Technical Appendix 8.6

Draft Habitat Management Plan

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SCOTTISHPOWER RENEWABLES

Hollandmey
Renewable Energy Development

Habitat Management Plan

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Draft

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1 Introduction

ScottishPower Renewables (UK) ltd ('SPR') is leading the UK in the operation and development of renewable technologies and proposes to develop Hollandmey Renewable Energy Development (hereafter referred to as the 'proposed Development') within north eastern Caithness in the Scottish Highlands.

As part of the Environmental Impact Assessment ('EIA') for the proposed Development an assessment has been made of the potential ecological impacts. As such, this Draft Habitat Management Plan ('HMP') has been developed to not only mitigate for the loss of priority habitat (**Hollandmey Renewable Energy Development EIA Report, Chapter 8: Ecology and Biodiversity**) but also to enhance the local area for biodiversity through large scale habitat restoration.

SPR manages all HMP's internally and is currently delivering HMP's at 30 windfarm sites across the UK, encompassing a total land management area of approximately 10,000 ha.

2 Purpose of the HMP

The overall purpose of the HMP is to implement positive land management for the benefit of landscape and nature conservation which will mitigate any adverse impacts that the proposed Development may have had. In addition to purely mitigating against any adverse impacts, SPR is committed to enhancing the habitat value of the proposed Development has taken the opportunity to provide not only mitigation, but larger scale enhancement of local habitat features to provide wider benefits for nature and biodiversity. This HMP defines the Aims and Objectives of the land management that will be implemented on the proposed Development to achieve this overall purpose.

The Hollandmey Renewable Energy Development EIA describes the direct and indirect impacts the proposed Development will have on the habitats present. It is predicted that the proposed Development will result in the total loss (both direct and indirect impacts) of 10.05 ha of regionally important blanket bog communities (M15d, M19a and M25a) and 35.43 ha of marshy grassland communities (M23b). Although these impacts were assessed as being not significant in the context of the EIA regulations, it is the purpose of this HMP to not only mitigate for these losses but provide an overall net gain for habitats in the local area through the restoration of 168 ha of afforested blanket bog.

The HMP has been written in a manner that provides a clear link between management and monitoring and focuses on *habitat* criteria which are aspects that can be managed directly, and *species* criteria which are used to partially indicate habitat quality.

3 Management Structure and Reporting

The HMP will run from the first commissioning of the proposed Development to its decommissioning and will be managed wholly by SPR. The HMP is viewed as an iterative document which will be updated throughout the process in line with the results of monitoring.

4 Site Location and HMP Area

The proposed Development is located approximately 8 km south west of John O'Groats and 16 km east of Thurso (**Figure 1**) and sits within The Highland Council administrative area. The proposed Development comprises 10 wind turbines, battery storage and ground mounted solar arrays with associate infrastructure.

The HMP area lies to the north east of the proposed Development application boundary (**Figure 1**) and currently comprises 168 ha of commercial forestry which encloses the Phillips Mains Mire Site of Special Scientific Interest (SSSI).

The proposed Development is predominantly covered by commercially managed coniferous woodland comprised of a Sitka spruce/lodgepole pine mix. The HMP area is similar with an underlying habitat of predominantly blanket bog which was cultivated and planted with conifers in the mid 1980/early 1900's. The Phillips Mains Mire SSSI appears to have been unaffected by the surrounding forestry with the most recent Site Management Statement (2006) concluding that the site was in a favourable condition. However, it was also noted that:

> *"The long-term condition of the site will be influenced by the future of the surrounding forestry. Further tree removal from the hydrological unit, and restoration to blanket bog would benefit the SSSI."*

The proposals within this HMP to fell and restore 168 ha of peatland habitat will provide a significant net gain for the site and a multitude of benefits that go far beyond like for like compensation. Felling the forestry will provide an open habitat surrounding the Phillips Mains Mire SSSI, re-instating the site as a valuable habitat for many wader species and promoting and preserving the favourable conservation status of the site.

5 Habitat Overview and Status

The HMP area comprises primarily deep peat (>50 cm) habitat grading into shallower peat on the outer periphery (**Figure 2**) which is currently afforested. For the purposes of management, the HMP area comprises the broad habitat type described below:

1. Modified Blanket mire and wet heath occurring on peatland generally >30 cm depth.

Peatland habitats comprising a blanket mire grading out to wet/dry heath occupy the majority of HMP area and represent "natural" habitats (albeit in a modified state) which would be expected to occur in a system unaltered by anthropogenic influences. As described in Section 4 the peatland habitat has been modified to accommodate commercial forestry. Peatland habitats in good condition provide a multitude of environmental benefits, particularly for biodiversity, ecology, hydrology and as part of the carbon cycle, among others. Afforestation of peatlands has many negative impacts on the underlying peat including altering the underlying hydrology, drying out the peat and ultimately leading to oxidation and loss of the peat mass. Removal of the trees and restoration of the underlying hydrology is key to restoring the overall habitat to a functional peatland for biodiversity, carbon storage and many other ecosystem services.

It is therefore the proposal of the HMP to fell the HMP area and restore the underlying modified blanket bog habitat. SPR is already delivering 8,500 ha of peatland restoration through its renewable energy developments. SPR is at the forefront of research and innovation into peatland restoration techniques and was appointed lead author by the International Union for Conservation of Nature (IUCN) of the chapter on deforested peatland restoration within the Commission of Inquiry on Peatlands Report (Robson *et al*., 2019). More detail on the experience SPR has in forest to bog restoration such as that outlined in this HMP can be found there.

6 Aims and Objectives

Overview

The primary intention of this HMP is to deliver large scale restoration of deforested blanket bog habitat.

Delivery Process

The delivery of an HMP is based on achieving the various Aims, which are assessed by measuring the extent to which clearly defined Objectives and their associated condition indicators have been met. The definition of each Objective is therefore a key requirement for an HMP to allow progress to be assessed in a quantified, objective way which has clear implications for whether the overall Aims are likely to be met and any management measures which need to be put in place or amended.

A summary of the stages applied to each Objective within this HMP is shown in **Figure 3**. For Objectives where the required management is not obvious, or the processes not well enough understood to allow them to be defined in detail, a programme of trials is advocated to allow the methods, costs, rates and effects of management measures to be assessed before being implemented more widely.

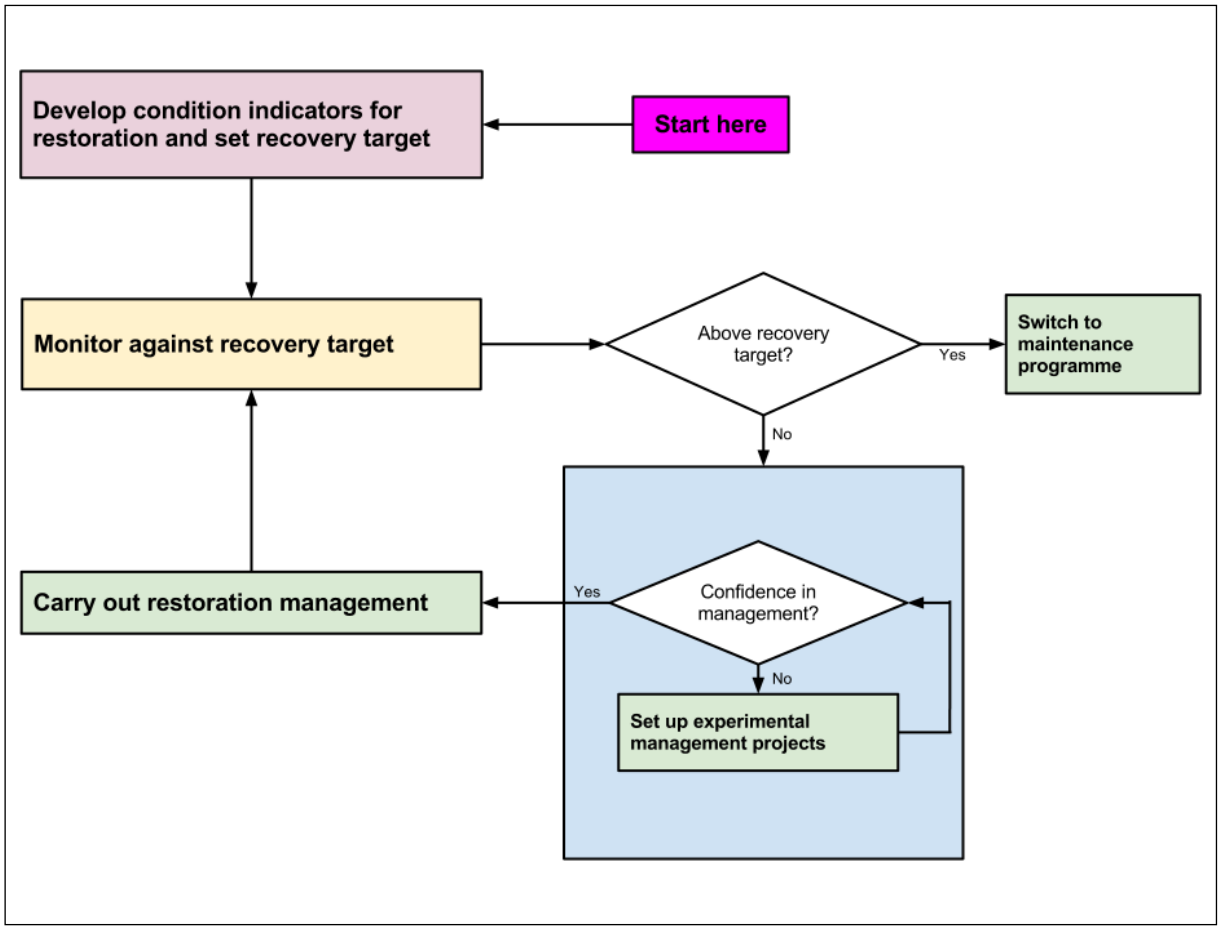


Figure 3: Process for monitoring and management to achieve habitat restoration, redrawn from Hurford and Schneider (2007).

Overall Weighted Score

In order to assess the success and outcome of the Aims, a scoring system will be used to express the outcome of monitoring results, this is displayed in **Table 1** below. Some Objectives are considered to be more fundamental than others to achieve in order for habitats to be restored and therefore are higher weighted accordingly (see individual Objectives within each Aim for the weighting). This allows an overall weighted average score for the entire monitored area to be produced out of 100 (total = percentage of plots meeting each objective x weighting) and compared against the table below, with 100 demonstrating each Objective is met at every sample location. This method allows an overall assessment of restoration progress to be made.

Table 1: Overall Weighted Score

Condition Class	Weighted average range
Very poor	< 60.0
Poor	60.01-70.0
Acceptable	70.01-80.0
Good	80.01-90.0
Excellent	90.01-100

Aims and Objectives are described for the restoration of deforested blanket bog below. Management measures that will be undertaken across the HMP area are described in **Section 7**, and a description of the monitoring that will be implemented to assess the progress of the Aims using each Objective is included in **Section 8**.

Aim 1: Restore conditions for deforested blanket mire habitat

Definition and Distribution

The definition of deforested blanket mire habitat covered by Aims 1 and 2 is defined as all deforested areas within the HMP boundary where peat depth is >0.5 m. The distribution of this habitat is shown in **Figure 2** and covers a total area of approximately 168 ha.

Background

SPR have undertaken comprehensive research and monitoring on deforested peatland sites to understand the underlying hydrology and have such developed techniques which demonstrably restore blanket bog conditions. The key issue arising from extensive afforestation of blanket bog is a disruption to the water table. With extensively elevated ground along ridges as a result of ploughing creating habitat that is out with the water table level and therefore too dry for bog vegetation to recolonise out with the furrows (**Photo 1**). In addition, the presence of conifer regeneration from seed can cause additional drying pressure through evapo-transpiration as well as shading as the trees increase in size.

Photo 1: Post felling bog habitat showing elevated ridge with stumps visible and associated regeneration of conifers.

Condition Requirements
The conditions required for the restoration of blanket mire within these areas are defined as follows:

- water table depth must be close to ground level throughout the year, including the main drought period April – August; and
- regenerating trees must be absent.

Objectives
Based on these requirements a set of Objectives have been defined which will allow progress to be monitored (see **Table 2**). An Objective is considered to be met when monitoring (**Section 8**) indicates that at least 70% of sample plots meet the criteria except for tree regeneration which requires 90% of sample plots to be met.

Table 2: Description Aim 1 Objectives

	Objective	Description
Bog water table	1.1	The bog water table should be no deeper than 20 cm from the surface of the main peat mass on each sampled plot when assessed in summer 'drought conditions' (defined as the time at which water table levels on site are considered to in the lowest 10% of their measured range, and rainfall has been negligible for at least 3 weeks; surveys undertaken any time between 1st April and 31st August). Weighting: 20%
	1.2	The bog water table should be no deeper than 10 cm below the surface of the main peat mass on each sampled plot when assessed in summer 'drought conditions'. Weighting: 15%
	1.3	The bog water table should be at or above the surface of the main peat mass on each sampled plot when assessed in summer 'drought conditions'. Weighting: 5%
Tree regeneration	1.4	Conifer trees, broadleaf trees and exotic shrubs (e.g. Rhododendron) should be absent from each sampled plot. Weighting: 5%
	1.5	Conifer trees, broadleaf trees and exotic shrubs (e.g. Rhododendron) should be < 1m in height if present. Weighting: 5%

Aim 2: Improve quality of deforested blanket mire habitat

Definition and Distribution

The definition of deforested blanket mire habitat covered by Aims 1 and 2 is defined as all deforested areas within the HMP boundary where peat depth is >0.5 m. The distribution of this habitat is shown in **Figure 2** and covers a total area of approximately 168 ha.

Background

The long-term aspiration (>5 years) is to restore the blanket mire habitat to a high quality (**Photo 2**). However, the precise vegetation assemblage which would be expected is difficult to define and variation is expected between the various mesotope types.

Photo 2: *Drosera rotundifolia*, *S. papillosum*, *Narthecium ossifragum* and *Vaccinium oxycoccus* are species typically found on relatively unmodified blanket mire

Objectives

A number of indicators have been used to formulate Objectives which reflect different aspects of blanket mire quality over time (**see Table 3**). These will be compared against suitable reference areas where possible to allow the quality of the restored blanket mire to be assessed in context. An Objective is considered to be met when at least 70% of sample plots meet the criteria.

Table 3: Description of Aim 2 Objectives

	Objective	Description
Sphagnum and peat	2.1	At least one species of Sphagnum should be present (predicted community M17, 18 or 19) on each sampled plot. Weighting: 10%
	2.2	*Sphagnum papillosum* or *S. magellanicum* should be present (predicted community is M17 & 18) on each sampled plot. Weighting: 5%
	2.3	Sphagnum spp. should account for at least 30% of basal cover on each sampled plot. Weighting: 10%
	2.4	Visible trampling or uprooting impacts of large grazing mammals on Sphagnum hummocks (or lawns) should be absent on each sampled plot. Weighting: 2.5%
	2.5	Bare peat should comprise <1% of 'basal' cover on each sampled plot, in situations where it is arising due to trampling effects or disturbance by machinery (where sites are naturally eroding this target can be modified to suit). Weighting: 5%
Higher plants	2.6	*Eriophorum* spp. should be present on each sampled plot. Weighting: 5%
	2.7	*Calluna vulgaris* should be present on each sampled plot. Weighting: 5%
	2.8	*Calluna vulgaris* of at least 20 cm average canopy height and with < 20% leading shoots browsed by deer/sheep on average, should be present on each sampled plot. Weighting: 2.5%
	2.9	'True grasses' foliar cover should be less than 5% on each sampled plot. Weighting: 2.5%
	2.10	The combined cover of *Calluna vulgaris*, *Eriophorum* spp. and *Tricophorum cespitosum* should account for no more than 75% of foliar cover on each sampled plot. Weighting: 2.5%

7 Habitat Management Measures

7.1 Physical Interventions on blanket mire

Physical interventions are defined as measures which comprise mechanical treatment to an area of land. These treatments will be carried out at an appropriate time post felling once modelling of catchments for water quality purposes has been undertaken.

7.1.1 Description

SPR have undertaken several trial projects to investigate types of intervention and their associated costs, environmental risks and practical considerations relevant to forest-bog restoration as detailed in the previously referenced IUCN report. A summary of techniques is presented in **Table 4** below.

Table 4: Summary of restoration techniques

Technique	Description	Drain/furrow disruption	Conifer regeneration removal
Cross-tracking	Uses a tracked excavator to flatten plough ridges and disrupt drainage pathways and kill conifer regeneration	Yes	Yes
Ground-smoothing	Uses an excavator bucket to upturn stumps, infill furrows and drains, and bury conifer regeneration Untreated buffers of 5 m are left at 50 m intervals and adjacent to watercourses, although these may be increased to 10m depending on sensitivity (e.g. water vole mitigation and adjacent on watercourses connected to a downstream SAC at NatureSot's request)	Yes	Yes
Hand clearance	Hand felling of conifer regeneration using clearing saws or chainsaws	No	Yes (densities <2500/ha)
Wave damming	Creating dams approx. 4 m apart within existing drains and double ploughed furrows to stop water flow.	Yes	No
Raking	Uses an excavator to rake conifer regenerating into brash lanes which are used to facilitate machine access across stumps	No	Yes

The precise areas where each technique will be implemented will be determined when undertaking the detailed planning of restoration work approximately 2 years post-felling. It is envisaged that a combination of measures will typically be required within each defined area depending on ground conditions, topography and the extent of factors affecting restoration (i.e. conifer regeneration, stump sizes, drain status etc.). It is estimated that the first cohort of interventions will occur 3 years post-felling and be undertaken in sequential cohorts for a further 4-8 years depending on the baseline water quality parameters which will be monitored and defined after felling. These timescales are subject to review during the detailed planning process.

All methods require forestry residues (lop and top referred to collectively as brash) to be left on site after harvesting of the stem wood materials (>7 cm diameter) in order to facilitate access by tracked excavators during the operational phase. Forestry residues are also important in protecting the exposed peatland soils which are generated by several of the methods, both in terms of pluvial, fluvial and Aeolian erosive forces, frost heave and by providing sheltered micro-climates for vegetation to establish.

For any areas where machinery access to extract timber is impossible due to ground conditions, or where the quantity of standing timber required to form the brash lanes would result in no timber being extracted (i.e. all timber available is used to construct the brash lane) alternative methods of clearing trees such as in-situ mulching may be proposed by the contractor in consultation with SPR's ecology team and SEPA. Alternative methods will only be deemed acceptable if the quantity and distribution of material left on site is beneficial to the restoration process by providing a thin layer of protective mulch as per SEPA Guidance Note LUPS-GU27.

The detailed planning work will include a due diligence exercise to identify sensitive receptors, catchment scale water quality assessment (predominantly DOC), mitigation measures (including natural silt screens using untreated vegetated strips) and a monitoring plan for suspended solids during and after the works are implemented, and actions to take in response to monitoring results.

7.1.2 Programme

Interventions which require landscape-scale physical interventions will be phased over multiple years to mitigate against any negative environmental impacts which could otherwise arise as a result of the treatment works. A range of criteria will be applied to determine how areas should be prioritised over this period which is briefly described below.

1. Elevation/hillslope position (deforested areas of blanket mire): deforestation monitoring undertaken by SPR on other sites has shown that areas of watershed/spur mesotope blanket mire tends to be drier and hence in poorer condition than mesotopes lower down hillslopes. It is also considered that drain/furrow disruption measures should start at the top of the drainage network as starting further down would cause any dams/infilling measures to have greater risk of erosion/failure due to upstream catchments still using the drains as preferential pathways. Therefore, blanket mire management units in the highest elevations were given higher priority for physical intervention.
2. Impact magnitude: the degree of existing impact due to drains, based on density, size and visual occlusion in unplanted mire and the veracity of conifer regeneration in deforested areas. A higher priority has been given to areas with larger and more active drains and those deforested areas with a greater density of regenerating conifers.

Detailed monitoring will be undertaken on the first cohort of treated land using the protocol described in **Section 8** to assess the results against the Objectives detailed in this HMP. If monitoring shows Objectives are unlikely to be met, further detailed monitoring may be implemented on additional cohorts of treated land.

8 Bog Monitoring Protocol

The following monitoring protocol will be implemented on the first cohort of treated areas, which is standardised to monitoring carried out on other SPR sites making both progress against Objectives and comparison between sites entirely empirical.

8.1 Overview

Sites will be monitored using a regular grid of points, spaced at 100 m intervals across all land identified for treatment work (deforested or open range (unplanted); shallow or deeper peat). On areas flagged for bog restoration, the full protocol (described in the following sections of this appendix) will be employed. On areas where peat is shallower, and restoration to 'non-bog' habitats is planned, a sub-set of the full protocol will be employed.

At each point, under the full protocol, data will be gathered on (i) depth to the bog water table, (ii) tree regeneration, (iii) vegetation cover and (iv) factors relating to treatment work itself (change in rate of bare peat cover, integrity of dams etc). Supporting data will be gathered continuously from instruments (water level loggers & weather station) at select locations to help interpret dipwell data, for at least 5 years from treatment, and from watercourses (Dissolved Organic Carbon (DOC) and Suspended Solid (SS) concentrations) to help understand the impacts of treatment work carried out. Additional data will also be gathered on select sites (nested sub-set of main monitoring points) at certain points in time to help expand the knowledge base for future operations, including measures of drain occlusion rate, prospects for future peat accumulation etc.

Points will ideally be visited for the first time prior to treatment in order to gather baseline data. Sites will then be visited after treatment work has been completed in Years 1, 2, 4, 6, 8, 10, 15, 20 and 25. Hydrology data will be gathered twice a year (during the spring or summer drought) for the first 3 years (baseline then Year 1 & Year 2), whereas all other data will only be gathered once a year in the years specified (as per the list above).

Once gathered, the field data will be backed up, input to PC and passed through a standardised analysis model to produce a range of outputs (charts and maps). These will include calculation of 'condition scores' as well as presentation of the key raw data which is used to derive the scores.

8.2 Locating and Marking Sampling Locations

Stage 1: The first stage of the protocol is to identify the range of locations to be sampled, locate them in the field, lay them out in a suitable location and mark them ready for assessment.

1. **Mapping of points**
    a. A 100 m-spaced grid of points should be generated and used to create a base map for survey work.
    b. Points should be mapped on a 1: 25,000 OS backdrop; relevant infrastructure and site hazards should also be shown.
    c. Points should be labelled and classified into types (i.e. deforestation plots or open range).
    d. A GPS upload file should be created to facilitate location of points.

2. **Location of points**
    a. Maps and GPS should be used to gain safe access to each mapped point.
    b. Once at the mapped point assess the suitability of the location for assessment:

        i. Check the depth of peat present and record to the nearest cm (capped at 600 cm).

        ii. DEFORESTED SITES: If the point is on peat of depth 50 cm or greater then apply the full protocol for BOG habitat as described herein. If the point is on peat < 50 cm in depth then aim to gather only a subset of the data NON BOG habitats protocol.[1]

        iii. OPEN RANGE SITES: If the point is on peat of depth 50 cm or greater then apply the full protocol for BOG habitat as described herein. If the point is on peat < 50 cm in depth but the ground vegetation comprises species assemblages associated with mire then apply the BOG protocol also. Otherwise, aim to gather only a subset of the data NON BOG habitats protocol.

        iv. Irrespective of habitat type and peat depth, make sure that no part of the sampling set up will fall in areas where an assessment would yield unsuitable results such as:

[1] This protocol is simply a sub-set of the elements described herein, focusing solely on vegetation composition and the nature of tree cover present on the site. The relevant sections for assessment are marked in the document.

- Power lines (overhead or underground)
- Roads / road verges / borrow pits / site compounds / other hard standings and infrastructure (e.g. Met mast).
- Other land disturbed by windfarm construction
- Footpaths
- ATV tracks where quad bikes are commonly driven
- Areas of standing timber (unless the survey has been specially designed for this purpose e.g. at EIA stage or to inform a felling application)
- Unsafe ground (e.g. quaking bog, fell-to-waste areas, windblown areas, crags, very steep slopes etc)
- Areas which have been disturbed for drain damming on open range (local peat borrow pits)
- Areas where domestic animals have been atypically active (e.g. around feeding stations over winter etc).
- BOG protocol only: streams and immediate stream banks, where atypical habitat is often present
- BOG protocol only: other areas of atypical habitat (e.g. fens, nutrient-rich flushes etc)
- BOG protocol only: areas where vegetation in sampling quadrats has been suppressed by shading or resource competition from tree regeneration.

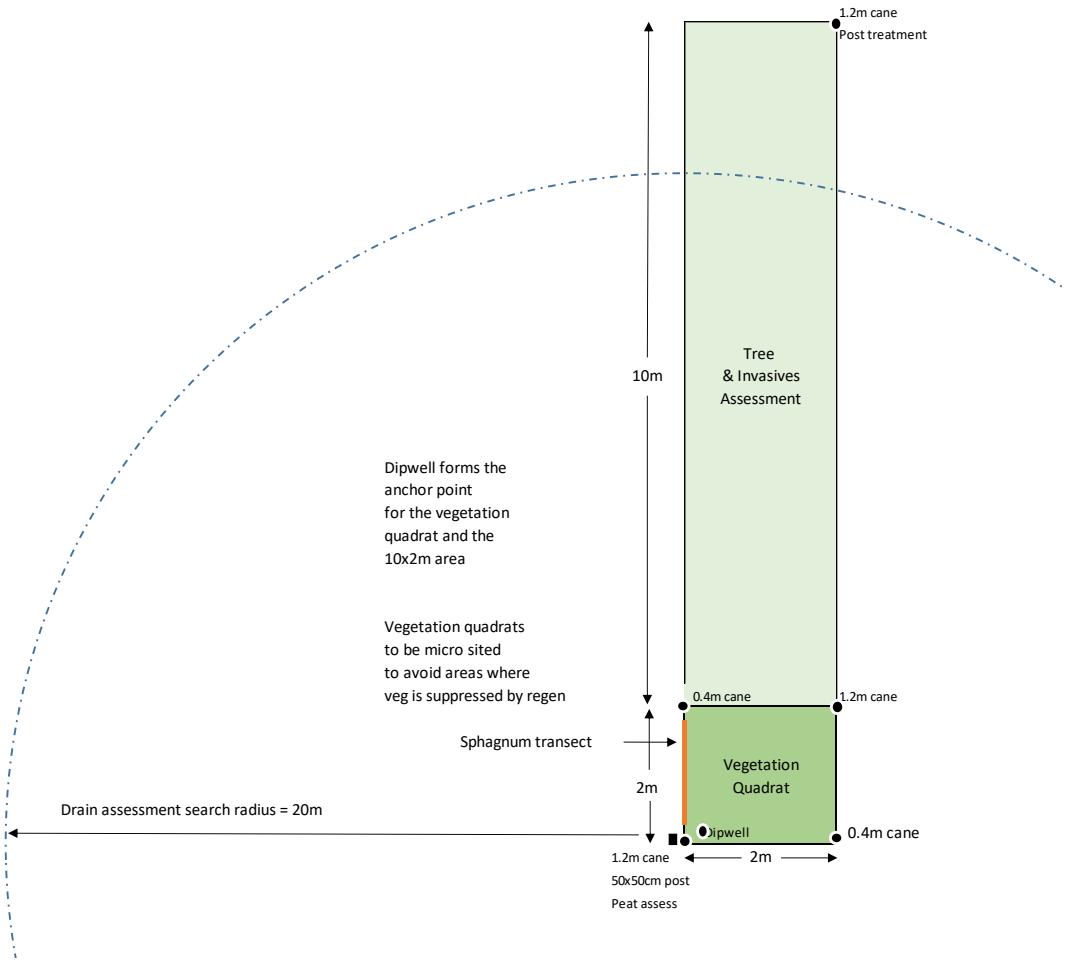
c. If the location is not suitable then move to a point where the habitat is suitable for the purposes of the assessment using the following approach:

   i. Systematically move the point 5 m north, then north-east, then east, then south-east etc. (8 points of the compass) in a circle, until a suitable location has been found. A suitable location will be defined as one where all data will be gathered from suitable habitat (see later in this protocol – each point has a range of different sizes and shapes of plot associated with it, on which data will be gathered).
   ii. If no suitable location is found then repeat at 10 m radius on the same basis intervals until a location is found.
   iii. If no location can be found by the time you have reached 50 m from the original centre point then record the point as un-suitable for assessment and move to the next one.
   iv. If no suitable point can be found: create a data sheet with the plot details and note the reasons why the plot was considered unsuitable.

v. If a suitable location can be found: record the distance and direction of re-location to the new point, and record the new GPS co-ordinates.

3. Marking the assessment area

a. Full plot layout and marking for BOG habitat is shown in the following diagram (for NON BOG, only the quadrat and 10 m transect will be set up and used) – the plot set up is oriented north, as shown in the diagram, unless conditions on site necessitate a change (e.g. to S facing) in which case the data sheet needs to be marked to confirm this decision and why it was made.



b. Most of the permanent marking shown in the above diagram will be put in place after treatment of the site because of the degree of disruption that can be expected when machinery is working. Exceptions to this may be

open range sites where, for example, drain spacing is relatively wide and machine disturbance might be limited. However, it is unlikely even on these sites that full marking would be placed before management interventions are complete.

c. If pre-treatment baseline data are to be gathered: assessment plots will be marked using the 1.2 m bamboo cane in the SW corner of the quadrat only. Data will be gathered using temporarily-marked plots (various items can be used e.g. marking tape, temporary post etc, as suits).

d. For the BOG protocol the full plot layout (used post-treatment) will consist of the following elements (NON BOG elements marked ***):

    i. A dipwell 'cored' at a suitable location (a suitable location is either a 'plough shoulder' or at Sphagnum lawn level; relocate locally around the GPS point to find a suitable location). Once the dipwell is in place, it should sit 20 cm north-east of the main 1.2 m marker cane (i.e. just inside the SW corner of the 2x2 m quadrat).
    ii. 2x2 m vegetation quadrat formed around the dipwell location, with 40 cm and 120 cm bamboo markers in place as per the diagram above.***
    iii. Peat physical properties sampling location (if specified) – this should be obtained from a core just outside the SW corner of the 2x2 m quadrat. Peat depth should also be assessed here (if specified).
    iv. Tree-related data should be gathered on a 10x2 m plot that starts on the north edge of the 2x2 m quadrat and runs northwards. Invasive species data will also be gathered on this plot, along with any supporting data relating to afforestation and felling.***
    v. An assessment of drain status will be undertaken on the nearest drain within a 20 m search radius of the plot centre.

e. Full plot marking, which should be installed after treatment work is complete, will be as follows:

    i. The dipwell will be sleeved with land drain (25 mm) and a cane, which will act as the larker (see next section of the protocol, which describes installation).
    ii. The southwest corner of the 2x2 m quadrat will be marked using a 50x50 mm treated wooden post inserted level with vegetation canopy level (or 20 cm above the peat surface on recently treated sites). Use a marker pen to write the plot code on the post.

iii. Use a 0.4 m cane to mark the other corners of the quadrat (inserted to 20 cm depth).
iv. On deforestation areas only[2]: a 1.2 m bamboo cane should be inserted beside the post, to leave approx. 0.7 m above ground. A length of orange nylon forest marking tape will be wrapped and knotted around both the post and cane 20 cm above ground level, to bind them together. Another length of tape (30 cm) will be tied onto the top of the bamboo cane, and the end knotted to stop it fraying. Use a marker pen to write the plot code on the top marker tape (on the bamboo). Another 1.2 m cane should be placed in the same way on the NE corner, to help facilitate speedy relocation. Insert so that 0.7 m is out of the ground.
v. On deforestation areas only: where tree regen' is present a 1.2 m bamboo should be used to mark the northeast corner of the 10x2 m plot also. Insert so that 0.7 m is out of the ground.

[2] Tall visible markers may attract sheep on open range areas, which might confound long-term monitoring of browsing rates.

8.3 Plot Assessments

Stage 2: The second stage of the protocol is to gather the field data required. When in BOG restoration areas the full protocol should be used. On parts of the site where NON-BOG habitat is being restored (e.g. by hand clearance of conifers or raking using a machine) a sub-set of the protocol should be employed (marked ***)

NOTE: In advance of undertaking an assessment it is recommended that surveyors visit a suitable reference site (e.g. T77 at Black Law) to familiarise themselves with an example of an un-modified 'high-quality' blanket bog. The development of the SPR bog monitoring protocol and associated scoring system used data from such sites for calibration purposes. Visiting such a site in advance of work beginning, and perhaps undertaking a 'dry run' of the protocol, will provide a benchmark for consideration and reference when surveyors are assessing their own plots.

1. **Peat-based assessments**

   a. Peat depth ***: take a full depth measure adjacent to the main plot marker using a 6m probe. Record the peat depth to the nearest 10 cm where peat is >1m and to the nearest cm if <1 m. Ensure the probe is not penetrating soft boulder clay layers at the base of the peat – visually check the end of the probe for grey layers which may be indicative of this. The probing point should be at 'plough shoulder' or Sphagnum lawn (inter-tussock) level.

   b. Peat properties with depth (if specified): use an auger to obtain a peat core to 1 m depth. Cut out segments at the 5 cm, 50 cm and 1 m levels for analysis (% soil moisture, bulk density, pH and Von Post score will be measured in lab conditions, if deemed necessary, from early cohorts of plots on each windfarm site to help understand pattern and process on the sites being treated. Data will be gathered from up to n=30 locations per treatment cohort depending on the likely range of variability that will be encountered. The work would be undertaken at baseline then repeated 4, 10 and 15 years after treatment.

2. **Dipwells – groundwater hydrology**

   a. Dipwell installation[3]:

      i. Identify a suitable site for the well – either on a plough shoulder (the zone between the ridge and furrow) in deforested areas or at *Sphagnum* lawn level (or inter-tussock level) in open range.

[3] Installation can be done at any time in the year.

ii. Core to 1.2 m using a 30 mm hand auger - extract as much of the core as possible.
iii. If assessing pre-treatment simply line this with a short 15 cm section of 25 mm land drain to preserve the entrance to the well. Place a wire flag beside the sleeve to aid with re-location
iv. In the post treatment phase, insert a 1m long section of 25 mm land drain into the hole, with 1.2 m bamboo zip-tied to it to provide rigidity, leaving 10 cm of the well proud of the surface. Install diagonal bracing canes at 45 degrees to the vertical well to prevent vertical movement and tie these to the well using zip ties.
v. Trim the plastic well to be level with the cane it is fastened to – this will then form a reference mark for measurements.
vi. Fit a cork bung to the top to prevent rain ingress.

b. Dipwell monitoring:

NOTE: Dipwell monitoring needs to be undertaken in spring or summer 'drought conditions', which typically on most SPR sites occur sometime(s) between April and August[4].

i. 'Acrotelm' depth assessment[5]: At the time of installation (or during an early monitoring visit if lacking time) assess the depth from the ground surface adjacent to the dipwell to the top of the main peat mass (the 'acrotelm depth'). Use a serrated blade to cut vertically into the ground and isolate a column of vegetation (or needle litter and roots) and soil then carefully remove this by hand (in sections if it breaks) until the 'release point' is located. This is typically the point where collapsed *Sphagnum* stems meet directly with well decomposed peat, and is often obvious when the column is held at both ends and gently pulled apart. Measure the depth from the vegetation surface to the release point and record (cm) then re-instate the material. [All data from dipwells will then be referenced using this point as a datum when analysis work is undertaken.]

ii. Dipwell measures: Once the well has equilibrated (leave a week, or if short of time fill with water and leave to discharge for at least 24 hours) the depth to the bog water table can be measured. In the field, use a buzzing

[4] The target set for restoration is that the bog water table is within a certain distance of the ground surface when the site is strongly drawn down, as this is the time when specialist bog plants find it hardest to survive.
[5] This is not strictly the acrotelm, but a measure of the depth of vegetation and lightly decomposed material lying on top of the main peat mass (often called the catotelm, albeit not strictly accurate). We use acrotelm as a term of convenience here.

stick ideally (or equivalent) to assess the depth. The approach used is to measure from the rim of the well sleeve, at the point where the bracing canes are tied on, down to the top of the water table and record depth (cm). Also measure the distance vertically from the well sleeve rim down to the ground surface, again at the bracing canes, to help ascertain afterwards if the well sleeve has moved relative to the ground surface.

3. Plant cover cover*:**

The following measures are carried out in the 2x2 m quadrat unless otherwise stated.

NOTE 1: Vegetation monitoring ideally needs to be undertaken towards the end of the growing season (September onwards) in the first 5 years for recently treated deforestation sites, because changes in the level of re-colonisation are so rapid in the first 5 years from the point at which bare peat cover is at its highest. Other sites, and older deforested sites, can be monitored more or less at any time of the year, within reason.

NOTE 2: If gathering pre-treatment baseline data, this quadrat should not be located in areas where vegetation is suppressed by the overhead shade cast by regenerated trees.

a. First stage – characterise general levels of plant cover of the quadrat:

   i. Basal cover:
      a) Record the total moss cover: % basal cover (by eye) of all moss species combined
   ii. Foliar cover (totaling 100%)
      a) Total vascular cover: % foliar cover (by eye) of all vascular plants combined
      b) Total cover of stumps, brash etc (deforestation sites only): % foliar cover (by eye) of brash, roots, stumps etc combined (exclude wood now covered in mosses; include this in mosses category).
      c) Total cover of bare peat: % foliar cover (by eye).
      d) Total 'other' foliar cover (confirm what it comprises – most likely mosses).

b. Second stage – characterise the quadrat in more detail:

   i. Bare peat cover: % basal cover (by eye)
   ii. Moss cover: % basal cover (by eye) of (i) non-*Sphagnum* mosses as a whole and (ii) *Sphagnum* mosses by group/key species:

      a) *S. magellanicum*
      b) *S. papillosum*

c) 'Other thick-branched *Sphagna'*
d) *S. cuspidatum*
e) *S. capillifolium*
f) 'Other thin-branched *Sphagna*'

iii. Vascular plants: confirm presence/absence of key plants present and % cover of each type estimated by eye (foliar layer).[6] These will be in the following categories:

a) Dwarf shrubs species = *Calluna vulgaris, Erica tetralix, Erica cinerea, Vaccinium myrtillus, Vaccinium vitis-idea;*
b) True grass species = *Molinea caerulea*, 'all others';
c) Sedges = *Eriophorum vaginatum*, *E. angustifolium*; *T. Cespitosum,* all other sedges;
d) Specialist bog plants: *Drosera rotundifolia, Narthecium ossifragum, Vaccinium oxxycocus;*
e) Rushes = *Juncus effusus*, 'all others';
f) Ferns = *Pteridium aquilinum*, 'all others'; and
g) Other flowering plants of interest: note as required, with a focus on: (i) other bog specialists and (ii) non-native or invasive species.

iv. Horizontal distribution of *Sphagnum*: the spatial distribution of *Sphagnum* moss cover will be mapped on each quadrat using a point intercept method at 20 cm intervals along the western side of the quadrat (i.e. between the plot marker in the southwest corner and the cane in the northwest corner). At each point record the presence / absence of *Sphagnum* and place it into one of four key categories:

- (i) *S. magellanicum/papillosum*;
- (ii) *S. capillifolium*;
- (iii) *S. cuspidatum*; and
- (iv) others.

To ensure the data are protected from surveyors repeatedly visiting the same area, there should be a buffer zone of 20 cm out from the west edge of the quadrat where there is no trampling (additionally there should be no trampling inside the quadrat).

v. Vertical structure of *Sphagnum*: On post-treatment monitoring visits on deforested sites, and for all visits to open range sites, the depth of *Sphagnum* moss present at each of the 'horizontal' sampling points

[6] Only certain plants will be ID'd to species level; many will be to group/genus level only (e.g. most grasses) to save time.

described above will be recorded (down to 'solid ground'; defined through use of blunt-ended narrow diameter pin).

vi. Structure of *Calluna*: assess the 'mean canopy top height' of *Calluna* on each quadrat by measuring maximum plant height at 4 locations within the 2x2 quadrat and recording the average (the presumption is in favour of taking 1 measurement per quadrant, unless the *Calluna* distribution is very clumped in which case measures can be obtained to provide a sensible average).

vii. Large mammal impacts:

a) The % of *Calluna* shoots browsed (on the hardened off previous year's growth and *not* the fresh, actively growing current year's fresh growth if working in summer or autumn) will be recorded (check the end of 10 'long shoots' and record % from this e.g. 4 of 10 browsed = 40%)
b) Quantify the % of total *Sphagnum* cover on the 2x2 m quadrat which has been (ii) visibly compressed by trampling or (ii) uprooted by large mammals when grazing (example: 10% total *Sphagnum* cover on the quadrat can still be 100% trampled or uprooted; possible to have both types of impact present but they should, in combination, add 100% maximum).

viii. Other impacts on *Calluna*: the % of measured *Calluna* cover on each quadrat that appears to have died back or otherwise been damaged by insects in some way (record impact as a % of the total cover (e.g. if *Calluna* cover is 50% of quadrat, it can still have 100% of cover damaged).

ix. Community type: carry out an assessment of the plant assemblages for the treatment cohort and ascertain the closest NVC community type(s) present (only for 'blanket bog-like communities: base assessment on community constants for M17, M18, M19 & M20 and note significant deviations from what is expected). Other habitat types categorised to Phase 1 level. Assessment at baseline and after 10 years and 20 years (for open range) but only at Year 10 and 20 for deforestation (communities often don't fit well on deforested sites prior to treatment). The assessment will use the data from the 2x2 m plots and will be based on a combination of field judgement (reference to keys) at the time, on a per plot basis, and analysis using all the 2x2 m quadrat data afterwards.

4. Tree cover (and previous crop status, if applicable)*:**

All the data listed below will be gathered on deforested sites. A sub-set (+++) will be gathered on open range sites.

a. In each 10x2 m assessment area assess the following;

i. Felling type: at baseline (i) use desk-based data (Geographic Information System (GIS) shapefiles) to identify if conventional felling used or mulching used (or other method; based on site maps) and (ii) on site record if the 2x2 m quadrat being sampled is located on a brash lane or not.

ii. Original planting stock: if possible[7] estimate the (i) typical spacing (cm) between tree rows (average 3 rows), tree stumps on rows and (ii) the average stump diameter (cm) (check 4 and average).

iii. Ploughing characteristics: if possible measure the typical difference in height (cm) from the top of the ridge (ignoring stumps) to the plough shoulder then measure the typical difference from the shoulder to the furrow base (cm) (to the solid peat in the base, not just to the top of the current moss/needle surface).

iv. Regenerated trees+++: on the 10 m x 2 m plot count up the number of trees present by species group (Sitka, Lodgepole, other conifer OR broadleaf) and by height class (< 1 m, 1-2 m, > 2 m). If stem density on the 10x2 m plot is very high, reduce the plot width to 1m (or even 0.5 m) if required. If this is still difficult/time-consuming to assess then assess in 5 sub plots of 1x1 m spread evenly along the 10 m plot axis. Record what assessment area was used (as length x width m; if sub plots note as e.g. 5 @ 1 x1 m).

v. Tree coning+++: assess coning frequency in each of the 3 conifer species groups as follows: (i) % trees with cones present on branches at time of survey and (ii) % of trees with cones present on the ground (i.e. coned last year and/or in the years before).

vi. Exotics/invasive species+++: confirm if *Rhododendron* or other alien shrubs are obviously present on the 10x2 m plot; estimate the % foliar cover of each species group present to the nearest 5%.

[7] On sites that have been deforested for a long time stumps may be obscured by vegetation growth and this may not be possible; often only possible for conventionally-felled areas only as the stumps are left above ground (mulched sites often end up with all stumps cut to ground level and with many obscured by mulch).

vii. Link to ground vegetation assessment+++: confirm the approx. % cover of land within the 10x2 m plot (and otherwise within the reduced plot size) which appears to have had its vegetation suppressed by the canopies of re-colonised trees (vascular plants clearly suppressed by shading and/or needle fall).

5. Surface drainage:

Drainage data will be gathered only for open range plots, because all drains on deforested sites will be in-filled as part of treatment work. Site data in GIS will be used to identify plots where there are drains within a 20 m radius of each proposed sampling point. The closest drain points will be identified on survey maps and its GPS location given.

a. At each selected area the following will be assessed;

i. Drain spacing: measure the distance from selected drain to next nearest drain using a 30 m tape measure – record to the nearest 0.1m (only if GIS from drains drawing not available to do this at design stage).

ii. Width: Typical drain width (cm) across top of drain from edge to edge.

iii. Depth: depth (cm) from ground surface (ignoring spoil on edges; accounting for obvious oxidized cross-sections[8]) to solid materials in the drain base / estimate of original depth (if deeper than this). This can be estimated by probing with a cane to identify textural differences, or by excavation/coring.

iv. Occlusion status: for a 5 m section of drain running from the monitoring point confirm (i) % drain base that comprises bare peat and the % drain base that is vegetated at the basal level and (ii) typical height (cm), from the existing solid base, of the moss and vascular plant canopies in the drain base.

v. Activity level: confirm if the drain is presently (i) holding water, (ii) flowing slowly or (iii) flowing strongly (unlikely given summer conditions but useful to know if they are).

[8] That is, try to estimate drain depth ignoring any obvious oxidised edge (i.e. add on some depth, as if the original ground level was still present at the drain edge).

6. Surface drainage (additional info, gathered post-treatment):

NOTE: The checks detailed below need to be undertaken in winter during a period of high rainfall and high water tables, soon after treatment work has been completed. It need only be undertaken in the first year after damming, but might be needed several times to ensure the treatment appears to have been initially effective. The tests apply only to open range sites. This data will be gathered on a project specific data sheet.

a. Drain block integrity+++ check the nearest 5 dams (or 'blocks' if an alternative method employed) to the monitoring point for structural integrity. If water is flowing through or around the sides in a manner than is eroding the dam structure (or has been when flows were high) then record this.

b. Water levels behind drain blocks+++ check and record the level at which water is holding behind each sampled dam. Markers (TBC) will likely need to be put in place so that this process is objective and repeatable.

c. Drain wall wetting+++ check if water levels in each dam have risen to cover the drain sidewall – record what % of the drain side wall remains un-wetted.

7. Fixed point images

Images will be taken at a minimum of 3 MP resolution and with due care so that the lens is not fogged up, obscured or out of focus.

a. At each plot take the following images:

   a. 2x2 m quadrat context: from 4 m south of the 2x2 m plot take a shot focused on the 2x2 m quadrat centre.

   b. 10x2 m plot: From the same location as above, take an image looking along the 10x2 m transect (top of the image in the viewfinder should be the end of the plot, assuming you can see it through any regen' trees).

   c. 2x2 m quadrat detail: walk to the SW corner of the 2x2 m plot and take an overhead shot of the southwestern quadrant i.e. 1x1 m area immediately adjacent to wooden peg (try to ensure wooden plot marker post is in the bottom left hand corner of the image for spatial reference).

   d. Drain assessment point: take an image of the 5 m section of drain assessed, with a marker in place at the assessment point and also take an image of the horizontal marker cane location (where applicable).

e. Permanent photo points: take a set of images at cardinal bearings N/E/S/W at selected locations with good vantage points over the main treatment areas (minimum of 2 per cohort).

8. Target notes

On a separate sheet take target notes of interesting features or observations made on site (particularly aspects of site response to treatment). Name the note with initials/date and target number i.e. DJ/090315/TN1. Record a GPS reference and take an illustrative photo.

9. Supporting data (instruments and other specialised data):

A range of supporting data will be needed to help interpret the data gathered on the formal plots, and also to help contribute to research work.

NOTE: Elements marked***. These items will be installed at the outset of treatment work (and ideally at baseline stage) to help interpret wider plot monitoring data. However, it is likely that these elements will be phased out after c. 5 years once a good understanding of site weather patterns and surface hydrology has been gained.

a. Bog Water Table loggers: these will installed to provide continuous information on the behaviour of the water table post-treatment***. Loggers are needed to help understand whether the dipwell data, which is to be gathered in 'drought conditions', is actually gathered when the site is heavily drawn down[9]. There will be 3 loggers per cohort treated on each windfarm site, for the first 2 cohorts treated on each windfarm and site type (deforestation / open range)[10]. The loggers will be installed so that they reflect broadly the lower limit, the upper limit and the average level of the bog water table as measured in the dipwells in each cohort[11]. Loggers will where possible be installed at easy-to-access locations. Loggers will be installed after treatment unless (i) research requirements suggest early installation would be useful or (ii) it is a site where loggers have not previously been installed hence

[9] The organisations tasked with running the monitoring program will need to 'weather watch' from March onwards to determine the best times at which to visit sites and measure water table depths. The depths ideally need to be assessed twice per season, at baseline and for the first 2 years after treatment, and then once thereafter on each site visit. Available tools to help with this process include: (i) SEPA river levels data, (ii) weather forecasts and (iii) local rain and water table data being obtained regularly from other intensively studied SPR sites.

[10] 3 per cohort so if the site is less than 100ha then 3 instruments would still be needed. The instruments can, in theory, be left for a long period without being downloaded albeit there is a risk that they malfunction in the intervening period and the monitoring period is then partly or wholly devoid of data.

[11] The expectation is that logger data and weather station data will be used to predict the behaviour of the bog water table in the remaining dipwells within a cohort. At a certain point in time these instruments might not be required and then could be moved to another cohort/site as suits.

pre-treatment data would be useful to have. If installed, data from these will be downloaded routinely onsite visits. Downloads will be noted on a specific data sheet.

b. Basic weather station (incl. rainfall, temp, relative humidity, sunlight) may be installed at each windfarm where major restoration work is being undertaken, to help understand how variations in weather, particularly in spring and summer, influence the results obtained from dipwell and transducer monitoring of the bog water table.*** If installed data from this will be downloaded routinely on site visits. Downloads would be noted on a specific data sheet.

c. Peat accumulation markers may be placed at up to 30 points across early cohorts of deforested land to provide a definitive point for future assessment of the evidence for 'peat formation' occurring (Yr + 10 and onwards). These comprise strips of mesh pinned to the ground at known points that can be uncovered at a later date. These will be installed after treatment. A modified approach may be adopted on early stage open range treatment sites also, to help expand the knowledge base. If installed, the meshes will be monitored in years 10, 15, 20 and 25. A specific data sheet will be used for this.

d. Occlusion status: On Open Range areas, the rate of occlusion of drains may be monitored to better understand how effective damming treatments are. The approach will be to mark up a sub-set of up to n = 30 drain occlusion assessment points in the cohort with a horizontal surface marker (suitable material e.g. a long fibre glass rod) inserted into each side of the drain so it 'bridges it. Identify the location with a marker peg at either end. A measurement (cm) will be made vertically down from regularly spaced markers (zip ties attached to horizontal rod) on the horizontal rod to the lowest 'solid' point in the drain base, and also to the top of the moss canopy within the drain. This work will only be done after treatment work has been undertaken, on a project-specific data sheet.

e. Surface levels: At the same selected sub-set of drains as above, or in specific study areas if a particular research program requires it, it will be useful to confirm if the level of the land either side of each drain appears to have oxidized / slumped as a result of drainage. This will be done by a 'levels survey' with a dumpy or equivalent. Again, this will be done after treatment work is completed, on a project-specific data sheet.

f. Fluvial carbon export: DOC/SS concentrations in watercourses connected to treatment sites should ideally be assessed and compared to the runoff from an unmodified bog (if available for assessment); spot samples should be obtained when on site. This will be gathered on a specific data sheet.

9 References

Robson et al., (2019) IUCN Commission of Inquiry on Peatlands Update: Peatlands and Forestry

Figure 1: Site Location and HMP Area

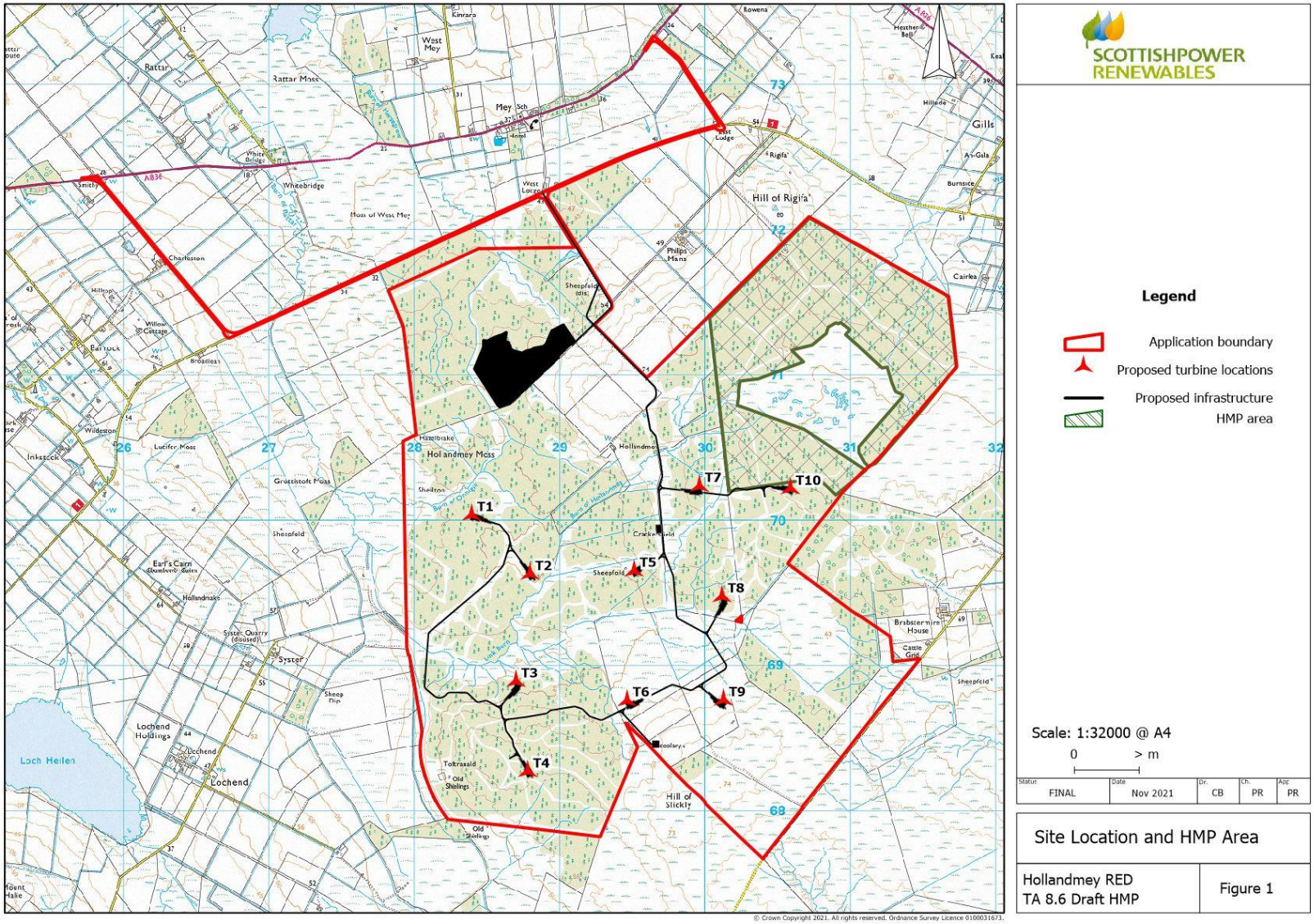
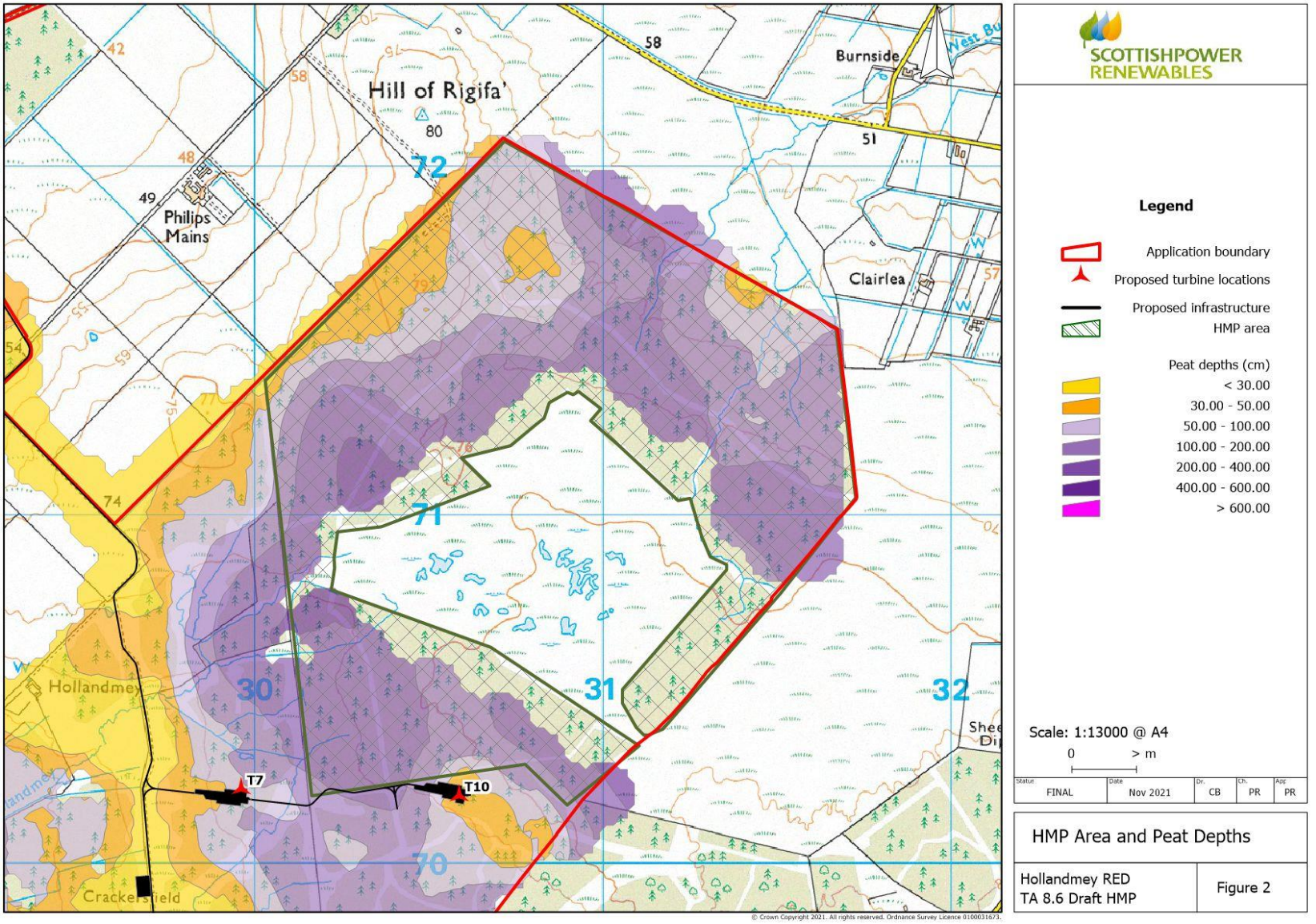


Figure 2: HMP Area Peat Depths



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