A9 DUALLING
PERTH TO INVERNESS

Appendix 10.2

Peat Stability Risk Assessment

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TRANSPORT SCOTLAND
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1. Introduction

1.1. Background

1.1.1. This report forms a Technical Appendix to Chapter 10 Geology, Soils and Groundwater of the A9 Dualling Dalraddy to Slochd Stage 3 Environmental Statement (ES), and should be read with reference to this chapter.

1.1.2. The Proposed Scheme is located along the existing A9 corridor including the settlements of Dalraddy, Aviemore, Carrbridge and Slochd, all within The Highland Council area, where peat and peaty soils have been identified within the Design Manual for Roads and Bridges (DMRB) Stage 2 assessment. The Proposed Scheme comprises of the dualling of the existing mainline carriageway, with three junction upgrades, as well as additional access tracks and upgraded drainage network.

1.1.3. The potential risk of landslip hazards, as well as peaty soils and high groundwater levels were identified as potential constraints within the A9 DMRB Stage 1 assessment. Feedback from stakeholders as part of the DMRB Stage 2 assessment have highlighted the requirement for a Soil and Peat Management Plan for the Proposed Scheme. Due to the presence of peat within the study area, including Scottish Natural Heritage (SNH) Priority Peatland Classes 1 and 3, and previous landslips in the area, a peat stability assessment was also carried out as part of early Stage 3 design work to assess if there was a requirement for detailed peat stability work. This Technical Appendix provides these assessments, including details of the fieldwork survey methodology, which supplement and support the Soil and Peat Management Plan (Technical Appendix 10.3).

1.1.4. Blanket bog, raised bog and fens are widespread in Scotland, particularly in upland areas and have the potential to be affected by infrastructure developments. These are protected under the European Commission Habitats Directive 92/43/EEC and form part of the Scottish Biodiversity Strategy. These habitats are of high value due to their rarity and vulnerability and are susceptible to changes in hydrology.

1.1.5. Peatland landslides can occur after intense rainfall, or from other triggers such as unloading or loading of peat mass, with failures initiating slides which can result in peaty flows of debris[i]. This has the potential to affect downstream receptors such as surface watercourses or other valuable habitats, as well as other infrastructure and assets such as roads, residential areas and farmland located downstream.

1.1.6. This peat stability landslide risk assessment approach is in accordance with the Scottish Government's Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments[i].

1.2. Aims

1.2.1. The aims of this Peat Stability Assessment are to:

- Provide a good level of understanding of site baseline (pre-development) peat stability conditions;
- Aid the design process in order to avoid or reduce interaction with identified peat stability locations of concern;

- Identify the receptors that would be subject to adverse consequences, should a peatslide occur;
- Report peat stability risk assessment outcomes of the final design following the principles of the Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments[i]; and
- Provide recommendations on further work, mitigation measures and specific construction methods that should be implemented at the pre-construction stage to minimise the risk of peat instability at the Proposed Scheme.

1.3. Study Area

1.3.1. The assessment study area extends to a 250m buffer of the Dalraddy to Slochd Stage 3 Proposed Scheme boundary.

1.4. Method

1.4.1. The method adopted, following Scottish Government Guidance[i], for the peat stability assessment of the Dalraddy to Slochd scheme has involved the following stages:

- Desk study review of peat stability literature and available site data;
- Landslide hazards and aerial photography review;
- Site reconnaissance including peat depth survey to characterise the prevailing ground conditions and identify existing or potential peat instability;
- Ground investigation at specific locations of concern to provide additional data;
- Initial stability analysis to identify likelihood, using a purposefully cautious factor of safety method;
- Identification of receptors to evaluate consequence;
- Initial risk assessment undertaken to identify locations of concern;
- Revised risk assessment based on additional site information, 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 Proposed Scheme.

1.4.2. 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 various datasets.

1.4.3. The peat stability assessment applied a phased approach, which has been undertaken concurrently with the layout design of the Proposed Scheme and the Environmental Impact Assessment. The process is necessarily iterative, such that the peat depth survey and stability analysis work have been revisited and refined as the project design has progressed through DMBR Stages 2 and 3.

1.4.4. The final peat stability assessment has been undertaken on the Proposed Scheme, with the outcomes of this report informing the Geotechnical Risk Register.

2. Desk Study

2.1. Information Sources

2.1.1. The following guidance documents have been used to inform the assessment:

- Scottish Government 'Peat Landslide Hazard and Risk Assessment: Best Guidance Practice for Proposed Electricity Generation Developments'[i];
- Scottish Government 'Developments on Peatland: Site Surveys'[ii]; and
- SEPA Regulatory Position statement – Developments on Peat[iii].

2.1.2. The desk studies included a review of the following information:

- Ordnance Survey digital raster mapping, 1:50,000 and 1:10,000 scale;
- Ordnance Survey Terrain 5 Digital Terrain Model (DTM) data (5m resolution);
- Topographic Survey Data (for limited areas of the route);
- BLOM aerial photography (10cm resolution);
- 1:2,500 aerial photography and grid Digital Terrain Model (DTM);
- British Geological Survey 1:50,000 digital geological mapping, bedrock, superficial and linear geology;
- Scottish Natural Heritage (SNH) Carbon-rich soil, deep peat and priority peatlands habitat map[iv];
- Transport Scotland 'Scottish Road Networks Landslide Study'[v];
- MacArthur Green NVC Survey Dalraddy to Slochd[vi] (May 2017);
- Transport Scotland 'A9 Dualling A9 Dualling Dalraddy to Slochd Advance Works Report on Ground Investigation' Final Report (December 2015)[vii];
- Raeburn 'A9 Dualling Dalraddy to Slochd: Report on Stage 2 Preliminary Ground Investigation' Final Report (2017)[viii];
- Raeburn Engineering 'Report on the Ground Investigation for Dalraddy to Slochd' Final Peat Probing Results (2016);
- A9 Dualling Northern Section: Dalraddy to Slochd Geotechnical Preliminary Sources Study Report; and
- Soil Survey of Scotland 1:250,000 mapping of soil types[ix].

2.2. Literature Review of Peat Instability

2.2.1. 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 0.3m 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.
- Catotelm (base 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. This material has a low structural integrity and may act as a liquid in terms of physical or geotechnical qualities.

2.2.2. The peat within the study area is characterised as blanket peat (with associated habitat known as blanket bog or blanket mire), this is an undecomposed organic material that generally remains wet to the surface. Blanket peat is formed under cool, wet climatic conditions, which, in combination with high acidity and nutrient deficiency, depress microbiological activity. Blanket peat is widespread in upland and western areas of Scotland.

2.2.3. 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 when the peat body is saturated and is an important issue to consider in relation to potential peat stability failures.

2.2.4. 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.

2.2.5. A series of large scale (mass movement) peat events in autumn 2003, including at Derrybrien and Dooncanton in the Republic of Ireland and South Shetland, Scotland, led to an increased recognition of the mass movement hazard, particularly in relation to development design and construction of wind farm projects on peatland. This led to Scottish Government Guidance for energy developments being published in 2006 and updated in 2017[i] to assess development risk of peat landslide.

2.2.6. Peat mass movement events have been classified by geomorphologists[x], 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[xii]. 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[xiii];
- 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[xii].

2.2.7. In comparison with other peat mass movement phenomena described[xii], peat landslides and peaty debris slides typically involve lower volumes of material, estimated as 500 - 50,000m^3, with estimated velocities of 0.1 - 5m/s for peat landslides and 0.1 - >10m/s for peaty debris slides.

2.2.8. The Scottish Network Landslides Study, published in 2005 by the Scottish Executive[v], created a system for assessing the hazards posed by debris flows. It ranks hazards based on their potential relative effects on road users and the Scottish road network, which includes peat flows. The report makes reference to a number of roads, including the A9 at Slochd, where debris flows have been reported (see Section 2.5). The dataset provided as part of study indicates a number of Medium, High and Very High hazard ranking sites. This includes the steep slopes west of the A9 at Craigellachie, west of the

A9 at Avielochan, between the A9 and A95 at Avingormack, north and south of the A9 at Black Mount and the B9154, Slochd Beag and along both sides of the carriageway at Slochd summit. However, these debris slides will include non-peat materials. There has been an associated report prepared on Geotechnical Hazards that should be read in conjunction with this report which is focussed on peat landslide risk.

2.2.9. 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.
- 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.

2.2.10. 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[xi] and seasonal accumulation of snow may also be a factor, in terms of both weight and snowmelt input.
- 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.

2.2.11. Examples of mass peat instability can occur on peat of less than 1.0m 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.

2.2.12. There are a number of geotechnical variables in relation to peat properties, those applicable to the Factor of Safety (FoS) stability methodology, which AMJV applies, are detailed below. The FoS calculation and method is discussed in more detail later in 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 on site, to full depth with an accuracy of +/- 0.05m;
- Slope angle – measured using site Digital Terrain Model 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 on site 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 range between 4 - 20kN/m^2 [xi] with higher values for less humified/decomposed peat.
- Cohesive strength of peat – back-calculated using site-specific data using a 99 percentile value from the site peat probe data, this parameter largely dictates the shear strength of the peat in the factor of safety calculation. As above, literature values of shear strength suggest a range between 4 - 20kN/m^2 [xiii].
- 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 referenced in a number of papers[xi].
- 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.
- 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[xi].

2.2.13. 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, 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 or Troels-Smith, is considered to be a better practical indicator of shallow shear strength for peat bodies.

2.2.14. 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. Catotelmic amorphous peat is generally considered to be classified as H6 - H10, i.e. moderately strongly decomposed to completely decomposed[xii]. The Troels-Smith classification system can be used to describe unconsolidated sediments (including organic deposits) in the field. The physical properties includes degree of darkness, stratification, elasticity and dryness, as well as sharpness of upper boundary[xiii].

2.2.15. 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.

2.3. Baseline Conditions

2.3.1. The Proposed Scheme extends between the areas of Dalraddy and Slochd to the existing Tomatin South junction, in close proximity to the towns of Aviemore and Carrbridge, along the corridor of the existing A9 carriageway. The route crosses the lower slopes slopes of Gael-charm Mor (824 mAOD), Carn Beinn Ghuilbin (578mAOD), Carn Lethendry (438mAOD), Carn Bad nan Luibhean (471mAOD) and Carn nan Bain-tigherna (634mAOD). The highest point of the Proposed Scheme is located at Slochd Summit at approximately 403mAOD, with the lowest point of the scheme located at the southern end of the Proposed Scheme at the Allt na Fhearna, near Dalraddy, at 222mAOD.

2.3.2. Slope angles across the site vary, with shallow gentle slopes encountered in the areas of Avielochan, woodland areas around Alvie and Carrbridge and the extensive areas of peatland at Black Mount. Some of the steepest slopes, including existing near-vertical rock cuts, are located at Craigellachie and at Slochd Summit, with convex slope angles often exceeding 30º at Slochd, upslope of the existing A9 carriageway. These slopes often feature shallow soils with bedrock exposures.

2.3.3. Analysis of the slope angle map, derived from the digital terrain model (DTM) data, provides data that slope angles range from <1° to 66° across the Proposed Scheme, with an average slope angle of 10°. Applying a 50m x 50m grid cell system across the site, approximately 16% of the cells covering the Proposed Scheme have mean slope angles of 4° or less, with 55% having a mean slope angle of 10° or less. Less than 32% of the grid cells have a mean slope angle of 12° or greater.

2.3.4. The Proposed Scheme lies primarily within the catchment of the River Spey (and River Findhorn at northern extent) and crosses the River Dulnain, as well as crossing numerous smaller watercourses, unnamed tributaries and drainage channels that form part of the existing road network. A number of standing waterbodies are located within the Proposed Scheme area, generally adjacent to the southbound carriageway (to the east of the existing A9), including Loch Alvie, Loch Puladern and Avielochan.

2.3.5. Desktop studies show that peat is present across the Proposed Scheme area, primarily in the Carrbridge, Black Mount and Slochd areas. Areas of deeper peat are mostly confined to isolated pockets, with shallower peat and peaty soils located across the study area. A large proportion of the study area features areas of conifer forestry and pastoral farmland, with a small proportion of built-up area and other land uses such as quarrying.

2.3.6. Further information on the hydrology, hydrogeology, geology, geomorphology and vegetation within the study area are provided in Environmental Statement Chapter 10: Geology, Soils and Groundwater and also Chapter 11: Road Drainage and the Water Environment.

Carbon-Rich Soils, Deep Peat and Priority Peatland

2.3.7. The Scottish Natural Heritage (SNH) Carbon and Peatland Map, is a GIS vector dataset covering Scotland 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). This map identifies carbon-rich soils, deep peat and priority peatland in Scotland.

2.3.8. 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.

2.3.9. The dataset indicates areas of Class 1 Priority Peatland within the Study Area, primarily west of Granish at NH 894 147, west of the existing Black Mount Junction at NH 862 238, north of Black Mount at NH 883 243 and north of Slochd at NH830 259. Further areas of Class 3 peatland were identified immediately north of Black Mount. Superficial geology mapping also indicates small areas of peat located in Avingormack, south of Carrbridge, and north-west of Slochd, with wider extensive peat deposits west of Black Mount. There are also Class 5 areas of conifer forestry which have deeper peaty soils, including north-west of Aviemore, north-west of Carrbridge and across wider upland areas north and north-west of Slochd. Soil mapping suggests a large proportion of the Proposed Scheme features peaty soils, such as peaty podzols and peaty gleys, rather than peat.

2.3.10. Full baseline conditions for the Proposed Scheme are discussed in detail within Chapter 10: Geology, Soils and Groundwater of the DMRB Stage 3 assessment. This chapter should be referred to for this information.

2.4. Historical Information

2.4.1. In 2002 a failure was reported at the A9 at Slochd, with the presence of the trunk road contributing to the failure of the road below (the existing cycle path) reported by the Scottish Landslides Study. This detailed the influence and contribution of drainage to the failure which concentrated runoff in the failure area.

2.4.2. Other peat slides have been recorded both along the A9 carriageway, and in other nearby areas of the Highlands. A number of landslides were reported in August 2014 following heavy rainfall, including the A9 to the north of Dunkeld causing an A9 closure for two days[v].

2.4.3. Landslides have also been reported in similar settings across other trunk roads in Scotland, such as the A83 at the Rest and be Thankful and the A85 at Glen Ogle.

2.5. Climate

2.5.1. The Meteorological (Met.) Office regional climate information locates the Proposed Scheme within the Northern Scotland regional climatic area. Rainfall across this region varies from over 4000mm per annum near Fort William to less than 700mm per annum along the Moray Firth coast.

2.5.2. Data from the Met. Office monitoring station at Aviemore for the 1981–2010 period is the nearest location to the Proposed Scheme, located at NGR 2897 8143 at an altitude of 228m AOD, with the Aviemore weather station having a standard annual average rainfall (SAAR) of 977mm.

2.5.3. The SAAR values for both Dalraddy and Slochd Summit have been derived from the Flood Estimation Handbook (FEH). Dalraddy, located approximately 6km to the southwest of the Aviemore weather station at an altitude of 220mAOD has a SAAR of

850mm. Slochd Summit, located approximately 12km to the northwest of the Aviemore weather station at an altitude of 405mAOD has a SAAR of 1001mm.

2.5.4. The greater rainfall value derived for the Slochd Summit is a reflection of the higher elevation, with prevailing winds from the southwest delivering more precipitation across this higher ground. Monthly rainfall trends across the Study Area would be expected to be similar to that recorded at Aviemore.

2.5.5. The UK Climate Projections Report provides an indication of regional climate trends across the UK taking account of climate change. Within this document probabilistic projections of climate change suggest that Northern Scotland will experience slightly increased temperatures in both summer and winter. This may result in a reduction in summer precipitation and an increase during winter.

2.5.6. If climate change leads to drier summers, low flows and water shortages may occur in prolonged periods of dry weather. Increase in winter precipitation could increase the risk of and extent of flooding.

2.6. Aerial Photography

2.6.1. A number of aerial photography sources were made available as part of the baseline desktop assessment. This includes the BLOM 10cm (2014) dataset, and aerial imagery at 25cm resolution (2015).

2.6.2. As the majority of peat deposits are confined to the northern section of the scheme, with primarily agricultural land, built-up areas and forestry within the southern section of the scheme around Aviemore, more detail has been provided in these areas.

2.6.3. The woodland area south of Carrbridge shows small areas without tree cover, with darker brown areas indicative of peat. West of Black Mount, rockier outcrops are visible towards the existing carriageway, with a progression from green to brown moorland areas, potentially suggesting increasing presence and depth of peat. A small number of drains running west-east are visible at the northern end of the peatland adjacent to the A9, with drains also visible on the northern side between the A9 and adjacent B9153.

2.6.4. At the Slochd Summit and adjacent areas east of the existing A9, the aerial imagery shows a number of areas with exposed rock, areas of tree cover, as well as heather shrub vegetation with some areas of peat. Due to the steep slopes in this area there were few signs of existing drainage with the exception of the Bogbain Burn close to the existing A9. The area immediately south of the existing Tomatin Junction features large areas of bare peat which has remained bare since 2005 aerial imagery was collected. A number of drains are visible flowing north-east to south-west away from the existing A9 towards the Allt Cosach, spaced between 50-100m apart. The steep slopes and shallow soils north of Slochd feature a patchwork of peat and rock outcrop.

2.7. Landslide Hazards

2.7.1. The Scottish Road Network Landslide Study GIS dataset covers the Proposed Scheme area. A number of areas within the study area were identified as Medium, High or Very High Hazard ranking sites (based on their classification). This includes areas west of the A9 at Craigellachie, west of the A9 at Avielochan, east of the A9 at Avingormack, north and south of the existing A9 at Black Mount, Slochd Beag and Slochd Summit. It should be noted the areas include all types of debris flow, not specifically peat movement.

2.7.2. A report on the 'Upslope Hazards: Slochd Summit and Craigellachie[xiv]' was produced following preliminary site walk overs carried out by AMJV Engineering Geologists to map existing boulder fields, assess potential for future rockfall and risk associated with the A9 dualling. This report identified eight areas with high concentrations of boulders. Site observations also noted areas of peatland at the crest of the peak of Carn nam Bain-tighearna and shallow failures of topsoil/peat present across the slope where there is no vegetation cover.

2.8. Vegetation

2.8.1. National Vegetation Classification (NVC) surveys were carried out within a 250m buffer of the existing A9 carriageway during May and July 2017.

2.8.2. A number of mire habitats were reported throughout the Carrbridge and Slochd areas, primarily located at low gradient areas such as Black Mount, the steeper slopes at Slochd also featured peatland (blanket bog) habitat.

2.8.3. Two areas of muirburn (MB) upslope of the existing A9 at Torr Mor, Slochd around NGR NH 834 254, where burning has been previously carried out on as part of existing land management practices. Burning could act as a trigger for peat instability, by reducing vegetation 'anchor' effect on sloping ground.

2.8.4. A number of M10 *Carex dioica* and M32 *Philonotis fontana* habitats were identified within the study area, which are associated with spring sources and anticipated to be groundwater-fed. These are located in upslope areas at Slochd above the existing southbound carriageway, approximately 70-240m north-east. These are also supported by target notes which report the presence of springs, flushes and rills. These habitats are indicative of groundwater levels at the surface.

3. Site Reconnaissance and Field Surveys

3.1. Site Reconnaissance

3.1.1. An initial peat walkover survey was carried out in June 2015 as part of the DMRB Stage 2 assessment, reviewing areas of peat identified during the desk study within 250m of the scheme. Following the design confirmation of the Proposed Scheme and initial peat stability analysis, a further site walkover was carried out in September 2017 to visit areas previously not available for access. Whilst peat deposits are present across the scheme, none of the locations visited found evidence of large-scale peat mass movement events.

3.1.2. Illustrations 1 to 7 provide photographs and descriptive text of a representative sample of the study area, detailing the range of landforms, vegetation and erosion patterns encountered.

Illustration 1: Blanket bog habitat at Crannaich, low gradient with areas of deep peat (NH 905 211)

Illustration 3.1 shows an area of swamp and blanket bog at Crannaich at 269mAOD, looking north adjacent to the existing A9. The area features primarily deciduous woodland which is boggy underfoot. There are isolated areas of deeper peat of up to 4.3m depth. Typical slope angles are less than 6^{o} with the exception of the existing road embankment.

Illustration 2: Swamp habitat facing north towards Highland Railway line, underlain by peat (NH 792 319)

Illustration 2 shows swamp habitat adjacent to A938 at 274mAOD, looking north towards the Highland Mainline. The area features a swamp surrounded by grassland and woodland to the south. Peat depths vary with a maximum depth of 2.55m measured in the centre of the swamp. The area is flat, with artificial embankments along the existing A9 and railway line containing this feature.

Illustration 3: Looking east towards Black Mount junction along southbound carriageway (NH 862 238)

Illustration 3 shows marshy grassland in the foreground, facing east towards Black Mount junction, with mire habitats including Class 3 Priority Peatland area located in the background adjacent to the existing A9 at 360mAOD. This area of blanket bog features peat depths of up to 2.8m in the centre of the area. Typical slope angles are less than 6o, with the exception of the existing road embankment.

Illustration 4: Class 1 peatland west of Black Mount, facing east and downslope of existing A9 (NGR NH 861 238)

Illustration 4 shows an extensive area of Class 1 priority peatland blanket bog, looking east along the existing A9. This area features an average peat depth of 3m, with a maximum depth of 5.3m. Slope angles are typically less than 6^{o} and relatively flat across the peatland, with the existing A9 on a raised embankment.

Illustration 5: Area of degraded peat adjacent to existing northbound A9 (NGR NH 867 238)

Illustration 5 shows an area of degraded peatland adjacent and south of the existing A9, facing south-west. The peatland habitat adjacent and parallel to the existing A9 was noted to be in a poor condition, with large areas of exposed and eroded peat with low levels of vegetation cover, numerous drains and high levels of superficial deposits mixed into the peat.

Illustration 6: Hill slopes at Slochd Summit facing north-west (NGR NH 823 255)

Illustration 6 shows steeper slopes at Slochd Summit, often exceeding 30º. The A9 runs north-west to south-east through this valley. The slopes feature thin peaty podzols with rocky outcrops, featuring a combination of mire and heath habitats.

Illustration 7: Exposed peat facing south-east from the slopes of Carn a' Gharbh-choire towards Slochd (NGR NH 828 260)

Illustration 7 shows eroded peat with limited vegetation cover north of Slochd, west of the existing A9. Maximum peat depths of 7.6m were recorded within the scheme footprint, with slope angles are typically less than 6o, with steeper slopes located upslope and downslope towards the A9. The Highland Mainline Railway is located within a cutting between this area and the existing A9.

3.2. Peat Depth Surveys

Fieldwork

3.2.1. Two stages of peat probing surveys were carried out. The first peat probing survey was carried out as part of the Stage 2 Advanced Ground Investigation works in December 2015 over a three week period and collated data from seven areas where peat was anticipated to potentially be present. A grid was created for each area, with each grid cell measuring 50m by 50m. Depth measurements were taken every 50m, and more frequent probing conducted (up at a frequency of up to every 5m) where peat depths were notably variable.

3.2.2. These surveys focused on gaining a good overall understanding of the site and collecting peat depth data, where access was possible, under the Stage 2 Proposed Options scheme footprint. Access to some locations was restricted by dense forestry cover. The forest cover reduced physical access and also location-positioning data (from handheld GPS).

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

3.2.4. Following this feedback, plus input from other disciplines as part of the Stage 2 Assessment, an Emerging Preferred Route Option for the Stage 3 assessment was provided. The site was revisited in March 2017 as part of the Stage 2 Preliminary Ground Investigation, with further data gathered to refine our knowledge of conditions in specific areas. This focused on collecting additional peat probing data as well as a number of peat cores. This information fed into the Stage 3 design process.

3.2.5. For all peat probing surveys 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 and the depth recorded. There were a total of 791 peat depths recorded, with no results exceeding the depth of peat probes. The deepest record was 7.6m, located north-west of Slochd and 90m from the nearest infrastructure.

3.2.6. The underlying substrate can sometimes be inferred from the 'feel' of the rod reaching total depth; for example, the rod suddenly hitting a solid surface with a ringing sensation would suggest bedrock, a 'gritty' feel at total depth suggests sandy or gravelly material, and a gradually increasing difficulty in pushing in the rod suggests clayey material underlying the peat.

3.2.7. In addition to peat probing data, information was available on peat depths from other Ground Investigation works where peat was encountered. This data was collected during a number of phases of Ground Investigation work:

- Stage 2 Preliminary Ground Investigation works – July 2015 (peat encountered at 60 borehole, 76 trial pit and 4 peat core locations); and
- A9 Dualling Kincraig to Dalraddy Ground Investigation works – June to October 2014 (peat encountered at 124 GI locations).

3.2.8. At the time of report writing, the Stage 3 Preliminary Ground Investigation works had commenced but not concluded and this data will provide further information at the detailed design stage. This GI activity commenced in December 2017 and is programmed to continue for approximately five months.

3.2.9. The collected data from all peat probing surveys and other Ground Investigation data are summarised in Table 3.1; 67.8% of the 1,279 points (791 plus 488 GI locations) surveyed had a peat depth result of less than 0.5m, with 81.6% of the results less than 1.0m. The peat depth locations are presented on Figure A10.2.1.

Table 3.1: Results of peat probing survey

Peat Depth Range (m)	No. of points	% of Points	Average Depth in range (m)
<0.5	867	67.8%	0.17
0.5 to <1.0	177	13.8%	0.65
1.0 to <1.5	99	7.7%	1.13
1.5 to <2.5	63	4.9%	1.90
2.5 to <4.0	47	3.8%	3.84
4.0m +	26	2.0%	5.10
Total	1,279	100%	0.61

3.2.10. There are a number of locations with deeper peat in well-defined areas, often in areas of low slope angle and some of which are adjacent to the existing A9 carriageway and sometimes confined by existing A9 and Highland Mainline Railway embankments.

3.2.11. Some erosion of peat was noted, particularly within the peatland area west of Black Mount and north-west of Slochd, adjacent to the Highland Mainline Railway.

Indicative Peat Depth Mapping

3.2.12. The use of a regular grid for terrain analysis 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 landscape, 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.

3.2.13. The resolution of digital terrain model (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 will return spurious results with a false indication of accuracy. A 50m grid was used in line with AMJV's established peat stability analysis method as this is a suitable 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.

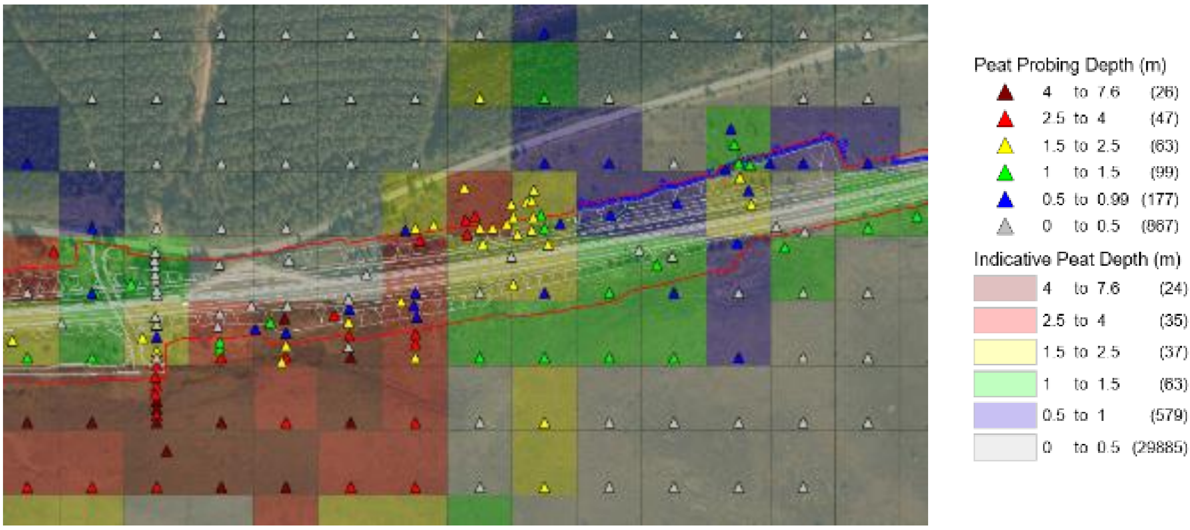
3.2.14. To inform the refinement of the infrastructure layout, the results of the initial peat probing survey were used to produce an extrapolated indicative peat depth map for the study area. A grid of 50m x 50m cells was overlaid across the site and a peat depth range assigned to each cell. The peat depth ranges used are detailed in Table 3.2.

Table 3.2: Indicative Peat Depth Categories

Peat Depth Range (m)	Peat Depth Category Number	Peat Depth Category
<0.5	1	Not Peat
0.5 to <1.0	2	Shallow
1.0 to <1.5	3	Moderate
1.5 to <2.5	4	Deep
2.5 to < 4.0	5	Very Deep
4.0m +	6	Exceptionally Deep

3.2.15. Blanket peat tends to form in areas with high rainfall and low temperatures. In the Scottish context, blanket peat can be 5m or more in thickness, especially in hollows or valleys, but is generally not much more than 3m deep and often much less. Peat depth category names and ranges were chosen in the context of road construction; for example, the cut-off between reusable fibrous peat and unusable amorphous peat is typically around 1.0m. The threshold depth for very shallow peat of 0.5m is based on the Soil Survey of Scotland definition[ix], as used in the Scottish Government Guidelines[i].

Illustration 8. Sample of Indicative Peat Depth Map



3.2.16. Illustration 8 shows an enlarged portion of the peat depth mapping. Each cell is 50m x 50m with areas shallower than 0.5m (not peat) coloured grey, shallow peat coloured blue, moderate depth peat coloured green, deep peat in yellow and very deep peat coloured red. The full indicative peat depth map is included in Figure A10.2.1.

3.2.17. From observation it is clear that both slope and elevation have an influence on the development of peat, although the exact mechanism is not well understood 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 can be seen that the 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.

3.2.18. As can be seen from Illustration 8 and Figure A10.2.1, where a cluster of peat probing points are 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 wide range of depth categories a precautionary 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.

3.2.19. The peat depth category breakdown for both the actual probing data and the extrapolated grid is given in Table 3.3. On Table 3.3, the rows representing indicative peat depth grid data for 'measured depths' represents those cells where peat depth was recorded, these are generally closest to the planned infrastructure and thus more representative of site conditions than the indicative peat grid.

Table 3.3: Peat Depth Category Breakdown

Peat Depth Category (m)		<0.5	0.5 - <1.0	1.0 - <1.5	1.5 - <2.5	2.5m – <4.0m	4.0m +	Total
Probing Data	No. of points	867	177	99	63	47	26	1,279
	% of points	67.8%	13.8%	7.7%	4.9%	3.8%	2.0%	100%
Indicative Peat Depth Grid	No. of cells	29,885	579	63	37	35	24	30,623
	% of cells	97.6%	1.9%	0.2%	0.1%	0.1%	0.1%	100%
Indicative Peat Depth Grid (measured depths)	No. of cells	681	100	61	37	35	24	938
	% of cells	72.6%	10.7%	6.5%	3.9%	3.7%	2.6%	100%

3.2.20. The initial peat depth map was used to inform the scheme design. The areas identified as having deep peat were avoided as far as practicable, considered alongside other constraints as part of the Stage 3 design development.

3.2.21. Peat contours and a peat depth raster file were also produced using the above dataset, to assist with soil and peat volumes required for the Soil and Peat Management Plan (Appendix 10.3), where further information on this methodology is detailed.

3.3. Soil Sampling and Peat Cores

3.3.1. Following desktop review, a number of peat areas were identified as representative of peatland at or close to the Proposed Scheme. Four core locations were selected, with samples collected at different depths below ground surface to evaluate peat characteristics that may vary with depth and influence the potential for peat instability. The core data also informs peat typology for the Soil and Peat Management plan (Appendix 10.3). Peat core locations are shown on Figures A10.2.1 and A10.2.2 and core photographs are provided in Annex C of this document.

3.4. Methodology

3.4.1. At each of the peat core locations, measurements and samples were collected to determine the following parameters:

- peat probing to maximum depth to improve definition of peat depth characteristics at each location;
- peat cores gained by Russian corer to base of peat for laboratory analysis of bulk density, moisture content and total organic carbon;
- description of peat core and photograph of core; and
- Von Post classification of peat core.

3.4.2. Coring was undertaken using a Russian corer, using 1m extension rods to log each sample to the base of the peat. Samples were taken between 9th and 20th April 2017. Following photography of the extracted core (provided in Annex C), each 0.5m length of undisturbed core was carefully removed into a marked plastic bag, which was sealed and then transported for laboratory analysis for bulk density and moisture content. Samples were delivered to the laboratory on 12th June 2017 for analysis.

3.4.3. Von Post classification was evaluated immediately on site, after core extraction and lab sample bag transfer, using the remaining core material. This process involved evaluating water expression and colour of any water expressed, peat expression and noting plant material extracted in the core using both the Von Post and Troels-Smith classification schemes.

3.5. Results

3.5.1. The locations and results are summarised in Tables 3.4 and 3.5, with full details of the laboratory results and definitions of the Von Post and Troels-Smith classification system provided in Annex B. Core locations are shown on Figures A10.2.1 and A10.2.2 for 11 samples taken from 4 locations, with photographs provided in Annex C.

3.5.2. The areas listed on Tables 3.4 and 3.5 relate to Peat Stability Risk Areas discussed later in this report (and provided as datasheets in Annex A).

Table 3.4: Von Post and Troels-Smith Classification of Peat Cores Collected During Stage 2 Preliminary GI (March 2017)[viii] Indicative Peat Depth Categories

Location ID Sample date Peat Excavation Area ID (if applicable)	Core NGR	Depth of core section (m)	Von Post		Troels-Smith Scheme					
			Von Post Class	Water Content	Darkness	Stratification	Elasticity	Dryness	Boundary	Components
DS-PC-01 13/04/17 Area E	NH 863 298	0.1	H2	B1	Nig2	Stf2	Elas2	Sicc1	-	Tb1, Th1, As2
		0.5	H4	B2	Nig3	Stf0	Elas2	Sicc2	Lim1	Tb1, Th1, TI+, As2
DS-PC-02 10/04/17 Area E	NH 864 239	0.3	H2	B2	Nig3	Stf0	Elas3	Sicc2		Tb+, Th1, TI1, As2
		0.5	H4	B3	Nig3	Stf2	Elas2	Sicc1		Tb+, Th1, TI1, As2
		1.00	H5	B3	Nig3	Stf3	Elas2	Sicc1		Tb1, Th2, TI+ As1, Gmin+
		1.30	H5	B3	Nig3	Stf3	Elas2	Sicc1		Tb1, Th2, TI+, As1, Gmin+
		1.50	H7	B3	Nig3	Stf2	Elas2	Sicc1		Tb1, Th2, TI+, As1, Gmin+

Location ID **Sample date** **Peat Excavation Area ID (if applicable)**	**Core NGR**	**Depth of core section (m)**	**Von Post**		**Troels-Smith Scheme**					
			Von Post Class	**Water Content**	**Darkness**	**Stratification**	**Elasticity**	**Dryness**	**Boundary**	**Components**
		2.00	H8	B3	Nig3	Stf2	Elas2	Sicc1		Tb1, Th2, Tl+, As1, Gmin+
		2.40	H8	B3	Nig3	Stf2	Elas2	Sicc1		Tb1, Th2, Tl+, As1, Gmin+
DS-PC-03 14/04/17 Area D	NH 880 241	0.2	H2	B3	Nig3	Stf0	Elas2	Sicc2		Tb1, Th1, As2, Ag+
		0.4	H5	B3	Nig1	Stf0	Elas0	Sicc1		Tb1, Th1, As+, Ag1, Gmin1
DS-PC-04 09/04/17 260m N of Area B	NH 905 821	0.05	H4	B2	Nig3	Stf0	Elas2	Sicc2		Tb1, Th1, Dh+,As2
		0.50	H5	B2	Nig2	Stf2	Elas2	Sicc2	Lim1	Tb1, Th2, Tl+, As1
		0.75	H5	B2	Nig2	Stf2	Elas2	Sicc2	Lim3	Tb1, Th2, Tl+, As1
		1.00	H6	B3	Nig3	Stf2	Elas2	Sicc2		Tb1, Th2, Tl+, As1
		1.50	H8	B3	Nig3	Stf2	Elas2	Sicc2	Lim2	Tb1, Th2, Tl+, As1
		1.85	H8	B3	Nig3	Stf3	Elas2	Sicc2		Tb1, Th2, Tl+, As1, Gmin+

Table 3.5: Laboratory testing of Peat Cores Collected During Stage 2 Preliminary GI (March 2017)[viii]

Location ID & Sample date Peat Excavation Area ID (if applicable)	Core NGR	Depth (m)	Laboratory testing		
			Moisture Content %	Bulk Density (Mg/m^3)	Dry Bulk Density (Mg/m^3)
DS-PC-01 13/04/17 Area E	NH 863 298	0.0	174	1.23	0.45
DS-PC-02 10/04/17 Area E	NH 864 239	0.0	831	1.24	0.13
		0.5	1014	1.16	0.10
		1.0	924	1.28	0.13
		1.5	700	1.50	0.19
		2.0	808	1.43	0.16
DS-PC-03 14/04/17 Area D	NH 880 241	0.0	353	0.38	0.08
DS-PC-04 09/04/17 260m N of Area B	NH 905 821	0	579	1.17	0.17
		0.5	717	1.42	0.17
		1.0	748	1.35	0.16
		1.5	709	1.30	0.16

3.6. Interpretation

3.6.1. The Von Post classifications of the peat cores ranged from insignificantly decomposed (H2) to areas with moderately strongly decomposed to very strongly decomposed peat (H6 to H8 classifications). Von Post classification categories are provided in Annex B. Von Post classification generally increased with depth, with all cores showing at least moderately decomposed peat (H5) below 1m depth. All core samples had dry-medium moisture content (B1-B3) estimated *in situ*.

3.6.2. The Troels-Smith classification of the peat cores is provided in Annex B. Cores typically recorded Nig3 darkness values (partly decomposed peat). Stratification varied within the core dataset, often variable for same location at different core depths. Elasticity was generally evaluated as an intermediate value of Elas2. Dryness values for all cores were Sicc1 or Sicc2, representing thoroughly saturated and saturated samples, respectively. Component materials in cores included moss remains and roots and stems of herbaceous plants and clay particles in all samples, with woody remains found in all samples collected at depths greater than 0.5m. Sand was noted within cores taken at DS-PC02, DS-PC-03 and DS-PC-04, with silt noted only for core DS-PC-03 at a shallow depth of 0.2m. There were no core records of very decomposed plant remains, nor darkness shade evidence of fully decomposed peat in any sample.

3.6.3. Bulk density is the weight of soil in a given volume, with the associated dry bulk density obtained following heating of the sample to remove moisture. Peat has a relatively low dry bulk density in comparison with other soils, which is considered to be due to a combination of factors, including entrapped gas, high water content and the presence of low density organic content in the peat body[xiii]. Bulk density measurements were taken from the 11 core samples. These returned bulk density results ranging between 0.38 - 1.50Mg/m^3, with an average value of 1.22Mg/m^3. Peat results would be expected to lie within the range of 0.9 - 1.4Mg/m^3 [xiii] [xv] and the Proposed Scheme results are generally within this range, with one notable lower outlier for DS-PC-03, 0.38Mg/m^3 recorded at 0.0m depth (surface), with the highest value being 1.50Mg/m^3 at DS-PC-02 recorded at a depth of 1.5m. The bulk densities which are higher which may be a result of water loss between sampling and testing, or reflective of higher sand and clay components as these align to higher dry bulk density values. Low bulk density values would reduce associated shear stress on a peat slope.

3.6.4. Dry bulk density values range between 0.08 - 0.19Mg/m^{3,} with an average of 0.17Mg/m^3, which is slightly higher than average literature values of 0.12Mg/m^3. There is a general increase in dry bulk density with depth for samples DS-PC-02 and DS-PC-04, although the wet bulk and dry bulk density values for the DS-PC-02 2.0m depth sample are lower than anticipated. The dry bulk density value for DS-PC-01 is also unusually high and coincident with a low moisture content. Higher dry bulk density values from samples immediately below the surface are much higher than standard literature acrotelmic values (0.04 – 0.34Mg/m^3), ranging between 0.08 - 0.45Mg/m^3, potentially indicative of peaty soil influence or damage to the acrotelm.

3.6.5. The moisture content varies between 174 - 1014%, generally increasing with depth for most samples. As the moisture content of peat is typically around 900%, and generally within the range of 600-800%[xvi], samples DS-PC-01 and DS-PC-03 indicate that these shallow peat samples are relatively dry with a deeper water table.

3.6.6. In summary, the peat core results suggest that the levels of decomposition and organic material at the representative peat core locations are less than would be typically expected in peat, indicating that some core locations may be peat-containing soils, which would be expected to have a greater structural integrity than peat and of less sensitivity in terms of excavation and re-use. The core data indicates that shallow cores retained physical structure and that peat material is increasingly decomposed at greater depth, with catotelmic amorphous peat likely to be present at depths greater than 1.0m.

4. Factor of Safety Preliminary Stability Analysis

4.1.1. To establish the stability of peatland areas, AMJV 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.

4.1.2. This peat stability assessment initially determines areas considered of greatest risk of slope failure, based on factor of safety slope stability calculations, these areas were then considered in greater detail, including site visits to gather further information.

4.1.3. Using the collated data a preliminary analysis of slope stability can be carried out using the infinite slope model. The stability of a slope can be assessed by calculating the factor of safety *F* which is the ratio of the sum of resisting forces (shear strength) and the sum of the destabilising forces (shear strength):

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

4.1.4. Where c' is the effective cohesion, γ is the unit weight of saturated peat, γ_w is the unit weight 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.

4.1.5. The Factor of Safety (FoS), *F*, represents the ratio of the forces resisting a slide to the forces causing the material to slide. Clearly, if $F > 1$ then the slope is stable and normally if $F > 1.4$ then there is a degree of comfort that the slope will not fail. The boundary value of 1.4 is in agreement with the current recommendations of Eurocode 7[xvii].

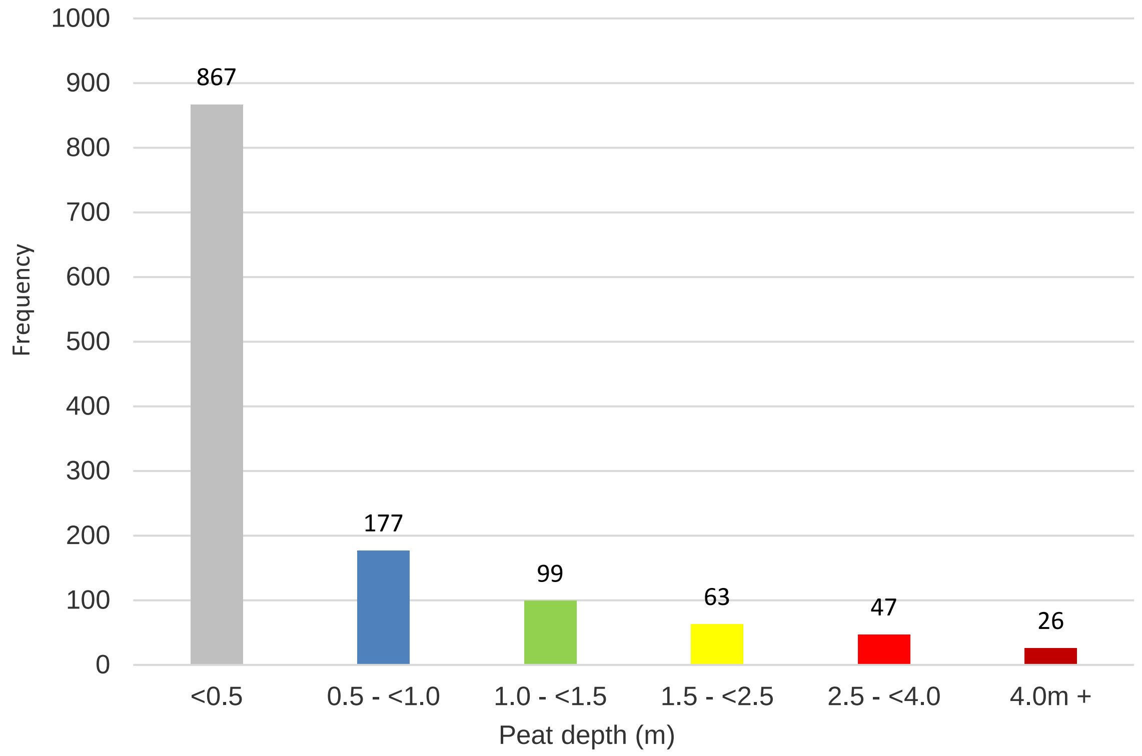
4.1.6. To get an indication of the stability of the peat under and adjacent to the scheme footprint, the factor of safety can be calculated for each peat probing location. In addition, to gain a better view of peat stability in the areas surrounding the infrastructure, factor of safety calculations can be carried out for the grid cells of the indicative peat depth map in the vicinity of the infrastructure.

4.1.7. 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 close to the Proposed Scheme.

4.1.8. 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 average slope values for each grid cell. The average 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.

4.1.9. 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. Taking a conservative approach, the upper bound of each range has been used, where actual data is not held. Measured peat depths are presented as a histogram in Illustration 9.

Illustration 9. Peat Depth Histogram



4.1.10. The unit weight of water, γ_w, is known to be 9.81kN/m^3 (bulk density of 1.0Mg/m^3).

4.1.11. 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 0.5 to 1.4Mg/m^3. Laboratory analyses undertaken on site samples collected by or on behalf of AMJV have returned bulk density values generally ranging between 0.4 and 1.5Mg/m^3. Based on this experience and also externally published values from more extensive peatland studies[xviii], an average bulk density value of peat of 1.0Mg/m^3 has been used for the preliminary FoS calculations.

4.1.12. If it is assumed that an area of 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. On-site 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. Consequently, a water table ratio, m, of 1.0 has been chosen, which is considered conservative given most of the site exhibits drier conditions.

4.1.13. The angle of internal friction in peat also varies, decreasing with increasing decomposition and moisture content. In some instances, although not in this study area, 'quaking bog' has been observed where the peat takes the form of a slurry beneath a surface mat of vegetation. In such a situation the angle of internal friction will be very low. For the FoS calculations, a φ' value of 5° has been selected in line with the conservative approach.

4.1.14. Finally, a value for the effective cohesion, c', must be derived. Literature values for c' in peat vary widely, ranging from 2.5 to 8kN/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.

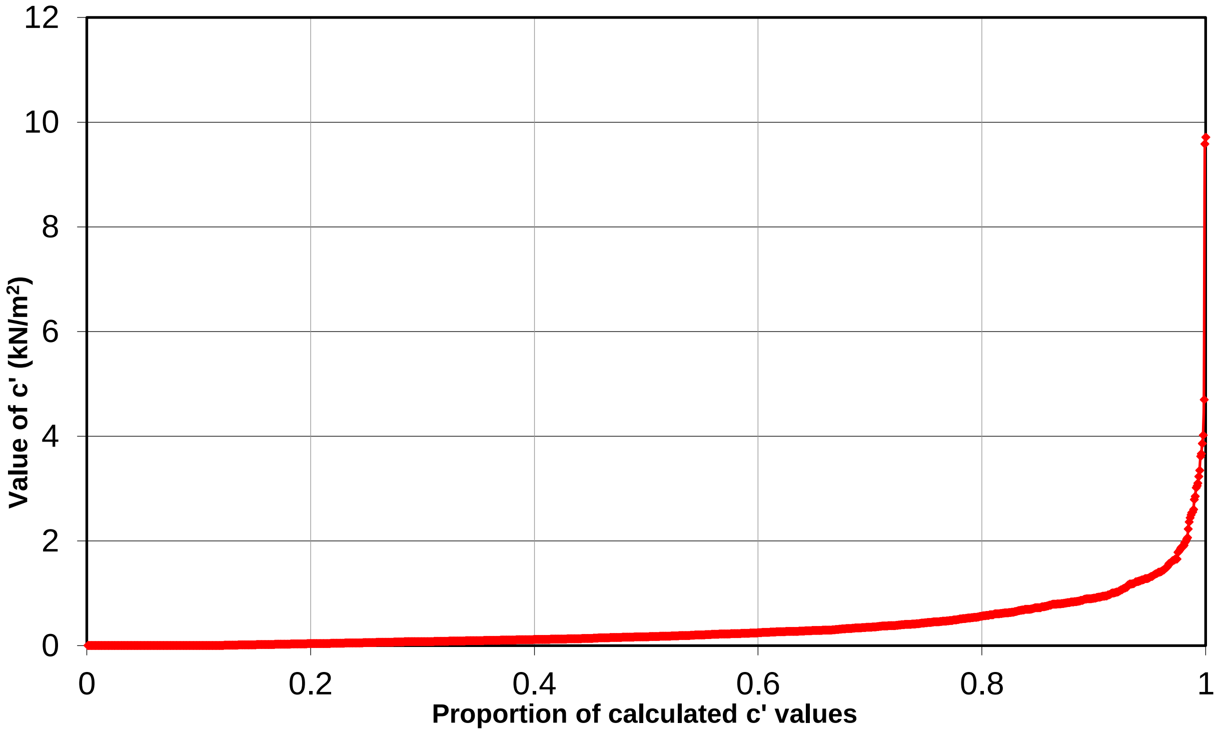
Estimation of Cohesive Strength

4.1.15. 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.

4.1.16. 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.

4.1.17. In the study area 1,279 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 Illustration 10. For example, reading from the graph, 0.8 (or 80%) of the probing locations require a theoretical c' value of 0.56kN/m^2 or less to be stable and retain peat on the slope.

Illustration 10. Estimate of Minimum Cohesive Strength, c'



4.1.18. From this work it is possible to state, with confidence, that across the site as a whole the shear strength of the peat is unlikely to be less than 2.80kN/m^2 as this is the value of the 99th percentile point on the graph. The basis for making his statement 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, in particular 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;
- 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.

4.1.19. For the purposes of the Factor of Safety Assessment a *c'* value of 2.80kN/m^2 has been used. This value is very conservative in comparison with estimates derived from other sites around Scotland, largely due to the shallow peat found on most slopes within the study area. The actual effective cohesion of any peat within the study area is therefore likely to be higher than 2.80kN/m^2 (compare with literary values of 2.5 – 8kN/m^2), however, this value has been chosen to ensure a conservative assessment using data from the site.

Factor of Safety (FoS) Stability Results

4.1.20. 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 infrastructure. The results of the FoS assessment for the probing points and site grid cells are summarised in Table 2.4. The FoS assessment maps generated with these values are shown in Figure A10.2.2.

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

Table 4.1: Summary of Factor of Safety Assessment

Factor of Safety	**No peat in Grid (<0.5 m peat)**	**≥3.0**	**1.4 - <3.0**	**1.0 - <1.4**	**<1.0**	**Total**
Probing Data (points)	N/A	1,159	97	10	13	1,279
% of points	N/A	90.6%	7.6%	0.8%	1.0%	100%
Grid Cells	29,885	514	149	47	28	30,623
% of Grid Cells	97.6%	1.7%	0.5%	0.2%	0.1%	100%
Grid Cells (with measured data)	681	145	78	17	17	938
% of Grid Cells (with measured data)	72.6%	15.5%	8.3%	1.8%	1.8%	100%

4.1.22. In selecting the 99th percentile value of the back-calculated c' strengths, one is implicitly condemning 0.5% 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 a reasonable distance from the Proposed Scheme infrastructure.

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

4.1.24. To summarise, 98.2% of the peat probing locations on the site have a FoS of 1.4 or greater, where stability can be assumed with a degree of comfort. In relation to grid cells with measured depths (i.e. predominantly those grid cells closest to proposed infrastructure), cell locations with FoS values greater than 1.4 (including cells with peat less than 0.5m depth) represent 96.4% of the site, again these are locations where stability can be assumed with a degree of comfort.

4.1.25. The results demonstrate that the vast majority of the Proposed Scheme will 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 and moderate or steep slopes occur within the same grid cell. Such areas, where close to the Proposed Scheme, have been considered further as potential risk areas.

5. Initial Risk Assessment

5.1. Conceptual Model

5.1.1. Based on the data collated from the desk study, reconnaissance survey, peat probing and FoS stability analysis the peat landslide risk across the site can be classified. The Guidelines[i] define risk as a function of likelihood and consequence and this has been applied by AMJV as:

Risk = Likelihood x Adverse Consequence

5.1.2. 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 0.5 m) these areas were identified as ‘N/A – Not Peat’.

5.1.3. Central to AMJV’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.

5.2. Likelihood

5.2.1. In AMJV’s method, the primary and non-subjective measure of likelihood of slope stability is the Factor of Safety (FoS) calculation. When this has a value greater than 1.4 it is generally regarded that a slope is ‘safe’.

5.2.2. 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* 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 5.1 and 5.2, respectively.

5.2.3. The initial likelihood classification of grid cells across the site is presented as Figure A10.2.3.

Table 5.1: Criteria Relating to Initial Likelihood scores

Likelihood	Local Context
Almost certain	Not applied at initial likelihood stage
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

Table 5.2: Summary of Initial Likelihood classifications for grid cells

Likelihood	No Peat	Negligible	Unlikely	Likely	Probable	Almost Certain	Total
No. of Grid Cells	29,885	514	149	47	28	n/a	30,623
% of Grid Cells	97.6%	1.6%	0.5%	0.2%	0.1%	n/a	100%
No. of Grid Cells (with measured peat depth)	681	145	78	17	17	n/a	938
% of Grid Cells (with measured peat depth)	72.6%	15.5%	8.3%	1.8%	1.8%	n/a	100%

5.3. Adverse Consequence

5.3.1. The Guidelines identify that 'Consequence' relates to impact upon receptors, this would include property, existing infrastructure and assets, environmental features and/or the Proposed Scheme. 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; and
- Proposed Scheme infrastructure (access tracks, areas for scheme construction.).

5.3.2. 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 including:

- 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.
- 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 kilometres. 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.

5.3.3. Table 5.3 assembles the above considerations to outline the degrees of consequence. Using the table, the three columns would be 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.

Table 5.3: Criteria Relating to Consequence scores

Consequence	Habitat	Proposed Scheme Infrastructure	Public/Private Infrastructure
Extremely High	Large loss/damage to aquatic habitat, i.e. within designated site, and Ancient Woodland	Not applicable	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 aquatic habitat, i.e. designated site, and Ancient Woodland (within 100m)	Not applicable	Damage to minor/ unclassified roads and tracks (within 100m); Impact on private utilities, including local electrical connection, water and waste water (within 250m).
Moderate	Large loss/damage to hydrology features shown on 1:10,000 OS mapping (within 50m) Peat grid cells identified with peat depth >1.0m	Interruption to construction of Proposed Scheme (within the Land Made Available (LMA)	Not applicable

Consequence	Habitat	Proposed Scheme Infrastructure	Public/Private Infrastructure
Low (default position)	Medium loss/damage to hydrology features shown on 1:10,000 OS mapping	Not applicable	Not applicable
Very Low (not applied)	Small temporary loss/damage to common terrestrial and/or aquatic habitat	No damage to assets	No damage to assets

5.3.4. The consequence classification of cells is provided in Table 5.4 and presented on Figure A10.2.3. The majority of the study area (89.3%) is classified as having an Extremely High consequence value, this is due to the study area following a corridor generally within 100m of the existing A9, the Highland Mainline Railway and/or the Proposed Scheme. These sensitive features dominate the study area.

Table 5.4: Summary of Consequence classifications for grid cells

Consequence	Extremely High	High	Moderate	Low	Very Low	Total
No. of Grid Cells	17604	4823	925	7271	n/a	30,623
% of Grid Cells	57.6%	15.7%	3.0%	23.7%	n/a	100%
No. of Grid Cells (with measured peat)	838	28	23	49	0	938
% of grid cells (with measured peat)	89.3%	3.0%	2.5%	5.2%	0%	100%

5.4. Initial Risk Assessment Outcomes

5.4.1. The likelihood (solely based on FoS) and consequence values were applied to the Proposed Scheme for the initial risk assessment, with the resulting areas shown on Figure A10.2.4. A summary of the cell counts was provided in Tables 6.2 and 6.3 for each classification.

5.4.2. The results of the initial likelihood and consequence grid cell categorisations reflect the characteristics of the site. The dominant topography features the valley slopes both upslope and downslope of the existing A9, with areas of deep peat often associated with flat areas at the base of the slope. The context of the site with the existing A9 road, Highland Mainline Railway, infrastructure and properties leads to a consequence of extremely high along the majority of the Proposed Scheme, with areas of peat often located away from these areas.

5.4.3. The Guidelines' risk scoring is determined via a matrix table, combining likelihood and consequence. This has been provided as Table 5.5 and replicates the matrix in the Guidance[i]. An initial risk value has been derived for each grid cell through combining the Likelihood and Consequence ratings using the matrix in Table 5.5. A summary of the grid cell counts for each risk category is provided in Table 5.6.

Table 5.5: Risk Matrix Based on Likelihood and Consequence Values

Adverse Consequence						
Peat Landslide Likelihood		Extremely High	High	Moderate	Low	Very Low
	Almost certain	High	High	Moderate	Moderate	Low
	Probable	High	Moderate	Moderate	Low	Negligible
	Likely	Moderate	Moderate	Low	Low	Negligible
	Unlikely	Low	Low	Low	Negligible	Negligible
	Negligible	Low	Negligible	Negligible	Negligible	Negligible

Table 5.6: Summary of Initial Risk outcomes and Guideline actions

Initial Risk	Number of Grid Cells	% of Grid Cells	Number of Grid Cells (measured peat depth)	% of Grid Cells (measured peat depth)	Suggested Guideline[i] Actions
High	23	<0.1%	17	1.8%	"Avoid project development at these locations"
Moderate	23	<0.1%	17	1.8%	"Project should not proceed unless hazard can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce hazard ranking to low or negligible"
Low	304	1.0%	201	21.5%	"Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation and re-design at these locations"
Negligible	388	1.3%	22	2.3%	"Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate"
N/A - No Risk	29,885	97.6%	681	72.6%	*Not applicable as not peat*
Total	30,623	100%	938	100%	

5.4.4. As can be seen on Table 5.6, the majority of the site has been assessed as having either 'No Risk' or 'Negligible' risk of peatslide hazard at the initial risk assessment stage. 'Moderate' and 'High' risk cells tend to cluster together and are typically located where peat depths greater than 0.5m were recorded on or close to steep slopes, comprising less than 0.2% of the grid cells.

5.4.5. All of the 'Moderate' and most of the 'High' risk cells are located within 100m of the existing A9, Proposed Scheme and the Highland Mainline Railway, evaluated as receptors with Extremely High consequence and largely determining the initial risk outcome.

5.4.6. When considering the grid cells with measured peat depth, which is a better indicator of areas where infrastructure is planned, less than 4% of cells recorded either a ‘Moderate’ or ‘High’ initial risk.

5.4.7. Figure A10.2.4 shows the Proposed Scheme overlaid on the Initial Risk mapping, with initial ‘High’ or ‘Moderate’ risk cells identified as red or orange cells, respectively. These cells cluster into 8 areas and further location-specific information has been focused on these in the Revised Risk Assessment section and datasheets provided in Annex A:

- Seven areas initially identified which include at least one initial ‘High’ risk grid cell, based on likelihood defined by factor of safety combined with consequence values - Areas A, C, D, E, F G, H; and
- One area initially identified which include at least one initial ‘Moderate’ risk grid cell, but no ‘High’ risk cells, based on likelihood defined by factor of safety combined with consequence values – Area B.

6. Revised Risk Assessment / Detailed Assessment

6.1.1. For each of the 8 areas (Peat Stability Risk Areas A-H) identified as being of high or moderate risk from the initial risk assessment, a detailed assessment has been undertaken and reported on 8 individual datasheets. This includes description of the peat depths, factor of safety values, local characteristics including geomorphology and geotechnical information, aerial images and available photographs. These datasheets also identify site-specific mitigation and a revised risk level taking into account the additional information gathered scrutiny at each location. The individual datasheets for each area are provided in Annex A, with an overview of the locations presented in Figure A10.2.4. The Peat Stability Risk Areas are also shown in the context of peat depth and factor of safety datasets on Figures A10.2.1 and A10.2.2, respectively.

6.1.2. The detailed assessment datasheets provided in Annex A display the initial risk values for grid cells (each cell measuring 50m x 50m), with cells highlighted of bordered in red (high risk) and orange (moderate risk). The probe location triangles are coloured to represent peat depth ranges (as per colour-coding on Table 3.3 and Figure A10.2.1) and each probe point also includes a background square coloured to identify the FoS category (using the FoS colour range previously displayed on Table 4.1 and Figure A10.2.2).

6.1.3. 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, 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.
- 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[i] included suggestions of probability values, these have been included in italics as a contextual reference.

6.1.4. In addition to good practice and design measures, there are also a number of specific mitigation measures that are proposed to be deployed to reduce risk (generally the likelihood aspect) at particular locations, with further details in Section 7.

6.1.5. The revised risk information on the eight individual datasheets (Annex A) reflects the refinement of risk, 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.

Table 6.1: **Criteria Relating to Revised Likelihood Values**

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 1.5m. Topography: convex breaks in slope; extensive unconfined slopes Drainage: converging flow paths; large contributing area; peat pipes *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 *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 1.0m Topography: generally rounded/undulating landforms

Likelihood / Hazard	Regional Context	Local Context
		Drainage: suspicious absence of surface channels; indications of peat pipes *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 1.0m on slopes Topography: generally rounded/undulating landforms Drainage: natural well defined channels; artificial improvements to drainage *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 1.0m on slopes Topography: concave or no break in slope; small confined slopes Drainage: diverging flow paths; small contributing area; natural well defined channels; artificial improvements to drainage *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 0.5 m or confirmed as non-peat material.

6.1.6. Following the revised risk assessment process, Table 6.2 records the revised risk outcomes and these are also shown across the site on Figure A10.2.5.

6.1.7. Following review of specific locations, collating data on local ground conditions and other relevant characteristics, the areas which were initially 'High' or 'Moderate' risk cells have been downgraded to 'Low Risk' and there are no locations that remain of 'High' or 'Moderate' risk specific to peat instability close to the Proposed Scheme.

6.1.8. Note that the remaining 'High' risk cell is outside of the Proposed Scheme area, is not proposed for development and is not considered further.

Table 6.2: Summary of Revised Risk outcomes and actions

Revised Risk	Number of Grid Cells	% of Grid Cells	Number of Grid Cells (measured peat depth)	% of Grid Cells (measured peat depth)	Suggested Guideline[i] Actions
High	1	<0.1%	0	0%	"Avoid project development at these locations"
Moderate	0	0%	0	0%	"Project should not proceed unless hazard can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce hazard ranking to low or negligible"
Low	344	1.1%	230	24.6%	"Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation and re-design at these locations"
Negligible	388	1.3%	22	2.3%	"Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate"
N/A - No Risk	29,890	97.6%	686	73.1%	*Not applicable as not peat*
Total	30,623	100%	938	100%	

7. Mitigation and Good Practice Measures

7.1.1. The purpose of the peat slide risk assessment is to identify areas of the site which are potentially at most risk of peat instability and thereafter assess construction impacts. Where avoidance is not possible mitigation measures require to be implemented. In addition to specific mitigation measures which may be deployed at particular locations, there are a number of generic construction good practice measures that should be considered. A number of these are set out in Table 7.1 below (NB this list is not exhaustive).

7.1.2. It should also be noted that areas of peat were considered as part of the DMRB Stage 2 and 3 design process, to minimise impacts where possible. However, as no risks specifically relating to peat stability risks were identified, this was not considered further within the design process.

7.1.3. Good practice guidance documents, such as Floating Roads on Peat[xix], Managing Geotechnical Risk[xx] and Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments[i] should be consulted to inform the design and construction processes. All site investigation work will be undertaken in compliance with relevant British Standards, including BS 5930: 1999[xxi] and BS 6031: 2009[xxii].

7.1.4. The application of good practice techniques during forestry clearance will also act to reduce the potential for peat instability, in terms of both likelihood of occurrence and magnitude of any event. Following forestry clearance, in areas with previously restricted access, surveys shall be undertaken to record peat depths and for evidence of peat instability.

7.1.5. On-site construction staff are often the best placed to provide advance notification of potential problems, provided they are trained to do so and there is a reporting mechanism in place. 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 2.1 of this report. The suspected identification of any of these indicators should be assessed by specialist geotechnical personnel.

Table 7.1: Good Practice and Mitigation Measures

Potential Actions	Good Practice	Mitigation Measure
1. Geotechnical specialist on-site during the construction phase to undertake advance inspection, carry out regular monitoring and provide ongoing advice at locations of concern	✓	✓
2. Maintain and update geotechnical risk register or similar management system	✓	✓
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 an incipient peatslide or of the event occurring	✓	
5. Microsite the proposed infrastructure in order to avoid the problem area (subject to non-violation of other constraints)	✓	
6. Ensure that good ground- 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		✓
8. Ensure artificial drainage does not concentrate flows onto slopes 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.	✓	
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	✓	

Potential Actions	Good Practice	Mitigation Measure
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 breaks-in-slope or other potentially unstable slopes	✓	✓
13. Avoid removing slope support, particularly where slope stability has been highlighted as of concern.	✓	✓
14. Consideration of piled support to assets in deep peat and/or risk areas, potentially also involving a load transfer platform		✓
15. Establish / re-establish vegetation as soon as possible to improve slope stability and provide sediment transport control	✓	
16. 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		✓
17. Modify slope geometry to provide a 'weighted toe'		✓
18. Use of retaining structures, such as gabions for terracing		✓
19. 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		✓
20. 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	✓	
21. Where blasting of rock is required within 1km of locations of peat stability concern, the peat area should be monitored. This would involve visits in advance of blasting to assess for current or historic instability and during the period of blasting the area should be revisited to assess any change in condition. Changes in condition should be reported and consideration given of adapting the blasting strategy to minimise adverse effect and feedback provided should change be apparent or suspected		✓

8. Summary and Recommendations

8.1.1. The study area for the Proposed Scheme between Dalraddy to Slochd has been assessed for the risk of slope instability using a quantitative assessment method based on plane failure analysis. The areas of the site highlighted as having low Factors of Safety coincident with or adjacent to the Proposed Scheme footprint have been considered in more detail.

8.1.2. The conservative nature of the methodology applied leads to identification of the least stable areas on any specific site, meaning that on inherently stable sites, the procedure will still identify locations initially considered of 'High' or 'Moderate' risk, with this risk relative to the remainder of the site. Seven areas with 'High' risk and one area with 'Moderate' risk were initially highlighted in Section 5 (Initial Risk Assessment), based on peat probing and desktop factor of safety calculations specific to this site. For each area, the potential effect of road construction was considered and re-assessed following collation of specific characteristics of each location including ground investigation data, with deeper peat often located in flat areas at the base of slopes (including artificial embankments) and appropriate mitigation measures recommended, where necessary, to then arrive at a revised (or residual) risk level which is provided as Figure A10.2.4. The individual datasheets are provided as Annex A.

8.1.3. Following the Detailed Assessment process, taking account of local ground conditions plus appropriate piling techniques, slope monitoring, slope support and drainage controls as specific mitigation, all areas of the site are considered to be of 'Low' revised risk or less concern (i.e. 'Negligible' or non-peat) in terms of peat instability.

8.1.4. The Guidelines[i] quote that "'Negligible' and 'Low' risk cells are considered to be suitably mitigated by employing site-wide good practice measures and ensuring stability information is communicated to detailed design team within a Geotechnical Risk Register. Micrositing may be used to improve the associated infrastructure locations, where other constraints permit."

8.1.5. Further geotechnical investigation are underway and additional data shall be gathered as part of the site geotechnical investigations, which will take place post-consent and prior to construction. This is standard practice and will inform the final, detailed design of the Proposed Scheme, along with detailed mitigation, such as appropriate piling techniques, embankment material, slope monitoring programme and drainage designs including routes and discharge locations, that are to be implemented during construction, undertaken by an appropriately qualified geotechnical engineer. This includes slope monitoring to the west of the existing A9 and Highland Mainline Railway during blasting of rock slopes at Slochd Summit.

8.1.6. Whilst mitigation measures have been identified in this document, the suggested techniques are not exhaustive and it is expected that designers and contractors will use these and other techniques, as appropriate, to effectively manage the peat stability risk. Management of peat stability risk will remain a consideration throughout the subsequent detailed design processes, including additional site investigation, pre-construction activities and during construction, subject to the scheme receiving consent. The need for risk management has been emphasised throughout this report and forms a standard part of any construction project. Risk management will include the regular review of the Geotechnical Risk Register, supported by appropriate actions within the contractor's Construction Method Statement (CMS) in due course.

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[xv] Barnes (2010). Soil Mechanics Principles and Practice. Third Edition.
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[xviii] Lindsay (2010). Peatbogs and carbon: a critical synthesis to inform policy development in oceanic peat bog conservation and restoration in the context of climate change. University of East London Environmental Research Group. Accessed January 2017.
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Annex A. Peat Stability Risk Areas

<u>Areas with Initial 'High' and/or 'Moderate' Risk of Peat Instability</u>

Area A

Area B

Area C

Area D

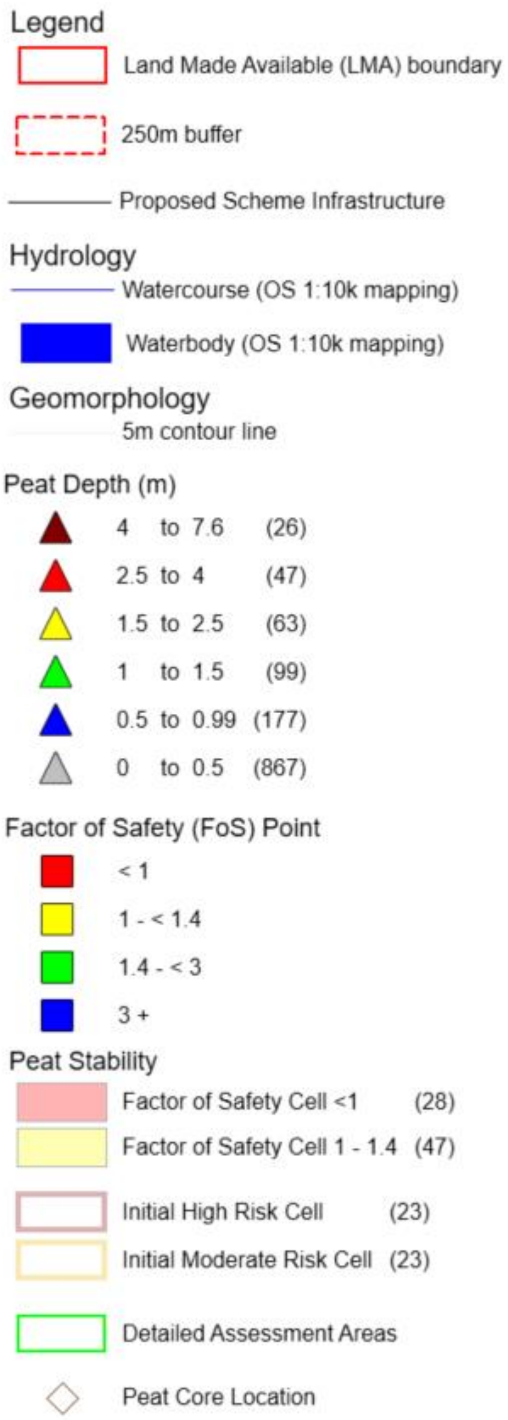
Area E

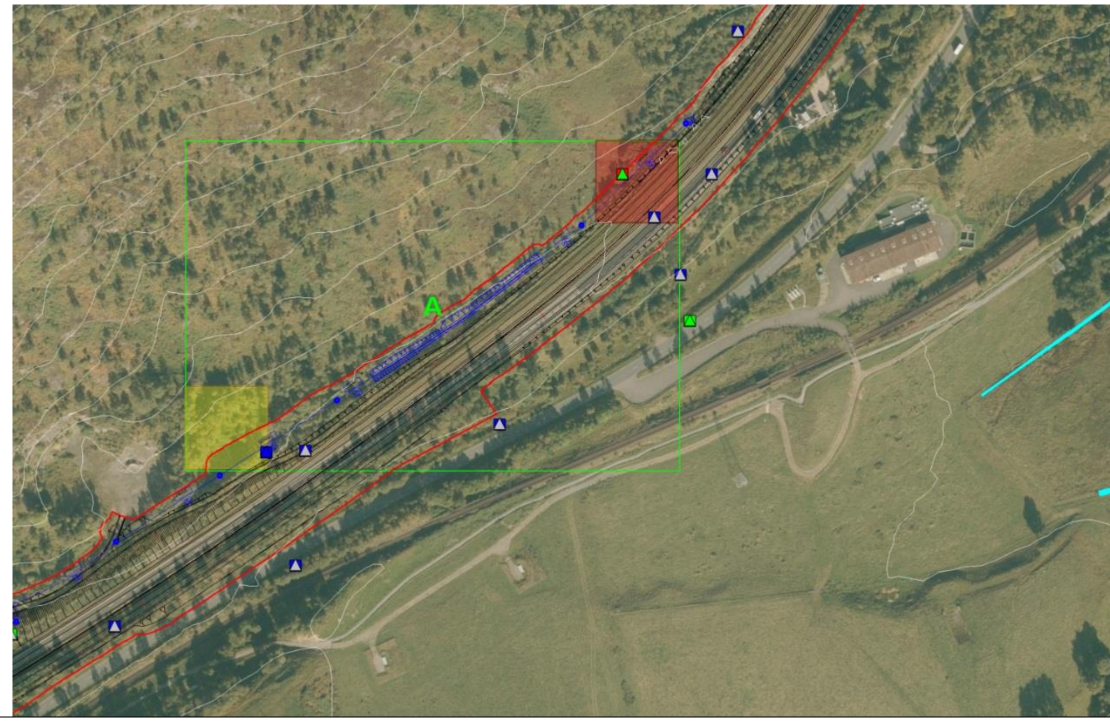
Area F

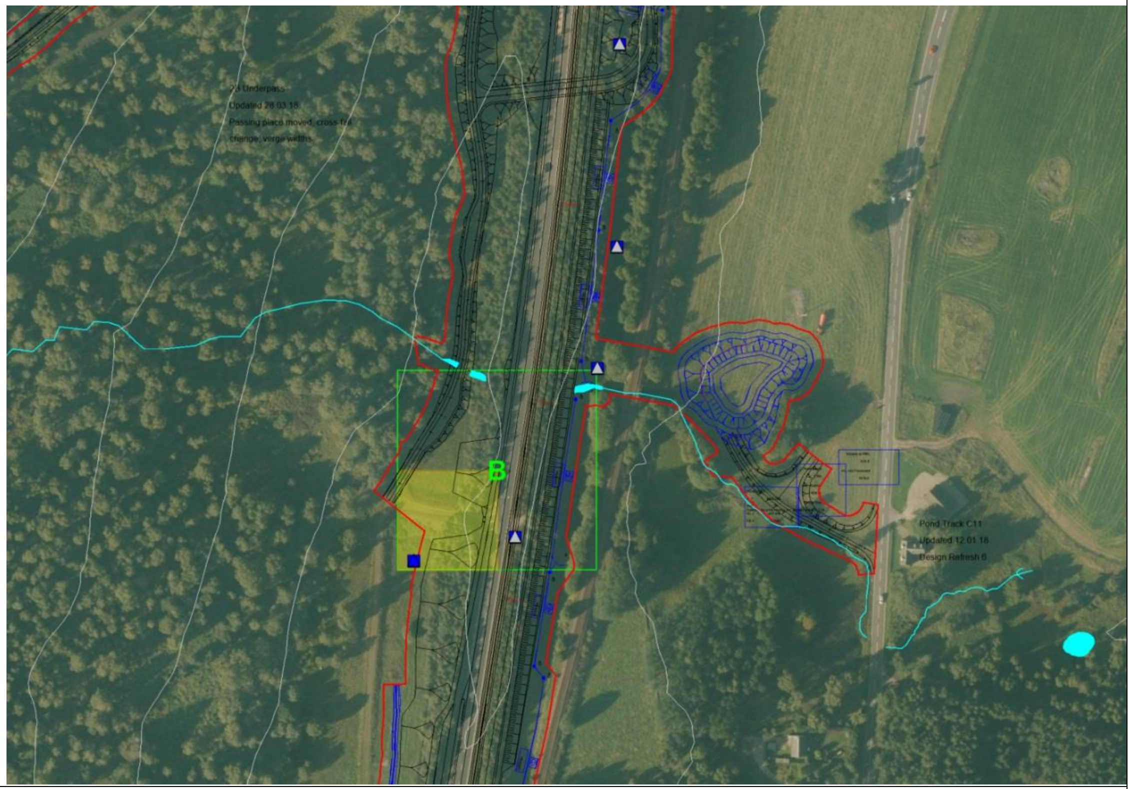
Area G

Area H

<u>Legend for Detailed Assessment</u>



Area A Kinakyle NGR NH 887 109		
Initial Likelihood - Probable; Consequence – Extremely High; Initial Risk - High Revised Likelihood – N/A (Not Peat); Consequence – Extremely High; Revised Risk – N/A **Area Description:** This area is upslope of the existing northbound A9 carriageway north of Kinakyle, with soil depths ranging from 0.3 to 1.2m, with an average depth of 0.55m. Deep soil depths are confined to two specific locations, both in areas of deciduous woodland, upslope of the existing A9 embankment. This area slopes south-east, with a maximum slope angle of 30º recorded approximately 40m upslope of the existing A9 in the north-east area. Aerial imagery shows both cells of concern feature local rocky outcrops. No peat instability was noted during site surveys. **Infrastructure Planned:** This area features mainline widening, with a new access road and small cuttings in the south-west of this area, with larger cuttings associated with the new access road and northbound mainline widening in the north-east. There are new drainage ditches proposed between the two cells of concern, adjacent to the northbound carriageway.	Aerial Overview of Area A	
FoS Assessment: Cells identified of moderate risk (with FoS 1 to < 1.4) have relatively minor infrastructure planned in the south-east, but larger extensive earthworks in the north-east where slopes are being altered. Soil and peat depth records vary between 0.3m and 1.2m. The factor of safety values for peat probes ranged from 0.73 to 29.0, for local grid cells the highest concern factor of safety value was 0.97. The area was identified as of initial concern based on FoS, primarily due to the high slope angles associated with the existing cuttings and deeper probe depth recorded nearby within same grid cell. However, NVC surveys indicate these areas do not feature peatland habitats and both GI locations record topsoil and sand present, therefore no peat core was obtained in this area. **Specific Mitigation, Potential Scale and Receptor:** N/A – No peat within the area. Downslope receptors include the existing A9, B9154 and the River Spey, 240m south-east. **Revised Risk:** This is not considered a peat location taking into account Ground Investigation and ecology data. Taking account of local characteristics: N/A (Not Peat).	Photograph at NGR NH 888 110, looking north-west along the bank from the existing northbound carriageway.	

<table>
<tr><th colspan="3">Area B Kinveachy NGR NH 909 184</th></tr>
<tr><td>Initial Likelihood - Likely; Consequence – Extremely High; Initial Risk - Moderate
Revised Likelihood – N/A (Not Peat); Consequence – Extremely High; Revised Risk – N/A (Not Peat)</td><td rowspan="3">Aerial Overview of Area B</td><td rowspan="3">
</td></tr>
<tr><td>Area Description:
This area is downslope of the existing northbound A9 carriageway and features one measured soil depth of 0.9m. A small access track runs north-south, parallel to the existing A9.
The area features grassland, with woodland to the west. It is generally low gradient, however, the existing A9 embankment has a maximum slope angle of around 25º. The Allt Cnapach watercourse flows east underneath the existing A9 carriageway and the Highland Mainline Railway, immediately north of the area. There is also an existing unnamed drain which runs along the northbound carriageway.
Ground Investigation works at BHDS2078 recorded a gravelly silty topsoil with low organise content, underlain by sand and gravel.
No instability was noted during site surveys.</td></tr>
<tr><td>Infrastructure Planned:
This area features southbound mainline widening, including new embankments, and a new access track north of the area, which runs north-east parallel to the A9. A new SuDs pond is proposed east of the area on the southbound side of the mainline carriageway.</td></tr>
<tr><td>FoS Assessment:
The factor of safety values for peat probes ranged from 3.4 to 28.1, for local grid cells the highest concern factor of safety value was 1.37 with a soil/peat depth of 0.9m located in this area. Cells identified of initial moderate risk (FoS 1 to < 1.4) where proposed embankments will be located, where soil/peat depths records range up to 0.9m.
The area was identified as of initial moderate risk using FoS, primarily due to the high slope angles associated with the existing embankments and deep soil recorded nearby within same grid cells, with the proximity of receptors such as the existing A9 and the Allt Cnapach.
This area is not considered to have peat deposits, based on the Ground Investigation logs, therefore no peat stability issues are anticipated.</td><td rowspan="3">Photograph taken from NGR NH 910 184 facing south between existing A9 carriageway and farm track.</td><td rowspan="3"></td></tr>
<tr><td>Specific Mitigation, Potential Scale and Receptor:
N/A – No peat within the area.
Downslope receptors include the Allt Cnapach watercourse, located 50m north, with smaller tributaries, drainage channels, the existing A9 and the Proposed Scheme downslope.</td></tr>
<tr><td>Revised Risk:
This is not considered a peat location taking into account Ground Investigation data.
Taking account of local characteristics: N/A (Not Peat).</td></tr>
</table>

Area C Feith Mhor NGR NH 907 208

Initial Likelihood - Probable; Consequence – Extremely High; Initial Risk - High

Revised Likelihood - Unlikely; Consequence – Extremely High; Revised Risk - Low

Area Description:

This area is immediately adjacent to and downslope of the existing southbound A9 carriageway and features peat depths ranging from 0.3 to 3.2m, with an average depth of 1.53m. Deep peat is concentrated in a 50m x 200m zone of swamp and blanket bog habitat surrounded by woodland to north, west and south, the Highland Mainline Railway to the east and existing A9 to the west at a topographic low point.

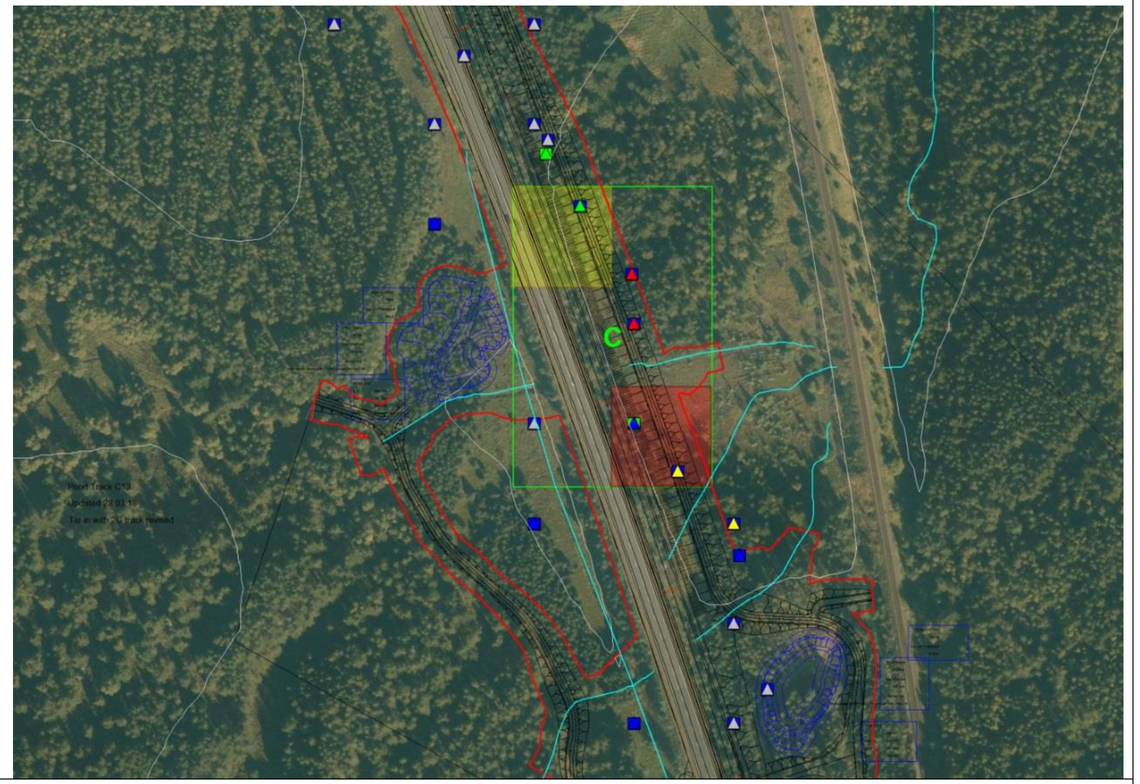
The area is generally low gradient and the existing A9 embankment has a maximum slope angle of around 30°. The maximum peat depth record was 3.2m.

No peat instability was noted during site surveys.

Infrastructure Planned:

This area features southbound mainline widening, including new embankments, and a new access track running north-east parallel to the A9 which serves the new SuDs pond to the south. The embankment to the east will be piled to avoid removing peat from beneath the Proposed Scheme. Flood compensation will also be included upstream of the Proposed Scheme to reduce flooding impacts in Area C within the downslope area.

Aerial Overview of Area C



FoS Assessment:

The factor of safety values for peat probes ranged from 1.48 to 12.0. A single high risk and single moderate risk grid cell were identified in this area, with the highest concern factor of safety cell value of 0.97, with a peat depth of 1.6m located in this cell.

Recalculating FoS for the highest risk cell, using average bulk density values from nearby peat core DS-PC-04 3 (1.31Mg/m^3) results in a revised FoS of 0.85. Note that individual probe locations in this area recorded FoS values >1.4.

The cells of concern within this area were primarily determined by the steep slope angles associated with the existing embankments and deeper peat recorded within same cells at the base of the embankment, with steep slopes and deeper peat not coincident.

Peat is unlikely to move via peatslide from the *in situ* low-gradient location.

Specific Mitigation, Potential Scale and Receptor:

Section 7 details standard good practice measures, including careful drainage design. Where infrastructure crosses extensive areas of peat, such as Area C, underlying peat is to be piled, in order to improve stability of road infrastructure and embankment and reduce excavation of peat and associated environmental effect. This area is included within the Geotechnical Risk Register, with local presence of peat recorded.

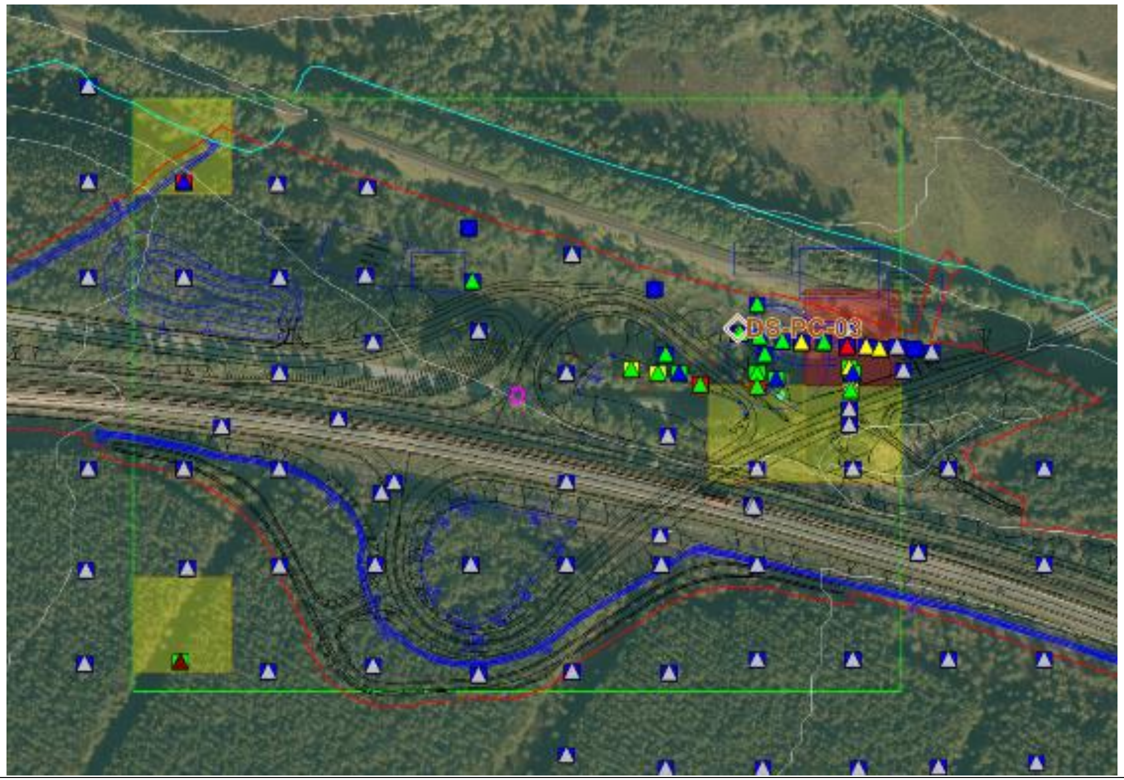
Downslope receptors include the Feith Mhor watercourse and its tributaries, with the Highland Mainline Railway 50m downslope to the east.

Revised Risk:

This is considered a stable location at base of valley.

Taking account of local characteristics, good practice and mitigation: Low Risk.

Photograph taken from NGR NH 907 208 looking north over swamp area, with existing A9 embankment to the west.

<table>
<tr><th colspan="3">Area D Proposed Black Mount Junction NGR NH 881 240</th></tr>
<tr><td>Initial Likelihood - Probable; Consequence – Extremely High; Initial Risk - High
Revised Likelihood - Unlikely; Consequence - Extremely High; Revised Risk - Low</td><td rowspan="3">Aerial Overview of Area D</td><td rowspan="3"></td></tr>
<tr><td>Area Description:
The area is located within a flat basin between the raised embankments of both the B937 to the south and Highland Mainline Railway to the north and features peat depths ranging from 0.0 to 2.55m, with an average depth of 0.92m. The area features a mix of conifer woodland, semi-natural woodland and grassland along shallow sloping embankments, with deep peat concentrated in a 50m x 150m area of swamp between these embankments. The area is generally flat, with shallow slopes less than 10º, with steeper slopes at the existing embankments, where gradients increase up to 25º.
The area of peat is located at a topographic low point. Peat core DS-PC-03 was obtained in this area. Peat was classified as H5 Moderately Decomposed at 0.4m depth. The superficial geology of Area D is glacial sand and gravels
No instability was noted during site surveys.</td></tr>
<tr><td>Infrastructure Planned:
This area is within the scheme footprint of the Proposed Black Mount junction and features new junction (carriageway) and embankments. Piling has been evaluated but is not currently proposed at this junction location. A SuDs pond located between the junction and the Highland Mainline Railway.
No infrastructure is planned in the south-west of Area D, with a drainage ditch in the north-west as part of the drainage design.</td></tr>
<tr><td>FoS Assessment:
The factor of safety values for peat probes ranged from 0.76 to 1000* (*for locations with 0.0m depth record). Initially a single high risk cell (FoS of 0.67, with the 2.55m depth within this cell) and four moderate risk cells (FoS between 1.10 - 1.38) were identified.
The area was identified as of initial high risk using FoS, primarily due to the high slope angles associated with the existing embankments and deeper peat recorded nearby within same grid cells. However, deep peat is typically located on much lower slope angles within these cells.
Recalculating FoS for lowest cell, using a local bulk density value at peat core DS-PC-03 (0.38Mg/m^3) results in a revised FoS value of 0.93. Note that individual probe locations in this extensively surveyed area generally recorded FoS values >1.4, other than 3 isolated locations.
Peat is unlikely to move via peatslide from the in situ low-gradient location.</td><td rowspan="3">Photograph from NGR NH 881 240 facing north from the B938 over swamp area towards the Highland Mainline Railway.</td><td rowspan="3"></td></tr>
<tr><td>Specific Mitigation, Potential Scale and Receptor:
Section 7 details standard good practice measures, including careful drainage design and monitoring of slopes. Ongoing consideration of alternative methods to excavation of local peat are underway in Area D, however, piling is not currently planned. This area is included within the Geotechnical Risk Register, with local presence of peat recorded.
Downslope receptors include the Bogbain Burn and the Highland Mainline Railway.</td></tr>
<tr><td>Revised Risk:
This is considered a stable location at base of existing embankments.
Taking account of local characteristics, good practice and mitigation: Low Risk.</td></tr>
</table>

Area E Black Mount NGR NH 863 238

Initial Likelihood - Probable; Consequence – Extremely High; Initial Risk - High

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

Area Description:

This area features extensive peatland with the existing A9 running east-west through the area, as well as an existing layby and the B937 road running parallel to this. An extensive peat depth survey was undertaken locally, with peat depths ranging from 0.0 to 5.4m and an average depth of 1.53m. Deeper peat is concentrated in two areas of blanket bog, the first being approximately 60 x 100m wide on the southbound side, and the second area featuring peat adjacent to the northbound carriageway approximately 50m wide along 300m of carriageway. The area features a steep embankment supporting the existing A9, with an average slope angle of 15º, with very shallow slope angles elsewhere in this area.

Two peat cores were obtained from the area, DS-PC-01 and DS-PC-02. The peat at DS-PC-01 was recorded as H4 Slightly Decomposed at a depth of 0.5m, with peat at DS-PC-02 recording increasingly decomposed peat with increasing depth and H8 Very Strongly Decomposed at depths beyond 2m.

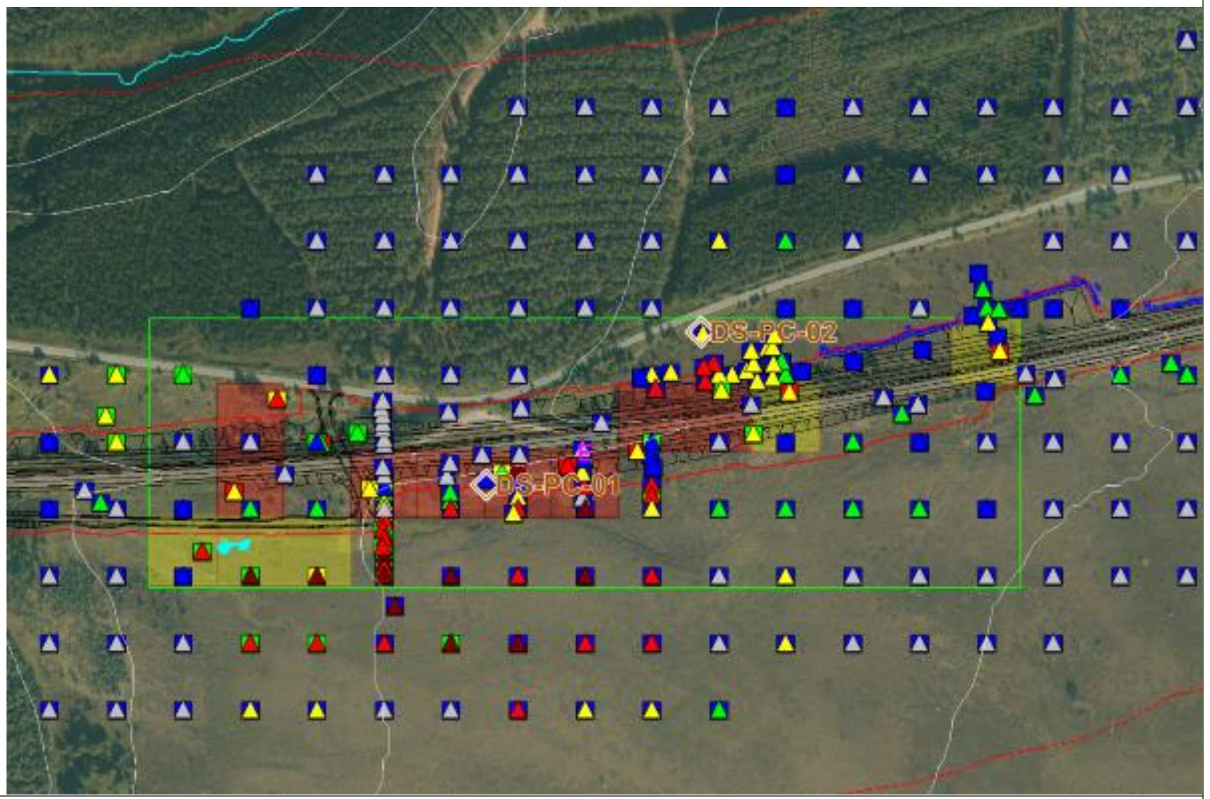
No instability was noted during site surveys.

Infrastructure Planned:

This area includes southbound widening of the mainline carriageway and the associated embankment, with a new underpass connected to a new access track adjacent and parallel to the northbound carriageway. Drainage ditches are proposed at the base of the embankment along the southbound carriageway.

It is proposed that peat will be crossed using piling techniques along both the northbound and southbound carriageway in this area.

Aerial Overview of Area E



FoS Assessment:

Eight high risk cells (FoS < 1) and four moderate risk cells was initially identified (FoS 1 to < 1.4), most of which are adjacent to the existing A9 carriageway and associated embankment slope, with peat depths of up to 5.4m recorded.

The factor of safety values for peat probes ranged from 0.29 to 1000* (*for 0.0 m depth record), for local grid cells the highest concern factor of safety value was 0.53, with a maximum individual peat depth record of 4.6m within this cell. The cells identified as of concern using FoS are primarily determined by the high slope angles associated with the existing embankment, often with deep peat recorded within the peatland at the base.

Recalculating FoS for the highest risk cell, using average bulk density values from DS-PC-01 and DS-PC-02 (1.30Mg/m3) results in a revised FoS value of 0.58.

Individual probe locations in this extensively surveyed area generally recorded FoS values >1.4, other than at a small number of deep peat locations, often in close proximity to the steep embankments, these outcomes may be due to accuracy of handheld GPS.

Peat is unlikely to move via peatslide from the *in situ* low-gradient location.

Specific Mitigation, Potential Scale and Receptor:

Section 7 details standard good practice measures, including careful drainage design and monitoring of slopes. Where infrastructure crosses peat, such as Area E, underlying peat is to be piled, in order to improve stability of road infrastructure and reduce the environmental impacts associated with peat removal. This area shall be noted on the Geotechnical Risk Register, with local presence of peat and potential slope stability issues recorded.

Downslope receptors include the Allt Ruaidh watercourse, with upslope receptors including the existing A9 and unclassified road.

Revised Risk:

This is considered a stable location at base of existing embankments.

Taking account of local characteristics, good practice and mitigation: Low Risk.

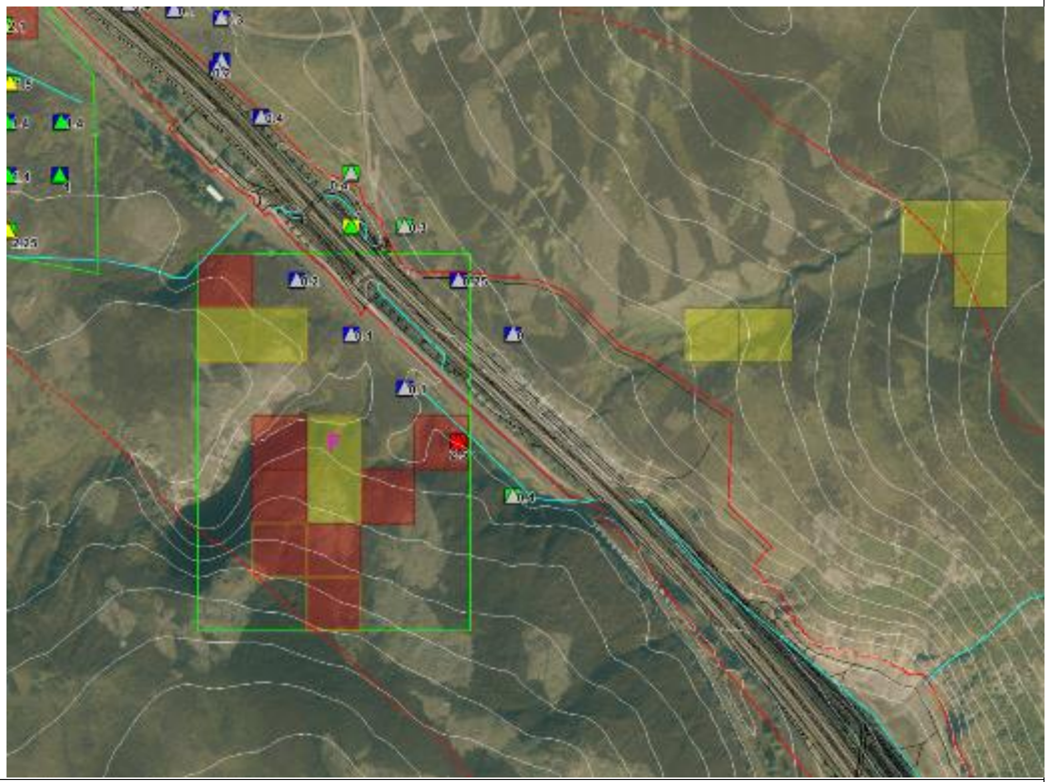
Photograph from NGR NH 864 238 facing east looking over Class 1 Priority Peatland, with the existing A9 carriageway to the north, and existing Black Mount Junction in the background.

Area F North of Slochd Mor NGR NH 835 254

Initial Likelihood - Probable; Consequence – Extremely High; Initial Risk - High

Revised Likelihood - Unlikely; Consequence – Extremely High ; Revised Risk - Low

Aerial Overview of Area F



Area Description:

This area features the lower slopes of Slochd Mor upslope of the existing A9 and Highland Mainline Railway. NVC surveys show a variety of habitats including blanket bog, dry heather and muirburn. Peat depths range from 0.1 to 2.5m, with an average depth of 0.63m. The deeper peat in this area is likely to be relatively confined and an isolated deposit, with the local peat depths generally less than 0.5m.

Steeper slopes are located in the centre of this area, with gradients of up to 40º. There are also artificial slopes associated with the existing A9 and Highland Mainline Railway.

No peat core was obtained from the area.

Infrastructure Planned:

This area features southbound mainline widening, and extensive slope engineering works adjacent to the southbound carriageway. Area F is separated from proposed works by the Highland Mainline Railway and the existing cycle track.

Due to the earthworks required within the Slochd area, blasting of rock is required at the Slochd Summit rock cut, upslope of the southbound carriageway within the wider valley. There is therefore some potential for blast-induced vibrations to trigger movement events including peatslides.

Photograph from NGR NH 836 254 facing west, looking along the hill slopes above the A9, with steep slopes and rock outcrops prominent.

FoS Assessment:

Eight cells of high risk (FoS < 1) and four moderate risk cell were initially identified (FoS 1 to < 1.4), which includes the area adjacent to the existing Highland Mainline Railway.

The factor of safety values for peat probes ranged from 0.29 to 19.0, for local grid cells the highest concern factor of safety value was 0.40, with the isolated 2.5m individual peat depth recorded within this cell, located at the base of the valley. The area was identified as of initial high risk using FoS, primarily due to deeper peat located on a moderate average slope. Adjacent to this area, peat depth records are generally very shallow, less than 0.5m. The deeper peat zone is uphill of both the Proposed Scheme and the Highland Mainline Railway.

Recalculating FoS for the highest risk cell, using average bulk density value from across the Proposed Scheme (1.22Mg/m³) results in the FoS value remaining low at 0.38. This cell is considered to be an isolated deep pocket of peat.

Specific Mitigation, Potential Scale and Receptor:

Section 7 details standard good practice measures. This area shall be noted on the Geotechnical Risk Register, with local presence of peat and potential slope stability issues recorded.

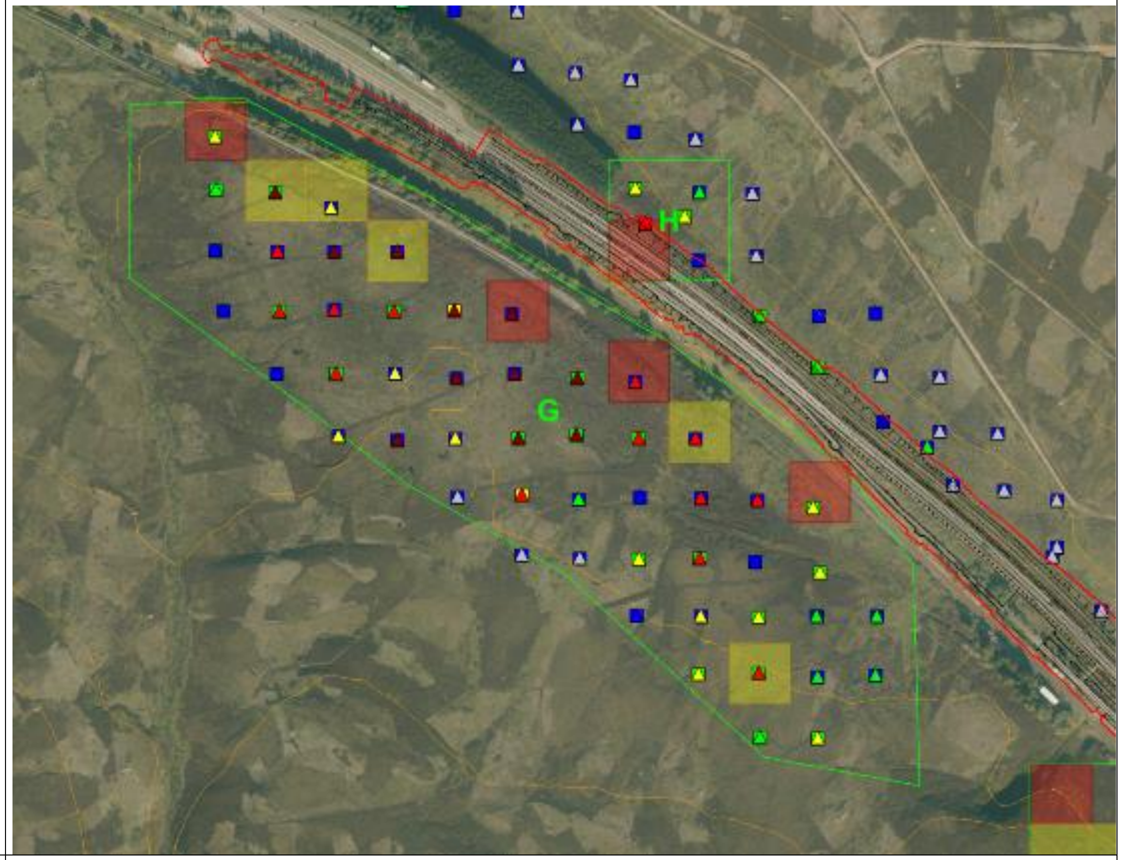
As blasting is anticipated at the Slochd Summit to the east of Area F, there is the potential for blast-induced vibration that could trigger peat instability. Further peat surveys should be conducted in this area to determine extent of deeper peat and this area should be monitored pre-blasting and during blasting for changes in stability, as per mitigation noted in Section 7. Feedback from monitoring may lead to slope stabilisation measures being adopted, given receptors downslope.

Downslope receptors include the existing A9, the Highland Mainline railway (located between Area F and the Proposed Scheme) and the Bogbain Burn watercourse immediately at the base of the slope.

Revised Risk:

This area is considered an isolated deep pocket of peat on an otherwise non-peat hillslope.

Taking account of local characteristics, good practice and mitigation: Low Risk.

Area G Carn a' Gharbh-choire NGR NH 829 259		
Initial Likelihood - Probable; Consequence – Extremely High; Initial Risk - High Revised Likelihood - Unlikely; Consequence – Extremely High; Revised Risk - Low **Area Description:** This area is upslope of the existing A9 carriageway with peat depths in this area ranging from 0.2 to 7.6m, with an average depth of 2.72m. This area is located within Class 1 Priority Peatland at the base of the slopes of Carn a' Garbh-choire, with NVC surveys recording dry heath, blanket bog and bare peat in this area. The Highland Mainline Railway is located in a cutting adjacent to Area G, located between Area G and the Proposed Scheme. Slope angles in this area are generally shallow (less than 6º) with the exception of the existing artificial Highland Mainline Railway cuttings which feature slope angles of up to 30º. **Infrastructure Planned:** Area G is upslope of mainline carriageway widening along the northbound carriageway, with associated drainage features planned adjacent to this area.	Aerial Overview of Area G	
FoS Assessment: Four cells of high risk (FoS < 1) and five cells of moderate risk (FoS 1 to < 1.4) were identified, with no Proposed Scheme infrastructure planned at these locations. The factor of safety values for peat probes ranged from 1.12 to 68.0, for local grid cells the highest concern factor of safety value was 0.54, with a maximum peat depth of 7.6m within this cell. Recalculating FoS for the highest risk cell, using the average bulk density values from across the Proposed Scheme (1.22Mg/m^3, respectively) results in the FoS value of 0.67. The area features both high and moderate risk cells due to the presence of deep peat and steep slope angles (due to cutting) within the same cells but not coincident. The infrastructure planned is located outside of Area G at the base of the valley and unlikely to cause impact. **Specific Mitigation, Potential Scale and Receptor:** Section 7 details standard good practice measures, including careful drainage design and monitoring of slopes. This area shall be noted on the Geotechnical Risk Register, with local presence of peat and potential slope stability issues recorded. Downslope receptors include an unnamed tributary of the Midlairgs Burn flowing north adjacent to the area, and the Bogbain burn flowing east at the south end of the area. The Highland Mainline Railway and the existing A9 both run parallel and adjacent to the north-eastern boundary of this area. Telegraph poles are also located parallel and adjacent to the railway line. **Revised Risk:** This is considered a stable location upslope of the Highland Mainline Railway. Taking account of local characteristics, good practice and mitigation: Low Risk.	NGR NH 828 260 facing east from the adjacent to the Highland Mainline Railway towards the slopes of Carn a'Gharbh-choire	

Area H Slochd Summit NGR NH 830 261

Initial Likelihood - Probable; Consequence – Extremely High; Initial Risk - High

Revised Likelihood - Unlikely; Consequence – Extremely High; Revised Risk - Low

Area Description:

This area is upslope of the existing A9 carriageway and features peat depths ranging from 0.5 to 3.1m, with an average peat depth of 1.66m. Peat is generally deeper in the south-west of the area towards the base of the slope above the existing A9.

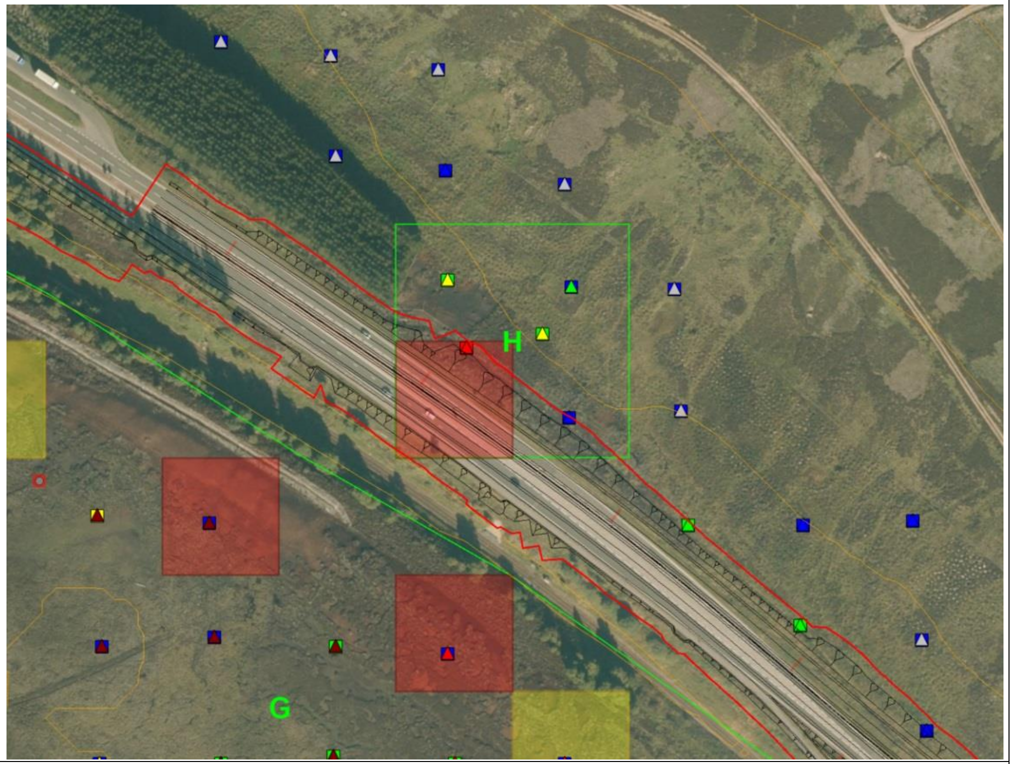
The area is generally of low gradient (less than 6°), with artificial steeper slopes located along the cutting of the existing A9.

Downstream receptors include the existing A9 mainline and the Midlairgs Burn located 420m west, and an existing estate access track located 70m upslope.

Infrastructure Planned:

This area features cuttings associated with southbound mainline widening and upgrade, immediately east of the existing dualled section, where it currently is a single lane carriageway in each direction.

Aerial Overview of Area H



FoS Assessment:

The factor of safety values for peat probes ranged from 0.78 to 7.3, for local grid cells the highest concern factor of safety value was 0.63, where the maximum peat depth of 3.1m was recorded.

Recalculating FoS for the highest risk cell, using average bulk density values from across the Proposed Scheme (1.22Mg/m^3) results in the FoS value being recalculated as 0.62.

This cell has steep slope angles associated with the existing A9 cutting and deep peat located upslope, however these are not coincident.

Specific Mitigation, Potential Scale and Receptor:

Section 7 details standard good practice measures, including careful drainage design and monitoring of slopes. Further peat surveys should be conducted in this area to determine the extent and characteristics of deeper peat adjacent to the cuttings anticipated for the Proposed Scheme.

This area shall be noted on the Geotechnical Risk Register, with local presence of peat and potential slope stability issues recorded.

Revised Risk:

This is considered a stable location but care should be taken to investigate local peat conditions in advance of cutting construction.

Taking account of local characteristics, good practice and mitigation: Low Risk.

NGR NH 830 260 facing north from the southbound A9 carriageway towards Slochd Summit

Annex B. Laboratory Results

TERRA TEK — SITE INVESTIGATION AND LABORATORY SERVICES

Site: A9 DUALLING: DALRADDY TO SLOCHD STAGE 2 PRELIMINARY GROUND INVESTIGATION

Client: Transport Scotland

Engineer: Atkins/Mouchel Joint Venture

Contract No **24464**

~ Indicates test not carried out

Exploratory Hole	Depth m	Sample Ref	Sample Type	Lab Sample ID	Non Engineering Sample Description	Moisture Content %	Atterberg limits: Liquid Limit %	Atterberg limits: Plastic Limit %	Atterberg limits: Plasticity Index	Atterberg limits: Percentage retained 425µm %	Atterberg limits: Atterberg Classification	Particle Density Mg/m³	Density: Bulk Mg/m³	Density: Dry Mg/m³	Total Stress: Shear Strength kPa	Total Stress: Apparent Cohesion C kPa	Total Stress: Angle of Shearing Resistance Phi	Other Tests
BHDS2086	14.20		B	329102	Brown clayey gravelly very silty SAND. Gravel is fine to medium with some siltstone.													PSD
BHDS2087	1.00		B	329103	Dark brown slightly clayey silty very gravelly SAND. Gravel is fine to coarse.													PSD, 4.5kg Compaction, MCV Cal.
BHDS2087	5.10		B	329105	Brown slightly clayey silty very sandy fine to coarse GRAVEL.													PSD, MCV Cal.
DS-PC-01	0.00-0.00		B	418783	Dark brown PEAT	174							1.23	0.45				
DS-PC-02	0.00-0.00		B	418784	Dark brown PEAT	831							1.24	0.13				
Notes	Opinions and interpretations are outside the scope of UKAS accreditation				UKAS Accredited Test Y/N	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	See individual report sheets

Test details are given on the 'Notes on Laboratory Procedures' sheet

Originator	Approved
LA	L.A. 05/07/2017

SUMMARY OF GEOTECHNICAL TESTS

TTK **Table F1**

Sheet 63 of 111

Classification Summary - Final.xls
Version 005 - 29/03/2017

Lab Project No C6002-FINAL : 05/07/2017 14:03:22
Unit 2 Springfield Road, Chesham, Bucks, HP51PW

TERRA TEK SITE INVESTIGATION AND LABORATORY SERVICES

Site	A9 DUALLING: DALRADDY TO SLOCHD STAGE 2 PRELIMINARY GROUND INVESTIGATION	Contract No	24464
Client	Transport Scotland	~ Indicates test not carried out	
Engineer	Atkins/Mouchel Joint Venture		

Sample Identification							Atterberg limits						Density		Total Stress			
Exploratory Hole	Depth m	Sample Ref	Sample Type	Lab Sample ID	Non Engineering Sample Description	Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Percentage retained 425µm %	Atterberg Classification	Particle Density Mg/m³	Bulk Mg/m³	Dry Mg/m³	Shear Strength kPa	Apparent Cohesion C kPa	Angle of Shearing Resistance Phi	Other Tests
DS-PC-02	1.00		B	418786	Dark brown PEAT	924							1.28	0.13				
DS-PC-02	2.00		B	418788	Dark brown PEAT	808							1.43	0.16				
DS-PS-02	0.50		B	418785	Dark brown PEAT	1014							1.16	0.10				
DS-PS-02	1.50		B	418787	Dark brown PEAT	700							1.50	0.19				
DS-PS-03	0.00-0.00		B	418789	Dark brown PEAT	353							0.38	0.08				
Notes	Opinions and interpretations are outside the scope of UKAS accreditation				UKAS Accredited Test Y/N	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	See individual report sheets

Test details are given on the 'Notes on Laboratory Procedures' sheet

Originator	Approved
LA	L.A. 05/07/2017

SUMMARY OF GEOTECHNICAL TESTS

Table F1

Sheet 64 of 111

Classification Summary - Final.xls
Version 005 - 29/03/2017

Lab Project No C6002-FINAL : 05/07/2017 14:03:24
Unit 2 Springfield Road, Chesham, Bucks, HP51PW

TERRA TEK
SITE INVESTIGATION AND LABORATORY SERVICES

Site	A9 DUALLING: DALRADDY TO SLOCHD STAGE 2 PRELIMINARY GROUND INVESTIGATION	Contract No	24464
Client	Transport Scotland		~ Indicates test not carried out
Engineer	Atkins/Mouchel Joint Venture		

Sample Identification							Atterberg limits						Density		Total Stress			
Exploratory Hole	Depth m	Sample Ref	Sample Type	Lab Sample ID	Non Engineering Sample Description	Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Percentage retained 425µm %	Atterberg Classification	Particle Density Mg/m³	Bulk Mg/m³	Dry Mg/m³	Shear Strength kPa	Apparent Cohesion C kPa	Angle of Shearing Resistance Phi	Other Tests
DS-PS-04	0.00-0.00		B	418791	Dark brown PEAT	579							1.17	0.17				
DS-PS-04	0.50		B	418792	Dark brown PEAT	717							1.42	0.17				
DS-PS-04	1.00		B	418793	Dark brown PEAT	748							1.35	0.16				
DS-PS-04	1.50		B	418794	Dark brown PEAT	709							1.30	0.16				
HPDS2072	0.50		B	418795	Brown fine to coarse GRAVEL and one cobble with much silty clayey sand.													PSD
Notes	Opinions and interpretations are outside the scope of UKAS accreditation				UKAS Accredited Test Y/N	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	See individual report sheets

Test details are given on the 'Notes on Laboratory Procedures' sheet

Originator	Approved
LA	L.A. 05/07/2017

SUMMARY OF GEOTECHNICAL TESTS

Table F1

Sheet 65 of 111

Classification Summary - Final.xls
Version 005 - 29/03/2017

Lab Project No C6002-FINAL : 05/07/2017 14:03:26
Unit 2 Springfield Road, Chesham, Bucks, HP5 1PW

Extended Von Post Classification Table

Fine Fibres (F)	
Symbol	**Content of fibres and stems smaller than 1mm in diameter or width**
F0	None
F1	Low content
F2	Moderate content
F3	High content

Coarse Fibres (R)	
Symbol	**Content of fibres, stems and rootlets greater than 1mm in diameter or width**
R0	None
R1	Low content
R2	Moderate content
R3	High content

Wood Remnants (W)	
Symbol	**Wood remnants content**
W0	None
W1	Low content
W2	Moderate content
W3	High content

Humification (H)			
Symbol	**Decomposition**	**Plant Structure**	**Content of amorphous material**
H1	none	Easily identified	None
H2	Insignificant	Easily identified	None
H3	Very slight	Still identifiable	Slight
H4	Slight	Not easily identified	Some
H5	Moderate	Recognisable but vague	Considerable
H6	Moderately strong	Indistinct	Considerable
H7	Strong	Fairly recognisable	High
H8	Very strong	Very indistinct	High
H9	Nearly complete	Almost recognisable	Complete
H10	Complete	Not dispernable	Complete

Water Content (B)		
Symbol	**Estimated water content**	**Actual water content (suggested)**
B1	Dry peat	0%
B2	Low moisture content	0-500%
B3	Medium moisture content	500-1000%
B4	High moisture content	1000-2000%
B5	Very high moisture content	>2000%

Troels-Smith Scheme Classification

Components		
Name	**Code**	**Description**
Grana minora	Gmin	Fine medium and coarse sand (0.06-2.0mm)
Grana majora	Gmaj	Fine, medium and coarse gravel (2-60mm)
Argilla steatodes	As	Clay (<0.002mm)
Argilla granosa	Ag	Silt (0.06-0.002mm)
Turfa herbacea	Th	Roots, stems and rhi-zomes of herbaceous plants
Turfa bryophytica	Tb	The protonem, rhizods, stems, leaves etc. of mosses
Turfa lignosa	Tl	Roots and stumps of woody plants and their trunks, branches and twigs
Detritus lignosus	Dl	Detrital fragments of wood and bark >2mm
Detritus herbosus	Dh	Fragments of stems and leaves of herbaceous plants >2mm
Detritus granosus	Dg	Woody and herbaceous humified plant remains 0.1-2mm that cannot be separated
Limus detrituosus	Ld	Fine detritus organic mud (particles <0.1mm)
Limus ferrugineus	Lf	Mineral and/or organic iron oxide
Substantia humosa	Sh	Humified organics beyond identification
Anthrax	Anth	Charcoal
Stirpes	Stirp	Tree stump
Sratum confusum	Sc	Disturbed stratum

Quantification of components	
Code	**Component Proportion**
+	Minor component (<25%)
1	25%
2	50%
3	75%
4	100%

Degree of humicity (denoted as superscript)	
Humicity	**Description**
0	Plant structure fresh. Yields colourless water on squeezing
1	Plant structure well-preserved. Squeezing yields dark coloured water. 25% deposited squeezes through fingers
2	Plant structure partially decayed though distinct. Squeezing yields 50% deposit through fingers.
3	Plant structure decayed and indistinct. Squeezing yields 75% deposit through fingers
4	Plant structure barely discernible or absent. 100% passes through fingers on squeezing

Physical Properties			
Name	**Code**	**Descriptor**	**Description**
Nigror	nig	Degree of darkness	
		0	The shade of quartz sand
		1	The shade of calcareous clay
		2	The shade grey clay
		3	The shade of partly decomposed peat
		4	The shade of quartz black, fully decomposed peat
Name	**Code**	**Descriptor**	**Description**
Stratification	stf	Degree of stratification	
		0	Complete heterogeneity
		1	Intermediate between 0 and 4
		2	Intermediate between 0 and 4
		3	Intermediate between 0 and 4
		4	Very thin horizontal layers
Name	**Code**	**Descriptor**	**Description**
Elasticitas	elas	Degree of elasticity	
		0	Totally inelastic, plastic
		1	Intermediate between 0 and 4
		2	Intermediate between 0 and 4
		3	Intermediate between 0 and 4
		4	Elastic
Name	**Code**	**Descriptor**	**Description**
Siccitas	sicc	Degree of dryness	
		0	Clean water
		1	Thoroughly saturated, very wet
		2	Saturated
		3	Not saturated
		4	Air dry
Name	**Code**	**Descriptor**	**Description**
Limes superior	lim	Boundary	
		0	>1cm boundary area - *diffusus*
		1	<1cm and >2mm - *conspicuus*
		2	<2mm and >1mm - *manifestus*
		3	<1mm and >0.5mm - *acutus*
		4	<0.5mm

Annex C. Peat Core Photos

Figure 7. Peat Core DS-PC-01 taken at depth 0 – 0.5m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 8. Peat Core DS-PC-02 taken at depth 0 – 0.5m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 9. Peat core DS-PC-02 taken at depth 0.5 – 1.0m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 10. Peat Core DS-PC-02 taken at depth 1.0 – 1.5m

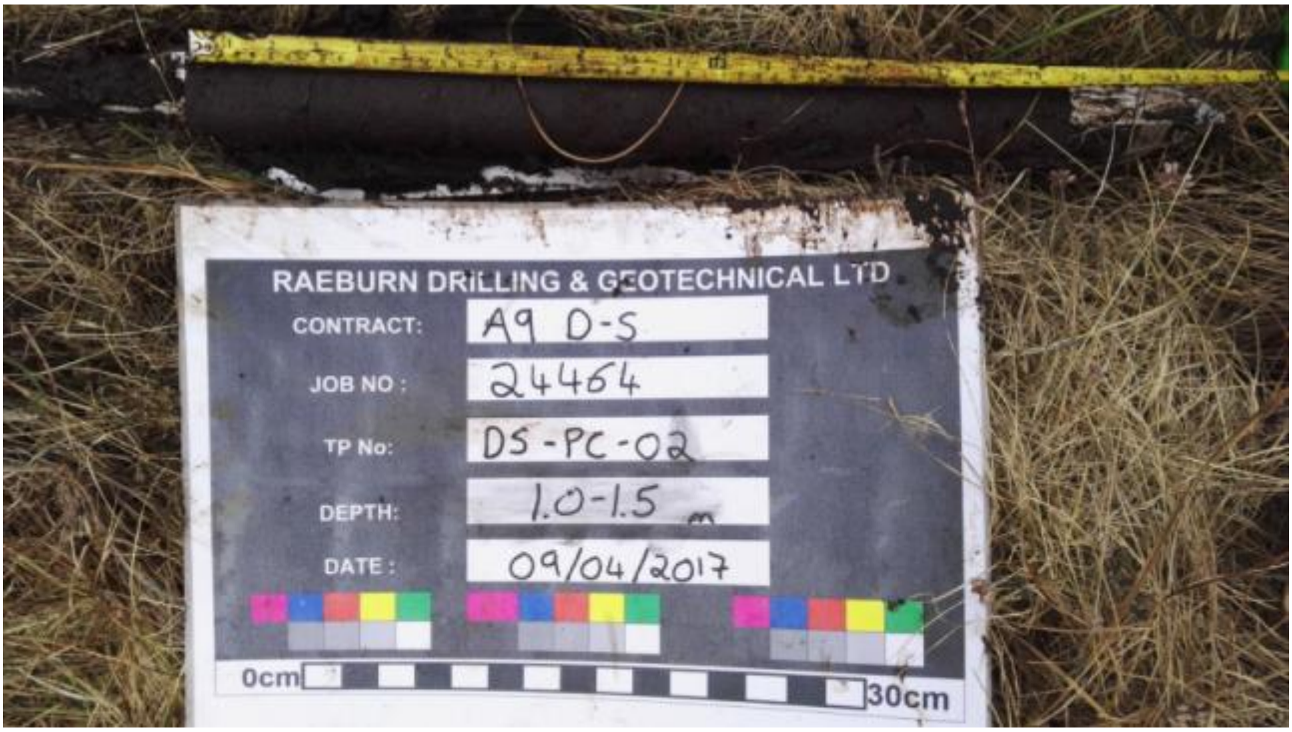


Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 11. Peat Core DS-PC-02 taken at depth 1.5 – 2.0m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 12. Peat Core DS-PC-02 taken at depth 2.0 – 2.4m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 13. Peat Core DS-PC-03 taken at depth 0 – 0.4m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 14. Peat Core DS-PC-04 taken at depth 0 – 0.5m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 15. Peat Core DS-PC-04 taken at depth 0.5 – 1.0m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 16. Peat Core DS-PC-04 taken at depth 1.0 – 1.5m

Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).

Figure 17. Peat Core DS-PC-04 taken at depth 1.5 – 1.85m

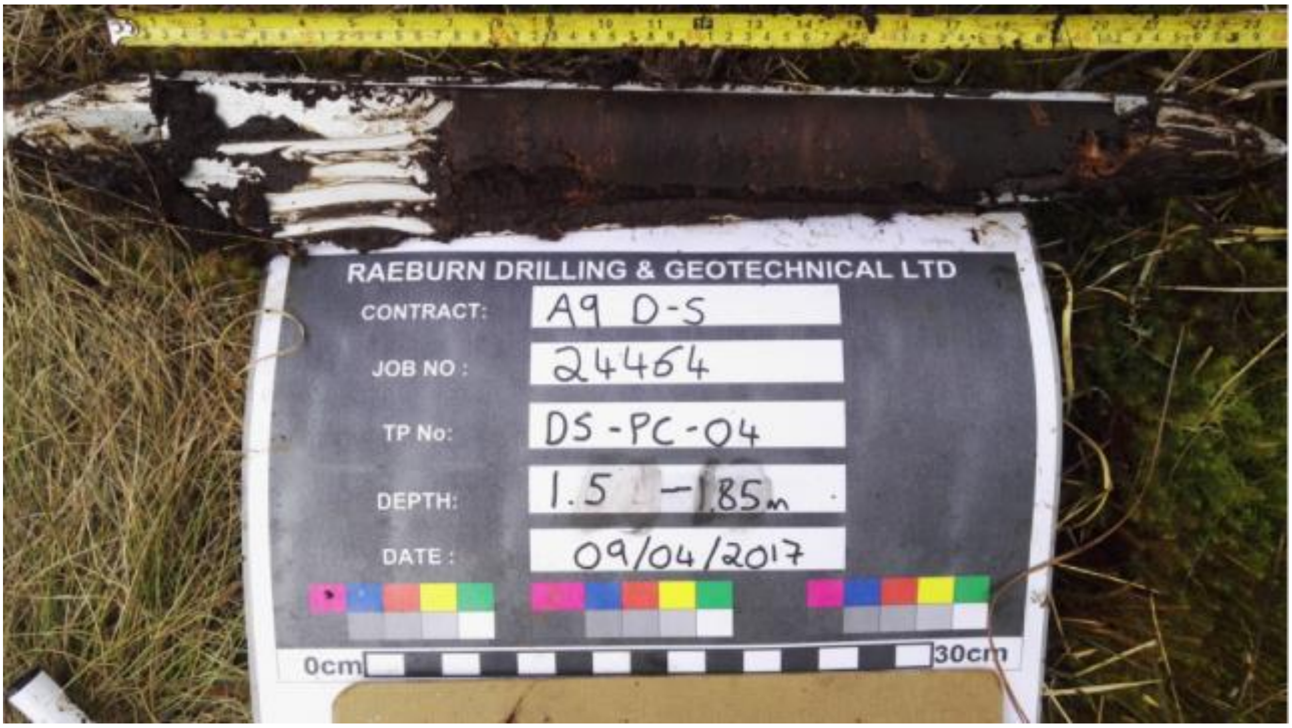


Figure Source: A9 Dualling: Dalraddy to Slochd Stage 2 Preliminary Ground Investigation draft report (2017).