Appendix 6-1 Peat Landslide Hazard Risk Assessment

Knockanarragh Wind Farm

Statkraft

Prepared by:

SLR Environmental Consulting (Ireland) Ltd

35 Friary Street, Kilkenny, R95 FP62

SLR Project No.: 501.00727.00008

Client Reference No: 00727

5 March 2024

Revision: 0

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
0	5 March 2024	Paul Gordon	Alan Huntridge	Paul Gordon
	Click to enter a date.			
	Click to enter a date.			
	Click to enter a date.			
	Click to enter a date.			

Basis of Report

This document has been prepared by SLR Environmental Consulting (Ireland) Ltd (SLR) with reasonable skill, care and diligence, and taking account of the timescales and resources devoted to it by agreement with Statkraft (the Client) as part or all of the services it has been appointed by the Client to carry out. It is subject to the terms and conditions of that appointment.

SLR shall not be liable for the use of or reliance on any information, advice, recommendations and opinions in this document for any purpose by any person other than the Client. Reliance may be granted to a third party only in the event that SLR and the third party have executed a reliance agreement or collateral warranty.

Information reported herein may be based on the interpretation of public domain data collected by SLR, and/or information supplied by the Client and/or its other advisors and associates. These data have been accepted in good faith as being accurate and valid.

The copyright and intellectual property in all drawings, reports, specifications, bills of quantities, calculations and other information set out in this report remain vested in SLR unless the terms of appointment state otherwise.

This document may contain information of a specialised and/or highly technical nature and the Client is advised to seek clarification on any elements which may be unclear to it.

Information, advice, recommendations and opinions in this document should only be relied upon in the context of the whole document and any documents referenced explicitly herein and should then only be used within the context of the appointment.

Table of Contents

Tables in Text

Figures in Text

Photos in Text

1.0 Introduction

SLR Environmental Consulting (Ireland) Ltd. was commissioned by Statkraft to undertake a Peat Landslide Hazard & Risk Assessment (PLHRA) for the proposed Knockanarragh Wind Farm. The site is in the north of Co. Westmeath, immediately west of the N52, between Delvin and Clonmellon.

Statkraft proposes to develop eight wind turbines at the site, with associated infrastructure, including access tracks, cables, and an electrical substation.

The purpose of this report is to consider the potential risk of peat slides occurring at the site such that suitable controls and appropriate methodologies can be employed during construction and commissioning of the wind farm to mitigate against these risks. This report incorporates data gathered during a Phase 1 peat survey carried out at the site by SLR in October 2022, August 2023 and March 2024.

1.1 Background

The importance of assessing the stability of peat deposits in relation to wind farm developments came to the fore because of peat slides during the construction of Derrybrien Wind Farm, Ireland in 2003. Although no fatalities were associated with these failures, there was a significant environmental impact.

Wind farms tend to be constructed in upland areas which are associated typically with significant blanket peat deposits. However, the proposed development at Knockanarragh is in a low-lying area, with an undulating topography with no significant hill slope gradients.

Peat instability is influenced by many factors, including, but not limited to, peat thickness, hill slope gradient, underlying geology and subsurface hydrology.

1.2 Objectives of Report

This PLHRA is primarily concerned with the potential influence of the peat on the development of the wind farm. The main objective is to assess the potential peat stability at the proposed development, identify areas of potential concern and identify mitigation measures to ensure the maintenance of peat stability before, during and after construction. All aspects of construction should be based on ensuring minimum disruption to the peat areas.

This PLHRA is based upon the following:

- Desktop review of available desktop data, including:
  - Environmental Protection Agency (EPA) and Teagasc soil and subsoil data;
  - Geological Survey of Ireland (GSI) bedrock and geomorphological data;
  - Satellite (Google and Bing) imagery (see Figure 1).
- Site walkover; and
- Peat probing and sampling carried out in the vicinity of proposed turbine locations T1, T3 and T7

1.3 Site Location and Description

The proposed development is c. 2.8km northeast of Delvin, in Co. Westmeath. The site can be accessed directly from existing agricultural entrances and access tracks from the N52 and local roads to west and northwest of the N52. The site covers an area of c. 331Ha. The site borders the River Boyne and Blackwater SAC (2299) to the north, northwest, west and southwest.

The site consists of a mixture of agricultural land, primarily grazing, and forestry. Some of the forestry is on land that was previously used for peat extraction. There is an active quarry in the northern part of the site, immediately to the south of proposed turbine location T3. The quarry, its access road and associated lands cover c. 18.6ha and are excluded from the proposed site. There are a few small ponds to the east and southeast of the quarry. They have the appearance of turloughs but are not listed as such by the GSI.

The land is generally flat to gently undulating, with a very gradual slope from c. 100m AOD in the west to c. 80m AOD in the east. The lowest point is along Darcy's Crossroads Stream, which forms part of the northwest boundary of the proposed development, near turbine locations T1 and T2. The highest point in the site is at 103m AOD, c. 780 southeast of turbine location T3.

There are several eskers running through the area, some of which show signs of having been locally used for sand and gravel extraction. There are no residential properties within the site but there are some along the N52, c. 1km southeast of turbine location T3.

Photo 1: Typical Agricultural land near location T8. Esker slope on right hand side.

Photo 2: Boggy land near proposed locations T1, T2 and T3.

Photo 3: Exposed esker c. 500m southwest of location T2.

1.4 Project Description

The project is likely to comprise the following:

- Eight (8) no. wind turbines with tip heights of 175m – 180m inclusive;
- Permanent foundations supporting the wind turbines and associated crane hard standings (used during construction, operational repair and decommissioning);
- An external transformer at the base of each turbine;
- Up to 6km of permanent tracks into the site from public roads,
- Underground cabling within the wind farm site;
- One (1) no. electrical substation with access track, cabling and hardstanding west of Clonmellon.

In addition, the following activities will be required during the construction phase of the project:

- Establishment of temporary site laydown areas/construction compound;
- Establishment of a construction compound;
- Extraction of stone from two borrow pits; and
- Removal and management of material during foundation and track construction

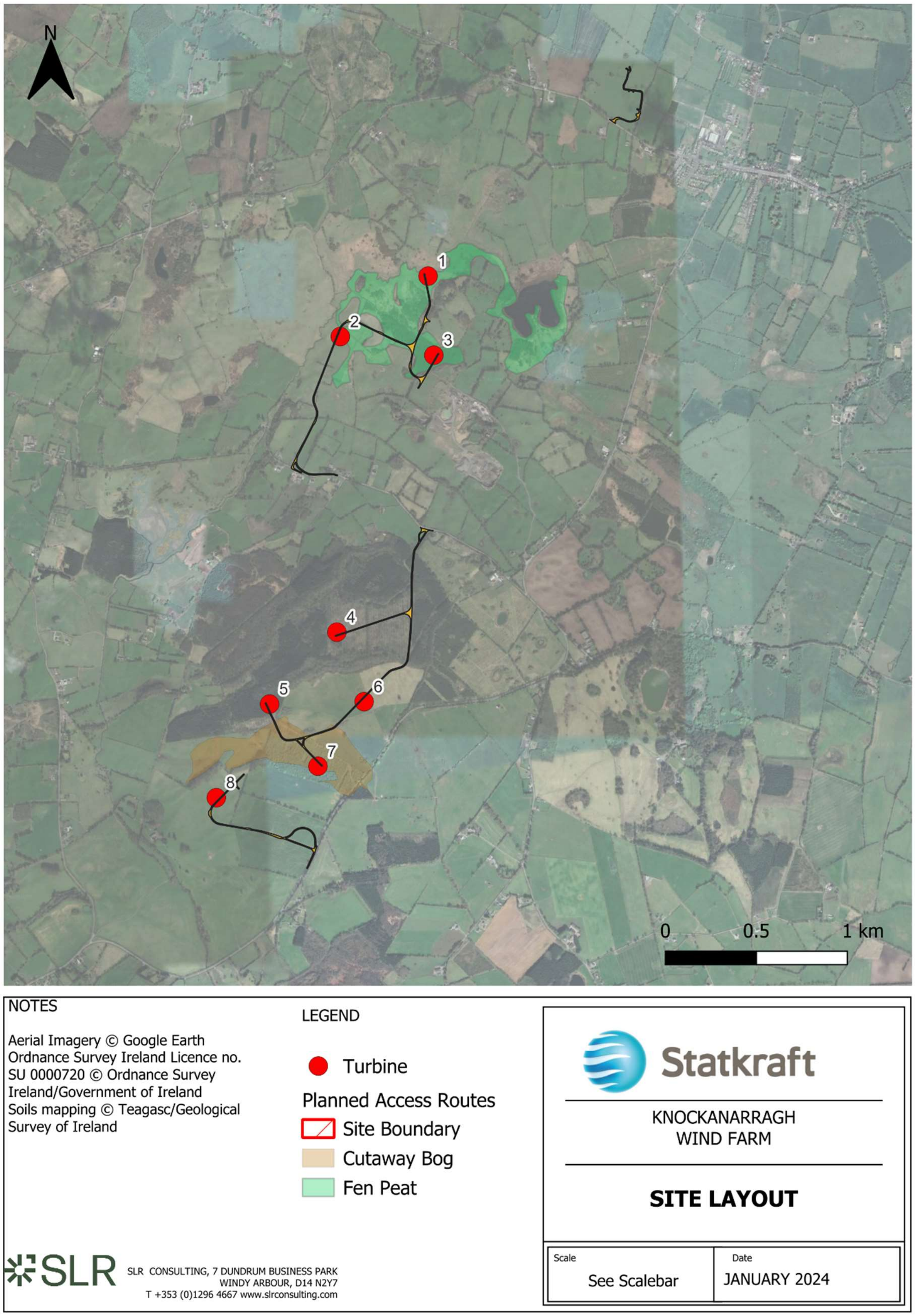

Figure 1: Proposed Site Layout

2.0 Site Baseline

The site baseline has been developed using available data, an initial site walkover and Phase 1 peat probing and sampling.

2.1 Geological Setting

2.1.1 Superficial Geology

The superficial geology at the site has been mapped and classified by Teagasc and the EPA and the soil associations underlying the site (see

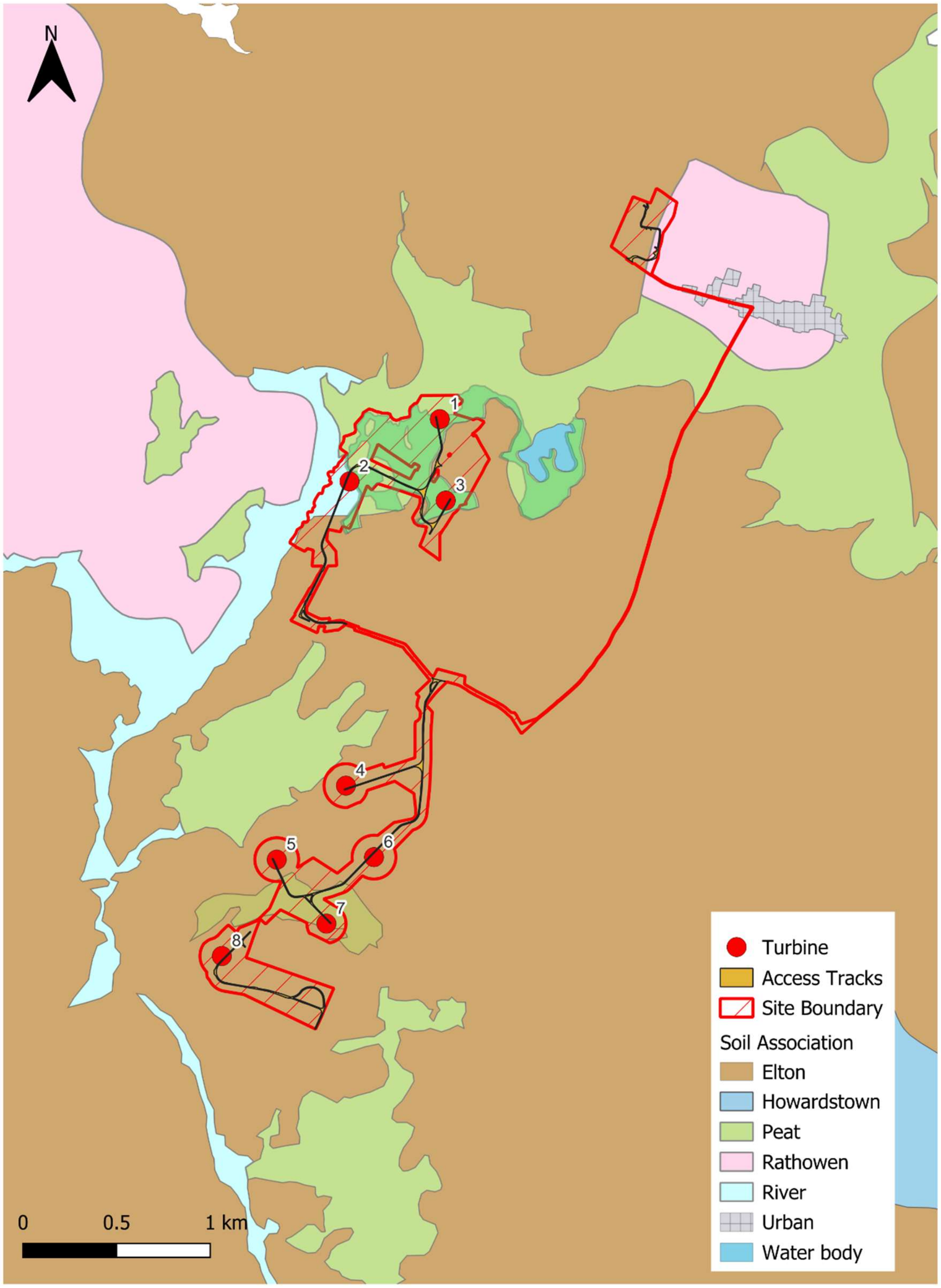

Figure 2: Soil Associations at the Proposed Site

) are:

- Elton series, derived from glacial till;
- Peat; and
- River Alluvium.

There are two relevant areas of peat mapped; in the north of the site, underlying T1, T3 and in the south, underlying T7. Previous mapping by Teagasc has identified the northern peat area as fen peat, and the southern area as cut peat/cutaway bog.

Both areas were selected for further investigation, with the cut peat area being less likely to have significant thicknesses of peat. Satellite/aerial imagery from 1995 indicates that peat was being harvested commercially at that time. The area is now underlain by forestry and agricultural land.

Most fen peats in Ireland have been drained for agriculture and it appears that this occurrence has been at least partially drained. Fen peats typically have poor drainage and are suitable for grazing only. They can be important habitats from an ecological perspective.

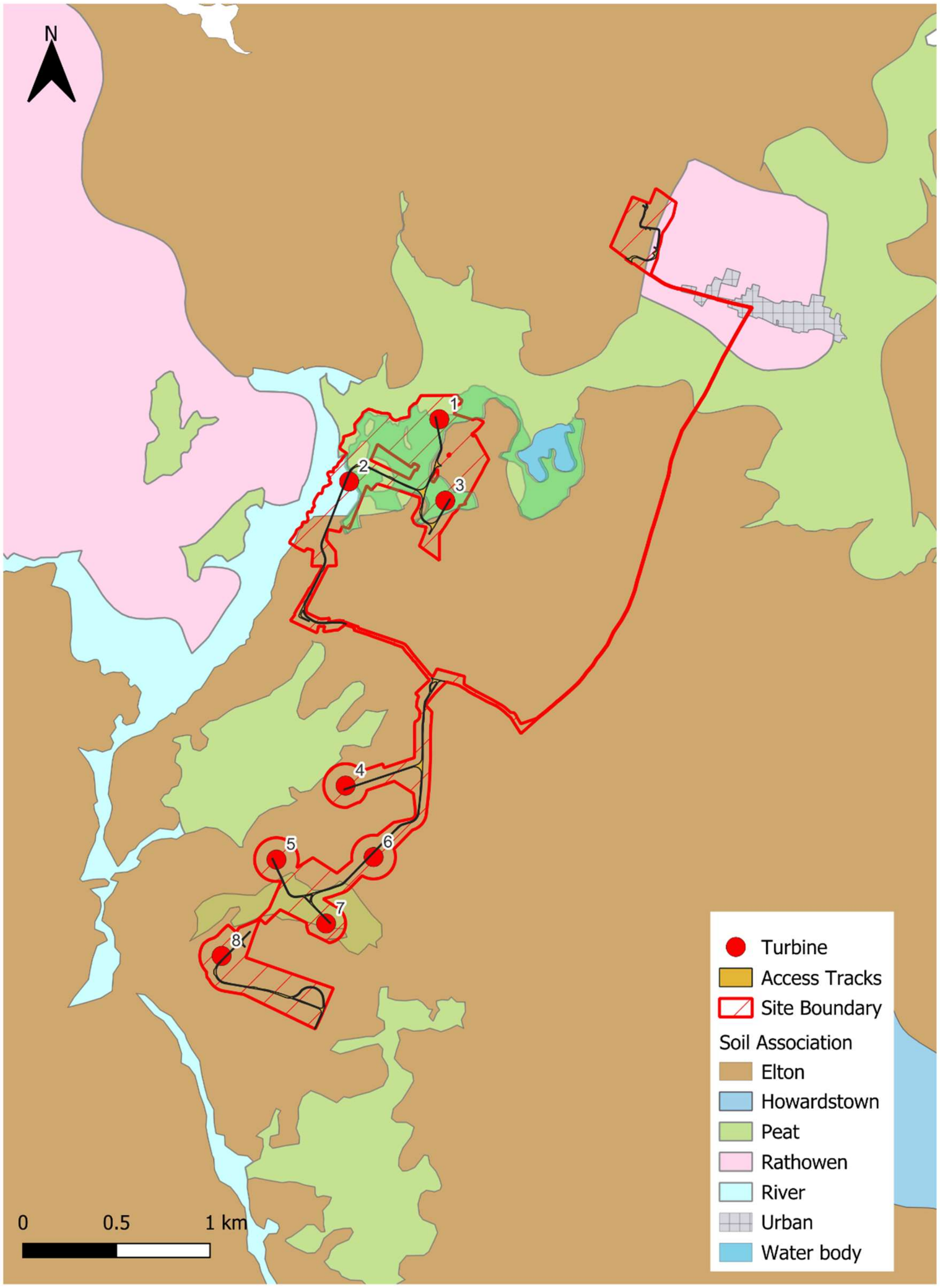

Figure 2: Soil Associations at the Proposed Site

2.1.2 National Landslide Susceptibility

The GSI's landslide susceptibility classification map for the area was reviewed. More than 90% of the site, including all proposed access tracks and turbine locations, are classified as low or low (inferred) for landslide susceptibility (see Figure 3). There are some small zones classified as moderately low on the margins of the site; given the location of these areas at the site in relation to the proposed development it is considered that the risk to the proposed development is negligible.

Photo 4: Forestry at the area mapped as cut peat.

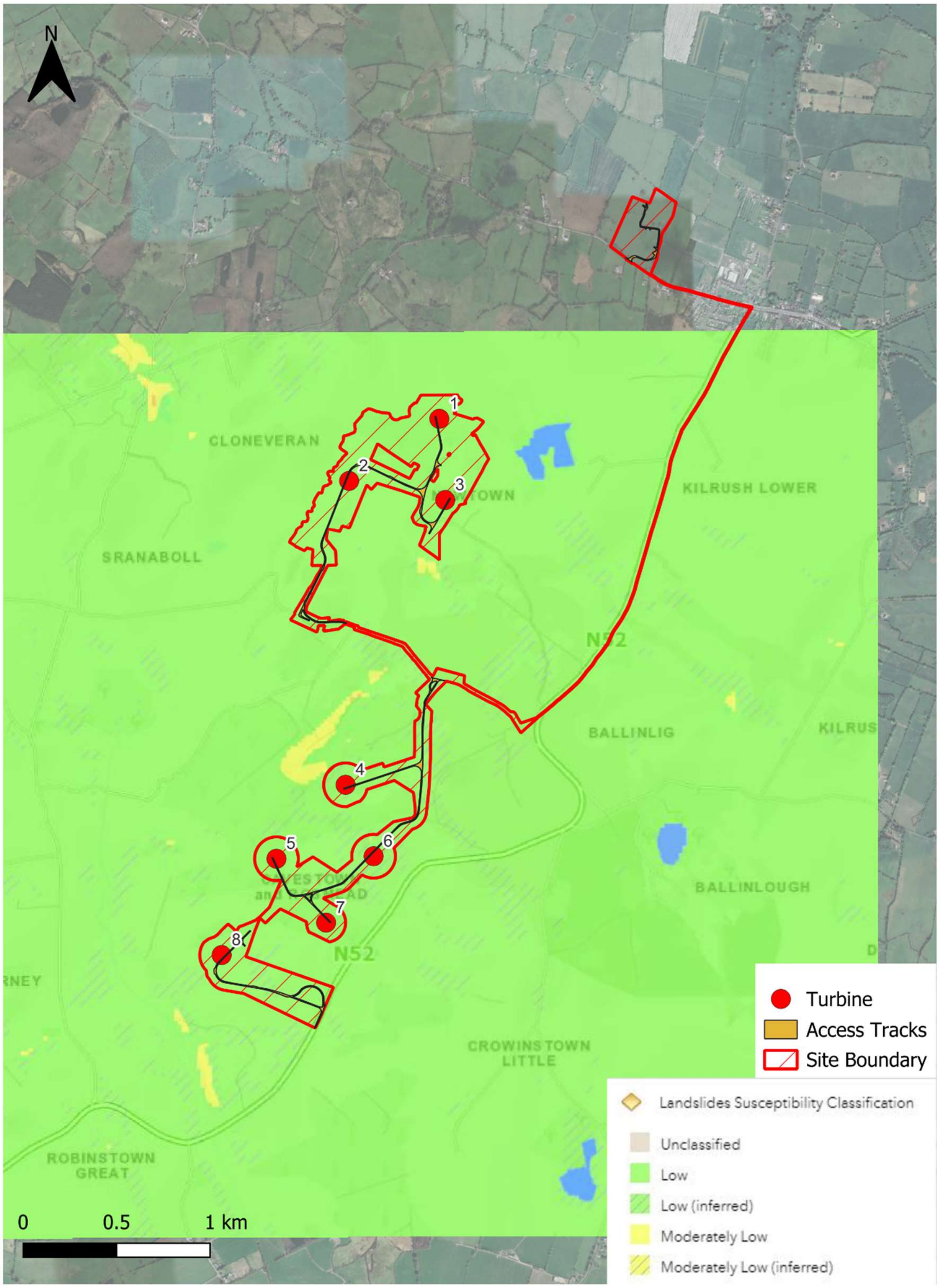

Figure 3: Landslide Susceptibility for the site (GSI)

Photo 5: Undulating land near location T2

2.1.3 Bedrock Geology

The proposed site is entirely underlain by the Lucan Formation, a Lower Carboniferous mixed package of limestones and shales with chert bands. The Lucan Formation occurs extensively throughout the Dublin basin, an area extending westwards from County Dublin, through the central and northern midlands. The Lucan Formation in this area is described by the GSI as a locally important aquifer which is moderately productive only in local zones.

There is no bedrock outcrop recorded by GSI at the site. There is one quarry, which is active and has not been visited to date and is not part of the site.

No major geological structures are recorded at the site on the GSI mapping. One northwest trending fault is interpreted to terminate close to the western boundary of the site. However, given the lack of variation in the bedrock geology and the relative lack of outcrop, it is not likely that the location of such faults can be known with any certainty.

2.1.4 Mining and Quarrying

One existing quarry has been identified to the north, outside the Site boundary (see Figure 1). No other active quarries are known. It is likely that some of the eskers have been used as a source of gravel at a very local level, but there is no evidence of commercial production apart from the quarry that has already been identified.

2.1.5 Hydrology

The site drains into the D'Arcys Crossroad Stream, which in turn drains into the Stoneyford River and ultimately to the River Boyne. The hydrological network into which the site drains is part of the River Boyne and River Blackwater SAC. D'Arcys Crossroad Stream is given a water quality classification of 'moderate'.

There is a cluster of small ponds, thought to be turloughs, in the northern part of the site, southeast of the quarry.

2.1.6 Hydrogeology

The aquifer underlying the study area is classified by the GSI as Locally Important Aquifer (LI), which is bedrock which is moderately productive only in local zones. This refers to the Lucan Formation Calp bedrock of dark limestone and shale.

The GSI shows the presence of localised eskers across the study area, these are not classified as aquifers and there is no gravel aquifer in the study area.

All of the proposed turbines are underlain by the Athboy Groundwater Body. Both substation layouts are located close to the boundary of the Athboy and Newtown Lough Fen Groundwater Bodies. The substation excavations are not expected to extend into the bedrock aquifer and so there will not be any direct pathway between the substation construction works and Newtown Lough Fen Groundwater Body.

2.2 Rainfall

Storm Events, or periods of intense heavy rainfall, are often seen as a trigger for instability events. Data provided by Met Eireann for the Robinstown weather station (see Figure 4), c. 6 km northeast of the site, shows that the average monthly rainfall (2012-2023) is 81.7 mm, while the maximum monthly rainfall in that period was 238.2 mm, with only five months having a total rainfall of >200 mm.

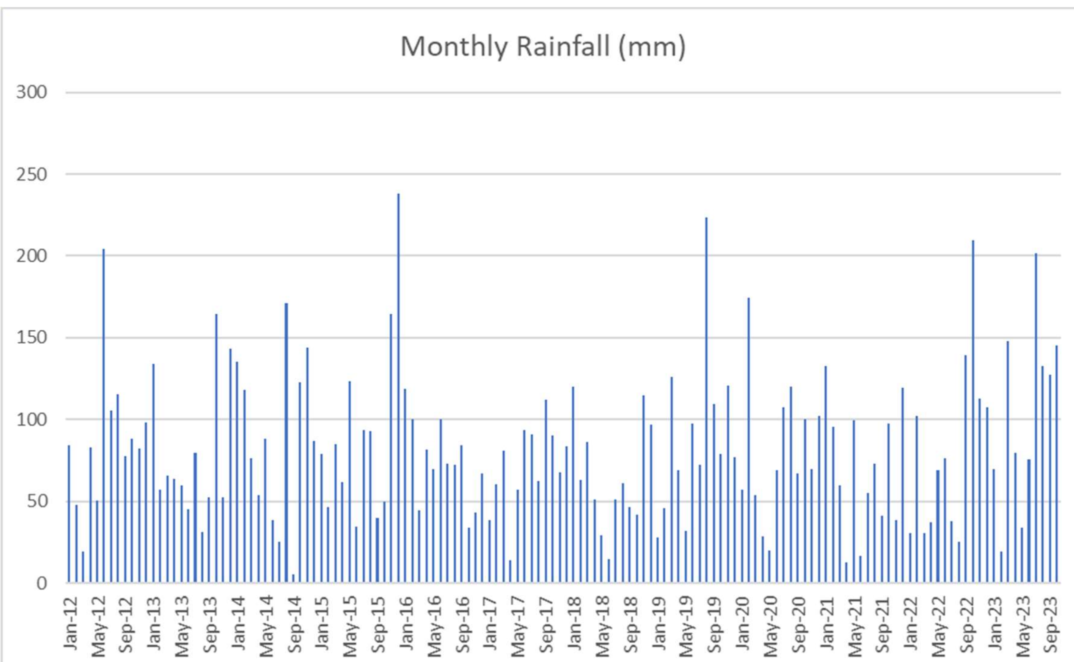

Figure 4: Total Monthly Rainfall at Robinstown Weather Station (2012-2023)

3.0 Peat Instability

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

- Significant peat depths over impermeable bedrock or minimal soil;

- The presence of slope gradients greater than 4° (approximately) and general topography;
- Natural drainage paths;
- Evidence of past failures, including soil creep;
- Drainage features at the base of slopes which could lead to undercutting;
- Forestry plantations and artificial drainage; and
- Recent climate patterns.

It should be noted that peat instability is not a recent phenomenon and there is documentary evidence of peat landslides dating back over 500 years[1]. Many landslides that involve peat have no human interference that could be considered as a trigger and this should be borne in mind when considering the susceptibility of a site to potential instability.

3.1 Occurrence and Development of Peat

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

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

Lindsay[2] defined two main types of peat bog, raised bog and blanket bog, which are prevalent on the west coast of Europe along the Atlantic seaboard. In Ireland, the dominant peatland is raised bog which occurs in the midlands where glacial lakes were once present. Raised bog is predominantly supplied with water and nutrients in the form of precipitation. Blanket peat is usually considered to be hydrologically disconnected from the underlying mineral layer. Fens are peatlands that in addition to precipitation, also receive groundwater[3]. Fens tend to accumulate in areas of low relief.

There are two distinct layers within a peat bog, the upper acrotelm and the lower catotelm. The acrotelm is the fibrous surface to the peat bog[4], typically less than 0.5 m thick; which exists between the growing bog surface and the lowest position of the water table in dry summers. Below this are various stages of decomposition of the vegetation as it slowly becomes assimilated into the body of the peat.

---

[1] Smith, L.T., (Ed) (1910), 'The literary of John Leland in or about the years 1535-1543.' Vol.5, Part IX. London: AF Bell and Sons.

[2] Lindsay, R.A., (1995), 'Bogs: The ecology, classification and conservation of Ombrotrophic Mires.' Scottish Natural Heritage, Perth.

[3] National Parks and Wildlife Service, (2015). 'National Peatlands Strategy'.

[4] Ingram, H.A.P., (1978), 'Soil layers in mires: function and terminology'. Journal of Soil Science, 29, 224-227.

A fen is a wetland system with a permanently high water level at or just below its surface. It's principal source of nutrients is from surface or groundwater and the substrate is an alkaline to slightly acidic peat soil. The vegetation is usually dominated by sedges. Fens occur throughout the country, most commonly in the west and midlands of Ireland[5].

For geotechnical purposes the degree of decomposition (humification) can be estimated in the field by applying the 'squeezing test' proposed by von Post and Grunland[6] (1926). The humification value ranges from H1 (no decomposition) to H10 (highly decomposed). The extended system set out by Hobbs[7] provides a means of correlating the types of peat with their physical, chemical and structural properties.

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

3.1.1 Peat Shear Strength

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

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

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

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

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

[5] Irish Peatlands Conservation Council https://www.ipcc.ie/a-to-z-peatlands/fens/

[6] von Post, L. and Grunland, E., (1926), 'Sodra Sveriges torvillganger 1' Sverges Geol. Unders. Avh., C335, 1-127.

[7] Hobbs, N.B., (1986), 'Mire morphology and the properties and behaviour of some British and foreign peats.' Quarterly Journal of
Engineering Geology, London, 19, 7-80.

particles to give the material a significant frictional resistance. It should be noted, however, that any quotation of shear strength for peat should be treated with extreme caution.

3.1.2 Peat Stability

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

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

- The geographical limits which could be affected by potential instability are not confined to the artificial boundaries imposed by land ownership; landslip occurring above a site could affect the site and property down slope or downstream of the site for several kilometres.
- Agriculture and grazing have a substantial effect on peat areas, and this can be compounded in areas that have been managed to improve grazing. Grazing compacts the peat surface reducing the rainwater infiltration and the additional nutrients change the ecological balance of the original peat bog. Agricultural management can include surface drainage and periodic burning, both of which can leave the surface of the peat bare for a period of time resulting in temporary desiccation of the surface. Subsequent wetting of the peat and resumption of peat accumulation results in the former desiccated and possibly ash covered surface being incorporated into the body of the peat which introduces a weak discontinuity in the profile; this in turn becomes another unknown factor in the stability assessment.
- Forestry has a substantial effect on slope stability particularly in the early stages as the creation of a forest involves disruption of the natural equilibrium and drainage of the slopes and the installation of artificial drains by deep ploughing. The construction of access tracks further disrupts the drainage and concentrates groundwater flow into narrow, fast flowing erosive streams. The work by Winter et al[8] noted that forest tracks can act to retard or concentrate the down slope flow of water and thus aid its penetration into the slope below.
- Natural Drainage – some of the precipitation falling onto a natural upland peat bog would be absorbed into the low permeability catotelm peat. However, most of the water would run-off as sheet flow through upper, high permeability acrotelm. Thus, the water is transmitted to the lower slopes in a reasonably controlled manner through a range of interconnections that operate at different scales and speed. Failure to understand this and to disrupt the transmission process for the groundwater could result in instability.
- Artificial Drainage - where agricultural drainage has been used to improve the quality of the grazing or to promote forestry it reduces the overall volume of water entering the bog and transfers this water to the edges more rapidly. This can result in ditches and

[8] Winter, M.R., Macgregor, F. and Shackman, L. (2005a), 'Scottish tracks networks landslide study' Trunk tracks: network management division, published report series. The Scottish Government.

streams becoming enlarged, causing increased erosion and a greater silt burden in the stream water.

3.2 Peat Mass Stability

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

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

3.2.1 Types of Failure

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

- Bog Bursts or Bog Flows – the emergence of a fluid form of well humified, amorphous peat from the surface of a bog, followed by the settling of the residual peat, in-situ9;
- Peat Slides – the failure of the peat at or below the peat/ substratum interface leading to translational sliding of detached blocks of surface vegetation together with the whole underlying peat stratum8; and
- Bog Slide – an intermediate form of instability where failure occurs on a surface within the peat mass with rafts of surface vegetation being carried by the movement of a mass of liquid peat.

3.2.2 Bog Bursts

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

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

[9] Dykes, A.P and Kirk, K.J., (2001), 'Initiation of a multiple peat slide on Cuilcagh Mountain, Northern Ireland.' Earth Surface Processes and Landforms, 26, 395-408.

[10] Crisp, D.T., Dawes, M. & Welch, D. (1964), 'A Pennine Peat Slide', The Geographical Journal, Vol 130, No4, pp519-524

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

3.2.3 Peat Slides

Peat slides tend to be translational failures with a defined shear surface at or close to the interface with the substrate.

The factors generally considered to influence susceptibility to peat slide failures are listed below:

- Peat depth up to 2.0m;
- Slope gradients between 5° and 15°;
- Natural or artificial drainage cut into the surrounding peat landscape;
- Greater humification of the lower catotelm within the waterlogged ground; and
- Lower surface tensile strength of the fibrous peat and vegetation.

It is noted that some of the factors causing instability are common to both bog bursts and peat slides.

The peat – substrate interface is the primary zone of failure and is enhanced by elevated water content at this boundary and softening or weathering of the lower mineral surface. For this reason, any investigation or probing should try to distinguish the nature of the lower mineral substrate.

3.2.4 Bog Slides

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

3.2.5 Natural Instability

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

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

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

4.0 Site Work

4.1 Peat Depth Survey

4.1.1 Methodology

The surveys carried out followed best practice guidance for developments on peatland[10].

Given the limited occurrence of peat at the site, it was determined that it was necessary to survey the area around proposed turbine location T1, and associated access tracks, as it is the only one affected by peat.

The initial survey was undertaken in October 2022, by Sam Irwin and Saul Sanchez, two of SLR's field geologists.

A second survey was undertaken in August 2023, by Saul Sanchez and Hannah McGillycuddy. This second survey was undertaken only in the area of T1. The proposed location of T1 was moved slightly westwards since the October 2022 survey and a second survey was therefore conducted. Following a similar location change for T3, a final survey was undertaken by Paul Gordon and Hannah McGillycuddy in March 2024.

All surveys were designed by Paul Gordon, with input from Colin Duncan. Colin has conducted PLHRAs in Scotland and Ireland for >20 years. Paul has >25 years' experience as a geologist, having designed and implemented site investigation on a range of projects, in Ireland and internationally.

4.1.1.1 Peat Depth Analysis

Peat surveying took place in October 2022, September 2023 and March 2024. For the first survey, the thickness of the peat was assessed using a graduated fibre glass peat probe, which can be extended to over 10 m depth. The second survey used a shorter peat probe with a maximum probe depth of 1.2m. This was pushed vertically into the peat to refusal and the depth recorded, together with a unique location number and the coordinates from a handheld Global Positioning System instrument (GPS). The accuracy of the GPS was quoted as ±4 m, which was considered sufficiently accurate for this preliminary reconnoitre.

The third survey used an extendable probe with a maximum penetration of 2.6m. This survey was undertaken in an area of thick tree cover, resulting in poor GPS coverage, therefore the probing locations were measured for distance and compass bearing from known points on the map.

All data were uploaded to a PC for incorporation into various figures and analysis assessments. Where the peat probing met refusal on a hard substrate, the 'feel' of the refusal can provide an insight into the nature of the substrate. The following criteria were used to assess likely material:

- Solid and abrupt refusal – rock;
- Solid but less abrupt refusal with grinding or crunching sound – sand or gravel;
- Rapid and firm refusal – clay; and
- Gradual refusal – dense peat or soft clay.

The peat depth data has been incorporated into various figures and analysis assessments included within this report.

A peat auger was used to recover disturbed samples from a range of depths for an estimate of moisture content. The auger was also used to determine the thickness of the peat and to recover samples of the substrate when the material is cohesive.

5.0 Slope Stability/Ground Conditions

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

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

5.1 Shear Strength

The strength of the peat in the upper acrotelm is significantly influenced by the root and fibres that are abundant in this layer. There are many influences on the stability of the peat and observing or measuring high shear strength should not be used to assume a high degree of stability. The peat observed at the site has a strong root and fibres system and remains competent after hand-digging.

5.2 Stability Risk Assessment

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

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

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

5.3 Peat Survey Results

The results of the probing exercise are detailed in the following sections and the peat depths identified on-site are shown in Figure 4 – Peat Depth. The peat survey at the south area (in October 2022), mapped as cut bog, found no peat. The area had previously been visited as part of the site walkover and no peat was observed. This was confirmed by the peat probing survey. Sample points for the south area are shown in Figure 6.

5.3.1 North Area Fen Peat

The peat was found to vary across the site in terms of thickness and coverage in both the October 2022, August 2023 and March 2024 surveys. The slopes on-site are detailed in Figure 5. When viewed in conjunction with the Peat Depth Plans (Figure 6), it is evident that the peat is generally limited to flat expanses that mimic the topographic flat lying areas.

A total of 153 probe holes were undertaken, with the results summarised in

below.

Table 1: Peat Probing Data

Peat Thickness (m)	No. of probes	Percentage of total probes
0 (no peat)	13	8%
0.01 - 0.49	14	9%
0.5 - 0.99	51	33%
1.0 - 1.49	30	20%
1.5 - 1.99	31	20%
2.0 - 2.49	8	5%
2.5 - 2.99	3	2%
3.0 - 3.49	1	1%
3.5 - 3.99	1	1%
4.0 - 4.49	1	1%
Total	153	100%

In summary, the peat surveys shows that:

- Peat across the area varies in terms of thickness, from 0.1m to 4.0m. 70% of the area surveyed either has no peat developed, or has a peat thickness of <1.5m;
- Peat development in the immediate vicinity of proposed location T1 is limited
- Peat development in the immediate vicinity of proposed location T3 is variable in thickness
- The thickest peat is associated with particularly flat topography (<1° of slope);
- As expected for fen peat, it is developed in a relatively low-lying area.

Accumulations of peat up to 0.5m thick are considered to be too thin to be classified as true peat deposits and are often classified as organic soils or peaty soils.

The underlying soil/peat thickness at each location was recorded and the data used to draw the interpreted peat thickness map, presented as Figure 6.

In most cases, the peat is underlain by clay or peaty clay. Gravel is also present as a substrate.

5.3.2 Peat Condition

The probing investigation identified the following characteristics within the peat:

- Soft to firm from surface to base of peat;
- Vegetation present throughout the profile; and
- Peat is competent, with probe holes remaining open to their full depth when the probe is withdrawn.

SLR supplemented the probing with a hand auger to confirm the nature of the peat and substrate at depth. The substrate is peaty clay, which is quite stiff.

Table 2: von Post Classification for Peat Humification

Degree of Humification	Decomposition	Plant Structure	Content of Amorphous Material	Material Extruded on Squeezing	Nature of Residue
H1	None	Easily identified	None	Clear, colourless water	Not pasty
H2	Insignificant	Easily identified	None	Yellowish water	
H3	Very slight	Still identifiable	Slight	Brown, muddy water; no peat	
H4	Slight	Not easily identifiable	Some	Dark brown, muddy water; no peat	Somewhat pasty
H5	Moderate	Recognisable but vague	Considerable	Muddy water and some peat	Strongly pasty
H6	Moderately strong	Indistinct (more distinct after squeezing)	Considerable	About ⅓ peat squeezed out; water dark brown	Fibres and roots more resistant to decomposition
H7	Strong	Faintly recognisable	High		
H8	Very strong	Very indistinct	High	About ⅔ peat squeezed out; also some pasty water	
H9	Nearly complete	Almost unrecognisable		Nearly all the peat squeezed out as a uniform paste	Fibres and roots more resistant to decomposition
H10	Complete	Not discernible		All the peat passes between the fingers; no free water visible	

Based on field observations, most of the peat would be classified as H2 to H4, showing no significant decomposition. The peat is quite fibrous and competent.

6.0 Peat Landslide Hazard and Risk Assessment

A peat landslide hazard and risk assessment has been undertaken for the site. Prior to peat probing, a joint site visit by Statkraft and SLR, comprising a geologist, an engineer and planners, and appraisal of the data, the potential for a peat slide occurring at the site was initially assessed as negligible, this was based on the fact that:

- Although there is some peat present on-site, the wind farm infrastructure has generally avoided the thickest areas of peat;

- No evidence of historical or current peat slide activity was observed at the site (having reviewed historical imagery dating back to 1985);
- There is little elevation change across the site, with the topography best described as slightly undulating; and
- Conclusions of a detailed walkover and results from probing.

Where areas of medium and high risk peat instability are present, then further assessment is necessary.

To further quantify this initial assessment, analysis of the terrain at site utilising GIS has been undertaken to analyse slopes and gradients, as shown on Figure 5. The site-specific slope data has been combined with site specific peat depth data and using Irish Government guidance for the assessment of the risk of instability in peat, an assessment of peat slide risk has been completed.

The method of risk and hazard assessment has been developed with reference to the Irish Guidance[11]. Key factors which may have an effect on the stability of the peat deposits have been identified leading to an assessment of the **RISK** of peat instability. The potential impact of any instability, the **HAZARD**, was then considered for identified potential receptors. Scores were attributed to the key factors that have the greatest influence on peat stability.

Risk scores were determined, which, when combined with an assessment of vulnerability of potential targets, were developed into an assessment of the hazard. In order to differentiate between risk and hazard, the following nomenclature has been adopted (see Table 3).

Table 3: Risk and Hazard

Risk	Hazard
Negligible	Insignificant
Low	Significant
Medium	Substantial
High	Serious

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

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

The stability of peat is a complex subject and there are numerous inter-relationships that affect the stability.

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

The characteristics of the peat failure phenomena have been incorporated in a stability risk assessment to evaluate the risk of instability occurring within the peat areas. The main factors

[11] Dept of Housing, Planning & Local Government (2019). Draft Revised Wind Energy Development Guidelines.

controlling the stability of the peat mass are the surface gradients, the depth and condition of the peat at each location and the type of substrate.

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

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

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

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

6.1 Slope Gradient

The site is generally flat-lying, with local undulations. The steepest slopes are associated with eskers. While eskers can be up to several km in length, in this area, they are quite narrow, c. 20m, so it is relatively straightforward to avoid them.

Open-source slope and elevation data from the EU Copernicus programme have been used to generate a digital terrain model (DTM) and a gridded image of slope angles in the area (see Figure 5).

By simple inspection it is clear that steeper slopes pose a greater risk of instability than shallow gradients. Therefore, a graduated gradient scale from 0° to >12° (the practical maximum gradient on which peat is commonly observed) has been applied (see Table 4).

Table 4: Coefficient for Slope Gradients

Slope Angle (degrees)	Slope Angle Coefficient
<2	1
2-4	2
4-8	4
8-12	6
>12	8

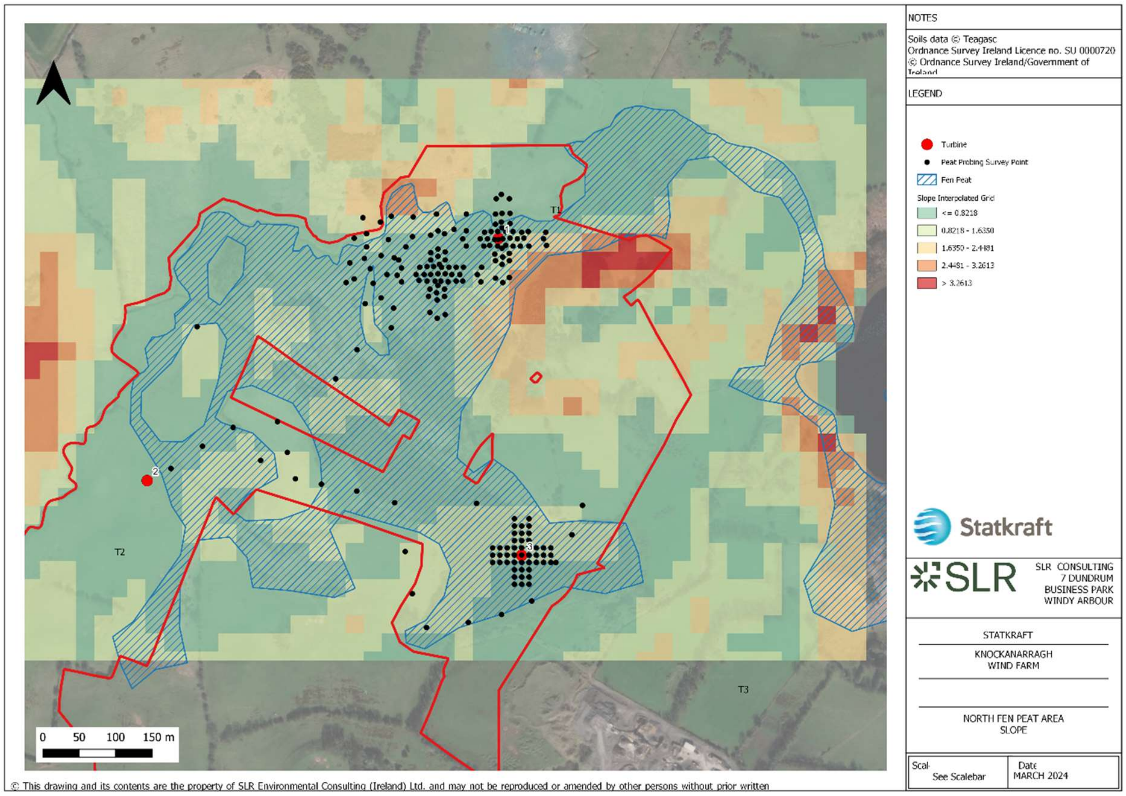

Figure 5: Slope Analysis at North Fen Peat Area

6.2 Peat Thickness and Ground Conditions

The ground conditions were assessed by using peat depths recorded during peat probing. Thin peat was classed as being 0.5m to 1.5m thick, with deposits in excess of this being classed as thick. The thickness ranges used are intended to reflect the risk of instability associated with both peat slides (in thin peat) and bog slides. Where the probing recorded peat less than 0.5m thick, this has been considered to be an organic soil rather than peat. Table 5 gives the coefficients applied to the various ground conditions. Figure 6 shows peat thickness in the north fen peat area.

Two zones of relative peat thickness (>2.5m) have been identified 80-100m from proposed turbine location T1 (see Figure 6). The largest, c.540m^2, is c.100m to the southwest of T1. There is a more limited zone centred around a single survey point c. 90m west-southwest of T1. No temporary or permanent infrastructure is planned for either of these locations and it is therefore thought that the risk of instability in relation to these areas is negligible.

The peat depth around T3 varies from 0.4m to 2.6m, with an average of c.1.45m. Thickness in this area varies considerably, with no real pattern. The presence of tree roots means that the peat is particularly competent. In areas with relatively shallow peat, <1.0m, some refusals may be due to tree roots, although more than one attempt to insert the probe further into the ground was made in all such cases.

There is no evidence on site of current or historic instability.

Table 5: Coefficients for Peat Thickness and Ground Conditions

Ground conditions	Ground conditions coefficient
Peaty or organic soil (<0.5 m)	1
Thin Peat (0.5 – 1.5 m)	2
Thick Peat (>1.5 m)	3*
Slips /collapses / creep / flows	8

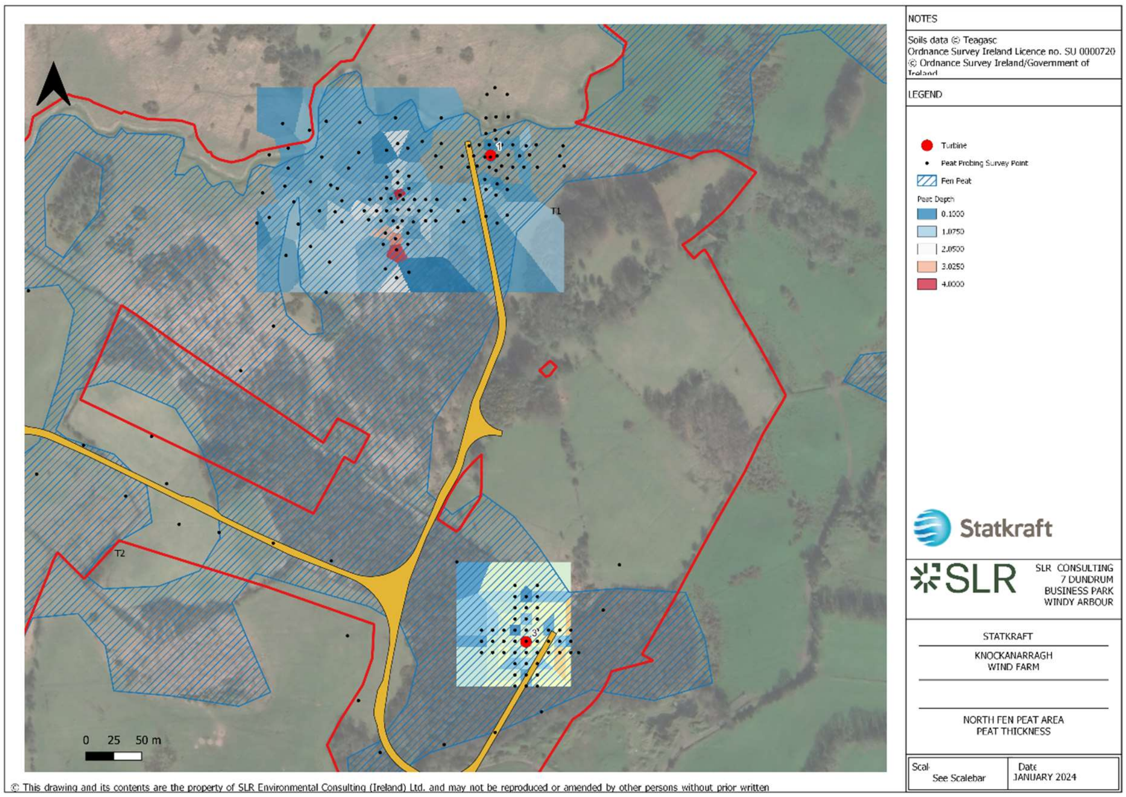

Figure 6: Peat Thickness (metres) in the North Fen Peat Area

6.3 Substrate

As noted above, most failures in thin peat layers occur at the interface with the underlying substrate; the nature of the substrate has a very large influence on the probable level of stability. Where sand and/or gravel (derived from glacial till) form the substrate, the effective strength of the interface can be considered to be good with comparatively high friction values. Under these conditions, failure is likely to occur in a zone within the peat, just above the interface. Further factors are necessary to cause a failure of this nature (increased pore pressures within the peat) and occurrence of such events is rare.

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

A rock substrate provides a high strength stratum, however, the rock surface can be smooth, and, depending on the dip orientation of the strata, it can provide a very weak interface. For these reasons, at this stage, a rock interface has been given the same risk rating as clay. The coefficients for substrate conditions are given in Table 6, below.

Table 6: Coefficients for substrate conditions

Substrate Conditions	Substrate Coefficients
Sand/gravel (granular)	1
Clay	2
Rock	2
Not proven	3
Slip material (Existing materials)	5

When the overall thickness of the peat is not proven, a higher risk rating is applied to accommodate unknown factors.

6.4 Risk Rating

The risk rating coefficient (score) was derived by multiplying the coefficients for the key factors (with historic instability as 1) identified the above sections together to produce a risk rating which is a measure of the likelihood of peat instability, and this enables potential areas of concern to be highlighted.

For the stability risk assessment, Potential Stability Risk classes were applied as shown in Table 7.

Table 7: Risk Rating

Risk Rating Coefficient	Potential Stability Risk (Pre- Mitigation)	Action
<5	Negligible	No mitigation action required.
5 - <15	Low	As for negligible condition plus development of a site-specific construction and management plan for peat areas.
15 - <31	Medium	As for Low condition plus may require mitigation to improve site conditions.
>31	High	Unacceptable level of risk, the area should be avoided. If unavoidable, detailed investigation and quantitative assessment required to determine stability and sensitivity to minor changes in strength and groundwater regime combined with long term monitoring.

The rating system used here has been established by SLR over many years of undertaking PLHRA and is considered to be very robust. The consideration of substrate in the assessment adds an impact that is not considered by some guidelines.

Of the 135 locations that were probed in areas of peat development, 43 have been classified as low risk and 92 as negligible risk (see Appendix A). No medium or high-risk locations were identified. These quantitative results are consistent with observations made during the site walkover and the subsequent peat probing survey.

Of the 35 closest locations to proposed turbine location T1, 24 are classified as negligible risk and 11 as low risk. All probe locations along proposed access tracks have been classified as negligible risk (see Figure 7).

Of the 51 closest locations to proposed turbine location T3, 21 are classified as negligible risk and 30 as low risk (see Figure 7).

Given the overall negligible to low risk of peat instability at the site, a hazard ranking is not considered to be necessary.

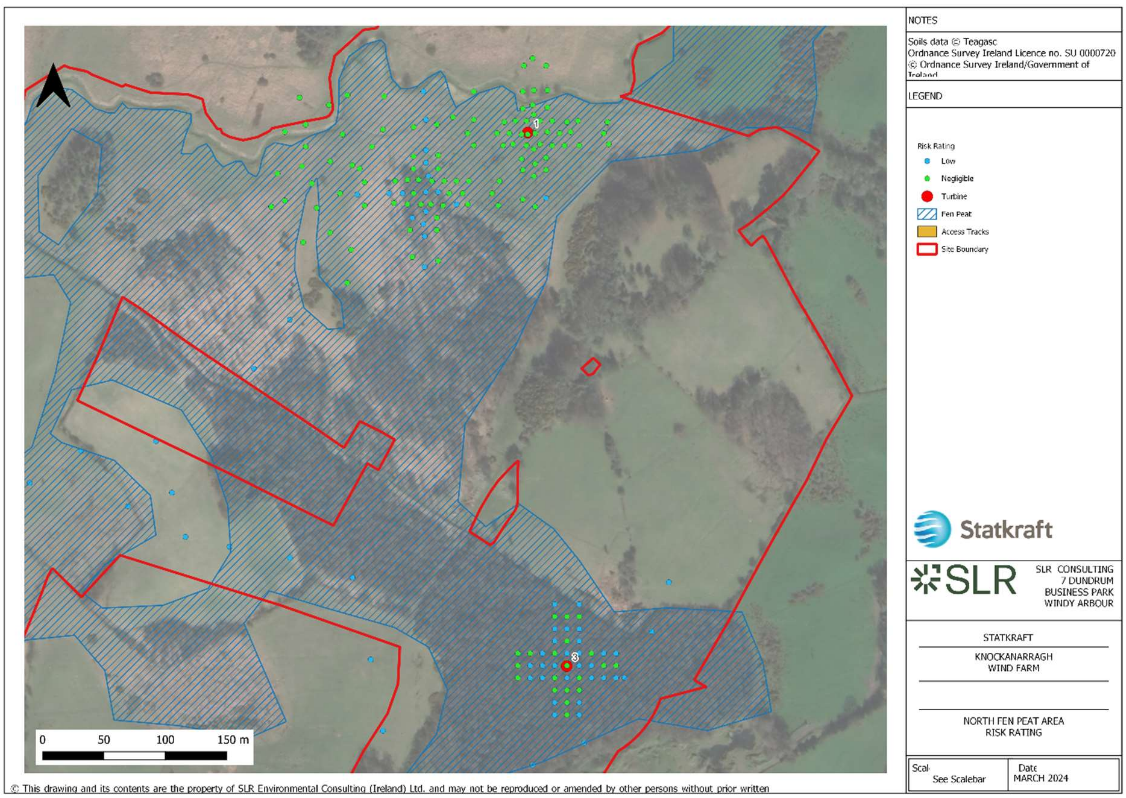

Figure 7: Risk rating in North Fen Peat Area

7.0 Construction Issues and Mitigation Measures

It is recognised that peat development in the area is limited, however the following measures should be considered good practice on sites with peatlands.

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

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

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

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

Notwithstanding any of the above controls and mitigation measures, detailed design and construction practices would need to consider the particular ground conditions and the specific works at each location throughout the construction period.

The following list of general and specific drainage mitigation measures is provided in an attempt to minimise the risk of potentially inducing peat landslides during construction of the development.

7.1 General Measures

- Raise Health and Safety awareness of the peat environment at the proposed development for construction staff by incorporating the issue into the site induction. Include peat slide risk assessment information (e.g. peat instability indicators, best practice and emergency procedures) in tool box talks with relevant operatives e.g. plant operatives;
- Introduce a ‘Peat Hazard Emergency Plan’ to provide instructions for site staff in the event of a peat slide or discovery of peat instability indicators;
- For sections of track that require track side cuttings into peat, suitable support measures would need to be designed to maintain the stability of the adjacent peat terrain;
- Refine/optimise the design through the pre-construction phase following completion of a detailed ground investigation; and

- Develop methodologies to ensure that accelerated degradation and erosion of exposed peat deposits does not occur as the break-up of the peat top mat has significant implications for the morphology, and thus hydrology, of the peat (e.g. minimise off-track plant movements within areas of peat).

7.2 Drainage Measures

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

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

7.3 Construction Recommendations

A summary of recommendations for site specific infrastructure is provided in the following sections. The complexity of peat stability has been discussed in this report and by Lindsay and Bragg[3], amongst others.

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

7.3.1 Wind Turbine Locations and Crane Pads

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

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

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

The excavations for wind turbine bases and crane pads should be kept to a minimum where possible but it is likely that the required hard stratum would be typically several metres deep, beneath soft materials (peat), unless directly on rock. The very soft nature of peat means that unsupported cut or excavated slopes could be unstable unless shallow gradients are used. The overall width of such an excavation would be up to 28 m diameter at the original ground surface, depending on the thickness of the peaty soil/peat and glacial till and appropriate methods of stabilising the temporary slopes should be considered. Foundation excavation would produce large volumes of peat and this should be reused across the Site in an environmentally acceptable manner for restoration. Peat would not be used to back fill the excavation void within the footprint of the foundation as it would have a very low strength.

Peat could be used as backfill outside the foundation footprint and also to dress verges to tracks and around wind turbine bases, in line with current Waste Management guidance[15]. Management of the water in the peat, by maintaining existing drainage during excavation is essential to avoid creating conditions likely to increase the risk of a peat slide.

7.3.2 Access Tracks

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

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

Wherever possible, the following principles should be adopted:

- Maintenance of existing drainage is critical therefore all existing drainage tracks must be maintained and where necessary, channelled below the proposed track construction. Upslope side drainage ditches to the track would be required on side-long ground; the ditches should be constructed with small dams and cross drains where necessary so that:
- Water can pass below the track at regular intervals;
- Scour and erosion is avoided in the side ditches due the limited volume and velocity, concentrated discharges to the peat on the down slope side of the track are avoided;
- The camber of the track should encourage surface water to drain to the up-slope side drainage ditch;
- Track gradients to be maintained at the recommended gradients from the wind turbine supplier, typically shallower than 1 v: 8 h to facilitate access by the large specialist vehicles for both construction and transport of the wind turbine components. The maximum acceptable gradients are usually defined by the appointed wind turbine manufacturer.
- Identify and mark all existing drainage features within the access track corridors; these drainage features should be maintained (not enhanced) during the construction and operational phases of the Proposed development;

- Install cross drains at regular intervals to maintain interstitial groundwater flow through the peat mass below the tracks where track settlement could reduce the natural permeability;
- Install additional drainage in areas up-slope to any track to prevent ponding and possible instability;
- Install small dams at regular intervals along the track side drains to prevent significant water velocities in the side drains causing deep erosion in the peat;
- Where track construction is required over peat areas in excess of 1m deep, this may be undertaken with a floating track construction, where the integrity of the peat allows;
- Cut and fill should be avoided in peat greater than 1m deep if possible; if not, the following requirements on side long ground (across contours) should be adopted;
- Excavate to a sound stratum;
- The majority of construction surface's to be essentially horizontal with a slight fall to aid drainage;
- Where the depth of cut is deemed unstable, employ a stepped or benched surface with the intention of minimising the exposed surface of the up-slope cut face;
- Protect all exposed peat surfaces from erosion and desiccation, by ensuring the integrity and moisture content of the peat is maintained; and
- The top of cut slopes should be provided with a small bund to retain the peat to prevent desiccation and maintain the local stability of the peat.

7.3.3 Cable Routes

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

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

The construction of the cable route would minimise disturbance to drainage by taking cable route alongside existing access track and around the wind turbines adjacent to new tracks. Cable trenches would be reinstated as soon as possible to minimise the time they are left open and to avoid trenches acting as conduits for surface water, causing erosion and potential silt run off.

Mitigation may be required within the trench to maintain local hydrological conditions and hydraulic connection in sensitive habitats. This may include clay plugs/ peat bunds to prevent the trenches from becoming a preferential flow path for water flows.

7.3.4 Borrow Pit

The proposed borrow pit will be required to comply with appropriate construction and quarrying regulations. It should be deliberately sited to avoid excavating peat and no significant construction mitigation will be required.

7.3.5 Temporary Compounds

Temporary compounds should be located on areas without peat, on relatively flat ground and should require minimal construction management.

7.3.6 Further Work

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

8.0 Conclusions

The following conclusions have been made in relation to peat and the proposed development at the site:

- There is no longer any peat in the area described by Teagasc as Cut Peat.
- The conclusion regarding the area described as Fen Peat has been classified as negligible to low risk.
- There is one small area (c. 35m by 25m) of relatively thick peat identified c 110m southwest of proposed turbine location T1. It is >45m away from any planned infrastructure, either temporary or permanent.
- The extent and thickness of the identified peatland is such that it affects the area of only two proposed turbines and it is not expected to present a significant geotechnical challenge to the development.

Following a review of published work and the observation and analysis undertaken for the proposed development, the hazard from peat instability at the site will be negligible if the recommendations contained in this report are adopted.

9.0 Further Work

More detailed ground investigations will be required to facilitate the geotechnical design of the various foundations and access track, particularly the vertical and horizontal alignment and the design of the river/stream crossings. These will be incorporated into the Construction Method Statement which will be submitted to the Planning Authority for approval as part of the condition compliance prior to any site works commencing.

Appendix A Peat Survey Results Risk Rating

Surface	Comments	Substrate	Peat Depth	Slope (°)	X	Y	Slope Coeff	Thickness Coeff	Substrate Coeff	Risk Rating Coefficient	Risk Rating
Peat	0-0.1 easy push (top soil), >0.1 very hard (gravelly material)	Gravel	0.1	0.463489	663094	768007	1	1	1	1	Negligible
Peat	0-0.15m easy push (peat), 0.15-0.8 medium (peaty clay), > 0.8 very hard	Clay	0.15	0.491697	663074	768116	1	1	2	2	Negligible
Peat	0.2m to refusal	Gravel	0.2	0.610454	662958	768051	1	1	1	1	Negligible
Peat	0-0.2 easy push (peat), 0.2-0.5 medium, >0.5 very hard	Gravel	0.2	0.689713	662945	767919	1	1	1	1	Negligible
Peat	0-0.4m easy push (peat), >0.4 very hard	Gravel	0.4	0.848281	663093	768118	1	1	1	1	Negligible
Peat	0.4 peat to solid boundary	Gravel	0.4	1.46521	662981	768140	1	1	1	1	Negligible
Peat	0.4m easy push peat, 0.4-1m easy to hard at base	Clay	0.4	0.619037	662762	767827	1	1	2	2	Negligible
Peat	0.4m peat easy push, medium to hard push to 0.8m	Clay	0.4	1.27025	663269	767705	1	1	2	2	Negligible
Peat	0-0.5m easy push (peat), >0.5 very hard	Gravel	0.5	0.155082	663074	768092	1	2	1	2	Negligible
Peat	0.5m peat, Peaty clay below	Clay	0.5	0.848281	663106	768124	1	2	2	4	Negligible
Peat	0.5m peat, peaty clay below to 2m as per other probes	Clay	0.5	2.30081	663082	768145	2	2	2	8	Low
Peat	0.5m peat to gravelly boundary	Gravel	0.5	0.837408	662986	768118	1	2	1	2	Negligible
Peat	0.5m to solid boundary layer	Gravel	0.5	0.837408	662986	768100	1	2	1	2	Negligible
Peat	0-0.6m easy push (peat), 0.6-1.9 medium to hard (peaty clay)	Clay	0.6	0.514865	663093	768042	1	2	2	4	Negligible
Peat	0-0.6m easy push (peat), 0.6-2.5m medium hard to push	Clay	0.6	0.155082	663078	768073	1	2	2	4	Negligible
Peat	0-0.6m easy push (peat), 0.6-1m medium (peaty clay), >1m very hard	Clay	0.6	0.502112	663094	768082	1	2	2	4	Negligible
Peat	0.6m Peat, peaty clay below	Clay	0.6	0.317012	663040	768100	1	2	2	4	Negligible
Peat	0.6m peat, peaty clay below	Clay	0.6	0.317012	663049	768114	1	2	2	4	Negligible
Peat	0.6 peat, peaty clay to 1.4	Clay	0.6	0.699488	662984	768022	1	2	2	4	Negligible
Peat	0.6m peat to refusal	Gravel	0.6	0.432116	663026	767749	1	2	1	2	Negligible
Peat	0-0.7m easy push (peat), 0.7-1.5m hard, 1.5-2.7 medium to hard (peaty clay)	Clay	0.7	0.490944	663080	768053	1	2	2	4	Negligible
Peat	0-0.7m easy push (peat), 0.7-1.9m medium to hard (peaty clay)	Clay	0.7	0.155082	663059	768072	1	2	2	4	Negligible
Peat	0-0.7m easy push (peat), >0.7 very hard	Gravel	0.7	0.210381	663034	768071	1	2	1	2	Negligible

Surface	Comments	Substrate	Peat Depth	Slope (°)	X	Y	Slope Coeff	Thickness Coeff	Substrate Coeff	Risk Rating Coefficient	Risk Rating
Peat	0.7m peat easy push,	Unknown	0.7	0.235249	663006	768088	1	2	3	6	Low
Peat	0.7m peat, peaty clay below	Clay	0.7	0.985427	663123	768145	1	2	2	4	Negligible
Peat	0.7m peat, peaty clay below	Clay	0.7	1.19852	663050	768141	1	2	2	4	Negligible
Peat	0-1.5m easy push peat possibly peaty clay to solid boundary, potentially gravel	Clay	0.7	1.58333	663020	768142	1	2	2	4	Negligible
Peat	0.7m peat, peaty clay below	Clay	0.7	0.235249	662983	768084	1	2	2	4	Negligible
Peat	0-0.8m easy push (peat), 0.8-1.8m medium to hard push (peaty clay)	Clay	0.8	0.690903	663119	768072	1	2	2	4	Negligible
Peat	0.8m easy push (peat), after 0.8 hard solid refusal (likely gravel).	Gravel	0.8	0.995903	663143	768052	1	2	1	2	Negligible
Peat	0.8m easy push (peat), 2.2 hard push (peaty clay)	Clay	0.8	0.506839	663098	768052	1	2	2	4	Negligible
Peat	0-0.8m easy push (peat), medium push >2.7m	Clay	0.8	0.366078	663071	768032	1	2	2	4	Negligible
Peat	0.8m easy push peat, 0.8-2.7m medium to hard push Peaty clay	Clay	0.8	0.175724	663030	768082	1	2	2	4	Negligible
Peat	0.8m easy push Peat,	Unknown	0.8	0.500784	663016	768110	1	2	3	6	Low
Peat	0.8 peat to solid boundary gravelly	Gravel	0.8	0.502848	662969	768056	1	2	1	2	Negligible
Peat	0.8m peat, 1.4m peaty clay	Clay	0.8	0.37381	663014	768062	1	2	2	4	Negligible
Peat	0.8m to refusal	Gravel	0.8	1.23859	663050	767624	1	2	1	2	Negligible
Peat	0.9m easy push (peat), 0.9-1.8 medium to hard (peaty clay)	Clay	0.9	0.743308	663144	768072	1	2	2	4	Negligible
Peat	0-0.9m easy push (peat), 0.9-2.7m medium to hard (peaty clay)	Clay	0.9	0.193069	663073	768010	1	2	2	4	Negligible
Peat	0-0.9m easy push (peat), >0.9 very hard	Gravel	0.9	0.155082	663074	768082	1	2	1	2	Negligible
Peat	0-0.9m easy push (peat), >0.9 very hard	Gravel	0.9	0.502112	663094	768093	1	2	1	2	Negligible
Peat	0.9m peat	Unknown	0.9	0.175724	663024	768085	1	2	3	6	Low
Peat	0-0.9m peat, peaty clay below to 1.8m	Clay	0.9	1.75827	663005	768134	1	2	2	4	Negligible
Peat	0-0.9m easy push, 0.9-2.7m easy to hard push	Clay	0.9	0.370844	662719	767796	1	2	2	4	Negligible
Peat	0.9m easy push, medium to hard push to refusal at 2m	Clay	0.9	0.648816	663247	767667	1	2	2	4	Negligible

Surface	Comments	Substrate	Peat Depth	Slope (°)	X	Y	Slope Coeff	Thickness Coeff	Substrate Coeff	Risk Rating Coefficient	Risk Rating
Peat	0-1m easy push (peat), 1-2m hard push (peaty clay) possible to push but hard	Clay	1	0.506839	663103	768062	1	2	2	4	Negligible
Peat	0-1m easy push (peat), >1m very hard	Gravel	1	0.514865	663093	768032	1	2	1	2	Negligible
Peat	0-1m easy push (peat), 1-2.7 medium to hard (peaty clay)	Clay	1	0.155082	663069	768073	1	2	2	4	Negligible
Peat	1m peat, peaty clay below to 1.5m	Clay	1	0.235249	662991	768070	1	2	2	4	Negligible
Peat	0-1m easy push peat, party clay to 1.6m	Clay	1	0.337758	662995	768050	1	2	2	4	Negligible
Peat	0-1.1m Easy push (peat) to boundary, 1.1-4m Medium to hard push (peaty clay)	Clay	1.1	0.490944	663074	768062	1	2	2	4	Negligible
Peat	0-1.1m easy push (peat), 1.1-1.5m medium to hard push (peaty clay)	Clay	1.1	0.995903	663138	768062	1	2	2	4	Negligible
Peat	0-1.1m easy push (Peat), 1.1-2.5m medium to hard push (peaty clay)	Clay	1.1	0.502112	663089	768072	1	2	2	4	Negligible
Peat	1.1m easy push (peat), 1.1-2.7 medium to hard push (peaty clay).	Clay	1.1	0.71472	663118	768053	1	2	2	4	Negligible
Peat	0-1.1m easy push (peat), 1.1-2.4m medium hard, 2.4-2.7m hard. Peaty clay residue on the end of the rod.	Clay	1.1	0.490944	663069	768053	1	2	2	4	Negligible
Peat	0-1.2m easy push (peat), 1.2-1.9m medium push, 1.9m+ hard push refusal	Clay	1.2	0.502112	663099	768072	1	2	2	4	Negligible
Peat	0-1.2m easy push (peat), 1.2-1.8m medium to hard until refusal	Clay	1.2	0.690903	663109	768072	1	2	2	4	Negligible
Peat	0-1.2m easy push (peat), 1.2-2.7m medium to hard (peaty clay)	Clay	1.2	0.506839	663088	768053	1	2	2	4	Negligible
Peat	0-1.2 easy push, 1.2-2.7 medium	Clay	1.2	0.553962	663020	767989	1	2	2	4	Negligible
Peat	1.2m easy push, 1.9m medium to hard push	Clay	1.2	0.590405	662974	767765	1	2	2	4	Negligible
Peat	0-1.3m easy push (peat), 1.3-2.5m medium to hard push (peaty clay), firm boundary at 2.5m, peaty clay residue on rods from up to 2.5m	Clay	1.3	0.71472	663114	768062	1	2	2	4	Negligible

Surface	Comments	Substrate	Peat Depth	Slope (°)	X	Y	Slope Coeff	Thickness Coeff	Substrate Coeff	Risk Rating Coefficient	Risk Rating
Peat	0-1.3m easy push (peat), 1.3-2.7m medium to hard (peaty clay)	Clay	1.3	0.479447	663058	768054	1	2	2	4	Negligible
Peat	0-1.3m easy push (peat), 1.3-2.5m medium to hard push (peaty clay)	Clay	1.3	0.479447	663034	768052	1	2	2	4	Negligible
Peat	1.3m peat, 2m peaty clay	Clay	1.3	0.638959	663023	768016	1	2	2	4	Negligible
Peat	1.4 of peat, 1.4-2.3 peaty clay	Clay	1.4	0.699488	663006	768030	1	2	2	4	Negligible
	0-1.5m Easy pushed(Peat), 1.5-2.2m harder push clayey peat, 2.2-3m easy push, 3-4m hard push (peaty clay)	Clay	1.5	0.533686	663084	768097	1	3	2	6	Low
Peat	0-1.5m easy push, 1.5-3.2m medium push, 3.2-4m hard push (dry peaty residue on stick and wet clay rich on last rod)	Clay	1.5	0.37381	663028	768061	1	3	2	6	Low
	0-1.6m Easy push (Peat), 1.6-2.5m Harder push peaty CLAY (could push further than 2.5m but hard pushing so likely not peat)	Clay	1.6	0.506839	663084	768063	1	3	2	6	Low
Peat	0-1.6m easy push (peat), 1.6-2.2m medium to hard push	Clay	1.6	0.506839	663094	768063	1	3	2	6	Low
Peat	1.6m easy push (peat), 2.7m medium to hard push (peaty clay).	Clay	1.7	0.71472	663109	768053	1	3	2	6	Low
	1.8m Peat, 3m Clayey Peat, 4m+ Peaty CLAY	Clay	1.8	0.502112	663084	768087	1	3	2	6	Low
Peat	0-1.8m easy (peat), 1.8-2.5m medium to hard push (peaty clay)	Clay	1.8	0.479447	663054	768062	1	3	2	6	Low
Peat	1-1.9m easy push (peat), 1.9-2.9m medium (peaty clay), 2.9m not bedrock but refusal due to difficulty	Clay	1.9	0.848281	663084	768122	1	3	2	6	Low
	0-2m easy push (peat), 2-4m medium hard push (peaty clay)	Clay	2	0.490944	663065	768062	1	3	2	6	Low
Peat	0-2.1m easy push (Peat), 2.1-3.6m Medium (peaty clay), 3.6m-4m hard boundary (still possible to push but with difficulty)	Clay	2.1	0.506839	663084	768047	1	3	2	6	Low
Peat	0-2.1m Easy push (peat), 2.1-4m Medium to hard push	Clay	2.1	0.193069	663083	768002	1	3	2	6	Low

Surface	Comments	Substrate	Peat Depth	Slope (°)	X	Y	Slope Coeff	Thickness Coeff	Substrate Coeff	Risk Rating Coefficient	Risk Rating
	(peaty clay). Peat residue on end of probe at 4m										
Peat	0-2.7m easy push (peat)	Gravel	2.7	0.366078	663073	768042	1	3	1	3	Negligible
Peat	0-3.2m Easy push (peat), 3.2-4m hard push (peaty clay)	Clay	3.2	0.366078	663082	768037	1	3	2	6	Low
Peat	0-3.8m Easy push (peat), 3.8-4m hard push (peaty clay)	Clay	3.8	0.366078	663083	768027	1	3	2	6	Low
	4m of probe with relative ease, clay and peat residue on end of probes	Clay	4	0.502112	663086	768076	1	3	2	6	Low
Peat	T3 Location	Clay	0.4	1.1717	663199	767717	1	1	2	2	Negligible
Peat		Clay	0.4	1.08225	663189	767687	1	1	2	2	Negligible
Peat		Clay	0.6	0.62603402	663199	767647	1	2	2	4	Negligible
Peat		Clay	0.6	1.05078995	663159	767677	1	2	2	4	Negligible
Peat		Clay	0.6	1.16692996	663239	767677	1	2	2	4	Negligible
Peat		Clay	0.7	0.62603402	663189	767667	1	2	2	4	Negligible
Peat		Clay	0.7	1.15438998	663219	767687	1	2	2	4	Negligible
Peat	Hard push	Clay	0.9	1.1717	663199	767697	1	2	2	4	Negligible
Peat		Clay	0.9	0.138816	663199	767637	1	2	2	4	Negligible
Peat		Clay	0.9	0.62603402	663189	767657	1	2	2	4	Negligible
Peat		Clay	0.9	1.18509996	663209	767717	1	2	2	4	Negligible
Peat		Clay	0.9	1.05078995	663159	767687	1	2	2	4	Negligible
Peat	Firm base	Clay	1	1.15438998	663229	767677	1	2	2	4	Negligible
Peat		Clay	1.1	0.62603402	663199	767657	1	2	2	4	Negligible
Peat		Clay	1.1	0.70338899	663209	767657	1	2	2	4	Negligible
Peat		Clay	1.1	1.05078995	663169	767687	1	2	2	4	Negligible
Peat		Clay	1.3	1.1717	663189	767717	1	2	2	4	Negligible
Peat	Soft but lots of roots	Clay	1.3	0.62603402	663189	767667	1	2	2	4	Negligible
Peat	Increasingly firm, no refusal	Clay	1.4	1.08225	663199	767677	1	2	2	4	Negligible
Peat		Clay	1.4	0.67019099	663159	767667	1	2	2	4	Negligible
Peat	No refusal	Clay	1.4	0.70338899	663209	767667	1	2	2	4	Negligible
Peat	Soft	Clay	1.5	1.1717	663189	767707	1	3	2	6	Low
Peat		Clay	1.5	1.05078995	663169	767677	1	3	2	6	Low

Surface	Comments	Substrate	Peat Depth	Slope (°)	X	Y	Slope Coeff	Thickness Coeff	Substrate Coeff	Risk Rating Coefficient	Risk Rating
Peat		Clay	1.6	1.08225	663199	767687	1	3	2	6	Low
Peat		Clay	1.6	0.62603402	663189	767647	1	3	2	6	Low
Peat		Clay	1.6	0.886329	663209	767727	1	3	2	6	Low
Peat		Clay	1.6	1.05078995	663179	767687	1	3	2	6	Low
Peat	Easy push	Clay	1.6	0.67019099	663169	767667	1	3	2	6	Low
Peat		Clay	1.7	1.08225	663189	767677	1	3	2	6	Low
Peat	firm base	Clay	1.7	0.98196203	663189	767727	1	3	2	6	Low
Peat	Firm base	Clay	1.7	1.08225	663189	767677	1	3	2	6	Low
Peat	Firm base	Clay	1.7	1.05078995	663179	767677	1	3	2	6	Low
Peat		Clay	1.8	1.1717	663199	767707	1	3	2	6	Low
Peat		Clay	1.8	0.62603402	663199	767667	1	3	2	6	Low
Peat		Clay	1.8	1.1717	663189	767697	1	3	2	6	Low
Peat	Refusal	Clay	1.8	1.15438998	663209	767687	1	3	2	6	Low
Peat	Firm base	Clay	1.8	0.70338899	663209	767647	1	3	2	6	Low
Peat		Clay	1.9	0.138816	663189	767637	1	3	2	6	Low
Peat	Firm base	Clay	1.9	1.18509996	663209	767697	1	3	2	6	Low
Peat		Clay	1.9	1.18509996	663209	767707	1	3	2	6	Low
Peat		Clay	1.9	1.15438998	663219	767677	1	3	2	6	Low
Peat		Clay	1.9	1.15438998	663229	767687	1	3	2	6	Low
Peat	Firm base	Clay	1.9	0.67019099	663179	767667	1	3	2	6	Low
Peat	Very firm clay base, fibrous peat	Clay	1.9	0.70338899	663219	767667	1	3	2	6	Low
Peat	Firm base	Clay	2	0.20857801	663209	767637	1	3	2	6	Low
Peat	Very firm base	Clay	2.1	1.15438998	663209	767677	1	3	2	6	Low
Peat		Clay	2.1	0.70338899	663209	767667	1	3	2	6	Low
Peat		Clay	2.1	1.15438998	663209	767677	1	3	2	6	Low
Peat		Clay	2.2	0.64881599	663239	767667	1	3	2	6	Low
Peat		Clay	2.5	0.70338899	663229	767667	1	3	2	6	Low
Peat		Clay	2.6	1.16692996	663239	767687	1	3	2	6	Low
Peat	0-0.3 peat, >0.3 bedrock	Rock	0.3	0.560187	662973	767959	1	1	2	2	Negligible
Peat	0-0.2 easy push (peat), 0.2-0.5 medium, >0.5 very hard	Clay	0.2	0.689713	662944	767919	1	1	2	2	Negligible

Surface	Comments	Substrate	Peat Depth	Slope (°)	X	Y	Slope Coeff	Thickness Coeff	Substrate Coeff	Risk Rating Coefficient	Risk Rating
Peat	0.4m easy push peat, 0.4-1m easy to hard at base	Clay	0.4	0.619037	662761	767826	1	1	2	2	Negligible
Peat	0-0.9m easy push, 0.9-2.7m easy to hard push	Clay	0.9	0.370844	662717	767796	1	2	2	4	Negligible
Peat	1.2m easy push, 1.9m medium to hard push	Clay	1.2	0.590405	662973	767765	1	2	2	4	Negligible
Peat	0.6m peat to refusal	Rock	0.6	0.432116	663024	767749	1	2	2	4	Negligible
Peat	0.8m to refusal	Clay	0.8	1.23859	663049	767624	1	2	2	4	Negligible
Peat	0.9m easy push, medium to hard push to refusal at 2m	Clay	0.9	0.648816	663246	767667	1	2	2	4	Negligible
Peat	0.4m peat easy push, medium to hard push to 0.8m	Clay	0.4	1.27025	663268	767705	1	1	2	2	Negligible
Soil	River crossing	Gravel	0	0.972836	662753	767990	1	1	2	2	Negligible
Soil	0.2 depth with probe, dark grey gravelly clay soil, not peat	Soil	0	0.558315	662803	767852	1	1	2	2	Negligible
Soil	soil not peat	Soil	0	0.336965	662864	767860	1	1	2	2	Negligible
Soil	0.2m soil	Soil	0	1.21355	662877	767818	1	1	2	2	Negligible
Soil	soil	soil	0	0.997206	662841	767807	1	1	2	2	Negligible
Soil	soil	soil	0	1.42469	662888	767782	1	1	2	2	Negligible
Soil	soil	soil	0	0.634103	662924	767774	1	1	2	2	Negligible
Soil	soil	soil	0	0.839787	663039	767682	1	1	2	2	Negligible
Soil	soil	soil	0	0.898036	663068	767578	1	1	2	2	Negligible
Soil	soil	soil	0	0.947221	663126	767585	1	1	2	2	Negligible
Soil	soil	soil	0	0.0944747	663171	767596	1	1	2	2	Negligible
Soil	soil	soil	0	0.0236477	663213	767614	1	1	2	2	Negligible
Soil	soil	soil	0	0.529032	663282	767745	1	1	2	2	Negligible

Making Sustainability Happen