

Hazard	Cause	Consequence
		Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment.
Mitigation	Storage site selection and stockpile design by a suitably qualified and experienced geotechnical engineer; In general, the temporary storage of peat in a single dedicated area shall be avoided wherever possible; Peat storage height shall not exceed 1m; Routine maintenance and inspection of peat storage mounds; Additional mitigation measures as described in standalone Peat Management Plan for proposed development.	
Creep, long term settlement of structures	<u>Tracks or hardstand founded on peat and or poor or variable foundation soils</u>	Ongoing settlement and damage of infrastructure, e.g. damage to access track running surface.
Mitigation	Contingency of routine maintenance of infrastructure and drainage elements to ensure longer term issues do not cause a build-up of effects leading to higher level consequences e.g. larger scale instability.	

5 CONCLUSIONS & RECOMMENDATIONS

Construction Risks

- 5.1 The factors which influence natural and induced peat slope failures were discussed in detail during the introduction of this report. The following construction related factors are highlighted for consideration.
- Movement can occur following over-loading of peat slopes, e.g. by placement of fill, stockpiling and end-tipping directly onto peat slopes;
 - Suitability of drainage measures and the prevailing groundwater conditions are also key factors to consider during construction. Increasing pore water pressures within peat deposits decreases the stability of a slope;
 - In extreme events, peat can act as a viscous fluid and travel over very shallow slopes. The re-working or excessive handling of peat can reduce the shear strength to residual levels and hence lead to 'liquid' peat behaviour;
 - The rate of construction can have a major influence on the stability of peat land environments. Rapid loading and limited time for excess pore pressure dissipation can also decrease the stability state of peat slopes;
 - Excavation across a side slope, a convex slope / break in slope can induce peat failure;
- 5.2 Therefore, the most significant but highly unlikely impact is death or injury to site personnel. More likely is disruption to the proposed infrastructure through infrastructure damage leading to time and cost impacts on the development and Impact through damage of the environment.

Conclusions

- 5.3 The peat depths across the site are on average <1m with a mean peat depth across the development calculated to be 0.75m. It should be noted that where peat probes indicate shallow depths 0.1m to 0.3m that the deposits are likely to be composed of a topsoil and mineral subsoil.
- 5.4 The mean un-drained shear strength determined across the Development is (34kPa). This indicates peat of low shear strength. A conservative characteristic value of 15kPa has been used in the slope stability modelling.
- 5.5 The risk ranking produced in this report are a combination of the overall likelihood with the potential environmental/impact effect of a peat instability event. With increased proximity to watercourses exposure of such an event is vastly increased as watercourses act as a sensitive off-site receptor and can carry peat debris to further offsite receptors.
- 5.6 The derived risk rankings are based on the risk of peat failure occurring without appropriate mitigation and control measures in place during construction. It should be highlighted that through geotechnical risk management, strict construction management and

implementation of relevant control measures, this shall reduce the risk of peat failure across the development to residual to low levels.

- 5.7 The qualitative risk assessment should be reviewed prior to construction and further refined following intrusive ground investigation.
- 5.8 The offsite proposed access does not traverse peat deposits, the terrain contains evidence of instability within underlying glacial sub-soils along the adjacent river valley. Slope stability assessments therefore should be carried out for this infrastructure element as part of any future geotechnical investigations.

Recommendations

- 5.9 The preliminary geotechnical risk register for the site cites key control measures which are required to reduce the risk of peat slide to residual levels. However, there should be wider consideration of these measures across all areas of the proposed development which may be influenced by the proposed construction. This is critical where infrastructure may impact terrain and slope conditions beyond the proposed working areas.
- A detailed intrusive ground investigation should be carried out (post-consent) and as part of the pre-construction phase of development. This investigation should seek to further characterise the peat deposits with emphasis on, in-situ shear strength testing and targeted undisturbed sampling and laboratory testing. All peat samples recovered should be classified in accordance with the Von Post system, (Hobbs, 1986) and current British and Eurocode standards for site investigation;
 - Groundwater level information should be collated as part of any future ground investigation;
 - The results of a detailed ground investigation should be assessed with respect to refining the peat stability assessment at all infrastructure locations. All pertinent control measures and mitigation measures should be revised, and their implementation supervised following the results of the ground investigation and construction design phase of works;
 - Continued assessment and monitoring throughout the construction phase of works and at suitable intervals post construction should be implemented to ensure the control measures are suitable and are providing adequate mitigation against peat instability;
 - Construction practices should be managed through the Construction Method Statement (CMS) and within the wider context of the Construction Environmental Management Plan (CEMP). The CMS should be prepared by the appointed principal contractor and reviewed by a suitably experienced geotechnical engineer who has read and understood this report. The following general recommendations are provided in line with the, Good practice during wind farm construction, (2019) guidance:
 - Avoid peat arisings being placed as local concentrated loads on peat slopes without first establishing the stability condition of the ground and slope system. Stockpiling on areas of deep peat and in close proximity to steep slopes should be avoided.
 - Avoidance of uncontrolled and concentrated surface water discharge onto peat slopes as this may act as contributory factor to failure. All water discharged from

excavations during construction phase should be directed away from all areas identified as susceptible to peat failure and should be managed by a suitably designed site drainage management plan.

- All excavations where required should be adequately supported to prevent collapse and the destabilising peat deposits adjacent to excavations.
- A system of daily reporting should be established during construction and utilised to monitor the geotechnical performance of slopes including peat, sub-soil and bedrock. This should be implemented and undertaken by a suitable experienced and qualified geotechnical engineer. Post construction this monitoring procedure should be curtailed to allow for annual or ad-hoc inspection as required.

Floating Track Construction

5.10 MacCulloch, (2006) advises that a 'floating' type road construction which leaves the peat deposits in situ may be advantageous with respect to preventing peat failure. This method of construction has a lower impact on the internal groundwater flow within the peat land. However, there are cases where groundwater flow within the peat can be detrimentally affected. The following control measures should be implemented as part of the design and construction of 'floating' access track:

- Prevent the rupture of vegetation surface of the peat by avoiding the use of large sharp rock fill;
- Prevent the overloading and subsequent shearing of the peat throughout construction and use of the 'floating' track;
- Monitoring of the long-term settlement of the 'floating' track is necessary to predict the effects of reducing permeability within the peat and hence increasing groundwater pressures beneath the track construction. Through ongoing monitoring additional drainage relief measures can be implemented when conditions for peat failure are predicted;
- Do not position 'floating' access track on or adjacent to convex side slopes.

5.11 An additional control on the construction and use of 'floating' track is through the strict management of construction traffic loading. This may involve the timing between heavy traffic to be staggered to prevent the effect of cyclic loading over short time periods reducing the shear strength of the peat. In order to assess the maximum loading rate or timing between heavy construction traffic it may be necessary to monitor the vertical deformation of the 'floating' track sections following loading and recording the time taken for recovery of vertical deformation. The use of simple settlement plates and survey pegs can be used to achieve this. The frequency of trafficking for heavy loads must then be timed to allow deformation of the 'floating' road to recover its deformation.

5.12 MacCulloch (2006) generally advises that in order to prevent injury or an environmental incident, it is important that there is a robust procedure in place should it become apparent that a peat failure is imminent.

Cut/Fill Track Construction

- 5.13 Across areas of the Development not mantled by deep blanket peat and on slopes; the construction of proposed access tracks should be considered by excavation and replacement method, MacCulloch, (2006). Excavated peat is removed and targeted for suitable re-use. Aggregate would be used to form the subgrade and running surface of the track.
- 5.14 For 'Cut' track construction the risk of peat failure is therefore focussed on the peat deposits adjacent to the access track, and the placement of peat arisings. In these areas the following control measures are listed by MacCulloch, (2006):
- Careful excavation of peat deposits by appropriate machine excavator to limit localised peat failures which can occur on the edge of the track excavation. This is in order to prevent a minor failure triggering retrogressive peat failure affecting a larger area of peat adjacent to the track;
 - Temporary drainage systems followed by establishment of a permanent drainage network. Silt traps and small retaining structures may be required especially in proximity to water crossings to prevent siltation and blockage of watercourses;
 - Ongoing monitoring and on demand maintenance when silt traps require emptying and temporary drainage reinstated if blocking occurs. This will assist in maintaining hydrology baseline conditions;
 - The permanent drainage system must direct surface water flow away from the 'cut' track to prevent peat failure within the track bunds;

General Earthworks

- 5.15 It has been identified that there is a requirement for the excavation of peat and superficial deposits during construction of the wind farm. Initially the vegetated peat layer and any topsoil should be stripped and temporarily stockpiled away from areas of deep peat and instability risk. The design of this stockpile must be agreed by a suitably qualified geotechnical engineer. When working in areas of deep peat (i.e. >1.0m) no peat or overburden should be stored on such deposits as this may lead to instability. The following options for peat storage may be considered:
- Dedicated peat storage areas designed under the advisement of a suitable qualified geotechnical engineer and conform to up to date regulations and waste directives.
 - Re-use of peat in dressing-off of batters on access tracks, finishing of cable trenching works, the landscaping of turbine bases. Peat must be re-used to ensure stability and its long terms sustainability i.e. the prevention of drying of desiccation.
 - Excavated glacial till and weathered rock may be used as backfill to turbine bases should material be deemed geotechnically suitable. All related works must be carried out in accordance with an agreed CEMP and conform to site restoration plans.
 - For in-situ and undisturbed peat; site vehicle movements must be minimised across such areas, throughout construction and post construction. Observation and monitoring for settlement, deformation or signs of failure along access tracks and critical working areas must be implemented. This may be achieved with a network of

settlement plates and survey markers which can be periodically re-surveyed, and any differential movements identified. It is recommended that all earthworks are designed in accordance with current national standards.

5.16 The following risk mitigation is recommended with regards to peat storage:

- Storage site selection and stockpile design would be undertaken by a suitably qualified and experienced engineer;
- In general, the temporary storage of peat in a single dedicated area shall be avoided;
- Peat storage on areas of low / negligible peat slide risk only
- Peat storage height shall not exceed 1m;
- Routine maintenance and inspection of peat storage areas would be undertaken;
- Additional mitigation measures are detailed in Natural Power's Peat Management Plan submitted along with the Peat Stability Assessment.

6 REFERENCES

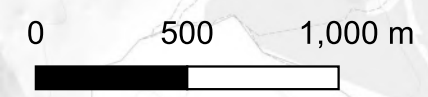
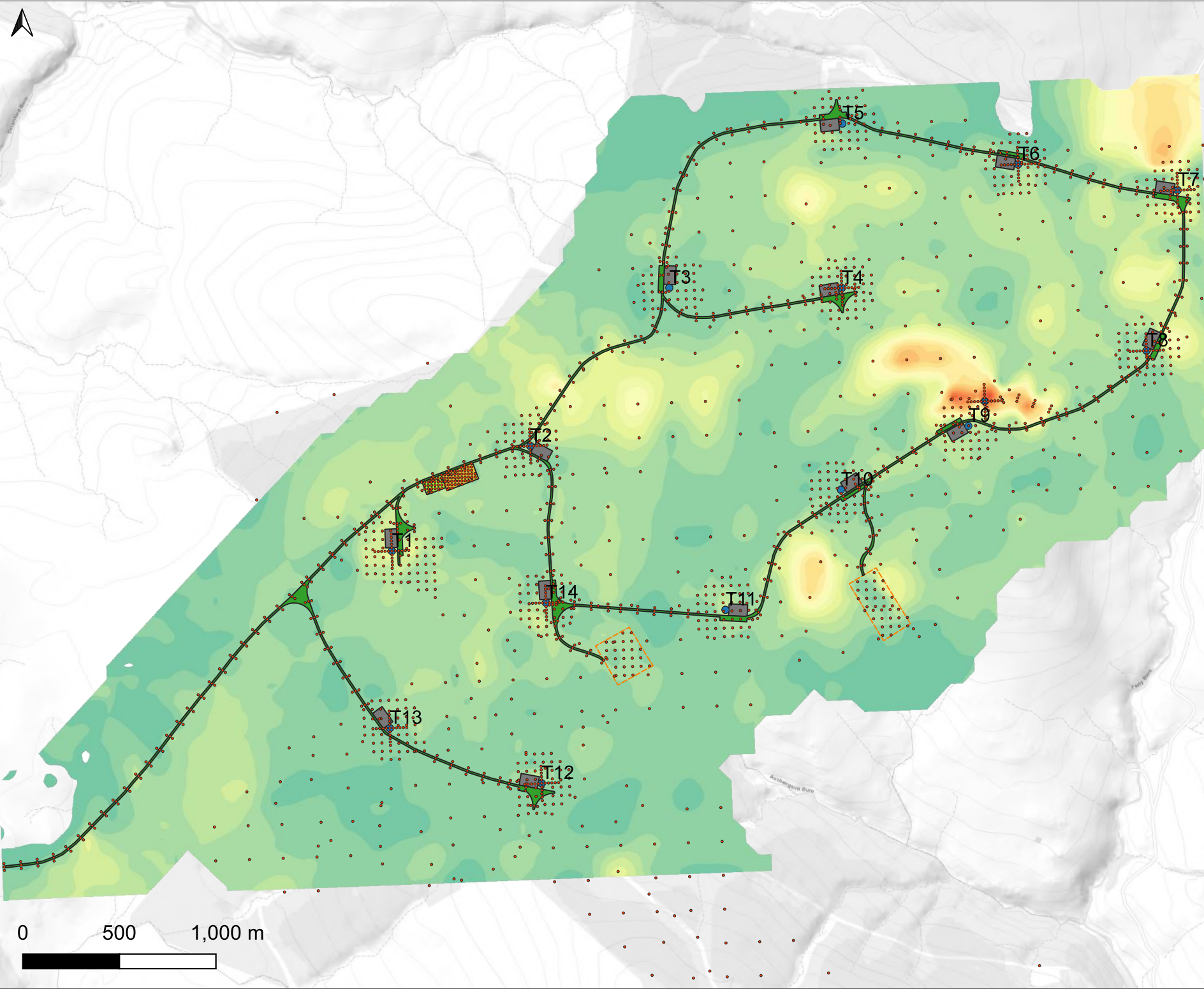
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7 GLOSSARY

Term	Definition
Acrotelm	The thin aerobic zone at the surface of the mire usually fibrous and containing the majoring of groundwater flow through the peat mass, underlain by the thick anaerobic zone called the catotelm, usually a higher degree of humification and lower shear strength.
Bog Burst / Flow	Failure of a raised bog (i.e. bog peat) involving the break-out and evacuation of (semi-) liquid basal peat. A flow is formed of highly humified basal peat from a clearly defined source area.
Bulk Density	The normal in situ density of a soil, i.e. its mass divided by its volume.
Catotelm	see acrotelm.
Consolidation	The process by which a soil decreases in volume.
Construction Method Statement	(CMS), a detailed written description of how a particular construction activity will be carried out safely and in an environmentally compliant manner.
Diamicton	Glacially derived soil which is poorly sorted and contains soil particles ranging in size from clay to boulders.
Geographical Information System (GIS)	Form of technology capable of capturing, storing, retrieving, editing, analysing, comparing and displaying spatial environmental information.
Geo-hazard	Geological hazard, either natural or man-made, which threatens either humans or the environment in which they live.
Geo-membrane	Non-porous sheet that has a very low permeability (in engineering terms impermeable) usually formed of polyethylene.
Geo-textiles	Man-made fabrics, generally made from plastics but also may be made from natural materials, used in construction.
Groundwater	Water located beneath the ground surface in soil pore spaces and in the fractures of rock formations.
Ground Investigation	Specialist intrusive phase of site investigation with associated monitoring, testing and reporting to a national standard.
Hagg	Natural gully or weathering structure in surface of peat mass.
Hazard	Something with a potential for adverse consequences / harm.
Humification	The process of decomposition of a peat soil.
Hydrological regime	The statistical pattern of a river's constantly varying flow rate.
Mitigation	The limitation of undesirable effects / impact of a particular event.
Mitigation Measures	Actions in place to limit the undesirable effects / impact of a particular event.
Peat Slide	Failure of a blanket bog involving sliding of intact peat and the mineral substrate material or immediately above the contact with the underlying mineral soil substrate.
Peat debris slide	Shallow translational failure of a hillslope with a mantle of blanket peat in which failure occurs by shearing wholly within the mineral substrate and at a depth below the interface with the base of the peat such that the peat is only a secondary influence on the failure.
Permeability	The rate at which water and air moves through a soil.
Pore water	The water filling the voids between grains of soil

Term	Definition
Primary consolidation	The process by which a soil decreases in volume through the expulsion of internal pore water
Overland flow	Water passing rapidly over or through the surface layer of soil.
Peat	A largely organic substrate formed of partially decomposed plant material
Precipitation	Deposition of moisture including dew, hail, rain, sleet and snow.
Risk	The combination of the probability of an event and the magnitude of its consequences
Residual Risk	The risk remaining after mitigation measures have been undertaken.
Rockhead	The upper surface of rock mass beneath the superficial soil cover.
Runoff	Surface runoff is the flow of water over the surface that can result due to the surrounding soils lacking the capacity to infiltrate further water or due to the surface water flowing off infrastructure such as access tracks and hardstands.
Secondary Consolidation	The compression of a soil that takes place after primary consolidation due to creep, compression of organic matter etc.
Sedimentation	The tendency for particles in suspension to settle out of the fluid in which they are entrained.
Site Investigation	The overall process of discovery of information concerning a site, the appraisal of data, assessment and reporting. Can include desk, non-intrusive and intrusive investigation.
Shear strength	The maximum shear stress which a material can withstand without rupture/ failure
Shear vane	In situ test using a x4 blade steel vane pushed into the ground and rotated to provide an indication to the undrained shear strength of a soil.
Superficial Deposits	Young, sediments and soil deposits occurring at the surface.
Surcharge	An additional mass of material or load applied to an existing soil or structure
Topography	The physical features of a geographical area.
Undisturbed Sample	A sample of soil whose condition is sufficiently close to the actual condition of the soil in situ to be used to approximate the properties of the soil in the ground.
Water resources	The supply of groundwater and surface water in a given area.



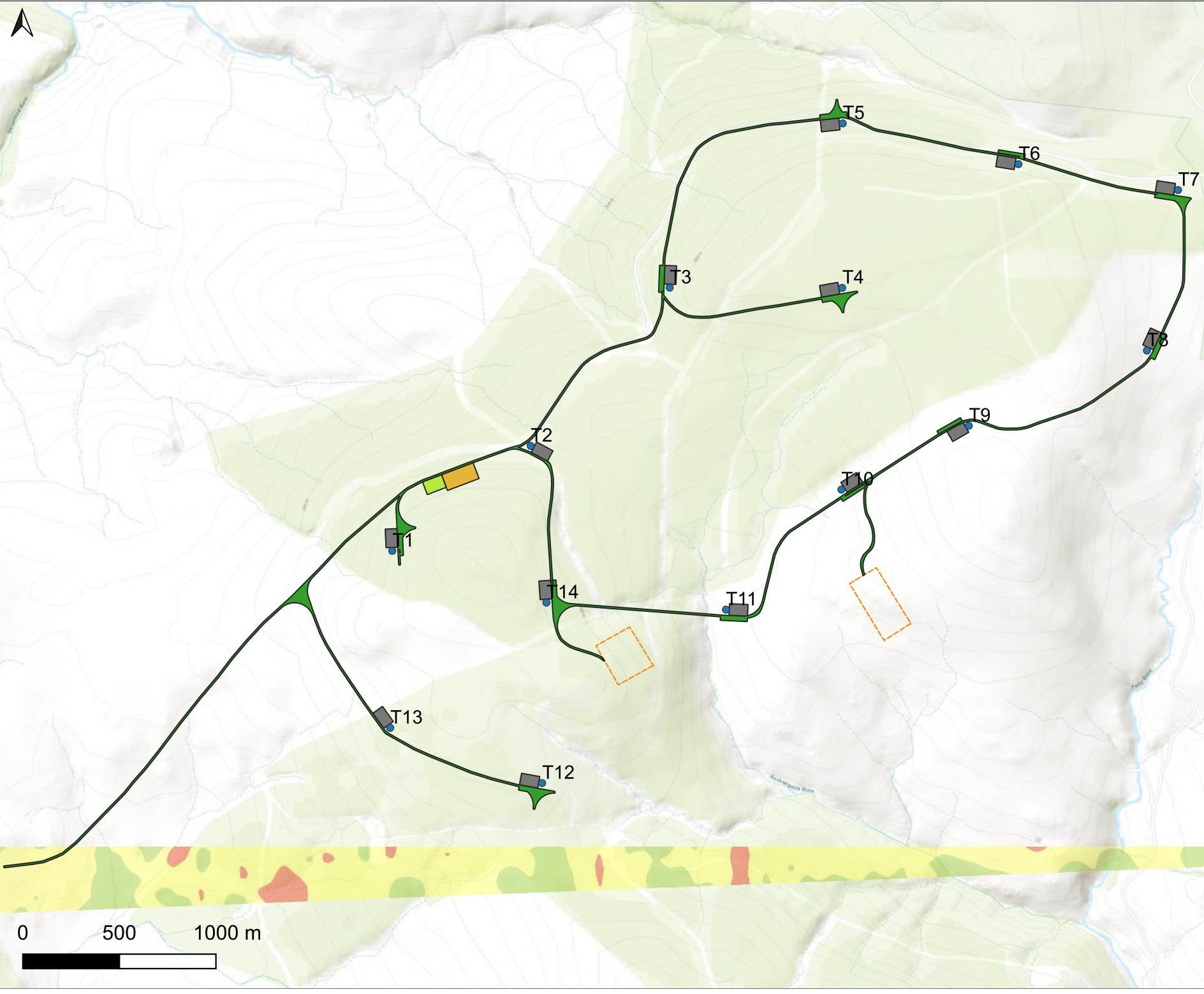
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Map Legend:

Notes:
Peat Depth Interpolation calculated with kriging method in Surfer version 17.
Probe data points shown to indicate coverage.

B	Second Issue		26/08/22
A	First Issue		19/11/20
Rev	Description	By/Ch	Date
Status: First Issue			
Project: Craiginmoddie Wind Farm			
Client: EnergieKontor			
Drawing Title: Peat Depth Map			
Drawn: GG	Checked: CM	Approved:GG	
Scale: AS SHOWN @ A3		Date: 26/08/22	
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Notes:
Slope Angle calculations based on aerial photo derived 2m resolution DSM.

A	First Issue		19/11/20
Rev	Description	By/Ch	Date

Status: First Issue

Project: Craiginmoddie Wind Farm

Client: EnergieKontor

Drawing Title: Slope Angle Map

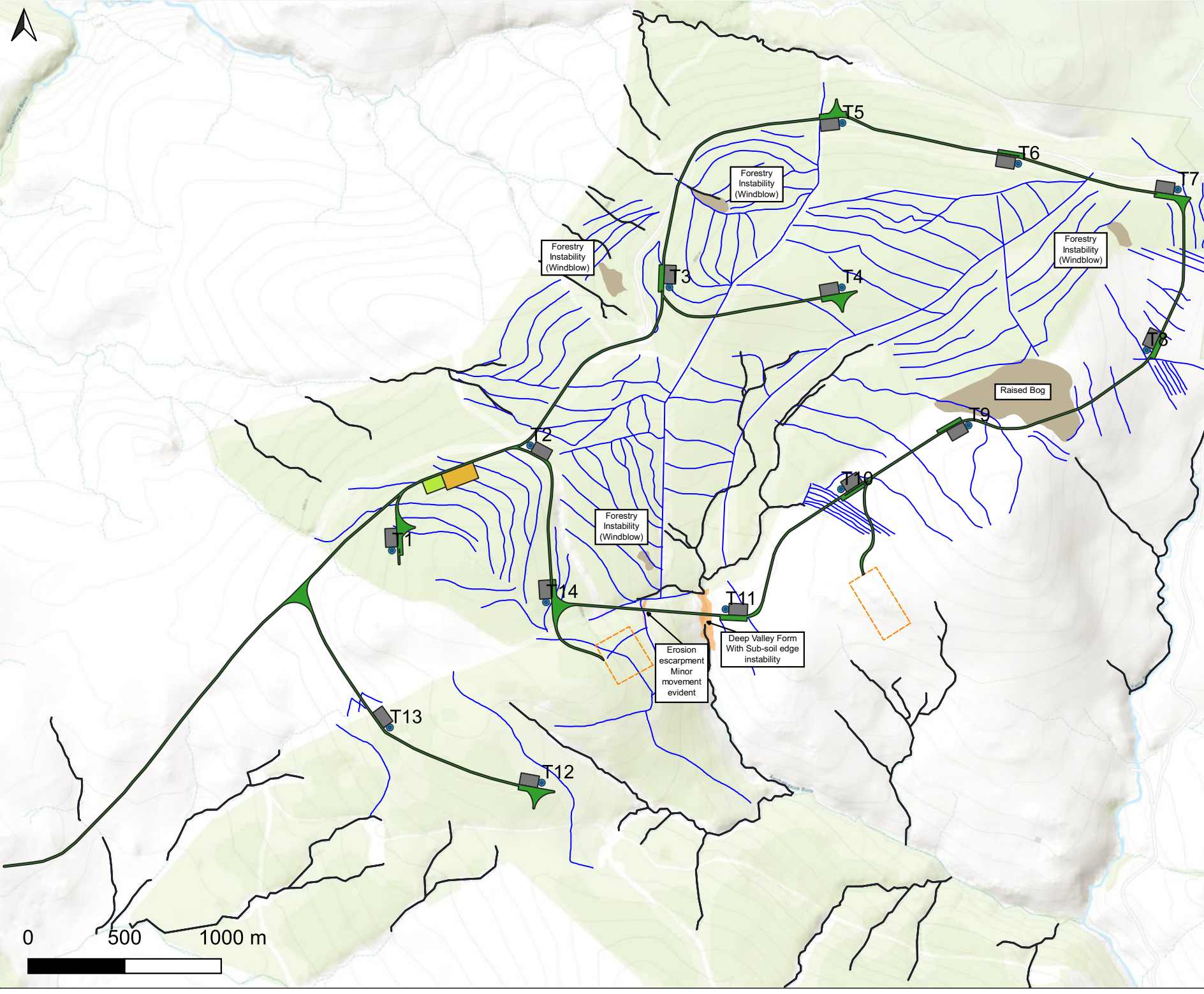
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Map Legend:

- Artificial Drainage
- Main Watercourse
- Access Track
- Crane Pad
- Turbine Foundations
- Substation
- Compound
- Crane Pads
- Borrow Pit Search Area

Notes:

Rev	Description	By/Ch	Date
A	First Issue		19/11/20

Status: First Issue

Project: Craiginmoddie Wind Farm

Client: EnergieKontor

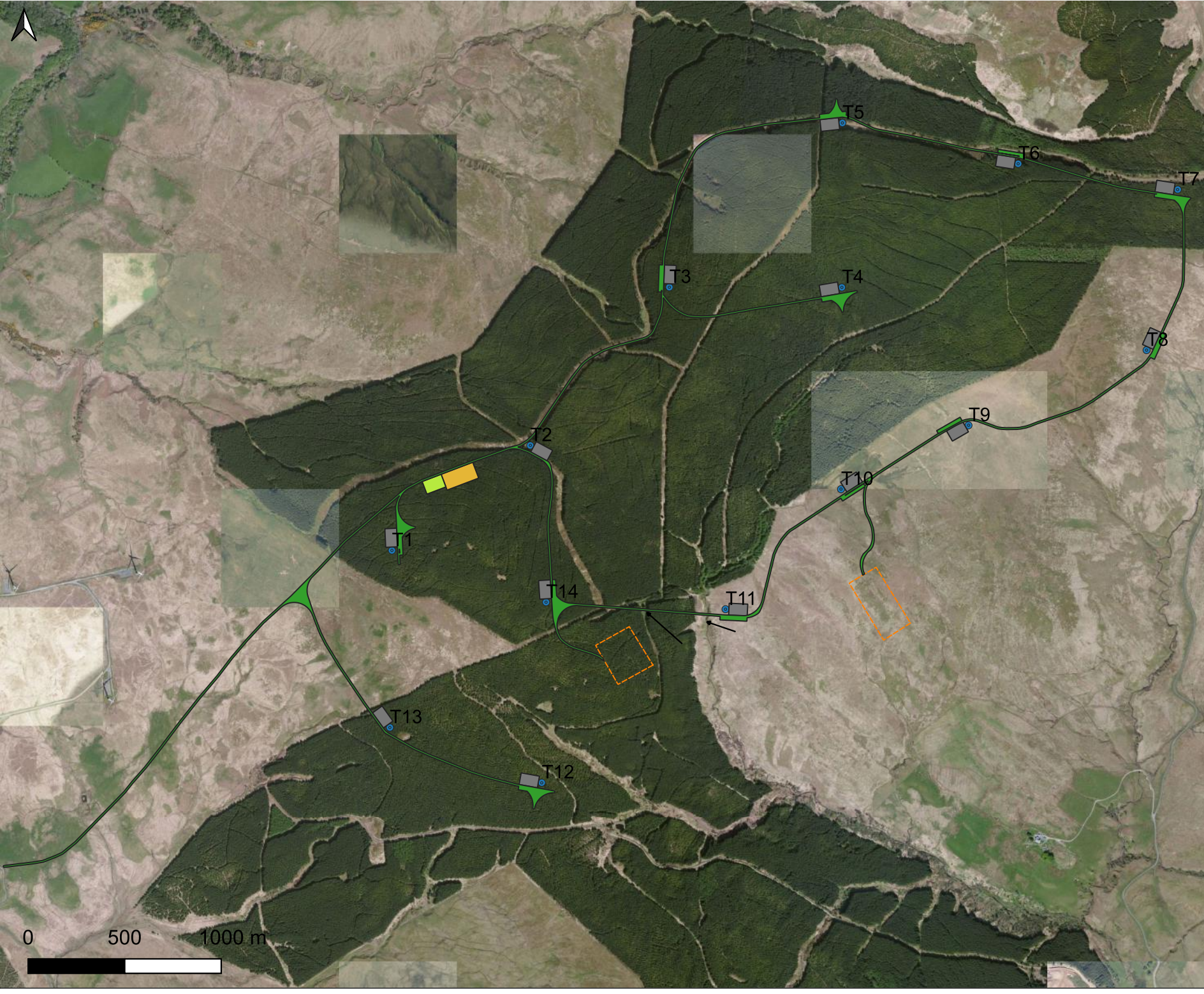
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Map Legend:

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- Crane Pad
- Turbine Foundations
- Substation
- Compound
- Crane Pads
- Borrow Pit Search Area

Notes:

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A	First Issue		19/11/20

Status: First Issue

Project: Craiginmoddie Wind Farm

Client: EnergieKontor

Drawing Title: Aerial Photo Map

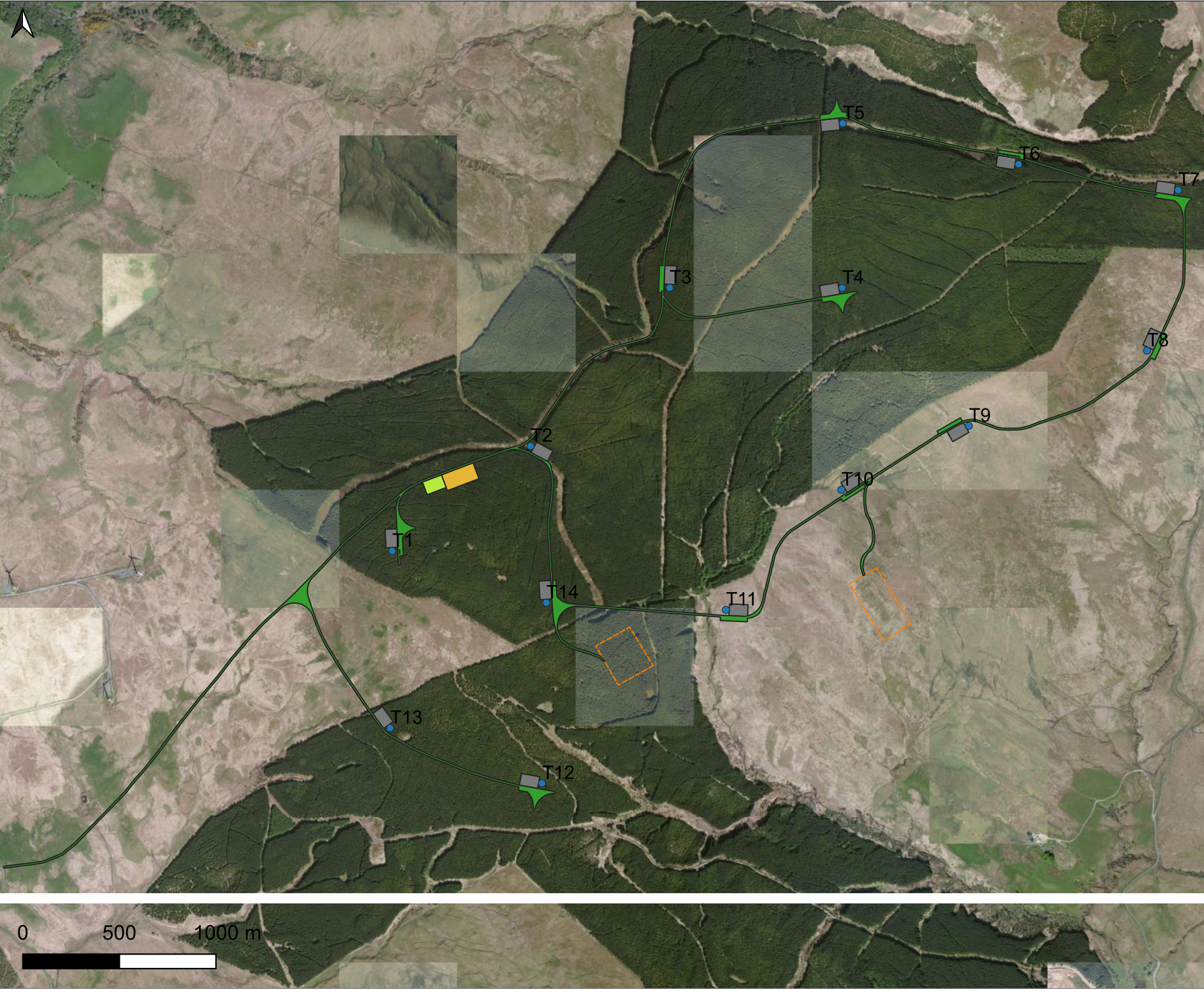
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Map Legend:

- FOS: >1.3
- FOS: 1.0-1.3
- FOS: <1.0
- Access Track
- Crane Pad
- Turbine Foundations
- Substation
- Compound
- Crane Pads
- Borrow Pit Search Area

Notes:
Infinite Slope Analysis:
Transitional slab sliding model:
Peat Undrained shear strength - 15kPa;
Surface surcharge 20kPa modelled.

A	First Issue		19/11/20
Rev	Description	By/Ch	Date

Status: First Issue

Project: Craiginmoddie Wind Farm

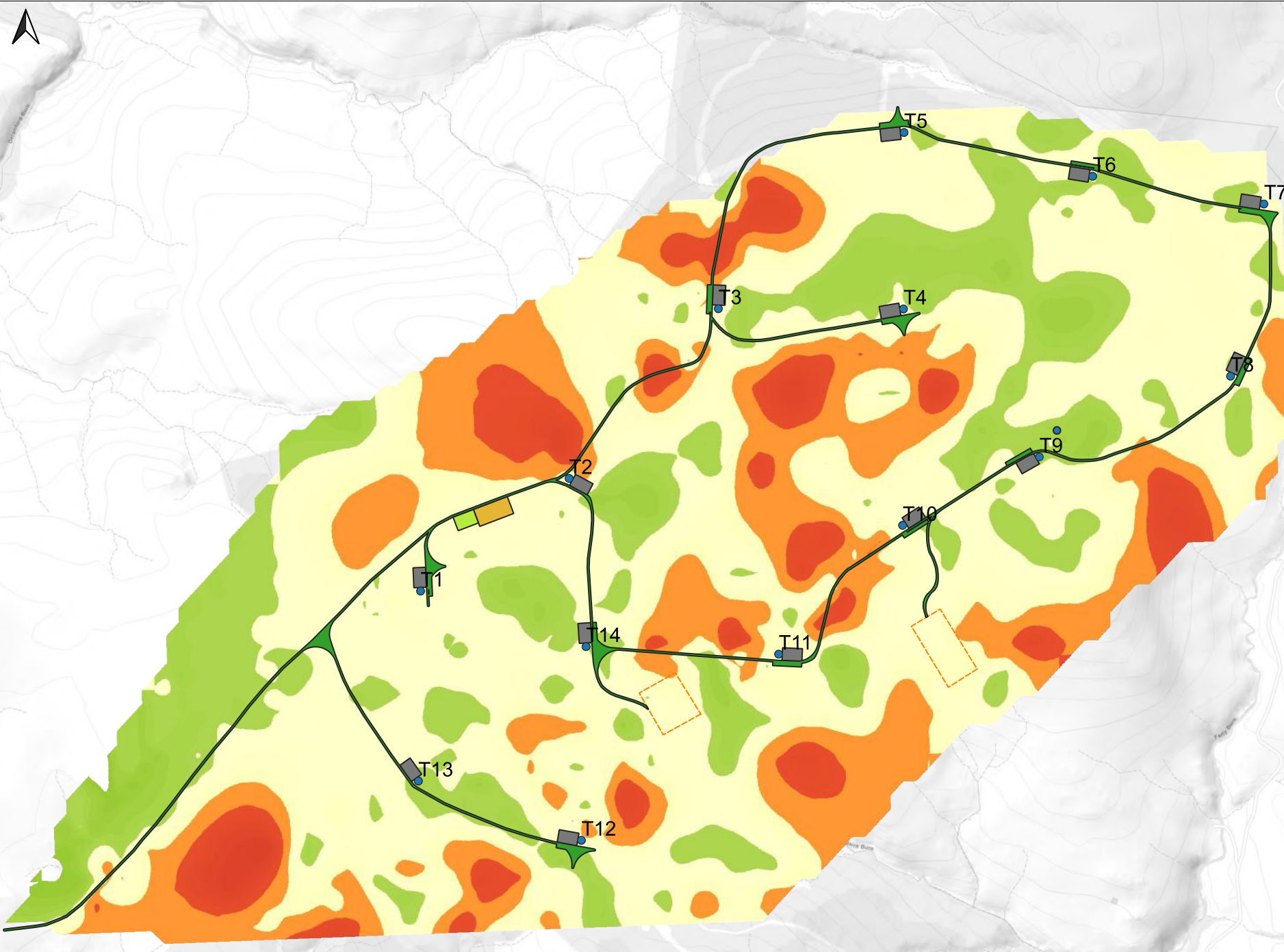
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Drawing Title: Factor of Safety Map

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Map Legend:

High Risk

Medium Risk

Low Risk

Negligible Risk

Notes:
Risk map (pre-mitigation) devised from development survey data:
Peat depth, slope angle and proximity to main watercourse;
Detailed risk assessment for each infrastructure location including infrastructure impact and necessary control measures included in Report: 1238941.

B	Second Issue		26/08/22
A	First Issue		19/11/20
Rev	Description	By/Ch	Date

Status: Final

Project: Craiginmoddie Wind Farm

Client: EnergieKontor

Drawing Title: Peat Slide Risk Map

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