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Technical Appendix

Lairdmannoch Energy Park

Technical Appendix 8-1: Peat Landslide Hazard and Risk Assessment

Lairdmannoch Energy Park Limited

wind2

May 2025

Contents

Contents

Glossary of Terms

Term	Definition
The Applicant	Lairdmannoch Energy Park Limited
The Agent	Atmos Consulting Limited
Environmental Advisors and Planning Consultants	Atmos Consulting Limited
Environmental Impact Assessment	Environmental Impact Assessment (EIA) is a means of carrying out, in a systematic way, an assessment of the likely significant environmental effects from a development.
Environmental Impact Assessment Regulations	Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017
Environmental Impact Assessment Report	A document reporting the findings of the EIA and produced in accordance with the EIA Regulations
The Proposed Development	Lairdmannoch Energy Park
The Proposed Development Site	The full application boundary as per Figure 1-1

List of Abbreviations

Abbreviation	Description
AOD	Above Ordnance Datum
BGS	British Geological Society
BPG	Best Practice Guidance
CEMP	Construction Environmental Management Plan
DWPA	Drinking Water Protected Area
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
ECU	Energy Consents Unit
FoS	Factor of Safety
GIS	Geographical Information System
Ha	hectare
HMP	Habitat Management Plan
kV	Kilovolt
LIDAR	Light Detection And Ranging
NGR	National Grid Reference
NVC	National Vegetation Classification
OHL	Overhead Line
OPMP	Outline Peat Management Plan
PLHRA	Peat Landslide Hazard and Risk Assessment
SEPA	Scottish Environmental Protection Agency

1 Introduction

1.1 Background

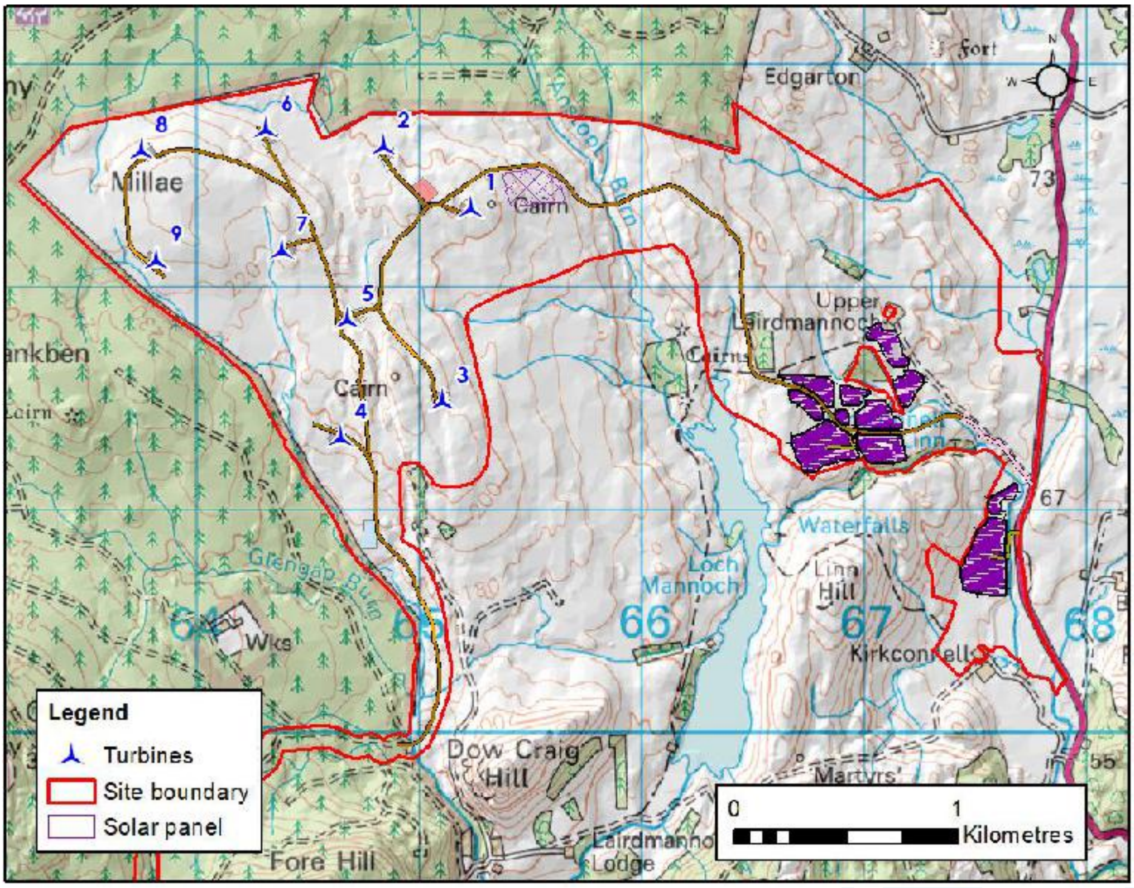
Lairdmannoch Energy Park Limited (the Applicant) is seeking consent under Section 36 of the Electricity Act (Scotland) 1989 (as amended) to develop a wind farm consisting of 9 wind turbines at up to 180 m to tip height, ground mounted solar panels, battery energy storage systems (BESS) and associated infrastructure including electrical transformers, hardstandings, access roads, cabling, borrow pit and electrical substation (the 'Proposed Development').

The Proposed Development is located on land northeast of Gatehouse of Fleet and approximately 10km west of Castle Douglas. The Proposed Development Site lies entirely within the Dumfries and Galloway Council (DGC) planning authority area.

The Site is centred on National Grid Reference (NGR) (approximate) NX 66233 62404 with all infrastructure located approximately 7km from the town of Gatehouse of Fleet.

The Proposed Development Site covers an area of approximately 612.2 ha. The western portion of the site features the Wind Development with the eastern section featuring the Solar Development. An overview of the site location is shown on **Plate 1**.

Plate 1 Overview map of Proposed Development



The Proposed Development would consist of nine wind turbines each with a tip height of 180m above ground level (agl), ground mounted solar panels, a battery energy storage system (BESS) and associated infrastructure including:

- Access tracks;
- Turbine foundations and crane hardstandings;
- Substation;
- One borrow pit;
- Underground cabling;
- Temporary construction compound;
- Solar infrastructure including a power station and switching and breaking station; and
- Up to eight watercourse crossings.

The Scottish Government Best Practice Guidance (BPG) provides a screening tool to determine whether a peat landslide hazard and risk assessment (PLHRA) is required (Scottish Government, 2017).

This is in the form of a flowchart, which indicates that where blanket peat is present, slopes exceed 2° and proposed infrastructure is located on peat, a PLHRA should be prepared. These conditions exist at the Proposed Development Site and therefore a PLHRA is required.

1.2 Scope of Work

The scope of the PLHRA is as follows:

- Characterise the peatland geomorphology of the Proposed Development Site to determine whether prior incidences of instability have occurred and whether contributory factors that might lead to instability in the future are present across the Proposed Development 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 risks to acceptable levels such that the Proposed Development is developed safely and with minimal risks to the environment.

The contents of this PLHRA have been prepared in accordance with the BPG, noting that the guidance "should not be taken as prescriptive or used as a substitute for the developer's [consultant's] preferred methodology" (Scottish Government, 2017).

The first edition of the Scottish Government Best Practice Guidance (BPG) 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 BPG was reissued in 2017, though without fundamental changes to the core expectations. A key change was to provide clearer steer on the format and outcome of reviews undertaken by the Energy Consents Unit (ECU) checking authority and related expectations of report revisions, should they be required.

In section 4.1 of the BPG, the key elements of a PLHRA are highlighted, as follows (Scottish Government, 2017):

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

Section 1.3 describes how this report addresses this indicative scope.

The spatial scope of the PLHRA is limited to the wind turbine area and associated infrastructure since no peat was identified within the footprint of proposed infrastructure east of the proposed borrow pit.

1.3 Report structure

This report is structured as follows:

- Section 2 gives context to the landslide risk assessment methodology through a literature based account of peat landslide types and contributory factors, including review of any published or anecdotal information available concerning previous instability at or adjacent to the Proposed Development Site;
- Section 3 provides a description based on desk study and Proposed Development Site observations, including consideration of aerial or satellite imagery, digital elevation data, geology and peat depth data;
- Section 4 describes the approach to and results of an assessment of peat landslide likelihood under both natural conditions and in association with construction of the Proposed Development;
- Section 5 describes the approach to and results of a consequence assessment that determines potential impacts on Proposed Development Site receptors and the associated calculated risks; and
- Section 6 provides mitigation and control measures to reduce or minimise these risks prior to, during and after construction.

Assessments within the PLHRA have been undertaken alongside assessments for the Peat Management Plan (Appendix 8.2) and have been informed by results from peat surveys undertaken by Atmos Consulting. Where relevant information is available elsewhere in the Environmental Impact Assessment Report (EIAR), this is referenced in the text rather than repeated in this report.

1.4 Approaches to assessing peat instability for the Proposed Development

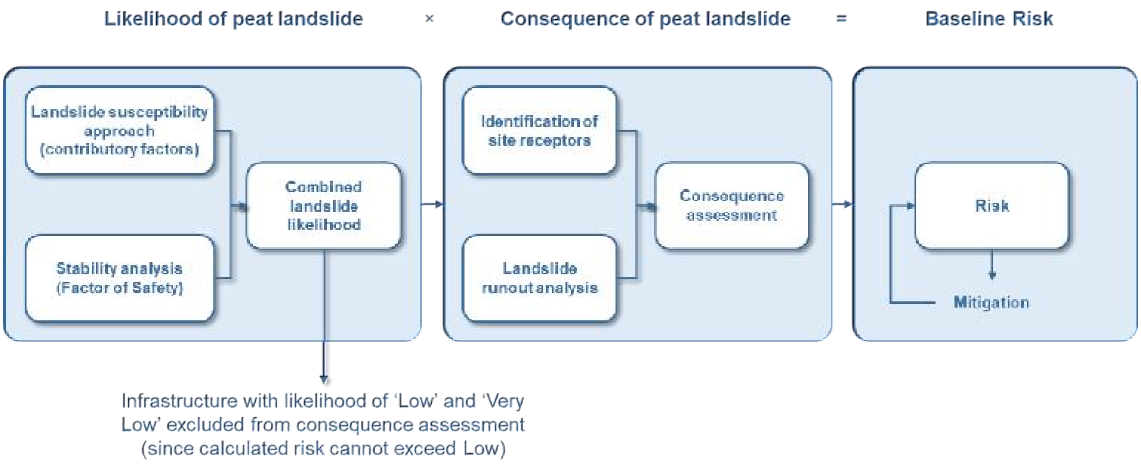
This report approaches assessment of peat instability through both a qualitative contributory factor-based approach and via more conventional stability analysis (through limit equilibrium or Factor of Safety (FoS) analysis).

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.

The advantage of the FoS approach is also 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.

To reflect these limitations, both approaches are adopted and outputs from each approach integrated in the assessment of landslide likelihood. Plate 2 shows the approach:

Plate 2 Risk assessment approach



1.5 Team competencies

This PLHRA has been undertaken by a chartered geologist with 25+ years experience of mapping and interpreting peatland terrains and peat instability features. Geomorphological walkover survey was undertaken by the same individual. Peat depth probing was undertaken by Atmos Consulting, and additional Proposed Development Site observations and photographs were made available from these surveys to the PLHRA team.

2 Background to peat instability

2.1 Peat Instability in the UK and Ireland

This section reviews published literature to highlight commonly identified landscape features associated with recorded peat landslides in the UK and Ireland. This review forms the basis for identifying similar features at the Proposed Development and using them to understand the susceptibility of the Proposed Development Site to naturally occurring and human induced peat landslides.

Peat instability, or peat landslides, are a widely documented but relatively rare mechanism of peatland degradation that may result in damage to peatland habitats, potential losses in biodiversity and depletion of peatland carbon stores (Evans & Warburton, 2007).

Public awareness of peat landslide hazards increased significantly following three major peat landslide events in 2003, two of which had natural causes and one occurring in association with a wind farm.

On 19th September 2003, multiple peat landslide events occurred in Pollatomish (Co. Mayo, Ireland; Creighton and Verbruggen, 2003) and in Channerwick in the Southern Shetland Islands (Mills et al, 2007). Both events occurred in response to intense rainfall, possibly as part of the same large-scale weather system moving northeast from Ireland across Scotland.

The former event damaged several houses, a main road and washed away part of a graveyard. Some of the landslides were sourced from areas of turbary (peat cutting) with slabs of peat detaching along the cuttings. The landslides in Channerwick blocked the main road to the airport and narrowly missed traffic using the road. Watercourses were inundated with peat, killing fish inland and shellfish offshore (Henderson, 2005).

In October 2003, a peat failure occurred on an afforested wind farm site in Derrybrien, County Galway, Ireland, causing disruption to the site and large-scale fish kill in the adjoining watercourses (Lindsay and Bragg, 2004).

The Derrybrien event triggered interest in the influence of wind farm construction and operation on peatlands, particularly in relation to potential risks arising from construction induced peat instability. In 2007, the (then) Scottish Executive published guidelines on peat landslide hazard and risk assessment in support of planning applications for wind farms on peatland sites.

Since then, a number of peat landslide events have occurred both naturally and in association with wind farms (e.g. Plate 3). In the case of wind farm sites, these have rarely been reported, however landslide scars of varying age are visible in association with wind farm infrastructure, e.g. on Corry Mountain, Co. Leitrim and at Sonnagh Old Wind Farm, Co. Galway (near Derrybrien; Cullen, 2011)).

In December 2016, a plant operator was killed during excavation works in peat at the Derrysallagh wind farm site in Co. Leitrim (Flaherty, 2016) on a plateau in which several published examples of instability had been previously reported.

A peat landslide was also reported in 2015 near the site of a proposed road for the Viking Wind Farm on Shetland (The Shetland Times, 2015) though this was not in association with construction works.

Other recent natural events include another failure in Galway at Clifden in 2016 (Irish News, 2016), Cushendall, Co. Antrim (BBC, 2014), in the Glenelly Valley, Co. Tyrone in 2017 (BBC, 2018), Drumkeeran in Co. Leitrim in July 2020 (Irish Mirror, 2020) and Benbrack in Co Cavan in July 2021 (The Anglo-Celt, 2021).

Noticeably, the vast majority of reported failures since 2003 have occurred in Ireland and Northern Ireland, with one reported Scottish example occurring on the Shetland Islands (Mid Kame), an area previously associated with peat instability.

Two occurrences of instability in association with construction works on the Viking Wind Farm have been reported (July 2022 and May 2024), though in both cases, these have involved failure of peat or mineral spoil at track margins rather than the triggering of a new 'peat slide' by groundworks.

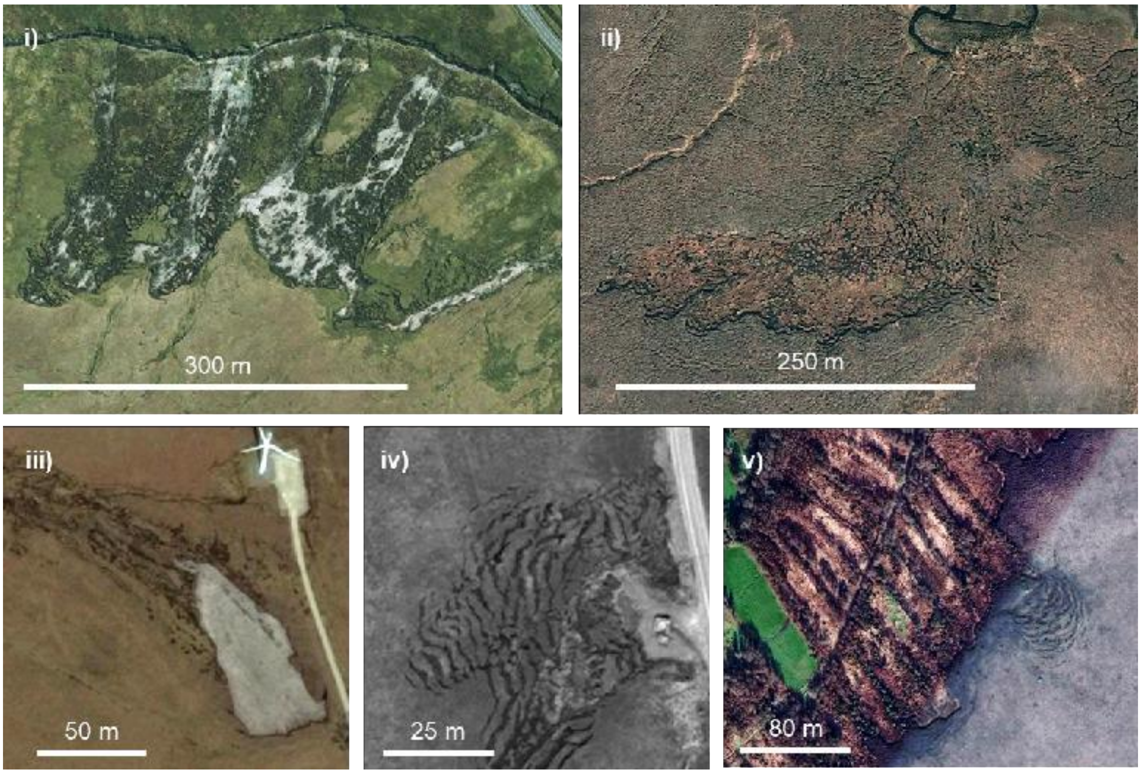


Plate 3 Characteristic peat landslide types in UK and Irish peat uplands: Top row - natural failures: i) multiple peat slides with displaced slabs and exposed substrate, ii) retrogressive bog burst with peat retained within the failed area; Bottom row - failures possibly induced by human activity: iii) peat slide adjacent to turbine foundation, iv) spreading around foundation, v) spreading upslope of cutting

This section of the report provides an overview of peat instability as a precursor to the Proposed Development Site characterisation in Section 3 and the hazard and risk assessment provided in Sections 4 and 5. Section 2.2 outlines the different types of peat instability documented in the UK and Ireland. Section 2.3 provides an overview of factors known to contribute to peat instability based on published literature.

2.2 Types of Peat Instability

Peat instability is manifested in a number of ways (Dykes and Warburton, 2007) all of which can potentially be observed on site either through site walkover or remotely from high resolution aerial photography:

- **minor instability:** localised and small-scale features that are not generally precursors to major slope 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 (Scottish Government, 2017); 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, i.e. creep.
- **major instability:** comprising various forms of peat landslide, ranging from small scale collapse and outflow of peat filled drainage lines/gullies (occupying a few-10s cubic metres), to medium scale peaty-debris slides in organic soils (10s to 100s cubic metres) to large scale peat slides and bog bursts (1,000s to 100,000s cubic metres).

Evans and Warburton (2007) present useful contextual data in a series of charts for two types of large-scale peat instability – peat slides and bog bursts. The data are based on a peat landslide database compiled by Mills (2002) which collates site information for reported peat failures in the UK and Ireland.

Separately, Dykes and Warburton (2007) provide a more detailed classification scheme for landslides in peat based on the type of peat deposit (raised bog, blanket bog, or fen bog), location of the failure shear surface or zone (within the peat, at the peat-substrate interface, or below), indicative failure volumes, estimated velocity and residual morphology (or features) left after occurrence.

For the purposes of this assessment, landslide classification is simplified and split into three main types, typical examples of which are shown in Plate 3. Dimensions, slope angles and peat depths are drawn from charts presented in Evans and Warburton (2007).

The term "peat slide" is used to refer to large-scale (typically less than 10,000 of 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 0.5m and 1.5m) and on moderate slope angles (typically 5°-15°, see Plate 4).

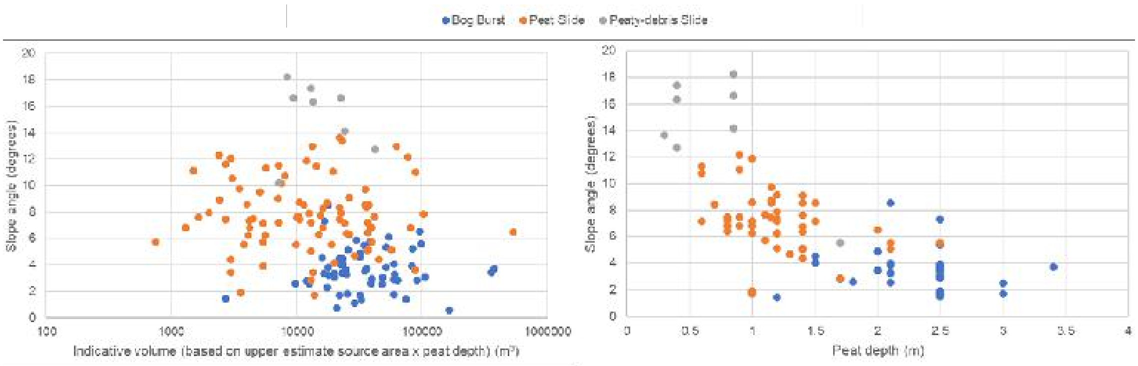


Plate 4 Reported slope angles and peat depths associated with peat slides and bog bursts (from literature review of locations, depths and slope angles, after Mills, 2002)

The term "bog burst" is used to refer to very large-scale (usually greater than 10,000 of 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 1.0m and up to 10m) 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 (e.g. Bowes, 1960).

The term "peaty soil slide" is used to refer to small-scale (1,000s 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 (Dykes and Warburton, 2007). Their small size means that they often do not affect watercourses and their effect on habitats is minimal.

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 and Caithness. There are no published failures or news reports of landslides in proximity to the Proposed Development.

2.2.1 Factors Contributing to Peat Instability

Peat landslides are caused by a combination of factors – triggering factors and reconditioning factors (Dykes and Warburton, 2007; Scottish Government, 2017). Triggering factors have an immediate or rapid effect on the stability of a peat deposit whereas preconditioning factors influence peat stability over a much longer period. Only some of these factors can be addressed by site characterisation.

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

i. Impeded drainage caused by a peat layer overlying an impervious clay or mineral base (hydrological discontinuity);

ii. A convex slope or a slope with a break of slope at its head (concentration of subsurface flow);

iii. Proximity to local drainage, either from flushes, pipes or streams (supply of water);

iv. Connectivity between surface drainage and the peat/impervious interface (mechanism for generation of excess pore pressures);

v. 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);

vi. Increase in mass of the peat slope through peat formation, increases in water content or afforestation;

vii. 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;

viii. Loss of surface vegetation and associated tensile strength (e.g. by burning or pollution induced vegetation change);

ix. 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

x. 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.

Triggering factors are typically of short duration (minutes to hours) and include:

i. Intense rainfall or snowmelt causing high pore pressures along pre-existing or potential rupture surfaces (e.g. between the peat and substrate);

ii. Rapid ground accelerations (e.g. from earthquakes or blasting);

iii. Unloading of the peat mass by fluvial incision or by artificial excavations (e.g. cutting);

iv. 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

v. Loading by plant, spoil or infrastructure.

External environmental triggers such as rainfall and snowmelt cannot be mitigated against, 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.

2.2.2. Consequences of Peat Instability

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

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 associated with public water supply);
- Site drainage (blocked drains / ditches leading to localised flooding / erosion); and
- Visual amenity (scarring of landscape).

While peat failures may cause visual scarring of the peat landscape, most peat failures revegetate fully within 50 to 100 years and are often difficult to identify on the ground after this period of time (Feldmeyer-Christe and Küchler, 2002; Mills, 2002). Typically, it is short-term (seasonal) effects on watercourses that are the primary concern or impacts on public water supply.

3 Site Characterisation

3.1 Topography

The Proposed Development lies on gentle, undulating hills that fall from west to east towards the Anstool Burn in the centre of the Proposed Development Site and the Tarff Water, which drains from Loch Mannoch, to the east.

There are no pronounced summits, though Millae (245 m AOD) and Flee Cairn (c. 225 m AOD) represent the highest elevations (**Figure 8-1-1**). LiDAR data shows a strong north-to-south geological structure which governs the relief within the wind farm area, this transitioning to a less organised undulating / hummocky terrain in the east of the Proposed Development Site where the Solar Development is located.

Plate 5 shows a 3D perspective view of the Proposed Development Site with satellite imagery superimposed and key geographical features highlighted.

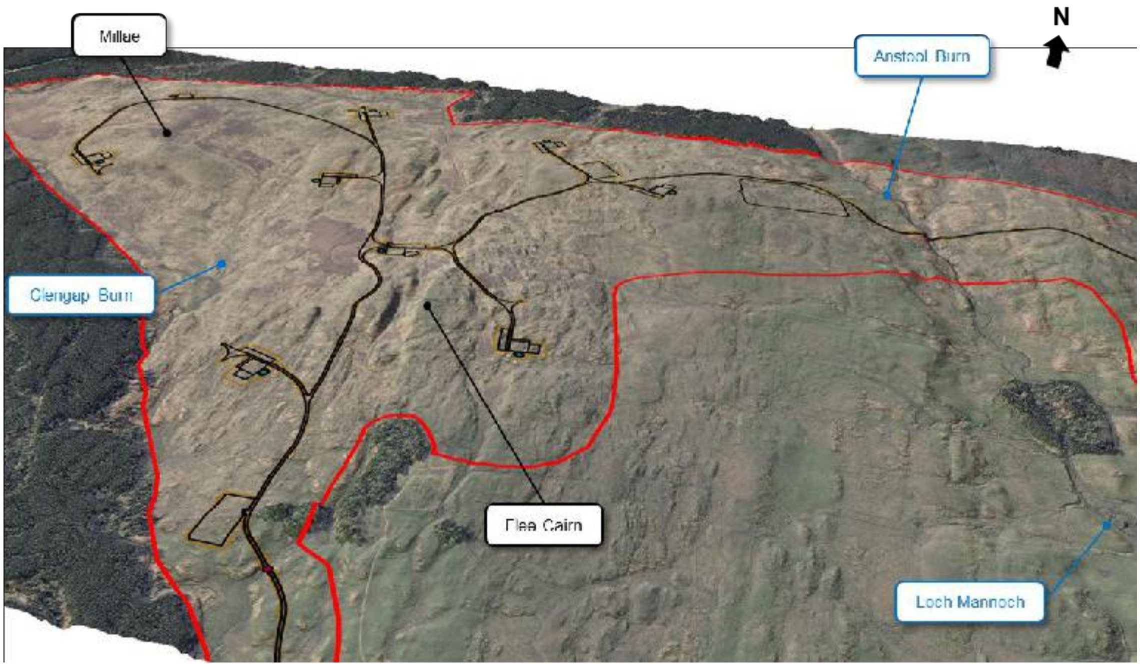


Plate 5 3D perspective view of the Proposed Development Site (strong north-south bedrock structure visible) (bing imagery © 2024 Microsoft Corporation © Maxar CNES (2024) Distribution Airbus DS)

In keeping with the low relief at the Proposed Development Site, slope angles are generally low, particularly in the northwest within the wind turbine area where slopes are generally < 5°. Where the bedrock structure is at or close to the ground surface, slope angles frequently exceed 10°. The Proposed Development Site is relatively compartmentalised from west to east with numerous elongate troughs separated by structurally controlled bedrock ridges.

3.2 Geology

The inset panel of **Figure 8-1-3** shows the solid geology of the Proposed Development Site mapped from 1:50,000 scale publicly available BGS digital data and indicates the Proposed Development Site to be underlain by sedimentary wacke of the Cairnharrow Formation, except in the far southeast where wacke of the Kirkmaiden Formation are present.

The main panel of **Figure 8-1-3** shows the superficial geology of the Proposed Development Site, also derived from BGS digital data. No data is shown for much of the Proposed Development Site, with peat deposits in the northwest, localised alluvium and glaciofluvial deposits in the centre of the Proposed Development Site and alluvium along the Tarff Water in the east. There are no geological designations within the Proposed Development Site.

3.3 Hydrology

Figure 8-1-4 shows the main hydrological features of the Proposed Development Site superimposed on satellite imagery. All of the watercourses and minor headwater tributaries in the turbine area drain into Loch Mannoch, either via Anstool Burn in the north or Glengap Burn in the west and south. Loch Mannoch then drains via Tarff Water into the River Dee well outside the Proposed Development Site boundary.

The geological structure of the Proposed Development Site has a strong control on watercourse alignments, with watercourses generally draining north or south before joining Anstool Burn or Glengap Burn. Breaks in the geology have allowed a series of shorter tributaries to crosscut the slopes, falling east directly into Loch Mannoch.

The Proposed Development Site has been heavily modified by artificial drainage cut into the peatlands to improve soil conditions. This has affected surface vegetation leading to an extensive sward of *Molinia* which conceals the drains below knee to waist hight grassy sward. LiDAR data shows the true extent of drainage, which has a total drain length within the wind farm area of c. 82.5 km. Drains, mapped from LiDAR, are shown on **Figure 8-1-4**.

The entire Proposed Development Site lies within the Tarff Water Drinking Water Protected Area (DWPA) catchment (Chapter 8 of the EIAR provides more detail).

3.4 Land Use

The Proposed Development Site is surrounded by coniferous forestry, with the *Molinia* dominated parts of the Proposed Development Site experiencing natural generation of conifers. The Proposed Development Site is otherwise used for rough grazing. There are a number of cultural heritage features within the Proposed Development Site, including clearance cairns and prehistoric settlement remains (including a hut circle and cairn). There are no obvious signs of peat cutting.

3.5 Peat Depth and Character

Peat depth probing was undertaken in several phases in alignment with Scottish Government guidance (2017):

- 429 probes were collected between October 2020 and December 2020 to provide a Phase 1 100 m grid'
- A further 103 probes were collected on a 100 m grid in October 2023 along the main access track corridor and in the area proposed for solar infrastructure' and
- 1,109 probes were collected along the track centreline with 10 m offsets and on a 20 m grid across all wind farm infrastructure footprints.
- Probing was uplifted from a 20 m grid to a 10 m grid across all wind farm infrastructure in January and February 2025 taking the total number of probes collected to 2,727 probes.

Records of substrate identified using the refusal method indicated bedrock or granular substrate over the vast majority of the Proposed Development Site.

Interpolation of peat depths was undertaken in the ArcMap GIS environment using a natural neighbour approach. This approach was selected because it preserves recorded depths at each probe location, unlike some other approaches (e.g. kriging), is computationally simple, and minimises 'bullseye' effects. The approach was selected after comparison of outputs with three other standard interpolation methods (inverse distance weighted, kriging and TIN; ESRI, 2025).

The peat depth model is shown on **Figure 8-1-5** with probing locations superimposed.

Much of the Proposed Development Site lacks peat, with probed depths <0.5 m. The most extensive peat deposits lie in the northwest of the Proposed Development Site where slope gradients are very gentle and in linear north-to-south aligned troughs that sit between bedrock outcrops in the centre of the Proposed Development Site. Here, peat depths reach close to 4.0 m in depth.

Comparison of the peat depth model with the layout indicates that significant efforts have been made during layout design to Proposed Development Site infrastructure out of the deepest peat areas and to route access tracks onto shallower peat:

- In the northwest, turbines generally avoid peat, with only Turbine 9 having an appreciable overlap, however, the footprint has been optimised to minimise overlap with peat >1.0 m. The track in this area has been routed around the deepest peat rather than directly across it;
- In the centre of the Proposed Development Site, the access tracks have been routed along bedrock areas with a small crossing of the peat trough axis by the hardstanding footprint of T5. Turbines 4, 5 and 6 largely avoid peat; and
- The eastern turbine string (Turbines 1, 2 and 3) avoid peat, even though there are several large pockets in this area.

The inset panel on **Figure 8-1-5** shows the Carbon and Peatland (2016) Map for the Proposed Development Site and indicates a generally good correlation between the north-south aligned peat within troughs (shown to be Class 1) and in the northwest (also Class 1) with Class 1 shown over much of the remaining area.

Given the absence of peat over much of the Class 2 area, this classification does not provide a good fit to peat conditions on the ground.

3.6 Peatland Geomorphology

Satellite imagery available as an ArcGIS Basemap layer was used to interpret and map features within the Proposed Development Site boundary. Additional imagery from different epochs available on both Google Earth™ and bing.com/maps was also referred to in order to validate the satellite imagery interpretation.

The resulting geomorphological map (**Figure 8-1-6**) was subsequently verified during a site walkover undertaken in September 2020 by a Chartered Geologist / peatland geomorphologist with over 20 years' experience of assessing peat landslides. Plates 6 and 7 show typical features identified during the walkovers.

Plate 6 Typical ground conditions in the northwest of the Proposed Development Site: a) bedrock escarpment above undulating terrain b) peat filled trough between bedrock ridges (limits of peat deposit shown with hashed lines)

Figure 8-1-6 shows the key features of the Proposed Development Site. The presence, characteristics and distribution of these features are helpful in understanding the hydrological function of a peatland, the balance of erosion and peat accumulation (or condition), and the sensitivity of a peatland to potential land-use changes.

The west of the Proposed Development Site comprises gentle planar peatland with widespread *Molinia* concealing the ground surface. Review of LiDAR data shows few geomorphological features under the grassland. Two large peat basins sit alongside the Proposed Development Site boundary in the west.

Bedrock is close to surface in many locations, and shows a strong north-south orientation. Where it is more subdued, peat is thin over the undulating terrain. Occasional flushes are present in the north of the Proposed Development Site adjacent to shallow linear (natural) drainage patterns that are confluent with the upper reaches of the Anstool Burn.

While artificial drains are widespread, they are rarely visible at the ground surface, however, this is not to say that they are not functional, with the extensive grass cover and heather indicating relatively dry conditions.

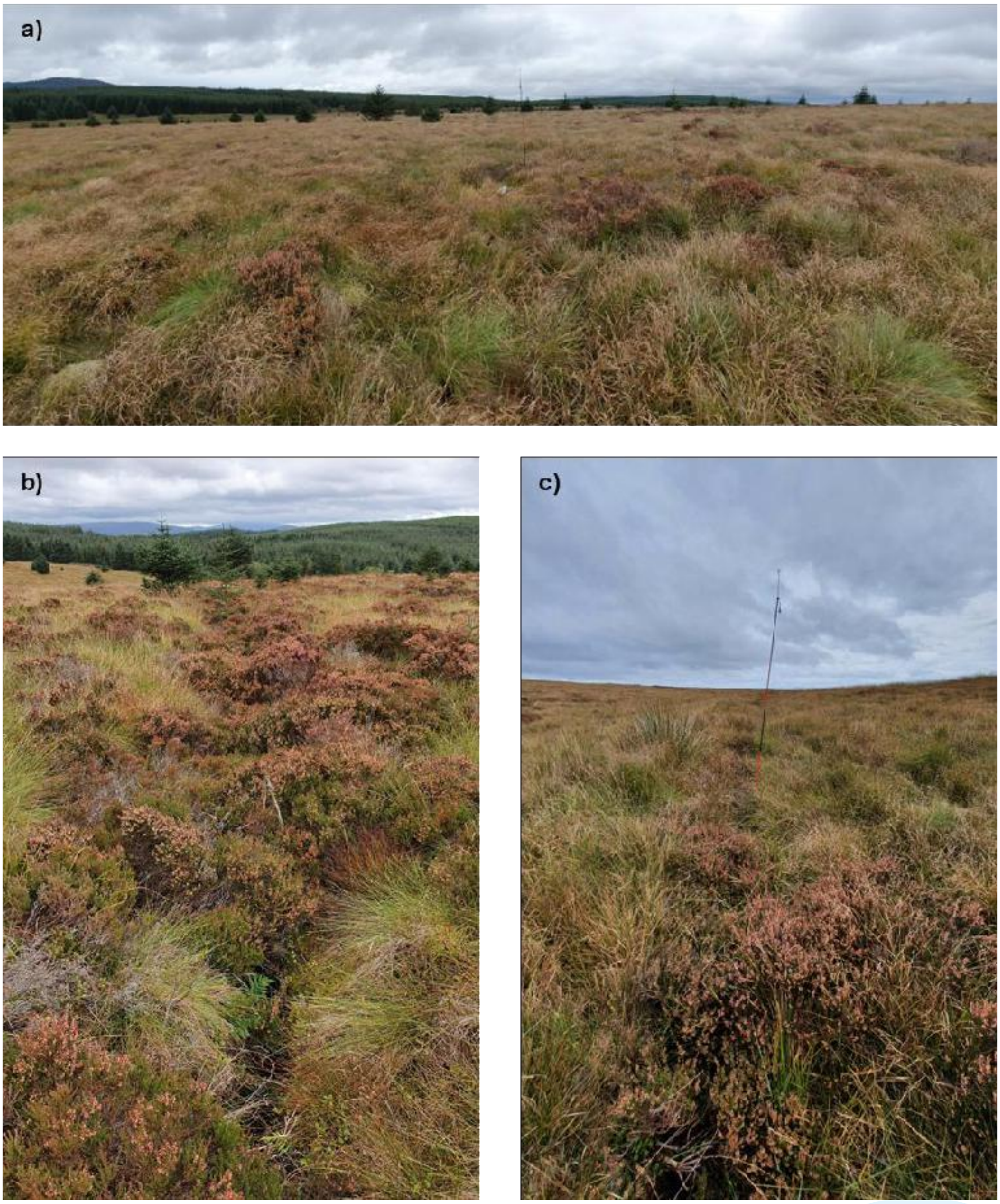


Plate 7 a) Grassy sward with localised heather and natural regeneration of conifers in the middle distance, b) a subdued natural drainage feature in the north of the Proposed Development Site, a well vegetation artificial drain

4 Assessment of Peat Landslide Likelihood

4.1 Introduction

This section provides details on the landslide susceptibility and limit equilibrium approaches to 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

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

Due to the combination of moderate slopes and thinner peat on the Proposed Development Site, the most likely mode of failure is peat slides, and this is the failure mechanism considered in this report This is in keeping with the most likely mode of failure for the peat depths and slope angles present at the Proposed Development Site (see **Plate 4** and **Figures 8-1-1** and **8-1-4**).

4.2 Limit Equilibrium Approach

4.2.1 Overview

Stability analysis has been undertaken using the infinite slope model to determine the Factor of Safety (FoS) for a series of 25 m x 25 m grid cells within the Proposed Development boundary.

This is the most frequently cited approach to quantitatively assessing the stability of peat slopes (e.g. Scottish Government, 2017; Boylan et al, 2008; Evans and Warburton, 2007; Dykes and Warburton, 2007; Creighton, 2006; Warburton et al, 2003; Carling, 1986).

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.

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) (Scottish Government, 2017):

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

In this formula c' is the effective cohesion (kPa), γ is the bulk unit weight of saturated peat (kN/m^3), γw is the unit weight of water (kN/m^3), 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 (°).

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.

The use of cut and fill foundations and tracks across almost the whole construction footprint suggest this is an appropriate approach. 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.

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 factor of safety 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 factor of safety greater than 1.4 are generally considered to be stable.

There are numerous uncertainties involved in applying geotechnical approaches to peat, not least because of its high water content, compressibility and organic composition (Hobbs, 1986; Boylan and Long, 2014).

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.

Representative data inputs have been derived from published literature for drained analyses considering natural site conditions.

4.2.2 Data Inputs

Stability analysis was undertaken in ArcMap GIS software. A 25 m x 25 m grid was superimposed on the full Proposed Development Site extent and key input parameters derived for each grid cell. In total, c. 9,220 grid cells were analysed.

A 25 m x 25 m cell size was chosen because it is sufficiently small to define a credible landslide size and avoid 'smoothing' of important topographic irregularities.

Two forms of analysis have been undertaken:

i. Baseline stability: input parameters correspond to undisturbed peat, prior to construction, and under water table conditions typically associated with instability (i.e. full saturation). Effective stress parameters are used in a drained analysis; and

ii. Modified (loaded) stability: input parameters correspond to disturbed peat, subsequent to construction, with peat loaded by floating track and typical vehicle loads. Total stress parameters are used in this undrained analysis.

Areas where peat has been excavated (e.g. the excavated peat itself and the peat upslope of the excavation) have not been modelled since it is assumed that safe systems of work will include buttressing of / support to excavations.

Table 8-1-1 shows the input parameters and assumptions for the baseline stability analysis. 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'. These values fall at the low end of a large range of relatively low values (when compared to other soils).

Table 8-1-2 shows the input parameters and assumptions for the modified stability analysis. The analysis employs a 5.5 m wide floating track and assumes representative loads for a multi-axle crane with maximum axle load of 12 t moving over the floated surface.

The analysis assumes pre-loading of the peat by floating track during which the track is built in layers and pore pressures are allowed to dissipate. The combined weight of the track and peat are then modelled in an undrained analysis utilising the heaviest vehicle loads likely to use the access the track.

4.2.3 Results

The outputs of the drained analysis (effective stress) are shown for both parameter combinations in **Figure 8-1-7**. The more conservative combination (minimum c' and ϕ', inset panel) suggests that only the steeper parts of the Proposed Development Site on the periphery of bedrock areas would be unstable ($F < 1$) or of marginal stability ($F < 1.4$).

The best estimate parameters show a similar pattern but with the majority of the Proposed Development Site showing stability. Both sets of results are consistent with the stability of peat in general – peat landslides are very rare occurrences given the wide distribution of peat soils in England, Scotland and Wales.

Table 8-1-1: Geotechnical Parameters for Drained Infinite Slope Analysis

Effective cohesion (c')	2, 5	Credible conservative cohesion values for humified peat based on literature review	5, basal peat (Warburton et al., 2003) 8.74, fibrous peat (Carling, 1986) 7 - 12, H8 peat (Huat et al, 2014) 5.5 - 6.1, type not stated (Long, 2005) 3, 4, type not stated (Long, 2005) 4, type not stated (Dykes and Kirk, 2001)
Bulk unit weight (γ)	10.5	Credible mid-range value for humified catotelmic peat	10.8, catotelm peat (Mills, 2002) 10.1, Irish bog peat (Boylan et al 2008)
Effective angle of internal friction (ϕ')	20, 30	Credible conservative friction angles for humified peat based on literature review (only 20° used in analysis)	40 - 65, fibrous peat (Huat et al, 2014) 50 - 60, amorphous peat (Huat et al, 2014) 36.6 - 43.5, type not stated (Long, 2005) 31 - 55, Irish bog peat (Hebib, 2001) 34 - 48, fibrous sedge peat (Farrell & Hebib, 1998) 32 - 58, type not stated (Long, 2005) 23, basal peat (Warburton et al, 2003) 21, fibrous peat (Carling, 1986)

Slope angle from horizontal (β)	Various	Mean slope angle per 25m x 25m grid cell	5m digital terrain model of the Proposed Development Site
Peat depth (z)	Various	Mean peat depth per 25m x 25m grid cell	Interpolated peat depth model of the Proposed Development 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)	

Table 8-1-2: Geotechnical Parameters and Assumptions for Undrained Infinite Slope Analysis

Undrained shear strength (Su)	5	Published values show undrained shear strength is typically very similar to effective cohesion (c')	4-30, medium and highly humified (Boylan et al, 2008) 4, more humified (Boylan et al, 2008) 5.2, peat type not stated (Long et al, 2005) 5, Irish bog peat (Farrell and Hebib, 1998)
Bulk unit weight (γ)	10.5	Reduction in volume under floating road is balanced by increased density, so pre-load parameters are used	See Table 8-1-1
Slope angle from horizontal (β)	Various	Credible slope angles for which floating tracks are proposed	See Table 8-1-1
Peat depth (z)	Various	Reduction in volume (i.e. depth) under floating road is balanced by increased density, so pre-load parameters are used	See Table 8-1-1
Crane axle load (t)	12 t	Axle load corresponding to the maximum haul weight that is not considered an "abnormal load"	

In order for a section of floating track to be considered a potential source zone, two or more contiguous 25 m cells must have Factors of Safety of <1.4. This reflects the tendency of regularised grids to produce single cell outliers in results. Two contiguous cells of similar value would indicate a trend more reflective of the locality.

The outputs of the undrained analysis incorporating crane loads on floating track are shown on inset panels on **Figure 8-1-7** and indicate that all proposed lengths of floating track are in areas with Factors of Safety indicating stability.

4.3 Landslide Susceptibility Approach

4.3.1 Overview

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. These slope facets vary in size and are different to the regular grid used for the FoS approach. The number and size of slope facets varies from one part of the Proposed Development Site to another according to the complexity of ground conditions.

In total, c. 4,995 facets were considered in the analysis, with an average area of c. 1,090 m^2 (or an average footprint of c. 33 m x 33 m, consistent with smaller to medium scale peaty soil or peat slides reported in the published literature.

Eight contributory factors are considered in the analysis: slope angle (S), peat depth (P), substrate geology (G), peat geomorphology (M), drainage (D), slope curvature (C), forestry (F), and land use (L).

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.

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

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

In practice, a maximum score is unlikely, as the chance of all contributory factors having their highest scores in one location is very small. The following sections describe the contributory factors, scores and justification for the Proposed Development.

4.3.2 Slope Angle (S)

Table 8-1-3 shows the slope ranges, their association with instability and related scores for the slope angle contributory factor. Slope angles were derived from the 5 m digital terrain model shown on **Figure 8-1-2** 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’ (e.g. Plate 4).

A differentiation in scores is applied for peat slides and bog bursts reflecting the shallower slopes on which the latter are most frequently observed.

Note that the slope model is a TIN (interpolated from irregularly spaced measures of elevation) and these sorts of slope model tend to simplify slopes into triangular surfaces – this can have the effect of steepening or shallowing slopes relative to their actual gradients.

Table 8-1-3: Slope Classes, Association with Instability and Scores

≤2.5	Slope angle ranges for peat slides are based on lower and upper limiting angles for observations of occurrence (see Plate 2.2) and increase with increasing slope angle until the upper limiting angle.	0
2.5 - 5.0		1
5.0 – 7.5		3
7.5 - 10.0		3
>10 – 15.0		3
>15.0		3

Figure 8-1-8 shows the distribution of slope angle scores. Much of the Proposed Development Site has moderate slopes in excess of 5° and therefore has the highest slope score.

4.3.3 Peat Depth (P)

Table 8-1-4 shows the peat depths, their association with instability and related scores for the peat depth contributory factor. Peat depths were derived from the peat depth model shown on **Figure 8-1-5** and reflect the peat depth ranges most frequently associated with peat landslides (see Plate 4).

Table 8-1-4: Peat Depth Classes, Association with Instability and Scores

>1.5	Bog bursts are the dominant failure mechanism in this depth range where basal peat is more likely to be amorphous	1
0.5 - 1.5	Peat slides are the dominant failure mechanism in this depth range where basal peat is less likely to be amorphous	3
<0.5	Organic soil rather than peat, failures would be peaty-debris slides rather than peat slides or bog bursts and are outside the scope	0

The distribution of peat depth scores is shown on **Figure 8-1-8**. Peat is absent over much of the Proposed Development Site, but where present is typically of moderate depth (0.5 – 1.5 m) and is therefore assigned the highest score.

4.3.4 Substrate Geology (G)

Table 8-1-5 shows substrate type, association with instability and related scores for the substrate geology contributory factor. The shear surface or failure zone of reported 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).

Peat failures are frequently cited in association with glacial till deposits in which an iron pan is observed in the upper few centimetres (Dykes and Warburton, 2007). 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 8-1-5: Substrate Geology Classes, Association with Instability and Scores

Soft clay or iron pan	Failures are often associated with soft clay substrates and/or iron pans	3
Granular clay or clay dominated alluvium	Failures are more frequently associated with substrates with some clay component	2
Granular or bedrock	Failures are less frequently associated with bedrock or granular (silt / sand / gravel) substrates	1

The Proposed Development Site is largely underlain by granular substrate or bedrock and therefore has the lowest substrate score (**Figure 8-1-8**).

4.3.5 Peat Geomorphology (M)

Table 8-1-6 shows the geomorphological features typical of peatland environments, their association with instability and related scores.

Table 8-1-6: Peat Geomorphology Classes, Association with Instability and Scores

Incipient instability (cracks, ridges, bulging)	Failures are likely to occur where pre-failure indicators are present	3
Planar with pipes	Failures generally occur on planar slopes, and are often reported in areas of piping	3
Planar with pools / patterned ground with pools / quaking bog	Bog bursts are more likely in areas of perched water (pools) or subsurface water bodies (quaking bog)	2
Flush / Sphagnum lawn (diffuse drainage)	Peat slides are often reported in association with areas of flushed peat or diffuse drainage	3
Planar (no other features)	Failures generally occur on planar slopes rather than dissected or undulating slopes	2
Peat over undulating bedrock	Failures are rarely reported in areas of peat with frequent rock outcrops	1
Patterned ground / slightly eroded (incl. minor gullies)	Failures are rarely reported in areas with patterned ground, gullying or bare peat	1
Heavily eroded (extensive gullies) / bare peat	Failures are not reported in areas that are heavily eroded or bare	0
Afforested / deforested peatland	Considered within Forestry (F), see below	0

Figure 8-1-8 shows the geomorphological classes from **Figure 8-1-6** re-coloured to correspond with Table 8-3-6. Large planar areas in the west of the Proposed Development Site have the highest score.

4.3.6 Artificial Drainage (D)

Table 8-1-7 shows artificial drainage feature classes, their association with instability and related scores. Transverse (or contour aligned) / oblique artificial drainage lines may reduce peat stability by creating lines of weakness in the peat slope and encouraging the formation of peat pipes.

A number of peat failures have been identified in published literature which have failed over moorland grips (Warburton et al, 2004). The influence of changes in hydrology becomes more pronounced the more transverse the orientation of the drainage lines relative to the overall slope.

The effect of drainage lines is captured through the use of a 30 m buffer on each artificial drainage line (producing a 60 m wide zone of influence) present within the peat soils at Proposed Development Site. Each buffer is assigned a drainage feature class based on comparison of the drainage axis with elevation contours (**Figure 8-1-8**).

Table 8-1-7: Drainage Feature Classes, Association with Instability and Scores

Drains aligned along contours (<15 °)	Drains aligned to contour create lines of weakness in slopes	3
Drains oblique (15-60°) to contour	Most reports of peat slides and bog bursts in association with drainage occurs where drains are oblique to slope	2
Drains aligned downslope (<30° to slope)	Failures are rarely associated with artificial drains parallel to slope or adjacent to natural drainage lines	1
No / minimal artificial drainage	No influence on stability	0

4.3.7 Slope Curvature (C)

Table 8-1-8 shows slope (profile) curvature classes, association with instability and related scores. Convex and concave slopes (i.e. positions in a slope profile where slope gradient changes by a few degrees) have frequently been reported as the initiation points of peat landslides by a number of authors.

The geomechanical reason for this is that 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 (e.g. Dykes & Warburton, 2007; Boylan and Long, 2011).

However, review of reported peat landslide locations against Google Earth elevation data indicates that the majority of peat slides occur on rectilinear (straight) slopes and that the reporting of convexity as a key driver may be misleading. Accordingly, rectilinear slopes are assigned the highest score.

Table 8-1-8: Slope Curvature Classes, Association with instability and Scores

Rectilinear Slope	Peat slides are most frequently reported on rectilinear slopes, while bog bursts are often reported on rectilinear slopes	3
Convex Slope	Peat slides are often reported on or above convex slopes while bog bursts are most frequently associated with convex slopes	2
Concave Slope	Peat failures are occasionally reported in association with concave slopes	1

The 5 m digital terrain model and OS contours were used to identify areas of noticeable slope convexity and concavity across the Proposed Development Site. Axes of convexity and concavity (running along the contour) were assigned a 50 m buffer to produce 100 m (upslope to downslope) buffer zones and these were assigned scores in accordance with Table 8-1-8 above.

4.3.8 Forestry (F)

Table 8-1-9 shows forestry classes, their association with instability and related scores. A report by Lindsay and Bragg (2004) on Derrybrien suggested that row alignments, desiccation cracking and loading (by trees) could all influence peat stability.

Table 8-1-9: Forestry Classes, Association with Instability and Scores

Deforested, rows oblique to slope	Deforested peat is less stable than afforested peat, and inter ridge cracks oblique to slope may be lines of weakness	3
Deforested, rows aligned to slope	Deforested peat is less stable than afforested peat, but slope aligned inter ridge cracks have less impact	2
Afforested, rows oblique to slope	Afforested peat is more stable than deforested peat, but inter ridge cracks oblique to slope may be lines of weakness	2
Afforested, rows aligned to slope	Afforested peat is more stable than deforested peat, but potentially less stable than unforested (never planted) peat	1
Windblown	Windblown trees have full disruption to the underlying peat and residual hydrology due to root plate disturbance	0
Not afforested	No influence on stability	0

Very little of the Proposed Development Site is afforested or has undergone forest preparations except for sporadic areas of woodland in the east of the Proposed Development Site away from areas of peat (see **Figure 8-1-8**).

4.3.9 Land use (L)

Table 8-1-10 shows land use classes, association with instability and related scores. A variety of land uses have been associated with peat failures (see Section 2.2.1).

While it is hypothesised that burning may cause desiccation cracking in peat and facilitate water flows to basal peat (and potential shear surfaces), there is little evidence directly relating burnt ground to peat landslide events.

Table 8-1-10: Land Use Classes, Association with Instability and Scores

Machine cutting	Machine cutting may compartmentalise slopes, but has been reported primarily in association with peat slides	3
Quarrying	Quarrying may remove slope support from upslope materials, and has been observed with spreading failures (bog bursts)	2
Hand cutting (turbary)	Hand cutting may remove slope support from upslope materials, and has been reported with raised bog failures	1
Burning (deep cracking to substrate)	Failures are rarely associated with burning, but deep desiccation cracking will have the most severe effects	2
Burning (shallow cracking)	Failures are rarely associated with burning, shallow desiccation cracking will have very limited effects	1
Grazing	Failures have not been associated with grazing, no influence on stability	0

Land use is limited to grazing and scored accordingly (**Figure 8-1-8**).

4.3.10 Generation of Slope Facets

The eight contributory factor layers shown on **Figure 8-1-8** were combined in ArcMap. Scores for each facet were then summed to produce a peat landslide likelihood score.

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 (in a similar format to the Scottish Government BPG).

Table 8-1-11 describes the basis for the likelihood classes.

Table 8-1-11: Likelihood classes derived from the landslide susceptibility approach

≤ 7	Unmodified peat with no more than low weightings for peat depth, slope angle, underlying geology and peat morphology	Very Low	1
8 - 12	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
13 - 17	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
18 - 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

A judgement was made that for a facet to have a moderate or higher likelihood of a peat landslide, a likelihood score would be required exceeding both the worst-case peat depth and slope angle scores summed (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 13 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.

4.3.11 Results

Figure 8-1-9 shows the outputs of the landslide susceptibility approach for peat slides. The results indicate that the majority of the Proposed Development Site has a 'Very Low' or 'Low' likelihood of a peat slide with scattered and localised areas of 'Moderate' likelihood, typically associated with areas of drainage cut oblique to slope or along contour in areas of moderate slope and moderate peat depth.

There are no areas identified with 'High' or 'Very High' landslide likelihoods. When compared with the stability analysis approach, areas of Moderate likelihood correlate relatively well with areas of lower factor of safety.

4.3.12 Calculated Risk

In order for there to be a 'Medium' or 'High' risk, likelihoods must be Moderate or higher (see **Table 8-1-12** and **Table 8-1-13** below) in areas overlapping with infrastructure. This provides a screening basis for the likelihood results.

Five areas of infrastructure have been identified that overlap with Moderate likelihood areas of Factors of Safety <1.4 via the best estimate (baseline) analysis or modified crane loaded analysis. These are shown in purple on **Figure 8-1-10** and are taken forward for consequence assessment in section 5.

Table 8-1-12: Risk ranking as a product of likelihood and consequence

		Adverse Consequence (Scores Bracketed)				
		Very High (5)	**High (4)**	**Moderate (3)**	**Low (2)**	**Very Low (1)**
Peat Landslide Likelihood (Score Bracketed)	**Very High (5)**	High	High	Medium	Low	Low
	High (4)	High	Medium	Medium	Low	Negligible
	Moderate (3)	Medium	Medium	Low	Low	Negligible
	Low (2)	Low	Low	Low	Negligible	Negligible
	Very Low (1)	Low	Negligible	Negligible	Negligible	Negligible

Table 8-1-13: Suggested action given each level of calculated risk

Score	Risk Level	Action Suggested for Each Zone
17-25	High	Avoid project development at these locations
11-16	Medium	Project should not proceed in MEDIUM areas unless risk can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce risk ranking to LOW or NEGLIGIBLE.
5-10	Low	Project may proceed pending further post-consent investigation in LOW areas to refine risk level and/or mitigate any residual hazards through micro-siting or specific design measures.
1-4	Negligible	Project should proceed with good practice monitoring and mitigation of ground instability/ landslide hazards at these locations as appropriate.

5 Assessment of Consequence and Risk

5.1 Introduction

In order to calculate risks, the potential consequences of a peat landslide must be determined. This requires identification of receptors and an assessment of the consequences for these receptors should a peat landslide occur. This section describes the consequence assessment and then provides risk results based on the product of likelihood and consequence.

5.2 Receptors

Peat uplands are typically host to the following receptors: watercourses and associated water supplies (both private and public), terrestrial habitats (e.g. groundwater dependent terrestrial ecosystems or GWDTEs) and infrastructure, both those that are related to the wind farm and other infrastructure, e.g. roads and power lines. These are considered for the Proposed Development below.

5.2.1 Watercourses

The Proposed Development Site is drained by numerous watercourses, most of which are headwater tributaries of the Anstool Burn in the north and Glengap Burn in the south, both of which ultimately drain into Loch Mannoch, a Scottish Water reservoir.

Loch Mannoch and watercourses within 5 km (in-channel distance) of the reservoir are assigned a consequence score of 4 to reflect potential changes in turbidity resulting from ingress of peaty debris from potential landslides. Watercourses greater than 5 km from the reservoir are assigned a consequence score of 3, since it is very unlikely that any significant uplift in turbidity will be experienced over and above baseline levels.

5.2.2 Habitats

Priority peatland habitats, either those of national interest or those not considered of national interest are very limited within the Proposed Development Site. While blanket bog habitats are valuable, they generally recover from instability events through revegetation over a matter of years to decades and therefore a consequence score of 3 is assigned for all open blanket bog habitats within the Proposed Development Site (**Table 8-1-14**).

Table 8-1-14: Consequence scores for receptors

Receptor and type	Consequences	Score	Justification
Watercourses (aquatic habitats)	Short term increase in turbidity and acidification, potential fish kill	3	Undesignated watercourse, no sensitive species noted
Watercourses (DWPA)	Short term increase in sediment load affecting water quality at offtakes	4	Minor remedial works may be required
Watercourses (non DWPA, or >5 km away)	Short term increase in sediment load with no effect on offtakes due to lack of transmission	3	No long term effects
Terrestrial habitats	Short to medium term loss of vegetation cover, disruption of peat hydrology, carbon release	3	Best habitats noted to be wet modified bog, long term effects unlikely

Receptor and type	Consequences	Score	Justification
			following revegetation
Cultural heritage features	Short term burial (not erosion or scour) to structures, possible loss of cairns	4	Buried heritage features unlikely to be impacted, fragile surface structures may be damaged
Wind farm infrastructure (Project)	Damage to infrastructure, injury to site personnel, possible loss of life	5	Loss of life, though very unlikely, is a severe consequence; financial implications of damage and re-work are less significant

5.2.3 Cultural heritage

There are numerous cultural heritage features distributed across the Proposed Development Site. Buried features or structures comprised of stone are unlikely to be damaged, however, there is potential for loosely arranged features (such as cairns) to be smothered and/or damaged. A score of 4 is assigned for these features.

5.2.4 Infrastructure

The Proposed Development Site is relatively isolated, with no non-wind farm infrastructure. Infrastructure that would be most affected in the event of a peat landslide would be the Proposed Development infrastructure. These effects would be most likely during construction, at which time personnel would be using the access track network or be present at infrastructure locations for long periods.

While commercial losses would be important to the Applicant, loss of life / injury would be of greater concern, and a consequence score of 5 is assigned for any infrastructure locations subject to potential peat landslides (**Table 8-1-14**).

However, risks to life can be mitigated through safe systems of working. These infrastructure risks are not considered to be 'environmental' risks and are not explicitly considered in the consequence assessment below.

5.3 Consequences

5.3.1 Overview

A consequence assessment has been undertaken by determining the potential for landslides sourced at infrastructure locations with a Moderate natural likelihood of peat instability to impact the receptors identified above.

For example, if a turbine is located in a Moderate (likelihood score of 3) area of open slope and is located 50 m from a watercourse (with a consequence score of 5), it is probable that a landslide triggered during construction would reach that watercourse.

The calculated risk would be a product of the likelihood and consequence scores (likelihood: 3 x consequence: 5 = risk: 15, see Plate 8) and be equivalent to a "Medium" risk.

In order to determine the likelihood of impact on watercourses and infrastructure, 'runout pathways' have been defined that show the estimated maximum footprint of the landslide. Runout pathways are divided in a downslope direction into 50 m, 100 m, 250 m and 500 m zones on the basis of typical runout distances detailed in Mills (2002).

The likelihood of runout passing from one runout zone to the next (e.g. from the 50 m zone into the 100 m zone) is based on the proportion of the published peat landslide population that reaches each runout distance shown on Plate 8 (0-50 m: 100%, 50-100 m: 87%, 100-250 m: 56%, 250-500 m: 44%).

The source zone area is either the footprint of hardstandings or non-linear infrastructure, or where an access track is the source, the track length multiplied by a typical landslide downslope length of 25 m.

Figure 8-1-10 shows in purple all infrastructure locations that overlap with Moderate likelihoods, based on the combined landslide likelihood scores described in Section 4.

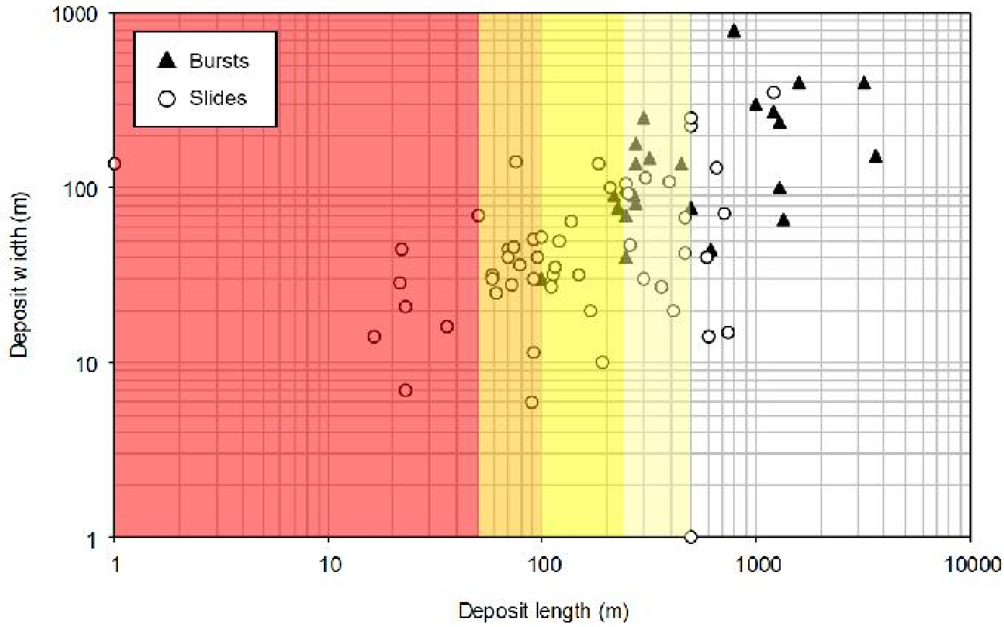


Plate 8 Runout distances for published peat landslides (after Mills, 2002), colours on the plot correspond to runout pathway zones on Figure 8-1-10

5.3.2 Local limits on runout (watercourses)

All runout pathways defined on **Figure 8-1-10** terminate at watercourses if within 500 m of the source zone, reflecting the position of watercourses at valley floors / within topographic lows. At this point, debris is regarded as entering the watercourse and risk is calculated as the product of consequence (dependent on the watercourse consequence score) and likelihood (from section 4).

If watercourses contain physical barriers (e.g. weirs), are highly sinuous within low floodplains and may encourage stranding of debris, or if streams are too small to convey material, then runout may also be considered to stall where these restrictions come into effect.

5.3.3 Local limits on runout (slope curvature)

Plate 8 shows runout distances based on published literature. Typically, runout distances would be expected to be less where slope angles decline with distance from the source zone (i.e. on concave slopes) whereas the full runout lengths shown on Plate 8 may be achievable on steepening (convex) slopes or rectilinear slopes.

5.3.4 Local limits on runout (peat thickness in source zone)

Landslide runout may be "supply-limited" by the availability of peat material generated in the failure or source zone. Typically, mobilised material thins with increasing distance from the source zone as rafts of landslide material break down into blocks, and blocks become abraded and roll, breaking down further into a blocky slurry (Plate 9).

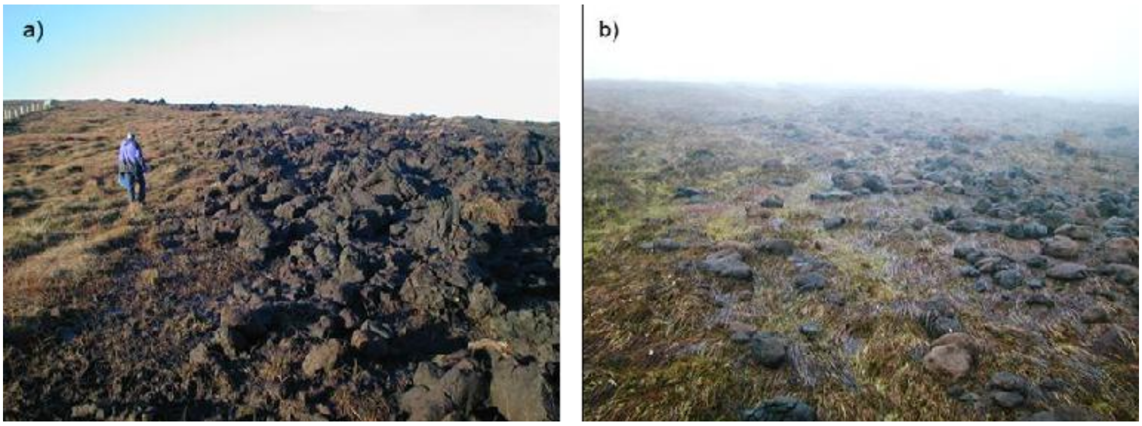


Plate 9 Examples of landslide runout (Dooncarton, Co. Mayo): a) blocky debris mid-slope, b) abraded and rolled blocks in lower slope

Following identification of runout zones, additional analysis has been undertaken to approximate this effect. The analysis assumes a source volume equivalent to the source footprint (if not a track, then the polygon shown as the Source Zone on **Figure 8-1-10**, or if a track section, then the track length x 50 m).

This source footprint is multiplied by the average peat depth in the source zone (from the peat depth model) to calculate a volume, and this volume is then distributed over the full runout pathway (i.e. mobilised volume / runout area) to generate an average thickness of deposit.

As the runout length and area increases, the volume thins, in keeping with observed peat landslide deposits. Where deposits fall below 0.2 m in thickness, it is assumed that runout will stall due to the roughness of surface vegetation relative to the thickness of landslide material.

If the thickness is calculated to be 0.2 m or less in the zone adjoining a watercourse, then it is judged that the runout will stall prior to reaching it or be negligible in volume on entry and there will be no significant impact on that watercourse (even if a landslide occurs). **Plate 10** shows a schematic of the full runout approach to assessing consequences.

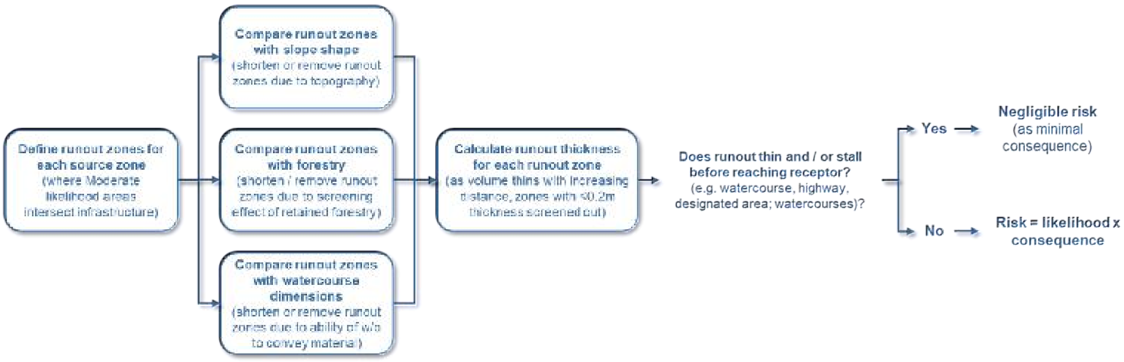


Plate 10 Runout approach to assessing consequences

5.3.5 Results of runout analysis

Of the 5 source zones, 4 zones have runout zones with the potential to reach named watercourses:

- Source Zone 2: Unnamed tributary to Loch Mannoch;
- Source Zone 3: Unnamed tributary to Loch Mannoch;
- Source Zone 4: Unnamed tributary >5 km from Loch Mannoch; and
- Source Zone 5: Unnamed tributary >5 km from Loch Mannoch.

Of these, runout from Source Zone 2 would likely stall within the 100-250 m zone due to slope concavity. Due to the relatively shallow peat in all source zones, peat would thin sufficiently in all five of the runout zones prior to reaching the watercourses, runout thicknesses being <0.1 m for zones 1 and 7 and < 0.2 m for zones 2-5. Therefore consequences apply to terrestrial habitats only. No cultural heritage features are present within runout zones.

5.4 Calculated Risk

Risk levels have been calculated as a product of likelihood and consequence and are shown on **Figure 8-1-11** for each runout pathway. Each runout zone is colour coded to match the risk rankings shown on **Table 8-1-13**. For each zone, the score for the most sensitive environmental receptor has been chosen for the risk calculation (i.e. a conservative approach).

Figure 8-1-11 indicates that risks are calculated to be "Low" across the Proposed Development Site. No source zones give rise to a "Medium" or "High" calculated risk.

Based on the calculated risks shown on **Figure 8-1-11**, site-wide good practice measures are considered to be sufficient to manage and mitigate any construction induced instability risks. This is considered in the next section.

6 Risk Mitigation

6.1 Overview

A number of mitigation opportunities exist to further reduce the risk levels identified at the Proposed Development Site.

These range from infrastructure specific measures (which may act to reduce peat landslide likelihood, and, in turn, risk) to general good practice that should be applied across the Proposed Development Site to engender awareness of peat instability and enable early identification of potential displacement and opportunities for mitigation.

Risks may be mitigated by:

i. Post-consent site specific review of the ground conditions contributing to Moderate likelihoods which may result in a reduced likelihood, and in turn, further reduction in risk; examples include tension cracks along the peat escarpment and artificial drains aligned oblique to contour; and

ii. Precautionary construction measures – including use of monitoring, good practice and a geotechnical risk register relevant to all locations.

Based on the analysis presented in this report, risks are calculated to be "Low" across the Proposed Development Site, and site-specific mitigation is not required to reduce risks pre-consent. Sections 6.2 to 6.4 provide information on good practice pre-construction, during construction and post-construction (i.e. during operation).

6.2 Good Practice Prior to Construction

Site safety is critical during construction, and it is strongly recommended that detailed intrusive site investigation and laboratory analysis are undertaken ahead of the construction period in order to characterise the strength of the peat soils in the areas in which excavations are proposed, particularly where these fall in areas of Moderate (or greater, if present) likelihood. These investigations should be sufficient to:

1. Determine the strength of free-standing bare peat excavations;
2. Determine the strength of loaded peat (where excavators and plant are required to operate on floating hardstandings or track, or where operating directly on the bog surface); and
3. Identify sub-surface water-filled voids or natural pipes delivering water to the excavation zone, e.g. through the use of ground penetrating radar or careful pre-excavation site observations.

A comprehensive Geotechnical Risk Register should be prepared post-consent, but pre-construction, detailing sequence of working for excavations, measures to minimise peat slippage, design of retaining structures for the duration of open hole works, monitoring requirements in and around the excavation and remedial measures in the event of unanticipated ground movement.

The risk register should be considered a live document and updated with site experience as infrastructure is constructed. Ideally, a contractor with experience of working in deep peat should be engaged to undertake the works.

6.3 Good Practice During Construction

The following good practice should be undertaken during construction:

For excavations:

- 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 that natural drainage pathways are maintained or diverted such alteration of the hydrological regime of the Proposed Development Site is minimised or avoided; 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).

For cut 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 water remains free-flowing and that no blockages have occurred.

For floating tracks:

- Allow peat to undergo primary consolidation by adopting rates of road construction appropriate to weather conditions;
- 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 secondary compression phase; and
- Prior to construction, setting out the centreline of the proposed track to identify any ground instability concerns or particularly wet zones.

For storage of peat and for restoration activities:

- Ensure stored peat is not located upslope of working areas or adjacent to drains or watercourses;
- Undertake site specific stability analysis for all areas of peat storage (if on sloping ground) to ensure the likelihood of destabilisation of underlying peat is minimised;
- 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;
- Undertake regular monitoring of emplaced peat in restoration areas to identify evidence of creep or pressure on retaining structures (dams and berms); and
- Maximise the interval between material deliveries over newly constructed tracks that are still observed to be within the primary consolidation phase.

In addition to these control measures, the following good practice should be followed:

- The geotechnical risk register prepared prior to construction should be updated with site experience as infrastructure is constructed;
- Full site walkovers should 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 should be overseen by an appropriately qualified geotechnical engineer with experience of construction on peat sites;
- Awareness of peat instability and pre-failure indicators should be incorporated in site induction and training to enable all site personnel to recognise ground disturbances and features indicative of incipient instability;
- A weather policy should be agreed and implemented during works, e.g. identifying 'stop' rules (i.e. weather dependent criteria) for cessation of track construction or trafficking; and
- Monitoring checklists should be prepared with respect to peat instability addressing all construction activities proposed for the Proposed Development Site.

It is considered that taken together, these mitigation measures are considered to be sufficient to reduce risks to construction personnel to Negligible by reducing consequences to minor injury or programme delay (i.e. Moderate consequences) with a Very Low likelihood of occurrence.

6.4 Good Practice Post-Construction

Following cessation of construction activities, monitoring of key infrastructure locations should continue by full site walkover 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;
- Changes in the character of peat drainage within a 50 m buffer strip of tracks and infrastructure (e.g. upwelling within the peat surface upslope of tracks, sudden changes in drainage behaviour downslope of tracks);
- Blockage or underperformance of the installed site drainage system;
- Slippage or creep of stored peat deposits; 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.

This monitoring should be undertaken on a quarterly basis in the first year after construction, biannually 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.

7 References

BBC (2014) Torrential rain leads to landslides in County Antrim. https://www.bbc.co.uk/news/uk-northern-ireland-28637481 accessed 19/07/2018

BBC (2018) Glenelly Valley landslides were 'one-in-3,000 year event'. https://www.bbc.co.uk/news/uk-northern-ireland-43166964 accessed 19/07/2018

Bowes DR (1960) A bog-burst in the Isle of Lewis. Scottish Geographical Journal. 76, pp. 21-23

Boylan N and Long M (2011) In situ strength characterisation of peat and organic soil using full-flow penetrometers. Canadian Geotechnical Journal, 48(7), pp1085-1099

Boylan N and Long M (2014) Evaluation of peat strength for stability assessments. Geotechnical Engineering, 167, pp422-430

Boylan N, Jennings P and Long M (2008) Peat slope failure in Ireland. Quarterly Journal of Engineering Geology, 41, pp. 93–108

Carling PA (1986) Peat slides in Teesdale and Weardale, Northern Pennines, July 1983: description and failure mechanisms. Earth Surface Processes and Landforms, 11, pp. 193-206

Creighton R (Ed) (2006) Landslides in Ireland. Geological Society of Ireland, Irish Landslides Working Group, 125p

Creighton R and Verbruggen K (2003) Geological Report on the Pollatomish Landslide Area, Co. Mayo. Geological Survey of Ireland, 13p

Cullen C (2011) Peat stability – minimising risks by design. Presentation at SEAI Wind Energy Conference 2011, 45p

Dykes A and Warburton J (2007) Mass movements in peat: A formal classification scheme. Geomorphology 86, pp. 73–93

Dykes AP and Kirk KJ (2001) Initiation of a multiple peat slide on Cuilcagh Mountain, Northern Ireland. Earth Surface Processes and Landforms, 26, 395-408

ESRI (2025) Comparing interpolation methods. Accessed 28/04/2025. Available at: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/comparing-interpolation-methods.htm

Evans MG & Warburton J (2007) Geomorphology of Upland Peat: Erosion, Form and Landscape Change, Blackwell Publishing, 262p

Farrell ER and Hebib S (1998) The determination of the geotechnical parameters of organic soils, Proceedings of International Symposium on Problematic Soils, IS-TOHOKU 98, Sendai, 1998, Japan, pp. 33–36

Feldmeyer-Christe E and Küchler M (2002) Onze ans de dynamique de la vegetation dans une tourbiere soumise a un glissement de terrain. Botanica Helvetica 112, 103-120

Flaherty R (2016) Man dies in suspected landslide at wind farm in Co Sligo. Irish Times, 13/12/2013, https://www.irishtimes.com/news/crime-and-law/man-dies-in-suspected-landslide-at-wind-farm-in-co-sligo-1.2903750, accessed 19/07/2018

Hebib S (2001) Experimental investigation of the stabilisation of Irish peat, unpublished PhD thesis, Trinity College Dublin

Henderson S (2005) Effects of a landslide on the shellfish catches and water quality in Shetland. Fisheries Development Note No. 19, North Atlantic Fisheries College

Hobbs NB (1986) Mire morphology and the properties and behaviour of some British and foreign peats. Quarterly Journal of Engineering Geology, London, 1986, 19, pp. 7–80

Huat BBK, Prasad A, Asadi A and Kazemian S (2014) Geotechnics of organic soils and peat. Balkema, 269p

Irish Mirror (2020) Photos show massive mudslides in Leitrim after heavy flooding. https://www.irishmirror.ie/news/irish-news/mudslides-drumkeeran-leitrim-flooding-photos-22281581 accessed 01/09/2021

Irish News (2016) Major landslide sees 4,000 tonnes of bog close popular Galway tourist route. https://www.independent.ie/irish-news/major-landslide-sees-4000-tonnes-of-bog-close-popular-galway-tourist-route-34830435.html accessed 19/07/2018

Lindsay RA and Bragg OM (2004) Wind farms and blanket peat. A report on the Derrybrien bog slide. Derrybrien Development Cooperative Ltd, Galway, 149p

Long M (2005) Review of peat strength, peat characterisation and constitutive modelling of peat with reference to landslides. Studia Geotechnica et Mechanica, XXVII, 3-4, pp. 67–88

Mills AJ (2002) Peat slides: Morphology, Mechanisms and Recovery, unpublished PhD thesis, University of Durham

Mills AJ, Moore R, Carey JM and Trinder SK (2007) Recent landslide impacts in Scotland: possible evidence of climate change? In. McInnes, R. et al (Eds) Landslides and climate change: challenges and solutions, Proceedings of Conference, Isle of Wight, 2007

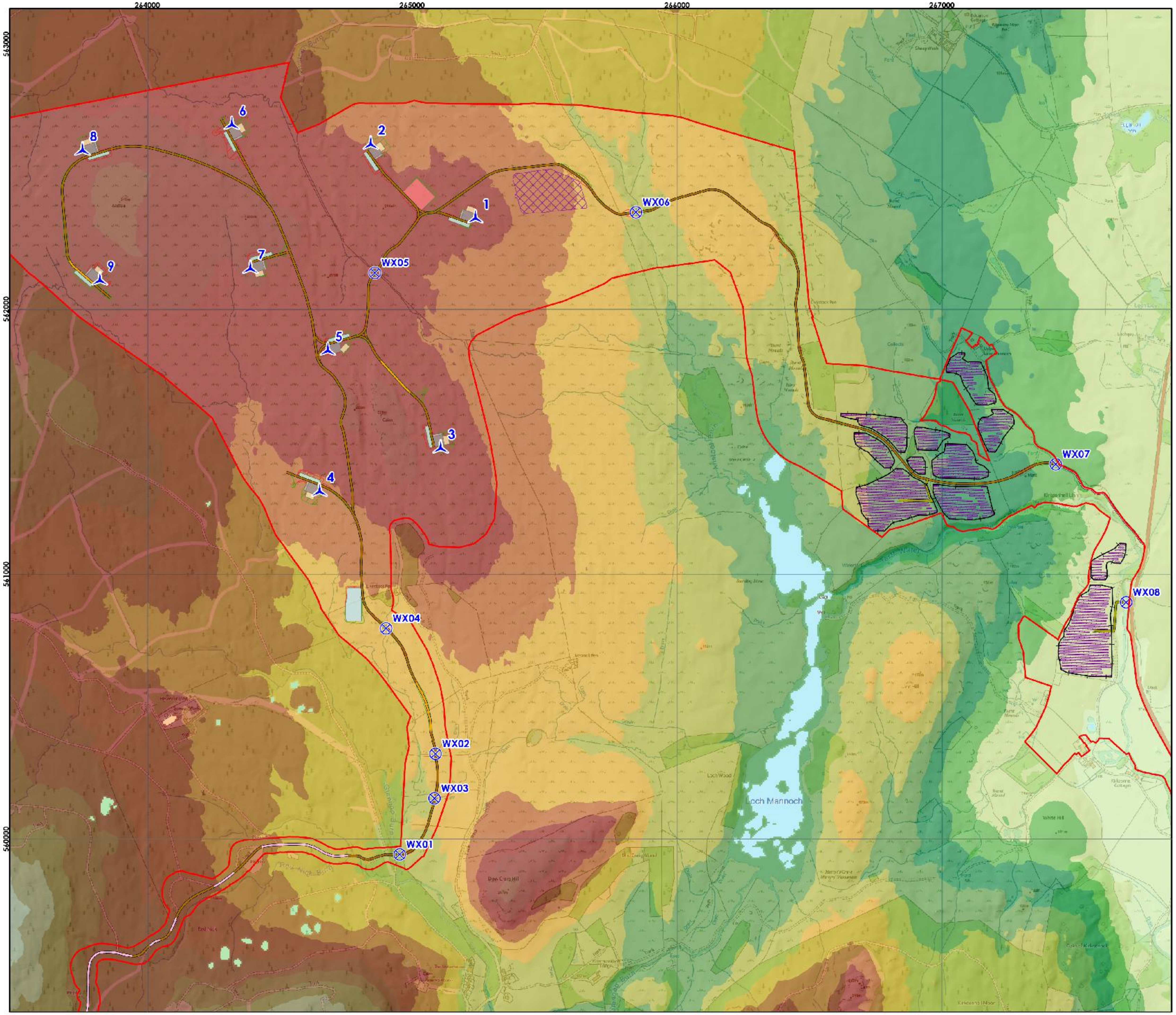
Scottish Government (2017) Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments (Second Edition). Scottish Government, 84p

The Anglo-Celt (2021) Hillwalker captures aftermath of landslide. https://www.anglocelt.ie/2021/07/22/hillwalker-captures-aftermath-of-landslide/ accessed 23/07/2021

The Shetland Times (2015) Mid Kame landslip on proposed windfarm site. http://www.shetlandtimes.co.uk/2015/10/30/mid-kame-landslip-on-proposed-windfarm-site accessed 19/07/2018

Warburton J, Higgitt D and Mills AJ (2003) Anatomy of a Pennine peat slide, Northern England. Earth Surface Processes and Landforms, 28, pp. 457-473

Warburton J, Holden J and Mills AJ (2004). Hydrological controls of surficial mass movements in peat. Earth Science Reviews, 67, pp. 139-156



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wind2

Figure 8.1.1 Elevation

Key

	Elevation (m)
Site Boundary	41 - 60
Watercourse Crossings	61 - 80
Turbines	81 - 100
Security fence	101 - 120
Access track - cut	121 - 140
Access track - floating	141 - 160
Access track - upgraded / widened	161 - 180
Access track - solar	181 - 200
Turbine foundation	201 - 220
Crane hardstanding	221 - 240
Auxiliary crane area	241 - 260
Tower storage	261 - 280
Blade storage	281 - 300
Substation and BESS	301 - 320
Construction compound	
Borrow Pit	
Solar panel	
Power Station	
Switching and Breaking Station	
Earthworks - fill	
Earthworks - cut	

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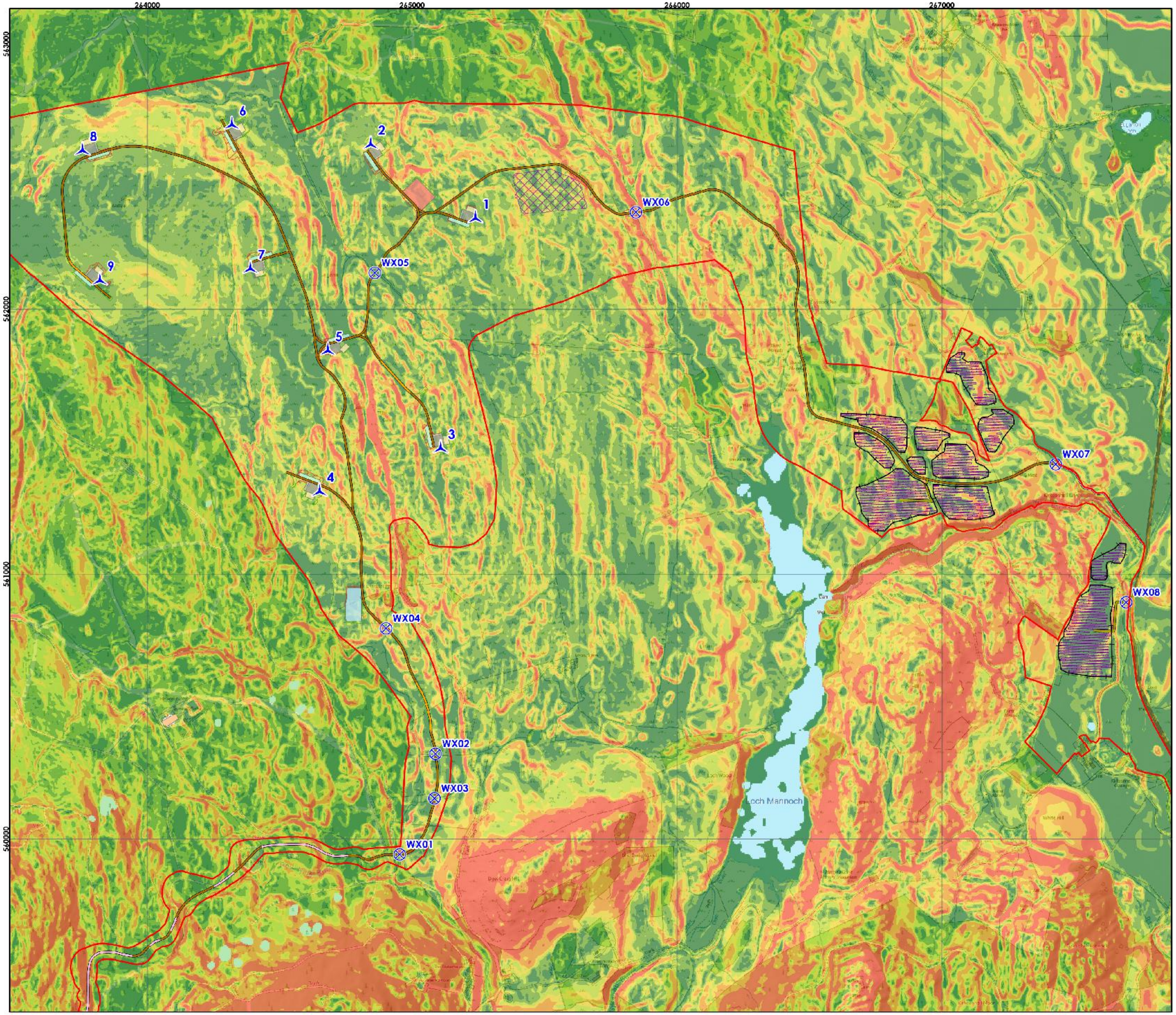

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Figure 8.1.2 Slope

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxiliary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut

Slope (°)

- 0.0 - 2.5
- 2.5 - 5.0
- 5.0 - 7.5
- 7.5 - 10.0
- 10.0 - 15.0
- > 15.0

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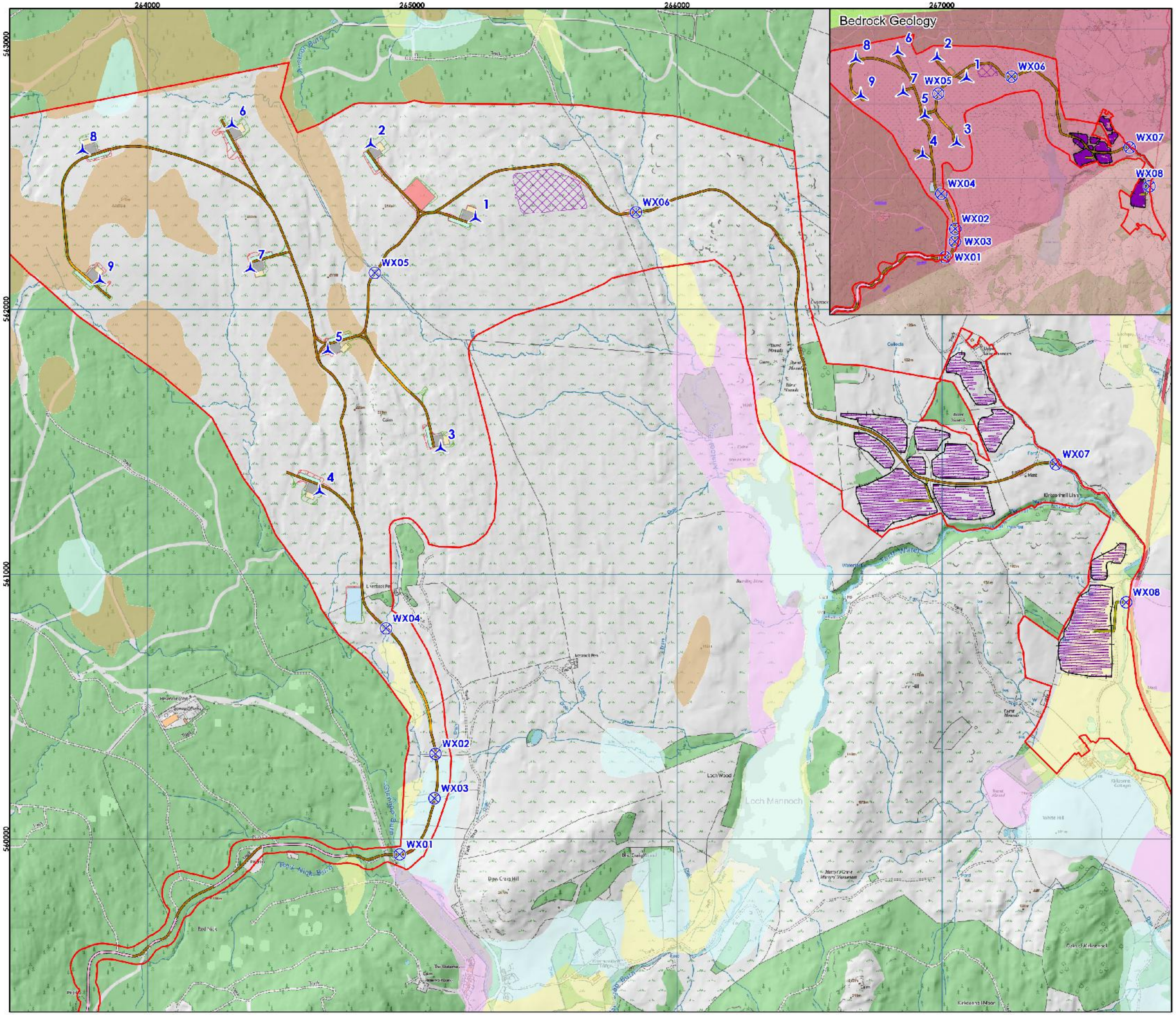

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Figure 8.1.3 Geology

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - Floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxiliary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut

Superficial Geology

- Alluvium - Clay, silt, sand and gravel
- No Deposits
- Peat
- Till, Devensian - Diamicton
- Glaciofluvial Deposits - Gravel, Sand and Silt
- Sediment

Bedrock Geology (Inset)

- Cairnharrow Formation - Wacke
- Gala Unit 7 - Wacke
- Kirkmaiden Formation - Wacke
- Moffat Shale Group - Mudstone
- North Britain Siluro-Devonian Calc-Alkaline Dyke Suite - Microdiorite, Porphritic

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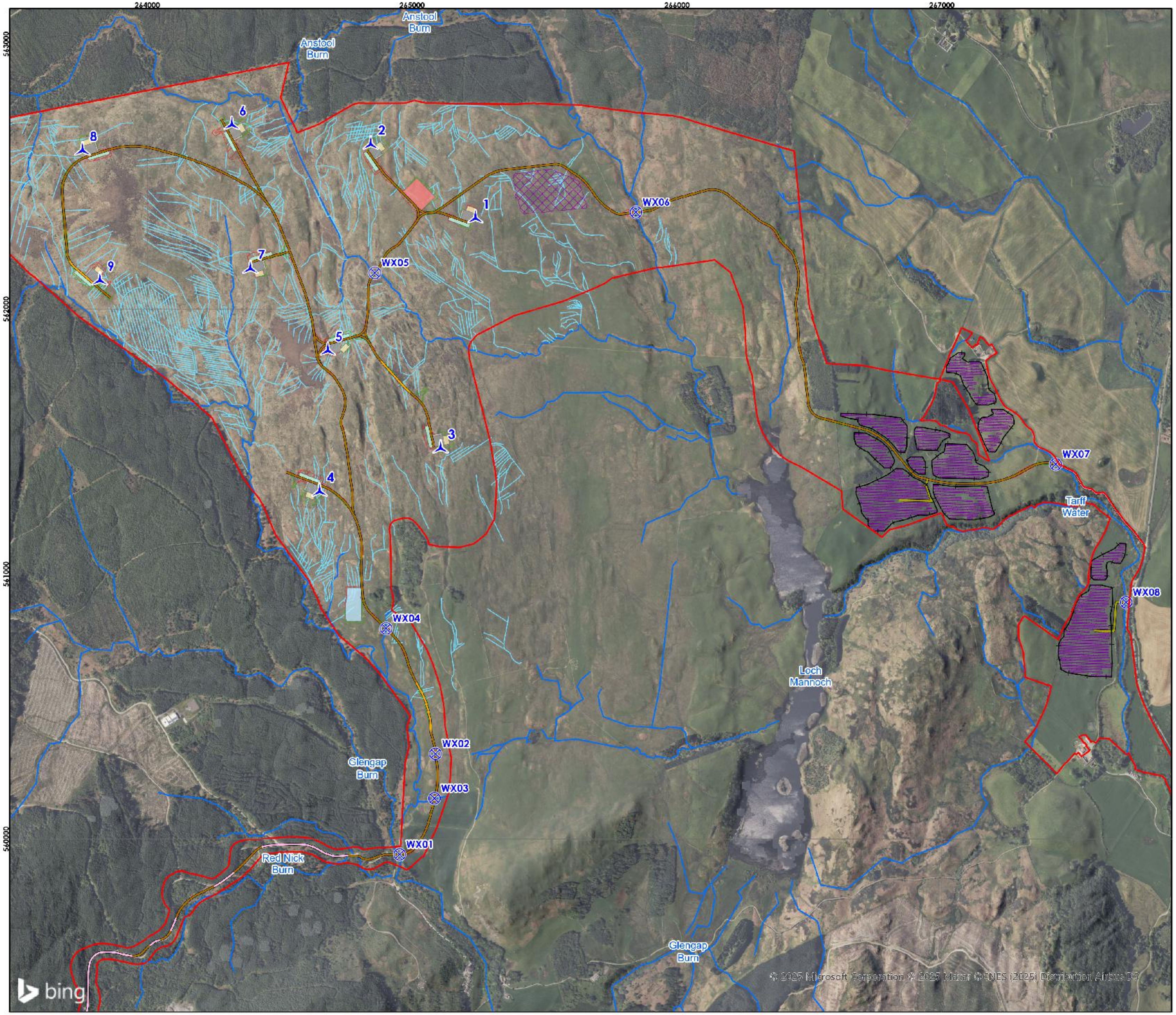

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Figure 8.1.4 Hydrology

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxiliary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut

Hydrology
- Drains
- Watercourses

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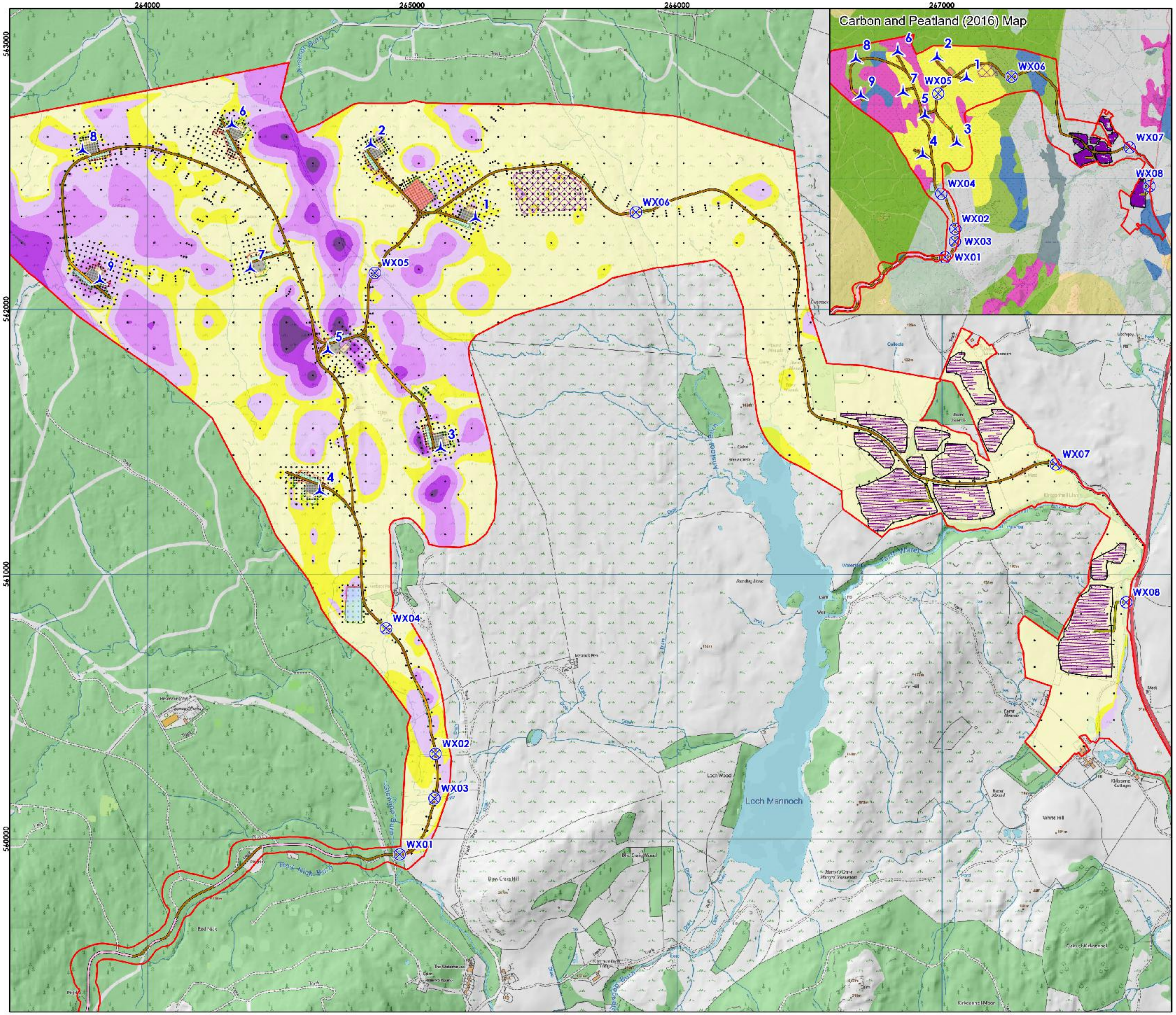

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Figure 8.1.5 Peat Depth

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxillary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut

Peat Depth (m)

- <= 0.35
- >0.35 - 0.50
- >0.50 - 1.00
- >1.00 - 2.00
- >2.00 - 3.00
- >3.00 - 4.00
- Probe Locations

Carbon and Peatland (2016) Map (Inset)

- Class 1
- Class 2
- Class 3
- Class 4
- Class 5
- Mineral Soil
- Unknown Soil
- Non Soil

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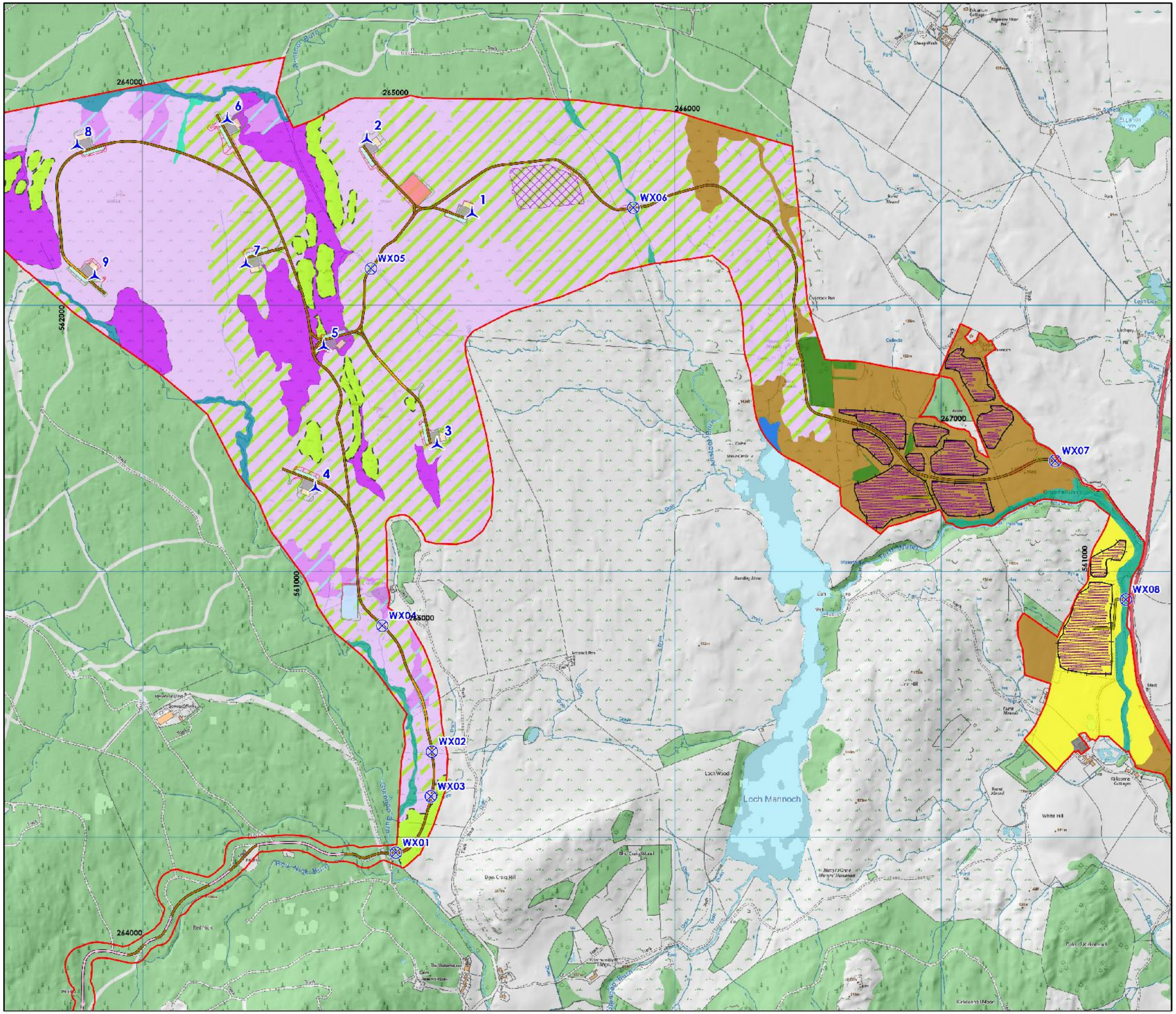

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Figure 8.1.6 Geomorphology and Land Use

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxiliary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut

Geomorphology and Land Use

- Thin peat/soil over bedrock
- Patchy peat / soil over bedrock
- Planar peat basins
- Linear drainage
- Planar (peat / soil)
- Flush
- Drainage pathway
- River valley
- Water body
- Planar hillside
- Forestry
- Undulating hillside
- Made ground

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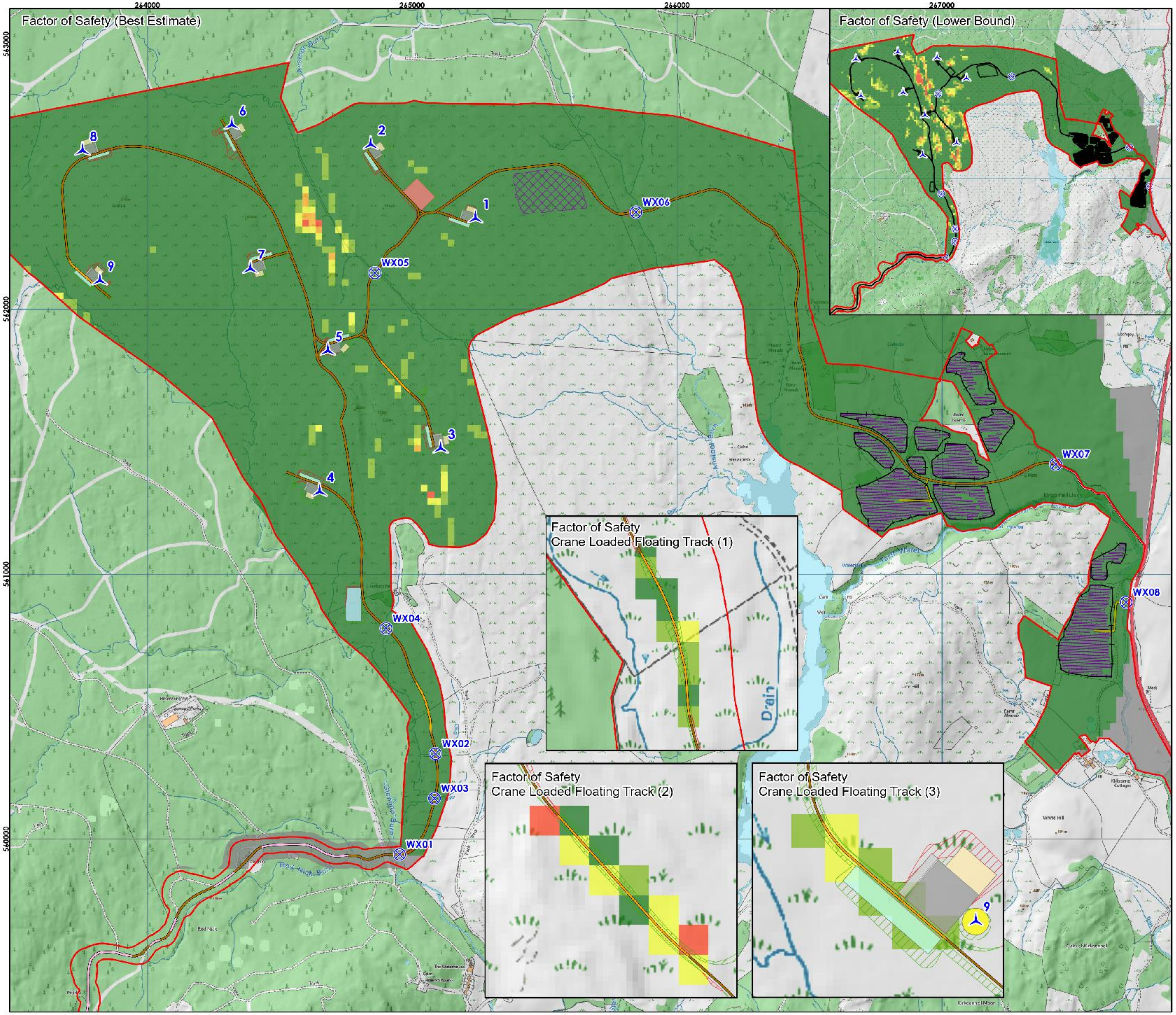

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Figure 8.1.7 Factor of Safety

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxillary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut

Factor of Safety

- < 1.00 'Unstable'
- 1.01 - 1.40 'Marginally Stable'
- 1.41 - 2.00 'Stable'
- 2.01 - 3.00 'Stable'
- > 3.01 'Stable'
- No Calculation

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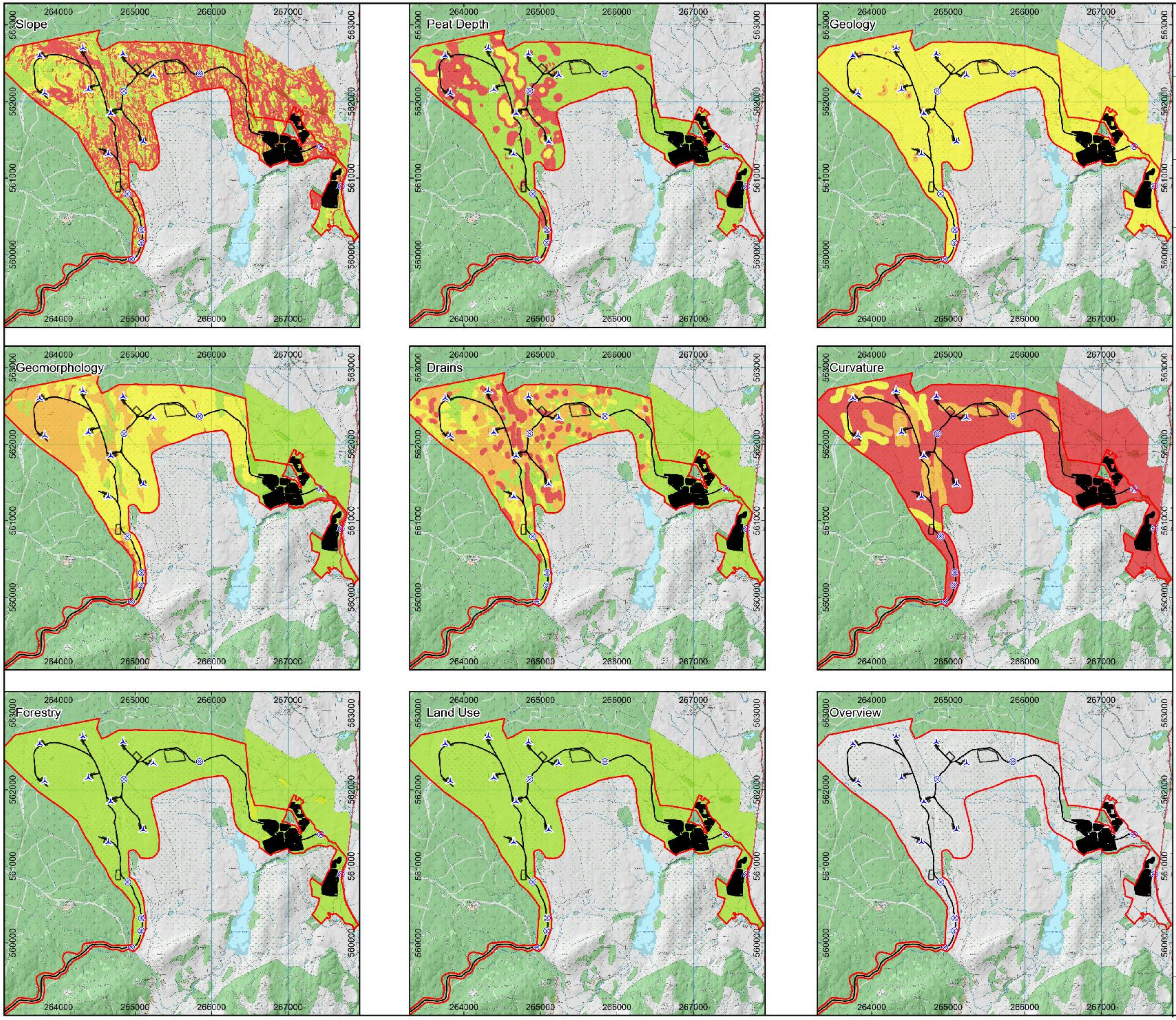
Figure 8.1.8 Contributory Factors



Key

- Site Boundary
- Turbines
- Infrastructure

Contributory Factor Score

- 0
- 1
- 2
- 3

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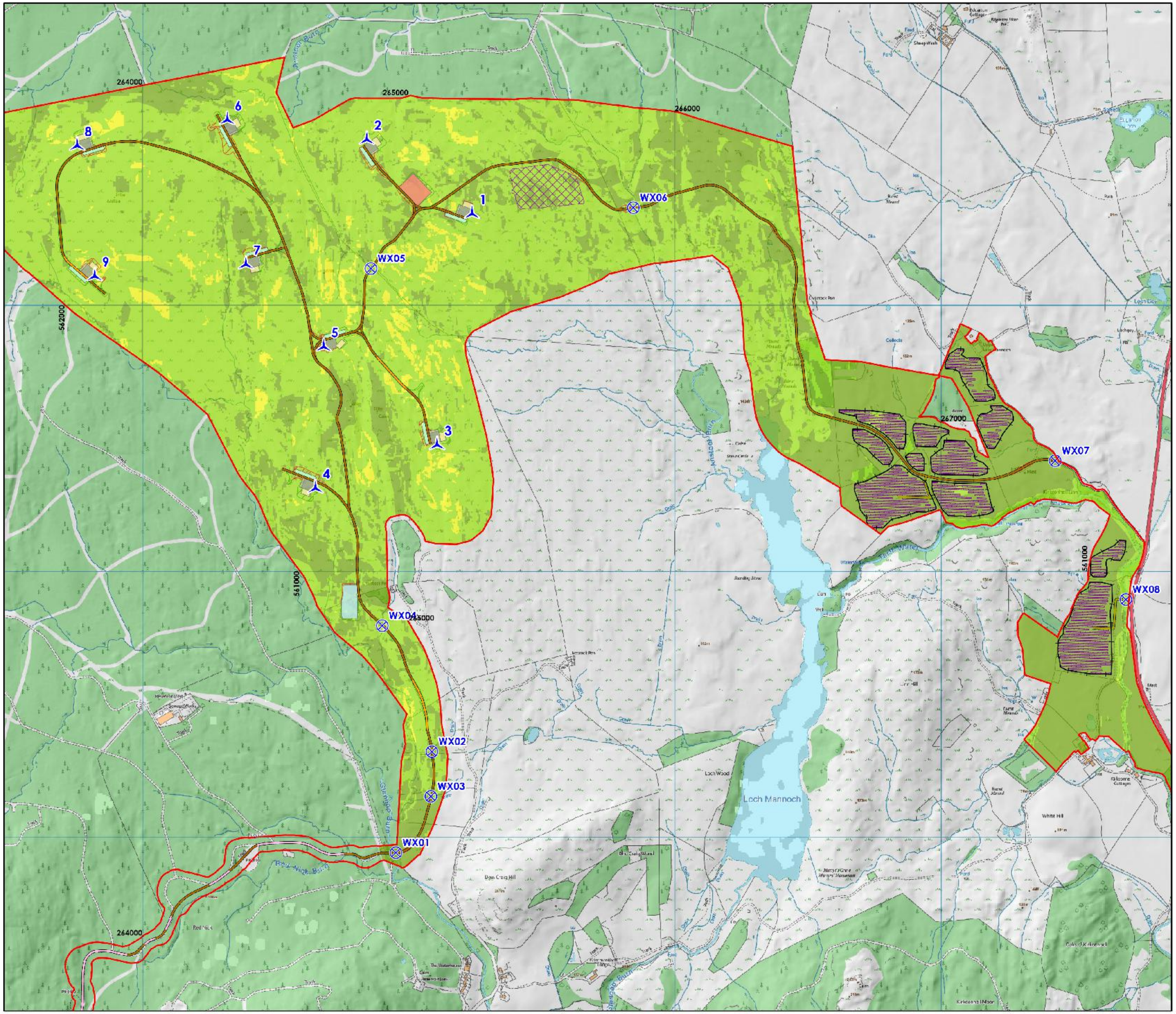

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Figure 8.1.9 Landslide Likelihood

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxiliary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut

Landslide Likelihood

- Very Low
- Low
- Moderate
- High (none calculated)
- Very High (none calculated)

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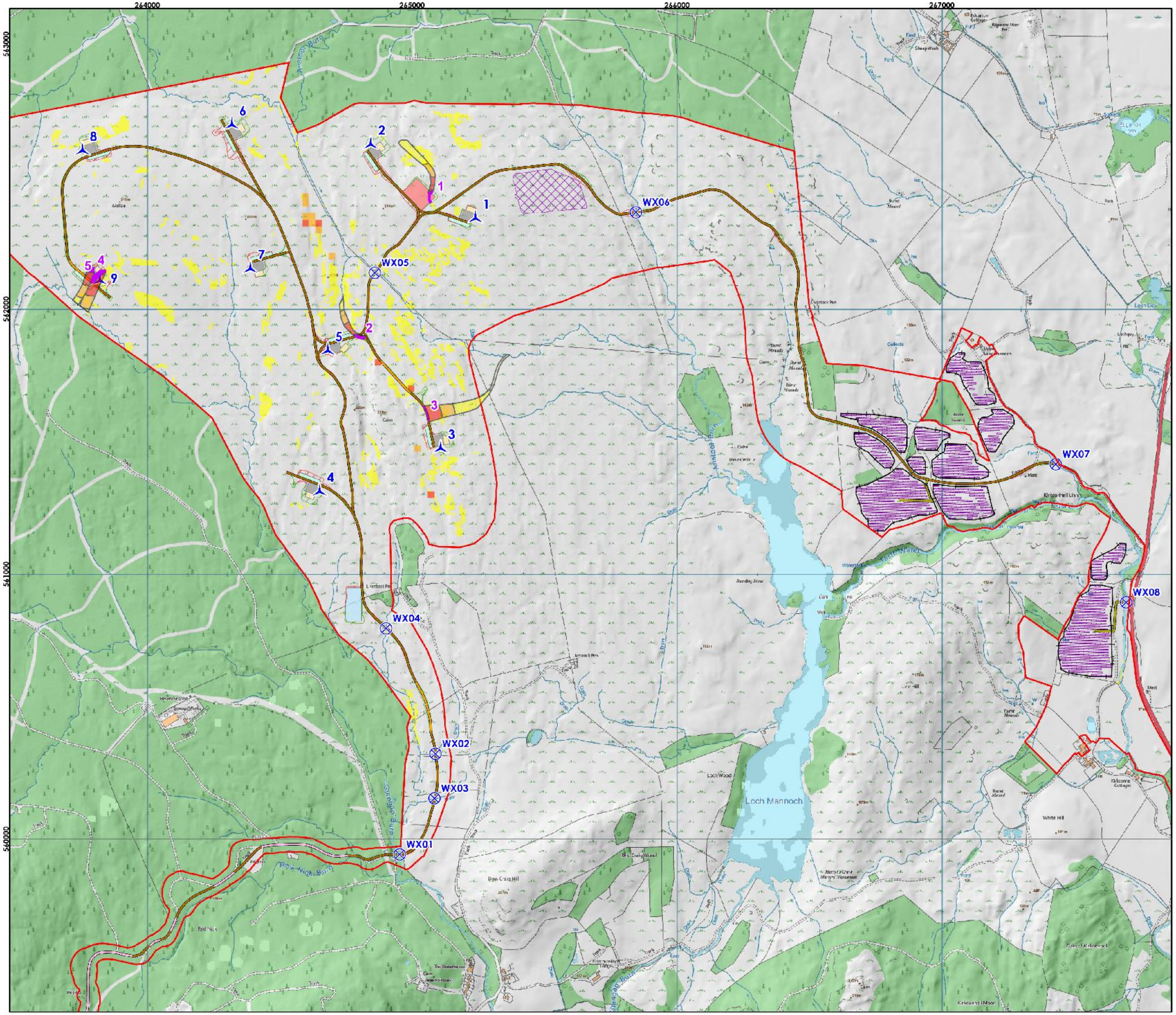
0 500 1,000 2,000 Metres

N

Scale @ A3: 1:13,500

Date of edit: 23/04/2025	Turbine layout: Rev10	Drawing number: 01
Drawn by: RH	Checked by: AM	Approved by:



Lairdmannoch Energy Park

wind2

Figure 8.1.10 Source and Runout Zones

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - Floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxiliary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut
- Source Zones

Runout Zones

Distance [m]

- 50
- 100
- 250
- 500

Landslide Likelihood

- Moderate
- High (none calculated)
- Very High (none calculated)

Factor of Safety

- < 1.00 'Unstable'
- 1.01 - 1.40 'Marginally Stable'

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0 500 1,000 2,000

Metres

N

Scale @ A3: 1:13,500

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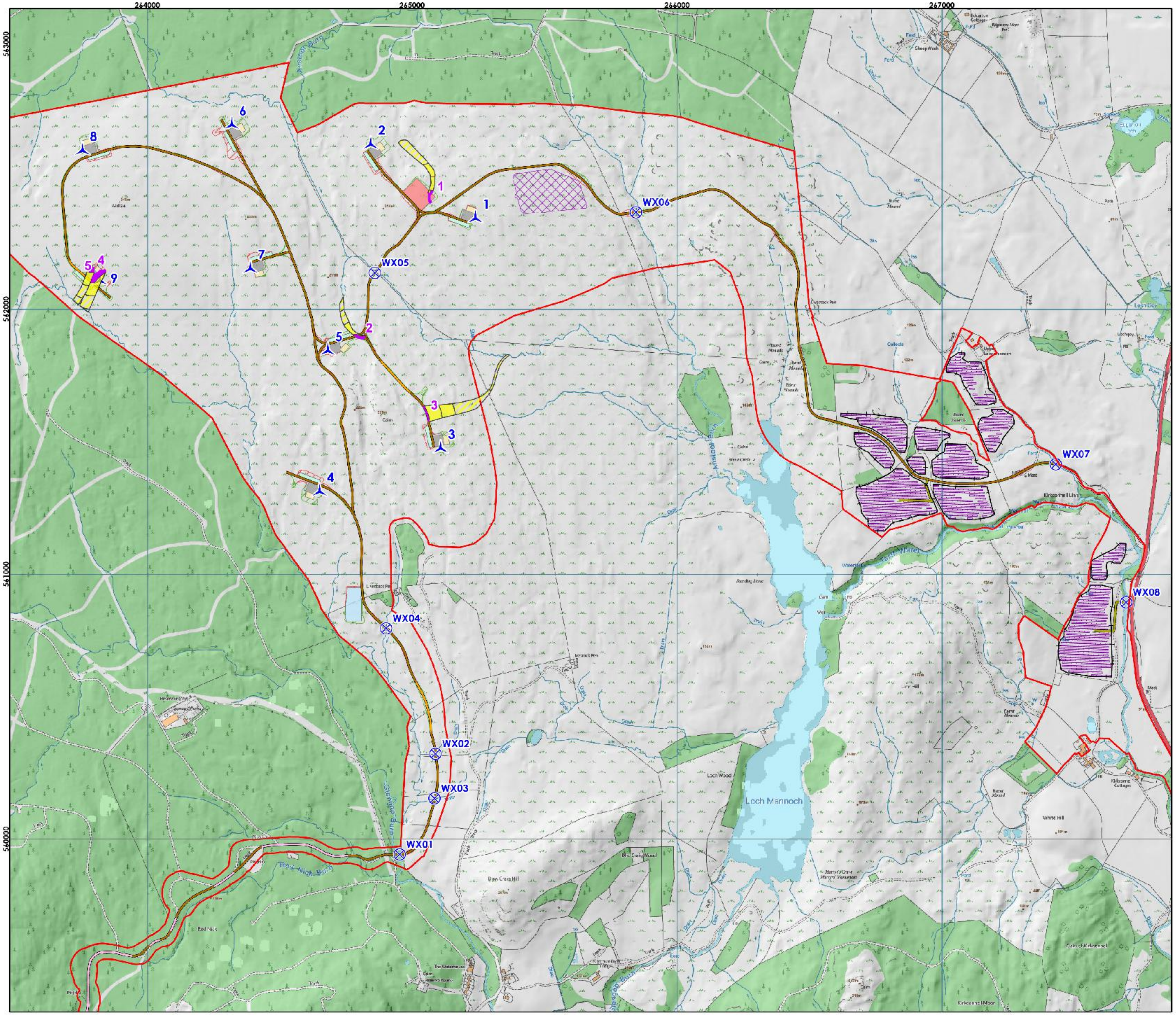

Lairdmannoch Energy Park

wind2

Figure 8.1.11 Calculated Risk

Key

- Site Boundary
- Turbines
- Watercourse Crossings
- Security fence
- Access track - cut
- Access track - floating
- Access track - upgraded / widened
- Access track - solar
- Turbine foundation
- Crane hardstanding
- Auxiliary crane area
- Tower storage
- Blade storage
- Substation and BESS
- Construction compound
- Borrow Pit
- Solar panel
- Power Station
- Switching and Breaking Station
- Earthworks - fill
- Earthworks - cut
- Source Zones

Calculated Risk

- Low
- Low (Limited)

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0 500 1,000 2,000

Metres

N

Scale @ A3: 1:13,500

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