Technical Appendix 9.1: Watercourse Crossing Report

Ørsted

Revised Larbrax Wind Farm EIA Report

Appendix 9.1: Watercourse Crossing Report

December 2024

Kaya Consulting Limited
Stanhope House, 12 Stanhope Place
Edinburgh, EH12 5HH
Tel: 0131 466 1458, Web: www.kayaconsulting.co.uk

Kaya Consulting Limited
Stanhope House, 12 Stanhope Place
Edinburgh, EH12 5HH
Tel: 0131 466 1458, Web: www.kayaconsulting.co.uk

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1 Introduction

This appendix contains the data on proposed engineering activities in the water environment and forms part of the EIA Report for the proposed Revised Larbrax Wind Farm (Proposed Development). This appendix should be read in conjunction with **Chapter 9: Hydrology, Hydrogeology, Geology and Peat** of the Revised Larbrax Wind Farm EIA Report. The locations of the proposed watercourse crossings and 50m buffers from watercourses are illustrated in **Figure 9.2** of the EIA Report.

The Site covers an area of approximately 495ha and is located solely within the administrative boundary of Dumfries and Galloway Council, approximately 9km west of the town of Stranraer.

There are a number of small, existing tracks but the main track runs north to south through the centre of the Site, forking into two at Loch More. The Proposed Development will upgrade a section of this existing track and establish new tracks leading to each turbine. The new access track will run eastwards, skirting the edges of Larbrax Moor and crossing the Green Burn, before reaching the B738.

Extensive hydrology site walkovers were conducted in July and August in 2023, and May 2024 as part of the peat and hydrology surveys of the site. Watercourses in the vicinity of the Proposed Development were recorded during the hydrology walkover and used to feed into iterations of design layout constraints.

New watercourse crossings were avoided as much as possible in the design and existing tracks were utilised. **Table 1** presents data on the existing and proposed watercourse crossings that will be utilised for the Proposed Development. The locations of the existing and proposed watercourse crossings are illustrated in **Figure 9.2** in the EIA Report. New crossings are labelled NC1-4 and existing crossings to be upgraded are labelled UC1-4.

The Scottish Environment Protection Agency (SEPA) recommend a buffer of 50m around each waterbody/watercourse in their windfarm scoping guidance. This was achieved for most of the Proposed Development, with the exception of parts of the existing track, watercourse crossings and three locations along proposed new tracks (labelled A-C). The 50m buffer from watercourses is shown in **Figure 9.2** of the EIA Report. Areas where the 50m buffer could not be achieved (Areas A-C) are described and assessed in **Table 2**.

2 Watercourse Crossings and Buffers

2.1 Watercourse Crossings

The watercourse crossings of the proposed and existing access tracks have been identified from a combination of Ordnance Survey mapping, Bing aerial imagery and hydrology field surveys. Data for each crossing is provided in **Table 1** below. The Proposed Development will use four existing crossings and proposes four new crossings. The existing track and watercourse crossings will be upgraded and widened. Culvert/bridge dimensions and watercourse descriptions at the existing crossings are provided in **Table 1**, as is a representative photograph.

There is a water flow pathway with boggy ground (crossing NC1) in the vicinity of T2 that will require to be crossed by new wind farm tracks. Two new crossings are also required along a section of new track immediately to the south of the fishing pond: crossing NC2 is a flow outlet from the pond; crossing NC3 is a shallow drain. The fourth new crossing spans the Green Burn as part of the new track (crossing NC4). The track also runs through approximately 50m of the Green Burn floodplain to the west of the river. A flood risk assessment (**Appendix 9.4**) has been carried out to assess the flood risk at crossing NC4 given its proximity to the B738 road.

Catchment areas upstream of each new watercourse crossing were calculated in GIS software based on LiDAR Phase 3 DTM topographic data (where available) or OS mapping, supplemented by field observations. The catchment areas upstream of the track crossings NC1, NC2, NC3 and NC4 are approximately, 0.007km^2, 0.037km^2, 0.002km^2 and 2.99km^2, respectively, with the largest catchment being upstream of the Green Burn crossing (crossing NC4). All new crossings are proposed to be bottomless culvert (see **Appendix 9.4** for further details of the Green Burn crossing).

Engineering activities on minor watercourses do not normally require authorisation under the SEPA CAR Regulations[1]. SEPA defines minor watercourses as those not shown on the 1:50,000 scale Ordnance Survey maps. Of the four new crossings proposed, three are on minor watercourses and therefore fall under General Binding Rules (GBR) 6 and GBR 9 (see SEPA (2024) for full details of the relevant GBRs). These crossings will not require registration or a licence under CAR; however, the work will follow general good construction practice and GBR 6 and GBR 9.

One of the proposed new crossings (NC4) will require a simple licence under CAR and will require specific mitigation measures.

2.2 Watercourse Buffers

The access track crosses into the 50m buffer of a drain depicted on the 1:25,000 OS map in the east of the Site (B). The drain could not be accessed due the *Rhododendron* scrub. From the map, the drain appears to emerge slightly from the scrub, however when visiting this area, there was no indication of a channel or wet ground, despite being on a slope. It therefore seems unlikely that if there is a drain, it would extend this far north. The drain is also upslope of the access track so the risk of sediment/pollution entering the water environment during construction is low.

[1] *SEPA (2024) Water Environment (Controlled Activities) (Scotland) Regulations 2011 – A Practical Guide, Version 9.4 July 2024*

The locations where a buffer could not be achieved are detailed in **Table 2**, along with photographs and details of potential effects and additional mitigation required.

Table 1: Watercourse Crossing Details

ID	Name	Easting	Northing	Field Notes / Comments	Width (m)	Bed Sediment	Bank Erosion (yes/no)	Natural Channel (yes/no)	Crossing Type	Existing Culvert/ Bridge Dimensions	Catchment (km^2)	Minor Watercourse (yes/no)[2]	CAR Authorisation Required (yes/no)	Photograph
NC1	Unnamed watercourse	196485	562207	No channel but likely a flow pathway; boggy despite dry day	-	-	-	-	New crossing, Bottomless culvert	N/A	0.007	Yes	No	
NC2	Unnamed drain	196785	562180	Outflow from pond. No water	1	Soil	N	N	New crossing, Bottomless culvert	N/A	0.037	Yes	No	

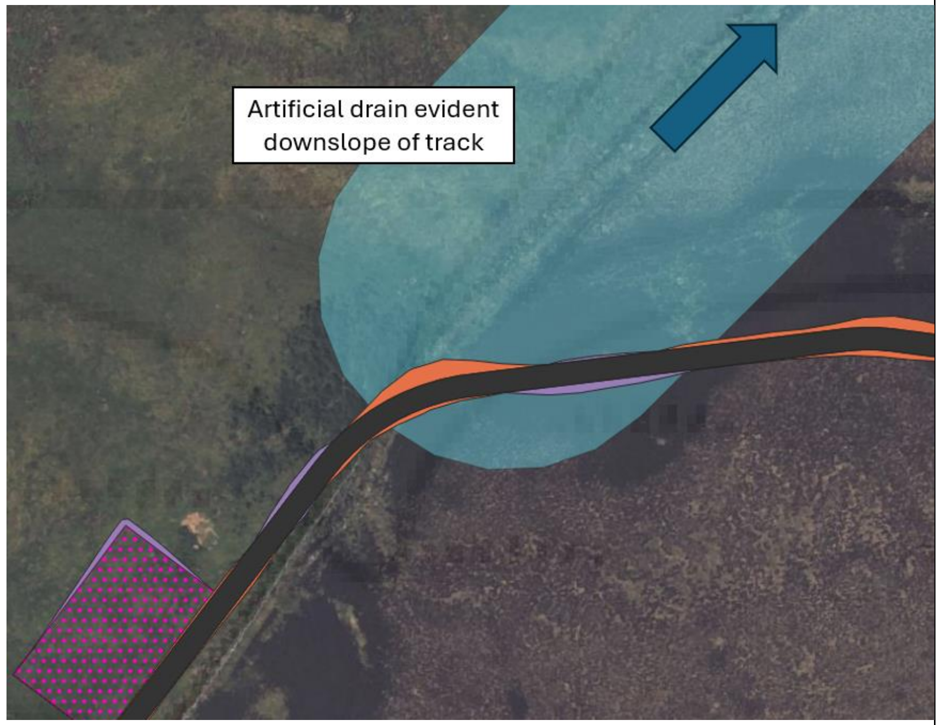
[2] *A minor watercourse is defined by SEPA as one that is not shown on 1:50,000 scale Ordnance Survey maps. SEPA do not normally require an authorisation for engineering activities on minor watercourses with the exception of culverting for land-gain, dredging and permanent diversions/realignments.*

ID	Name	Easting	Northing	Field Notes / Comments	Width (m)	Bed Sediment	Bank Erosion (yes/no)	Natural Channel (yes/no)	Crossing Type	Existing Culvert/ Bridge Dimensions	Catchment (km^2)	Minor Watercourse (yes/no)²	CAR Authorisation Required (yes/no)	Photograph
NC3	Unnamed drain	196899	562097	Channel not well defined; no water present	0.4	None – grass in drain	N	N	New crossing, Bottomless Culvert	N/A	0.002	Yes	No	
NC4	Green Burn	197959	561926	Flows alongside main road, variable widths and bank heights	2.2	Cobble and Gravel	Y	Y	New crossing; Bottomless Culvert (see **Appendix 9.4 and Figure 4.11b**)	N/A	2.99	No	Yes (Simple License)	

ID	Name	Easting	Northing	Field Notes / Comments	Width (m)	Bed Sediment	Bank Erosion (yes/no)	Natural Channel (yes/no)	Crossing Type	Existing Culvert/ Bridge Dimensions	Catchment (km²)	Minor Watercourse (yes/no)²	CAR Authorisation Required (yes/no)	Photograph
UC1	Unnamed watercourse	196450	562297	Probably ephemeral	0.75	Gravel	Y, from cattle	N	Upgrade to existing track, Bottomless Culvert	N, ford	0.018	Yes	No	
UC2	Unnamed watercourse	196609	562252	Blocked culvert so effectively a ford	0.6	Gravel	Y	N	Upgrade to existing track, Bottomless Culvert	-	0.029	Yes	No	

ID	Name	Easting	Northing	Field Notes / Comments	Width (m)	Bed Sediment	Bank Erosion (yes/no)	Natural Channel (yes/no)	Crossing Type	Existing Culvert/ Bridge Dimensions	Catchment (km^2)	Minor Watercourse (yes/no)[2]	CAR Authorisation Required (yes/no)	Photograph
UC3	Unnamed drain	197074	561846	Flows though culvert and continues underground	1.5	Clay/silt	Y	N	Upgrade to existing track, Bottomless Culvert	200mm diameter	0.019	Yes	No	
UC4	Unnamed drain	197140	561716	-	0.6	Clay/silt	N	N	Upgrade to existing track, Bottomless Culvert	320mm diameter	0.027	Yes	No	

Table 2: Watercourses where a 50m buffer to infrastructure was encroached

ID	Name	Width of watercourse (top of bank)	Watercourse Description	Infrastructure and Ancillary Works Description	Temporary or Permanent	Width of buffer strip achieved	Water feature upgradient or downgradient of Proposed Development	Potential Effect/ Comment	Additional Mitigation	Photograph
A	Unnamed drain	No channel at encroachment location. Strip of boggy vegetation measures ~3.5m. Becomes artificial drain further downslope.	No distinct channel – boggy area with vegetation.	New access track	Permanent	22 m	Downgradient	Flow path analysis indicates that surface water runoff paths are from the proposed track towards the drain. At the closest point, the proposed track is ~4m higher than the drain. There is a risk of sediment/pollution entering the water environment during construction. Embedded mitigation (i.e. construction SuDS and permanent drainage) will be included in the design. Surface water runoff will be treated and attenuated. Buffer width is considered adequate for the size of water feature.	Additional mitigation (e.g. silt fences, settlement ponds) will be installed during construction to reduce the risk of sediment/silt run-off during construction.	
B	Unnamed drain (unconfirmed)	Unknown	The drain is depicted on the 1:25,000 OS map however it could not be accessed due to *Rhododendron* scrub. There is no indication of a channel, flow pathway or water at the closest point downgradient of the drain.	New access track	Permanent	~5 m from the drain endpoint depicted on the OS map. However, the drain is likely to begin further south due to the underlying topography (if present at all).	Upgradient	The presence of the drain could not be confirmed. However, given that it is upgradient of the new track, there is low risk that sediment/pollution will enter into the drain. The mapped drain sits 4 m higher than the proposed access track	Further investigation to locate this drain will be carried out prior to construction. If it is present, additional mitigation will be installed during construction to reduce the risk of sediment/silt run-off during construction, if required. -	

ID	Name	Width of watercourse (top of bank)	Watercourse Description	Infrastructure and Ancillary Works Description	Temporary or Permanent	Width of buffer strip achieved	Water feature upgradient or downgradient of Proposed Development	Potential Effect/ Comment	Additional Mitigation	Photograph
C	Loch More	N/A	A small loch in the centre of the Site	Upgrades to existing access track	Permanent	24 m	Upgradient	The loch sits ~2-3 m higher and upgradient of the track so there is unlikely to be a direct effect resulting from the construction and operation of the track.	No additional mitigation needed	

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1 Introduction

Kaya Consulting Limited was commissioned by Ørsted, through LUC, to undertake a peat depth survey for the Revised Larbrax Wind Farm (the Proposed Development) in Dumfries and Galloway. The proposed site (the Site) is located on Galdenoch Moor approximately 9km to the west of the town of Stranraer.

The Site covers an area of approximately 345 hectares (ha) and comprises mixed heath and bog, shelterbelt woodland, and agricultural/pastoral fields. The survey area within the Site for the peat depth survey covers ~188 ha in area. **Figure 2** (see end of document) shows the site boundary and extent of the peat survey area.

The terrain across the Site is consistent, with much of the land sloping west towards the North Channel.

This report covers the methodology and output of the Phase 1 (preliminary, low-density) and the Phase 2 (detailed, high-density) peat surveys undertaken at the Site. The purpose of the surveys was to establish an understanding of the peat depths at the Site to help optimise site design and layout.

The Phase 1 peat depth survey comprised surveying a 100m grid across a large area of the proposed site for infrastructure within the Site boundary. The results of the Phase 1 peat depth survey helped inform the initial layout of the Proposed Development. The Phase 1 peat depth survey carried out in 2023 by Kaya Consulting and was supplemented by previously collected peat depth data completed in 2013 by AECOM to inform the EIA for the Consented Larbrax Wind Farm. The results from both studies are compiled into a singular dataset and presented in this report. The split between the two surveys is shown in **Figure 3**.

The Phase 2 survey used a 10m grid to cover most areas in detail where there will be infrastructure associated with the Proposed Development. A 20m grid was used for the proposed locations of Turbines 3 and 4, as results from the Phase 1 survey indicated that there was no peat (probe depths >0.5m) in these locations. The survey extent includes the footprint of the turbine foundations, working areas, and construction compounds. Additional survey, at 50m intervals with offsets, was undertaken along proposed access tracks.

This appendix should be read in conjunction with **Chapter 9: Hydrology, Hydrogeology, Geology and Peat** of the Revised Larbrax Wind Farm EIA Report.

2 Methodology

2.1 Desk-based Initial Assessment

The NatureScot (2016) Carbon and Peatland Map was consulted prior to the Phase 1 peat survey. The map contains information on the likely peatland classes present within the survey area. The Carbon and Peatland map was developed to be used as "*a high-level planning tool to promote consistency and clarity in the preparation of spatial frameworks by planning authorities*".

Within the Carbon and Peatland Map, Class 1 and Class 2 peatlands are identified as areas of "*nationally important carbon-rich soils, deep peat and priority peatland habitat*". Class 1 peatlands are also "*likely to be of high conservation value*" and Class 2 "*of potentially high conservation value and restoration potential*".

The Carbon and Peatland Map for the Site is shown in **Figure 2** (see end of document). The peatland mapping indicates that there are areas of Class 1, Class 3, Class 4, and Class 5 peatland within the Site. The Class 1 peatland is predominantly concentrated on Galdenoch Moor and Larbrax Moor in the eastern part of the site. The relevant Class descriptions are below:

- Class 1 – Nationally important carbon-rich soils, deep peat and priority peatland habitat. Areas likely to be of high conservation value.
- Class 3 – Dominant vegetation cover is not priority peatland habitat but is associated with wet and acidic type. Occasional peatland habitats can be found. Most soils are carbon-rich soils, with some areas of deep peat.
- Class 4 – Area unlikely to be associated with peatland habitat or wet and acidic type. Area unlikely to include carbon-rich soils.
- Class 5 – Soil information takes precedence over vegetation data. No peatland habitat recorded. May also include areas of bare soil. Soils are carbon-rich and deep peat.

The majority of the northern, southern and western parts of the Site are classed as non-soil, with no peat indicated.

The results of the desk-based assessment indicated that peat was likely to be present within the boundaries of the Site.

2.2 Survey Methodology

The survey methodology follows current guidance in Scotland (Scottish Government, Scottish Natural Heritage, SEPA (2017) Peatland Survey. Guidance on Developments on Peatland, on-line version only).

The field survey was undertaken by a hydrologist with the appropriate experience of assessing hydrology, hydrogeology, geology, soil, and peat in for onshore windfarms.

2.2.1 Survey Dates

An initial Phase 1 peat depth survey was undertaken in 2013 by AECOM, covering part of the Site.

The following surveys were undertaken by Kaya Consulting:

- Phase 1 survey - 26th to 27th July 2023 (inclusive) - the weather conditions were mixed, with dry, sunny weather on the 26th morning, followed by a prolonged period of rainfall throughout the afternoon and evening. The 27th followed with sun and no rain.
- Phase 2 survey - 1st to 2nd May 2024 (inclusive) and 16th May 2024 - the weather conditions were warm and sunny, with intermittent rain showers on the 16th. Peat depth and core data were unaffected by the conditions.
- Additional Phase 2 survey to inform alternative routes for the access track - 30th May 2024 - the weather was sunny and warm.

2.2.2 Phase 1 Peat Survey

The following methods were employed for the Phase 1 peat survey:

- The survey area was sampled using a 100m systematic grid. The survey points probed by Kaya Consulting were aligned to best fit the Ordnance Survey (OS) British National Grid. The grid was generated using QGIS software. It should be noted that the AECOM peat depth data collected in 2013 was not aligned with the OS British National Grid.
- A total of 197 sampling points were surveyed across the surveys undertaken by AECOM in 2013 and Kaya Consulting in 2023. The split between the surveys is shown in **Figure 3**.

It should be noted that steep terrain and livestock limited access to certain locations on the 100m grid within the survey extent. Where a probe location could not be accessed no data was collected but observations were made. The inaccessible locations are concentrated along the western edge of the Site where the land use and adjacent peat depths indicated that no peat was present.

2.2.3 Phase 2 Peat Survey

The following methods were employed for the Phase 2 peat survey:

- Peat probing was undertaken on a 10m grid around most areas of proposed infrastructure, including the Turbine 1 and 2 footprints, borrow pit, construction compound and substation.
- A 20m grid was sampled across the footprints of Turbines 3 and 4, as the Phase 1 survey indicated no peat in these areas.
- The proposed access track route centreline was probed at 50m intervals, with 10m offsets probed on either side of the track. Additional 25m and 50m offsets were also probed along the track leading to Turbine 1 as well as a large section along the proposed track running east towards the main road (B738).
- A small area along the access track leading to the main road was also probed in an approximate 10m grid to inform the location of the track junction and alternative routing.
- A total of 1,161 sampling points were surveyed. The extent of the Phase 2 peat survey is illustrated in **Figure 3**.
- The peat survey was carried out using an extendable fibreglass utility probe capable of sampling to 5m.
- Peat cores were taken using a gouge auger (20mm diameter) to confirm the existence and composition of peat. Cores were taken at proposed turbine locations and other infrastructure. The locations of the cores are shown in **Figure 3** and **Figure 4**.

It should be noted that ~15 points were inaccessible along the section of track layout first proposed due to dense rhododendron scrub and deep peat (**Photo 6** and **Figure 2**). The peat depth data that exists is considered sufficient to inform the assessment, although further probing in this area prior to construction is recommended.

3 Peat Survey Results

3.1 Peat Depths

The Scottish Government guidance document on peat landslide hazard and risk assessment (Scottish Government, 2017) defines peat as a soil greater than 50cm in depth, with an organic matter content of more than 60%. Soils of less than 50cm depth are classified as organo-mineral soils, with soils less than 25cm not classified as peat. This is further evidenced by JNCC (2011), SNH (Bruneau, et al, 2014) and the James Hutton Institute (2019).

Within the surveyed area at the Site:

- 69.1% of probes were recorded as having a depth of less than 25cm. These probes are not classified as peat.
- 16.9% of probes were recorded as having a peat depth of between 25-50cm. These probes are classified as organo-mineral soils and not formally considered to be peat.
- 8.5% of probes were recorded as having a peat depth of between 50-100cm.
- 5.4% of the probes were recorded as having a peat depth of over 100cm. The maximum probed depth was 540cm.

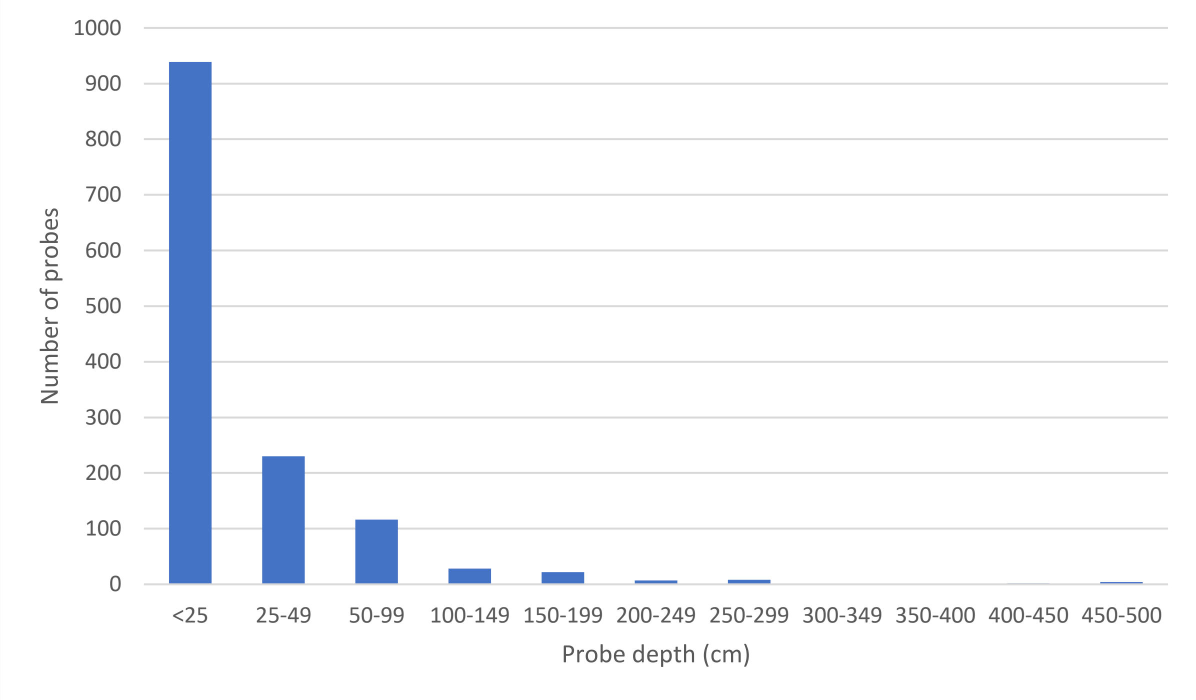
A summary of the probe depth data is presented in **Table 1** and **Figure 1**.

Figure 2 and **Figure 3** at the end of the report shows the extent of the peat survey undertaken. **Figure 4** provides the spatial distribution of peat depths recorded within the surveyed area.

Table 1: Peat Depth Summary

Probe Depth Range (cm)	Number of Probes	Percentage of Total Probes
< 25	939	69.1%
25 – 49	230	16.9%
50 – 99	116	8.5%
100 – 199	50	3.7%
> 200	23	1.7%
Total	**1,358**	**100%**

Figure 1: A histogram showing the peat depth distribution across the Phase 1 and Phase 2 peat surveys



3.2 Peat Cores

Table 2 shows the information collected from the peat coring. A total of 9 cores were taken; the locations of which are shown in **Figure 4**.

Despite the lack of deep peat across much of the Site, a consistent approach was taken to the core sampling, with a core taken in the centre of each turbine location; the borrow pit; and substation. Two cores were additionally taken in areas of deep peat along the track leading to the B738.

Table 2: Collected Core Data

Core Location	ID	Peat	Acrotelm Thickness (cm)	Catotelm Thickness (cm)	Von Post	Notes
T1	1	No	10	0	N/A	Mineral soil
T2	2	No	5	0	N/A	Mineral soil
T3	3	No	15	0	H6	Peaty soil
T4	4	No	5	0	N/A	Mineral soil
Borrow pit	5	No	20	0	H3	Peaty soil
Substation	6	Yes	15	50	H3-H4	Clay base
Construction Compound	7	Yes	10	20	H3-H4	Clay base
Track Buffer 1	8	Yes	25	75	H2/H6	Clay base
Track Buffer 2	9	Yes	15	85	H3/H7	Clay base

Photo 1: Representative peat cores

3.3 Peatland Condition

The survey area within the Site is composed predominantly of undulating grass fields with limited areas of peat in areas of proposed infrastructure; see **Photo 2** for an example of the typical land cover. Most of the grassed area within the survey extent had been extensively grazed by sheep and cattle. **Photo 3** shows the soil horizon in the eastern part of the site, showing no peat. It should be noted that there were isolated small pockets of peaty soil in topographic depressions in the western part of the survey area (see **Photo 4**).

Local topography on the site affects the peat distribution across the survey area with deep peat found in local topographic low points in the western part of the Site; an example of an area of peat at Galdenoch Moor is shown in **Photo 4**. The most extensive area of peat was found on Larbrax Moor, a slightly raised plateau of peatland located in the eastern part of the survey area.

A small area of quaking bog was also found in a topographic depression close to the B738 in the east of the Site, indicating waterlogged conditions in the peat (**Photo 5**).

The area of moorland in the northern part of the survey area (see **Photo 6**) did not contain areas of deep peat (>50cm) but there was peaty soil present.

An approximately 60m wide strip of dense *Rhododendron ponticum* scrub lines the eastern border of the site, making it largely inaccessible for probing (**Photo 7**). A small area which the track crosses over is identified as Class 1 peat on the NatureScot (2016) Carbon and Peatland map but overlaps with the location of Rhododendron on the ground (**Figure 2**). Although there is some deep peat here, this type of vegetation is not peatland. Therefore, this area could not be considered Class 1 peat. Similarly, the field just north of the road leading to Meikle Larbrax Cottages is identified as Class 1 on the Carbon and Peatland map but is in fact pasture and contains no peat (**Figure 2**).

Photo 2: The pastoral grassland in the western part of the survey area.

Photo 3: An exposed soil horizon in the eastern part of the survey area.

Photo 4: An example of an isolated pocket of peaty soil in the western part of the survey area.

Photo 5: Galdenoch Moor.

Photo 6: The quaking bog in the east of the survey area.

Photo 7: Rhododendron lining the eastern boundary of the site.

4 Summary and Recommendations

Kaya Consulting Limited was commissioned by Ørsted, through LUC, to undertake a Phase 1 and Phase 2 peat depth survey for the Proposed Development in Dumfries and Galloway.

This report covers the methodology and output of all the peat surveys undertaken by Kaya Consulting at the Site. The purpose of the survey was to establish an understanding of the peat depths at the site to optimise design and layout to minimise both the extent of disruption to peatlands and the quantity of peat excavated.

The peat surveys carried out in 2023 and 2024 by Kaya Consulting supplemented previously collected peat depth data completed in 2013 by AECOM. The results from both studies are compiled into a singular dataset and presented in this report.

A total of 1,358 probes were collected across the Phase 1 and Phase 2 peat survey (including the 2013 AECOM data) for the Proposed Development and the results summarised below:

- 69.1% of probes were recorded as having a depth of less than 25cm. These probes are not classified as peat.
- 16.9% of probes were recorded as having a peat depth of between 25-50cm. These probes are classified as organo-mineral soils and not formally considered to be peat.
- 8.5% of probes were recorded as having a peat depth of between 50-100cm.
- 5.4% of the probes were recorded as having a peat depth of over 100cm.

A total of 9 cores were taken across the survey area, all in areas at or adjacent to proposed infrastructure. It was estimated that the acrotelm layer was between 5cm and 25cm. Clay was the dominant source of base material.

The majority of the survey area was grassland and did not contain peat. Deeper areas of peat were restricted to topographic low points, most widespread across Galdenoch Moor and Larbrax Moor.

It should be noted that ~15 points were inaccessible along a section of track near the site entrance due to dense scrub. The intention would be that the area is probed following scrub removal to ensure that the track alignment avoids any deep pockets of peat.

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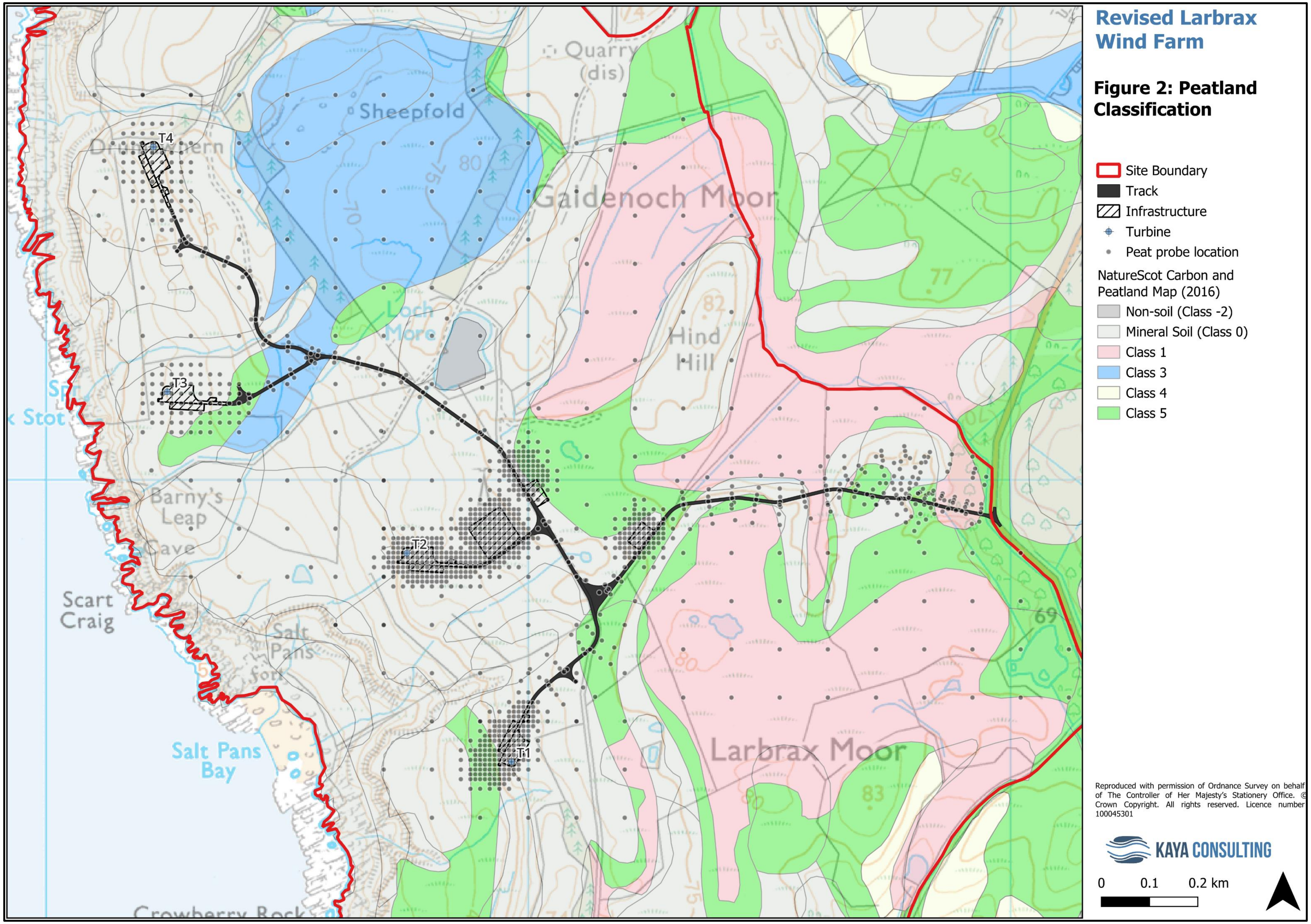
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Figure 2: Peatland Classification
Site Boundary
Track
Infrastructure
Turbine
Peat probe location
NatureScot Carbon and Peatland Map (2016)
Non-soil (Class -2)
Mineral Soil (Class 0)
Class 1
Class 3
Class 4
Class 5
T1
T2
T3
T4
Sheepfold
Quarry (dis)
Gaidenoch Moor
Hind Hill
Loch More
Barny's Leap
Cave
Scart Craig
Salt Pans
Salt Pans Bay
Larbrax Moor
Crowberry Rock
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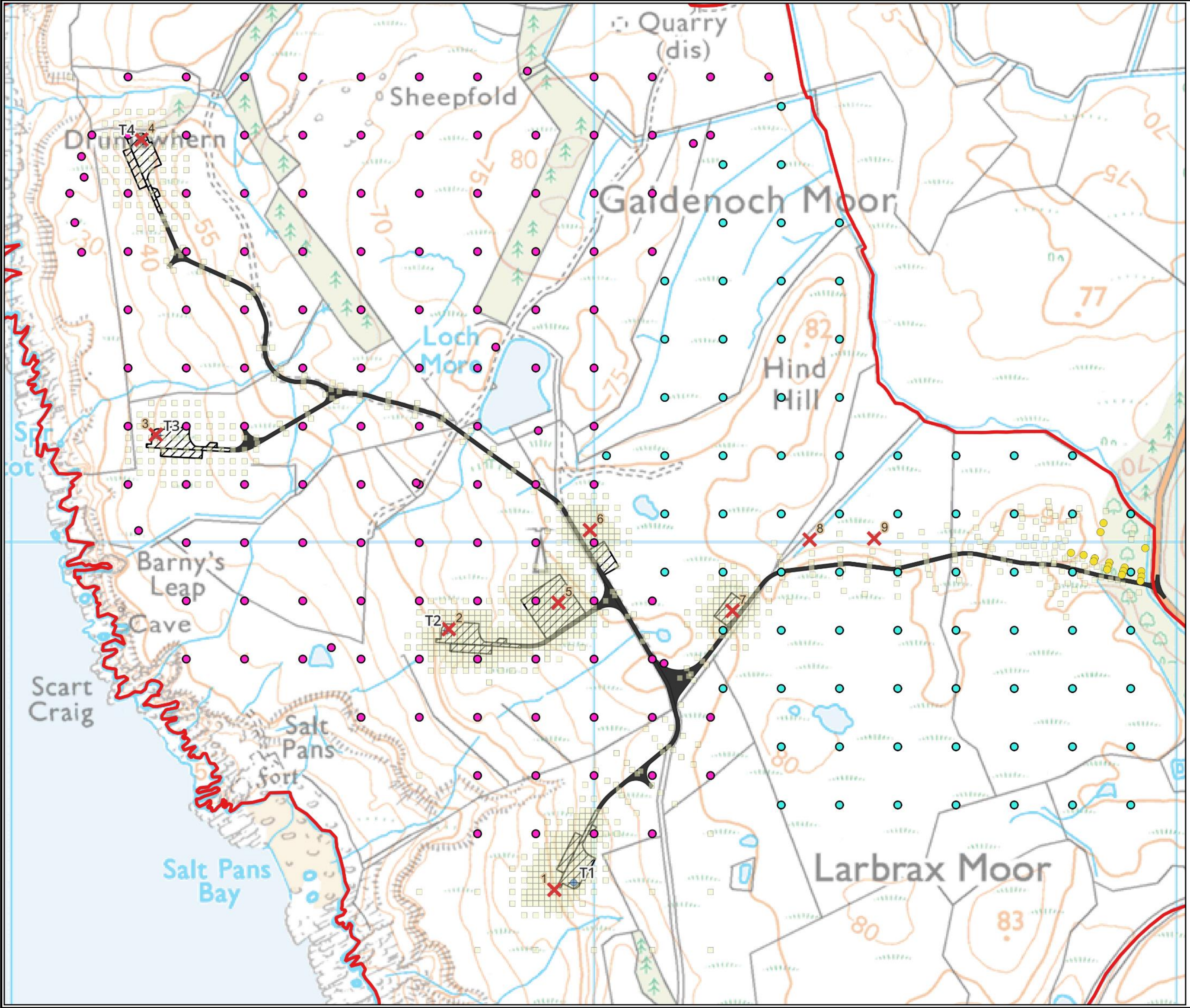
KAYA CONSULTING
0
0.1
0.2 km



Revised Larbrax Wind Farm

Figure 3: Peat Probe Locations

- Site Boundary
- Track
- Infrastructure
- Peat core locations
- Phase 1 probe (AECOM)
- Phase 1 probe (Kaya)
- Phase 2 probe (Kaya)
- Inaccessible probe location

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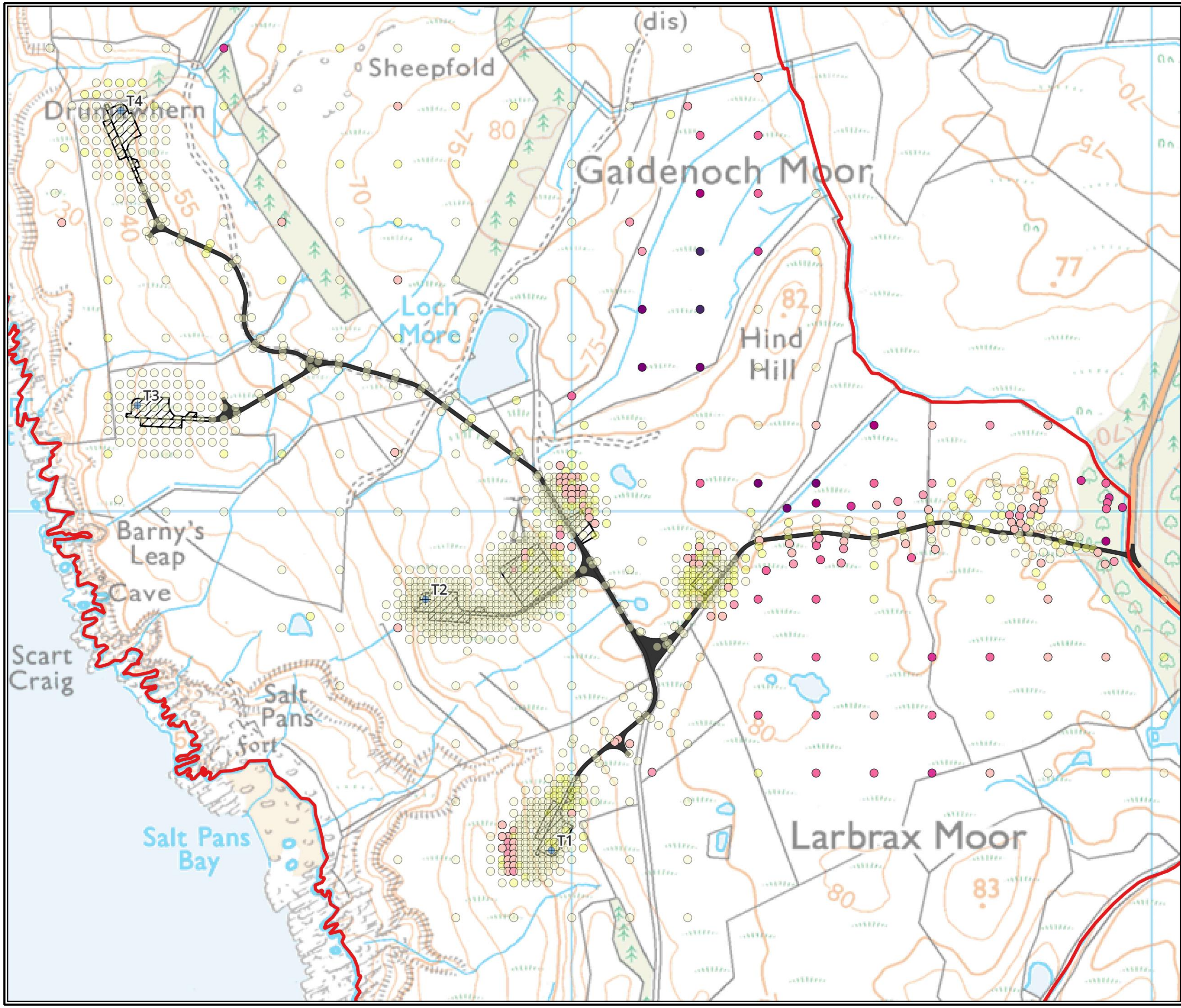

Revised Larbrax Wind Farm

Figure 4: Peat Probe Depths

Site Boundary
Track
Infrastructure
Turbine

Peat probe depth (cm)
- 0 - 25
- 25 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 500
- >500

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0 0.1 0.2 km

Technical Appendix 9.3: GWDTE Assessment

Ørsted

Larbrax Wind Farm EIA Report

Appendix 9.3: Groundwater Dependent Terrestrial Ecosystem Assessment

December 2024

Kaya Consulting Limited
Stanhope House, 12 Stanhope Place
Edinburgh, EH12 5HH
Tel: 0131 466 1458, Web: www.kayaconsulting.co.uk

Kaya Consulting Limited
Stanhope House, 12 Stanhope Place
Edinburgh, EH12 5HH
Tel: 0131 466 1458, Web: www.kayaconsulting.co.uk

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1 Introduction

Groundwater Dependent Terrestrial Ecosystems (GWDTEs) are types of wetlands that are specifically protected under the Water Framework Directive. GWDTEs should be considered in terms of their hydrology and their ecology. This Appendix has been provided to 'bridge the gap' between the two disciplines of Ecology and Hydrology by providing information from both disciplines to complete the assessment of potential effects of the proposed Revised Larbrax Wind Farm (hereafter referred to as the Proposed Development) on GWDTEs.

This Appendix should be read in conjunction with **Chapter 9: Hydrology, Geology, Hydrogeology and Peat, Chapter 7: Ecology** and **Appendix 7.1: National Vegetation Classification and Habitat Survey** of the EIA Report. The assessment draws together detailed information from these documents, summarising where applicable.

The Scottish Environmental Protection Agency (SEPA) has produced detailed guidance[1] on how to assess impacts of proposed development on GWDTEs and the following assessment is based on this.

[1] SEPA (2017). Land Use Planning System SEPA Guidance Note 31. Guidance on Assessing the Impacts of Development Proposals on Groundwater Abstractions and Groundwater Dependent Terrestrial Ecosystems.

2 Identification of GWTDEs

The following is an excerpt from the EU GWDTE Technical Report[2] which defines a GWDTE in the context of the Water Framework Directive:

'*In order for terrestrial ecosystems to be considered as part of the classification for groundwater bodies (GWBs), they need to be 'directly dependent' on the groundwater body (GWB). This means that the GWB should provide quantity (flow, level) or quality of water needed to sustain the ecosystems which are the reasons for the significance of the GWDTE. This critical dependence upon a GWB is most likely where groundwater supplies the GWDTE for a significant part or a significant time period of the year*.'

Therefore, for a habitat to be designated as a GWDTE, there must be significant hydrogeologic connectivity between the groundwater body and the habitat.

Potential GWDTEs were initially identified during Phase 1 habitat and National Vegetation Classification (NVC) surveys (see below) undertaken by MacArthur Green. Potential GWDTEs were then visited by hydrologists to characterise the hydrogeological connectivity of each habitat unit and to determine the level of groundwater dependency. The results of the GWDTE assessment are described below.

2.1 Habitat and Vegetation Surveys

Phase 1 habitat and NVC surveys were undertaken in June 2023. The survey extent and results are described in Appendix 7.1. Where Phase 1 habitat types had potential to support GWDTE vegetation communities, further investigation was undertaken. Phase 1 habitat types that have potential to support GWDTE communities include:

- A1.1.1 Broadleaved Semi-Natural Woodland
- B1.1 Unimproved Acidic Grassland
- B5 Marshy Grassland
- D2 Wet Dwarf Shrub Heath
- E1.7 Wet Modified Bog
- E2.1 Acid/Neutral Flush/Spring

Where appropriate, within habitats coded as above, the NVC method[3] was used to identify potential GWDTE communities. Upon determining the NVC community, a decision tool was used to establish the level of dependency of each community on groundwater. **Table 1** below shows the decision-making tool used in determining GWDTE presence.

Table 1: GWDTE Decision Tool[4]

Criteria	Yes	No
A. Is the GWDTE vegetation evidently influenced by groundwater? (i.e. base-enriched (M10, M11, M37 and/or M38) and/or discharging from an evident point source such as a spring head (M31, M32, M33).		

[2] European Commission, Directorate-General for Environment, Technical report on groundwater dependent terrestrial ecosystems . Technical report. No 6, Publications Office, 2012, https://data.europa.eu/doi/10.2779/93018

[3] Rodwell, J.S. 1991-2000. British plant communities. 5 Volumes. Cambridge University Press

[4] Botanaeco (2018) GWDTE Decision Tool. Available at: https://botanaeco.co.uk/gwdte

Criteria	Yes	No
If the answer to A is 'Yes' then field assessment ends at this stage and the GWDTE is treated as 'high', as per the guidance. If 'No', continue to B.		
B. Is the GWDTE polygon associated with an evident surface water feature? i.e. is the vegetation located within one of the following topographic locations:		
Watershed/ridge		
Watercourse		
Floodplain		
Ponding location, pond, loch, etc (localised depression)		
Surface water conveyance (drain, gully, rill, etc.)		
If the answer to B is 'Yes' then the GWDTE polygon is no more than 'moderate' and very likely to be 'low'. Additional floristic and environmental data should be collected, including photographs to allow for further, desk-based determination of the groundwater dependency. If 'No', continue to C.		
C. Is the GWDTE polygon associated with an ombrogenous system? i.e. with blanket bog or wet heath habitat. This is especially relevant to M6 and M25:		
Presence/persistence of distinctive bog habitat, species and/or associations.		
Deep peat not confined to depressions/valleys (>0.5 m visible in drains or hagged areas).		
If the answer to C is 'Yes' then the GWDTE is no more than 'moderate' and very likely to be 'low'. Additional floristic and environmental data should be collected, including photographs to allow for further, desk-based determination of the groundwater dependency.		

2.2 GWDTE Baseline

2.2.1 Ecology

Chapter 7: Ecology and **Appendix 7.1** present the Phase 1 habitat survey results, the NVC survey results, and the potential GWDTEs identified. Potential GWDTEs based on ecology surveys are mapped in **Figure 7.4**. The habitat survey results are discussed in detail in **Appendix 7.1** and are not repeated here. The GWDTE baseline is presented below.

Habitats that have the potential to be groundwater dependent were mapped by the ecology team as shown in **Table 2**. Based on SEPA guidance[1] the potential groundwater dependency of these communities, based on the vegetation alone is also provided in the table.

Table 2: Potential GWDTEs, based on NVC code

Potential GWDTE NVC Code	Groundwater Dependency as per SEPA (2017)[1]
M6 *Carex echinata - Sphagnum fallax/denticulatum* mire	High
W4 *Betula pubescens – Molina caerulea* woodland	High
M23 *Juncus effusus/acutiflorus – Galium palustre* rush pasture	High

Potential GWDTE NVC Code	Groundwater Dependency as per SEPA (2017)[1]
M15 *Trichophorum germanicum - Erica tetralix* wet heath	Moderate
M25 *Molinia caerulea - Potentilla erecta* mire	Moderate
M27 *Filipendula ulmaria - Angelica sylvestris* mire	Moderate
MG10 *Holcus lanatus - Juncus effusus* rush-pasture	Moderate
U6 *Juncus squarrosus - Festuca ovina* grassland	Moderate
Je[5] *Juncus effusus* acid grassland	Moderate

Based on the SEPA guidance, NVC classes M15, M25, M27, MG10, U6 and Je have the potential to have a moderate dependency on groundwater and M23, W4 and M6 have the potential to have a high dependency on groundwater. Areas of habitat that have the potential to be groundwater dependent are widespread across the Site (see **Figure 7.4**). However, it is noted that the areas shown in **Figure 7.4** often comprise a mosaic of NVC communities, for example M15 might only cover 20% of a polygon, with the remaining 80% being some other non-GWDTE communities (e.g. often an amalgamation of communities associated with marshy grassland, wet heath and mire habitats). To be conservative, the entire polygon was mapped by ecologists as *potentially* groundwater dependent on **Figure 7.4**.

The hydrology team considered that the habitats that indicate a high likelihood of groundwater dependency (i.e. M6, M23 and W4) were generally located close to watercourses (indicating a surface water influence) or associated with hillside flushes and within gullies. Therefore, it is considered that these plant communities have, at-most, low groundwater dependency, with the exception of one localised GWDTE (GWDTE 2, See **Section 2.2.2** and **3**).

Further hydrology and hydrogeological survey investigations were undertaken to determine the level of hydrological connectivity and subsequent groundwater dependency at indicative GWDTE polygons.

2.2.2 Hydrology

A survey was undertaken by two hydrologists in August 2023 to groundtruth the GWDTE polygons noted to have high and moderate GWDTE potential based on vegetation to establish the level of actual groundwater dependency associated with each.

The hydrology team recorded two GWDTEs during the survey.

- GWDTE 1 corresponds with the moderate potential GWDTE M27b NVC community.
- GWDTE 2 corresponds with the high potential GWDTE M25a/M15b/Je community.

Based on the results of the survey by hydrologists and ecologists and the desk-based assessment, a number of adjustments were made to the turbine locations to consider the presence of GWDTEs. Where possible, the GWDTEs have been buffered by 250 m (for turbines and borrow pits) or by 100 m (tracks, construction compound etc), as per SEPA guidance.

[5] In light of the SEPA classification on potential GWDTEs the non NVC type 'Je' should also qualify for potential GWDTE status. The classification of moderate sensitivity is keeping in line with other similar *Juncus* spp. dominated grassland communities (e.g. MG10).

However, GWDTE 1 is just within the 250m buffer from turbine T3 and as such a detailed assessment is carried out below and more description of GWDTE 1 is provided in **Table 3**. GWDTE 2 is located outwith the 250m buffer and is therefore not considered further.

Several of the potential GWDTE polygons are located within surface water drainage pathways and subsequently may be influenced by any alteration to surface/sub-surface drainage. Any proposed tracks or other infrastructure which pass across these drainage pathways should include suitable drainage to avoid blocking hydrological pathways and maintain hydrological connectivity.

Table 3: Details of GWDTE 1, which is located within 250m from excavations >1m deep

Potential GWDTE	Phase 1	NVC	Potential groundwater dependency based on NVC class[1]	Hydrogeological setting	Actual groundwater dependency based on site surveys	Distance from infrastructure
GWDTE 1 (identified by hydrologists)	H8.4 Coastal Grassland	M27 - *Filipendula ulmaria - Angelica sylvestris* mire	Moderate	A small groundwater seep originating on the coastal cliff face in the west of the Site (see **Photo 1**). There is a small surface watercourse/ drain which flows as a surface feature above the cliff (**Figure 1**). It is considered likely that this contributes some water to the seep (i.e. it is not fully groundwater fed.)	Moderate, based on presence of a distinct groundwater seep, although it is likely that there is indirect surface water contribution into the rocks from the small watercourse above. Flow rates from the seep were very low at the time of the site visit.	GWDTE 1 is 212m south-west of T3.

3 Effects Assessment

Following ecological identification of potentially groundwater dependent habitats and an assessment of the levels of groundwater dependency of the specific habitats, this section provides an assessment of the potential effects of the Proposed Development upon groundwater flow to GWDTE 1, as described in **Table 3**.

A site-specific qualitative risk assessment of the GWDTE was carried out based on the available data on local geology, hydrology, ecology and hydrogeological regime. There is no available data on sub-surface flows and in the absence of data, it is considered that the movement of sub-surface water is primarily driven by topography.

Flow routing analysis was carried out in QGIS software using OS 5m terrain data. In the absence of data on groundwater levels and flow paths, analysis of topography and surface water flows paths was used to infer hydrological and hydrogeological connectivity to the project infrastructure.

The assessment of impact on a groundwater flow path is made with reference to distance, slope, aspect, typical water table levels and features such as watercourses. This assessment is made with imperfect knowledge of the exact extent that a particular impact may have and imperfect knowledge of specific sub-surface flow paths. As such, it takes a precautionary approach using the available information.

Two specific aspects are considered in the assessment. One is the likelihood of an impact upon a flow path feeding an area of groundwater. The second aspect is the likelihood that an area of groundwater may be drained at an un-naturally fast rate following the introduction of drainage for infrastructure / access tracks / turbine bases.

The SEPA Guidance[1] for assessing impacts of development on GWDTEs recommends a 250 m buffer zone from all excavations >1 m and a 100 m buffer for excavations <1 m deep. The two buffers are shown on **Figure 9.3** in the EIA Report and **Figure 1** in this appendix. Based on the project description and construction methods outlined in **Chapter 4: Development Description** of the EIA Report, excavations for the turbine foundations and borrow pits will be >1 m, while access tracks and other infrastructure (compounds, tracks and substation/battery storage) will <1 m.

A site-specific assessment of GWDTE 1 follows. All other potential GWDTE polygons mapped by the ecologists were considered to have a low dependency on groundwater and are not GWDTEs and are not considered further.

GWDTE 1 is located close to the top of the coastal cliff face along the western edge of the Site. A distinct fracture-fed seep was observed coming out of the cliff indicating a groundwater contribution (**Photo 1**).

T3 and associated hardstandings are within the 250 m buffer of the seep location and moderately dependent NVC polygon. Based on site surveys (see **Table 3**), the GWDTE is considered to be moderately dependent on groundwater. Thus, the sensitivity of the receptor is medium (based on **Table 9.2** in the EIA Report). The location of the GWDTE is shown on **Figure 1** and described in context with available geological, peat and hydrological information.

Figure 1: Location of moderately dependent GWDTE 1 in hydrological setting, showing indicative surface water flow paths and proposed infrastructure (100 m and 250 m buffers from infrastructure also shown).

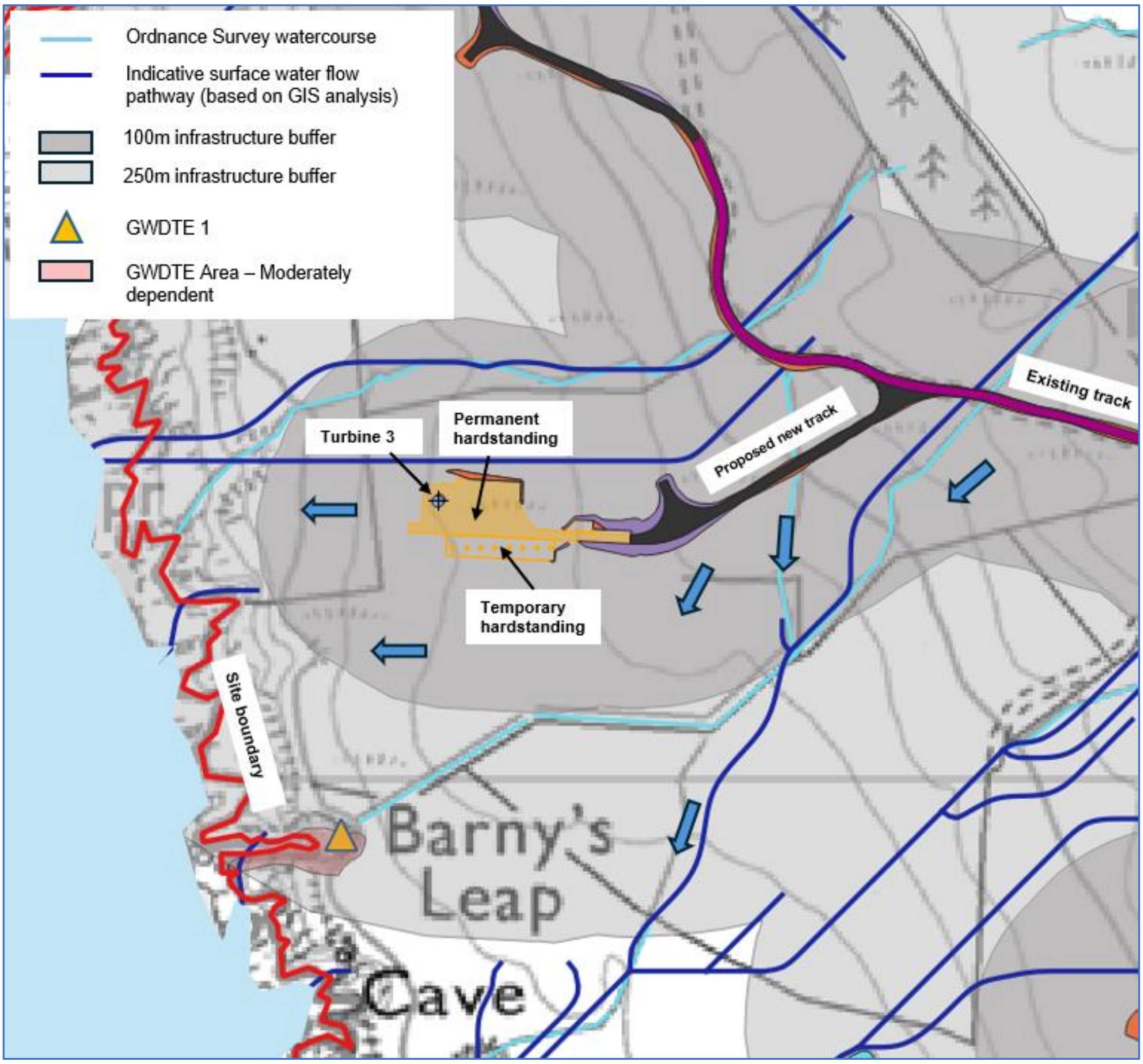

Photo 1: (a) Fracture-fed seep (b) Moderately Dependent GWDTE, looking down the cliff).

British Geological Survey (BGS) 1:50K bedrock geology maps indicate that the geology around the GWDTE comprises of Wacke Sedimentary of the Kirkcolm Formation (**Figure 9.4** in the EIA report). These highly indurated greywackes are classified as having low aquifer productivities (Class 2C), with limited groundwater in the near surface weathered zone and secondary fractures.

BGS 1:50K superficial geology maps indicate that the superficial drift geology at the GWDTE site comprises glaciofluvial deposits (**Figure 9.4** in the EIA report). The vegetation surrounding the GWDTE is located on shallow mineral soil.

The GWDTE is located downgradient of T3 close to the top of the coastal cliff and surface water flow paths indicate that the area drains west towards the sea (**Figure 1**). The turbine T3 is ~212m north-east of the GWDTE and is upslope of the GWDTE at an elevation of ~35m Above Ordnance Datum (AOD). The coastal cliff edge is at ~25m AOD, some 10m lower than the proposed turbine, and the GWDTE is 2-5m lower down the cliff (**Photo 1**). The turbine itself and permanent infrastructure drain westwards towards the sea. Flow path analysis shows that the GWDTE is not within the flow path draining T3 and excavation for the foundation of T3 is not considered to have any impact on groundwater flows to the GWDTE, as the excavation location sits over 10m higher than the GWDTE seep location and 212m away. It is noted that the GWDTE, whilst it does have a groundwater contribution it is likely that the surface watercourse/ drain above it contributes at least some of the water to the seep.

Based on the above, it is considered that the Proposed Development will not have an effect on the GWDTE. The GWDTE is of **medium** sensitivity and the magnitude of the change is assessed to be **none**, resulting in an effect significance of **none**.

Embedded design measures (e.g. SUDS) and best practice site management and construction techniques will further minimise the risk of pollution/sediment to the GWDTE. Best practice construction techniques as set out in the guidance document "Good Practice during Wind Farm Construction" (2019) will be employed to ensure that the infrastructure does not affect groundwater flow or chemistry to sensitive receptors. Wind farm track will be designed with suitable drainage to enable subsurface flows to be maintained in areas where moderate or high potential GWDTEs are present. Thus, there is not expected to be any long-term effect on hydrology and sub-surface flows during operation.

4 Summary and Conclusions

GWDTE were buffered and considered early in the design process for the Proposed Development. Where possible, the recommended 250 m buffer has been avoided for siting turbines and borrow pits, and 100 m buffer has been avoided for siting roads, tracks and trenches, as per SEPA guidance[1]. However, it has not been possible to avoid all buffers.

There is one GWDTE where infrastructure is proposed within the recommended buffers. This has been assessed in detail and reported herein. Based on the GWDTE Decision Tool (**Table 1**), it was assessed to have a moderate dependency on groundwater.

The effects of the Proposed Development on the GWDTE location are assessed as none – see **Table 4** below. Embedded mitigation design measures (e.g. SUDS) and best practice site management and construction techniques will further minimise the risk of pollution/sediment to the GWDTE.

Table 4: Summary of Assessment of GWDTEs within 100 m of excavations <1m deep and 250 m from excavations >1m deep

GWDTE	Groundwater dependency based on site surveys	Distance from infrastructure	Significance before additional mitigation (including embedded mitigation measures)	Additional Mitigation	Significance after additional mitigation
GWDTE 1	Moderate	P1 is 212m south-west of T3.	None	n/a	None

It is noted that several of the potential GWDTE polygons do have some habitats which have a surface or sub-surface water influence, and any proposed tracks that pass through these areas should include suitable drainage to avoid blocking hydrological pathways and maintain hydrological connectivity.

Technical Appendix 9.4: Flood Risk Assessment

Ørsted

Larbrax Wind Farm, EIA Report

Appendix 9.4: Flood Risk Assessment

December 2024

Kaya Consulting Limited
Stanhope House, 12 Stanhope Place
Edinburgh, EH12 5HH
Tel: 0131 466 1458, Web: www.kayaconsulting.co.uk

Kaya Consulting Limited
Stanhope House, 12 Stanhope Place
Edinburgh, EH12 5HH
Tel: 0131 466 1458, Web: www.kayaconsulting.co.uk

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1 Introduction

Kaya Consulting Limited was commissioned by Ørsted to undertake a Flood Risk Assessment for a new access to the proposed Revised Larbrax Wind Farm.

The proposed access is located off the B738 near Larbrax Moor, approximately 9km to the west of Stranraer in Dumfries and Galloway.

The Green Burn flows north, parallel to the B738 at this location. Consultation of the SEPA flood map indicates that there are some areas of flooding around the proposed crossing. Due to the small catchment of the burn, this flood risk is defined as 'Surface water flooding' in the SEPA maps. But as these maps do not show risk from small watercourses, it is likely that this flood risk is due to overtopping of the Green Burn. SEPA maps are not suitable for site specific flood risk assessments, so this report looks to better refine the flood risk at the site.

The scope of this report includes the following:

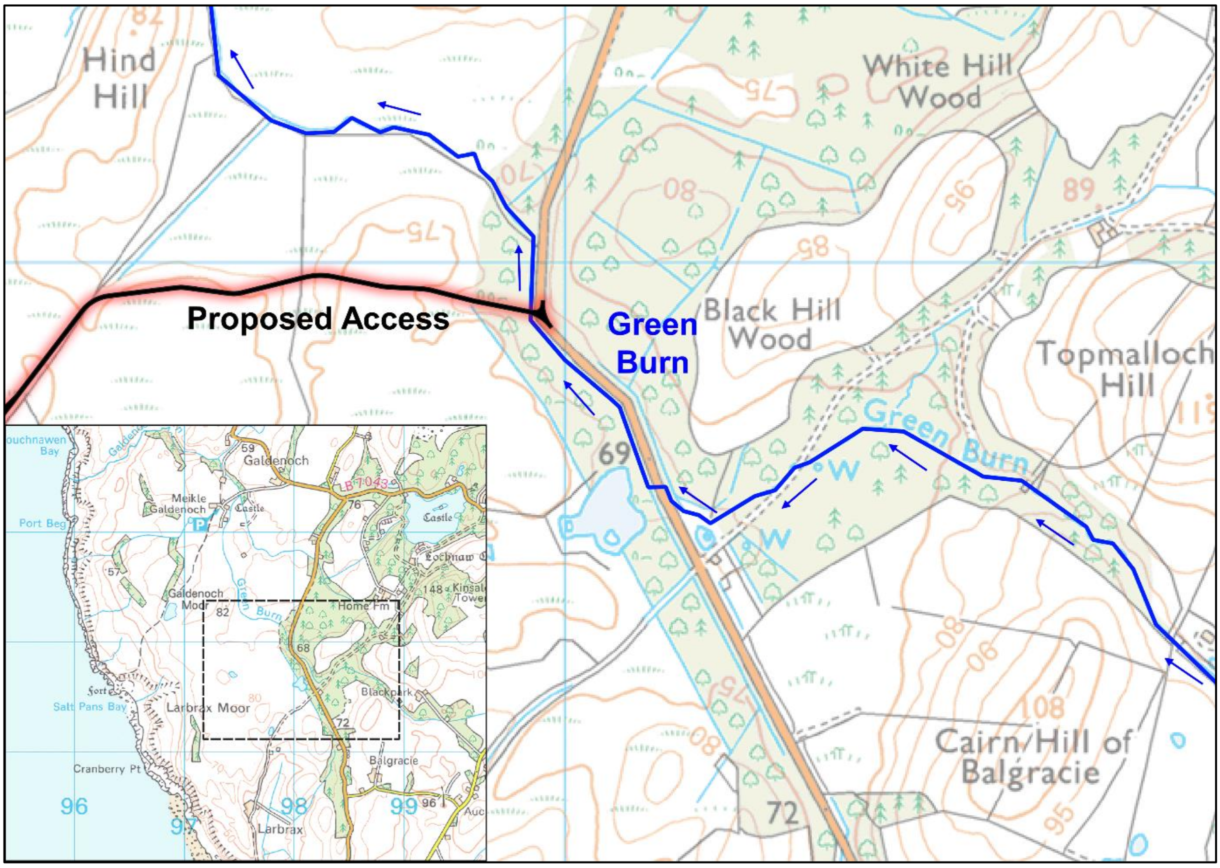
- Assessment of design flows at Green Burn;
- Construction of a hydraulic flood model;
- Sensitivity analysis of results;
- Construction of post-development model based on drawings provided by the client; and
- Assessment of impact on downstream flows and flood risk to the public road;

Information made available to Kaya Consulting Limited for the study includes the following:

- Site location map
- Proposed Access Track Plan
- Topographical survey information
- LiDAR DTM data

A general location map of the site is shown in **Figure 1**.

Figure 1: Proposed Access Location



2 Hydrology and Design Flow Estimation

OS Maps indicate that the Green Burn originates in Blackpark Moss approximately 2.2km to the southeast of the proposed access crossing. The burn flows west through areas of woodland and grassland before reaching the B738. The burn flows under the road in a 1.5m wide culvert approximately 350m upstream of the proposed crossing point. The burn then continues north/northwest parallel to the road for approximately 430m before changing direction to flow west.

Topographic survey of the channel at the proposed crossing location indicates that the top of channel width is approximately 2.2m, with a varying depth of between approximately 0.3 – 0.9m.

2.1 Design Flow Estimation

A hydrological analysis was undertaken to estimate the design flows that could reach the Green Burn downstream of the proposed crossing.

FEH catchment descriptors (**Table 1**) including the catchment boundary (**Figure 2**) for the Green Burn downstream of the proposed crossing were extracted from the FEH Web Service to provide detailed catchment parameters for flow estimation.

A watershed analysis was undertaken using Phase 3 Scottish LiDAR to confirm the extents of the extracted FEH catchment. The results of the watershed analysis provided a catchment area within 2% of the FEH catchment. The unmodified FEH catchment and associated characteristics were therefore taken forward for design flow estimation.

Table 1: FEH Catchment Characteristics For Green Burn

Parameter	Value	Parameter	Value
AREA	2.9875	FPLOC	1.008
ALTBAR	101	LDP	3.93
ASPBAR	274	PROPWET	0.57
ASPVAR	0.21	RMED-1H	10.1
BFIHOST	0.404	RMED-1D	35.3
BFIHOST19	0.418	RMED-2D	47.4
DPLBAR	2.29	SAAR	1115
DPSBAR	58.8	SAAR4170	1050
FARL	1	SPRHOST	42.48
FPEXT	0.072	URBEXT1990	0
FPDBAR	0.51	URBEXT2000	0

Given the size of the catchment, design flows were estimated using the FEH Rainfall-Runoff method, the Revitalised FEH Rainfall-Runoff method (ReFH2) and IH124.

NPF4 requires developments to be assessed against the impacts of climate change. Climate change consideration for small catchments (less than 30km^2) in the Solway River Basin Region must consider climate change uplift at a 38% increase in rainfall intensity following SEPA's Climate change allowances for flood risk assessment in land use planning (2024) guidance. This uplift is for the period 2080-2100 and is therefore considered conservative given the developments operational lifespan of 35-years.

The resulting design flows are shown in **Table 2** below. The higher flows estimated using the ReFH2 method were employed.

Table 2: Design Flow Estimates

Design Event	Flow Estimation Methodology (m^3/s)		
	FEH-RR	ReFH2	IH124
1 in 200-Year	6.33	7.52	4.58
1 in 200-Year + CC	9.28	10.93	6.32

Figure 2: Green Burn FEH Catchment Downstream of the Access Crossing

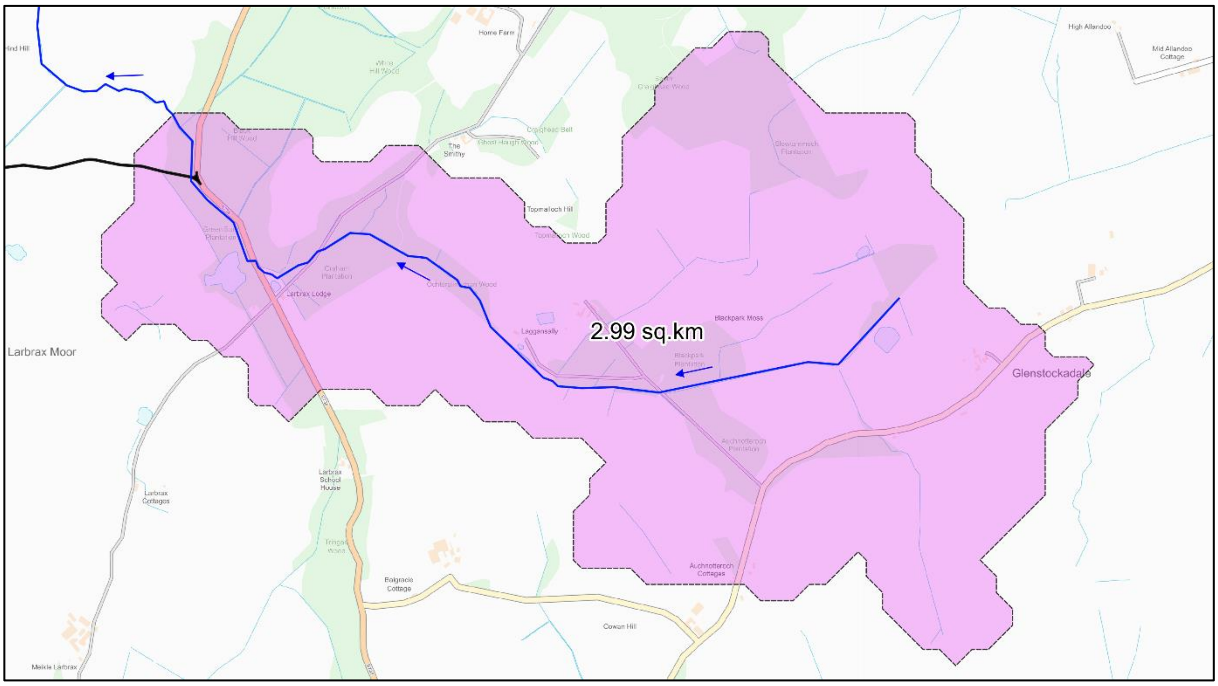


Photo 1: Green Burn Downstream of B738 Crossing

Photo 2: Green Burn Immediately Upstream of Proposed Crossing

Photo 3: Green Burn flowing along the eastern Site boundary (next to the B738), looking upstream

3 Hydraulic Model

3.1 Model Set-Up

A 2D model of the Green Burn was constructed using HEC-RAS mathematical modelling software for this assessment – the extents of the modelled reaches are shown in **Figure 3**.

The upstream extent of the model starts immediately downstream of the B738 crossing, conservatively assuming an unattenuated flow hydrograph (i.e. no impact on B738 crossing on flow able to reach the site).

The DTM (Digital Terrain Model) was developed by nesting a 2D bathymetric grid derived from 14 surveyed channel cross-sections of the Green Burn into Phase 3 LiDAR, the location of the surveyed sections is shown in **Figure 3**. Surveyors attempted to take spot levels on the left bank floodplain, however the vegetation was too dense to make access possible.

The model was set up with a variable grid size of between 2 – 5m, utilising finer resolutions through breaklines at the location of the watercourse.

The model was run using a spatially varied roughness grid. Manning's "n" roughness values were assigned to grid as below and as shown in **Figure 3**:

- Manning's n of 0.075 assigned to the channel in-line with a sluggish reach, weedy, with deep pools[1].
- Manning's n of 0.16 assigned to the floodplain consisting of dense brush[1].
- Manning's n of 0.02 assigned to the road

Unsteady flow hydrographs were used for the upstream boundaries as derived in **Section 2**.

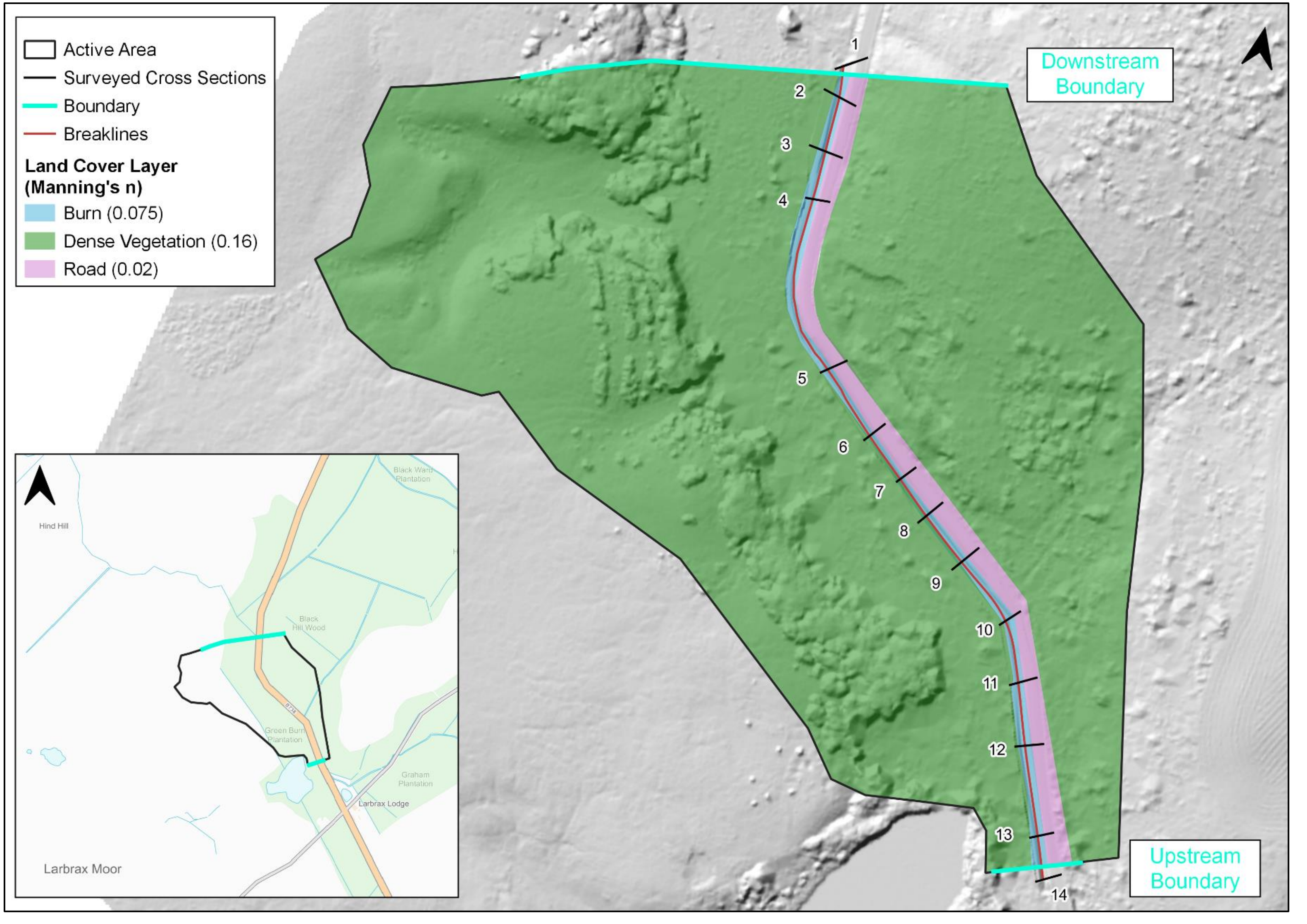
Normal depth conditions were used for the downstream boundary, with a slope of 0.003 based on the topographic survey and LiDAR.

The model was run for a period of 8 hours with an adaptive time step of 2 seconds.

The overall volume accounting error (mass balance error) was less than 0.1%, which is well within normal measures of model suitability.

[1] *Open-channel hydraulics (Chow, 1959)*

Figure 3: HEC-RAS Model Set-Up



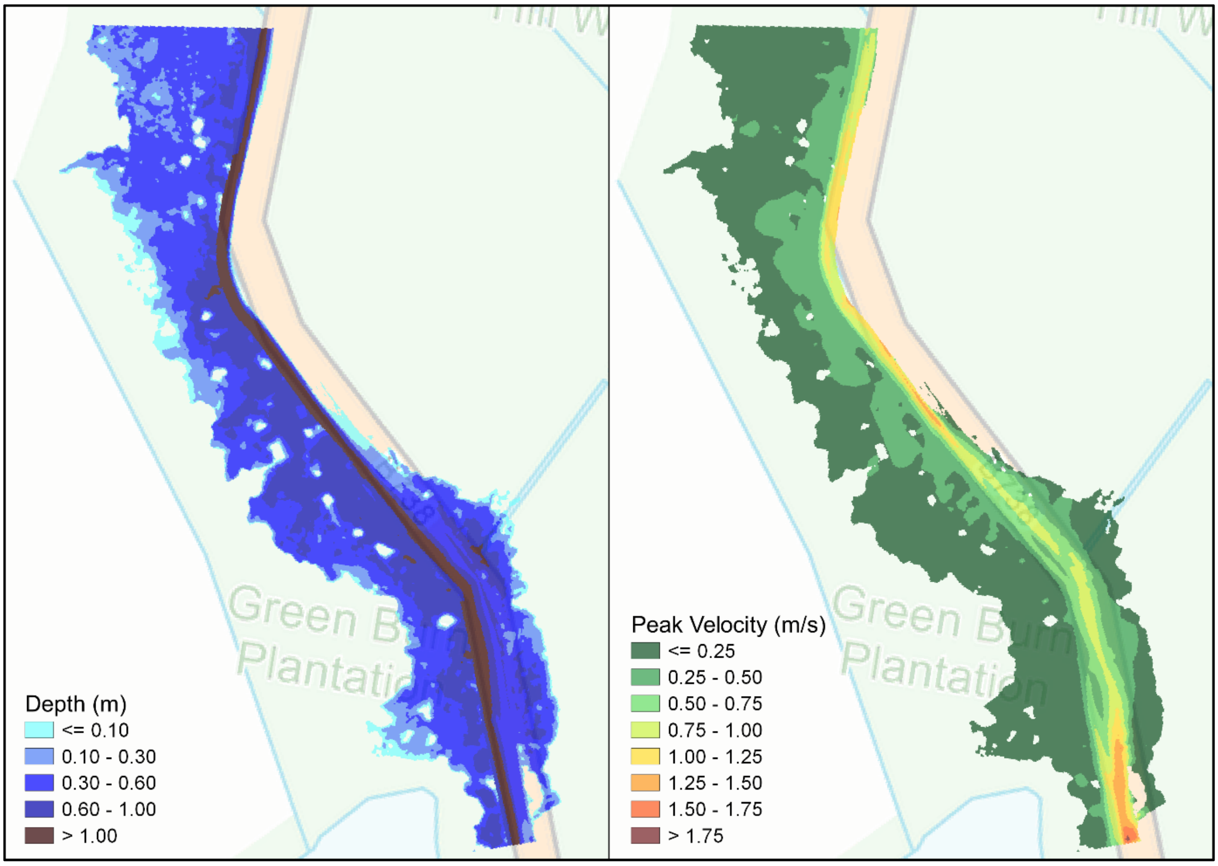
3.2 Model Results

The results of the modelling are shown in **Figure 4**.

Flood waters are predicted to spill from both the left and right banks of the channel in the upper extent of the modelled reach, flooding the existing road. In the middle and downstream reaches, flood waters are confined to the channel and left bank floodplain, with the existing road predicted to remain free of flooding.

Maximum velocities within the channel are approximately 1.8 m/s, with maximum velocities in the floodplain of approximately 0.8 m/s. The average peak velocity across the entire domain is 0.31 m/s.

Figure 4: 1 in 200-Year plus Climate Change Depths and Velocities



3.3 Sensitivity Analysis

A model sensitivity analysis provides a statistical illustration of the effect of changing key model parameters on the key model outputs (in this case maximum water levels at the site). By re-running the model for a range of scenarios with one altered parameter in each respective run, we can isolate and analyse the influence of each parameter on the model outputs. If model parameters are varied within the range of possible input values, then a sensitivity analysis can also provide an indication of uncertainty associated with the model predictions.

Two sensitivity analysis scenarios were assessed relative to the 1 in 200-year plus climate change uplift base case, a 25% increase in Manning's n friction values across the entire model domain, and a 50% reduction in downstream boundary slope.

The results of the sensitivity analysis models are mapped in **Figure 5** and are presented as the increase in peak flood depth relative to the base case.

Increasing manning's n by 25% sees the maximum peak depth increase by approximately 0.25m, with an average increase of 0.08m. The area of greatest increase is at the downstream reach, where floodwaters spill onto the B738.

Reducing the downstream boundary slope by 50% sees similar results with the maximum peak depth increased by approximately 0.24m at the road. Elsewhere increases in peak depth are confined to the downstream reaches of the model as would be expected.

The main depth change for the sensitivity runs is at the downstream end of the model, where increasing friction predicts overtopping onto the road. The change in water levels is low, but as the model overtops the road onto the ditch to the east of the road, the change in water depths in this area is relatively high, as illustrated in **Figure 6**.

Given the above, the model is not considered to be highly sensitive to changes in Manning's n given the already conservative Manning's n values assigned to the base case model. Likewise, the model is not considered to be highly sensitive to changes in downstream boundary slope, with depth increases restricted to areas immediately upstream of the boundary.

Figure 5: Results of Sensitivity Analysis (Increase in flood depth relative to 200-year base case)

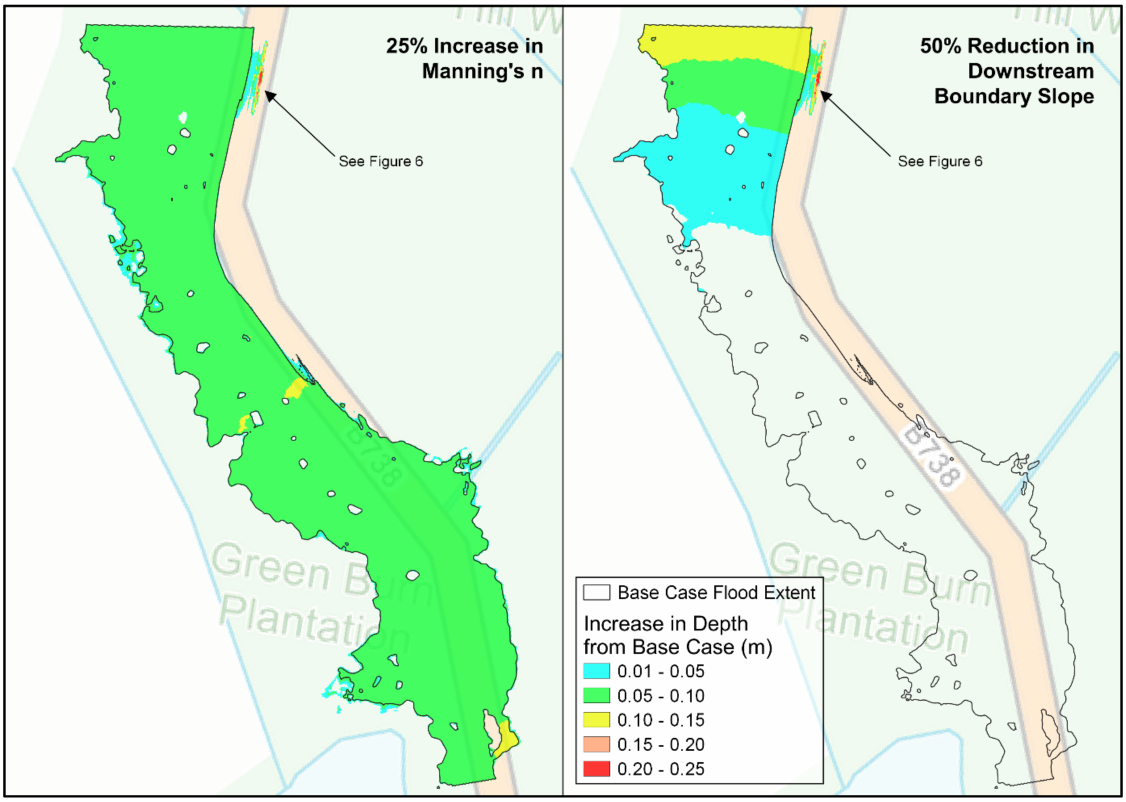
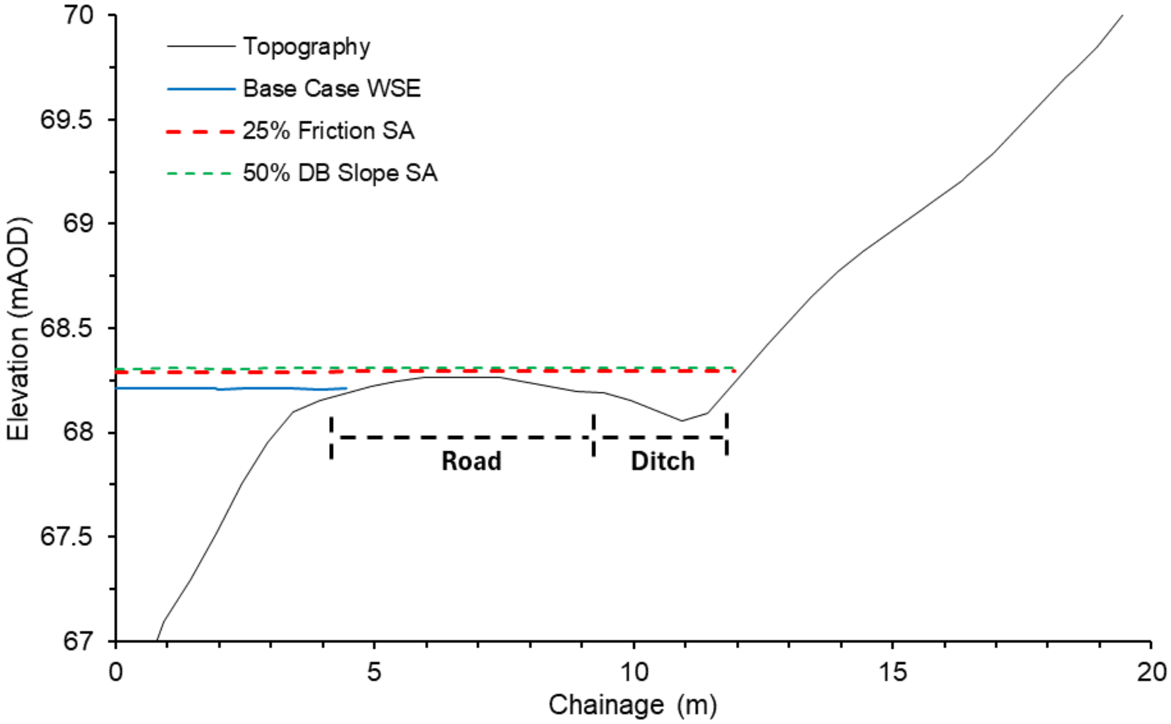


Figure 6: Cross Section of Water Levels at Area of Greatest Increase



4 Proposed Crossing

4.1 Crossing Options

A new access to the proposed Revised Larbrax Wind Farm is proposed off the B738. The access point is approximately 350m downstream of the existing B738 Green Burn culvert.

Two options have been considered for the crossing as below and as shown in **Figure 7**:

Option 1: Bottomless culvert at the Green Burn. Access track raised above 200-year plus climate change flood levels on the left bank with seven 2m bypass culverts under the track aligned with the direction of flow.

Option 2: Bottomless culvert at the Green Burn. Track flush with existing ground levels on the left bank floodplain. A small section of the proposed track will be raised above the floodplain for level access with the existing road.

Figure 8 shows the indicative bottomless culvert design for the access track junction, as per **Figure 4.11b** in the EIA Report.

Figure 7: Modelled Crossing Options

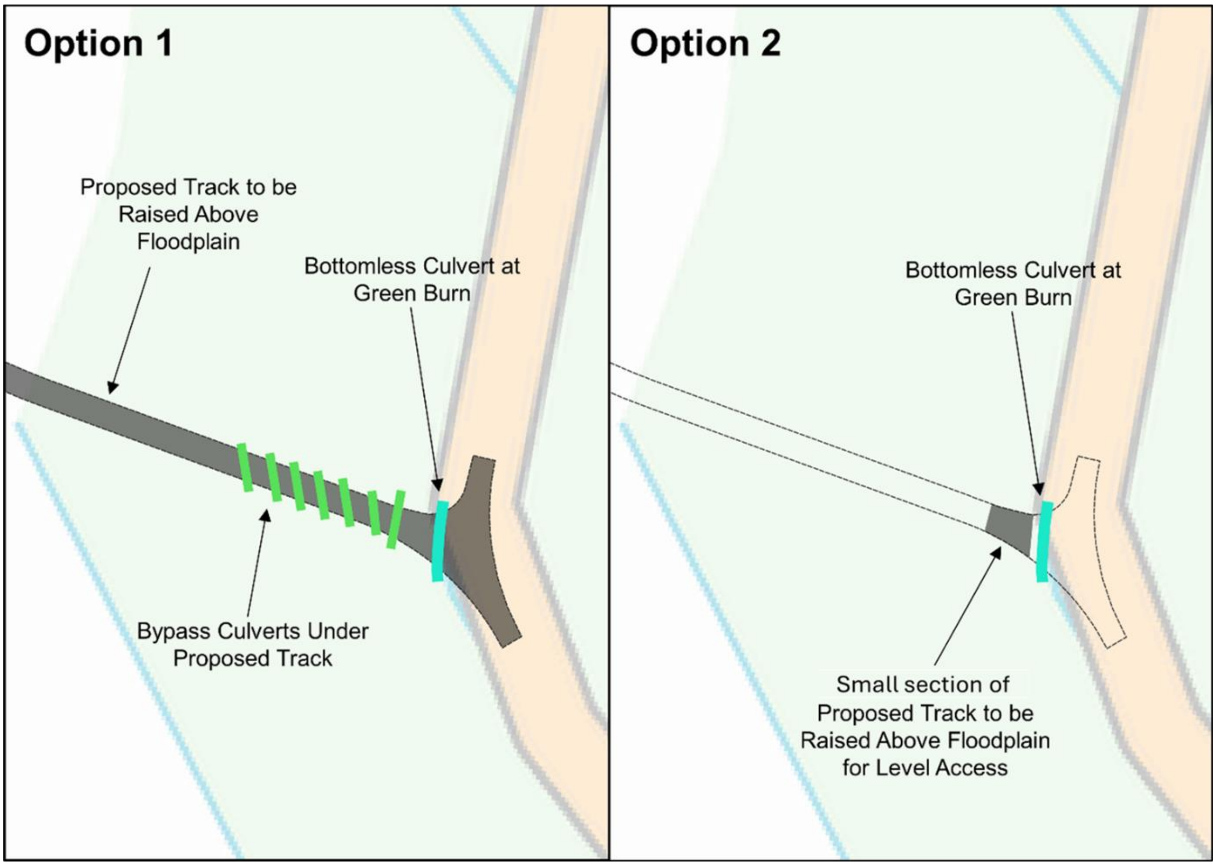
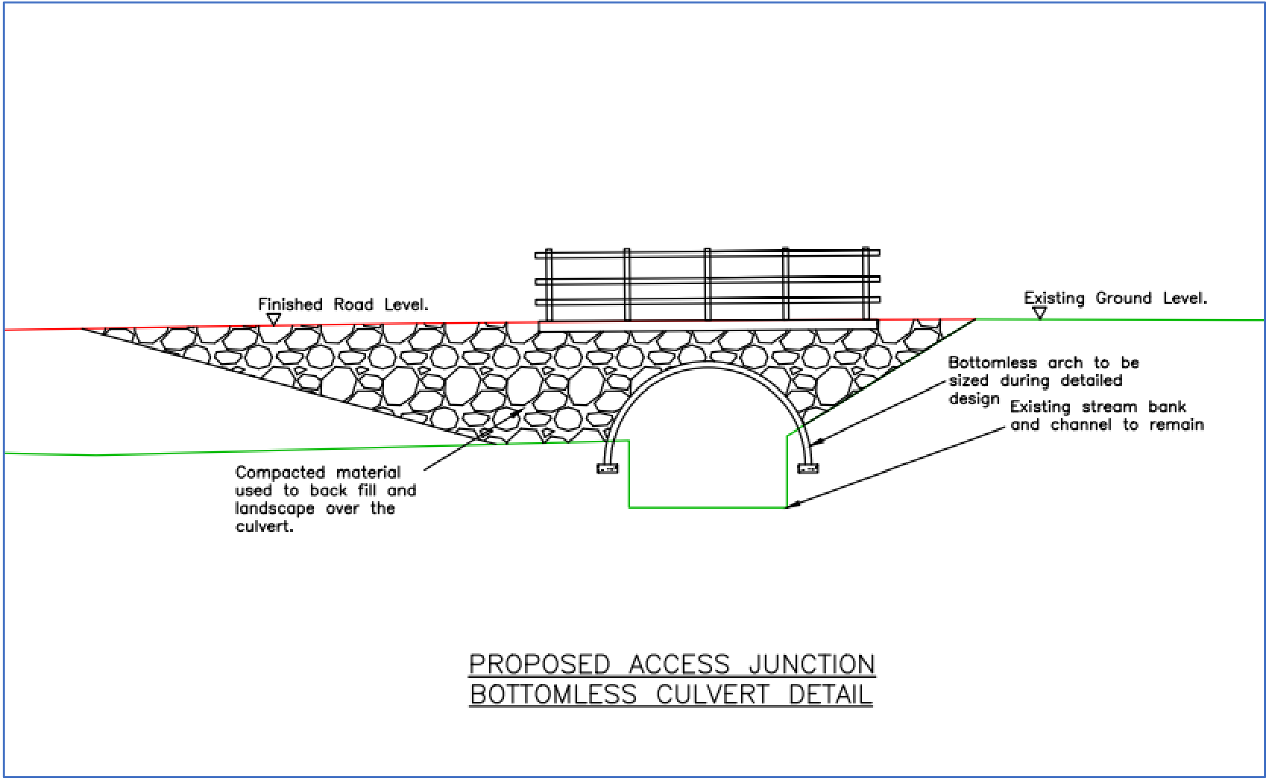


Figure 8: Bottomless Culvert Detail



4.2 Modelling of Proposed Crossing Options

The model was updated to reflect the two potential design options described above and ran for the 1 in 200-year plus climate change uplift event.

The results of the modelling for option 1 are shown in **Figure 9**.

The results show a minor increase in peak flood level within the channel (up to 0.02m) immediately upstream of the bottomless culvert and a minor increase in peak depth within the left bank floodplain immediately upstream of the raised track (up to 0.09m). There is a minor increase (0.01m) in flooding at the already flooded section of the B738.

The results of the modelling for option 2 are shown in **Figure 10**.

The results show a minor increase in peak flood level within the channel (up to 0.02m) immediately upstream of the bottomless culvert and a minor increase in peak depth within the left bank floodplain (up to 0.05m). The areas of increased peak depth are restricted to within approximately 100m upstream of the crossing and the model does not predict an increase in flooding at the B738.

A comparison of flow hydrographs taken downstream of the crossing for both options shows no variation in shape or peak flow in comparison to the base case 200-year plus climate change uplift event as shown in **Figure 11**.

4.3 Proposed Crossing Recommendations

It is recommended that Option 2 be taken forward for detailed design as a cut and fill track that is flush with existing ground levels does not lead to a modelled increase in flooding at the existing B738. Therefore, based on this it could be taken forward for detailed design, assuming agreement with the local authority and SEPA.

Option 2 would not allow for dry access from this location during a flood event, however it is understood dry access will be available from the wind farm via alternative routes. Further discussion of the legislative and Policy Aspects is discussed in **Section 5**.

Table 3 provides peak depths for a range of return periods at the location of the proposed access track in the floodplain. This is provided to give an indication of the probability of given depths during the construction period.

Given the small size of the catchment (approximately 3km^2), the response to rainfall would be flashy and peak flood depths would not be sustained for periods longer than a day.

Table 3: Peak Depths at Proposed Access Track for a Range of Return periods

Return Period (Year)	Annual Exceedance Probability (AEP)	Approximate Peak Depths (m)
2	50.0%	0.15
5	20.0%	0.25
10	10.0%	0.32
30	3.3%	0.40
50	2.0%	0.43
75	1.3%	0.46
100	1.0%	0.48
200	0.5%	0.53

Although most of the track will remain flush with ground levels, a small section to tie the proposed road to the existing main road will be raised and sloped into the floodplain. Calculations based on the pre- and post-development option 2 modelling suggest a loss of floodplain storage of around 50m^3. The client is in control of land up to approximately 350m upstream of the crossing, so compensatory storage would be able to be provided at the detailed design stage, once there is a final design of the crossing.

Figure 9: Option 1 Model Results with Comparison to Pre-development Base Case

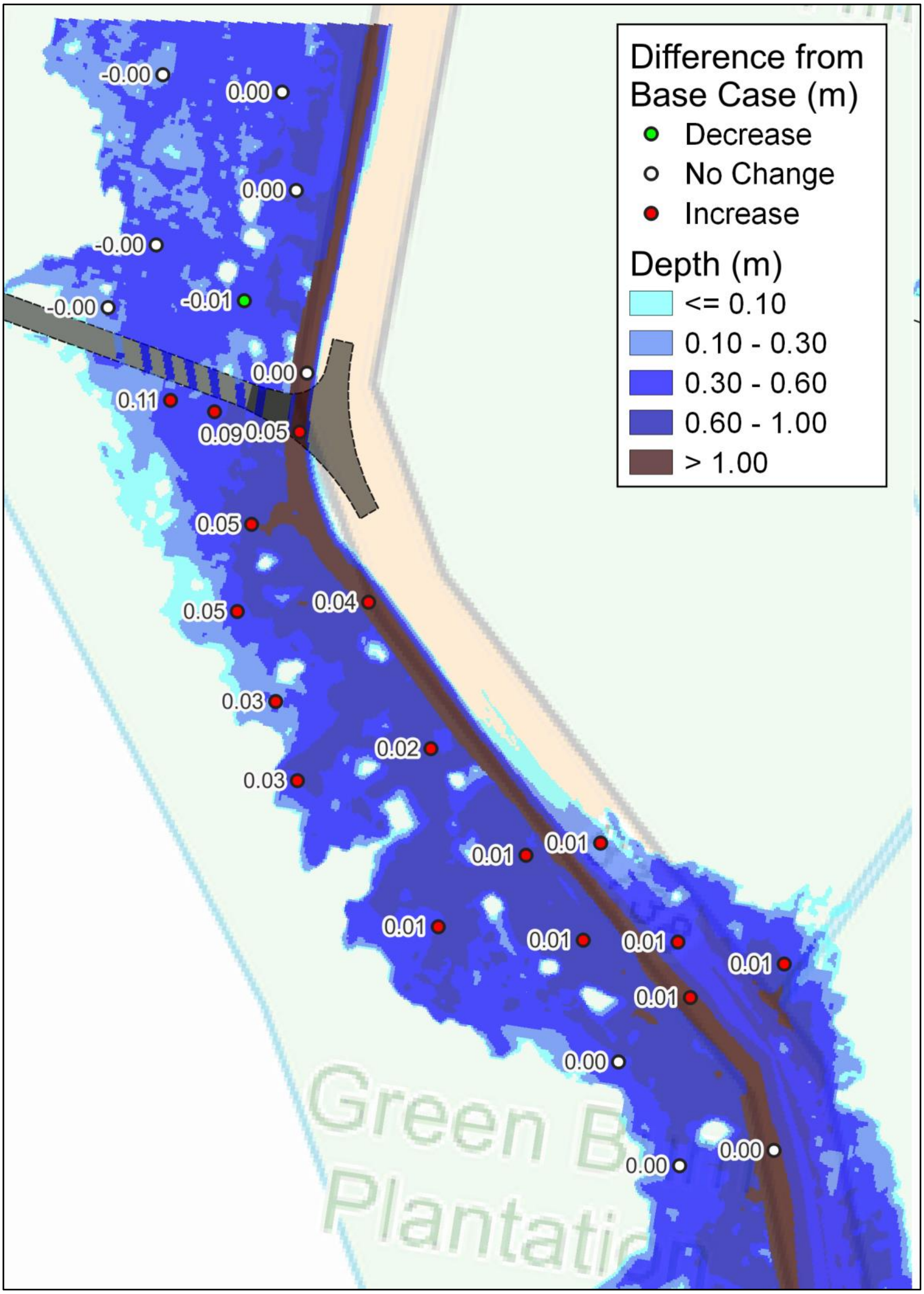


Figure 10: Option 2 Model Results with Comparison to Pre-development Base Case

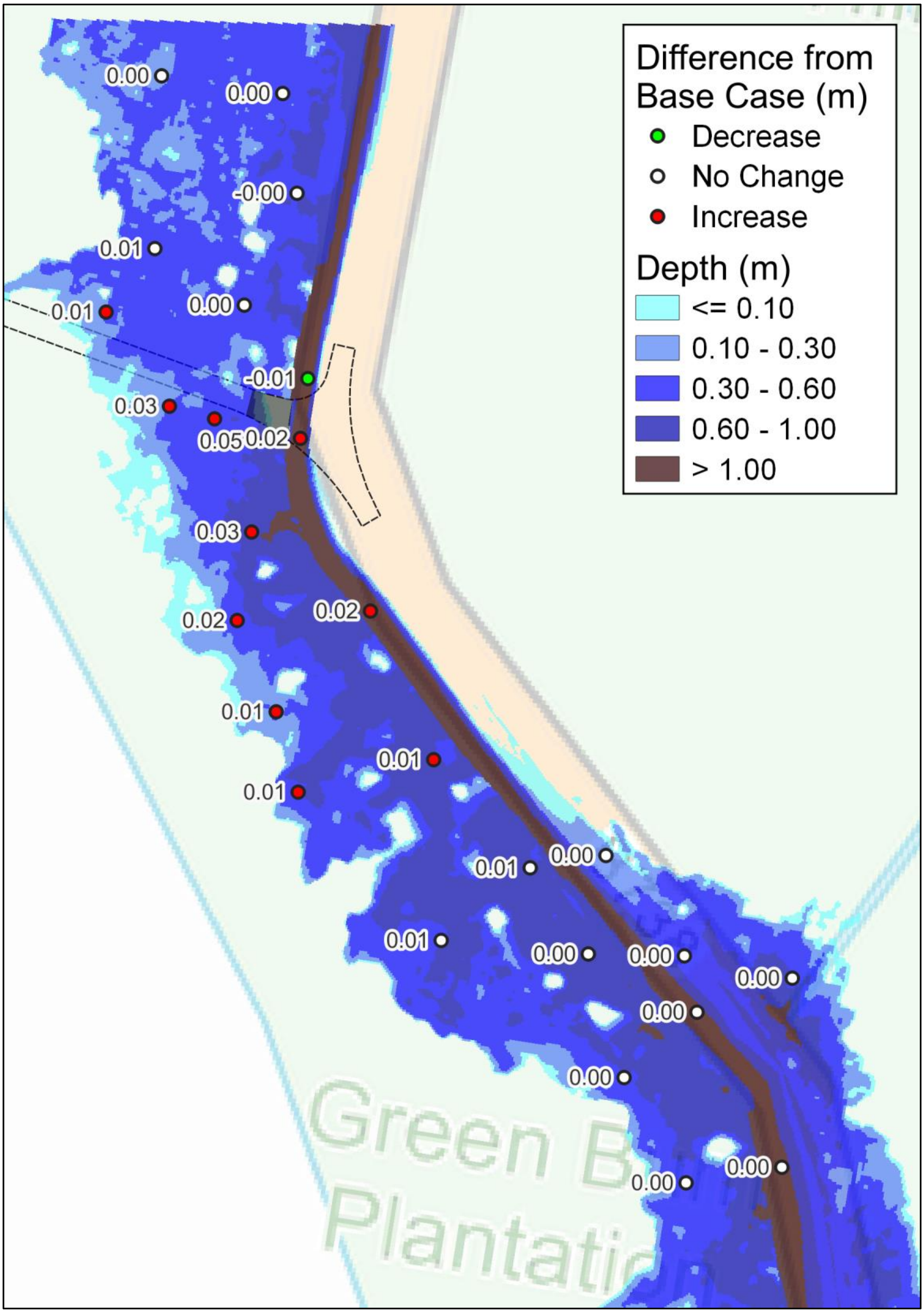
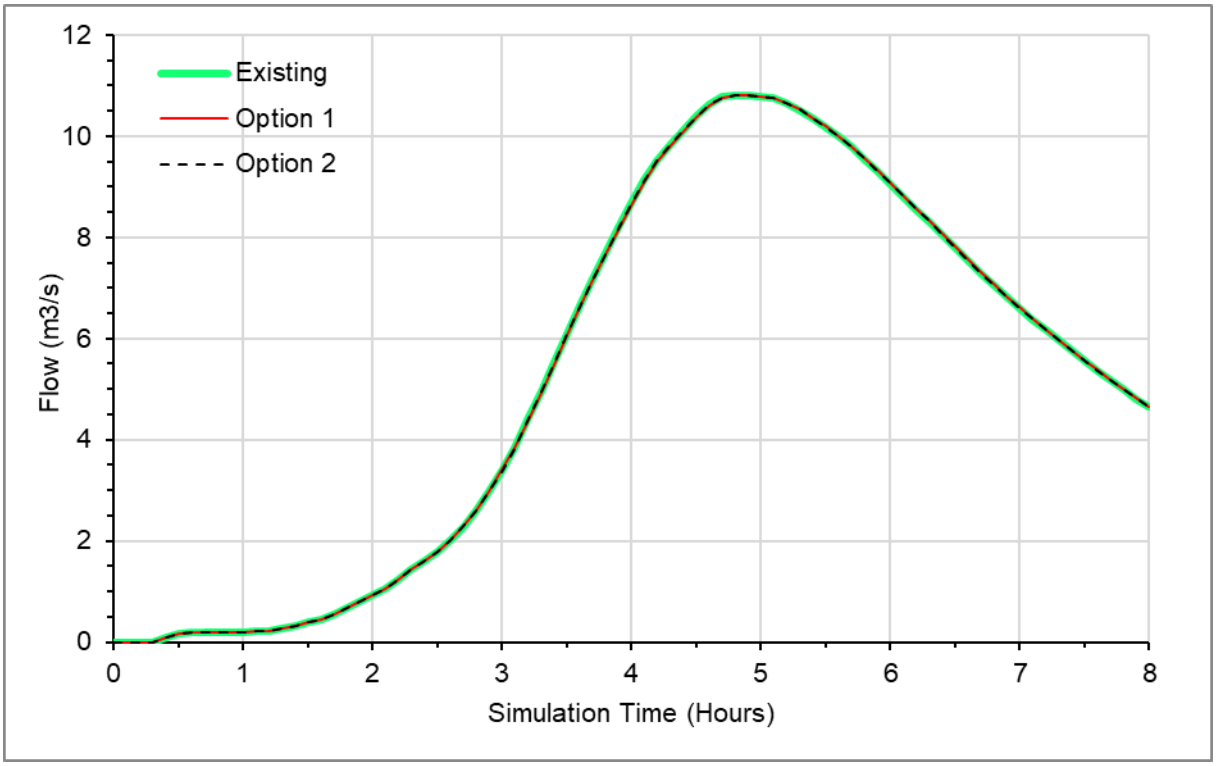


Figure 11: Comparison of Flows Downstream of Crossing



5 Legislative and Policy Aspects

A review of the requirements under National Planning Framework 4 (NPF4) for Option 2 is discussed below.

5.1 NPF4

Based on NPF4, the first principle is avoidance of areas at flood risk from the 1 in 200-year plus climate change flood event. As described in Policy 22, NPF4 does support development in flood risk areas if they fall under a number of exceptions, including for " i. *essential infrastructure where the location is required for operational reasons*".

SEPA Land Use Vulnerability guidance and NPF4 includes 'All forms of renewable, low-carbon and zero emission technologies for electricity generation and distribution and transmission electricity grid networks and primary substations' as 'Essential Infrastructure'. For such sites then development would need to demonstrate that;

a. all risks of flooding are understood and addressed;
b. there is no reduction in floodplain capacity, increased risk for others, or a need for future flood protection schemes;
c. the development remains safe and operational during floods;
d. flood resistant and resilient materials and construction methods are used; and
e. future adaptations can be made to accommodate the effects of climate change

The access track forms part of the essential infrastructure as is assessed against the above in **Table 4**.

Table 4: Comparison with Requirements for Exceptions under NPF4

Requirement under Policy 22 of NPF4	Response
All risks of flooding are understood and addressed	All risks are considered in the FRA with the Green Burn modelled in detail
There is no reduction in floodplain capacity, increased risk for others, or a need for future flood protection schemes	Calculations based on existing proposals suggests a loss of floodplain storage of around 50m^3 to tie the proposed road to the existing main road. The client is in control of land up to approximately 350m upstream of the proposed crossing, so compensatory storage would be able to be provided at the detailed design stage, once there is a final design of the crossing. In this way the road would not decrease floodplain capacity. Water levels and flows are not increased downstream of the site as a result of the proposals, with no increase in flooding at the existing road. Small increases in flood levels are limited to land within the site. No flood protection schemes proposed

The development remains safe and operational during floods	The proposed access track is predicted to flood but safe access/egress from the wind farm is available from other routes.
Flood resistant and resilient materials and construction methods are used	Not required for this development
Future adaptations can be made to accommodate the effects of climate change	Climate change is considered in the design event and modelling

5.2 CAR License

Any crossings or changes to watercourses within the site may require CAR licensing under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR). CAR licenses are not required as part of a planning application and are generally conditioned as part of planning consent.

However, during the planning process sufficient information should be provided in a planning application so SEPA can identify whether it is likely that a CAR license would be granted. It is anticipated that the Green Burn crossing will require a simple license under the CAR Regulations.

Details of crossings and CAR requirements are provided in **Table 1** in **Appendix 9.1**.

6 Summary and Conclusions

Kaya Consulting Limited was commissioned to undertake a Flood Risk Assessment for a new access to the proposed Revised Larbrax Wind Farm.

The proposed access is located off the B738 near Larbrax Moor, approximately 9km to the west of Stranraer in Dumfries and Galloway. The Green Burn flows north, parallel to the B738 at this location.

A 2D model of the Green Burn was constructed using HEC-RAS mathematical modelling software for this assessment utilising surveyed channel cross sections for the nested bathymetry grid.

In the 1 in 200-year plus climate change event, flood waters are predicted to spill from both the left and right banks of the channel, partially inundating the B738. The road at the proposed crossing location was predicted to remain free of flooding.

Two options have been considered and modelled for the proposed crossing. Both options incorporate a bottomless culvert at Green Burn, with a raised access track and bypass culverts in Option 1, and an unraised track in Option 2.

The results of the proposed options modelling show minor increases in peak flood level within the channel and immediately upstream of the track location. There is a minor increase in flooding on the B738 with Option 1, but no increase with Option 2. Neither option show an increase in flows downstream of the crossing.

It is therefore recommended that Option 2 be taken forward for detailed design.

Although Option 2 would not allow for dry access from this location during a flood event, it is understood dry access will be available from the wind farm via alternative routes.

The proposed access track is considered suitable for development in a flood risk area under NPF4 following exception “ i. *essential infrastructure where the location is required for operational reasons,* and can be designed to accommodate the necessary requirements for exception.

It should be noted that the risk of flooding can be reduced, but not totally eliminated, given the potential for events exceeding design conditions and the inherent uncertainty associated with estimating hydrological parameters for any given site.

Technical Appendix 9.5: Outline Peat Management Plan

EAST POINT GEO
An ABL Group Company

Consulting Report

Appendix 9.5 - Outline Peat Management Plan
Revised Larbrax Wind Farm

Dumfries & Galloway, Scotland
Orsted

EPG-034989-D-001v01

12/08/2024

Prepared for
LUC

Client
Orsted

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1. INTRODUCTION

1.1. Background

Orsted (the Applicant) is seeking planning permission under the Town and Country Planning (Scotland) Act 1997 for the construction and operation of the Revised Larbrax Wind Farm Dumfries and Galloway, Scotland (hereafter the ‘Proposed Development’).

The Site for the Proposed Development lies approximately 9 km to the west of Stranraer adjacent to the coastline and is approximately 3.45 km^2 (c. 345 ha) in area (**Error! Reference source not found.Error! Reference source not found.**). Galdenoch Castle is located just outside the Site to the north, Black Hill Wood and White Hill Wood lie to the east and Mill Hill to the south.

The Proposed Development will comprise:

- Four turbines of 149.9 m tip height with associated hardstandings.
- Approximately 2 km of new tracks.
- Approximately 1 km of upgraded tracks.
- One borrow pit.
- One construction compound.
- One substation.

Plate 1.1 Location of the Proposed Development

This Peat Management Plan (PMP) follows guidance (Scottish Renewables & SEPA, 2012) on the assessment of peat excavation and reuse for wind farms in Scotland, and accompanies **Chapter 9:**

Hydrology, Hydrogeology, Geology and Peat of the EIA Report. The PMP was prepared in parallel with a Peat Landslide Hazard and Risk Assessment (PLHRA, **Appendix 9.6**) and is informed by peat depth probing undertaken by Kaya Consulting and documented in **Appendix 9.2**.

1.2. Scope of Work

The scope of the PMP is as follows:

- Summarise the design principles adopted for design of the wind farm with respect to peat soils, including the approach to peat characterisation and the identification of opportunities taken to minimise impacts on peatlands within the Site.
- Calculate the potential volumes of peat and soil that may be excavated in association with wind farm construction, including consideration of acrotelmic and catotelmic peat.
- Identify and justify reuse of acrotelmic and catotelmic peat where it cannot be reinstated at source.
- Identify good practice measures to ensure excavated peat is stored safely and with minimal loss of function prior to its reinstatement.

1.3. Report Structure

This report is structured as follows:

- Section 2 provides an outline of relevant guidance relating to the excavation, storage and reuse of peat.
- Section 3 provides an overview of the Site and proposed wind farm infrastructure based on the scheme described in the main EIA chapters and on desk study review of site information.
- Section 4 describes the approach to and results of peat excavation calculations, and summarises opportunities for reuse of excavated peat soils within the Site.
- Section 5 provides general good practice measures and measures specific to the conditions at the proposed site.

Where relevant information is available elsewhere in the Environmental Impact Assessment Report (EIA), this is referenced in the text rather than repeated in this report.

2. CONTEXT TO PEAT MANAGEMENT

2.1. Peat as a Carbon Store

Priority peatland habitats comprise blanket bog, lowland raised bog, lowland fens, and part of the upland flushes, fens and swamps, as listed in the UK Biodiversity Action Plan (UK BAP). Blanket bog is the most widespread of these habitat types in Scotland, and therefore it is blanket bog that is usually of relevance for proposed developments/wind farms in upland areas.

Blanket bogs in the UK started forming in the early Holocene, with most UK bogs initiating prior to 6,000 years ago under cooler and wetter conditions than at present. Where bogs remain waterlogged and peat forming plant species persist, blanket bog is still considered to be actively forming and accumulating organic matter, and therefore can be considered a carbon sink. A bog that is not losing carbon/peat but is no longer accumulating organic matter can be considered a carbon store, and a degrading bog can be considered a carbon source (Mills et al, 2021).

A peatland may change state between sink, store and source through natural processes or as a result of human activity. The purpose of the peat management plan is to avoid impacts on the peat carbon stores at wind farm sites by avoiding peat, where possible, or by minimising impacts where peat cannot be avoided. Where there are opportunities to improve peat condition, e.g. through restoration, and in so doing, help convert carbon sources into stores or sinks, this may also be facilitated by the peat management plan (usually in conjunction with the Habitat Management Plan).

2.2. Good Practice Guidance

Where peat is to be excavated in association with built infrastructure, it may be considered to be a waste product under the following legislation:

- Environmental Protection Act 1990 (as amended).
- Landfill (Scotland) Regulations 2003 (as amended).
- The Waste Management Licensing (Scotland) Regulations 2011.

In order to address this legislation, a number of guidance documents have been issued to assist applicants in responsibly planning, installing and operating infrastructure in peatland settings. This PMP has been informed by this collective good practice, which includes the following documents:

- Good Practice during Wind Farm Construction, Version 4 (Scottish Renewables, Scottish Natural Heritage, Scottish Environmental Protection Agency, Forestry Commission Scotland, 2019).
- Developments on Peat and Off-Site Uses of Waste Peat, WST-G-052 (SEPA, 2017).
- Peatland Survey. Guidance on Developments on Peatland (Scottish Government, Scottish Natural Heritage and SEPA, 2017a).
- Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments (Second Edition) (Scottish Government, 2017).
- Carbon and Peatland 2016 Map (GIS) (Scottish Natural Heritage, 2016a).
- Carbon-rich Soils, Deep Peat and Priority Peatland Habitat Mapping, Consultation Analysis Report (Scottish Natural Heritage, 2016b).
- Scotland's National Peatland Plan - Working for our future (Scottish Natural Heritage, 2015a).
- Constructed Tracks in the Scottish Uplands, 2nd Edition (Scottish Natural Heritage, 2015b).

- Developments on Peatland: Guidance on the assessment of peat volumes, reuse of excavated peat and the minimisation of waste (Scottish Renewables and SEPA, 2012).
- Floating Roads on Peat - A Report into Good Practice in Design, Construction and Use of Floating Roads on Peat with particular reference to Wind Farm Developments in Scotland (Scottish Natural Heritage and Forestry Commission Scotland, 2010).

In general terms, the guidance considers appropriate activities to be undertaken at the planning (Environmental Impact Assessment), post-consent/pre-construction and construction stages. The overarching principles are generally the same across the different guidance documents and are set out below.

During planning (EIA):

i. Determine at a sufficient level of detail the distribution of peat within a site in order to assess the likely level of impact of proposed works.

ii. Calculate the volumes of peat likely to be excavated during construction.

iii. Demonstrate how excavated peat will be managed (ii and iii together comprising an assessment of the "peat and soil balance").

These activities are normally considered within a PMP, delivered as part of the Environmental Impact Assessment at the planning stage.

Assuming planning permission is granted, during the pre-construction period:

i. A refined peat and soil mass balance should be calculated through further site investigation works (including intrusive works such as detailed probing across final infrastructure footprints and/or trial pits to verify the nature of probed materials).

ii. Further detailed topographic survey and design level excavation, storage and reuse plans should be drafted to enable contractors to bid for and implement the works.

iii. Key good practice measures should be identified within the PMP that integrate with other related plans or control documents for construction, including, where applicable, the Construction Environmental Management Plan, Site Waste Management Plan, Habitat Management Plan (where relevant) and Geotechnical Risk Register.

During the construction stage:

i. Utilise micro-siting to optimise infrastructure locations relative to final pre-construction information gathered on site.

ii. Monitor, adjust and implement the PMP to accommodate deviations in expected peat volumes and adapt reuse measures to actual site volumes.

iii. Set-up monitoring programmes to identify the new post-construction baseline and provide a basis for monitoring the success of the PMP and identify appropriate mitigation where necessary.

Through the different stages of the project, the strategy should be to prevent disturbance to and losses of peat through appropriate reuse, wherever possible.

2.3. Approach at the Revised Larbrax Wind Farm

The strategy for peat management for the Proposed Development follows SEPA's guidance for developments on peat and uses of waste peat (SEPA, 2017) and aligns with National Planning

Framework 4, Soils, Policy 5 in employing the mitigation hierarchy with respect to carbon-rich soils and peatlands. The hierarchy is as follows:

- **Prevent** the creation of waste peat by minimising overlap of infrastructure with peat, where it is possible to do so, and given other site and design constraints that may influence turbine locations and associated infrastructure (such as tracks).
- **Reuse** peat on site in construction, reinstatement or in restoration (restoring off-site will require environmental authorisation).
- **Recycle** as a soil substitute or for use in other works (where on-site or off-site use in restoration is not possible).

Disposal of peat (i.e. export from the site as waste) is no longer considered an acceptable outcome for materials generated during construction.

At Larbrax, prevention has formed the primary peat management strategy with reuse for restoration being proposed in a small area of the Site. Outline details of this strategy are provided below, and full detail of excavation, reuse and restoration proposals are provided in Section 4.

2.3.1. Prevent

Prevention involves minimising the amount of peat excavated during construction by informed layout planning. The extent to which this is possible is not just a function of the amount of peat on site, but also of the presence of other constraints (e.g. landscape visual impacts, hydrology, terrestrial ecology) and the practical requirements of wind farm construction (e.g. minimum turbine spacings, acceptable gradients for tracks / hardstandings).

At Larbrax, peat is relatively limited in extent, and therefore efforts have been made to minimise overlap as far as possible. This has resulted in:

- All turbines and hardstandings avoiding peat.
- All tracks avoiding peat, with the exception of very minor overlap on a corridor of thin peat / organic soil between Larbrax Moor and an adjacent valley floor mire to the north, one turning head on the approach to Turbine 1 and the junction access to the public road.
- All ancillary infrastructure avoiding peat, with the exception of a very minor pocket of peat under the proposed borrow pit.

As a result, the proposed layout has prevented peat excavation over most of its footprint.

2.3.2. Reuse / restoration

The volume of peat proposed for excavation is minimal (see Section 4). While peat cuttings are relatively widespread in peat covered parts of the site, for the most part they are too distant from proposed infrastructure to access with machinery and therefore peat cannot be translocated to these locations. A small peat cutting is present adjacent to a proposed track, and all peat excavated from elsewhere on site will be used to restore this cutover area.

All non-peat materials will be used to reinstate / tie-in proposed infrastructure to the surrounding landscape in line with Good Practice guidance detailed in Section 2.1 and from wider good practice approaches developed as part of wind farm construction.

This is considered in further detail in Section 4.

2.3.3. Disposal

There will be no disposal of peat as part of the Proposed Development.

3. BASELINE CONDITIONS

3.1. Site Overview

The Site rises from the coastline on the western site boundary over cliffs and undulating slopes to straddle Larbrax Moor in the south and Galdenoch Moor in the north. The moors occupy largely flat terrain situated between the coastal hills in the west of the Site and a series of hill summits outside and to the east of the Site. The main peaks are Larbrax Moor at 83 m AOD and Hind Hill on Galdenoch Moor at 82 m AOD (Figure 9.5.1). Plate 3.1 provides a perspective view of the Site showing the main features.

The majority of the slopes in the east of the site are gentle (>2.5°) with some isolated steep slopes around Hind Hill and Larbrax Moor. The majority of the slopes in the west of the site, closer to the coast, are steeper (2.5° - 10°). The peak slopes occur on the cliffs at the coast, with some exceeding 30°. The maximum slope near the infrastructure is 15° (see Figure 9.5.2). There are ample areas of non-peat covered terrain on gentle slopes on which to temporarily store excavated materials.

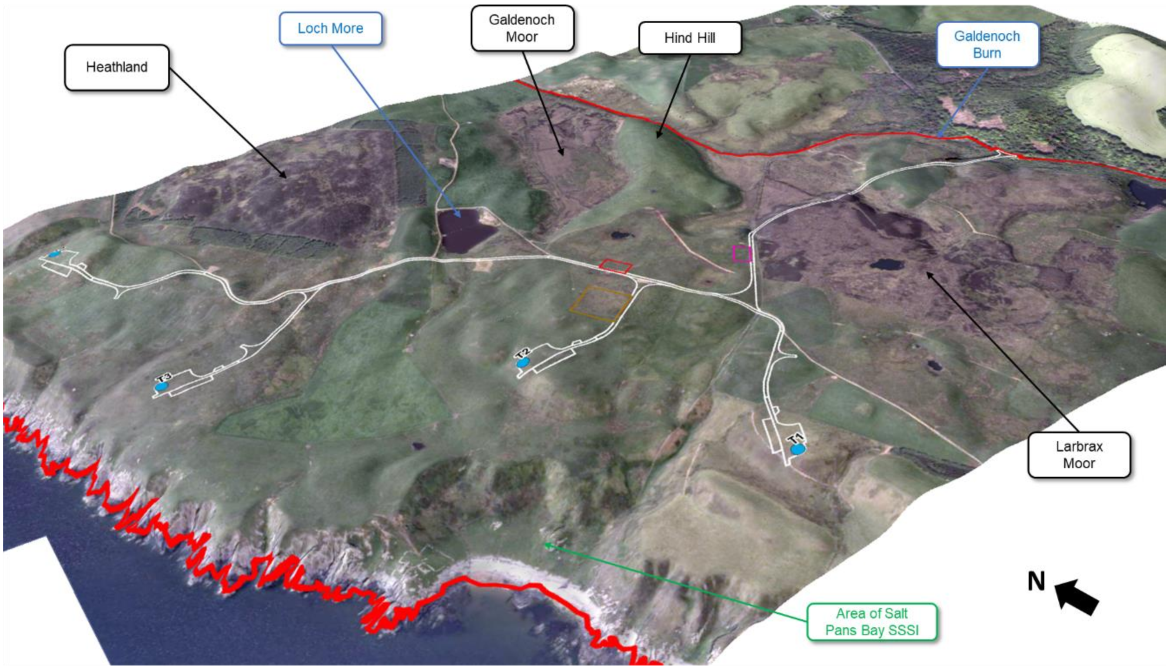

Plate 3.1 Perspective view of site (2x vertical exaggeration). © 2024 Microsoft Corporation © 2018 DigitalGlobe © CNES (2018) Distribution Airbus DS

There are three main peatland units within the Site: Galdenoch Moor, Larbrax Moor and a narrow valley mire that sits below Larbrax Moor and Hind Hill. Both Galdenoch Moor and Larbrax Moor have been subject to peat cutting in the past, while Galdenoch Moor has also been cut by a number of artificial moor drains. Most of the moorland is characterised by heather. There is a relatively large area of heather-dominated heath in the north of the site, but peat depths here are minimal.

Land use is predominantly for livestock grazing in non-moorland areas of the Site.

Section 3 of the PLHRA (**Appendix 9.6**) provides a more detailed account of site conditions.

3.2. Peat Depth

Peat depth probing was undertaken in multiple phases in accordance with Scottish Government (2017) guidance. A peat survey report (**Appendix 9.2**) documents the findings of these site investigations:

- Phase 1 probing was undertaken on a 100 m grid in July 2023 and comprised 224 probes (this number including initial probing undertaken by AECOM in 2013 for the Consented Larbrax Wind Farm).
- Phase 2 probing was undertaken in May 2024 at 50 m intervals with 10 m offsets along tracks, on a 10 m grid within turbine footprints closer to the main peat deposits and 20 m grids on steeper slopes where peat was generally absent.
- An additional set of Phase 2 probing was undertaken to inform alternative access track layouts following a decision to avoid peat so far as possible on Larbrax Moor. The two sets of Phase 2 probing comprised a further 1,134 probe locations in total.
- In total 1,358 probes and 9 cores were collected. All cores (which were taken in non-peat locations at turbines, the substation, borrow pit and construction compound) showed a clay substrate.

Interpolation of peat depths was undertaken in the ArcMap GIS environment using a natural neighbour approach. This approach was selected because it preserves recorded depths at each probe location, unlike some other approaches (e.g. kriging), is computationally simple, and minimises 'bullseye' effects. The approach was selected after comparison of outputs with three other methods (inverse distance weighted, kriging and TIN). Figure 9.5.3 shows the interpolated peat depth model, with probing locations superimposed. A summary of peat distribution is provided below.

- Peat is generally present in the eastern half of the Site on the gentle terrain east of the cliffs and hills.
- The deepest deposits are found in Galdenoch Moor and in a similar valley mire to the south on the opposing side of Hind Hill. Shallower deposits (but still in excess of 1.0 m in depth) are found on Larbrax Moor. Deep deposits are also present in the valley draining Loch Beg in the far north of the surveyed area, though these appear to be confined to the narrow valley floor.
- Peat thins rapidly out of the flat valley floors within which Galdenoch Moor and the adjacent valley mire are located.

Comparison of the peat depth model with the layout indicates that significant efforts have been made during layout design to site infrastructure out of areas of peat. None of the four turbines are located in peat soil, with only two probes showing peat within the area of the proposed borrow pit. There is very minor overlap with peat on the edge of Larbrax Moor where the access track along a gentle sideslope separating Larbrax Moor from the unnamed valley mire below, while the turning head for Turbine 1 also overlaps a small pocket of peat.

3.3. Peat Geomorphology and Condition

A detailed account of peat geomorphology is provided within the PLHRA (**Appendix 9.6**) based on geomorphological mapping of the site from satellite imagery and subsequent field walkover and verification. The geomorphology as relevant to peat excavation and reuse can be summarised as follows:

- Where present, peatland comprises relatively featureless heather-dominated terrain with limited / no natural erosion features or areas of bare peat. Therefore there are very limited opportunities to undertake restoration of erosion features.
- Artificial cuttings are relatively widespread, however the entire ground surface has been lowered over large areas and there are relatively few upstanding ‘baulks’ left remaining between which to infill.
- While moor drains are present, mainly on Galdenoch Moor, they are not widespread and are generally well vegetation (if probably still functional).

The Carbon and Peatland 2016 Map indicates Galdenoch Moor and Larbrax Moor to comprise Class 1 peatlands. These are described as “nationally important carbon-rich soils, deep peat and priority peatland habitat”. Around the fringes of these moors the deposits are Class 5 which are classed as peat soil but with no peatland vegetation. The area to the north of Loch Mare correspond to Class 3, where the soils are “predominantly peaty soil with some peat soil” and the “dominant vegetation cover is not priority peatland but is associated with wet and acidic type”.

4. PEAT EXCAVATION AND STORAGE

4.1. Excavation calculations

The majority of infrastructure comprising the Proposed Development will require full excavation of the peat or soils underlying the infrastructure footprints during construction. However, some infrastructure is not required post-construction (the construction compound, blade laydowns and working areas) and the peat excavated from these areas will be directly reinstated. In this section, the following terms are used to describe groundworks associated with peat / soil and wind farm infrastructure:

- **Permanently excavated:** peat will be permanently removed from the infrastructure footprint, stored locally and reused elsewhere.
- **Temporarily excavated:** peat will be temporarily removed from the infrastructure footprint, stored locally and fully reinstated at the point of excavation post-construction.
- **Landscaping:** the process of using peat to 'dress' the boundaries of infrastructure.
- **Restoration:** the use of excavated materials to improve the quality of land areas that are considered degraded through mechanisms other than associated with wind farm construction (e.g. through cutting or erosion); the term is not used to describe reinstatement activities at infrastructure.

Excavation volumes have been calculated as the product of the average peat depth under each footprint (derived from the peat model) and the indicative footprint area (detailed for each infrastructure type below). Earthworks footprints are included in the calculations, with the assumption that areas of both cut and fill earthworks will require removal of top soil / peat prior to placement of fill materials or in order to achieve the desired ground surface for cuts.

Functional peatlands in the uplands are characterised by a two-layer hydrological system of acrotelmic peat overlaying catotelmic peat. The acrotelm is the upper, less humified layer of a peatland, within which the water table fluctuates seasonally, while the catotelm is a more humified, permanently saturated layer of very low permeability containing the majority of the carbon store.

For each infrastructure item, the upper 0.3m of the peat profile is assumed to be acrotelm and any remaining depth is assumed to be catotelm. A 0.3m thickness of turf and underlying peat is a sufficiently thick continuous layer to avoid damaging the roots of the excavated vegetation and provide a coherent ‘turf’ to relay.

Soils less than 0.5m in depth are assumed to be organic (or other) soils other than peat and are classed as 'soil' for the purposes of this assessment.

4.1.1. Turbines, hardstandings, secondary crane pads and blade lay downs

Each turbine location will comprise a permanent circular turbine foundation nested within a main hardstanding (up to 64 m x 32 m), and a temporary hardstanding for blade laydowns set within a wider working area (14 m x 70 m). One temporary secondary hardstanding is proposed of c. 18 m x 8 m. All footprints will be fully excavated to substrate and replaced with coarse aggregate. The permanent hardstandings must remain in place for routine maintenance and decommissioning.

Plate 4.1 shows the layout for these infrastructure components.

The permanently excavated volumes for turbines and main hardstandings are based on each infrastructure footprint multiplied by the average peat depth determined from detailed infrastructure probing (see Figure 9.5.3). Temporarily excavated volumes for the blade laydowns and earthworks are calculated in the same way.

Table 4.1 shows excavation volumes.

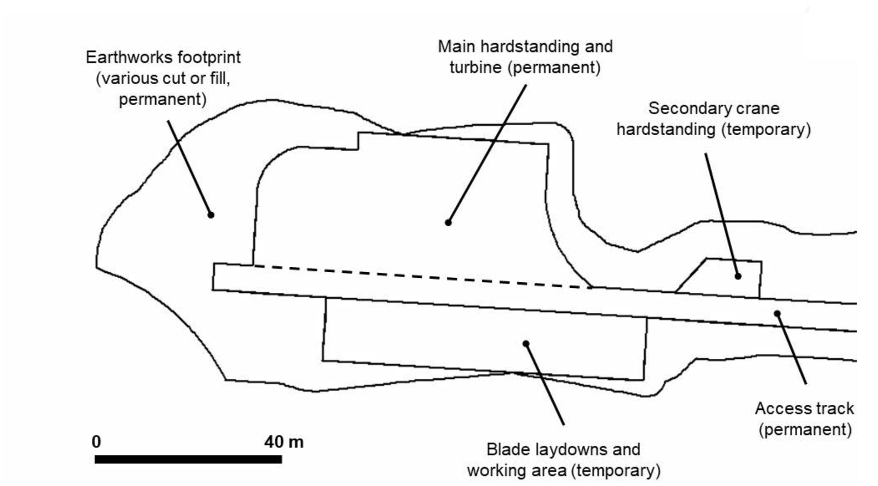

Plate 4.1 Indicative layout for turbines, hardstandings and track and indicative peat batter extent (see section 4.2)

4.1.2. Access tracks

Access tracks comprise a 6 m wide running surface and will be of cut and fill construction. While floating tracks were considered for the Proposed Development, there is only one section of track that fully overlaps peat for a distance exceeding 50 m, this being a c. 65 m section on the approach to the B738 at the main site access. This length is already short for consideration as floating track (since transition lengths are needed into and out of each-section), but given the need to avoid differential settlement between the main highway and on-site track, the decision was made to adopt a non-floating multi-culvert construction methodology in this location (in part to mitigate flood risk).

Table 4.1 shows excavation volumes.

4.1.3. Cable trenches

Cable trenches are to be excavated alongside access tracks and all peat excavated prior to cable placement will be directly reinstated after installation. Reinstatement is likely to be undertaken immediately after installation with very short-term sidecasting of materials, and therefore peat disturbed in this activity is not considered in the overall peat mass balance calculations.

4.1.4. Construction compound

The construction compound (50 m x 30 m) will provide storage for site plant and materials and will be reinstated post-construction. Therefore it is temporarily excavated, with all excavated peat stored locally and reinstated. The associated excavation volumes are shown on Table 4.1

4.1.5. Substation

The substation will be permanently excavated to substrate over a footprint of c. 50 m x 30 m. The excavated peat volume based on detailed probing is shown in Table 4.1.

4.1.6. Summary

Table 4.1 shows the excavation volumes for Proposed Development infrastructure separated into acrotelmic peat, catotelmic peat, total peat and soil.

Figures are quoted to 1 m^3 to avoid rounding errors leading to inaccurate totals in later tables rather than to imply accuracy of calculations to 1 m^3. Due to the careful avoidance of peat areas by iterative layout design, the total volume of peat to be excavated is c. 1,577 m^3. For context, an individual turbine main hardstanding and foundation, if set within 1.0 m depth of peat, would generate >2,000 m^3 of peat alone, therefore to excavate less than this amount across the full infrastructure is evidence of a very peat-sensitive approach to design.

Infrastructure	Type of Excavation	Excavation Volume (m^3)			
		Acrotelm	Catotelm	Total Peat	Soil
Access tracks	Cut & Fill	378	811	1,189	2,740
Turbine foundations and main hardstandings	Permanently excavated	0	0	0	961
Blade laydowns and 2nd crane hardstandings	Temporarily excavated	0	0	0	315
Substation	Permanently excavated	0	0	0	154
Construction Compound	Temporarily excavated	0	0	0	455
Borrow pit	Temporarily excavated	46	92	138	737
Earthworks	Permanently excavated	97	153	250	2,267
	Totals	**521**	**1,056**	**1,577**	**7,630**

Table 4.1 Peat excavation volumes for all infrastructure

The next section describes reuse proposals for peat and soil excavated during construction.

4.2. Reuse

4.2.1. Peat

Excavated peat will be re-used to reinstate what appears to be a cutover area adjacent to the temporary construction compound and on the north side of Larbrax Moor. The cutover area comprises a large embayment adjacent to a walled boundary on very gentle slopes. The boundary of the area, although well vegetated with heather, features a pronounced step up onto the surface of Larbrax Moor behind it. Peat is largely absent within the embayment but up to 1.0 m deep in the planar terrain behind. The position of the cutover area is shown opposite the temporary construction compound on Plate 4.2.

A new track will be constructed on the opposing side of the existing wall and will pass the temporary construction compound. This will facilitate movement of excavated materials from their respective sources to the proposed reuse area.

The reuse proposals are to place an average depth of 0.85 m of peat into the cutover area, set behind a mineral berm of equivalent height. This will re-extend Larbrax Moor to the wall, where it is likely it was originally present. The total area available for peat reuse is 1,900 m^2, which, at a depth of 0.85 m, will hold the full volume of peat excavated (1,577 m^3, from Table 4.1), including that which has been temporarily excavated and may be less viable placed back in its original location. Based on the excavation calculations, an area of c. 1,735 m^2 of acrotelmic peat (equivalent to c. 521 m^3 in volume) will be available for reinstatement, and therefore nearly the full cutover area can be reinstated with acrotelmic material (under which catotelmic material will placed).

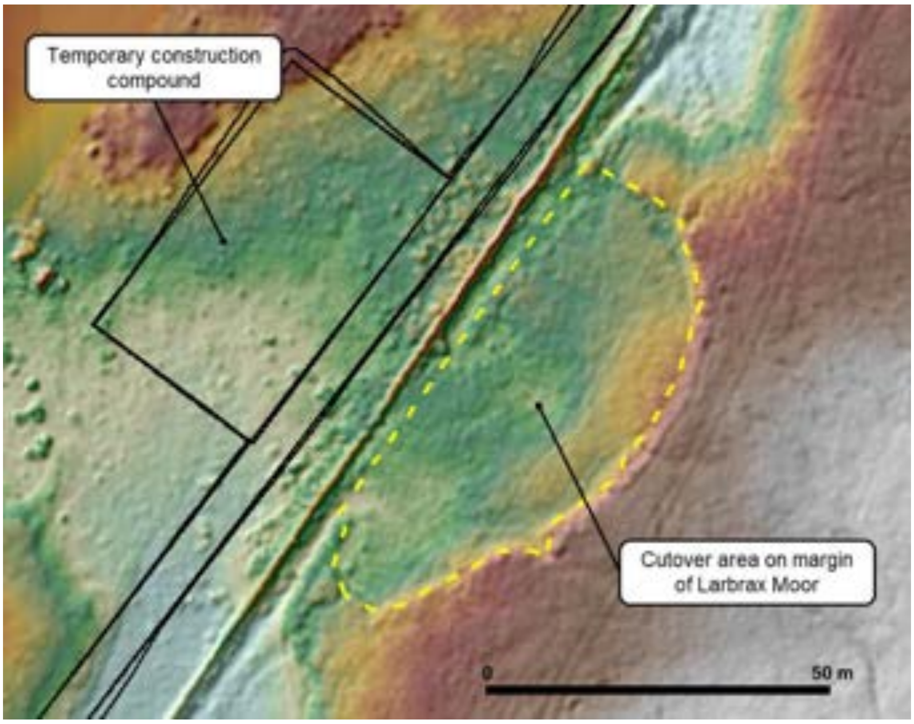

Plate 4.2 Location of proposed reuse area

Because the proposed reuse area lies slightly below the top of Larbrax Moor, shedding of water to the northwest should help maintain water flows to the newly restored peatland area.

4.2.2. Soil

Due to the relatively thin soils present across much of the Site, the overall soil volume proposed to be excavated is c. 7,630 m^3. Excavated soils will either be reinstated within their original locations (temporary construction compound, blade laydowns and secondary hardstandings, borrow pit) or used to tie-in (or landscape) the surroundings of infrastructure by providing a vegetated top surface to areas of earthwork cut and fill.

Based on the earthwork footprints shown on Figure 9.5.3, there is a total area of c. 25,130 m^2 requiring tying in or landscaping. If distributed equally across the full extent of earthwork cut and fill, the average soil reuse depth would be c. 0.24 m, which is sufficient soil depth to maintain a rooting medium for vegetation found in non-peatland areas of the site.

4.3. Summary

The volumes of peat and soil materials to be reused are summarised in Table 4.2, in line with the proposals above.

Type of restoration	Restoration Volume (m^3)			
	Acrotelm	Catotelm	Total	Soil
Restoration of cutover area adjacent to temporary construction compound	521	1,056	1,577	0
Direct soil reinstatement in temporary infrastructure locations	0	0	0	1,507
Reuse of soil for tying in earthworks	0	0	0	6,123

Table 4.2 Estimated volumes of peat required for peat restoration

4.4. Peat Balance

The peat and soil balance for the Proposed Development is shown in Table 4.3 below. The table indicates that there is sufficient room within the cutover area to be restored to appropriately reuse all excavated peat.

There is also sufficient surface area across all earthworks to accommodate any soils not directly reinstated within temporary infrastructure locations.

Activity	Peat Balance (m^3)		
	Acrotelm	Catotelm	Total
Total excavation during construction (Exc. Vol.)	521	1,056	1,577
Total re-use in restoration of cutting (Re-use Vol.)	521	1,056	1,577
Peat mass balance (Exc. Vol. - (Re-use Vol. + Rest. Vol.))	**0 (Balance)**	**0 (Balance)**	**0 (Balance)**

Table 4.3 Peat mass balance

The next section summarises good practice for excavation, handling, storage re-use and monitoring associated with peat excavations at the Proposed Development.

4.5. Recommended storage locations

Where possible, in order to avoid multiple handling of peat, excavated materials will be transported directly to their point of reuse. Where this is not possible, for example due to construction phasing e.g. a requirement to temporarily store adjacent to working areas prior to reinstatement, storage will be required locally. In these cases, it is important to ensure peat is stored safely with minimal risk of instability of stored materials while they are kept in good condition prior to reinstatement. Section 5 provides good practice advice on peat storage.

5. GOOD PRACTICE

5.1. Background

Good practice measures in relation to peat excavation and reuse are now generally well defined following a number of years of practice (at wind farm sites) across the UK and Ireland. In Scotland in particular, there is an increasing body of experience relating to peat restoration, facilitated by Peatland Action (Scottish Natural Heritage, 2017). As a result, there are a number of specialist contractors who have experience in the planning, design and implementation of peat restoration works in the Scottish uplands. A key step in delivering the restoration proposals described above is identification of appropriate contractors to implement the restoration plans at each location.

The sections below outline good practice measures related to excavation and handling, storage, and reinstatement and restoration of peat in association with wind farm construction.

5.2. Excavation and handling

The following good practice measures are proposed for excavation and handling:

- A minimum thickness of 300 mm of acrotelmic peat or turved organic soil should be excavated where sufficient soil is present; where less than 300 mm is present, the full depth of soil and surface vegetation should be excavated.
- Excavation and transport of peat/soil shall be undertaken to avoid cross-contamination between soil horizons (e.g. organic soil and underlying mineral soil / substrate).
- Where possible, cross-tracking of plant over undisturbed vegetation should be minimised, and excavated materials transported to their storage locations along constructed track.
- If working is required away from constructed roads / tracks, the use of long reach excavators should be encouraged in order to minimise cross-tracking.
- If landscaping of road / track margins is required for temporary works, it is preferable for vegetated organic soils to be used for this purpose rather than acrotelmic peat (which should be stored).
- Wherever possible, double handling of peat should be minimised (in particular for catotelmic peat) by direct transport of materials to their point of storage.

5.3. Storage

The following good practice measures are proposed for storage:

- Eliminate storage where possibly by single handling from the point of excavation to a location of reuse.
- If storage cannot be avoided, minimise storage time by taking a holistic approach to excavation and restoration such that catotelmic peat (in particular) is used as soon as possible after excavation.
- Store excavated acrotelmic and catotelmic peat separately during excavation works, which will be undertaken by an experienced contractor specialising in peat groundworks and restoration.
- Acrotelmic peat and turved soil blocks should be stored turf side up to prevent damage to vegetation.

- Storing in areas of minimal gradient where 'runoff' or drainage away from the point of storage is minimised (these areas will also satisfy to avoid areas of lower stability)
- Fewer, larger stores will be preferable to a greater number of small stores, since the total potential area of drying surface will be less.
- Where storage is required in the medium term, preparing the peat to minimise the surface exposed to drying (e.g. through blading off of catotelmic peat and use of appropriate cover to minimise moisture loss).
- The Ecological Clerk of Works (ECoW) should work with an appointed Geotechnical Engineer (GE) to review the placement and condition of stored peat.
- Storage areas should be outside any area identified in the PLHRA as of 'Moderate' or greater natural likelihood (see Appendix 9.6) and should be more than 50 m away from watercourses, away from sensitive habitats and away from the edge of excavations.
- Peat and soil stores should be appropriately bunded to prevent risks from material instability and prevent runoff of sediment and water from the stockpiles
- The condition of the excavated peat, in particular its moisture content, should be regularly monitored and local water utilised to periodically 'refresh' stored peat and prevent desiccation.
- A Sustainable Drainage System (SuDS) should be implemented to control water and sediment loss during storage (this also applies to reinstated areas, see below).

5.4. Reinstatement and Restoration

The following good practice measures are proposed for reinstatement and restoration:

- Where possible, turves and underlying catotelmic peat should be reinstated at the locations from which they were removed.
- Any bare peat exposed at the surface of a reinstated area should be seeded with a seed mix or translocated vegetation appropriate to the locality.
- Where insufficient turves are available to full cover reinstated soils, a checkerboard pattern of turf blocks should be used, with turf squares no less than 1 m^2 to act as seed points interspersed amongst the bare areas.
- Reinstated ground levels should tie in with the surrounds, and any bulking up should be avoided by tamping down soils and turves.
- If appropriate, temporary fencing may be required to enable vegetation to establish following reinstatement works and prevent damage by livestock, deer or rabbits.

5.5. Monitoring

During construction, monitoring should be undertaken in any areas where peat is stored, as follows:

- Regular visual inspection of the outer peat surface of any stored peat to identify any evidence for drying or cracking.
- Regular coring of stored peat to log the moisture content of stored peat (using the von Post scale to monitor changes in moisture content for peat on the outside and within the peat mound).

- Clear specification of an action plan in response to these observations, including modifications to coverings, implementation of watering, or construction of temporary berms to retain water in the storage footprint.
- Acceleration of re-use for vulnerable stores if so identified.

Key to the success of the strategy for peat management will be careful monitoring of the post-construction works and any restoration activities. A monitoring programme should be initiated once restoration and peat reinstatement works have been completed, and should include:

- Review of % vegetation cover and vegetation composition in areas of bare peat that have been reinstated or in any areas that have been seeded (due to a lack of available turved material).
- Review of stability of deposits in their new locations.
- Fixed point photography in order to aid review over a series of monitoring intervals.

If required, mitigation recommendations should follow from the monitoring and include:

- Specification of seeding appropriate to the target vegetation or stabilisation with geotextile if revegetation is not occurring naturally (which will assist re-wetting and retention of moisture contents).
- Construction of wood dams (or equivalent) if any creep of peat soils is evident at any restored location.

Monitoring should be carried out for a minimum of five years after construction and reinstatement works have concluded.

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EIA Report
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Figure 9.5.1 Elevation

Site boundary	
PLHRA Extent	
Turbine	
Hardstanding temporary	
Hardstanding permanent	
Temporary borrow pit	
Temporary construction compound	
Substation/battery storage	
Track to be upgraded	
Proposed new track/access junction	
Tree/scrub removal	
New watercourse crossing	
Existing (upgraded) watercourse crossing	

Elevation (m)

0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
>=100

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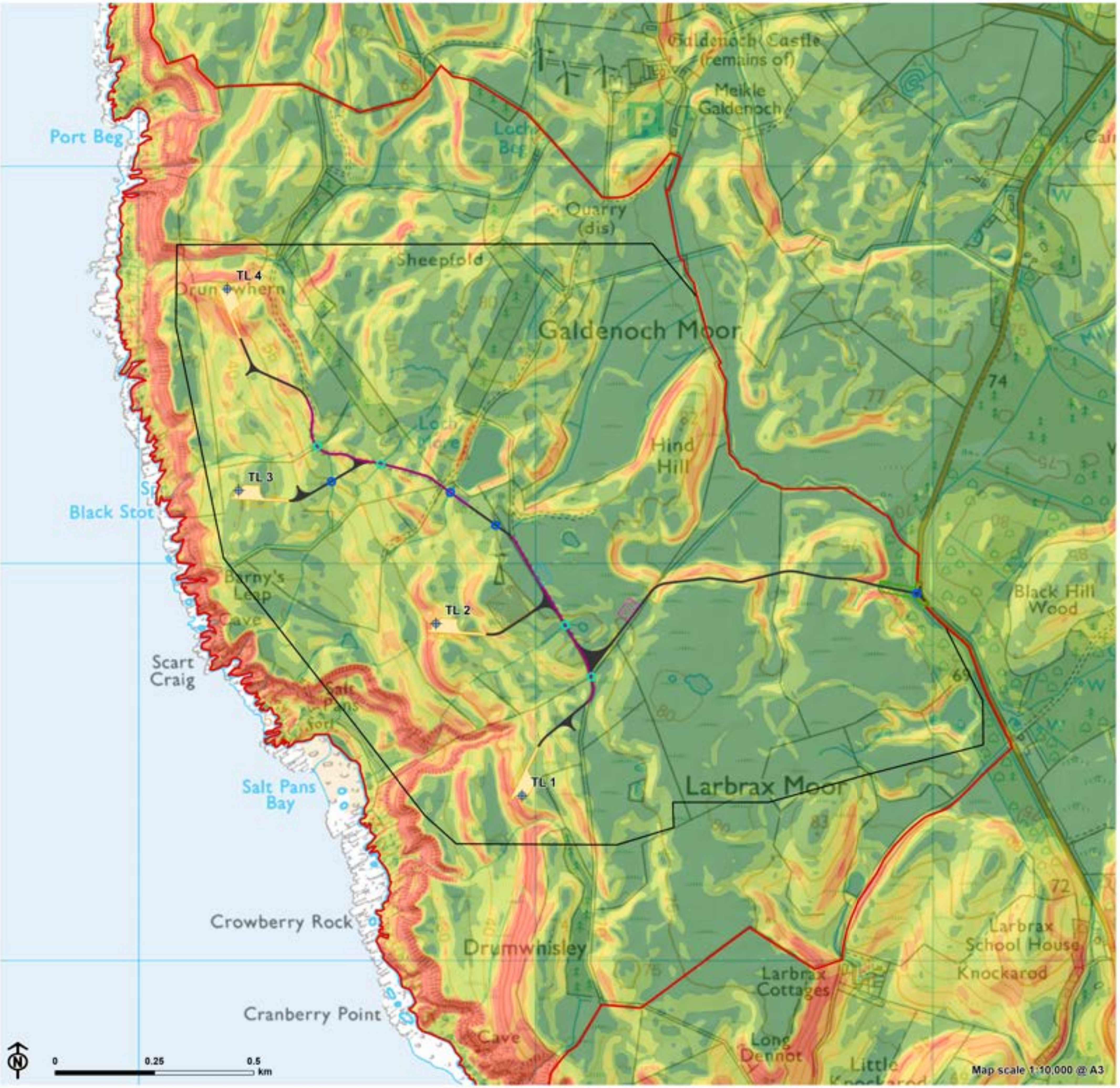
LUC

Figure 9.5.2 Slope



- Site boundary
- PLHRA Extent
- Turbine
- Hardstanding temporary
- Hardstanding permanent
- Temporary borrow pit
- Temporary construction compound
- Substation/battery storage
- Track to be upgraded
- Proposed new track/access junction
- Tree/scrub removal
- New watercourse crossing
- Existing (upgraded) watercourse crossing

Slope (°)

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

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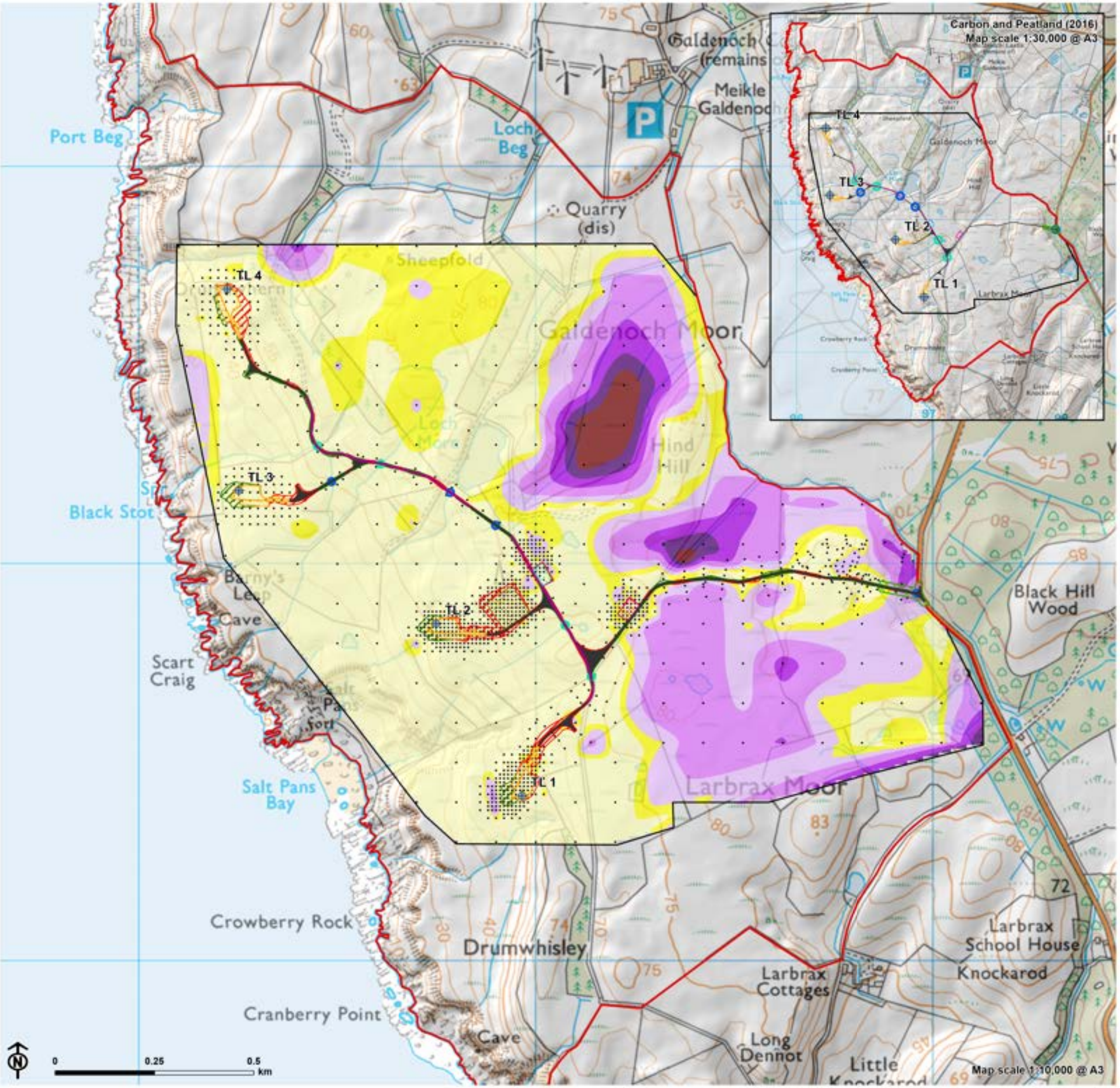
Figure 9.5.3 Peat Depth



	Site boundary
	PLHRA Extent
	Turbine
	Hardstanding temporary
	Hardstanding permanent
	Temporary borrow pit
	Temporary construction compound
	Substation/battery storage
	Track to be upgraded
	Proposed new track/access junction
	Tree/scrub removal
	New watercourse crossing
	Existing (upgraded) watercourse crossing
	Earthwork (Cut)
	Earthwork (Fill)

Peat Depth (m)

- <= 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- > 4.0
- Peat Depth Probes

Carbon and Peatland (2016) Map (Inset)

- Non-soil
- Unknown soil type
- Mineral soil
- Class 1
- Class 2
- Class 3
- Class 4
- Class 5

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Technical Appendix 9.6: Peat Landslide Hazard and Risk Assessment

Consulting Report

Appendix 9.6 - Peat Landslide Hazard and Risk Assessment
Revised Larbrax Wind Farm

Dumfries & Galloway, Scotland
Orsted

EPG-034989-001-01

09/08/2024

Prepared for
Land Use Consultants

Client
Orsted

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1. INTRODUCTION

1.1. Background

Orsted (the Applicant) is seeking planning permission under the Town and Country Planning (Scotland) Act 1997 for the construction and operation of the Revised Larbrax Wind Farm, Dumfries and Galloway, Scotland (hereafter the ‘Proposed Development’).

The Site for the Proposed Development lies approximately 8 km to the west of Stranraer adjacent to the coastline and is approximately 3.45 km^2 (c. 345 ha) in area (Plate 1.1**Error! Reference source not found.**). Galdenoch Castle is located just outside the Site to the north, Black Hill Wood and White Hill Wood lie to the east and Mill Hill to the south.

The Proposed Development will comprise:

- Four turbines of 149.9 m tip height with associated hardstandings.
- Approximately 2 km of new tracks.
- Approximately 1 km of upgraded tracks.
- One borrow pit.
- One construction compound.
- One substation.

Plate 1.1 Proposed location of Larbrax wind farm

The Scottish Government Best Practice Guidance (BPG) provides a screening tool to determine whether a peat landslide hazard and risk assessment (PLHRA) is required (Scottish Government, 2017). This is in the form of a flowchart, which indicates that where blanket peat is present, slopes exceed 2° and proposed infrastructure is located on peat, a PLHRA should be prepared. These conditions exist at the Proposed Development site and therefore a PLHRA is required.

1.2. Scope of Work

The scope of the PLHRA is as follows:

- Characterise the peatland geomorphology of the site to determine whether prior incidences of instability have occurred and whether contributory factors that might lead to instability in the future are present across the site.
- Determine the likelihood of a future peat landslide under natural conditions and in association with construction activities associated with the Proposed Development.
- Identify potential receptors that might be affected by peat landslides, should they occur, and quantify the associated risks.
- Provide appropriate mitigation and control measures to reduce risks to acceptable levels such that the Proposed Development is developed safely and with minimal risks to the environment.

The contents of this PLHRA have been prepared in accordance with the BPG, noting that the guidance "*should not be taken as prescriptive or used as a substitute for the developer's [consultant's] preferred methodology*" (Scottish Government, 2017). The first edition of the Scottish Government Best Practice Guidance (BPG) was issued in 2007 and provided an outline of expectations for approaches to be taken in assessing peat landslide risks on wind farm sites. After ten years of practice and industry experience, the BPG was reissued in 2017, though without fundamental changes to the core expectations. A key change was to provide clearer steer on the format and outcome of reviews undertaken by the Energy Consents Unit (ECU) checking authority and related expectations of report revisions, should they be required.

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

i. An assessment of the character of the peatland within the application boundary including thickness and extent of peat, and a demonstrable understanding of site hydrology and geomorphology.

ii. An assessment of evidence for past landslide activity and present-day instability e.g. pre-failure indicators.

iii. A qualitative or quantitative assessment of the potential for or likelihood of future peat landslide activity (or a landslide susceptibility or hazard assessment).

iv. Identification of receptors (e.g. habitats, watercourses, infrastructure, human life) exposed to peat landslide hazards; and

v. A site-wide qualitative or quantitative risk assessment that considers the potential consequences of peat landslides for the identified receptors.

Section 1.3 describes how this report addresses this indicative scope.

The spatial scope of the PLHRA is limited to the area in which infrastructure has been considered as part of the Proposed Development and therefore in which peat depth data has been collected. This is shown as a black boundary set within the wider red line boundary on Figures 9.6.1 to 9.6.8.

1.3. Report Structure

This report is structured as follows:

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

Assessments within the PLHRA have been undertaken alongside assessments for the Peat Management Plan (Appendix 9.5) and have been informed by results from the Peat Survey (Appendix 9.2). Where relevant information is available elsewhere in the Environmental Impact Assessment Report (EIA Report), this is referenced in the text rather than repeated in this report.

1.4. Approaches to assessing peat instability for the Proposed Development

This report approaches assessment of peat instability through both a qualitative contributory factor-based approach and via more conventional stability analysis (through limit equilibrium or Factor of Safety (FoS) analysis). The advantage of the former is that many observed relationships between reported peat landslides and ground conditions can be considered together where a FoS is limited to consideration of a limited number of geotechnical parameters. The disadvantage is that the outputs of such an approach are better at illustrating relative variability in landslide susceptibility across a site rather than absolute likelihood.

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

To reflect these limitations, both approaches are adopted and outputs from each approach integrated in the assessment of landslide likelihood. **Error! Reference source not found.**Plate 1.2 shows the approach:

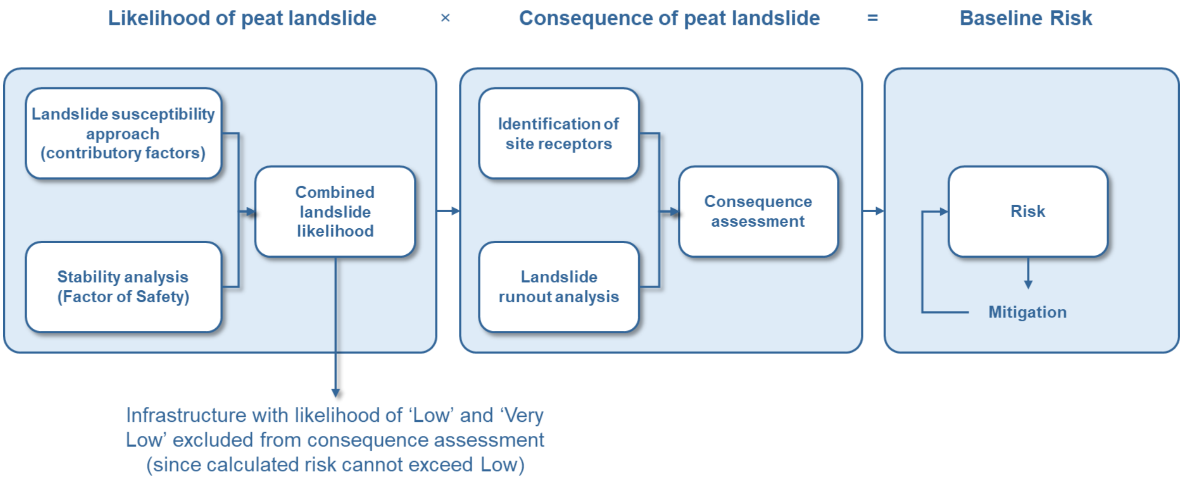

Plate 1.2 Risk assessment approach

1.5. Team competencies

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

2. BACKGROUND TO PEAT INSTABILITY

2.1. Peat Instability in the UK and Ireland

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

Peat instability, or peat landslides, are a widely documented but relatively rare mechanism of peatland degradation that may result in damage to peatland habitats, potential losses in biodiversity and depletion of peatland carbon stores (Evans & Warburton, 2007). Public awareness of peat landslide hazards increased significantly following three major peat landslide events in 2003, two of which had natural causes and one occurring in association with a wind farm.

On 19th September 2003, multiple peat landslide events occurred in Pollatomish (Co. Mayo, Ireland; Creighton and Verbruggen, 2003) and in Channerwick in the Southern Shetland Islands (Mills et al, 2007). Both events occurred in response to intense rainfall, possibly as part of the same large scale large-scale weather system moving northeast from Ireland across Scotland. The former event damaged several houses, a main road and washed away part of a graveyard. Some of the landslides were sourced from areas of turbary (peat cutting) with slabs of peat detaching along the cuttings. The landslides in Channerwick blocked the main road to the airport and narrowly missed traffic using the road. Watercourses were inundated with peat, killing fish inland and shellfish offshore (Henderson, 2005).

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

The Derrybrien event triggered interest in the influence of wind farm construction and operation on peatlands, particularly in relation to potential risks arising from construction induced peat instability. In 2007, the (then) Scottish Executive published guidelines on peat landslide hazard and risk assessment in support of planning applications for wind farms on peatland sites. While the production of PLHRA reports is required for all Section 36 energy projects on peat, they are now also regarded as best practice for smaller wind farm applications. The guidance was updated in 2017 (Scottish Government, 2017).

Since then, a number of peat landslide events have occurred both naturally and in association with wind farms (e.g. Plate 2.1). In the case of wind farm sites, these have rarely been reported, however landslide scars of varying age are visible in association with wind farm infrastructure on Corry Mountain, Co. Leitrim, at Sonnagh Old Wind Farm, Co. Galway (near Derrybrien; Cullen, 2011), and at Corkey Wind Farm, Co. Antrim. In December 2016, a plant operator was killed during excavation works in peat at the Derrysallagh wind farm site in Co. Leitrim (Flaherty, 2016) on a plateau in which several published examples of instability had been previously reported. A peat landslide was also reported in 2015 near the site of a proposed road for the Viking Wind Farm on Shetland (The Shetland Times, 2015) though this was not in association with construction works.

Other recent natural events include another failure in Galway at Clifden in 2016 (Irish News, 2016), Cushendall, Co. Antrim (BBC, 2014), in the Glenelly Valley, Co. Tyrone in 2017 (BBC, 2018), Drumkeeran in Co. Leitrim in July 2020 (Irish Mirror, 2020) and Benbrack in Co Cavan in July 2021 (The Anglo-Celt, 2021). Noticeably, the vast majority of reported failures since 2003 have occurred in Ireland and Northern Ireland, with the one reported Scottish example occurring on the Shetland Islands, an area previously associated with peat instability. Two occurrences of instability in association with construction works on the Viking Wind Farm have been reported (July 2022 and May 2024), though in both cases, these have involved failure of peat or mineral spoil at track margins rather than the triggering of a new 'peat slide' by groundworks.

Plate 2.1 Characteristic peat landslide types in UK and Irish peat uplands: Top row - natural failures: i) multiple peat slides with displaced slabs and exposed substrate, ii) retrogressive bog burst with peat retained within the failed area; Bottom row - failures possibly induced by human activity: iii) peat slide adjacent to turbine foundation, iv) spreading around foundation, v) spreading upslope of cutting

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

2.2. Types of Peat Instability

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

- **minor instability:** localised and small-scale features that are not generally precursors to major slope failure and including gully sidewall collapses, pipe ceiling collapses, minor slumping along diffuse drainage pathways (e.g. along flushes); indicators of incipient instability including development of tension cracks, tears in the acrotelm (upper vegetation mat), compression ridges, or bulges / thrusts (Scottish Government, 2017); these latter features may be warning signs of larger scale major instability (such as landsliding) or may simply represent a longer term response of the hillslope to drainage and gravity, i.e. creep.

- **major instability:** comprising various forms of peat landslide, ranging from small scale collapse and outflow of peat filled drainage lines/gullies (occupying a few-10s cubic metres), to medium scale peaty-debris slides in organic soils (10s to 100s cubic metres) to large scale peat slides and bog bursts (1,000s to 100,000s cubic metres).

Evans and Warburton (2007) present useful contextual data in a series of charts for two types of large-scale peat instability – peat slides and bog bursts. The data are based on a peat landslide database compiled by Mills (2002) which collates site information for reported peat failures in the UK and Ireland. Separately, Dykes and Warburton (2007) provide a more detailed classification scheme for landslides in peat based on the type of peat deposit (raised bog, blanket bog, or fen bog), location of the failure shear surface or zone (within the peat, at the peat-substrate interface, or below), indicative failure volumes, estimated velocity and residual morphology (or features) left after occurrence.

For the purposes of this assessment, landslide classification is simplified and split into three main types, typical examples of which are shown in Plate 2.1. Dimensions, slope angles and peat depths are drawn from charts presented in Evans and Warburton (2007). The term “peat slide” is used to refer to large-scale (typically less than 10,000 of cubic metres) landslides in which failure initiates as large rafts of material which subsequently break down into smaller blocks and slurry. Peat slides occur ‘top-down’ from the point of initiation on a slope in thinner peats (between 0.5 m and 1.5 m) and on moderate slope angles (typically 5°-15°, see Plate 2.2).

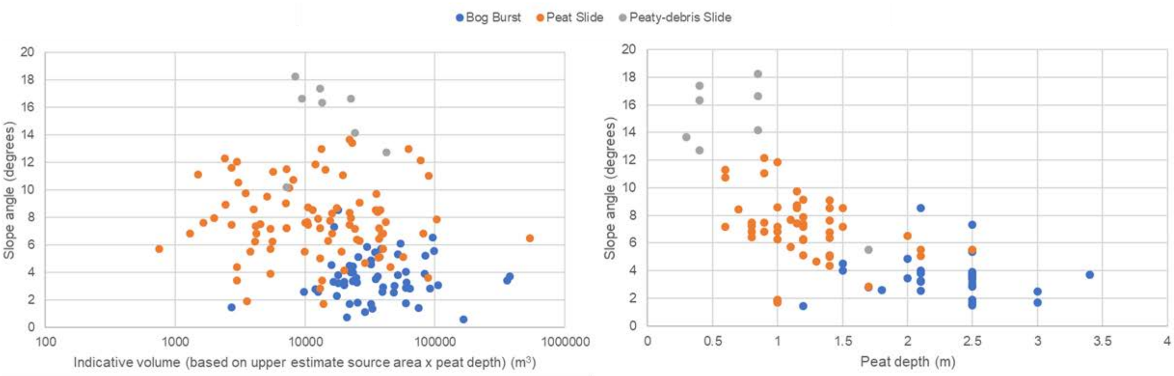

Plate 2.2 Reported slope angles and peat depths associated with peat slides and bog bursts (from literature review of locations, depths and slope angles, after Mills, 2002)

The term “bog burst” is used to refer to very large-scale (usually greater than 10,000 of cubic metres) spreading failures in which the landslide retrogresses (cuts) upslope from the point of failure while flowing downslope. Peat is typically deeper (greater than 1.0m and up to 10m) and more amorphous than sites experiencing peat slides, with shallower slope angles (typically 2°-5°). Much of the peat displaced during the event may remain within the initial failure zone. Bog bursts are rarely (if ever) reported in Scotland other than in the Western Isles (e.g. Bowes, 1960).

The term “peaty soil slide” is used to refer to small-scale (1,000s of cubic metres) slab-like slides in organic soils (i.e. they are <0.5 m thick). These are similar to peat slides in form, but far smaller and occur commonly in UK uplands across a range of slope angles (Dykes and Warburton, 2007). Their small size means that they often do not affect watercourses and their effect on habitats is minimal.

Few if any spreading failures in peat (i.e. bog bursts) have been reported in Scotland, with only one or two unpublished examples in evidence on the Isle of Lewis and Caithness. There are no published failures or news reports of landslides in proximity to the Site and none are visible on multi-epoch satellite imagery for the Site.

2.2.1. Factors Contributing to Peat Instability

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

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

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

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

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

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

v. Artificially cut transverse drainage ditches, or grips (elevating pore water pressures in the basal peat-mineral matrix between cuts, and causing fragmentation of the peat mass).

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

vii. Reduction in shear strength of peat or substrate from changes in physical structure caused by progressive creep and vertical fracturing (tension cracking or desiccation cracking), chemical or physical weathering or clay dispersal in the substrate.

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

ix. Increase in buoyancy of the peat slope through formation of sub-surface pools or water-filled pipe networks or wetting up of desiccated areas.

x. Afforestation of peat areas, reducing water held in the peat body, and increasing potential for formation of desiccation cracks which are exploited by rainfall on forest harvesting.

Triggering factors are typically of short duration (minutes to hours) and any individual trigger event can be considered as the ‘straw that broke the camel’s back’:

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

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

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

iv. Focusing of drainage in a susceptible part of a slope by alterations to natural drainage patterns (e.g. by pipe blocking or drainage diversion).

v. Loading by plant, spoil or infrastructure.

External environmental triggers such as rainfall and snowmelt cannot be mitigated against, though they can be managed (e.g. by limiting construction activities during periods of intense rain). Unloading of the peat mass by excavation, loading by plant and focusing of drainage can be managed by careful design, site specific stability analyses, informed working practices and monitoring.

2.2.2. Consequences of Peat Instability

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

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

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

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

3. BASELINE CONDITIONS

3.1. Topography

The Site rises from the coastline on the western site boundary over cliffs and undulating slopes to straddle Larbrax Moor in the south and Galdenoch Moor in the north. The moors occupy largely flat terrain situated between the coastal hills in the west of the Site and a series of hill summits outside and to the east of the Site. The main peaks are Larbrax Moor at 83 m AOD and Hind Hill on Galdenoch Moor at 82 m AOD (Figure 9.6.1). Plate 3.1 provides a perspective view of the Site showing the main features.

The majority of the slopes in the east of the site are gentle (>2.5°) with some isolated steep slopes around Hind Hill and Larbrax Moor. The majority of the slopes in the west of the site, closer to the coast, are steeper (2.5° - 10°). The peak slopes occur on the cliffs at the coast, with some exceeding 30°. The maximum slope near the infrastructure is 15° (see Figure 9.6.2).

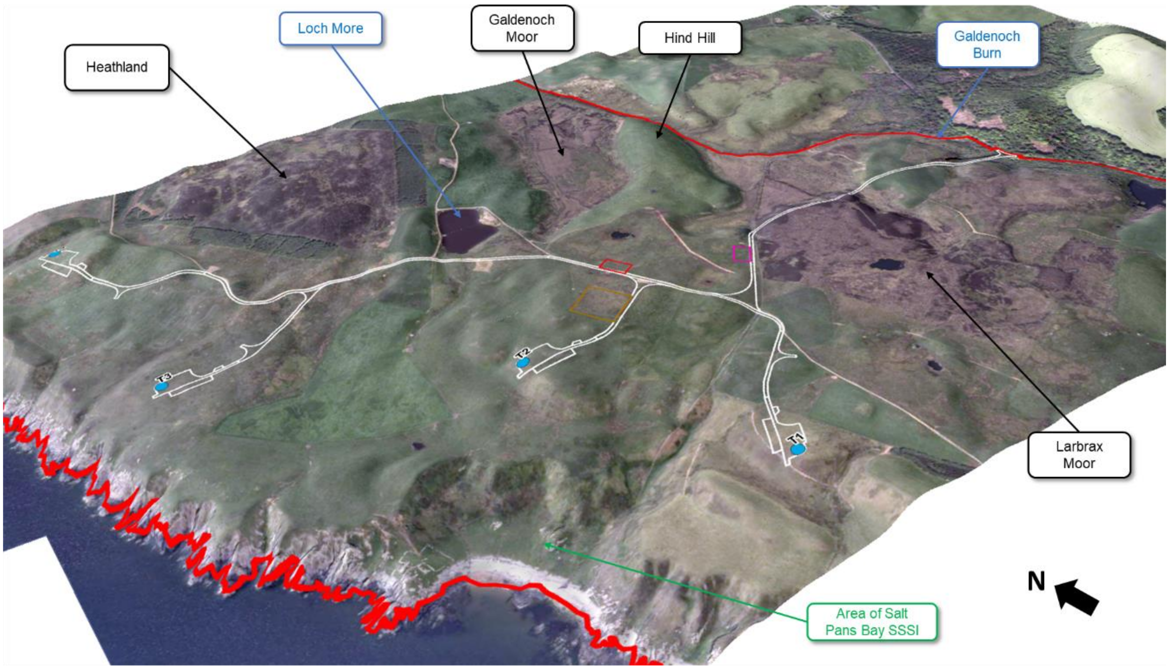

Plate 3.1 Perspective view of site (2x vertical exaggeration). © 2024 Microsoft Corporation © 2018 DigitalGlobe © CNES (2018) Distribution Airbus DS

3.2. Geology

The inset panel of Figure 9.6.3 shows the solid geology of the Site mapped from 1:50,000 scale publicly available BGS digital data and indicates the majority of the site to be underlain by wacke of the Kirkcolm Formation with the far northern extent of the Site is underlain by wacke of the Galdenoch Formation. Wacke are sandstones with a potentially appreciable clay matrix component. The Site Management Statement for the Salt Pans Bay SSSI, which is designated for its maritime cliff habitat (NatureScot, 2010), notes that the shales and slates of these formations are overlain by boulder clays (a generic term for glacial till) and acidic soils.

The main panel of Figure 9.6.3 shows the superficial geology of the site, also derived from BGS digital data, indicating much of the site to be made up of glaciofluvial deposits (gravel, sand and silt). There are several locations, such as on Galdenoch and Larbrax Moors, where this is shown to be overlain with peat. Elsewhere in the site, away from the infrastructure there are some Devensian till deposits, some alluvium and some beach deposits.

There are no geological designations within the site boundary.

3.3. Hydrology

The Site is drained to the west by a number of minor unnamed watercourses that rise from springs above the cliff line, typically between the 50 and 75 m contours. Being close to the coastline, these are all very minor watercourses with minimal catchment area.

The central ‘plateau’, on which Larbrax Moor is located and below which Galdenoch Moor sits as a valley mire (Plate 3.2), hosts several small lochans, the largest being Loch More (Plate 3.3), which has been partly realigned along its southeastern border (Figure 9.6.4).

Galdenoch Moor has been subject to artificial drainage in the past, with a series of linear moor drains running northeast across the very flat moor surface to join Galdenoch Burn (e.g. Plate 3.2). In contrast, Larbrax Moor shows little evidence of drainage on Ordnance Survey data, with some minor drains in the east. Galdenoch Burn is joined by Green Burn outside the site boundary to the south. None of the streams within the site have the capacity to transport landslide debris any significant distance due to their small dimensions and very low gradients. Both Galdenoch Burn and Green Burn are recorded by SEPA has being of Moderate status and Moderate ecological potential.

Plate 3.2 a) Galdenoch Moor located in a subdued valley, b) a subtle drainage line marked by a slight vegetation change (arrowed), c) a rare bog pool within Galdenoch Moor

Chapter 9 of the EIAR indicates that there are no private water supplies (PWS) within the site boundary. There are also no Drinking Water Protected Areas.

3.4. Land Use

Land use is predominantly agricultural across most of the Site, principally for grazing of livestock. There are local areas of woodland plantation. While the site has been cut in the past, baulks (raised areas between cuts) are sparse and well vegetated and differences in elevation caused by cutting are most clearly shown on LiDAR data (Plate 3).

3.5. Peat Depth and Character

The inset panel on Figure 9.6.5 shows the Carbon and Peatland (2016) Map categories for the Site and indicates the peat deposits on Galdenoch and Larbrax Moors to be Class 1 peatlands. These are described as "nationally important carbon-rich soils, deep peat and priority peatland habitat". Around the fringes of these moors the deposits are Class 5 which are classed as peat soil but with no peatland vegetation. The area to the north of Loch Mare correspond to Class 3, where the soils are "predominantly peaty soil with some peat soil" and the "dominant vegetation cover is not priority peatland but is associated with wet and acidic type".

Peat depth probing was undertaken in multiple phases in accordance with Scottish Government (2017) guidance. A peat survey report (Appendix 9.2) documents the findings of these site investigations:

- Phase 1 probing was undertaken on a 100 m grid in July 2023 and comprised 224 probes (this number including initial probing undertaken by AECOM in 2013 for a previous scheme).
- Phase 2 probing was undertaken in May 2024 at 50 m intervals with 10 m offsets along tracks, on a 10 m grid within turbine footprints closer to the main peat deposits and 20 m grids on steeper slopes where peat was generally absent.
- An additional set of Phase 2 probing was undertaken to inform alternative access track layouts following a decision to avoid peat so far as possible on Larbrax Moor. The two sets of Phase 2 probing comprised a further 1,134 probe locations in total.
- In total 1,358 probes and 9 cores were collected. All cores (which were taken in non-peat locations at turbines, the substation, borrow pit and construction compound) showed a clay substrate.

Interpolation of peat depths was undertaken in the ArcMap GIS environment using a natural neighbour approach. This approach was selected because it preserves recorded depths at each probe location, unlike some other approaches (e.g. kriging), is computationally simple, and minimises 'bullseye' effects. The approach was selected after comparison of outputs with three other methods (inverse distance weighted, kriging and TIN). Figure 9.6.5 shows the interpolated peat depth model, with probing locations superimposed. A summary of peat distribution is provided below.

- Peat is generally present in the eastern half of the Site on the gentle terrain east of the cliffs and hills.
- The deepest deposits are found in Galdenoch Moor and in a similar valley mire to the south on the opposing side of Hind Hill. Shallower deposits (but still in excess of 1.0 m in depth) are found on Larbrax Moor. Deep deposits are also present in the valley draining Loch Beg in the far north of the surveyed area, though these appear to be confined to the narrow valley floor.
- Peat thins rapidly out of the flat valley floors within which Galdenoch Moor and the adjacent valley mire are located.

Comparison of the peat depth model with the layout indicates that significant efforts have been made during layout design to site infrastructure out of areas of peat. None of the four turbines are located in peat soil, with only two probes showing peat within the area of the proposed borrow pit. There is very minor overlap with peat on the edge of Larbrax Moor where the access track along a gentle sideslope separating Larbrax Moor from the unnamed valley mire below, while the turning head for Turbine 1 also overlaps a small pocket of peat.

3.6. Peatland Geomorphology

Satellite imagery available as an ArcGIS Basemap layer was used to interpret and map features within the site boundary. Additional imagery from different epochs available on both Google Earth™ and bing.com/maps was also referred to in order to validate the satellite imagery interpretation. The resulting geomorphological map (Figure 9.6.4) was subsequently verified during a site walkover undertaken in October 2023 by a Chartered Geologist and peatland geomorphologist with over 25+ years' experience of assessing peat landslides. Plates 3.2 to 3.4 show typical features identified during the walkovers.

Figure 9.6.4 shows the key features of the Site. The presence, characteristics and distribution of these features are helpful in understanding the hydrological function of a peatland, the balance of erosion and peat accumulation (or condition), and the sensitivity of a peatland to potential land-use changes.

The western half of the Site comprises large areas of improved ground used for grazing for livestock and unimproved heath and grassland falling to the coastal cliffs. Several areas of woodland are present across the Site, including surrounding a large area of heath between Loch Beg and Loch More.

Plate 3.3 a) Loch Morem in the centre of the Site, b) the flat, heather covered terrain of Larbrax Moor, c) heathland in the north of the site, d) scrubby grassland above cliffs in the west of the site

Where peat is present, there is limited surface morphology, with the two valley bogs having planar surfaces apparently subject to historical cutting. The cut margins are generally very subdued indicating the cuttings are likely to be very old. LiDAR coverage is available for much of the eastern half of the Site and clearly shows the cutting morphology in these areas (Plate 3.4). While artificial drains are present in the peat covered areas, they are now very subdued (Plate 3.2b).

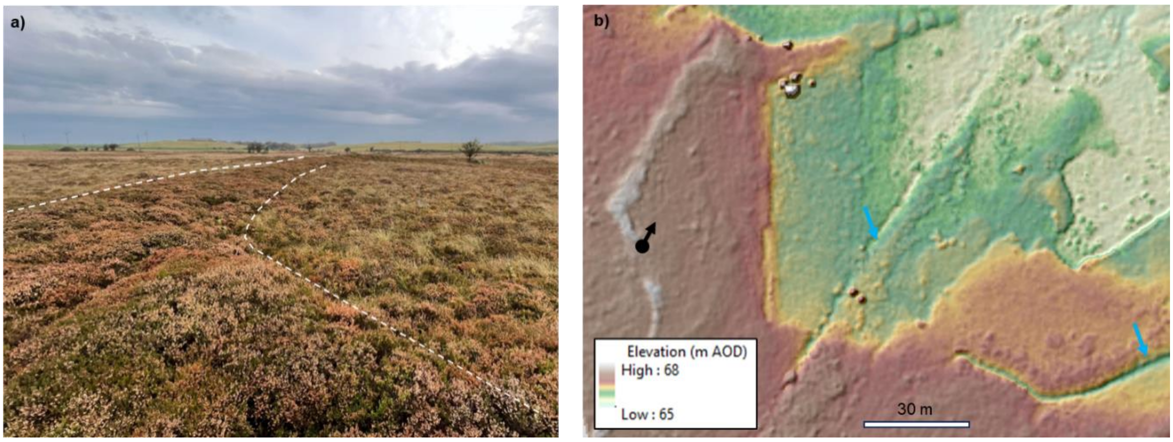

Plate 3.4 a) a baulk of intact peat raised above the lowered and cutover surface, b) location of photo shown by black arrow, different elevations caused by cutting are clearly visible on LiDAR data, as are drains (arrowed blue).

The next section integrates the desk and field assessments described above to identify the spatial variation in landslide likelihood across the Site.

4. ASSESSMENT OF PEAT LANDSLIDE LIKELIHOOD

4.1. Introduction

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

Risk = Probability of a Peat Landslide x Adverse Consequences

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

Due to the high variability in peat depth and slope angle, including gentle slopes with deep peat and steeper slopes with thin peat, both peat slide and bog burst mechanisms are considered in this report. This is in keeping with the most likely mode of failure for the peat depths and slope angles present at the site (see Plate 2.2 and Figures 9.6.1 and 9.6.4).

4.2. Limit Equilibrium Approach

4.2.1. Overview

Stability analysis has been undertaken using the infinite slope model to determine the Factor of Safety (FoS) for a series of 25 m x 25 m grid cells within the Proposed Development boundary. This is the most frequently cited approach to quantitatively assessing the stability of peat slopes (e.g. Scottish Government, 2017; Boylan et al, 2008; Evans and Warburton, 2007; Dykes and Warburton, 2007; Creighton, 2006; Warburton et al, 2003; Carling, 1986). The approach assumes that failure occurs by shallow translational landsliding, which is the mechanism usually interpreted for peat slides. Due to the relative length of the slope and depth to the failure surface, end effects are considered negligible and the safety of the slope against sliding may be determined from analysis of a 'slice' of the material within the slope.

The stability of a peat slope is assessed by calculating a Factor of Safety, F, which is the ratio of the sum of resisting forces (shear strength) and the sum of driving forces (shear stress) (Scottish Government, 2017):

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

In this formula c' is the effective cohesion (kPa), γ is the bulk unit weight of saturated peat (kN/m^3), γw is the unit weight of water (kN/m^3), z is the vertical peat depth (m), h is the height of the water table as a proportion of the peat depth, β is the angle of the substrate interface (°) and ϕ' is the angle of internal friction of the peat (°). This form of the infinite slope equation uses effective stress parameters, and assumes that there are no excess pore pressures, i.e. that the soil is in its natural, unloaded condition. The use of cut and fill foundations and tracks across almost the whole construction footprint suggest this is an appropriate approach. The choice of water table height reflects the full saturation of the soils that would be expected under the most likely trigger conditions, i.e. heavy rain.

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

There are numerous uncertainties involved in applying geotechnical approaches to peat, not least because of its high water content, compressibility and organic composition (Hobbs, 1986; Boylan and Long, 2014). Peat comprises organic matter in various states of decomposition with both pore water and water within plant constituents, and the frictional particle-to-particle contacts that are modelled in standard geotechnical approaches are different in peats. There is also a tensile strength component to peat which is assumed to be dominant in the acrotelm, declining with increasing decomposition and depth. As a result, analysis utilising geotechnical approaches is often primarily of value in showing relative stability across a site given credible and representative input parameters rather than in providing an absolute estimate of stability. Representative data inputs have been derived from published literature for drained analyses considering natural site conditions.

4.2.2. Data Inputs

Stability analysis was undertaken in ArcMap GIS software. A 25 m x 25 m grid was superimposed on the full site extent and key input parameters derived for each grid cell. In total, c. 3,940 grid cells were analysed. A 25 m x 25 m cell size was chosen because it is sufficiently small to define a credible landslide size and avoid 'smoothing' of important topographic irregularities.

Table 4-1 shows the input parameters and assumptions for the baseline stability analysis. The shear strength parameters c' and ϕ' are usually derived in the laboratory using undisturbed samples of peat collected in the field and therefore site-specific values are often not available ahead of detailed site investigation for a development. Therefore, for this assessment, a literature search has been undertaken to identify a range of credible but conservative values for c' and ϕ' quoted in fibrous and humified peats. FoS analysis was undertaken with conservative ϕ' of 20° and values of 2 kPa and 5 kPa for c'. These values fall at the low end of a large range of relatively low values (when compared to other soils).

4.2.3. Results

The outputs of the drained analysis (effective stress) are shown for both parameter combinations in Figure 9.6.6. The more conservative combination (minimum c' and ϕ', inset panel) suggests that localised areas of peat along the bog margins may be unstable (F: <1.0), however, this is not consistent with site observations nor with the stability of peat in general – peat landslides are very rare occurrences given the wide distribution of peat soils in England, Scotland and Wales. The less conservative combination (main panel) gives more credible results, with the steeper slopes where peat thins showing marginal stability (F: 1.0 - 1.4).

Parameter	Values	Rationale	Source
Effective cohesion (c')	2, 5	Credible conservative cohesion values for humified peat based on literature review	5, basal peat (Warburton et al., 2003) 8.74, fibrous peat (Carling, 1986) 7 - 12, H8 peat (Huat et al, 2014) 5.5 - 6.1, type not stated (Long, 2005) 3, 4, type not stated (Long, 2005) 4, type not stated (Dykes and Kirk, 2001)
Bulk unit weight (γ)	10.5	Credible mid-range value for humified catotelmic peat	10.8, catotelm peat (Mills, 2002) 10.1, Irish bog peat (Boylan et al 2008)

Effective angle of internal friction (ϕ')	20, 30	Credible conservative friction angles for humified peat based on literature review (only 20° used in analysis)	40 - 65, fibrous peat (Huat et al, 2014) 50 - 60, amorphous peat (Huat et al, 2014) 36.6 - 43.5, type not stated (Long, 2005) 31 - 55, Irish bog peat (Hebib, 2001) 34 - 48, fibrous sedge peat (Farrell & Hebib, 1998) 32 - 58, type not stated (Long, 2005) 23, basal peat (Warburton et al, 2003) 21, fibrous peat (Carling, 1986)
Slope angle from horizontal (β)	Various	Mean slope angle per 25 m x 25 m grid cell	5 m digital terrain model of site
Peat depth (z)	Various	Mean peat depth per 25 m x 25 m grid cell	Interpolated peat depth model of site
Height of water table as a proportion of peat depth (h)	1	Assumes peat mass is fully saturated (normal conditions during intense rainfall events or snowmelt, which are the most likely natural hydrological conditions at failure)	

Table 4-1 Geotechnical parameters for drained infinite slope analysis

It should be noted that limit equilibrium methods are not well suited to analysis of retrogressive failures on gentle slopes in which liquefaction of basal materials may play a key role in failure, and therefore in this report, more emphasis is placed on the qualitative likelihood assessment described in Section 4.3).

4.3. Landslide Susceptibility Approach

4.3.1. Overview

The landslide susceptibility approach is based on the layering of contributory factors to produce unique 'slope facets' that define areas of similar susceptibility to failure. These slope facets vary in size and are different to the regular grid used for the FoS approach. The number and size of slope facets varies from one part of the site to another according to the complexity of ground conditions. In total, c. 6,393 facets were considered in the analysis, with an average area of c. 515 m^2 (or an average footprint of c. 22 m x 22 m, consistent with smaller to medium scale peaty soil or peat slides reported in the published literature.

Eight contributory factors are considered in the analysis: slope angle (S), peat depth (P), substrate geology (G), peat geomorphology (M), drainage (D), slope curvature (C), forestry (F), and land use (L). For each factor, a series of numerical scores between 0 and 3 are assigned to factor 'classes', the significance of which is tabulated for each factor. The higher a score, the greater the contribution of that factor to instability for any particular slope facet. Scores of 0 imply neutral / negligible influence on instability.

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

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

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

4.3.2. Slope Angle (S)

Table 4-2 shows the slope ranges, their association with instability and related scores for the slope angle contributory factor. Slope angles were derived from the 5 m digital terrain model shown on Figure 9.6.1 and scores assigned based on reported slope angles associated with peat landslides rather than a simplistic assumption that 'the steeper a slope, the more likely it is to fail' (e.g. Plate 2.2). A differentiation in scores is applied for peat slides and bog bursts reflecting the shallower slopes on which the latter are most frequently observed.

Slope range (°)	Association with instability	Peat slide	Bog burst
≤2.5	Slope angle ranges for peat slides and bog bursts are based on lower and upper limiting angles for observations of occurrence (see Plate 2.2 and increase with increasing slope angle until the upper limiting angle e.g. peat slides are not observed on slopes <2.5°, while bog bursts are not observed on slopes > 7.5°). It is assumed that beyond 7.5° the mode of failure will be peat slides.	0	2
2.5 - 5.0		1	3
5.0 – 7.5		3	0
7.5 - 10.0		3	0
10 – 15.0		3	0
>15.0		3	0

Table 4-2 Slope classes, association with instability and scores

Figure 9.6.7 shows the distribution of slope angle scores across the site for peat slides. An equivalent set of scores is also available for bog bursts corresponding to Table 4-2 (though not shown here).

4.3.3. Peat Geomorphology (M)

Table 4-3 shows the geomorphological features typical of peatland environments, their association with instability and related scores. Being an open moorland site (rather than afforested), there is a strong degree of confidence in the identification and mapping of these features, where present.

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

Table 4-3 Peat geomorphology classes, association with instability and scores

Figure 9.6.7 shows the geomorphological classes from Figure 9.6.4 re-coloured to correspond with Table 4-3. The relatively features plateau and valley bogs that form the main peat deposits have been classified as planar (no other features) with diffuse drainage (bog) corresponding to flushes.

4.3.4. Substrate Geology (G)

Table 4-4 shows substrate type, association with instability and related scores for the substrate geology contributory factor. The shear surface or failure zone of reported peat failures typically overlies an impervious clay or mineral (bedrock) base giving rise to impeded drainage. This, in part, is responsible for the presence of peat, but also precludes free drainage of water from the base of the peat mass, particularly under extreme conditions (such as after heavy rainfall, or snowmelt).

Peat failures are frequently cited in association with glacial till deposits in which an iron pan is observed in the upper few centimetres (Dykes and Warburton, 2007). They have also been observed over glacial till without an obvious iron pan, or over impermeable bedrock. They are rarely cited over permeable bedrock, probably due to the reduced likelihood of peat formation.

Substrate Geology	Association with instability	Peat slide	Bog burst
Cohesive (clay) or iron pan	Failures are often associated with clay substrates and/or iron pans	3	3
Granular clay or clay dominated alluvium	Failures are more frequently associated with substrates with some clay component	2	2
Granular or bedrock	Failures are less frequently associated with bedrock or granular (silt / sand / gravel) substrates	1	1

Table 4-4 Substrate geology classes, association with instability and scores

Wacke have been scored as granular clay, while other areas have been scored as granular substrate or bedrock (Figure 9.6.7).

4.3.5. Artificial Drainage (D)

Table 4-5 shows artificial drainage feature classes, their association with instability and related scores. Transverse (or contour aligned) / oblique artificial drainage lines may reduce peat stability by creating lines of weakness in the peat slope and encouraging the formation of peat pipes. A number of peat failures have been identified in published literature which have failed over moorland grips (Warburton et al, 2004). The influence of changes in hydrology becomes more pronounced the more transverse the orientation of the drainage lines relative to the overall slope.

Drainage Feature	Association with instability	Peat slide	Bog burst
Drains aligned along contours (<15 °)	Drains aligned to contour create lines of weakness in slopes	3	3
Drains oblique (15-60°) to contour	Most reports of peat slides and bog bursts in association with drainage occurs where drains are oblique to slope	2	2
Drains aligned downslope (<30° to slope)	Failures are rarely associated with artificial drains parallel to slope or adjacent to natural drainage lines	1	1

No / minimal artificial drainage	No influence on stability	0	0

Table 4-5 Drainage feature classes, association with instability and scores

The effect of drainage lines is captured through the use of a 30 m buffer on each artificial drainage line (producing a 60 m wide zone of influence) present within the peat soils at the site. Each buffer is assigned a drainage feature class based on comparison of the drainage axis with elevation contours (transverse, oblique or aligned, as shown in Table 4-5). Buffers are shown on Figure 9.6.7.

4.3.6. Peat Depth (P)

Table 4-6 shows the peat depths, their association with instability and related scores for the peat depth contributory factor. Peat depths were derived from the peat depth model shown on Figure 9.6.7 and reflect the peat depth ranges most frequently associated with peat landslides (see Plate 2.2).

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

Table 4-6 Peat depth classes, association with instability and scores

The distribution of peat depth scores is shown on Figure 9.6.7. Scores for bog bursts are not shown on Figure 9.6.7 but are inversely proportional for the two classes that describe peat.

4.3.7. Slope Curvature (C)

Table 4-7 shows slope (profile) curvature classes, association with instability and related scores. Convex and concave slopes (i.e. positions in a slope profile where slope gradient changes by a few degrees) have frequently been reported as the initiation points of peat landslides by a number of authors. The geomechanical reason for this is that convexities are often associated with thinning of peat, such that thicker peat upslope applies stresses to thinner 'retaining' peat downslope. Conversely, buckling and tearing of peat may trigger failure at concavities (e.g. Dykes & Warburton, 2007; Boylan and Long, 2011). However, review of reported peat landslide locations against Google Earth elevation data indicates that the majority of peat slides occur on rectilinear (straight) slopes and that the reporting of convexity as a key driver may be misleading. Accordingly, rectilinear slopes are assigned the highest score.

Profile Curvature	Association with instability	Peat slide	Bog burst
Rectilinear Slope	Peat slides are most frequently reported on rectilinear slopes, while bog bursts are often reported on rectilinear slopes	3	2
Convex Slope	Peat slides are often reported on or above convex slopes while bog bursts are most frequently associated with convex slopes	2	3

Concave Slope	Peat failures are occasionally reported in association with concave slopes	1	1

Table 4-7 Slope curvature classes, association with instability and scores

The 5 m digital terrain model and OS contours were used to identify areas of noticeable slope convexity across the site. Axes of convexity (running along the contour) were assigned a 50 m buffer to produce 100 m (upslope to downslope) convexity zones and these were assigned scores in accordance with Table 4-7 above.

Given the undulating nature of the site there is a relatively even mix of rectilinear, concave and convex slopes across the site.

4.3.8. Forestry (F)

Table 4-8 shows forestry classes, their association with instability and related scores. A report by Lindsay and Bragg (2004) on Derrybrien suggested that row alignments, desiccation cracking and loading (by trees) could all influence peat stability.

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

Table 4-8 Forestry classes, association with instability and scores

Only small parcels of land within the site are afforested with scores shown on Figure 9.6.7).

4.3.9. Land use (L)

Table 4-9 shows land use classes, association with instability and related scores. A variety of land uses have been associated with peat failures (see 2.2.1). While it is hypothesised that burning may cause desiccation cracking in peat and facilitate water flows to basal peat (and potential shear surfaces), there is little evidence directly relating burnt ground to peat landslide events.

Land Use	Association with instability	Peat slide	Bog burst
Machine cutting	Machine cutting may compartmentalise slopes, but has been reported primarily in association with peat slides	3	2

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

Table 4-9 Land use classes, association with instability and scores

Aside from grazing, which is likely to have a minimal effect, cutting is the primary land use on site. Where peat has been largely removed or is very thin due to cutting, the peat surface is considered as planar and is unscored. Areas upslope of cutting where cutting has removed the support from the slopes above are assigned a high score - these buffers are visible on Figure 9.6.7.

4.3.10. Generation of Slope Facets

The eight contributory factor layers shown on Figure 9.6.7 were combined in ArcMap to produce approximately 6,963 slope facets. Scores for each facet were then summed to produce a peat landslide likelihood score. These likelihood scores were then converted into descriptive 'likelihood classes' from 'Very Low' to 'Very High' with a corresponding numerical range of 1 to 5 (in a similar format to the Scottish Government BPG).

Summed Score from Contributory Factors	Typical site conditions associated with score	Likelihood (Qualitative)	Landslide Likelihood Score
≤ 7	Unmodified peat with no more than low weightings for peat depth, slope angle, underlying geology and peat morphology	Very Low	1
8 - 12	Unmodified or modified peat with no more than moderate or some high scores for peat depth, slope angle, underlying geology and peat morphology	Low	2
13 - 17	Unmodified or modified peat with high scores for peat depth and slope angle and / or high scores for at least three other contributory factors	Moderate	3
18 - 21	Modified peat with high scores for peat depth and slope angle and several other contributory factors	High	4
> 21	Modified peat with high scores for most contributory factors (unusual except in areas with evidence of incipient instability)	Very High	5

Table 4-10 Likelihood classes derived from the landslide susceptibility approach

Table 4-10 describes the basis for the likelihood classes. A judgement was made that for a facet to have a moderate or higher likelihood of a peat landslide, a likelihood score would be required exceeding both the worst-case peat depth and slope angle scores summed (3 in each case, i.e. 3 x 2 classes) alongside three intermediate scores (of 2, i.e. 2 x 3 classes) for other contributory factors. This means that any likelihood score of 13 or greater would be equivalent to at least a moderate likelihood of a peat landslide. Given that the maximum score attainable is 24, this seems reasonable.

4.3.11. Results

Figure 9.6.8 shows the outputs of the landslide susceptibility approach for peat slides and bog bursts. The results indicate that the majority of the site has a 'Low' or 'Very Low' likelihood with small pockets of 'Moderate' likelihood of a peat slide or bog burst under natural conditions.

Areas of 'Moderate' likelihood are typically located on the margins of the plateau bog or the edges of the valley bogs. There are no areas identified with 'High' or 'Very High' landslide susceptibility and only localised areas of 'Very Low' likelihood. When compared with the stability analysis approach, the outputs of this approach indicate slightly more of the site to be at lower stability under natural conditions.

4.3.12. Combined Landslide Likelihood

Figure 9.6.8 shows in purple the one source location identified from the combined landslide likelihood for peat slides and bog bursts. This is located on the main access track running along the northern margin of Larbrax Moor and where peat depths are c. 0.5 m.

		Adverse Consequence (scores bracketed)				
		Very High (5)	High (4)	Moderate (3)	Low (2)	Very Low (1)
Peat landslide likelihood (scores bracketed)	Very High (5)	High	High	Medium	Low	Low
	High (4)	High	Medium	Medium	Low	Negligible
	Moderate (3)	Medium	Medium	Low	Low	Negligible
	Low (2)	Low	Low	Low	Negligible	Negligible
	Very Low (1)	Low	Negligible	Negligible	Negligible	Negligible

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

Plate 4.1 Top: risk ranking as a product of likelihood and consequence; Bottom: suggested action given each level of calculated risk

Section 5 of this report describes the consequence assessment and risk calculation for all areas where infrastructure intersects "Moderate" likelihood of a peat landslide.

5. ASSESSMENT OF CONSEQUENCE AND RISK

5.1. Introduction

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

5.2. Receptors

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

5.2.1. Watercourses

The Proposed Development site is drained by very minor watercourses with very limited competence to convey material any distance downstream. The Galdenoch Burn / Green Burn are noted in Chapter 9 to be of Medium sensitivity given their Moderate ecological status and potential. Watercourses are therefore a consequence score of 3.

5.2.2. Habitats

While blanket bog habitats are valuable, they generally recover from instability events through revegetation over a matter of years to decades and therefore a consequence score of 3 is assigned for all open blanket bog habitats within the Proposed Development site (Table 5-1).

The Salt Pans Bay SSSI located in the west of the site is assigned a Score of 5 (high sensitivity), however, no source or runout zones are identified local to the feature.

Receptor and type	Consequence	Score	Justification for Consequence Score
Watercourses (aquatic habitats)	Short term increase in turbidity and acidification, potential fish kill	3	Undesignated watercourse, no sensitive species noted
Terrestrial habitats (non-designated)	Short to medium term loss of vegetation cover, disruption of peat hydrology, carbon release	3	Long term effects unlikely following revegetation
Salt Pans Bay SSSI	High value cliff edge habitat	5	Designated habitats with high sensitivity
Wind farm infrastructure (Project)	Damage to infrastructure, injury to site personnel, possible loss of life	5	Loss of life, though very unlikely, is a severe consequence; financial implications of damage and re-work are less significant

Table 5-1 Receptors considered in the consequence analysis

5.2.3. Infrastructure

The Proposed Development site is host to agricultural land uses, however, no access tracks, grazed fields, dwellings or other infrastructure are located in the pathway of the identified source zone.

Infrastructure that would be most affected in the event of a peat landslide would be the Proposed Development infrastructure, in particular the track on which the source zone is located. Effects would be most likely during construction, at which time personnel would be using the access track network or be present at infrastructure locations for long periods. While commercial losses would be important to the Applicant, loss of life / injury would be of greater concern, and a consequence score of 5 is assigned for any infrastructure locations subject to potential peat landslides (Table 5-1). However, risks to life can be mitigated through safe systems of working. These infrastructure risks are not considered to be 'environmental' risks and are not explicitly considered in the consequence assessment below.

5.3. Consequences

5.3.1. Overview

A consequence assessment has been undertaken by determining the potential for landslides sourced at infrastructure locations with a Moderate natural likelihood of peat instability to impact the receptors identified above. For example, if a turbine is located in a Moderate (likelihood score of 3) area of open slope and is located 50 m from a watercourse (with a consequence score of 5), it is probable that a landslide triggered during construction would reach that watercourse. The calculated risk would be a product of the likelihood and consequence scores (likelihood: 3 x consequence: 5 = risk: 15, see Plate 4.1) and be equivalent to a "Medium" risk.

In order to determine the likelihood of impact on watercourses and infrastructure, 'runout pathways' have been defined that show the estimated maximum footprint of the landslide. Runout pathways are divided in a downslope direction into 50 m, 100 m, 250 m and 500 m zones on the basis of typical runout distances detailed in Mills (2002). The likelihood of runout passing from one runout zone to the next (e.g. from the 50 m zone into the 100 m zone) is based on the proportion of the published peat landslide population that reaches each runout distance shown on Plate 5.1 (0-50 m: 100%, 50-100 m: 87%, 100-250 m: 56%, 250-500 m: 44%). The source zone area is either the footprint of hardstandings or non-linear infrastructure, or where an access track is the source, the track length multiplied by a typical landslide downslope length of 25 m.

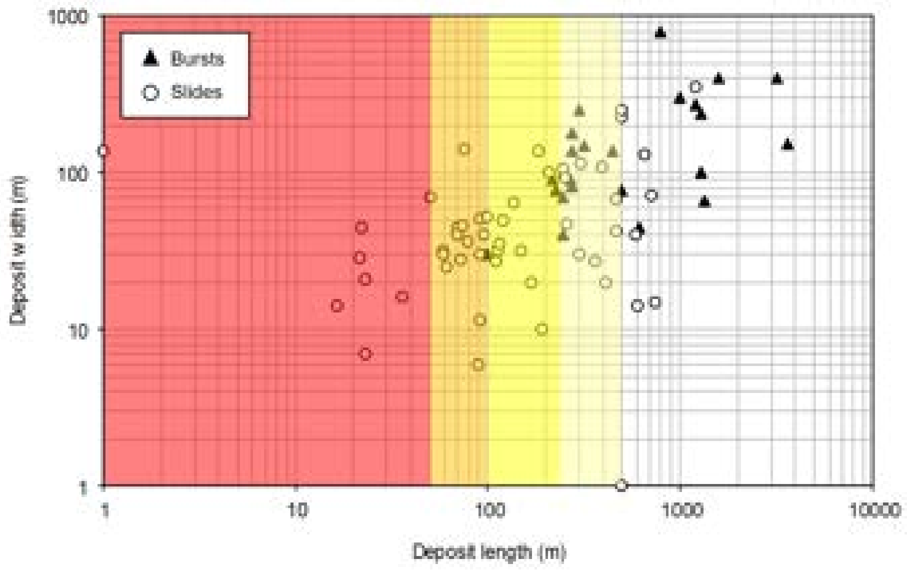

Plate 5.1 Runout distances for published peat landslides (after Mills, 2002), colours on the plot correspond to runout pathway zones on Figure 9.6.8

The left inset on Figure 9.6.8 shows the one identified source zone overlapping with an area of moderate likelihood based on the combined landslide likelihood scores described in Section 4.

5.3.2. Local limits on runout (Watercourses)

Where runout pathways terminate at “blue line” watercourses (those shown on 1:10,000 scale Ordnance Survey maps), an assessment has been made of the ability to convey landslide material along the watercourse. This reflects the significant variability in dimensions of “blue line” watercourses on the ground such that some may be several metres wide and metres deep (and therefore able to transmit materials kilometres downstream) where others may be <0.5 m in width, highly sinuous and sometimes discontinuous (disappearing under the peat surface) and therefore unable to convey landslide material. The 250-500m runout zone terminates in Galdenoch Burn, however it is considered very unlikely that conveyance of material would occur any significant distance downstream.

5.3.3. Local limits on runout (slope curvature)

Plate 5.1 shows runout distances based on published literature. Typically, runout distances would be expected to be less where slope angles decline with distance from the source zone (i.e. on concave slopes) whereas the full runout lengths shown on Plate 5.1 may be achievable on steepening (convex) slopes or rectilinear slopes. The runout zones shown on Figure 9.6.8 encounter very gentle topography within the 50-100m zone with a drop of less than 2m over the remainder of the runout envelope. As a result, runout is not expected to enter the 250-500m zone.

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

Landslide runout may be “supply-limited” by the availability of peat material generated in the failure or source zone. Typically, mobilised material thins with increasing distance from the source zone as rafts of landslide material break down into blocks, and blocks become abraded and roll, breaking down further into a blocky slurry (Plate 5.2).

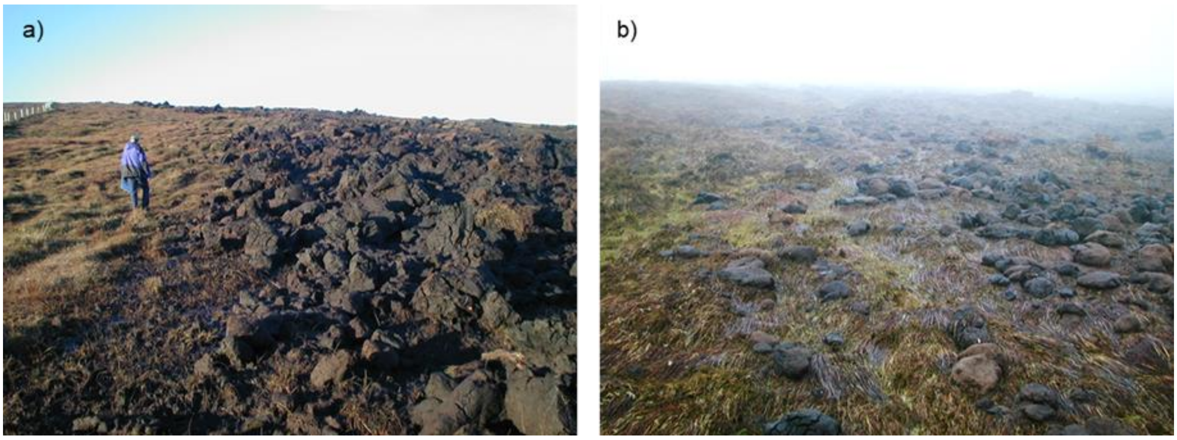

Plate 5.2 Examples of landslide runout (Dooncarton, Co. Mayo): a) blocky debris mid-slope, b) abraded and rolled blocks in lower slope

Following identification of runout zones, additional analysis has been undertaken to approximate this effect. The analysis assumes a source volume equivalent to the source footprint (0 m - 50 m zone) multiplied by the average peat depth in this source zone (from the peat depth model). This volume is then distributed over the full runout pathway (i.e. mobilised volume / runout area) to generate an average thickness of deposit. As the runout length and area increases, the volume thins, in keeping with observed peat landslide deposits. Where deposits fall below 0.2 m in thickness, it is assumed that runout will stall due to the roughness of surface vegetation relative to the thickness of landslide material. If the thickness is calculated to be 0.2 m or less in the zone adjoining a watercourse, then it is judged that the runout will stall prior to reaching it or be negligible in volume on entry and there will be no significant impact on that watercourse (even if a landslide occurs).

Based on the source volume at the access track, any potential landslide debris would thin to less than 0.2m prior to entry to the 250-500m runout zone. This is primarily a function of the thin 'source depth' of peat at the track location (c. 0.5 m in depth).

Plate 5.3 shows a schematic of the full runout approach to assessing consequences.

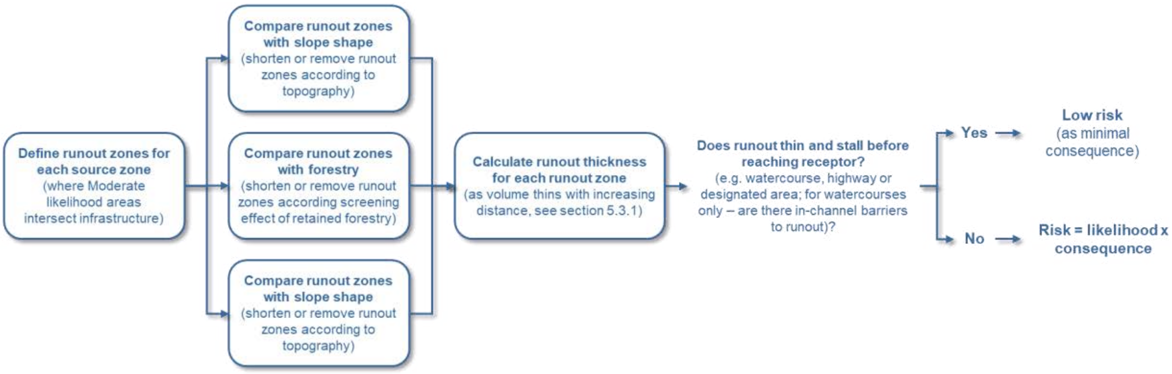

Plate 5.3 Runout approach to assessing consequences

5.3.5. Results of runout analysis

The runout analysis indicates that were a peat landslide to occur at the identified source location, runout would not occur as far as the Galdenoch Burn and impacts would be limited to short to medium term deposition over the valley mire to the north of the track.

5.4. Calculated Risk

Based on the relatively low consequences of an impact to non-designated valley mire (and release of a small volume of non-designated blanket bog above the track), risks are calculated to be no higher than Low. Therefore, site-wide good practice measures are considered to be sufficient to manage and mitigate any construction induced instability risks. This is considered in the next section.

6. RISK MITIGATION

6.1. Overview

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

Risks may be mitigated by:

i. Post-consent site specific review of the ground conditions contributing to Moderate likelihoods which may result in a reduced likelihood, and in turn, further reduction in risk;

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

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

6.2. Good Practice Prior to Construction

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

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

A comprehensive Geotechnical Risk Register should be prepared post-consent but pre-construction detailing sequence of working for excavations, measures to minimise peat slippage, design of retaining structures for the duration of open hole works, monitoring requirements in and around the excavation and remedial measures in the event of unanticipated ground movement. The risk register should be considered a live document and updated with site experience as infrastructure is constructed. Ideally, a contractor with experience of working in deep peat should be engaged to undertake the works.

6.3. Good Practice During Construction

The following good practice should be undertaken during construction:

For excavations:

- Use of appropriate supporting structures around peat excavations (e.g. for turbines, crane pads and compounds) to prevent collapse and the development of tension cracks.

- Avoid cutting trenches or aligning excavations across slopes (which may act as incipient back scars for peat failures) unless appropriate mitigation has been put in place.
- Implement methods of working that minimise the cutting of the toes of slope, e.g. working up-to-downslope during excavation works.
- Monitor the ground upslope of excavation works for creep, heave, displacement, tension cracks, subsidence or changes in surface water content.
- Monitor cut faces for changes in water discharge, particularly at the peat-substrate contact.
- Minimise the effects of construction on natural drainage by ensuring that natural drainage pathways are maintained or diverted such alteration of the hydrological regime of the site is minimised or avoided; drainage plans should avoid creating drainage/infiltration areas or settlement ponds towards the tops of slopes (where they may act to both load the slope and elevate pore pressures).

For cut tracks:

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

For storage of peat and for restoration activities:

- Ensure stored peat is not located upslope of working areas or adjacent to drains or watercourses.
- Undertake site specific stability analysis for all areas of peat storage (if on sloping ground) to ensure the likelihood of destabilisation of underlying peat is minimised.
- Avoid storing peat on slope gradients >3° and preferably store on ground with neutral slopes and natural downslope barriers to peat movement.
- Monitor effects of wetting / re-wetting stored peat on surrounding peat areas, and prevent water build up on the upslope side of peat mounds.
- Maximise the interval between material deliveries over newly constructed tracks that are still observed to be within the primary consolidation phase.

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

- The geotechnical risk register prepared prior to construction should be updated with site experience as infrastructure is constructed.
- Full site walkovers should be undertaken at scheduled intervals to be agreed with the Local Authority to identify any unusual or unexpected changes to ground conditions (which may be associated with construction or which may occur independently of construction).
- All construction activities and operational decisions that involve disturbance to peat deposits should be overseen by an appropriately qualified geotechnical engineer with experience of construction on peat sites.

- Awareness of peat instability and pre-failure indicators should be incorporated in site induction and training to enable all site personnel to recognise ground disturbances and features indicative of incipient instability.
- A weather policy should be agreed and implemented during works, e.g. identifying ‘stop’ rules (i.e. weather dependent criteria) for cessation of track construction or trafficking.
- Monitoring checklists should be prepared with respect to peat instability addressing all construction activities proposed for site.

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

6.4. Good Practice Post-Construction

Following cessation of construction activities, monitoring of key infrastructure locations should continue by full site walkover to look for signs of unexpected ground disturbance, including:

- Ponding on the upslope side of infrastructure sites and on the upslope side of access tracks.
- Changes in the character of peat drainage within a 50 m buffer strip of tracks and infrastructure (e.g. upwelling within the peat surface upslope of tracks, sudden changes in drainage behaviour downslope of tracks).
- Blockage or underperformance of the installed site drainage system.
- Slippage or creep of stored peat deposits.
- Development of tension cracks, compression features, bulging or quaking bog anywhere in a 50 m corridor surrounding the site of any construction activities or site works.

This monitoring should be undertaken on a quarterly basis in the first year after construction, biannually in the second year after construction and annually thereafter. In the event that unanticipated ground conditions arise during construction, the frequency of these intervals should be reviewed, revised and justified accordingly.

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Figure 9.6.1 Elevation

Site boundary
PLHRA Extent
Turbine
Hardstanding temporary
Hardstanding permanent
Temporary borrow pit
Temporary construction compound
Substation/battery storage
Track to be upgraded
Proposed new track/access junction
Tree/scrub removal
New watercourse crossing
Existing (upgraded) watercourse crossing

Elevation (m)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
>=100

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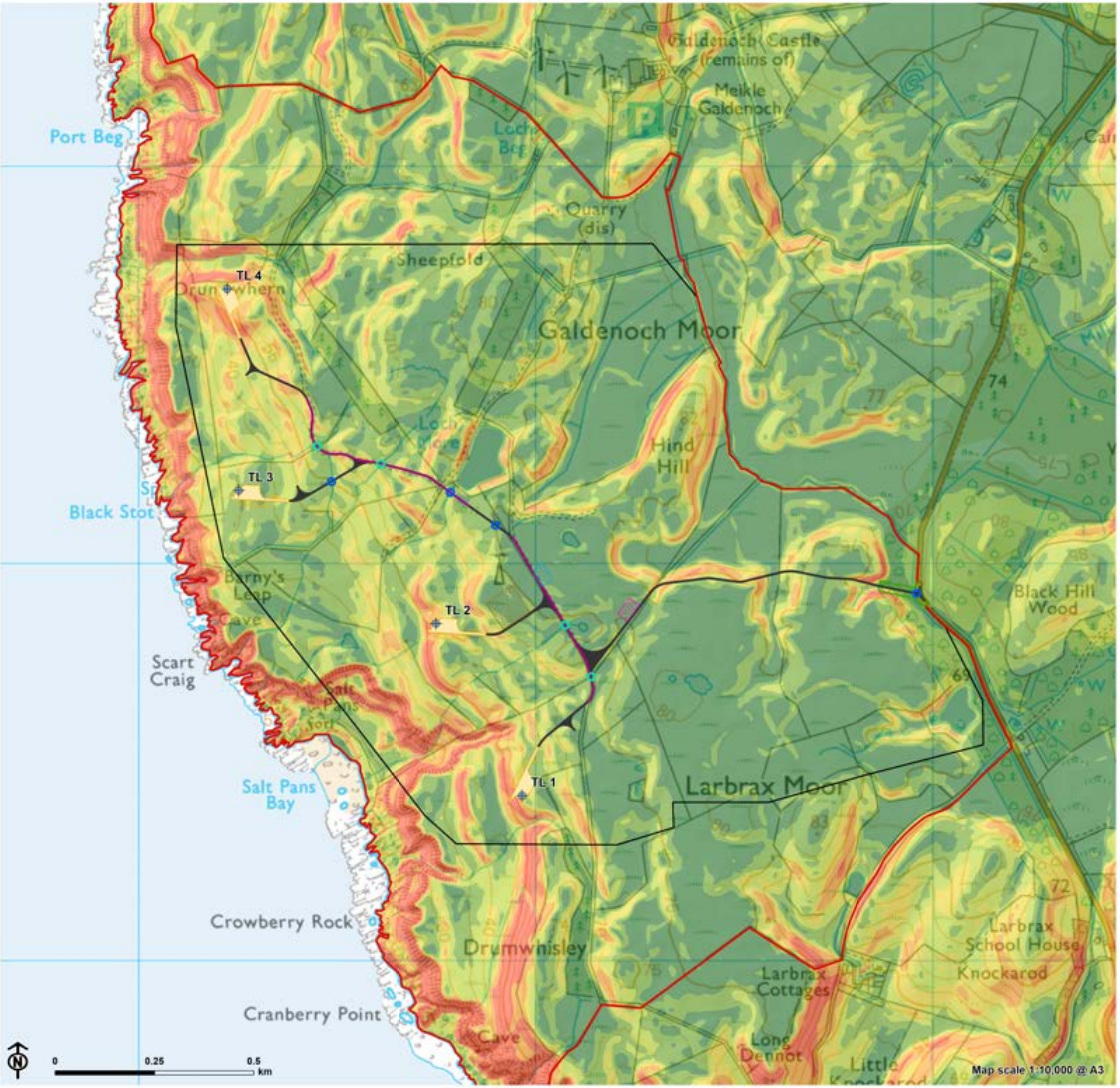

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Figure 9.6.2 Slope

- Site boundary
- PLHRA Extent
- Turbine
- Hardstanding temporary
- Hardstanding permanent
- Temporary borrow pit
- Temporary construction compound
- Substation/battery storage
- Track to be upgraded
- Proposed new track/access junction
- Tree/scrub removal
- New watercourse crossing
- Existing (upgraded) watercourse crossing

Slope (°)

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

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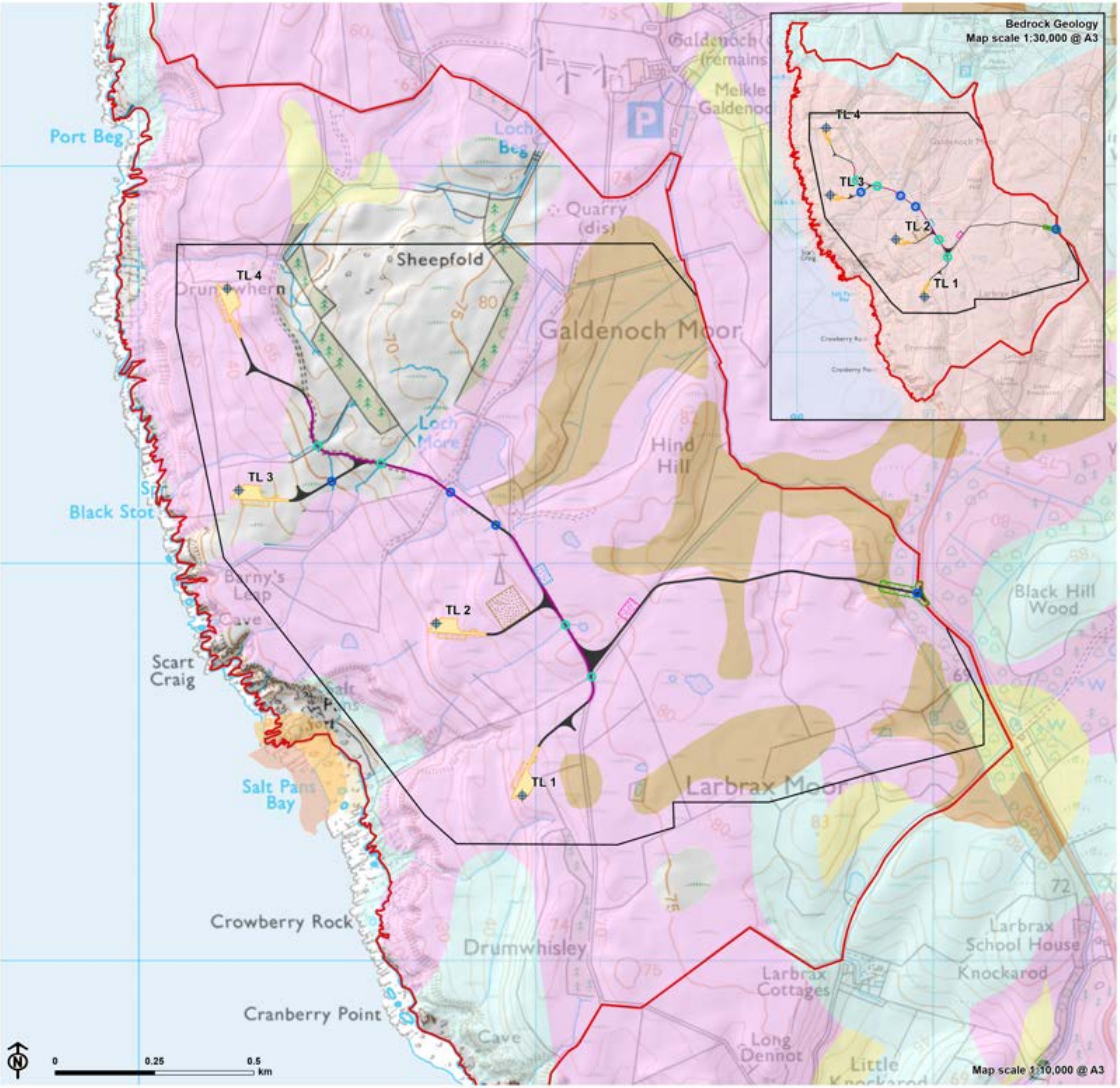
Figure 9.6.3 Geology



- Site boundary
- PLHRA Extent
- Turbine
- Hardstanding temporary
- Hardstanding permanent
- Temporary borrow pit
- Temporary construction compound
- Substation/battery storage
- Track to be upgraded
- Proposed new track/access junction
- Tree/scrub removal
- New watercourse crossing
- Existing (upgraded) watercourse crossing

Superficial Geology

- Alluvium - Silt, sand and gravel
- Glaciofluvial Deposits - Gravel, sand and silt
- Marine Beach Deposits - Clay, silt, sand and gravel
- Peat
- Raised Marine Beach Deposits Of Holocene Age - Gravel, sand and silt
- Till, Devensian - Diamicton
- Bedrock

Bedrock Geology (Inset)

- Galdenoch Formation - Wacke
- Kirkcolm Formation - Wacke

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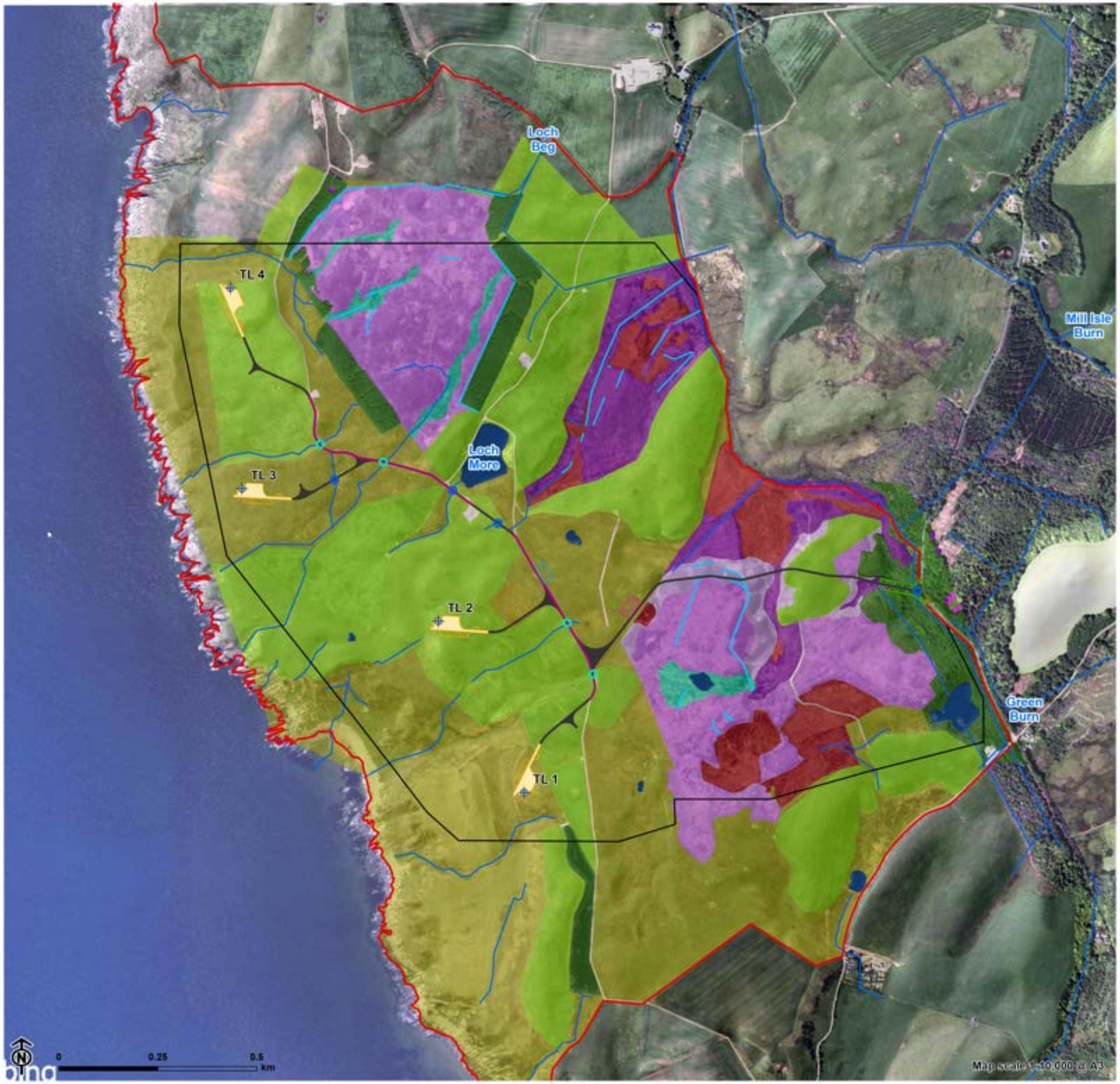
Figure 9.6.4 Geomorphology, hydrology and land use



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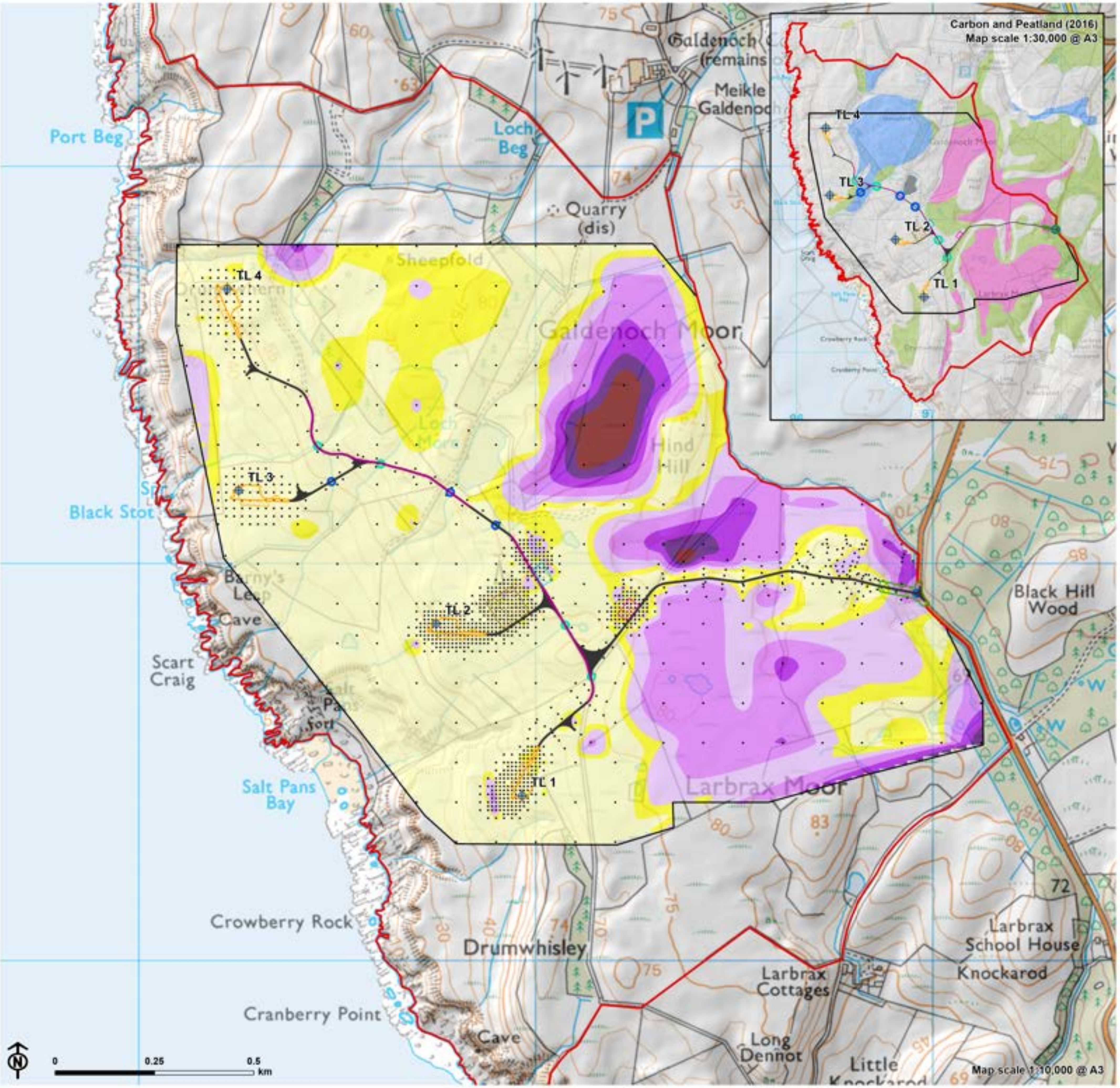

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Figure 9.6.5 Peat Depth

- Site boundary
- PLHRA Extent
- Turbine
- Hardstanding temporary
- Hardstanding permanent
- Temporary borrow pit
- Temporary construction compound
- Substation/battery storage
- Track to be upgraded
- Proposed new track/access junction
- Tree/scrub removal
- New watercourse crossing
- Existing (upgraded) watercourse crossing

Peat Depth (m)

- <= 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- > 4.0
- Peat Depth Probes

Carbon and Peatland (2016) Map (Inset)

- Non-soil
- Unknown soil type
- Mineral soil
- Class 1
- Class 2
- Class 3
- Class 4
- Class 5

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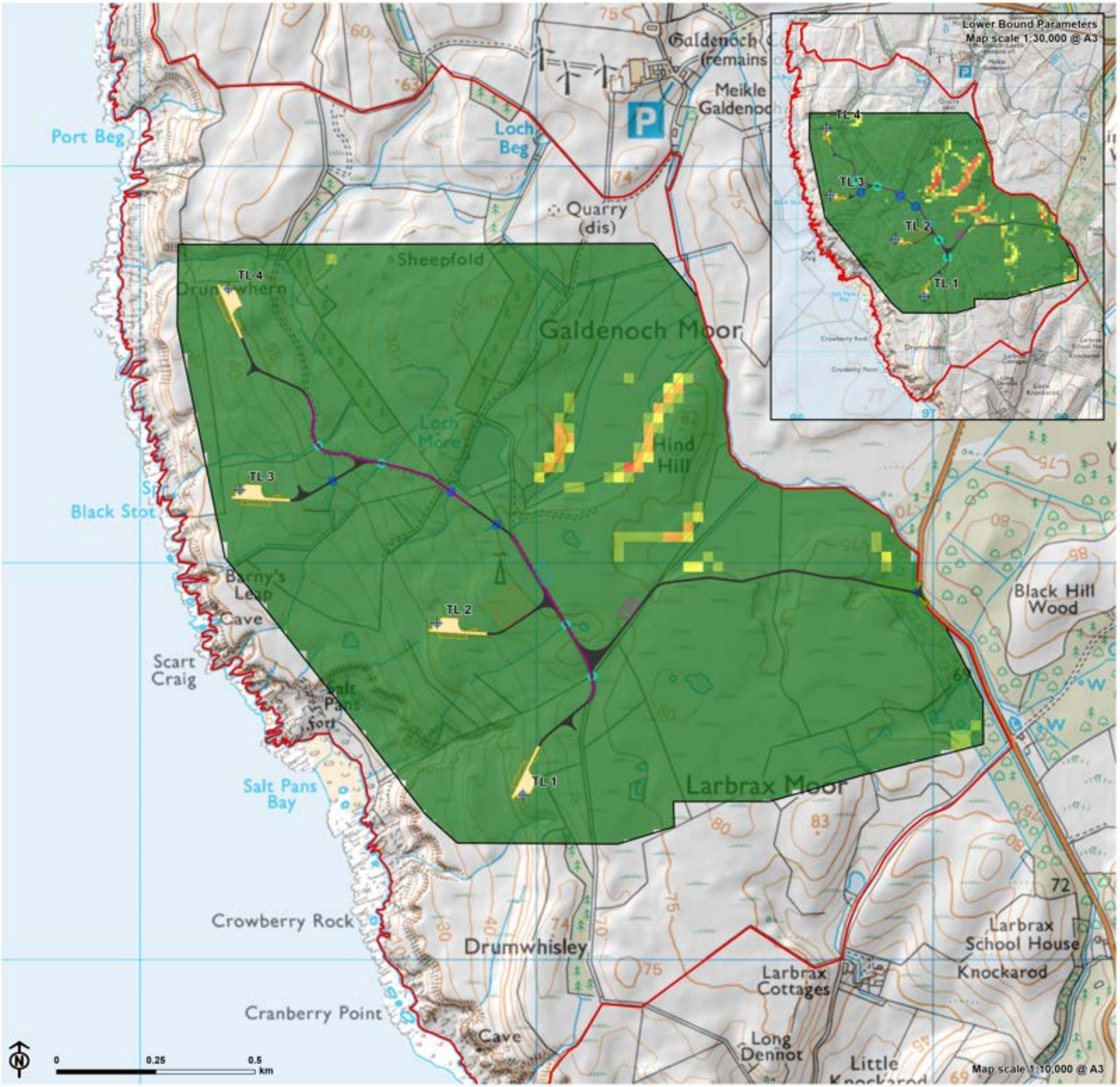
Figure 9.6.6 Factor of Safety



- Site boundary
- PLHRA Extent
- Turbine
- Hardstanding temporary
- Hardstanding permanent
- Temporary borrow pit
- Temporary construction compound
- Substation/battery storage
- Track to be upgraded
- Proposed new track/access junction
- Tree/scrub removal
- New watercourse crossing
- Existing (upgraded) watercourse crossing

Factor of Safety (Best Estimate Parameters)

- < 1.00 "Unstable"
- 1.01 - 1.40 "Marginally Stable"
- 1.41 - 2.00 "Stable"
- 2.01 - 3.00 "Stable"
- > 3.01 "Stable"

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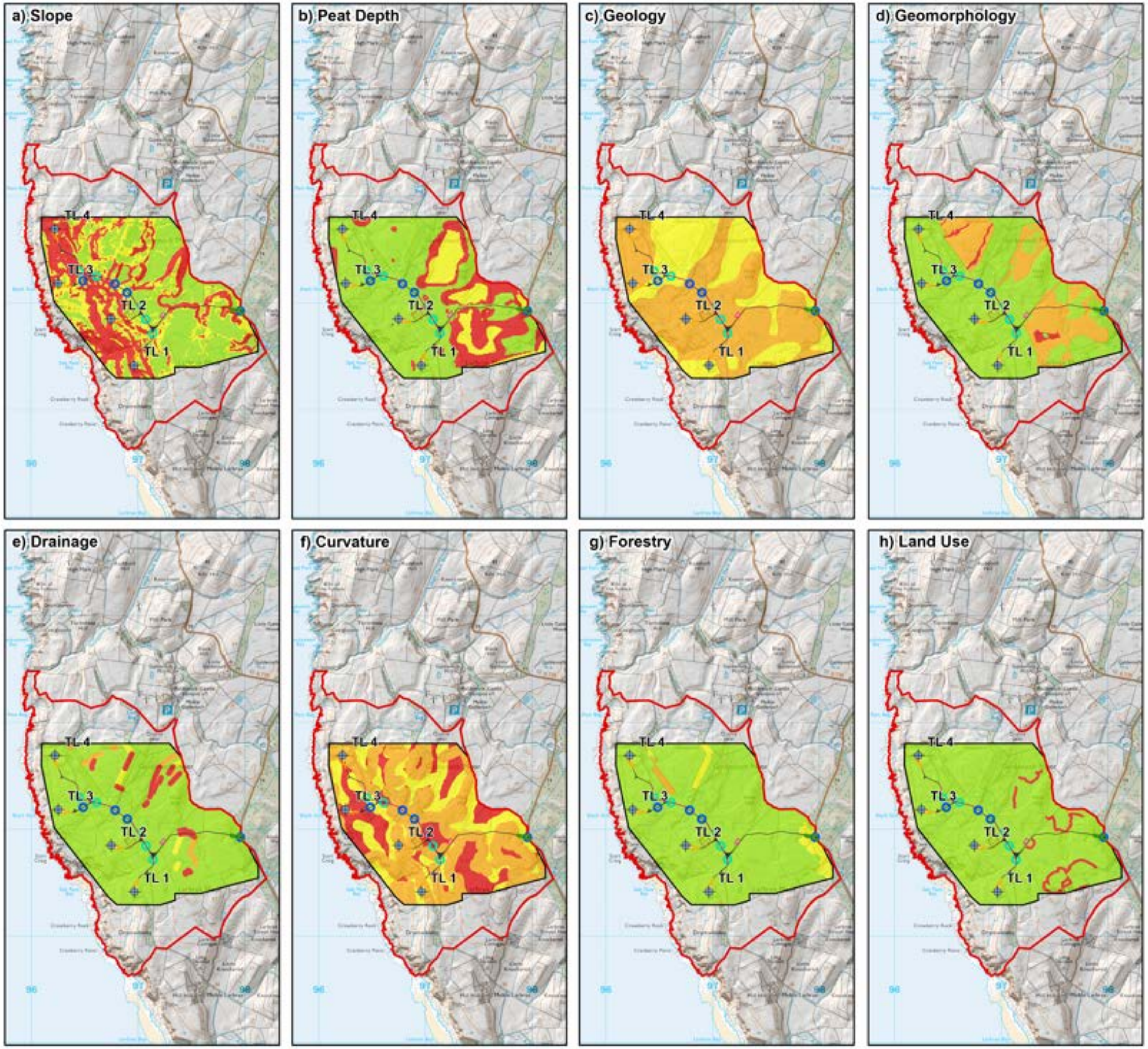
Figure 9.6.7 Contributory Factors



- Site boundary
- PLHRA Extent
- Turbine
- Hardstanding temporary
- Hardstanding permanent
- Temporary borrow pit
- Temporary construction compound
- Substation/battery storage
- Track to be upgraded
- Proposed new track/access junction
- Tree/scrub removal
- New watercourse crossing
- Existing (upgraded) watercourse crossing

Contributory Score

- 0
- 1
- 2
- 3

0 1 2 km

Map scale 1:38,000 @ A3

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Figure 9.6.8 Likelihood and Runout

- Site boundary
- PLHRA Extent
- Turbine
- Hardstanding temporary
- Hardstanding permanent
- Temporary borrow pit
- Temporary construction compound
- Substation/battery storage
- Track to be upgraded
- Proposed new track/access junction
- Tree/scrub removal
- New watercourse crossing
- Existing (upgraded) watercourse crossing
- Salt Pans Bay SSSI

Peat Landslide Likelihood

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

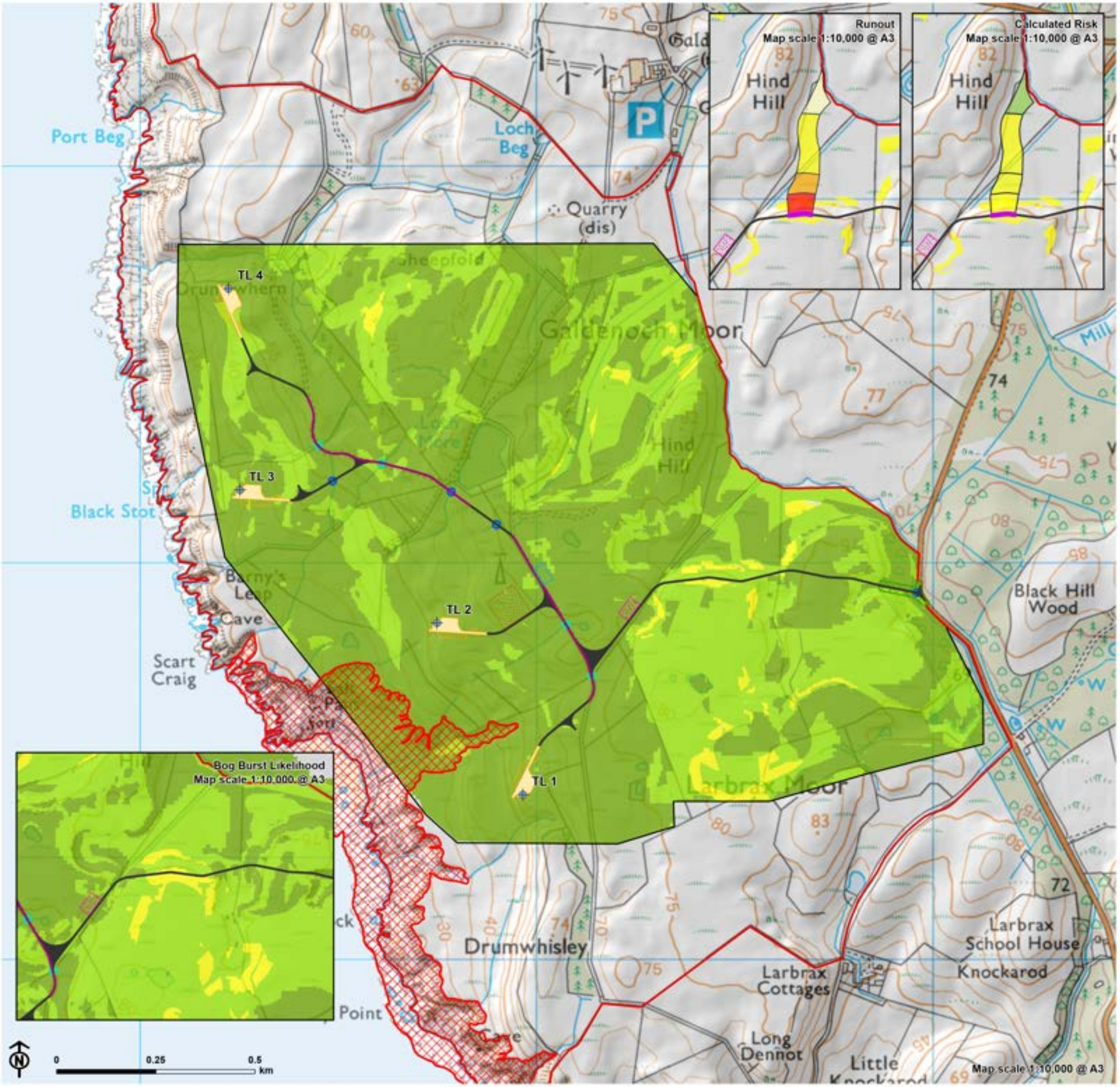
Runout Zones (Inset)

Distance (m)

- 50
- 100
- 250
- 500

Calculated Risk (Inset)

- High (none calculated)
- Medium (none calculated)
- Low
- Negligible
- Source Zone (Inset)



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