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Peat Instability Hazard Assessment

Kinnelhead Wind Farm

15 April 2025

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CONTENTS

1. INTRODUCTION

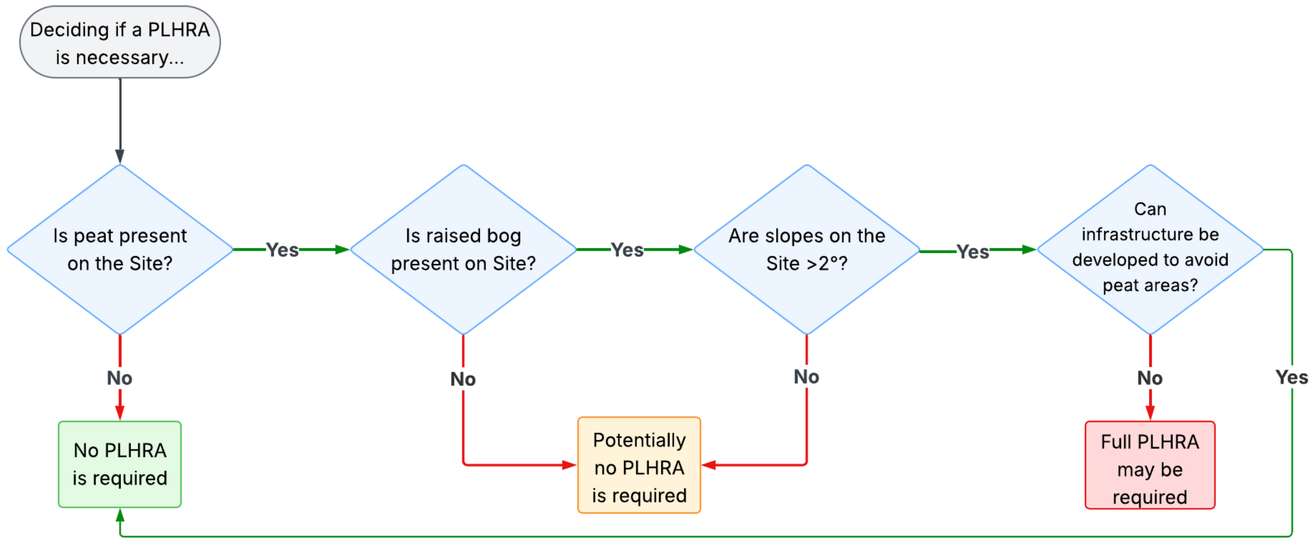
1.1 Project Description

Locogen Consulting Ltd have been commissioned by RES (*'The Client'*) to undertake a Peat Instability Hazard Assessment (PIHA) for the proposed Kinnelhead Wind Farm (*'the Proposed Development'*). This document should be read in conjunction with Chapter 9 of the Kinnelhead Wind Farm Scoping Report.

The proposed Kinnelhead Wind Farm development is located approximately 5km from the town of Beattock in Dumfries and Galloway. The Proposed Development Area in its undeveloped state is comprised of upland agricultural and forestry land at Kinnelhead farm DG10 9RQ (*'the Site'*). The Site has an approximate area of 14km^2 with 26 turbines and associated infrastructure proposed. The Site boundary and proposed access spur is shown in Figure A1, in Appendix A.

As part of the Scottish Government Best Practice Guidance (BPG) there is a screening tool to determine whether a Peat Landslide Hazard and Rish Assessment (PLHRA) is required[1].

A flow diagram checklist can be used to check if a PLHRA is required for the proposed development[1].



Flow Chart 1: An overview to check if a Peat Landslide Hazard and Risk Assessment is required.

[1] Scottish Government, 2017. Peat Landslide and Hazard Risk Assessment: Best Practice Guide for Proposed Electricity Development. Available at: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments

1.2 Scope of Work

To perform a preliminary PLHRA the following is required following guidance from the Peat Landslide and Hazard Risk Assessment Guide[1]:

- Review publicly available data including BGS Data.
- Assess the slopes across the proposed development area from publicly available information.
- Undertake a Site walkover.
- If peat is present on the Site,
    - Characterise the peatland geomorphology of the Site,
        - a) Includes the quality of the peat.
        - b) Estimated thickness of the peat deposits.
    - Review if prior incidences of peat instability can be observed either from historic maps or from Site walkovers.
    - Review the likelihood of future peat landslides under,
        - a) natural conditions,
        - b) in associated with construction activities with the proposed development,
        - c) review across the Site potential receptors from any peat landslide,
        - d) assess and indicate potential mitigation and control measures, where required, to lower the impact to acceptable levels so that the proposed development could proceed safely and with minimal risk to the environment.

2. PEAT INSTABILITY WITHIN THE BRITISH ISLES

2.1 Peat

In the United Kingdom there are three main types of peatland habitats within the UK[2].

- Blanket bog (most commonly found in uplands).
- Raised bog (localised domes of peat in lowland areas primarily fed by rainfall).
- Fens (fed by mineral-rich groundwater and river water, as well as rainfall).

To classify peat, which is a highly variable material, a commonly used system is the Von Post classification scale. Lennart Von Post developed the scale in 1926 for the Soil Survey of Sweden which has been widely adopted for the assessment of peat, this is presented in Table 1.

H1 is the starting formation of peat and H10 represents fully decomposed peat. The classification is subjective but provides a system to understand the peat type and quality on Site. This scale also provides information that contributes to the potential for peat instability. The peat classes closer to H1 are less likely to be involved in peat instability due to their fibrous qualities and in being within the early stages of decomposition, whilst the greater the value the more likely the peat is to be unstable.

Table 1: Lennart von Post Peat Scale

von Post Humification Scale	Description
H1	Completely undecomposed peat which, when squeezed, releases almost clear water. Plant remains are easily identifiable. No amorphous material present.
H2	Almost entirely undecomposed peat which, when squeezed, releases almost clear or yellowish water. Plant remains are still easily identifiable. No amorphous material present.
H3	Very slightly decomposed peat which, when squeezed, releases muddy brown water, but from which no peat passes between the fingers. Plant remains still identifiable, and no amorphous material present.
H4	Slightly decomposed peat which, when squeezed, releases very muddy brown water. No peat is passed between the fingers, but plant remains are slightly pasty and have lost of their identifiable features.
H5	Moderately decomposed peat which, when squeezed, releases very muddy brown water with a very small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains quite indistinct although it is still possible to recognize certain features. The residue is considered pasty.
H6	Moderately highly decomposed peat with a very distinct plant structure. When squeezed, about one-third of the peat escapes between the fingers.

[2] UK Centre for Ecology and Hydrology. Peatlands Factsheet. Available at: Peatland factsheet.pdf

	The residue is very pasty but shows the plant structure is still visible before squeezing.
H7	Highly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structures present. When squeezed, about on-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.
H8	Very highly decomposed peat with a large quantity of amorphous material and very indistinct plant structure. When squeezed, about two-thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The pant material remaining in the hand consists of residues such as roots and fibres that resist decomposition.
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed, it is a fairly uniform paste.
H10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.

2.2 Background of Peat Instability

Peat instability can be classified into two forms[3].

- **Minor instability**; localised and small-scale features that are not generally precursors to major slope failure and that include gully sidewall collapses, pipe ceiling collapses, minor slumping along diffuse drainage pathways (e.g. along flushes); indicators of incipient instability including development of tension cracks, tears in the acrotelm (upper vegetation mat), compression ridges, or bulges / thrusts; these latter features may be warning signs of larger scale major instability (such as landsliding) or may simply represent a longer term response of the hillslope to drainage and gravity, i.e. creep.
- **Major instability:** comprising various forms of peat landslide, ranging from small scale collapse and outflow of peat filled drainage lines/gullies (occupying a few-10s cubic metres), to medium scale peaty-debris slides in organic soils (10s to 100s cubic metres) to large-scale peat slides and bog bursts (1,000s to 100,000s cubic metres).

It is necessary for wind farm developments to consider peat in the development of a Site, as indicated in Section 1.2. Peat instability has the potential to cause significant effects which may cause loss of protected habitat, loss of important carbon stores, disruption to water courses, and increase the risk of further instability.

In recent years there have been a number of issues involving peat instability which have been reported, both naturally occurring and as a result of construction activities.

2.2.1 Naturally Occurring Peat Events

A peat slide occurred at Pollatomish, County Mayo, Ireland in September 2003[4], this saw several longitudinal planar failures occur, in both peat and weathered rock. The events were caused by a period of intense rainfall following a dry

[3] Mills, A. J. and Rushton, D. 2023. A risk-based approach to peatland restoration and peat instability. NatureScot Research Report 1259.

[4] Long, M., and Jennings, P. 2006. Analysis of the peat slide at Pollatomish, County Mayo, Ireland. *Landslides* 3.1, pp.51–61. Available at: Analysis of the peat slide at Pollatomish, County Mayo, Ireland | Landslides

summer which formed in cracks. This, combined with the reactivation of old cracks and the opening of peat fuel cuttings, then allowed rapid water ingress during heavy rainfall.

An increase in pore water pressure, as a result of heavy rainfall, significantly reduced the margin of safety for a landslide. Analysis indicated the majority of the failure surface was located on weathered bedrock. Failures were found to have occurred on the steeper upper slopes.

2.2.2 Man-made Peat Failures

The Derrybrien Bog Slide occurred in October 2023 and was a direct result of wind farm construction[5]. The area had evidence of previous instability; however, it is likely the wind farm construction may have concentrated a water flow, resulted in instability following a dry weather period. Following the initial bog slide, a period of heavy rain caused a second slide to occur which entered the Owendalulleegh River and eventually Lough Cutra. This resulted in a significant environmental event occurring.

A significant peat slide occurred on 07 May 2024 on the Viking Wind Farm in Shetland. It is not yet clear what the cause of the peat slide is and if the construction contributed to the slide, but a significant volume of peat material moved and posed a risk to the personnel working in the Site area together with the longer-term environmental effects that will be being assessed.

2.3 Factors Identified That Cause Peat Instability

A number of different items can cause peat instability[1]. These can be considered as both triggering factors and reconditioning factors. These have been observed with the naturally occurring and manmade landslides studies.

Triggering factors have an immediate effect (within hours or days) whilst preconditioning can be an item that is much longer term.

Preconditioning factors:

- Blocked or impaired drainage where underlying the peat is a relatively impermeable surface such clay or unfractured bedrock.
- Proximity to local drainage such as streams or flushes or manmade drainage pipes.
- Surface drainage that discharges to peat generated pore pressures.
- Where drainage ditches are cut across artificially, or grips in drainage ditches where waterflow is altered/impaired and caused potential excess pore pressures.
- Increase in peat mass through natural formation which could be a result of afforestation which could increase the water pressure.
- Tension cracking or desiccation cracking through dry periods which results in changes to the structure of peat and potential reduction in shear strength.
- Surface vegetation loss (through burning practices or climatically induced); likely to also reduce tensile strength.
- Naturally occurring peat pipes results in sub-surface pools, or the peat pipes become water filled.
- Afforestation of peat areas resulting in potential desiccation; reduction in water held in the peat; pools of water on the surface where tracking has taken place.

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[5] Lindsay, R., A. and Bragg, O., M. 2004. Wind Farms and Blanket Peat – A report on the Derrybrien bog slide. Available at: (PDF) Wind Farms and Blanket Peat - The Bog Slide of 16th October 2003 at Derrybrien, Co. Galway, Ireland.

Triggering factors:

- Intense rainfall events (could also be snowmelt) resulting in increased water volumes which could result in potential ruptures.
- Mining/blasting works or naturally occurring earthquakes which could cause ground disruption.
- Peat cutting (uncontrolled) which could cause disruption to water flows.
- Manmade drainage blocking that could be a distance away that had consequences on the Site.
- Unplanned loading of peat with spoil; infrastructure etc. where a floating road is so heavy it has disrupted the pathway for the peat resulting in water flow disruption.

There may be other factors as well which are local to a Site which may be identified through Site walkovers, but the factors shown above should be assessed for all Sites where there is the potential for a peat slide.

2.4 Issues arising from Peat Instability

The main consequences that can occur are either peat slides or bog bursts. Also, an initial peat slide or bog burst could be small, but following an event the disruption that has occurred this event could then be reactivated and be much more significant as shown in the Derrybrien bog slide and so there can be a lack of awareness of the longer-term consequences.

Receptors of peat instability are described in Sections 2.4.1 and 2.4.1

2.4.1 Natural

- Watercourses and lochs/ponds which can extend well beyond the Site if a significant event.
- Habitats.
- Wildlife.
- Visual if a landscape is scarred.

2.4.2 Within a wind farm area

- Development of the wind farm so access roads, turbines, substations which could be affected.
- Personnel working on the Site if at the time of the instability.
- If the instability travels some distance can affect recreational users of the Site or people outside of the Site on the downslope.

3. DESK STUDY

A review of publicly available data sources has been undertaken to better understand the Site. These are reviewed below.

3.1 Site Context

3.1.1 Geology and hydrology

Information held by British Geological Survey (BGS) has been reviewed. The maps reviewed are the 1:50,000k maps for the geology and have been produced as figures contained in Appendix A.

Bedrock Geology

The BGS indicates that the Site is bedrock is founded upon Queensberry Formation consisting of Sandstone; Mudstone; Siltstone and Conglomerate. Outside the Site boundary, trending in a NE-SW direction is the Moffat Shale Group which is a mudstone (see Figure A2, Appendix A).

Drift & Superficial Geology

The BGS indicates a range of superficial deposits on the Site (Figure A3, Appendix A), these include:

- Alluvium of silt, sand and gravel.
- Till, Devensian – Diamicton.
- Glaciofluvial Deposits – Gravel, sand and silt.
- Peat (only small area is mapped even though a central hill is called Peat Hill which is not included in the peat area).
- Large areas are unmapped and so indicate either bedrock at surface or unmapped deposits.

Carbon and Peatland Map

The Carbon and Peatland 2016 Map produced by the Scottish Government, categorises peat conditions into classes[6]. It identified the Site as having Class 1, 3, 4 and 5 peat present as well as some mineral soil (Class 0), these are defined as:

- Class 1 – "Nationally important carbon-rich soils, deep peat and priority peatland habitat. Areas likely to be of high conservation value."
- Class 3 – "Dominant vegetation cover is not priority peatland habitat but is associated with wet and acidic type. Occasional peatland habitats can be found. Most soils are carbon-rich soils, with some areas of deep peat."
- Class 4 – "Area unlikely to be associated with peatland habitats or wet and acidic type. Area unlikely to include carbon-rich soils".
- Class 5 – "Soil information takes precedence over vegetation data. No peatland habitat recorded. May also include areas of bare soil. Soils are carbon-rich and deep peat."
- Class 0 (Mineral Soil) – "Peatland habitats are not typically found on such soils".

Figure A4 in Appendix A presents the distribution of the Carbon and Peatland classes on the Site.

[6] Scotland's Soils. 2016. Carbon and Peatland 2016 Map. Available at: Carbon and peatland 2016 map | Scotland's soils

3.1.2 Hydrology

The Site is split between two main surface water catchments, The River Annan catchment on the eastern side and the River Clyde catchment to the west with the dividing lines along Harestanes heights, Mid Height and Mount Glass.

The Site is drained by several minor watercourses, with the largest being the Crook Burn and Kinnel water. Crook Burn flows north into the Daer Reservoir and sits within the River Clyde catchment.

Kinnel Water (*ID: 10653*) is a designated watercourse under the Water Framework Directive WFD), It has a 'Good' overall status and sits within the River Annan catchment. Most minor watercourses within the Site boundary are tributaries of the Kinnel Water.

3.1.3 Historical Information

Two historic maps have been viewed from 1962 which show the area to be very similar to the view of the Site today. The forestry around Craighoar Hill has not been developed yet in 1962. No other significant differences are observed across the area.

3.1.4 Topography

The topography of the Site ranges from 230m AOD to 650m AOD with much of the Site between 300m AOD and 560m AOD. The eastern corner of the Site is much lower, and the western corner is a high point. Currently access to the area is from the east where Kinnelhead Farm and Kinnelhead Cottage area located.

The slopes across the Site are variable with much of the Site up to 10° in slope but there is a central ridge running approximately north to south with slopes up to 50° locally. There are other isolated steeply sloping areas within the Site boundary.

A number of areas are named (Figure A5, Appendix A), including:

- Peat Hill (400m AOD) as you enter the area from the east.
- Craighoar Hill (530m AOD) where the forestry is located to the northeast with Blairmack (320m AOD) at the eastern edge of the forestry.
- then centrally located is Mount Glass (540m AOD); Harestanes Heights (560m AOD) and Mid Height (550m AOD).
- to the western boundary is Penbreck (590m AOD), Earncraig Hill (590m AOD) coming to Queensbury (650m AOD) in the southwestern corner (highest point of the development area).
- and then to Lamb Hill (550m AOD) on the southern side.
- finally on the northern boundary is Hamarty Hill (520m AOD)

3.1.5 Aerial Imagery

Aerial imagery was utilised to give an insight into the land uses and features of the Site. Most noticeably, in the north-east of the Site an area of forestry is visible, of which more than half has been felled. It should be noted; the aerial imagery is outdated and through Site visits it was found that almost the entire area has now been felled. On the eastern half of the Site, there are two access tracks present, including on the south-east boundary in the north-eastern side which are associated with the forestry area.

Contrastingly, the western half of the Site is inaccessible by car due to an absence of access roads. A number of watercourses are present across the Site, as well as manmade drainage channels however inferring from the aerial imagery, they do not appear to be recent constructions. Some areas of hagg and gully systems are visible from aerial imagery, indicating erosive processes and potentially deep peat. These are located on the western side of the Site.

4. SITE RECONNAISSANCE AND FIELD SURVEYS

4.1 Site Reconnaissance

A Site reconnaissance survey was conducted on 22 January 2025 by Locogen Consulting Ltd. The purpose of the survey was to confirm the presence of peat within the Site boundary and any areas immediately bordering it. The survey was also focussed on identifying evidence of peat movement and any significant hydrological or hydrogeological features. The survey was undertaken following the desk-based review and prior to the beginning of the phase 1 peat probing surveys.

Prior to the reconnaissance survey visit, areas of interest, obtained from the desk study, were marked up on QGIS. Notes and images were taken during the survey using a tablet and QField software, allowing for georeferencing of all points.

Conditions during the survey were observed to be cold and clear, with some light showers throughout the day. Two parking locations were identified to the north and south of the Site. The Site was then walked to view the areas of interest and record any notable features. Intermittent peat depth measurements were also recorded.

4.1.1 Evidence of Previous Peat Instability

There was no significant peat instability observed during the peat probing that took place. No evidence of tension cracks within the peat or creep of peat were noted during the survey, however there were large areas of hagg and gully systems with exposed peat. These areas are characterised by erosive processes and cause a drying of the exposed peat. These areas pose a low risk of instability due to being drained by the channels which have formed and eroded the peat deposits.

Some waterlogged areas were noted; however, these were not deemed to pose a significant risk to stability due to the low slope angle and erosive channels that had formed, allowing a natural drainage route. The area at the base of Harestanes Heights and Craighoar Hill was particularly wet. Areas comprised of hagg, and gully systems also tended to be waterlogged in the channels. An example photo is shown in Figure A6, Appendix A.

4.1.2 Assessment of peat type and character

Peat depth and type were found to vary across the Site. There were areas of no peat, often associated with the tops of hills, while in the valley sections the peat depth found to be greater than 1m.

The character of the peat that was exposed was observed to be fibrous with lots of root matter visible at shallow depths. The peat was observed to become more amorphous with depth. The peat has been assessed to range between H4-H6 on the Von Post Scale and was dark in colour. A full analysis of the peat composition will be undertaken during the phase 2 survey assessment, this initial assessment has only been conducted in areas with visible peat.

4.1.3 Man-made Observations

The Site is primarily characterised as modified agricultural land, with several large hills. The Site includes a felled forestry section and associated tracks to the north, this area includes an old, open borrow pit (see Figure A7, Appendix A). This has been captured in the peat instability assessment. There are also several historic stone structures across the Site area, which are assumed to be sheep folds. There are two scheduled monuments located within the Site boundary, however these Site within the residential buffer.

Man-made drainage channels were noted as several locations across the Site, these contribute to the draining of natural peat habitats. These channels were observed in the south and central sections of the Site. These drainage channels have been observed to run either directly downslope or slightly oblique to the slope.

4.1.4 Topographical Observations

It was noted during the survey that some areas were comprised of very steep exposed rock. These areas were marked up and removed from peat probing for the phase 1 peat survey. These points were then given a peat depth measurement of 0m to 0.1m on account of the exposed rock and lack of any soil cover, an example photo of this seen in Figure A8, Appendix A.

4.2 Phase 1 Peat Survey

In line with the guidance from the Scottish Government[1] an initial phase 1 peat probing assessment has been undertaken across the Site. Peat depth was measured on a 100x100m grid to identify areas of deep peat and identify constraints for the layout of the Proposed Development. Measurements were recorded to a resolution of 0.1m, with notes on peat condition, vegetation and hydrological conditions also recorded at each point. The results were then mapped to spatially present the depths of the measured points across the Site, this is shown in Figure B1, in Appendix B.

The results were further analysed to create an interpolated map which mathematically predicts a peat depth for the whole Site. The interpolated map uses the Inverse Distance Weighted (IDW) method, this method assumes that the mapped variable decreases in influence with distance from the sample point. This provides an estimate of depth in the areas between the points. Where no measurement was taken, the interpolation is filled in using the nearby points. The function v.surf.idw was applied to the data set in QGIS to create the interpolation map, this is presented in Figure B2, in Appendix B.

5. QUALITATIVE PEAT INSTABILITY HAZARD ASSESSMENT

With the data collected above from public sources, the Site reconnaissance survey and the peat probing survey a qualitative assessment can be made on the peat instability across the Site.

This is both a semi quantitative analysis which is outlined in Section 5.1 and 5.2 below. This is then combined with a landslide susceptibility assessment outlined in Section 5.3. The overall results then provide a qualitative assessment of the potential peat instability and is reported in Section 0.

From the initial peat probing a large of part of the Site has areas of peat greater than 1.50m, with depths of up to 4m observed. These areas have been considered as deep as have a higher potential for peat instability. There are also locally steep slopes across the area but generally the peat depths are much shallower or not present where these steeper slopes are present.

5.1 Quantitative Analysis

With the data available a preliminary quantitative analysis of stability using the infinite slope model which is an approach indicated to be used by the Peat Landslide and Hazard Risk Assessment Guide[1] to determine a Factor of Safety (FoS) has been performed using the following formula:

$$F = \frac{C' + (\gamma - h\gamma_w)\, z \cos^2 \beta \tan\phi'}{\gamma z \sin\beta \cos\beta}$$

- F is the Factor of Safety (greater than 1.4 is stable, between 1 and 1.4 is considered marginally stable and less than 1 is unstable)
- c' is the effective cohesion of soil (where 'soil' is an engineering term for unconsolidated material, in this case peat)
- γ is the bulk unit weight of peat (kN/m^3)
- h is the height of the water table as a proportion of the peat depth
- γw is the unit weight of water (kN/m^3)
- z is the vertical depth of the peat
- β is the slope angle
- φ' is the effective angle of internal friction of the peat

Using this approach an assumption is made that any failure that occurs is shallow transitional landsliding, which is a common failure mechanism for peat and so a reasonable assumption.

The choice of the water table height is one of the most significant elements that affects the calculation for peat. Under heavy rain where the peat would be most saturated the water table could be assumed to be at the top surface of the peat and so the water table is assumed at surface for the purposes of the calculation.

Due to the lack of information Site-specific geotechnical input parameters for peat soils for the Site are limited to unit weight. The quantitative analysis therefore has taken data from published literature and other recent data sources for assessment for effective cohesion and angle of internal friction parameters.

Sensitivity analysis has been performed to assess the impact of varying those parameters where Site-specific data is unavailable, to provide a guide to the likely stability of peat slopes. Due to lack of information the parameters chosen are considered conservative, and likely to overstate the hazard, rather than understate it.

The geotechnical characteristics of peat are wide and variable due to the nature of peat. It is difficult to geotechnically test peat due to the variability of the material and the different stages of decomposition where fibrous material can affect any laboratory results and provide an unrealistic interpretation. At present there is no Site-specific data so the results of the quantitative analysis should be treated with caution. The results of the stability modelling have, however, also been compared to the semi-quantitative analysis to identify areas where the two methods generated similar results, and where they diverge.

5.2 Semi-Quantitative Analysis Approach

A semi-Quantitative analysis has also been performed to compare with the quantitative analysis. Considered for this analysis is:

- Peat depth.
- Slope Angle.
- Geomorphological features.
- Water bodies across the Site.
- Areas of previous instability.

To assess the risk of a peat landslide the following is followed:

Risk = Probability of a Peat Landslide x Adverse Consequences

To assess the probability of a peat landslide this report considers the peat landslide likelihood. As there are no collected and geotechnically tested soil/peat data for the Site published literature has been reviewed and conservative values have been selected.

From the Site reconnaissance survey in Section 4.1.2 the exposed peat observed has been assessed to be in the H4-H6 range of the von Post scale, so a fibrous peat in the upper surface becoming more amorphous with depth. The other values used in the semi-quantitative analysis are identified in Table 2.

Table 2: Factors used in the semi-quantitative analysis approach.

Parameter	Values to be used	Rationale	References
c' (Effective cohesion)	6 and 10	Conservative values for humified peat from literature	Range 10 – 12 for H5-H6 peat[7] Range 5.5-6.1 – peat class not provided [8]
Y (Bulk unit weight)	10	Estimate in mid-range between published data	Range 8.5-12[9] Range 8.5-12.2 – Range of peat[10]
Φ' (effective angle of internal friction)	20, 30	There is a wide range of friction angles in published data.	Range 36.6° to 43.5°[11] Range 15° to 25°[10]
B (Slope angle from horizontal)	A range have been chosen from the calculated values	Using the publicly available topographic maps slope angles have been calculated for each peat probe location and used in the calculation	
Z (Peat depth)	Depths have been interpolated	Data from 100m peat probing grid used	
H (Height of water table as a proportion of peat depth)	1	Due to the nature of peat it is assumed to be fully saturated which would be the condition most likely to result in a peat failure naturally	

5.2.1 Results of the Semi-quantitative analysis approach

Peat probing has been performed across the Site area at 100m x 100m centres which has informed the semi-quantitative approach. The values chosen will require to be validated through peat sampling on Site. From the exposed areas of peat across the Site the peat has been classified as H4-H6. The peat sampling will enable this assessment to be refined as well as the in-situ peat strength.

Four maps were created for each version of the Factor of Safety, and these are displayed in Figure C1-4, in Appendix C. The values each map uses for 'effective cohesion' and 'effective angle of internal friction' are identified in Table 3.

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[7] Kazemian, S., Huat, B.B., Prasad, A. and Barghchi, M., 2011. A state of art review of peat: Geotechnical engineering perspective. *International Journal of the Physical Sciences*, *6*(8), pp.1974-1981. Available at: Microsoft Word - Kazemian et al pdf.doc

[8] Boylan, N., Jennings, P. and Long, M., 2008. Peat slope failure in Ireland. *Quarterly Journal of Engineering Geology and Hydrogeology*, *41*(1), pp.93-108. Available at: https://www.researchgate.net/publication/245379146_Peat_slope_failure_in_Ireland

[9] Zainorabidin, A. and Wijeyesekera, D.C., 2008. Geotechnical characteristics of peat. *Advances in Computing and Technology.* Available at: Zainorabidin, A (2008) AC&T 71-78.pdf

[10] Huat, B.K.B; Prasad, A; Asaidi. A & Kazemian. S, 2014. Geotechnics of Organic Soils and Peat. CRC Press. Taylor & Francis Group

[11] Mesri, G. and Ajlouni, M., 2007. Engineering properties of fibrous peats. *Journal of geotechnical and geoenvironmental engineering*, *133*(7), pp.850-866. Available at: Engineering Properties of Fibrous Peats | Journal of Geotechnical and Geoenvironmental Engineering | Vol 133, No 7

Table 3: Factor of Safety Assessment for Semi-Quantitative Analysis

Figure	c' (Effective cohesion)	Φ' (effective angle of internal friction)	Justification of values used
Appendix C, Figure C1: Factor of Safety V1	6	20	Conservative Assessment as both c' and Φ' are low for H4-H6 peat
Appendix C, Figure C2: Factor of Safety V2	6	30	Likely Assessment as although c' is low, may be likely if peat is closed to H6 and Φ' is reasonable
Appendix C, Figure C3: Factor of Safety V3	10	20	Possible Assessment if peat is closer to H4 for c', Φ' would be low though if peat is H4.
Appendix C, Figure C4: Factor of Safety V4	10	30	Likely Assessment as both c' and Φ' are both reasonable for H4-H6 peat

The current results indicate that most of the Site is considered stable (Figure C4, Appendix C). As peat depth does not affect the semi-quantitative assessment it can also be seen that when lower values are used (Figure C1, Appendix C), more areas are quantified as unstable however it should be noted that these correspond to areas which only have shallow peat, with depths mostly below 0.5m thickness. The peat depths are not as deep here due to the steep slopes and rock ridges as aforementioned in Section 3.1.4. The risk of a peat slide in the area is considered low, but following a detailed wind farm layout these areas should be assessed.

5.3 Landslide Susceptibility Approach

The proposed Kinnelhead wind farm development has been reviewed, and several factors are taken into consideration to understand the risk of a landslide occurring.

The peat probing survey has so far only been conducted on a 100m x 100m grid whilst performing the initial assessment across the Site area to gain an understanding of the Site.

The contributory factors for the analysis are:

- Slope angle (S).
- Peat depth (P).
- Substrate geology (G).
- Peat geomorphology (M).
- Drainage (D).
- Slope curvature (C).
- Forestry (F).
- Land use (L).

For all the above factors scores of between 0 and 3 have been assigned. These scores reflect classes for each factor which are discussed below. The higher the score (closer to 3) the more significant that factor will be to potential instability. Scores of 0 are considered neutral or negligible influence.

All the factors are considered for an area and are summed together resulting in a maximum possible value of 24. However, this is unlikely to have all maximum factors for a location. The resultant score is the Peat Landslide Likelihood Score (S_{PL}) as shown in the calculation below.

$$S_{PL} = S_S + S_P + S_G + S_M + S_D + S_C + S_F + S_L$$

Each of the factors are discussed below in more detail together with an explanation of the scoring system. A map has been created to show the potential instability associated with each individual factor, as well as a final map combining the information of all 8 factors, these are found in Appendix C as Figures C5-C13.

5.3.1 Slope Angle (S)

The slopes on the Site vary between 0 to 49 degrees. The Site has no observed raised bogs where very low gradients are of concern[1] and has areas covered by blanket bog. 2° slopes or greater is where a PLHRA is required, and this is considered in Table 4 below.

Table 4: Slope Angle Instability Assessment

Slope range (°)	Instability Assessment	Peat Slide
≤2.0	Under 2.0° in a blanket bog the slope is considered to not be a risk	0
2.0-4.0	Increase in slope increases the risk of a potential slide occurring	1
4.0-6.0	Increase in slope increases the risk of a potential slide occurring	2
6.0-8.0	Increase in slope increases the risk of a potential slide occurring	3
8.0-10.0	Increase in slope increases the risk of a potential slide occurring	3
10.0-15.0	Increase in slope increases the risk of a potential slide occurring	3
>15.0	Increase in slope increases the risk of a potential slide occurring	3

Most of the Site is in excess of 2° slopes with only the eastern access to the Kinnelhead Farm area being relatively flat and then isolated locations in the rest of the wind farm. Moving westwards towards Peat Hill there are slopes in excess of 10° on the eastern side of the hill with the western side largely below 8°.

The central part of the Site has a steep ground in excess of 15° forming a ridge from north to south including Craighoar Hill; Harestanes Heights and Mount Glass.

On the western side there is another steep gulley to the west of Hamarty Hill down to the watercourse with slopes in excess of 10° running north to south. A steep sided ridge then runs north to south, in excess of 10° along Penbreck towards Queensferry.

The interpolated assessment of the slope angles is shown in Figure C5, in Appendix C. Much of the Site has a rating of 3 due to the slopes being in excess of 6°.

5.3.2 Peat Depth (P)

Peat probing has been performed across the Site on a grid 100m x 100m. In general, an increasing thickness of peat will result in an increasing risk of a peat slide. However, it is noted that the thicker the peat the less likely the peat will be on steeper slopes and so less likely to result in a slide. Table 5 is the assessment criteria that has been considered for the Kinnelhead wind farm Site.

Table 5: Peat Depth Instability Assessment

Peat depth (m)	Instability Assessment	Peat Slide
No peat	Areas of no peat	0
≤0.5	Due to depth this is considered more likely to be an organic soil rather than peat and so a low risk of a peat slide	1
0.5-1.5m	Peat likely to be in range H1-H4 as blanket bog develops over time so a more fibrous peat	2
>1.5m	Thick peat deposits	3

From the current peat probing exercise the depth of peat across the Site has been found to be a maximum of 3.50m depth based the grid performed. There will likely be locally some deeper sections, but the grid performed has provided a good indication of the peat depth across the Site area. There have also been areas of little/no peat across the Site, often where steep slopes are located but the majority of the Site falls between 0.5-1.5m recorded peat depth.

The assessment of the peat depth across Site derived from the peat depth probing exercise is shown in Figure C6, in Appendix C.

5.3.3 Substrate Geology (G)

The influence of substrate geology is shown in Table 6. The more granular the underlying substrate the less likely a slide can occur due to the higher friction.

Where a clay material is present the water within the peat will have had the potential to soften the upper clay layers resulting in low undrained shear strengths and/or low effective strength parameters.

The bedrock will be a high strength stratum but the bedrock surface, which is unknown at present could be a smooth surface and so could present a failure surface.

Table 6: Substrate Geology Instability Assessment

Substrate	Instability Assessment	Peat Slide
Sand/Gravel	High friction	1
Bedrock	Bedrock is sandstone from BGS, could have smooth surfaces in places	2
Clay	Can present a slip surface and have a weak interface due to saturated upper layer below peat (Alluvium and Till have also been include here as no records are available from the site for these materials and so the assumption is that they are clay rich)	3

Unknown	Where strata is unknown same risk rating as clay	3

From the geological maps there are limited superficial deposits with till, consisting of a mixture of clays, sands and gravels, can also contain boulders being the most common. Due to the unknown nature of the till and the potential for it to be largely clay has a rating of 3 using Table 6 but this is likely conservative.

A small amount of alluvium is recorded along the edges of the watercourses again classified as a clay with the above table. Peat is shown is areas too, however Peat Hill is not shown as containing peat and from the peat probing it is understood that there is an inconsistency with the BGS mapping, following the BGS mapping this area has a rating of 2 from Table 6 as considered bedrock in absence of any superficial deposits.

In the southeastern there is a small area of glacifluvial deposits which have a rating of 1 as sands and gravels.

The assessment of the substrate geology is shown in Figure C7, in Appendix C.

5.3.4 Peat Geomorphology (M)

Detailed mapping of the development area has not yet been performed; however a Site walkover has taken place, and an initial assessment has been made. This is preliminary and a more detailed assessment is required. Table 7 provides the geomorphological features that are recommended to be considered for the Site.

Table 7: Geomorphological Classes for Peat Instability Assessment

Geomorphology	Instability Assessment	Peat Slide
Incipient instability (cracks, ridges, bulging)	Where these have been observed in the development area. Not all of the site has been surveyed in detail however for instability.	3
Planar with pipes	Planar slopes are the most likely locations for failure locations, particularly where piping is also present	3
Planar with pools / quaking bog	Bog bursts are more likely where permanent pools of water are present or subsurface water (quaking bog where the bog is floating on the pool of water)	2
Planar	Planar slope but with no other features present and peat shows no signs of instability	2
Peat in between rock outcrops	Where peat is located in low points between rock outcrops there and so considered unlikely to have a peat slide	1
Slightly eroded / minor gullies / dendritic drainage	These are normally areas of gulleys or no peat and so are considered unlikely	1
Rock ridges or areas with no peat	Where no peat is present peat failure cannot occur	0
Heavily eroded or hagged peat / bare peat / extensive gullies	Failures have not been reported in heavily eroded areas	0
Forested areas or made ground	Covered within Forestry (F) or Land Use (L) in lower sections	0

From the peat probing performed the maximum depth reached was 3.5m. Following the Site reconnaissance survey there is only one hagged area observed in the southwestern section of the Site. No other significant peat geomorphology was observed across the Site area.

The visual assessment of the peat geomorphology across the Site is shown in Figure C8, in Appendix C.

5.3.5 Artificial Drainage (D)

Manmade drainage within peat can have a significant effect as these are not natural drainage channels and so there could reduce peat stability. The installation of moorland grips or similar are known to have contributed to peat failures [12].

The orientation of artificial drainage also has an impact, if in a transverse direction the effect will be more significant than oblique or downslope as the potential to hold water will be greater. Table 8 provides the drainage classes that should be considered for the Site.

Table 8: Drainage Classes for Peat Instability Assessment

Drainage Feature	Instability Assessment	Peat Slide
Drains aligned along contours (<15° orientation to slope)	Travelling transverse can result in water pathways being broken with the peat, and water not draining as expected resulting in issues	3
Drains running obliquely (15-60°) to the slope contours (can be variable due to the topography being traversed)	Oblique drains have often been reported at areas where peat slides or bog bursts have been ben observed	2
Drains travelling downslope (<30° to then slope)	Less likely to have failures with drains downslope as water is transported away, however potential for drains to become locally blocked which could be result in local issues	1
No drainage	No effect on the overall instability	0

Drainage across the proposed development area has been assessed both from the initial Site walkover and from google earth images. There are small areas of drainage in the central area of the Site however most of the Site does not have any artificial drainage.

The visual assessment of the artificial drainage is shown in Figure C9, in Appendix C.

5.3.6 Slope Curvature (C)

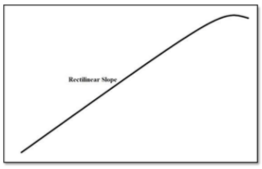
The slope curvature is an important feature. There are three main slopes considered and an assessment of the importance of the slopes is shown in Table 9.

[12] Dykes, A. and Warburton, J. 2007. Significance of geomorphological and subsurface drainage controls on failures of peat-covered hillslopes triggered by extreme rainfall. *Earth Surface Processes and Landforms*, 32, 1841-1862.

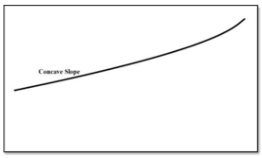
Table 9: Slope Curvature Classes for Peat Instability Assessment

Drainage Feature	Instability Assessment	Peat Slide
Rectilinear Slope	Peat slides are frequently associated with rectilinear slopes, also bog bursts are often reported on rectilinear slopes.	3
Convex Slope	Peat slides have often been reported on convex slopes or at the top of the convex slopes. Bog bursts are commonly associated with convex slopes.	2
Concave Slope	Concave slopes peat failures are occasionally reported.	1
Undulating ground	Where the ground is irregular and undulating over short slope lengths peat slides are no foreseen to occur.	0

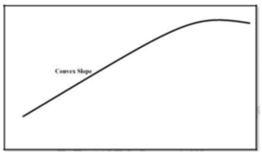
- Rectilinear slope is where the slope is constant; slope angle remains constant; profile is a straight profile.



- Concave Slope is often found at the base of a hill which becomes shallower with distance.



- Convex Slopes are often found on the upper parts of the slope leading to the crest/summit.



Reviewing the topography of the Site from both the OS mapping and the Site walkover there are few areas of undulating ground. The rock outcrops in the centre. No slopes are considered to be rectilinear across the Site area.

The visual assessment of the slope curvature is shown in Figure C10, in Appendix C.

5.3.7 Forestry (F)

Afforested slopes are considered to provide stability to peat however there are effects from the alignment of the peat. Deforested slopes potentially result in instability with exposed peat being affected by rainfall events with pathways potentially present from the process of removing the forestry, desiccation cracks may be present, potential erosion of the peat through rainfall events. Table 10 provides assessment criteria for the forestry within the Site development area.

Table 10: Forestry Classes for Peat Instability Assessment

Forestry Feature	Instability Assessment	Peat Slide
Deforested areas with the rows oblique to the slope angle	Deforested the area is at higher risk then when afforested. Oblique to the slope can result in desiccation cracks, can also have areas where the process of removing the forestry has resulted in pools of water created in the peat which could lead to instability.	3
Deforested areas with the rows aligned with the slope	Deforested the area is at higher risk then when afforested. As the rows are with the slope then water should be able to travel away from the slope, however there is still potential for instability along inter ridge cracks.	2
Afforested areas with the rows oblique to the slope	These afforested areas are more stable than deforested areas however with oblique rows could result in instability with water pooling locally.	2
Afforested areas with rows aligned to slope	Considered more stable than deforested slopes, and more stable with the rows aligned to the slope. However less stable than undeveloped areas of peat.	1
Windblown area	Where windblown trees are present the disturbance has already taken place to the area with the roots causing disruption and disturbance. No further disturbance envisaged.	0
No forestry	No forestry to influence stability.	0

There is a small area of forestry located to the northeast of the Site. Most of the forestry had been deforested at the time of the Site reconnaissance survey with the rows aligned with the slope so a rating of 2. The afforested area is aligned with the slope and has a rating of 1.

Most of the potential development area has no forestry and appears to have no historic forestry and so has a rating of 0.

The visual assessment of the forestry is shown in Figure C11, in Appendix C.

5.3.8 Land Use (L)

This covers all the potential activities that take place across the Site such as peat cutting; quarrying etc. which are discussed in Table 11.

Table 11: Land Use Classes for Peat Instability Assessment

Land Use Feature	Instability Assessment	Peat Slide
Mechanical excavation of peat	Where significant quantities of peat have been excavated can result in a potential weakness in the lower slope of the peat if support has been removed or potential for water build up above the area of peat if an area has been excavated.	3
Quarry/borrow pit	Quarrying activities can remove support from a slope had result in potential peat instability.	2
Hand excavation of peat	Hand cutting is much less significant due to the method used than mechanical excavation but can result in instability.	1

Burning of vegetation	Although the burning process is the vegetation with the vegetation removed cracking can occur in the now exposed peat area resulting in potential desiccation.	1
Grazing	Grazing of upland peat areas is not known to result in any instability.	0

5.3.9 Calculation of slope facets

Form the information in this section the different factors above have been implemented across the Site and have been used to create a peat landslide likelihood score. An assessment has been made for the Site with the likelihood ranging from ‘very low’ to ‘very high’ which is in line with the range proposed by the Scottish Government BPG.

Table 12: Likelihood Classes Derived from the Landslide Susceptibility Approach

Overall score from the contributory factors	Expected conditions on site from the scoring	Likelihood (Qualitative)	Landslide Likelihood Score
≤ 7	Unmodified peat with no evidence of any historic failures or potential likelihood of failure from the assessment of the different factors	Very Low	1
8-12	Unmodified or modified peat with low to moderate scores apart from peat depth, peat morphology which could be high	Low	2
13-17	Unmodified or modified peat with high scores for peat depth and slope angle plus some other high scores	Moderate	3
18-21	Modified peat with high scores for peat depth and slope angle and many other factors	High	4
>21	Modified peat with high scores for most factors	Very High	5

Table 12 contains the basis and assessment for the likelihood classes. The highest results from the contributory factors have been slope and peat depth. Most of the other factors have been relatively low in scoring.

With the peat probing having so far been undertaken on a 100m x 100m grid across the Site this is a preliminary assessment to assist in the understanding and development of the Site. It is expected that as the Site development is refined then additional information will be collected for the proposed development areas and this assessment will be revisited and updated.

5.3.10 Results of the qualitative analysis

Taking all the contributory factors together in Section 5.3 an overall image has been produced in line with the classification in 5.3.9. This is shown in Figure C13, in Appendix C. The scores have resulted are either very low or low with only a small section in the northwest being scored as moderate and is related to the now deforested area.

5.3.11 Combined Landslide Likelihood

The results of semi-quantitative analysis approach (Section 0) have then been considered with the results from qualitative approach (Section 5.3.10). As discussed, the semi-qualitative assessment indicates there may be areas with a low factor of safety when the lower values are used, however these areas are where there is less than 0.5m of peat.

Overall, the Site is considered to be stable but will require reassessment once a wind farm layout has been implemented taking into account all factors.

6. CONSEQUENCE AND RISK ASSESSMENT

6.1 Introduction

To understand the risks that could be present from a peat slide within the Site area and therefore to assess the consequences of a peat landslide the receptors on a Site area needs to be understood and what the implications a peat slide would have on these receptors. This is currently a preliminary review of the Site, and a more detailed assessment would be required once an initial windfarm layout has been determined.

Adverse consequence scores for the receptors are considered as shown in Table 13 below. The adverse consequence scores are again a qualitative assessment of the receptors. The peat landslide score is taken from Section 4 which forms the left-hand side assessment and for the most is either very low or low.

Table 13: Adverse Consequences Scores

		Adverse Consequence Scores (score in brackets)				
		Very High (5)	**High (4)**	**Moderate (3)**	**Low (2)**	**Very Low (1)**
Peat Landslide Likelihood (Score)	**Very High (5)**	High	High	Medium	Low	Low
	High (4)	High	Medium	Medium	Low	Negligible
	Moderate (3)	Medium	Medium	Low	Low	Negligible
	Low (2)	Low	Low	Low	Negligible	Negligible
	Very Low (1)	Low	Negligible	Negligible	Negligible	Negligible

Following the assessment of the adverse consequence scores then a recommendation is provided for the project for the actions listed Table 14 in line with Table 13. This is intended as a guide across the Site area to place infrastructure in the locations where the lowest consequences are considered.

Table 14: Adverse Consequence Risk Actions

Score	Risk Level	Action Suggested for each Area
17-25	**High**	Where high risk avoid development in these areas. This applies to all infrastructure
11-16	**Medium**	Medium risk areas should be avoided unless mitigations can be put in place that reduces the risk. Where possible the risk should be reduced to low or negligible
5-10	**Low**	Development can proceed in low-risk areas, however where there is an opportunity to reduce further to negligible through strategies such as micrositing or specific design measures these should be implemented
1-4	**Negligible**	Development can proceed following best practice guidelines and continuing mitigation of ground instability / landslide hazards as appropriate

6.2 Receptors

The receptors that are normally considered for peat upland areas are watercourses and water supplies (the water supplies considered are both public and private); terrestrial habitats (groundwater dependent terrestrial ecosystems (GWDTE)) and infrastructure. This covers both the windfarm itself, and infrastructure associated with the windfarm such as power lines, substations etc.

6.2.1 Watercourses

There are a number of minor watercourses located across the Site area. As mentioned in section 3.1.2, Kinnel Water is a designated watercourse, with a 'Good' overall status. Crook Burn flows north into the Daer Reservoir, which also has a classification of 'Good'. It is therefore considered that a consequence value rating of 3 should be applied (moderate) to these watercourses.

6.2.2 Habitats

As part of the ecological assessment the Site has been surveyed to Phase 1 Habitat methodology[13] and to National Vegetation Classification[14] (NVC). The Site supports a mosaic of habitats; however, the primary habitat types include unimproved acid grassland (B1.1), wet modified bog (E1.7), blanket sphagnum bog (E1.6.1), flush and spring – acid/neutral flush (E2.1), and wet dwarf shrub heath (D2).

[13] Joint Nature Conservation Committee, 2016. Handbook for Phase 1 habitat survey: A technique for environmental audit. Available at: Handbook for Phase 1 habitat survey

[14] Joint Nature Conservation Committee. National Vegetation Classification (NVC). Available at : NVC | JNCC - Adviser to Government on Nature Conservation

Mapped to NVC classification, bog and flush and spring habitats fall within the mires category. Wet modified bog and Blanket bog generally support M17 *Scirpus cespitosus – Eriophorum vaginatum* blanket mire, and *M20 Eriophorum vaginatum* blanket and raised mire communities. Whereas the flush and spring habitat supports communities more synonymous with groundwater including M23 *Juncus effusus/acutiflorus –Galium palustre* rush-pasture, and M6 *Carex echinata – Sphagnum recurvum/auriculatum* mire. A full assessment of the groundwater dependency will be included as part of the EIA.

Habitats will be fully assessed as part of the ecology chapter of the EIA (Chapter 6). This chapter will assess the potential for habitats to be classed as UK Biodiversity Action Plan Priority Habitats and will determine the impacts from the proposed development.

Taking into account the information above an adverse consequence rating of 3 is recommended to be used for habitats.

6.2.3 Infrastructure

The existing infrastructure is the tracks and borrow pit that relate to the previously forested area. Locogen's understanding is that the whole Site, including the previously forested area is being considered for wind farm development and so this infrastructure is considered low risk.

There is no other infrastructure within the Site boundary apart from the Kinnelhead farm and cottages. No development is considered near these locations but are included within the Site boundary as these are part of the land holding.

A windfarm is present on the southern side of the Site but again outside of the Site boundary.

It is therefore considered that there will be little impact on any existing infrastructure and a consequence rating of 1 is currently recommended.

6.3 Consequences

The consequences are very low to low across the Site area as the peat likelihood score is very low to low with the Kinnelhead Water being the considered the main consequence of the peat slide as a receptor.

A number of habitats have been identified across the area as discussed in section **Error! Reference source not found.** a nd should be considered for the overall wind farm layout. Through the development of the wind farm these habitats could be affected and so careful consideration is required as receptors from the development.

6.3.1 Further works

Once a windfarm and infrastructure layout has been finalised then a further review in detail of the proposed turbine locations and access tracks should be undertaken.

Each part of the infrastructure should be reviewed, where required a peat landslide run-out analysis is recommended to be performed using in-situ data and more detailed peat assessment.

7. RISK ASSESSMENT

Overall, the current assessment of the Site area is that the risk of a peat slide is low and so the consequences of a peat slide are also low. However, there is expected to be modifications made to the Site layout, meaning an updated assessment will be required to include the final turbine and track layout. This will be included in the phase 2 PLHRA.

There is shown to be a potential peat slide risk from the semi-quantitative assessment, however, may of the potential areas of concern are where shallow peat (less than 0.5m) is present from the initial peat probing grid. It is recommended that where these areas are impacted by the wind farm layout, a further assessment is performed.

Many assumptions have been made in this preliminary assessment relating to the peat characteristics and depth; however, a conservative approach has been taken which has not highlighted a significant risk.

8. MITIGATION AND BEST PRACTICE

Overall, the Site is low risk for potential peat instability to occur from the works, apart from a couple of small areas. However, a more detailed analysis of the Site is recommended once a Site layout is better understood.

8.1 Overview

To reduce risk further on Site, peat depths in the areas of any infrastructure should be confirmed with additional peat probing on at least a 25m grid. Peat slides are unlikely to occur where the peat depth is less than 0.5m and should be considered negligible if less than 0.2m of peat.

therefore, if peat depth is less than 0.2m then a peat slide is highly unlikely. In areas with less than 0.5m of peat, the quality of the peat should be assessed. If in the range of H1-H3 then again, a peat slide is considered unlikely.

8.2 Construction Good Practice

8.2.1 Prior to Construction

Prior to construction and once a final layout has been selected, a geotechnical risk register should be produced for each turbine; access track and any other infrastructure. These risk registers should contain the following:

- Expected peat strength and therefore the handling required based on the peat type.
- Drainage required to ensure peat downslope is not affected by the construction and operation of the wind farm.
- If floating roads are required assess the peat depth and quality to understand the design of the floating road to minimise the impact to the peat in this area.
- These documents should be live documents as more detailed information is available through the construction process.

8.2.2 During Construction

There are a number of processes that can be followed during construction and these are detailed below:

- Do not perform construction processes that removes a natural ‘toe’ of peat which could result in instability.
- Prevent drainage that crosses slopes and has the potential to increase the pore pressure within the peat.
- Whilst construction is taking place monitor both upslope and downslope of the construction areas monitoring for the formation of tension cracks; and heave or displacement observed; changes to the overall groundwater regime.
- Do not surcharge peat areas with material that has been excavated.
- Monitor the weather to assess the potential impact on peat in areas that are under construction, if there is a potential for peat to be affected by periods of heavy rainfall due to the construction stage then temporary measures may be required.
- Long dry periods of weather may also have created conditions for peat instability if the peat has partially dried out.
- Inductions for personnel on Site regarding peat and features to look out for should be included so all Site workers are aware of the risks of peat. This will also highlight areas of concern to geotechnical engineers for assessment.
- Soils should always be stripped in sequence and then stored separately to prevent cross contamination between layers.
- Do not allow soils to dry out whilst in temporary storage as could change the structure of the soil.
- Peat and soils should be stored in stockpiles no greater than 2m in height.
- Construction works should be managed to avoid excavation during periods where peat is likely to be wetter, such as high precipitation events.

9. SUMMARY AND RECOMMENDATIONS

9.1 Summary

A preliminary assessment of the Kinnelhead Wind Farm development area has been undertaken. A phase 1 peat survey has been performed on a 100m x 100m grid. A Site reconnaissance survey was also undertaken which, together with the phase 1 survey results, has informed the results presented in Section 5. From the data and information gathered so far, there is a low to very low risk of a peat slide across the Site.

A preliminary consequence assessment has also been performed, reviewing what could be impacted within the Site development area. This assessment indicates that there is a low to very low consequence from development of the Proposed Development.

The following points summarise the conclusions drawn from the assessments undertaken at this stage:

- The Kinnel Water is a designated watercourse and so a windfarm design should look to minimise interaction with the watercourse. A conservative 50m buffer has been applied to all watercourses on Site.
- The peat depths across the Site are up to 3.9m from the initial peat probing.
- From the exposed peat a von Post classification of H4-H6 is currently considered for the peat on Site. This will be reviewed during the phase 2 surveys.
- The qualitative assessment has been assessed to have either a low or very low rating with only a small area in the deforested area classified as medium.
- The semi-quantitative assessment has indicated that most of the area has a factor of safety of greater than 1.0, with many areas greater than 1.4. Where there is a rating of less than 1.0 these areas frequently associated with steeper slopes and areas of less than 0.5m peat depth.

9.2 Recommendations

Using the information that has been provided within this report an updated Site layout should be created, considering constraints identified within this report, as well as those highlighted in the scoping report.
Once a layout has been provided, it is then recommended to build on this dataset and perform a more detailed assessment but limited to the layout footprint. This would be include:

- phase 2 peat probing
    - Along access tracks on a minimum 50m spacing, with 10m offsets, and reduced spacing if significant differences are observed over a short distance (>1m difference between peat probes)
    - At the turbine locations and crane pads with 25m spacing of the area and up to 50m outside of the area to confirm the peat depths. If the peat depth changes by more than 0.5m depth across the site area, then further peat probes will be required to understand the peat depth difference over the site on a 10m grid.
- Peat Classification
    - Obtain peat samples for detailed analysis to better refine the von Post peat classification.
    - 1 sample minimum at every turbine location
    - 1 sample per every 500m of track
- Peat strength testing
    - Perform in-situ strength testing at every turbine location. Minimum 5 locations to obtain both the intact shear strength and the residual shear strength.
    - Perform in-situ strength testing along the tracks at 250m centres.
- Review all the other factors such as slope geomorphology; drainage across the Site and confirm the current preliminary qualitative assessment.

- Update the peat hazard landslide risk assessment with the new data and rerun the semi-quantitative risk assessment with in-situ geotechnical data and confirm the von Post peat classification across the Site.
- Provide a detailed risk assessment
    - For each turbine
    - For each access road
    - For any other infrastructure such as substation, borrow pits as required.

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