Technical Appendix 2.5: Peat Landslide Hazard and Risk Assessment

Technical Appendix 2.5: Peat Landslide Hazard and Risk Assessment

1.1 Introduction

1.1.1 Ramboll was commissioned by Artfield Forest Wind Farm Ltd ('the Applicant') to undertake a Peat Landslide Hazard and Risk Assessment (PLHRA) for the Proposed Development and is a Technical Appendix to the EIAR.

1.1.2 The PLHRA has been prepared in accordance with appropriate guidance and best practice, namely the Scottish Government Peat Landslide Hazard and Risk Assessment Best Practice Guide (2017)[1]. This Technical Appendix assesses the potential risk of peat slide at the Site as well as providing a precis of the geological and hydrological conditions. The Technical Appendix also outlines suitable mitigation measures, where required, to reduce risks identified. A full description of the Proposed Development is provided in Chapter 2: Development Description (EIAR Volume 2) but in summary comprises:

- 12 three-bladed horizontal axis wind turbines;
- Internal/ external transformers and related switchgear at each turbine;
- associated turbine foundations;
- a permanent free-standing meteorological mast;
- a network of on-site tracks with associated water crossings, passing places and turning heads;
- a main site junction on C3w (existing Gass Farm entrance), along with any necessary road improvements works on the public road network;
- a secondary site access for use during construction only;
- search areas of up to four borrow pits;
- a substation compound, including energy storage facility;
- two temporary site construction compounds (including concrete batching plant);
- a permanent anemometer mast or LiDAR compound including associated foundations and hardstanding;
- a network of on-site buried electrical cables;
- engineering operations; and
- forestry felling and restocking and associated ancillary works.

1.1.3 This Technical Appendix represents the findings and opinions of experienced geotechnical and environmental consultants based upon the information obtained from a variety of sources as detailed. Ramboll believes the information obtained from third parties is reliable but does not guarantee its authenticity, but professional judgement has been used in its interpretation.

1.1.4 This Technical Appendix is supported by the following:

- Figure 2.5.1: Elevation;
- Figure 2.5.2: Slope Angle;
- Figure 2.5.3: Solid Geology;
- Figure 2.5.4: Geomorphology and Hydrology;
- Figure 2.5.5: Peat Depth Survey and Interpolated Peat Depths;
- Figure 2.5.6: Factor of Safety;
- Figure 2.5.7: Contributory Factors; and
- Figure 2.5.8: Peat Slide Likelihood.

Objectives of the Study and Scope

1.1.5 The objectives of the PLHRA are to:

- undertake a desk top review of available geological, habitat, hydrogeological and topographical information;
- 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;
- reporting 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.

1.1.6 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.

1.1.7 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.'

1.2 Desk Study

Site Location and Setting

1.2.1 The Site is located approximately 8 km northwest of Kirkcowan and 15 km west of Newton Stewart, Dumfries and Galloway, and covers an area of approximately 800 hectares (ha). The Site is centred at approximate Ordnance Survey Grid Reference NX 24367 66928 (as shown in EIAR Volume 3a: Figure 1.1: Site Location).

1.2.2 The Site is dominated by commercially managed plantation forestry. The Site also supports areas of sheep grazed pasture in the south east and recently felled and replanted woodland together with compartments of mixed plantation woodland.

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

1.2.3 The Site location and setting are described in more detail within Chapter 2: Development Description (EIAR Volume 2).

Topography

1.2.4 The Site topography is generally undulating at elevations of between 182 m Above Ordnance Datum (AOD) and 110 m AOD, (as shown on EIAR Volume 4: Figure 2.5.1).

1.2.5 Slope angles at the Site, as shown on Figure 2.5.2 (EIAR Volume 4), are generally shallow (<5°) but with some localised areas >20° which are associated with hill formations predominantly located to the northern and central Site parts of the Site. Wind turbines and associated infrastructure have been located away from the steeper slope angles where practicable.

Geology

1.2.6 The 1:50,000 scale geological mapping available from the British Geological Survey (BGS)[2] shows the majority of the Site to be underlain by Wacke of the Portpatrick Formation and Glenwhargen Formation. A fault is present within the northernmost area of the Site and the underlying geology is Wacke of the Kirkcolm Formation Figure 2.5.3 (EIAR Volume 4).

1.2.7 The superficial geology of the Site predominantly comprises peat with the south east of the Site comprising Diamicton Till. Some areas are mapped as having no superficial deposits present which could imply that rockhead is relatively shallow in these areas.

1.2.8 The Scottish Natural Heritage carbon rich soils, deep peat and priority habitat[3] shows the Site as predominantly 'Class 4' or 'Class 5' soils, which are defined as mineral or peat soils with no peatland vegetation. These areas are predominantly forested or clear-felled land. Small areas of 'Class 1' and 'Class 2' soils (priority peatland habitat), which are of national importance are present along the northern boundary, and southern parts of the Site, shown on Figure 2.5.4 (EIAR Volume 4).

Hydrology

1.2.9 The Tarf Water flows in an easterly direction along the northern margin of the Site before altering to a southerly direction as it passes through the Site. The topography of the Site is such that the whole Site is within the catchment of the Tarf Water. A small area in the west of the Site (on which no site infrastructure is proposed), drains initially to the Drumpall Burn, before eventually discharging to the Tarf Water, approximately 1.5 km downstream of the southern boundary of the Site.

1.2.10 The Tarf Water is a Special Area of Conservation (SAC, 'River Bladnoch') which is designated due to the presence of Atlantic salmon *Salmo salar*.

1.2.11 The Purgatory Burn (which forms the north west boundary of the Site), discharges to the Tarf adjacent to the north boundary of the Site. As the Tarf Water flows around the northern margin of the Site, and southwards through the Site, a number of small, unnamed burns and drains discharge surface waters to the Tarf Water from the site area.

1.2.12 Surface water features recorded at the Site are based on a review of Ordnance Survey mapping and site observations, which are shown on Figure 2.5.5 (EIAR Volume 4).

1.2.13 The 1:625,000 UK Digital Hydrogeological Data map shows the Site is located over a low productivity aquifer comprising Portpatrick Formation and Glenwhargen Formations. Flow is virtually all through fractures and other discontinuities in highly inundated greywackes with limited groundwater in near surface weathered zone and secondary fractures.

1.2.14 The Site is underlain by the Galloway groundwater body. The groundwater body is designated as being in 'Good' overall condition including being of 'Good' water quality.

1.2.15 The average annual rainfall for the nearest weather station (Met Office weather station at West Freugh) is 1048.6 mm, based on the most recent dataset (1981 to 2010)[4].

Land Use

1.2.16 The majority of the Site is currently used for plantation forestry. An area of the Site to the south is currently used for grazing sheep and cattle.

1.2.17 The plantation forestry within Artfield Forest is predominantly mature tree growth which has not undergone felling/ restructuring. Forestry within Meikle Cairn is a mixture of primary and secondary plantation. Gass Forest has recently been subject to a series of felling and secondary forestry plantation.

1.2.18 No evidence of extensive quarrying was noted during the site walkover. One borrow pit location was noted to the east on the Meikle Cairn site. It is assumed the borrow pit was used to source aggregate for the forestry tracks. This finding along with evidence of rock outcropping noted during the peat survey, indicates that rockhead is present at shallow depth in areas of the Site outside areas of the deep peat.

Geomorphology

Peat Geomorphology

1.2.19 Digital aerial photography and Digital Terrain Model (DTM) LiDAR data was used to interpret and map geomorphological features within the developable areas of the Site. This interpretation and the resulting geomorphological map, as shown in Figure 2.5.5 (EIAR Volume 4), were subsequently verified during site walkover and survey undertaken by an experienced peatland geomorphologist and hydrologist in September 2020. No notable geomorphological features were noted but drainage channels and watercourses were included in the assessment.

1.2.20 The geomorphological features recorded are shown on Figure 2.5.5 (EIAR Volume 4). The presence, characteristics and distribution of peatland geomorphological features have been defined to understand the hydrological function of the peatland, with particular reference to the balance of erosion and peat accumulation (or condition), and the sensitivity of peatland to potential land-use changes.

1.2.21 As noted above, the Site has 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 forestry areas 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.

1.2.22 No significant evidence of instability features were identified, with very few haggs, groughs, and other features noted. No pipes were observed (e.g. through collapsed pipe ceilings or underground water flow). No major instability features, evidence of incipient instability or past landslides were noted.

Peat Depth and Character

1.2.23 Two peat depth probing surveys were undertaken at the Site, with a combined total of 1,708 peat probes taken. This comprised 338 peat depth probes during the Phase 1 survey, as part of a low resolution survey across the developable area of the Site, and a further 1,370 probes during Phase 2 survey based on a more mature development layout. An additional 517 peat probes taken as part of

[2] https://mapapps.bgs.ac.uk/geologyofbritain/home.html

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

[4] https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcu2pdv8y

the previous Gass Wind Farm application were also used. The combined peat depth dataset was 2,225 probes. The results of the surveys were used to inform the design layout of the Proposed Development.

1.2.24 Most of the developable area of the Site has either no peat present or has a shallow depth of peat present (~60% <0.5 m in depth). These areas of shallow peat can be considered as organo-mineral soils. These are further summarised as follows:

- 449 no. samples (20.0%) located on land with no peat/ absent;
- 886 no. samples (40.0%) located on land with less than or equal to 50 cm depth of peat or organo-mineral soil;
- 260 no. samples (12.0%) fell on land with between 51 cm and 100 cm depth of peat; and
- 630 no. samples (28%) located on land with more than 100 cm depth of peat.

1.2.25 The maximum depth of peat recorded at the Site was 6.4 m, located in the south western part of the Site during the peat survey for the Gass Wind Farm. The maximum depth of peat recorded during the Phase 1 peat probe survey was 5.5 m, located to the north western part of the Site. The maximum depth of peat recorded during the Phase 2 peat probe survey was 5.7 m, located east of Turbine 10. The mean peat depth recorded was 0.87 m.

1.2.26 The peat depth data was interpolated in GIS using an inverse distance weighting approach, the results of which are shown on Figure 2.3.1 (EIAR Volume 4).

1.2.27 Overall, the peats sampled across the developable area of the Site were relatively shallow, particularly in the southern and central parts of the Site. Deeper areas of peat were noted, particularly in the north western, north eastern and south western areas of the Site. The peat was found to be generally dry and in a state of advanced decomposition. This is likely to be as a result of the presence of coniferous plantation across the Site, which has resulted in modification to the integrity and composition of the peat and carbon rich soils.

1.2.28 The Proposed Development's infrastructure has been located away from these deeper peat locations where practicable, taking into account other environmental and technical constraints, or microsited to minimise potentially significant adverse effects.

1.2.29 Further details of the peatland condition and findings from the peat surveys are included in the Peat Depth Survey Report (EIAR Volume 4: Technical Appendix 2.3).

1.3 Peat Instability

Types of Peat Instability

1.3.1 Peat instability can be defined as being 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:

1.3.2 Minor instability – 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 incipient instability including development of tension cracks, tears in the acrotelm (upper vegetation mat), compression ridges, or bulges/ thrusts[1]; these latter features may be warning signs of larger scale major instability (such as landsliding) or may simply represent a longer term response of the hillslope to drainage and gravity (such as creep); and

1.3.3 Major instability - comprising various forms of peat landslide, ranging from small scale collapse and outflow of peat filled drainage lines/ gullies (occupying a few tens of cubic metres), to medium scale peaty-debris slides in organic soils (tens to hundreds of cubic metres) to large scale peat slides and bog bursts (thousands to hundreds of thousands of cubic metres).

1.3.4 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.

1.3.5 The term 'peat slide' is used to refer to large-scale (typically less than 10,000 cubic metres) landslides in which failure initiates as large rafts of material which subsequently break down into smaller blocks and slurry. Peat slides occur 'top-down' from the point of initiation on a slope in thinner peats (between 0.5 m and 1.5 m) and on moderate slope angles (typically 5° to 15°).

1.3.6 The term °bog burst° is used to refer to very large-scale (usually greater than 10,000 cubic metres) spreading failures in which the landslide retrogresses (cuts upslope) from the point of failure while flowing downslope. 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°). Much of the peat displaced during the event may remain within the initial failure zone. Bog bursts are rarely (if ever) reported in Scotland other than in the Western Isles[5].

1.3.7 The term °peaty soil slide° is used to refer to small-scale (thousands of cubic metres) slab-like slides in organic soils (i.e. they are <0.5 m thick). These are similar to peat slides in form, but far smaller and occur commonly in UK uplands across a range of slope angles[6]. Their small size means that they often do not affect watercourses and their effect on habitats is minimal.

1.3.8 Few if any spreading failures in peat (i.e. bog bursts) have been reported in Scotland, with only one or two unpublished examples in evidence on the Isle of Lewis. Reports of peat slides are also rare in Scotland in comparison to Ireland, Northern Ireland and England, either because they rarely occur or have not been reported. The deep peat conditions on-site are conducive to both peat slides and bog bursts and hence both failure mechanisms are considered in the following analysis.

Factors Contributing to Peat Instability

1.3.9 Peat landslides are caused by a combination of factors, triggering factors and preconditioning factors[1,6]. Triggering factors have an immediate or rapid effect on the stability of a peat accumulation whereas preconditioning factors can influence peat stability over a much longer period. Only some of these factors can be addressed by site characterisation.

1.3.10 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 (hydrological discontinuity);
- a convex slope or a slope with a break of slope at its head (concentration of subsurface flow);
- proximity to local drainage, either from flushes, pipes or streams (supply of water);
- connectivity between surface drainage and the peat/ impervious interface (mechanism for generation of excess pore pressures);
- artificially cut transverse drainage ditches, or grips (elevating pore water pressures in the basal peat mineral matrix between cuts, and causing fragmentation of the peat mass);
- increase in mass of the peat slope through peat formation, increases in water content or afforestation;

[5] Bowes DR (1960) A bog-burst in the Isle of Lewis. Scottish Geographical Journal

- reduction in shear strength of peat or substrate from changes in physical structure caused by progressive creep and vertical fracturing (tension cracking or desiccation cracking), chemical or physical weathering or clay dispersal in the substrate;
- loss of surface vegetation and associated tensile strength (e.g. by burning or pollution induced vegetation change);
- increase in buoyancy of the peat slope through formation of sub-surface pools or water-filled pipe networks or wetting up of desiccated areas; and
- afforestation of peat areas, reducing water held in the peat body, and increasing potential for formation of desiccation cracks which are exploited by rainfall on forest harvesting.

1.3.11 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 along pre-existing or potential rupture surfaces (e.g. between the peat and substrate);
- rapid ground accelerations (e.g. from earthquakes or blasting); unloading of the peat mass by fluvial incision or by artificial excavations (e.g. cutting);
- focusing of drainage in a susceptible part of a slope by alterations to natural drainage patterns (e.g.by pipe blocking or drainage diversion); and
- loading by plant, spoil or infrastructure.

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

Consequences of Peat Instability

1.3.13 Both peat slides and bog bursts have the potential to be large in scale, disrupting significant areas of blanket bog and with the potential to discharge large volumes of material into watercourses.

1.3.14 A key part of the risk assessment process is to identify the potential scale of peat instability should it occur and identify the receptors of the consequences. Potential sensitive receptors of peat failure are:

- the development infrastructure and turbines (damage to turbines, tracks, substation, etc);
- site workers and plant (risk of injury/ death or damage to plant);
- wildlife (disruption of habitat) and aquatic fauna;
- watercourses and lochs (particularly if associated with public water supply);
- site drainage (blocked drains/ ditches leading to localised flooding/ erosion); and
- visual amenity (scarring of landscape).

1.3.15 While peat failures may cause visual scarring of the peat landscape, most peat failures revegetate fully within 50 years to 100 years and are often difficult to identify on the ground after this period of time. Typically, it is short-term (seasonal) effects on watercourses that are the primary concern or impacts on public water supply.

Good Practice Guidance

Scottish Government Guidance

1.3.16 The first edition of the Scottish Government peat landslide hazard best practice guidance was issued in 2007 and provided an outline of expectations for approaches to be taken in assessing peat landslide risks on wind farm sites. After ten years of practice and industry experience, the guidance was reissued in 2017[1], though without fundamental changes to the core expectations. A key change was to provide a clearer steer on the format and outcome of reviews undertaken by the Energy Consents Unit checking authority and related expectations of report revisions, should they be required.

1.3.17 In Section 4.1 of the peat landslide hazard best practice guidance, the key elements of a PLHRA are highlighted, as follows:

- an assessment of the character of the peatland within the site boundary including thickness and extent of peat, and a demonstrable understanding of site hydrology and geomorphology;
- an assessment of evidence for past landslide activity and present-day instability e.g. pre-failure indicators;
- a qualitative or quantitative assessment of the potential for or likelihood of future peat landslide activity (or a landslide susceptibility or hazard assessment);
- identification of receptors (e.g. habitats, watercourses, infrastructure, human life) exposed to peat landslide hazards; and
- a site-wide qualitative or quantitative risk assessment that considers the potential consequences of peat landslides for the identified receptors.

1.3.18 The above elements are considered within this Technical Appendix in the assessment of the Site.

Approaches to Assessing Peat Instability

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

1.3.20 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.

1.3.21 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 the geomechanical basis for stability analysis in peat is limited given the nature of peat as an organic, rather than mineral soil.

1.3.22 To reflect these limitations, both approaches are adopted and outputs from each approach integrated in the assessment of landslide likelihood. This is based on:

Probability of Peat Landslide x Consequence of Peat Landslide = Risk

1.4 Assessment of Peat Landslide Likelihood

Introduction

1.4.1 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

1.4.2 The probability of a peat landslide is expressed in this Technical Appendix as peat landslide likelihood and is considered below.

Limit Equilibrium Approach

1.4.3 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 developable area of 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 landsliding, 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.

1.4.4 The stability of a peat slope is assessed by calculating a FoS, F, which is the ratio of the sum of resisting forces (shear strength) and the sum of driving forces (shear stress)[1]:

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

In this formula:

- c is the effective cohesion (kPa);
- γ is the bulk unit weight of saturated peat (kN/m³);
- 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 (°).

1.4.5 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.

1.4.6 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.

1.4.7 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 to indicate marginal stability (providing an allowance for variability in the strength of the soil, depth to failure, etc). Slopes with a FoS greater than 1.4 are generally considered to be stable.

1.4.8 There are numerous uncertainties involved in applying geotechnical approaches to peat, not least because of its high water content, compressibility and organic composition. Peat comprises organic matter in various states of decomposition with both pore water and water within plant constituents, and the frictional particle-to-particle contacts that are modelled in standard geotechnical approaches are different in peats. There is also a tensile strength component to peat which is assumed to be dominant in the acrotelm, declining with increasing decomposition and depth. As a result, analysis utilising geotechnical approaches is often primarily of value in showing relative stability across a site given credible and representative input parameters rather than in providing an absolute estimate of stability. With this in mind, representative data inputs have been derived from published literature and used for drained analysis only.

Data Inputs

1.4.9 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.

1.4.10 Table 2.5.1 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 2.5.1: 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*)[6] 3, 4 - peat type not stated (*Long, 2005*)[6] 5 - basal peat (Warburton *et al*., 2003)[7] 8.74 - fibrous peat (*Carling, 1986*)[8] 4 - peat type not stated (*Dykes and Kirk, 2001*)[9] 7 – 12 - H8 peat (*Huat et al, 2014*)[10]
Bulk Unit Weight (γ)	10.5	Credible mid-range value for humified catotelmic peat	10.1 – catotelm peat (*Mills, 2002*)[11] 10.1 – Irish bog peat *(Boylan et al, 2008)*[12]
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*)[10] 50 – 60 - amorphous (*Huat et al, 2014*)[10] 36.6 - 43.5 - peat type not stated (*Long, 2005*)[6] 31 – 55 - Irish bog peat (*Hebib, 2001*)[13] 34 – 48 - fibrous sedge pear *(Farrell & Hebib, 1998)*[14] 32 – 58 - peat type not stated (*Long, 2005*)[6] 23 - basal peat (*Warburton et al, 2003*)[7] 21 - fibrous peat (*Carling, 1986*)[8]
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

1.4.11 Figure 2.5.6 (EIAR Volume 4) 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 2 kPa). The results indicate that even with conservative parameters, FoS 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

[6] Long M (2005) Review of peat strength, peat characterisation and constitutive modelling of peat with reference to landslides
[7] Warburton *et al* (2003) Anatomy of a Pennine peat slide, Northern England. Earth Surface Processes and Landforms
[8] Carling (1986) Peat slides in Teesdale and Weardale, Northern Pennines, July 1983: description and failure mechanisms
[9] Dykes and Kirk (2001) Initiation of a multiple peat slide on Cuilcagh Mountain, Northern Ireland
[10] Huat et al (2014) Geotechnics of organic soils and peat
[11] Mills (2002) Peat slides: Morphology, Mechanisms and Recovery
[12] Boylan N, *et al* (2008) Peat slope failure in Ireland
[13] Hebib (2001) Experimental investigation of the stabilisation of Irish peat
[14] Farrell and Hebib (1998) The determination of the geotechnical parameters of organic soils

review of aerial imagery. Some small localised areas of the Site were noted to have a FoS <1.4, the closest of which were to the north of Turbine 10.

Landslide Susceptibility Approach

1.4.12 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.

1.4.13 Eight contributory factors are considered in the analysis:

- slope angle (S);
- peat depth (P);
- substrate geology (G);
- peat geomorphology (M);
- drainage (D);
- forestry (F);
- slope convexity (C); and
- land use (L).

1.4.14 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.

1.4.15 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):

$$S_{PL} = S_S + S_P + S_G + S_M + S_D + S_F + S_C + S_L$$

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

Slope Angle (S)

1.4.17 Table 2.5.2 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 2.5.2: 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

1.4.18 Figure 2.5.7 (EIAR Volume 4) shows the distribution of slope angle scores across the Site. The results indicate that the slope angles across most of the Site are low (<5°) but with some localised steeper areas.

Peat Depth (P)

1.4.19 Table 2.5.3 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 2.3.1 and reflect the peat depth ranges most frequently associated with peat slides (Evans and Warburton, 2007)[15].

Table 2.5.3: 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

1.4.20 Figure 2.5.7 (EIAR Volume 4) shows the distribution of peat depth scores across the Site. The results indicate that more than half of the Site is covered by peat thicknesses <0.5 m.

Substrate Geology (G)

1.4.21 Table 2.5.4 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).

1.4.22 Peat failures are frequently cited in association with glacial till deposits in which an iron pan is observed in the upper few centimetres[16]. 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 2.5.4: 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

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

[1616] Dykes A. and Warburton J. (2007) *Mass movements in peat: A formal classification scheme. Geomorphology 86.* (Evans & Warburton, 2007)

1.4.23 Figure 2.5.7 (EIAR Volume 4) shows the distribution of substrate geology scores across the Site. The results indicate that the Site is underlain mostly by permeable bedrock, which is consistent with the solid geology recorded.

Peat Geomorphology (M)

1.4.24 Table 2.5.5 shows the geomorphological features identified across the Site, their significance and related scores.

Table 2.5.5: 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

1.4.25 Figure 2.5.7 (EIAR Volume 4) shows the distribution of geomorphology scores across the Site. The results indicate that other than one area of bare peat recorded in the west of the Site there are no significant geomorphological features associated with the peat.

Drainage (D)

1.4.26 Table 2.5.6 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[17]. 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 2.5.6: 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

1.4.27 Figure 2.5.7 (EIAR Volume 4) shows the distribution of drainage feature scores across the Site.

Forestry (F)

1.4.28 Table 2.5.7 shows forestry classes, their significance and related scores. The Site has 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.

Table 2.5.7: 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

1.4.29 Figure 2.5.7 (EIAR Volume 4) shows the distribution of forestry feature scores across the Site.

Slope Convexity (C)

1.4.30 Table 2.5.8 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 2.5.8: 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

1.4.31 Figure 2.5.7 (EIAR Volume 4) shows the distribution of convexity feature scores across the Site.

Land Use (L)

1.4.32 Table 2.6.9 shows land use classes, significance and related scores. A variety of land uses have been associated with peat failures which form the scoring and potential for failure.

Table 2.6.9: 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
Other Land Use	Failures are rarely associated with other forms of land use	0

1.4.33 Figure 2.5.7 (EIAR Volume 4) shows the distribution of land use feature scores across the Site.

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

Likelihood Scores

1.4.34 The eight contributory factor layers shown on Figure 2.5.7 (EIAR Volume 4) 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 2.5.10 below.

Table 2.5.10: 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

1.4.35 Table 2.5.10 describes the basis for the likelihood classes, and professional judgement was used 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

1.4.36 The results of the Peat Slide Likelihood are shown on Figure 2.5.8 (EIAR Volume 4) and indicate that most of the Site is considered to be of 'low' or 'very low' likelihood of a peat landslide. Areas of Moderate likelihood are not located within areas associated with Proposed Development infrastructure. Whilst no observations of significant instability were noted during the peat surveys, the Land Use Feature Class Scores, as shown in Table 2.5.9, have not been modified for this assessment.

1.5 Assessment of Consequence and Risk

1.5.1 Based on the assessment of consequence of risk methodology1, three receptors have been identified at the Site, and are assessed in Table 2.5.11:

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

Table 2.5.11: Assessment of Consequence and Risk

Receptor	Consequence	Score	Justification for Score
Watercourses	Increased turbidity and acidification, fish kill, blockage of drainage, effects on private water supplies	3	Hydrology has been scoped out of the EIAR. Private water supplies have been assessed
Non-riverine Habitats	Medium term loss of vegetation cover, disruption of peat hydrology, carbon release	3	Effects on peatland habitats, though the effects of peat 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 the wind farm are less significant

1.5.2 Based on the likelihood and FoS assessment previously outlined, it is considered that the combined likelihood of peat landslide in association with the construction of the Proposed Development is acceptable. Risk mitigation measures to reduce the potential peat slide risk associated with the Proposed Development are proposed in Section 1.6 below.

1.6 Risk Mitigation

1.6.1 A number of mitigation measures could be used to reduce the risk levels identified at the Proposed Development. 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.

1.6.2 Typically, risks could be mitigated by:

- micrositing, use of the 50 m micrositing allowance to refine layout and reduce further the overlap between infrastructure and peat soils;
- obtaining improved 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.

1.6.3 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.

Mitigation Recommended

1.6.4 A comprehensive intrusive ground investigation would be undertaken post-consent to support the engineering design of turbine foundations, tracks and ancillary infrastructure for the Proposed Development. This would comprise suitable field and laboratory testing to further inform the peat stability baseline, and further design mitigation used as appropriate to reduce the likelihood of peat instability.

1.6.5 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.

1.6.6 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 be agreed with the Local Authority 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 (e.g. for turbines, 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).

1.6.7 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.

1.6.8 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.

1.6.9 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.

1.6.10 This monitoring would be undertaken on a quarterly basis in the first year after construction, bi-annually in the second year after construction and annually thereafter. In the event that unanticipated ground conditions arise during construction, the frequency of these intervals should be reviewed, revised and justified accordingly, and a geotechnical risk register maintained by the operator.

Figures

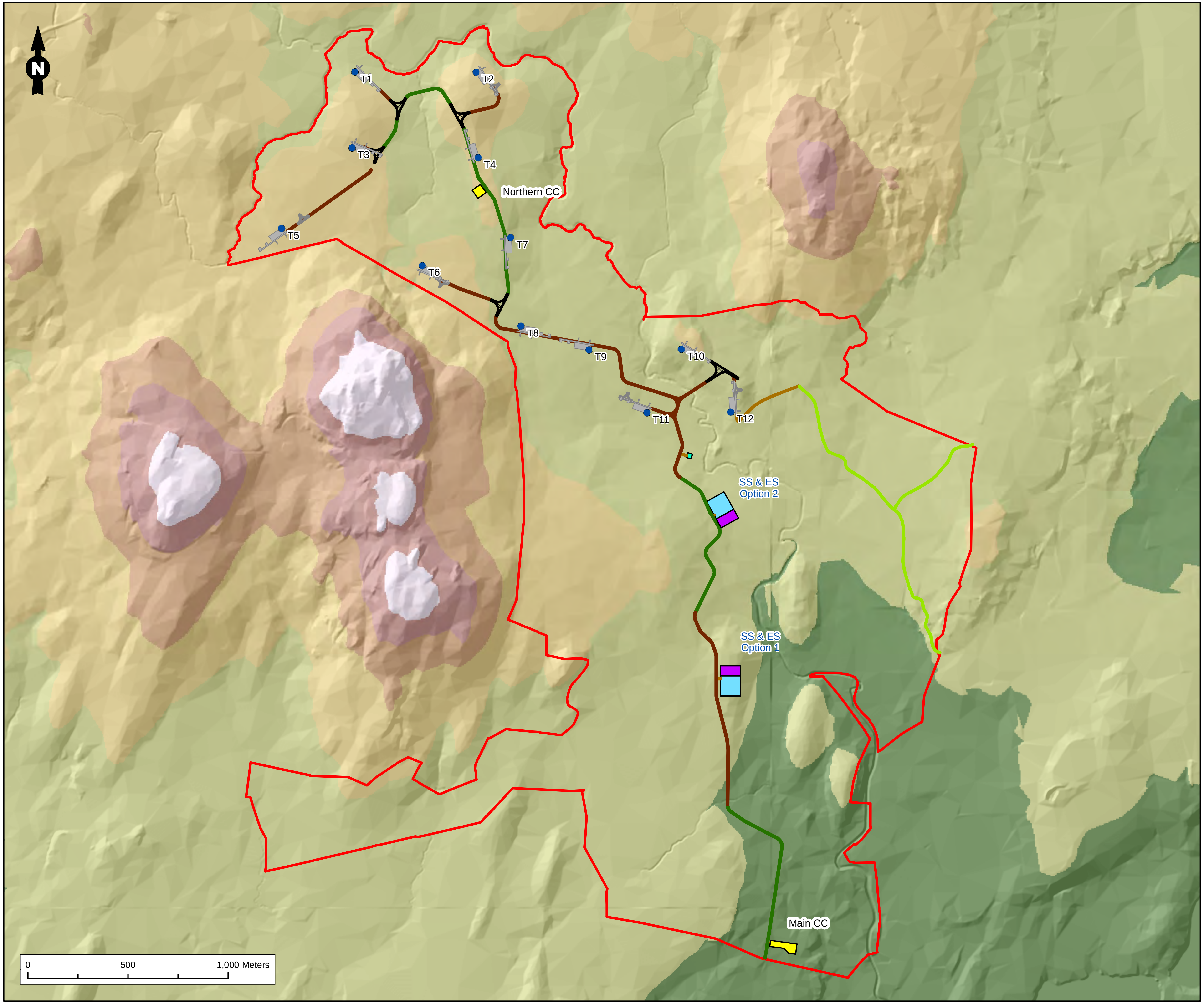
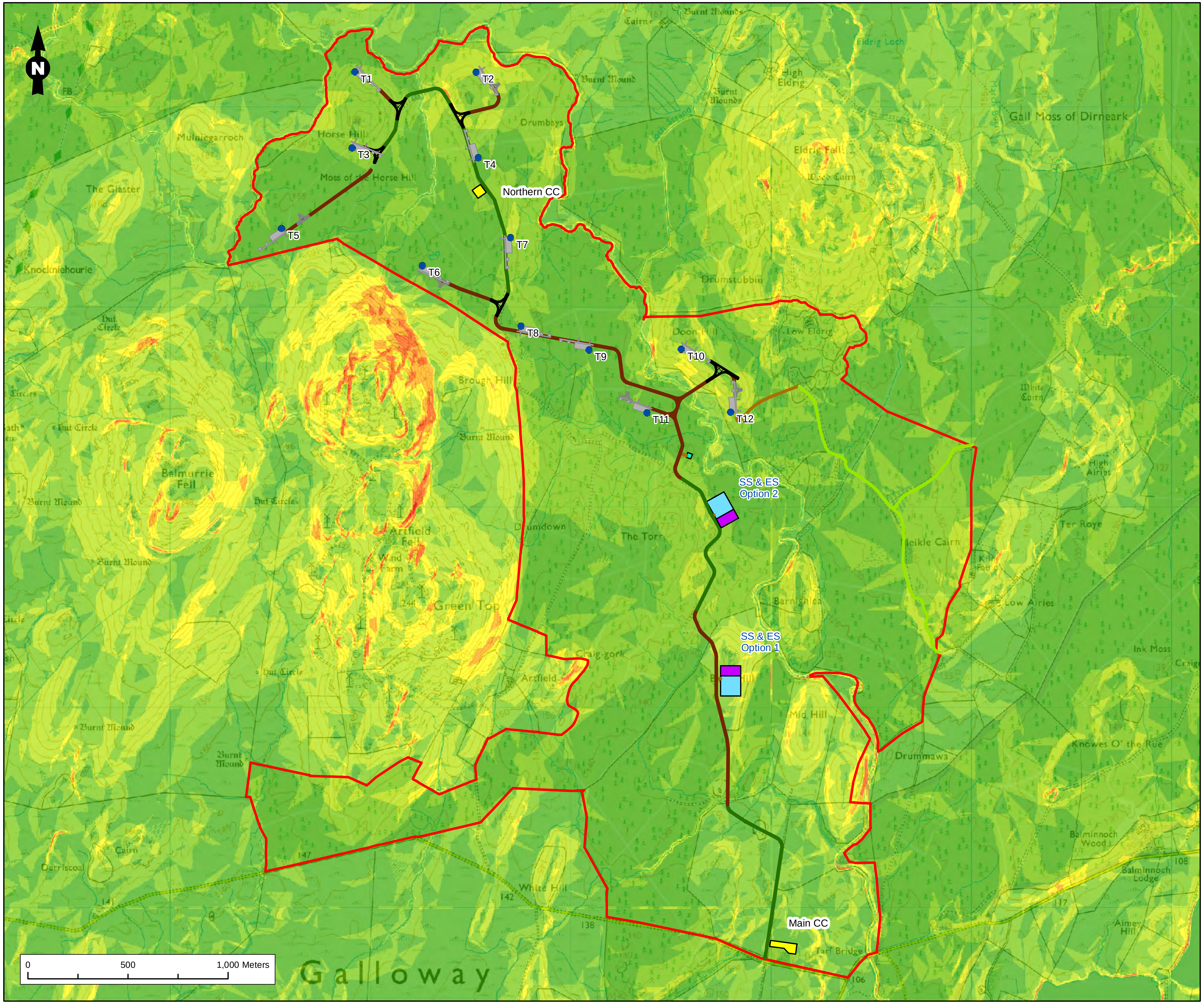


Figure Title	
Elevation	
Project Name	
Artfield Forest Wind Farm	
Project Number: 1620008937	Figure No.: 2.5.1
Date: January 2021	Prepared By: AB
Scale: 1:18,000 @A3	Issue: 1
Client: Artfield Forest Wind Farm Ltd	

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.



Legend

- Site Boundary
- Proposed Turbine
- Proposed Temporary Construction Compound (CC)
- Proposed Substation Option (SS)
- Proposed Turbine Hardstanding
- Proposed Turning Head (Unloaded)
- Proposed Turning Head (Loaded)
- Existing Forestry Track No Upgrade
- Existing Forestry Track Upgrade
- New Track (Infrastructure only 4m)
- New Track (6m)
- Proposed Met Mast and associated hardstanding
- Proposed Energy Storage Option (ES)

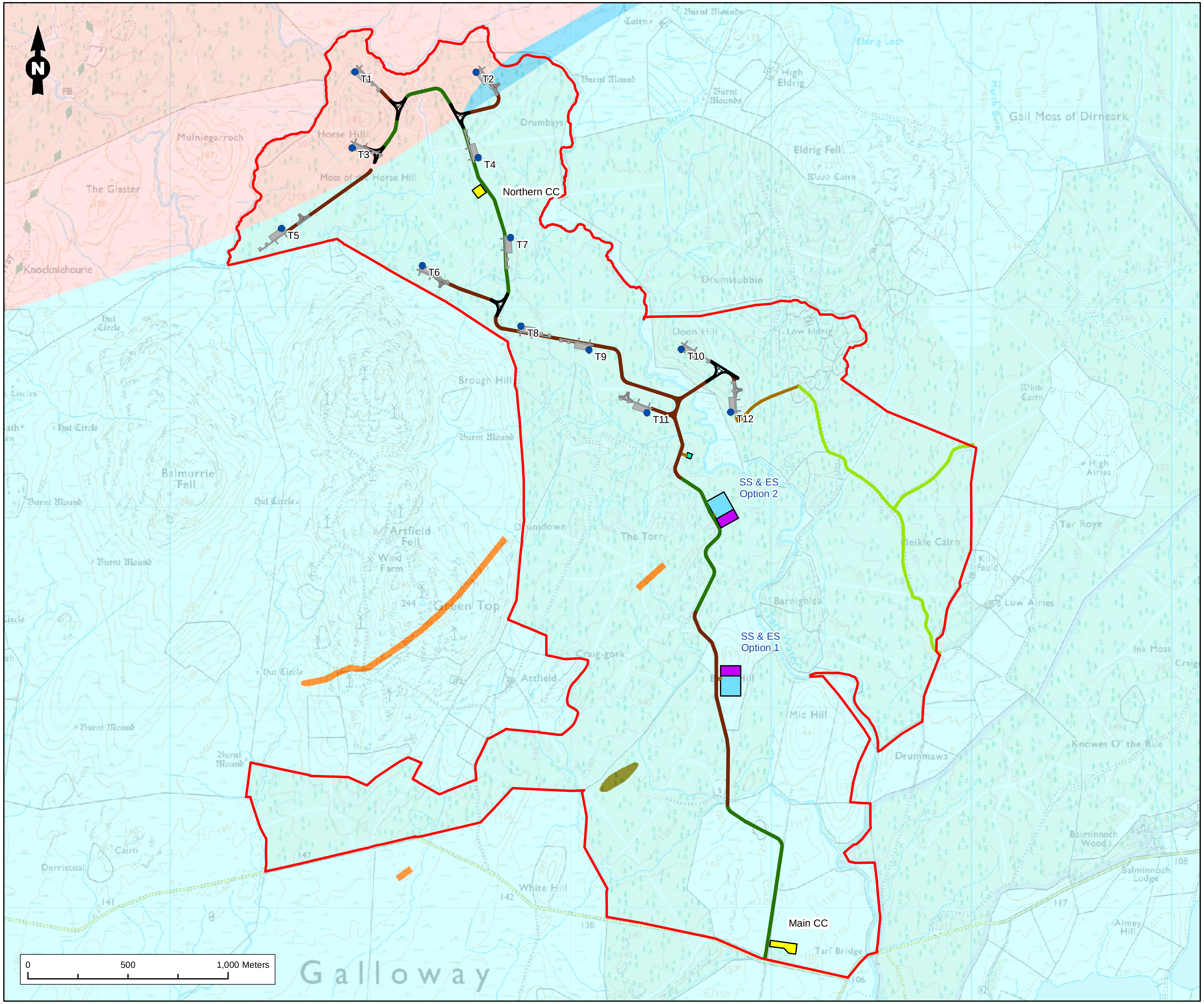
Slope Angle (degrees)

- 0.0 - 2.0
- 2.1 - 5.0
- 5.1 - 10.0
- 10.1 - 15.0
- 15.1 - 20.0
- 20.1 - 35.0
- 35.1 - 62.4

Figure Title Slope Angle	
Project Name Artfield Forest Wind Farm	
Project Number 1620008937	Figure No. 2.5.2
Date January 2021	Prepared By AB
Scale 1:18,000 @A3	Issue 1
Client **Artfield Forest Wind Farm Ltd**	

RAMBOLL

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.



Legend

- Site Boundary
- Proposed Turbine
- Proposed Temporary Construction Compound (CC)
- Proposed Substation Option (SS)
- Proposed Turbine Hardstanding
- Proposed Turning Head (Unloaded)
- Proposed Turning Head (Loaded)
- Existing Forestry Track No Upgrade
- Existing Forestry Track Upgrade
- New Track (Infrastructure only 4m)
- New Track (6m)
- Proposed Met Mast and associated hardstanding
- Proposed Energy Storage Option (ES)

Bedrock Geology

- Kirkcolm Formation - Wacke
- Moffat Shale Group - Mudstone
- North Britain Siluro-Devonian Calc-Alkaline Dyke Suite - Felsite
- North Britain Siluro-Devonian Calc-Alkaline Dyke Suite - Lamprophyre
- Portpatrick Formation - Wacke

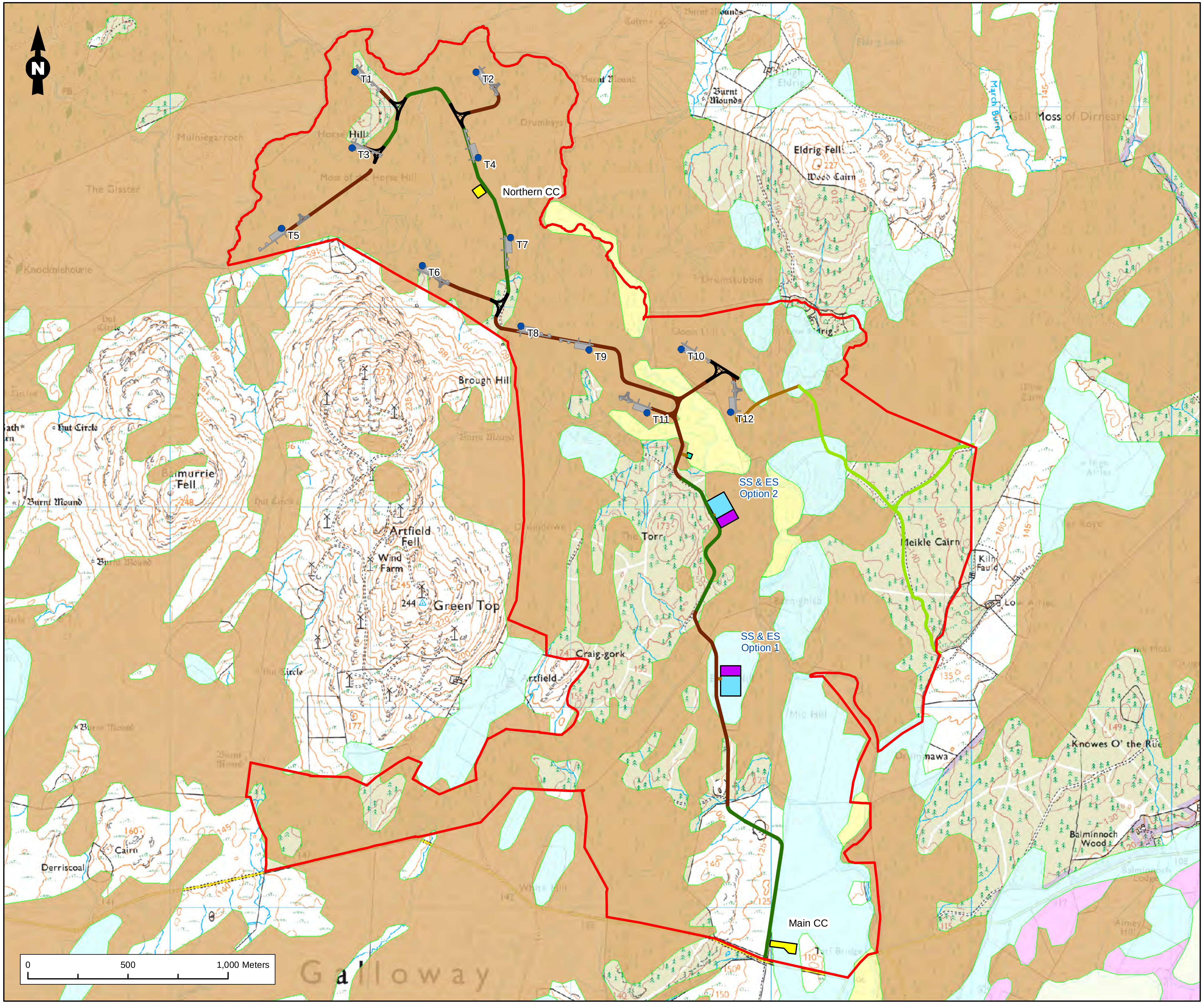
Figure Title
Bedrock Geology

Project Name
Artfield Forest Wind Farm

Project Number	Figure No.
1620008937	2.5.3.1
Date	**Prepared By**
January 2021	AB
Scale	**Issue**
1:18,000 @A3	1

Client
Artfield Forest Wind Farm Ltd

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.



Legend

- Site Boundary
- Proposed Turbine
- Proposed Temporary Construction Compound (CC)
- Proposed Substation Option (SS)
- Proposed Turbine Hardstanding
- Proposed Turning Head (Unloaded)
- Proposed Turning Head (Loaded)
- Existing Forestry Track No Upgrade
- Existing Forestry Track Upgrade
- New Track (Infrastructure only 4m)
- New Track (6m)
- Proposed Met Mast and associated hardstanding
- Proposed Energy Storage Option (ES)

Superficial Geology

- Alluvium - Silt, Sand And Gravel
- Glaciofluvial Deposits - Gravel, Sand And Silt
- Peat - Peat
- Till, Devensian - Diamicton

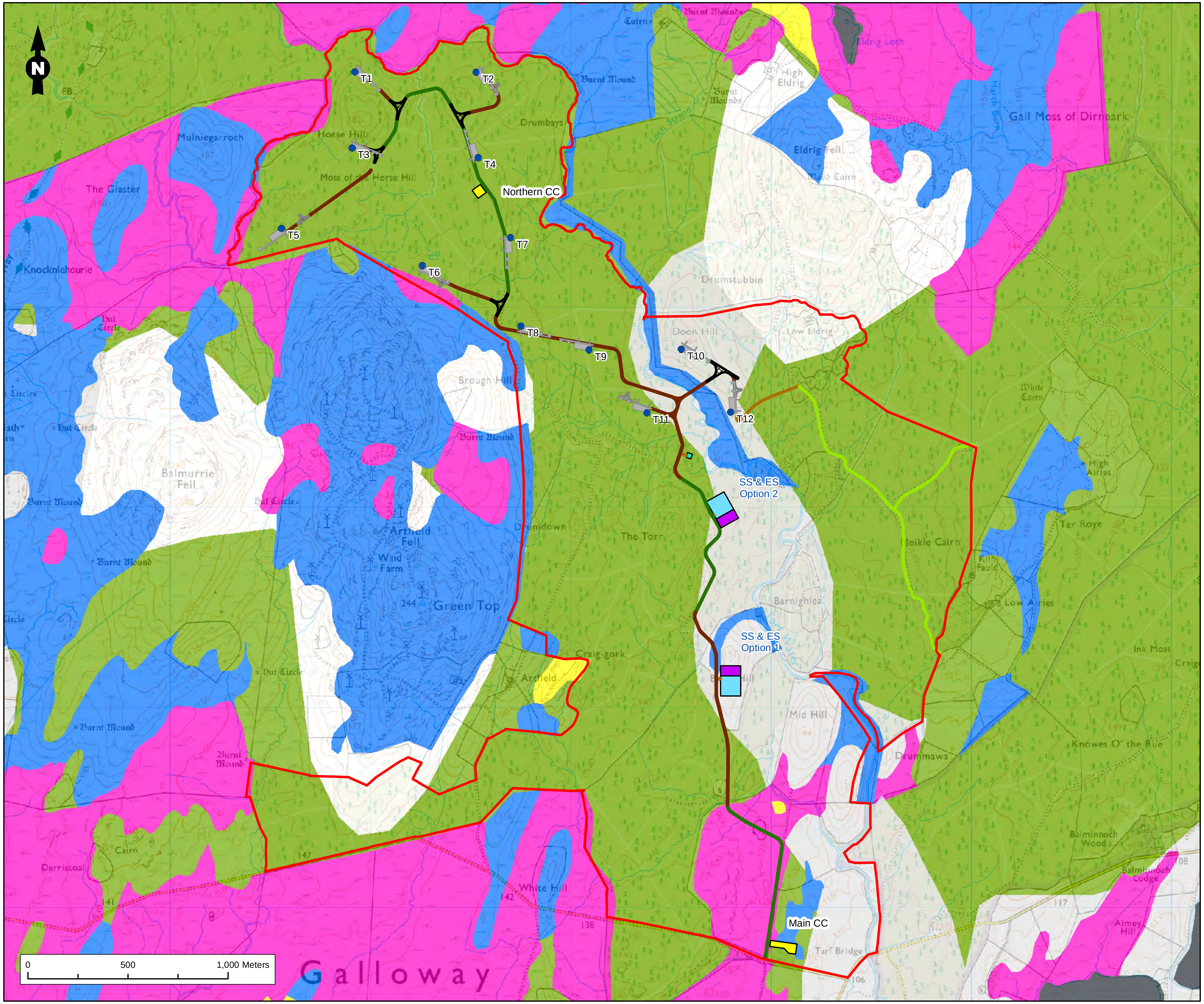
Figure Title
Superficial Geology

Project Name
Artfield Forest Wind Farm

Project Number	Figure No.
1620008937	2.5.3.2
Date	Prepared By
January 2021	AB
Scale	Issue
1:18,000 @A3	1

Client
Artfield Forest Wind Farm Ltd

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.



Legend

- Site Boundary
- Proposed Turbine
- Proposed Temporary Construction Compound (CC)
- Proposed Substation Option (SS)
- Proposed Turbine Hardstanding
- Proposed Turning Head (Unloaded)
- Proposed Turning Head (Loaded)
- Existing Forestry Track No Upgrade
- Existing Forestry Track Upgrade
- New Track (Infrastructure only 4m)
- New Track (6m)
- Proposed Met Mast and associated hardstanding
- Proposed Energy Storage Option (ES)

Carbon and Peatland 2016 - Importance

- Unknown soil type
- Mineral soils
- 1
- 2
- 3
- 4
- 5

Figure Title
Carbon and Peatland 2016

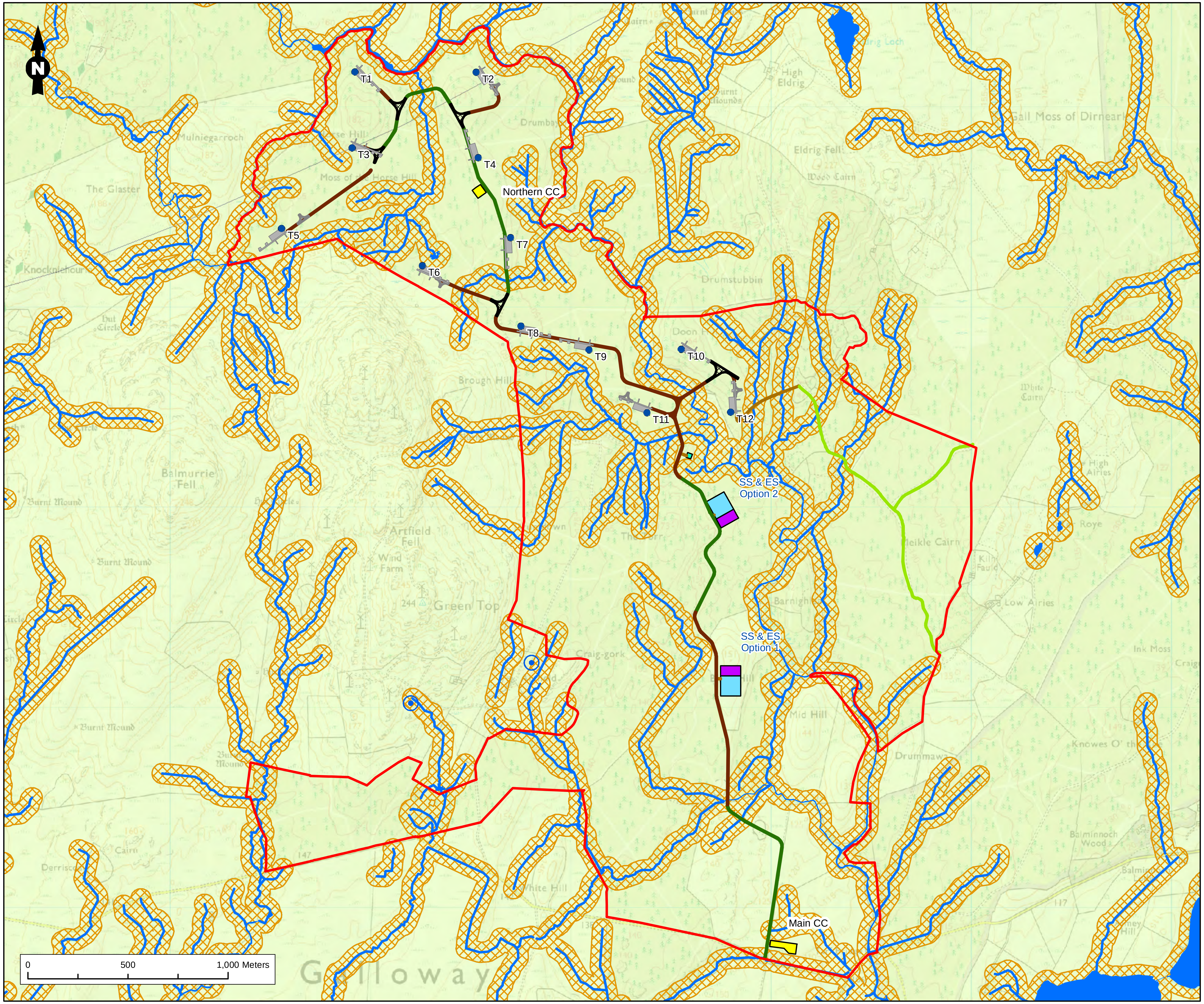
Project Name
Artfield Forest Wind Farm

Project Number	Figure No.
1620008937	2.5.4
Date	Prepared By
January 2021	AB
Scale	Issue
1:18,000 @A3	1

Client
Artfield Forest Wind Farm Ltd

RAMBOLL

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.



Legend

- Site Boundary
- Proposed Turbine
- Proposed Temporary Construction Compound (CC)
- Proposed Substation Option (SS)
- Proposed Turbine Hardstanding
- Proposed Turning Head (Unloaded)
- Proposed Turning Head (Loaded)
- Existing Forestry Track No Upgrade
- Existing Forestry Track Upgrade
- New Track (Infrastructure only 4m)
- New Track (6m)
- Proposed Met Mast and associated hardstanding
- Proposed Energy Storage Option (ES)
- Private Water Supply
- Surface Water
- Watercourse 50m Buffer

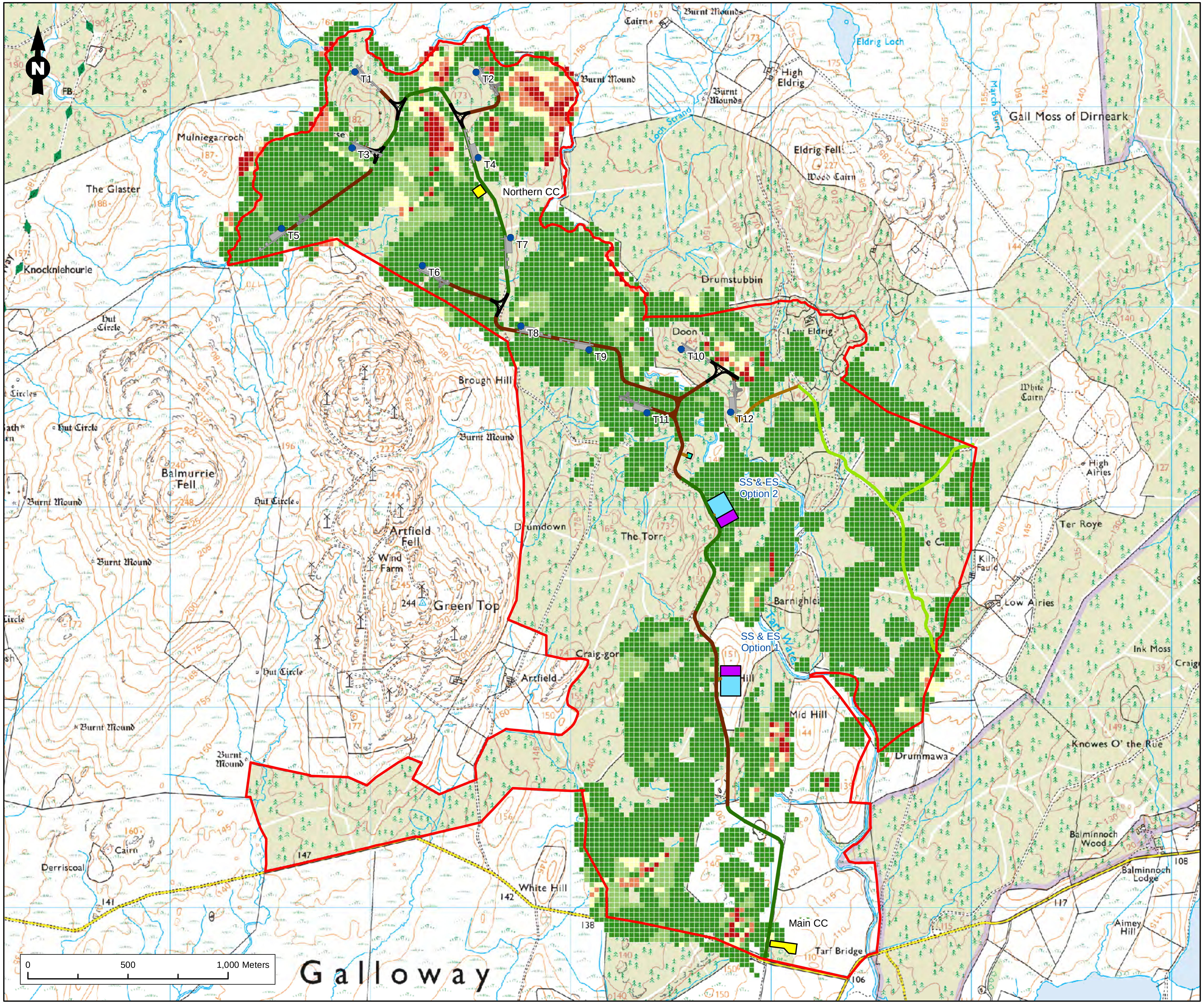
Aquifer Classification

- Low productivity aquifer

Figure Title Geomorphology & Hydrology	
Project Name Artfield Forest Wind Farm	
Project Number 1620008937	Figure No. 2.5.5
Date January 2021	Prepared By AB
Scale 1:18,000 @A3	Issue 1
Client **Artfield Forest Wind Farm Ltd**	

RAMBOLL

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.



Legend

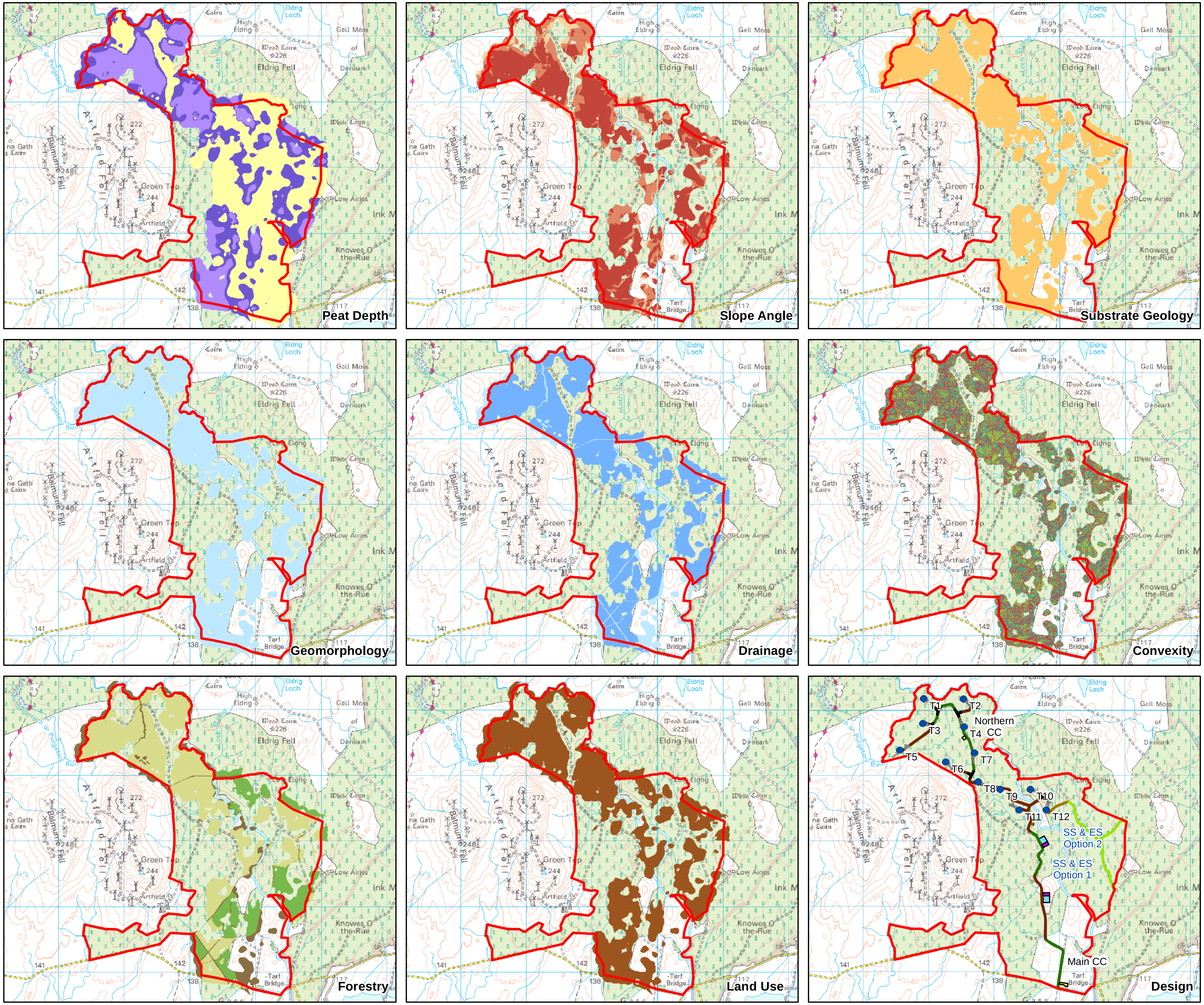
- Site Boundary
- Proposed Turbine
- Proposed Temporary Construction Compound (CC)
- Proposed Substation Option (SS)
- Proposed Turbine Hardstanding
- Proposed Turning Head (Unloaded)
- Proposed Turning Head (Loaded)
- Existing Forestry Track No Upgrade
- Existing Forestry Track Upgrade
- New Track (Infrastructure only 4m)
- New Track (6m)
- Proposed Met Mast and associated hardstanding
- Proposed Energy Storage Option (ES)

Factor Of Safety

- < 1.0 (Unstable)
- 1.1 - 1.4 (Marginally unstable)
- 1.5 - 2.0 (Stable)
- 2.1 - 3.0 (Stable)
- > 3.0 (Stable)

Figure Title Factor of Safety	
Project Name Artfield Forest Wind Farm	
Project Number 1620008937	Figure No. 2.5.6
Date January 2021	Prepared By AB
Scale 1:18,000 @A3	Issue 1
Client **Artfield Forest Wind Farm Ltd**	

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.



Legend

- Site Boundary

Peat Depth Scores (P)
- Score 1: < 0.5 m
- Score 2: >1.5 m
- Score 3: 0.5 - 1.5 m

Slope Angle Scores (S)
- Score 0: <= 2 deg
- Score 2: 2 - 5 deg
- Score 3: 5 - 10 deg
- Score 3: 10 - 15 deg
- Score 2: 15 - 20 deg
- Score 1: >20 deg

Substrate geology scores (G)
- Score 0: Permeable bedrock
- Score 1: Impermeable bedrock
- Score 2: Glacial till
- Score 3: Glacial till with iron pan

Peat geomorphology scores (M)
- Score 0: No peat geomorphological features observed
- Score 1: Existing peat slide / hag / peat cutting / bare ground
- Score 2: Flush/diffuse natural drainage

Drainage scores (D)
- Score 0: No drainage lines
- Score 1: Drain aligned to slope
- Score 3: Drain oblique to slope

Profile convexity scores (C)
- Score 0: Rectilinear slope
- Score 2: Concave slope
- Score 3: Convex slope

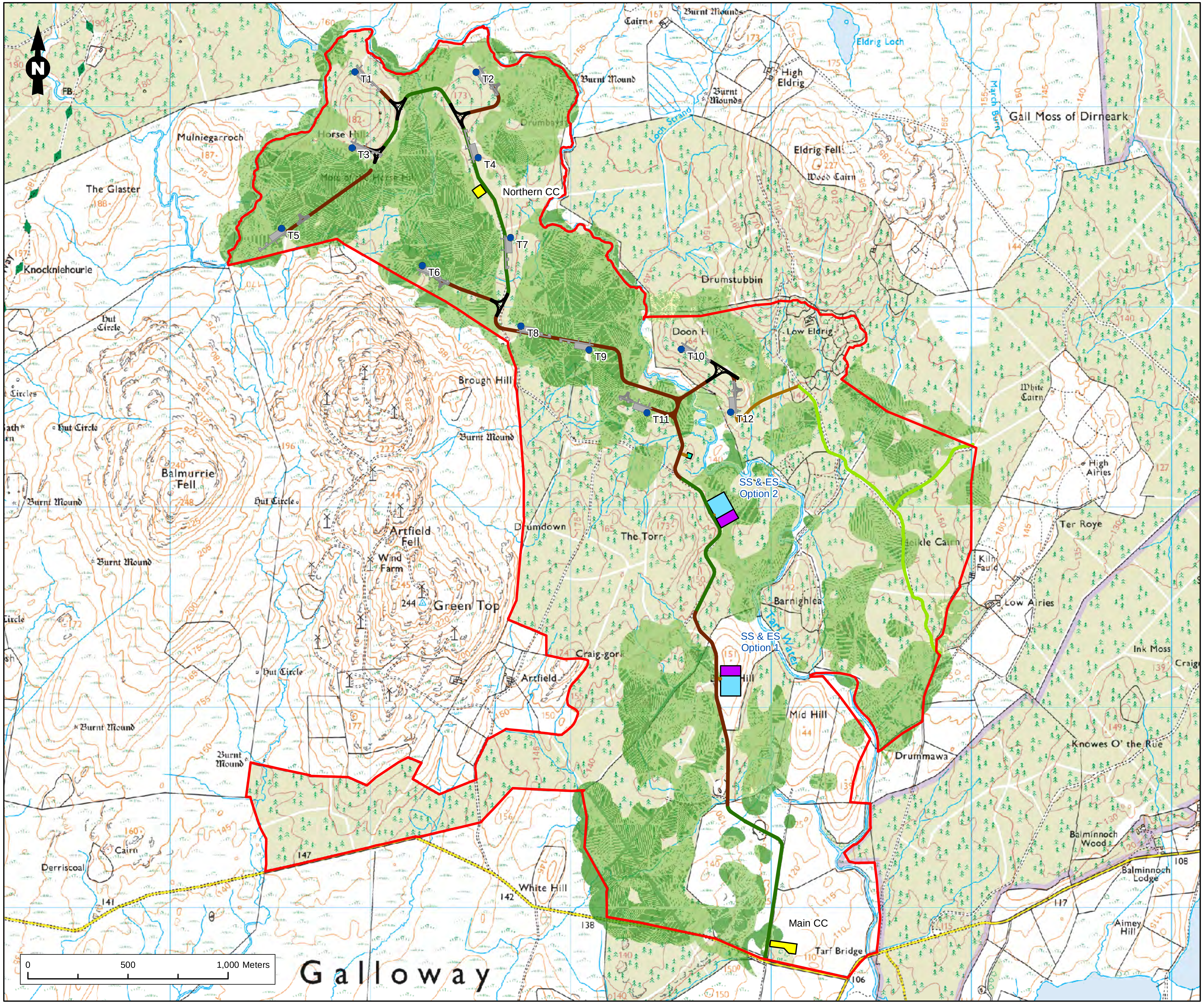
Forestry Scores (F)
- Score 0: Not afforested
- Score 1: Afforested aligned
- Score 2: Deforested aligned
- Score 2: Afforested oblique
- Score 3: Deforested oblique

Land Use Scores (L)
- Score 0: Other land use
- Score 1: Burning
- Score 2: Adjacent
- Score 3: Cutting/turbary

Figure Title: Geomorphology & Hydrology	
Project Name: Artfield Forest Wind Farm	
Project Number: 1620008937	Figure No.: 2.5.7
Date: January 2021	Prepared By: AB
Scale: 1:55,000 @A3	Issue: 1
Client: Artfield Forest Wind Farm Ltd	

RAMBOLL

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.



Legend

- Site Boundary
- Proposed Turbine
- Proposed Temporary Construction Compound (CC)
- Proposed Substation Option (SS)
- Proposed Turbine Hardstanding
- Proposed Turning Head (Unloaded)
- Proposed Turning Head (Loaded)
- Existing Forestry Track No Upgrade
- Existing Forestry Track Upgrade
- New Track (Infrastructure only 4m)
- New Track (6m)
- Proposed Met Mast and associated hardstanding
- Proposed Energy Storage Option (ES)

Summed Score / Likelihood Score

- <= 6 (Very Low, 1)
- 7- 11 (Low, 2)
- 12 - 16 (Moderate, 3)
- 17 - 21 (High, 4)
- 22 - 24 (Very High, 5)

Figure Title Peat Slide Likelihood	
Project Name Artfield Forest Wind Farm	
Project Number 1620008937	Figure No. 2.5.8
Date January 2021	Prepared By AB
Scale 1:18,000 @A3	Issue 1
Client **Artfield Forest Wind Farm Ltd**	

RAMBOLL

Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.