Fred.Olsen Renewables

APPENDIX A6.2 – Peat Slide Risk Assessment

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Appendix A6.2 Peat Slide Risk Assessment

Contents

Date:	10/10/2021	Job reference:	14220UKC
Issue:	B	File name:	
Description:	Peat Slide Risk Assessment – *Updated with additional detailed probing 07/22*		
Prepared by:	Sam Fisher	Checked by:	Gavin Germaine
Edited/checked:	Gavin Germaine	Date:	15/10/2021
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1 Introduction

1.1.1 This report was updated in July 2022 following the collection of additional soil probing information. All probe data is presented as part of the Further Environmental Information (FEI) submission. Natural Power the author of the original Peat Slide Risk Assessment did not consider the collection of additional probe information to be a requirement and stand-by the original risk analysis. However, the additional detailed probing survey has been undertaken based on the external recommendations of Ironside Farrar in their Stage 1&2 Checking Reports (Ref: 63068).

1.1.2 This additional FEI information specifically addresses their remaining open recommendations as presented in the Stage 2 Checking Report (63068):

- No.3: Additional detailed probing is required at all infrastructure locations.
- No.10: Following additional probing review risk assessment at discrete track section between T16/T17 and either side of T10

1.1.3 Additional detailed soil probe data points were collected across the proposed infrastructure layout targeting areas to increase the density of recorded data points. The findings of this additional probing correlates with the existing conclusions on peat depth and distribution across this development. Topography is dominated by a large open basin with shallow terrain slope angles. Where peat is present it is predominantly measuring less than 0.5m depth and thus the shallow slope angles coupled with shallow peat places the development within the lowest peat slide risk categories.

1.1.4 Following review of this additional probing information. Natural Power has not found any increase in the overall risk category for the development and stands by the conclusions of the original report. The updated peat depth interpolation map is provided at Figure A1 – Interpolated Peat Depth for information.

1.2 *Reporting Experience*

1.2.1 **Report Author** - Sam Fisher is a geotechnical engineer at Natural Power and geologist by training (MSc Engineering Geology) and Fellow of the Geological Society of London with over 5 years of relevant geotechnical experience. On behalf of Natural Power, Sam has been involved in field work and reporting of multiple peat slide risk assessments for renewable energy projects across Scotland and Northern Ireland.

1.2.2 **Report Approver** - Gavin Germaine is a principal geotechnical engineer at Natural Power and an engineering geologist by training (MSc Engineering Geology) with greater than 12 years of relevant geotechnical experience. Gavin is a Chartered Geologist (CGeol) and a Fellow of the Geological Society of London. Over the last decade he has completed multiple peat slide risk assessments for wind energy projects across the UK and Ireland. Gavin has further provided expert technical advice as part of public inquiry and joined international teams examining new geotechnical investigation techniques for in-situ testing and sampling of peat.

1.3 *Objectives*

1.3.1 This Peat Stability Assessment comprises a semi-quantitative peat stability risk assessment covering the proposed Lethen Wind Farm. The primary objectives of this study are to:

- Present a desk study pertinent to the subject of peat stability assessment at the development;

- Report on walkover and geomorphological mapping exercise to inform the assessment;
- Identify any areas of existing instability or which may pose a risk to development;
- Provide robust and targeted recommendations for any future construction process and mitigate any potential contributory factors to elevated risk of instability.

1.3.2 This report has been undertaken in general accordance with the Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Development, second edition, published by the Scottish Government in April 2017.

1.3.3 Peat surveys have been carried out in line with Scottish Government guidance: Scottish Government, Scottish Natural Heritage, SEPA (2017) Peatland Survey, Guidance on Developments on Peatland.

1.4 Data Sources

1.4.1 The peat stability assessment utilises data and visual assessment collected during two phases of site survey. This data and information are combined with desk study and review of all salient published materials. The following data sources have been integrated into this assessment: (Table 1).

Table 1 – Data Sources

Data Source	Location	Date
British Geological Survey – Onshore Geological Map Data: (Linear Features, Mass movement deposits, Artificial ground, superficial deposits, bedrock geology, faulting,1:50,000 scale)	http://mapapps2.bgs.ac.uk/geoindex/home.html	2021
British Geological Survey – Engineering Geology Viewer: 1:1M Superficial Engineering Geology; 1:1M Bedrock Engineering Geology	http://mapapps.bgs.ac.uk/engineeringgeology/home.html	2021
British Geological Survey – Hydrogeological Map of Scotland: 1:625,000 Scale	http://www.largeimages.bgs.ac.uk/iip/hydromaps.html?id=scotland.jp2	1988
National Soil Map of Scotland – main soil types originally mapped at 1:250,000 scale	http://soils.environment.gov.scot/maps/	1947-1981
National Library of Scotland, Historical mapping	https://maps.nls.uk/	Various
Historical Aerial Photograph Data **ESRI Satellite World Imagery**	https://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/tile/{z}/{y}/{x}	2021
Online news archival search	Various	2021
SEPA rainfall data	www.sepa.org.uk/rainfall/	2021

1.5 Scope of Work

1.5.1 The following work programme has been followed:

- Stage 1: (100m grid, development wide) peat probing survey to ascertain the depth and distribution of peat deposits (Q4 2018);
- Stage 2 detailed peat survey across infrastructure location where peat depth of >0.5m was predicted in Stage 1 (Q2 and Q3 2021);
- In-situ strength testing, peat coring and sampling at targeted deep peat locations (June 2021);
- Site walkover, reconnaissance survey: These surveys conducted by a geotechnical engineer, covering all key aspects and locations across the Proposed Development (June 2021).

1.6 Description of Development

1.6.1 The Proposed Development will consist of the erection, operation, and subsequent decommissioning of 17 wind turbines. The Proposed Development includes associated turbine foundations and transformers, energy storage, hardstanding areas for erecting cranes at each turbine location, a series of on-site tracks connecting each turbine, underground cables linking the turbines to the grid connection, an on-site substation, a construction compound, up to three borrow pits, and a permanent meteorological mast.

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

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

1.6.4 There will be two temporary construction compounds / storage areas to provide a secure area for site office facilities and storage of materials and compounds. These will be constructed adjacent to the site track, with a hardcore base, surrounded by a security fence and locked gates.

1.6.5 Transformers to step-up the voltage exported from each turbine will either be placed within the wind turbines themselves, or in a small secure external transformer housing placed next to each wind turbine tower, depending on the final turbine choice.

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

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

1.6.8 A grid connection will be required to feed the electricity generated by the wind farm into the distribution network for the operational period of the wind farm. The final details of the grid connection including the precise route and an assessment of any impacts on the environment will be determined by the Distribution Network Operator (DNO) at a later date. The new grid connection may be subject to a separate design and consent process under Section 37 of the Electricity Act 1989. Wind farms are typically connected to the grid via underground cable connections.

1.7 *Location*

1.7.1 The Proposed Development is located within the Highland Council local authority area, approximately 10 km northwest of Grantown-on-Spey. The Proposed Development will be located in an area of open moorland. The centre of the development is approximated to British National Grid (BNG) NS 9322 3567. Figures 1.6.1 – 1.6.2:

Figure 1.6.1 – Regional Location

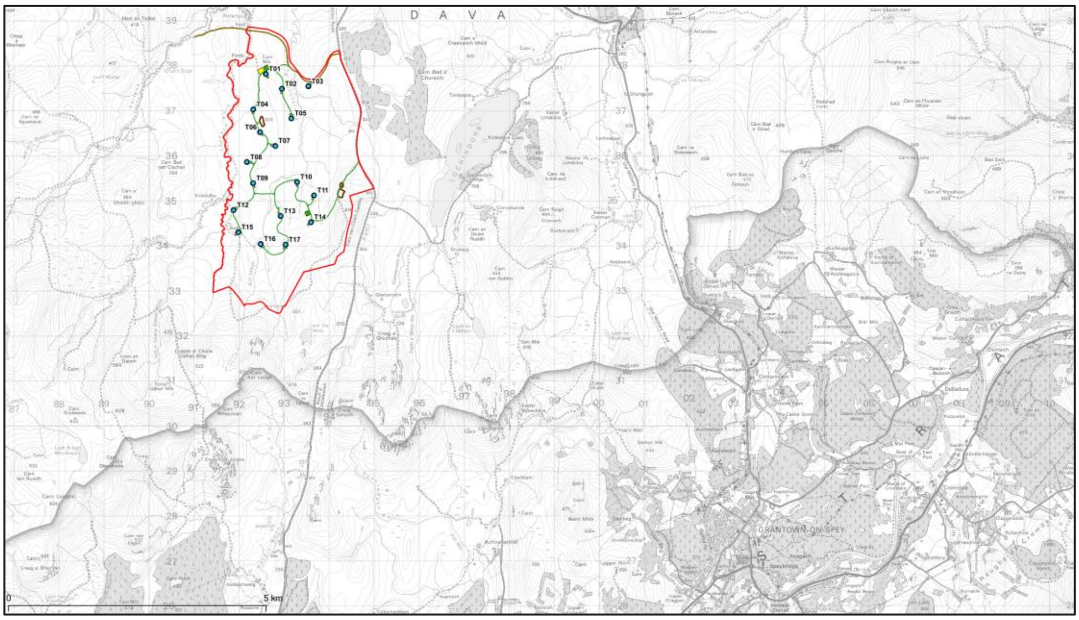
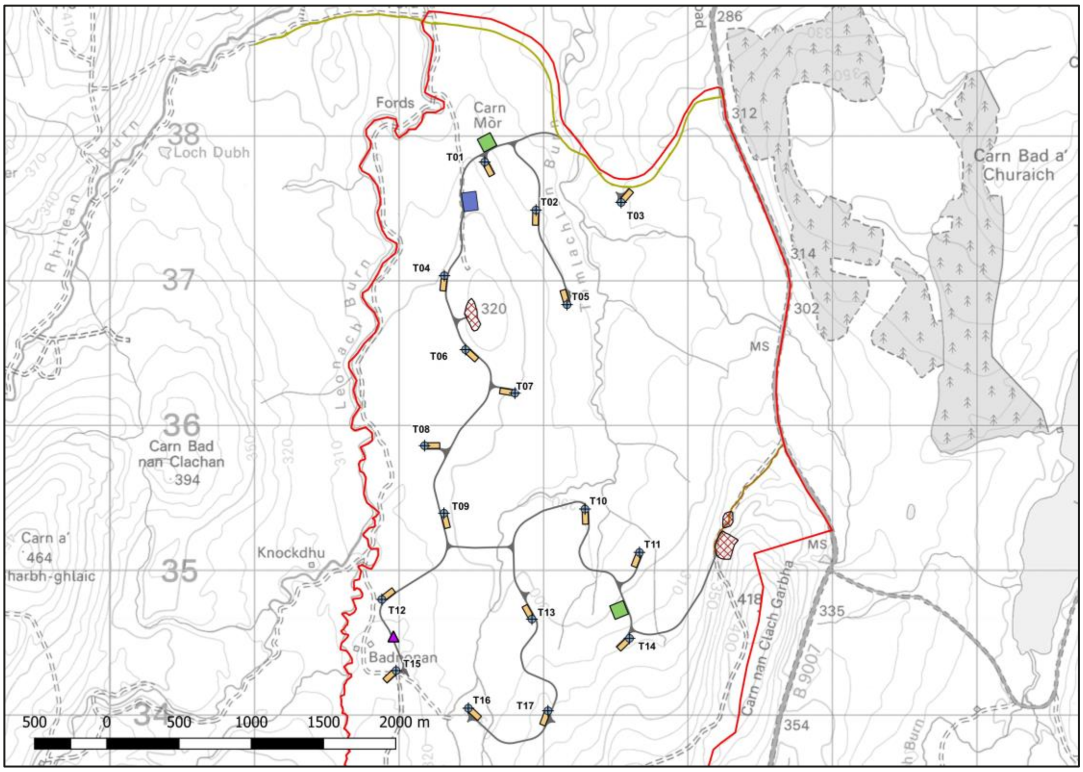


Figure 1.6.2 – Development Area



1.8 Terrain Description

1.8.1 The proposed infrastructure locations occupy a large open basin across open moorland. A topographic high is reached on the south-eastern site boundary at Carn nan Garbha of 418 m Above Ordnance Datum (AOD).

1.8.2 The key findings of the site reconnaissance are represented on the Geomorphological Map (Figure A3, Appendix A). A selection of photographs taken during the walkover survey depict the range of site environs, provided below.

Figure 1.7.1 – Typical Site Terrain – note absence of slopes in main site area

Figure 1.7.2 – Typical Site Terrain - note absence of slopes in main site area

1.8.3 Figure 1.7.3 provides an overview of the terrain across the development. Showing a generally encapsulated low angled terrain bordered to the east, south and west by rising terrain elevations. There are no continuous steep slopes within the development.

Figure 1.7.3 – 3D Terrain View

2 Survey Methodology

2.1 *Data Review*

2.1.1 In preparation of this report, an initial desk-based assessment has been undertaken to allow subsequent surveys to be targeted onto the peatland. Table 1 highlights the key sources of information for this study.

2.1.2 Online searches for local peat or major landslides returned several instances within the region. None however had similar ground conditions or were in close proximity to the Proposed Development.

2.1.3 Readily accessible aerial imagery records dating to 2005 and does not show any major changes occurring through to the present day.

2.1.4 Natural Power's project directory and online sources were searched for reports of peat slide incidents on nearby wind farm developments. These searches did not provide any pertinent information.

2.2 *Geomorphological Mapping*

2.2.1 Reconnaissance and geomorphological mapping were carried out at the development during June/July 2021. This exercise provided opportunity for geotechnical engineers to visualise the terrain, access geological and soil exposures, examine slope systems, vegetation cover and record any hydrological features impacting peat stability.

2.2.2 The culmination of this survey and desk-based review of aerial photographs was the production of a geomorphology map, Figure A3, Appendix A.

2.2.3 All major geomorphological elements are shown.

2.3 *Peat / Soil Survey*

2.3.1 Natural Power carried out the Stage 1 probe survey implementing a 100m grid of probes across the development infrastructure areas. Peat depths were recorded using probes inserted into the peat and measuring the depth to refusal. This provides a wide-ranging dataset, but the data carries the following limitations:

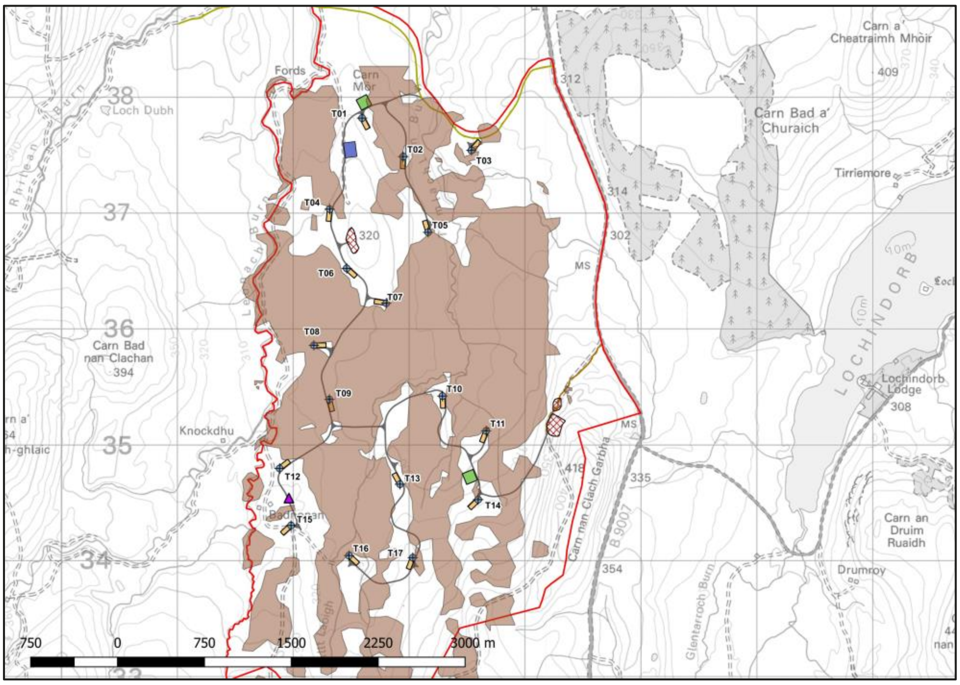
- Peat probes may record depth to obstructions (e.g. tree roots, rock clasts) and not the true depth of the peat;
- Peat probes may over-estimate peat depth where the underlying soil strata is very soft;
- Peat probes can underestimate peat depth in very dry peat deposits due to early refusal of the probe.

2.3.2 Detailed probing was undertaken at locations confirmed as peat (soil probes >0.5m and visual reconnaissance confirmed the extent of peat). Detailed Stage 2 soil probes were completed during July 2022 to complete coverage across the proposed development. Figure 2.3.1 below indicates the surveyed extent of peat deposits within the development. In-situ hand shear vane tests were conducted to provide an estimate of undrained shear strength within the peat at relevant turbine locations. Supplementary to this, peat cores have been taken at select locations to provide confirmation of peat depth, material classification and morphology.

2.3.3 Peat depth mapping is shown on drawing: Figure A1, Appendix A. To prepare the interpolated peat depth mapping; a spatial interpolation method termed 'Ordinary Kriging' was applied.

2.3.4 Terrain Slope Angle Map (Figure A2, Appendix A) is comprised from digital elevation model data, carrying a grid resolution of 5m. The risk assessment considers slope angle across two areas. Initially slope angle is used to screen the site for instability within the slope stability numerical assessment. This is adjoined to qualitative assessment of the slope angle category in terms of an empirical contributory factor to failure. This combined approach ensures a robust assessment of the risk and increases the sensitivity of the assessment to characterise risk more accurately across large development sites.

Figure 2.3.1 – Surveyed Extent of Peat



3 Geology & Environment

3.1 Solid Geology

3.1.1 According to the British Geological Survey (BGS), and as illustrated in Figure 3.1; the rock units across the development are predominantly meta sedimentary in origin. These rock units are likely to contained tectonised, sheared and altered rock types of predominantly pelite, semi-pelite and quartzite.

3.1.2 The Slochd Psammite Formation: Migmatitic Pelite and Migmatitic Semipelite. Metamorphic Bedrock formed approximately 850 to 1000 million years ago in the Tonian Period. Originally sedimentary rocks. Later altered by low-grade metamorphism.

3.1.3 Flichity Semipelite Formation - Semipelite, Migmatitic. Metamorphic Bedrock formed approximately 850 to 1000 million years ago in the Tonian Period. Originally sedimentary rocks formed in shallow seas. Later altered by high grade regional metamorphism.

3.1.4 Beinn Bhreac Psammite Formation - Psammite, Gneissose-micaceous. Metamorphic Bedrock formed approximately 850 to 1000 million years ago in the Tonian Period. Originally sedimentary rocks. Later altered by high grade regional metamorphism.

3.1.5 There are no mapped faults or fissures within the development.

3.1.6 The Solid Geology map of the site is presented in Figure A.5, Appendix A.

3.2 Superficial Geology

3.2.1 The BGS map data for superficial deposits only includes glacial deposits and peat. The valley forms on site are anticipated to be the focus for the deepest glacial soils. Peat soils are also known to be presented and depicted on the peat depth mapping (Appendix A).

3.2.2 There are no BGS mapped mass movement (landslide deposits) within the development.

3.2.3 The Superficial Geology map of the site is presented in Figure A.6, Appendix A.

3.3 Hydrology

3.3.1 A summary of the hydrological regime is presented below. It is highlighted that a separate hydrology baseline study has been undertaken. The details are provided in EIA Report Chapter 9 for Geology, Hydrology & Hydrogeology.

3.3.2 Hydrologically, the Proposed Development lies within the watershed of the River Findhorn which discharges into the Moray Firth at Findhorn on the north coast. Figure 9.1 in Volume 2 of the EIA Report shows a hydrological overview of the Proposed Development.

3.3.3 The upper catchment and headwaters of the Tomlachlan Burn is situated entirely within the Proposed Development boundary. The two main tributaries of the Tomlachlan Burn are the Caochan Gortach and the Allt Laoigh. The Proposed Development is bounded to the west by the Leonach Burn. The watercourses are characterised by moorland riparian habitat, meandering channels with gravel, boulder, and bedrock riverbed materials.

3.3.4 The Leonach Burn flows in a northerly direction joining the River Findhorn approximately 2.4 km downstream at British National Grid (BNG) 292112 840547. The Tomlachlan Burn also flows in a northerly direction joining the River Findhorn at a slightly lower location, approximately 4.4 km downstream at BNG 293889 842183.

3.3.5 During the site survey surveyors noted extensive areas of artificial moorland drainage across the site. This artificial drainage will have impacted the pre-existing natural hydrology of the site and has been captured on Figure A3, Appendix A.

3.3.6 The highest rainfall totals are typically experienced during the winter months with the highest average monthly rainfall totals of 120 mm recorded . The lowest rainfall totals are typically recorded during the spring with average monthly rainfall totals of approximately 60mm recorded during this season.

3.4 *Hydrogeology*

3.4.1 Bedrock underlying the site is classified as a low productivity aquifer comprising metamorphic rock. Flow is likely to be virtually all through fractures and other discontinuities. It is likely that there are small amounts of groundwater in near surface weathered zones and secondary fractures.

3.4.2 Where well sorted granular fluvially deposited superficials are present, groundwater flows may be more significant. However, the majority of the site is overlain with relatively lower permeability peat and glacial till.

3.4.3 The hydrogeological regime within superficial deposits at the site will likely vary significantly by deposit. The glacial till is anticipated to have a wide-ranging permeability with flow focused through lenses and interbedded sand and gravel layers. The peat will exhibit very low to moderate permeability with flow though the matrix of the peat soil and higher flows anticipated where peat is less humified and comprising fibrous material.

3.4.4 The presence of groundwater dependent terrestrial ecosystems is considered within Chapter 9 of the EIA Report. The presence of GWDTEs associated with source zones to the minor watercourses have been incorporated for consideration within the peat slide risk assessment.

3.5 *Land Use*

3.5.1 Historical mapping for the site has been reviewed from the National Library of Scotland archive. Earliest mapping available was from Ordnance Survey 'Outline' series for the late 19th Century. Indications are that the development area has largely been unchanged and dedicated to upland farming and estate agricultural practices.

3.5.2 The site walkover survey has identified an extensive network of artificial cut drainage ditches which are not evident on the historical mapping and thought to be contemporaneous with the estate management practices. No evidence of instability is recorded on the historical mapping. Evidence of extensive muirburn practices is present with some indication that this is leading to soil erosion in some part of the site.

3.5.3 The Proposed Development sits within open moorland habitat which is managed for grouse. The land management has altered the natural forming peatland structure.

3.5.4 Limited historical aerial imagery records were available for the development area; however, available records typically corroborate with the findings of the historical mapping review.

3.6 *Designated Sites*

3.6.1 There are two designated sites within 5 km of the Proposed Development. These are Carn na Tri-tighearnan, Site of Special Scientific Interest (SSSI) / Special Area of Conservation (SAC) which lies approximately 4.5 km to the north-west of the site. The River Spey SAC lies approximately 4.6 km to the south and west of the site. Both are considered at significant distance from the site that they are not considered primary receptors for the peat slide risk assessment.

4 Peat Slide Risk Assessment

4.1 *Peat Distribution*

4.1.1 In total 1,118 locations were surveyed during Stage 1 for peat depth across the development. A further 1,536 locations were surveyed during a Stage 2 detailed survey. Across infrastructure areas the mean peat depth is calculated to be 0.75m.

4.1.2 A map displaying the range of peat depths across the Proposed Development is presented in Figure A1, Appendix A. Peat depths recorded were predominately within the range of <= 0.5 m (49.7 % of total surveyed points). In terms of spatial coverage, the steeper slopes at the southern end of the Proposed Development recorded the shallower peat depths. Within the surveyed area pockets of deeper peat within the range of 1.5 to greater than 3 m were identified within the north-eastern and central section of the Proposed Development.

4.1.3 In line with current guidance[1], peat is defined as an organic soil which contains 60% organic matter and exceeds 0.5 in thickness.

4.1.4 The peat has been extensively modified by a network of artificial drainage. This artificial drainage network will have lowered the water table in the vicinity of drainage ditches, this can result in a loss of peat forming conditions and continuous subsidence.

4.2 *Peat Morphology*

4.2.1 A 25mm hand shear vane was used to measure undrained shear strength of the in-situ peat deposits. Vane testing was undertaken at Turbines T03, T04, T11, T13 and T15 where soil conditions were of sufficient depth.

4.2.2 It is highlighted that the shear vane has a small surface area compared to the scale of the soil structure within the peat. The scale effect can lead to an underestimation of peat strength. The hand shear vane therefore only provides a preliminary and conservative estimate of peak and re-moulded un-drained shear strength.

4.2.3 Where a significant increase in the un-drained shear strength was recorded at the basal contact of the peat, it is inferred from peat cores derived from the same location that the highest un-drained shear strength values represent the glacial till interface. This material comprises stiff grey sandy clay soil.

4.2.4 The un-drained shear strength (Cu) ranges from **13kPa to 37kPa** with a mean value of **20kPa**. The mean re-moulded shear strength is recorded at **13kPa**. Indications are the peat has very low to low shear strength with the lowest values were recorded at Turbine T13 and T15.

4.2.5 The degree of humification has been recorded at locations where deep peat was core sampled (T03, T04, T11, T13 and T15). The peat has been characterised according to the Von Post Classification (Von Post & Granland, 1926). Table 4.2 below presents the classifications.

[1] The Scottish Government (2017), Guidance on Developments on Peatland

Table 4.2 – Von Post Classification of Peat Cores

Turbine ID	Peat Depth	Von Post Class	Description
75m SW T03	2.70	H4-H6	Very soft to soft brown plastic pseudo-fibrous to amorphous PEAT.
T04	0.50	H3 & H7	Very soft brown spongey fibrous PEAT. (H3) Soft dark brown plastic pseudo-fibrous PEAT. (H7)
200m NW T11	2.70	H5-H6	Very soft to soft dark brown plastic pseudo-fibrous PEAT.
T13	0.65	H4 & H7	Soft dark brown plastic pseudo-fibrous PEAT. (H4) Very soft dark brown plastic pseudo-fibrous PEAT. (H7)
250m SE T15	0.70	H6	Very soft brown plastic pseudo-fibrous PEAT

4.2.6 The peat encountered across the development is typically soft to very soft and fibrous in the acrotelmic surface layer. In the deeper deposits, characteristically humification increases with depth at the catotelmic layer.

Figure 4.2.1 – Typical peat core taken from 75 Southwest of Turbine T03.

4.3 Risk Assessment Method

4.3.1 Natural Power has undertaken the assessment following the principles of the Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments (PLHRAG) (Scottish Executive 2017). Updated as a second edition in April 2017, this guide provides best practice methods which should be applied to identify, mitigate and manage peat slide hazard and associated risks in respect of consent application for electricity generation projects in the UK.

4.3.2 This guidance clearly acknowledges risk assessment as an iterative process and as such this assessment should be updated throughout the development process and as more information becomes available particularly as pre-construction phases are reached.

4.4 Causes of Peat Slide

4.4.1 Discussions of the factors which contribute to peat failure have been presented in Table 4.4.

Table 4.4 – Contributory Factors to Peat Instability

Factor	Discussion
Groundwater Infiltration	There are two processes which may facilitate groundwater infiltration: • Periods of drying, resulting in cracking of the peat surface; and • Slope creep resulting in additional tension cracks. Drying out of the upper peat, particularly in areas of thinner peat, is likely to result in the development of near-surface cracks which could facilitate ingress of water into the peat.
Surface Loading	Any mechanisms which increase the surface load on a peat deposit can increase the likelihood of failure. This can include surface water ponding and surcharge loading, for example; construction earthworks.
Vegetation Loss	Loss of vegetation can have a negative impact, making the peat susceptible to weathering, increasing rates of infiltration and a loss of strength. In particular muirburn which accelerates loss of established vegetation and may in turn trigger accelerated rates of soil erosion.
Soil Weathering/ Erosion	Weathering can weaken in-situ peat materials and destabilise a slope system. This may be in the form of weathering of peat or underlying mineral soils which could reduce shear strength at the peat/ mineral soil interface. Vertical cracking and slope creep may slowly break down peat structure over long periods of time. This can develop into peat 'hagging', which is a strong indication that natural weathering processes are ongoing. Peat hags expose the peat to increased weathering rates and may provide preferential surface water flow pathways. There was minimal record of peat hagging across the development with shallow soil erosion more dominant.
Precipitation	The likely failure mechanism following a period of heavy rainfall is linked to the infiltration of surface water. There is a resulting build-up of pore water pressures within the soils and therefore reduced effective shear strength. This may be focussed within the peat deposit or at the interface between the peat and underlying mineral soil. Secondary effects may include swelling of the peat deposit and increased loading due to surface water ponding. Snow and subsequent melt can have a similar effect.
Slope Morphology	There are three main effects arising from slope morphology: Firstly, the concentration of tensile stress at the apex of a convex slope predisposes the slope for failure initiation at that point. In a convex slope the material lower down supports the material above which is held in compression. A concave slope has the opposite characteristics as material at the base maintains the apex in tension. Secondly, at the point of maximum slope convexity, because of favourable down-slope drainage conditions, a body of relatively well-drained and relatively strong peat material develops. This body of peat acts as a barrier providing containment for growth of peat upslope. This relatively well drained body of peat can subsequently fail due to a build-up of lateral pressure on the upslope face. In this scenario the slope is not supported from below so eventually the lateral pressures exceed the forces resisting sliding. The apex or point of convexity is also a likely initiation point for slope failure due to the slope tension being concentrated at this point. Thirdly a failure mechanism is postulated where springs are present in locations immediately down-slope of the relatively well drained peat body. Under these circumstances high pore pressure gradients within the peat can lead to hydraulic failure and undermining of the relatively well drained peat body resulting in a breach and loss of lateral support to peat upslope. Evolving slope morphology can be

	significant; for example, in the case of slope undercutting by water erosion. Any mechanism by which mass is removed from a slope toe or deposited on a slope crest will contribute to instability.
Peat Depth & Slope Angle	Peat slides correspond in appearance and mechanism to translational landslides and tend to occur in shallow peat (up to 2.0m) on slopes between (5° – 15°). A great majority of recorded peat landslides in Scotland, England & Wales are of the peat slide type. MacCulloch, (2005) highlights that a slope angle of 20° appears to be the limiting gradient for the formation of deep peat. Therefore, the risk assessment has assigned slope angles >20° to be an unlikely contributory factor to failure. Slope angle indicators and corresponding probability factors have been similarly adapted from MacCulloch, (2005). Boylan et al, (2008) indicates that most peat failures occur on slope angles between 4° and 8°. It is postulated that this may correspond to the slope angles that allow a significant amount of peat to develop that over time becomes potentially unstable. Thus, for this assessment <3degrees has been assigned a low risk.
Hydrology	Natural watercourses and artificial drainage measures have often been identified as a contributory factor of peat failure. Preferential drainage paths may allow the migration of water to a failure plane therefore triggering failure when groundwater pressures become elevated. Within a peat mass, sub surface peat pipes can enable flow into a failure plane and facilitate internal erosion of slopes. It is also noted that in some instances, agricultural works can lead to the disturbance of existing drainage networks and cause failures. Multiple drainage ditch networks are present across the development as a result of the managed estate practices.
Existing / Relict Failures	The presence of relict failures and any indication of previous instability are often important, indicating that site conditions exist that are conducive to peat failure. Relict peat slides may be dormant over long periods and be re-activated by any number of the contributory factors discussed in this table. None were noted during the site survey.
Anthropogenic Effects	Human impact on peat environments can include a range of affects associated with wind farm construction. Activities such as drainage, access tracks across peat, peat cutting, and slope loading are all examples. Rapid ground acceleration is one such example where shear stress may be increased by trafficking or mechanical vibrations.

4.5 *Peat Failure Definition*

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

4.5.2 The potential for peat failure at the development is examined with respect to the activities envisaged during construction and operation of the wind farm. There are several classification systems for the mass movement of peat that were drawn together by PLHRAG, (2017).

4.5.3 Hutchinson (1988) defines the two dominant failure mechanisms namely peat flows and peat slides.

- **Peat Flows & Bog Bursts:** are debris flows involving large quantities of water and peat debris. These flow down slope using pre-existing channels and are usually associated with raised bog conditions.
- **Peat Slides:** comprise intact masses of peat moving bodily down slope over comparatively short distances. A slide which intersects an existing surface water channel may evolve into a debris flow and therefore travel further down-slope. Slides are historically more common within blanket bog settings.

4.5.4 Due to coverage of peat at the Proposed Development and proximity of surface watercourses / head waters, peat slides are considered the dominant mode of potential peat failure.

4.6 *Geotechnical Principles*

4.6.1 The main geotechnical parameters that influence peat stability are:

- Shear strength of peat;
- Peat depth;
- Pore water pressure (PWP);
- Loading conditions.

4.6.2 The stability of any slope is defined by the relationship between resisting and destabilising forces. In the case of a simplified 'infinite' slope model with a translational failure mode: sliding is resisted by the shear strength of the basal failure plane and the element of self-weight acting normal to the failure plane. The stability assessments within this study consider an undrained 'total stress' scenario when the internal angle of friction (ϕ') = zero.

4.6.3 An undrained peat deposit may be destabilised by; mass acting down the slope, angle of the basal failure plane and any additional loading events. The ratio between these forces is the Factor of Safety (FoS). When the FoS is equal to unity (1) the slope is in a state of 'limiting equilibrium' and is sensitive to small changes in the contributory factors leading to peat failure.

4.6.4 The infinite slope model as defined in Skempton et al. (1957)[2] has been adapted to determine the FoS of a peat slope. A modified approach has been used; assuming a minimum FoS (Typically 1.3 after, BS6031: 2009).

4.6.5 The infinite slope analysis is based on a translational slide. This analysis adopts total stress (undrained) conditions in the peat. This state applies to short-term conditions that occur during construction and for a time following construction until construction induced pore water pressures (PWP) dissipate. (PWP requires time to dissipate as the hydraulic conductivity can be low in peat deposits). The following assumptions were used in the analysis of peat deposits across the proposed wind farm development:

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

4.6.6 The analysis method for a planar translational peat slide along an infinite slope was for calculated using the following equation in total stress terms highlighted by MacCulloch, (2005) and originally reported by Barnes, (2000):

$$F = Cu / (\gamma * z * \sin\beta * \cos\beta)$$

4.6.7 Where:

F = Factor of Safety (FoS)

Cu = Undrained shear strength of the peat (kPa)

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

γ = Bulk unit weight of saturated peat (kN/m^3)

z = Peat depth in the direction of normal stress

β = Slope angle to the horizontal and hence assumed angle of sliding plane (degrees)

4.6.8 Undrained shear strength values (Cu) are used throughout this assessment. Effective strength values are not applicable for the case of rapid loading of the peat during short term construction phase of works hence the formula cited above, has been adopted. Figure A8, Appendix A, maps out the calculated FoS for the development when applying a conservative 13kPa as the undrained shear strength for peat soils. This mapping includes the predicted FoS where a 20kPa surcharge is applied to the surface.

4.7 *Risk Assessment Method*

4.7.1 A semi quantitative risk assessment has been used to determine the risk of peat failure. The methodology is defined in PLHRAG, (2017) and has been augmented with methods set out by Clayton (2001). Given the remote location of the site, and proximity from major trunk roads or residences, environmental receptors have been the primary focus of the assessment. Risk factors are summarised on Table 4.7.1.

4.7.2 The assessment uses the infinite slope stability analysis and presents analysis of factor of safety (FoS) across the development. The calculated FoS, is complemented with an assessment of the slope angle, peat depth and key geomorphological features. A peat slide risk map has been produced using GIS computation of these factors. (Figure A7, Appendix A). The risk map is a useful tool for screening wide areas of the site, additional engineering judgement has been applied according to discrete conditions within Table 4.9 of this report.

Table 4.7.1 – Peat Slide Risk Factors

Contributory Factor	Comment	Criteria	Probability	Scale
Peat Depth* **(A)**	Peat slides tend to occur in shallow peat (up to 2.0m). The majority of recorded peat landslides in Scotland, England & Wales are of the peat slide type.	0 – 0.5m >3.0m 0.5 – 1.0m 2.0 – 3.0m 1.0 – 2.0m	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
Slope Angle* **(B)**	It has been acknowledged that peat slide tends to occur in shallow peat (up to 2.0m) on slopes between 5^o and 15^o. Slopes above 20^o tend to be devoid of peat or only host a thin veneer deposit.	0 – 3^o >20^o >3 – 9^o 16 – 20^o 10 – 15^o	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
FoS **(C)**	Values are from Infinite slope model using Cu characteristic value of 13kPa derived from hand shear vane in-situ testing. Slope angle and peat depth also input to this factor.	≥ 1.3 1.29-1.20 1.10-1.19 1.00-1.09 <1.0	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
Cracking **(D)**	Visual assessment undertaken in the field during detailed probing survey and covers the same extends of this survey. Field workers examined for evidence of any major crack networks which may allow surface water to penetrate the peat mass. Reticulate cracking was not investigated as this normally requires intrusive ground investigation to remove the surface fibrous layer.	None Few Frequent Many Continuous	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
Groundwater **(E)**	Challenging to evaluate without very detailed mapping and/or intrusive data. Look for entry / exit points. Evidence of surface hollows, collapse features at surface reflecting evidence of sub-surface peat pipe network, audible indicators including the sound of sub-surface running ground water surrounding proposed infrastructure locations	None Few Frequent Many Continuous	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
Surface *Hydrology **(F)**	Ranging from wet flushes to running burns to hags. Must be evaluated in conjunction with the season and weather preceding the site visit. Artificial drains (grips) have also been identified across the site. Their presence is generally linked to historical peat cutting sites which are factored into the risk assessment.	None Few Frequent Many Continuous	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
Previous Instability **(G)**	Visual survey, scale and age are important as small to medium relict failures may be easy to detect but very large ones may require remote imaging. Recent failures should be obvious due to the scar left.	None Few Frequent Many Continuous	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
Land Management **(H)**	Anthropogenic influences: removal of vegetation can be associated with de-stabilising peat deposits. This can occur as a result to surface disturbance and remoulding of peat through excavation, vehicle movements and loading. Changes in land use activities may also be associated with changes in drainage conditions. Criteria based on evidence of disturbance of peat deposit, i.e. broken surface, scarring or disrupted hydrology.	None Few Frequent Many Continuous	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5

**Denotes where used in GIS risk mapping exercise (Figure A7, Appendix A)*

4.7.3 Environmental Impact Zones are based on proximity buffer zones applied to the main watercourses within the Proposed Development. Watercourses have been determined to be a primary sensitive receptor to a peat failure event. Table 4.7.2 denotes the potential impact scales to the environment.

Table 4.7.2 – Watercourse Impact Buffers

Criteria	Potential Impact	Scale
Proposed access road/turbine within 50m of watercourse	High	4
Proposed access road/turbine within 50-100m of watercourse	Medium	3
Proposed access road/turbine within 100-150m of watercourse	Low	2
Proposed access road/turbine greater than 150m from watercourse	Negligible	1

4.7.4 A qualitative risk ranking is calculated from the probability of occurrence for the main contributory factors (where >1) multiplied by the highest magnitude impact scale. Table 4.7.3 identifies the risk ranking based on concepts of PLHRAG, (2017).

Table 4.7.3 – Risk Rank Category

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

4.8 Numerical Stability Analysis

4.8.1 Slope stability was assessed at each turbine location using slope angle measurements, peat depth, and undrained shear strength measured using an in-situ hand shear vane.

4.8.2 The current baseline peat condition is assumed to be in a state of equilibrium at the infrastructure locations. Surcharge loading has been considered to demonstrate the effect of construction works proposed as part of the Proposed Development.

4.8.3 The FoS against peat sliding has been calculated for all positions where peat depth has been recorded. FoS across the development is calculated using the relationship set out in Section 4.6 and using GIS analysis tools to apply the stability equation. For the GIS analysis slope geometry has been established from 5m resolution digital terrain model and characteristic undrained shear strength of 13kPa to ensure the model is conservative. In addition, a 20kPa surface surcharge load has been modelled. Thus, the sensitivity of slopes to failure is assessed under construction conditions.

Stability Analysis Discussion

4.8.4 The numerical stability analysis indicates no potential for translational peat slide at proposed turbine and infrastructure locations under current equilibrium or modelled surcharge loading conditions.

4.8.5 In the absence of more detailed sub-surface data, the surface slope angle has been used as a reference to the likely slope surface angle at the base of the peat in the analysis. Further advanced in-situ test methods should be considered as part of a detailed site investigation phase usually carried out post-consent.

4.8.6 **Wind Turbines:** FoS values for the turbine locations, when allowing for a 20kPa surcharge load have been derived. The lowest FoS was calculated was 5.6 for proposed turbines T2, T5 and T11. The natural slope condition has been calculated to be stable and was observed to be so around the wind turbine locations during the field survey.

4.8.7 **Access tracks:** Where slope and peat conditions permit; access track will be constructed of a floating type to reduce impacts on peat. Areas of track with an elevated peat slide risk of are discussed in Table 4.11. The elevated risk is primarily attributed to close-proximity or crossing of watercourses, slope gradient and peat depth. These elements should be mitigated and managed through detailed engineering design incorporating watercourse protection measures, slope stabilisation and micro-siting of the routes. These would be fully defined as part of the construction environmental management plan and detailed civil infrastructure design. This report should therefore be reviewed as part of the pre-construction design phase.

4.8.8 Slope stability assessments will be carried out during design phase for site tracks, hardstands and other relevant structures ensuring the proposed design results are safe, stable and environmentally compliant. It is Natural Power’s view that, if during design phase structures are proposed (i.e. floating tracks) additional numerical stability assessment should be carried out by the appointed designer.

4.9 *Risk Assessment*

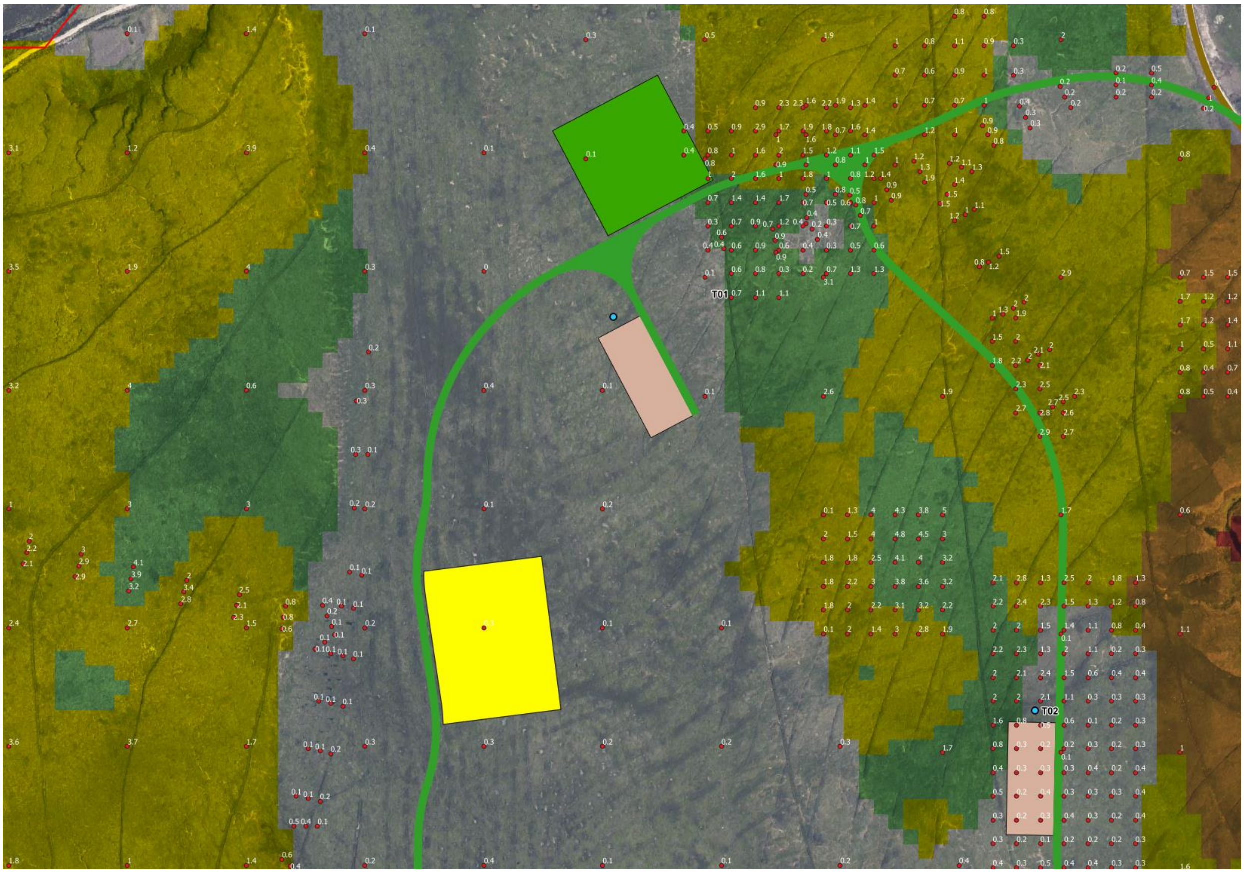
4.9.1 The potential environmental impact of a peat slide triggered by proposed wind farm construction is obtained from assessing the proximity to watercourses as the primary sensitive receptor within the development. The position of proposed infrastructure has also been considered by the risk assessment. The nearest habitations are Dunearn Lodge situated approximately 2.2km northeast of the development. The terrain is isolated from the surrounding higher ground and public infrastructure beyond.

4.9.2 Risk rankings for the proposed turbine positions situated on peat are presented in Table 4.9. Across each turbine the unmitigated risk scoring has been provided along with aerial photo information. Engineering judgement on the risk rating with applied control measures is also provided.

4.9.3 The risk ranking map is appended to this report (Figure A7, Appendix A). The risk map provides a representation of the risk zonation across the site and includes all infrastructure elements. The map is based on a development wide GIS analysis and should not be viewed in isolation without the narrative of this report. The Risk Mapping further does not show residual risk following implementation of control measures.

4.9.4 The indicative residual risk rating is provided assuming implementation of appropriate mitigation measures. Further detail of the risk assessment is highlighted within the preliminary geotechnical risk register presented in Table 4.13.

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		Risk Ranking Residual Risk
T01 Temporary Compound 1 Substation	1	**Peat Depth - Absent**	0	Negligible (No Peat
		Slope Angle (3-9°)	3	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management	2	

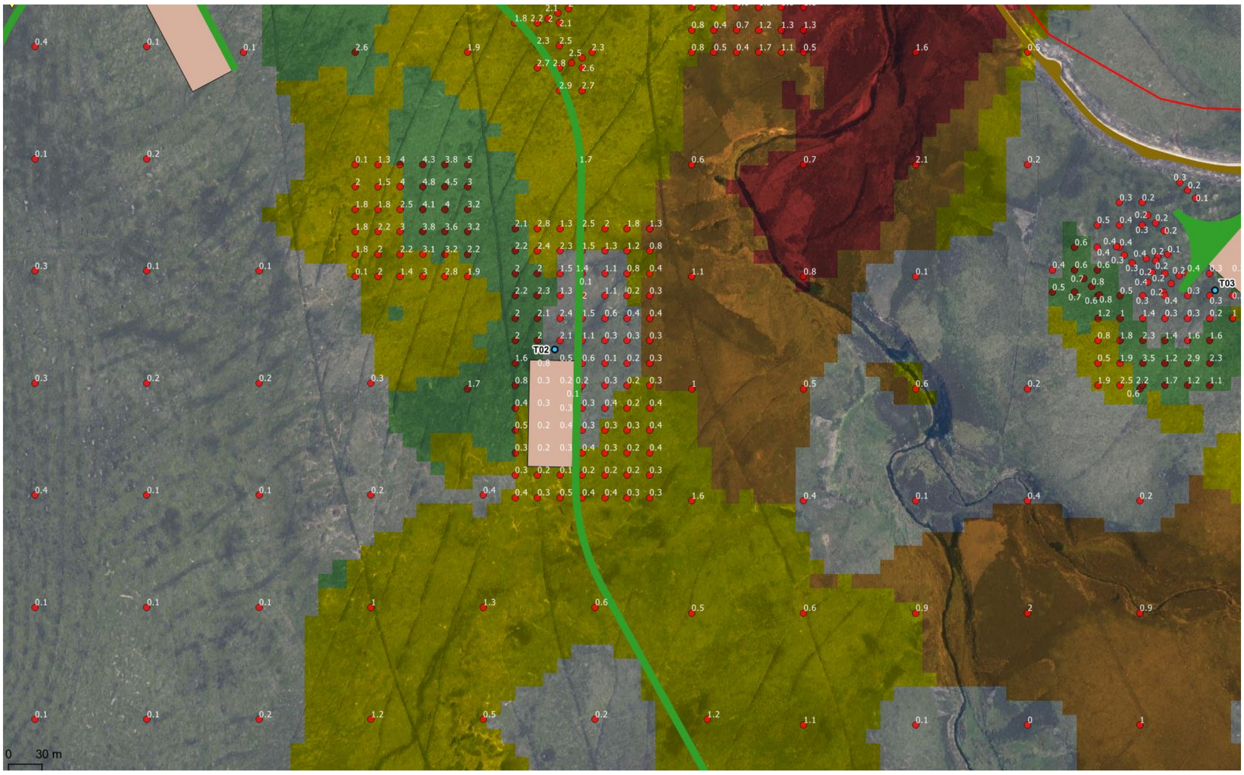


T01 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible as peat is absent at this location.
- Existing drainage ditches and hydrological regime should be maintained and prevented from blocking leading to increased power water pressures in surrounding peatland to northwest;

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		Risk Ranking Residual Risk
T02	1	Peat Depth (0.5m)	3	Low 6
		Slope Angle (3-9°)	3	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	Negligible
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

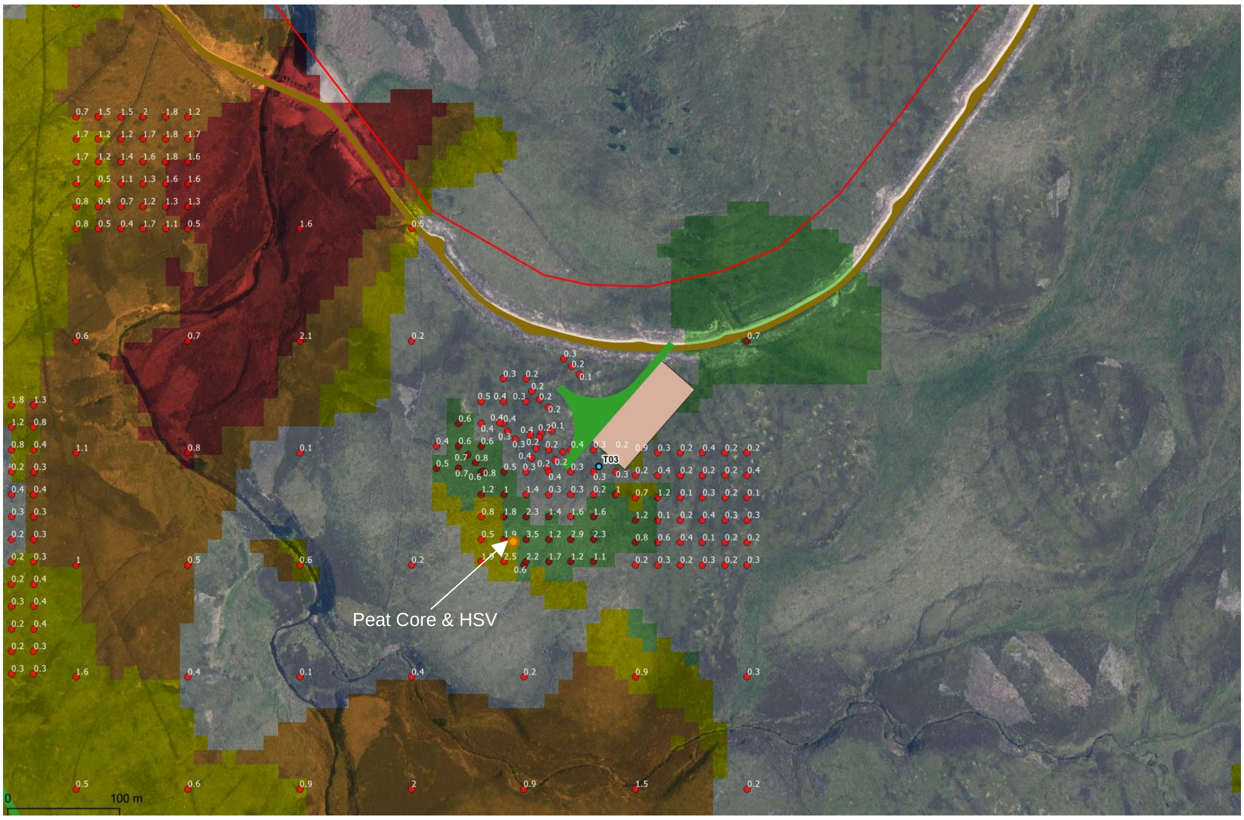


T02 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Turbine has been micro-sited onto shallowest peat deposits.
- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible through the use of low impact construction techniques and best practice methods for construction over peatland.
- No temporary storage or stockpile of earthworks material downslope to the north of the turbine position.

WTG ID	Impact Scale Environment & Infrastructure	Contributory Factors (Probability/Exposure)		Risk Ranking Residual Risk
T03	1	Peat Depth – Absent at Location	0	Negligible (No Peat
		Slope Angle (<3)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

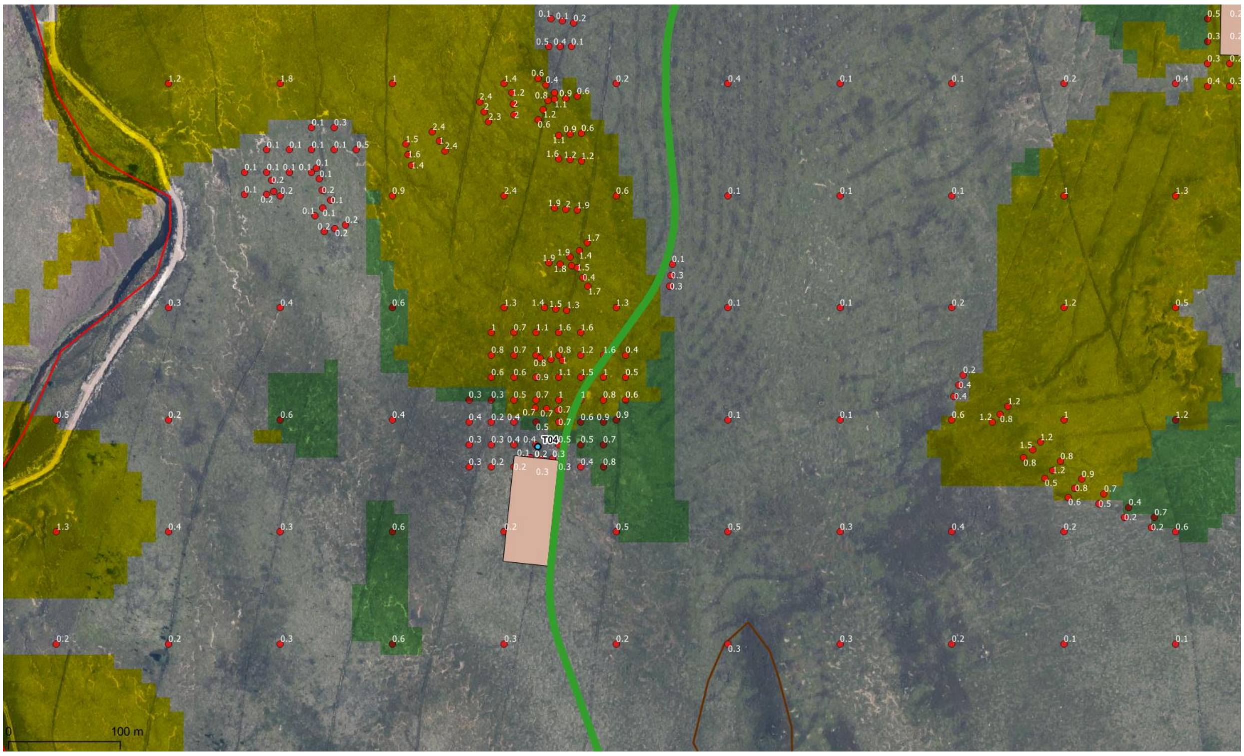


T03 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible as surveys found this area not to be peat land.
- Terrain angle is very shallow at this location.

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		Risk Ranking Residual Risk
T04	1	Peat Depth (0.3m)	1	(Negligible) 2
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	Negligible
		Hydrology	1	
		Previous Instability	1	
		Land Management	2	



T04 Location – Bing Aerial Imagery – 1:2,500 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible due to the thin peat soils present and very shallow terrain slope angle.

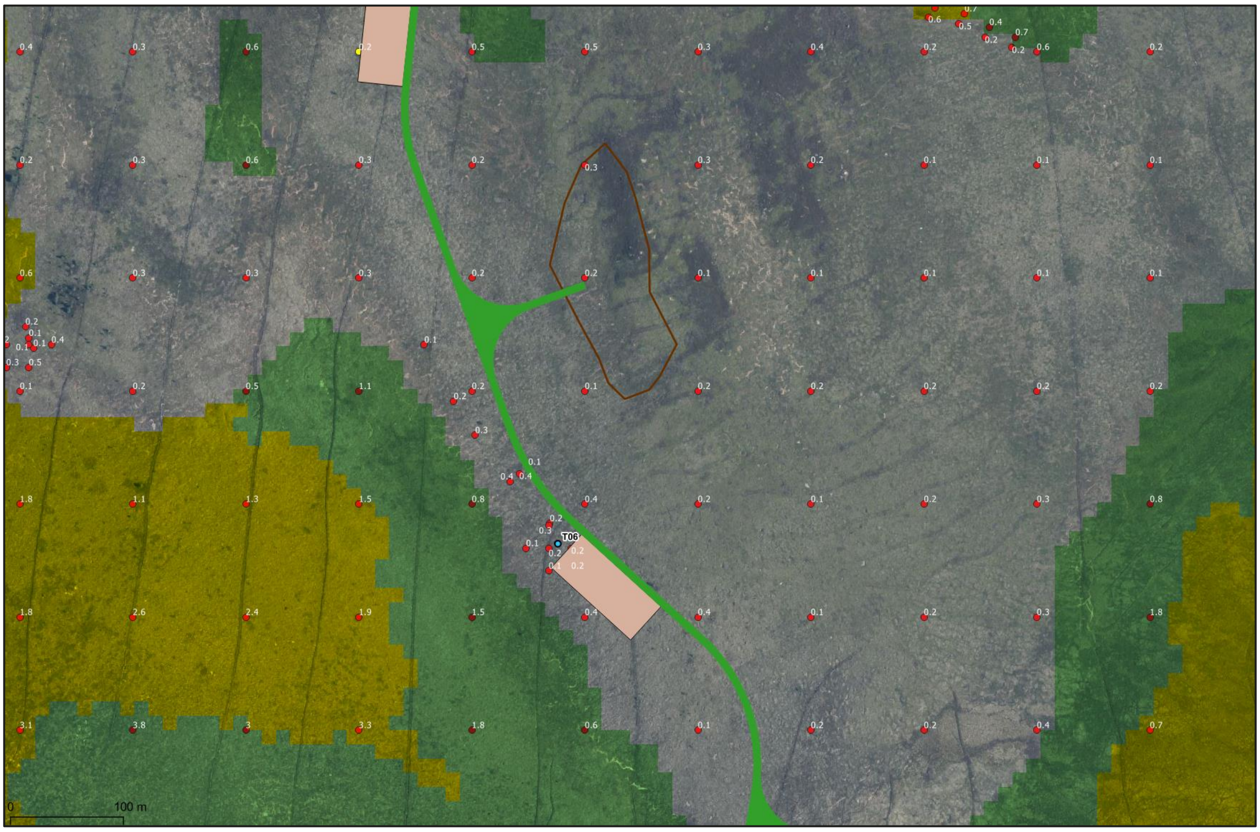
WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		<u>Risk Ranking</u> Residual Risk
T05	*2*	Peat Depth (Mean = 0-0.5m)	1	<u>(Low)</u> <u>6</u>
		Slope Angle (>3-9°)	3	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	Negligible
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

T05 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. Peat survey indicated limited peat at this location soil probes 0.2 – 0.5m.

WTG ID	Impact Scale Environment & Infrastructure	Contributory Factors (Probability/Exposure)		**Risk Ranking** Residual Risk
T06	1	Peat Depth Absent	0	**Negligible (No Peat)**
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	



T06 Location – Bing Aerial Imagery – 1:2500 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible as there are not conditions present at the turbine foundation which may give rise to a peat slide. Peat is absent and terrain slope angle is very shallow.

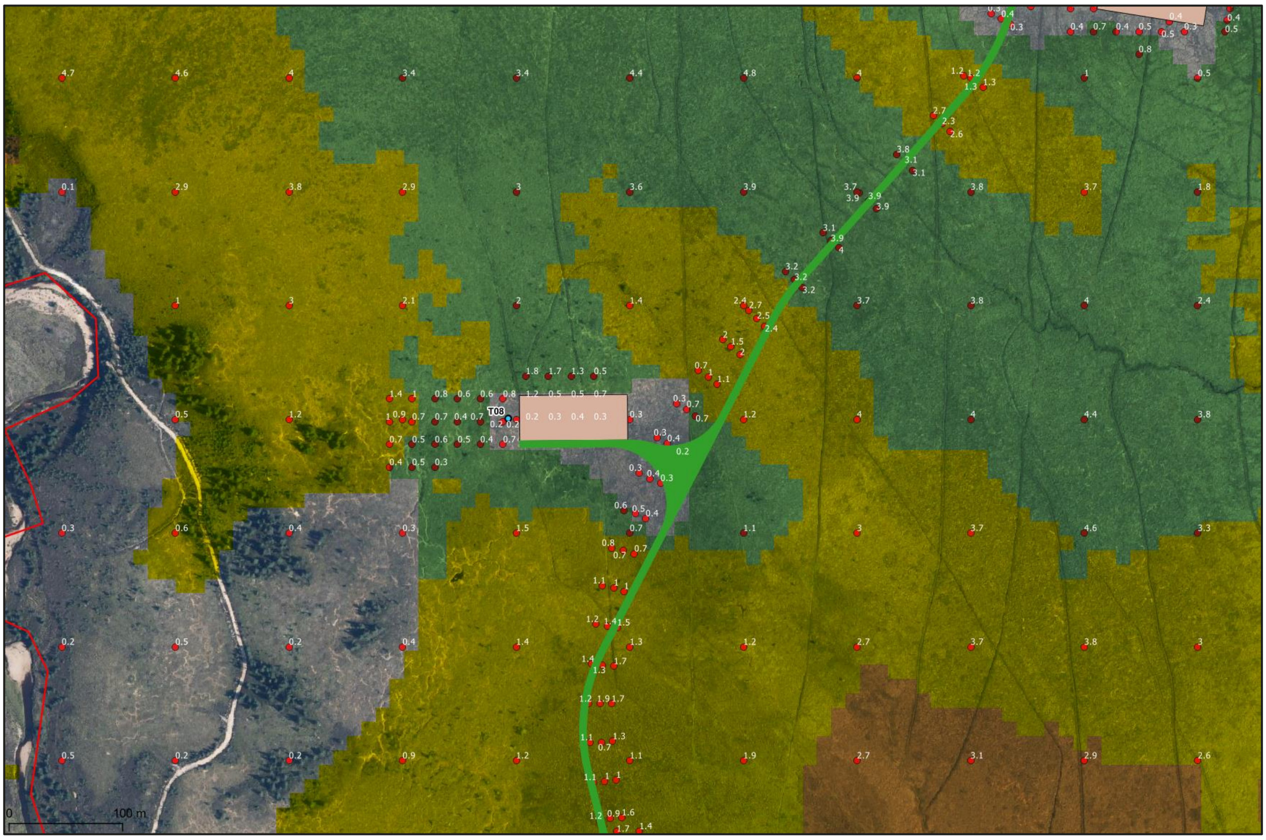
WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure		Risk Ranking Residual Risk
T07	1	Peat Depth (Mean = 0-0.5m)	1	(Negligible) 2
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	Negligible
		Hydrology	1	
		Previous Instability	1	
		Land Management	2	

T07 Location – Google Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should be negligible as shallow peat is confirmed and terrain slope angle is very shallow.

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		Risk Ranking Residual Risk
T08	1	Peat Depth (0.5)	3	(Negligible) 3
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	(Negligible)
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	



T08 Location – Google Aerial Imagery – 1:5,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible given the shallow peat and absence of sloping terrain at this location.

WTG ID	Impact Scale Environment & Infrastructure	Contributory Factors (Probability/Exposure)		Risk Ranking Residual Risk
T09	1	Peat Depth (Mean = 0.6m)	3	**Low** **5**
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	**Negligible**
		Hydrology	1	
		Previous Instability	1	
		Land Management	2	

T09 Location – Bing Aerial Imagery – 1:2,500 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should reduce to negligible given the shallow slope angle;
- There should be no temporary stockpiling of peat materials on peat deposits >0.5m deoth.
- There should be no stockpiling of peat or earthworks on the deep peat deposits towards the west of the turbine position.

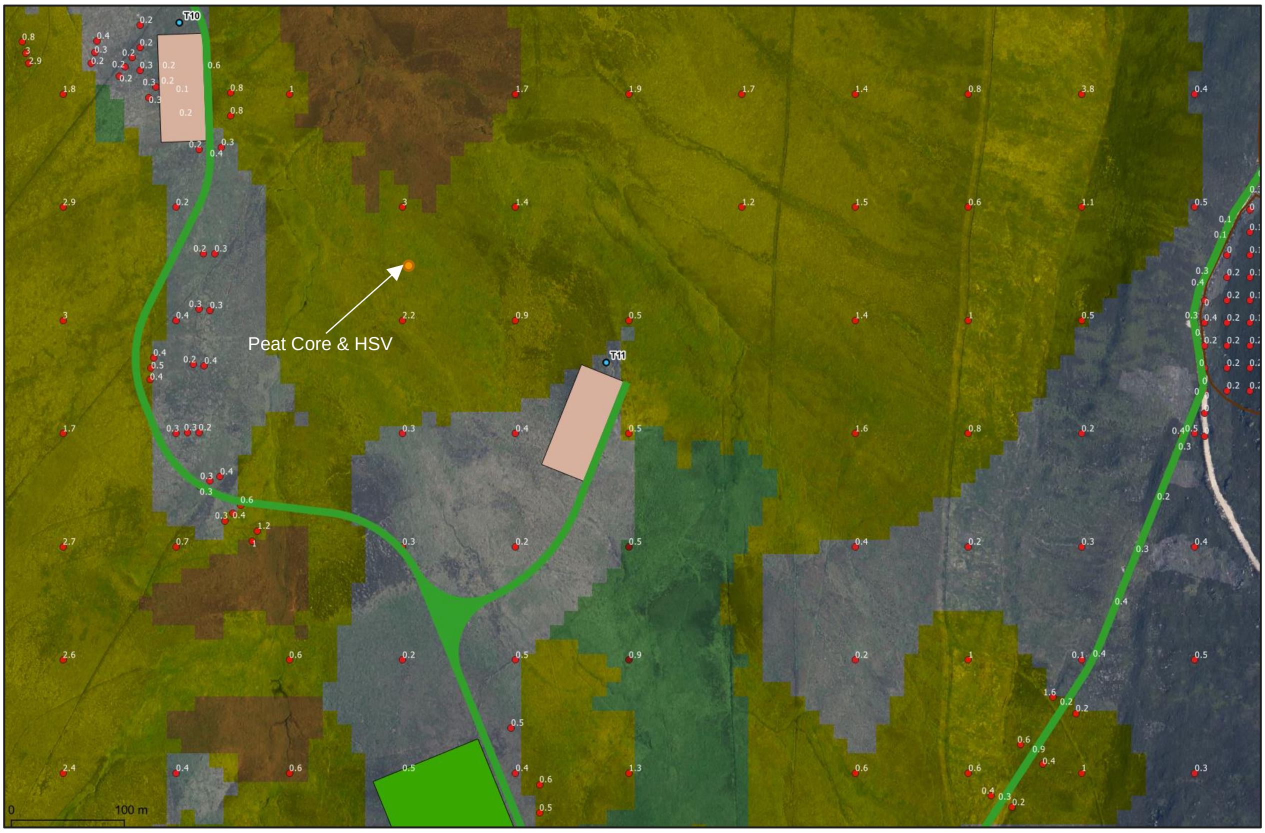
WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		Risk Ranking Residual Risk
T10	2-3	Peat Depth – Peat Absent	0	Negligible (No Peat)
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

T10 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible due to the absence of peat and shallow terrain slope angles.
- There should be no temporary stockpiling of peat materials west from the infrastructure where peat depths are indicated to increase.

WTG ID	Impact Scale Environment & Infrastructure	Contributory Factors (Probability/Exposure)		Risk Ranking Residual Risk
T11	2-3	Peat Depth (0.4-0.5m)	1	(Low) 9
		Slope Angle (3-9°)	3	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	Negligible
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

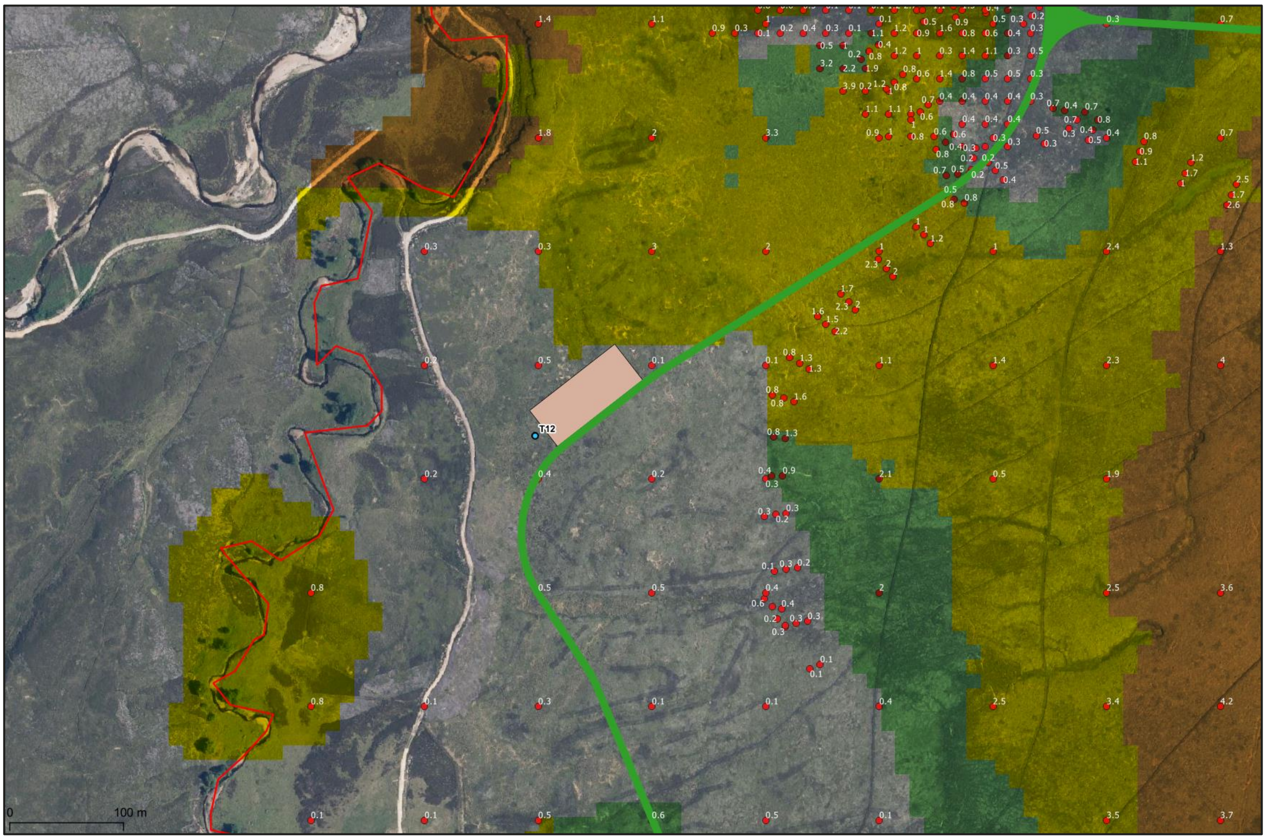


T11 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible through the use of low impact construction techniques and best practice methods for construction over peatland.

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		Risk Ranking Residual Risk
T12	2	Peat Depth Absent	0	Negligible 2
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	Negligible
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

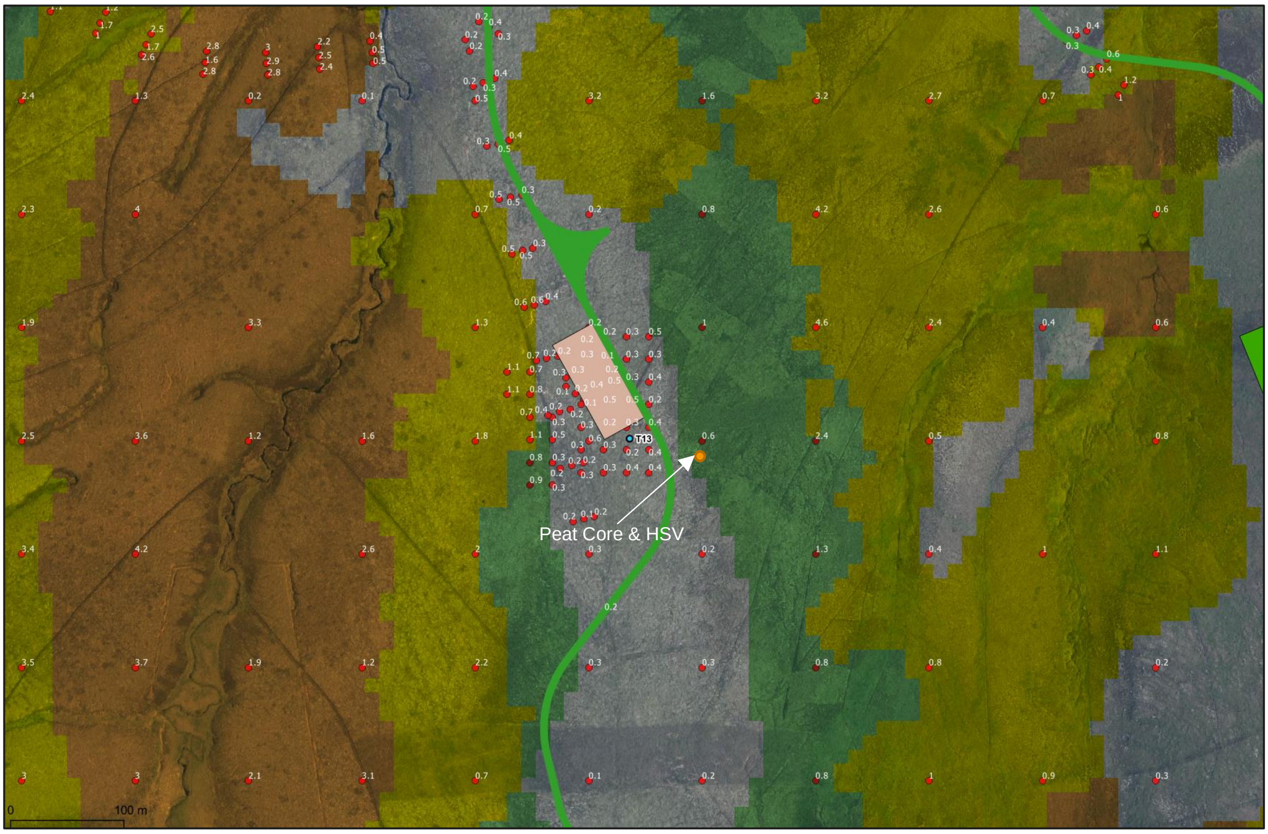


T12 Location – Bing Aerial Imagery – 1:2,500 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk is negligible due to the absence of peat at this infrastructure location.

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure		Risk Ranking Residual Risk
T13	1	Peat Depth (Absent)	0	Negligible (Peat Absent)
		Slope Angle (<3°)	1	
		FoS (6.03)	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management	2	



T13 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible peat is thin or absent at this location with no sloping terrain.

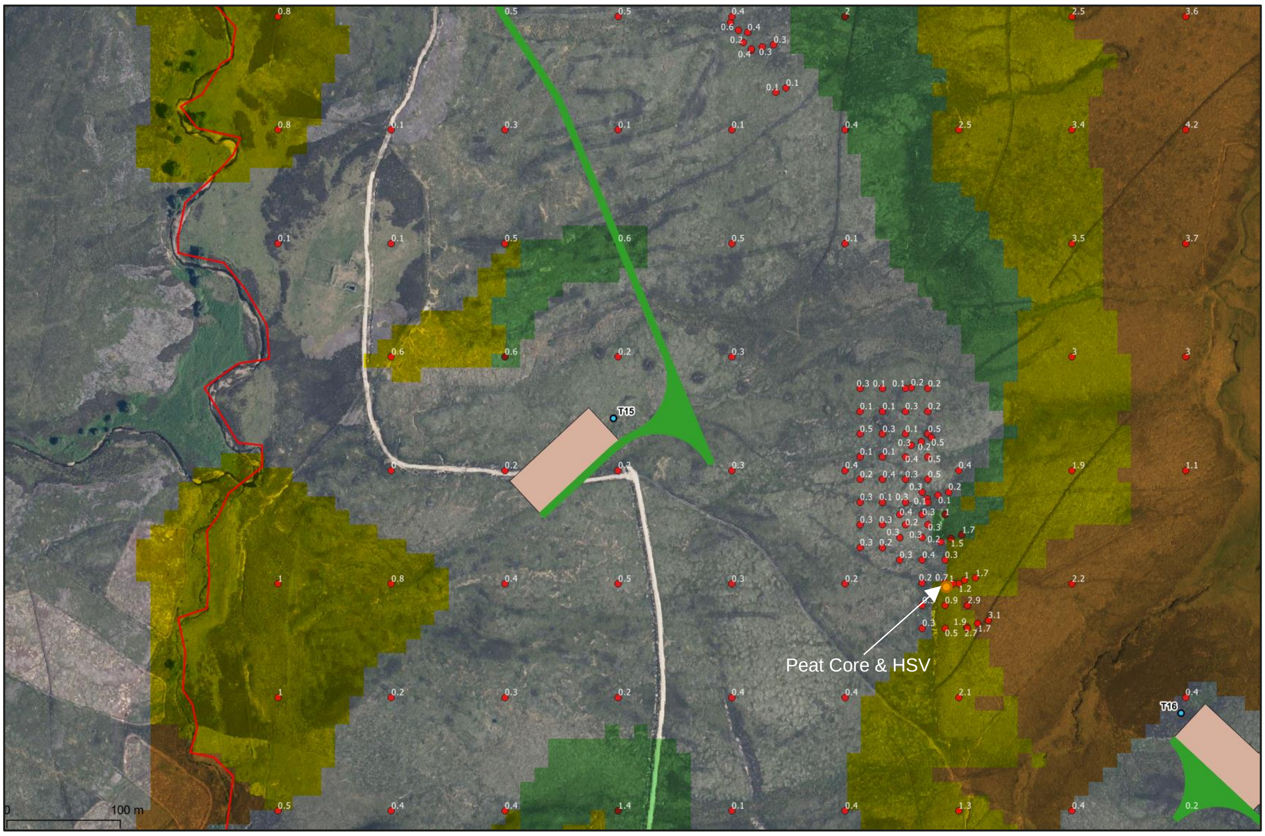
WTG ID	Impact Scale Environment & Infrastructure	Contributory Factors (Probability/Exposure		Risk Ranking Residual Risk
T14	1	Peat Depth (0.1-0.6)	3	Low 6
		Slope Angle (3-9°)	3	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	Negligible
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

T14 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain low through the use of low impact construction techniques and best practice methods for construction over peatland.

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure		Risk Ranking Residual Risk
T15	3	Peat Depth (Absent)	0	Negligible (Peat Absent)
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

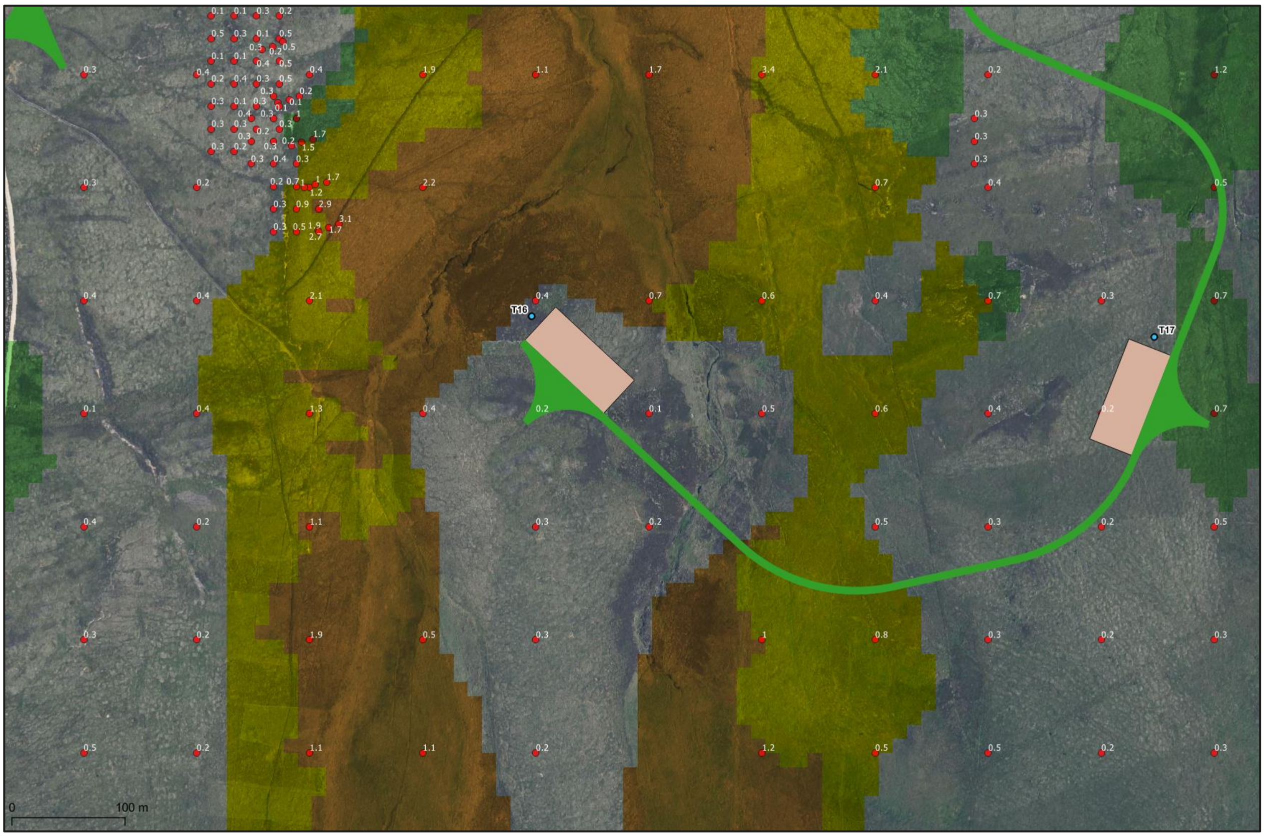


T15 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible the location contains no peat deposits and is of a low terrain slope angle. Recent cut access track construction through the area has had no impact on ground stability.

WTG ID	Impact Scale Environment & Infrastructure	Contributory Factors (Probability/Exposure)		Risk Ranking Residual Risk
T16	3	Peat Depth (Absent)	0	Negligible (Peat Absent)
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	



BPB Location – Bing Aerial Imagery – 1:2,500 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible as peat deposits are thin or absent and there is not sloping terrain.
- Risk increases towards the north with proximity to the tributary watercourse. Hence limits on construction area should be marked out.
- There shall be no temporary storage or stockpiling to the north where instability risk increases;

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		Risk Ranking Residual Risk
T17	3	Peat Depth (Absent)	0	Negligible (Absent Peat)
		Slope Angle (<3°)	1	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management	1	

Substation Location – Bing Aerial Imagery – 1:2,500 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible, there is no record of peat and terrain slope angles are very low.

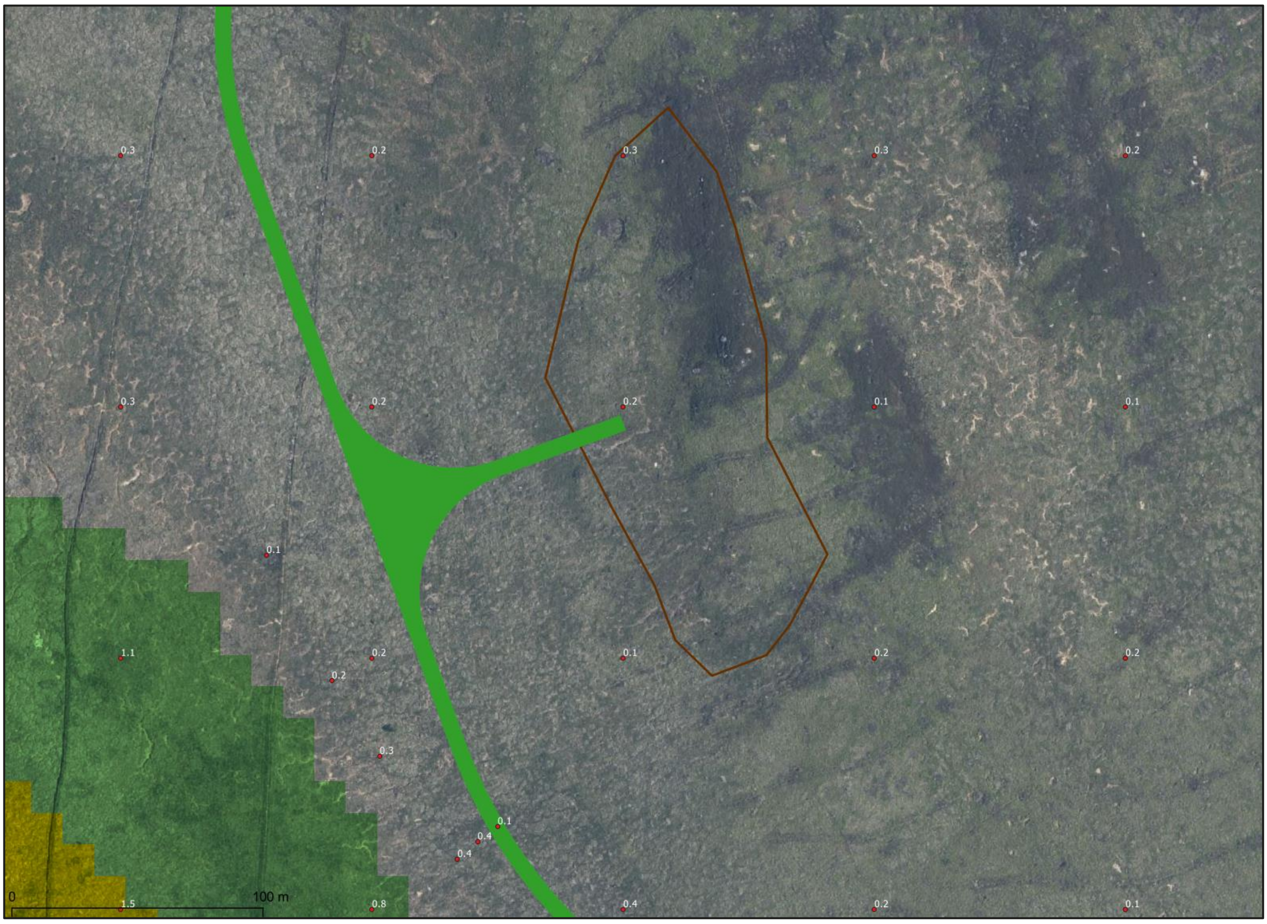
WTG ID	Impact Scale Environment & Infrastructure	Contributory Factors (Probability/Exposure		Risk Ranking Residual Risk
Temporary Compound 2	1-2	**Peat Depth (Peat Absent)**	0	Negligible (No Peat
		Slope Angle (3-9°)	3	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management (Muirburn Evident)	2	

Temporary Compound 2 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible as peat is absent at this location with probes indicating peat soils and mineral soil to a depth of 0.5m.
- A significant area of Muirburn is evident across the northern half of the compound location which may have the effect of accelerating weathering of soil and increasing the chances of release of suspended solids into drainage and watercourse systems. Thus, effective drainage design will be required to control run-off and ensure buffering prior to discharge.

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure)		Risk Ranking Residual Risk
Borrow Pit BP1	1	**Peat Depth (Peat Absent)**	0	**Negligible (No Peat**
		Slope Angle (3-9°)	3	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management (Muirburn Evident)	2	



BP1 Location – Bing Aerial Imagery – 1:1,500 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible as peat is absent at this location with probes indicating peat soils and mineral soil to a depth of 0.3m. Bare soil and evidence for shallow bedrock level was apparent at this location and hence its selection as a potential borrow pit search area.
- A significant area of Muirburn and soil erosion is evident across borrow pit BP1 which may have the effect of accelerating weathering of soil and increasing the chances of release of suspended solids into drainage and watercourse systems. Thus, effective drainage design will be required to control run-off and ensure buffering prior to discharge.

WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure		Risk Ranking Residual Risk
WTG ID	Impact Scale Environment & Infrastructure	Contributary Factors (Probability/Exposure		Risk Ranking Residual Risk
Borrow Pit BP2 & 3	**1**	**Peat Depth (Peat Absent)**	0	**Negligible (No Peat**
		Slope Angle (15-20°)	4	
		FoS	1	
		Peat cracking / Infiltration	1	
		Groundwater Flow	1	
		Hydrology	1	
		Previous Instability	1	
		Land Management (Muirburn Evident)	1	

BP2 & BP3 Location – Bing Aerial Imagery – 1:3,000 Scale

Location Specific Mitigation:

- Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible as peat is absent at this location with probes indicating peat soils and mineral soil to a depth of 0.3m. Bare soil and evidence for shallow bedrock level was apparent at this location with steep slope angles and hence its selection as a potential borrow pit search area.

4.10 *Risk Summary – Main Infrastructure*

4.10.1 Table 4.10 below summarises the risk ranking for each turbine location. The principal contributory factors are also stated.

Table 4.10 – Peat Slide Risk Ranking by Location

Turbine ID	Risk Rank	Residual Risk (With Controls)	Factors to Consider
T01	Negligible		No Peat Recorded at Location
T02	Low	Negligible	Turbine is micro-sited onto shallow peat
T03	Negligible		No Peat Recorded at Location
T04	Negligible		Turbine is micro-sited onto shallow peat
T05	Low	Negligible	Peat largely absent at location but proximity to edge of peat deposits and main watercourse
T06	Negligible		No Peat Recorded at Location
T07	Negligible		No slope system at this location
T08	Negligible		No slope system at this location
T09	Low	Negligible	Mean peat depth 0.6m very low slope angle
T10	Negligible		No Peat Recorded at Location
T11	Low	Negligible	No slope system at this location
T12	Negligible		No Peat Recorded at Location
T13	Negligible		No Peat Recorded at Location
T14	Low	Negligible	Mean peat depth 0.6m with increased slope angle
T15	Negligible		No Peat Recorded at Location
T16	Negligible		No Peat Recorded at Location
T17	Negligible		No Peat Recorded at Location
Temporary Compounds	Negligible		No Peat Recorded at Location
BP1	Negligible		No Peat Recorded at Location
BP2 & 3	Negligible		No Peat Recorded at Location

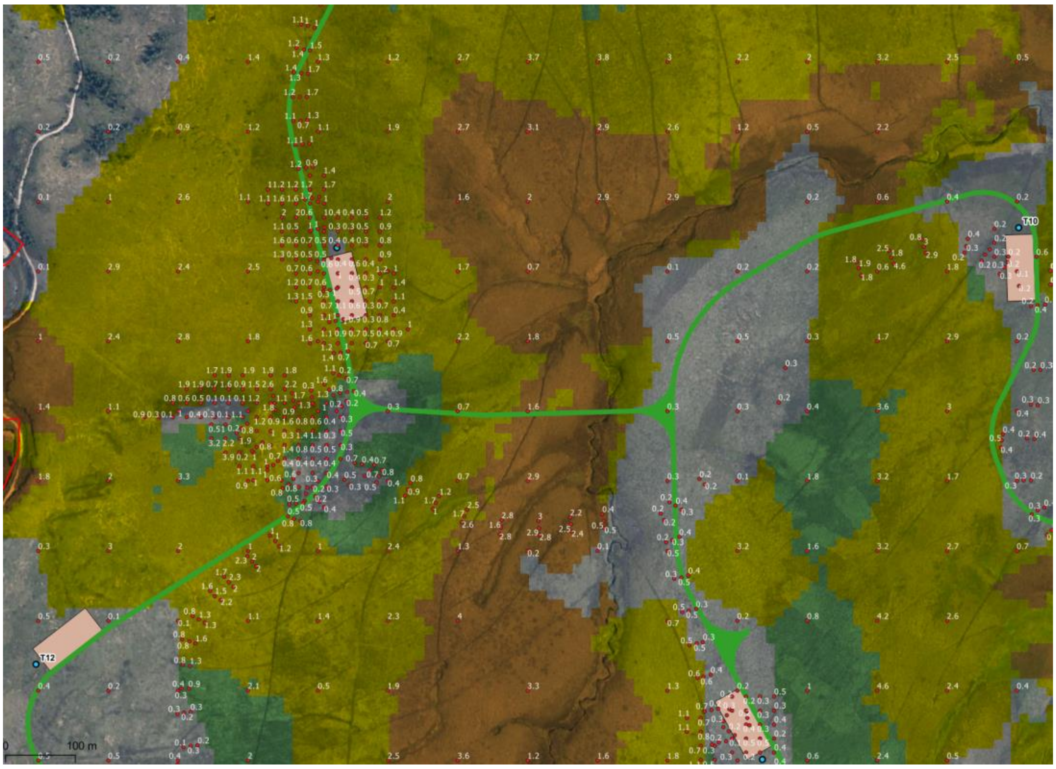
4.10.2 The risk assessment reflects the probability of peat material entering a main watercourse and being entrained to an offsite receptor without any mitigation. The assessment also considers potential for peat slides to affect existing infrastructure. This however has not factored due to the remote position of infrastructure and absence of peat deposits. Areas close to watercourses are therefore the focus of mitigation measures set out within the geotechnical risk register. Discussion on potential run-out of peat slide/failure events is provided in Section 4.12.

4.11 *Risk Summary – Access Infrastructure*

4.11.1 The proposed access track configuration has been reviewed. The highest risk areas would be where track alignments cross the watercourses and are coincident with slope systems and moderate peat depths. The areas of unmitigated elevated risk can be seen in Figure A7, Appendix A.

4.11.2 Table 4.11 below highlights track sections which indicate elevated risk of peat instability and therefore will require targeted mitigation to ensure peat slides can be prevented and risk reduced to the low or negligible category.

Track Element
T09 Link Track - Medium



Contributors to elevated peat slide risk:

- Crossing of main watercourse
- Peat depth – up to 1.6m west of water crossing
- Slope angle increases in immediate vicinity of watercourse otherwise low angle (<3degrees)

Specific Mitigation:

The following mitigation is required along this track section in order to reduce the risk to low:

Cross track drainage which prevents any ponding or build-up of groundwater pressure within the peat upslope or beneath the access infrastructure. Where possible existing drainage systems should be utilised and maintained – note artificial drains are present;

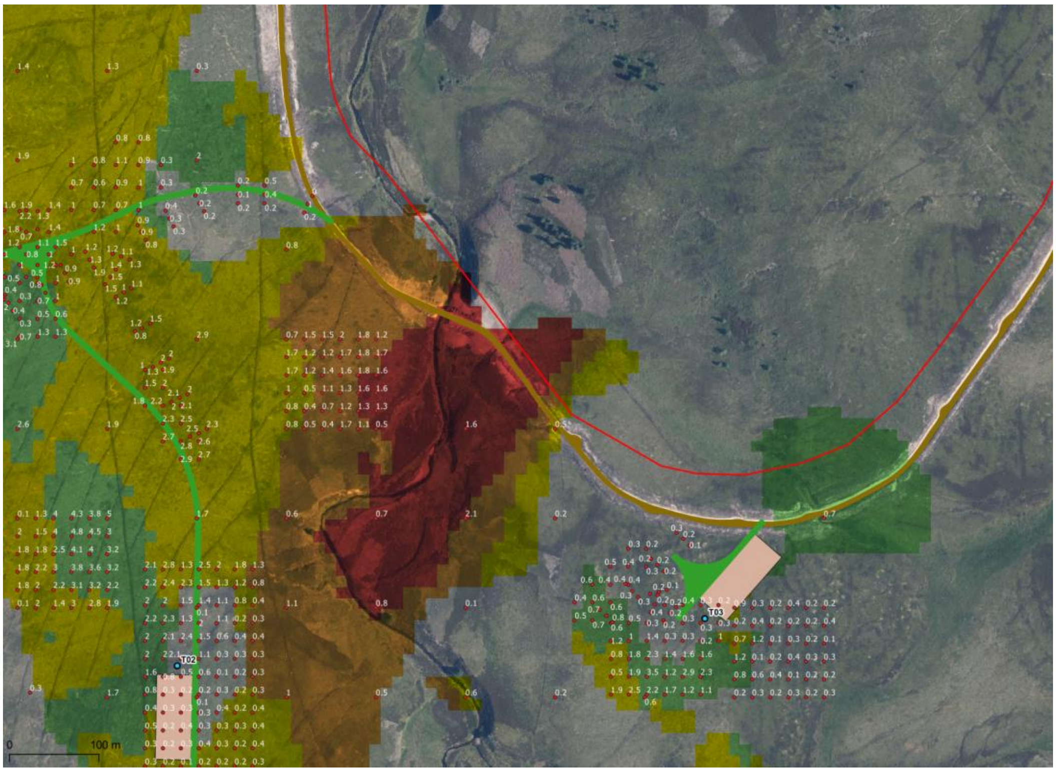
No stockpiling or surcharging of the peatland along this specific access track section;

Where detail design proves floating access, track is safe to use, this should be the preferred method of track construction to reduce the impact on peatland by avoiding excavation.

A system of ongoing monitoring throughout the construction phase should be in effect to monitor any movement in the peat. A rapid reaction strategy should be developed to ensure measures can be deployed to protect the watercourse in the event of any movement. This may include installation of downslope retaining systems to prevent peat material entering the watercourse.

Track Element

Upgrade Track to T03 - Low



Contributors to elevated peat slide risk:

- Crossing of main watercourse
- Peat depth elevated to the south of potential construction works
- Slope angle increases in immediate vicinity of watercourse

Specific Mitigation:

The following mitigation is required along this track section in order to reduce the risk to low:

Minimise upgrade construction works and where possible utilise existing infrastructure where suitable;

No stockpiling or surcharging of the peatland to the south of this specific access track section;

A system of ongoing monitoring throughout the construction phase should be in effect to monitor any movement in the peat. A rapid reaction strategy should be development to ensure measures can be deployed to protect the watercourse in the event of any movement.

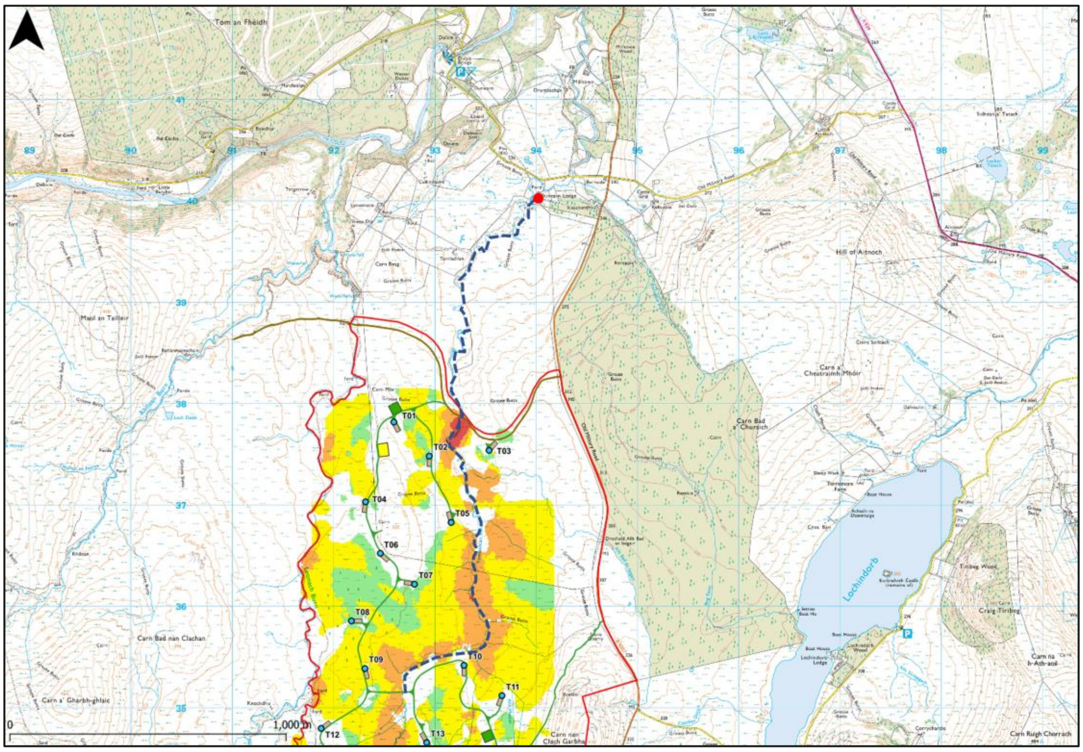
4.12 *Peat Slide Run-Out*

4.12.1 The assessment considers environmental receptors (main watercourses) to be the primary focus of the risk assessment. Minor or ephemeral watercourses have been assessed not to be primary receptors or unlikely to transmit peat slide material to offsite receptors, these have been excluded from the assessment.

4.12.2 The determination has been that entrained peat flows would primarily be channelled along watercourses downslope of proposed infrastructure. As run-out pathways are generally in excess of 2km before a larger watercourse or road infrastructure is reached it is postulated that surface water pollution would be the primary hazard rather than mass movement and destruction or severing of existing infrastructure through peat landslide.

4.12.3 The risk assessment therefore has relied on the mapping of watercourses within the development to establish impact scales (Figure A4, Appendix A). Figure 4.12 below traces the run-out course of potential peat slide event which may enter a watercourse on site and be entrained to an offsite receptor.

Figure 4.12 – Peat Slide / Debris Flow Run – Out Pathway



4.12.4 The habitation at Dunearn Lodge approximately 2.2km north of the site boundary has been considered. Given the significant distance and low risk of the planned infrastructure from peat slide with applied control measures; there is considered to be a low to negligible risk to this receptor downstream from the development.

4.12.5 The risk of run out and significant damage to the wider hydrological environmental is deemed low, providing the relevant control measures outlined in his report are implemented.

4.12.6 Terrain angles are not generally within the range which would lead to a large scale peat slide (<3 degrees).

4.13 *Preliminary Risk Register*

4.13.1 A preliminary geotechnical risk register is presented in Table 4.13 below. Key Control measures for the hazards have also been identified. A complete geotechnical risk register should be utilised on an individual turbine basis throughout the construction phase and amended accordingly as new information is received.

Hazard	Cause	Consequence
Peat Landslide	High rainfall, and increased surface water infiltration leading to build up of pore water pressure	Instability of peat deposits and underlying superficial deposits around earthworks; Contamination of natural watercourses and damage to hydrological systems; Harm to personnel and damage to plant / equipment; Destruction of built infrastructure
Mitigation	Due consideration given to prevailing ground and weather condition when scheduling construction works. i.e. avoid opening new excavation during heavy precipitation and ensure sufficient drainage measures are in place to support construction activities. Ensure a contingency is in place to concentrate on more suitable construction activities during wet weather. The drainage design should be such that its construction is in sequence with providing necessary drainage to new areas of excavation and construction in advance of works. i.e. ensure cut-off ditches are in place prior to opening new excavation. The drainage design should as far as practicable preserve the natural hydrological regime and should not inundate areas with run-off which were previously not subjected to such effects. Monitoring weather forecast with site specific weather station. Monitoring (visual) regular site inspection to detect early indications of ground movement (tension cracks, groundwater issues).	
Peat Landslide	Concentrated loads placed at the top of slope system or on marginally stable peat deposits	Contamination of natural watercourses and damage to hydrological systems; Rapid ground movement and mobilisation of material down slope of construction operations; Harm to personnel, plant and equipment; Destruction of temporary or permanent construction works.
Mitigation	Robust and strict controls on the phasing and pace of construction must be in place. This would be most effectively managed through the construction method statement and peat management plan. Plant operatives should be briefed in detail regarding the side-casting and stockpiling of materials. Medium to high-risk areas particularly should be demarked by	

Hazard	Cause	Consequence
	high visibility ticker tape or similar as a warning not to stockpile any materials in the deeper peat areas. Ensure the peat depth contour mapping is available and has a high visibility during construction; A programme of frequent inspections should be implemented during excavation and access track construction works. This should be carried out by suitably experienced and qualified personnel. Where stockpiles are placed in suitable areas, these should be closely monitored through the use of high accuracy GPS level and visual survey.	
Peat Landslide	Uncontrolled surface water flows	Rapid erosion around and within temporary and permanent earthworks leading to a destabilising effect on peat slopes, loss of toe support and or increase of pore pressures through increased rates of infiltration.
Mitigation	Detailed drainage design undertaken with sufficient capacity to buffer the effects of short periods of high intensity rainfall, perhaps though the implementation of buffer/ settlement ponds to collect surface run-off and release at a slower rate. The positioning of such elements should be at locations at low risk of peat instability. Geotechnical supervision of major de-watering operations should be in place to ensure outflows are not being directed into terrain at higher risk of peat instability. Due consideration should be given to prevailing ground and weather conditions when scheduling construction works.	
Peat Landslide	Inadvertent removal of toe support to slope system	Localised instability associated with temporary and permanent earthworks; Harm to personnel and equipment/plant through mass movement of peat and spoil; Long term ground movements/ creep, causing deterioration and damage to temporary and permanent earthworks; Contamination of natural watercourses and damage to hydrological systems from peat material mobilised down slope.
Mitigation	Avoidance action during geotechnical design stage; Routine geotechnical inspection; Contingency plans for slope stabilisation measures. This could involve the provision of engineered toe support to affected slopes comprising gabion style retaining structures.	
Peat Landslide	Increased subsurface groundwater flow and 'piping' failure beneath natural peat deposits, temporary and permanent earthworks	Localised instability associated with temporary and permanent earthworks; Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment.
Mitigation	Ensure geotechnical design prevents blockages of groundwater flow. This may be achieved through the use of free draining fills and ensuring temporary and permanent earthworks do not cause the build-up of groundwater pressures.	

Hazard	Cause	Consequence
	A programme of geotechnical inspections should be implemented throughout construction phase. Ensuring focus extends beyond immediate areas of construction, both up-slope and down-slope to detect any unforeseen effects on stability.	
Bearing Capacity Failure (Peat Surface)	Increased loading of low shear strength deep peat deposits	Localised instability and settlement associated with temporary and permanent earthworks; Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment; Contamination of natural watercourses and damage to hydrological systems from peat material mobilised down slope.
Mitigation	Due consideration given to the prevailing ground and weather conditions when scheduling site works; Ensure detailed peat depth contour plan to be used in construction planning and design; Use of appropriate plant machinery (low ground pressure and long reach to avoid over loading peat deposits); A programme of geotechnical inspections will be implemented during excavation works; Geotechnical monitoring post-construction.	
Peat Failure	Mass movement of temporary storage mounds and bunds	Localised instability and settlement associated with temporary and permanent earthworks. Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment.
Mitigation	Storage site selection and stockpile design by a suitably qualified and experienced geotechnical engineer; In general, the temporary storage of peat in a single dedicated area shall be avoided wherever possible; Peat storage height shall not exceed 1m; Routine maintenance and inspection of peat storage mounds; Additional mitigation measures as described in standalone Peat Management Plan for proposed development.	
Creep, long term settlement of structures	Tracks or hardstand founded on peat and or poor or variable foundation soils	Ongoing settlement and damage of infrastructure, e.g. damage to access track running surface.
Mitigation	Contingency of routine maintenance of infrastructure and drainage elements to ensure longer term issues do not cause a build-up of effects leading to higher level consequences e.g., larger scale instability.	

5 Conclusions

5.1.1 Lethen Wind Farm has been characterised in the lowest peat slide risk categories. There are discrete areas of the development where risk is elevated however in general the terrain and soil conditions are not major factors which could lead to large scale peat instability.

5.1.2 Proposed infrastructure has been optimised to avoid peat deposits with 70% of proposed turbine locations and infrastructure sited away from peat.

5.1.3 Terrain Slope angles are predominantly less than 3 degrees and significant slope systems are not present across the development which could give rise to large scale peat slide.

5.1.4 The development is surrounded by elevated terrain with infrastructure proposed across lower lying ground.

5.1.5 There is a single main watercourse acting as a potential pathway for peat slide or debris flows with downstream receptors a significant distance >2km from the development boundary.

5.1.6 The development contains a variety of artificial drainage measures, hill tracks and is subject to muirburn practices. The impacts from these activities are clear and have accelerated soil erosion in many areas of the site. This is focussed across the shallow mineral soils and these elements have not been associated with any peat instability.

5.1.7 The initial risk rankings are based on the risk of peat failure occurring without appropriate mitigation and control measures in place during construction. It should be highlighted that through geotechnical risk management, strict construction management and implementation of relevant control measures, this shall reduce the risk of peat failure across the development to residual low and negligible levels.

5.1.8 The qualitative risk assessment should be reviewed prior to construction and further refined following intrusive ground investigation.

5.1.9 In July 2022 additional detailed soil depth probing has been undertaken to address external recommendations made in the ECU Stage 2 Checking Report. Following completing of this additional probing there has been no cause to alter the main conclusions of this risk assessment.

Key Risks

5.1.10 The factors which influence natural and induced peat slope failures were discussed in detail during the introduction of this report. The following construction related factors are highlighted for consideration.

- Movement can occur following overloading of peat slopes, e.g., by placement of fill, stockpiling and end-tipping directly onto peat slopes.
- Suitability of drainage measures and the prevailing groundwater conditions are also key factors to consider during construction. Increasing pore water pressures within peat deposits decreases the stability of a slope.
- In extreme events, peat can act as a viscous fluid and travel over very shallow slopes. The re-working or excessive handling of peat can reduce the shear strength to residual levels and hence lead to ‘liquid’ peat behaviour.
- The rate of construction can have a major influence on the stability of peat land environments. Rapid loading and limited time for excess pore pressure dissipation can also decrease the stability state of peat slopes.
- Excavation across a side slope, a convex slope / break in slope can induce peat failure.

5.1.11 Therefore, the most significant but highly unlikely impact is death or injury to site personnel. Disruption through infrastructure damage leading to time and cost impacts on the development and impact through damage of the environment are also deemed low risk across the development.

5.2 Recommendations

5.2.1 The preliminary geotechnical risk register for the site cites key control measures which are required to reduce the risk of peat slide to residual levels. However, there should be wider consideration of these measures across all areas of the Proposed Development which may be influenced by the proposed construction. This is critical where infrastructure may impact terrain and slope conditions beyond the proposed working areas.

- A detailed intrusive ground investigation should be carried out (post-consent) and as part of the pre-construction phase of development. This investigation should seek to further characterise the peat deposits with emphasis on, depth, classification, in-situ shear strength testing and targeted undisturbed sampling and laboratory testing. All peat samples recovered should be classified in accordance with the Von Post system, (Hobbs, 1986) and current British and Eurocode standards for site investigation.
- Groundwater level information should be collated as part of any future ground investigation.
- The results of a detailed ground investigation should be assessed with respect to refining the peat stability assessment at all infrastructure locations. All pertinent control measures and mitigation measures should be revised, and their implementation supervised following the results of the ground investigation and construction design phase of works.
- Continued assessment and monitoring throughout the construction phase of works and at suitable intervals post construction should be implemented to ensure the control measures are suitable and are providing adequate mitigation against peat instability.
- Construction practices should be managed through the Construction Method Statement (CMS) and within the wider context of the Construction Environmental Management Plan (CEMP). The CMS should be prepared by the appointed principal contractor and reviewed by a suitably experienced geotechnical engineer who has read and understood this report. The following general recommendations are provided in line with the Good practice during wind farm construction (2019) guidance:
  - Avoid peat arisings being placed as local concentrated loads on peat slopes without first establishing the stability condition of the ground and slope system. Stockpiling on areas of deep peat and in close proximity to steep slopes should be avoided.
  - Avoidance of uncontrolled and concentrated surface water discharge onto peat slopes as this may act as contributory factor to failure. All water discharged from excavations during construction phase should be directed away from all areas identified as susceptible to peat failure and should managed by a suitably designed site drainage management plan.
  - All excavations where required should be adequately supported to prevent collapse and the destabilising peat deposits adjacent to excavations.
  - A system of daily reporting should be established during construction and utilised to monitor the geotechnical performance of slopes including peat, sub-soil and bedrock. This should be implemented and undertaken by a suitably experienced and qualified geotechnical engineer. Post construction this monitoring procedure should be curtailed to allow for annual or ad-hoc inspection as required.

Floating Track Construction

5.2.2 MacCulloch, (2006) advises that a 'floating' type road construction which leaves the peat deposits in situ may be advantageous with respect to preventing peat failure. This method of construction has a lower impact on the internal groundwater flow within the peat land. However, there are cases where groundwater flow within the peat can be detrimentally affected. The following control measures should be implemented as part of the design and construction of 'floating' access track:

- Prevent the rupture of vegetation surface of the peat by avoiding the use of large sharp rock fill;
- Prevent the overloading and subsequent shearing of the peat throughout construction and use of the 'floating' track;
- Monitoring of the long-term settlement of the 'floating' track is necessary to predict the effects of reducing permeability within the peat and hence increasing groundwater pressures beneath the track construction. Through ongoing monitoring additional drainage relief measures can be implemented when conditions for peat failure are predicted;
- Do not position 'floating' access track on or adjacent to convex side slopes.

5.2.3 An additional control on the construction and use of 'floating' track is through the strict management of construction traffic loading. This may involve the timing between heavy traffic to be staggered to prevent the effect of cyclic loading over short time periods reducing the shear strength of the peat. In order to assess the maximum loading rate or timing between heavy construction traffic it may be necessary to monitor the vertical deformation of the 'floating' track sections following loading and recording the time taken for recovery of vertical deformation. The use of simple settlement plates and survey pegs can be used to achieve this. The frequency of trafficking for heavy loads must then be timed to allow deformation of the 'floating' road to recover its deformation.

5.2.4 MacCulloch (2006) generally advises that in order to prevent injury or an environmental incident, it is important that there is a robust procedure in place should it become apparent that a peat failure is imminent.

Cut/Fill Track Construction

5.2.5 Across areas of the Proposed Development not mantled by deep blanket peat and on slopes; the construction of proposed access tracks should be considered by excavation and replacement method, MacCulloch, (2006). Excavated peat is removed and targeted for suitable re-use. Aggregate would be used to form the subgrade and running surface of the track.

5.2.6 For 'Cut' track construction the risk of peat failure is therefore focussed on the peat deposits adjacent to the access track, and the placement of peat arisings. In these areas the following control measures are listed by MacCulloch, (2006):

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

Earthworks

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

- Dedicated peat storage areas designed under the advisement of a suitable qualified geotechnical engineer and conform to up-to-date regulations and waste directives.
- Re-use of peat in dressing-off of batters on access tracks, finishing of cable trenching works, the landscaping of turbine bases. Peat must be re-used to ensure stability and its long terms sustainability i.e., the prevention of drying of desiccation.
- Excavated glacial till and weathered rock may be used as backfill to turbine bases should material be deemed geotechnically suitable. All related works must be carried out in accordance with an agreed CEMP and conform to site restoration plans.
- For in-situ and undisturbed peat; site vehicle movements must be minimised across such areas, throughout construction and post construction. Observation and monitoring for settlement, deformation, or signs of failure along access tracks and critical working areas must be implemented. This may be achieved with a network of settlement plates and survey markers which can be periodically re-surveyed, and any differential movements identified. It is recommended that all earthworks are designed in accordance with current national standards.

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

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

6 Glossary

Term	Definition
Acrotelm	The thin aerobic zone at the surface of the mire usually fibrous and containing the majoring of groundwater flow through the peat mass, underlain by the thick anaerobic zone called the catotelm, usually a higher degree of humification and lower shear strength.
Bog Burst / Flow	Failure of a raised bog (i.e. bog peat) involving the break-out and evacuation of (semi-) liquid basal peat. A flow is formed of highly humified basal peat from a clearly defined source area.
Bulk Density	The normal in situ density of a soil, i.e. its mass divided by its volume.
Catotelm	see acrotelm.
Consolidation	The process by which a soil decreases in volume.
Construction Method Statement	(CMS), a detailed written description of how a particular construction activity will be carried out safely and in an environmentally compliant manner.
Diamicton	Glacially derived soil which is poorly sorted and contains soil particles ranging in size from clay to boulders.
Geographical Information System (GIS)	Form of technology capable of capturing, storing, retrieving, editing, analysing, comparing and displaying spatial environmental information.
Geo-hazard	Geological hazard, either natural or man-made, which threatens either humans or the environment in which they live.
Geo-membrane	Non-porous sheet that has a very low permeability (in engineering terms impermeable) usually formed of polyethylene.
Geo-textiles	Man-made fabrics, generally made from plastics but also may be made from natural materials, used in construction.
Groundwater	Water located beneath the ground surface in soil pore spaces and in the fractures of rock formations.
Ground Investigation	Specialist intrusive phase of site investigation with associated monitoring, testing and reporting to a national standard.
Hagg	Natural gully or weathering structure in surface of peat mass.
Hazard	Something with a potential for adverse consequences / harm.
Humification	The process of decomposition of a peat soil.
Hydrological regime	The statistical pattern of a river's constantly varying flow rate.
Mitigation	The limitation of undesirable effects / impact of a particular event.
Mitigation Measures	Actions in place to limit the undesirable effects / impact of a particular event.
Peat Slide	Failure of a blanket bog involving sliding of intact peat and the mineral substrate material or immediately above the contact with the underlying mineral soil substrate.
Peat debris slide	Shallow translational failure of a hillslope with a mantle of blanket peat in which failure occurs by shearing wholly within the mineral substrate and at a depth below the interface with the base of the peat such that the peat is only a secondary influence on the failure.
Permeability	The rate at which water and air moves through a soil.
Pore water	The water filling the voids between grains of soil

Primary consolidation	The process by which a soil decreases in volume through the expulsion of internal pore water
Overland flow	Water passing rapidly over or through the surface layer of soil.
Peat	A largely organic substrate formed of partially decomposed plant material
Precipitation	Deposition of moisture including dew, hail, rain, sleet and snow.
Risk	The combination of the probability of an event and the magnitude of its consequences
Residual Risk	The risk remaining after mitigation measures have been undertaken.
Rockhead	The upper surface of rock mass beneath the superficial soil cover.
Runoff	Surface runoff is the flow of water over the surface that can result due to the surrounding soils lacking the capacity to infiltrate further water or due to the surface water flowing off infrastructure such as access tracks and hardstands.
Secondary Consolidation	The compression of a soil that takes place after primary consolidation due to creep, compression of organic matter etc.
Sedimentation	The tendency for particles in suspension to settle out of the fluid in which they are entrained.
Site Investigation	The overall process of discovery of information concerning a site, the appraisal of data, assessment and reporting. Can include desk, non-intrusive and intrusive investigation.
Shear strength	The maximum shear stress which a material can withstand without rupture/ failure
Shear vane	In situ test using a x4 blade steel vane pushed into the ground and rotated to provide an indication to the undrained shear strength of a soil.
Superficial Deposits	Young, sediments and soil deposits occurring at the surface.
Surcharge	An additional mass of material or load applied to an existing soil or structure
Topography	The physical features of a geographical area.
Undisturbed Sample	A sample of soil whose condition is sufficiently close to the actual condition of the soil in situ to be used to approximate the properties of the soil in the ground.
Water resources	The supply of groundwater and surface water in a given area.

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