3.1. Site Reconnaissance and Preliminary Ground Investigations

An initial Site walkover survey was carried out by Garne Geotechnical Services from 31st August to 3rd September 2020. Additional walkover surveys were made on 13th and 14th October 2020, 4th and 5th March 2021, 5th and 6th October 2021, 19th November 2021, 25th and 26th January 2022 and 18th August 2022, following layout design changes. The walkovers included peat gouge cores taken at both the turbine base and substation locations.

A total of 389 peat probes, 7 gouge cores and 130 hand-held shear vane tests were undertaken within the EIAR red-line boundary, at turbine bases, at turbine hardstands, at the proposed substation location and along proposed access tracks at nominal 100m centres. A further 376 probes were undertaken outside the current EIAR boundary, within the Derroura Forest to the east, and along the proposed grid connection route to Screebe. An additional 54 peat probes, 54 shear vanes and 2 gouge cores were undertaken near the proposed ecological enhancement area near Maam Cross. Measurements of slope were also made using a hand-held inclinometer at each of the shear vane test locations. The approximate peat probe depths are shown in Figure 5. Details of each probe location are presented in Appendix 1, which also includes probes undertaken outside the current EIAR boundary.

During the walkovers, notes were also made of the land use, peat depth, drainage features, geomorphology, slope, and any other features that could affect slope stability. The walkover and ground investigations found peat up to 5.5m in depth in places with an average depth of 0.94m, moderate slopes (1 to 25° with an average slope of 7°) and poor to moderately well drained ground.

3.2. Peat Strength and Description

Hand shear vane tests were carried out during the site walkovers using a Geonor H-60 shear vane to provide indicative results for the in-situ shear strength of the peat at preliminary investigation stage. The uncorrected shear strength values recorded ranged from 4kPa to 40kPa with an average of 18kPa. To account for the fibrous and heterogeneous nature of peat, a correction factor of 0.5 is recommended (Mesri & Ajlouni, 2007). The corrected peat strengths therefore range from 2kPa to 20kPa, with an average of 9kPa.

3.3. Laboratory Test Results

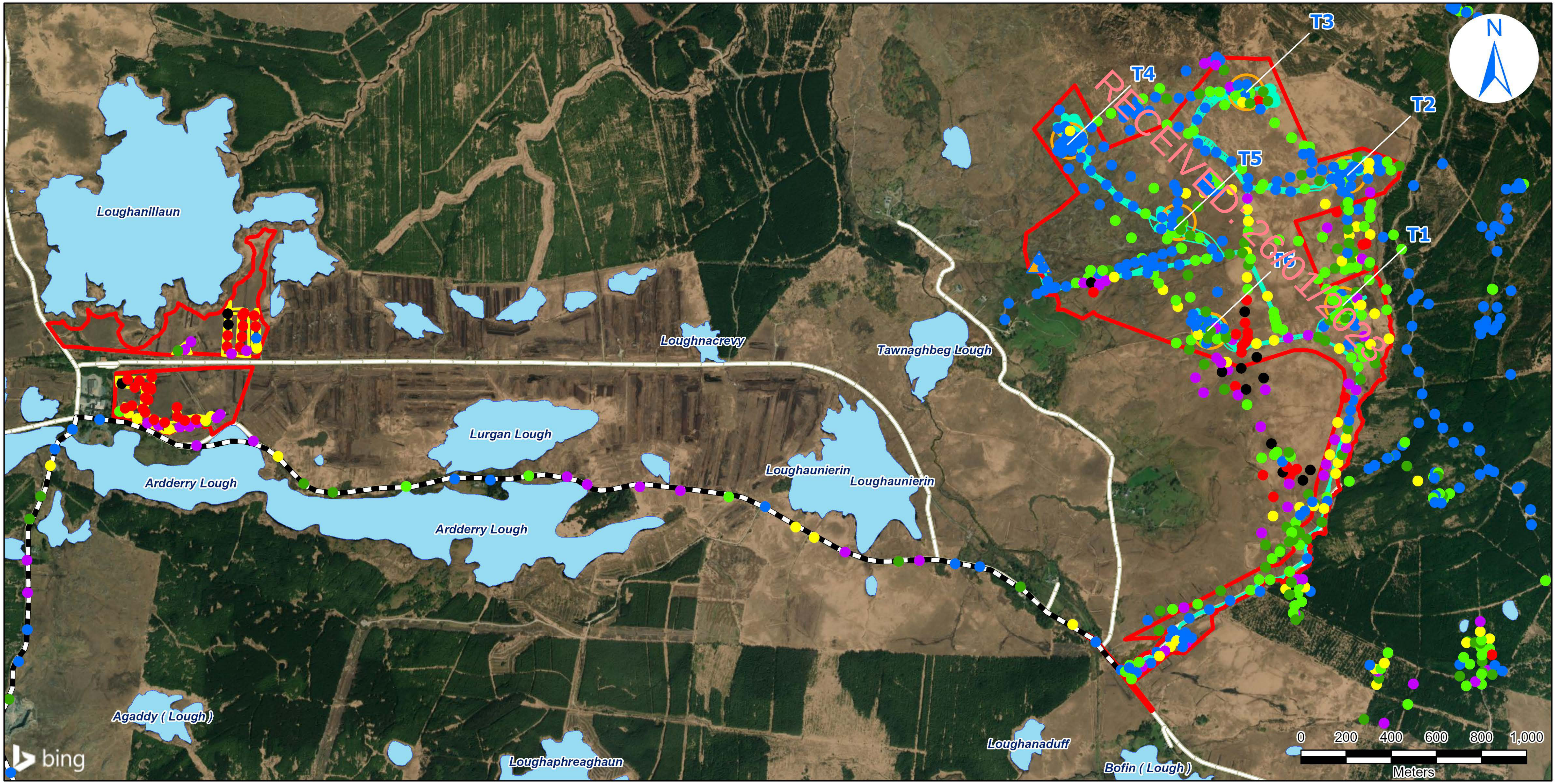
A number of peat samples were recovered from the turbine base and substation locations using a gouge core and sent to an accredited laboratory for moisture content and organic carbon content analysis. The results of the testing are presented in Appendix 2 of this report. Moisture contents of between 560% (moist, B3) and 1080% (wet, B4) were recorded in laboratory tests.

3.4. Topography, Geomorphology and Drainage

The topography of the site is gently sloping with an average slope of about 7° (as measured on-site using a hand-held clinometer) and with slopes locally recorded up to 25° at some probe locations. The turbines are generally located on areas of moderate slope (4 to 19°, average 12°) but with low peat depths (0.3 to 1.2m, average 0.52m). The turbines are mostly located within areas of minimal peat cover (less than 0.5m depth). Due to the predominantly regular slope of the ground, little ponding was observed, however most of the peat was saturated during the field surveys.

3.5. Existing Land Use

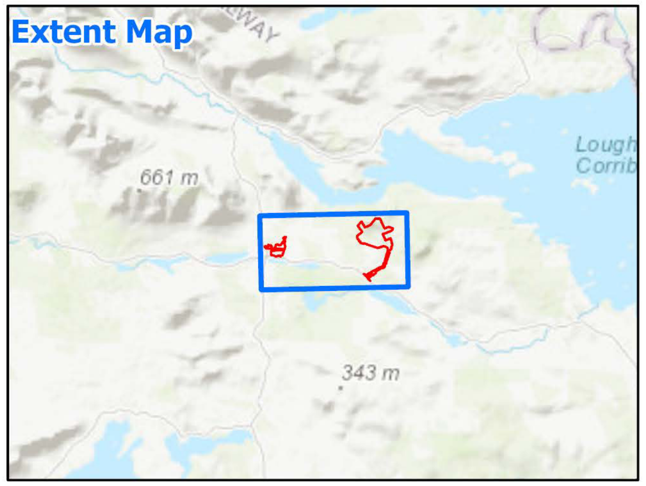
The site area is largely intact bog, containing typical bog vegetation (grasses, reeds and low shrubs). Land use is predominantly rough grazing for small flocks of sheep and small herds of cattle. There is some evidence of recent turf cutting near the lower-lying western parts of the site.



Legend

Peat Depth

- ≤ 0.5 m
- 0.5 - 1 m
- 1 - 1.5 m
- 1.5 - 2 m
- 2 - 3 m
- 3 - 4 m
- > 4 m
- Met Mast
- Grid Connection Route
- Turbine Locations
- Spoil Storage Areas
- Redline Boundary
- Hardstand and Roads
- Lakes
- Roads



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Project: Tullaghmore Wind Farm	
Map Title: Peat Depth Survey Results	
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Figure Number: 5	Page Size: A3
Date Exported: 24/08/2022	Scale: 1:17,000
Revision Number: 6	Prepared By: DP
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EMPower, Jennings O'Donovan & Partners, Andrew Garne Geotechnical Services and EcoQuest Environmental

Prepared by EcoQuest Environmental with design data provided by Jennings O'Donovan & Partners and with Peat Depth Data Provided by Andrew Garne Geotechnical Services

4. Peat Stability Risk Assessment (PSRA)

The fieldwork for the Peat Stability Risk Assessment (PSRA) was carried out by Senior Engineering Geologist Mr Andrew Garne B.Sc., M.Sc., P.Geo. between 31 August to 4 September 2020, 13th and 14th October 2020, 4th and 5th March 2020, 5th and 6th October 2021, 19th November 2021, 25th and 26th January 2022 and 18th August 2022, with particular reference to the following reports, papers and guidance documents.

Full references are given in the bibliography (Section 6):

- Peat Landslide Hazard and Risk Assessments (2017)
- General Soil Map of Ireland (1980)
- Wind Farm Planning Guidelines (2006)
- IWEA Best Practice Guidelines for the Irish Wind Energy Industry. (2012)
- IGI – Geology in Environmental Impact Statements (2013)
- Development on Unstable Land. (1990)
- Landslides in Ireland (2006)
- Guidelines for the risk management of peat slips on the construction of low volume/low cost roads over peat. (2006)
- Hydrological controls of surficial mass movements in peat (2004)
- Slope Instability in Ireland with particular reference to peat failures (2009)
- Peat slope failure in Ireland (2008)
- Eurocode 7: Geotechnical Design (2005)

The primary elements of the PSRA included:

1. Undertaking a desk study assessment to obtain information available on existing geological conditions at the proposed site location.
2. Undertaking a site walkover to identify geological constraints across the site.
3. Undertaking a ground investigation including peat probes, gouge cores and shear vanes.
4. Preparation of a peat stability risk assessment report.

4.1. Qualitative Slope Stability Assessment

A qualitative slope stability assessment was made for each of the turbine and substation locations. Table 1 below outlines the contributing factors and hazard scoring system used in the assessment (after MacCulloch, 2006).

Table 1: Qualitative Hazard Scoring System

Contributing Factor	Method of Assessment	Value/Indicator	Probability of contributing to peat movement	Hazard Score
Moisture Content of Peat	Visual or Lab	B1 (dry)	Negligible	1
		B2 (damp) <500%	Unlikely	2
		B3 (moist) 500-1000%	Probable	3
		B4 (wet) 1000-2000%	Likely	4
		B5 (very wet) >2000%	Very likely	5
Degree of Humification	Visual (Von Post Scale)	H1-H2 (fibrous, clear water)	Negligible	1
		H3-H4 (fibrous, brown water)	Unlikely	2
		H5-H6 (pseudo-fibrous)	Probable	3
		H7-H8 (amorphous, some fibres)	Likely	4
		H9-H10 (amorphous paste)	Very likely	5
Peat Depth	Peat probes and Gouge Cores	0 - 0.5m	Negligible	1
		0.6 - 1.0m	Unlikely	2
		1.1 - 1.5m	Probable	3
		1.6 - 2.0m	Likely	4
		>2.1m	Very likely	5
Slope Angle	Measured with inclinometer	0 to 3	Negligible	1
		4 to 9	Unlikely	2
		10 to 15	Probable	3
		16 to 20	Likely	4
		20 +	Very likely	5
Cracking or evidence of slips	Visual	None evident	Negligible	1
		Few	Unlikely	2
		Frequent	Probable	3
		Many	Likely	4
		Continuous/significant	Very likely	5
Shear Strength	Hand Vane	>21kPa	Negligible	1
		16-20kPa	Unlikely	2
		11-15kPa	Probable	3
		6-10kPa	Likely	4
		0-5kPa	Very likely	5
Surface Hydrology (gulleys, channels hags, pools, flushes, water courses)	Visual	None evident	Negligible	1
		Few	Unlikely	2
		Frequent	Probable	3
		Many	Likely	4
		Continuous/significant	Very likely	5
Weather	Weather Records	Previous very dry period in excess of 5yrs	Negligible	1
		Previous very dry period within 4 - 5yrs	Unlikely	2
		Previous very dry period within 3 - 4yrs	Probable	3
		Previous very dry period within 2 - 3yrs	Likely	4
		Previous very dry period within 1 - 2yrs	Very likely	5

In accordance with the recommendations of the Scottish Executive, peat depths of 0.5m or less are generally considered to be topsoil and/or vegetative acrotelm and are therefore considered to represent a negligible risk of peat stability. Accordingly, only the three locations where peat depth is in excess of 0.5m have been assessed for stability (T2, T5 and the substation). Table 2 shows the results of the assessment.

Table 2: Qualitative Hazard Assessment Results

Contributing Factor	T1	T2	T3	T4	T5	T6	Sub
Moisture Content		3			4		4
Degree of Humification		3			3		3
Peat Depth		2			3		4
Slope Angle		3			3		1
Cracking or evidence of slips		1			1		1
Shear Strength		4			1		3
Surface Hydrology		1			1		1
Weather		1			1		1
Hazard Score		**18**			**17**		**18**

Combined Hazard Score	Probability
32 to 40	Very High
26 to 31	High
20 to 25	Medium
14 to 19	Low
8 to 13	Very Low

The table shows that three of the seven locations assessed contain a thickness of peat greater than 0.5m (rating of between 2 and 4). It should be noted that the characteristic peat depth has been used rather than the maximum recorded depth as outliers may represent localised deep pockets which would not affect the overall stability of the area.

The qualitative slope stability assessment suggests that the risk of slope failure at these locations is considered to be low. This assessment is in contradiction to the GSI landslide susceptibility mapping which shows that turbine T4 is located in an area of high susceptibility. Several of the proposed access tracks also pass through areas of high or moderately high susceptibility according to the GSI landslide susceptibility mapping.

4.2. Quantitative Slope Stability Analysis

Total stress analyses for translational slides within the peat have been undertaken in accordance with the principles of Eurocode 7-1: Geotechnical Design (IS EN 1997-1) Design Approach 3(12). This design approach is considered to be the most logical approach for slope stability analysis as it includes partial factors for both material properties and variable loads (for example traffic loads).

In accordance with the principles of the Eurocode, rather than using a global factor of safety as per previous design codes, partial factors are applied to the chosen characteristic values to obtain design values. Actions (influences) are multiplied by the partial factors, while resistances are divided by the partial factors. As discussed previously, peat depths of less than 0.5m are normally considered to represent a negligible risk of instability (due to being predominantly vegetative acrotelm) and have therefore not been included in the Safety Ratio calculations.

Table 3 shows the partial factors that have been applied to the characteristic values to give the design values used in the slope stability analyses.

Table 3: IS EN 1997-1 Partial Factors Used to Derive Design Parameters

Set	Partial Factor		Parameter
M2	γ_{cu} γ_{γ}	1.4 1.0	Corrected undrained shear strength Soil Density
A2	γ_{Q}	1.3	Traffic Loading (variable unfavourable)
R3	$\gamma_{R;e}$	1.0	Earth Resistance

In accordance with Eurocode 7, geotechnical checks must be carried out to ensure that the resistance preventing a slide is greater than or equal to the actions which cause a slide, i.e.:

Ed <= Rd
Where;
Ed = Sum of design actions
Rd = Sum of design resistances

In order to verify that this condition is met, the following formula has been applied, using the design values obtained using the partial factors given in Table 3. The resulting “safety ratio” must be equal or greater than 1.0 in order to verify that the above condition is met. i.e.:

$$\frac{Cu}{\gamma z \cos\beta \sin\beta} = \text{or} > 1.0$$

Where;

C_u = corrected shear strength of peat (value obtained from hand shear vane)
γ = density of peat (normally assumed to be 1.0 mg/m^3)
z = thickness of peat layer in metres (measured from probes/gouge core)
β = slope angle at turbine location (from clinometer readings)

4.2.1. Limitations of Slope Stability Analysis

The application of traditional stability analysis such as this should be used with caution due to the compressibility of peat and because the analysis does not account for the fibrous nature of the peat. Cognisant of the organic and highly variable nature of peat, uncertainties related to the directional dependence on which the strength of peat is based, the reliability of traditional methods of field shear strength measurement, presence of gas within the peat and the combination of factors (some not quantifiable or applicable in a calculation matrix) triggering slope failure, the failure mechanisms being employed in the traditional analysis may not necessarily be representative of in-situ failure mechanisms.

Despite the limitations outlined above, this method of slope analysis is still considered useful as an indicator of possible areas of instability and its use is in accordance with current industry best practice.

4.2.2. Shear Strength Values

The shear strength values were obtained using a Geonor H-60 hand-held shear vane with a correction factor of 0.5 based on published correlation data. This correction factor is considered quite conservative and is therefore appropriate for preliminary analysis of the slope sections for preliminary design purposes.

Shear strength at the base of a peat mass is often the governing factor in peat stability and analysis; therefore, shear strength values chosen for the stability analysis are based on a characteristic value representative of the shear strength of the peat recorded generally within 0.5m of the base of the peat body in the vicinity of the turbines, unless this is significantly higher than the typical shear strengths recorded at other depths, in which case the lower value is normally used.

Based on the field vane shear strength data, corrected shear strength values of 2kPa to 20kPa (average 8.9kPa) were determined as the characteristic values for the slope stability analysis. No differentiation between the upper acrotelm (where present) and lower catotelm layers has been assumed for the purpose of the stability analysis in order to provide a more conservative analysis.

4.3. Slope Stability Analysis Results

The calculated in-situ safety ratios at the proposed turbine and substation locations are presented in Table 4 along with the typical peat depth (not necessarily the maximum depth recorded), characteristic corrected shear strength and typical slope angle. As discussed previously, a ratio of less than 1.0 (shaded red in Tables 4 and 5) indicates that the slope currently has an inadequate factor of safety against failure and therefore is potentially unstable in the long term without the implementation of suitable mitigation measures. Ratios of 1.0 or greater indicate an adequate factor of safety against failure and indicate that the location is considered stable.

Figures 6 to 9 show the locations for each of the slope stability calculations. These calculations are based on the current ground and do not include any surcharge loadings. The results show only 3 locations of elevated risk within two areas (indicated by red dots). The two areas are located approximately 80m northwest of T03 and approximately 400m south of T01.

Figures 10 to 13 show the locations for each of the slope stability calculations with the addition of a 20kPa surcharge. This load is equivalent of stockpiling approximately 2m depth of peat, or a typical loading from a “floating road” with construction traffic. The calculations now show 29 locations of elevated risk within the red line boundary (indicated by red dots), being located around turbines T02, T03 and T05, along the proposed access road to T02 and T03 (Figure 9), between turbines T01 and T06 (Figure 10), and along the access track to the south of turbine T01 (Figures 10 and 11).

Table 4: Slope Stability Analysis Results – Turbines & Substation

Location	Slope°	Depth (m)	Measured Cu	Corrected Cu	Factored Cu	Safety Ratio	Safety Ratio +20kPa Surcharge
Substation	2	1.2	20	10	7.1	17.1	5.4
T1	19	0.3	10	5	3.6	n/a	n/a
T2	12	0.7	10	5	3.6	2.5	0.5
T3	14	0.3	30	15	10.7	n/a	n/a
T4	8	0.3	25	12.5	8.9	n/a	n/a
T5	13	1.2	25	12.5	8.9	3.4	1.1
T6	4	0.3	20	10	7.1	n/a	n/a

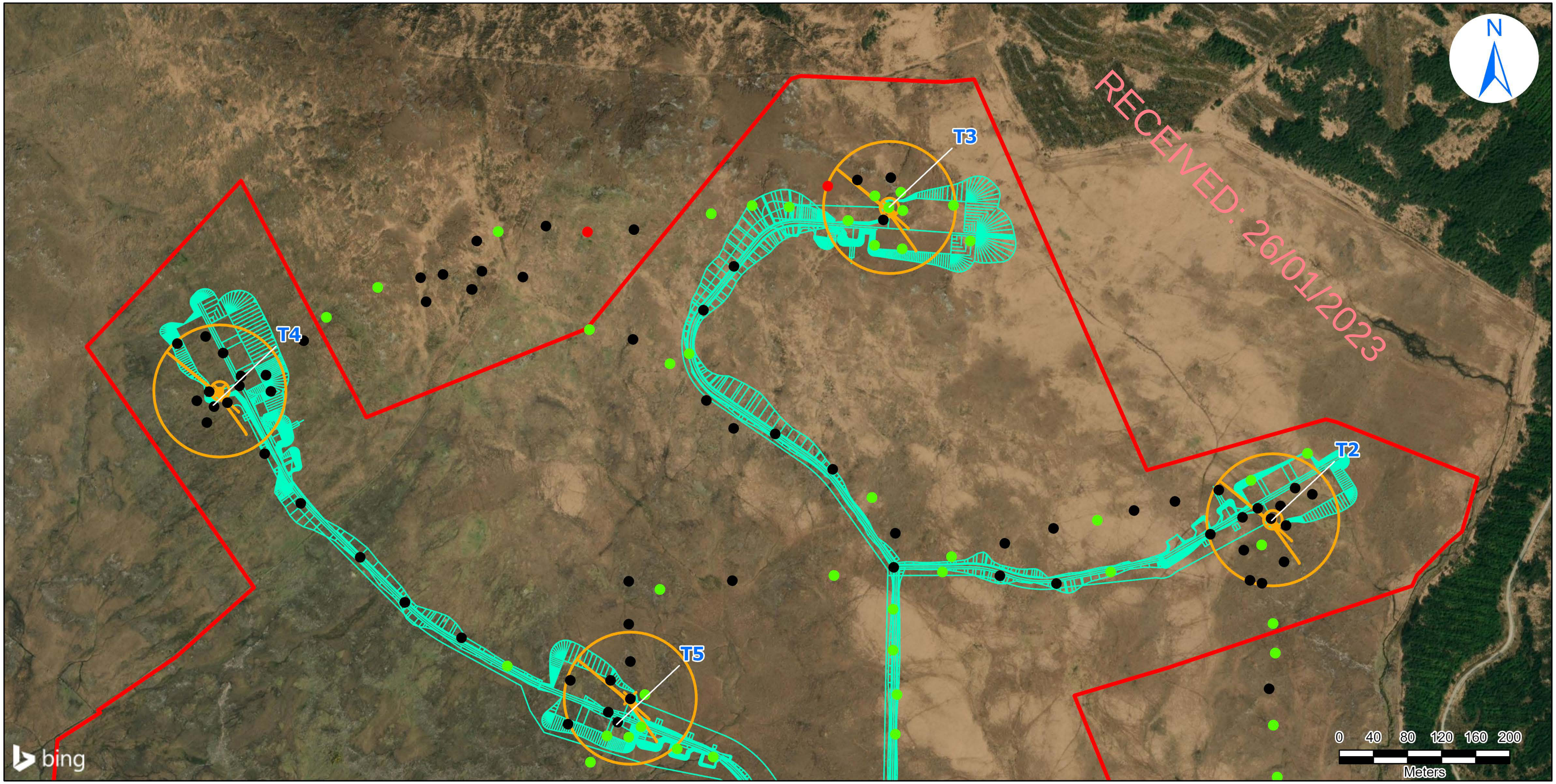
Table 5 presents the results of analysis along the proposed access tracks at nominal 100m centres. These calculations are based on the observations of peat depth (from peat probes), corrected shear strengths (from hand-held shear vane tests) and slope measurements (from clinometer readings):

Table 5: Slope Stability Analysis Results – Access Tracks

Probe No.	Slope°	Depth (m)	Measured Cu	Corrected Cu	Factored Cu	Safety Ratio	Safety Ratio +20kPa Surcharge
51	3	1.9	10	5	3.6	3.6	1.5
52	3	1.8	5	2.5	1.8	1.9	0.8
53	3	1.4	5	2.5	1.8	2.4	0.9
54	3	2.2	5	2.5	1.8	1.6	0.7
55	3	1.9	4	2	1.4	1.4	0.6
56	3	1.4	8	4	2.9	3.9	1.4
57	4	0.2	40	20	14.3	n/a	n/a
58	4	0.2	40	20	14.3	n/a	n/a
59	3	0.2	35	17.5	12.5	n/a	n/a
60	3	3	4	2	1.4	0.9	0.5
61	3	1.1	5	2.5	1.8	3.1	0.9
62	2	1.5	18	9	6.4	12.3	4.5
63	2	1.1	12	6	4.3	11.2	3.3
64	2	0.6	12	6	4.3	20.5	3.8
65	2	0.7	10	5	3.6	14.6	3.1
66	2	2	9	4.5	3.2	4.6	2.0
67	2	2.1	12	6	4.3	5.9	2.6
68	5	0.4	10	5	3.6	n/a	n/a
69	5	1.2	30	15	10.7	10.3	3.2
70	4	0.6	18	9	6.4	15.4	2.9
71	4	1	16	8	5.7	8.2	2.3
72	4	1	12	6	4.3	6.2	1.7
73	4	0.6	10	5	3.6	8.6	1.6
74	4	0.2	20	10	7.1	n/a	n/a
75	4	0.9	22	11	7.9	12.5	3.2
76	4	0.4	30	15	10.7	n/a	n/a
77	3	0.9	15	7.5	5.4	11.4	2.9
78	4	1	20	10	7.1	10.3	2.9
79	3	1	15	7.5	5.4	10.3	2.8
80	3	0.6	30	15	10.7	34.2	6.4
81	3	0.6	25	12.5	8.9	28.5	5.3
82	3	1.2	24	12	8.6	13.7	4.3
83	3	2	12	6	4.3	4.1	1.8
84	3	0.2	10	5	3.6	n/a	n/a
85	4	1.5	10	5	3.6	3.4	1.3
86	4	1.3	12	6	4.3	4.7	1.6
87	5	0.2	30	15	10.7	n/a	n/a
88	5	0.9	8	4	2.9	3.7	0.9
89	4	0.8	8	4	2.9	5.1	1.2

Probe No.	Slope°	Depth (m)	Measured Cu	Corrected Cu	Factored Cu	Safety Ratio	Safety Ratio +20kPa Surcharge
90	6	0.3	30	15	10.7	n/a	n/a
91	6	0.9	10	5	3.6	3.8	1.0
92	6	0.2	25	12.5	8.9	n/a	n/a
93	10	0.4	25	12.5	8.9	n/a	n/a
94	8	0.3	25	12.5	8.9	n/a	n/a
95	8	0.4	20	10	7.1	n/a	n/a
96	8	0.3	25	12.5	8.9	n/a	n/a
97	8	0.2	26	13	9.3	n/a	n/a
98	8	0.5	26	13	9.3	n/a	n/a
99	8	0.7	10	5	3.6	3.7	0.8
100	7	0.2	25	12.5	8.9	n/a	n/a
101	7	0.2	25	12.5	8.9	n/a	n/a
102	8	0.3	18	9	6.4	n/a	n/a
103	12	1.2	8	4	2.9	1.2	0.4
104	10	0.4	15	7.5	5.4	n/a	n/a
105	20	0.4	20	10	7.1	n/a	n/a
106	20	0.6	14	7	5.0	2.6	0.5
107	15	0.4	25	12.5	8.9	n/a	n/a
108	3	1.7	15	7.5	5.4	6.0	2.4
109	10	0.2	25	12.5	8.9	n/a	n/a
110	5	1.7	26	13	9.3	6.3	2.5
111	10	0.3	30	15	10.7	n/a	n/a
112	10	0.3	25	12.5	8.9	n/a	n/a
113	12	0.2	30	15	10.7	n/a	n/a
114	12	0.2	25	12.5	8.9	n/a	n/a
115	10	0.9	35	17.5	12.5	8.1	2.1
116	15	0.9	18	9	6.4	2.9	0.7
117	12	0.2	18	9	6.4	n/a	n/a
118	12	0.4	20	10	7.1	n/a	n/a
119	12	1.5	10	5	3.6	1.2	0.4
120	8	1.2	25	12.5	8.9	5.4	1.7
121	4	2.1	8	4	2.9	2.0	0.9
122	5	1.6	15	7.5	5.4	3.9	1.5
123	5	1.9	8	4	2.9	1.7	0.7
124	6	0.9	8	4	2.9	3.1	0.8
125	4	0.8	6	3	2.1	3.8	0.9
126	4	1.8	8	4	2.9	2.3	0.9
127	4	1.3	8	4	2.9	3.2	1.1
128	4	1.7	10	5	3.6	3.0	1.2
129	5	0.8	15	7.5	5.4	7.7	1.8
130	3	3.1	6	3	2.1	1.3	0.7
132	2	5.5	10	5	3.6	1.9	1.3
135	2	3.6	10	5	3.6	2.8	1.7
136	5	0.4	10	5	3.6	n/a	n/a
137	2	3.7	12	6	4.3	3.3	2.0
138	2	1.2	20	10	7.1	17.1	5.4
139	10	0.5	25	12.5	8.9	n/a	n/a
140	10	0.3	25	12.5	8.9	n/a	n/a
141	10	0.3	25	12.5	8.9	n/a	n/a
142	3	1	10	5	3.6	6.8	1.9
143	2	1.2	20	10	7.1	17.1	5.4

Probe No.	Slope°	Depth (m)	Measured Cu	Corrected Cu	Factored Cu	Safety Ratio	Safety Ratio +20kPa Surcharge
145	2	2.8	15	7.5	5.4	5.5	2.8
147	5	0.3	20	10	7.1	n/a	n/a
154	1	0.6	30	15	10.7	102.3	19.2
155	1	0.8	40	20	14.3	102.3	24.1
157	1	1.1	20	10	7.1	37.2	11.1
165	3	0.9	30	15	10.7	22.8	5.9
166	5	0.9	18	9	6.4	8.2	2.1
167	3	0.7	10	5	3.6	9.8	2.1
169	3	1.1	10	5	3.6	6.2	1.8
170	3	1.3	10	5	3.6	5.3	1.8
172	17	0.7	20	10	7.1	3.6	0.8
177	15	0.7	25	12.5	8.9	5.1	1.1
179	25	0.6	30	15	10.7	4.7	0.9
184	15	1	20	10	7.1	2.9	0.8
186	20	1.1	8	4	2.9	0.8	0.2
189	15	1.1	18	9	6.4	2.3	0.7
190	15	0.9	24	12	8.6	3.8	1.0
191	12	0.9	15	7.5	5.4	2.9	0.8
193	10	0.7	11	5.5	3.9	3.3	0.7
194	18	1.1	18	9	6.4	2.0	0.6
195	15	1	10	5	3.6	1.4	0.4
197	15	0.6	25	12.5	8.9	6.0	1.1
198	8	2.3	8	4	2.9	0.9	0.4
203	20	0.6	25	12.5	8.9	4.6	0.9
204	15	0.8	30	15	10.7	5.4	1.3
216	1	1.6	20	10	7.1	25.6	9.7
217	1	1.9	10	5	3.6	10.8	4.5
218	1	2.1	16	8	5.7	15.6	7.0
219	1	2	16	8	5.7	16.4	7.1
221	1	2.5	10	5	3.6	8.2	4.0
223	1	0.7	20	10	7.1	58.5	12.4
224	1	0.7	20	10	7.1	58.5	12.4
226	1	1	20	10	7.1	40.9	11.4

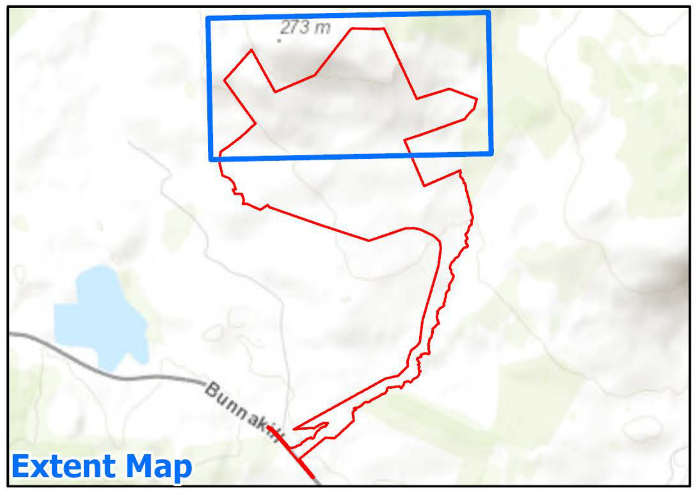


Legend

Safety Ratio (No Surchage)

- FOS N/A (≤ 0.5m Peat)
- ≤ 1
- >1

- Turbine Locations
- Redline Boundary
- Hardstand and Roads



Client: Jennings O'Donovan & Partners	
Project: Tullaghmore Wind Farm	
Map Title: Calculated Safety Ratios for T2, T3, T4 and T5 (No Surcharge)	
Spatial Reference Name: IRENET95 Irish Transverse Mercator	
Figure Number: 6	Page Size: A3
Date Exported: 24/08/2022	Scale: 1:4,500
Revision Number: 6	Prepared By: DP
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Prepared by EcoQuest Environmental with design data provided by Jennings O'Donovan & Partners and with Peat Depth Data Provided by Andrew Garne Geotechnical Services