Creag Dhubh to Inveraray 275 kV Connection Environmental Impact Assessment

Volume 4 | Technical Appendix 10.3

Peat Landslide Hazard and Risk Assessment

July 2022

CONTENTS

List of Abbreviations

BGS	British Geological Survey
CIEEM	Chartered Institute of Ecology and Environmental Management
EcIA	Ecological Impact Assessment
ECoW	Environmental Clerk of Works
EIA	Environmental Impact Assessment
EIA Report	Environmental Impact Assessment Report
GWDTE	Groundwater Dependent Terrestrial Ecosystems
LoD	Limits of Deviation
NVC	National Vegetation Classification
OHL	Overhead Line
SAC	Special Area of Conservation
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage
SSSI	Site of Special Scientific Interest

1 INTRODUCTION

1.1 The Proposals

1.1.1 This Appendix presents information relevant to the Creag Dhubh to Inveraray 275 kV Connection. It should be read in conjunction with **Volume 2** of the **EIA Report** for full details of the Proposed Development.

1.1.2 Scottish Hydro Electric Transmission plc (the Applicant) who, operating and known as Scottish and Southern Electricity Networks Transmission (SSEN Transmission), own, operate and develop the high voltage electricity transmission system in the north of Scotland and remote islands.

1.1.3 Due to the growth in renewable electricity generation in the north and north east of Scotland, upgrade of the transmission network is required in order to provide the necessary increase in transmission capacity.

1.1.4 The Applicant is proposing to apply for consent under Section 37 of the Electricity Act 1989 to construct and operate a 9 km double circuit 275 kV OHL, supported by steel lattice towers between a proposed substation at Creag Dhubh and the recently constructed Inveraray-Crossaig 275 kV capable OHL circuit, in Argyll, Scotland (the 'Proposed Development'). The Proposed Development is shown in **Figure 2.1: Proposed Development (EIAR Volume 3a).**

1.2 Requirement for this Report

1.2.1 This report presents baseline data collected from a desk-based review of published data and current data from field surveys.

1.2.2 The objectives of the Peat Landslide Hazard and Risk Assessment (PLHRA) are to:

- undertake a desk based review of published information including geological, hydrogeological and topographical information, to inform the baseline for the PLHRA;
- undertake site visits to identify evidence of, and potential for, active, incipient or relict peat instability, including identification of the location of features as required;
- report on evidence of any active, incipient or relict peat instability, and the potential risk of future instability, describing the likely causes and contributory factors;
- identify potential controls to be imposed during the construction phase to minimise the risk of any peat instability at the Site; and
- provide recommendations for further work or specific construction methodologies to suit the ground conditions to mitigate against any increased risk of potential peat instability.

1.2.3 The scope of the PLHRA is as follows:

- characterise the peatland geomorphology to determine whether there have been prior occurrences of instability, and whether contributory factors that might lead to instability in future are present across the Site;
- determine the likelihood of a future peat landslide under natural conditions and in association with construction activities associated with the Proposed Development;
- identify potential receptors that might be affected by peat landslides, should they occur, and quantify the associated risks; and
- provide appropriate mitigation and control measures to reduce the risks to acceptable levels such that the Proposed Development is constructed safely with minimal risks to the environment.

1.2.4 The contents of this PLHRA have been prepared in accordance with the Scottish Government's Best Practice Guidance[1], noting that the guidance 'should not be taken as prescriptive or used as a substitute for the developer's [consultant's] preferred methodology'.

[1] Scottish Government (2017). Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity.

2 METHODOLOGY

2.1 Desk Study

2.1.1 The PLHRA was undertaken following SEPA best practice guidance[1]. A desk study and field surveys were implemented to gather baseline conditions of the Site and allow a PLHRA to be completed. The desk study included an overview of the following elements to inform the baseline design:

- Bedrock and superficial geology from BGS[5] Mapping;
- Peatland and peat characteristic information from The Scottish Natural Heritage (NatureScot) carbon rich soils, deep peat and priority habitat[6;]
- Habitat survey information from **Chapter 8: Ecology (EIAR, Volume 2**);
- Hydrogeological and Hydrology information from **Chapter 11: Water Environment (EIAR Volume 2**); and
- Topographical information taken from published Digital Terrain Model (DTM) LIDAR data.

2.2 Field Survey

2.2.1 Two rounds of peat surveys were undertaken across the Site, based on the Proposed Development design. The surveys were designed based on best practice guidance for surveying developments on peatland[2].

2.2.2 The first survey was undertaken during April 2022 and included:

- Towers: Peat probing was carried out at 10 m intervals along cardinal points for a total of 50 m from the centre of each tower location; and
- Access tracks: 50 m intervals along the track and at points every 10 m perpendicular to the centreline on either side of the proposed track.

2.2.3 The second survey was undertaken in June 2022 and included:

- Access tracks (Revised Layout June 2022): 50 m intervals along the track and at points every 10 m perpendicular to the centreline on either side of the proposed track.

2.2.4 Peat cores were taken using a Russian auger, with a sample volume of 0.5 l, and a number of field tests and observations were undertaken to identify:

- Depth of acrotelm;
- Degree of humification (using Hodgson, 1974[3]), to establish amorphous, intermediate, fibrous and content; and
- Degree of humification using the Von Post, (Hobbs, 1986[4]) classification.

2.2.5 Samples were subsequently submitted to a soils testing laboratory to analyse each sample for Bulk Density, Loss on Ignition (Organic Content), Moisture Content, and pH. Results of the testing are required for peat stability analysis detailed within this report.

2.2.6 During each survey observations of peat instability or peat geomorphological conditions were recorded to inform this assessment.

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[2] Scottish Government, Scottish Natural Heritage, SEPA. (2017). *Peatland Survey. Guidance on Developments on Peatland, online version only.*

[3] Hodgson, J.M (1974) Soil Survey Field Handbook.

[4] Hobbs N.B. (1986). Mire morphology and the properties and behaviour of some British and Foreign peats. Quarterly Journal of Engineering Geology, 19, pp7-80.

2.3 Limitations and Assumptions

2.3.1 Surveying has been undertaken based on the Proposed Development design and associated infrastructure locations available at the time of the survey. As such the reporting can only present an assessment of peat slide risk within the survey area, at the point of the s37 application submission. Should the infrastructure design change outside the incorporated limits of deviation, then further surveying and subsequent amendments to the PLHRA reporting may have to be undertaken.

3 RESULTS

3.1 Desk Study

Topography

3.1.1 The Site topography is generally undulating across the central tower locations T9 to T20 at elevations of between 100 m and 150 m Above Ordnance Datum (AOD). Ground levels fall moderately sharply across the north of the Site between Towers T1 to T9 at elevations of 100 to 225 m (AOD). Steeper rising ground is also located to the south west of the Site between Towers T20 and T29, rising to approximately 250 m (AOD). Ground levels then fall to the south of the Site between Towers T29 and T34 between elevations of 250 to 150m (AOD). Topography elevations are shown on **Figure 10.3.1** (**Annex A)**.

3.1.2 Slope angles at the Site, as shown on **Figure 10.3.2 (Annex A)**, are summarised below:

- Towers T1 to T7 generally shallow (<5°);
- Towers T7 to T11 generally moderate (5.1 to 10°);
- Towers T11 to T18 moderately steep (15.1 to 20) to steep (>20);
- Towers T18 to T22 moderately steep (15.1 to 20);
- Towers T22 to T25 generally moderate (5.1 to 10°);
- Towers T25 to T29 moderately steep (15.1 to 20); and
- Towers T29 to T34 generally shallow (<5°) to moderately steep (15.1 to 20).

3.1.3 The steeper gradients >20°identified to the west of the Site are associated with upland hill and moorland terrain.

Geology

3.1.4 The 1:50,000 scale geological mapping available from the British Geological Survey (BGS)[5] shows the majority of the northern and central regions of the Site to be underlain by the Tayvallich Volcanic Formation of the Argyll Group comprising Metalava and Metatuff. Originally igneous rocks formed by eruptions of magma, which later were altered by low-grade metamorphism. These rocks were formed approximately 541 to 1000 million years ago. To the south of the Site BGS mapping shows similar aged rocks of the Crinan Grit Formation, quartzite and pellite Metamorphic Bedrock also of the Argyll Group. The 1:50,000 BGS mapping is shown on **Figure 10.3.3a (Annex A).**

3.1.5 Dalradian Supergroup, Metagabbro and Metamicrogabbro metamorphic rock is also noted to be present where igneous intrusions have occurred.

3.1.6 A fault zone is shown to be present to the south west of Tower T21 trending north east to south west.

3.1.7 The superficial geology of the Site predominantly comprises Glacial deposits of Hummocky Till (diamicton), sands and gravels. Alluvial River terrace deposits are also shown to be present within river valley formations to the east of the Site. The 1:50,000 BGS mapping is shown on **Figure 10.3.3b (Annex A).**

3.1.8 BGS mapping shows peat deposits are located outside of the Proposed Development.

3.1.9 Areas of the Site, predominantly surrounding hill formations, are mapped as having no superficial deposits present which could imply that rockhead is relatively shallow in these areas.

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[5] BGS Geological Mapping https://mapapps.bgs.ac.uk/geologyofbritain/home.html.

3.1.10 The Scottish Natural Heritage carbon rich soils, deep peat and priority habitat[6] mapping (**Figure 10.4, EIAR Volume 3a**) shows limited areas of peat to the north and south of the Site located on forestry. The peat deposits are shown to be either 'Class 2' or 'Class 5' soils, the former being defined as 'Nationally important carbon-rich soils, deep peat and priority peatland habitat'. Class 5 soils are defined as 'Dominant vegetation cover is not a priority peatland habitat'.

Hydrogeology

3.1.11 The BGS 1:625,000 scale hydrogeology mapping defines the Argyll Group rocks underlying the Proposed Development as impermeable. Any groundwater flow within the bedrock will be limited to the weathered zone or secondary fractures.

3.1.12 It is likely that the groundwater within the Site will be limited to superficial deposits and the weathered bedrock zone.

Surface Water Features

3.1.13 The Proposed Development is located wholly within the catchment of the River Aray. The River Aray flows in a southerly direction from the proposed Creag Dhubh Substation eventually discharging into Loch Fyne approximately 3 km south of the Inveraray – Crossaig connection point.

3.1.14 The proposed Creag Dhubh Substation is located close to the upstream source area of the River Aray. The Proposed Development runs in a southerly direction to the west of the River Aray but does not cross it. The Proposed Development does, however, cross a large number of tributaries that flow in an easterly direction into the River Aray. The Erallich Water is the largest tributary crossed with the remaining watercourses unnamed burns typically <1 m in width and <0.5 m in depth.

3.1.15 The River Aray was assessed by SEPA[7] in 2020 as being of 'Moderate' overall status under the Water Framework Directive classification scheme and being of 'Moderate' ecological status and 'Good' Physico-Chemical status.

3.1.16 The Erallich Water is the largest tributary crossed by the Proposed Development and was classified by SEPA in 2020 as being in 'Moderate' overall condition. None of the other tributaries are assessed under the Water Framework Directive.

3.1.17 The Proposed Development is not situated within a Scottish Government Surface Water Drinking Water Protected Area. The nearest Drinking Water Protected Area is situated approximately 700 m to the north east of the River Aray and Creag Dhubh substation (the Cladich Water DWPA) and is therefore not in hydrological connection to the Proposed Development A second DWPA is located 4.5 km to the south of the Proposed Development.

Land Use

3.1.18 Commercial forestry is a key land use across the north and south of the Site, particularly across the hillslopes which fall towards Loch Awe. Further details on forestry are located in **Chapter 14: Forestry (EIAR Volume 2**).

3.1.19 The central regions of the Site are dominated by farming activity and the electricity transmission line.

3.1.20 Further details on land use are presented in **Chapter 6: Landscape and Visual Amenity (EIAR Volume 2)**, and further details on the habitats present are found in **Chapter 8: Ecology (EIAR Volume 2).**

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[6] Scottish Natural Heritage. (2016). Carbon and Peatland 2016 map (http://map.environment.gov.scot/soil_maps/).

[7] SEPA Water Environment hub. https://www.sepa.org.uk/data-visualisation/water-environment-hub/ [Accessed March 2022]

Geomorphology

3.1.21 Digital aerial photography and Digital Terrain Model (DTM) LIDAR data was used to interpret and map geomorphological features within the Site. This interpretation and the resulting geomorphological map, as shown in **Figure 10.3.4, Annex A** were subsequently verified during site walkover surveys undertaken by an experienced peatland geomorphologist and hydrologist in April and June 2022.

3.1.22 The geomorphological features recorded are shown on **Figure 10.3.4, Annex A**. The presence, characteristics and distribution of peatland geomorphological features have been defined to understand the hydrological function of the peatland, with reference to the balance of erosion and peat accumulation (or condition), and the sensitivity of peatland to potential land-use changes.

3.1.23 Areas to the north and south of the Site have historically been intensively managed with significant areas of commercial forestry plantation and felling, with artificial drainage measures used. In some areas diffuse natural drainage systems were also noted. Within the commercial plantation and other forestry areas (Semi natural and/ or Ancient Woodland) it was noted that the acrotelmic peat was highly modified as a result of planting and felling activities. No evidence of peat erosion or instability were generally noted within the forestry areas.

3.1.24 No significant evidence of peat instability features was identified during the surveys, with very few haggs, groughs, or other peat erosion noted. Several localised areas of peat flushes were recorded across the Site which displayed basal erosion of peat due to surface water run-off. No major instability features, evidence of incipient instability or past landslides were noted.

3.2 Field Survey

3.2.1 Results from the peat surveys are detailed within **Technical Appendix 10.1: Peat Depth Survey Results (EIAR Volume 4).**

Peat Depth and Character

3.2.2 Most of the Site has either no peat present or has a shallow depth of peat present (approximately 84% were <0.5 m in depth). These areas of shallow peat can be considered as organo-mineral soils. These are further summarised as follows:

- 1,395 no. samples (64%) located on land with no peat/ absent;
- 442 no. samples (20%) located on land with less than or equal to 50 cm depth of peat or organomineral soil;
- 145 no. samples (7%) fell on land with between 51 cm and 100 cm depth of peat; and
- 201 no. samples (9%) located on land with more than 100 cm depth of peat.

3.2.3 The survey results indicate that the peat depth is variable ranging between 0.0 m and 4.6 m thickness. The peat thickness on the Site was found to be mostly shallow, with some deep pockets of peat near Tower 15 and between Towers 31A and 36A. The peat probe depth and interpolated contours are shown on **Figure 10.3.5, Annex A**. The mean peat depth recorded was 0.11 m (10.6 cm).

3.2.4 Overall, the peat sampled across the Site were relatively shallow, with occasional deep pockets recorded. The peat was found to be generally dry and in a state of weak to moderate decomposition. For areas of peat within the forestry, this is likely to be due to the coniferous plantation and associated extensive artificial drainage, which has resulted in modification to the integrity and composition of the peat and carbon rich soils.

3.3 Peat Instability

Types of Peat instability

3.3.1 Peat instability can be defined as either 'minor instability' or 'major instability' and observed by both field observations and through desk top review of aerial/satellite imagery of the Site:

- Minor instability can be defined as localised and small scale features that are not generally precursors to major failure and including gully sidewall collapses, pipe ceiling collapses, minor slumping along diffuse drainage pathways (e.g., along flushes). Indicators of minor instability include presence tension cracks, compression ridges, or bulges; and
- Major instability can be defined by peat landslides.

3.3.2 For the purposes of this assessment, landslide classification is simplified and split into three main types:

- multiple peat slides with displaced slabs and exposed substrate;
- bog burst with peat retained within the failed area; and
- multiple peat soil slides with displacement of thin soils exposing substrate.

3.3.3 The term 'peat slide' is used to refer to large-scale landslides and occur 'top-down' from the point of initiation on a slope in thinner peats (between 0.5 and 1.5 m) and on moderate slope angles (typically 5-15°).

3.3.4 The term 'bog burst' is used to refer to very large-scale failures where peat is typically deeper (greater than 1.0 m and up to 10 m) and more amorphous than sites experiencing peat slides, with shallower slope angles (typically 2-5°).

3.3.5 'Peaty soil slide' is used to refer to small-scale slab-like slides in organic soils generally <0.5 m thick.

Factors Contributing to Peat Instability

3.3.6 Peat landslides are caused by a combination of factors, triggering factors and preconditioning factors The combined factors are discussed in greater detail in **Section 3.4**. Triggering factors have an immediate or rapid effect on the stability of a peat deposits, whereas preconditioning factors can influence peat stability over a much longer period of time.

3.3.7 Preconditioning factors may influence peat stability over long periods of time (years to hundreds of years), and include:

- impeded drainage caused by a peat layer overlying an impervious clay or mineral base;
- slope convexity/concavity;
- proximity to local drainage, either from flushes, pipes or streams;
- connectivity between surface drainage and the peat substrate interface;
- artificially cut transverse drainage ditches, or grips;
- increase in mass of the peat slope through peat formation, increases in water content or afforestation;
- reduction in shear strength of peat or substrate caused by progressive creep, chemical or physical weathering or clay dispersal in the substrate;
- loss of surface vegetation effecting tensile strength (e.g., by burning or pollution induced vegetation change);
- increase in buoyancy of the peat slope through formation caused by wetting up of desiccated areas; and
- afforestation/deforestation of peat areas, causing desiccation of peat or rehydration/swelling due to subsequent forest harvesting.

3.3.8 Triggering factors are typically of short duration (minutes to hours) and any individual trigger event can be considered as a result of cumulative events:

- intense rainfall or snowmelt causing high pore pressures;
- rapid ground accelerations (e.g., from earthquakes or blasting);
- unloading of the peat mass by drainage or by artificial excavations (e.g., cutting);
- drainage in susceptible parts of a slope by alterations to natural drainage patterns (e.g.by pipe blocking or drainage diversion); and
- loading by plant, spoil or infrastructure

3.3.9 External environmental triggers such as rainfall and snowmelt cannot be mitigated, though they can be managed (e.g., by limiting construction activities during periods of intense rain).

3.3.10 Unloading of the peat mass by excavation, loading of the peat by plant and focusing of drainage can be managed and mitigated by careful design, site specific stability analyses, informed working practices and monitoring.

Approaches to Assessing Peat Instability

3.3.11 This report considers a qualitative contributory factor-based approach and conventional stability analysis (through limit equilibrium or Factor of Safety (FoS) analysis).

3.3.12 The advantage of the former is that many observed relationships between reported peat landslides and ground conditions can be considered together where a FoS is limited to consideration of a limited number of geotechnical parameters. The disadvantage is that the outputs of such an approach are better at illustrating relative variability in landslide susceptibility across a site rather than absolute likelihood.

3.3.13 The advantage of the FoS approach is that clear thresholds between stability and instability can be defined and modelled numerically. However, in reality, there is considerable uncertainty in input parameters and it is a generally held view that geotechnical stability analysis in peat is limited given the nature of peat as an organic material, rather than mineral soil.

3.3.14 To reflect these limitations, both approaches are adopted and outputs from each approach integrated in the assessment of landslide likelihood.

3.4 Assessment of Peat Landslide Likelihood

Introduction

3.4.1 This section provides details on the landslide susceptibility and limit equilibrium approaches to the assessment of peat landslide likelihood used in this report. The assessment of likelihood is a key step in the calculation of risk, where risk is expressed as follows:

Risk = Probability of a Peat Landslide x Adverse Consequences

3.4.2 The probability of a peat landslide is expressed in this PLHRA as peat landslide likelihood and is considered below.

Limit Equilibrium Approach

3.4.3 Stability analysis has been undertaken using the infinite slope model to determine the FoS for a series of 25 m x 25 m cells within the Site. The limit equilibrium approach has been applied within areas where the peat thickness is over 0.5 m. The limit equilibrium approach is the most frequently cited approach for the quantitative assessment of the stability of peat slopes. The approach assumes that failure occurs by shallow translational land sliding, which is the mechanism usually interpreted for peat slides. Due to the relative length of the slope and depth to the failure surface, end effects are considered negligible and the safety of the slope against sliding may be determined from analysis of a 'slice' of the material within the slope.

3.4.4 The stability of a peat slope is assessed by calculating a Factor of Safety, F, which is the ratio of the sum of resisting forces (shear strength) and the sum of driving forces (shear stress):

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

In this formula:

- c is the effective cohesion (kPa);
- γ is the bulk unit weight of saturated peat (kN/m^3);

- γw is the unit weight of water (kN/m³);
- z is the vertical peat depth (m),
- h is the height of the water table as a proportion of the peat depth;
- β is the angle of the substrate interface (°); and
- φ' is the angle of internal friction of the peat (°).

3.4.5 This form of the infinite slope equation uses effective stress parameters, and assumes that there are no excess pore pressures, i.e., that the soil is in its natural, unloaded condition.

3.4.6 The choice of water table height reflects the full saturation of the soils that would be expected under the most likely trigger conditions, i.e., heavy rain.

3.4.7 Where the driving forces exceed the shear strength (i.e., where the bottom half of the equation is larger than the top), F is <1, indicating instability. A FoS between 1 and 1.4 is normally taken in engineering terms to indicate marginal stability (providing an allowance for variability in soil strength, depth to failure). Slopes with a FoS greater than 1.4 are generally considered to be stable.

3.4.8 There are numerous uncertainties involved in applying geotechnical approaches to peat, not least because of its high water content, compressibility and organic composition[8]. There is also a tensile strength component to peat which is assumed to be dominant in the acrotelm, which reduces with regards to decomposition and depth. As a result, analysis utilising a purely geotechnical approach is used to show an overall estimate of peat stability using published values rather than an absolute estimate of stability.

Data Inputs

3.4.9 Stability analysis was undertaken using GIS software and a 25 m x 25 m grid was superimposed on areas of peat only, with key input parameters derived for each grid cell. A 25 m x 25 m cell size was chosen because it is sufficiently small to define a minimum credible landslide size and avoid 'smoothing' of important topographic irregularities. Given the cell size of the input DTM, which provides a key input parameter, any smaller cell size would be unlikely to provide significant benefits.

3.4.10 **Table 3.1** shows the input parameters and assumptions for the stability analyses undertaken. The shear strength parameters c' and φ' are usually derived in the laboratory using undisturbed samples of peat collected in the field and therefore site specific values are often not available ahead of detailed site investigation for a development. Therefore, for this assessment, a literature search has been undertaken to identify a range of credible but conservative values for c' and φ' quoted in fibrous and humified peats. FoS analysis was undertaken with conservative φ' of 20° and values of 2 kPa and 5 kPa for c'.

Table 3.1 Geotechnical Parameters for Drained Infinite Slope Analysis

Parameter	Values	Rationale	Source
Effective Cohesion (c')	2, 5	Credible conservative cohesion values for humified peat based on literature review	5.5 - 6.1 - peat type not stated (Long, 2005)[9] 3, 4 - peat type not stated (Long, 2005)[9] 5 - basal peat (Warburton et al., 2003) [10] 8.74 - fibrous peat (Carling, 1986)[11] 4 - peat type not stated (Dykes and Kirk, 2001)[12]

[8] Boylan N and Long M (2014) Evaluation of peat strength for stability assessments.
[9] Long M (2005) Review of peat strength, peat characterisation and constitutive modelling of peat with reference to landslides.
[10] Warburton et al (2003) Anatomy of a Pennine peat slide, Northern England. Earth Surface Processes and Landforms.
[11] Carling (1986) Peat slides in Teesdale and Weardale, Northern Pennines, July 1983: description and failure mechanisms.
[12] Dykes and Kirk (2001) Initiation of a multiple peat slide on Cuilcagh Mountain, Northern Ireland.

Parameter	Values	Rationale	Source
			7 – 12 - H8 peat (Huat et al, 2014)[13]
Bulk Unit Weight (γ)	10.5	Credible mid-range value for humified catotelmic peat	Laboratory testing of peat cores
Effective Angle of Internal Friction (φ')	22	Credible conservative friction angle for humified peat based on literature review	40 – 65 - fibrous (Huat et al, 2014)[13] 50 – 60 - amorphous (Huat et al, 2014)[13] 36.6 - 43.5 - peat type not stated (Long, 2005)[9] 31 – 55 - Irish bog peat (Hebib, 2001)[14] 34 – 48 - fibrous sedge pear (Farrell & Hebib, 1998)[15] 32 – 58 - peat type not stated (Long, 2005)[9] 23 - basal peat (Warburton et al, 2003)[10] 21 - fibrous peat (Carling, 1986)[11]
Slope Angle from Horizontal (β)	Various	Mean slope angle per 25 m x 25 m grid cell	5 m DTM of site
Peat Depth (z)	Various	Mean peat depth per 25 m x 25 m grid cell	Interpolated peat depth model of site
Height of Water Table as a Proportion of Peat Depth (h)	1	Assumes peat mass is fully saturated (normal conditions during intense rainfall events or snowmelt, which are the most likely natural hydrological conditions at failure)	Assumed

Results

3.4.11 **Figure 10.3.6, Annex A** shows the results for drained analysis of the peat areas at the Site for the more conservative of the two parameter sets above (φ' of 22° and c' of 5 kPa). The results indicate that even with conservative parameters, Factors of Safety demonstrate stability across most of the Site (FoS >1.5). This is consistent with the lack of observation of instability features during the site walkover and on review of aerial imagery (see **Section 3.1**).

Landslide Susceptibility Approach

3.4.12 The landslide susceptibility approach is based on the layering of contributory factors to produce unique 'slope facets' that define areas of similar susceptibility to failure. The number and size of slope facets will vary from one part of the Site to another according to the complexity of ground conditions. As with the limit equilibrium approach, facets were only defined in areas of true peat.

3.4.13 Eight contributory factors are considered in the analysis:

- slope angle (S);
- peat depth (P);
- substrate geology (G);
- peat geomorphology (M);

13 Huat et al (2014) Geotechnics of organic soils and peat.

14 Hebib (2001) Experimental investigation of the stabilisation of Irish peat

15 Farrell and Hebib (1998) The determination of the geotechnical parameters of organic soils

- drainage (D);
- forestry (F);
- slope convexity (C); and
- land use (L).

3.4.14 For each factor, a series of numerical scores between 0 and 3 are assigned to factor 'classes', the significance of which is tabulated for each factor. The higher a score, the greater the contribution of that factor to instability for any particular slope facet. Scores of 0 imply neutral/ negligible influence on instability.

3.4.15 Factor scores are summed for each slope facet to produce a peat landslide likelihood score (SPL), the theoretical maximum being 24 (8 factors, each with a maximum score of 3):

$$SPL = SS + SP + SG + SM + SD + SF + SC + SL$$

3.4.16 In practice, a maximum score is unlikely, as the chance of all contributory factors having their highest scores in one location is very small.

3.4.17 Figures to show the spatial distribution of each factor across the Site are shown in **Figures 3.7a-h, Annex A**.

Slope Angle (S)

3.4.18 **Table 3.2** shows the slope ranges, their significance and related scores for the slope angle contributory factor. Slope angles were derived from the 5 m DTM and scores assigned based on reported slope angles associated with peat landslides rather than a simplistic assumption that 'the steeper a slope, the more likely it is to fail'.

Table 3.2 Slope Classes, Significance and Scores

Slope Range (°)	Significance	Score
>20.0	Failure typically occurs as peaty debris slides due to low thickness of peat	1
15.1-20.0	Failure typically occurs as peaty debris slides due to low thickness of peat	2
10.1-15.0	Failure typically occurs as peat slides, bog slides or peaty debris slides, a key slope range for reported population of peat failures	3
5.1-10.0	Failure typically occurs as peat slides, bog slides or peaty-debris slides, a key slope range for reported population of peat failures	3
2.1-5.0	Failure typically occurs as bog bursts, bog flows or peat flows; peat slides and peaty debris slides rare due to low slope angles	2
≤2.0	Failure is very rarely associated with flat ground, neutral influence on stability	0

3.4.19 **Figure 10.3.2, Annex A** shows the distribution of slope angle scores across the Site. The results show the slope angles across most of the Site are generally either shallow (2.1 to 5.0°) or moderate (5.1 to10°) but with some localised steeper gradients around upland hill and river valley formations.

Peat Depth (P)

3.4.20 **Table 3.3** shows the peat depths, their significance and related scores for the peat depth contributory factor. Peat depths were derived from the peat depth model shown on **Figure 10.3.5, Annex A** and reflect the peat depth ranges most frequently associated with peat slides (Evans and Warburton, 2007)[16] .

[16] Evans & Warburton (2007) Geomorphology of Upland Peat: Erosion.

Table 3.3 Peat Depth Classes, Significance and Scores

Depth Range (m)	Significance	Score
>1.5	Sufficient thickness for any type of peat failure	2
1.0-1.5	Sufficient thickness for peat slide or bog slide	3
0.5-1.0	Sufficient thickness for peat or bog slide and peaty-debris slide but not for bog burst	3
<0.5	Organic soil rather than peat, failures would be peaty-debris slides	1
No Organic Soil	No organic soil and therefore failures cannot be interpreted as peat slides, neutral influence on stability	0

3.4.21 **Figure 10.3.5, Annex A** shows the distribution of peat depth scores across the Site. The results indicate that the Site is predominantly covered by peat thicknesses <0.5 m. Forested Areas show localised areas of peat accumulation of generally <1.5 m but in places up to 3.0 m.

Substrate Geology(M)

3.4.22 **Table 3.4** shows substrate type, significance and related scores for the peat depth contributory factor. The shear surface or failure zone of peat failures typically overlies an impervious clay or mineral (bedrock) base giving rise to impeded drainage. This, in part, is responsible for the presence of peat, but also precludes free drainage of water from the base of the peat mass, particularly under extreme conditions (such as after heavy rainfall, or snowmelt).

3.4.23 Peat failures are frequently cited in association with glacial till deposits in which an iron pan is observed in the upper few centimetres[17] . They have also been observed over glacial till without an obvious iron pan, or over impermeable bedrock. They are rarely cited over permeable bedrock, probably due to the reduced likelihood of peat formation.

Table 3.4 Substrate Geology Classes, Significance and Scores

Substrate Geology	Significance	Score
Glacial Till with Iron Pan	Failures often associated with underlying till; particularly where impermeable iron pan provides polished shear surface	3
Glacial Till	Failures often associated with underlying till	2
Impermeable Bedrock	Failures sometimes associated with bedrock, particularly if smooth top surface	1
Permeable Bedrock	Failures rarely associated with permeable bedrock (peat is often thin or absent), neutral influence on stability	0

3.4.24 **Figure 10.3.3, Annex A** shows the distribution of substrate geology scores across the Site. The results indicate that the Site is underlain mostly by impermeable bedrock, which is consistent with the solid geology recorded.

Peat Geomorphology (G)

3.4.25 **Table 3.5** shows the geomorphological features identified across the Site, their significance and related scores.

[17] Dykes A. and Warburton J. (2007) Mass movements in peat: A formal classification scheme. Geomorphology 86. (Evans & Warburton, 2007).

Table 3.5 Peat Geomorphology Classes, Significance and Scores

Geomorphology	Significance	Score
Adjacent/ upslope (<50 m) to existing instability (peat slide, peaty-debris slide, bank failure)	Failures often associated with underlying till; particularly where impermeable iron pan provides polished shear surface	3
Incipient instability (tension crack, compression ridge, bulging, quaking bog)	Failures are likely to occur where incipient failure morphology is observed	3
Undrained intact planar peat	Failures are most frequently recorded in intact peat, planar peat	2
Diffuse natural drainage/ pool/ flush	Failures are often associated with areas of diffuse subsurface drainage (such as flushes)	2
Pipe/ Collapsed Pipe	Failures are often associated with areas of soil piping	2
Existing Peat Slide	Failures typically stabilise and do not reactivate after the initial event	1
Gullied/ Dissected/ Hagged/ Eroded Peat/ Bare Peat/ Bare Ground	Failures are rarely recorded in peat fragmentated by erosion	1

3.4.26 **Figure 10.3.4, Annex A** shows there are no significant geomorphological features within the development area that are associated with the historic peat slide failure.

Drainage (D)

3.4.27 **Table 3.6** shows artificial drainage feature classes, their significance and related scores. Transverse / oblique drainage lines may reduce peat stability by creating lines of weakness in the peat slope and encouraging the formation of peat pipes. Review of published literature indicates that a number of peat failures have been identified which have failed over moorland grips[18] . The influence of changes in hydrology become more pronounced the more transverse the orientation of the drainage lines are relative to the overall slope.

Table 3.6 Drainage Feature Classes, Significance and Scores

Significance	Score
Failures are sometimes reported in association with artificial drains oblique/transverse to slope	3
Failures are rarely associated with artificial drains parallel to slope	1
Neutral influence on stability	0

3.4.28 **Figure 10.3.4, Annex A** shows the distribution of drainage feature scores across the Site. Artificial drainage was observed within commercial forestry and across moorland areas (e.g., open moorland habitat areas characterised by underlying peat). These were found to be parallel to the slope.

Forestry (F)

3.4.29 **7** shows forestry classes, their significance and related scores. Areas of the Site have been extensively managed for both afforested and deforested areas. In both cases it was noted that the alignment of the forestry was predominantly aligned to the slope.

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[18] Warburton J, Holden J and Mills AJ (2004). Hydrological controls of surficial mass movements in peat

Table 3.7 Forestry Classes, Significance and Scores

Forestry Class	Significance	Score
Afforested area (with mature trees), ridge and furrows oblique to slope	Peat underlying forestry stands with rows aligned oblique to slope has inter ridge cracks which are conducive to slope instability	2
Afforested area (with mature trees), ridge and furrows aligned to slope	Peat underlying forestry stands with rows aligned with slope is conducive to slope instability, but less so than where rows are aligned oblique to slope	1
Deforested area (few or no trees), ridge and furrows oblique to slope	Peat underlying deforested stands has a higher water table and more neutral buoyancy, but retains inter ridge cracks (lines of weakness) conducive to instability; alignment of cracks oblique to slope is most conducive to instability	3
Deforested area (few or no trees), ridge and furrows aligned to slope	Peat underlying deforested stands has a higher water table and more neutral buoyancy, but retains inter ridge cracks (lines of weakness), however, orientation of these cracks is less critical when aligned to slope	2
Not Afforested	Neutral influence on stability	0

3.4.30 **Figure 10.3.7g, Annex A** shows the distribution of forestry feature scores across the Site.

Slope Convexity (C)

3.4.31 **Table 3.8** shows profile convexity classes, significance and related scores. Convex and concave slopes (i.e., positions in a slope profile where slope gradient changes by a few degrees) can be associated with the initiation point of peat landslides. Convexities are often associated with thinning of peat; such that thicker peat upslope applies stresses to thinner 'retaining' peat downslope. Conversely, buckling and tearing of peat may trigger failure at concavities.

Table 3.8 Convexity Feature Classes, Significance and Scores

Convexity Feature	Significance	Score
Convex Slope	Peat failures are often reported on or above convex slopes	3
Concave Slope	Peat failures are occasionally reported in association with concave slopes	1
Rectilinear Slope	Rectilinear slopes show no particular predisposition to failure, neutral influence on stability	0

3.4.32 **Figure 10.3.7f, Annex A** shows the distribution of convexity feature scores across the Site.

Land use (L)

3.4.33 **Table 3.9**Error! Reference source not found. shows land use classes, significance and related scores. Several forms of land uses have been associated with peat failures which form the scoring and potential for failure.

Table 3.9 Land Use Feature Classes, Significance and Scores

Land Use	Significance	Score
Cutting/ Turbary	Peat failures are often associated with peat cuttings/turbary	3
Adjacent Quarrying	Failures are occasionally reported adjacent to quarries (usually as bog bursts, bog flows or peat flows)	2
Burning	Failures are rarely associated with burning though this activity may create pathways for water to the base of peat	1

Land Use	Significance	Score
Other Land Use	Failures are rarely associated with other forms of land use	0

3.4.34 **Figure 10.3.7h, Annex A** shows that no significant land use areas are situated within the proposed development area.

Likelihood Scores

3.4.35 The eight contributory factor layers shown on **Figure 10.3.8, Annex A** were combined in GIS software to produce likelihood scores for a peat landslide. These likelihood scores were then converted into descriptive 'likelihood classes' from 'Very Low' to 'Very High' with a corresponding numerical range of 1 to 5, and are described in **Table 3.10**.

Table 3.10 Likelihood Classes Derived from the Landslide Susceptibility Methodology

Summed Contributory Factor Scores	Typical Site Conditions Associated with Score	Qualitative Likelihood	Peat Landslide Likelihood Score
≤6	Unmodified peat with no more than low weightings for peat depth, slope angle, underlying geology and peat morphology	Very Low	1
7-11	Unmodified or modified peat with no more than moderate or some high scores for peat depth, slope angle, underlying geology and peat morphology	Low	2
12-16	Unmodified or modified peat with high scores for peat depth and slope angle and/ or high scores for at least three other contributory factors	Moderate	3
17-21	Modified peat with high scores for peat depth and slope angle and several other contributory factors	High	4
>21	Modified peat with high scores for most contributory factors (unusual except in areas with evidence of incipient instability)	Very High	5

3.4.36 **Table 3.11** describes the basis for the likelihood classes. Professional judgement was made that for a facet to have a moderate or higher likelihood of a peat landslide, a likelihood score would be required equivalent to both the worst case peat depth and slope angle scores (3 in each case, i.e., 3 x 2 classes) alongside three intermediate scores (of 2, i.e,. 2 x 3 classes) for other contributory factors. This means that any likelihood score of 12 or greater would be equivalent to at least a moderate likelihood of a peat landslide. Given that the maximum score attainable is 24, this seems reasonable.

Results

3.4.37 The results of the Peat Slide Likelihood are shown on **Figure 10.3.8, Annex A** and indicate that the majority of the Site is considered to be of 'low' or 'very low' likelihood of a peat landslide.

3.4.38 Two areas are located within an area of "Moderate" likelihood. These include:

- Temporary access track to Tower T6; and
- Permanent access track between Tower T28 and Tower T30.

3.4.39 However, The FoS results, shown on **Figure 10.3.6, Annex A**, suggest that both areas are "stable". Further required remedial actions are described within **Section 3.5** and **Section 4.2**

3.4.40 In order for there to be a "High" or "Medium" risk associated with Proposed Development, combined peat landslide likelihood must be "Moderate" or higher at an infrastructure location, as defined by Scottish Government Guidance[19]

3.4.41 Where combined peat landslide likelihoods are assessed as "Low" or "Very Low", post-consent site investigations and application of good practice construction mitigation methods should be employed prior to and during construction as detailed in **Section 3.5** and **Section 4.2**

3.5 Peat Slide Risk Assessment and Mitigation

3.5.1 **Table 3.11** defines the stability risk assessment based on the peat slide likelihood and the required mitigation actions for each Risk Level.

Table 3.11 Risk Assessment

Peat Slide Likelihood	Potential Stability Risk (Pre-Mitigation)	Mitigation Action
Very Low	Very Low	No peat present>0.5 m and therefore no mitigation action required
Low	Unlikely/Low	Development of a site-specific construction and management plan for peat areas
Moderate	Likely/Medium	As for Low condition plus may require mitigation to improve site conditions.
High	Probable High	Unacceptable level of risk, the area should be avoided. If unavoidable, detailed investigation and quantitative assessment required to determine stability with long term monitoring.
Very high	Almost Certain/Very high	Unacceptable level of risk, the area should be avoided

3.5.2 **Table 3.12** shows the risk level and required mitigation measures for the Proposed Towers and Proposed Access Tracks.

Table 3.12 Risk Level and Mitigation

Tower/ Infrastructure	Peat Depth m (Max)	Risk Level	Comment /Mitigation
Tower T1	1.8	Low	Deep peat recorded but Low risk due to low likelihood. Tower Construction methodology review (Refer to **Section 4**)
Tower T2	3.5	Low	Deep peat recorded but Low risk due to low likelihood. Tower Construction methodology review (Refer **Section 4**)
Tower T3	2.5	Low	Deep peat recorded but Low risk due to low likelihood. Tower Construction methodology review (Refer **Section 4**)
Tower T4	0.8	Low	Deep peat >0.5 m recorded at two locations; Low risk due to low likelihood

[19] Scottish Government. (2017) Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments

Tower/ Infrastructure	Peat Depth m (Max)	Risk Level	Comment /Mitigation
Tower T5	0.8	Low	Deep peat >0.5 m recorded at two locations; Low risk due to low likelihood
Tower T6	0.9	Low	Deep peat recorded but Low risk due to low likelihood. Tower Construction methodology review (Refer **Section 4**)
Tower T7	0.8	Low	Deep peat recorded but Low risk due to low likelihood. Tower Construction methodology review (Refer Section 4)
Tower T8	0.8	Low	Deep peat >0.5 m recorded at one location; Low risk due to low likelihood
Tower T9	1.8	Low	Deep peat recorded but Low risk due to low likelihood. Tower Construction methodology review (Refer **Section 4**)
Tower T10	0.5	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T11	0.6	Low	Deep peat >0.5 m recorded at one location; Low risk due to low likelihood
Tower T12	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T13	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T14	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T15	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T16	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T17	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T18	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T19	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T20	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T21	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T22	0.4	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T23	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T24	1.7	Low	Deep peat >0.5 m recorded 30 m to east of tower location. Tower Construction methodology review (Refer **Section 4**)

Tower/ Infrastructure	Peat Depth m (Max)	Risk Level	Comment /Mitigation
Tower T25	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T26	0.1	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T27	0.4	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T28	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T29	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Tower T30	1.5	Low	Deep peat >0.5 m recorded 20 m to east of tower location Tower Construction methodology review (Refer **Section 4**)
Tower T31	1.1	Low	Deep peat >0.5 m recorded 10 m to east of tower location. Tower Construction methodology review (Refer **Section 4**)
Tower T32	1.5	Low	Deep peat >0.5 m recorded 10 m to south of tower location. Tower Construction methodology review (Refer **Section 4**)
Tower T33	0.1	Very Low	Deep peat >0.5 m recorded. No mitigation required
Tower T34	0.6	Low	Deep peat >0.5 m recorded at one location, Low risk due to low likelihood
ITE/ITW Tower and pole locations	0.4	Very Low	Deep peat >0.5 m recorded. No mitigation required
Access Tracks			
Permanent Track to T3	<0.5 centre, 1.8 25m to east	Low	Deep peat on shallow (<5°) to moderate slope angle (5-10°) presenting low likelihood (Refer **Section 4** for mitigation)
Temporary track T3 to T5	0.8 centre, 1.8 10m to east near T3	Low	Deep peat on shallow slope angle (<5°), shallow peat (<0.5m) on moderate slope (5-10°) presenting low likelihood (Refer **Section 4** for mitigation)
Temporary Track to T6	2.5 centre	Medium	Track located on deep peat with moderate slope angle (5-10°). (Refer **Section 4** for mitigation)
Temporary Track T7 to T8	0.4	Low	Track predominantly located on shallow peat with moderate slope angle (5-10°) presenting low likelihood. (Refer **Section 4** for mitigation)
Temporary Track T8 to T9	1.8 max near T9	Low	Track located on predominantly shallow (<0.5m) with locally deep peat. Moderate (5-10°) slope angle presenting low likelihood. (Refer **Section 4** for mitigation)
Temporary Track T9 to T10	1.8	Low	Track predominantly located on shallow peat with locally deep peat. Moderate slope angle (5-10°) to moderately steep

Tower/ Infrastructure	Peat Depth m (Max)	Risk Level	Comment /Mitigation
			(10-15°) presenting low likelihood. (Refer **Section 4** for mitigation)
Permanent Track to T11	0.3	Very Low	No peat recorded>0.5 m depth. No mitigation required
Permanent Track T11 to T15	0.4	Very Low	No peat recorded>0.5 m depth. No mitigation required
Temporary Track T10 to T15	0.8 to south of track	Low	Track predominantly located on shallow peat or no peat and on steep slope angle (15-20°) presenting low likelihood. (Refer **Section 4** for mitigation)
Temporary Track to T12	0.5	Very Low	No peat recorded>0.5 m depth. No mitigation required
Permanent Track T15 to T20	<0.5m Centre, 1.3m to south of track near T19	Low	Predominantly shallow or no peat on moderate (5-10°) to steep (15-20º) slope angle presenting low likelihood. (Refer **Section 4** for mitigation)
Temporary Track to T19	0.1	Very Low	No peat recorded>0.5 m depth. No mitigation required
Temporary Track T20 to T21	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Temporary Spur to A819	<0.5m, (locally 2.5m)	Low	Predominantly shallow to locally deep peat on very shallow (<3º) to moderate (5-10º) slope presenting low likelihood. (Refer **Section 4** for mitigation)
Permanent Track T21 to T22	0.6	Low	Track predominantly located on shallow peat with steep slope angle (10-15°) presenting low likelihood. (Refer **Section 4** for mitigation)
Permanent Track T22 to T24	0.4	Very Low	No peat recorded>0.5 m depth. No mitigation required
Temporary Track T23	0.2	Very Low	No peat recorded>0.5 m depth. No mitigation required
Permanent Track T23 to T25	0.7	Low	Track predominantly located on shallow peat. Areas of deep peat near T25 on shallow slope angle (<3°) presenting low likelihood. (Refer **Section 4** for mitigation)
Permanent Track T24	2.5	Low	Track located on deep peat with shallow (<5.0) slope angle presenting low likelihood. (Refer **Section 4** for mitigation)
Temporary Track T26	0.2	Very Low	No peat recorded>0.5 m depth. No mitigation required
Temporary Track T26 to T27	0.7, (locally 2.5)	Low	Predominantly shallow locally deep peat on moderate (5-10°) slope angle presenting low likelihood. (Refer **Section 4** for mitigation)
Temporary Track T27 to T28	0.4	Very Low	No peat recorded>0.5 m depth. No mitigation required

Tower/ Infrastructure	Peat Depth m (Max)	Risk Level	Comment /Mitigation
Temporary Track T29	0.0	Very Low	No peat recorded>0.5 m depth. No mitigation required
Permanent Track T28 to T30	0.9, (locally 2.3)	Medium	Predominantly shallow, locally deep peat on shallow moderate gradient (5-10°) to moderately steep (10-15º) presenting moderate likelihood. Realign track away from deep peat area to mitigate. (Refer **Section 4** for mitigation)
Temporary Track T30 to T31	0.6	Low	Predominantly shallow peat with moderate (5-10°) slope angles presenting low likelihood (Refer **Section 4** for mitigation)
Temporary Track to T32	0.0	Very Low	No peat recorded >0.5 m depth. No mitigation required
Permanent Track to T33	1.1	Low	Deep peat but shallow slope gradient (<3°) presenting low likelihood (Refer **Section 4** for mitigation)
Permanent Track to T34	0.6	Low	Track predominantly located on shallow peat shallow slope angle (~5°) presenting low risk. (Refer **Section 4** for mitigation recorded

From **Table 3.12**, all of the Proposed Towers, temporary towers and poles pose low likelihood for peat slide. A total of two track locations are classed as Medium risk.

3.5.3 Where track areas are located in areas of deep peat which possess medium risk potential of peat slide, micrositing the track outside the medium area would be required.

3.6 Consequence Evaluation

3.6.1 Based on the assessment of consequence of risk methodology, as defined by best practice Guidance[20], three receptors have been identified at the Site, and are assessed for consequence in **Table 3.13**:

- watercourses;
- non-riverine habitats; and
- Proposed Development infrastructure.

Table 3.13 Assessment of Consequence and Risk

Receptor	Consequence	Score	Justification for Score	Consequence Scale
Watercourses	Increased turbidity and acidification, fish kill, blockage of drainage, effects on private water supplies	3	Water Quality, Flood risk and Private water supplies have been assessed within **Chapter 7: Water Environment, EIAR Volume 2.**	High
Non-riverine Habitats	Medium term loss of vegetation cover, disruption	3	Effects on peatland habitats, though the effects of peat	High

[20] Scottish Government. (2017) Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments

Receptor	Consequence	Score	Justification for Score	Consequence Scale
	of peat hydrology, carbon release		landslides are generally short in duration	
Proposed Development Infrastructure	Damage to infrastructure, possible injury, loss of life	5	Loss of life, though unlikely, is a severe consequence; financial implications of damage and repair to infrastructure are less significant	Extremely high

3.6.2 Areas of moderate likelihood of peat slide, as described in the previous section, would be mitigated through design and micrositing of infrastructure. **Table 3.14** shows how the Risk Level is defined for each of the consequences when applied to Low or Very Low likelihood classification which is considered applicable for the Site.

Table 3.14 Risk levels derived from Likelihood vs Consequence

Receptor	Qualitative Likelihood worst case (See Table 3.12)	Consequence Scale/ Score (See Table 3.13)	Risk Level	Minimum Distance to Receptor
Watercourses	Low (2)	High (3)	Low	50 m
Non-riverine Habitats	Low (2)	High (3)	Low	50 m
Proposed Development Infrastructure	Low (2)	Extremely High (5)	Low	1 km (Stronmagachan)

3.6.3 Based on the combined Qualitative Likelihood vs Consequence and the findings within the FoS assessment previously outlined, it is considered that the combined risk level of peat landslide in association with the construction of the Proposed Development is assessed as being Low risk. This assessment of Risk level is based on low likelihood vs high or very high consequence as outlined in Table 5.3 of SEPA best practice guidance[1] and illustrated in the Image 1 extract below:

Image 1 - Table 5.3: Extract from Scottish Government (2017). Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments

Table 5.3 Indicative risk levels

Peat landslide probability or likelihood		Adverse consequence				
		Extremely High	High	Moderate	Low	Very Low
	Almost certain	High	High	Moderate	Moderate	Low
	Probable	High	Moderate	Moderate	Low	Negligible
	Likely	Moderate	Moderate	Low	Low	Negligible
	Unlikely	Low	Low	Low	Negligible	Negligible
	Negligible	Low	Negligible	Negligible	Negligible	Negligible

4 MITIGATION MEASURES AND RECOMMENDATIONS

4.1.1 A number of mitigation measures could be used to reduce the risk levels identified above. These range from infrastructure-specific measures (which could act to reduce peat landslide likelihood, and, in turn, risk) to general good practice that should be applied across the Site to engender awareness of peat instability and enable early identification of potential displacements and opportunities for mitigation.

4.1.2 Typically, risks could be mitigated by:

- micrositing, use of the 100 m Limit of Deviation (LOD) for access tracks to refine layout and reduce further the overlap between infrastructure and peat soils;
- obtaining further Site information post-consent and pre-construction, in doing so demonstrating that input parameters to the likelihood assessment are overly conservative; and
- precautionary construction measures – use of monitoring, good practice and a geotechnical risk register in all locations.

4.1.3 These mitigation measures would further reduce the already minimal risks present at the Site and are detailed below for the construction and post-construction phases.

4.2 Mitigation Recommended

4.2.1 A comprehensive intrusive geotechnical assessment should be undertaken post-consent based on the combined ground investigation, previously undertaken, to support the engineering design of tower foundations, tracks and ancillary infrastructure for the Proposed Development.

4.2.2 Appropriate field and laboratory testing would also be undertaken as part of the comprehensive ground investigation to confirm the peat stability baseline across the Site to cover the areas affected by the tracks and ancillary infrastructure, and further design mitigation used as appropriate to reduce the likelihood of peat instability (where required).

4.2.3 A geotechnical risk register would be prepared detailing any ground risks identified during the ground investigation and providing mitigation measures as appropriate. The risk register should be considered a live document and updated throughout the phases of the Proposed Development. The monitoring requirements discussed in the following paragraphs would be undertaken by the Applicant's contractor.

4.2.4 During construction of the Proposed Development the following mitigation would be undertaken for excavations:

- a geotechnical risk register would be prepared for the Proposed Development following intrusive investigations post consent and location specific stability analyses;
- site inspections and audits would be undertaken at scheduled intervals to identify any unusual or unexpected changes to ground conditions (which may be associated with construction or which may occur independently of construction);
- all construction activities and operational decisions that involve disturbance to peat deposits would be overseen by an appropriately qualified geotechnical engineer with experience of construction on peat sites;
- awareness of peat instability and pre-failure indicators would be incorporated in site induction, tool box talks, and training to enable all site personnel to recognise ground disturbances and features indicative of incipient instability;
- monitoring checklists would be prepared with respect to peat instability addressing all construction activities forming the Proposed Development;
- use of appropriate supporting structures around peat excavations, where required, (e.g., for towers, crane pads and compounds) to prevent collapse and the development of tension cracks;

- avoid cutting trenches or aligning excavations across slopes (which may act as incipient back scars for peat failures) unless appropriate mitigation has been put in place;
- implement methods of working that minimise the cutting of the toes of slope, e.g., working up-to-downslope during excavation works;
- monitor the ground upslope of excavation works for creep, heave, displacement, tension cracks, subsidence or changes in surface water content;
- monitor cut faces for changes in water discharge, particularly at the peat-substrate contact; and
- minimise the effects of construction on natural drainage by ensuring natural drainage pathways are maintained or diverted such that there is no significant alteration of the hydrological regime of the Site; drainage plans should avoid creating drainage/infiltration areas or settlement ponds towards the tops of slopes (where they may act to both load the slope and elevate pore pressures).

4.2.5 During construction of the Proposed Development the following mitigation would be undertaken for excavated tracks:

- maintain drainage pathways through tracks to avoid ponding of water upslope;
- monitor the top line of excavated peat deposits for deformation post-excavation; and
- monitor the effectiveness of cross-track drainage to ensure it water remains free-flowing and that no blockages have occurred.

4.2.6 During construction of the Proposed Development the following mitigation would be undertaken for floating tracks:

- Allow peat to undergo primary consolidation by adopting rates of road construction appropriate to weather conditions.
- Monitor the effects of secondary compression over the life of the development, where required, while the tracks are utilised (can be up to 35 years) to ensure running surfaces remain elevated above the ground surface and does not cause ponding.
- Identify ‘stop’ rules, i.e., weather dependent criteria for cessation of track construction based on local meteorological data.
- Run vehicles at 50% load capacity until the tracks have entered the second compression phase.
- Prior to construction, setting out the centreline of the proposed track to identify any ground instability concerns or particularly wet zones.

4.2.7 During construction of the Proposed Development the following mitigation would be undertaken for temporary storage of peat and restoration activities:

- where practicable, ensure temporary stores of peat are located on non-peat soils to minimise potential for instability of the underlying soils;
- avoid storing peat on slope gradients >3° and preferably store on ground with neutral slopes and natural downslope barriers to peat movement;
- monitor effects of wetting/ re-wetting stored peat on surrounding peat areas, and prevent water build up on the upslope side of peat mounds; and
- maximise the interval between material deliveries over newly constructed tracks that are still observed to be within the primary consolidation phase.

4.2.8 During the operational phase of the Proposed Development monitoring of key infrastructure locations would continue through Site walkovers and inspections by the Applicant’s maintenance contractor to look for signs of unexpected ground disturbance, including:

- ponding on the upslope side of infrastructure sites and on the upslope side of access tracks;
- subsidence and lateral displacement of tracks;

- changes in the character of natural or artificial peat drainage within a 50 m buffer strip of tracks and infrastructure (e.g., development of quaking bog, waterlogging of previously dry drains);
- blockage or underperformance of the installed site drainage system;
- slippage or creep of stored peat deposits (including in restored peat cuttings); and
- development of tension cracks, compression features, bulging or quaking bog anywhere in a 50 m corridor surrounding the site of any construction activities or site works.

4.2.9 Monitoring would be undertaken during construction and as part of the commissioning phase the need for on-going monitoring would be reviewed and any ongoing monitoring requirements identified.

5 CONCLUSION

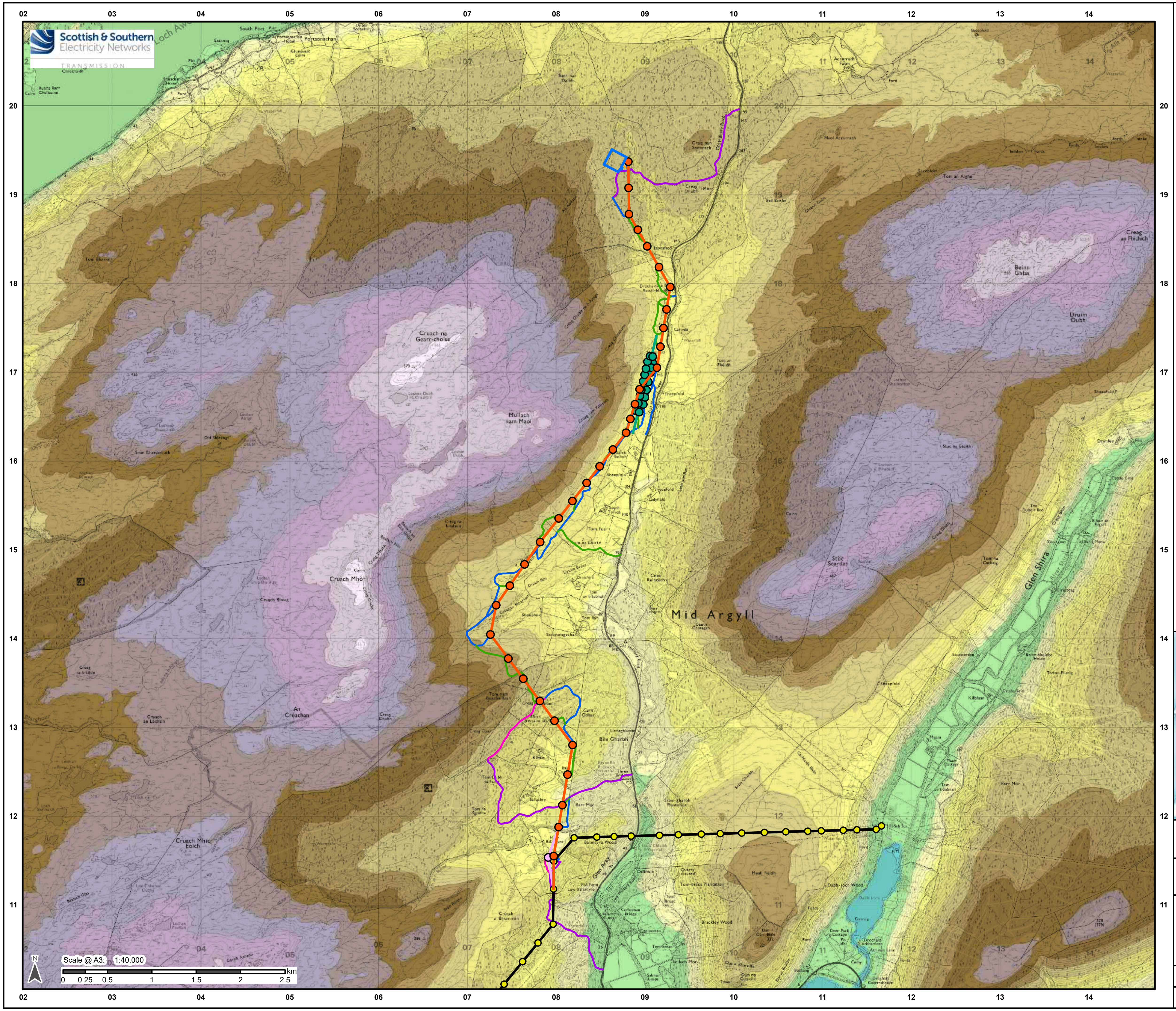
5.1.1 The majority of the Site is considered to be low or very low risk with regards to peat slide risk.

5.1.2 Where areas of medium risk have been identified then micrositing of towers and infrastructure away from these areas is considered best practice. Where this is unachievable then piled foundation construction methods for tower foundations will reduce the risk of peat instability and reduce the need for peat excavation.

5.1.3 Where new and temporary access tracks are located on deep peat with low potential for instability then the use of floating track construction may be used to avoid excavation of peat.

Annex A – Figures

Scottish & Southern Electricity Networks
TRANSMISSION



Legend

- Proposed Alignment Towers
- Proposed Alignment
- Proposed Creag Dhubh Substation (Separate Application)
- Inveraray - Crossaig Towers
- Inveraray - Crossaig OHL

Temporary Diversions

- ITE / ITW 132 kV Diversion
- 275 kV Diversion
- ITE / ITW 132 kV Diversion Poles
- 275 kV Diversion Towers

Access Tracks

- Creag Dhubh Access Track
- Access Tracks - Track To Be Maintained
- Proposed Access Route (Perm)
- Proposed Access Route (Temp)
- Existing Access Tracks Upgrade

Elevation (m)

-1.3 - 0	300.1 - 350
0.1 - 50	350.1 - 400
50.1 - 100	400.1 - 450
100.1 - 150	450.1 - 500
150.1 - 200	500.1 - 550
200.1 - 250	550.1 - 600
250.1 - 300	

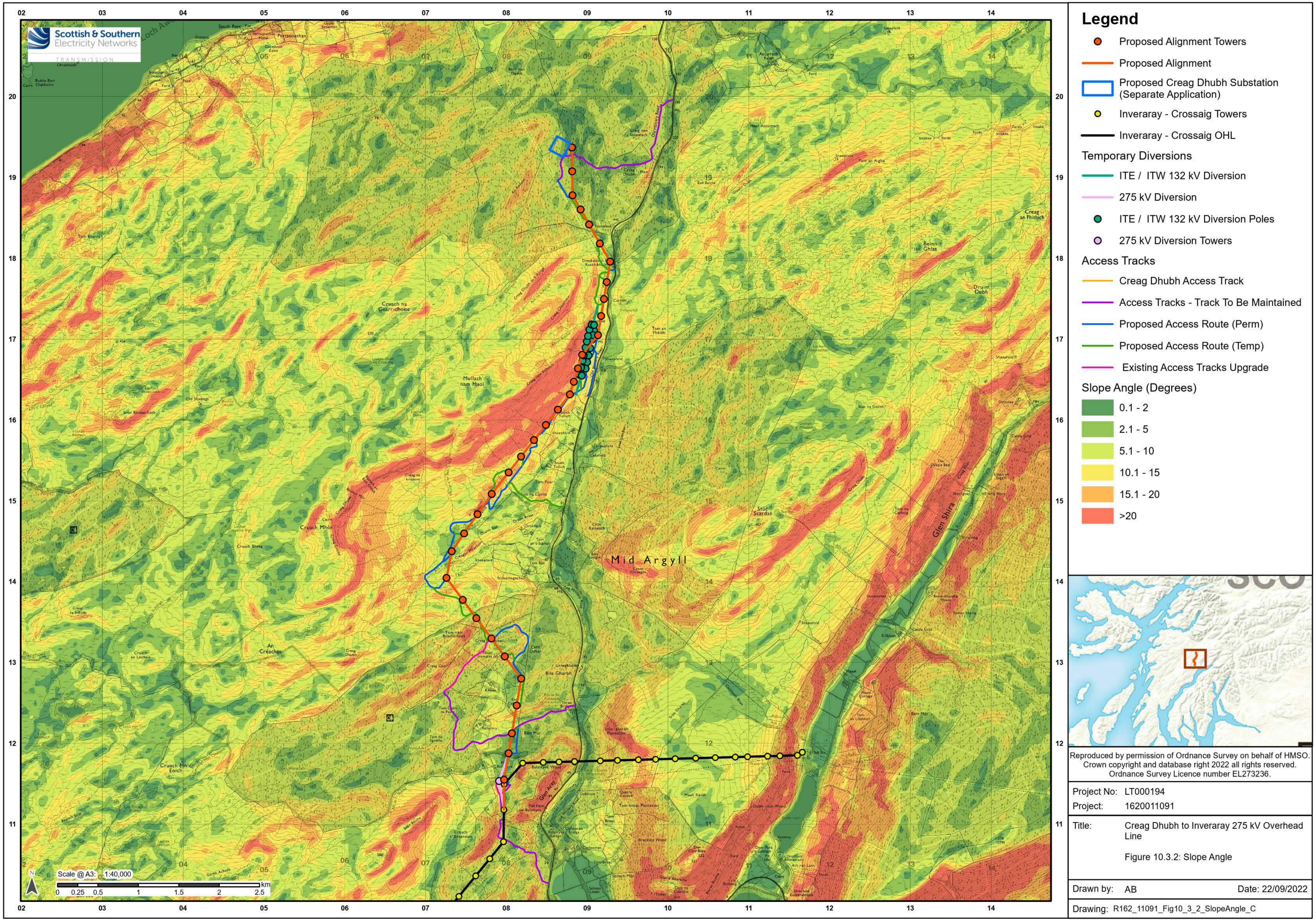
Project No: LT000194
Project: 1620011091

Title: Creag Dhubh to Inveraray 275 kV Overhead Line

Figure 10.3.1: Elevation

Drawn by: AB
Date: 22/09/2022

Drawing: R162_11091_Fig10_3_1_Elevation_C



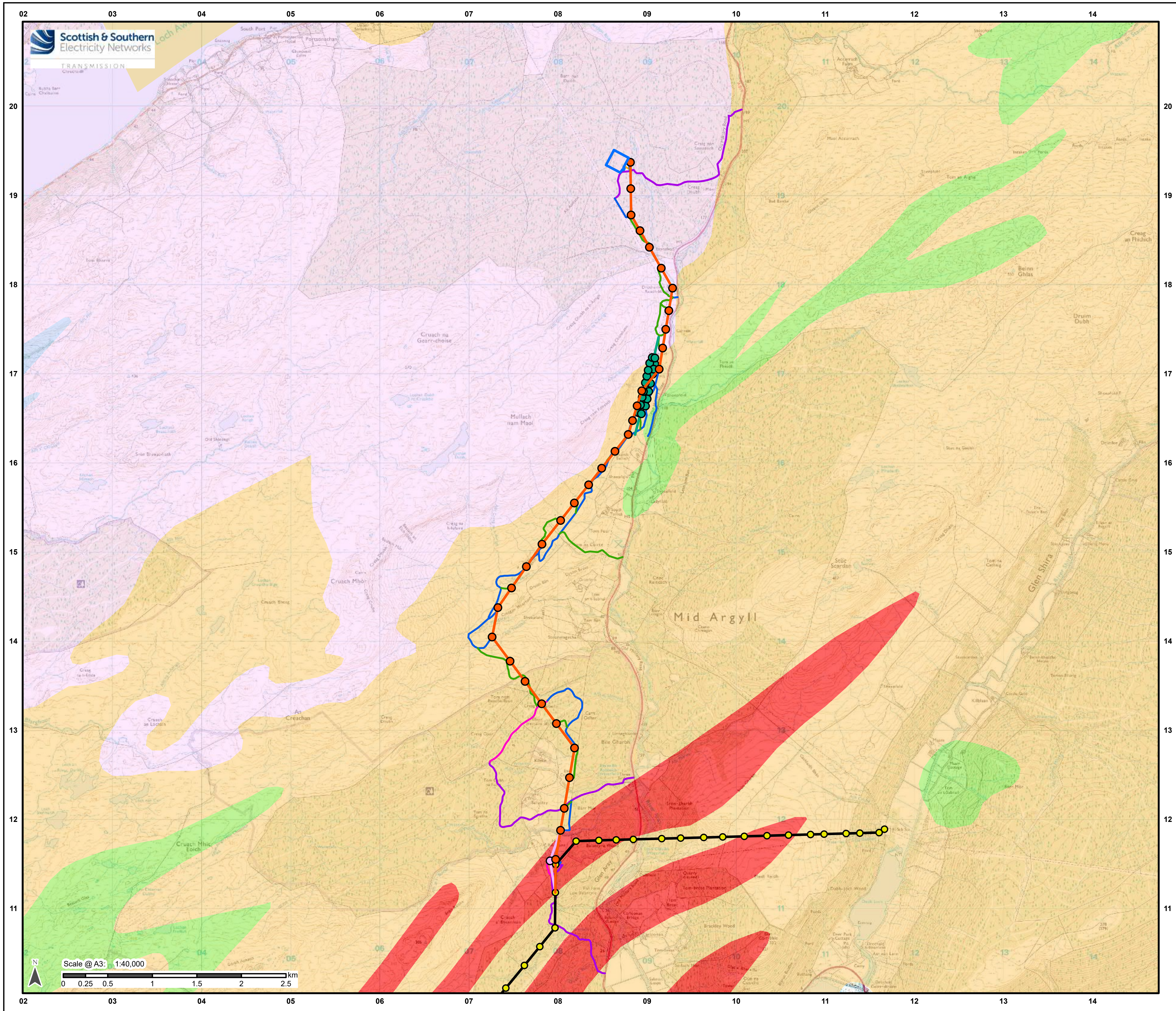
Project No: LT000194
Project: 1620011091

Title: Creag Dhubh to Inveraray 275 kV Overhead Line

Figure 10.3.2: Slope Angle

Drawn by: AB
Date: 22/09/2022

Drawing: R162_11091_Fig10_3_2_SlopeAngle_C



Legend

- Proposed Alignment Towers
- Proposed Alignment
- Proposed Creag Dhubh Substation (Separate Application)
- Inveraray - Crossaig Towers
- Inveraray - Crossaig OHL

Temporary Diversions

- ITE / ITW 132 kV Diversion
- 275 kV Diversion
- ITE / ITW 132 kV Diversion Poles
- 275 kV Diversion Towers

Access Tracks

- Creag Dhubh Access Track
- Access Tracks - Track To Be Maintained
- Proposed Access Route (Perm)
- Proposed Access Route (Temp)
- Existing Access Tracks Upgrade

BGS Bedrock Geology

- UNNAMED IGNEOUS INTRUSION, LATE SILURIAN TO EARLY DEVONIAN - FELSIC-ROCK
- ARGYLL GROUP - PSAMMITE, SEMIPELITE AND PELITE
- SOUTHERN HIGHLAND GROUP - PSAMMITE AND PELITE
- UNNAMED EXTRUSIVE ROCKS, NEOPROTEROZOIC - MAFIC LAVA AND MAFIC TUFF
- UNNAMED IGNEOUS INTRUSION, NEOPROTEROZOIC - MAFIC IGNEOUS-ROCK

Project No: LT000194
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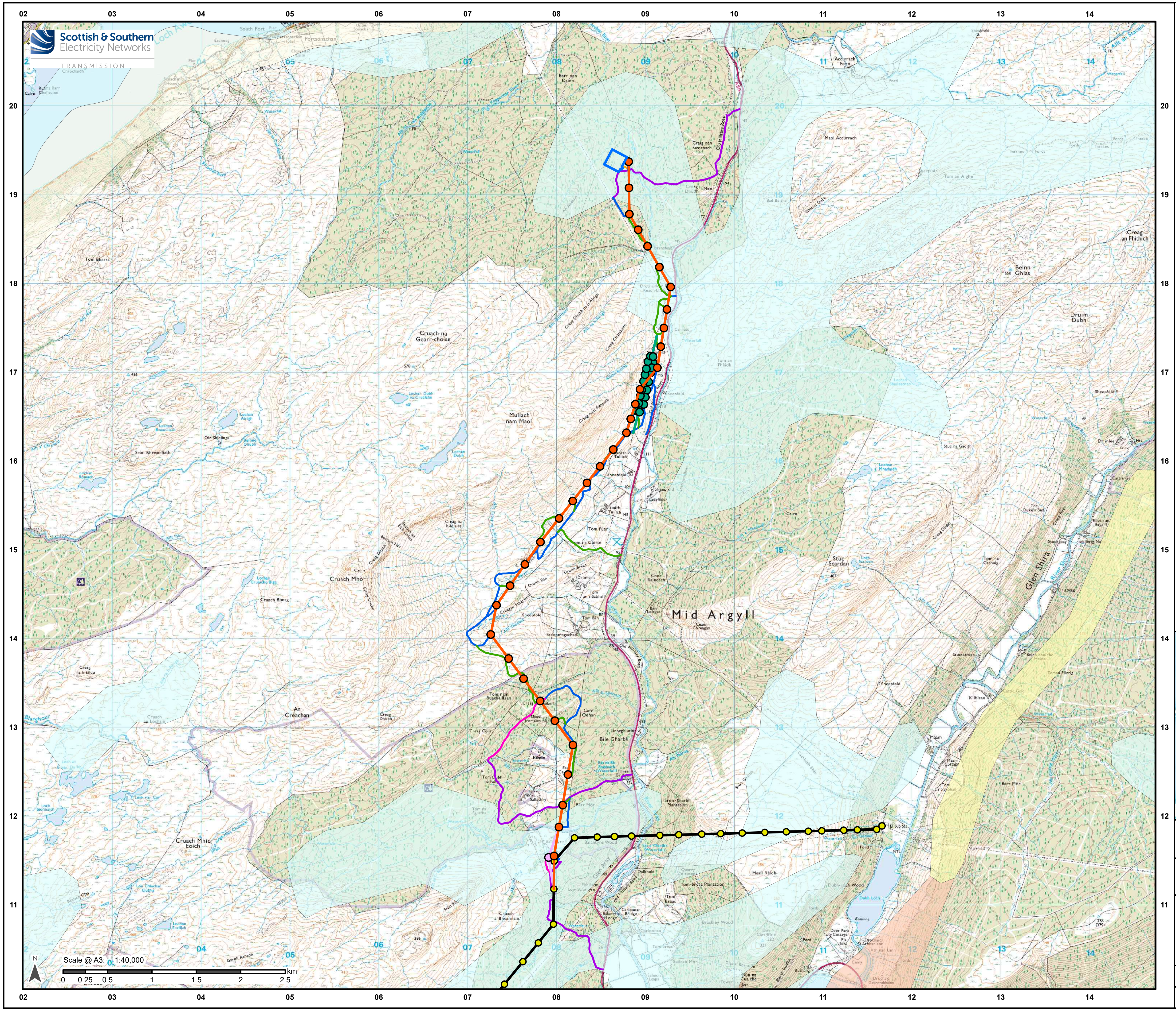
Title: Creag Dhubh to Inveraray 275 kV Overhead Line

Figure 10.3.3a: Bedrock Geology

Drawn by: AB Date: 22/09/2022

Drawing: R162_11091_Fig10_3_3a_BedrockGeology_C



Legend

- Proposed Alignment Towers
- Proposed Alignment
- Proposed Creag Dhubh Substation (Separate Application)
- Inveraray - Crossaig Towers
- Inveraray - Crossaig OHL

Temporary Diversions

- ITE / ITW 132 kV Diversion
- 275 kV Diversion
- ITE / ITW 132 kV Diversion Poles
- 275 kV Diversion Towers

Access Tracks

- Creag Dhubh Access Track
- Access Tracks - Track To Be Maintained
- Proposed Access Route (Perm)
- Proposed Access Route (Temp)
- Existing Access Tracks Upgrade

BGS Superficial Geology

- Aluvium - Clay, Silt and Sand
- Raised Marine Deposits - Sand and Gravel
- Till - Diamicton
- Unknown

Project No:	LT000194
Project:	1620011091
Title:	Creag Dhubh to Inveraray 275 kV Overhead Line Figure 10.3.3b: Superficial Geology
Drawn by:	AB
Date:	22/09/2022
Drawing:	R162_11091_Fig10_3_3b_SuperficialGeology_C