peat landslides during construction of the proposed Development.
6.1 General

- Raise Health and Safety awareness of the peat environment at the proposed Development for construction staff by incorporating the issue into the Site Induction. Include peat slide risk assessment information (e.g. peat instability indicators, best practice and emergency procedures) in tool box talks with relevant operatives e.g. plant drivers;
- Introduce a ‘Peat Hazard Emergency Plan’ to provide instructions for Site staff in the event of a peat slide or discovery of peat instability indicators;
- For sections of track that require track side cuttings into peat, suitable support measures would need to be designed to maintain the stability of the adjacent peat terrain;
- Refine/optimise the design through the pre-construction phase following completion of a detailed ground investigation; and
- Develop methodologies to ensure that accelerated degradation and erosion of exposed peat deposits does not occur as the break-up of the peat top mat has significant implications for the morphology, and thus hydrology, of the peat (e.g. minimise off-track plant movements within areas of peat).

6.2 Drainage Measures

Drainage design for the proposed Development is a critical mitigation measure in maintaining the hydrological conditions. In order to maintain hydrological conditions the following requirements of the drainage measures should be met;

- Development of drainage systems that would not create areas of concentrated flow or cause over, or under, saturation of peat habitats;
- Development of robust drainage systems that would require minimal maintenance;
- A robust design of drainage systems and associated measures (i.e. silt traps, etc.) to minimise sedimentation into natural watercourses. Method statements should be prepared in advance to mitigate against a slide occurring and should include, but not be limited to, the use of check dams and erosion protection to limit flows and prevent contamination of watercourses; and
- Measures shall be put in place to ensure drainage systems are well maintained, to include the identification and demarcation of zones of sensitive drainage or hydrology in areas of construction, e.g. inclusion of maintenance regimes for drainage systems into a construction management plan or similar.

6.3 Construction Recommendations

A summary of recommendations for Site specific infrastructure is provided in the following sections.

The complexity of peat stability has been discussed in this report and by Lindsay and Bragg 4, amongst others. Following a review of published work and the observation and analysis undertaken for the proposed Development, there would be a negligible hazard from peat instability if the recommendations contained in this report are adopted.

Suitable guidance and documentation in the form of a construction method statement/CEMP would be established before work commences to ensure good construction practices. Due to the complex inter-reactions affecting peat stability it is proposed that the recommendations given below are used as a set of guidelines to generate a detailed design concept. The concept should include the range of potential risks discussed in this report and the design should be sufficiently flexible to allow for continual modification and up-dating as construction progresses.

6.4 Turbine Locations and Crane Pads

It is proposed that construction of the turbine foundations would require excavation of peat and subsoil to create a suitable area for the foundation of the base.

It is the objective of this assessment to consider the potential risk from peat instability and to recommend solutions and mitigation measures to eliminate, or at least reduce the risk to a manageable level. Risk reduction can best be achieved by minimising the effect of any construction works and an appropriate CEMP/construction method statement is an integral element in ensuring that all parties understand and acknowledge the potential consequences of a peat slide.

In general, the bearing stresses imposed by a turbine are relatively low and the main requirement of the base is to resist the overturning moments generated by the wind acting on the turbine. Gravity base foundations are designed to control bearing pressures to a level appropriate to the local ground conditions and provide stability against turbine loading.

The excavations for turbine bases and crane pads should be kept to a minimum where possible but it is likely that the required hard stratum would be typically several metres deep, beneath soft materials (peat), unless directly on rock. The very soft nature of peat means that unsupported cut or excavated slopes could be unstable unless shallow gradients are used. The overall width of such an excavation would be up to 28 m diameter at the original ground surface, depending on the thickness of the peaty soil/peat and glacial till and appropriate methods of stabilising the temporary slopes should be considered. Foundation excavation would produce large volumes of peat and this should be reused across the Site in an environmentally acceptable manner for restoration. Peat would not be used to back fill the excavation void within the footprint of the foundation as it would have a very low strength. Peat
could be used as backfill outside the foundation footprint and also to dress verges to tracks and around turbine bases, in line with current Waste Management guidance\textsuperscript{15}. Management of the water in the peat, by maintaining existing drainage during excavation is essential to avoid creating conditions likely to increase the risk of a peat slide.

6.5 Substation

The substation is sited on an area of limited peat cover with probing intersecting soils of 0.1 m thick.

6.6 Borrow Pits

The proposed 6 No. borrow pits are sited on areas of limited peat cover (<0.5 m). Borrow pit 4 is located off the existing track near the entrance to the Site, where rock was previously extracted for the existing Arecleoch Windfarm. Borrow pits 2 & 3 were also used for Arecleoch Windfarm and may be reopened and used for the access track to the proposed Development.

6.7 Access Tracks

The general principles regarding the construction of the access tracks in peat that minimises the risk of instability and environmental effects are discussed below.

In order to maintain the current level or improve the stability of the peat mass on the slopes around the access track, it is necessary to ensure that the construction methods do not seriously disrupt the established drainage and that no areas are surcharged, either by water discharge or spoil.

Wherever possible, the following principles should be adopted:

- **Maintenance of existing drainage is critical, therefore all existing drainage tracks must be maintained and where necessary, channelled below the proposed track construction. Upslope side drainage ditches to the track would be required on side-long ground; the ditches should be constructed with small dams and cross drains where necessary so that:**
  - Water can pass below the track at regular intervals;
  - Scour and erosion is avoided in the side ditches due the limited volume and velocity, concentrated discharges to the peat on the down slope side of the track are avoided;
- **The camber of the track should encourage surface water to drain to the up slope side drainage ditch;**
- **Track gradients to be maintained at the recommended gradients from the turbine supplier, typically shallower than 1 v: 8 h to facilitate access by the large specialist vehicles for both construction and transport of the turbine components. The maximum acceptable gradients are usually defined by the appointed turbine manufacturer;**
- **Identify and mark all existing drainage features within the access track corridors; these drainage features should be maintained (not enhanced) during the construction and operational phases of the proposed Development;**
- **Install cross drains at regular intervals to maintain interstitial groundwater flow through the peat mass below the tracks where track settlement could reduce the natural permeability;**
- **Install additional drainage in areas up-slope to any track to prevent ponding and possible instability;**
- **Install small dams at regular intervals along the track side drains to prevent significant water velocities in the side drains causing deep erosion in the peat;**
- **Where track construction is required over peat areas in excess of 1 m deep, this may be undertaken with a floating track construction, where the integrity of the peat allows;**
- **Cut and fill should be avoided in peat greater than 1.0 m deep if possible; if not, the following requirements on side long ground (across contours) should be adopted:**
  - Excavate to a sound stratum;
  - The majority of construction surface’s to be essentially horizontal with a slight fall to aid drainage;
  - Where the depth of cut is deemed unstable, employ a stepped or benched surface with the intention of minimising the exposed surface of the up-slope cut face;
  - Protect all exposed peat surfaces from erosion and desiccation, by ensuring the integrity and moisture content of the peat is maintained; and
  - The top of cut slopes should be provided with a small bund to retain the peat to prevent desiccation and maintain the local stability of the peat.

\textsuperscript{15} Scottish Renewables and SEPA, Developments on Peatland: Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste, 2012;
6.8 Cable Routes

The general principles regarding the construction of the cable trenches in peat that minimises the risk of instability and environmental effects are discussed below.

In order to maintain the current level or improve the stability of the peat mass on the slopes around the cable route, it is necessary to ensure that the construction methods do not seriously disrupt the established drainage and that no areas are surcharged, either by water discharge or spoil.

The majority of the cable routes would be likely located within areas of shallow peat. The construction of the cable route would minimise disturbance to drainage by taking cable route alongside existing access track and around the turbines adjacent to new tracks.

6.9 Crossing Watercourses

The access tracks would cross a number of existing watercourse and particular care would be required to ensure conformity in the settlement characteristics between the crossing structure and the approaches to avoid undue settlement.

6.10 Temporary Construction Compound

The proposed location for the construction compound and potential batching plant are located on an area with some existing hardstandings and no significant peat (average probing depth of 0.5 m) and therefore not considered an issue at this Site. Any peat/peaty soil removed would be stored on a temporary basis and reinstated on completion of construction.

6.11 Further Work

This report should be considered as the first stage in the development of a fundamental understanding of the various inter-relationships that govern and control the peat lands at the Site.

More detailed ground investigations would be required to facilitate the geotechnical design of the various foundations and access track.

7.0 Conclusion

The Site has been assessed for potential hazards associated with peat instability; the assessment has been based on:

- a walk-over survey by an experienced geologist;
- a thorough inspection of the digital terrain map at a scale of 1:25,000;
- review of historical and geological maps and publications and aerial photography; and
- review of peat depth and peat core data.

A detailed geotechnical probing exercise at 1,781 locations in areas of identified peaty soil/peat to determine the thickness thereof; and the overall conclusion regarding peat stability is that there is a negligible to low risk of peat instability over most of the Site although some limited areas of medium and high risk have been identified. For these areas, a hazard impact assessment was completed which concluded that, subject to micro siting and the employment of appropriate mitigation measures, all these areas can be considered as an insignificant risk. Additional mitigation measures have been identified in areas where hazards are already considered insignificant to further reduce the risk of potential hazards occurring.

The areas of thick peat generally mimic the topography and coincide with the flatter gradients (<4°). The steeper slopes have significantly less peat and in general comprise mainly peaty soils (<0.5 m).
FIGURE 10.1.1

Proposed Site Context
FIGURE 10.1.2
Superficial Geology
FIGURE 10.1.3
Solid Geology
Legend

- Application Boundary
- Application Boundary 1km
- Buffer
- Proposed Turbine Layout
- Proposed Permanent Met Mast
- Existing Track
- Proposed Existing Upgrade Track
- Proposed New Track
- Proposed Turning Head
- Proposed Construction Compound
- Proposed Laydown Storage Area
- Proposed Borrow Pit Search Area
- Proposed Crane Pad
- Proposed Substation

Solid Geology Legend

- Dalreoch Formation - Wacke
- Galloway Formation - Wacke
- Glen App Conglomerate Member - Conglomerate and Sandstone, Interbedded
- Kirkcolm Formation - Wacke
- Traboyack Formation - Wacke

Igneous Rocks
- Balcreuchan Group - Basalt, Lava-Pillowed
- Ballantrae Ophiolite Complex - Gabbro
- Ballantrae Ophiolite Complex - Serpentinite
- Downan Point Lava Formation - Basalt, Lava-Pillowed
- North Britain Palaeogene Dyke Suite - Microgabbro

Technical Appendix 10.1
Arecleoch Windfarm Extension - EIAR
Solid Geology

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Solid Geology Data obtained via BGS WMS.
British Geological Survey @NERC. All Rights Reserved.
FIGURE 10.1.4

Peat Depth Plan
Interpolated Peat Depth

- No Peat
- ≤ 0.50 m
- 0.51 - 1.00 m
- 1.01 - 2.00 m
- 2.01 - 3.00 m
- 3.01 - 4.00 m
- 4.01 - 5.00 m
- 5.01 - 6.00 m
- 6.01 - 7.00 m
- 7.01 - 8.00 m
- 8.01 - 9.00 m
- 9.01 - 10.00 m

Legend
- Application Boundary
- Proposed Turbine Layout
- Proposed Permanent Met Mast
- Existing Track
- Proposed Existing Upgrade Track
- Proposed New Track
- Proposed Turning Head
- Proposed Construction Compound
- Proposed Laydown Storage Area
- Proposed Borrow Pit Search Area
- Proposed Crane Pad
- Proposed Substation

Arecleoch Windfarm Extension - EIAR
Technical Appendix 10.1
Peat Depth
FIGURE 10.1.5

Peat Depth Plan >0.5m
FIGURE 10.1.6
Slope Plan
Legend

- Application Boundary
- Proposed Turbine Layout
- Proposed Permanent Met Mast
- Existing Watercourse Crossing
- Proposed Existing Upgrade Watercourse Crossing
- Proposed New Watercourse Crossing
- Existing Track
- Proposed Existing Upgrade Track
- Proposed New Track
- Proposed Turning Head
- Proposed Construction Compound
- Proposed Laydown Storage Area
- Proposed Borrow Pit Search Area
- Proposed Crane Pad
- Proposed Substation

Slope (degrees)
- 0 - 2
- 2 - 4
- 4 - 8
- 8 - 12
- >12

Arecleoch Windfarm Extension - EIAR
Technical Appendix 10.1
Slope Plan

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FIGURE 10.1.7
Peat Slide Risk Plan
FIGURE 10.1.8

Aerial Plan with Geomorphological Interpretation
Legend
- Application Boundary
- Proposed Turbine Layout
- Existing Track
- Proposed Existing Upgrade Track
- Proposed New Track
- Proposed Borrow Pit Search Area
- Deep Flat Lying Peat
- Steep Slopes

Aerial Plan with Geomorphological Interpretation

Datum: OSGB36
Projection: TM
Rev Date By Comment
A 27/03/19 LM First Issue.
Legend

- Application Boundary
- Proposed Turbine Layout
- Existing Track
- Proposed Existing Upgrade Track
- Proposed New Track
- Proposed Borrow Pit Search Area
- Deep Flat Lying Peat
- Steep Slopes

Legend

Application Boundary
Proposed Turbine Layout
Existing Track
Proposed Existing Upgrade Track
Proposed New Track
Proposed Borrow Pit Search Area
Deep Flat Lying Peat
Steep Slopes

Aerial Plan with Geomorphological Interpretation

Rev Date By Comment
A 27/03/19

Datum: OSGB36
Projection: TM

Rev Date Org No 00481.00049.10.1.8.1
A 27/03/19 Arecleoch Windfarm Extension - EIAR
Technical Appendix 10.1

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Acreleach Wind Farm Extension

PEL Consulting Ltd Confidential
### Aerie Loch Wind Farm Extension

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**Note:** This table represents the potential instability of the peat layers at Aerie Loch Wind Farm Extension. The data includes the ID, position, ENU coordinates, peat depth, slope, slope coefficient, substrate type, peat type, peat coefficient, substrate coefficient, and potential instability. The potential instability is indicated as Low or High.
### Areltech Wind Farm Extension

#### Peat Risk Rating

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**Note:** The table above provides a list of peat risk ratings for different positions with specific details such as ID, position, E, N, peat depth, slope, slope coefficient, substrate, peat type, peat coefficient, substrate coefficient, risk coefficient, and potential instability. Each record in the table indicates the level of risk associated with the peat layer at a given location.
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Arealoch Wind Farm Extension

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Ardleoch Wind Farm Extension

190415 Ardleoch Extension Peat Risk Rating

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Protest data

SLR Consulting Ltd Confidential

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