Appendix 10.1b Peat Slide Hazard and Risk Assessment -Interpretive Report

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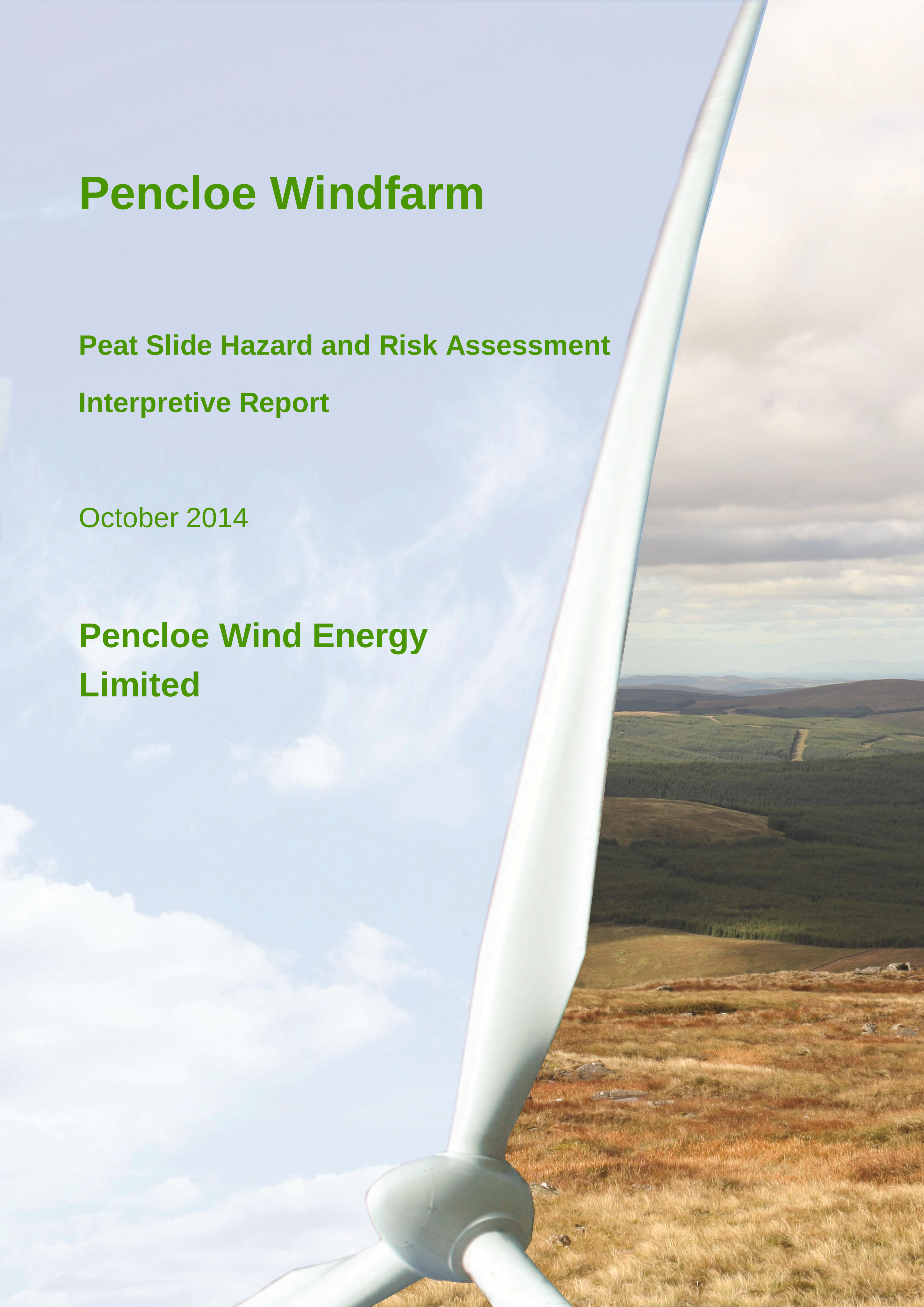
Pencloe Windfarm

Peat Slide Hazard and Risk Assessment

Interpretive Report

October 2014

Pencloe Wind Energy Limited



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Executive Summary

1. In recent years, peat landslides (peat slides) have emerged as a new and significant consideration for windfarm projects on peatlands. Developers need to understand peat slide risk and demonstrate that it is being properly controlled, kept under review and further reduced as and when possible. This is the Interpretive Report for the preliminary peat slide risk assessment undertaken for the proposed Pencloe Windfarm. The Factual Report is provided in a separate document.

2. Desk studies and field surveys using the Peat slide Hazard Rating System (PHRS) were employed to evaluate peatland stability at the Pencloe application site. This work identified the salient features of the local bedrock, geomorphology, topography, peat profile, glacial drift deposits, drainage and weather that influence peat slope stability.

3. Rainfall is an important trigger for peat sliding events and it is noteworthy that the local microclimate at the application site features very high total rainfall.

4. Peat slide potential increases with clayey sub-soils that not only impede water flows but also provide smooth slip surfaces. At Pencloe, substrata of greywacke bedrock and drift deposits of glacial and / or alluvial sands and gravels predominate.

5. The peatland at Pencloe has been extensively disturbed by commercial forestry activities over the past 40 to 50 years. The natural drainage characteristics of the application site have been significantly affected by the introduction of manmade drainage channels and ditches associated with the forestry plantations. Some evidence of peat erosion (hagging), minor peat slide activity and sub-profile drainage was observed upon the open moorland around Struther's Brae hill in the southeast of the application site. Peat thicknesses are variable across the application site although on the whole, relatively shallow. A maximum peat depth of 3.3m was recorded.

6. The peat profile contains limited roots and fibrous material and is generally highly decomposed. Numerous steep slopes and wet ground conditions increase peat slide susceptibility in certain areas.

7. The Peat slide Hazard Rating System (PHRS) provides a comparative method for ranking sites by geohazard. It was used to assess the peat slide hazard at Pencloe. Based on the PHRS scores as well as terrain analysis, important design parameters have been established in support of the layout design.

8. Specific design constraints for layout purposes include:

   - Steep slopes should be avoided as far as possible and development operations restricted to areas having gradients of less than 10^{o}.
   - Based upon the recorded peat depths and proposed infrastructure layout, it is not anticipated that any turbines or significant sections of track will lie within areas of peat with a thickness greater than 2m. It is recommended that additional confirmatory peat depth probing is carried out along the proposed access track routes within the turbine envelope once the design details have been finalised.
   - Areas of boggy or saturated deep peat should be avoided as far as possible. Any encroachments should be assessed for peat slide risk by a geotechnical engineer and measures developed for ground improvement where necessary.

- A single turbine (T6) and limited sections of the proposed access track route are shown to be located within areas of moderate peat slide risk. Where possible, turbine positions and access track alignments should be microsited into lower peat slide risk areas. Where infrastructure must remain within areas of moderate risk, it may be necessary to undertake more detailed ground investigation and risk assessment and to adopt strict engineering controls during construction to minimise the risk of peat sliding. All construction works which encroach into areas of moderate peat slide risk should be assessed by a geotechnical engineer and measures developed for ground improvement where necessary.

9. An overall PHRS score of 149 for the proposed turbine envelope area places it in the low category of peat slide risk. In certain locations the score exceeds 200 and very locally, 300, which corresponds to a moderate risk level although such areas appear localised and the majority of the turbine envelope is considered to have a low risk of peat slide susceptibility.

10. Engineering responses may be required to deal with localised instability during the construction phase of the project. These responses can be implemented under geotechnical supervision. A geotechnical risk register for the project is provided herein for the purpose of managing geotechnical risk during the construction phase.

1. Introduction

Pencloe Wind Energy Ltd (PWEL) is proposing to construct a windfarm within Forestry Commission Scotland (FCS) land at Pencloe, near New Cumnock, East Ayrshire (Figure 1 of the Factual Report). The windfarm development will involve erecting twenty one wind turbines each with an anticipated capacity of 3.3 MW, the upgrade and construction of access tracks and installation of a control building and substation.

A geo-engineering study on peat slope stability was carried out to consider the risk of peat slides occurring at the application site, such that suitable controls and methodologies can be employed during design and construction to mitigate these risks.

This is the Interpretive Report for the Peat Slide Hazard and Risk Assessment for the Pencloe Windfarm. It should be read in conjunction with the separate Factual Report which summarises the work carried out and the information obtained. Both documents were prepared in accordance with the format recommended in the Scottish Executive's best practice guide (Scottish Executive, 2006). In addition, the documents comply with the latest guidance on good practice during windfarm construction (Scottish Renewables et al, 2010) as well as the International Peat Society strategy for responsible peatland management (Clarke and Rieley, 2010).

1.1. Site Location

The Pencloe application site is located within an area of upland commercial forestry in the north eastern part of the Carsphairn Forest, approximately 5 km south of New Cumnock within East Ayrshire. The entire application site occupies an area of approximately 871 ha. The Peat Slide Risk Assessment has been carried out primarily within the proposed development area.

The application site boundary and surrounding area is shown in Figure 1 of the Factual Report.

1.2. Scope and Purpose of the Investigation

SKM Enviros (now Jacobs) was commissioned to undertake a study of peat slide risks for the application site at Pencloe. A constraints based approach was used to provide design guidance for the preliminary layout. This report has been compiled with the following aims:

- To estimate the geotechnical risks associated with peat slides;
- To identify key areas of the windfarm potentially affected by unstable peat conditions;
- To suggest strategies for mitigation of peat slide risk and recommend additional surveys, if required and
- To formulate a preliminary geotechnical risk register for the project.

This report provides a summary of the work undertaken to date, an overall interpretation of the hazard and risks associated with mass movement of peat and an appraisal of engineering and mitigation considerations. The report also includes an initial geotechnical risk register for the project.

1.3. Field and Laboratory Studies

An estimate of the risk of peat sliding was undertaken at the proposed application site by using the Peat Slide Hazard Rating System (PHRS; Nichol, 2006). The system is based on a number of factors, including the identification of the salient features of local bedrock, glacial drift deposits, geomorphology, topography, peat profile, peat strength, drainage and weather that may influence peat slope stability across the application site.

The assessment involved:

- A front end desk-study concerning peat slides in general in order to focus upon the development of hazard models and provide an estimation of the nature, size (magnitude) and frequency characteristics of peat sliding events deemed to have immediate background relevance to this study. The findings are incorporated in this report.

- Site walkovers and field surveys in order to estimate the size, frequency, likelihoods and consequences of peat slide events by identifying and delineating specific hazard-prone areas within the application site. The principal approach involved the Peat Slide Hazard Rating System (PHRS) which provides a comparative method for ranking sites by peat slide geohazard potential. The field data are presented in the accompanying Factual Report.

- Laboratory testing to determine certain properties of the peat profile at the Pencloe Windfarm site. The information and data obtained are presented in the accompanying Factual Report.

At the pre-construction stage, further ground investigations will be required for detailed design purposes and to verify ground conditions at turbine positions, along the routes of new access tracks and at the substation location.

2. Site Conditions and Material Properties

2.1. Peat Profile

Peat is essentially an accumulation of plant remains at various stages of decomposition, formed in waterlogged areas. It developed as a result of the cool wet climate (Lindsay, 1995). The peat at Pencloe proved variable in depth although on the whole, relatively shallow. Localised thicknesses up to 3.3m encountered.

The peat profile at Pencloe is observationally accessible at several places across the application site mainly in banks of drainage ditches. A number of detailed inspections were also made using hand gouge auger holes. The profile was described as comprising light brown to dark red brown amorphous, plastic to slightly fibrous peat beneath the present-day root mat.

Much of the peat body at the application site has been extensively disturbed i.e. by afforestation or agricultural improvement and this has locally resulted in significant disturbance to the natural water table and acrotelmic horizon. Generally, the peat on the application site possesses low to very low engineering properties, often depending on the level of saturation and clay content.

At Pencloe, within non forested peat bearing areas the surface vegetation consists predominantly of sphagnum and other mosses, grasses (including cotton grass), rushes and heather. Within the forested areas, little vegetation was noted other than moss and fungi.

Laboratory derived moisture content values ranged from 414% to 859%.

The Von Post data sheets for the peat cores are presented in Appendix D and summarised in Section 4.1. Survey locations are shown in Figures 5.5 & 5.6 of the Factual Report.

2.2. Seismicity

For the Ayrshire region, the Eurocode 8 seismic hazard zoning maps for the UK (Musson and Sargeant, 2007) indicate that horizontal Peak Ground Acceleration (PGA) values with 10% probability of being exceeded in 50 years (475 year return period) are generally less than 0.02g which is exceedingly low. Accordingly, in relation to the present study, seismic tremors are unlikely to induce mass movements in peat in either marginally stable slopes or saturated peatland areas.

2.3. Local Climate

The East Ayrshire region of Scotland has a relatively wet and cool climate, due to predominantly westerly rain-bearing winds associated with Atlantic depressions. Rainfall is generally well-distributed throughout the year but there is a marked seasonal variation. The frequency of Atlantic depressions is normally greatest during the winter but, unlike other areas of the UK, Scotland tends to remain under their influence for much of the summer too. Autumn and early winter are the wettest seasons, especially from October to January and spring and early summer is normally the driest part of the year, especially from April to June.

The Flood Estimation Handbook (CEH Institute of Hydrology, 1999) indicates a figure of 1868mm/year and based upon this data source, a figure of 1870 mm was used as the estimated annual rainfall at Pencloe for the purposes of the peat slide hazard assessment.

2.4. Peat Slide Inventory

2.4.1. Existing Information

Peat slides are defined as the downward and outward movement of peat masses. This definition is intended to embrace a wide array of ground movements associated with peatlands. As such, peat slides range from catastrophic and rapid downhill flows to minor slips and longitudinal cracking on gentle slopes.

A literature survey concerning peat slides, their field relations, distribution, occurrence and consequences is summarised in Table 1. This indicates that in relation to the effects of peat slide events, they rarely affect people directly by causing injury or death.

Table 1. A Selection of Recorded Peat Slide Events and their Consequences

Authors	Location	Event	Date	Trigger	Size (000 m^3)	Consequences
Acreman (1991)	Pennygrant Hill, Scotland	Multiple peat slides	25 July 1983	Intense rainfall	1	Land, building and fences damaged; fish killed.
Barkley (1887) Bailey (1879)	Port Stanley, Falkland Islands	Compound peat slide	2 June 1886	Intense rainfall	40	Damage to buildings, roads and harbour. Death of 1 person.
Bowes (1960)	Morsgail, Lewis, Scotland	Peat slide	20 November 1959	Heavy rainfall, lake breach	4	Erosion, land damage, fish kills
Winter et al (2005)	Channerwick, Shetland, Scotland	Peat slide	19 September 2003	Intense rainfall	500	Damage to buildings, roads, bridge and services; sheep killed.
Carling (1986); McCahon et al (1987)	Nein Head II, North Pennines, England	Multiple peat slides	17 July 1983	Intense rainfall	31	Erosion, land damage, fish kill.
Colhoun et al (1965)	Glendun, Antrim, Ireland	Peat slide	10 November 1963	Intense rainfall	400	Damage to land, buildings, roads, a bridge and farm machinery; erosion.
Crisp et al (1964)	Meldon Hill, England	Multiple peat slides	6 July 1963	Intense rainfall	6	Erosion, land damage.
Dykes and Jennings (2011)	Geevagh, Sligo, Ireland	Multiple peat slides	13 August 2008	Intense rainfall	180	Blocked roads, damaged community centre, destroyed bridge and environmental deterioration
Dykes and Jennings (2011)	Ballincollig Hill, Tralee, Kerry, Ireland	Peat slide	22 August 2008	Windfarm construction works and peat extraction	130	Blocked watercourse and environmental deterioration
Dykes and Kirk (2001)	Cuilcagh Mountain, Ireland	Compound peat slide	25 October1998	Rainstorm and degraded ditches	10	Erosion, land damage.
Fleming (2003)	Derrybrien, Galway, Ireland	Peat slide	October 2003	Intense rainfall and windfarm construction	40	Damage to bridges, blocked roads and fish kill / watercourse pollution
Gallart et al (1994)	Tierra del Fuego, Argentina	Multiple peat slides	1957-1970	Steep slopes, snowfalls and earthquakes	8	Temporary environmental deterioration.

Authors	Location	Event	Date	Trigger	Size (000 m^3)	Consequences
Hemingway and Sledge (1946)	Danby-in-Cleveland, England	Peat flow	12 August 1938	Rainstorm	100	Damage to walls and buildings, sheep killed.
Hungr and Evans (1985)	Prince Rupert, Canada	Peat flow	1982	Excessive loading	10	Land damage and construction delays.
Long and Jennings (2006)	Pollatomish, Mayo Ireland	Multiple peat slides	19 September 2003	Intense rainfall and steep slopes	200	Damage to buildings, roads and cemetery; village evacuated.
McEwen and Withers (1989)	Solway Moss, Carlisle England	Peat slide and flow	16 November 1771	Intense rainfall	3,700	Damage to buildings, farmland and roads; cattle, horses and fish killed.
Nichol et al (2007)	Capel Currig, North Wales	Peat slide	8 November 2005	Intense rainfall	1	Damage to road, one person injured.
Nichol (2009)	Glenfiddich, Scotland	Peat slide	18 August 2004	Rainstorm	1	Damage to land, track and bridge.
Selkirk (1996)	Stony Creek, Macquarie Island	Multiple peat slides	February 1992	Steep slope, rainfall and seismicity	2	Temporary environmental deterioration
Sollas et al (1897)	Knocknageedha, Ireland	Peat flow	28 December 1896	Intense rainfall	5,000	Damage to land, buildings, roads and bridges; death of 8 persons.
Tallis (1987)	Holme Moss, England	Peat slide	23 July 1777	Intense rainfall	10	Erosion, land damage.
Warburton et al (2003)	Hart Hope, N.Pennines, England	Peat slide	February 1995	Heavy rainfall, clayey substrate	31	Erosion, land damage.
Wilson and Hegarty (1993)	Skerry Hill, Antrim, Ireland	Multiple peat slides	November 1991	Heavy rainfall and degraded drainage ditches	3	Erosion, land damage.
Wilson et al (1996)	Carntogher, Londonderry, Ireland	Peat flow	10 September 1993	Heavy rainfall and degraded drainage ditches	300	Damage to land, fences and services; sheep and fish killed.

The principal concern at the present day appears to focus on potential damage to water bodies, watercourses and fisheries interests. Other impacts on the environment include the loss of peat, discolouration of downstream watercourses by dissolved organic matter, loss of wildlife habitats, visual obtrusion on the local landscape, removal of vegetation cover and exposure of bare faces of peat to erosion. Moreover, the perception prevails that peat slides are increasing in frequency and that, at least in part, this is the result of increased human activity encroaching on peatland areas.

This perception gained considerable support following the peat slide incident in 2003 at Derrybrien, Co. Galway, Republic of Ireland (Fleming, 2003). The Derrybrien peat slide is of considerable significance to the present project because the chief factor contributing to the ground movements was the construction of a 60MW windfarm (71 turbines) in the adjoining ground. The peat slide occurred in the Slieve Aughty Mountains of Galway on 16 October 2003. The initial ground movements were relatively minor. However, torrential rain on 22 and 23 October triggered a second surge that escalated into a massive peat slide. It damaged two bridges, obstructed two roads and polluted watercourses. In addition, the Shannon Regional Fisheries Board estimated that over 100,000 fish could have been in the affected waters and they claim that over 50% of these fish died.

At the Derrybrien site, the peat depth ranged up to 5.5m overlying glacial clayey till of Late Pleistocene age and bedrock of sandstone and conglomerate of Devonian age. The peat slide occurred in a forested area, on gently sloping ground with gently dipping rockhead (~10-15^{o}). Beneath the peat, the glacial till formed a localised channel which appears to have acted as a subsurface drainage path for surface water. The peat slide starting zone measured around 100m wide but the runout zone extended up to about 300 m wide and stretched for over 2 km in length.

All work on the windfarm site ceased and engineers devised emergency measures to stem the flow of the peat slide. Three check dams or rock bunds with drainage channels were built to arrest the flow of material and allow water and fines through. The rock bunds around 10m wide and up to 4m high contained pipes and channels to drain the material behind. The key lessons and recommendations include:

- Concentrated loads such as excavated material from turbine foundation excavations should not be placed on marginally stable ground;
- Concentrated water flow onto peat slopes and unstable excavations should be avoided;
- Construction should be supervised by qualified and experienced geotechnical personnel;
- Robust drainage plans should be developed;
- Modified work practices should be adopted that do not affect existing stability and
- Ground investigation and movement monitoring practices should be reviewed.

Importantly for the Pencloe Winddfarm project, the events at Derrybrien demonstrate the potential for construction activities at turbine sites and their associated access roads to induce ground movements that may adversely affect the construction programme and the environment.

2.4.2. Peat Slides in Great Britain

Recently reported examples of peat slides in Scotland include slips at Pennygany Hill in the Cheviots on 25 July 1983 (Werrity & Ingram, 1985); on steep north-facing slopes on Barra and Vatersay, Western Isles in 1992 (Gilberston & Grattan, 1995); Morsgail, Lewis also in the Western Isles on 20 November 1959 (Bowes, 1960); Glenfiddich in the Grampians on 18 August 2004 (Nichol, 2009) and Channerwick, Shetland on 19 September 2003 (Dykes & Warburton, 2008).

Only one peat slide case history report exists for Wales at Capel Curig on 8 November 2005 (Nichol et al, 2007). However, in northern England, well documented examples of peat slides in the Pennines include Cabin Clough on 30 July 1934 (Montgomery & Shimwell, 1985); Meldon Hill on 6 July 1963 (Crisp et al, 1964); Noon Hill and Langdon Head on 17 July 1983 (Carling, 1986) and Hart Hope during February 1995 (Warburton et al, 2003).

2.4.3. Peat Slides at Pencloe

Since previous peat slide activity around the windfarm site may serve as an indicator and guide to future slope movements, evidence of peat slope instability was sought in the field by walkover inspections.

Several minor peat slide features were observed at the application site during the field survey, although these appeared to be confined to an area of open moorland to the north and west of Struther's Brae hill in the south eastern part of the application site.

It is evident that the peat geomorphology within this area has been considerably affected by erosion, primarily in the form of peat 'hagging' (see Plate 1 below) and the minor peat slide features encountered within this area appeared to be closely associated with natural weathering processes. Surface water run-off, wind and frost action are likely to be the most significant factors in shaping the local geomorphology.

Photo 1 - Peat hagging north of Struther's Brae hill

The observed peat slide features appeared to be relatively small scale, comprising potential relic minor translational slips which generally appeared to be associated with breaks in slope where the down gradient peat profile has been weathered away resulting in an exposed peat face or 'scar'. Such features were locally observed up to 25m in length and 10m width, with exposed faces up to approximately 1m in height and some minor slumping of the exposed peat faces was also noted (see Plate 2 below).

Photo 2 – Minor peat slide feature and slumping northwest of Struther's Brae hill

No other noteworthy peat slide localities were identified elsewhere across the application site although occasional minor indications of peat instability were encountered along the banks of streams, which are considered to be a normal part of the development of river systems.

It should be noted that the land use at the application site, comprising commercial forestry plantations, is likely to have significantly reduced the likelihood of peat slides occurring, both as a result of the introduction of artificial drainage conduits and the physical presence of tree root systems acting to stabilise the peat matrix.

2.5. Sinkholes and Sub-profile Drainage

Sinkholes provide surface evidence of the presence of open subterranean conduits and appeared to be very limited throughout the application site at Pencloe.

The natural drainage characteristics of the area have been significantly altered by the presence of forestry plantation lines and ditches which act as highly effective drainage conduits. A network of man-made drainage channels are present across the application site, which in turn discharge to natural watercourses.

Active subsurface drainage pipes in the peat profile appear absent over much of the application site, however examples of such features were locally observed within the south eastern area around Struther's Brae, where several minor collapsed soil pipes were noted in proximity to survey points T205, T206, T223 and T224.

Potential surface indications of sub-profile drainage including lines of rushes and grass lanes, were also observed at various locations throughout the survey area. Based on surface observations and using the scale given by Jones (1978) the pipe frequency across the bulk of the application site is estimated at 5-15 per km^2 which is considered relatively low.

According to Wilson & Smart (1984), the presence of subsurface pipes is thought to be a key contributory factor in preparing sites for failure.

2.6. Peat Depths and Strengths

At any given site, the depth of penetration of a probe may provide a rough indication of the thickness of the peat profile. The findings of the field investigation are reproduced in the accompanying Factual Report. A total of 876 peat depth values were used to create a peat depth contour map to depict the patterns of variation in peat depth across the application site (Figure 6 of the Factual Report). This included values recorded as part of the initial peat depth survey.

At the application site, peat depths encountered within the main turbine envelope during the surveys ranged from 0 m to 3.3 m. Some 33 no. survey points recorded a complete absence of peat, such locations were typically associated with bedrock outcrops, access tracks or areas of spoil. Glacial Clay was encountered at the surface at a number of points.

Peat measurements in excess of 3.0 m were only recorded at two locations, within the south eastern area of the application site. The average peat depth across the application site has been calculated as 0.62 m.

The surveys indicated that across the majority of the northern and central site areas, the peat deposits, which largely comprise well decomposed peat and peaty organic soils, are <0.5 m in depth. Peat was found to be virtually absent from the northern most 'neck' of the site which comprises grazing land, with the exception of very localised patches (up to 1.2 m in depth) encountered 10 – 15 m to the west of the existing access track just south of Pencloe Farm.

Within the remaining areas of the site, peat deposits were more widely encountered although still found to typically <1.0 m depth. Where peat deposits in excess of 1 m were observed, these were found to be relatively localised and sporadic in nature as can be seen on Figure 6 of the Factual Report. The most significant accumulations of peat were recorded in the southern and eastern areas of the FCS land where thicknesses up to 2 m were frequently recorded and occasionally in excess of 3 m.

Although the results of the depth probings are interesting in their own right and useful for engineering design purposes, the benefits for peat slide assessment purposes appear limited. Indeed, typical depths of peat of only 0.8m, 0.6 m and 0.55 m are recorded at several well-known peat slide localities at Hart Hope (Warburton et al., 2003), Meldon Hill West (Crisp et al., 1964) and Llyn Ogwen (Nichol et al., 2007), respectively.

Peat strength was estimated using the penetration of a probe as a guide. Values varied depending on a range of factors, including type of stratum and degree of saturation. In general, the peat profile at Pencloe was noted to be relatively consistent with depth, with limited profiling.

2.7. Terrain Analysis

One of the simplest and most efficient methods of evaluating peat slide risk involves the application of terrain evaluation procedures. The observational method used in this study was based primarily on the combined assessment of geomorphology, topography and geology by the trained-eye of a professional geo-engineer. However, other peat slide attributes of secondary importance also taken into consideration include orientation to the wind, orientation to the sun and forest cover.

The analysis included both desk studies and field investigations. Three classes of peat slide susceptibility were adopted. Category I for low to very low susceptibility, Category II for moderate susceptibility and Category III for high to very high susceptibility.

The findings are incorporated in the field data sheets in the accompanying Factual Report and indicate the relative chance of slope failures occurring over time. The zones do not predict where peat slides will occur during the next rainfall event. Instead, it can be expected that over time, high susceptibility zones will experience more peat slides than lower susceptibility categories.

The findings for the Pencloe Windfarm site indicate that within the turbine envelope, Category I zones predominate. However a number of Category II zones were recorded, predominantly within the southern portion of the proposed turbine envelope.

With regards to the proposed access track routes outside the turbine envelope, Terrain Category I zones also predominate although several Category II zones were recorded along the track alignment to the west of Meikle Hill.

3. Evaluation of Stability

3.1. Peat Slide Hazard Rating System – Survey and Results

The Peat slide Hazard Rating System (PHRS; Nichol, 2006) was used to evaluate stability. The PHRS is a proactive tool to rationally address peat slide hazards and provide a defensible, standardised way to assess priority by numerically differentiating the apparent risk at potential peat slide sites. The principal features of the assessment criteria and scores for the hazard rating system are summarised in Table 2 below.

- **Table 2 Peat Slide Hazard Rating System (PHRS)**

Category	Rating Criteria and Score			
	3 Points	9 Points	27 Points	81 Points
Rainfall and climate	Low to moderate precipitation	Moderate precipitation	High precipitation	Very high precipitation
Presence of water on the slope	No water on slope; Few water bodies	Intermittent water on slope; Occasional water bodies	Continual water on slope Many water bodies	Continual water on slope Major water bodies
Rockhead or subsoil	Irregular rockhead or granular subsoil of sand and gravel	Undulating rockhead or granular subsoil	Planar and regular rockhead or cohesive subsoil	Smooth, polished and regular rockhead or cohesive subsoil of clay
Peat profile and depth	Single layer profile less than 1 m deep	Double layer profile less than 2 m deep	Triple layer profile greater than 2 m deep	Complex profile greater than 4 m deep
Peat strength (vane shear test)	40kPa	30kPa	20kPa	10kPa
Slope and slope regularity	2° ; even	5° ; uneven	10° ; irregular	15° ; very irregular
Geomorphology and site history	Few differential erosion features	Occasional erosion features	Many erosion features	Major erosion features
Sub-profile damage	Few pipes	Occasional pipes	Many pipes	Many pipes and sinkholes
Peat slide history	Few slides	Occasional slides	Many slides	Major peat slide events
Potential peat slide severity	Few consequences; small impacted area	Minor consequences; minor impacted area	Many consequences; large impacted area	Major consequences; large impacted area

3.2. Grid Positions – PHRS Scores

3.2.1. Turbine Envelope

To illustrate the variation across the windfarm site, detailed investigations were carried out at 535 individual positions on a 100m grid basis across the proposed turbine envelope, each resulting in a different PHRS rating. The PHRS method was used in order to provide a comparative method for ranking sites by peat slide geohazard potential. The 535 grid positions and identifiers are shown in Figures 5.1-5.4 of the Factual Report and the results of the PHRS are listed in the Factual Report and illustrated graphically in Figure 7 of the Factual Report.

All of the positions received the same high PHRS score of 100 for rainfall and climate. The scores for all the positions on site are summarised below:

- The vast majority (489 no.) of positions received low scores of <200; these locations benefited from typically shallower peat profiles and low potential peat slide susceptibility;
- A total of 45 no. positions received scores of between 200 and 299 which is considered to present a moderate risk of peat slide activity. These locations typically lie within areas of the site where two or more criterion were notably prevalent, often including, but not limited to, increased peat thickness or slope angle, ground saturation and / or increased frequency of previous peat failures, erosional or sub profile drainage features and
- Only a single grid position recorded a relatively high score of >300. This maximum score of 307 was recorded for grid position T237 within the south eastern area of the site and was attributable to the presence of a significant thickness (3.2m) of saturated peat which comprised a complex strength profile and lay in proximity to previous peat failures.

The majority of locations received comparably low scores for the type of substrata as this was typically recorded as sands and gravels, which may also be representative of completely weathered bedrock. Higher scores were applied where either a smooth bedrock profile or glacial till was confirmed as the substrata. Typically high scores were applied with respect to slope angles and this reflects the highly variable topography of the site. Scores relating to sub profile drainage were generally low across the site given the observed scarcity of such features.

PHRS scores are intended as a means of comparing different sites and as a tool for prioritising mitigation. The PHRS system itself does not attach any particular significance to the total score for each site and leaves it to the project engineers to draw their own conclusions based on an understanding of the local conditions that apply. However, as a rule of thumb, sites with a rating of less than 200 are assigned a low priority while those with a rating of more than 400 are identified for urgent attention.

The average score calculated for the proposed wind turbine envelope was 149 which places the site in the low risk category. Although as indicated above there are 45 no. locations which have moderate peat slide risk scores of >200 and one location >300 which may warrant some further consideration. For comparison purposes, PHRS scores of 373, 482 and 434 apply in relation to the well-established peat slide localities at Morsgail, Isle of Lewis, Scotland (Bowes, 1960), Derrybrien, Galway, Republic of Ireland (Fleming 2003) and Hart Hope, North Pennines, England (Warburton et al, 2003), respectively.

3.2.2. Access Tracks

Detailed PHRS scores were also carried out at 78 no. individual positions along the main proposed access track route lying outside the turbine envelope. The 78 positions and identifiers are shown in Figures 5.1 – 5.4 of the Factual Report and the results of the PHRS are listed in the Factual Report and illustrated graphically in Figure 7 of the Factual Report.

As above, all of the positions received the same high PHRS score of 100 for rainfall and climate. The scores for all the positions along the access track are summarised below:

- The vast majority (75 no.) positions received low scores of <200; these benefited from shallow peat profiles, few erosional features and low potential peat slide severity;

- Three isolated positions received scores of between 200 and 299 which indicates a potentially moderate risk of peat slide activity. These scores were recorded for positions TR11, TR61 & TR79. Survey position TR11 is located at the northern end of the track route close to Pencloe Farm, whilst the remaining two are located within the FCS land closer to the turbine envelope. Moderately severe slope angles, peat thickness, degree of saturation and proximity to existing erosional features were the primary attributes to these scores and
- No track positions received high scores of >300.

3.3. Design Considerations and Peat Slide Zonation Plan

By combining the results of terrain analysis and the geohazard potential established by the PHRS scores with an analysis of individual grid positions and Factor of Safety calculations, several constraints emerge that are useful in guiding the layout design process for turbine positions and access tracks. The findings are summarised in the peat slide hazard zonation plan (Figure 9). The zonation plan is developed by consideration of all these factors, but is more heavily weighted towards the PHRS scoring system as this represents the most comprehensive assessment of peat stability undertaken at the site and prevents double counting of site specific factors which are common to the different methodologies adopted.

Terrain Categories of 2 or above, as well as high PHRS scores and low factors of safety were associated with areas exhibiting wet ground, high slope angles, deep peat and/or evidence of peat instability and erosion. These areas should be avoided as far as possible. This along with other pertinent factors has been used to determine the zonation of the Risk zones at the site. It can be seen that the majority of the proposed development area falls within the low risk category however a number of localised areas have recorded a moderate or, very locally, moderate-high risk of peat instability and these can be observed on Figure 9.

Perhaps the most evident constraint to emerge from the PHRS survey is the significance of severe slope angles across the site and it is noted that, second to rainfall, this category accounted for the highest PHRS scores. Accordingly, it is recommended that areas exhibiting slope angles greater than 10° or within 50 m of a significant watercourse is adopted as a constraint in design.

Further discussion around mitigation measures is outlined in Section 5.

3.4. Geotechnical Considerations

Failure occurs and peat slide initiation is possible when the force from the downslope weight of peat (shear force) is combined with a triggering mechanism, thus resulting in exceedance of the available shear strength between layers of strata. However, strong variations in peat properties (and stability) across slopes pose difficulties and so there is always residual uncertainty. Many methods available for the analysis of slope stability include a factor of safety, which is the ratio of resisting forces to the driving forces acting on a mass of peat on a potential failure surface:

$$F = Resisting\ forces\ (\text{“}strength\text{”})\ /\ (Disturbing\ forces\ (\text{“}stress\text{”})$$

Therefore, for a given failure mode, if the calculated Factor of Safety (F) is greater than 1.0 the slope will not fail unless there is a change in circumstances. As such, F values less than 1.0 indicate a failure is imminent. A plan showing the calculated factors of safety for the site is reproduced in Figure 8 and the data is included in Appendix B.

Whilst it is difficult to determine the actual geotechnical parameters of the peat in a site specific manner, a generic approximation has been used to undertake the slope stability calculation described above. The calculation requires a value for cohesion (C’) and angle of internal friction (Φ’) and the following values have been used based on the results of the undrained shear strength values (Cu) recorded during the field survey:

- For undrained shear strength of <10kPa, C' = 1 kPa
- For undrained shear strength between 10 and 20 kPa, C' = 2kPa
- For undrained shear strength between 20 and 30 kPa, C' = 3kPa
- For undrained shear strength between 30 and 40 kPa, C' = 4kPa
- For undrained shear strength >40 kPa, C' = 5kPa

A universal value for (Φ') of 25° has been adopted for all locations.

3.5. Turbine Envelope

The F value at each of the 535 grid locations was calculated based on the assumption that peat slides predominantly occur as a translational slide using the infinite slope model calculation. Utilising established methods, it is identified that all factors of safety were calculated >1. However two locations recorded F values between 1 and 1.3 (Grid Positions T133 and T372), which is lower than would be considered stable in the longer term. In addition a total of 29 points recorded an F value between 1.3 and 2. Whilst these points would be considered stable in their present condition, any deterioration in their current condition could reduce their F further with the associate possibility of increased peat slide risk. A plan showing a contour map of F values across the site is provided as Figure 8.

3.6. Access Track

The F value at each of the 78 locations along the access track was also by the method described above. No low factors of safety (<1) were identified along the length of the track. However, two locations recorded an F value between 1.3 and 2. Whilst these points would be considered stable in their present condition any deterioration in their current condition could reduce their F further with the associated possibility of increased peat slide risk.

The assessment of F across the site has been considered in the production of the peat slide hazard zonation plan (Figure 9), along with several other factors.

4. Discussion Regarding Mitigation Measures

4.1. General

Evaluation of peat slide susceptibility across the site at Pencloe demonstrated that the majority of the site has a low risk however localised areas of the site may be prone to peat slide hazards and warrant careful consideration. The design constraints established herein should result in a layout for positions of turbines and routes for access roads that fall within the low category of risk for peat slide geohazard potential. Whilst localised areas of moderate risk have been identified at the site, no areas of high risk were recorded.

Peat slide hazard mitigation is the result of logical thinking and action, involving a logically sequenced risk reduction strategy and a well-organised approach so that time is used as efficiently as possible. Based on the findings of the investigations carried out to date on peat slide susceptibility at the Pencloe Windfarm site, potentially unsafe terrain can be avoided during the design process but special care and attention may be required at certain places.

As a general condition, all areas of high risk should be avoided by any proposed windfarm infrastructure. It is considered that steep slopes should be avoided as far as possible and development operations restricted to areas having gradients of less than 10°. In addition it is considered that in general areas of peat in excess of 2 m should generally be avoided for turbine locations. Floating road type construction and suitable engineering control measures should be incorporated for access tracks which cross peat of greater than 2 m.

4.2. Proposed Windfarm Infrastructure

The result of the assessment indicates that one of the currently proposed turbine positions (T6) is located in an area indicated as having moderate risk of peat slide activity, in addition several lie within close proximity of such zones. No infrastructure is proposed in areas of high risk of peat slide activity. Whilst it is considered feasible to construct turbines within areas of moderate risk, it would be preferable to microsite them to areas of low risk where possible.

T6 lies in an area of moderate peat slide hazard and the two closest grid positions yielded PHRS scores of 207 (T103) and 249 (T77) and recorded peat depths of 1.1m and 1.5m respectively. However grid position T102 to the northwest of the proposed T6 position returned a lower PHRS score of 129 and a peat depth of 0.3m. As such it is recommended that this turbine is micrhisted 50m to the northwest.

Should T6 remain in its current position, further detailed qualitative slope stability risk assessment prior to construction and further ground investigation may be necessary to determine the risk of instability affecting it. Adherence to strict engineering controls will be required to enable construction to proceed. The additional investigation may involve boreholes, trial pitting, closer definition of peat depths and determination of other geological characteristics across the area.

In addition to the above, it is recommended that peat in excess of 2m should be avoided for turbine positions. Where this proves unfeasible, suitable engineering control measures should be adopted for peat of this depth.

The results of the PHRS scoring indicate that the majority of the proposed track route currently lies within low risk areas of potential peat slide activity, however a limited number of sections cross areas of moderate peat slide risk. It is recommended that where possible, access tracks should be microsited to areas of lower risk. Any proposed track routes remaining within moderate risk zones may require further geotechnical assessment and adherence to strict engineering controls during construction.

As far as possible, tracks should follow routes parallel to slopes and avoid steep sidelong ground and should be approved by a geotechnical engineer before construction commences. The provision of special drainage measures may be necessary during construction.

Based upon the recorded peat depths and proposed track layout, it is not anticipated that significant sections of track will lie within areas of peat with a thickness greater than 2 m and therefore it is considered unlikely that floating roads will be required. It is recommended that additional peat depth probing is carried out along the proposed access track routes within the turbine envelope once these design details have been finalised.

4.3. Special Measures Relating to Loose Peat

Excavation of peat at turbine sites and along access roads will give rise to a series of subsoil storage mounds. Considerable guidance already exists in the technical literature on the procedures for design and construction of subsoil storage mounds (e.g. Garrard and Walton, 1990; Geoffrey Walton Practice, 1991) and is not reiterated herein. However, it is strongly recommended that proposed peat repository sites are selected on the basis of geotechnical criteria and design and construction of subsoil storage mounds should be supervised by a geotechnical engineer.

4.4. Geotechnical Risk Register

It is recommended that a system of geotechnical risk management is adopted during the detailed design and construction phases of the project as a key element in the overall risk assessment for the project (see Clayton, 2001). The latest revision of the geotechnical risk register for Pencloe is presented in Appendix A in order to demonstrate that geotechnical risk may be properly controlled, kept under review and further reduced as and when possible, as well as to demonstrate that geotechnical risk management has commenced.

The geotechnical risk register is a “live document” and once commenced is continued through to project completion. Regular reviews of existing risks as well as the addition of newly discovered risks are incorporated in the register.

4.5. Effects of the Construction

Although the ground conditions at the Pencloe site are predominantly favourable, the potential impacts relating to the construction of the windfarm that might influence peat stability need to be considered as a matter of prudence. The first potential impact involves concentrated loads, such as material from turbine foundation excavations, being placed on marginally stable ground at the top of a slope. The second involves removal of toe support at the bottom of a slope. The third relates to the adverse concentration of water flows within a slope or into unstable excavations. These matters are discussed below (a - d) and elaborated in the Geotechnical Risk Register presented as Appendix A.

a) Head Loading

Concentrated loads, such as excavated material placed on the slope, create the single most adverse effect on the stability of a slope. Accordingly, during the construction phase, all excavated materials should be removed to temporary storage mounds positioned off-slope at a safe position certified by a geotechnical engineer.

Loading associated with the construction of any floating roads may lead to unstable ground conditions. Accordingly, all tracks will be, as far as possible, constructed under geotechnical supervision and monitored during and after construction.

b) Removal of Toe Support

Excavation of the slope for turbine foundations or for excavated tracks may remove toe support and increase potential for ground movements. The earthworks and any excavation should be designed and undertaken in such a way as to avoid any excavation of toe support material. The excavation of any temporary slopes should be fully designed.

c) Adverse Concentration of Water Flows

Disturbance to the natural drainage system may increase potential for peat instability. However, the design should incorporate substantial improvements to the drainage of the site and since peat sliding almost invariably involves increased pore water pressures, it follows that robust drainage plans and engineering control of water during the development should result in a significant overall reduction in the risk of peat instability.

d) Other

Peat slide potential also increases with:

- Rockhead smoothness;
- Clayey subsoils that impede water flows and provide smooth slip-surfaces;
- Localised steep gradients;
- Presence of solifluction planes;
- Improvements such as drainage works and
- Localised erosion features such as animal paths and stream channels.

Accordingly, construction activities should be carried out under geotechnical supervision, as required and protection measures should be implemented using the observational method.

4.6. Peat Slide Control Mitigation Measures

The design and construction process incorporates methods for preventing peat slides or minimising their effects. The various methods either prevent peat masses from moving out of place or protect sensitive sites by keeping peat masses that do move out of place from reaching a target site. These include:

- Limited duration improvements to remove loose blocks or masses of peat;
- Earthworks to create interception ditches;
- Minor modifications to track alignments to avoid difficult ground;
- Drainage works to collect or divert uncontrolled water flows;
- Installation of multi-rows of recycled plastic pin-piles;
- Installation of arrays of plate piles;
- Gabion barrier walls to apply direct support to a peat face;
- Rockfill buttressing to provide support for large masses of unstable peat and

- Channel training works such as ditch deepening and reshaping to mitigate erosion.

The excavation for turbine bases and crane pads should be kept to a minimum, but it is likely that the necessary suitable founding stratum will be at least 1 m below the base of the peat. The soft and compressible nature of the peat means that unsupported cut or excavated slopes will be unstable unless shallow gradients are used. The overall width of such an excavation at formation level could be up to 20 m and over 30 m at the original ground surface. Therefore in areas of deep peat, excavation should be undertaken within a rock retaining bund, whereby rock boulders are placed through the peat and excavation advanced within. This results in a smaller area of required excavation and reduces the requirement for dewatering and peat disposal.

For the construction of access tracks it is important that construction methods do not disrupt the established drainage and that no areas are surcharged by water discharge or spoil. In general the following principles should be adopted.

- Access roads in areas of peat greater than 2 m should be of floating type construction and an allowance should be made for their long term maintenance as a result of on-going settlement.
- Construction of tracks parallel or perpendicular to slope contours, but avoidance of obliquely crossing slope contours where detailed cut and fill operations may be required.
- Where floating roads are not constructed excavation down to a suitable founding stratum for the road should be undertaken.
- The existing drainage is critically important therefore all existing drainage routes should be maintained and where necessary, channelled below the proposed route. Upslope drainage ditches will be required and constructed with cross drains so water can pass freely across the carriageway at regular intervals. This will also prevent erosion in side ditches due to their capacity being exceeded and concentration of water on the down slope area.
- The camber of the road should be constructed to encourage water to drain to the up slope drainage ditch.
- Road gradients should be maintained at less than 1v:11h to allow access for the typical range of construction traffic expected.

There will be a requirement of access tracks to cross a number of watercourses at the Pencloe site. In general, culverted crossings are considered to be most appropriate for such crossings.

Flexible, corrugated, galvanised steel or plastic culverts are considered to be better suited to these conditions than rigid concrete box culverts as they are easier to handle and do not require immediate access from both sides of the watercourse. Such flexible culverts would be suitable for all stream and ditch crossings and founded on suitable engineered bedding material to provide conformity of settlement between the culvert and the approach structure. Some differential settlement can be accommodated with localised back filling. A programme of regular inspection and maintenance will be required during the construction period and throughout the life cycle of the windfarm before any significant movement of infrastructure is undertaken. Where crossing spans are larger, it may be possible to construct several culverts adjacent to each other.

4.7. Potential Losses Resulting from Peat Slides

From a ground engineering standpoint, major peat slide events at Pencloe are avoidable. However, consideration has been given to potential consequences associated with the three zones of a peat slide.

A peat slide starting zone (or zone of origin) is the location where unstable peat fails and begins to move. The backscar (or crown, fracture line, head, initiation point) of a peat slide defines the upper limit of the starting zone for each peat slide. While the lower limit of peat slide origin is usually ill defined, it is sometimes quite obvious. Consequences in the starting zone of a peat slide may include disruption of the ground surface, exposure of peat faces, loss of vegetation and habitats and reduction in lateral ground support.

The track (or zone of transition) is the slope below the starting zone that connects the starting zone with the zone where debris collects (runout zone). While the track is the major terrain feature for large peat slides, it is often ill defined in peat slides with a short run out distance. Peat slide speed attains its maximum value in the track but speed variations are smallest there. Consequences along the track may include disruption of the ground surface and watercourses, destruction of vegetation and habitats and damage to physical assets such as fences, forest plantation, buildings and roads.

The runout zone (or zone of deposition or accumulation) is the area where deceleration is rapid, debris is deposited and the peat slide stops. An abrupt change in slope can mark the transition between track and runout zone but this is often not the case. Consequences in the runout zone may include disruption of the ground surface and watercourses, destruction of vegetation and habitats and in particular, damage to fisheries interests.

The three zones vary and are specific for every individual peat slide.

The foregoing comments should not be taken to indicate any particular likelihood of peat sliding at Pencloe. However, careful management of the site and appropriate geotechnical supervision of the construction works should be implemented.

5. Conclusions and Recommendations

At Pencloe, a windfarm development is proposed on an expanse of commercial forestry land. The geology of the site is varied and consists of areas of peat underlain by occasional Glacial Till deposits and bedrock. However there are certain areas of the site where peat and superficial deposits are absent and bedrock is shown to be exposed at the surface. The results of the fieldwork survey generally confirm the findings of the desk study.

A comprehensive multi-factor approach was adopted to identify peat slide prone areas within the Pencloe site. A total of 535 positions on a 100m grid pattern within the proposed turbine envelope were examined in detail and the results of the study were used to establish constraints to avoid areas identified as potentially vulnerable to ground movements. The average peat slide score for the turbine envelope is 149 and classifies Pencloe as a low category site for peat slide risk.

The key design considerations and recommendations in relation to the Pencloe Windfarm site are as follows:

- A notable feature of the Pencloe site is steep slopes. These should be avoided and as far as possible and development operations restricted to areas having gradients of less than 10^{o}.
- Based upon the recorded peat depths and proposed infrastructure layout, it is not anticipated that any turbines or significant sections of track will lie within areas of peat with a thickness greater than 2 m. It is recommended that additional confirmatory peat depth probing is carried out along the proposed access track routes within the turbine envelope once the design details have been finalised.
- Areas of boggy or saturated peat should be avoided as far as practicable. Any encroachments should be assessed for peat slide risk by a geotechnical engineer and measures developed for ground improvement where necessary.
- A single turbine (T6) and limited sections of the proposed access track route are shown to be located within areas of moderate peat slide risk. Where possible, turbine positions and access track alignments should be microsited into lower peat slide risk areas. Where infrastructure must remain within areas of moderate risk, it may be necessary to undertake more detailed ground investigation and risk assessment and to adopt strict engineering controls during construction to minimise the risk of peat sliding. All construction works which encroach into areas of moderate peat slide risk should be assessed by a geotechnical engineer and measures developed for ground improvement where necessary.

Particular care is required in relation to the detailed design of proposed crossings of watercourses. Various short-term and long-term strategies and measures exist for peat slide risk control purposes and include a comprehensive range of engineering responses to deal with peat slide problems. These strategies can be managed using the geotechnical risk register and implemented during construction under geotechnical supervision.

On the Pencloe Windfarm site, the “elements at risk” may be classified broadly into two categories: (1) environmental impairment and (2) impacts on land, commercial assets and infrastructure. Overall, based on the findings of the PHRS scores, the potential risks to both these categories of receptor generally appear to be low. However, where localised moderate risk areas of peat instability have been identified, adequate control measures will need to be incorporated during construction works to protect any vulnerable watercourses.

The PHRS scores will be used as part of a constraint based design process, which will, where practical and micrositing allows, avoid the areas of moderate peat slide risk. If any site infrastructure is proposed in the vicinity of areas where the peat slide risk is moderate, further ground investigation or detailed peat slide assessments will be required.

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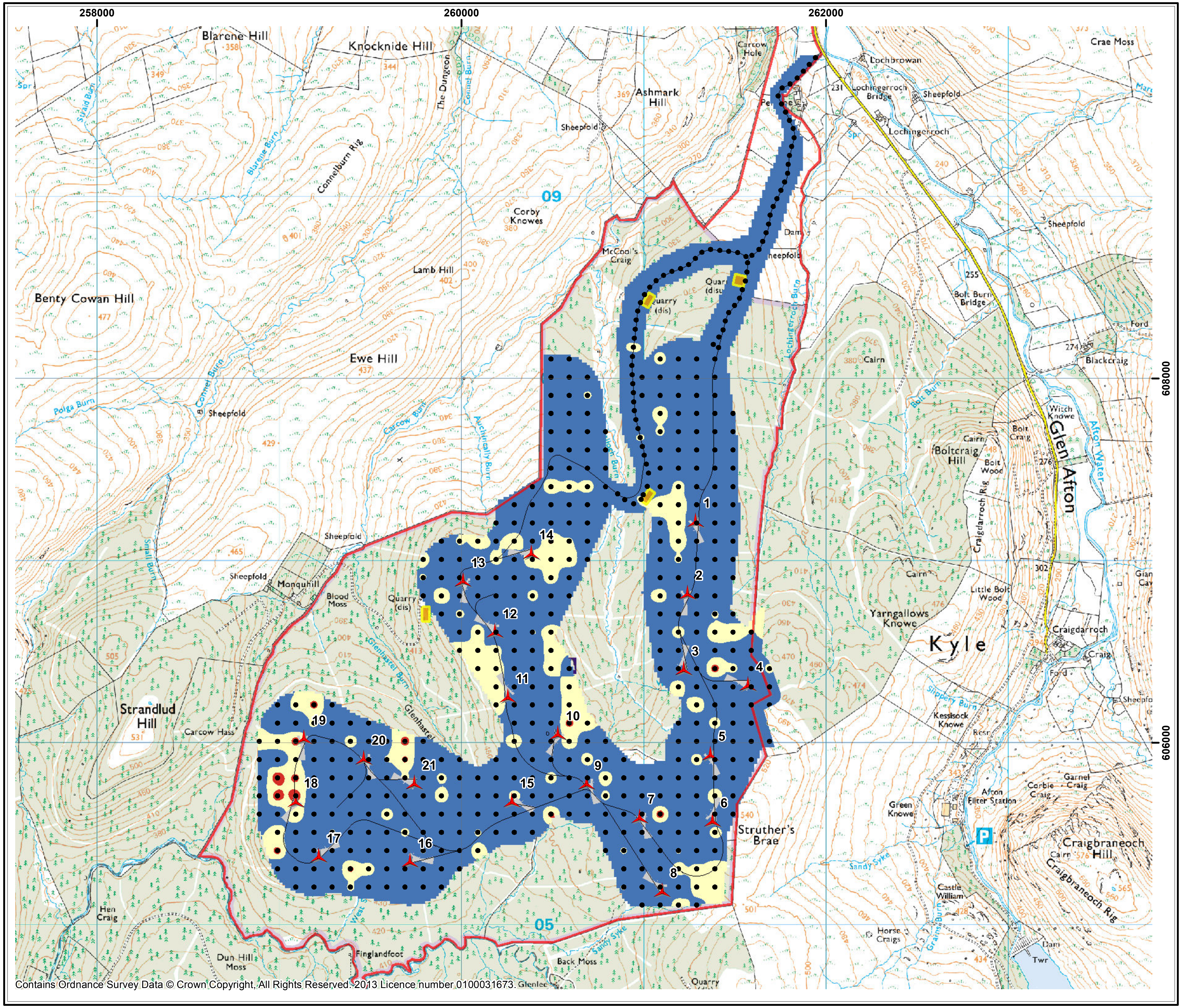
Figures



Key:

- Peat Probe Locations

Proposed Infrastructure

- Turbine
- Track
- Hardstanding
- Site Boundary
- Borrow pit

Factor of Safety

- 1 - 2
- 2 - 3
- 3 - 4

0 250 500 750 1,000
Metres

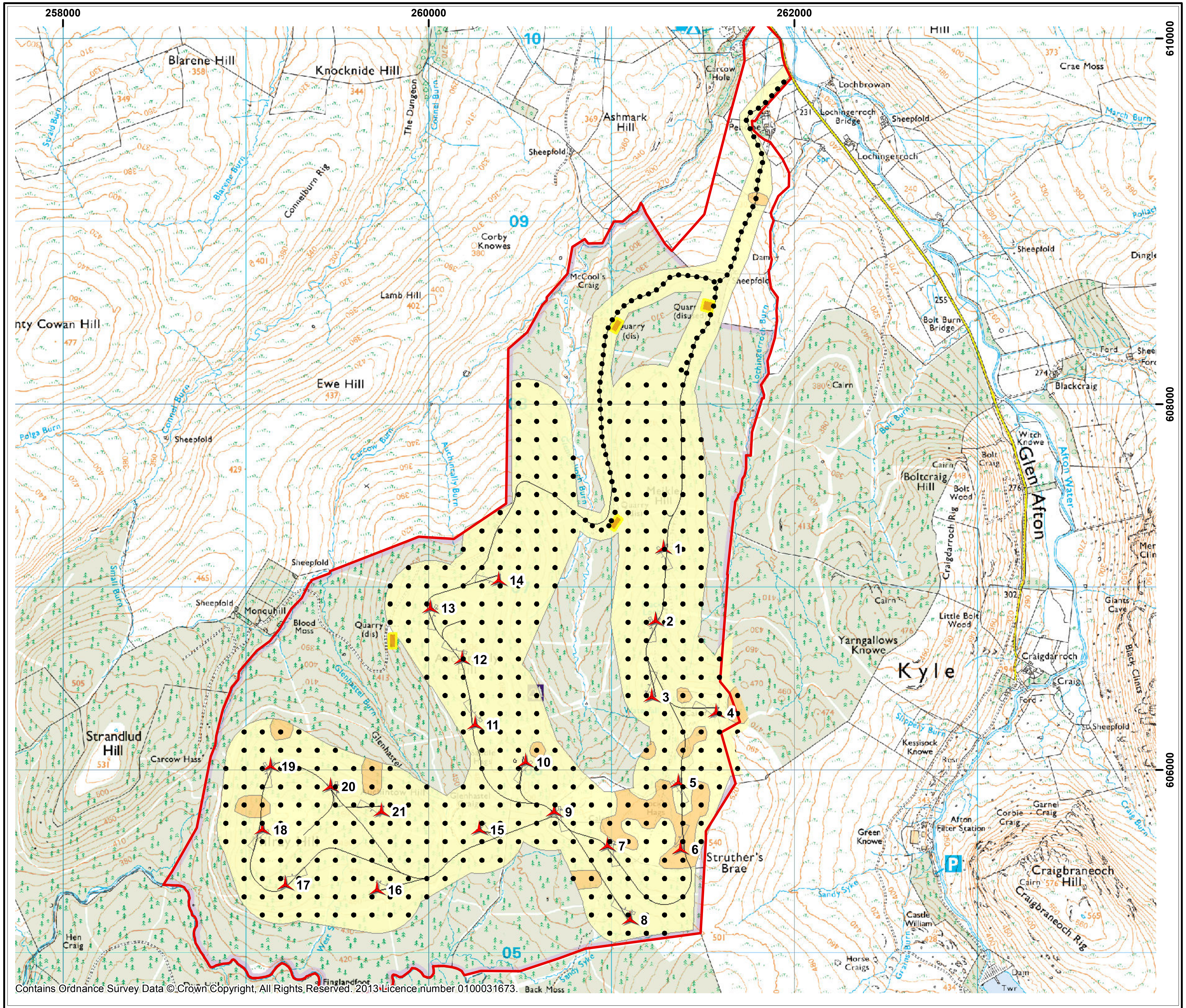
N

PENCLOE WINDFARM

FIGURE 8
FACTOR OF SAFETY (FoS) PLAN

SCALE	PROJECT CODE
1:20,000 @ A3	JE30643
CONTENT	DRAWN
SA	SP
CHECKED	DATE
SA	15/09/2014

JACOBS



Key:

- Peat Probe Locations

Proposed Infrastructure

- Turbine
- Track
- Site Boundary
- Borrow pit
- Hardstanding

PSRA Hazard Zones

- Moderate
- Low

0 250 500 750 1,000
Metres

N

PENCLOE WINDFARM

FIGURE 9
PEAT SLIDE HAZARD ZONATION PLAN

SCALE 1:20,000 @ A3	PROJECT CODE JE30643
CONTENT SA	DRAWN SP
CHECKED SA	DATE 15/09/2014

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Appendix A Managing Geotechnical Risk

Hazard / Risk	Cause	Construction Stage			Consequences	Mitigation	Following Mitigation Stage		
		Probability	Impact	Risk Rating			Probability	Impact	Risk Rating
Peat slide Event	Unstable excavations	4	2	8	Localised instability	Appropriate geotechnical design Routine geotechnical inspection. Contingency plans for slope stabilisation measures.	2	1	3
Peat slide Event	Removal of toe support to slopes	3	3	9	Slow ground movements	Avoidance action during geotechnical design stage. Routine geotechnical inspection. Contingency plans for slope stabilisation measures.	2	2	4
Peat slide Event	Steep slopes	4	4	16	Instability	Appropriate geotechnical design. Routine geotechnical inspection. Avoidance action during layout design stage.	1	3	3
Peat slide Event	Surface water erosion	3	1	3	Localised instability	Establish vegetation cover on slopes. Suitable temporary surface water management. Addressed in drainage plans.	2	1	2
Peat slide Event	Subterranean pipes	2	2	4	Localised instability	Blockage prevention using free draining fill. Detailed site investigations of foundation and track locations will be carried out at the pre-construction stage, prior to detailed construction designs being produced. Detailed construction designs will be produced with input from a geotechnical engineer. The geotechnical risk register will be updated following site investigations and detailed design at the preconstruction stage. A programme of geotechnical inspections will be implemented during excavation works.	2	1	2
Peat slide Event	Pockets of soft wet ground	5	2	10	Localised instability	Due consideration given to the prevailing ground and weather conditions when scheduling site works. Detailed site investigations of foundation and track locations will be carried out at the pre-construction stage, prior to detailed construction designs being produced. Detailed construction designs will be produced with input from a geotechnical engineer. The geotechnical risk register will be updated following site investigations and detailed design at the preconstruction stage. A programme of geotechnical inspections will be implemented during excavation works. Programme and cost contingency.	3	1	3
Peat slide Event	Construction of cable trenches in road verge	2	3	6	Instability	Appropriate geotechnical design. Detailed site investigations of foundation and track locations will be carried out at the pre-construction stage, prior to detailed construction designs being produced. Detailed construction designs will be produced with input from a geotechnical engineer. The geotechnical risk register will be updated following site investigations and detailed design at the preconstruction stage.	1	1	1

Hazard / Risk	Cause	Construction Stage			Consequences	Mitigation	Following Mitigation Stage		
		Probability	Impact	Risk Rating			Probability	Impact	Risk Rating
	Construction of cable trenches in road verge (continued)	2	3	6	Instability	A programme of geotechnical inspections will be implemented during excavation works. Geotechnical monitoring of verges post-construction.	1	1	1
Peat slide Event	Tear in reinforcing geotextile fabric	2	3	6	Instability / Local settlements	Addressed in material specification. Addressed in construction supervision.	1	1	1
Peat slide Event	Mobilised temporary storage mounds	4	4	16	Localised instability	Storage site selection by geotechnical engineer. Routine maintenance of peat storage mounds.	2	2	4
Ultimate limit state failure (bearing capacity)	Construction loading and poor ground conditions	3	2	6	Bearing capacity failure / Ground deformation / Need to rebuild	Appropriate geotechnical design. Excavation of shallow peat along tracks. Expose competent formation at turbine sites. Adopt floating road construction over deep peat, if appropriate.	1	1	1
Serviceability limit state failure (settlement)	Construction loading and poor ground conditions	5	2	10	Excessive settlement / Construction delayed / Additional fill required	Ground improved with addition of rock fill. Adopt geotechnical monitoring of tracks. Contingency to re-level tracks on completion. Quantities contingency.	3	1	3
Unexpected Ground Conditions	Ground conditions differ from those indicted in the project ground investigations	3	3	9	Construction delayed / Design review required	Monitor works in progress. Use experienced staff on site. Detailed site investigations of foundation and track locations will be carried out at the pre-construction stage, prior to detailed construction designs being produced. Detailed construction designs will be produced with input from a geotechnical engineer. The geotechnical risk register will be updated following site investigations and detailed design at the preconstruction stage. A programme of geotechnical inspections will be implemented during excavation works. Programme and cost contingencies.	1	1	1
Creep, long term settlement of tracks	Poor and variable foundation soils	5	1	5	Ongoing settlement	Contingency for routine maintenance.	3	1	3
Slope Instability	Use of unsuitable fill materials	2	3	6	Instability	Addressed in material specification. Detailed site investigations of foundation and track locations will be carried out at the pre-construction stage, prior to detailed construction designs being produced. Detailed construction designs will be produced with input from a geotechnical engineer. The geotechnical risk register will be updated following site investigations and detailed design at the preconstruction stage. A programme of geotechnical inspections will be implemented during excavation works.	1	1	1

Hazard / Risk	Cause	Construction Stage			Consequences	Mitigation	Following Mitigation Stage		
		Probability	Impact	Risk Rating			Probability	Impact	Risk Rating
Erosion	Site clearance operations	4	3	12	Damage to root mat	Use low pressure construction plant. Preserve root mat wherever possible. Detailed site investigations of foundation and track locations will be carried out at the pre-construction stage, prior to detailed construction designs being produced. Detailed construction designs will be produced with input from a geotechnical engineer. The geotechnical risk register will be updated following site investigations and detailed design at the preconstruction stage. A programme of geotechnical inspections will be implemented during excavation works.	1	1	1
Variation from Design Assumptions	Unexpected ground conditions	2	3	6	Settlement and / or slope failure	Appropriate geotechnical design. Geotechnical monitoring during construction. Programme contingency.	1	1	1
Uncertainty of Construction Technique	Variable foundation soils	2	3	6	Delay	Programme contingency. Detailed site investigations of foundation and track locations will be carried out at the pre-construction stage, prior to detailed construction designs being produced. Detailed construction designs will be produced with input from a geotechnical engineer. The geotechnical risk register will be updated following site investigations and detailed design at the preconstruction stage. A programme of geotechnical inspections will be implemented during excavation works.	2	1	2
Uncertainty at transition zones and stream crossing points	Variable ground conditions	3	3	9	Variation in quantities and programme	Programme contingency Cost contingency.	2	2	4
Uncertain duration and degree of primary consolidation	Variable ground conditions	2	3	6	Delay / Additional fill requirement	Avoidance of areas of deep peat. Programme contingency. Cost contingency.	2	2	4
Design changes during construction	Change in loading, bearing and settlement characteristics	3	2	6	Various but could include slope failure, bearing failure or settlement	Design changes to be reviewed by geotechnical specialist.	1	1	1

Notes: 1. A 'Hazard' is a condition or physical situation with a potential for an undesirable event.

2. A 'Risk' is an uncertain event or set of circumstances that should it occur would have an effect on achieving the project objectives

3. Mitigation Measures include:

- Avoid the risk – by eliminating the uncertainty or using an alternative approach.
- Transfer the risk – by transferring the liability of the risk to another party.
- Mitigate the risk – by reducing the risk to an acceptable level by making it less likely that the risk event will occur.
- Accept and manage the risk – by assuming the risk as reasonable given the cost or effect on time or quality and even life.

Prepared by: S. Atkinson, Senior Geo-Environmental Engineer, 11/10/13

Approved by: P. Skinner, Principle Geotechnical Engineer, 11/10/13

Appendix B Factors of Safety

[redacted]

Grid position	Slope (°)	Angle of friction (°)	Cohesion (kPa)	Peat depth (m)	Unit weight (kN/m3)	Factor of Safety
T1	5	25	2	0.2	11	4.0
T2	8	25	3	0.3	11	4.0
T3	5	25	3	1.8	11	2.3
T4	6	25	3	1	11	3.1
T5	16	25	2	0.1	11	4.0
T6	16	25	2	0.2	11	3.6
T7	7	25	3	0.2	11	4.0
T8	4	25	2	1.2	11	2.9
T9	3	25	3	1	11	4.0
T11	5	25	3	0.7	11	4.0
T12	12	25	2	0.1	11	4.0
T13	4	25	3	0.6	11	4.0
T14	5	25	2	0.9	11	2.9
T15	8	25	3	0.3	11	4.0
T16	5	25	3	0.2	11	4.0
T17	5	25	2	0.4	11	4.0
T18	5	25	3	1.4	11	2.8
T19	8	25	3	0.9	11	2.6
T20	16	25	3	0.2	11	4.0
T21	15	25	2	0.2	11	3.8
T22	10	25	3	0.5	11	3.5
T23	8	25	3	0.4	11	4.0
T24	8	25	2	1	11	1.7
T25	7	25	3	1.1	11	2.5
T26	5	25	3	0.4	11	4.0
T27	4	25	3	0.3	11	4.0
T28	5	25	3	0.5	11	4.0
T29	7	25	5	0.7	11	4.0
T30	5	25	3	1.1	11	3.4
T31	2	25	3	1.8	11	4.0
T32	4	25	3	0.6	11	4.0
T33	10	25	3	0.6	11	2.9
T34	7	25	3	1	11	2.7
T35	8	25	3	0.8	11	2.8
T36	7	25	3	1.3	11	2.1
T37	15	25	2	0.5	11	1.6
T38	8	25	3	0.4	11	4.0
T39	12	25	3	0.2	11	4.0
T39	7	25	2	0.1	11	4.0

T40	6	25	3	0.9	11	3.4
T41	3	25	3	1.6	11	4.0
T42	5	25	3	0.5	11	4.0
T43	5	25	3	0.4	11	4.0
T44	3	25	3	1.2	11	4.0
T45	8	25	3	0.8	11	2.8
T46	5	25	3	0.3	11	4.0
T47	6	25	3	0.5	11	4.0
T48	7	25	2	0.8	11	2.3
T49	2	25	2	1.1	11	4.0
T50	3	25	3	2.8	11	2.8
T51	10	25	2	0.2	11	4.0
T52	6	25	3	0.8	11	3.8
T53	4	25	2	1.2	11	2.9
T54	6	25	2	0.5	11	4.0
T55	6	25	2	0.5	11	4.0
T56	12	25	2	0.4	11	2.5
T57	15	25	3	0.3	11	3.8
T58	8	25	3	0.5	11	4.0
T59	9	25	3	0.7	11	2.8
T60	8	25	3	0.7	11	3.2
T61	3	25	3	1.4	11	4.0
T62	3	25	3	1.4	11	4.0
T63	4	25	3	2	11	2.7
T64	5	25	3	0.9	11	4.0
T65	3	25	3	0.9	11	4.0
T66	5	25	2	0.4	11	4.0
T67	5	25	3	1.4	11	2.8
T68	3	25	2	0.3	11	4.0
T69	5	25	3	0.4	11	4.0
T70	3	25	2	0.4	11	4.0
T71	3	25	3	2.4	11	3.1
T72	4	25	3	1.8	11	2.9
T73	5	25	3	0.8	11	4.0
T74	10	25	3	0.4	11	4.0
T75	5	25	3	0.3	11	4.0
T76	2	25	2	1.5	11	4.0
T77	3	25	2	2.2	11	2.5
T78	16	25	2	0.1	11	4.0
T79	16	25	2	0.1	11	4.0
T80	14	25	2	0.4	11	2.1
T81	5	25	3	0.7	11	4.0
T82	6	25	3	0.4	11	4.0
T83	6	25	3	1	11	3.1
T84	8	25	2	0.3	11	4.0
T85	8	25	3	1	11	2.3
T86	5	25	3	1	11	3.7
T87	2	25	3	0.8	11	4.0

T88	4	25	3	1.2	11	4.0
T89	10	25	2	0.2	11	4.0
T90	2	25	3	1.6	11	4.0
T91	4	25	3	0.8	11	4.0
T92	4	25	2	0.3	11	4.0
T93	11	25	2	0.2	11	4.0
T94	5	25	3	2.8	11	1.7
T95	3	25	3	2.1	11	3.4
T96	10	25	3	0.3	11	4.0
T97	3	25	3	0.2	11	4.0
T98	4	25	3	0.9	11	4.0
T99	3	25	3	0.3	11	4.0
T100	9	25	3	1.7	11	1.4
T101	2	25	3	0.3	11	4.0
T102	2	25	2	0.3	11	4.0
T103	5	25	3	1.1	11	3.4
T104	6	25	3	0.2	11	4.0
T105	16	25	5	0	11	4.0
T105	5	25	2	0.3	11	4.0
T106	12	25	2	0.7	11	1.5
T107	10	25	3	1.4	11	1.4
T108	3	25	3	0.5	11	4.0
T109	7	25	3	0.1	11	4.0
T110	5	25	3	0.9	11	4.0
T111	16	25	3	0.1	11	4.0
T112	6	25	3	0.6	11	4.0
T113	5	25	3	0.3	11	4.0
T114	6	25	3	0.7	11	4.0
T115	12	25	3	0.7	11	2.2
T116	9	25	3	0.4	11	4.0
T117	16	25	2	0.1	11	4.0
T118	3	25	3	0.3	11	4.0
T119	7	25	3	1.2	11	2.3
T120	4	25	3	0.9	11	4.0
T121	7	25	3	0.2	11	4.0
T122	5	25	3	0.8	11	4.0
T123	3	25	2	0.3	11	4.0
T124	11	25	3	0.6	11	2.7
T125	4	25	3	0.8	11	4.0
T126	4	25	3	1.1	11	4.0
T127	7	25	3	0.4	11	4.0
T128	3	25	3	0.7	11	4.0
T129	4	25	3	1.3	11	3.7
T130	7	25	3	1.4	11	2.0
T131	3	25	2	0.2	11	4.0
T132	16	25	5	0	11	4.0
T133	15	25	3	1	11	1.3
T134	15	25	3	0.7	11	1.7

T135	3	25	3	0.6	11	4.0
T136	2	25	2	0.5	11	4.0
T137	5	25	3	0.7	11	4.0
T138	3	25	3	1.1	11	4.0
T139	4	25	3	0.6	11	4.0
T140	5	25	3	1.4	11	2.8
T141	5	25	3	0.3	11	4.0
T142	16	25	3	0.4	11	2.7
T143	12	25	3	0.5	11	2.9
T144	4	25	2	0.2	11	4.0
T145	16	25	2	0.1	11	4.0
T146	10	25	3	0.4	11	4.0
T147	16	25	3	0.2	11	4.0
T148	11	25	3	0.7	11	2.3
T149	12	25	3	0.4	11	3.6
T150	2	25	3	0.2	11	4.0
T151	16	25	3	0.5	11	2.2
T152	10	25	2	0.3	11	3.8
T153	5	25	3	0.2	11	4.0
T154	7	25	3	0.8	11	3.2
T155	5	25	3	0.4	11	4.0
T156	4	25	3	0.5	11	4.0
T157	12	25	3	0.4	11	3.6
T158	2	25	4	0.5	11	4.0
T159	16	25	2	0.1	11	4.0
T160	14	25	2	0.1	11	4.0
T161	12	25	3	0.5	11	2.9
T162	10	25	2	0.3	11	3.8
T163	6	25	3	0.5	11	4.0
T164	10	25	3	0.5	11	3.5
T165	7	25	3	0.5	11	4.0
T166	10	25	2	0.4	11	2.9
T167	12	25	3	0.9	11	1.7
T168	16	25	3	0.2	11	4.0
T169	16	25	3	0.3	11	3.6
T170	16	25	3	0.1	11	4.0
T171	15	25	3	0.2	11	4.0
T172	13	25	3	0.3	11	4.0
T173	2	25	3	0.8	11	4.0
T174	2	25	3	0.6	11	4.0
T175	6	25	3	0.7	11	4.0
T176	5	25	3	1.7	11	2.4
T177	16	25	3	0.2	11	4.0
T178	8	25	3	0.3	11	4.0
T179	10	25	2	0.2	11	4.0
T180	5	25	2	1.2	11	2.3
T181	4	25	3	1	11	4.0
T182	4	25	3	1.5	11	3.3

T183	2	25	3	0.5	11	4.0
T184	12	25	2	0.5	11	2.0
T185	10	25	3	0.7	11	2.6
T186	14	25	2	0.6	11	1.5
T187	5	25	3	0.2	11	4.0
T188	5	25	3	0.8	11	4.0
T189	8	25	3	1	11	2.3
T190	12	25	3	0.4	11	3.6
T191	8	25	3	0.7	11	3.2
T192	13	25	3	0.9	11	1.6
T193	16	25	3	0.1	11	4.0
T194	12	25	3	0.7	11	2.2
T195	6	25	3	1	11	3.1
T196	4	25	3	0.7	11	4.0
T197	12	25	3	0.7	11	2.2
T198	4	25	2	0.7	11	4.0
T199	16	25	2	0.1	11	4.0
T200	5	25	2	0.3	11	4.0
T201	10	25	3	0.3	11	4.0
T202	5	25	3	0.5	11	4.0
T203	10	25	3	0.1	11	4.0
T204	2	25	3	0.6	11	4.0
T205	5	25	2	0.3	11	4.0
T206	11	25	2	0.2	11	4.0
T207	16	25	3	0.2	11	4.0
T208	16	25	3	0.2	11	4.0
T209	8	25	3	0.8	11	2.8
T210	13	25	3	0.3	11	4.0
T211	8	25	3	0.5	11	4.0
T212	12	25	3	0.4	11	3.6
T213	5	25	3	0.8	11	4.0
T214	3	25	3	0.3	11	4.0
T215	5	25	3	0.8	11	4.0
T216	16	25	3	0.7	11	1.6
T217	7	25	3	1.1	11	2.5
T218	4	25	3	0.7	11	4.0
T219	5	25	3	0.8	11	4.0
T220	10	25	2	0.5	11	2.4
T221	8	25	2	0.2	11	4.0
T222	2	25	3	0.4	11	4.0
T223	14	25	2	0.3	11	2.8
T224	5	25	2	0.3	11	4.0
T225	6	25	2	0.5	11	4.0
T226	16	25	3	0.2	11	4.0
T227	16	25	3	0.4	11	2.7
T228	16	25	3	0.7	11	1.6
T229	7	25	3	0.7	11	3.6
T230	16	25	3	0.5	11	2.2

T231	5	25	3	1.1	11	3.4
T232	5	25	3	0.4	11	4.0
T233	6	25	3	0.2	11	4.0
T234	16	25	2	0.3	11	2.5
T235	9	25	2	0.7	11	2.0
T236	8	25	2	0.1	11	4.0
T237	2	25	2	3.2	11	3.1
T238	4	25	3	0.5	11	4.0
T239	16	25	2	0.1	11	4.0
T240	4	25	2	1.1	11	3.1
T241	5	25	2	2	11	1.6
T242	3	25	2	1.9	11	2.8
T243	5	25	2	1.1	11	2.5
T244	13	25	3	0.7	11	2.0
T245	3	25	3	0.6	11	4.0
T246	2	25	3	0.9	11	4.0
T247	4	25	2	0.3	11	4.0
T248	16	25	2	0.4	11	1.9
T249	5	25	3	1.7	11	2.4
T250	5	25	3	0.4	11	4.0
T251	6	25	3	0.6	11	4.0
T252	8	25	2	0.1	11	4.0
T253	6	25	3	0.3	11	4.0
T254	8	25	2	0.4	11	3.7
T255	4	25	2	0.6	11	4.0
T256	2	25	3	2.5	11	4.0
T257	4	25	2	0.4	11	4.0
T258	15	25	2	0.3	11	2.6
T259	15	25	2	0.1	11	4.0
T260	11	25	3	0.6	11	2.7
T261	7	25	3	1.3	11	2.1
T262	7	25	3	0.5	11	4.0
T263	4	25	2	0.1	11	4.0
T264	10	25	3	0.9	11	2.1
T265	16	25	2	0.2	11	3.6
T266	14	25	3	0.4	11	3.1
T267	10	25	3	0.2	11	4.0
T268	4	25	3	0.3	11	4.0
T269	10	25	2	0.9	11	1.5
T270	14	25	2	0.3	11	2.8
T271	10	25	2	0.3	11	3.8
T272	3	25	2	2.1	11	2.6
T273	4	25	2	0.9	11	3.6
T274	6	25	3	0.9	11	3.4
T275	4	25	4	0.3	11	4.0
T276	6	25	3	0.3	11	4.0
T277	2	25	2	3.3	11	3.0
T278	4	25	2	0.1	11	4.0

T279	16	25	3	0.5	11	2.2
T280	7	25	3	0.9	11	2.9
T281	7	25	3	1	11	2.7
T282	4	25	3	0.5	11	4.0
T283	7	25	3	0.5	11	4.0
T284	8	25	3	1	11	2.3
T285	8	25	2	0.3	11	4.0
T286	5	25	3	0.9	11	4.0
T287	3	25	3	0.6	11	4.0
T288	7	25	3	0.8	11	3.2
T289	6	25	3	0.8	11	3.8
T290	10	25	2	0.3	11	3.8
T291	5	25	2	0.1	11	4.0
T292	4	25	2	0.2	11	4.0
T293	8	25	3	1	11	2.3
T294	8	25	2	0.8	11	2.0
T295	4	25	2	0.7	11	4.0
T296	3	25	2	1.2	11	3.9
T297	5	25	2	1.3	11	2.2
T298	7	25	3	0.4	11	4.0
T299	6	25	3	1.3	11	2.5
T300	2	25	3	0.5	11	4.0
T301	5	25	3	0.6	11	4.0
T302	7	25	3	0.9	11	2.9
T303	15	25	4	0.7	11	2.3
T304	4	25	2	1	11	3.3
T305	13	25	3	0.6	11	2.3
T306	12	25	2	0.2	11	4.0
T307	14	25	3	0.6	11	2.1
T308	9	25	3	1	11	2.1
T309	8	25	2	0.5	11	3.0
T310	8	25	2	0.9	11	1.8
T311	6	25	2	0.4	11	4.0
T312	5	25	3	0.6	11	4.0
T313	5	25	2	0.5	11	4.0
T314	3	25	2	0.9	11	4.0
T315	4	25	2	0.6	11	4.0
T316	7	25	2	1.5	11	1.4
T317	10	25	3	0.3	11	4.0
T318	8	25	3	0.8	11	2.8
T320	4	25	3	0.2	11	4.0
T321	7	25	2	0.4	11	4.0
T322	8	25	2	0.2	11	4.0
T323	10	25	2	0.2	11	4.0
T324	3	25	3	0.4	11	4.0
T325	5	25	3	0.3	11	4.0
T326	8	25	2	0.3	11	4.0
T327	6	25	3	1.1	11	2.9

T328	5	25	3	0.9	11	4.0
T329	10	25	2	0.6	11	2.1
T330	13	25	2	0.1	11	4.0
T331	10	25	3	0.6	11	2.9
T332	5	25	2	1	11	2.7
T333	16	25	4	0.3	11	4.0
T334	4	25	3	0.8	11	4.0
T335	6	25	3	0.4	11	4.0
T336	10	25	2	0.1	11	4.0
T337	12	25	3	0.8	11	1.9
T338	10	25	3	0.5	11	3.5
T339	5	25	3	0.4	11	4.0
T340	4	25	3	1.5	11	3.3
T341	6	25	3	0.6	11	4.0
T342	16	25	2	0.3	11	2.5
T343	8	25	2	0.2	11	4.0
T344	5	25	2	0.5	11	4.0
T345	8	25	2	0.7	11	2.2
T346	4	25	3	0.5	11	4.0
T347	2	25	3	0.6	11	4.0
T348	6	25	3	0.4	11	4.0
T349	6	25	3	0.1	11	4.0
T350	13	25	4	0.3	11	4.0
T351	4	25	3	0.4	11	4.0
T352	3	25	2	0.5	11	4.0
T353	3	25	2	0.1	11	4.0
T354	15	25	3	0.4	11	2.9
T355	7	25	3	0.5	11	4.0
T356	10	25	3	0.5	11	3.5
T357	4	25	2	0.5	11	4.0
T358	2	25	2	0.4	11	4.0
T359	5	25	3	0.7	11	4.0
T360	5	25	3	0.6	11	4.0
T361	10	25	2	0.5	11	2.4
T362	6	25	2	0.1	11	4.0
T363	12	25	2	0.1	11	4.0
T364	10	25	3	0.6	11	2.9
T365	2	25	3	0.8	11	4.0
T366	16	25	2	0.2	11	3.6
T367	4	25	3	0.7	11	4.0
T368	3	25	3	0.7	11	4.0
T369	5	25	3	1.6	11	2.5
T370	12	25	3	0.4	11	3.6
T371	15	25	3	0.3	11	3.8
T372	10	25	3	1.8	11	1.2
T373	4	25	3	1	11	4.0
T374	14	25	3	0.5	11	2.5
T375	10	25	2	0.1	11	4.0

T376	3	25	3	0.7	11	4.0
T377	8	25	4	0.8	11	3.7
T378	8	25	3	0.9	11	2.6
T379	5	25	2	0.6	11	4.0
T380	12	25	3	0.8	11	1.9
T381	15	25	2	0.3	11	2.6
T382	10	25	2	0.5	11	2.4
T383	8	25	2	0.4	11	3.7
T384	16	25	2	0.1	11	4.0
T385	8	25	3	0.8	11	2.8
T386	6	25	3	0.2	11	4.0
T387	5	25	3	0.4	11	4.0
T388	4	25	3	0.8	11	4.0
T389	5	25	3	0.7	11	4.0
T390	14	25	3	0.4	11	3.1
T391	4	25	3	0.8	11	4.0
T392	7	25	2	0.1	11	4.0
T393	10	25	3	1.2	11	1.6
T394	10	25	3	1.1	11	1.7
T395	4	25	3	0.5	11	4.0
T396	8	25	3	0.8	11	2.8
T397	7	25	3	1.2	11	2.3
T398	8	25	2	0.5	11	3.0
T399	7	25	2	1	11	1.9
T400	3	25	3	0.5	11	4.0
T401	10	25	2	0.7	11	1.8
T402	12	25	3	0.5	11	2.9
T403	8	25	2	0.5	11	3.0
T404	16	25	2	0.1	11	4.0
T405	10	25	2	0.7	11	1.8
T406	5	25	3	0.4	11	4.0
T407	3	25	3	0.5	11	4.0
T408	5	25	2	0.2	11	4.0
T409	5	25	2	0.9	11	2.9
T410	6	25	3	0.4	11	4.0
T411	8	25	3	0.3	11	4.0
T412	11	25	2	0.8	11	1.5
T413	7	25	2	0.1	11	4.0
T414	4	25	2	1	11	3.3
T415	6	25	3	0.5	11	4.0
T416	10	25	2	0.3	11	3.8
T417	7	25	3	0.7	11	3.6
T418	6	25	3	0.8	11	3.8
T419	7	25	3	0.5	11	4.0
T420	10	25	3	0.4	11	4.0
T421	14	25	4	0.5	11	3.3
T422	14	25	3	0.5	11	2.5
T423	3	25	2	0.6	11	4.0

T424	5	25	3	0.3	11	4.0
T425	5	25	3	0.3	11	4.0
T426	2	25	2	0.6	11	4.0
T427	3	25	3	0.8	11	4.0
T428	7	25	3	0.8	11	3.2
T429	11	25	3	0.3	11	4.0
T430	16	25	2	0.1	11	4.0
T431	7	25	3	0.5	11	4.0
T432	10	25	2	0.2	11	4.0
T433	6	25	4	0.8	11	4.0
T434	6	25	3	0.6	11	4.0
T435	12	25	3	0.2	11	4.0
T436	10	25	3	0.3	11	4.0
T437	5	25	3	0.4	11	4.0
T438	10	25	3	1	11	1.9
T439	12	25	3	0.8	11	1.9
T440	3	25	3	0.9	11	4.0
T441	6	25	3	0.5	11	4.0
T442	4	25	3	0.3	11	4.0
T443	4	25	3	0.4	11	4.0
T444	2	25	3	0.8	11	4.0
T445	3	25	3	1.4	11	4.0
T446	10	25	3	0.4	11	4.0
T447	5	25	3	0.4	11	4.0
T448	16	25	3	0.2	11	4.0
T449	8	25	3	0.2	11	4.0
T450	6	25	4	0.6	11	4.0
T451	7	25	2	1	11	1.9
T452	12	25	2	0.4	11	2.5
T453	10	25	3	0.8	11	2.3
T454	7	25	3	0.7	11	3.6
T455	16	25	3	0.1	11	4.0
T456	12	25	2	0.4	11	2.5
T457	4	25	3	0.5	11	4.0
T458	5	25	3	0.5	11	4.0
T459	4	25	2	0.3	11	4.0
T460	5	25	2	1	11	2.7
T461	14	25	3	0.2	11	4.0
T462	3	25	3	1.1	11	4.0
T463	4	25	3	0.3	11	4.0
T464	3	25	3	0.2	11	4.0
T465	9	25	3	0.3	11	4.0
T466	4	25	2	1.1	11	3.1
T467	15	25	2	0.1	11	4.0
T468	2	25	3	0.8	11	4.0
T469	8	25	3	0.3	11	4.0
T470	2	25	5	0	11	4.0
T471	3	25	3	1.9	11	3.7

T472	16	25	3	0.3	11	3.6
T473	8	25	3	0.5	11	4.0
T474	4	25	3	0.7	11	4.0
T475	2	25	2	0.8	11	4.0
T476	4	25	3	0.3	11	4.0
T477	4	25	3	1.3	11	3.7
T478	6	25	3	0.8	11	3.8
T479	3	25	3	0.4	11	4.0
T480	5	25	3	1.2	11	3.2
T481	7	25	3	0.3	11	4.0
T482	5	25	3	0.5	11	4.0
T483	7	25	3	0.3	11	4.0
T484	3	25	3	0.7	11	4.0
T485	14	25	3	0.3	11	4.0
T486	7	25	3	0.5	11	4.0
T487	3	25	3	1.5	11	4.0
T488	16	25	3	0.3	11	3.6
T489	8	25	3	0.5	11	4.0
T490	5	25	2	0.4	11	4.0
T491	5	25	3	0.2	11	4.0
T492	6	25	2	0.4	11	4.0
T493	8	25	2	0.5	11	3.0
T494	6	25	3	0.3	11	4.0
T495	6	25	3	0.2	11	4.0
T496	4	25	2	1.3	11	2.7
T497	5	25	3	0.6	11	4.0
T498	6	25	3	0.4	11	4.0
T499	5	25	3	0.5	11	4.0
T500	3	25	2	0.3	11	4.0
T501	16	25	3	0.4	11	2.7
T502	4	25	3	0.3	11	4.0
T503	5	25	3	0.7	11	4.0
T504	5	25	2	0.4	11	4.0
T505	5	25	3	0.2	11	4.0
T506	3	25	3	0.3	11	4.0
T507	8	25	2	0.2	11	4.0
T508	4	25	3	0.8	11	4.0
T509	16	25	3	0.6	11	1.9
T510	3	25	3	0.3	11	4.0
T511	5	25	2	0.1	11	4.0
T512	5	25	3	0.4	11	4.0
T513	5	25	2	0.2	11	4.0
T514	5	25	3	0.3	11	4.0
T515	7	25	3	0.9	11	2.9
T516	4	25	3	1.9	11	2.8
T517	16	25	2	0.1	11	4.0
T518	12	25	3	0.3	11	4.0
T519	10	25	3	0.5	11	3.5

TR33	2	25	4	0.3	11	4.0
TR34	2	25	3	0.2	11	4.0
TR35	2	25	2	0.1	11	4.0
TR37	3	25	3	0.1	11	4.0
TR38	2	25	3	0.2	11	4.0
TR39	3	25	2	0.1	11	4.0
TR40	3	25	3	0.1	11	4.0
TR41	2	25	2	0.1	11	4.0
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TR43	2	25	3	0.2	11	4.0
TR44	4	25	2	0.1	11	4.0
TR45	4	25	2	0.2	11	4.0
TR46	3	25	2	0.1	11	4.0
TR47	6	25	4	0.3	11	4.0
TR48	4	25	2	0.1	11	4.0
TR49	4	25	3	0.5	11	4.0
TR50	4	25	3	0.7	11	4.0
TR51	4	25	4	0.6	11	4.0
TR52	4	25	3	0.2	11	4.0
TR53	4	25	3	0.4	11	4.0
TR54	5	25	2	0.5	11	4.0
TR55	15	25	2	0.1	11	4.0
TR56	7	25	2	0.1	11	4.0
TR57	2	25	2	0.3	11	4.0
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TR59	16	25	3	0.1	11	4.0
TR60	16	25	2	0.1	11	4.0
TR61	10	25	2	0.8	11	1.6
TR62	16	25	2	0.1	11	4.0
TR63	16	25	2	0.1	11	4.0
TR64	16	25	3	0.1	11	4.0
TR65	16	25	3	0.1	11	4.0
TR66	16	25	3	0.1	11	4.0
TR67	16	25	2	0.1	11	4.0
TR68	16	25	2	0.1	11	4.0
TR69	16	25	2	0.1	11	4.0
TR70	16	25	2	0.1	11	4.0
TR71	16	25	2	0.3	11	2.5
TR72	16	25	3	0.1	11	4.0
TR73	16	25	2	0.1	11	4.0
TR74	16	25	3	0.1	11	4.0
TR75	16	25	2	0.1	11	4.0
TR76	15	25	3	0.2	11	4.0
TR77	15	25	2	0.1	11	4.0
TR78	8	25	3	0.2	11	4.0
TR79	9	25	2	0.8	11	1.8

T520	4	25	3	0.3	11	4.0
T521	6	25	3	0.3	11	4.0
T522	4	25	3	0.5	11	4.0
T523	8	25	2	0.3	11	4.0
T524	3	25	3	1.2	11	4.0
T525	16	25	3	0.1	11	4.0
T526	14	25	2	0.2	11	4.0
T527	7	25	3	0.2	11	4.0
T528	3	25	2	0.1	11	4.0
T529	5	25	2	0.2	11	4.0
T530	4	25	3	0.6	11	4.0
T531	4	25	2	0.4	11	4.0
T532	12	25	3	0.6	11	2.5
T533	4	25	3	0.4	11	4.0
T534	2	25	4	0.3	11	4.0
T535	3	25	3	0.1	11	4.0
TR1	3	25	5	0	11	4.0
TR2	5	25	5	0	11	4.0
TR3	2	25	5	0	11	4.0
TR4	7	25	5	0	11	4.0
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TR8	6	25	5	0	11	4.0
TR9	3	25	5	0	11	4.0
TR10	5	25	5	0	11	4.0
TR11	4	25	3	1.6	11	3.2
TR12	4	25	5	0	11	4.0
TR13	4	25	3	0.1	11	4.0
TR14	7	25	5	0	11	4.0
TR15	10	25	5	0	11	4.0
TR16	8	25	5	0	11	4.0
TR17	6	25	5	0	11	4.0
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TR24	6	25	5	0	11	4.0
TR25	6	25	5	0	11	4.0
TR26	8	25	5	0	11	4.0
TR27	8	25	3	0.2	11	4.0
TR28	3	25	3	0.1	11	4.0
TR29	4	25	4	0.3	11	4.0
TR30	5	25	4	0.1	11	4.0
TR31	3	25	3	0.3	11	4.0
TR32	2	25	4	0.2	11	4.0