APPENDIX 3

Cyfoeth Naturiol Cymru
Natural Resources Wales

Llantysilio Mountain Fire Preliminary Assessment and SSSI Management Recommendations

Katharine Longden
Penny Anderson Associates Ltd

Report No 372

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1. Crynodeb Gweithredol

Paratowyd yr adroddiad hwn yn dilyn ymweliad rhagarweiniol tri diwrnod â Moel Morfydd, Sir Ddinbych, i asesu'r difrod i lystyfiant a phriddoedd yn dilyn y tanau gwyllt a ddigwyddodd am nifer o wythnosau yn ystod haf 2018, wnaeth ledu dros oddeutu 250 o hectarau o rostir sych yr ucheldir yn bennaf. Ymgymerwyd â'r arolwg ym mis Mehefin 2019, 11 mis ar ôl i'r tanau ddechrau.

Mae Adran 1 yn rhoi manylion am bwysigrwydd cadwraeth natur y safle a'i ddynodiadau cadwraeth gan y Deyrnas Unedig a'r Undeb Ewropeaidd. Nod yr adroddiad yw nodi opsiynau ar gyfer adfer lle bo angen, yn ogystal â chostau dangosol.

Mae methodoleg yr arolwg a chategorïau'r difrod tân yn cael eu disgrifio yn Adran 2. Yn gyffredinol, nodwyd pum categori difrod tân ac fe'u mapiwyd mor gywir â phosibl ar y safle, cymerwyd samplau pridd er mwyn asesu'r angen am ychwanegu maetholion neu galch ychwanegol i gynorthwyo adferiad planhigion a newid pH y pridd.

Mae Adran 4 yn disgrifio'r canfyddiadau ar y safle; mae'r cyfnod rhwng yr asesiad a'r tanau wedi golygu bod adferiad cynnar y llystyfiant yn amlwg mewn nifer o leoliadau yn ystod yr arolwg. Mae'n amlwg nad oes unrhyw arwyddion, neu arwyddion prin iawn o adferiad rhostir corlwyni a bydd angen rhywfaint o adferiad er mwyn cadw'r pridd ar y safle ac i gysylltu cynefinoedd tameidiog y safle dynodedig ehangach.

Amlinellir manylion ynglŷn â thechnegau adfer a chasglu data gwaelodlin mwy manwl yn Adran 5. Mae technegau adfer rhostir wedi'u datblygu'n gyffredinol ar gyfer ardaloedd gorgors (mwy na 40cm o fawn) ar lethrau lled fas. Disgrifir y rhain yn Adran 5, gyda chanllawiau ynglŷn â'u cymhwysedd i fawn mwy bas a phriddoedd tenau Moel Morfydd.

Y prif argymhelliad yw hau cymysgedd o laswellt maeth a hadau grug ar yr ardaloedd lle cafwyd y difrod mwyaf, lle mae'r mat gwreiddiau a'r banc hadau wedi'u colli, unwaith y mae nifer o foncyffion rhisgl bychan ac ardaloedd o rwydi jiwt wedi'u gosod mewn lle er mwyn atal golchi mwy o bridd i ffwrdd lle mae erydu a ffrydio eisoes yn digwydd. Argymhellir bod hadau yn cael eu hau o hofrennydd oherwydd nid yw cerdded ar draws priddoedd bregus a llethrau serth ar hyd ardaloedd mawr o'r safle yn ymarferol. Byddai'r difrod a achoswyd i adeiladwaith y safle a'r priddoedd yn helaeth iawn, ni ellid cyrraedd rhai ardaloedd o'r difrod a byddai materion iechyd a diogelwch sylweddol o bosibl wrth weithio ar lethrau serth. Os bydd angen triniaeth o'r awyr ar rai ardaloedd, yna mae'n debygol mai hadu'r ardal gyfan ar yr un pryd fyddai'r dull mwyaf cost-effeithiol.

Mae hefyd angen sicrhau bod y rhan fwyaf o'r hadau yn ymlynu at y pridd heb iddynt olchi neu chwythu i ffwrdd. Gellir cyflawni hyn drwy ddefnyddio tomwellt a deunydd gludiog (tackifier). Yn sylfaenol, gellir ychwanegu'r rhain mewn slyri sydd wedi'i gymysgu â dŵr (hydrohadu) neu ar ffurf sych (y cyfeirir ato yma fel 'hydrohadu sych') lle mae'r tomwellt a'r deunydd gludiog yn cael eu hactifadu yn dilyn glaw/pan maent yn dod i gysylltiad â dŵr. Nid oes un o'r dulliau hyn yn cael eu defnyddio'n eang ledled y DU ac mae angen cynnal trafodaethau rhwng contractwyr/cyflenwyr hydrohadau a gweithredwyr hofrenyddion er mwyn gallu datblygu dull gweithredol.

Cysylltwyd â phrosiectau adfer rhostiroedd eraill (Moors for the Future a Yorkshire Peat Partnership) ond maen nhw wedi cadarnhau nad ydynt yn defnyddio dulliau hydrohadu o'r awyr ar hyn o bryd (yn wlyb neu'n sych), sy'n golygu y byddai hwn yn ddull newydd o bosibl os ymgymerir ag ef.

Trafodir pori ar safle'r tân yn ystod adferiad yn fyr ac mae'n bwnc sydd angen trafodaethau manwl gyda Chominwyr, asiantaethau statudol ac, o bosibl, Llywodraeth Cymru. Mae cytundeb gyda'r Cominwyr yn hanfodol er mwyn sicrhau canlyniad adfer llwyddiannus.

Darperir y dull a argymhellir a chynllun gweithredu yn Adran 7. Mae angen casglu data gwaelodlin cyn dechrau ar y gwaith adfer, ac mae monitro yn hanfodol er mwyn cofnodi llwyddiant y technegau mewn gwahanol ardaloedd o'r safle ar draws amrediad o amodau'r safle (llethr ac agwedd). Bydd y monitro yn bwydo i'r Cynllun Adfer/Rheoli parhaus ar gyfer y safle h.y. triniaeth ychwanegol ar gyfer ardaloedd nad ydynt efallai yn ymateb yn ddigonol ar ôl un digwyddiad hadu yn unig, ychwanegiad planhigion plwg corlwyni i gynyddu amrywiaeth y rhywogaethau os nad ydynt yn cytrefu'n naturiol, creu rhwystrau tân o fewn llystyfiant newydd a phresennol, lefelau pori a rheoli, a datblygu cynllun rheoli tân ar gyfer y safle cyfan yn yr hirdymor.

Executive Summary

This report was prepared after a three-day preliminary visit to Llantysilio Mountain, Denbighshire, to assess the damage to the vegetation and soils following the wildfires that occurred for several weeks during the summer of 2018, which covered approximately 250ha of predominantly upland dry heath. The survey was undertaken in June 2019, eleven months after the start of the fires.

Section 1 gives details of the nature conservation importance of the site and its UK and European Union (EU) conservation designations. The aim of the report is to identify options for restoration where required, as well as indicative costs.

The methodology of the survey and the categories of fire damage are described in Section 2. Overall five fire damage categories were identified and mapped as accurately as possible on site, and soil samples were taken to assess the need for the application of additional nutrients or lime to assist plant regeneration and alter the soil pH.

Section 4 describes the findings on site; the time between the assessment and the fires has meant that early regeneration of the vegetation was evident in a number of locations during the survey. It is apparent that where there are no signs, or very limited signs, of dwarf shrub heath regeneration some level of restoration will be required both to retain the soils on site and to connect the fragmented habitat of the wider designated site.

Restoration techniques and more detailed baseline data collection are outlined in Section 5. Moorland restoration techniques have generally been developed for areas of blanket bog (over 40cm peat) and on relatively shallow slopes. These are described in Section 5, with guidance about their applicability to the shallower peats and thin soils of Llantysilio Mountain.

The key recommendation is to sow a nurse grass mix and heather seed on areas of the greatest damage, where the root mat and seed bank have been lost, once a number of small coir logs and areas of jute mesh have been fixed in place to prevent further wash out of soils where erosion and rills are currently occurring. It is recommended that seed application is undertaken from a helicopter because tracking over the fragile soils on steep slopes across large areas of the site is not practical. The damage caused to the fabric of the site and the soils would be very high, some areas of damage could not be reached and there would be potentially significant health and safety issues working on steep slopes. If aerial treatment is required over some areas then it will likely be most cost effective to seed the whole area at the same time.

There is also a need to ensure that the majority of seed adheres to the soil and does not wash or blow away. This can be achieved by the use of a mulch and ‘tackifier’. In theory these can be added in a slurry mixed with water (hydroseeding) or in a dry form (referred to here as ‘dry hydroseeding’) where the mulch and tackifier become activated after rain/when they come into contact with water. Neither methods are currently widely used in the UK and both require discussions between hydroseeding contractors/suppliers and the helicopter operators to allow a workable method to be developed. Other moorland restoration projects (Moors for the Future and Yorkshire

Peat Partnership) have been approached but have confirmed they are not currently using aerial hydroseeding (wet or dry), meaning this would likely be a novel approach if undertaken.

Grazing on the fire site during restoration is briefly discussed and is a topic that requires in depth discussions with the Commoners, Statutory agencies and possibly the Welsh Government. Agreement with the Commoners is vital to ensure a successful restoration outcome.

The recommended approach and Action Plan is provided in Section 7. Baseline data need to be collected before restoration starts, and monitoring is essential to record the success of the techniques in different areas of the site across the range of site conditions (slope and aspect). The monitoring will feed into the ongoing Restoration/ Management Plan for the site i.e. additional treatment on areas which may not respond sufficiently after only one seeding event, the possible addition of dwarf shrub plug plants to increase species diversity if they do not colonise naturally, the creation of fire breaks in the new and existing vegetation, grazing levels and management, and the development of a fire management plan for the whole site in the long-term.

2. Introduction and aims

Penny Anderson Associates Ltd. (PAA) was commissioned by Natural Resources Wales (NRW) in May 2019 to undertake a preliminary assessment of, and report on the damage to, Llantysilio Mountain caused by fire in July and August 2018 and to provide an assessment of the key ecological consequences of the fire.

This report aims to outline the impact of the fire on the habitats and soil condition and to identify options for restoration and indicative costs. This will be part of an evidence base for NRW's future decision-making regarding Site of Special Scientific Interest (SSSI) management.

2.1. Background

During July and August 2018 a major wildfire occurred on part of Llantysilio Mountain (SJ177468), near to Llangollen, in North East Wales. The site is within the Ruabon/Llantysilio Mountains and Minera SSSI and Berwyn and South Clwyd Mountains Special Area of Conservation (SAC).

The SSSI and SAC features are given below:

Ruabon/Llantysilio Mountains and Minera SSSI

The site is notified on biological grounds, primarily for its heather moor, limestone and neutral grassland habitats and for its species interest comprising a range of upland breeding birds, rare and uncommon plants and the use of mines and caves by bats. The site is also notified on geological grounds as it contains three sites of special interest within its boundaries.

Berwyn a Mynyddoedd de Clwyd/ Berwyn and South Clwyd Mountains SAC

EU Habitats Directive[1] Annex I habitats that are a primary reason for selection of this site:

- 4030 European dry heaths
- 7130 Blanket bogs

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site:

- 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*)
- 7140 Transition mires and quaking bogs
- 8120 Calcareous and calcshist screes of the montane to alpine levels (*Thlaspietea rotundifolii*)
- 8210 Calcareous rocky slopes with chasmophytic vegetation

[1] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

The fire site and conservation designations are shown in Figure 1. It is also within The Bryniau Clwyd a Dyffryn Dyfrdwy/Clwydian Range and Dee Valley Area of Outstanding Natural Beauty (AONB).

Approximately 250ha of the mountain was significantly affected by the fire that burned for around six weeks. The area was predominantly heather (*Calluna vulgaris*) dominated upland dry heath on shallow peat soils, and the severity of the burn was variable across the site. In many areas the effect on ground cover was very significant, resulting in bare ground/subsoil where upland dry heath previously occurred.

The affected land is privately owned but constitutes unenclosed Registered Common Land, used predominantly for sheep grazing. There is no current SSSI Management Agreement pertaining to the area, and there has been no significant heathland management in recent years. However, aerial photographs available on Google maps (dated April 2009) show significant heather burning/cutting on the area of the fire so the site has evidently been subject to active management in the past decade.

A draft report on the Llantysilio Mountain Fire by Denbighshire County Council's Communities Scrutiny Committee (DCC Undated) gave the following historic information about management on the site:

> *"On Llantysilio Mountain the graziers only had grazing rights, the rights to seek permission to undertake controlled burns and mowing/management work lay with the Estate and landowners. Whilst landowners were not obliged to undertake management or mitigating work on the mountain, in the past both the landowners and graziers had undertaken such work with the consent of NRW. The landowners and NRW would draw-up and agree upon a management plan which would enable the graziers to draw down money to undertake the moorland management work required. This work formed part of five year upland management agreements with the Estate. Such agreements had previously been in place, the last agreement lapsed on 1st September 2014 and included payments for burning and mowing. These management agreements related to habitat management, there had never been agreements in place relating to stocking levels."*

Although the fire site is part of a protected landscape there is very little information available about the habitats on the hills before the fire. There is no National Vegetation Classification (NVC) map and the Phase 1 habitat survey and map was undertaken in 1993 and has little detail. The greatest detail is provided by one target note from the 1993 survey that covers much of the burn area and has a more detailed map of the habitats, showing the areas dominated by heather, bilberry (*Vaccinium myrtillus*) and gorse (*Ulex* spp.) (Appendix 1 TN013).

Aerial photographs from 2014 and 2017 were made available for the site but there have been no aerial photographs flown since the fire damage occurred in July-August 2018.

There are a number of well-used footpaths across the site, several of which show some erosion and bare ground and are easily visible on the aerial photographs.

There are no known studies of the peat and soils on the SSSI or SAC. The current depths of peat and organic–enriched soils or surface horizon is shallow often around 15-20cm. This is often not classed as peat but this term has been used throughout the report as a simple way of describing the organic-rich substrate on site.

3. Methodology

The site was visited over the three-day period of 25-27th June 2019 by Katharine Longden an experienced moorland ecologist. She was accompanied on the first day by NRW's, conservation officer Ian Hughes and the contract project manager Philip Oliver. Both of whom supplied additional and contextual information.

Prior to the site visit a fire damage categorisation was devised and a recording form created to record the features of individual polygons identified in the field. The aim was to identify areas of different fire damage levels and describe the soils; peat thickness and vegetation cover along with the occurrence of vegetation regeneration.

It was also envisaged that quadrats would be taken listing the species present, percentage cover and vegetation height.

However, once on site, it became apparent that slight modifications to the fire damage categories were needed to reflect the situation on site and that the polygon characteristics were generally similar across the fire types rather than unique to the polygon and, therefore, there was no need to complete the proforma for individual polygons. The combined fire damage categories and descriptions are given below in Table 1.

Table 1 Fire Damage Categories (description)

Category	Description
1.	Nearly all the peat has been lost (<1cm), along with any signs of the litter layer, and root mat, with no erect stumps of heather or gorse plants remaining. Vascular plants are rare (<5% cover)
2.	As 1. above, but with a very soft surface where the peat has been ashed completely. The orange surface of this is hidden under superficial burnt peat or ash material. Vascular plants are rare (<5% cover)
3.	Erect heather or gorse stumps remain, but these protrude above the current surface showing that some peat has been lost all around them. Litter if present is charred. Some root network is occasionally present and helps hold the remaining peat in place. Peat depth is shallow <1cm. Very scattered bilberry regeneration (<5% over the area).
4.	Areas where there are many burnt heather or gorse stumps with a good root mat still in place, but showing loss of peat in between plants, but not throughout the whole area. More frequently there are 'plates' of peat present with good intact root mats and significantly more bilberry and heather regeneration interspersed with barer areas typical of the 1-3 categories above. Vascular plants are frequent (25-50% cover). The plate depths vary from 2-10cm deep.
5.	Burnt areas where most of the surface vegetation is still present, i.e. in flushes or where the fire moved more quickly. Generally intact peat surface (<25% bare peat/soil) generally 2-10cm deep.

These categories are also shown in Plates 1 to 10. Additional photographs were taken across the site to show the different effects of the burn, the original

vegetation where it remained, examples of active erosion and vascular plant regeneration across the site.

The site was mapped as accurately as possible on the 2017 aerial photographs during the site visit. The visit lasted two and a half days but unfortunately visibility was poor for much of this time. Good clear views were obtained on the final day which made the mapping more accurate in terms of assessing the extent of each category.

The route walked is plotted on Figure 2. This shows that some of the moorland edge areas were not visited due to a shortage of time and further visits to these areas will be required.

Additional target notes were made where there was a specific feature of interest or localised differences in vegetation, these include areas of erosion and water channels.

The difference in re-vegetation of vascular plants in the different burn categories meant that there was no value in undertaking 2x2m^2 quadrat recording as there is very little in Categories 1 to 3 and significant levels in Categories 4 and 5. The vegetation was able to be readily described and categorised without the need for this additional detailed data collection.

Five soil samples were taken in the different burn categories across the site, and the sample sites were chosen to represent typical situations in each of the categories. None were taken from a Category 4 area as this is a mosaic of Categories 3 and 5 and the soil samples from these two categories were considered sufficient to describe Category 4 soils.

Each soil sample was made up of several smaller samples in that vicinity. The soils were then sent for a basic soil analysis and assessment of the organic matter content.

4. Results

4.1. Fire Damage Categories

Figure 3 presents the mapped polygons and the allocated burn category. The red and orange colours represent burn Categories 1 and 3 respectively. Category 2 was found to occur in small areas, generally within the more damaged zones, but it was also occasionally found as small areas in the less damaged zones. At this stage of the project these Category 2 areas have not been individually plotted as that level of detailed mapping has not been undertaken.

The yellow areas indicate areas dominated by plates of intact peat and root mat (Category 4) but there could still be many smaller areas of higher damage categories scattered within the boundary. The green areas represent mainly intact areas that have relatively minor damage from the fire (Category 5).

Cross hatching and hatching on Figure 3 denotes a combination of the relevant categories and the proportions of the different categories are included in the total area. The hectarages of the different categories are given in Table 2 below.

Table 2 Fire Damage Categories (area)

Category	Area (ha)	Restoration priorities
1 & 3	113.14	113.14
3 & 4 mosaics	18.95	18.95
3 with c.30% 4	1.10	1.10
4 with c.40% 1/3	2.88	2.88
4 with 20% 3	7.72	
4	24.12	
4 and bracken	2.81	
4 and 5	35.94	
5	39.6	
Not surveyed	0.84	
Bracken (no burn category)	2.81	
Total Burn Area	249.91	136.07

It is clear from Table 2 that a significant area of the site has been badly affected by the fire with significant losses of peat and organic soils occurring in the 136.07ha dominated by Categories 1 and 3. In these areas most of the peat has been completely lost. On average it is estimated that the peat depth across the site was in the region of 5cm, so if the area of Categories 1 and 3 are multiplied by 5cm a very approximate figure for the volume of peat lost can be estimated. The calculation suggests that something in the region of 68,035m^3 of peat has been lost from the site as a result of the fire.

The areas of Categories 1 and 3 burn damage are now effectively bare ground with a thin organic layer or bare ground colonised by mosses. The main moss appears to be *Funaria hygrometrica* with some patches of *Polytrichum juniperinum*, both of which are effective colonisers of bare dry peat. The common name for *Funaria hygrometrica* is ‘bonfire-moss’ as it is a ruderal species and a colonist of bare, disturbed, nutrient-rich soils particularly

characteristic of old bonfire sites (Atherton *et. al*. 2010). *Polytrichum juniperinum* is also a pioneer on recently disturbed or burnt acidic soils. Its typical habitat is dry exposed acidic habitats.

There are a number of areas around the summit of Moel y Faen where there are remnants of a deeper peat layer. The remaining peat is highly modified by the effects of the fire, has a 'crust' on the top and is oxidising and drying very rapidly. This dry peat is then susceptible to wind and water erosion (Plates 11 and 12).

4.2. Geology and Soils

The underlying geology is of the Nantglyn Flags Formation which is a mudstone and siltstone sedimentary bedrock, Silurian in age formed 424-453 million years ago. It is of marine origin consisting of coarse to fine-grained sedimentary material created by a type of sediment gravity flow into deep water forming distinctively coarse to fine-grained graded beds. It is a hard rock and there are no superficial geological deposits over the underlying solid geology (British Geological Survey 2019).

Soils in the study area are of two types:

- 661c 'Manod' soil association described as a well-drained fine loamy soil or fine silty soils over rock. Shallow soils in places, with bare rock locally and steep slopes are common.
- 654a 'Hafren' soil association a loamy permeable soil over rock with a wet peaty surface horizon and bleached subsurface horizon, often with thin iron-pans. Some peat on higher ground. Rock and scree locally (Mackney *et al.* 1983; Cranfield University 2018).

The second soil type, the 'Hafren' soil association, better fits the soils seen on site, which can be described as organo-mineral soils or as having an organic-enriched surface horizon.

The results of the soil analysis are shown in Table 3. All the samples were taken from burnt areas but Sample 1, from the least damaged area (Category 5), is most likely to be similar to the former un-burnt state.

Most of the samples have a typically low pH (heathlands are commonly pH 3.5-5.5) except Sample 4, from the Category 2 fire damaged area, which has a less acidic pH of 7.5. The range of pH recorded is such that lime application is not considered necessary to facilitate vegetation establishment as part of any restoration programme (Gilbert and Anderson 1998).

The fire has, as expected, resulted in higher concentrations of phosphorus than typical of moorland situations. (Gilbert and Anderson 1998). The sample (1) from the least badly burnt area having the lowest phosphorus concentration. The concentrations of potassium are also elevated in the more severely burnt areas. Magnesium concentrations are within those frequently recorded on moorlands. The analysis suggests that the nutrient concentrations currently present in the soils are adequate to sustain heathland vegetation and that no additional fertilisers are required in the first instance (Gilbert and

Anderson 1998). The rate at which the nutrients may be lost through leaching is difficult to assess and if vegetation fails to establish then soils should be analysed again to ensure nutrients are adequate. Alternatively, soil samples could be taken immediately before finalising the restoration programme in any one area to ensure they are appropriate to the current situation on the ground.

Table 3 Results of the Soil Analysis

Fire Damage Category Sample Number	1 Sample 3	1 Sample 5	2 Sample 4	3 Sample 2	5 Sample 1
Analysis					
pH	4.1	4.4	7.5	5	4.2
Phosphorus (ppm)	41 (3.7)	53 (4.2)	103 (6.0)	83 (5.4)	25 (2.9)
Potassium (ppm)	110 (1.8)	121 (2.0)	211 (2.7)	152 (2.2)	86 (1.4)
Magnesium (ppm)	76 (2.5)	73 (2.4)	117 (3.2)	125 (3.3)	200 (4.3)
Calcium (ppm)	298	394	1857	638	836
Sulphur (ppm)	17	11	3	17	2
Iron (ppm)	2082	1399	1104	1499	282
Org. Matter - DUMAS* (%)	18.6	18.2	0.2	23.6	73.7
Physical Analysis					
Sand	73.32	57.28	56.98	52.84	65.40%
Silt	17.47	33.18	33.5	37.69	26.43%
Clay	9.21	9.54	9.52	9.47	8.17%
Soil Type	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
Biological Analysis					
Organic Carbon (%)	10.8	10.6	0.1	13.7	42.8

*A dry combustion reference method for measuring total organic carbon
(Bracketed figures are the MAFF[2] indices)

4.3. Intact Vegetation

There are a few small areas of intact vegetation within the fire boundary and these are centred on flushes and stream valleys where the vegetation was wetter and provided a smaller fuel load. Detailed species lists were not compiled for these areas, but there were generally a number of common grasses such as sweet vernal-grass (*Anthoxanthum odoratum*), mat-grass (*Nardus stricta*), common bent (*Agrostis capillaris*), wavy hair-grass (*Deschampsia flexuosa*) and occasionally Yorkshire fog (*Holcus lanatus*) and tufted hair-grass (*Deschampsia caespitosa*). Several areas supported soft-rush (*Juncus effusus*), with a substantial moss layer of *Rhytidiadelphus squarrosus*, *Pleurozium schreberi* and occasional *Sphagnum* species (Plate 13). Peat depths in the flushes were not measured.

[2] From Ministry of Agriculture, Fisheries and Food (MAFF) Reference Book 209

Some areas of unburnt vegetation on the boundary of the fire site and one small area within the main burn indicated the likely pre-fire composition of the vegetation at those points. Certainly there appears to be a high cover of bilberry in these areas and the heather is almost always in the region of 20yrs old or more (Plate 14). A detailed NVC survey (Rodwell 1991) was not undertaken on the remaining vegetation but appears to be most closely aligned with the *Calluna vulgaris-Vaccinium myrtillus* heath - H12. There are also a number of areas where gorse is a significant part of the vegetation. The peat depth in the areas with remaining dwarf shrub heath vegetation is typically 5-10cm.

Additional target notes on specific vegetation and points of interest are included in Appendix 2 with photographs where relevant and are mapped on Figure 4.

4.4. Erosion

Erosion is the loss of soils and other organic and inorganic material through the action of wind and rain. Rates of erosion and the potential for erosion are dependant on a number of factors, two of the major determinants are the slope and exposure of the site. Llantysilio Mountain is part of a ridge of hills which run west to east in the landscape. Contour data, used to create a slope model presented as Figure 5, shows that a significant amount of the burn site (22.7%) exceeds a 20° slope. Comparing the burn categories with the slope map shows that much of the less damaged area is on the shallower slopes and the most damaged areas are on the steep slopes. The prevailing weather comes from the south-west and in general the south-west facing slopes are the most damaged, with very little vegetation and significant areas of bare ground. This means that these areas are currently very inhospitable and natural re-vegetation will be very slow.

As discussed above, in the fire damage section, there has been significant peat loss from the site. This will include peat lost in the fire as the peat burnt and peat that has been lost post-fire due to erosion.

Photographs taken in October 2018 (the autumn after the fire) show a similar situation with large bare areas and on the deeper peats the cracked, disturbed and damaged pedestals. This suggests that the majority of the peat loss was during the actual fire and that the peat layer fuelled the fire as well as the vegetation.

Brash strewn across the site after the fire has been blown by the wind and in several areas there is no material on the ground surface indicating those areas which are particularly windswept and, therefore, at a higher risk of further soil erosion. This broken brash is holding peat/soils in place in some places and trapping sediment within surface run-off (Plate 15).

There are a number of water runnels/channels on the site - currently most are quite small with the larger ones only reaching a depth of 20cm and a width of 30-50cm (Plate 16). However, these channels are actively eroding the soil and clay subsoil. There is some incidental blocking of the channels by loose brash

around the site (Plate 17) but this is not sufficient to prevent the channels widening and deepening.

There is a need to accurately map the location and number of these channels to enable a more detailed restoration programme to be developed. All works to prevent water run-off must start at the top of the catchment (i.e. the top of the hill) and work down the course of the channel. Blocking the top of a system will prevent erosion lower down by reducing the quantity and speed of the water flow.

4.5. Natural Regeneration

On areas where the burn was less severe (Categories 4 and 5) there is abundant bilberry re-growth from the intact root mat and stems. Heather regeneration appears to be mainly from seed and is generally more patchy than the bilberry re-growth. The heather seedling density is very high in some areas (Plate 18). Only a few examples of stem re-growth were seen for heather. This is probably because the majority of the heather was quite old at the time of the fire and in such situations the heather cycle depends on the seed bank (Gimingham 1972) rather than stem re-growth.

Western gorse (*Ulex gallii*) was a significant component of the vegetation on the site, particularly on the steeper slopes at the edge of the site. There are several areas with frequent standing dead stems. However, the regeneration of the root stock is patchy (Plates 19-20).

Bell heather (*Erica cinerea*) was also recorded as small seedlings on the southern slopes of Moel Y Gamelin. This is a desirable species and will significantly add to the diversity of the vascular plant cover.

Bracken (*Pteridium aquilinum*) regeneration is significant across the site. It is recovering well from areas where it was clearly present in the past (i.e. can be seen on the 2017 pre-fire aerial photographs) and where the vegetation root mat is intact, but it is also occurring in areas where the root mat and, therefore, many of the rhizomes have been lost and in areas where it was not previously a major vegetation component. Bracken is known to ingress into heathland areas when the competing vegetation (i.e. the heath) is burnt and there is less competition for the bracken.

There are remarkably few undesirable vascular plants on the site, largely confined to scattered rosebay willowherb (*Chamaenerion angustifolium*) and occasional spear thistle (*Cirsium vulgare*). These species are wind blown and will be exploiting the nutrients in the ash and burnt peat remaining after the fire, both of which mean they rapidly colonise areas such as this. The expansion of these species and possibly also shrubs and trees is something that should be monitored, and if necessary action taken to reduce cover.

4.6. Mosses

As discussed above the two main mosses currently recorded on site are typical pioneer species on disturbed post-fire sites. There is nothing in the literature to suggest that they will prevent seedlings of vascular plants germinating through

the layer they form (which can be the case for larger moss species where they form extensive mats).

4.7. Grazing

The land affected is privately owned but constitutes unenclosed Registered Common Land, used predominantly for sheep grazing. At the current time there is no detailed knowledge of the numbers of sheep turned on to the common land units (CLU), although it is known that not all commoners currently utilise their rights. A comment in the draft Scrutiny Committee report (DCC Undated) noted in 2018 that:

> *"Whilst 10 graziers had registered rights to turn sheep up on to Llantysilio Mountain, only 4 of the graziers regularly utilised these rights. It was widely acknowledged that the non-utilisation of grazing rights was in the main attributed to the downturn in the agricultural economy, as there had been a reduction in demand for the smaller Welsh mountain lamb, the native breed of sheep which thrived on this type of terrain."*

There is no indication from the form of the dwarf shrubs that the common was over grazed before the fire or that it was subject to over-grazing at the time of the survey.

Vegetation for stock to graze within the area affected by the fire is limited. Grasses were generally sparse across the fire site although flowering grasses were seen in the flushes, and on the intact edges of the moor as well as on the sheep paths which criss-cross the area. Dwarf shrubs are restricted in height as there is very little vegetation untouched by the fire. On average the bilberry is 4-5cm tall and the heather almost entirely restricted to seedlings or a season's re-growth from the stems of existing plants.

Sheep were seen during the recent site visit and there were several different markings suggesting at least four commoners are using their rights currently. The carrying capacity of the land is significantly reduced from that pre-fire. Currently there do not appear to be any areas of re-growing vegetation which have been targeted by the stock but there is always a possibility that this may happen resulting in the re-vegetation of the site being delayed or compromised.

Occasional grouse droppings were seen but mainly in the areas with the most intact vegetation.

4.8. Summary

The fire has removed the majority of the peat and vegetation root mat from over 136.07ha of the site. This has left any remaining subsoil/peat exposed and vulnerable to further erosion (wind and rain). In these areas of high fire damage the plant rootstock and seed bank has largely been destroyed, limiting regeneration potential.

Significant intervention is required to encourage large-scale regeneration of desirable vascular plant species and to ensure less desirable species (i.e. bracken and weedy species) do not become more widely established.

The loss of large areas of habitat has, for the short term at least, isolated the hills to the west of the site from the rest of the SSSI and SAC. It is important to reconnect these areas with appropriate vegetation as rapidly as possible.

5. Restoration Techniques

5.1. Introduction

The survey has provided a preliminary map of the different areas of burn intensity but these would benefit from more detailed survey and possibly further subdivision to develop a detailed restoration specification.

The key objective is to achieve restoration of the whole site back to a dwarf shrub heath, thus re-establishing the pre-fire habitat, its nature conservation value, landscape value and the common land grazing. There are two main approaches: a non-intervention course that allows natural re-colonisation, or to support and enhance the natural colonisation process with various techniques. The proposed solutions are based on the likely rate of natural recovery as identified during the site visit, an assessment of the risks of 'doing nothing' in terms of erosion and duration of recovery, and the practicalities of any intervention approach (e.g. access).

The site has more heathland both to the west and east of the fire boundary (as evident on the 2017 aerial photographs), so local seed of native heathland species should be within reach of the site and arrive naturally. It is important that seed arriving naturally can establish, which means ensuring soil stability and favourable establishment conditions.

The strategy recommended uses both approaches, with natural re-generation being used to allow the less badly damaged areas to recover naturally without any further intervention. Active intervention with restoration measures is recommended in the more damaged areas, particularly those on steep slopes, where it is important to ensure a stable surface is retained or restored as quickly as possible to avoid further loss of soil or subsoil.

The most damaged areas are significant in scale and the restoration methods, initially, need to be at this large scale, with the proviso of resurveying and re-applying restoration measures at a later date if necessary.

The priority is, therefore, stabilisation of the remaining soils and peat that are assessed as being vulnerable to erosion and the concurrent re-vegetation of the bare areas to prevent further erosion, particularly on the areas identified as Categories 1 and 3, and restoration priorities (a combined area of 136.07ha).

The longer term goal should be to promote diverse vegetation structure (size/age) and composition, and introduce a management regime across this part of the site that includes management of fire risk. Following any restoration there will be a very large area of even aged vegetation (with potentially reduced biodiversity and increased fire risk over time) unless an active management regime is introduced.

The size of the areas involved, the steepness of the hillsides and the fragility of the remaining soils and peat all point towards the use of helicopter for restoration.

The steps which need to be considered are set out below:

5.2. The Baseline – Aerial Photography

There are currently no aerial photographs of the burnt area and it would be very useful for the current work and for future monitoring to commission aerial photography across the site. An unmanned aerial vehicle (UAV) fixed-winged drone would be capable of supplying the photography and a digital terrain model (DTM) at the same time. The aerial photography could be used to validate the burn intensity map (Figure 3) to ensure any further areas of high fire damage have not been missed.

We are not aware of any archaeological interest on the fire site, but this should be confirmed by consulting Clwyd-Powys Archaeological Trust before any restoration occurs. However, there is a hill fort to the west and there are a number of banks/field boundaries across the burnt area. There is an opportunity to locate, map and identify archaeological remains whist the site is not 'hidden' by vegetation and aerial photographs would be very helpful in this respect. This would also identify archaeological constraints if features are identified which would be included in the long-term management of the site.

5.3. Ground Stabilisation

The immediate concern is that soils are continually being lost from the site resulting in thinner soils that then become increasingly vulnerable to drought, fire and erosion. The soil loss is on-going and at an unknown rate. The bare ground is particularly vulnerable to rill and small gully formation in the soil layer. The loss of more soils/peat could also pose a pollution risk downstream as the material is washed into the watercourses. A vegetation cover is required on the bare areas to increase the surface roughness, slow the water flow and form a root mat to prevent further soil/peat loss.

There are a number of approaches worth exploring, which are more or less applicable in different circumstances.

5.3.1. Geotextiles – Jute Mesh

These have been used for bare, deep peat stabilisation. Bare peat provides a very inhospitable surface for plant growth and it is also vulnerable to erosion. In addition, jute material also has the advantage of retaining water for longer following rain which can prevent establishing seedlings drying out. Jute is the recommended geotextile. However, on this site, the large area to be stabilised makes the use of jute over the whole site impracticable, and anchoring of the jute may be more difficult on mineral soils than on peat as the shallow depth of soils may not secure the pins.

It may be appropriate to install some jute geotextiles on the exposed ridges by the main path (specifically near the summit of Moel y Faen) to encourage more rapid re-vegetation of these areas. The rapid re-establishment of dwarf-shrub heath adjacent to the paths in this area will re-focus the public pressure and trampling back on the existing path line and reduce the risk of trampling over a wider area.

5.3.2. Heather Brash

Heather brash is material cut from heather-dominated areas. It can be cut in long lengths and baled for transport or double chopped forage harvested and transported in ‘dumpy’ one tonne bags. The brash is used to create a layer of material which sticks to the soil/peat and provides a more conducive microclimate in which the desired species can germinate and establish. Heather brash can also introduce other vascular plants and bryophytes to the site which can form part of the restoration process.

However, the use of heather brash on steep slopes with little peat, i.e. the conditions found on site, would be (to our knowledge) experimental. Moors for the Future (MFF) and the Yorkshire Peat Partnership have used brash on steep sections of gully sides (up to *c.*6m long) with some success, but the site conditions were very different to that on Llantysilio Mountain. Typically the gully sides are steep but relatively sheltered, as they are gullies within the peat body; in addition the peat depth varies but is frequently over 40cm deep. In these situations the brash has a greater chance of ‘sticking’ to the peat rather than being blown away, although even here there is a tendency for the material to gather at the base of the gully.

5.3.3. Seed Mixes

Soil/peat stabilisation can also be achieved by sowing a ‘nurse crop’ seed mixture on the slopes. The principle is that the ‘nurse crop’ seed establishes quickly and stabilise the soils while the slower growing heathland species establish and grow. Typically a nurse crop of fast growing grass species is sown that holds the soils/peat in place through their root mat formation and the grass then provides shelter and protection for the desired heathland species to establish.

The desired species can be sown at the same time, i.e. as part of the mixture, or added later. Nurse crops have been used widely and successfully on acidic, infertile, bare and eroding peat where the growing conditions are very difficult. Uplands with steep slopes fit into this category. However, PAA’s experience has shown that it is not always needed in many situations where growing conditions are better.

One limitation of this approach is that many of the grasses in a nurse mix are not native varieties and inappropriate species may persist in the longer term if the nutrient concentrations are high enough or the conditions suitable for the nurse species to better establish. Native species are often more expensive and generally more limited in availability than the commonly used nurse species thus on a large scale project there many not be the capacity to use only native species.

5.3.4. Hydro-seeding

On steep slopes with little vegetation cover sudden storm events can result in washout of surface material and also of small seedlings or plants with poorly developed root formation. Any seeding/treatment of steep slopes is vulnerable to storm events washing away the materials added to the site so there is a real risk of failure without additional measures to hold the materials in place.

Hydro-seeding is a technique regularly used to apply seed, often along with fertiliser, to steep slopes to help stabilise the soil or surface material more quickly. It is often used on road schemes when a 'green look' is perceived as being required rapidly. The hydro-seeding 'solution/slurry' (comprising seed, fertiliser, stabiliser, fibre and dye) is typically sprayed onto the slope from a large tanker using hoses, often held and directed by hand although vehicle-mounted hoses are also used.

This technique has been used in moorland restoration in the past but as much of the focus on moorland restoration is on blanket bog, which is generally flat or gently sloping, the technique is not widely used and there are few companies with the equipment and experience to tackle this type of project.

Access and a water supply are requirements for hydro-seeding and neither is readily available at this site.

There are also some similar products available in a dry form from companies who provide the material to hydroseeding contractors in the UK. These are applied dry and become activated when it rains, again the material is normally spread by hose from a tanker. To our knowledge these dry products have not been used on large-scale moorland restoration projects but have the potential advantage of not requiring a local water source for application.

5.3.5. Coir Logs

Coir logs are biodegradable, coconut fibre bio-rolls. The dense fibre dissipates water energy and so protects the soils below the log from water scour. By slowing the water flow sediment from the water is frequently released and sediment builds up behind the log creating a growing medium for seedlings. They are particularly beneficial on projects where there is little soil medium and they reduce further loss of soil/peat from the site. The coir roll has to be bedded into the substrate to be most effective and occasionally, where flow rates are high, fixed into place with wooden stakes.

5.3.6. Summary

Considering the nature of the site, there is a need to prevent the rills and channels which are starting to form, from expanding. It is also our opinion that heather brash is unlikely to stick to those slopes that are most in need of re-vegetating and there is a concern that any grass nurse crop and heather seed could rapidly be lost from the site if heavy rain occurred before the grass was reasonably well established.

It is, therefore, recommended that coir logs are installed on the small artificial and newly formed rills and channels, in combination with hydro-seeding (wet or dry) a grass and heather seed mixture onto the areas of Category 1 and 3 burn damage.

5.4. Seed, Fertiliser and Lime

The soil samples show that at the moment the pH and fertility levels on site are suitable for heathland flora and that fertiliser and lime are not required. The soil

analysis for the area of fire damage Category 2 – 'all the peat lost along with the litter layer and root mat, with a very soft surface where the peat has been ashed completely' has returned a neutral pH. This burn type is very patchy amongst Categories 1 and 3 and, therefore, despite the higher pH, vegetation establishment will likely still occur.

The choice of seed is critical to success, it is important to choose a mix suitable for the site and apply at a rate that will establish quickly. The aim is to slow erosion but leave sufficient gaps for the dwarf shrubs to establish in the sward along with other airborne seeds from the adjacent moorland areas.

Ideally native grasses (wavy hair-grass, common bent and sheep's fescue (*Festuca ovina*)) are considered the best solution. However, there is likely to be insufficient availability of these native grasses to cover the area at a rate high enough to establish a good nurse crop. If there are local areas where these grasses could be harvested or purchased from, then this would be ideal, but if they are not available, the best alternative would be highland bent (*Agrostis castellana)* a grass that is very close to the native common bent in its character and growth. Indeed, it used to be described and used interchangeably in the seed trade as 'Browntop bent' (*Agrostis tenuis*).

Highland bent is a small-seeded grass with 15,000 seeds/gm and can be slightly more competitive in its growth than common bent so is more often used in amenity situations. However, in high altitude, exposed sites with low nutrient levels, its growth is typically restricted and it can form a useful nurse. It was successfully used in the early Peak District moorland restoration trials (Anderson *et al*. 1997) providing a thin but widespread sward for four years before gradually declining as native species displaced it. However, this was mostly on peat soils.

A range of nurse grass mixtures and rates have been used in a variety of situations. Many projects on deep peat use *Lolium* species as a nurse grass which is boosted initially by fertiliser and lime applications but then dies out as the nutrient levels and pH falls and other species increase. In another project in the South (Berkshire) on a heathland site PAA have used a sheep's fescue, wavy hair-grass and highland bent mixture 60:20:20 (percentage by weight). The site had some similarities in soil depth to that on Llantysilio Mountain although it was not as exposed, steep or elevated.

Seeding rates commonly vary from 90kg/ha to 40kg/ha on areas of bare blanket bog. In such situations MFF use the following seed mix at a rate of 50.35kg/ha.

Table 4 Moors for the Future Nurse Seed Mix for Deep Peat

Species (English)	Species (Latin)	Rate
Sheep's fescues	*Festuca ovina and F. longifolia*	24.0kg/Ha
Perennial rye grass (three varieties)	*Lolium perenne*	8.0kg/Ha, 7.0kg/Ha and 6.0kg/Ha
Browntop bentgrass	*Agrostis castellana*	4.0kg/Ha
Wavy hair-grass	*Deschampsia flexuosa*	1.0kg/Ha
Ling heather	*Calluna vulgaris*	0.32kg/Ha
Cross-leaved heath	*Erica tetralix*	0.03kg/Ha

The Yorkshire Peat Partnership use an alternative moorland grass mix given below sown at a rate of 10kg/ha. They also suggest sowing a dwarf-shrub seed mix of 50:50 *Calluna vulgaris:Erica tetralix* applied at a rate of 1.5kg per hectare.

Table 5 Yorkshire Peat Partnership Nurse Seed Mix for Deep Peat

Species (English)	Species (Latin)	% of Seed Mix
Common bent	*Agrostis capillaris*	20
Sheep's fescue	*Festuca ovina*	20
Wavy hair grass	*Deschampsia flexuosa*	30
Hare's-tail cotton-grass	*Eriophorum vaginatum*	30

Our recommendations for Llantysilio Mountain are more similar to the second list as we do not feel ryegrass is appropriate in this situation - the relatively high pH and nutrient levels raises a risk that it may not die out sufficiently over time and would not, therefore, function properly as a nurse crop.

Table 6 Recommended Seed Mix for Llantysilio Mountain

Species (English)	Species (Latin)	% of Seed Mix by Weight	% by Seed Number
Common bent / Highland bent	*Agrostis capillaris / A. castellana*	20	72.8
Sheep's fescue	*Festuca ovina*	60	17.5
Wavy hair grass	*Deschampsia flexuosa*	20	9.7

The recommendations are based on the need for a rapidly-establishing grass cover (*Agrostis* spp.) along with the introduction of native grasses. There may be scope to reduce the seeding rate but without trials to ensure that a sufficient cover can establish on the inhospitable steep, bare, dry slopes the recommended seeding rate is 40kg/ha.

The optimum time to sow the seed is in the spring/early summer (i.e. April or May) to allow the seed the longest time to establish before the following winter. Soils need to have warmed enough before sowing for grass seed to establish. If sown at this altitude (548m) in late summer/autumn, there is the risk of seed not establishing before, or not surviving through, the winter and the site would require reseeding in the spring.

In addition to the grass seeding it would be beneficial to add heather seed, ideally of local origin, at the same time. This is not for ground stabilisation but to provide a seed source in the areas (Category 1, 2 and 3 burns) where the seed bank has been lost. This direct addition of heather seed could be at a relatively low seeding rate as there will be additional seed rain from adjacent moorland areas and, in time, from heather that has recovered from the less damaged burnt areas.

The site visit indicated other dwarf shrub species and species of wet heath habitats were generally missing from the sward. There were a couple of areas where bell heather seedlings were germinating in a Category 4 burn zone, where plates of vegetation still supported a patchy seed bank. Crowberry (*Empetrum nigrum*) was recorded only rarely in the intact sward but there was no cross-leaved heath (*Erica tetralix*), cowberry (*Vaccinium vitis-idaea*), cranberry (*Vaccinium oxycoccos*), or cottongrasses (*Eriophorum* sp.) recorded. The site is not thought to be suitable for many of these species as it is too dry so adding these to the site as seed is not recommended.

The potential for the addition of a greater variety of dwarf shrub species should be reviewed after the initial grass establishment phase which will stabilise the ground and provide a nurse crop and a more sheltered micro climate for dwarf shrubs. Most of the other dwarf shrub species grow poorly when added as seed, bell heather being the exception. If diversification is required (due to the lack of a seed bank on large areas of the site) then it would be best to add plug plants of desired species if they have not established naturally on the site. Ideally the plugs should be derived from local vegetative stock and grown to order should the need for them arise.

5.5. Grazing

The map of the wildfire burn intensity (Figure 3) shows large areas of Categories 1 and 3, which means there is currently no vegetation for grazing stock in these areas. The pre-fire grazing levels on the common need to be better understood, i.e. the total number of rights across the common, the number actively used, the area of the common over which sheep can roam, and the area of various vegetation types within this. From this data the stock carrying capacity could be calculated and, as restoration proceeds, re-calculated as the area of available forage increases.

However, it would be beneficial to remove all grazing from the fire site during at least the first growing season after a nurse crop has been added to the site. A voluntary agreement to remove grazing for a minimum of two years would be ideal but all graziers would have to agree. This would allow maximum establishment of the grass seed and therefore maximum stabilisation of the soils. It would also allow the flowering and seeding of the sown grasses which in turn could maintain or increase the soil stabilisation on site depending on the effectiveness of the initial seeding.

If the removal of stock were possible from the damaged area then this would require a fence. Temporary fencing on Common Land is often difficult to

achieve as Common Land consent is required from the Welsh Government and this can be time-consuming and contentious. If a fence was required and consent given, only two relatively small lengths of fencing would be required to exclude the majority of the burnt area from the common (Figure 6). The first section (*c*.1.09km) could be erected over the saddle between Moel Y Caer and Moel Y Gamelin and a second shorter length (0.93km), west of Berwyn Quarry. These two sections of fence would link with the existing fences and allow the rest of the common to the west and south-east to be grazed.

If fencing could not be erected, then the sheep would have to be removed or numbers reduced across the entire common, including the undamaged areas to the west and south-east of the fire site, to avoid further degradation of the damaged areas. This would need to be agreed through dialogue with the graziers. However, removal of stock from these areas of intact vegetation would lead to a greater build-up of vegetation and therefore increase the fuel load for other potential fires unless increased management occurred during this period. Management of the heather is currently rather '*ad hoc*' and an increased cutting rotation would be required to negate the removal of stock. This may be hard to deliver if the commoners have no stock on the hill to benefit, as they may see it, from the management actions in the short-term. Additional payments may be required to achieve the desired outcome.

After the first couple of years a decision as to future grazing would need to be taken depending on the vegetation cover. Most damage to dwarf shrubs occurs over winter and late in the season. As the common is not currently grazed during the winter there may not be a need to maintain reduced numbers during the summer once the nurse grass has established, as long as there is enough for the stock to eat and there are no welfare issues. The scale of restoration is likely to be large enough not to worry about localised patches of over grazing, and having sheep on the common after the first season or two may help to reduce the spread of gorse and increase variation to the developing sward.

5.6. Bracken

Bracken is regenerating rapidly in areas where the burn intensity was light and more slowly in areas where the peat was removed and rhizomes damaged. The goal should be no increase in bracken cover from its previous, pre-fire, extent.

This could be assessed by mapping the areas of bracken from the 2017 aerial photographs and then remapping the current, post-fire, extent from the UAV survey (if commissioned) or the next planned aerial photo flights.

The most realistic way of undertaking bracken control on much of the site is by aerial spraying using an approved herbicide and annual follow up spot treatment with Glyphosate (or similar) in knapsack sprayers. The sooner the spraying can be undertaken the less time the plant has to rebuild stores in damaged rhizomes.

5.7. Gorse

Within the fire boundary there is no reservoir of un-burnt mature western gorse plants. Where there is some rootstock remaining, gorse seedlings are germinating and establishing. A similar management approach to that recommended for bracken could be applied, mapping pre-burn boundaries from the aerial photographs and then treating/cutting new areas which regenerate. It would also help to have the areas mapped as they regenerate to inform a longer term cyclical management regime.

Although western gorse is part of the natural vegetation on the hill there is a need to prevent the cover of this species increasing at the expense of heather and bilberry communities. As described above, monitoring the re-establishment of gorse is important to drive intervention measures if gorse begins to expand significantly across the site.

6. Restoration Costs

6.1. Introduction

The area for restoration consists of a considerable proportion of ground which is steeply sloping and which is generally inaccessible and at some distance from access tracks. The fragility of the slopes and the scarcity of the soil/peat resource is also a significant consideration in how to apply the restoration proposals.

6.2. Aerial Photography and Digital Surface Model

As discussed above, there is a need for up-to-date aerial photography of the site post burn. If this were undertaken by an UAV, in addition to obtaining high quality colour orthorectified/geo-referenced aerial photography of the site, an image-derived DSM at a resolution of 10cm could be obtained. From the DSM the distribution of small scale rills and gullies could be precisely mapped. This would enable accurate location of these features and make a considerable saving in mapping time on the ground.

An indicative cost of £5,600-£6,000 for the survey and production of aerial photographs and the DSM has been obtained. To fully assess the rilling and gullying there would be additional processing costs of around £1,500. This photography and information would also form the basis of future monitoring.

6.3. Helicopters

Helicopters are frequently used on moorland restoration projects to transport bulky materials and to cover large areas without impacting the ground surface. Helicopters fly high enough to avoid disturbing the ground surface with the rotors, this is only an issue when landing and taking off.

Helicopters do require a considerable set up fee to get the equipment and ground support in place but once in place large areas can be covered in a very short time. The size of helicopter required depends on the weights to be lifted and the distance from the road head to where the materials are needed.

There are certain helicopter companies who specialise in moorland restoration work and the following information has been gathered following a conversation with an experienced helicopter contractor company who undertakes a considerable amount of work for MFF.

6.4. Seeding

6.4.1. Air Drill

Seeding can be undertaken using an ‘air drill’, a specialised piece of equipment which blows seed down through a fixed attachment on the helicopter, giving enough force to ensure the seed reaches the ground and is not left ‘floating’ in the air. This equipment has an 18m boom and can be programmed to fly on a route to 0.5m accuracy whilst covering a strip of 18m on the ground with the seed. The helicopter pilot requires access to the restoration area shape files and if they are uneven edges there is a possibility of covering areas which are already vegetated. Currently air drill seeding is the most commonly used seeding method for seeding moorlands.

The spreading of a grass nurse crop and cleaned heather seed by helicopter across the whole site would take a day at around £12,000 with set up costs of approximately £5,000, therefore, totalling around £17,000.

The grass seed mix (as specified above, in Table 6) has been costed by two companies at very different prices; £50.80/kg or £24.00/kg. Availability of seed and origin will be a deciding factor in the final seed mix and cost. In the meantime the higher cost is used in the calculations.

At a rate of 40kg/ha and a cost of £50.80/kg, over 136.07ha (area of burn Categories 1 and 3) the cost of the seed is **£276,494.24**. This assumes the required quantity of wavy hair-grass and sheep's fescue seed are available.

Cutting collecting and cleaning local native grassland sources is an alternative method of obtaining the seed but this has not been costed as potential sources are unknown and the volume of seed would be an unknown quantity until the grass density in any potential donor field could be assessed.

The cost of collecting and cleaning heather seed is given as £155/kg in the MFF fact sheet and they suggest a seeding rate of 0.65kg/ha which totals £100.80/ha or **£13,715.86** for the seed across the site. This would be applied at the same time as the grass seed to reduce the cost of spreading and to give all seeds the maximum growing season.

6.4.2. Hydroseeding

Hydroseeding has been trialled from helicopters in this country but has not been undertaken on large-scale projects. MFF have a fact sheet – 'Application of moorland plants as seed'[3] which describes the method, but it reports that the problems[4] have generally outweighed the advantages on most moorland restoration projects. However, aerial hydro-seeding is undertaken successfully in America and with modification or specialised equipment there is potential for it to be successful here.

The seed costs given above would remain the same if applied by air drill or hydroseeding, but the application costs would increase significantly as the solution/slurry would need to be mixed on site or close by with water, binders fibre mulch and dye. Transportation of the solution would increase the helicopter flight time and it would need to refill frequently. The increase in water would increase the weight carried, the time spent and, therefore, the cost. The helicopter flight and set-up costs are likely to increase to somewhere in the region of £66,000.

The binder, fibre and other 'ingredients' in the mixture will add a further cost to the process estimated in the order of *c.*£0.25/m^2 which when multiplied over the 136.07ha is a cost of £340,175.

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[3] https://www.moorsforthefuture.org.uk/our-resources/file-preview?id=1424543

[4] Most commonly difficulty in maintaining the seed agitation in the tanks for even dispersal of seed in the mixture and clogging of seed delivery machinery.

However, by applying a binder to the seed it is much more likely that the seed will stay on the hillside, rather than be at risk of washing to the bottom of the slope, likely resulting in significantly better results overall.

There is a potential alternative of applying the seed, binder fibre/mulch in a dry form. This mixture could be spread from a specialised hopper under the helicopter but detailed discussions between the company supplying the hydroseed products and the helicopter company would need to be undertaken to work out the exact technical methodology (depending on size and texture of the cellulose mulch and binder) and the cost. This mixture of dry ingredients and helicopter delivery is not a method regularly used in Britain. It could however be cheaper than the mixing of the materials in water as the mixture would be much lighter than the traditional slurry. The overall cost would depend on the availability of practical application options.

Mycorrhizal fungi soil additives are available as a powder. These are reputed to increase the development of plants on bare soils where the litter layer and root mat has been lost. The addition of this to the bare soils may be worth considering but data about the effectiveness of the product is hard to gather, except from the manufacturers. There may be potential to add this to part of the site and run trials to see if it increases the vascular plant cover.

6.4.3. Discussion.

The cost of seed for a nurse crop and heather is significant and therefore the seed should be given the best survival chance. Weather events significantly affect the outcome of seeding - the seed can be washed or blown away or the seedlings can be desiccated by drought. To increase the likelihood of a positive outcome, the seed is best applied with mulch and/or binder and the addition of mycorrhizal fungi could also be considered. This ‘soup’ can, in theory, be applied wet or dry and delivery of both should be feasible by helicopter. However, currently we have been unable to find British examples and therefore costs are very preliminary. Further discussions and collaborations between a helicopter company and hydroseed suppliers are required to establish the feasibility of the options on this site.

Alternatively a double seeding operation could be undertaken a few weeks apart if the first did not appear to work well. However, there are problems with this option; the availability of grass seed may make it impossible to obtain the seed twice and so there is likely to be a cost to having the seed for a second run ‘reserved’, even if it is not used. It would also incur two helicopter operations and set ups and the seed would have no ‘protection’ in terms of mulch to retain moisture in close proximity. In addition, if the second sowing of seed was required the seeds/plants would have a significantly shorter growing period in which to establish before winter.

A single sowing of seed with mulch and binder and possibly mycorrhizal fungi is the recommended approach.

6.5. Coir Rolls

Coir rolls are required to stabilise the soils and hold back the water and silt in the water rills that are developing on the steeper slopes of the burnt areas. The locations requiring coir rolls are yet to be accurately mapped and would be dependant on the results of the detailed DSM analysis described above, but it is anticipated that several hundred would be required. An arbitrary number of 300 has been used to estimate costs.

The shallow nature of the channels means that a specially made roll at 200mm diameter and 1m length would be ideal. A price of £8.50 per metre has been quoted which, if 300 were required would total £2,550 for the rolls alone.

A helicopter would be required to drop dumpy bags of rolls at specific locations and the rolls would be placed into position by hand. The rolls weigh approximately 7kg each and, therefore, can easily be positioned by one person. They would need to be notched/tamped into position and on occasions wooden stakes may be required to ensure they are not washed out. Assuming half the rolls need stakes at a cost of £0.50/stake and 3 stakes per roll, this would be an additional cost of £225. In addition, there would be the cost of the helicopter to distribute the dumpy bags containing the rolls and additional labour costs for placing the rolls. Labour costs have been assumed as £150/day and that 20 logs can be placed and secured in a day. The cost of deploying the rolls around the site by helicopter would depend on whether the operations could be undertaken at a similar time, immediately prior to the helicopter seeding/hydro-seeding.

6.6. Jute Biodegradable Erosion Control Mesh

Jute mesh has been used in many restoration projects and has been shown to work well. On this project the extensive nature of the area of damage, the high visibility of the jute when newly applied, the steep slopes, thin soils and need for biodegradable pegs all combine to make it a less attractive option for the large areas of damaged peat. There is, however, a possibility that installing small areas may be valuable to redefine the path edges in some areas, for example.

The mesh (500g/m^2) is typically £0.85m^2 but can fall to £0.65m^2 if significant quantities are purchased. Biodegradable pins (150mm long, barbed polymer peg with mushroom head) are generally used at 2.5/m^2 at a cost of £9.00 per 100, equivalent to an additional £0.23/m^2. To purchase material to cover half a hectare/5,000m^2 would cost £5,400.

Laying the mesh and transporting (either by helicopter or low ground pressure vehicle depending on the accessibility of the areas to be treated) would be additional. Based on information from MFF we have estimated labour costs as £0.60/m. At this rate laying the jute would cost £3,000.

6.7. Heather Brash

When spreading heather brash on site to stabilise the ground surface ‘dumpy bags’ are often used to transport the brash to site, dropped in groups (16-20)

and then moved or spread from these pooled locations. Spreading is generally by hand to ensure that the brash is spread evenly and at the right thickness. There have been trials in the past to spread brash mechanically using a spinning plate spreader but the equipment frequently jammed which meant the process was inefficient.

The conditions on site and the size of the project could mean that it is worth researching this helicopter automated spreading system again to try to reduce the impact on the ground and the health and safety issues inherent with working on steep slopes.

However if hydroseeding were used onsite to spread the seed this would include a stabiliser and there would be no additional need for heather brash to be added to the site.

The cost of obtaining and spreading heather brash is very dependant on the location of the area to be cut (in relation to where the brash is to be spread), the ease of the terrain where cutting takes place, the height (and, therefore, volume of the heather cut) and the method of transport to the area where the brash is to be spread. Costs are, therefore, very site dependant but, in general terms, if a helicopter is used to transport bags of cut heather within a 4km radius of the cut site then a figure of £25/bag would cover transport costs with an additional £7-8/bag to spread it by hand.

Approximately 30 bags can be cut from a hectare and this can be spread over 2ha. The cost of transporting and spreading heather brash over 136ha is, therefore; 30 (bags) x 68 (ha cut) x £32.50 (cost per bag, including spreading) = £66,300. There would be additional cutting costs on top. The advantage of heather brash over seeding is that additional moorland species could be included in the heather brash and add diversity were this to be added to the more accessible areas of the site.

However, the hydroseeding application of a nurse and heather seed mix would be disturbed if brash were added afterwards and if added first the brash would create a barrier between the seed and the ground. It is, therefore, thought that the combination of brash and hydroseeding would not work well together on this site.

6.8. Bracken Spraying

It is very likely that bracken control will be required on areas of the site where the vegetation mat has been lost but where bracken rhizomes were deep enough to survive. Using the post-fire photographs, flown by a UAV discussed above, the area of bracken could be calculated and areas to be controlled identified.

Aerial bracken spraying is a well documented and successful way to control bracken if applied correctly, at the right time, and with reference to the local weather conditions so that it isn't washed off immediately by heavy rain. Based on an area of *c*.20ha the rate is *c*.£308/ha totalling £6,160 plus a set up charge of £320 for obtaining the permissions required for the spraying. Springs, water

courses and residential properties all need to be noted on the application form and the correct procedures followed to obtain permission.

Spraying needs to be followed up with targeted spraying of new/missed fronds in subsequent years.

6.9. Sheep Fencing

As discussed above it would be advantageous to keep sheep out of the burnt/damaged area while the nurse grass establishes during the first two years following seeding. The seed is too expensive to allow the whole project to fail because of high rates of sheep grazing. A sheep stock netting fence with a single top wire is, therefore, required on both the western and part of the eastern boundary (total length 2,020m) Using a cost of £10/m this could cost in the order of £20,200 or possibly more if the ground is particularly hard.

Table 7 Restoration Costs

Item	Rate	Approximate Cost (£)
2019		
Aerial photography and digital surface model	Flying the UAV and data analysis	5,600-6,000
Extraction of gullies/rills from the DSM	3 days data analysis	1,500
Helicopter costs for air seeding of nurse grass and heather seed	*Set up and 1 day seeding-*	*17,000*
Helicopter costs for hydro-seeding of nurse grass and heather seed*	Set up and 5 days' work	66,000
Seed cost for nurse crop	40kg/ha over 136.07ha	276,494
Seed cost for heather	0.65kg/ha over 136.07ha.	13,716
Cost for hydro-seed 'solution'	0.25/m^2 over 136.07ha	340,175
Cost for 'dry' hydro-seed mix	0.21/m^2 over 136.07ha	284,386
Cost for mycorrhizal fungi and bio-stimulant	90kg/ha over 136.07ha	61,568
Coir rolls and pins	£9.25/ roll Estimate 300	2,775
Labour for laying coir rolls	20 rolls/day/person £150/day	2,250
Jute mesh and pins	£1.08/1m Estimate 5,000m	5,400
Labour for laying jute mesh	£0.60/m	3,000
Cutting heather brash	Unknown	unknown
Transporting and spreading brash	*£32.50/bag, 2,040 bags*	*66,300*
Bracken spraying	£308/ha, 20 ha + set up £320	6,480
Sheep fencing	£10/m x 2,020m	20,200

* May reduce if 'dry' hydroseed mixture used as mixture is lighter and more can be carried in one load.
Items in italics are unlikely to be needed but are included as alternatives.

6.10. Monitoring

There needs to be detailed monitoring of the restoration works to ensure that the restoration is moving in the correct direction and to make adjustments to the approach to achieve the required outcome.

This would entail visits to the site by a suitably experienced and knowledgeable ecologist who could identify the general progress of plant establishment, identify any areas where establishment and survival might be poor, and the possible reasons for this, and devise remedial measures within the context of the works. It should also include an assessment of any significant tree establishment, as this may require control in the future.

Fixed point photographs based on some of those taken for this report would be useful to show visually the progress of re-vegetation.

It would also be advisable to include more detailed botanical monitoring that would involve many small randomly distributed quadrats (e.g. 30, 1m^2 divided into 25 equal cells, each cell being 20cm x 20cm) for each of the main restoration blocks to ensure progress is in the right direction. The presence and absence of species in each cell of the quadrat, along with basic environmental measures such as bare ground, erosion presence, etc, would be a relatively easy and repeatable way of monitoring progress.

In addition, overall cover in the quadrat of the main species (vascular and bryophytes) could all be recorded. This would give some quantitative idea of the rate of success, the variation of this across the different areas of the site, and provide valuable information if the whole project were properly documented in the event of future wildfires.

Although the recommendations are given based on the best knowledge of moorland restoration, it should be noted that there are many old wildfire sites where complete recovery has not been possible because of erosion and gullying, and sometimes, lack of control of grazing, or the difficulty of establishing vegetation on the charcoaled and bitumen encrusted peat. It is possible that there will be areas on this site which could suffer in the same way. Monitoring on an annual basis in the first five years would assist in identifying any very fragile or eroding areas where restoration is not working adequately.

It may be necessary to apply more intensive treatments in localised areas to arrest erosion in the future, such as the laying of geojute to slow down erosion, and intensive re-seeding measures additional to those proposed above.

However, the priority should be restoring the majority of the moor first, and then tackling the more problematic areas after a couple of years, once they can be identified, mapped and measured and effective appropriate ‘spot’ treatments be designed and applied.

The need to apply additional dwarf shrub species into the Category 1 and 3 areas would also be best assessed at this later phase of restoration works. Bilberry and bell heather may establish naturally, from seed blown or deposited in these areas from the adjacent maturing vegetation, but if it does not happen then plug plants grown from locally native material would be a good way to introduce such species relatively quickly.

7. Recommended Approach

The nature conservation and landscape importance of the site, the fragmentation of the larger site by the loss of the habitat in the fire zone and the widespread, high level of damage and habitat destruction means that the site should be restored to a heathland habitat at the earliest opportunity.

Early signs are that some areas are capable of natural regeneration towards a mixed heather and bilberry moorland habitat but that over half the site, 136.07ha (54%) is unlikely to regenerate to a heathland habitat without considerable external input in an acceptable timeframe. The longer the site is left bare then the more soil erosion will occur, exposing more rock and making heathland establishment more difficult. There is also the real possibility of invasive species, such as bracken, expanding rapidly to the detriment of the heathland habitat. Although a natural component of the vegetation, gorse is also likely to expand rapidly altering the habitats in a negative way.

Intervention to establish a nurse grass and then seeding with heather is highly recommended over the priority restoration areas shown in Figure 7. The scale, terrain and fragility of the site mean that helicopters will be required to undertake the majority of the restoration work. More discussion is required to determine the most practical way of applying seed to the slopes and keeping it in place long enough for a root mat to form and stabilise the soils – this could be a hydro-seed solution/slurry or a dry seed, mulch and binder mixture.

7.1. Recommended Plan of Action

Obtain funding and secure project officer/team

Obtain UAV aerial photograph and digital terrain data to create an accurate model. Use this to:

- Ground truth/refine the restoration areas on Figure 7;
- Use the DTM to prioritise areas for coir logs in erosion channels;
- Calculate accurately the areas for reseeding;
- Map the bracken fronts and areas of regeneration; and
- Determine on site if jute erosion control is required in small areas, possibly close to paths.

Set up a number of permanent quadrats in the different fire damage category areas and the small areas of deeper peat. In addition random quadrats in the areas to be restored would give reliable robust results on the effectiveness of restoration.

Erect temporary fencing on boundaries (Figure 6) and exclude sheep.

Refine seed specification and rates depending on availability of seed for the timescale and costs.

Put in place the coir logs and jute mesh prior to seeding.

Seed nurse grass and heather by aerial hydro-seeding (dry or wet) in the spring – April/May. Add mycorrhizal fungi if research shows advantageous or undertake a trial on part of the site to inform future restoration projects.

Treat expanding bracken fronts (July-August) by aerial spraying or backpack depending on the area, following analysis of areas.

Monitor annually and review the direction and speed of restoration each year both in the treated areas and in the smaller bare/damaged areas within the less damaged areas. If restoration is not moving in the right direction, i.e. to heathland, consider re-application or application of seed and or additional measures, i.e. further coir logs and jute mesh. Weather events immediately post seed application can alter the outcome of any restoration scheme, torrential rain or drought can cause failure.

Monitoring will also inform the need for the addition of other dwarf shrub species, further bracken treatment and the levelling and management of scrub and trees and non-desirable invasive species.

There may be opportunities, if heather cutting occurs locally, to use the brash to treat small bare areas within the larger areas of relatively lightly damaged vegetation. These areas will be identifiable on the post-burn aerial photographs and are often relatively accessible by low ground pressure vehicles.

Longer-term, the reintroduction of grazing and heather management to increase resilience to wild fire must been considered within the fire damaged area and across the wider SSSI with a dedicated fire management plan and sufficient annual heather cutting/burning management to prevent a uniform vegetation developing across the whole SSSI.

There is a need for a large investment in the first year of the project but also to cover ongoing monitoring and additional intervention if required for a minimum of five and ideally ten years.

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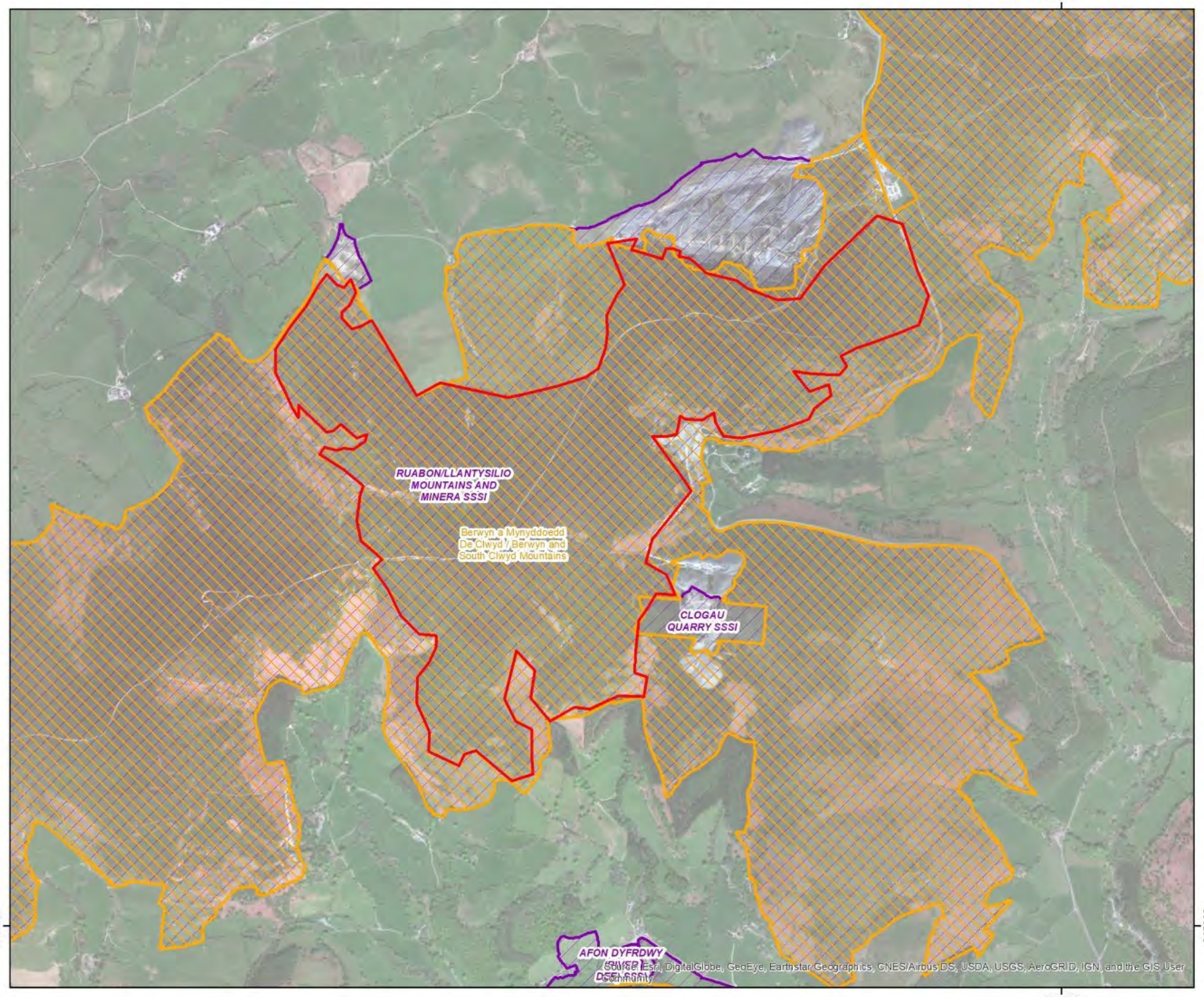
Abbreviations

AONB	Area(s) of Outstanding Natural Beauty
CLU	Common Land Units
DCC	Denbighshire County Council
DTM	Digital Terrain Model
EU	European Community
MFF	Moors for the Future
NRW	Natural Resources Wales
NVC	National Vegetation Classification
PAA	Penny Anderson Associates Ltd
SAC	Special Area(s) of Conservation
SSSI	Site(s) of Special Scientific Interest
UAVs	Unmanned Aerial Vehicles

9. Figures



Legend

- Approximate burn area
- Sites of Special Scientific Interest
- Special Areas of Conservation

N

ISO A3

Metres

0 50 100 200 300 400

Cyfoeth Naturiol Cymru Natural Resources Wales

Penny Anderson Associates Ltd.
Parklea, 60 Park Road,
Buxton, Derbyshire, SK17 6SN.
Telephone 01298 27086

Project Name: Llantysilio Mountain

Discipline: Ecology

Title: **Site Designations**

Scale	Drawing No.
1:15,000	Figure 1

Drawn By	Originator	Date
MDM	KL	04/10/2019

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Revision: 1.0

Figure 1 - Site - NARW01 MDM 15/08/19.mxd

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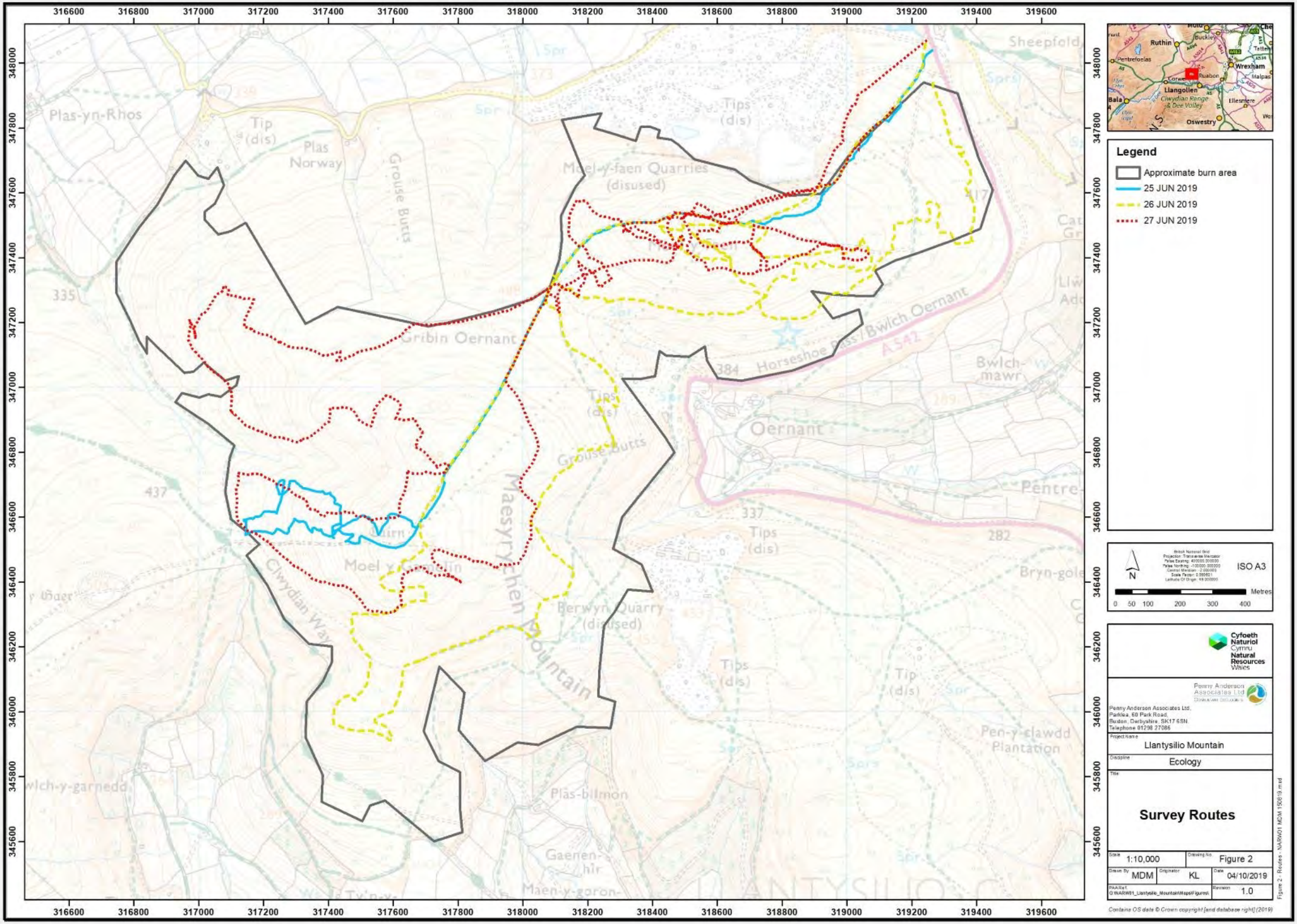
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Plas-yn-Rhos
Tip (dis)
Plas Norway
Grouse Butts
Moel-y-faen Quarries (disused)
Tips (dis)
Gribin Oernant
Horseshoe Pass / Bwlch Oernant
A542
Bwlch-mawr
Oernant
Maesyrychen Mountain
Moel y Gribin
Berwyn Quarry (disused)
Cwydian Way
Plas-bilmon
Gaenen-hir
Pen-y-clawdd Plantation
Bryn-gole
Pentre-
335
437
384
337
282
317
269
Legend
Approximate burn area
25 JUN 2019
26 JUN 2019
27 JUN 2019
Ruthin
Buckley
Mold
Pentrefoelas
Wrexham
Ruabon
Corwen
Llangollen
Cwydian Range & Dee Valley
Bala
Ellesmere
Oswestry
N
ISO A3
Metres
0 50 100 200 300 400
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Project Name
Llantysilio Mountain
Discipline
Ecology
Title
Survey Routes
Scale
1:10,000
Drawing No.
Figure 2
Drawn By
MDM
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Date
04/10/2019
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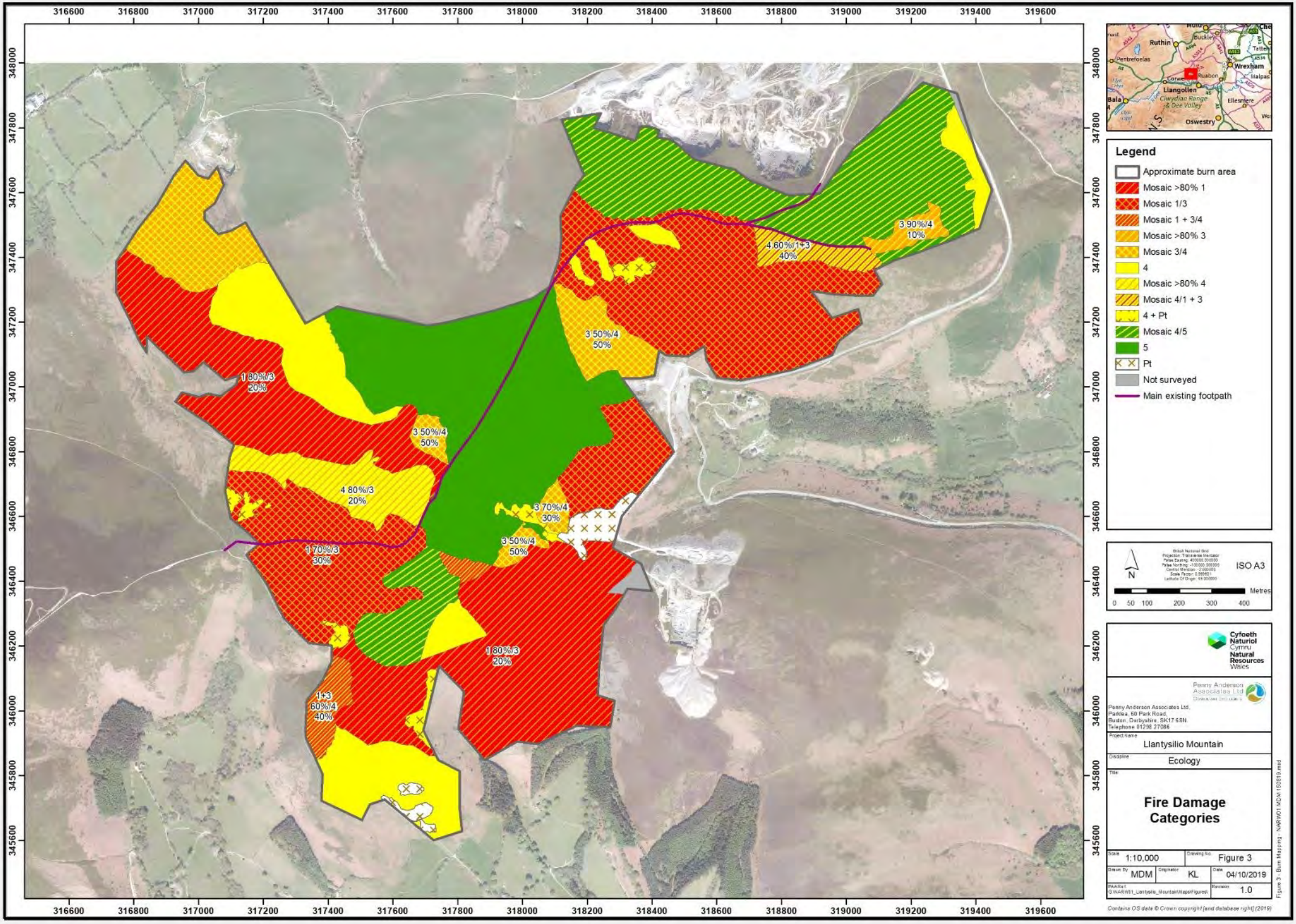
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50%
1 80%/3
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3 50%/4
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1+3
60%/4
40%
Ruthin
Buckley
Pentrefoelas
Wrexham
Ruabon
Corwen
Llangollen
Bala
Ellesmere
Oswestry
Cwydian Range & Dee Valley
Legend
Approximate burn area
Mosaic >80% 1
Mosaic 1/3
Mosaic 1 + 3/4
Mosaic >80% 3
Mosaic 3/4
4
Mosaic >80% 4
Mosaic 4/1 + 3
4 + Pt
Mosaic 4/5
5
Pt
Not surveyed
Main existing footpath
N
ISO A3
Metres
0 50 100 200 300 400
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Project Name
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Scale
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Date
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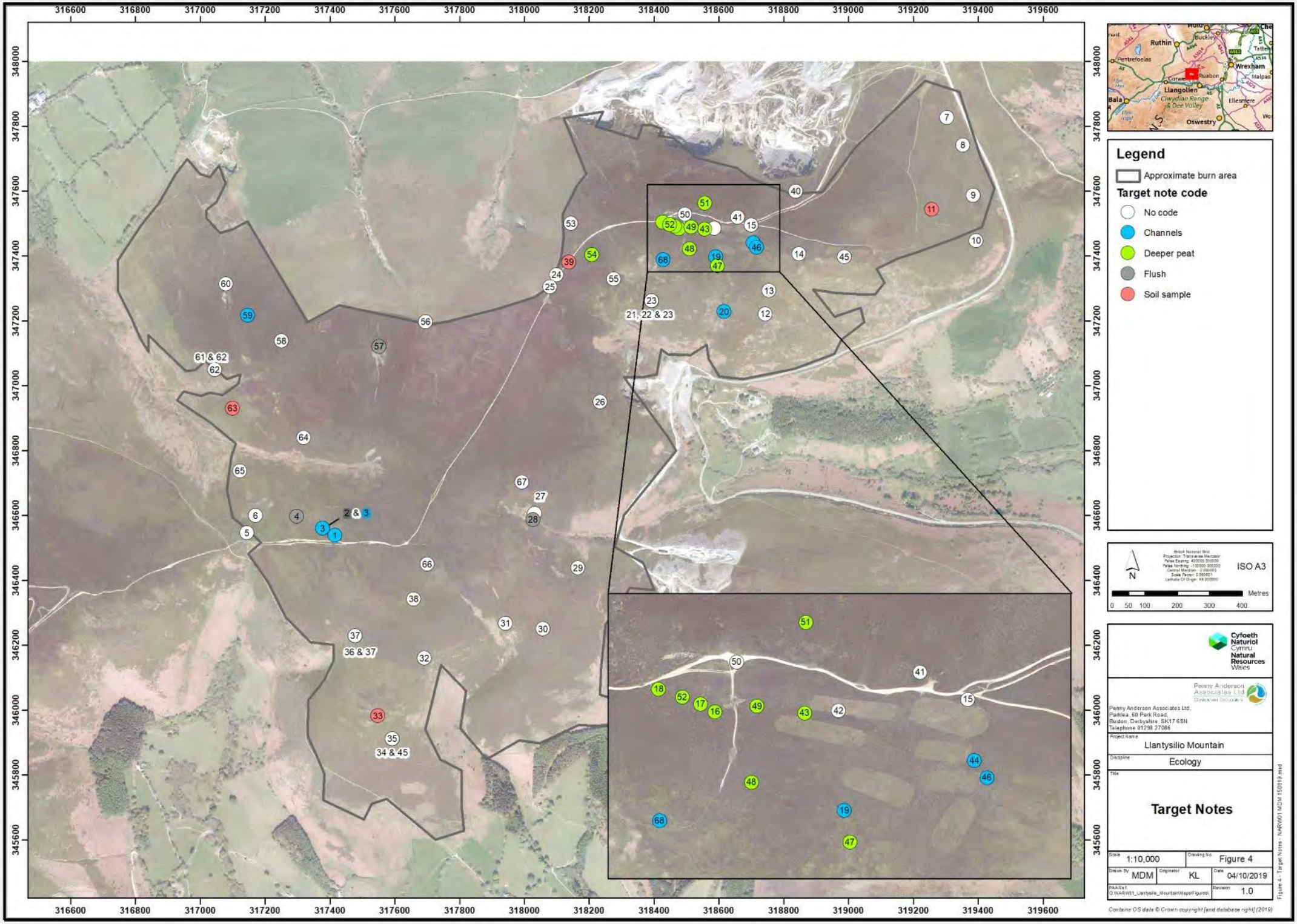
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Channels
Deeper peat
Flush
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Cyfoeth Naturiol Cymru Natural Resources Wales
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Discipline
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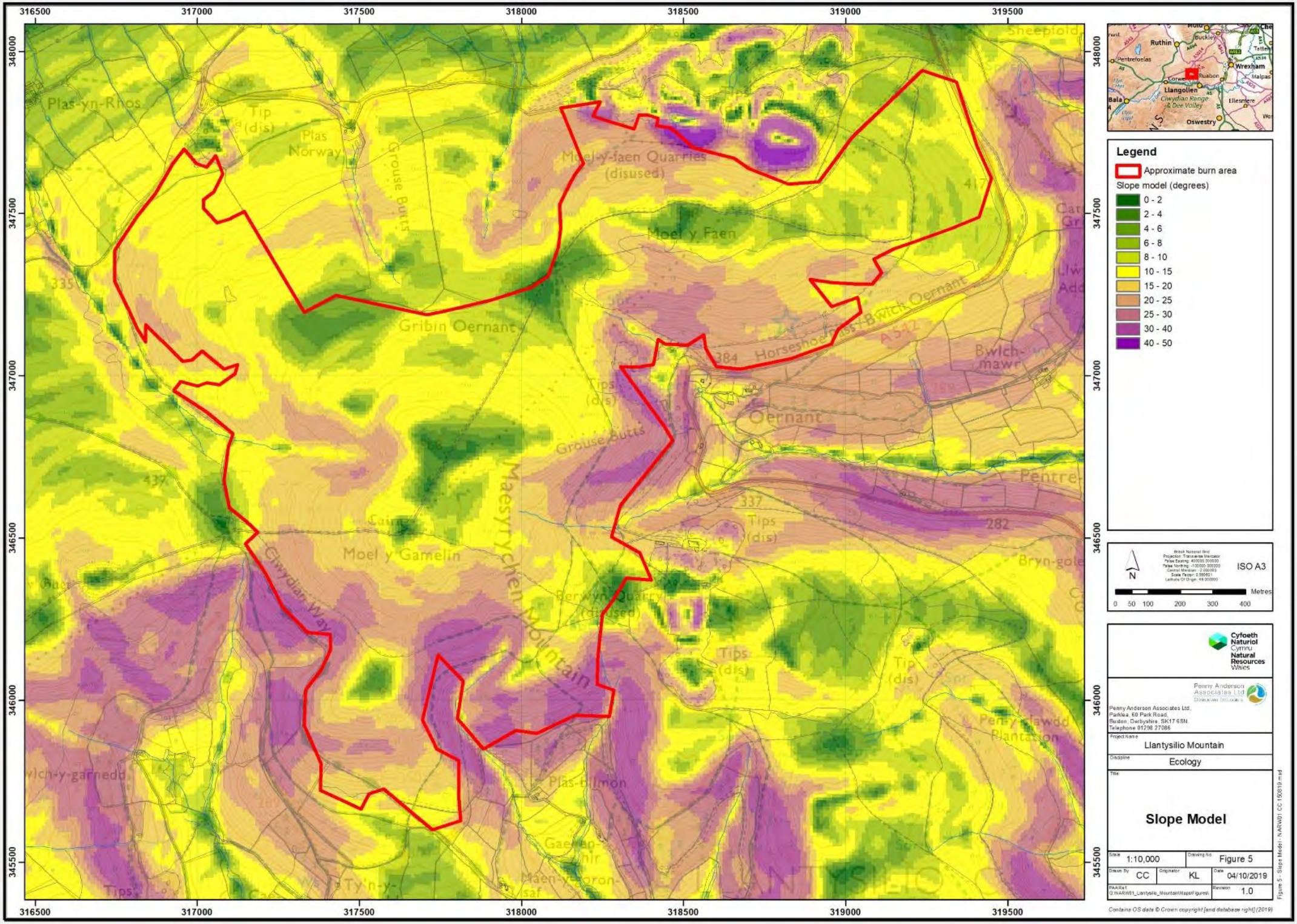
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346500
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Plas-yn-Rhos
Tip (dis)
Plas Norway
Grouse Butts
Moel-y-faen Quarries (disused)
Moel y Faen
Gribin Oernant
Horseshoe Pass
Bwlch Oernant
A542
Bwlch-mawr
Tips (dis)
Oernant
Grouse Butts
Pentre-
Maesyrychen Mountain
Moel y Gamelin
Cwrydian Way
Bryn-gole
Tips (dis)
Tip (dis)
Pen-y-clawdd Plantation
Plas-b'lmon
Gaer-llan-fair
Maen-y-foron-saf
Ty'n-y-
Legend
Approximate burn area
Slope model (degrees)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 40
40 - 50
N
ISO A3
Metres
0 50 100 200 300 400
Ruthin
Buckley
Pentrefoelas
Wrexham
Ruabon
Llangollen
Ciwydian Range & Dee Valley
Bala
Ellesmere
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Project Name
Llantysilio Mountain
Discipline
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Figure 5 - Slope Model - NARW01 CC 190819.mxd
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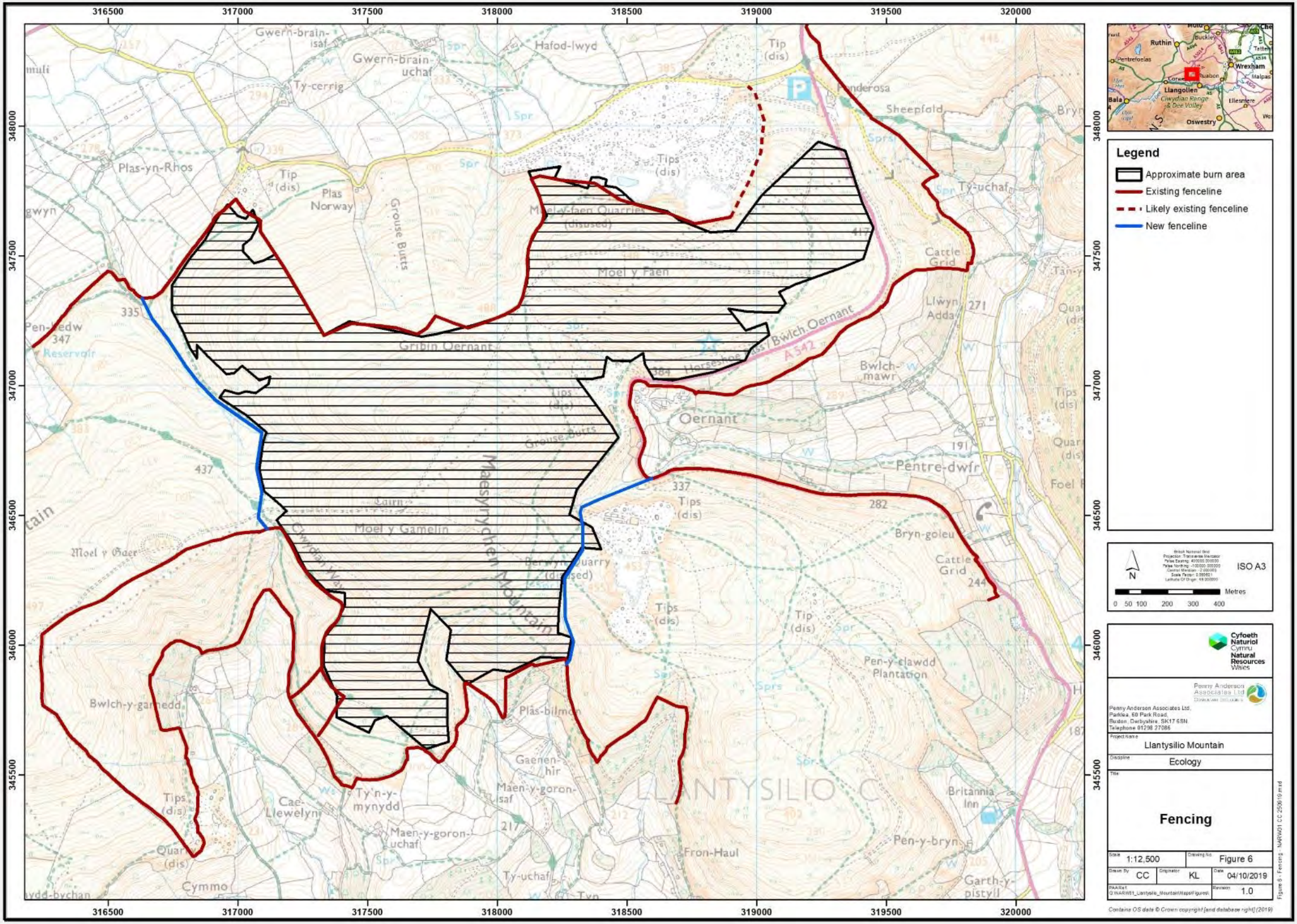
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Gwern-brain-isaf
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Hafod-lwyd
Tip (dis)
Ty-cerrig
Plas-yn-Rhos
Plas Norway
Grouse Butts
Moel-y-faen Quarries (disused)
Moel y Faen
Cattle Grid
Ty-uchaf
Llwyn Adda
Pen-y-cedw
Reservoir
Gribin Oernant
Bwlch Oernant
A542
Bwlch-mawr
Oernant
Pentre-dwfr
Maesyr-ychen Mountain
Cairn
Moel y Gamelin
Moel y Gader
Penwyn Quarry (disused)
Bryn-goleu
Tips (dis)
Pen-y-clawdd Plantation
Bwlch-y-garnedd
Plas-bilmon
Gaenen-hir
Ty'n-y-mynydd
Cae-Llewelyn
Maen-y-goron-saf
Maen-y-goron-uchaf
LLANTYSILIO
Britannia Inn
Pen-y-bryn
Fron-Haul
Garth-y-pistyll
Cymmo
Quar (dis)
Legend
Approximate burn area
Existing fenceline
Likely existing fenceline
New fenceline
N
ISO A3
Metres
0 50 100 200 300 400
Cyfoeth Naturiol Cymru Natural Resources Wales
Penny Anderson Associates Ltd
Penny Anderson Associates Ltd.
Parklea, 60 Park Road,
Buxton, Derbyshire, SK17 6SN
Telephone 01298 27086
Project Name
Llantysilio Mountain
Discipline
Ecology
Title
Fencing
Scale
1:12,500
Drawing No.
Figure 6
Drawn By
CC
Originator
KL
Date
04/10/2019
PAA Ref
Revision
1.0
Figure 6 - Fencing - NRW01 CC 25/09/19.mxd
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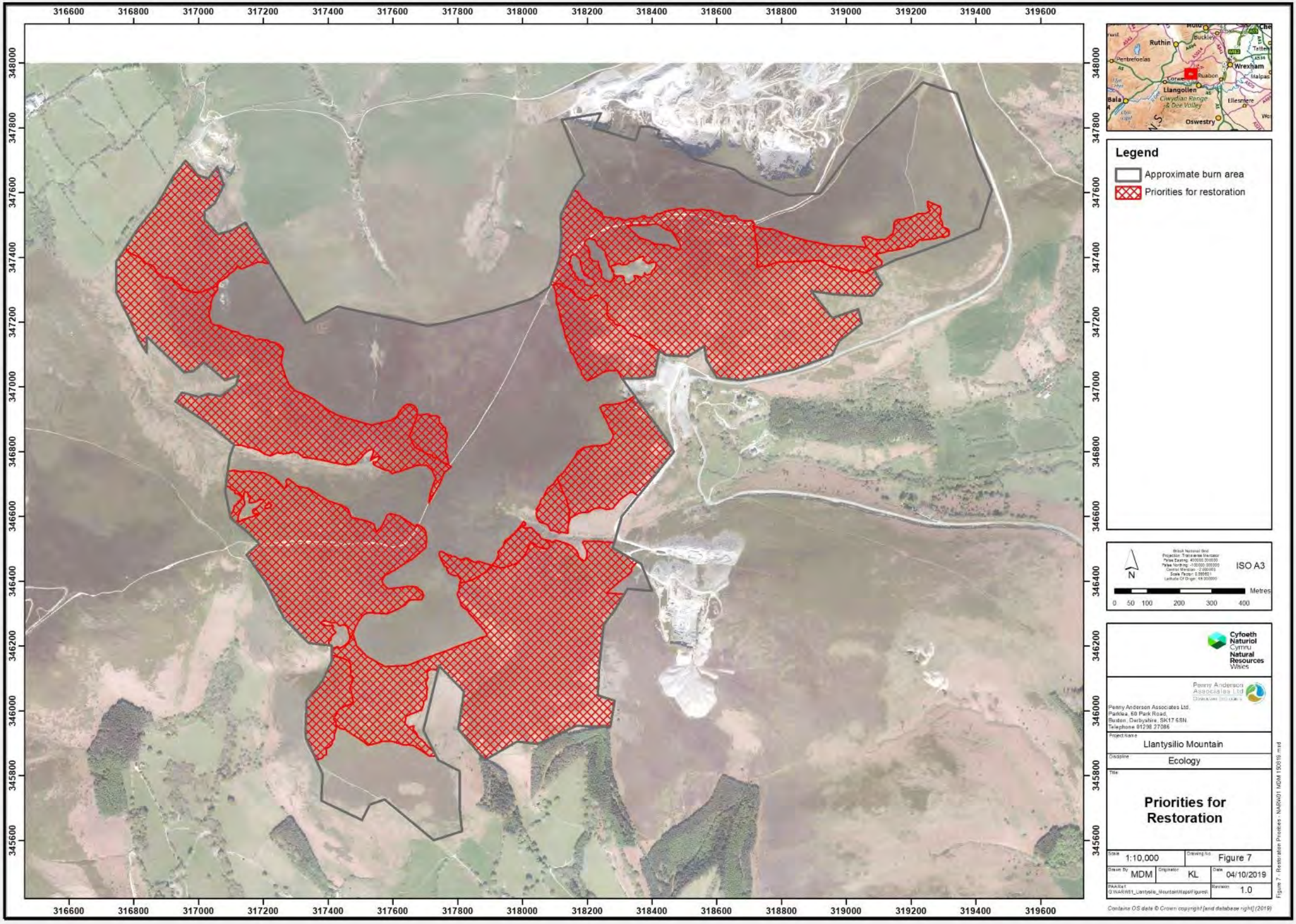
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Buckley
Mold
Pentrefoelas
Wrexham
Ruabon
Corwen
Llangollen
Bala
Ellesmere
Oswestry
Malpas
Cwydian Range & Dee Valley
Legend
Approximate burn area
Priorities for restoration
N
ISO A3
Metres
0 50 100 200 300 400
Cyfoeth Naturiol Cymru Natural Resources Wales
Penny Anderson Associates Ltd
Penny Anderson Associates Ltd.
Parklea, 60 Park Road,
Buxton, Derbyshire, SK17 6SN
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Discipline
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Title
Priorities for Restoration
Scale
1:10,000
Drawing No
Figure 7
Drawn By
MDM
Originator
KL
Date
04/10/2019
Revision
1.0
Figure 7 - Restoration Priorities - NAR4001 MDM 190816.mxd
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10. Appendices

10.1. Appendix 1 Target Notes from 1992

CORE INDEX ENTRY FORM

REGION/CHQ/COUNTRY CODE (eg 30,11) : CH
ORIGIN/RECORD TYPE (eg W=SSSI) : 31
RECORD NUMBER :
INDEX NUMBER : 013

AUTHOR : Christine Welsh.
DATE OF SOURCE OR PUBLICATION :
TITLE : Phase I Habitat Survey - Clwyd.

LOCATION OF ORIGINAL DATA/SOURCE : Mold.

ORIGINAL REFERENCE NUMBER : SJ14NE

KEYWORDS HABITATS : Heath, Bracken, Spoil, Grassland, Flush, Scrub, Conifer plantation
KEYWORDS OTHER : Phase I, Biological Survey of Common Land.

LEVEL OF SURVEY/EVALUATION :

SITE NAME : Part of Llantysilio Mountain (CL128d)

10 KM SQUARE/S : SJ14

GRID REFERENCE/S (eg SJ234234) : SJ 180 465
AREA OF SEARCH : Clwyd

LA DISTRICT/S (codes) : Glyndŵr
AREA (Ha) BY DISTRICT/S :

VICE COUNTY NUMBER/S : 50

SSSI CODE/S : SSSI
CONSERVATION STATUS CODE/S :

HABITAT RECORDS ENTERED ? (Yes/No) : Yes
SPECIES RECORDS ENTERED ? (Yes/No) : Yes

SITE DESCRIPTION/NOTES (brief) :

This site was not re-surveyed.
See: Medcalf & Aitchison (1993), Biological Survey of Common Land No. 31; RSRU / Science Report No. 39.

Checked ?	Entered on Coregsta ?		Version 25-1-97

SJ 14 NE, SJ 14 SE

RURAL SURVEYS RESEARCH UNIT
DEPARTMENT OF GEOGRAPHY,
U.C.W., ABERYSTWYTH.

BIOLOGICAL SURVEY OF COMMON LAND

NATURE CONSERVANCY COUNCIL

CL No: [128d] County: Clwyd...Glyndŵr... CODE [ ] Grid ref: [3180 3465] 10 Km sq. [SJ14] O.S. Sheet: [116]

CL Status: [F] Area (ha): [400].[3] Altitude: Max.[578] Med. [420] Min. [152] Vice County: [50]

SITE NAME: Part of Llantysilio mountain. Date of Visit: [29/7/92]
[ ] C = Information Collated

Recorder/ Compiler: [KAm] Time on Site: [3hrs] No. of photographs: [2] Access permission from:

CONSERVATION STATUS: [1] % [7] [2] % [7] [ ] % [ ] [ ] % [ ] [ ] % [ ]

(% = % of site) 1 = SSSI 2 = NCR Site 3 = NNR 4 = LNR 5 = ESA 6 = SPA 7 = National Park
8 = AONB 9 = Heritage Coast 10 = County Trust 11 = National Trust 12 = RSPB 13 = Ramsar 14 = Other (specify below)

General description of site: A large part of Llantysilio mountain comprising of heath on the ridge tops and bracken on the steeper hill sides with several large areas of quarry spoil.

Owner(s): 1 private owner

HABITATS (NVC/Phase 1) + Descriptions:		Areas (ha.)
D11	Dry dwarf shrub heath	249.9
C11	Continuous bracken	106.2
J22	Quarry spoil	15.7
A122	Coniferous plantation	7.9
B11	Acid grassland	6.7
E21	Acid flush	3.7
C12	Scattered bracken	3.4
A22	Scattered scrub	2.5
E4	Bare peat	1.9
A31	Scattered trees	1.3
D5	Acid grassland/dry heath mosaic	1.0
J36	Buildings	0.1
	Total Area:	400.3

Public access and recreation:
The unfenced A542 follows the eastern boundary of the common and two minor roads ajoin the southern side of the common. There is a RUPP on the western side and a dense network of public footpaths. A wide area of bare peat has been created by motor bike scrambling. The common has a moderate amount of informal recreational usage - more concentrated in the north and along the summit ridge to the ancient cairn at the summit of Moel y Gamelin.

MANAGEMENT:

Hay		Grazing Time:	
Mown		Spring	
Cattle			
Sheep	Y	Summer	
Horses			
Rabbits		Autumn	
Burning	Y		
Grouse		Winter	
Coppice		All year	
Planting		Irregular	
Thinning/felling			
Pollarding			
Recreation			
Fisheries			
Dumping			

Grazing Intensity:
Light to moderate

Managed by:
Conservators [ ] Management Committee [ ]
Other [ ] None [ ]
.....

Sources of information/references:
WFU report.

SITE CHARACTERISTICS:

Main Geology [ ][ ] Main Soils [ ][ ]
Slope [ ] Aspect [ ]
Ridge + Furrow [ ] Flooding [ ]
Scrub invasion [ ] Mature trees (>60 cm DBH) [ ]
Much dead wood [ ] Base-rich wet flushes [ ]
Bare ground: [Y] Origin Peat erosion.....
Litter accumulation: [ ] Type .....

General notes on site:
15 nights of pasture for sheep. These are cross-referenced with those under CLs 21, 22, 122, 123, 126, 127 and 213; some nights are exercisable over part of this unit only.

CL No: 128d County: CLWYD Glyndŵr Site name: Part of Llantysilio Mountain Grid ref: 3180 ~~3~~ 465

MAP: (show scale, north, adjacent habitats)

See Attached Map.

FAUNA: [The WFU report listed many bird species for this common. These were not noted at the time of the site visit at the end of the breeding season in late July. These included: ring ouzels, red grouse, whinchat, buzzard, curlew flying over, cuckoo, tree pipit, wheatear, linnet, stonechat, green woodpecker, jackdaw, and meadow pipit. At the time of the site visit red grouse droppings were seen, together with a buzzard and meadow pipits.

VEGETATION: [The site report was compiled from a site visit and the WFU report. The vegetation at the top of the Moel y Gamelin hill has an area of Calluna vulgaris heath with scattered Vaccinium vitis-idaea and Cladonia portentosa. Most of the hill top has varying ages of heath, with species composition depending upon the burning pattern. The eastern slope has several areas of fairly recent burns where Vaccinium myrtillus dominates, and some areas with a mixture of Vaccinium myrtillus, Calluna vulgaris and Ulex gallii. The north-western side of the hill carries a mature Calluna vulgaris heath with occasional Empetrum nigrum and a good bryophyte carpet. The hill forming a spur to the south-east has a Vaccinium myrtillus/Ulex gallii heath together with numerous areas of dense Pteridium aquilinum. At the southern edge are two areas of plantation woodland together with an area of Festuca ovina/Agrostis capillaris acid grassland and scattered Pteridium aquilinum. Along the eastern edge there are scattered trees of Crataegus monogyna and Sorbus aucuparia. The streams have small flushes associated with them which are dominated by Juncus effusus with Cardamine pratensis, Myosotis secunda, Chrysosplenium oppositifolium, Carex echinata, Ranunculus flammula and Sphagnum recurvum. The central area of the common has two large slate quarries: the central one is disused and has some sparse heath vegetation of Calluna vulgaris/Vaccinium myrtillus with occasional Ulex gallii, Festuca ovina and Agrostis capillaris. The northern area is still being worked. The WFU reported the notable lichen Cetraria islandica from the Berwyn quarry.

MANAGEMENT: The common is sheep grazed. To the north the grazing pressure is light; the southern spur has a moderate grazing pressure. The heath is managed by burning, creating stands of different age. Apart from an area at the top of Moel y Gamelin where the heather has a low growth form due to desiccation by the wind the heather is all in good condition with numerous flowers. (continued on a separate sheet)

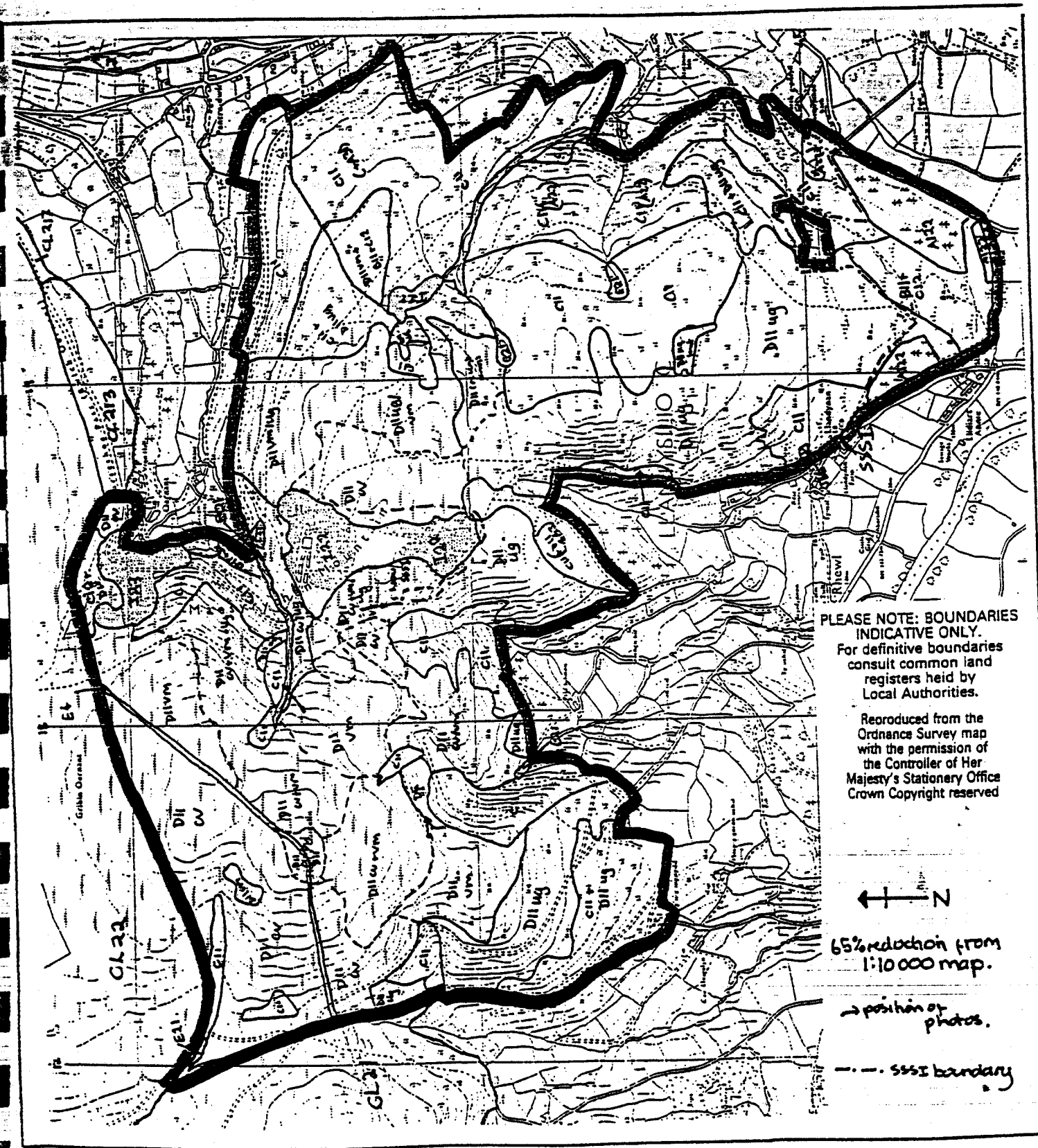
ADDITIONAL NOTES FOR CLWYD. GLYNDWR COMMON 128d
PART OF LLANTYSILIO MOUNTAIN.

MANAGEMENT: (continued) The ffridd areas of Ulex gallii and Pteridium aquilinum form an excellent habitat for small birds. The crags of the old quarry are also a good site for

The only real damage to this common has been the erosion of a 10 metre wide track, by motor bike scrambling, in the peat of the ridge top. The burning management may be encouraging the spread of Pteridium aquilinum. However on the northern section of the common, where the grazing pressure is lighter, this invasion is kept to the stream lines.

CLWYD Glyndŵr common 128d:

Part of Llantysilio Mountain.



10.2. Appendix 2 Target Notes and photographs from 2019 Survey

Llantysilio Mountain Target Notes

Target Note No	Date	Grid Ref		TN Code	Description	Photograph	Bearing
		Easting	Northing				
1	25.06.19	17416	46539	Ch	7-8m section of rill/gully, very soft substrate - Category 2 damage	2055	70
2	25.06.19	17377	46561	F	Small flush - unburnt: bilberry, soft-rush, common bent, sweet vernal-grass, star sedge, mat-grass, Yorkshire fog, tormentil, wavy hair-grass	2057	220
3	25.06.19	17377	46561	Ch	Erosion channel from flush, 30cm wide, 5cm deep. Slow water run off with coir logs	2058	290
4	25.06.19	17298	46598	F	Small flush, 20m x 7m; bilberry (f), soft rush (o), sheep's fescue (o), wavy hair-grass (o), crowberry (r), *Sphagnum fallax* (lo), common sedge (lo), woodrush (r).		
5	25.06.19	17144	46547		Existing unburnt vegetation: bilberry (a), heather (f), wavy hair-grass (f)	2061	320
6	25.06.19	17171	46600		Substrate loss, moving as unstable - very small scale *c* .50cm	2062	
7	26.06.19	19303	47828		Area of older heather and gorse, *c* .30 x 100m parallel to the road. Average peat loss 5-7cm. No action recommended as heather and bilberry regeneration good, occasional gorse regen. Category 4 - plates of vegetation.	2075, 2076	180
8	26.06.19	19353	47743		Minor catch ditch 2-3m wide, 0.5m deep. Well vegetated with grasses and soft-rush.	2078	150
9	26.06.19	19385	47588		Good area of heather regeneration, Transect with 5m stops. 18/20 had heather seedlings		
10	26.06.19	19394	47448		Unburnt vegetation at the edge: bilberry (a), heather (f), western gorse (f-ld), wavy hair-grass (f), crowberry (o), heath bedstraw (o), rowan saplings (lo), *Polytrichum commune* (o), *Hypnum jutlandicum* (o). Most vegetation 40-45cm tall, gorse <1m, rowan 2-3m.	2079	60
11	26.06.19	19257	47545	SS	Division between two burn categories. Category 3 (left, SS2) and 4/5mosaic (right, SS1). The Category 3 area needs restoration as 5-6cm peat lost and seed bank.	2080	180
12	26.06.19	18743	47222		Steep slope with gorse and bracken and very little else. Bilberry rare, bracken rhizomes are exposed and burnt in places, minimal erosion but increased moss cover.	2085	340
13	26.06.19	18755	47294		Increasing bilberry and bell heather in patches, 6 sheep seen here		
14	26.06.19	18848	47407		Very bare, Category 1, shale area visible *c* .50m^2 on small ridge	2086	2800
15	26.06.19	18700	47496		Hotspot on the crest burnt down to shale and areas of charred peat	2087	
16	26.06.19	18477	47485	P	Deeper peat, eroding and dried out, peat eroded a minimum of 10cm	2089	270
17	26.06.19	18464	47492	P	Peat erosion 15-17cm, area of deepest peat but very damaged non functioning, very dry.	2090	
18	26.06.19	18427	47505	P	Area of deeper peat now remaining as plates, cracked and damaged. Heather regeneration good where surface remains. Peat will dry and crack on edges so not stable in the long term. Limited scope for erosion control.	2091	160
19	26.06.19	18591	47398	Ch	Localised water erosion into clay material, 10-15cm below the new surface, 5 channels approx 10m long. Coir logs required to slow the flow, very soft ground.	2092	310
20	26.06.19	18616	47229	Ch	Riling down the slope, may be more upslope - check. Surface soft and vulnerable actively eroding 50cm wide x 10cm deep.	2096	10
21	26.06.19	18392	47263		Soil/peat erosion around gorse stumps, *c.* 10cm lost	2098	-
22	26.06.19	18392	47263		Photograph of bracken in valley leading to Oernant, clear potential for bracken to spread	2099	250
23	26.06.19	18392	47263		View of lower eastern slopes of Moel y and quarry tips	2100	220
24	26.06.19	18099	47343		NE slopes of Moel y Gamelin, Category 5 with occasional bare areas, the pre-burn management pattern is obvious in the response of the vegetation to the burn	2101	240
25	26.06.19	18079	47305		Soils by fence edge scrapped up leaving *c* .1m bare ground and c2m disturbed soils. Peat here after the burn very shallow *c* .4cm.		
26	26.06.19	18234	46951		Burn Category 2 with orange colouration	2105	-
27	26.06.19	18032	46607		Bracken area, some unburnt with acid grassland and bilberry underneath		
28	26.06.19	18027	46588	F	Flush on stream line with soft rush acid grassland and *Sphagnum palustre*	2106	280

Target Note No	Date	Grid Ref		TN Code	Description	Photograph	Bearing
		Easting	Northing				
29	26.06.19	18165	46439		80% of area Category 1, 20% Category 2. No heather and very little bilberry, occasional burnt/dead standing heather stick. Sheep in this area	2108	80
30	26.06.19	18057	46251		Burnt gorse stick, *c* .5cm proud of previous surface, with little regeneration.	2109	-
31	26.06.19	17942	46268		Whole side of the hill burnt (Categories 1 and 2), bracken in foreground, other green colour is moss	2110	170
32	26.06.19	17691	46161		South-western face of hill visible, Category 1 burn, no revegetation on steep slopes (bracken in valley not burnt)	2111	150
33	26.06.19	17548	45983	SS	Soil sample 3, Category 1		
34	26.06.19	17592	45912		Gorse regeneration	2114	-
35	26.06.19	17592	45912		Wider view, moderate natural revegetation	2115, 2116	150, 210
36	26.06.19	17478	46230		Plates of bilberry and gorse, Category 4 interspersed with bare areas, still requires revegetation assistance.	2117	200
37	26.06.19	17478	46230		Bare except for bracken, mosaic of Categories 1 and 3	2118	300
38	26.06.19	17658	46343		Locally frequent bell heather seedlings in this area		
39	26.06.19	18137	47382	SS	Soil sample 4, Category 2 burn	2119	-
40	27.06.19	18837	47601		Area of bare ground c.50m^2 Category 1/2 amongst a mosaic of Categories 4/5. Surface puffy with mosses colonising, some blown brash on surface. Several of these patches in area.	2121	240
41	27.06.19	18658	47520		Top of ridge, bare areas, very exposed. Use jute mess to help restoration here		
42	27.06.19	18586	47486		Close to the top of Moel y Faen, looking to the summit, soils/peat and brash in foreground, outcropping shale/rocks in distance	2122	300
43	27.06.19	18556	47484	P	Very small area of peat pedestals c.3x3m. Remaining peat up to 20cm tall, thin crust on surface and very fractured	2123	-
44	27.06.19	18706	47442	Ch	Erosion channels, 20cm deep, 40cm wide in soft substrate Category 2 burn		
45	27.06.19	18987	47398		Complex pattern of plates and bare areas, could map in detail or preferably revegetate whole area. Heather seedlings and bilberry shoots frequent on plates.	2125	40
46	27.06.19	18717	47427	Ch	Erosion channels in soft, Category 2 substrate. Approx 20 coir rolls needed 20cm x 1m	2126	290
47	27.06.19	18596	47370	P	Small coll/dip with area of deeper peat and soils. *c.* 20cm peat eroded/removed at the edges of the peat block. Several small erosion channels here too but very short with water dissipating over wide area. Appears a very hot burn with Category 2 damage close		
48	27.06.19	18509	47423	P	Deeper peat with some remaining pedestals, burnt and eroded, very oxidised and non functioning.	2127	300
49	27.06.19	18514	47490	P	Peat pedestals, 20 x10m area, burnt and eroded, very uneven and exposed.	2128	290
50	27.06.19	18496	47529		Existing vegetation bilberry and heather co-dominant with wavy hair-grass, sheep's fescue and heath bedstraw all frequent, Occasional *Rhytididelphous squarrosus* . Peat/soil 13cm deep, vegetation height 35cm max. Heather *c.1* 5 years plus and grazed hard last winter	2129	350
51	27.06.19	18557	47564	P	Deeper peat *c* .20cm on slope but with hard crust, eroding and fragile. Lots of dead heather stems in area and moss colonising but significant peat lost and no current heather regeneration.	2132	260
52	27.06.19	18448	47498	P	Area of damaged deeper peat *c* .20cm with areas of pedestals, no regeneration vegetation.	2134	260
53	27.06.19	18144	47501		A small area of intact surface, with abundant heather seedlings in a large area of Category 1/3 burn	2135	-
54	27.06.19	18208	47405	P	Area of deeper peats, very disturbed and eroded. *c.* 20m x 50m	2136	100
55	27.06.19	18276	47330		Edge of deep peat area. Original surface with bracken	2137	-
56	27.06.19	17695	47198		Large Category 5 area with occasional small areas of more serious burns. Regeneration of bilberry and heather good as after management burn	2138	260
57	27.06.19	17551	47122	F	Grassland /flush vegetation dominated by acid grassland species, *Sphagnum* and marsh thistle.		
58	27.06.19	17250	47139		Small patches of vegetation, smaller than typical Category 4 'plate' descriptions but moderate bilberry regeneration.	2139	-
59	27.06.19	17146	47218	Ch	Erosion channel less than 40cm wide and *c* .20cm deep in soft Category 2 burn substrate.		

Target Note No	Date	Grid Ref		TN Code	Description	Photograph	Bearing
		Easting	Northing				
60	27.06.19	17079	47315		Stone ring/shelter on old mine seam. Mixed Categories 3/4 ie peat/soils around individual plants not in plates, some bilberry regen but little heather. Very patchy mosaic could undertake more detailed mapping or treat whole area.	2140	260
61	27.06.19	17045	47050		Existing vegetation, heather and bilberry with grasses in a mosaic and occasional rowan	2142	180
62	27.06.19	17045	47050		View up slope of bare substrate with moss colonising	2143	90
63	27.06.19	17099	46931	SS	Very bare, Categories 1 and 3, only mosses and very occasional common bent, spear thistle and bracken. Soil sample 5 taken from Category 1 area.	2144	90
64	27.06.19	17319	46841		Steep slope with some dead standing heather stems, very occasional bilberry regeneration and scattered bracken fronds. Treat bracken up slope	2146	0
65	27.06.19	17122	46738		Edge of fire damage, eroded peat/soil and bracken turf	2150	-
66	27.06.19	17700	46450		Some significant bare areas (up to 40 x 40m) in this patch of vegetation. Bare areas not mapped.		
67	27.06.19	17993	46704		Series of rocky outcrops, more heavily burnt, bare, but as surrounded by regenerating vegetation not priorities for restoration		
68	27.06.19	18428	47389	Ch	Rills and/or bike damage, consider coir logs	2157	210

KEY
Ch - channels
P - deeper peat
F - flush
SS - soil sample

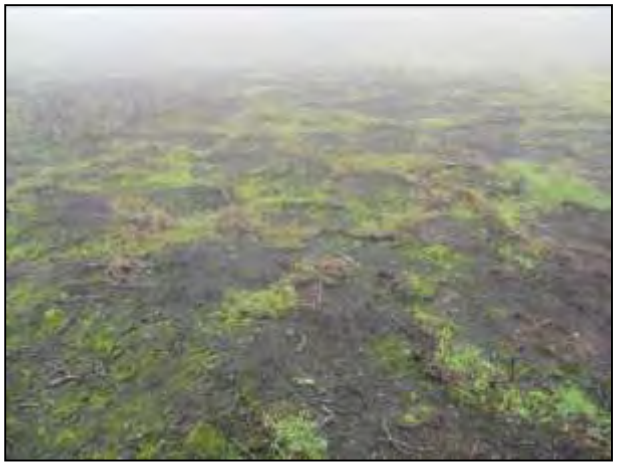
Target Note Number 1
Photograph 2055

Target Note Number 2
Photograph 2057

Target Note Number 3
Photograph 2058

Target Note Number 5
Photograph 2061

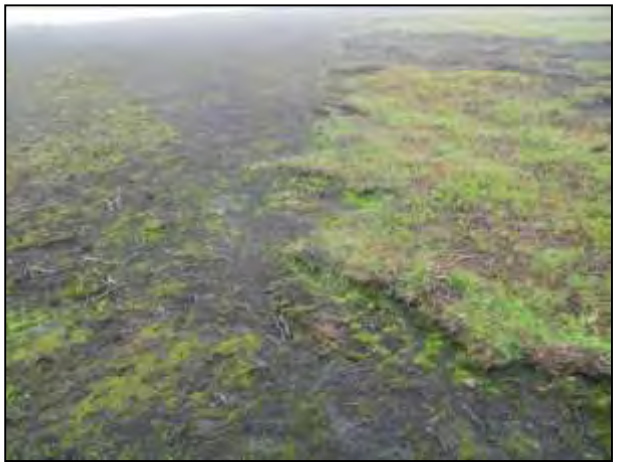
Target Note Number 6
Photograph 2062



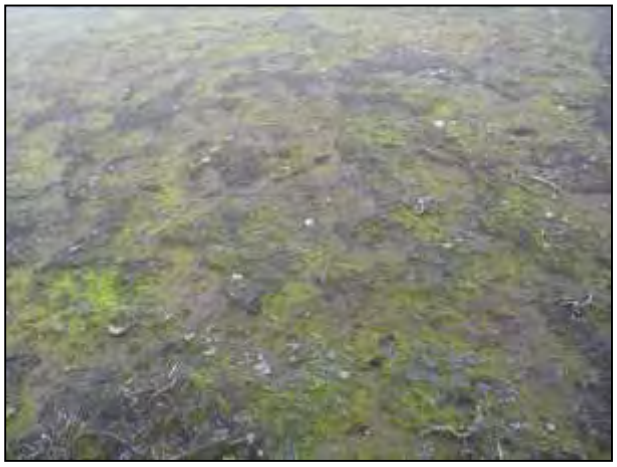
Target Note Number 7
Photograph 2075 and 2076

Target Note Number 8
Photograph 2078

Target Note Number 10
Photograph 2079



Target Note Number 11
Photograph 2080



Target Note Number 12
Photograph 2085

Target Note Number 14
Photograph 2086

Target Note Number 15
Photograph 2087

Target Note Number 16
Photograph 2089

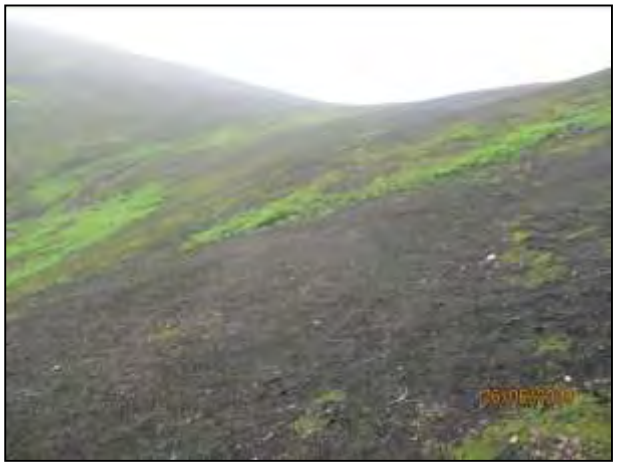
Target Note Number 17
Photograph 2090

Target Note Number 18
Photograph 2091

Target Note Number 19
Photograph 2092

Target Note Number 20
Photograph 2096

Target Note Number 21
Photograph 2098



Target Note Number 22
Photograph 2099

Target Note Number 23
Photograph 2100

Target Note Number 24
Photograph 2101

Target Note Number 26
Photograph 2105

Target Note Number 28
Photograph 2106

Target Note Number 29
Photograph 2108

Target Note Number 30
Photograph 2109

Target Note Number 31
Photograph 2110

Target Note Number 32
Photograph 2111

Target Note Number 34
Photograph 2114


Target Note Number 35
Photograph 2115 and 2116

Target Note Number 36
Photograph 2117

Target Note Number 37
Photograph 2118

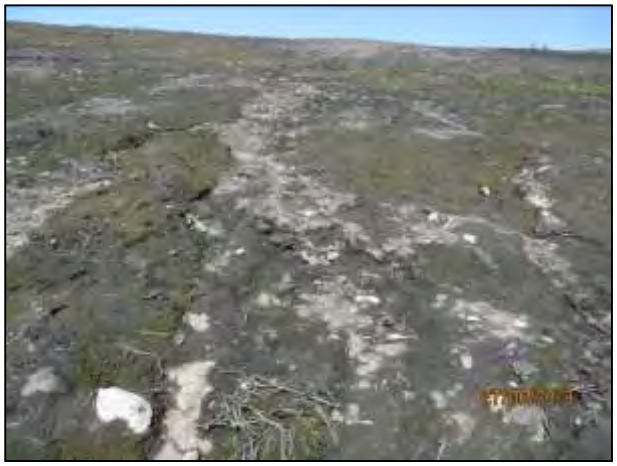
Target Note Number 39
Photograph 2119

Target Note Number 40
Photograph 2121

Target Note Number 42
Photograph 2122

Target Note Number 43
Photograph 2123

Target Note Number 45
Photograph 2125



Target Note Number 46
Photograph 2126

Target Note Number 48
Photograph 2127

Target Note Number 49
Photograph 2128

Target Note Number 50
Photograph 2129

Target Note Number 51
Photograph 2132

Target Note Number 52
Photograph 2134

Target Note Number 53
Photograph 2135

Target Note Number 54
Photograph 2136

Target Note Number 55
Photograph 2137

Target Note Number 56
Photograph 2138

Target Note Number 58
Photograph 2139

Target Note Number 60
Photograph 2140

Target Note Number 61
Photograph 2142

Target Note Number 62
Photograph 2143

Target Note Number 63
Photograph 2144

Target Note Number 64
Photograph 2146

Target Note Number 65
Photograph 2150

Target Note Number 68
Photograph 2157

10.3. Appendix 3 Plates 1 - 21

Category 1 Fire Damage

Plate 1

Plate 2

Category 2 Fire Damage

Plate 3

Plate 4

Category 3 Fire Damage

Plate 5

Plate 6

Category 4 Fire Damage

Plate 7

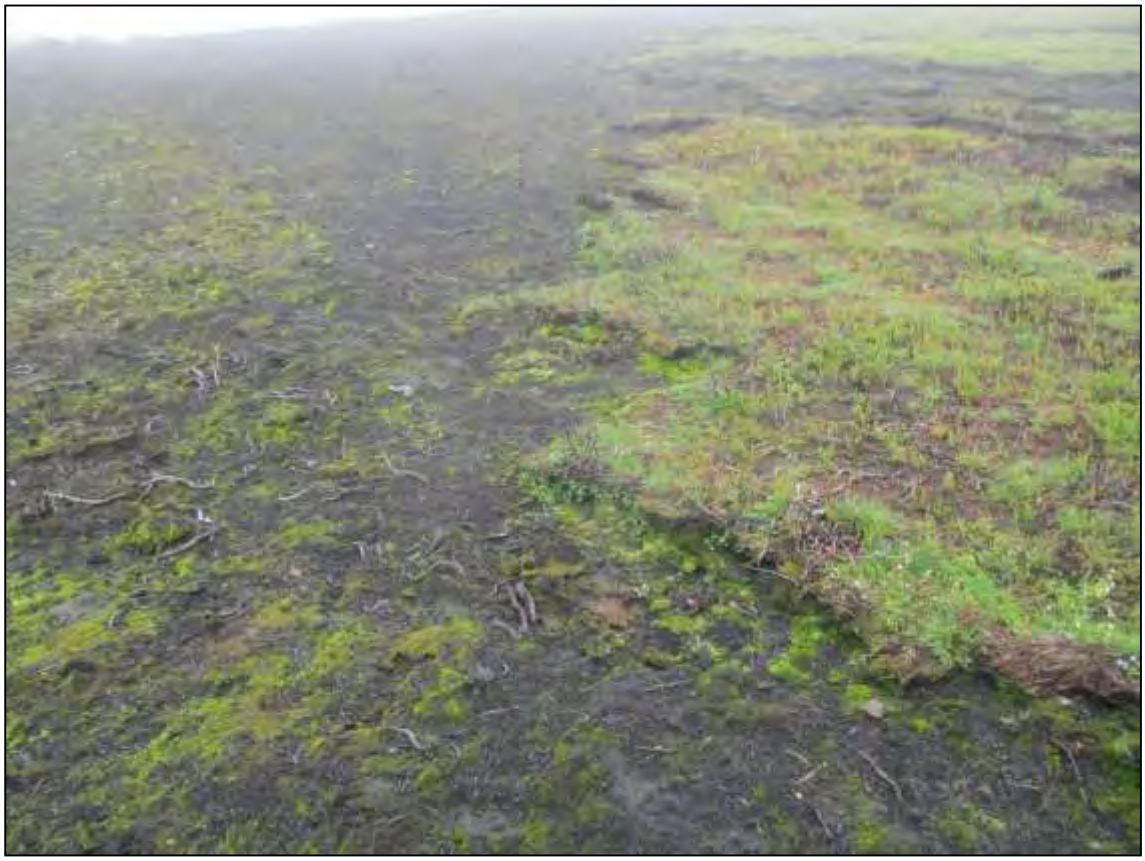


Plate 8 (right hand side only)

Category 5 Fire Damage

Plate 9 The whole hillside beyond the fenceline

Plate 10 Close-up of good heather regeneration after the fire

Areas of Deeper, Damaged Peat

Plate 11

Plate 12

Existing Vegetation Within the Fire Site

Plate 13 Flush

Plate 14 Dwarf Shrub Heath

Erosion

Plate 15 Loose heather stems are holding back soils which have washed off the bare ground upslope

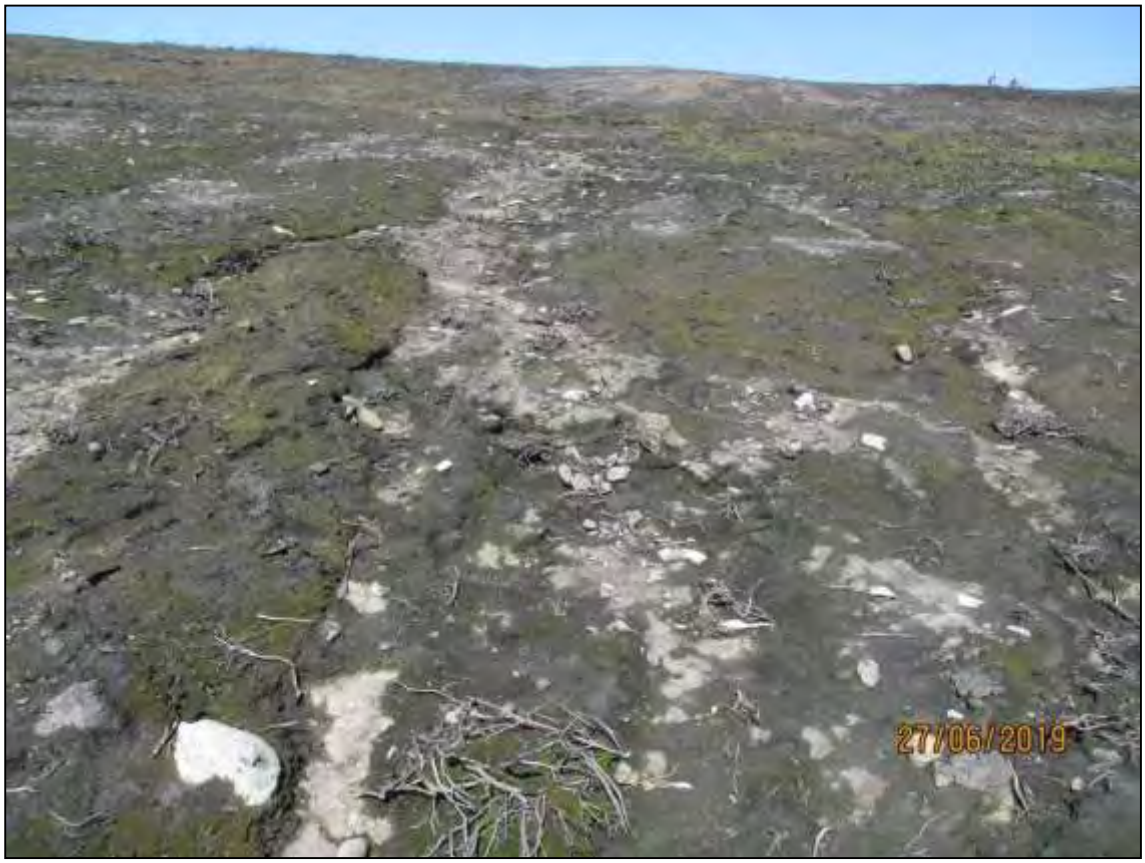


Plate 16 Water runnels/channels actively eroding

Plate 17 Natural blocking/damming of the water runnels/channels

Erosion

Plate 18 High density of heather seedlings

Plate 19 Abundant western gorse regeneration

Plate 20 Bracken regeneration with some intact root mat and bilberry associated

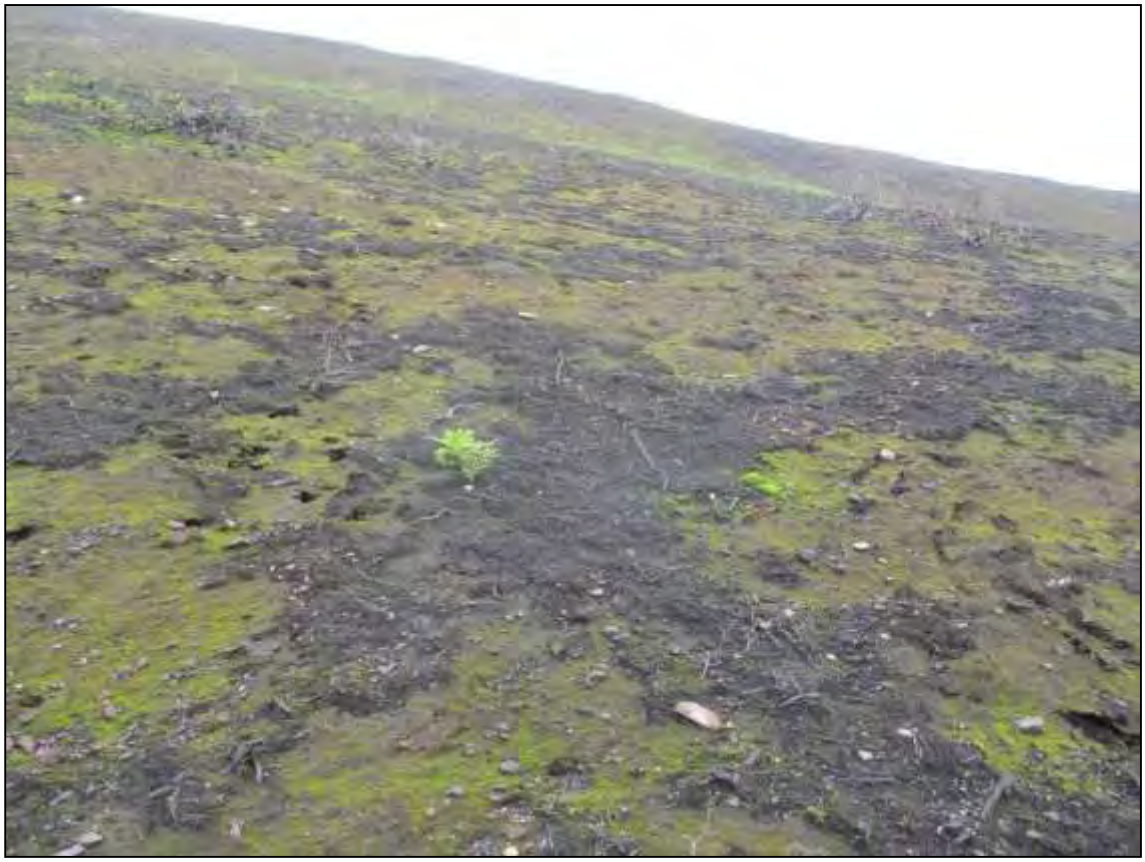


Plate 21 Isolated bracken fronds with no associated vegetation mat

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