Appendix 9

PEAT STABILITY RISK ASSESSMENT

PEAT STABILITY RISK ASSESSMENT

Ballinla Wind Farm

Ballinla Wind Farm Limited

June 2025

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Appendices

Appendix A –Factor of Safety Map

Appendix B - Peat Depth & Characterisation Data and Results of Infinite Slope Stability Analysis

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Executive Summary

Ballinla Wind Farm engaged Malachy Walsh and Partners (MWP) to complete a Peat Stability Risk Assessment for the Proposed Ballinla Wind Farm in Co. Offaly.

The location of the Ballinla Wind Farm infrastructure was designed from the outset with a constraint driven approach. This approached placed substation in area of low risk for peat slides and avoided environmentally sensitive areas.

MWP completed walkovers and surveys of the site. 86 peat probes were completed across the site with peat depths ranging from 0.27m to 4.04m. Shear strengths were recorded ranging from 7kPa to 85kPa.

MWP employed high resolution LiDAR data to create an accurate Digital Elevation Model (DEM) of the Site. An iterative design methodology was adopted using a constraint driven approach where ground slope was used as one of the key primary constraint criteria. Slope analysis from the DEM was used to place infrastructure in areas of the site with low ground slope.

MWP completed a two-stage peat stability risk assessment approach. Stage 1 was based on desk study information, site reconnaissance and assessment of contour data. Stage 1 concluded that further quantitative stability risk assessment was required for this site. Stage 2 involved quantitative risk assessment factor of safety analysis (Infinite Slope Stability Analysis), and application of the Peat Slide Hazard Rating System (PHRS) (Nichol, 2006). Both stages were completed for this project. This approach is in line with industry best practice guidance, as published by the Scottish Government PLHRA (Energy Consents Unit, Scottish Government, 2017).

The findings of the PHRS, carried out as part of the Stage 2 assessment, were that the risk level is “Negligible”.

Following on from the PHRS, MWP completed an Infinite Slope Stability Analysis (ISSA) for the site using the peat probe data and slope data from the LiDAR DEM to calculate the Factor of Safety (FoS) against peat slide for each location probed. The ISSA output indicated that the lowest FoS recorded was 2.8.

MWP completed assessments of the risk presented using the industry best practice guidance of the Scottish Executive and Scottish Government guidelines for Peat Landslide Hazard and Risk Assessments.

Design measures in the form of peat stability monitoring programme during construction has been proposed in order to further mitigate and manage risk.

1. Introduction

1.1 Overview

The proposed Ballinla Wind Farm development consists of a 7 wind turbine generator (WTG) wind farm and an on-site 110kV substation. A plan of the proposed development is provided in Figure 1-1.

Statkraft has requested Malachy Walsh and Partners (MWP) to complete a Peat Stability Risk Assessment (PSRA) as part of the planning application for a proposed wind energy development. MWP has extensive experience in completing PSRA's in upland peat areas, having completed PSRA's on over 20 planning applications and the construction of in excess of 30 wind farms located in peatland throughout Ireland.

The PSRA presented in this report has been carried out within the area of the proposed wind farm infrastructure and Proposed Grid Connection (which is subject to a future planning application).

MWP adhere to the latest industry standards when completing PSRAs. The guidance of the Scottish Government publication "Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments, Energy Consents Unit Scottish Government, Second Edition, April 2017" and the "Draft Revised Wind Energy Development Guidelines December 2019" have been used for this PSRA.

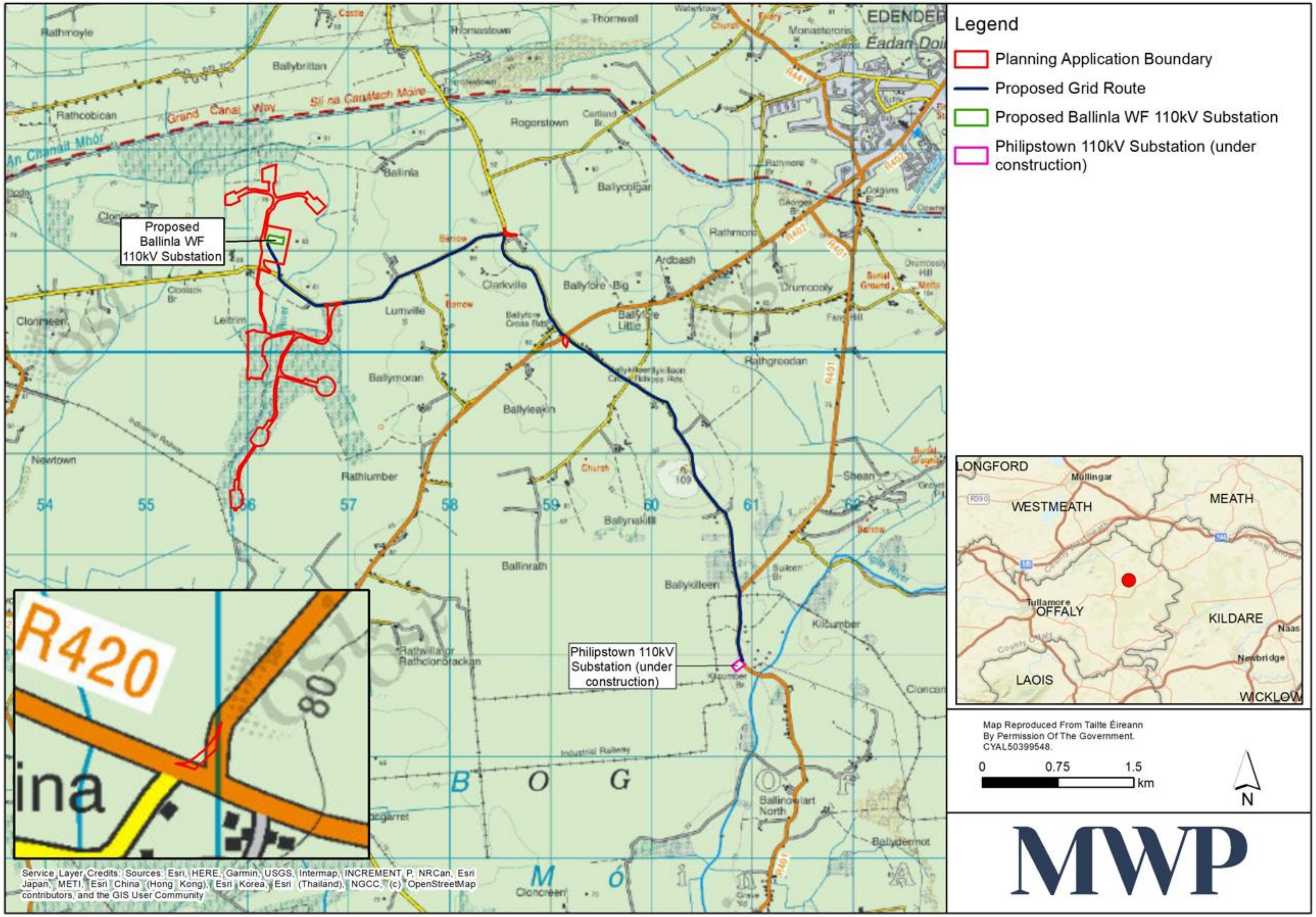

Figure 1-1: Proposed Wind Energy Development

1.2 Peat Stability Risk Assessment Methodology

The methodology used to complete the Peat Stability Risk Assessment for this site is set out in the following subsections of this report.

1.2.1 Relevant Guidelines

The following guidance documents were used in completing the assessment presented in this report:

- Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments, Energy Consents Unit Scottish Government, Second Edition 2017.
- British Standards Institute (2009). BS 6031:2009 Code of practice for earthworks.
- Draft Revised Wind Energy Development Guidelines December 2019.
- OPW Flood Risk Management Climate Change Sectoral Adaptation Plan, September 2019.

1.2.2 Approach

The approach to peat stability risk assessment taken in this report involves the below listed steps. These steps are in accordance with *"Draft Revised Wind Energy Development Guidelines December 2019"* and *"Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments, Energy Consents Unit Scottish Government, Second Edition 2017"*.

- A **scoping** exercise was carried out to determine whether a detailed Peat Landslide Hazard and Risk Assessment is required for this site.
- A **desk study** to gain an understanding of the quaternary geology, bedrock geology, hydrology, hydrogeology, landslide history, land use and topography of the site.
- **Site reconnaissance** to verify the findings of the desk study and further assess the geology, hydrology, topography and search for signs of past landslides or incipient instability.
- A thorough **ground investigation** to determine the extents and nature of the peat. This includes peat probes, shear strength readings and von post humification characteristics.
- An **assessment of ground conditions** across the site including the peat information, substrate information, topography and land use.
- A **quantitative analysis of peat stability** across the site using infinite slope stability analysis.
- A **risk assessment** which identifies the risk levels for various parts of the site based on the probability of a peat slide and the adverse consequence of the slide.
- Suggested **mitigation measures** depending on the level of risk for various parts of the site.

2. Scoping

A scoping exercise was carried out to determine whether a detailed Peat Landslide Hazard and Risk Assessment is required for this site. This scoping exercise reviewed whether peat was present onsite and reviewed the topography and slope angles within the site. A summary of the scoping process is provided in Figure 2-1 and a commentary on each of the scoping items reviewed is provided in Sections 2.1 to 2.3.

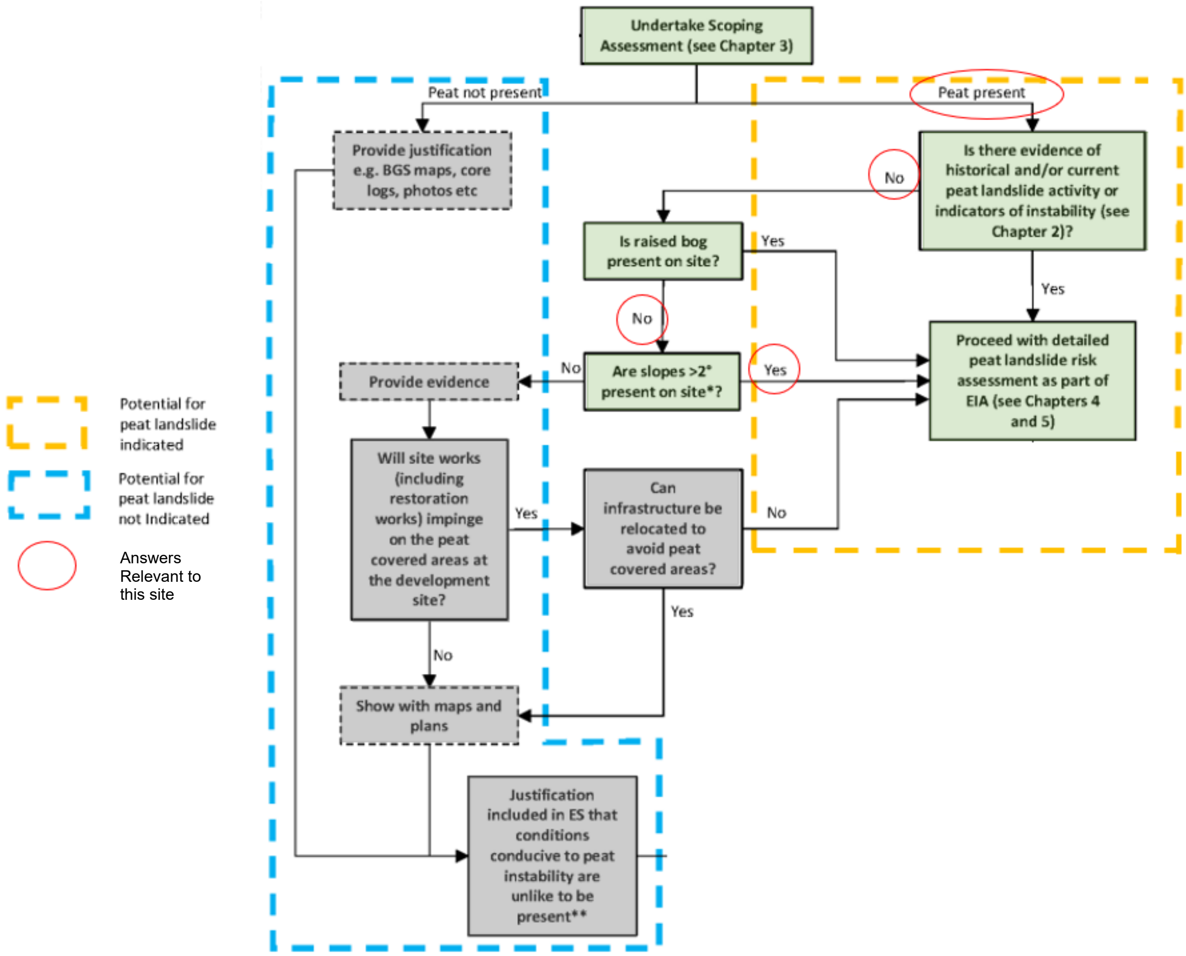

Figure 2-1: Summary Flow Chart of Scoping for Requirement for Detailed Peat Stability Risk Assessment

2.1 Presence of Peat

A review of the digital geological maps on the Geological Survey of Ireland website showed the presence of some Blanket Peat within the site. This was confirmed on the ground via initial site reconnaissance and subsequent peat probing. No evidence of peat instability was noted during the scoping exercise. Further detail on the geological maps, site reconnaissance findings and peat probing are provided in Section 3 of this report.

2.2 Slope

The Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments states that *"in blanket bogs, which typically mantle hillslopes, PLHRAs should be undertaken where slopes exceed 2°". (*PLHRA = Peat Landslide Hazard Risk Assessment).

A review of topographical maps and Lidar indicated the presence of slope angles greater than 2° within this site.

2.3 Outcome of Scoping Exercise

Blanket Peat and slope angles greater than 2° have been identified within this site, therefore a detailed Peat landslide hazard and risk assessment is required for this site.

3. Detailed Site Assessment

3.1 Desk Study

A desk study was undertaken to collate and review available information, datasets and documentation sources pertaining to the site's natural environment. The desk study involved the following:

- Examination of maps and aerial photography;
- Examination of Geological Survey of Ireland (GSI)/ EPA / Teagasc online soil and subsoil maps.

3.2 Site Reconnaissance Survey

Site reconnaissance surveys were carried out to verify the features identified during the desk study and to enable an interpretation of the site in the context of the surrounding environment.

Initial peat probing was carried out to verify the presence of peat and gain an initial understanding of the depth and extents of the peat. Dates of the site visits are provided in **Table 3-1.**

The following observations were made during the site reconnaissance:

- An engineering and geotechnical site walkovers were used to review characteristics of the site that needed consideration in the design. These include the public access road towards the site, the location of the site entrance, the existing drainage within the site, a review of the ground conditions and a review of the topography of the area.
- No evidence of historical landslides or incipient instability were noted during the site visits.

Table 3-1: Summary of Site Visits

Date	Personnel	Purpose of Site Visit
20/06/2023	Paddy Curran	Site Visit
29/06/2023	Graeme Thornton	Walk Over
08/03/2024	Conor McLoughlin	Site Visit
02/08/2024	Graeme Thornton	Site Walk Over

3.3 Ground Conditions Assessment

An assessment of ground conditions was carried out to gain a thorough understanding of the site in terms of peat stability. This assessment included the following reviews:

- Review of any site evidence of past landslides or incipient instability.
- Site hydrology and the impact of land-use on natural hydrology and peat thickness.
- Collection of peat depth data.
- Collection of peat characterisation data (geotechnical properties, humification, substrate, wetness etc).

3.3.1 Review of any Site Evidence for Past Landslides or Incipient Instability

A number of positive observations in term of stability of the site were noted as follows:

- There has been a landslide in 1989 noted on the Geological Survey of Ireland landslide database (Event ID GSI_LS03-0068).
- No evidence of historical landslides or incipient instability were noted during the site visits.

Figure 3-1: Landslide Mapping (from Geological Survey of Ireland (GSI)

3.3.2 Site Hydrology

The Proposed Development site is located within Figile Catchment and Boyne Catchment Hydrometric Areas. Refer to **Figure 3-2** for an overview of the catchment extents.

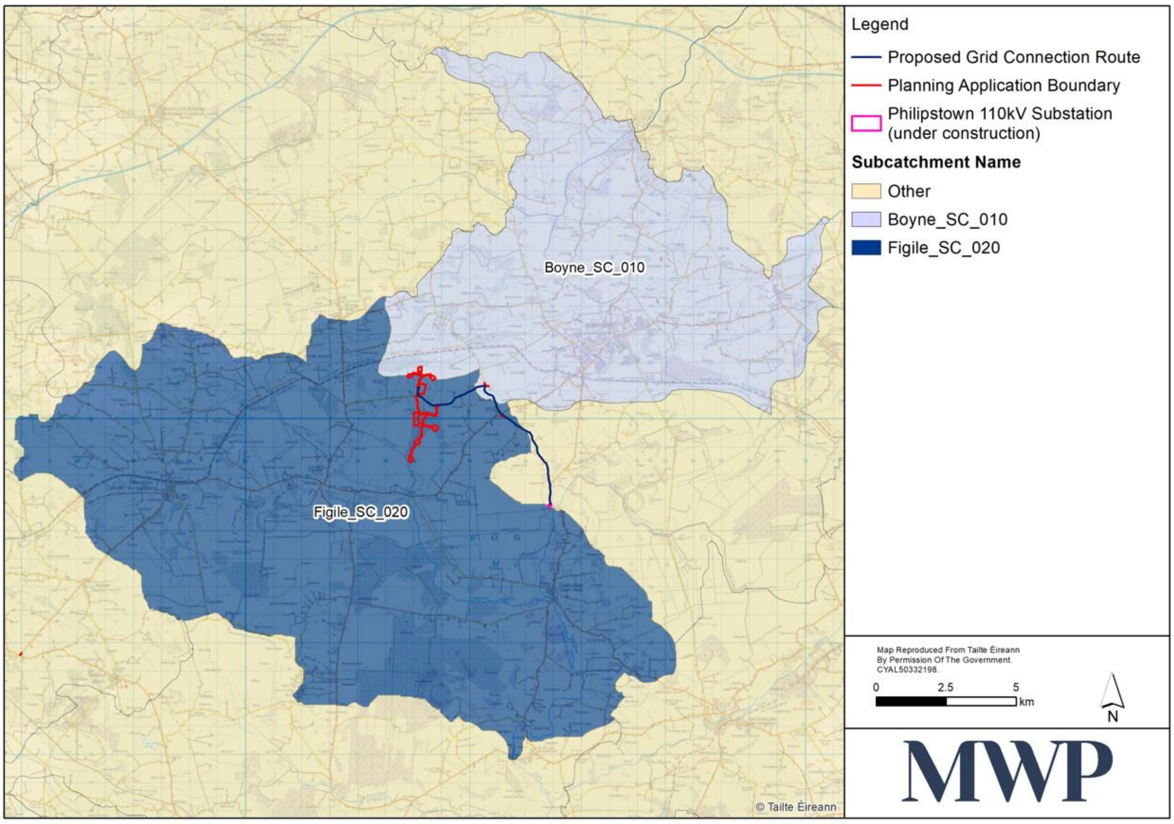

Figure 3-2 Catchment Areas

3.3.3 Impact of Land Use on Natural Hydrology and Peat Thickness

The land use at the site was reviewed during site visits and by reviewing the Corine Land Cover 2018 maps on the EPA website. The following land uses were mapped with in the study area:

- 231 – Pastures
- 312 – Coniferous Forests
- 211 – Non-irrigated land
- 412 – Peat bogs
- 313 – Mixed Forests
- 112 – Discontinuous urban fabric

3.3.4 Collection of Peat Depth and Characterisation Data

The following peat depth and characterisation data was collected for this report:

- 86 peat probes were carried out as part of the assessment (See data summary in **Figure 3-3**).
- 83 Hand Shear Vane Readings (See data summary in **Figure 3-4**).
- All of the above investigation data is included in Appendix B of this document. It should be noted that Infinite Slope Stability Analysis was also carried out at all locations where peat depths were established.

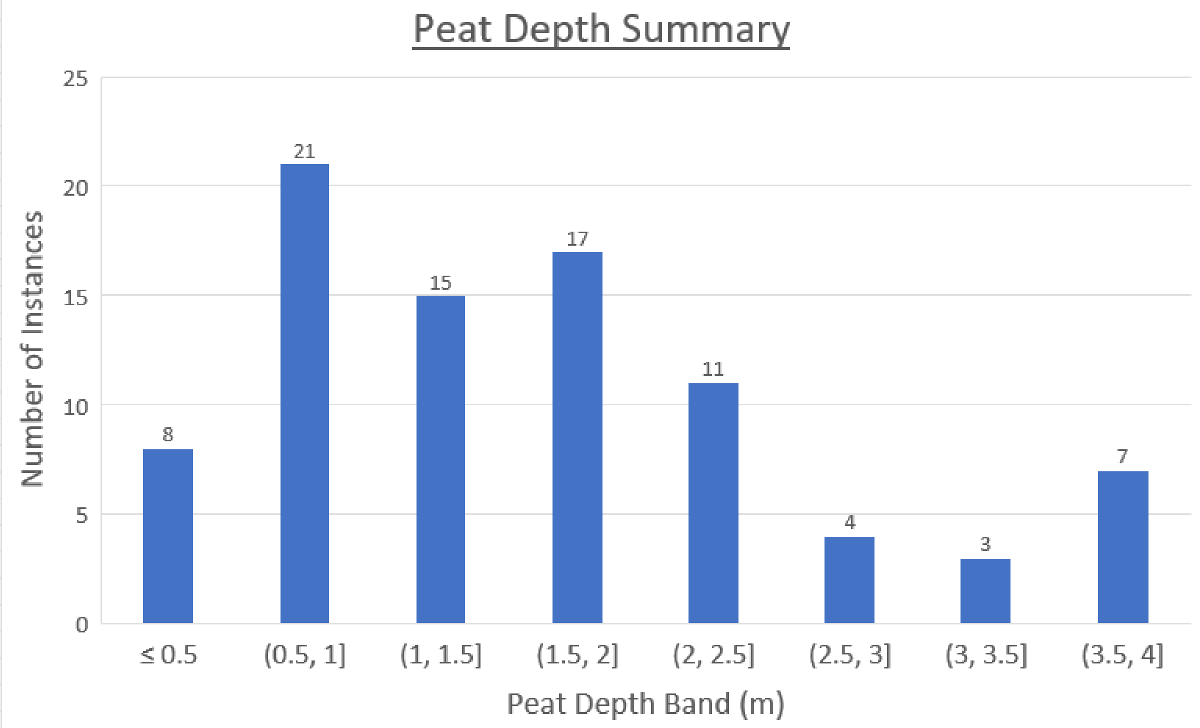

Figure 3-3: Peat Depth Data Summary

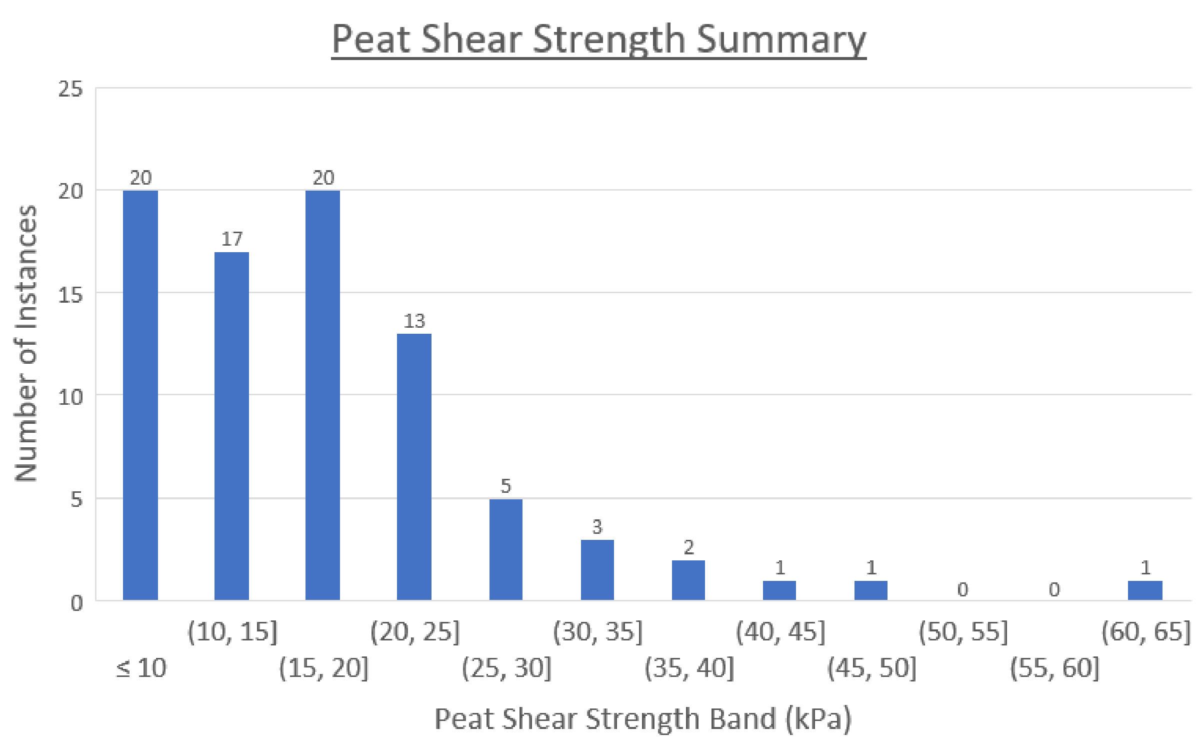

Figure 3-4: Peat Shear Strength Summary

3.3.5 Summary of Ground Conditions at each Turbine

A summary of the ground parameters at each turbine is provided in **Table 3-2**

Table 3-2: Summary of Ground Parameters at Turbines Centres

Turbine	Land use category (Geohive)	Peat shown on Geology Maps	Slope (^{0})	Approx. Peat Depth (m)
T1	Non-irrigated land	NO	N/A	N/A
T2	Non-irrigated land	NO	N/A	N/A
T3	Non-irrigated land	NO	N/A	N/A
T4	Coniferous Forests	YES	0.8	1.7
T5	Coniferous Forests	YES	0.9	2.3
T6	Mixed Forest	YES	2.6	3.1
T7	Mixed Forest	YES	0.5	2.0

4. Peat Stability Hazard and Risk Assessment

The information obtained from the desk study, site reconnaissance, ground investigation and LiDAR data was used to complete a peat stability hazard and risk assessment.

Risk can be expressed as the product of the probability of a [peat] landslide event and its adverse consequences (Scottish Government "peat-landslide-hazard-risk-assessments-best-practice-guide-proposed-electricity" April 2017), i.e.:

Risk = Probability of Landslide × Adverse Consequences *Eq. 1*

Estimation of the probability of a landslide was carried out through stability analysis, i.e. by providing a quantitative measure of slope stability incorporating consideration of slope form (slope angle), materials (shear strength) and loadings (overburden). This involved a quantitative analysis (infinite slope stability analysis) to determine the factor of safety against peat slide at each investigation point. The output from the infinite slope stability analysis was used as a quantification of the probability of a peat stability hazard.

Adverse consequences may include accidents, loss of life, environmental impacts or damage to site infrastructure and associated financial losses. The potential for adverse consequences reflects the exposure to peat landslide hazard of elements at risk within a specific area.

4.1 Assessment of Probability of Peat Slide – Infinite Slope Stability Analysis

The Scottish Executive Guidelines for Peat Landslide Hazard and Risk Assessments recommends the use of Infinite Slope Stability Analysis as a quantitative method to calculate a Factor of Safety (FoS) for each study area of a site.

Factors of safety were calculated for the un-drained condition using the equation below. This formula was applied across the area of proposed infrastructure within the wind farm site and results are displayed in the colour coded map in *Appendix A.*

$$FoS = \frac{S_u}{\gamma z Sin\theta Cos\theta}$$

where S_u= Shear Strength, γ = Density, z = depth, θ = Slope Angle

4.1.1 Peat Depth

The peat depths from the peat probes were used in the analysis. Details of the peat depths throughout the site are provided in Appendix B.

4.1.2 Slope Angle

For the purpose of calculating slope angle for each data point of the peat probe dataset, MWP used the Digital Elevation Model (DEM) created using the LiDAR data. For each peat probe point the AutoCAD software was used to interrogate the DEM at 3 points on a 5m radius around the peat probe (identified in red circles in the screenshot below). The software uses the elevation of those three points to create an inclined plane centred on the peat probe. The geometric slope of that inclined plane is then calculated mathematically to give the ground slope for each peat probe in the data set.

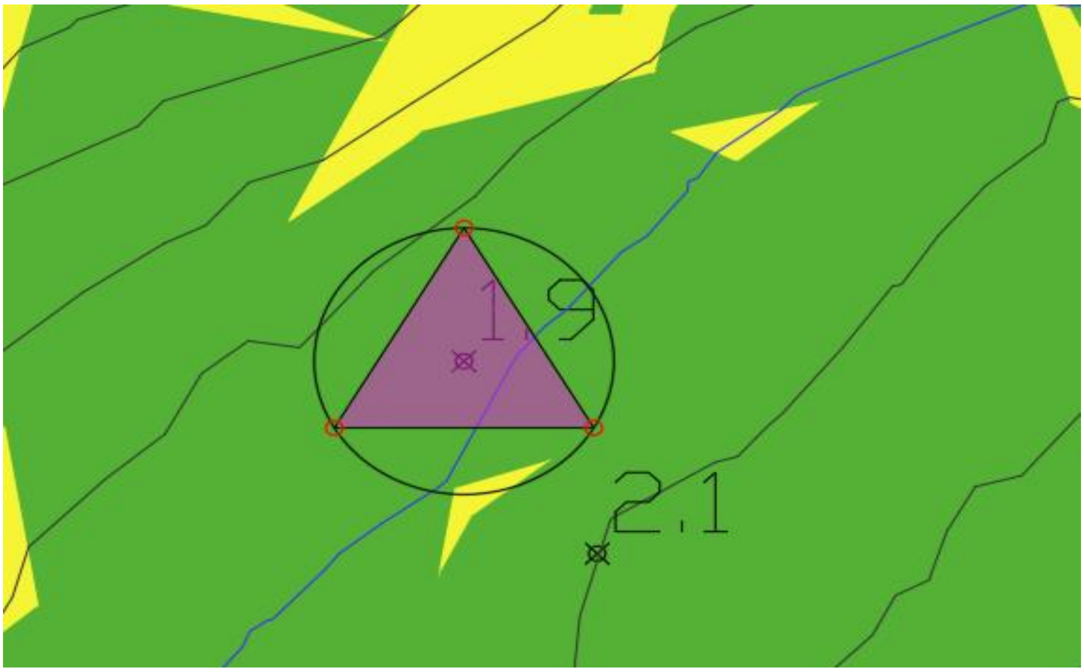

Figure 4-1: Example of DEM interrogation for slope dataset calculation

4.1.3 Shear Strength of Peat

Where peat depth was available, but shear strength readings weren't taken, a value of 5kPa was used in the stability analysis.

4.1.4 Bulk Density of Peat

For the purpose of calculating FoS a peat bulk density of 10kN/m^3 was adopted. This value has been adopted based on information from "Peat slope failure in Ireland, Article in Quarterly Journal of Engineering Geology and Hydrogeology", February 2008, N. Boylan, P. Jennings and M. Long. This paper states that the "bulk density of peat is typically similar to or less than that of water."

4.1.5 Surcharge

A surcharge of 20kPa which represents placement of an additional 2m of peat on the existing ground surface was used in the analysis. This value represents the additional peat that will be stored in the material deposition area as this area would experience the highest surcharge.

4.1.6 Future Climate Change

Future climate change has been taken into account in the analysis and assessment by using a surcharge loading in the analysis and by placing infrastructure in areas with a Factor of Safety against slope instability greater than 1.6 (20% higher than the minimum required by BS6031).

The surcharge can mimic additional load (during construction), or it can represent additional water (i.e. a future climate change scenario) on the slopes during construction or operational phase of the wind farm, or it can represent a combination of both scenarios. In either scenario, the analyses completed indicate that the slope stability risks at the Ballinla Wind Farm site poses a negligible risk (See Section 4.3).

OPW Flood Risk Management Climate Change Sectoral Adaptation Plan, September 2019, was reviewed when considering climate change in the peat stability assessment. The following is noted from this document:

"Met Éireann has predicted that in Ireland the autumns and winters may become wetter, with a possible increase in heavy precipitation events of approximately 20%, and that summers may become drier, with a projected 12-40% increase in the number of extended dry periods (Nolan, 2015)."

A FOS of 1.3 is the minimum FOS design required by "BS 6031:2009 Code of practice for earthworks". In order to account for future climate change and increase in precipitation, the minimum factor of safety used in the assessment presented in this report has been increased by 20% to 1.6 (ie 1.3 x 1.2 = 1.56 ≈ 1.6).

4.1.7 Operational and Decommissioning Phases of Project

During the operation and maintenance phase of a wind farm, movement of machinery is confined to the roads and crane hardstands, therefore there will be no surcharging of peat during these stages of the project life cycle. No large excavations will be required during operation and maintenance phase of the project. Therefore, surcharging of the peat is not envisaged during this phase of the project and the assessment presented in this report is more onerous than the operational and maintenance phase (i.e. the site has negligible risk for the Construction phase, therefore it has negligible risk for Operational Phase).

During the decommissioning phase, it is envisaged that the turbines will be removed but the foundations and roadways will be left in place. Crane hardstands will be covered over with topsoil/peat as opposed to being removed. Cables will be removed by pulling them out from the ducts as opposed to excavating them (the ducts themselves will remain in the ground). Therefore, no significant excavations or surcharging of the peat will occur during this phase of the project and the assessment presented in this report is more onerous than the decommissioning phase (i.e. the site has negligible risk for the Construction phase, therefore it has negligible risk for the Decommissioning Phase).

4.1.8 Factor of Safety Analysis Output

The output of the Factor of Safety (FOS) analysis for each peat probe location is detailed in Appendix A and Appendix B. A summary of the distribution of the calculated FOS is presented in Figure 4-2 and Figure 4-3.

A summary of the calculated factor of safety at the centre of each of the Proposed Turbine and Infrastructure Locations is provided in Table 4-1.

A FOS of 1.3 is the minimum FOS design required by "BS 6031:2009 Code of practice for earthworks". No infrastructure has been placed in areas with FOS<1.6 (allowing for future climate change as discussed in Section 4.1.6).

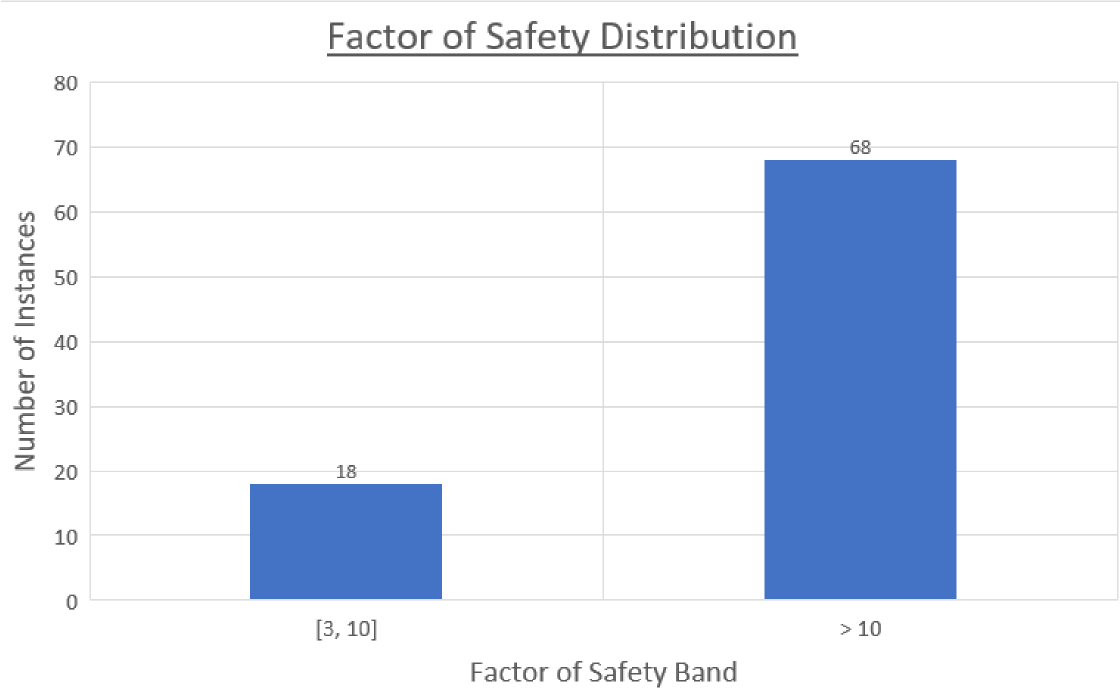

Figure 4-2: Factor of Safety Distribution

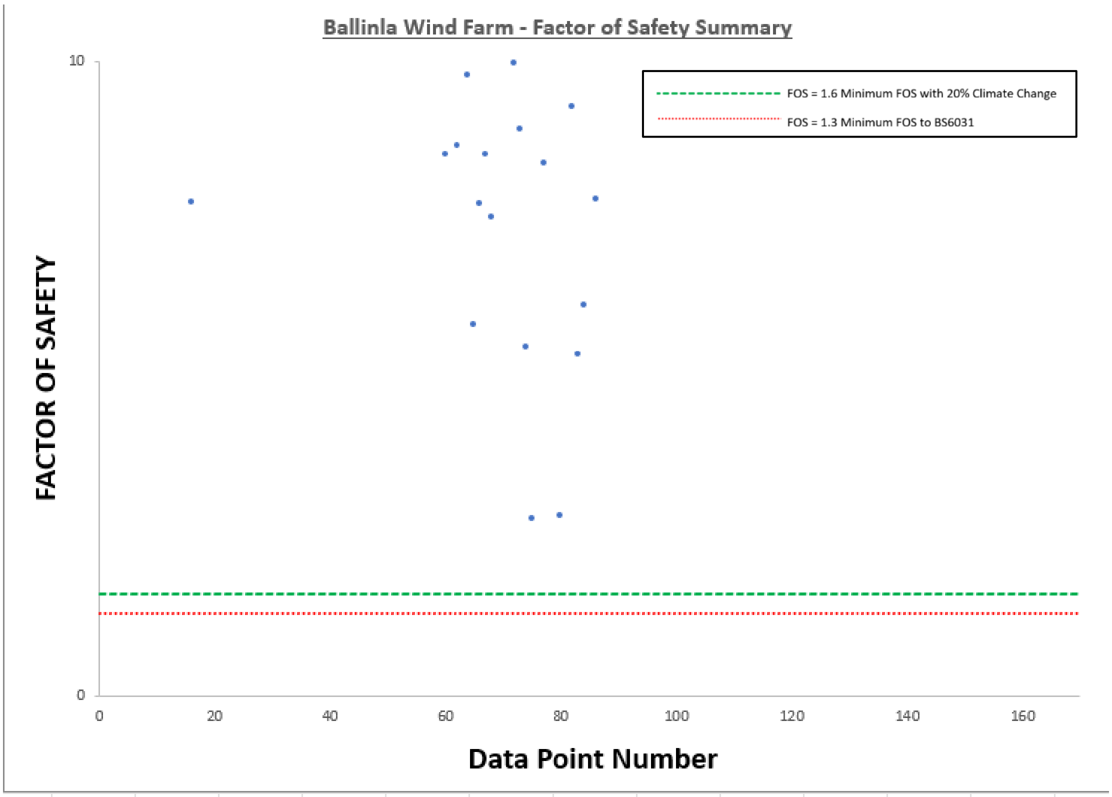

Figure 4-3: Factor of Safety Summary

Table 4-1: Summary of Factor of Safety at Proposed Infrastructure Locations

Turbine	Land use category	Slope (^{0})	Approx. Peat Depth (m)	Shear Strength (kPa)	Factor of Safety
T4	Coniferous Forests	0.8	1.7	16.9	32.6
T5	Coniferous Forests	0.9	2.3	31.9	44.2
T6	Mixed Forest	2.6	3.1	28.3	12.1
T7	Mixed Forest	0.5	2.0	9.2	25.5

4.1.9 Assessment of Probability of Occurrence Based on Factor of Safety Analysis

The probability of occurrence of a landslide for use in the risk assessment has been quantified below based on the factor of safety analysis completed for this site.

Table 4-2: Probability of Landslide based on Factor of Safety Analysis

Scale	Probability of Occurrence	FOS	Comment
5	Almost Certain	< 1	Factors of safety less than 1 indicate that a landslide is almost certain to occur
4	Likely	1 to 1.3	Above 1 indicates it is stable but below 1.3 is not acceptable in BS 6031:2009 standard
3	Unlikely	1.3 to 1.6	Slightly higher FOS than that required by BS 6031:2009 however a larger value is desirable to account for future climate change
2	Very Unlikely	1.6 to 2.0	Values above 1.6 are higher than what is required by BS 6031:2009 and have an additional 20% buffer for future climate change
1	Negligible	> 2.0	Values above 2 are considered to have a negligible probability of occurrence of landslide.

4.2 Assessment of Adverse Consequences

Potential adverse consequences, in the event that a peat landslide does occur, have been estimated. The intention was to represent consequences as a range that can be applied to specific areas of the development site. For example, the consequences of a landslide occurring for a watercourse depend on how far the landslide is from it, or on the importance of a watercourse from a habitat perspective, e.g. it may be designated as a Special Area of Conservation (SAC). A review was completed to identify potential receptors in the event of a peat slide.

Consequences and receptors considered include the following elements:

- The potential for harm to life during construction;
- The potential economic costs associated with lost infrastructure, or delay in programme;
- The potential for permanent, irreparable damage to the peat resource (both carbon stock and habitat) associated with mobilisation (and ultimately loss) of peat in a landslide; and
- The potential for ecological damage to watercourses, NHA, SAC or SPA subject to inundation by peat debris.

4.2.1 Potential Harm to Life During Construction

Peat slides have a potential to cause harm to life during construction if construction activities are not managed properly. For the purpose of assessing the adverse consequences associated with harm to life during construction, the peat depth has been used as the criteria for quantitatively assessing the potential for harm to life. Deeper deposits of peat increase the potential for inundation in peat and hence the potential for harm to life. The impact scale is shown below in Table 4-3. A score of 1 is considered a low rating and a score of 5 is considered a high rating.

Table 4-3: Impact Score - Potential Harm to Life Adverse Consequence

Impact Scale	Criteria Peat Depth (m)
1	0-1
2	1-2
3	2-3
4	3-4
5	4+

4.2.2 Potential Economic Costs Associated with Loss of Infrastructure

The economic costs associated with loss of Infrastructure has considered the distance of the Proposed Wind Farm infrastructure from public roads, power lines, gas lines, houses, railway lines etc. The following pieces of infrastructure have been identified and considered in this assessment:

- The existing high voltage electrical lines running through the site
- The existing houses in the area
- The existing public road
- No railway line has been identified within 5 km of the site
- No gas line has been identified within 5 km of the site

Table 4-4: Impact Scale - Potential Economic Costs Associated with Loss of Infrastructure

Impact Scale	Criteria Distance from Proposed Infrastructure (m)
1	Proposed infrastructure element greater than 150m from existing infrastructure
2	Proposed infrastructure element within 101 to 150m of existing infrastructure
3	Proposed infrastructure element within 51 to 100m of existing infrastructure
4	Proposed infrastructure element within 21 to 50m of existing infrastructure
5	Proposed infrastructure element within 20m of existing infrastructure

4.2.3 Potential Permanent Damage/Loss of Peat Resource

The assessment of potential Damage/Loss of Peat Resource has been based on the peat depth at each proposed piece of infrastructure. Deeper deposits of peat increase the potential volume of peat within a landslide and hence the potential damage / loss of the peat resource. The impact scale is shown below in Table 4-5.

Table 4-5: Impact Score - Potential Harm to Life Adverse Consequence

Impact Score	Criteria Peat Depth (m)
1	0-1
2	1-2
3	2-3
4	3-4
5	4+

4.2.4 The Potential for Ecological Damage to Watercourses/SACs/NHAs/SPAs

The potential for ecological damage to watercourses has been assessed based on the distance of proposed infrastructure to the watercourse. There is a Special Protection Area located approximately 17km northwest of the site and Special Area of Conservation located approximately 7.6km north of the site. The watercourses are shown as per Drawing No. 23882-MWP-00-00-DR-C-5019.

Table 4-6: Impact Score - Potential for Ecological damage to Watercourse

Impact Score	Criteria Distance from Proposed Infrastructure to watercourse (m)
1	Proposed infrastructure element greater than 150m from watercourse or NHA/SPA/SAC
2	Proposed infrastructure element within 101 to 150m of watercourse or NHA/SPA/SAC
3	Proposed infrastructure element within 51 to 100m of watercourse or NHA/SPA/SAC
4	Proposed infrastructure element within 21 to 50m of watercourse or NHA/SPA/SAC
5	Proposed infrastructure element within 20m of watercourse or NHA/SPA/SAC

4.2.5 Summary Table of Potential Adverse Consequences and Associated Impact Rating

In order to assess the overall risk based on the impact scores for each of the consequences discussed in previous sections, an adverse consequence rating is applied to the impact scores discussed in previous sections of this report. Table 4-7 summarises the Adverse Consequence Rating for each impact score band.

A summary of the impact criteria and associated impact scores for each of the proposed infrastructure locations is provided in Table 4-8 and Table 4-9.

Table 4-7: Impact Score - Adverse Consequence Rating for use in Risk Assessment

Adverse Consequence Rating	Total Impact Score	Description
1	0 to 4	Negligible
2	5 to 8	Low

Adverse Consequence Rating	Total Impact Score	Description
3	9 to 12	Moderate
4	13 to 16	High
5	16 to 20	Extremely High

Table 4-8: Impact Criteria Summary

Impact Criteria

	T4	T5	T6	T7
The potential for harm to life during construction (Peat depth in m)	1.7	2.3	3.1	2.0
The potential economic costs associated with lost infrastructure, or delay in programme (Distance to infrastructure in m)	810m Public Road 720m from house 500+m from pylon of HV line	810m Public Road 800m from house 500+m from pylon of HV line	650m Public Road 1570m from house 500+m from pylon of HV line	150m Public Road 1070m from house 500+m from pylon of HV line
The potential for permanent, irreparable damage to the peat resource (Peat depth in m)	1.7	2.3	3.1	2.0
The potential for ecological damage to watercourses subject to inundation by peat debris. (Distance to watercourse/NHA/SAC/SPA in m)	70m from water course 1000m+ from NHA No SAC or SPA within 1000m	90m from water course 1000m+ from NHA No SAC or SPA within 1000m	50m from water course 1000m+ from NHA No SAC or SPA within 1000m	20m from water course 1000m+ from NHA No SAC or SPA within 1000m

Table 4-9: Impact Score Summary

Impact Score

	T4	T5	T6	T7
The potential for harm to life during construction	2	3	4	2
The potential economic costs associated with lost infrastructure, or delay in programme	1	1	1	1
The potential for permanent, irreparable damage to the peat resource (both carbon stock and habitat) associated with mobilisation (and ultimately loss) of peat in a landslide	2	3	4	2
The potential for ecological damage to watercourses subject to inundation by peat debris	3	3	4	5
Sum of Scores	**8**	**10**	**13**	**10**
Adverse Consequence Rating	**2**	**3**	**4**	**3**
Adverse Consequence Description For Risk Assessment	**Low**	**Moderate**	**High**	**Moderate**

4.3 Determination of Risk

The risk associated with peat landslides at this site was calculated using the below formula and the scores from Table 4-2 and Table 4-9.

Risk = Probability of Landslide (From Table 4-2) × Adverse Consequences (From Table 4-9) *Eq. 2*

The risk associated with the site was quantified based on Table 4-10 from "Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments", Energy Consents Unit Scottish Government, Second Edition 2017.

A summary of the results of the risk assessment is provided in Table 4-11. It should be noted that Proposed Development has been located in areas identified as negligible risk within the site.

Table 4-10: Risk Score and Description Summary

			Adverse Consequence				
			Extremely High	**High**	**Moderate**	**Low**	**Very Low**
			5	**4**	**3**	**2**	**1**
Peat Slide Probability or Likelihood	**Almost Certain**	**5**	25 (High)	20 (High)	15 (Moderate)	10 (Moderate)	5 (Low)
	Likely	**4**	20 (High)	16 (Moderate)	12 (Moderate)	8 (Low)	4 (Negligible)
	Unlikely	**3**	15 (Moderate)	12 (Moderate)	9 (Low)	6 (Low)	3 (Negligible)
	Very Unlikely	**2**	10 (Moderate)	8 (Low)	6 (Low)	4 (Negligible)	2 (Negligible)
	Negligible	**1**	5 (Low)	4 (Negligible)	3 (Negligible)	2 (Negligible)	1 (Negligible)

Table 4-11: Risk Summary at Wind Farm Infrastructure

Turbine/Location	Probability / Likelihood Score (A)	Adverse Consequence Score (B)	Risk Rating Score (A x B)	Risk Description
T4	1	2	2	Negligible
T5	1	3	3	Negligible
T6	1	4	4	Negligible
T7	1	3	3	Negligible

4.4 Cumulative Impact

The cumulative impact of the development on peat stability has been reviewed.

Peat stability is local to the point of construction, and this has been assessed at 86 locations within the proposed Wind Farm site. Other local wind farms (e.g Mount Lucas Wind Farm, Moanvane Wind Farm and Derrinlough Wind Farm) have no potential to impact on peat stability at the Ballinla site and vice versa due to the topography of the area and distance between the wind farms.

Another important observation is the fact that the wind farms local to Ballinla, which have similar ground conditions, have been successful completed without occurrence of peat instability.

5. Mitigation Measures

The peat stability risk assessment described above has yielded a negligible risk rating for this site. The engineering response for areas with negligible risk level is that the "project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate". This is in accordance with **Table 5.4** of Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments, Energy Consents Unit Scottish Government, Second Edition 2017 (Scottish Guidelines).

Table 5-1: Suggested Actions for Peat Slide Risk Level

Risk Level	Action suggested for each zone
High	Avoid project development at these locations
Medium	Project should not proceed unless risk can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce risk ranking to low or negligible
Low	Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations
Negligible	Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate

The Scottish Guidelines outline the following as suggested mitigation hierarchy for landslides:

1. Avoid (by design)
2. Engineer (drainage, construction management)
3. Control slide (cast walls, catch ditches. i.e. emergency response)

The risk of peat slides is considered negligible at this site. However, good practices and precautionary measures should always be implemented when working on sites where peat is present.

Mitigation measures in the unlikely event of a slide are presented in 5.1 to 5.3. All of these mitigation measures shall be implemented at Ballinla Wind Farm. Peat movement is unlikely to occur, however, if onsite mitigation measures are not adhered to and peat movement is noted, a series of emergency responses and procedures that would be implemented are also listed below. Experience and vigilance are fundamental requirements when working on peat where inappropriate construction methodology can cause instability in otherwise stable conditions. Therefore, the appointed contractor shall review all of their methodologies, equipment, construction vehicle loads and safety procedures against the information in this report and produce temporary works designs appropriate to their procedures which take into account peat stability.

5.1 Design Mitigations (Avoidance of Hazards)

The design mitigation used on this project has avoided high risk areas with similar conditions to locations where peat slides have occurred on other wind farms. An iterative design process was followed where the layout was adjusted based on information from peat probe surveys and topographical surveys.

Examples of areas which have been avoided during the iterative design process include:

- The review of Quaternary Geology indicated that peat in only present in vicinity of T4 to T7.
- T1 to T3 are located in the area where there is no peat present and therefore peat stability risk is avoided for these turbines.

5.2 Engineered Mitigations

5.2.1 Drainage Design

The drainage strategy for the Proposed Wind Farm site will ensure minimal impact on the existing flow regime, water quality, and run-off quantity.

The nature of the ground conditions dictates the drainage methodology that can be employed. On wet sites with soft ground, roads are dug down to a more solid bearing stratum and this results in a requirement for roadside drains where dirty water will accumulate. Where ground conditions are good, and the top surface is deemed suitable as a bearing stratum, roads can be constructed from that surface. This latter method does not result in a requirement for roadside drains.

Dirty water is generated on wind farm sites predominantly during construction. The dirty water is generated through movement of soil material around the site and breaking down of the road surface under sustained loading from construction traffic. Silt removal from dirty water run¬off will be either by filtration or by means of settlement ponds as described below.

An important aspect of the treatment process is that clean water from outside the works area is not mixed with dirty water from within the works area. This minimises the quantity of water to be treated and consequently reduces the size and quantity of settlement ponds where they are used.

Clean water flows from the uphill side of catchments to the downhill side. Having this water pass through the works unimpeded reduces the risk of mixing with dirty water and ensures a smaller quantity of dirty water remains for treatment. Clean water will pass through roads of stone construction due to its porosity via overland flow. Separation of clean and dirty water drains is shown in Figure 5-2. Clean water cut-off drains will be provided on the uphill side of infrastructure where it is undesirable to have clean water enter the works. Such locations would be on the uphill side of material storage areas where overland flow is unlikely to pass through unimpeded and mixing with dirty water is likely to occur. These drains are routed through to the downhill side of the works and discharged through buffered outfalls.

Where drains are constructed they will incorporate a series of check dams that will attenuate the flow and provide storage for the increased runoff from exceptional rainfall events. Check dams will comprise a clean 100 mm to 150 mm crushed rock behind a Terram barrier that will be embedded into the base and sides of ditches by at least 100 mm.

A typical drainage design on a wind farm using settlement ponds is shown in **Figure 5-1**. The clean water interceptor drains are all positioned upslope to prevent any mixing of the clean and dirty water. The outflow from these drains is then piped under the road at suitable intervals and at low points depending on the site topography. In the illustration, dirty water drains collect all incident rainwater that falls on the infrastructure. This water then drains to settlement ponds for removal of sediment before it is discharged to the nearest watercourse.

Dewatering of turbine base excavations can result in significant flow rates to the drainage and settlement system if high-capacity pumps are used. Should pumping be required, temporary storage will be provided within the excavations and dewatering carried out at a flow rate that is within the capacity of the settlement ponds.

The outflow from the treatment system will be infiltrated into the ground via swales at the end of the settlement ponds.

Figure 5-1: Typical drainage design

Figure 5-2: Separation of clean and dirty water drainage on wind farm site

5.2.2 Construction Management

The appointed contractor and detailed designer will be required to produce a detailed Construction Stage Peat Management Plan which aligns with their detailed design and construction methodologies. This shall include details of site specific monitoring plans. Any residual stability risks that remain at the end of the construction phase shall be detailed in the Safety File.

The Construction Manager for the project should impart the philosophy that everyone on the site is aware of peat stability and report any sign of misalignment in monitoring posts. Vigilance is a fundamental requirement when working on peat where inappropriate construction methodology can cause instability in otherwise benign conditions. A Geotechnical Engineer experienced in working in the upland peat environment should be employed full-time to ensure the implementation of best practice in this environment. The methodology of all civil works should be reviewed by the Geotechnical Engineer and the monitoring posts should be the subject of a dedicated inspection on a weekly basis by the Geotechnical Engineer.

The following general measures incorporated into the construction phase of the project will assist in the management of the risks for this site:

- Appointment of experienced and competent contractors and detailed designers.
- The construction works on site should be supervised by experienced and qualified personnel.
- Ensure construction method statements are followed or where agreed modified/ developed.
- Allocate sufficient time for the project to be constructed safely with all peat stability mitigation measures included in the programme.
- Set up, maintain and report findings from monitoring systems, including sightline monitoring.
- Maintain vigilance and awareness through Tool-Box-Talks (TBTs) on peat stability.
- Prevent undercutting of slopes and unsupported excavations.
- No sidecasting of excavated material other than in areas selected for such activities by a suitably qualified environmental professional or site geotechnical engineer.
- Prevent placement of loads/overburden on marginal ground.
- Manage and maintain a robust drainage system. This will be the responsibility of the appointed contractor and their designer.
- In addition to the above, the following emergency response controls will also be implemented.
- A detailed emergency response plan for all elements of the construction stage will be prepared by the appointed contractor.
- A stockpile of crushed rock will be stored on site. That stockpile will be available in the event that rock material is required at short notice to build temporary barrages.
- Rolls of proprietary silt fences will be available onsite at all times should emergency siltation control measures be required.
- Mobile emergency lighting will be stored on site so that any required emergency works can be completed safety during hours of darkness should this be required depending on the time of day the landslide event occurred.
- Appropriate plant will be maintained onsite through the project so that it is available in the event of a landslide. This will include bog master excavators and dumper trucks.
- The Contractors Safety Plan shall include for a training day and mock emergency response drill (similar to a fire drill). This will train and prepare the onsite team to implement the emergency plan quickly and effectively.

Vigilance is a fundamental requirement when working on peat where inappropriate construction methodology can cause instability in otherwise stable conditions. Only competent and experienced contractors will be employed for this project.

5.2.2.1 Rainfall Mitigations

It is notable the previous peat slide in Ireland have generally occurred after prolonged periods of heavy rain (e.g. landslides at Meenbog, Derrybrien and Ballincollig Hill). Therefore, it is important to have precautions in place regardless of the negligible risk level of peat slide risk at the site. The detailed procedures for dealing with periods of prolonged rainfall include both prediction (forecasting) and monitoring.

The following weather forecasting systems are available and will be used on a daily/weekly basis during the construction stage of the wind farm, to allow site staff to direct proposed and planned construction activities:

- General Forecasts: Available on a national, regional and county level from the Met Éireann website (www.met.ie/forecasts). These provide general information on weather patterns including rainfall, wind speed and direction but do not provide any quantitative rainfall estimates;
- MeteoAlarm: Alerts to the possible occurrence of severe weather for the next 2 days. Less useful than general forecasts as only available on a provincial scale;
- 3-hour Rainfall Maps: Forecast quantitative rainfall amounts for the next 3 hours but does not account for possible heavy localised events;
- Rainfall Radar Images: Images covering the entire country are freely available from the Met Éireann website (www.met.ie/latest/rainfall_radar.asp). The images are a composite of radar data from Shannon and Dublin airports and give a picture of current rainfall extent and intensity. Images show a quantitative measure of recent rainfall. A 3-hour record is given and is updated every 15 minutes. Radar images are not predictive; and,
- Consultancy Service: Met Éireann provide a 24-hour telephone consultancy service. The forecaster will provide an interpretation of weather data and give the best available forecast for the area of interest.

Using the safe threshold rainfall values will allow planned works to be safely executed (from a peat stability and a water quality protection perspective) in the event of forecasting of an impending high rainfall intensity event.

Earthworks will be suspended if forecasting suggests any of the following rainfall events is likely to occur:

- >10 mm/hr (i.e. high intensity local rainfall events);
- >25 mm in a 24-hour period (heavy frontal rainfall lasting most of the day); or
- >half monthly average rainfall in any 7 days.

Prior to earthworks being suspended the following further control measures will be completed:

- All open peat/spoil excavations will be secured and sealed;
- Temporary or emergency drainage will be created to prevent back-up of surface runoff; and,

Working during heavy rainfall and for up to 24 hours after heavy events will not be allowed to ensure ground stability is maintained and to ensure that drainage systems are not overloaded.

An onsite rain gauge will be provided by the contractors and used to monitor site specific rainfall. This rain gauge will be used in conjunction with the Met Éireann information to review the above trigger levels. The worst-case of the onsite rain gauge or Met Éireann information will be used to ensure a cautious approach is followed.

5.2.3 Monitoring

The level of peat monitoring recommended for the site reflects the strategy of placing infrastructure in low risk areas of the site. With the siting of infrastructure using mitigation by avoidance higher risk parts of the site have been avoided as described in **Section 5.1**, sightline monitoring is considered appropriate for this site. The precautionary principle dictates that monitoring should be carried out in these areas where peat is present. The most effective monitoring regime is one that is self-evident. For the Ballinla site, it is considered that this can best be achieved using Sightline Monitoring.

Monitoring by sightlines entails driving a series of posts at approximately 5m centres, exactly aligned, across the section of bog being monitored. An illustration of this approach is given below in **Figure 5-3.** Any signs of distress or deformation in the bog will quickly manifest itself by some of the posts moving out of alignment. Early discovery of stress in the peat will give the developer an opportunity to implement emergency procedures to prevent the onset of a bog burst or localised peat slide. While the risk of such occurrence is low in this instance, the precautionary principle dictates that monitoring posts should be installed in work areas where peat is present.

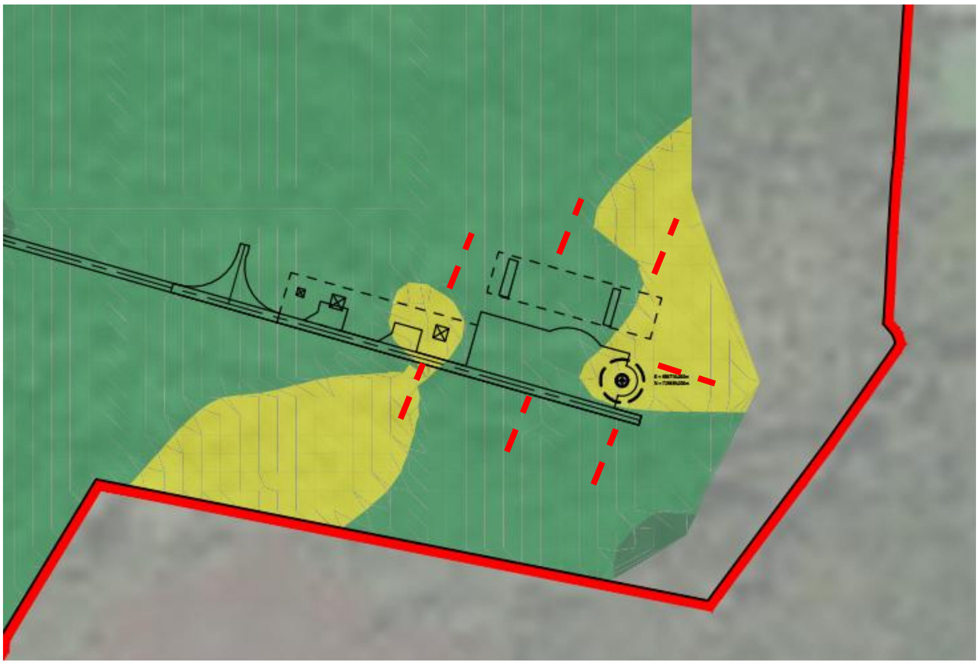

Figure 5-3: Example of Typical Sightline Post Layout

5.3 Control Slide

Emergency procedures are the responsibility of the appointed contractor and are to be included in the appointed contractor's method statements. These typically include the following:

- Emergency response procedures to protect the health and safety of workers and to implement containment procedures for remoulded peat slurry on or off site.
- Identification of potential flow paths of peat slides to determine accessible intervention points on or off site to construct barrages, settlement ponds and silt traps to contain the peat slurry and to prevent downstream contamination of watercourses.
- Stockpiling of rockfill on or off site to use in the construction of emergency containment barrages in the event of a slide.

In addition to the above, the following emergency response controls will also be implemented:

- A detailed emergency response plan for all elements of the construction stage will be prepared by the appointed contractor.
- A stockpile of crushed rock will be stored on site. That stockpile will be available in the event that rock material is required at short notice to build temporary barrages.
- Rolls of proprietary silt fences will be available onsite at all times should emergency siltation control measures be required.
- Mobile emergency lighting will be stored on site so that any required emergency works can be completed safety during hours of darkness should this be required depending on the time of day the landslide event occurred.
- Appropriate plant will be maintained onsite through the project so that it is available in the event of a landslide. This will include bog master excavators and dumper trucks.
- The Contractors Safety Plan shall include for a training day and mock emergency response drill (similar to a fire drill). This will train and prepare the onsite team to implement the emergency plan quickly and effectively.

6. Conclusion

Ballinla Wind Farm Limited engaged Malachy Walsh and Partners (MWP) to complete a Peat Stability Risk Assessment for the proposed Ballinla Wind Farm in Co. Offaly.

The location of the Proposed Ballinla Wind Farm infrastructure was designed from the outset with a constraint driven approach. This approached placed substation in area of low risk for peat slides and avoided environmentally sensitive areas.

MWP completed walkovers and surveys of the site. 86 peat probes were completed across the site with peat depths ranging from 0.27m to 4.04m. Shear strengths were recorded ranging from 7kPa to 85kPa.

MWP employed high resolution LiDAR data to create an accurate Digital Elevation Model (DEM) of the Site. An iterative design methodology was adopted using a constraint driven approach where ground slope was used as one of the key primary constraint criteria. Slope analysis from the DEM was used to place infrastructure in areas of the site with low ground slope.

MWP completed a two-stage peat stability risk assessment approach. Stage 1 was based on desk study information, site reconnaissance and assessment of contour data. Stage 1 concluded that further quantitative stability risk assessment was required for this site. Stage 2 involved quantitative risk assessment factor of safety analysis (Infinite Slope Stability Analysis), and application of the Peat Slide Hazard Rating System (PHRS) (Nichol, 2006). Both stages were completed for this project. This approach is in line with industry best practice guidance, as published by the Scottish Government PLHRA (Energy Consents Unit, Scottish Government, 2017).

The findings of the PHRS, carried out as part of the Stage 2 assessment, were that the risk level is “Negligible”.

Following on from the PHRS, MWP completed an Infinite Slope Stability Analysis (ISSA) for the site using the peat probe data and slope data from the LiDAR DEM to calculate the Factor of Safety (FoS) against peat slide for each location probed. The ISSA output indicated that the lowest FoS recorded was 2.8.

MWP completed assessments of the risk presented using the industry best practice guidance of the Scottish Executive and Scottish Government guidelines for Peat Landslide Hazard and Risk Assessments.

Design measures in the form of peat stability monitoring programme during construction has been proposed in order to further mitigate and manage risk.

7. References

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Nichol, D., 2006. Peatslide hazard rating system for wind farm development purposes. Proceedings of the 28th Annual Conference of the British Wind Energy Association (BWEA28, Glasgow), 00-00

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Appendix A

Factor of Safety Map

Appendix B

Peat Depth & Characterisation Data

and

Results of Infinite Slope Stability Analysis