Appendix 6.1

Peat Landslide Hazard and Risk Assessment

Table of Contents

List of Figures

1 Peat Landslide Hazard and Risk Assessment

1.1 Introduction

1. This report forms an appendix to Chapter 6: Hydrology, Hydrogeology, Geology and Soils of the Environmental Impact Assessment Report (EIAR) and should be read with reference to this chapter and associated figures.

2. The Proposed Development comprises up to 13 wind turbines and associated proposed infrastructure including access tracks, borrow pits and temporary construction compounds. The Proposed Development is located approximately 6 kilometres (km) south of Straiton, entirely within the South Ayrshire Council area, and is described fully in **Chapter 4: Development Description** of the EIAR. The Site consists mainly of commercial conifer plantation, with clear-felled areas predominantly in the east. Peat is recorded throughout the Site. The Study Area is defined as the peat depth grid, which was cropped to limit data to that within 250 metres (m) of the Site Boundary, expanded beyond this where peat probing data was available, this dataset includes all proposed infrastructure and also peat survey data collated from earlier design iterations, including data gathered upslope and downslope of locations of concern.

3. There are a number of existing forestry tracks within the Site due to current forestry land use, which have been utilised where possible to minimise environmental effect for the Proposed Development.

4. Under the Electricity Act 1989, Section 36, where the development of windfarms or overhead transmission lines electricity infrastructure may impact on peat, developers are required to submit a peat landslide hazard risk assessment. The Scottish Government developed a Guidance (Scottish Government, 2017b) to provide best practice information on methods for identifying, mitigating and managing peat landslide hazards and their associated risks. This Guidance has been used for this assessment.

5. WSP was commissioned in 2020 to undertake a peat stability assessment (PSA), also known as a Peat Landslide Hazard and Risk Assessment (PLHRA), for the Proposed Development, in conjunction with the soil and water elements of the EIAR. The qualifications and experience of the team is stated in **Section 1.10**.

6. This document presents WSP's method for peat stability assessment, the analyses performed and results obtained.

1.1.1 Aims

7. The broad aims of this assessment were to:

- provide a good level of understanding of site baseline (pre-development) peat stability conditions;
- aid the development design in order to reduce development activities that could cause an increased likelihood of peat stability, by careful consideration of infrastructure location and also construction techniques employed;
- identify the receptors that would be subject to adverse consequences, should a peatslide occur; and
- report peat stability risk assessment outcomes of the final design following the principles of the PLHRA: Best Practice Guide for Proposed Electricity Generation Developments (Scottish Government, 2017b).

1.1.2 Methods

8. The methods adopted by WSP for the PSA of the Proposed Development has involved the following stages:

- desk study review of peat stability literature and available site data;
- aerial photography review;
- site reconnaissance including peat depth survey to characterise the prevailing ground conditions and identify existing or potential peat instability;
- Ground Investigation (GI) at specific locations of concern to provide additional data;
- initial stability analysis to identify likelihood, using a purposefully cautious factor of safety (FoS) method;
- identification of receptors;
- initial risk assessment undertaken to identify locations of concern ('Moderate' or 'High' initial risk level);
- revised risk assessment based on additional site information and visits to locations of concern, presented as datasheets detailing local characteristics and appropriate mitigation for specific locations of concern; and
- summarising key findings, including appropriate recommendations for further investigations at later stages of the development, subject to planning consent.

9. The PSA applied a phased approach, with findings at each phase feeding into the iterative design process and associated Environmental Impact Assessment (EIA). This included gathering further site information as the design progressed and revising stability calculations using the best information available.

10. Further detail on each of these stages is provided in the following sections, with Geographical Information System (GIS) software employed to manage and identify relationships between the various spatial datasets.

11. Figures have been provided that demonstrate the data available and analysis undertaken within this assessment, as **Figures 6.1.1** to **6.1.14**.

1.2 Desk Study

1.2.1 Literature Review of Peat Stability

12. Peat is a soft to very soft, highly compressible and highly porous organic material which can consist of up to 90% water by volume. Scottish Government guidance defines peat as a soil with a surface organic layer greater than 0.5m depth, which has an organic matter content of more than 60%. Unmodified peat typically has two layers:

- acrotelm (surface layer) - often around 0.3 m) thick (but can vary widely in depth depending on local conditions), highly permeable and receptive to rainfall. It generally has a high proportion of fibrous material and often forms a crust under dry conditions; and
- catotelm (base layer) – in deeper peat deposits, this layer lies beneath the acrotelm and forms a stable colloidal substance which is generally impermeable. As a result, the catotelm usually remains saturated with little groundwater flow. A sub-division in catotelmic peat may occur, but is not always present, with fibrous catotelmic peat above amorphous catotelmic peat. Amorphous catotelmic peat is characterised as highly decomposed plant matter, with low structural integrity and may act as a liquid in terms of physical or geotechnical qualities, with associated challenges in terms of excavation, handling and storage.

13. The peat on the Site, where present, is predominantly characterised as blanket peat and peaty podzols (with associated habitat known blanket bog communities, wet heathland and rough grassland communities). Blanket peat tends to be formed in areas with high rainfall and low temperatures. In the Scottish context, blanket peat can be over 5m in depth, especially in hollows or valleys, but is generally much less. Peaty podzols are characteristic of any topographic position where aerobic conditions prevail and water can percolate freely through the upper part of the profile. Podzols are formed in acid, coarse textured, well drained materials. Blanket peat is the most common form of peat in Scotland, podzols are widespread throughout Scotland.

14. Peat is thixotropic, meaning that its viscosity decreases under applied stress. This property may be considered less important where the peat has been modified through artificial drainage and is drier but can be an important factor when the peat body is saturated and is an important issue to consider in relation to potential peat stability failures.

15. Peat movements can be small-scale or large-scale. Small-scale movements include slope terracing, slumps, collapse of peat banks and collapses above peat pipe features. These small-scale events are relatively widespread in peatland environments and have limited consequences to receptors, although they do provide useful indicators of peatland morphology and processes which may influence large-scale peat instability.

16. A series of large scale (mass movement) peat events in autumn 2003, including at Derrybrien in the Republic of Ireland, and Dooncanton in South Shetland, Scotland, led to an increased recognition of the mass movement hazard, particularly in relation to development design and construction of windfarm projects on peatland. This led to Scottish Government Guidance for energy developments being published in 2006 and updated in 2017 (Scottish Government, 2017b) to assess development risk of peat landslide. More recently, in November 2020 a mass movement of peat was recorded and widely reported at Meenbog Windfarm, in County Donegal, Republic of Ireland.

17. Peat mass movement events have been classified by geomorphologists (Dykes & Warburton, 2007), within a Scottish context the primary processes of concern are peat landslides and peaty debris slides, with limited evidence of historic bog bursts and other phenomena. These features are defined below:

- peat landslide – failure of a blanket bog slope, involving intact peat material shearing and sliding along at, or immediately above, the interface with underlying mineral soil, bedrock or boulder clay substrate (Dykes & Warburton, 2007). The peat above the shear plane generally initially moves as an intact mass, then breaks into smaller pieces and may then act as a liquid flow and follow drainage routes until material has been deposited (Boylan *et al*., 2008); and
- peaty debris slides - shallow translational failure of a slope, often on very steep gradients, with the failure zone occurring wholly in mineral soil substrate below a shallow organic soil surface layer which may be less than 0.5m depth. Surface peat is sheared and displaced due to failure of underlying material, rather than inherent peat instability (Dykes & Warburton, 2007).

18. In comparison with other peat mass movement phenomena described by Dykes & Warburton (2007), peat landslides and peaty debris slides typically involve lower volumes of material, estimated as 500 - 50,000m^3, with estimated velocities of 0.1 – 5.0m/s for peat landslides and 0.1 - >10.0m/s for peaty debris slides.

19. Peatland characteristics that may initially suggest a higher likelihood of peat mass movement, i.e. pre-disposition, include:

- increasing depth of peat;
- increasing slope angle;
- the presence of amorphous peat (well humified/decomposed); with less structural integrity and cohesion to remain on slope;
- convex slopes; instability may occur at or immediately downhill of the ‘break of slope’, often at the interface of deeper peat on a lower slope angle plateau or ridge; and
- waterlogged peat conditions; providing extra weight upon slope and lubricating transition zone/basal surface between peat and underlying materials, such as clay, mineral soil or bedrock.

20. Specific conditions that are generally recognised as triggers for mass movement of peat include:

- removal of slope support; reduces slope stability by natural or anthropogenic removal of support material below peat body. Could also be caused by decreased strength of slope materials on a temporal basis;
- additional loading of slope; reduction in slope stability due to increasing of mass of slope above the peat body. This could be a result of development design or ancillary activities such as stockpiling of materials or heavy plant movement;
- alteration to drainage patterns; increasing the mass of the peat body and lubricating the transition zone, potentially also increasing pore-water pressure at base of peat body. Can be a particular concern when intense rainfall follows a prolonged dry period, as fissures in peat body may enable rapid ingress to the transition zone. Prolonged wet periods in autumn and winter months in Ireland are considered as having a greater probability for peatslide events (Boylan *et al*., 2008) and seasonal accumulation of snow may also be a factor, in terms of both weight and snowmelt input; and
- vibration; construction activities such as piling, stockpiling of materials or traffic, including heavy plant, movement. Potentially also caused by earth movement at susceptible geological locations.

21. Examples of mass peat instability can occur involving peat of less than 1.0m depth and on relatively low gradient slopes (<5°), where appropriate combinations of conditions occur. Where depths are relatively shallow and gradients relatively shallow, events may be expected to be more limited in terms of area, volume of material and run-out distance. Peatslide events often commence on a susceptible slope and then follow drainage pathways downslope, with sediment release into such receptors.

22. There are a number of geotechnical variables in relation to peat properties. Those applicable to the FoS stability methodology applied by WSP are detailed below. The FoS calculation and method is discussed further in **Section 1.4** of this report. These variables include both site data and values based on academic literature. Where using literature values, conservative values are typically applied as a precautionary approach, which can then be potentially refined where there is justification to do so from further site information:

- depth of peat - measured onsite, to full depth with an accuracy of +/- 0.05m;
- slope angle – measured using site Digital Terrain Model (DTM) data at 5m resolution, for both peat probes and using mean values for grid cells;
- shear strength of peat – shallow shear vane tests were undertaken onsite as part of the detailed assessment, but fibre content in peat is likely to over-estimate results and data was not available from base of peat body. Literature values suggest an expected pressure (expressed as force per area) range between 4 - 20kN/m^2 (Boylan *et al*., 2008), with higher values for less humified/decomposed peat;
- cohesive strength of peat – back-calculated using site-specific data using a 99th percentile value from the site depth data, this parameter largely dictates the shear strength of the peat in the FoS calculation. As above, literature values of shear strength suggest a range between 4 - 20kN/m^2 (Boylan *et al*., 2008);
- undrained bulk density of peat – values for *in situ* peat range from 900 - 1300kg/m^3 quoted in various papers and reports, with a typical value of 1,000kg/m^3 (1.0Mg/m^3) referenced in a number of papers (Dykes, 2006 & Boylan *et al*., 2008).
- bulk density of water – Standard scientific value of 1,000kg/m^3;
- water table depth as ratio of peat depth – a value of 1 represents water level being constantly at surface, this is conservative as the water level will vary temporally and geographically across the Site, often dropping below ground level; and
- angle of internal friction – this is a difficult item to generalise with variables present in peat (particularly fibre content and water content), a lower angle is more susceptible to movement on a slope. At ‘quaking bog’ locations, where the peat takes the form of a slurry beneath a surface mat of vegetation, the angle of internal friction will be very low (less than 5°) as the peat will effectively act as a fluid, however peat values of up to 58° are quoted in literature (Boylan *et al*., 2008).

23. It is important to note that there are a number of limitations and concerns with regard to use of *in situ* shallow shear vane testing of peat and peaty soils, including the presence and orientation of fibres (e.g. vegetation matter) which may lead to an over-estimation of shear strength and that shear vane results from greater depth would be anticipated to record lower shear strength, due to higher level of decomposition and associated loss of structural integrity. The degree of peat decomposition, i.e. classified via Von Post, is considered to be a better practical indicator of shallow shear strength for peat bodies. However, it is considered that shallow shear vane data can provide useful data to enable comparison of different locations across a project area.

24. The Von Post classification system is a field-based method for characterising the level of peat humification/decomposition across 10 classes, with H1 categorised as completely undecomposed peat and H10 categorised as completely decomposed peat. Amorphous catotelmic peat is generally considered to be classified as H6 - H10, i.e. strongly decomposed or greater on this scale (Scottish Government, 2017a).

25. There are a number of recognised indicators that may occur in advance of mass peat instability, with the factors below particularly applicable to low velocity peatslides:

- the development of tension fracture cracking across the slope or in semi-circular patterns, particularly if these reach to base of peat;
- boggy ground or new springs appearing at the base of slopes;
- sudden reactivation of spring lines;
- peat creep or compression features, such as bulging of ground;

- displacement and leaning of trees, fence posts, dykes etc.; and
- breaking of underground services.

1.2.2 Information Sources

26. A desk study was undertaken, reviewing available information on the ground conditions within the Site; sources included:

- Ordnance Survey (OS) digital raster mapping, 1:50,000 and 1:25,000 scale;
- OS Historical mapping, 1:25,000 scale;
- OS Terrain 5 DTM data (5m resolution);
- British Geological Survey DiGMap-GB 1:50,000 digital geological mapping, bedrock, superficial and linear geology;
- British Geology Survey GeoSure Landslide Hazards dataset 1:50,000 digital mapping;
- British Geological Survey Hydrogeological Map of Scotland, 1:625,000 scale;
- James Hutton Institute Soil Maps of Scotland, 1:250,000 scale;
- James Hutton Institute Land Capability for Agriculture in Scotland;
- Aerial Imagery via Bing Aerial https://www.bing.com/maps/aerial, with this image also available via https://zoom.earth/#view=55.25042,-4.567607,14z/layers=esri (June 2018 image date);
- Aerial Imagery via ESRI World Imagery, embedded in ArcGIS software - https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9 (December 2009 image date, approximate); and
- Soil Survey of Scotland 1:250,000 Sheet 6 South-West Scotland, mapping of soil types.

1.2.3 Site Context

27. The Proposed Development is located approximately 6km south of Straiton, entirely within the South Ayrshire Council area. The Site consists mainly of commercial conifer plantation, with clear-felled areas predominantly in the east. There are a number of existing forestry tracks. Peat is present within the forestry as well as in open areas, such as forestry rides, clearings and in the vicinity of surface water bodies.

28. Elevation of the Site undulates, reaching a peak at Garleffin Fell, 430m above ordnance datum (AOD). There are a number of watercourses which are situated within or border the Site, with the majority of the Site within the Water of Girvan and the River Stinchar catchments. Further geomorphology and hydrology information is provided within **Chapter 6: Hydrology, Hydrogeology, Geology and Soils** of the EIAR.

29. There are two Site access points from the C46W public road. The northern access is located south of Tallaminnoch, approximately 9.0km south of Straiton. The southern Site access is approximately 800m south of the northern Site access. Both Site access then utilise a combination of existing forestry tracks and new access tracks. Existing forestry tracks shall require upgrade and widening. There will be a requirement for a network of new access tracks to be created within the Proposed Development to service the proposed infrastructure. These are shown on **Figure 6.1.1 Bedrock Geology** and **Figure 4.1 Site Layout** of the EIAR.

30. From the C46W public road, the access track extends to the west, through an area of forestry before reaching a junction north of Stob Hill. From this junction, there is an access track south into the south-eastern section of the Site where wind turbines 11 and 13 and the main temporary construction compound are located. The majority of this south-eastern region of the Site comprises forestry plantation, with some open land in the vicinity of the Tairlaw Burn. Slope gradients are mostly gentle, with some steeper slopes within the Stob Hill. The Tairlaw Burn drains this section of the Site and is crossed by the existing forestry track.

31. West of the Stob Hill junction, the existing forestry track continues west through areas of standing forestry and clear-felled areas, with some new access track proposed to link into a number of the wind turbines, the wind turbines in the western section of the Site are on higher ground. Slope gradients are mostly gentle, with steeper slopes east of wind turbine 2. This area is drained by the Palmullan Burn tributaries. The access track to wind turbine 4 crosses a number of Dalquhairn Burn tributaries in the south west of the Site.

1.2.4 Baseline Conditions

32. Baseline conditions in the Site are discussed in detail within **Chapter 6: Hydrology, Hydrogeology, Geology and Soils** of the EIAR. This chapter should be referred to for this information.

33. **Appendix 6.2 Soil and Peat Management Plan** of the EIAR includes details of peat depths at various infrastructure locations and an analysis of the potential locations where the more sensitive amorphous catotelmic peat may be anticipated.

34. Cross-sections of Site topography showing proposed infrastructure and Site photographs have been provided in **Chapter 6: Hydrology, Hydrogeology, Geology and Soils** of the EIAR.

1.2.4.1 Geology and Hydrology

35. Baseline information for geology and hydrology is provided in **Chapter 6: Hydrology, Hydrogeology, Geology and Soils** of the EIAR.

36. Bedrock geology, superficial deposits (superficial geology) and hydrology features are presented on **Figure 6.1.1 Bedrock Geology**, **Figure 6.1.2 Superficial Geology** and **Figure 6.1.3 Hydrology Overview**, respectively.

37. The distribution of rainfall is provided in **Chapter 6: Hydrology, Hydrogeology, Geology and Soils**, however, it is considered that extreme rainfall events are more likely triggers for mass peat instability, as identified in **Section 1.2**. Such events can occur at any time of year, although those occurring after prolonged dry periods may introduce higher risk as dry peat conditions may be more vulnerable to water ingress to base.

38. Drains are present in areas of afforestation, including clear-fell locations, these have not been mapped for the Proposed Development, with OS 1:10,000 mapped channels used in GIS and discussed during the assessment. Local drainage channels would be anticipated to reduce slope soil moisture content and reduce mass of peat; however, it is acknowledged that cut drainage channels could remove slope support (if located mid-slope or at base of slope). Drainage discharge locations can exacerbate erosion processes if flows converge at sensitive locations.

39. With much of the Site being subject to afforestation, some of which subsequently felled, the current ground conditions are heavily influenced by forestry practices (particularly drainage and ploughing). Post-felling, stumps and roots have typically been retained *in situ*, potentially acting as limiting factors in terms of potential instability occurrence and also the extent of any mass movement if it were to occur.

1.2.4.2 Carbon Rich Soils, Deep Peat and Priority Peatland Habitats

40. The Carbon and Peatland Map (Scottish Natural Heritage (SNH[1], 2016), a GIS vector dataset covering Scotland, presents the importance of these environmental interests. They have been derived using a matrix of soil carbon categories (derived from Soil Survey of Scotland maps) and peatland habitat types (derived from Land Cover of Scotland 1988 map).

41. With regard to Scottish Planning Policy 2014, carbon-rich soils, deep peat and priority peatland habitat importance categories 1 and 2 from the Carbon and Peatland Map are within Group 2 ('areas of significant protection'), where development should demonstrate that effects can be substantially overcome by siting, design or other mitigation.

[1] Now known as NatureScot.

42. The mapping indicates that approximately 0.3% of the Site is within Class 1 peat (SNH[2], 2016), located adjacent (east) of wind turbine 5 with the associated new access track encroaching on the periphery of this area. The mapping indicates that no Class 2 is identified within the Site (as shown within **Figure 6.4 Soils**).

43. Approximately 84.2% of the Site within Class 5, 5.4% within Class 0 and 0.1% within Class 3. These classes do not indicate peatland habitat. Class 5 predominates across the Site, with Class 0 in the vicinity of watercourses, typically where steeper slopes occur.

44. The outcomes of the more detailed peat survey, discussed below, provide site-specific peat depth information which supersedes the higher-level characterisation from the SNH Carbon and Peatland Map dataset. This more detailed peat information was used to inform the design of the layout of the Proposed Development and the subsequent assessment. Further information on peat management is provided in **Appendix 6.2 Soil and Peat Management Plan** of the EIAR.

1.2.4.3 Aerial Photography

45. The Bing Aerial imagery from 2018 and the earlier imagery from ArcGIS World Imagery show extensive afforestation over much of the Site and the network of existing forestry tracks, where trees have been clear-felled, evidence of modification to soil and peat from forestry-related ploughing and drainage activities can be readily observed. Existing quarries/borrow pits are also apparent, servicing the construction and maintenance of local forestry access tracks.

46. Aerial imagery was reviewed for features such as peat landslides, peaty debris slides, gully head failures and collapsing peat banks, with particular attention to areas within 100m of proposed infrastructure. No peat landslides, peaty debris slides nor gully head failures were noted on the Site.

47. There was some suspected evidence of fluvial erosion causing bank failure identified during the desk study, at a location 700m north of wind turbine 1, located outwith of the Site Boundary. Other fluvial erosion features may occur within the Site, given areas of steep slopes and high energy headwater channels.

48. Aerial Photography of the Site is provided as **Figure 6.1.4 Aerial Photography**.

1.2.4.4 GeoSure Landslide Hazards

49. GeoSure Landslide Susceptibility data from the British Geological Survey was entered into GIS and areas identified as being categorised as GeoSure Landslide Susceptibility Classes D or C were related to the Site and latterly to proposed infrastructure locations. The definitions for these classes are as follows:

- GeoSure Landslide Susceptibility Class D; slope instability problems are probably present or have occurred in the past. Land use should consider specifically the stability of the Site; and
- GeoSure Landslide Susceptibility Class C; slope instability problems may be present or anticipated. Site investigation should consider specifically the slope stability of the Site.

50. A number of proposed infrastructure locations were identified within the Site within or close to Class C zones. Wind turbine 4 is the nearest proposed infrastructure to any Class D zone, with the wind turbine located 180m north and upslope of a very small Class D zone, which is located outwith of the Site Boundary. Site visits were undertaken to verify peat instability features in close proximity to planned infrastructure.

51. The GeoSure hazard dataset has been incorporated alongside other geomorphology Site data collated and presented on **Figure 6.1.13 Geomorphology** and on datasheets provided in **Annex B**.

1.2.4.5 Historical Information

52. OS historical mapping was reviewed and identifies pre-forestry land use, likely to have been rough grazing. There was no evidence of peat instability using the OS Map 1937-61.

53. The GeoSure dataset alongside the aerial photography provided a useful indication of landslide or potential landslide locations. **Plate 6.1** displays Site aerial imagery with GeoSure data overlain.

54. No evidence of slope instability was noted within or on the margins of the Site from mapping and aerial photography. During site visits, surveyors did not observe any evidence of previous peat instability, including previous modifications for forestry land use and associated access track construction corridors.

1.2.5 Forestry

55. The Forestry Study Area within the Site extends to approximately 3,867.3 hectares (ha) and is discussed in detail in **Appendix 13.1 Forestry** of the EIAR. Forestry is located across the whole Site. The forests are planted on blanket peat, peaty podzols and peaty gleys.

56. Felling is required for infrastructure and construction of the Proposed Development. Where possible the Proposed Development infrastructure will be "keyholed" into the crops, where only the crops required for the infrastructure and its associated buffer zones (i.e. for bats) will be cleared. Where this is not possible, the crops will be felled back to the nearest wind firm edge or management boundary and the Proposed Development infrastructure will be keyholed into the restocking. It is anticipated that construction of the Proposed Development would require approximately 223.48ha of commercial plantation woodland to be felled to facilitate construction works and installation of permanent features such as the wind turbines and access tracks; some of which would be subsequently restocked.

57. As a result of the construction of the Proposed Development, there would be a net loss of woodland area. The area of stocked woodland in the Site would decrease by approximately 97.42ha. In order to comply with the criteria of the Scottish Government's Control of Woodland Removal Policy offsite compensation planting would be required. The Applicant is committed to providing appropriate compensatory planting. The extent, location and composition of such planting would be agreed with Scottish Forestry.

58. In relation to impacts from felling in afforested peatlands, impacts may include water level rising post felling, peat cracking due to drying out of the surface peat, and drainage changes causing peat to dry and shrink (Lindsay & Bragg, 2004). This may cause peat to become more unstable and such areas require consideration in relation to the proposed infrastructure.

59. Some areas of the Site have been felled, with it likely that further felling will occur as per the existing Land Management Plan, as crop reaches maturity or for other forestry management requirements, regardless of the proposed application.

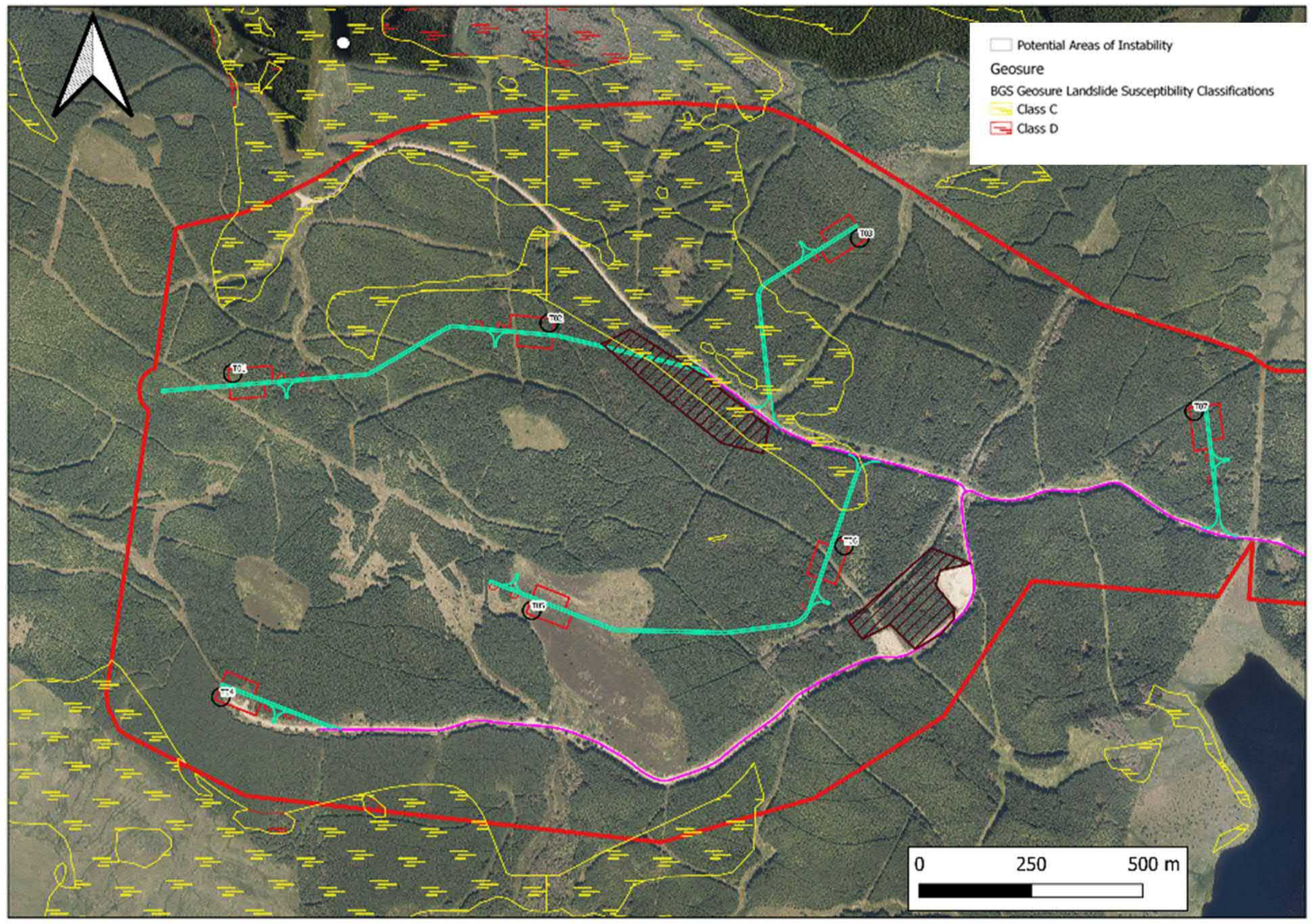


Plate 6.1 GeoSure and Aerial Image Data, Garleffin Fell

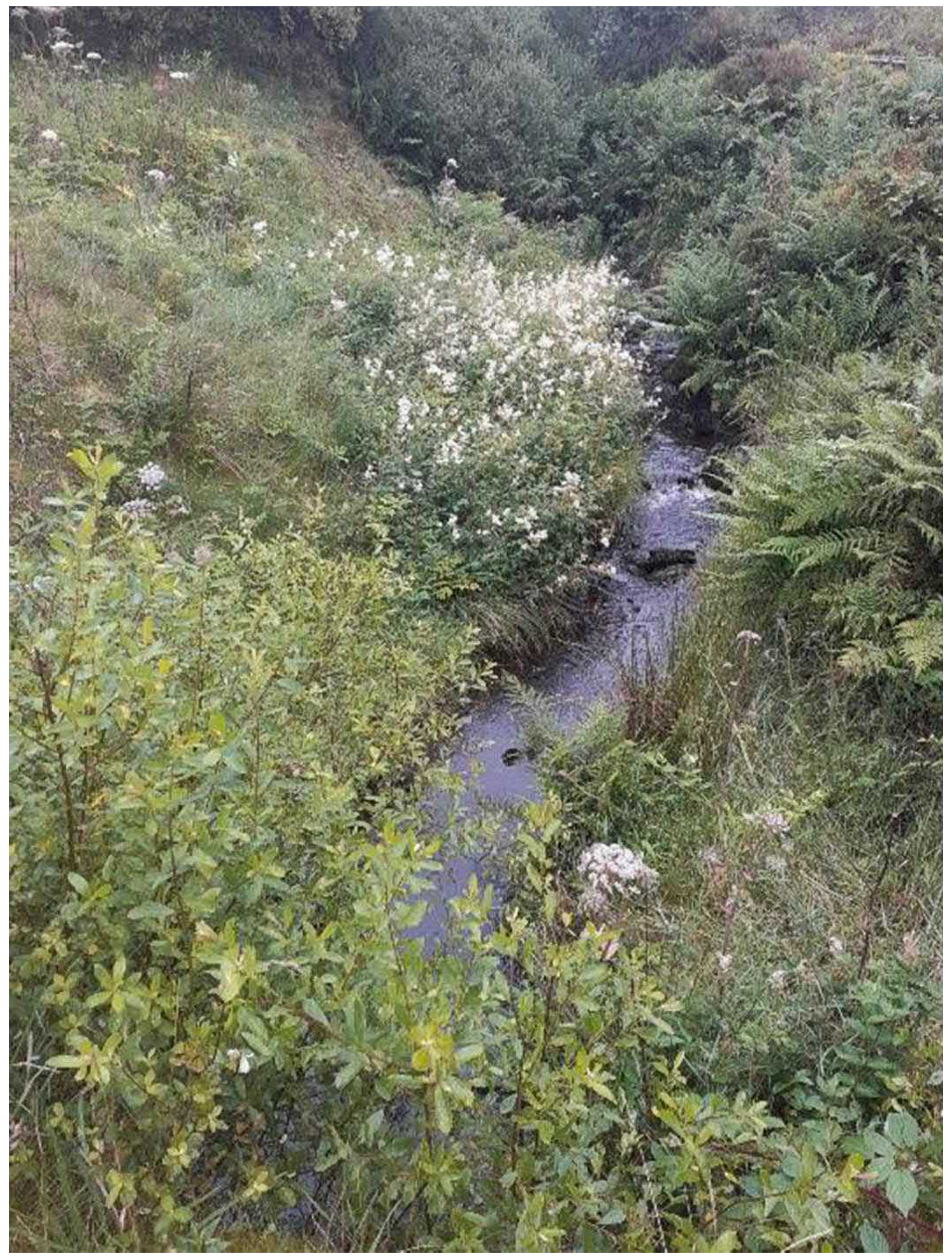
1.3 Site Reconnaissance and Field Surveys

60. Walkover and peat probing surveys were carried out at various stages between March 2020 and August 2021. These surveys focused on gaining a good overall understanding of the Site and collecting representative peat depth data, where forest access was possible, including all proposed infrastructure locations and nearby areas highlighted for further investigation from desk study or earlier phases of the peat stability assessment. The weather during the Site visits was generally good, although heavy rain conditions did occur during some visits. There were no occasions where frozen conditions prevented peat depth results being accurately recorded.

61. Site visits often collated multiple sets of site data concurrently, for example peat probing alongside peat coring and visits to areas suspected of instability from aerial photography. These items have been discussed separately but integrated visits enabled a better understanding of peat features at specific locations.

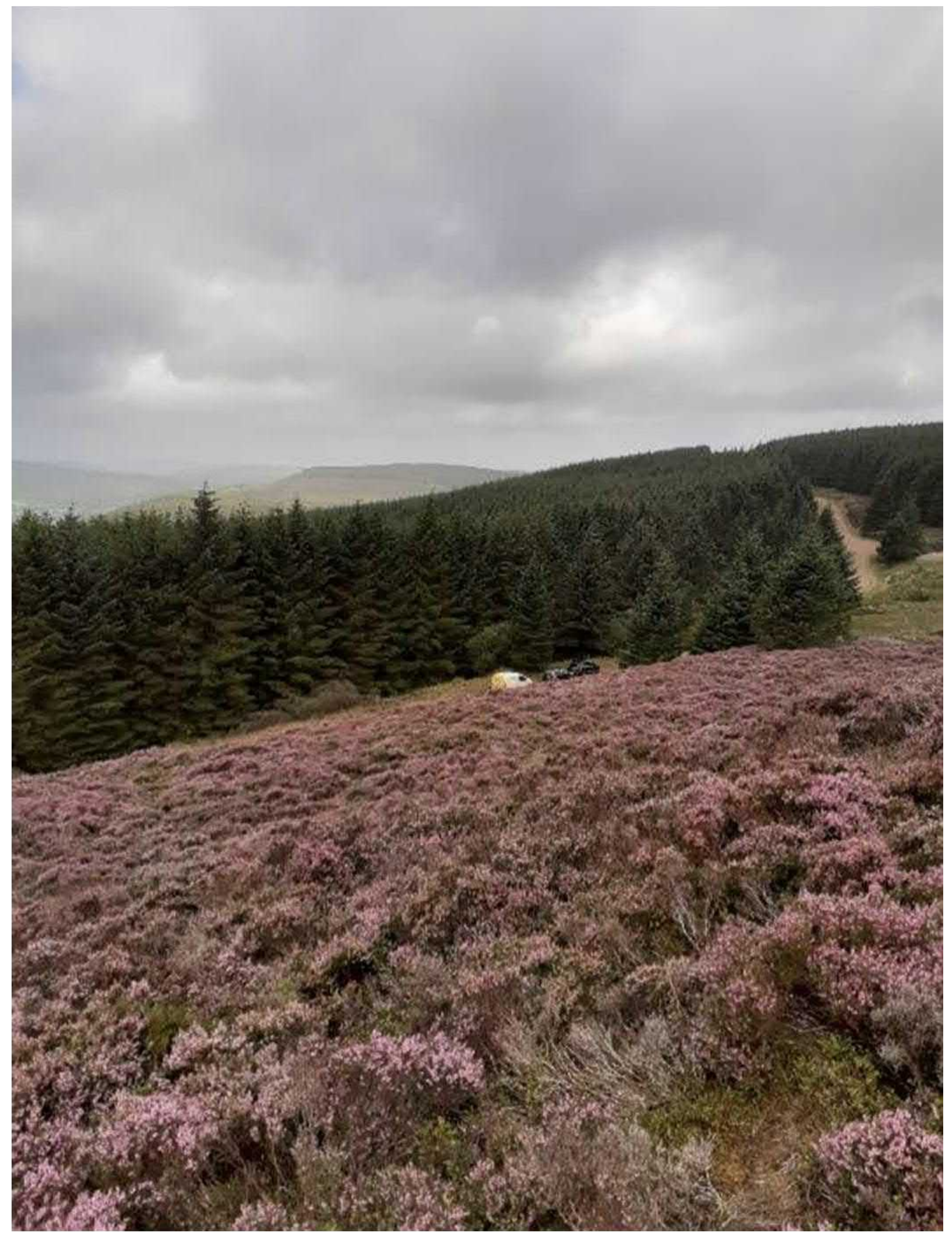
1.3.1 Site Reconnaissance

62. **Photographs 6.1** to **6.8** provide images and descriptive text of a representative sample of the Site, identifying the range of landforms observed. It should be noted that these photos provide context and do not necessarily indicate the location of proposed infrastructure, which has been located to avoid the steepest and deeper peat areas, where possible. Additional photographs are provided in **Annex B**. There were no locations onsite where peat instability such as peat debris slides or other evidence of peat erosion caused by fluvial erosion was noted.



Photograph 6.1 Looking upstream at Tairlaw Burn from NGR 239189, 597349.

Photograph taken at approximately 285m AOD from the existing forestry track crossing of the Tairlaw Burn in the south eastern part of the Site. The watercourse is located within an incised channel, with non-peat slopes measured at 0.20m. The slope gradient is moderate at 8º, and the flow observed was fast at the time of visit.



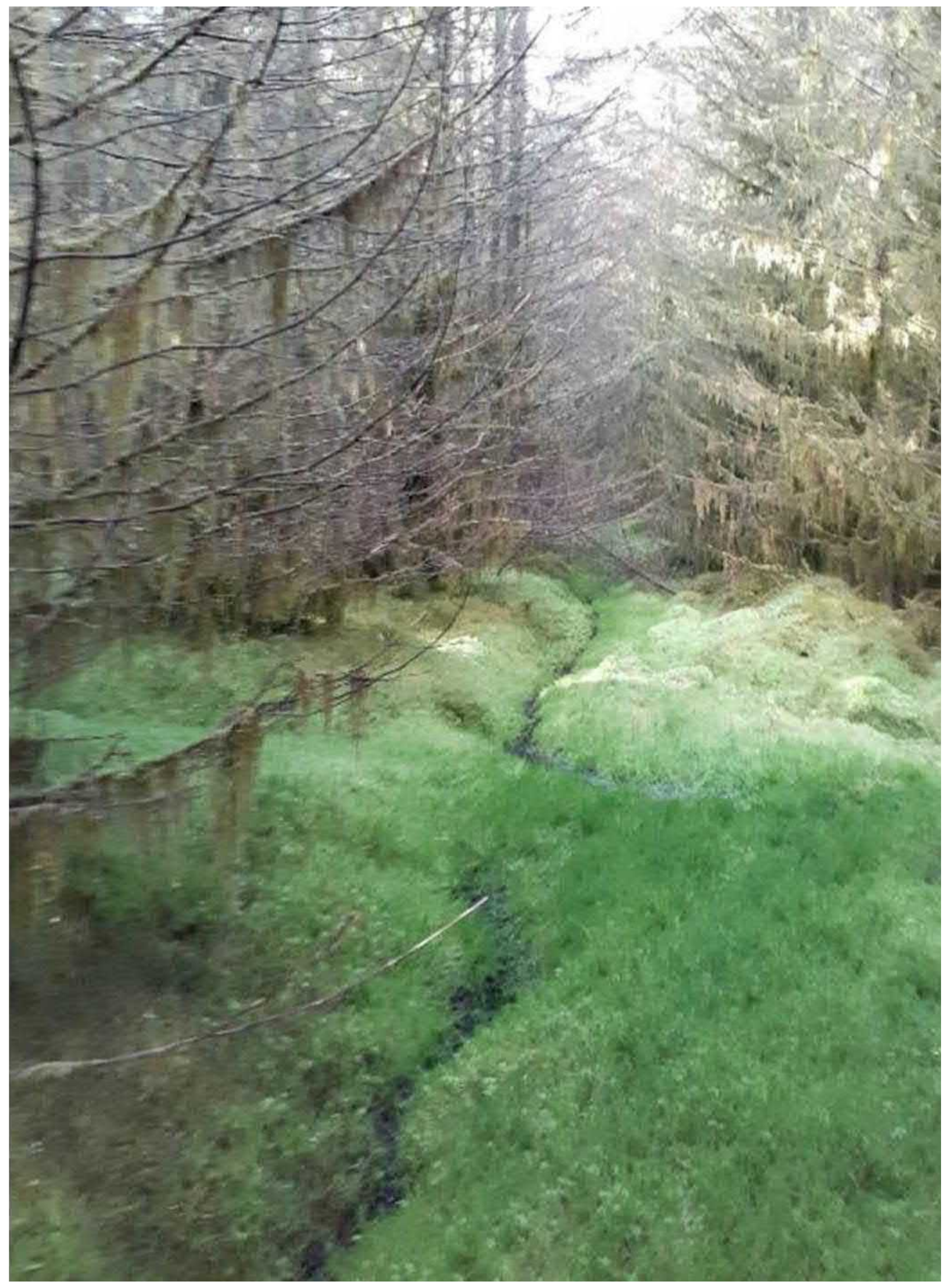
Photograph 6.2 Looking west towards the existing forestry track to be upgraded, from Glester Cairn, taken at NGR 235223, 598204.

Photograph taken at approximately 387m AOD at the lower slopes of Glester Cairn in the western part of the Site, where steep gradients were identified using OS mapping and DTM. Measured peat depths in the area were up to 0.50m at the top of the slope. At the location where the photograph is taken, the slope angle is approximately 15º, increasing to 27º downslope. This image shows some of the steeper slopes identified across the Site but no signs of instability were apparent.

Photograph 6.3 Looking east, lower southern slopes of Black Hill of Garleffin, taken at NGR 234298 599022.

Photograph taken at approximately 392m AOD, west of Garleffin Fell in the western part of the Site. This location was identified for its deep peat records and visited due to the proximity of wind turbine 1. The slope at this location is approximately 7º, increasing to 13º downslope. Measured peat depths in the area range between 0.82m and 2.77m. No signs of instability were noted within this afforested area.

This area is discussed in PSA Area B in **Annex B**.



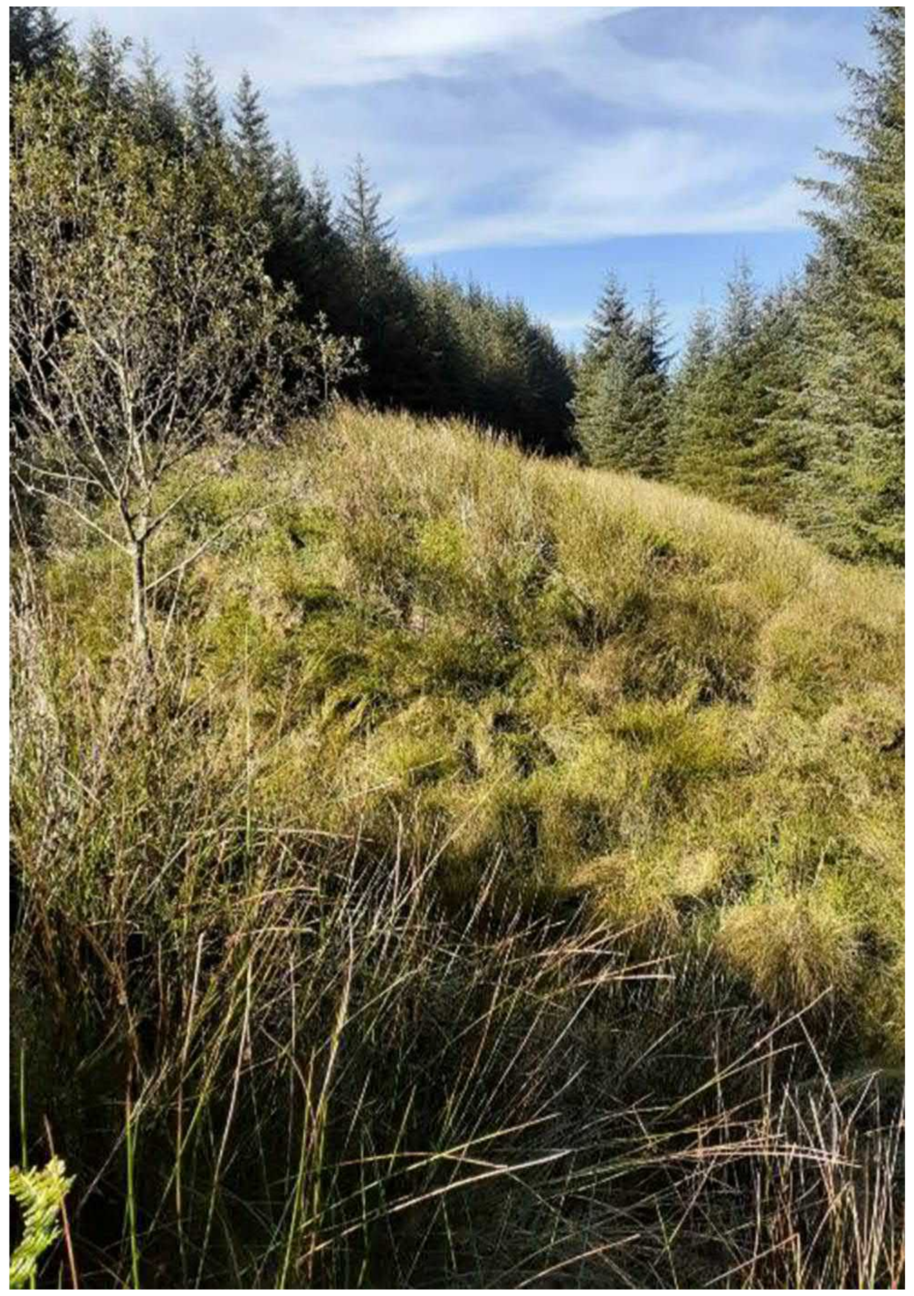
Photograph 6.4 View south from PC03 location within a forestry drainage channel, from NGR 235110, 599218.

Photograph taken at approximately 360m AOD at peat core PC03 location, showing a semi-natural forestry drainage channel within conifer plantation in the north western part of the Site. This location was identified for its deep peat records and visited due to the proximity of wind turbine 1. Measured peat depths in the area ranged between 0.69m and 1.59m. The slope gradient is moderate at 12º, with no apparent runoff noted at the time of the visit. No signs of instability were noted within this afforested area.

This area is discussed in PSA Area A in **Annex B**.

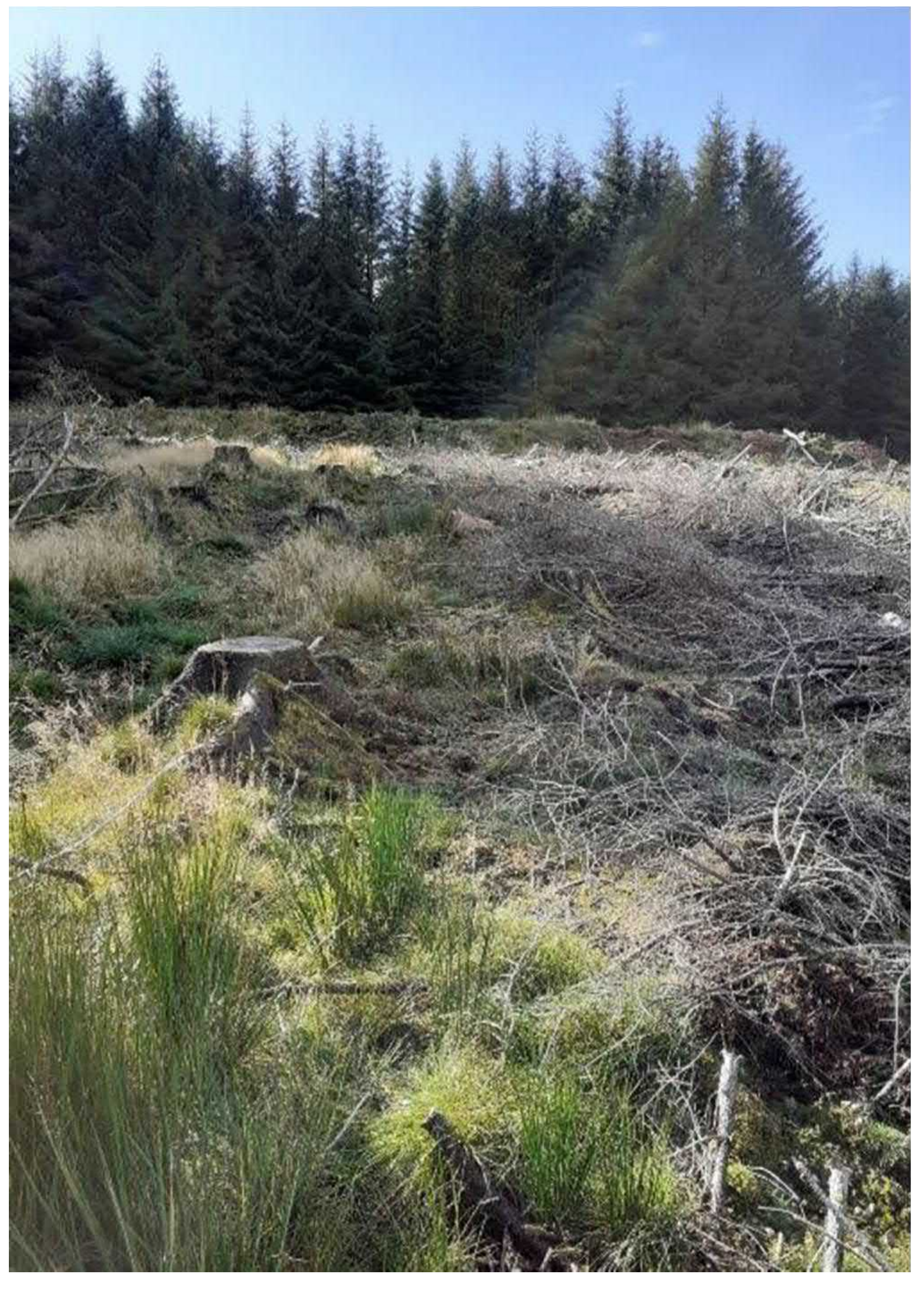
Photograph 6.5 View south within a drainage channel on the existing quarry in the central part of the Site, from NGR 237519, 598468.

Photograph taken at approximately 300m AOD showing exposed peat bank within a channel in the existing quarry, planned to be enlarged as borrow pit BP02. This horizon shows approximately 0.30m of peaty soil, overlying boulder clay and igneous rock material.



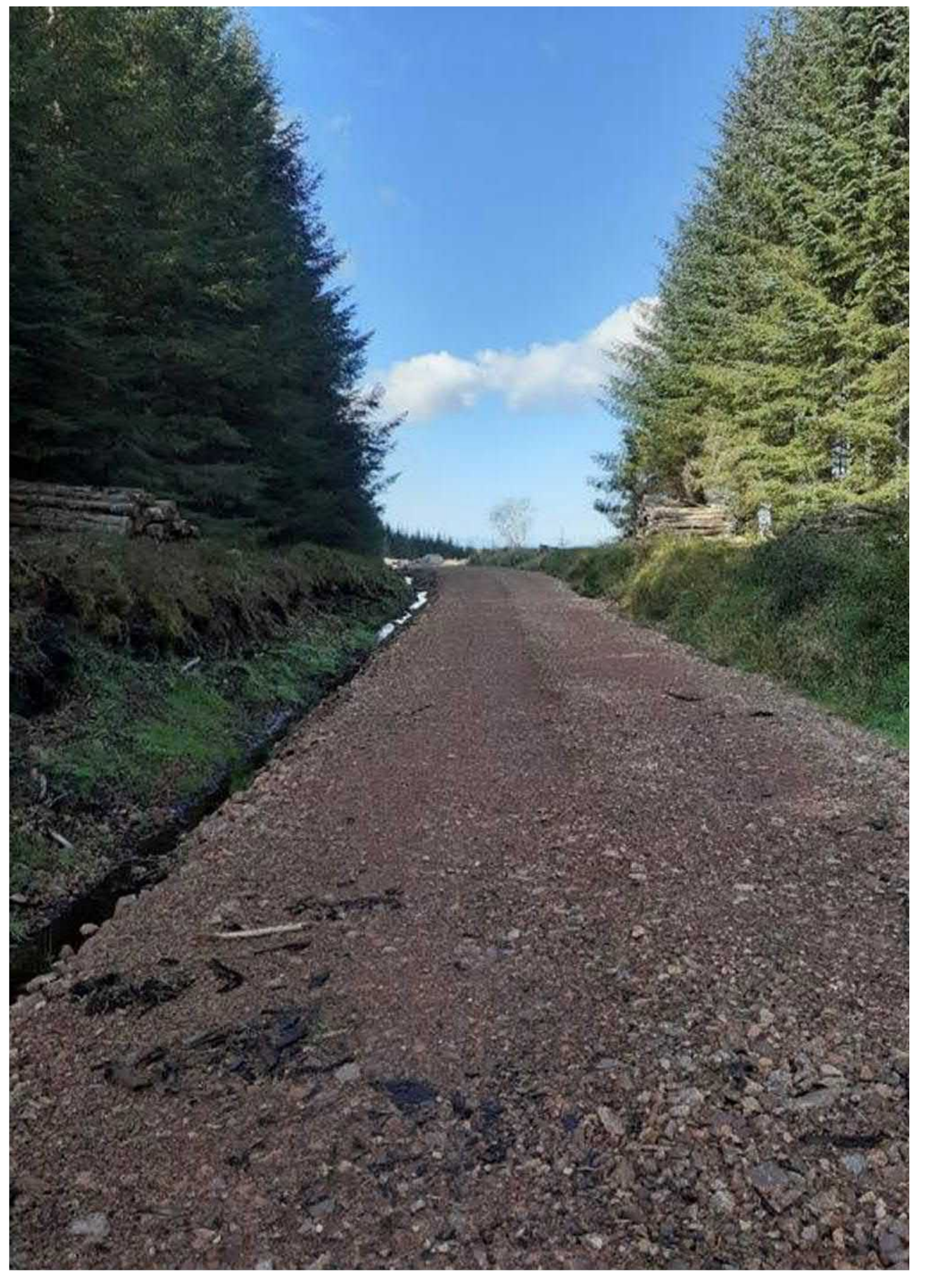
Photograph 6.6 View looking west towards the existing forestry track embankment from NGR 235497, 598945.

Photograph taken at approximately 340m AOD towards the existing forestry track embankment, in the western part of the Site, south of the peat core PC02 location. Measured peat depths in the area are generally less than 1.00m. Such bankings were noted in various trackside locations and may skew slope stability results when combining the artificially engineered slope angle with the depth of banked material. At the location where the photograph was taken, the slope angle is 11º, increasing to 18º at the break of slope. There were no signs of peat instability or mass movement.



Photograph 6.7 View looking south towards the existing forestry track at NGR 235121, 599351.

Photograph taken at approximately 349m AOD downslope of the existing forestry track in the western part of the Site, showing a recent clear-felled area with legacy forestry drainage. Tree roots are likely to bind the surface soil. Measured peat depths in the area ranged between 0.10m and 0.74m. The slope gradient is gentle, with no signs of instability noted.



Photograph 6.8 View looking west from the existing forestry track from NGR 235132, 599254

Photograph taken at approximately 357m AOD showing the existing forestry track in the western part of the Site, north of the peat core PC03 location. Image shows a cutting on upslope side (left of image) and banked-up material downslope (right of image), such bankings were noted in various trackside locations and may skew slope stability results when combining the artificially engineered slope angle with the depth of banked material. Measured peat depths in the area are generally less than 1.00m. At the location where the photograph was taken, the slope angle is approximately is 5º, increasing to 10º at the break of slope downslope. There were no signs of peat instability or mass movement.

This area is discussed in PSA Area A in **Annex B**.

1.3.2 Peat Depth Survey

1.3.2.1 Fieldwork

63. The peat depth survey for the Proposed Development was undertaken in a number of phases. Initially, peat probing was undertaken between March and July 2020 focussing on the areas in which the proposed infrastructure corridors were proposed. This allowed a representative dataset of peat depths on a variety of landforms, adjacent to stream channels, adjacent to existing forestry tracks and across slopes where potential proposed infrastructure would be required. The provisional wind turbine layout provided by the Design Team was also probed. Peat probing methodology was discussed and agreed with the Scottish Environmental Protection Agency (SEPA) for the Proposed Development during a call on the 11th May 2020, this included representative coverage of all proposed infrastructure including borrow pit search areas.

64. Peat probing was undertaken in two stages, Phase 1 and Phase 2, in line with the Guidance on Developments on Peatland (Scottish Government, 2017a).

65. WSP's approach does not include for the wider grid-based format that Scottish Government (2017) guidance suggests, with peat probing conducted to provide representative coverage of various landforms and then focussed peat probing on the planned development area. WSP had agreement from SEPA on the peat probing surveys methodology. Additional data was collected where a higher level of initial risk, in terms of peat stability, was determined.

66. This deviation from the Scottish Government Peatland Survey (2017) standard approach to peat survey is based on WSP's experience on previous windfarm EIA projects, based on an initial 100m x 100m grid coverage of the entire Site. WSP believe this is impractical on densely forested sites and that an appropriate level of detail can be obtained by a more targeted approach in the early stages.

67. WSP targeted peat surveys within the Scoping Developable Area identified to inform the early stages of the development process, focussing particularly on open ground and forest rides, where access through forestry presents difficulty and increased safety risks; also targeting any provisional layout locations, including wind turbines and any associated proposed infrastructure, where available, during the Phase 1 survey work. Though resulting in a reduced spatial density in peat depth data, we believe that sufficient and representative peat depth data was still achieved for the Scoping Developable Area. This approach aligns with our standard development-focussed and risk-based approach to peat surveys for onshore windfarm EIA, conducted on recent projects such as Clash Gour, North Lowther Energy Initiative and Glendye. Each of these are Section 36 developments and the peat data was accepted as thorough and robust by SEPA and Scottish Government appointed Peat Stability Advisor.

68. The Phase 1 surveys were undertaken to establish the nature and extent of peat onsite to enable design input. This involves probing for uncapped peat depth data focusing peat survey efforts within the Scoping Developable Area of the Site, utilising open ground/forest rides to gain a good representative coverage, plus any provisional layout locations during this Phase 1 work. This resulted in peat probing at an approximate frequency of every 50m within the Scoping Developable Area. This also included the production of a conjectural peat grid-based map for the Site. Phase 2 was used to inform detailed design iterations where further information may be required from specific locations (e.g. proposed infrastructure).

69. Phase 2 was used to inform detailed design iterations where further information may be required from specific locations (e.g. proposed infrastructure). Once the design layout was finalised WSP probed along the proposed infrastructure, using the following intervals:

- tracks (new and to be upgraded): every 50m;
- wind turbines: 10m crosshair at every wind turbine;
- hardstandings: one probe on each 50m grid within the proposed infrastructure; and
- borrow pits: one probe on each 50m grid within the proposed infrastructure.

70. Following data gathering and processing of the peat depth results, areas of confirmed or suspected deeper peat were identified and initial observations relating to peat stability were made (using the FoS technique detailed later in this report but with the abbreviated dataset available at this stage).

71. Following feedback on the design, plus input from other disciplines, a number of changes were suggested for the layout and the Site was revisited during August and September 2020 and further peat data gathered to refine our knowledge of conditions in specific areas. Proposed infrastructure locations were probed, with the strategy to gain depths every 50m along access track routes with additional depth data at wind turbine and borrow pit locations. This information fed into the final design decision. Upon provision of the final design, the complete layout was reviewed and additional probing undertaken where further data was required. During these visits, further peat probe records were also gathered at locations where there was potentially deeper peat or stability concerns at locations close to planned infrastructure.

72. Additional peat probing was undertaken as part of the peat stability risk assessment visit in October 2020, alongside other peat-related data collation, including aerial photography verification, shallow shear vane tests and peat coring for Von Post assessment and laboratory analysis, to further inform the understanding of peat characteristics and stability factors at identified locations of concern.

73. The peat depths were measured using Van Walt peat probing rods, consisting of multiple connecting 0.94m fibreglass sections, with depths measured via tape measure to an accuracy of ±0.05m. The rods were pushed into the ground until they could be pushed no further, with the depth recorded. There were 1,818 peat depths recorded on the Site, with no results exceeding the depth of peat probes, the deepest record being 7.00m, located 1.8km from the nearest planned infrastructure, south of Linfern Loch.

74. The collected data from the initial peat probing survey are summarised in **Table 6.1.1**; 35.8% of the points probed had a peat depth result of less than 0.50m (non-peat), with 62.4% of the results less than 1.00m and 76.7% less than 1.50m, the average peat depth was 0.99m. The peat depth results are mapped and presented as **Figure 6.1.5 Peat Overview** and in more detail on **Figures 6.1.5a-b**.

Peat/Soil Depth Range (m)	Number of locations surveyed	Percentage of locations surveyed	Average depth in range (m)
0.0 to <0.5	651	35.8%	0.25
≥0.5 to <1.0	483	26.6%	0.71
≥1.0 to <1.5	260	14.3%	1.24
≥1.5 to <2.0	187	10.3%	1.71
≥2.0 to <2.5	105	5.8%	2.21
≥2.5 to <4.0	116	6.4%	2.97
≥4.0	16	0.9%	4.65
Total / Aggregate	**1,818**	**100.0%**	**0.99**

Table 6.1.1 Results of the Peat Probing Survey

1.3.2.2 Indicative Peat Depth Mapping

75. The use of a regular grid for terrain analyses of this type is a standard recognised GIS technique and is widely applied in a range of situations. A grid system allows the application of a systematic process across the terrain, where a set of relevant properties need to be assigned to each particular location. In this analysis, these properties include slope angle and peat depth.

76. The resolution of DTM and base mapping must be taken into account, as using a very fine grid with a resolution identical to or finer than the DTM would return spurious results with a false indication of accuracy. For the Proposed Development, a 50m grid was used in line with WSP's established peat stability analysis method as this is a fine enough scale to provide an appropriate level of detail for analysis but also sufficiently large to gain meaningful results from the 5m resolution DTM and derived slope model.

77. To inform the refinement of the proposed infrastructure layout, the results of the initial peat probing survey were used to produce an extrapolated indicative peat depth map for the Study Area, creating a grid of 50m x 50m cells overlaid across the Site and applying a peat depth category to each. The peat depth ranges used are detailed in **Table 6.1.2**. Following final design, the peat depth grid was cropped to limit data to that within 250m of the Site Boundary, expanded beyond this where peat probing data was available, this dataset includes all proposed infrastructure and also peat survey data collated from earlier design iterations, including data gathered upslope and downslope of locations of concern.

Peat Depth Range (m)	Peat Depth Category Number	Peat Depth Category
0.0 to <0.5	1	No Peat
0.5 to <1.0	2	Shallow
1.0 to <1.5	3	Moderate
1.5 to <2.0	4	Moderately Deep
≥2.0 to <2.5	5	Deep
2.5 to <4.0	6	Very Deep
≥4.0	7	Exceptionally Deep

Table 6.1.2 Indicative Peat Depth Categories

78. Peat depth category names and ranges were chosen in the context of windfarm construction; for example, the threshold between cut-and-fill and considering floating access track construction is typically around 1.00m or 1.50m peat depth. Equally, the practicalities of constructing wind turbine foundations in peat more than 2.50m deep makes this a less attractive option. The threshold for very shallow peat of 0.50m is based on the Soil Survey of Scotland definition (The James Hutton Institute, 1982), as used in the Scottish Government guidelines (Scottish Government, 2007).

79. **Plate 6.2** shows an enlarged portion of the peat depth mapping. Each cell is 50m x 50m with peat categories colour coded as per **Table 6.1.2**. The full indicative peat depth map across the Site is included as **Figure 6.1.5 Peat Overview** and **Figures 6.1.5a-b.**

80. From observation, it is clear that both slope and elevation have an influence on the development of peat, although the exact mechanism is not definitive and there is no mathematical growth/decay model for the development and depth of peat. However, slope and elevation factors may be used intuitively when extrapolating from peat sampling data in the creation of an indicative peat depth map. It is often evident that deeper peat is generally found in flatter areas such as valleys, plateaux and hollows. Flat areas on hill summits tend to have relatively little peat; this is possibly due to a combination of exposure and slow growth rate as well as better drainage. Steep slopes also generally have less peat, owing for the most part to their better drainage and more rapid runoff.

81. As can be seen from **Plate 6.2** and **Figure 6.1.5 Peat Overview**, **Figure 6.1.5a Peat Detail – Western** and **Figure 6.1.5b Peat Detail - Eastern**, where a cluster of peat probing points is all within the same peat depth category this has been taken as a good indication of the general peat depth in the surrounding area and the indicative peat depth map has been coloured accordingly. However, where clusters of peat probing points have returned depths in a range of depth categories a cautious approach has been taken, with the indicative peat depth map being classified in line with the deepest category of peat found in the area. This leads to a conservative indicative peat depth map.

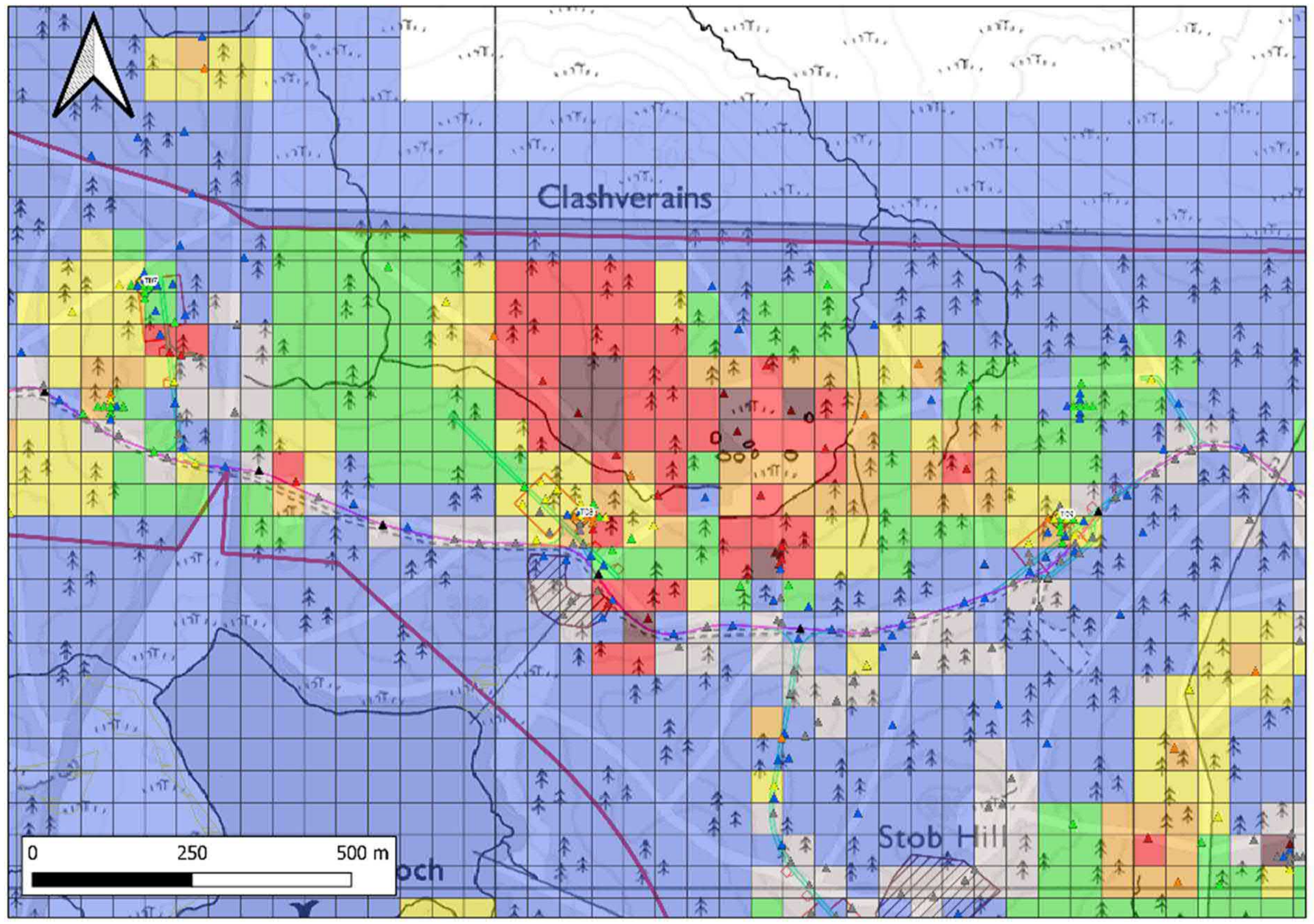


Plate 6.2 Sample of Indicative Peat Depth Map, North of Linfern Loch and Stob Hill

82. The peat depth category breakdown for both the actual probing data and the extrapolated grid is given in **Table 6.1.3**. On **Table 6.1.3**, the rows representing indicative peat depth grid data for 'measured depths' represents those cells generally closest to the planned infrastructure and thus more representative of site conditions underlying and close to the Proposed Development.

Peat Depth Range (m)		<0.50	0.50 - <1.00	1.00 - <1.50	1.50 - <2.00	2.00 - <2.50	2.50 - <4.00	≥4.00	Total
Probing Data	No. of points	651	483	260	187	105	116	16	**1,818**
	% of points	35.8%	26.6%	14.3%	10.3%	5.8%	6.4%	0.9%	**100.0%**
Indicative Peat Depth Grid	No. of cells	1,175	16,288	566	337	221	214	19	**18,820**
	% of cells	6.2	86.5	3.0	1.8	1.2	1.1	0.1	**100.0%**
Indicative Peat Depth Grid (measured depths)	No. of cells	463	303	147	112	66	80	14	**1,185**
	% of cells	39.1	25.6	12.4	9.5	5.6	6.8	1.2	**100.0%**

Table 6.1.3 Peat Depth Category Breakdown

1.3.3 Peat Cores and Shear Vane Data

83. Peat core locations were selected to specifically target areas where peat depths had previously been recorded that exceeded 1.00m, close to the final design, with core data collected on 2 October 2020 using a Russian corer and details provided in **Table 6.1.4**. Where peat depths were 2.00m or deeper, a second shallower core was also collected.

84. From Site samples, one location exhibited a Von Post value of H7 humification (PC05) and two values of H6 humification (PC01a and PC04) suggesting that amorphous catotelmic peat may be present at depths beyond 1.30m, but less humified material was identified at one of the same core locations at a depth 3.10m (PC01b), this is unusual as typically deeper peat would be expected to display a greater degree of humification. This outcome suggests the threshold for this material can be expected to vary with local conditions, perhaps with the lower material subject to differing drainage or vegetation inputs than the layer above and the presence of the local drainage channel may have altered shallow peat water content for the upper core.

85. Wet bulk density results from the six core samples issued to the laboratory ranged from 0.93 - 1.14Mg/m^3, these undrained bulk density values correlate well with the literature value of 1.0Mg/m^3. Dry bulk density was analysed as ranging from 0.09 - 0.18Mg/m^3. The bulk density laboratory outcomes are based on remoulded samples of peat presented, with this technique likely to lead to slightly greater bulk density outcome than *in situ* conditions (remoulded due to laboratory error). Core pH values were between 5.5 – 6.8 and total organic content (TOC) ranged from 7.5 – 19.0%.

86. Shear vane results provide information on the shear strength of the soil, which for peat is typically dictated by cohesive strength characteristics (Boylan *et al*., 2008). Shear strength of peat is generally considered to range between 4 - 20kN/m^2 (Boylan *et al*., 2008), with Site results of 3 - 33kN/m^2, broadly similar to the literature expectation (or slightly greater, which is likely to represent peaty soils or *in situ* fibres at test location). These were collected adjacent to core locations at shallow depths (0.30m to 1.00m). However, it is important to note that there are a number of limitations and concerns with regard to use of *in situ* shallow shear vane testing of peat and peaty soils, as discussed in the **Section 1.2.1**, with a lower bound value of 4kN/m^2 from literature review considered more appropriate and conservative. The shear vane used was calibrated in 2016, however, this equipment is safely boxed and not in regular use and is considered reasonably accurate for the purpose of establishing general peat characteristics. The Von Post classification is considered a more pragmatic indicator of shear strength characteristics from field data.

87. The level of decomposition at the representative peat core locations are less than may be typically expected in peat, indicating that some core locations would be expected to have a greater structural integrity and of less sensitivity in terms of excavation and re-use. The laboratory bulk density data is inconclusive but the pH and TOC analysis indicates that the cores collected represent peaty soils, with peat expected to have more acidic characteristics and a greater content of organic material.

88. Amorphous catotelmic peat has been considered present for the Proposed Development and various threshold depths discussed in **Appendix 6.2 Soil and Peat Management Plan** of the EIAR, with a threshold depth between acrotelmic and catotelmic peat suggested as 1.30m, given overall core data, however Site data suggests non-catotelmic material is often present at deeper threshold depths.

89. The geotechnical input provided to date does not replace geotechnical site investigations that would take place prior to construction commencing to inform the detailed site design, with the above information intended to provide design advice and the basis for assessment for the purposes of the application submission.

90. Peat core locations are presented on **Figure 6.1.6 Peat Core Locations**, with photographs for PC01a-PC05 provided in **Annex D**. Data from these sources were applied to the datasheet locations provided in **Annex B.**

Peat Core ID	National Grid Reference (NGR)	Core Depth (m)	Core Description and Results	Core Location Information
PC01a	NGR 237446, 598524	2.00	Von Post H6 - Strongly Decomposed. Considered amorphous catotelmic peat. Approximately one third of peat expressed and turbid water, plant structure clear. Shallow shear vane results taken at 0.30m depth: - 84 division: 27kN/m^2; - 100 division: 32kN/m^2; and - 80 division: 26kN/m^2. Laboratory analyses undertaken on sample returned: - Bulk density = 1.02Mg/m$^{3;}$ - Dry density = 0.10Mg/m$^{3;}$ - pH = 5.6; and - TOC = 7.9%.	No visual evidence of instability, low gradient, concave slope. Conifer plantation, within forestry ride. Forestry drainage present. Peat core shown on **Photograph 6.11**, **Annex D**.
PC01b	NGR 237446, 598524	3.10	Von Post H5 - Moderately Decomposed. Plan structure evident. Small amount of peat expressed, with turbid water expressed. Shallow shear vane results taken at 0.30m depth: - 84 division: 27kN/m^2; - 100 division: 32kN/m^2; and - 80 division: 26kN/m^2. Laboratory analyses undertaken on sample returned: - Bulk density = 0.93Mg/m$^{3;}$ - Dry density = 0.09Mg/m$^{3;}$ - pH = 5.8; and - TOC = 19.0%.	No visual evidence of instability, low gradient, concave slope. Conifer plantation, with forestry rides. Forestry drainage present. Peat core shown on **Photograph 6.12**, **Annex D**.
PC02	NGR 235508, 598987	1.90	Von Post H5 – Moderately Decomposed. Plant structure evident. Some peat expressed through fingers. Shallow shear vane results taken at 0.30m depth: - 10 division: 3kN/m^2; - 32 division: 10kN/m^2; and - 44 division: 14kN/m^2. Laboratory analyses undertaken on sample returned: - Bulk density = 1.14Mg/m$^{3;}$ - Dry density = 0.15Mg/m$^{3;}$ - pH = 5.8; and - TOC = 17.0%.	No visible evidence of instability in vicinity to the core. Topography levels in this area, sloping towards the north. Forestry plantation with moss carpet, suggesting high water table conditions. Peat core shown on **Photograph 6.13**, **Annex D**.
PC03	NGR 235110, 599218	1.40	Von Post H5 – Moderately Decomposed. Plant structure evident. Some peat expressed through fingers, no water expressed. Shallow shear vane results taken at 0.30m depth: - 52 division: 17kN/m^2; - 94 division: 30kN/m^2; and - 102 division: 33kN/m^2. Laboratory analyses undertaken on sample returned: - Bulk density = 1.05Mg/m$^{3;}$ - Dry density = 0.18Mg/m$^{3;}$ - pH = 5.8; and - TOC = 15.0%.	Core taken at base of a forestry drainage channel. No visible signs of instability locally. Topography is gentle to moderate, sloping towards the north. Peat core shown on **Photograph 6.14**, **Annex D**. This core location is shown on **Photograph 6.4** in the **Site Reconnaissance Section**. This core location is noted on PSA Area A in **Annex B**.

Peat Core ID	National Grid Reference (NGR)	Core Depth (m)	Core Description and Results	Core Location Information
PC04	NGR 234967, 599120	1.30	Von Post H6 - Strongly Decomposed. Considered amorphous catotelmic peat. Approximately one third of peat expressing through fingers, plant roots distinct on the sample and no water expressed. Shallow shear vane results taken at 0.30m depth: - 96 division: 31kN/m^2; - 62 division: 20kN/m^2; and - 86 division: 28kN/m^2. Laboratory analyses undertaken on sample returned: - Bulk density = 1.10Mg/m^3; - Dry density = 0.15Mg/m^3; - pH = 5.5; and - TOC = 7.5%.	No visible evidence of instability. Topography is gentle to moderate. Conifer plantation, with forestry drainage channels. Peat core shown on **Photograph 6.15**, **Annex D**. This core location is noted on PSA Area A in **Annex B**.
PC05	NGR 234318, 599042	1.60	Von Post H7 – Highly Decomposed. Considered amorphous catotelmic peat. Approximately half of peat expressing through fingers, plant roots distinct on the sample and no water expressed. Shallow shear vane results taken at 0.30m depth: - 44 division: 14kN/m^2; - 72 division: 23kN/m^2; and - 62 division: 20kN/m^2. Laboratory analyses undertaken on sample returned: - Bulk density = 0.95Mg/m^3; - Dry density = 0.09Mg/m^3; - pH = 6.8; and - TOC = 14.0%.	No visible evidence of instability. Topography is gentle to moderate. Conifer plantation, with forestry drainage channels flowing towards the north. Peat core shown on **Photograph 6.16**, **Annex D**. This core location is noted on PSA Area B in **Annex B**.

Table 6.1.4 Peat Core and Additional Ground Investigation Data

1.4 Factor of Safety Analysis

91. To establish the stability of peatland areas, WSP applies the 'Factor of Safety' methodology. This procedure involves the application of site data (peat depth and slope angle) alongside 'values for a number of further variables, with the more sensitive of these being the values allocated for cohesive strength and *in situ* (undrained) bulk density of peat. The values applied are based on literature review and are generally considered conservative, in accordance with a purposefully precautionary approach.

92. This PSA initially determines areas considered of greatest risk of slope failure, based on FoS slope stability calculations, these areas were then considered in greater detail, including site visits to gather further information.

93. Using the collated data an initial analysis of slope stability can be carried out using the infinite slope model. The stability of a slope can be assessed by calculating the FoS, F which is the ratio of the sum of resisting forces (shear strength) and the sum of the destabilising forces (shear stress):

$$F = \frac{c' + (\gamma - m\gamma_w) z \, Cos^2\beta \, Tan\phi'}{\gamma \, z \, Sin\beta \, Cos\beta}$$

94. Where c' is the effective cohesion, γ is the unit weight of saturated peat, γ_w is the bulk density of water, m is the height of the water table as a fraction of the peat depth, z is the peat depth in the direction of normal stress, β is the angle of the slope to the horizontal and φ' is the effective angle of internal friction.

95. The FoS, F, represents the ratio of the forces resisting a slide to the forces causing the material to slide. If F > 1 then the slope is stable and normally if F >1.4 then there is a degree of comfort that the slope would not fail. The boundary value of 1.4 is in agreement with the current recommendations of Eurocode 7 (BSI, 2004 & 2007).

96. To get an indication of the stability of the peat at the proposed infrastructure locations, the FoS can be calculated for each peat probing location. In addition, to gain a better view of peat stability in the areas surrounding the proposed infrastructure, FoS calculations can be carried out for the grid cells of the indicative peat depth map in the vicinity of the proposed infrastructure. To do this, we must know or be able reasonably to infer the parameters for the FoS equation for each probing location and grid cell.

97. The slope angle, β, can be derived from the DTM for the Site. With the peat probing locations, a single slope angle value is generated for each point, whilst the DTM is interrogated for maximum, minimum and mean slope values for each grid cell. The mean slope angle has been used in the grid FoS calculations, although the other statistics provide useful supporting information on the variability of slope within the cells.

98. The actual peat depth measurements recorded for each probing location are used in calculating the point FoS values. For the grid-based FoS assessment it is necessary to convert the indicative peat depth ranges into a specific figure for each range for use within the calculation (where no measured depth was recorded) and using the maximum depth record for cells with measured depths. Taking a conservative approach, the upper bound of each range has been used, where actual data is not held. Measured peat probing depth records are presented as a histogram in **Plate 6.3**, with reference to **Tables 6.1.1** and **6.1.3**; 35.8% of results are less than 0.50m and 62.4% are less than 1.00m.

99. The bulk density of water, γ_w, is known to be 1.00Mg/m^3.

100. The bulk density of peat is known to vary with the level of decomposition. A literature review has found quoted *in situ* undrained bulk densities ranging from 0.50 to 1.40Mg/m^3. Laboratory analyses undertaken on samples collected by or on behalf of WSP from other projects have returned bulk density values generally ranging between 0.80 and 1.40Mg/m^3, with results for this Site within this range, recorded as between 0.93 and 1.14Mg/m^3. Based on this experience and also after reviewing externally published values (Lindsay, 2010/Scottish Government, 2017a/Dykes & Warburton, 2007/Boylan *et al*., 2008) an average wet bulk density value of 1.00Mg/m^3 has been applied for the initial FoS calculations.

101. If it is assumed that the Site is covered with active blanket bog, it follows that the peat must be completely saturated, with a water table at or close to the surface. Onsite observations indicate that this assumption is only valid on limited, low slope angle, areas of the Site as ground conditions were fairly dry underfoot across much of the Site, with some of the forestry rides notably wetter. Consequently, a water table ratio, m, of 1.0 has been chosen, which is considered conservative given most of the Site exhibits drier conditions, but may occur locally during or following heavy rainfall 'trigger' events.

102. The angle of internal friction in peat also varies, decreasing with increasing decomposition and moisture content. For the FoS calculations, a φ' value of 5° has been selected as per WSP's conservative approach.

103. Finally, a value for the effective cohesion, c', must be derived. Literature values for c' in peat vary widely, generally ranging from 4 - 20kN/m^2. To provide an indication of the cohesive strength of the peat at this Site, a back-calculation using the FoS equation and actual peat depth probing data for the Site has been completed. The techniques involved are discussed below.

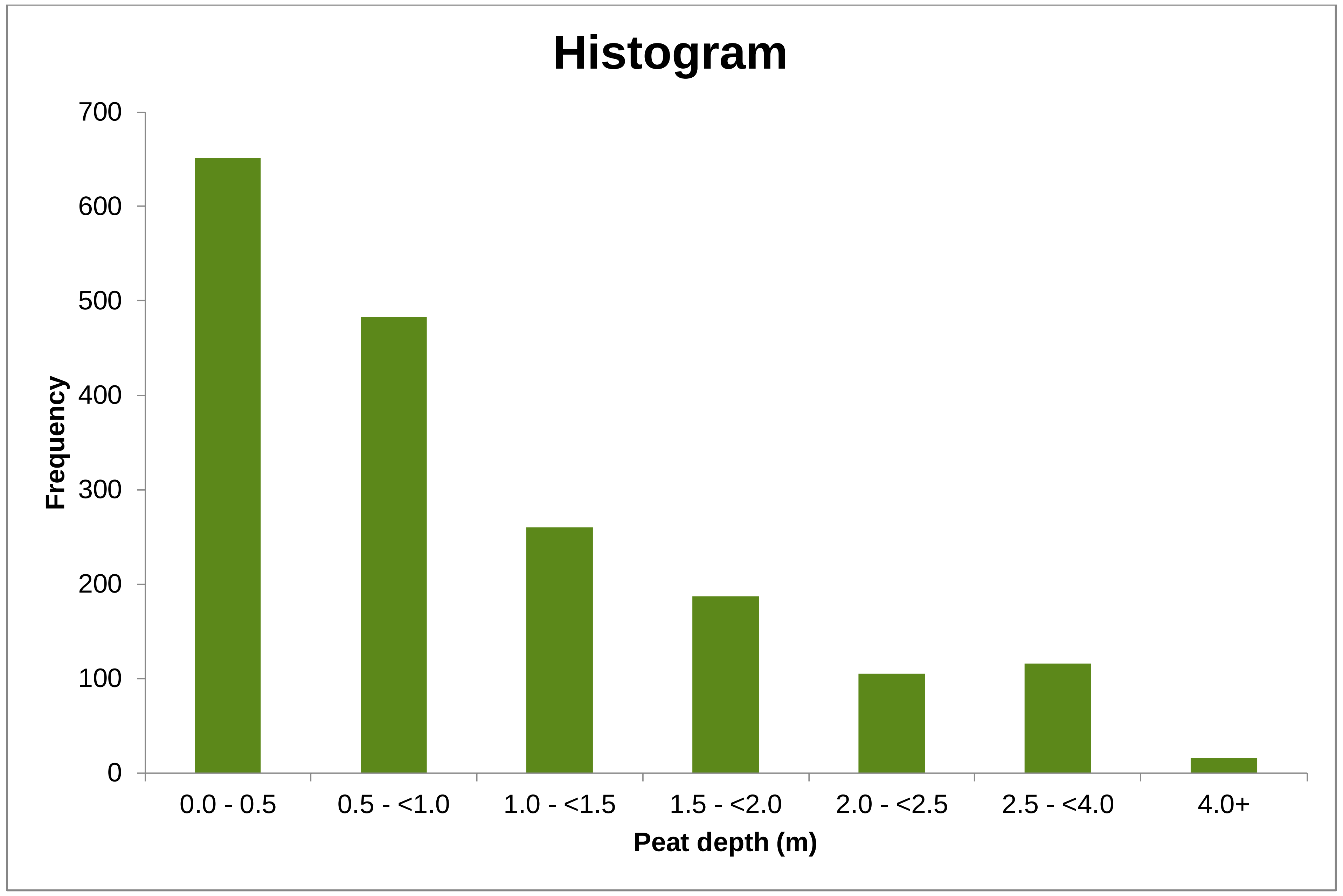


Plate 6.3 Peat Probe Depth Histogram

1.4.1 Estimation of Cohesive Strength

104. A range of field and laboratory tests can be carried out to determine the effective cohesion of a material. However, owing to its fibrous and thixotropic nature and the variation in strength with decomposition, peat is a particularly difficult material to analyse both in the field and in the laboratory. An alternative approach to assessing the strength of the peat is to rearrange the FoS equation to calculate a value of c' at actual peat probing locations. Essentially, this approach assumes that if the hillside is stable then the material must have at least a certain minimum strength.

105. Each peat probing location visited is known to have been stable at the time of the visit and therefore must have a FoS of at least 1. If we assume conservatively that F=1 and use values for the other parameters as discussed above, the FoS equation can be rearranged to allow derivation of a value for c' at each probing location. Slope angles for the probing points are generated from the DTM. It is important to note that the value of c' calculated for each location represents the minimum cohesive strength necessary for the peat to be stable at that location. In fact, the shear strength may be, and in most cases probably is, considerably higher.

106. In the Study Area, 1,818 locations have been probed during the different phases of fieldwork, c' values for each of these have been calculated and the distribution of these values is shown in **Plate 6.4**. For example, reading from the graph, 0.8 (or 80%) of the probing locations require a theoretical c' value of 0.87kN/m^2 or less to be stable and retain peat on the slope.

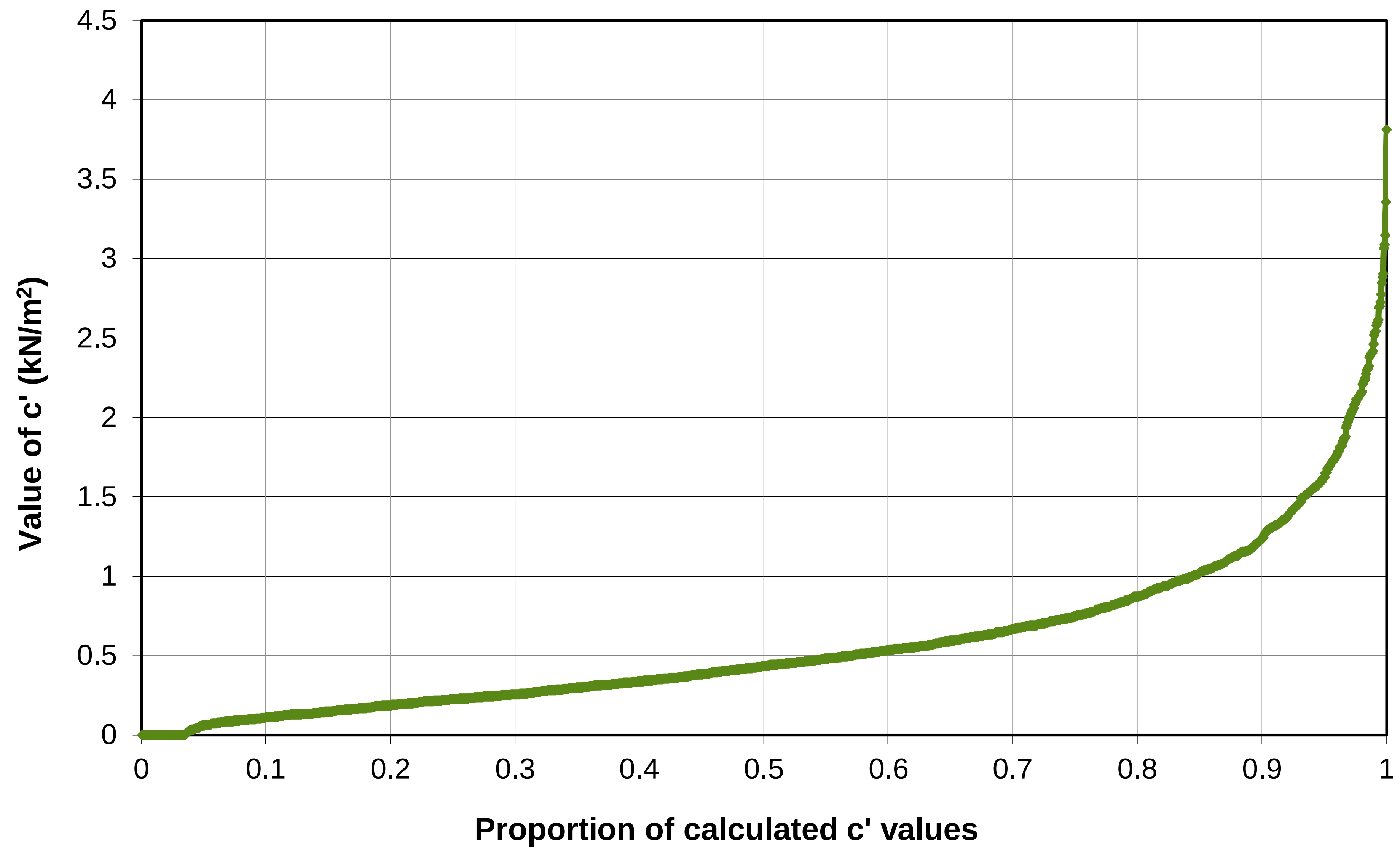


Plate 6.4 Estimate of Minimum Cohesive Strength, c'

107. From this work it is possible to state, with reasonable confidence, that across the Site as a whole the shear strength of the peat is unlikely to be less than 2.51kN/m^2 as this is the value of the 99th percentile point on the graph.

108. A similar approach was undertaken for determining the 99th percentile for grid cells, determined as 3.96kN/m^2, this value being higher than the point data due to inclusion of indicative depths for a number of cells.

109. The basis for applying these calculation details depends upon:

- the deliberate choice of conservative values for assumed parameters such as bulk density and water table level, coupled with the assumption of an FoS of 1 when back-calculating c' values;
- Recognition of what the calculations are stating, which is that these are the minimum strengths that would be required, not the actual *in situ* strengths. Therefore, where slopes are gentle and the peat shallow, very little shear strength is required to ensure stability of the slope. This accounts for the vast majority of the lower values;
- assuming a reasonable degree of homogeneity for peat properties, particularly strength, across the Site. This seems reasonable, except for very shallow peat where the acrotelm, which is more fibrous, represents a significant proportion of the total depth. Such areas are, in any case, unlikely to be areas of concern; and
- given the above considerations, it is the higher strength values that are relevant. If this were not the case, then one would expect large areas of the Site to be denuded of peat as it would not have the strength to adhere to the hillsides.

110. For the purposes of the FoS Assessment c' values of 2.51kN/m^2 and 3.96kN/m^2 have been used. These values are conservative in comparison with estimates derived from other sites around Scotland, largely due to the shallow peat found on most site slopes. The actual effective cohesion of the peat at the Site is therefore likely to be higher than 2.51kN/m^2, with 3.96kN/m^2 being more representative (compared with literary values of 4 - 20kN/m^2), with the application of these site-derived values ensuring a reasonably conservative initial assessment using data from the Site in tandem with an understanding of literary values.

1.4.2 FoS Stability Results

111. Having assigned measured or inferred values to each parameter in the FoS equation, it is now possible to calculate the FoS value for each probing location coinciding with proposed infrastructure and for each cell of the indicative peat depth grid in the vicinity of the proposed infrastructure. The results of the FoS assessment for the probing points and site grid are summarised in **Table 6.1.5**. The FoS assessment maps generated with these values are shown across the Site as series **Figure 6.1.7 Factor of Safety Overview**.

112. Once again, the grid cell values where measured data is available is considered more representative as is generally closer to the planned infrastructure.

Factor of Safety	No Peat in Grid (less than 0.5m)	≥3.0	1.4 - <3.0	1.0 - <1.4	<1.0	Total
Probing Data (points)	651	798	300	50	19	**1,818**
% of Probing Points	35.8	43.9	16.5	2.8	1.0	**100.0%**
Grid Cells	1,175	11,383	5,160	913	189	**18,820**
% of Grid Cells	6.2	60.5	27.4	4.9	1.0	**100.0%**
Grid Cells (with measured data)	463	617	99	5	1	**1,185**
% of Grid Cells (with measured data)	39.1	52.1	8.4	0.4	0.1	**100.0%**

Table 6.1.5 Summary of FoS Assessment

113. In selecting the 99th percentile value of the back-calculated c' strengths, one is implicitly condemning 1.0% of the sample locations to failure, plus any similar cells across the Site as a whole. As can be seen, there are a very small number of cells with a FoS value of less than 1; in theory these should either have failed or currently be failing. In reality this is unlikely to be the case and these results are a consequence of the conservative approach adopted. A similarly low number of points and cells have a FoS between 1.0 and 1.4, where stability can be considered marginal. The cells that fall into both these categories are scattered in clusters across the Site, the majority are at a reasonable distance from the proposed infrastructure and therefore based upon conservatively estimated, rather than actual, peat depths.

114. Note that where peat depth is less than 0.5m, these cells were not considered as peat and are removed from further stability investigation.

115. To summarise, 96.2% of the peat probing locations on the Site have a FoS of 1.4 or greater (including locations with peat less than 0.50m depth), where stability can be assumed with a degree of comfort. Related to grid cells with measured depths (i.e. predominantly those grid cells closest to the proposed infrastructure), cell locations with FoS values greater than 1.4 (including cells with peat less than 0.50m depth) represent 99.5% of the Site, again these are locations where stability can be assumed with a degree of comfort.

116. The results demonstrate that the vast majority of the proposed infrastructure would be built in areas where there is a degree of comfort in inferring stability. The cells identified as having marginal stability are generally clustered into areas where deeper peat are coincident with moderate slopes, or very steep slopes occur with >0.50m peat present.

1.5 Initial Risk Assessment

117. Based on the data collated from the desk study, reconnaissance survey, peat probing and FoS stability analysis the peat stability risk across the site can be classified. The Guidelines (Scottish Government, 2017b) define risk as a function of likelihood and consequence and this has been applied by WSP as:

118. Risk = Likelihood x Adverse Consequence

119. The risk level is derived by applying a matrix of likelihood and consequence outcomes to derive a risk value ranging from 'Negligible' to 'High Risk'. Additionally, where peat is not present (such as organic soils with depth less than 0.5m) these areas were identified as 'N/A – Not Peat'.

120. Central to WSP's analysis is a grid model of the Study Area, using 50m x 50m individual cell dimensions. It is therefore essential to have processes that assign likelihood and consequence ratings to the cells and build a map of spatial variability across the Study Area. The rationale for evaluating likelihood and consequence is given in the following sections.

1.5.1 Likelihood

121. In WSP's method, the primary and non-subjective measure of likelihood of slope stability is the FoS calculation. Low FoS value slopes are of greater stability concern, slopes with FoS values greater than 1.4 are generally regarded as 'safe'.

122. Within FoS analysis, the parameter which may be considered to have the greatest uncertainty is the shear strength of the peat. The derivation of this parameter has been discussed above. The back-calculation approach is more conservative (i.e. gives a safer assumption) than that commonly derived from *in situ* shear vane tests, which have known limitations when applied to peat. For the initial risk assessment, the likelihood is based solely on FoS, enabling an objective, reasonably cautious initial 'screening' approach to likelihood. The initial likelihood criteria and classification of cells is provided on **Tables 6.1.6** and **6.1.7**, respectively.

Likelihood	Factor of Safety
Almost certain	Not applied at initial likelihood stage, better determined in conjunction with additional data available from a
Probable	FoS <=1.0
Likely	FoS is between >1.0 and <=1.4
Unlikely	FoS is between >1.4 and <=3.0
Negligible	FoS > 3.0
N/A – Not Peat	Soil at depth shallower than 0.5m or confirmed as non-

Table 6.1.6 Criteria Relating to Initial Likelihood Values

Likelihood							
	Almost Certain	**Probable**	**Likely**	**Unlikely**	**Negligible**	**Not Peat**	**Total**
No. of Grid Cells	*Not Applied*	191	915	5,156	11,383	1,175	**18,820**
% of Grid Cells	*Not Applied*	1.0	4.9	27.4	60.5	6.2	**100.0%**
No. of Grid Cells (with measured peat depth)	*Not Applied*	1	5	99	617	463	**1,185**
% of Grid Cells (with measured peat depth)	*Not Applied*	0.1	0.4	8.4	52.1	39.1	**100.0%**

Table 6.1.7 Summary of Initial Likelihood Grid Classification

123. The initial likelihood classification of grid cells across the Site is presented as **Figure 6.1.8 Initial Likelihood**.

1.5.2 Adverse Consequence

124. The Guidelines (Scottish Government, 2017b), identify that 'Consequence' relates to impact upon receptors, this would include property, existing infrastructure and assets, environmental features and/or the proposed infrastructure. These terms need to be taken in their broader context if an itemised list of receptors is to be considered which would include:

- existing public and private infrastructure (roads, bridges, buildings, business facilities, etc.);
- terrestrial ecology;
- aquatic ecology and water quality;
- archaeology; and
- proposed infrastructure (access tracks, wind turbines, control building, cabling, etc.).

125. These features have varying dimensions of costs and magnitude caused by an occurrence of mass peat instability, but in addition there may be irretrievable personal, societal or habitat losses:

- costs: the only quantification provided within the Guidelines is in terms of project costs, which are easier to apply to infrastructure assets than to ecology. If ecology is of relatively minor importance for a particular site, economic impacts or delays in the construction programme may be the main drivers; and
- magnitude: naturally occurring peatslides have been observed to range in size from small-scale, localised slides involving tens of square metres to large-scale slides involving thousands of square metres and with run-out distances of km. Consequently, magnitude may be expressed in terms of area, peat volume and run-out distance and receptor. Provided sufficient peat probing has been undertaken and an indicative peat depth map produced, areas and peat volumes can be derived using professional judgement given local ground conditions. The associated run-out distance is of less significance than the receptor damaged and again should be considered taking account of local conditions to arrive at a realistic outcome.

126. **Table 6.1.8** assembles the above considerations to outline the degrees of consequence. Using the table, the three columns are considered, and professional judgement applied, to identify the appropriate 'Consequence' rating. The consequence values were identified and applied using mapping software to escalate the value based on local receptors, with the default (starting) position being that each grid cell was considered of 'Low' consequence, taking a reasonably precautionary approach.

127. The consequence classification of cells is provided in **Table 6.1.9**. The consequence classification of grid cells is presented as **Figure 6.1.10 Consequence**.

Consequence	Habitat	Proposed Infrastructure	Public/Private Infrastructure
Extremely High	Large loss/damage to valued terrestrial and/or aquatic habitat, i.e. within designated sites. Large loss/damage to archaeological designated sites.	N/A	Damage to property: domestic/public building or business (*within 100m*); Impact on railways or A class road or bridges, including lower category roads which provide key transport corridors in remote locations (*within 100m*); Impact on public utilities, water, gas, electricity, telecoms, etc. (*within 100m*).
High	Medium loss/damage to valued terrestrial and/or aquatic habitat, i.e., designated sites (*within 100m*). Medium loss/damage to archaeological designated sites (*within 100m*).	Damage to substation and/or control building *(within 100m).*	Damage to minor/unclassified public roads or bridges *(within 100m)*; Impact on private utilities, local electrical connection, water and wastewater *(within 100m).*
Moderate	Small loss/damage to valued terrestrial and/or aquatic habitat Large loss/damage to common terrestrial and/or hydrology features shown on 1:10,000 OS mapping (*within 50m*). Peat grid cells identified with peat depth 1.5m+.	Damage to planned or operational wind turbine or base *(within 100m)*. Damage to section of new access track, bridge, hardstanding, temporary construction compound and borrow pits *(within 50m)* which would require repair to enable functionality. Damage to car parking, or cable route (within 50m). Interruption to construction or operation of development.	Damage to section of existing unclassified access track, or bridge *(within 100m).*
Low *Default Position*	Medium loss/damage to common terrestrial and/ or hydrology features shown on 1:10,000 OS mapping.	Minor damage to section of access track which does not necessitate immediate repair for access.	-

Consequence	Habitat	Proposed Infrastructure	Public/Private Infrastructure
Very Low *Not Applied*	Small temporary loss/damage to common terrestrial and/or aquatic habitat.	No damage to assets.	No damage to assets.

Table 6.1.8 Criteria Relating to Consequence Values

	Consequence					
	Extremely High	High	Moderate	Low	Very Low	Total
No. of Grid Cells	1,800	3,349	6,547	7,124	0	**18,820**
% of Grid Cells	9.6	17.8	34.8	37.9	0.0	**100.0%**
No. of Grid Cells (with measured peat depth)	7	133	801	244	0	**1,185**
% of Grid Cells (with measured peat depth)	0.6	11.2	67.6	20.6	0.0	**100.0%**

Table 6.1.9 Summary of Consequence Grid Classification

128. The assessment extends at least 250m beyond the Site Boundary (the Study Area).

1.5.3 Initial Risk Assessment Outcomes

129. The likelihood (solely based on FoS) and consequence values were applied to the Site for the initial risk assessment, with the results shown on **Figure 6.1.8 Initial Likelihood** and **Figure 6.1.10 Consequence**, respectively, provided in **Annex A** of this document. A summary of the cell counts was provided in **Tables 6.1.7** and **6.1.9** for each classification.

130. In order to include nearby receptors, the Study Area (grid) extends at least 250m beyond the Site Boundary and includes earlier design iterations and available peat survey data. This enables consideration of features outwith the Site Boundary, such as archaeological sites, watercourses or properties. The Scoping Developable Area contains the proposed infrastructure and has been the primary focus of this assessment.

131. The results of the initial likelihood and consequence grid cell categorisations reflect the characteristics of the Site. The topography generally exhibits less than 10º slope angles, with some steeper slopes on Stob Hill, Garleffin Fell and Glester Cairn where gradients may exceed 20º for extended distances. Measured peat depths confirm that much of the steeper areas of the Site have shallow or no peat recorded (i.e. less than 0.50m depth), with peat depths often greater than 1.50m on slope angles of less than 5º. A few isolated zones of deeper peat were noted at steeper slopes, with these coincident locations being the main driver for higher FoS values at this Site. The fairly remote nature of the Site means that the locations with 'High' or 'Moderate' consequence of a peat landslide are focused upon archaeological features, surface water bodies, properties and their private water supply locations. The seven grid cell locations (with measured peat depths) which were identified with 'Extremely High' consequence are all within 100m of the C46W public road, where non-peat soils were generally present (less than 0.50m depth).

132. The Guidelines' risk scoring is determined via a matrix table, combining likelihood and consequence. This has been provided as **Table 6.1.10** and replicates Table 5.3 in the Guidance (Scottish Government, 2017b). An initial risk value has been derived for each grid cell through combining the Likelihood and Consequence ratings using the matrix in **Table 6.1.10**. A summary of the grid cell counts for each risk category is provided in **Table 6.1.11**.

133. Higher initial risk value cells are typically located on steeper slopes or where peat depths greater than 1.5m were recorded, in close proximity to the planned infrastructure and/or watercourse receptors.

134. As can be seen on **Table 6.11**, the vast majority of the Site has been assessed as having either 'No Risk' or 'Negligible' risk of peatslide hazard at the initial risk assessment stage (91.3% of cells with measured peat depth).

135. When considering the grid cells with measured peat depth, which are cells where peat probing data was collected and include all cells where infrastructure is planned, no cells recorded a 'High' initial risk and 0.2% of cells recorded a 'Moderate' initial risk. No 'High' initial risk has been identified in proximity to the planned infrastructure, with one cell of 'Moderate' initial risk within 5m of the Substation Compound.

		Adverse Consequence				
		Extremely High	High	Moderate	Low	Very Low
Peat Landslide Likelihood (over Development Lifetime)	Almost Certain	High	High	Moderate	Moderate	Low
	Probable	High	Moderate	Moderate	Low	Negligible
	Likely	Moderate	Moderate	Low	Low	Negligible
	Unlikely	Low	Low	Low	Negligible	Negligible
	Negligible	Low	Negligible	Negligible	Negligible	Negligible

Table 6.1.10 Risk Matrix Based on Likelihood and Consequence Values

Initial Risk	Number of Grid Cells	% of Grid Cells	Number of Grid Cells (with measured peat depth)	% of Grid Cells (with measured peat depth)	Suggested 'Guideline' Actions (Table 5.4, Scottish Government, 2017b)
High	0	0.0	0	0.0	*"Avoid project development at these locations".*
Moderate	517	2.7	2	0.2	*"Project should not proceed unless risk can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce risk ranking to low or negligible".*
Low	5,140	27.3	101	8.5	*"Project may proceed pending*

Initial Risk	Number of Grid Cells	% of Grid Cells	Number of Grid Cells (with measured peat depth)	% of Grid Cells (with measured peat depth)	Suggested 'Guideline' Actions (Table 5.4, Scottish Government, 2017b)
					further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations".
Negligible	11,988	63.7	619	52.2	*"Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate*".
N/A No Risk (Not Peat)	1,175	6.2	463	39.1	Non-peat material, no peatslide risk.
Total Cells:	**18,820**	**100.0%**	**1,185**	**100.0%**	

Table 6.1.11 Summary of Initial Risk Assessment Outcomes and Actions

136. **Figure 6.1.11 Initial Risk** shows the planned infrastructure layout overlaid on the Initial Risk mapping, from which 'Moderate' risk of peat instability are identified as orange cells. The nearest initial 'Moderate' risk cells to proposed infrastructure are; 5m south of the Substation Compound, 500m south west of the southern temporary construction compound, 800m north of wind turbine 1 and 700m west of wind turbine 11 on the eastern banks of Linfern Loch (all distances are approximate).

137. After review of initial risk results to exclude those outwith close proximity to planned infrastructure, regarded as highly unlikely to be adversely affected by the Proposed Development or to cause any adverse effects to the proposed infrastructure, there was only one grid cell identified of concern at an initial risk level above 'Low'. This positive outcome has been aided by ongoing peat stability constraint data being fed into the iterative design process, to avoid the more likely locations of concern.

138. In order to confirm these initial risk findings, it was considered appropriate to conduct a site visit to specific locations where Likelihood concerns (based on FoS between 1.0-1.4) had been identified in close proximity to proposed infrastructure, but an initial risk of 'Low' had been determined. This 'ground truthing' exercise was to ensure that these outcomes were considered reasonable as part of a sensitivity analysis of the theoretical data.

139. Four areas of the Site were identified for such confirmation and revised risk evaluation via 'Detailed Assessment', at locations adjacent to and including wind turbines 1 and 2, access track to be upgraded and Substation Compound; PSA Areas A, B, C and D, respectively.

1.6 Detailed Assessment and Revised Risk Assessment

140. For each of the four PSA Areas, A, B, C and D, a Detailed Assessment has been undertaken and reported on individual datasheets. This includes description of the peat depths, FoS values, local characteristics including geomorphology and geotechnical information, aerial images and available photographs. These datasheets also identify site-specific mitigation, considering the additional information gathered at each of the PSA Areas. The individual datasheets are provided in **Annex B**, with an overview of the locations presented in **Figure 6.1.12 Detailed Assessment**.

141. The detailed assessment datasheets display the FoS values for grid cells (each cell measuring 50m x 50m), with cells highlighted where FoS values are less than 1.4. The probe location triangles are coloured to represent peat depth ranges (as per colour-coding on **Tables 6.1 – 6.3**) and each probe point also includes a background square coloured to identify the FoS category, using the FoS colour range previously displayed on **Table 6.6**. Other appropriate GIS data provided on the aerial background image is listed on the legend at the beginning of **Annex B**.

142. The FoS value was the primary driver for assigning a likelihood to each grid cell in the model, as discussed for the initial risk assessment, however, regional and local context information may provide additional data that justifies changing the likelihood category at the revised risk assessment stage for locations of concern. These contextual factors are consolidated into **Table 6.1.12**, which provides rationale to assigning revised likelihood values to refine the assessment process:

- regional context; in a regional context some areas have a higher propensity for peatslide events than others and this may be evident from historical records, if reliable. Regional climatic factors influence the development of peat, its coverage and depth; at a site-level peat depths are determined from peat probing fieldwork rather than generalisations. Although the regional context does not provide any spatial differentiation within the Study Area, it may influence the level of caution applied; and
- local context; the variability of local factors material to the development of peatslides may be considered. The primary local factors not already incorporated into the FoS calculations include convex slopes, breaks of slope, drainage patterns, landuse, grazing intensity and incidental events such as fire, which may alter the likelihood of peatslides. These factors may operate across the whole Study Area, in which case they offer no spatial differentiation, but if localised to specific parts of the Site may be helpful in spatial characterisation. Identification of instability identified from aerial photography and confirmed by 'ground truthing' as non-peatslide events, such as peaty debris slides, may be relevant as these forms of instability are not caused by peat instability (rather, are due to the slope failure of material underlying the peat layer). The Guidance (Scottish Government, 2017b) included suggestions of probability values, these have been included in italics as a contextual reference.

Likelihood/ Hazard	Regional Context	Local Context
Almost Certain	The wider region (if it consists of similar condition units to the Study Area) has several historic peatslides. Study Area has several historic peatslides.	FoS <1.0 **Ancillary considerations:** Locally, indications of incipient mass peat instability such as tension cracks, bulges, misaligned fences or trees etc; Peat depths on slopes consistently over 1.5 m; Topography: convex breaks in slope; extensive unconfined slopes; Drainage: converging flow paths; large contributing area; peat pipes; GeoSure Landslide Hazard Class D; *Probability of mass peat instability event occurrence during lifetime of scheme considered greater than 1 in 3.*
Probable	Study Area has evidence of historic peatslide	FoS <1.0 **Ancillary considerations:** Locally, indications of incipient mass peat instability; Peat depths on slopes consistently over 1.0m; Topography: convex breaks in slope; extensive unconfined slopes; Drainage: converging flow paths; large contributing area; peat pipes; GeoSure Landslide Hazard Class D; *Probability of mass peat instability event occurrence during lifetime of scheme considered between 1 in 3 – 1 in 10.*
Likely	Study Area has evidence of historic peatslide	FoS is between 1.0 and 1.4 **Ancillary considerations:** Locally, no adjacent indications of incipient mass peat instability but some within 100m; Peat depths on slopes consistently over 1.00m; Topography: generally rounded/undulating landforms; Drainage: suspicious absence of surface channels indications of peat pipes; GeoSure Landslide Hazard Class C; *Probability of mass peat instability event occurrence during lifetime of scheme considered between 1 in 10 – 1 in 100.*
Unlikely	Study Area has no evidence of past peatslides.	FoS is between 1.4 and 3.0 **Ancillary considerations:** Locally, no indications of incipient mass peat instability Isolated peat depths over 1.00m on slopes; Topography: generally rounded/undulating landforms; Drainage: natural well-defined channels; artificial improvements to drainage; Not GeoSure Landslide Hazard Class D or C; *Probability of mass peat instability event occurrence during lifetime of scheme considered between 1 in 100 – 1 in 10,000,000.*
Negligible	The wider region (if it consists of similar condition units to the Study Area) has no historic peatslides. Study Area has no evidence of historic peatslides.	FoS > 3.0 **Ancillary considerations:** Locally, no indications of incipient mass peat instability; Peat depths less than 1.00m on slopes; Topography: concave or no break in slope; small confined slopes or pockets; Drainage: diverging flow paths; small contributing area; natural well-defined channels; artificial improvements to drainage; Not GeoSure Landslide Hazard Class D or C; *Probability of mass peat instability event occurrence during lifetime of scheme considered less than 1 in 10,000,000.*
N/A – Not Peat		Soil at depth shallower than 0.50m or confirmed as non-peat material.

Table 6.1.12 Criteria Relating to Revised Likelihood Values

143. To aid the revised risk assessment process, geomorphology data was collated to identify grid cells with potential landslide features identified on aerial photography, grid cells with peat depths greater than 1.50m, BGS GeoSure Landslide Hazard classes D and C, slope angles greater than 8º and detailed assessment-specific locations where convex breaks in slope were apparent from DTM data. These features are displayed with planned infrastructure on **Figure 6.1.13 Geomorphology**.

144. A series of individual GIS images are also presented in **Annex C** as **Plates 6.7-6.9**, **6.10-6.12**, **6.13-6.15** and **6.16-6.18** for PSA Areas A, B, C and D, respectively. These display aerial imagery, OS background mapping and DTM data for each area, as used by the assessment team.

145. Where aerial photography and/or GeoSure Landslide Hazards noted features close to infrastructure but not previously flagged by the initial likelihood approach (i.e. not initially classed as 'High' or 'Moderate' likelihood based solely on FoS values), enlarged Detailed Assessment datasheet locations were included to confirm local characteristics in representative areas and check appropriate revised risk level. PSA Areas A, B, C and D incorporate GeoSure and Aerial Photography data.

146. In addition to good practice and design measures, there are also a number of area-specific mitigation measures that are proposed to be deployed to reduce risk (generally the likelihood aspect) at particular locations, with further details in **Section 1.8**.

147. The revised risk information on the two individual datasheets (**Annex B**) reflects refinement, following consideration of specific characteristics for each area, using applicable ground investigation information and the identification and application of any appropriate mitigation measures during design, construction and operation.

148. Potential runout distances and volumes of material for each datasheet have been estimated, factoring-in local conditions, with these estimates recorded within the Detailed Assessment datasheets, alongside identified receptors within and outwith the Site Boundary.

1.6.1 Revised Risk Assessment Outcomes

149. Following Detailed Assessment of the four PSA Areas highlighted for sensitivity analysis, taking account of local ground conditions and application of appropriate good practice and area-specific mitigation measures, their likelihood was reduced from Likely to Unlikely. With reference to **Table 6.1.10**, this results in a revised risk of 'Low' for each of these locations.

150. Following the revised risk assessment process, **Table 6.1.13** records the updated risk outcomes and these are also shown on **Figure 6.1.14 Revised Risk**.

Revised Risk	Number of Grid Cells	% of Grid Cells	Number of Grid Cells (with measured peat depth)	% of Grid Cells (with measured peat depth)	Suggested 'Guideline' Actions
High	0	0.0	0	0.0	*"Avoid project development at these locations".*
Moderate	516	2.7	2	0.2	*"Project should not proceed unless risk can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce risk ranking to low or negligible".*
Low	5,141	27.3	101	8.5	*"Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations".*
Negligible	11,988	63.7	619	52.2	*"Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate".*
N/A No Risk (Not Peat)	1,175	6.2	463	39.1	Non-peat material, no peatslide risk.
Total Cells:	**18,820**	**100.0%**	**1,185**	**100.0%**	

Table 6.1.13 Revised Risk Outcomes

151. There are no locations of revised 'High' or 'Moderate' risk specific to peat instability at locations of proposed infrastructure, or within 500m.

1.7 Assessment Assumptions

152. Following previous peat stability report feedback from Ironside Farrar from similar sites, this section identifies key assumptions which have been applied during the preparation of this deliverable.

153. The key variables and most sensitive factors in the FoS analysis are peat depth and slope angle, which are directly applied using a large dataset of site information focussed on planned infrastructure positions, applying a back-calculated c' specific to site data and conservative lower-bound literature values for other calculation inputs. Thus, the assessment of peat stability at this EIAR stage follows an inherently conservative approach. The site visits to ascertain revised risk act as a form of sensitivity analysis, as the method bases initial probability directly upon FoS outcomes for the initial risk stage and typically leads to the identification of locations which can be justifiably reduced to a lower probability and potentially lower revised risk, following the collation of ancillary local information.

154. This assessment focussed upon undrained peat, at the detailed design stage it may be deemed appropriate to also conduct analysis drained peat for selected representative locations including PSA Areas A, B, C and D.

155. Existing drainage features have been identified, where relevant, in the **Annex B** Datasheets and would be included in the Geotechnical Risk Register. Similarly, forestry drains are recorded where applicable to PSA Datasheets. These channels are not all shown on mapping, with maps using OS information. Should additional channel mapping be considered appropriate at the detailed design stage, this could be undertaken.

156. Without detailed Ground Investigation information, all borrow pits remain subject to potential blasting operations, with each area subject to appropriate detailed planning for environmental sensitivities and rock recovery. The western part of the search area for borrow pit BP04 is located within PSA Area A and the eastern part of BP02 is located approximately 150m from PSA Area C, with no other borrow pits within 500m of any PSA Area. Further borrow pit information is available in **Appendix 6.6 Borrow Pit Assessment** of the EIAR. The detailed design would determine the footprint and confirm methodologies for extracting material from this borrow pit. These shall be included and assessed in the Geotechnical Risk Register, with appropriate placement and techniques adopted depending on rock characteristics, local constraints and project requirements.

157. Excavated peat would be reused locally, with side-casting during cut track construction anticipated and restoration of historic quarry sites and borrow pits opened for the Proposed Development. Peat would be re-used in as short a timescale as feasible and follow principles provided in **Appendix 6.2 Soil and Peat Management Plan** of the EIAR Post-consent, the detailed design would include details of plans for temporary storage of peat and associated methodologies for excavation/transfer/storage/reuse. The Geotechnical Risk Register would include peat storage as a specific risk, with applicable controls that would be kept up-to-date with current good practice and lessons learned from Site works.

1.8 Mitigation and Good Practice Measures

158. The purpose of the PSA is to identify areas of the Site which are potentially at most risk of peat instability and thereafter assess potential construction impacts. Where avoidance through design is not possible, mitigation measures require to be implemented to avoid or reduce the risk of peat instability. In addition to specific mitigation measures which may be deployed at particular locations, itemised in the specific detailed assessment datasheets. There are a number of generic construction good practice measures that would be applied, where applicable, as additional data becomes available at the pre-construction stage. A number of these potential actions are set out in **Table 6.1.14**.

159. With reference to **Table 6.14**, the area-specific mitigation measures identified for the Proposed Development are 1, 2, 5, 9, 12, 13, 17, 19 and 20.

160. Good practice guidance documents, such as Floating Roads on Peat (FCE & SNH , 2010), Managing Geotechnical Risk (Clayton, 2001) and Peat Landslide Hazard and Risk Assessments: Best Practice guide for Proposed Electricity Generation Developments (Scottish Government, 2017b) would be consulted to inform the design and construction processes. All site investigation work would be undertaken in compliance with relevant British Standards (BS), including BS 5930:1999 and BS 6031:2009.

161. The application of good practice techniques during forestry clearance necessary at this Site would also act to reduce the potential for peat instability, in terms of both likelihood of occurrence and magnitude of any event that does occur. Following forestry clearance, in areas with previously restricted access coincident with infrastructure plans, surveys shall be undertaken to record peat depths and any evidence of historic or potential peat instability.

162. Onsite construction staff are often the best placed to provide advance notification of potential problems, provided sufficiently trained and with an appropriate reporting mechanism. There are a number of recognised indicators for slope failures and these may indicate a potential peatslide or the commencement of a peatslide event, as outlined in **Section 1.2.1** of this report. The suspected identification of any of these indicators should be assessed by specialist peat stability or geotechnical personnel.

163. Additional items to those identified in **Table 6.1.14** may be introduced as further site data becomes available at pre-construction and construction stages.

Potential Actions	Good Practice	PSA Area-Specific Mitigation Measures, as applicable
1. Geotechnical specialist onsite during the construction phase to undertake advance inspection, carry out regular slope monitoring and provide ongoing advice at locations of concern.	✓	A, B, C and D
2. Maintain and update geotechnical risk register or similar management system.	✓	A, B, C and D
3. Construction staff should be made aware of peatslide indicators and emergency procedures (see below).	✓	
4. Emergency procedures should include steps to be taken on detection of any evidence of potential peat instability.	✓	
5. Microsite the wind turbine base or access track in order to avoid the area of concern (subject to non-violation of other constraints).	✓	A, B and D
6. Ensure that good groundwater and surface water control, such as moor gripping or drainage ditches, is in place in advance of construction activities.	✓	
7. Installation of stand-pipes / piezometers to monitor ground water levels and pore pressures.	✓	

Potential Actions	Good Practice	PSA Area-Specific Mitigation Measures, as applicable
8. Ensure artificial drainage does not concentrate flows onto slopes, gully heads or into excavations.	✓	
9. Ensure that sediment control measures are incorporated into all artificial drainage measures and including specific scour protection mitigation where steep slopes or high activity erosion processes are identified. Concrete aprons, rip rap, gabion/reno mattress or geotextile mats may be applicable options, depending on watercourse characteristics and sensitivities.	✓	A, B, C and D
10. Earthmoving activities should be restricted during and immediately after heavy and/or prolonged rainfall events, including use of weather forecasting and re-programming of construction activities as applicable. Particular care should be taken when heavy rainfall events are predicted following a prolonged dry spell.	✓	
11. The construction plan should minimise the extent and duration of open excavations and bare ground.	✓	
12. Avoid placing excavated material or other forms of loading on or immediately above breaks of slope or any other potentially unstable slopes.	✓	A, B, C and D
13. Avoid removing slope support, particularly where slope stability has been highlighted as of concern. Consider floating access track at appropriate locations to avoid removing slope support.	✓	A, B, C and D
14. Establish / re-establish vegetation as soon as possible to improve slope stability and provide sediment transport control.	✓	
15. Consider limiting loads crossing newly created peat embankments to enable pore water pressure in both embankment and underlying peat to reduce to pre-construction levels and original shear strength.	✓	
16. Modify slope geometry to provide a ‘weighted toe’.	✓	
17. Use of retaining structures, such as gabion terracing to support specific slopes.		A, B, C and D
18. In locations where limited opportunity for avoidance or other mitigation to reduce likelihood, the application of debris nets, catch fences, catch ditches and/or deflection systems to protect receptors and reduce adverse consequences. Such installations should be subject to routine inspection and maintenance.	✓	
19. Forestry clearance activities should be undertaken following good practice, including careful positioning of log piles to avoid overloading of slope, sediment control and consideration of retaining tree roots *in situ* for soil stabilisation in appropriate locations.	✓	A, B, C and D
20. Borrow pit blasting activities to take account of any peat stability locations of concern in the proximity, including seeking alternative methods that avoid blasting. If sensitive peat stability receptors are identified, there are a number of methods to manage, mitigate and monitor, such as careful placement, charge size, vibration monitoring and pre- and post-blasting slope monitoring.	✓	A and C

Table 6.1.14 Good Practice and Mitigation Measures

1.9 Summary and Recommendations

164. Peat depth probing in conjunction with slope angle mapping is a cost-effective method to establish peat depth and peat stability profiles across large areas. Combining this with aerial photograph interpretation and GeoSure datasets enables potential evidence of mass movement events to be efficiently identified.

165. The Proposed Development is underlain by peat of varying depths and shallower peaty soil, with an average depth across the Study Area of 0.99m. There are a number of steep slopes in the central and western parts of the Site, where deeper peat coincides with these slopes, especially at convex break of slope positions, the likelihood of peatslide increases. Areas identified as of higher likelihood for instability were primarily related to locations at or below convex breaks of slope or due to isolated deeper peat deposits recorded.

166. The conservative nature of the methodology applied leads to initial risk identification, based on FoS analysis, of the least stable areas on any specific site, initially considered of 'Moderate' or 'High' risk, with this risk level relative to the remainder of the Site. Within 500m of the proposed infrastructure, no areas with initial 'High' risk were identified, with one initial 'Moderate' risk location identified. Other locations of concern were avoided as part of the design process planned for the Proposed Development. In order to review the initial risk, four areas with FoS values between 1.0 and 1.4 (including the initial 'Moderate' risk location) at proposed infrastructure were identified and visited as part of the detailed assessment and revised risk process.

167. Site visits occurred at various phases of the Proposed Development design, between March 2020 and October 2020, to inform evolving iterative design, assessment and reporting processes. A further specific PSA visit was undertaken in October 2020 for 'ground truthing' to establish peatland and stability characteristics at particular locations of interest, including PSA Areas A, B and C identified. Further site data collated included humification testing, using the von Post classification system to establish fibrous and structural condition of peat at various locations and depths, laboratory analysis of cores, landform descriptions, additional peat probing and shallow shear vane data. PSA Area D was identified following a Site visit in August 2021 to gather additional peat data for the revised positioning of the Substation Compound, during this visit no signs of peat instability were evident and the core collected at PSA Area C is deemed to be representative of the local conditions.

168. **Annex B** provides datasheets for the two locations identified for 'Detailed Assessment'. PSA Area A, PSA Area B and PSA Area C were evaluated as of initial 'Low' risk with FoS values between 1.0 and 1.4, including extended coverage where GeoSure data suggested potential instability. PSA Area D was evaluated as of initial 'Moderate' risk with FoS value of 1.40. At these four locations further information was collated to refine the risk, with individual datasheets prepared to provide local details and discuss initial and revised risk assessment outcomes.

169. Following the Detailed Assessment process, 'Low' risk was confirmed for the locations visited. This takes account of local ground conditions and good practice forestry clearance plus appropriate micrositing to avoid/minimise disturbance of deeper peat and coincident breaks of slope, alongside slope monitoring, slope support measures, appropriate borrow pit excavation methodology and drainage controls as area-specific mitigation. No areas within 500m of the proposed infrastructure are considered to be above 'Low' revised risk (with the vast majority of the Site considered 'Negligible' risk or non-peat) in terms of peat stability assessment. Revised risk outcomes for the Site are shown on **Figure 6.1.14 Revised Risk**.

170. The Guidelines (Scottish Government, 2017b) quote the following requirements, for which 'Low' risk applies to this Site:

- High risk – 'Avoid project development at these locations';
- Moderate risk – 'Project should not proceed unless risk can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce risk ranking to low or negligible'';
- Low risk – 'Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations'; and
- Negligible risk – 'Project may proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate'.

171. Further geotechnical investigation is proposed as part of the Site investigations, which would take place post-consent and prior to construction. This is standard practice and would inform the final, detailed design of the Development, along with detailed mitigation, such as specific drainage designs including routes and discharge locations, to be implemented during construction, undertaken by an appropriately qualified geotechnical engineer. Any additional areas of concern identified by surveys following forestry clearance, should be added to the areas for further investigation.

172. Whilst good practice and specific mitigation measures have been identified in this document in order to minimise risk, the suggested techniques are not exhaustive and it is expected that a design consultancy and contractor would use these and other techniques, as appropriate, to effectively manage the peat stability risk.

173. Management of peat stability risk would remain a consideration throughout the subsequent detailed design processes, including additional site investigation, pre-construction activities and during construction, subject to the development receiving consent. A key issue is that the design remains 'live' and subject to ongoing optimisation, with the iterative design process continuing into construction phase. The contractor is able to microsite to reduce peat instability risk, whilst taking account of other local environmental and engineering constraints.

174. The need for risk management has been emphasised throughout this report and forms a standard part of any windfarm construction project. Risk management would include the regular review of the Geotechnical Risk Register, supported by appropriate actions within the contractor's Construction Method Statement (CMS) and Construction Environmental Management Plan (CEMP), in due course.

1.10 Technical Authors and Experience

175. The joint authors of this report were Stuart Bone BSc (Hons.) MSc PIEMA CWEM Cenv and Marta Ibanez Garcia BSc MSc PIEMA.

176. Stuart Bone is a Chartered Environmentalist (Cenv) and Chartered Water and Environmental Manager (CWEM) holding chartered status since 2005 and is also a Practitioner Member of the Institute of Environmental Management & Assessment (PIEMA). Stuart has a BSc (Hons.) in Environmental Geography from the University of Aberdeen and a MSc in Marine Resource Development and Protection from Heriot-Watt University. Stuart has over 20 years environmental experience, since 2006 focused on delivering PSA and other soil and water EIA deliverables in the renewable energy sector and highways. He has been involved in the planning of fieldwork and the delivery of Peat Stability Assessments since 2006, becoming a technical lead on these deliverables in 2012. Stuart has a strong understanding of peat morphology, geomorphological processes, environmental data collection, FoS stability analysis and risk assessment both from project experience and from his academic background. Stuart has a thorough familiarity of the latest guidance and promotes early data collation and stability interpretation to inform the iterative design process in accordance with good risk management principles. Stuart has provided technical reporting and guidance, supervision and in-depth review at every stage of this PSA process. Stuart visited the Site in October 2020 to review detailed assessment locations and supervise associated fieldwork.

177. Marta Ibanez Garcia is a qualified Environmental Scientist with a BSc and MSc in Environmental Management from Abertay University. She has been a Practitioner Member of the Institute of Environmental Management & Assessment (PIEMA) since 2017 and is currently working towards Chartership. She has six years' experience in environmental impact assessment, and delivering peat stability assessments, including planning and conducting fieldwork, since 2018. She worked previously in Quality and Environmental Management Systems implementation. Marta has been the joint report author and also responsible for planning peat surveys, conducting fieldwork, data interpretation and processing peat stability outcomes using QGIS software.

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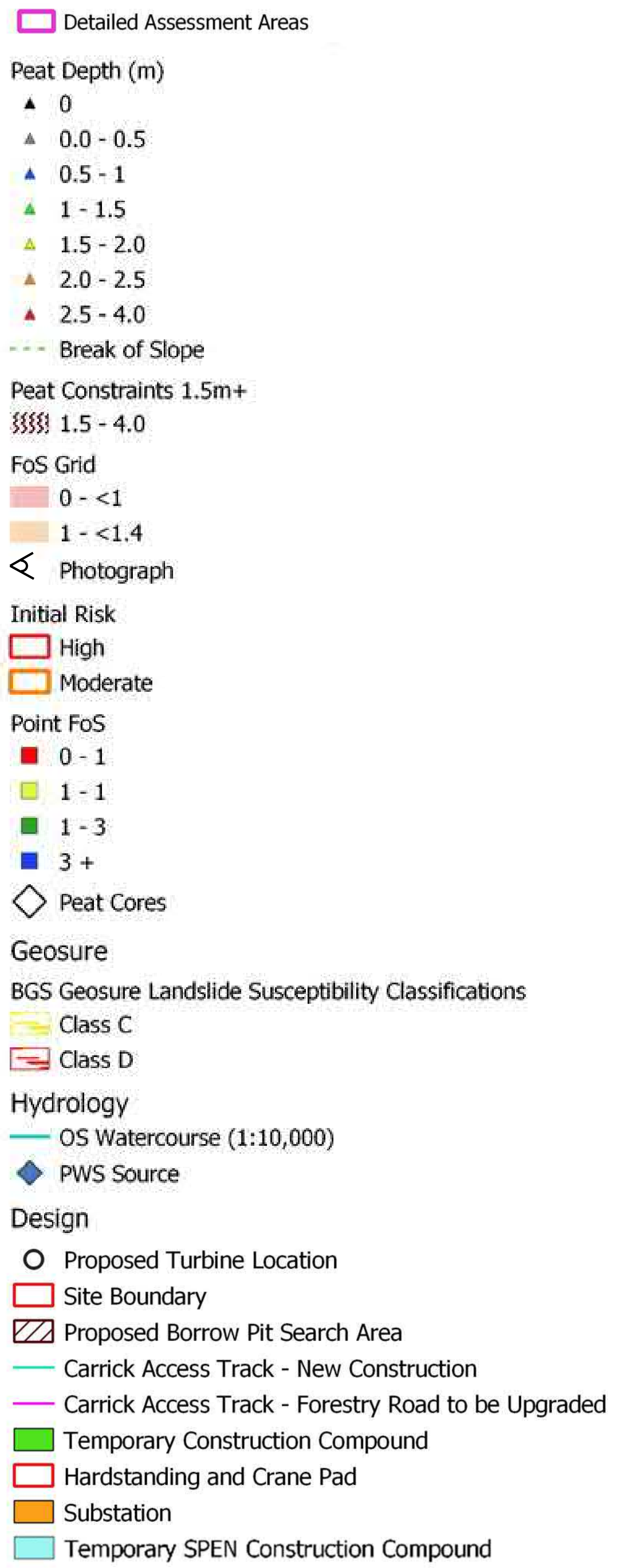
Annex A. Peat Stability Assessment Figures

Annex B. Detailed Assessment Datasheet Descriptions

Legend for Detailed Assessment Datasheets



PSA Area A: **Initial** Likelihood – Likely; Consequence – Moderate; **Risk – Low**

Revised Likelihood – Unlikely; Consequence – Moderate; **Risk – Low**

Good Practice and Design

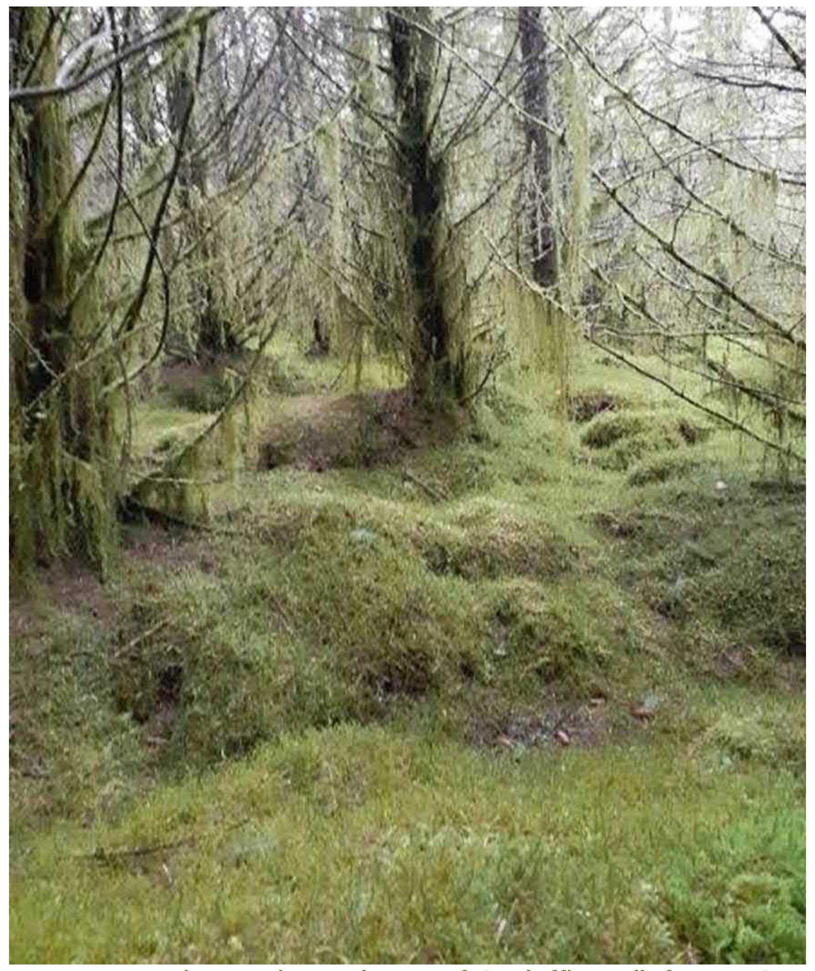
Section 1.8 details standard good practice measures. Wind turbine 2 and associated proposed infrastructure is located on a cell with a FoS value of between 1.0-1.4 in PSA Area A, although considered of 'Low' risk. This wind turbine position was formerly located at peat core PC03, subsequently relocated from the deeper peat and steeper slope at that location. The existing forestry track (not planned for upgrade) runs below and parallel to the breaks of slope of the Garleffin Fell and parallel to BP04.

Specific Mitigation, Potential Scale and Receptor

Section 1.8 lists standard mitigation measures.

Micrositing of the hardstanding, blade laydown area and access track to avoid or minimise disturbance of the deeper peat recorded at PC04 would reduce concern. Following forestry removal applying good practice, additional peat surveys and stability assessments should be undertaken pre-construction. Slope monitoring to be instigated to north and south of wind turbine 2, with care taken to avoid increasing loading of slope to north or removal of slope support to south, particularly at the breaks of slope, with a potential requirement to use gabion terraces/mattresses or other measures. At the detailed design stage, blasting at borrow pit BP04 should be evaluated for potential influence on the deeper peat identified on the slope at PC04 and PC03, with the offset distance maximised to reduce potential blasting influence. Track drainage should avoid converging large or high velocity flows onto slopes to north in order to avoid scour and/or bank collapse. This area should be recorded in the Geotechnical Risk Register.

Should peatslide occur; approximated width 30m, length 30m, at an average depth of 1.50m; volume of peat 1,350m^3; Receptors – local hillside, forestry, existing access track.



Photograph 6.9 Looking west from PSA Area A, on the northern slopes of Garleffin Fell, from NGR 234997, 599145

Photograph taken at approximately 380m AOD, looking west from the proposed wind turbine 2 hardstanding towards wind turbine 1. Also **Plates 6.1** and **6.7-6.9** and **Photographs 6.4** and **6.8**, in **Desk Study**, **Site Reconnaissance** and **Annex C**.

Revised Risk

Although this general area is identified by GeoSure as Class C, it has highly modified and variable peatland features with no evidence of peat instability from Site visit or aerial photograph, including from previous track construction.

Taking account of the peatland morphology, existing drainage, anticipated retention of tree roots, individual peat probe FoS, design and mitigation (including micrositing to avoid/minimise disturbance of deeper peat recorded at PC04), peat-related instability is reduced to Unlikely and the Revised Risk remains Low.

Area Details

This area is primarily identified due to the steep northern slopes of Garleffin Fell. Wind turbine 2, its associated proposed infrastructure and BP04 are located within PSA Area A, with grid cells within 100m of the wind turbine and 50m of the hardstanding, access track and borrow pit evaluated with 'Moderate' consequence outcomes. Aerial imagery shows this area as afforested with no evidence of instability, nor was any noted during the visit. PSA Area A images with OS background and DTM data are also provided in **Annex C**. BGS GeoSure mapping has identified the north and eastern parts of this area as Class C where '*slope instability problems may be present or anticipated*'.

Forestry activities would have modified the peat structure via ploughing and drainage on this slope, the anticipated retention of tree roots post-felling would reduce erosion potential and increase local slope stability.

Within 50m of wind turbine 2 and borrow pit BP04, peat depths were generally non-peat or shallow peat, with depths less than 1.00m and a mean probing depth of 0.85m across PSA Area A. A small isolated area of deeper results were recorded at peat core PC04 (of up to 1.83m) on the margin of the blade laydown area 50m south west of wind turbine 2, with a larger area of deeper peat (up to 1.59m) adjacent to the existing forestry track at PC03, 120m north east and downslope of wind turbine 2. Slope gradients are generally steeper in the east, with distinct breaks of slope above the existing forestry track (which is not planned for upgrade), with slope angles of up to 17º. Local slope angles are increased by the cuttings and bankings immediately to the west and east, respectively, of the existing forestry track, presumably using material excavated during the original track construction (see **Photographs 6.6** and **6.8** in **Site Reconnaissance Section**). From observation, this material appeared to be a mix of peaty soil, mineral soil and boulder clay, with no obvious bank instability.

Two peat cores were taken at this location, PC03 and PC04, at a slope angle of 12º for both, collected at depths of 1.40m and 1.30m, recording Von Post humification class H5 and H6; Moderately and Strongly Decomposed, respectively. This data suggests that amorphous catotelmic peat may be found locally at depths of 1.30m. The hand shear vane's lowest recorded value, at a depth of 0.30m, was 17kN/m^2.

The FoS values for peat probes ranged from 0.66 to 10.96, with the grid cell immediately south west of wind turbine 2 recording a FoS value of 1.13, based on a measured peat depth of 1.83m (at PC04) and mean slope angle of 11º. If applying a shear strength value of 4KN/m^2, as literature lower-bound value, to this FoS grid cell, the revised FoS outcome would be 1.15. If applying the lowest shallow hand shear vane outcome from Site investigations (17kN/m^2), the cell FoS value would be revised further to 4.87.

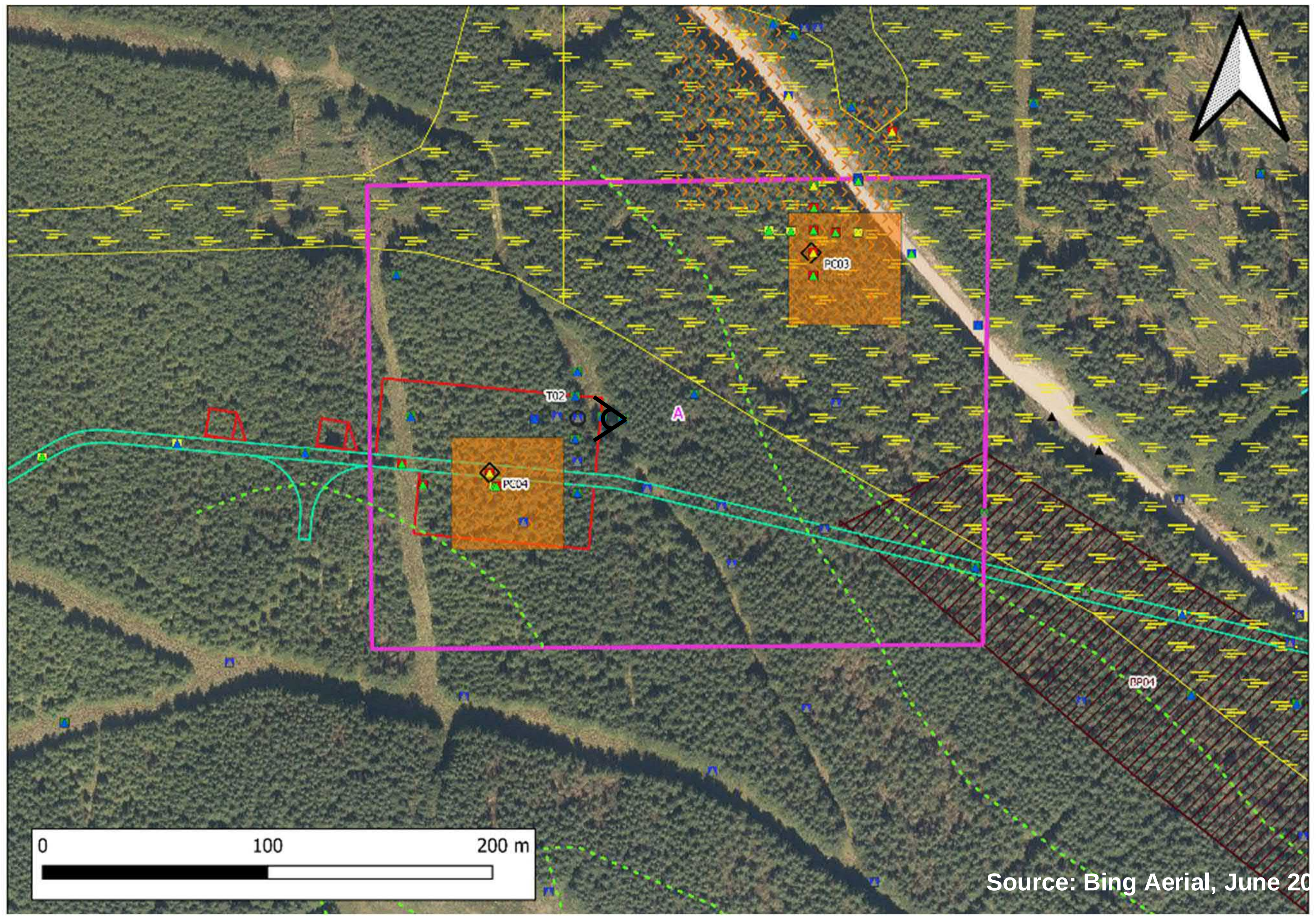


Plate 6.5 Aerial Image of PSA Area A

PSA Area B: **Initial** Likelihood - Likely; Consequence - Moderate; **Risk - Low**

Revised Likelihood - Unlikely; Consequence - Moderate; **Risk - Low**

Good Practice and Design

Section 1.8 details standard good practice measures. Part of the proposed wind turbine 1 associated hardstanding is located within a cell with a FoS value of 1.36. The new access track to wind turbine 1 is located immediately downslope and south of an area of level ground where deeper peat has been recorded. The local infrastructure has avoided the steeper slopes to the north, with a design improvement following peat survey leading to moving this wind turbine 20m west, from a former position on deeper peat 10m south of peat core PC05.

Specific Mitigation, Potential Scale and Receptor

Section 1.8 lists standard mitigation measures.

Micrositing to west should be considered for wind turbine 1 and associated hardstanding, blade laydown area and access track to avoid or minimise disturbance of the deeper peat and increase spacing to break of slope to north. Floating access track should be considered on approach to wind turbine 1, if feasible due to cross-slope. Following forestry removal applying good practice, additional peat surveys and stability assessments should be undertaken pre-construction to identify local characteristics. Slope monitoring to be instigated to north and south of wind turbine 1, with care taken to avoid increasing loading of slope to north (particularly close to the break of slope) or removal of slope support to south, with a potential requirement to use gabion terraces/mattresses or other measures. Track drainage should avoid converging large or high velocity flows onto slopes to north in order to avoid scour and/or bank collapse. Area should be recorded in the Geotechnical Risk Register.

Should peatslide occur; approximated width 50m, length 100m, at an average depth of 2.00m; volume of peat 10,000m^3; Receptors - local hillside, forestry and headwaters of Palmullan Burn, wind turbine 1 and associated proposed infrastructure.

Photograph 6.10 Looking north from PSA Area B at NGR 234298, 599022.

Photograph taken at approximately 390m AOD, looking north towards the proposed wind turbine 1.
Also see **Plates 6.1** and **6.10-6.12** and **Photograph 6.3**, in **Desk Study**, **Site Reconnaissance** and **Annex C**.

Revised Risk

Deep peat is present at wind turbine 1, with a break of slope below the planned infrastructure to north, however, no peat instability evidence was observed at this highly modified peatland location or identified on aerial imagery or GeoSure data.

Taking account of the peatland morphology, existing drainage network, anticipated retention of tree roots, design and mitigation (including slope management and micrositing to minimise disturbance of deeper peat), the Likelihood is reduced to Unlikely and the Revised Risk remains Low.

Area Details

This area is primarily identified due to deep peat deposits on the lower slopes to the west of Garleffin Fell. Given the proposed wind turbine 1 location and associated proposed infrastructure within 100m and the peat records over 1.50m, the consequence value is 'Moderate'. Aerial imagery shows this area as afforested with no evidence of instability, nor was any noted during the visit. This area is not identified within the BGS GeoSure mapping.

Forestry activities would have modified the peat structure via ploughing and drainage on this slope, the anticipated retention of tree roots post-felling would reduce erosion potential and increase local slope stability.

Consistent peat depths of over 1.50m, ranging up to 2.77m, were recorded on the relatively level ground adjacent to the new access track and wind turbine 1, with a mean probe depth of 1.54m for PSA Area B. Further north in this area, peat depths were generally less than 1.00m. Slope angles are generally less than 8^o to the south of the proposed new access track to wind turbine 1, steepening north of the access track position to approximately 13^o below the indistinct break of slope, 20m north of the wind turbine 1 hardstanding.

Peat core location PC05 was taken at a slope angle of 7^o at depth of 1.60m, recording Von Post humification class H7; Highly Decomposed. This data suggests that amorphous catotelmic peat is found at depths of 1.60m locally. The hand shear vane's lowest recorded value at a depth of 0.30m was 14kN/m^2.

The FoS values for peat probes ranged from 0.88 to 11.66, with one cell on the northern margin of the proposed wind turbine 1 hardstanding recording a FoS value of 1.36, which included a 2.23m peat depth record (with an FoS point value of 0.88) and a mean slope of 8^o. If applying a shear strength value of 4kN/m^2, as literature lower-bound value, to this FoS grid cell, the revised FoS outcome would be 1.38. If applying the lowest hand shear vane outcome from PC05, 14kN/m^2, the cell FoS value would be revised to 4.82.

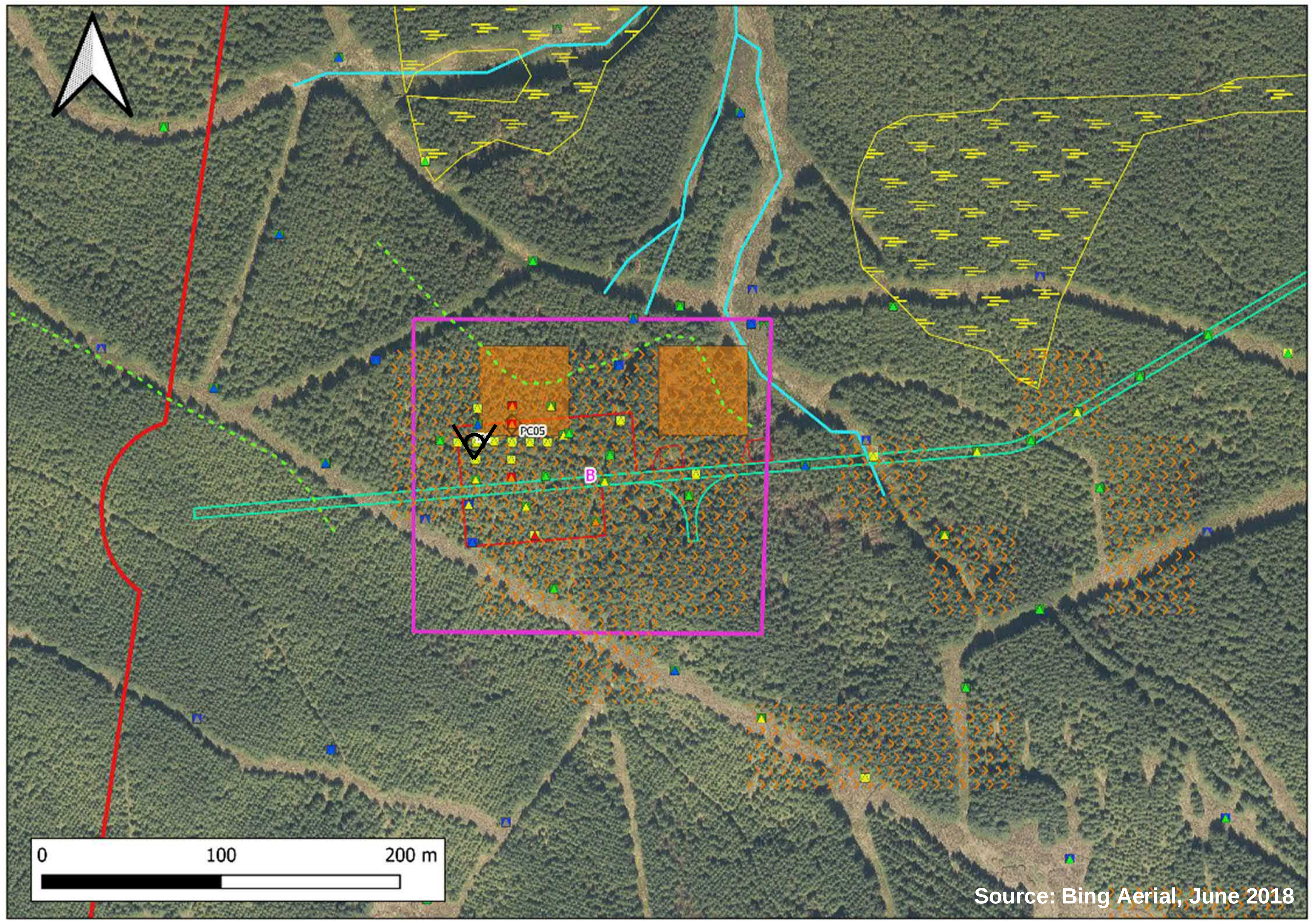


Plate 6.6 Aerial Image of PSA Area B

PSA Area C: **Initial** Likelihood - Likely; Consequence - Moderate; **Risk - Low**

Revised Likelihood - Unlikely; Consequence - Moderate; **Risk - Low**

Good Practice and Design

Section 1.8 details standard good practice measures. The proposed access track to be upgraded is located 75m south of a FoS value of 1.37. The local infrastructure has avoided the deeper peat to the north, with a design improvement following peat survey leading to moving wind turbine 8 approximately 20m west, from a former position on deeper peat.

Specific Mitigation, Potential Scale and Receptor

Section 1.8 lists standard mitigation measures.

Drainage design should avoid converging flows into areas potentially prone to failure. Drainage layers or similar techniques should be applied where track crosses flush zones, using pipes to maintain existing downslope hydrogeological conditions. Minimise loading of the gentle slope above this zone, with track bankings carefully designed to avoid excess material being placed on this slope. Any planned borrow pit blasting shall take account of local peat conditions and appropriate mitigation, including safety zone, will be adopted based on additional ground investigation data.

Continue to monitor and reappraise risk assessment during detailed design and construction. This location should be recorded in the Geotechnical Risk Register.

Should peatslide occur; approximated width 30m, length 70m, at an average depth of 2.90m; volume of peat 6,100m^3; Receptors - local hillside, forestry and tributary of Knockoner Burn.

Photograph 6.11 Looking south from PSA Area C at NGR 237446, 598524

Photograph taken at approximately 296m AOD, looking south towards the proposed track to be upgraded.
Also see **Plates 6.13-6.15** and **Photographs 6.13-14** in **Annex C**.

Revised Risk

The proposed infrastructure avoids crossing this deeper peat area, where amorphous catotelmic peat has been identified in this area. No peat instability evidence was observed at this peatland location or identified on aerial imagery or GeoSure data.

Taking account of the peatland morphology, existing drainage network, anticipated retention of tree roots, proposed design and mitigation, the Likelihood is reduced to Unlikely and the Revised Risk remains Low.

Area Details

This area is primarily identified due to deep peat deposits on the lower slopes to the west of Stob Hill. Given the peat records over 1.50m, the consequence value is 'Moderate'. Aerial imagery shows this area as afforested with no evidence of instability, nor was any noted during the visit. This area is not identified within the BGS GeoSure mapping.

Forestry activities would have modified the peat structure via ploughing and drainage on this slope, the anticipated retention of tree roots post-felling would reduce erosion potential and increase local slope stability.

Consistent peat depths of over 1.50m, ranging up to 4.87m, were recorded on the relatively level ground north of the access track to be upgraded, with a mean probe depth of 1.62m for PSA Area C. Further north in this area, peat depths were generally deeper than 2.0m. Slope angles are generally less than 2^o to the north of the proposed access track to be upgraded, steepening immediately north of the access track position to approximately 11^o, likely caused as a result of the existing track construction.

Peat core location PC01 was taken at a slope angle of 2^o and has a total peat depth of 4.87m. At this location, one of the samples taken at 2.00m depth (PC01a) recorded Von Post humification class H6; Strongly Decomposed. This data suggests that amorphous catotelmic peat is found at depths of 2.00m locally. Note Peat core PC01b identified non-amorphous catotelmic peat material at a greater depth of 3.10m at the same location. The hand shear vane's lowest recorded value at a depth of 0.30m was 26kN/m^2.

The FoS values for peat probes ranged from 1.46 to 6.33, with one cell 75m north of the proposed access track to be upgraded recording a FoS value of 1.37, which included a 4.87m peat depth record (with an FoS point value of 1.46) and a mean slope of 3^o. If applying a shear strength value of 4kN/m^2, as literature lower-bound value, to this FoS grid cell, the revised FoS outcome would be 1.39. If applying the lowest hand shear vane outcome from PC01, 26kN/m^2, the cell FoS value would be revised to 9.04.

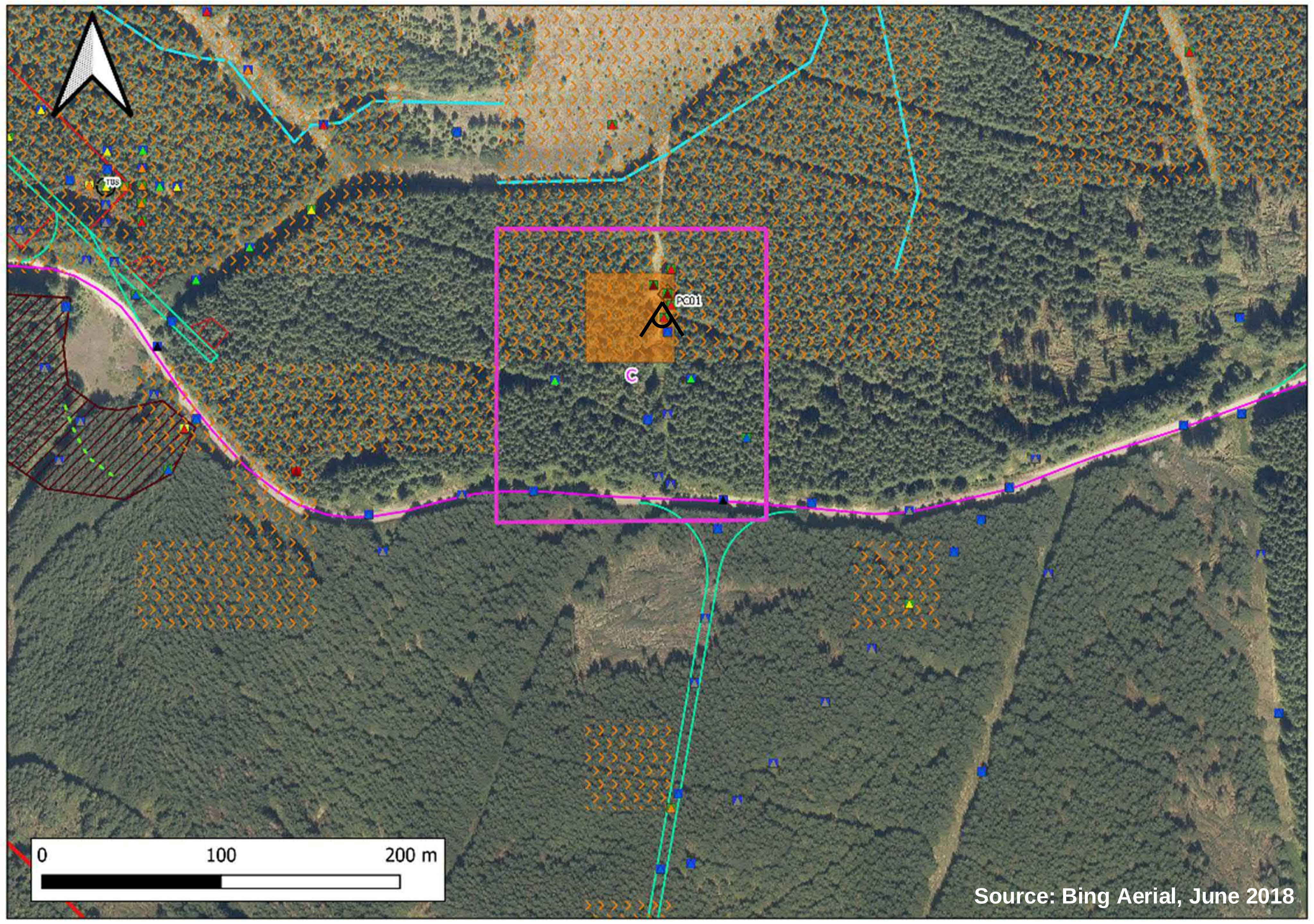


Plate 6.7 Aerial Image of PSA Area C

PSA Area D: **Initial** Likelihood - Likely; Consequence - High; **Risk – Moderate**

Revised Likelihood - Unlikely; Consequence - High; **Risk - Low**

Good Practice and Design

Section 1.8 details standard good practice measures. The Substation Compound is located 5m north-east of a cell with a FoS value of 1.40. The Substation Compound, the temporary SPEN Construction Compound and associated new access track are located immediately upslope and north of an area of level ground where deeper peat has been recorded. Following identification of peat depth, the Substation Compound was positioned to avoid the deeper peat to south and to the north.

Specific Mitigation, Potential Scale and Receptor

Section 1.8 lists standard mitigation measures.

Floating access track should be considered on approach to the Substation Compound, if feasible due to peat depths.

Additional peat stability assessments should be undertaken pre-construction to identify local characteristics. Micrositing of the temporary SPEN Construction Compound, Substation Compound and associated access track further to the north-east will reduce the risk of any instability, by avoiding the break of slope. Albeit indistinct, care should be taken to avoid removal of slope support or increasing loading of slope (e.g. stockpiling of materials or heavy plant movement) where convex breaks of slope occur. Monitoring will be undertaken of slopes close to break of slope, which may lead to a requirement for slope support or erosion protection, such as use of gabion terraces/mattresses or other measures.

Continue to monitor and reappraise risk assessment, particularly any sign of movements towards the Tairlaw Burn, during detailed design and construction. This location should be recorded in the Geotechnical Risk Register.

Should peatslide occur; approximated width 100m, length 50m, at an average depth of 2.50m; volume of peat 12,500m^3; Receptors – Substation Compound, the temporary SPEN Construction Compound and associated new access track, local hillside and Tairlaw Burn.

Photograph 6.12 Looking north from PSA Area D at NGR 238839, 597575.

Photograph taken at approximately 290m AOD, looking south from the temporary SPEN Construction Compound towards the PSA Area D.

Also see **Plates 6.16-6.18** and **Photographs 6.13-14** in **Annex C**.

Revised Risk

Although there is an indistinct break of slope running parallel to the southern edge of the Substation Compound and deep peat south-west of the Substation Compound, no peat instability evidence was observed at this highly modified peatland location or identified on aerial imagery or GeoSure data.

Taking account of the peatland morphology, existing drainage network, tree roots retained, design and mitigation (including slope management and micrositing to avoid the break of slope and minimise disturbance of deeper peat), the Likelihood is reduced to Unlikely and the Revised Risk is Low.

Area Details

This area is primarily identified due to deep peat deposits to the south-west of the Substation Compound. Given the proposed Substation Compound and the temporary SPEN Construction Compound locations and associated proposed infrastructure within 100m, the consequence value is 'High'. Aerial imagery shows this area as felled area with no evidence of instability, nor was any noted during the visit. From south-west to north-east, an indistinct break of slope runs parallel to the southern edge of the Substation Compound. The break of slope was not apparent during the Site visit but was identified on the DTM data. This area is not identified within the BGS GeoSure mapping.

This location has been clear-felled, with stumps retained *in situ* and large drainage channels flowing to north-east. These features have modified the peat body and limited potential for instability by reducing water content and anchoring peat via retained tree roots, also confining the extent of any mass movement.

Consistent peat depths of over 2.00m, ranging up to 3.69m, were recorded on the relatively level ground south of the new access track and Substation Compound, with a mean probe depth of 1.74m for PSA Area D. Further north-east in this area, where the proposed Substation Compound is located, peat depths were generally less than 1.00m. Slope angles are generally less than 6^o to the south-west of the Substation Compound and the temporary SPEN Construction Compound, steepening at the Tairlaw Burn Valley to approximately 8^o, 95m south of the temporary SPEN Construction Compound.

No peat cores were taken in this area, with the nearest core PC01 taken approximately 1.7km north-west, at a similar elevation (300m AOD) and peat depths and is therefore considered reasonably representative. Peat core location PC01 was taken at a slope angle of 2^o and has a total peat depth of 4.87m. At this location, one of the samples taken at 2.00m depth (PC01a) recorded Von Post humification class H6; Strongly Decomposed. This data suggests that amorphous catotelmic peat is found at depths of 2.00m regionally. Note Peat core PC01b identified non-amorphous catotelmic peat material at a greater depth of 3.10m at the same location. The hand shear vane's lowest recorded value at a depth of 0.30m was 26kN/m^2.

The FoS values for peat probes ranged from 0.75 to 10.89, with one cell within PSA Area D recording a FoS value of 1.40, which included a 3.69m peat depth record (with an FoS point value of 0.75) and a mean slope of 4^o. If applying a shear strength value of 4kN/m^2, as literature lower-bound value, to this FoS grid cell, the revised FoS outcome would be 1.41. If applying the lowest hand shear vane outcome from PC01, 26kN/m^2, the cell FoS value would be revised to 9.19.

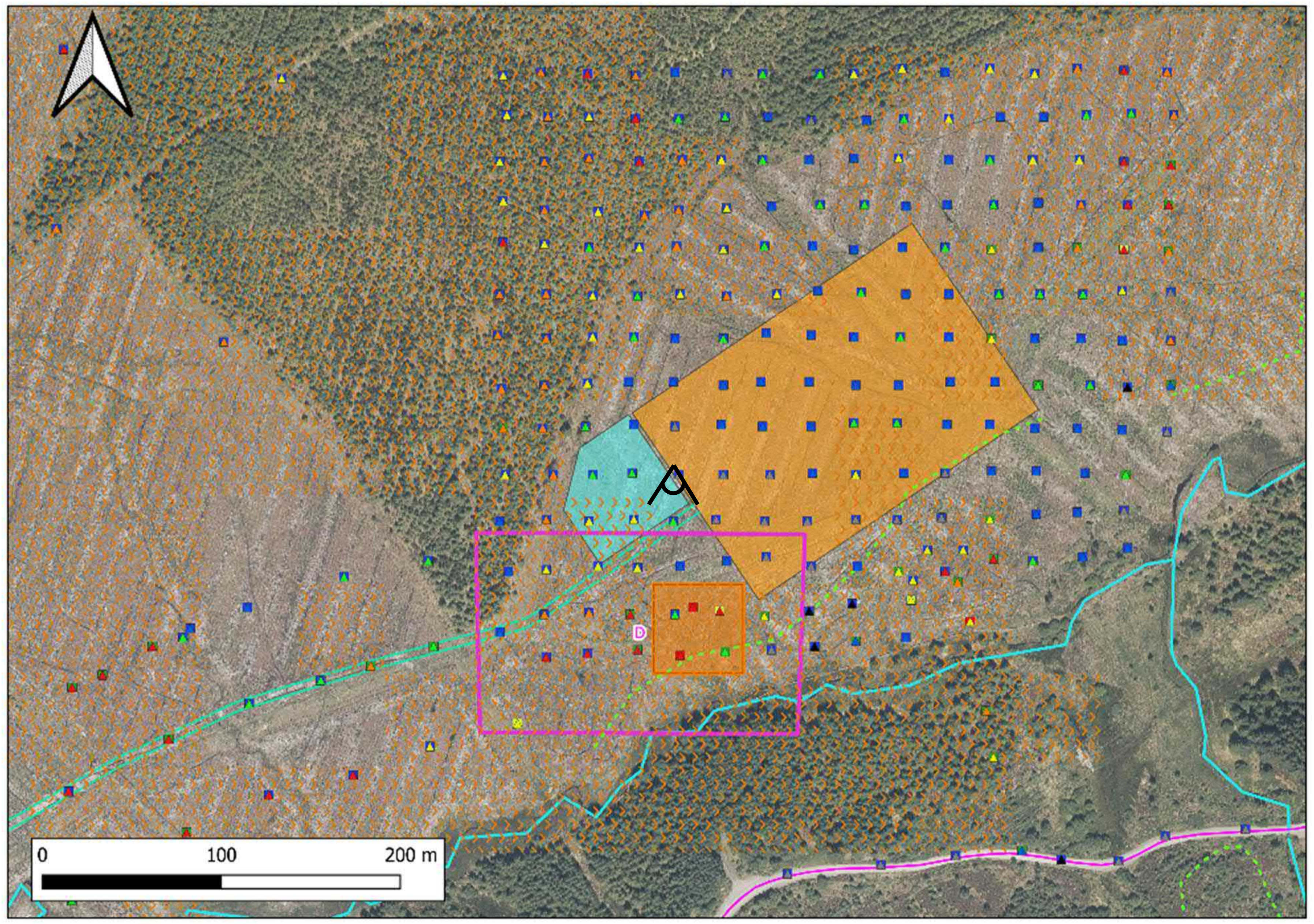


Plate 6.8 Aerial Image of PSA Area D

Annex C. Detailed Assessment GIS Images

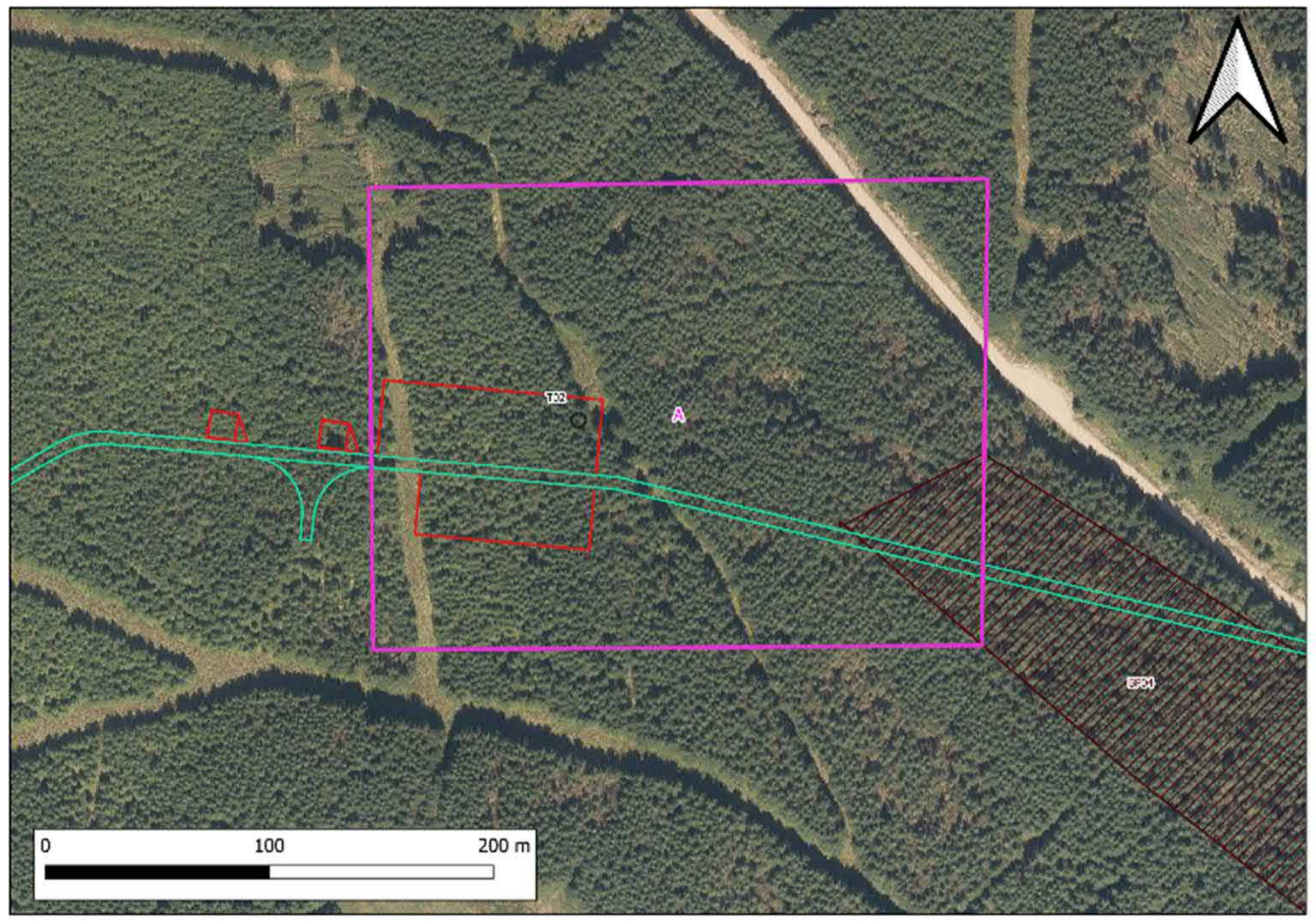


Plate 6.7 Aerial overview of PSA Area A

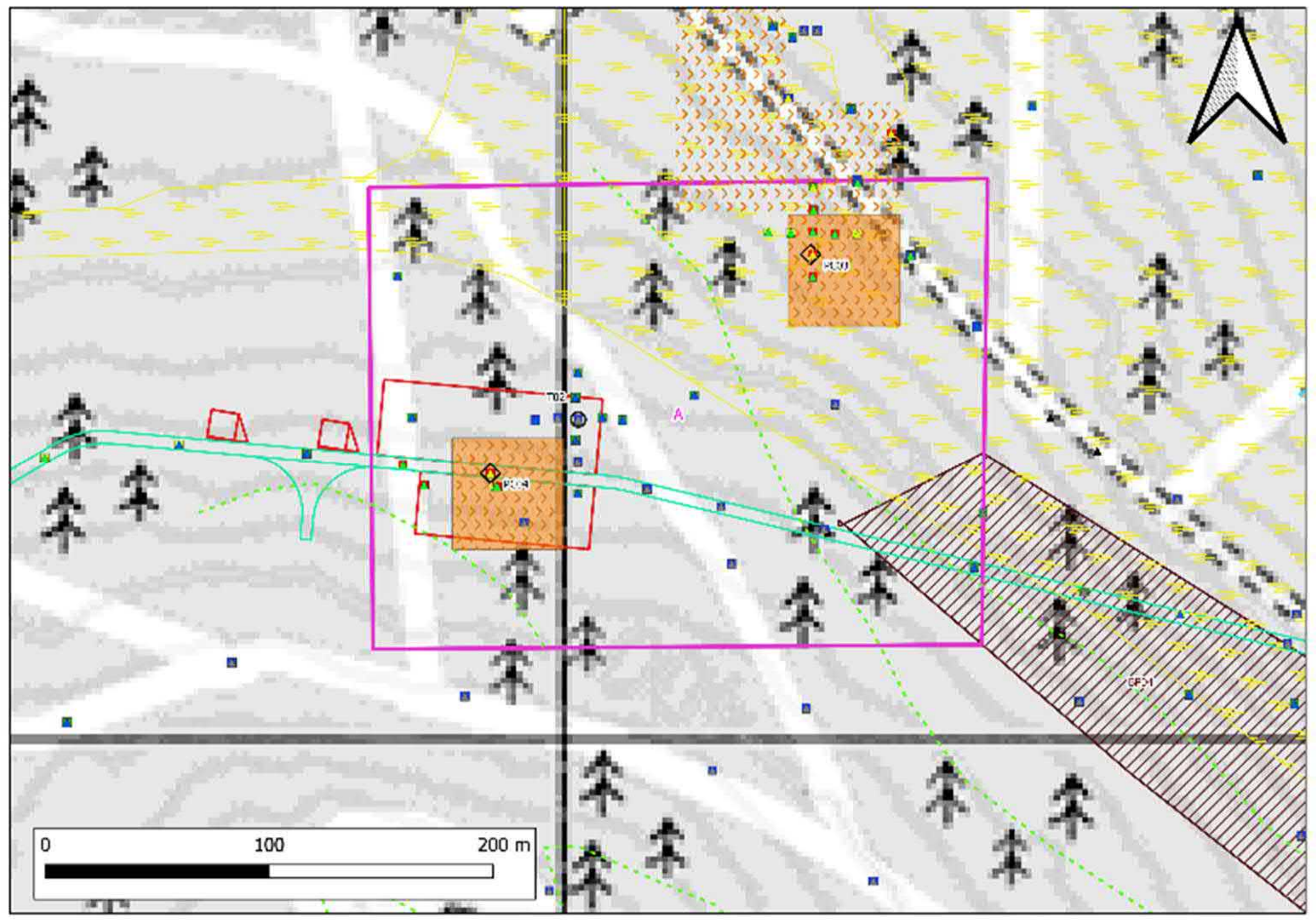


Plate 6.8 OS overview of PSA Area A

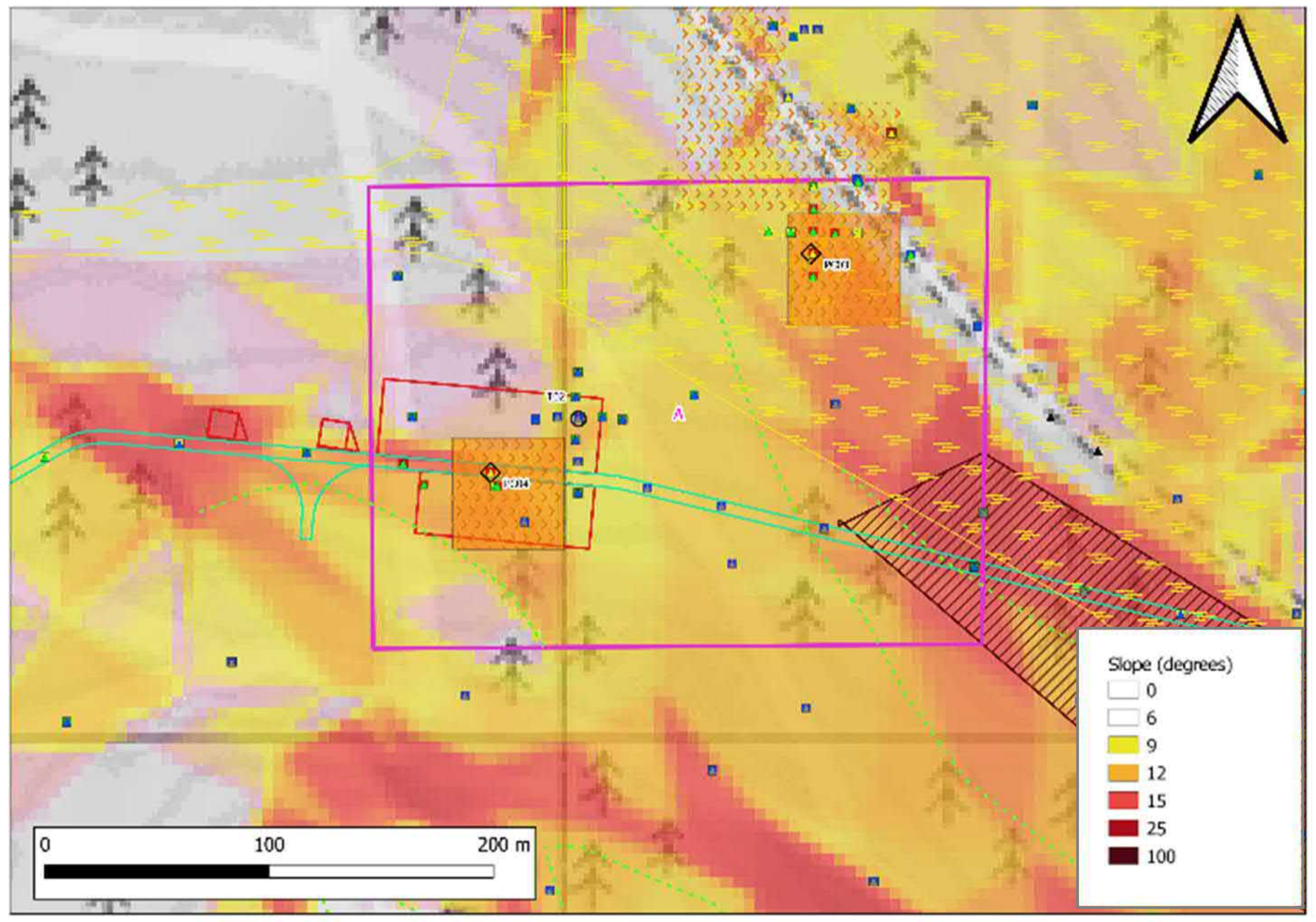


Plate 6.9 OS overview with DTM slope data of PSA Area A

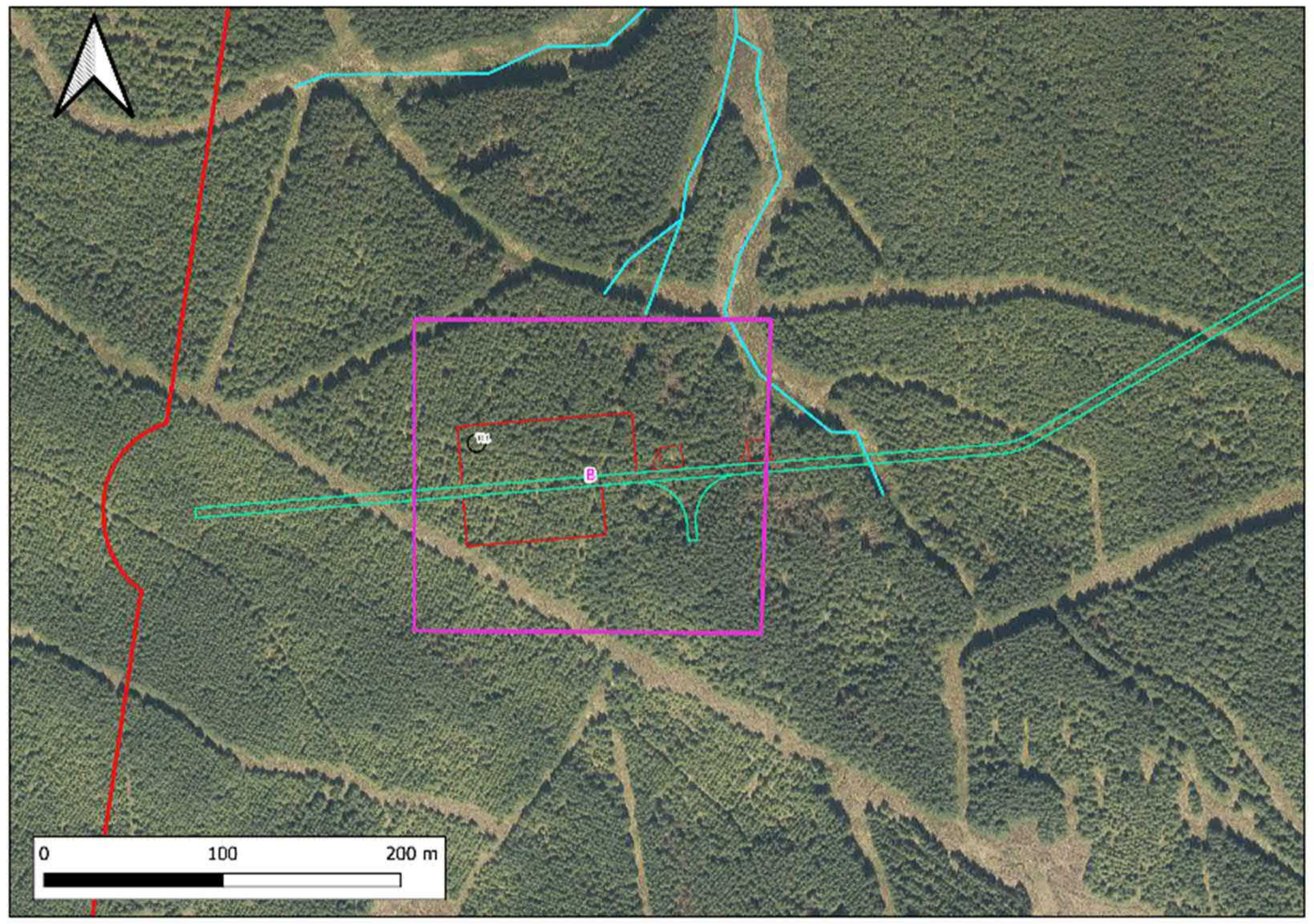


Plate 6.10 Aerial overview of PSA Area B

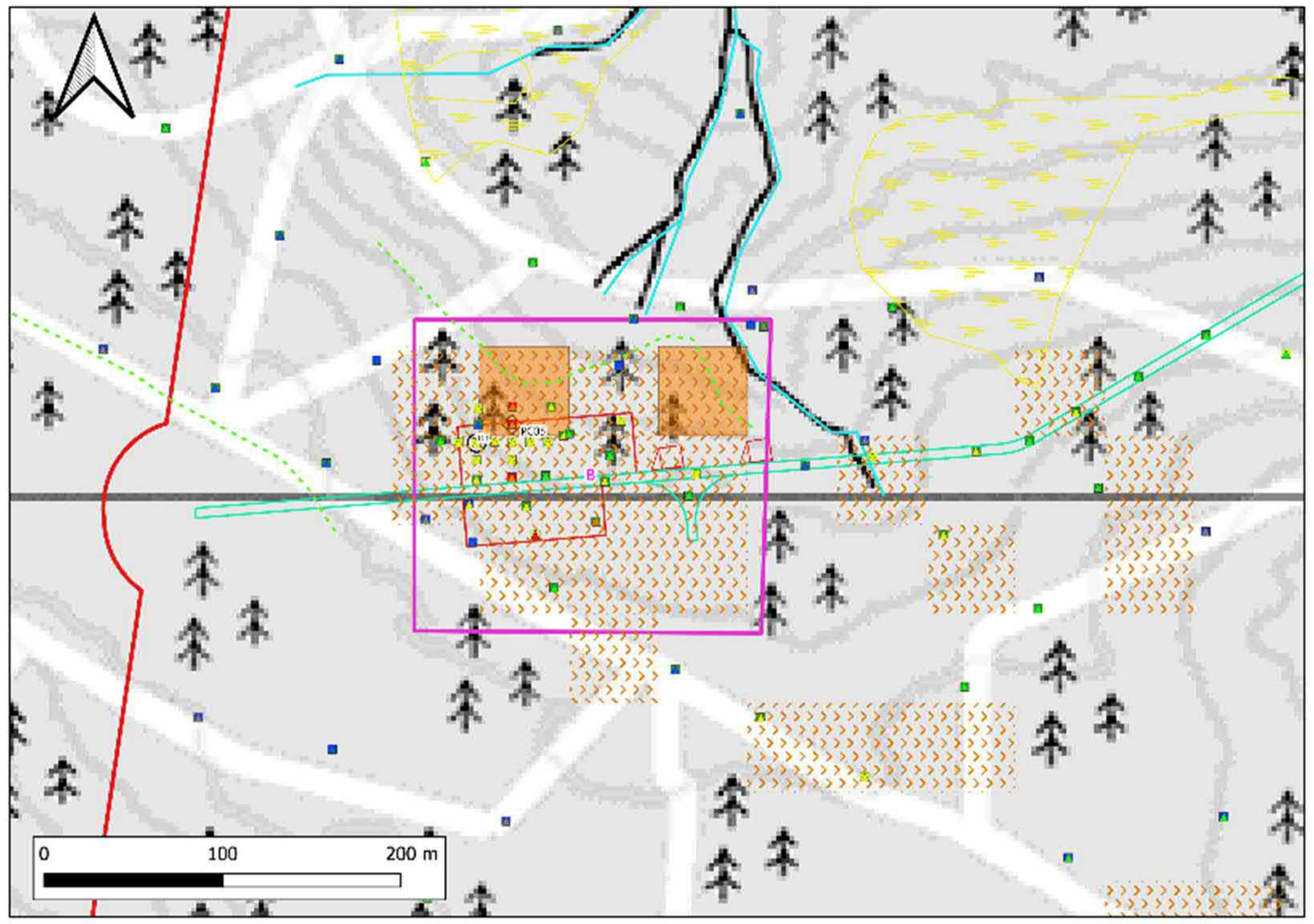


Plate 6.11 OS overview of PSA Area B

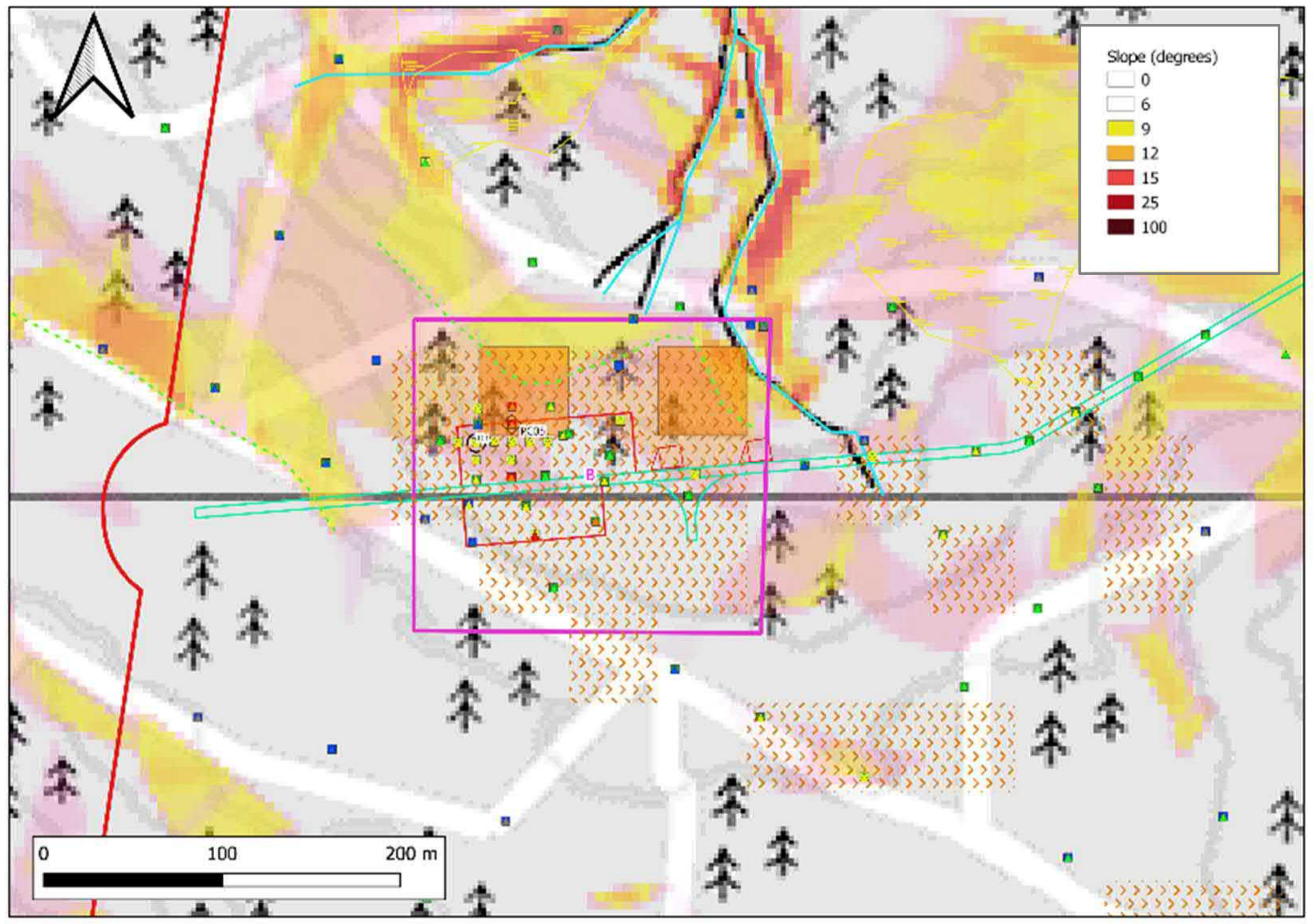


Plate 6.12 OS overview with DTM slope data of PSA Area B

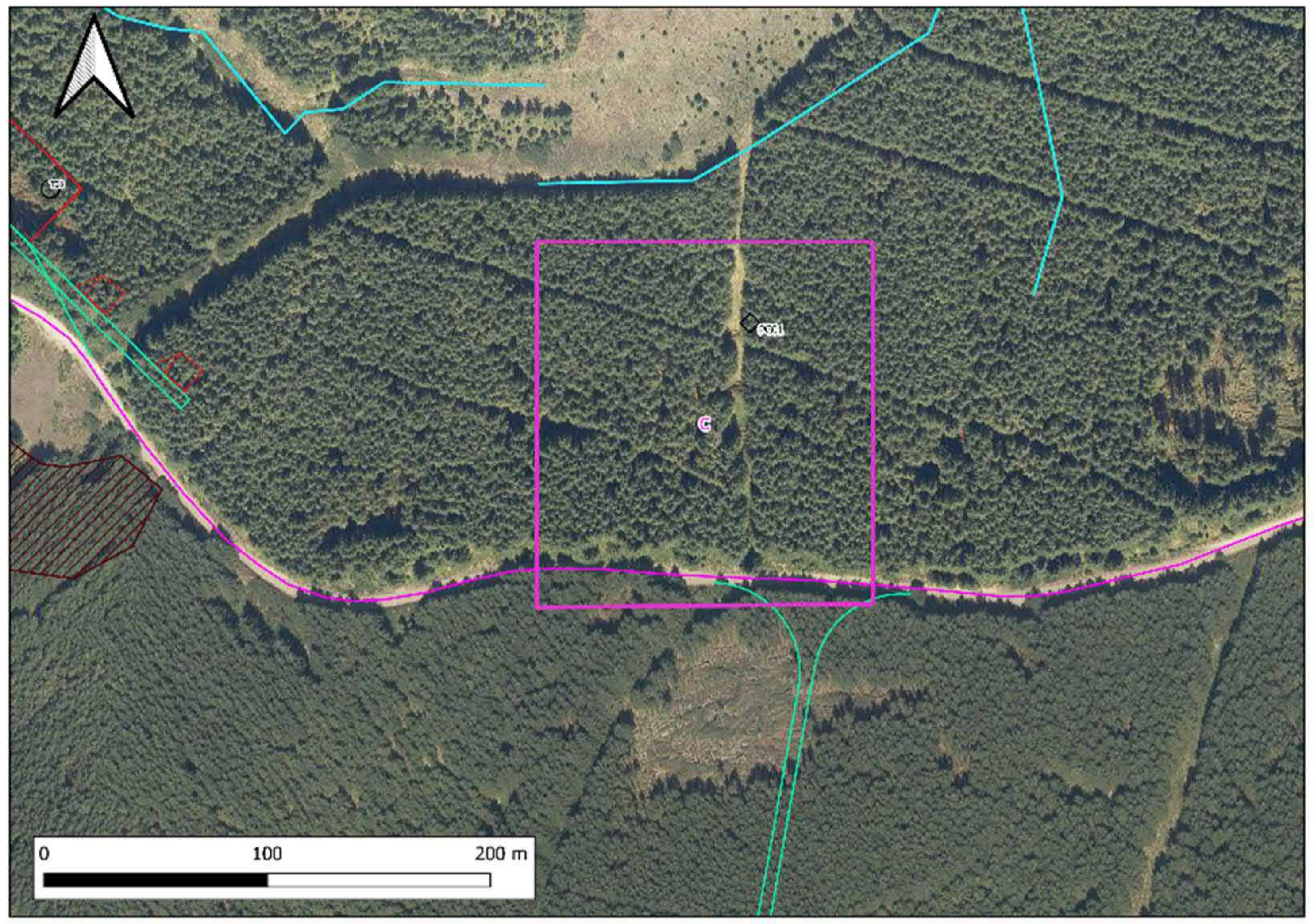


Plate 6.13 Aerial overview of PSA Area C

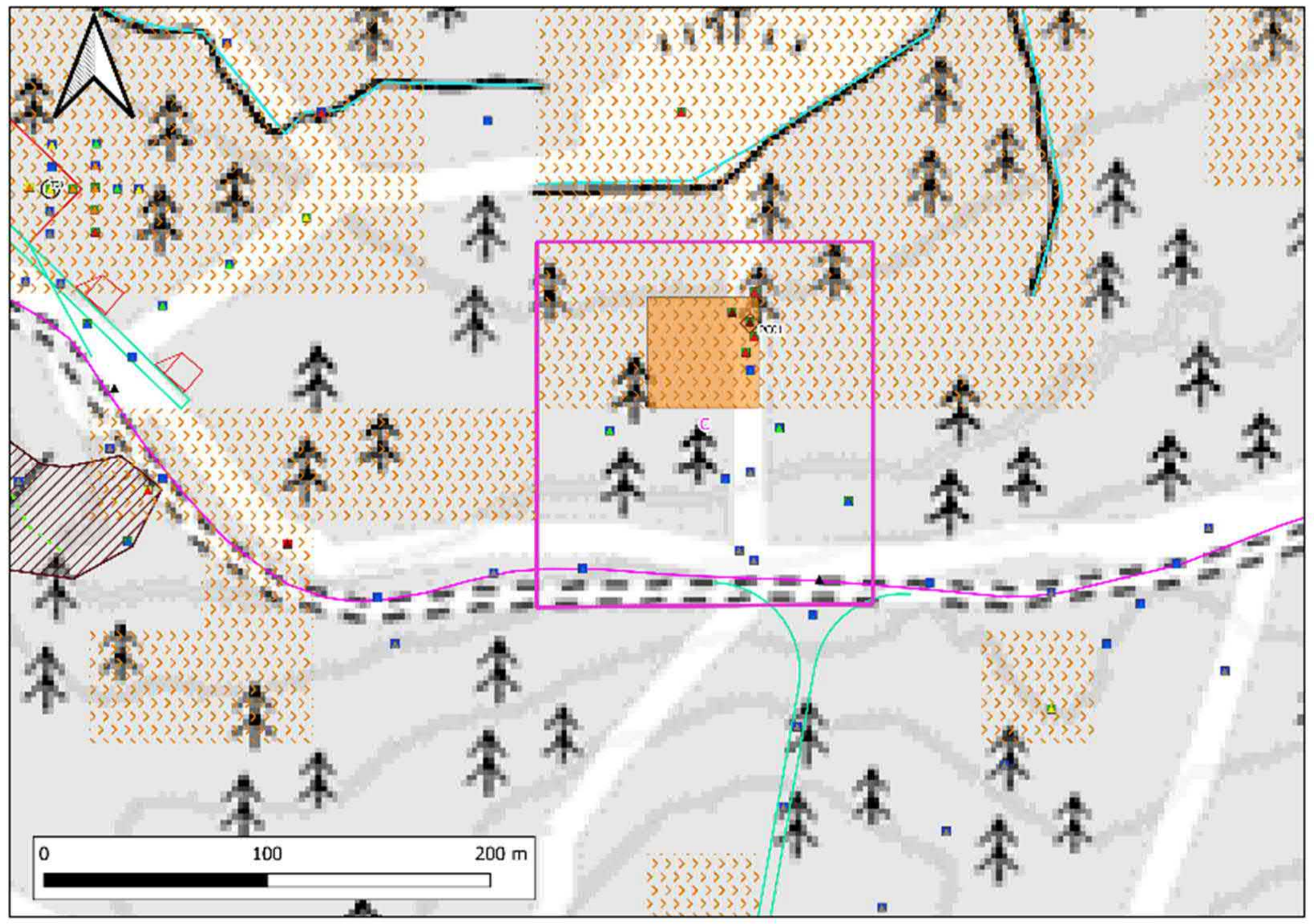


Plate 6.14 OS overview of PSA Area C

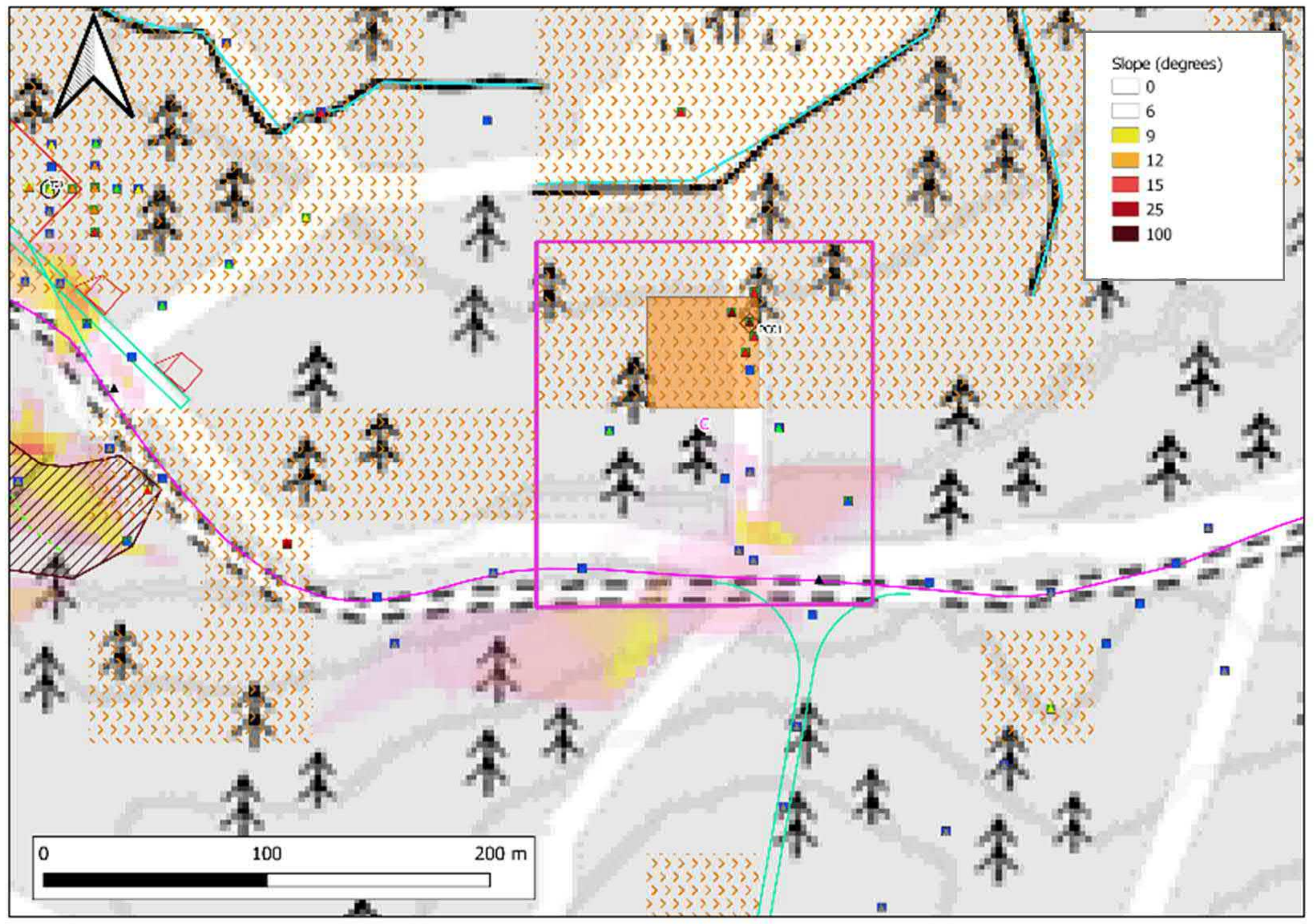


Plate 6.15 OS overview with DTM slope data of PSA Area C

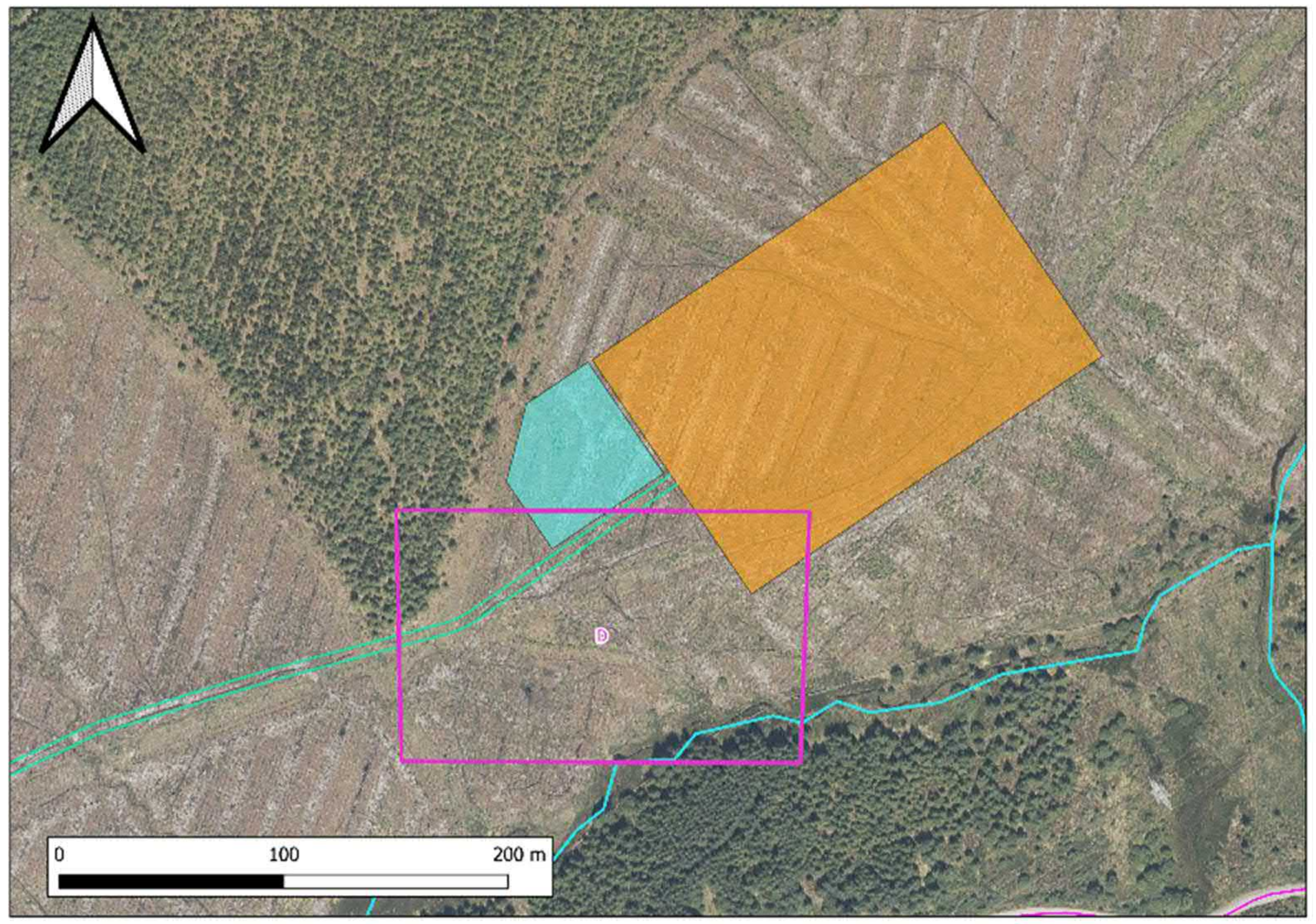


Plate 6.16 Aerial overview of PSA Area D

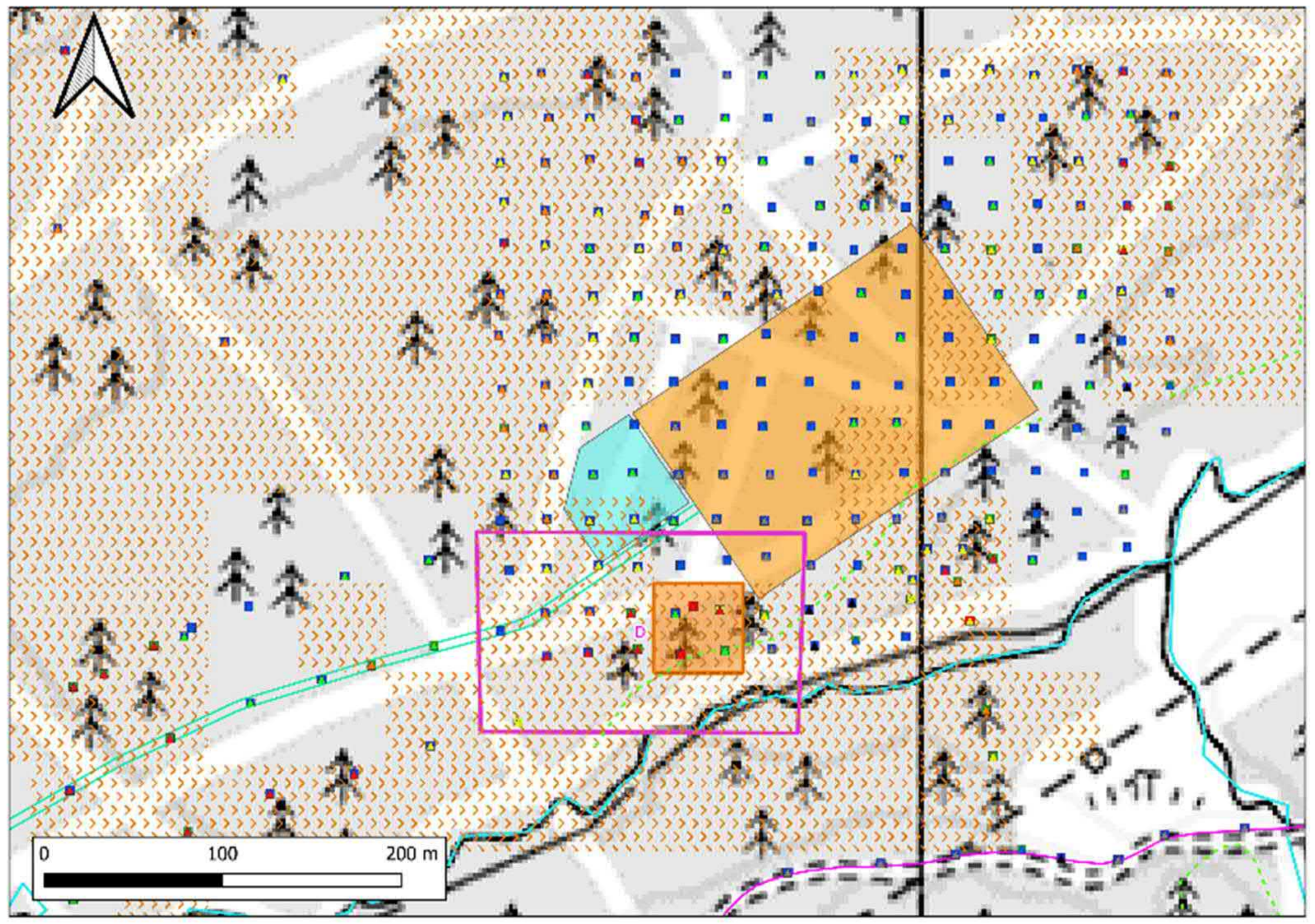


Plate 6.17 OS overview of PSA Area D

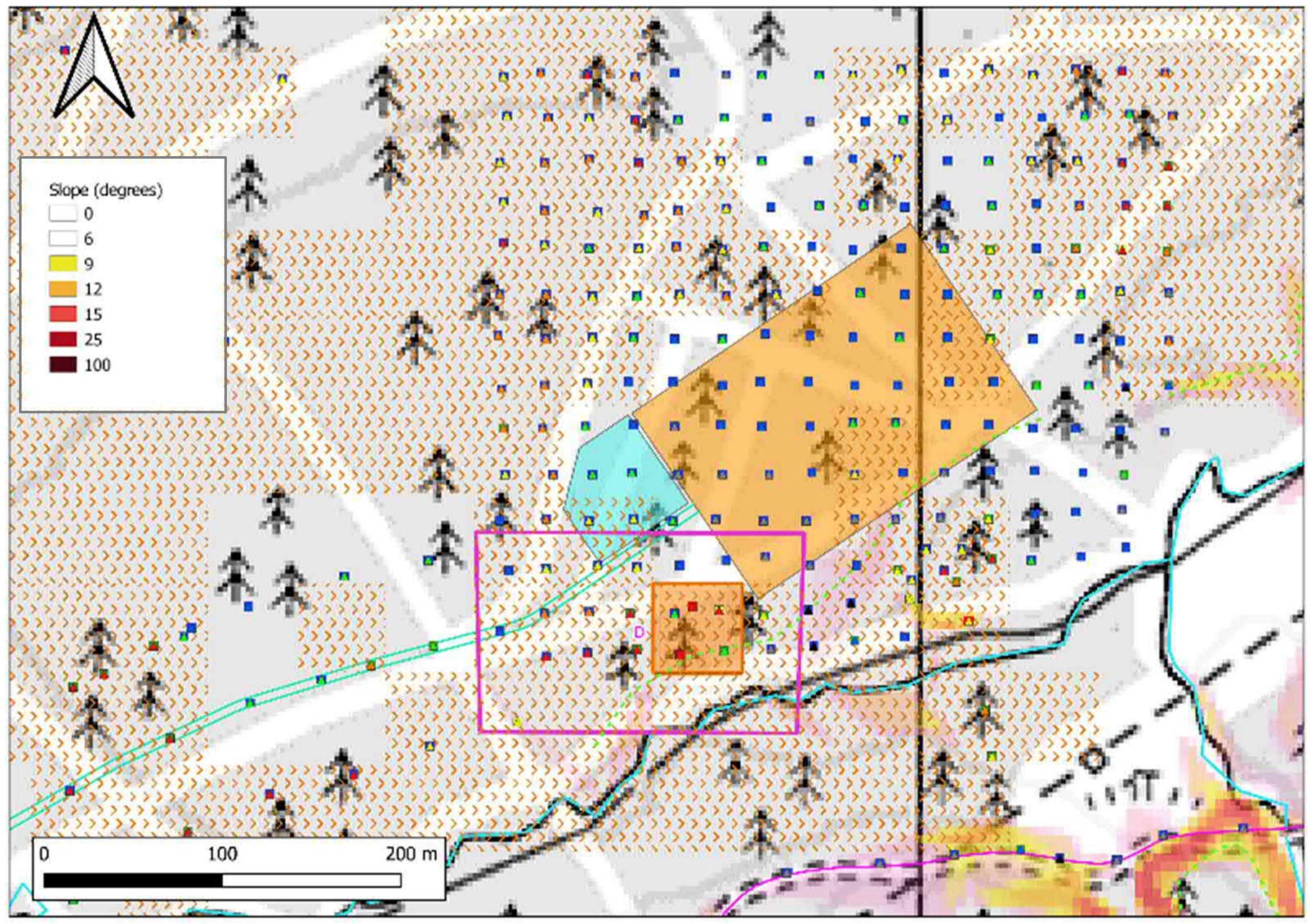


Plate 6.18 OS overview with DTM slope data of PSA Area D

The legend provided in **Annex B** also applies to these images.

Annex D. Peat Core Photographs

Photograph 6.13 Peat Core PC01a (shallow), NGR 237446, 598524

Photograph 6.14 Peat Core PC01b (deep), NGR 237446, 598524

Photograph 6.15 Peat Core PC02, NGR 235508, 598987

Photograph 6.16 Peat Core PC03, NGR 235110, 599218

Photograph 6.17 Peat Core PC04, NGR 234967, 599120

Photograph 6.18 Peat Core PC05, NGR 234318, 599042

Carrick Windfarm Project Team

ScottishPower Renewables
9th Floor ScottishPower Headquarters
320 St Vincent Street
Glasgow
G2 5AD

carrickwindfarm@scottishpower.com

www.scottishpowerrenewables.com

SCOTTISHPOWER RENEWABLES