Appendix 6-11

Biodiversity Enhancement Measures

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Carrownagowan Wind Farm

Biodiversity Enhancement Measures

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1 INTRODUCTION

Habitat enhancement measures are recommended to increase biodiversity at the Carrownagowan forestry site. The recommended enhancement measures are in line with the Clare County Biodiversity Action Plan 2017-2023, as informed by the seven strategic objectives and associated targets of the third National Biodiversity Action Plan 2017-2021 (DCHG 2017).

Habitat enhancement measures for the Carrownagowan forestry site have been developed in conjunction with the proposed wind farm EIAR, as there is an opportunity to increase biodiversity at this forested site. Higher ecological value habitats within the forestry site will be enhanced for biodiversity by implementing measures appropriate to the operational forestry site.

2 ENHANCEMENT MEASURES FOR RIVERS AND STREAMS

The physical enhancement recommendations based on a literature review and field study are outlined below. A map showing locations of recommended works is provided (See **Figure 1**). The full suite of recommendations is given in **Table 1**. Photographs of locations where enhancement measures are proposed can be found in **Appendix 1**.

Table 1. Location of proposed enhancement works on the Owenogarney River and Coumnagun Stream and environs.

Location	Irish Grid Ref		Recommended work
	x	y	
1	161319	177245	Bank protection and felling trees along embankment at RHS of channel
2	161323	177260	Notch stone weir and random boulders
3	161277	177250	Notch stone weirs on the Coumnagun and Owenogarney at their confluence
4	161233	177248	Installation of a stone weir, with pool head at existing riffle. Removal of Rhododendron
5	161191	177233	Installation of a stone weir, with pool head at existing riffle
6	161034	177221	Installation of stone weir to direct flow to right away from eroding left bank. Protect bank
7	161033	177305	Remove boulders to create pool and place boulders at upstream limit of pool to create plunge
8	161017	177334	Remove mature Sitka's from island as they risk eroding island if they fall and get uprooted
9	161003	177418	Natural plunge pool below a rapid: trimming of bank side trees/shrubs
10	160983	177457	Narrow the flow to pool by placing a boulder at both sides of the sill. Boulder bar across rhs of riffle at end of pool. This may result in the loss of the two vegetated clumps at downstream end of pool.
11	160961	177498	Create pool using stone weir between 2 relatively shallow rock boulders at riffles ca. 16m apart. Use stone in wall and hut nearby. Introduce random boulders and stone from wall to river where the bed comprises gravels and silt only
12	160935	177543	Bank protection and riparian maintenance along ca 50m of channel actively eroding. Fell Sitka trees and replant with willows on LHS. Introduce random boulders and stone from wall to river where the bed comprises gravels and silt only.
13	160935	177543	Create pools along eroding stretch with boulders/rocks from wall and beech logs using riffle at downstream end as pool tail. Cut back some hazel.

Location	Irish Grid Ref		Recommended work
	x	y	
14	160907	177590	Keep tree and place boulders upstream on LHS and to mid stream. Remove boulders from downstream to upstream. Grade RHS bank.
15	160948	177614	Installation of a stone weir, with pool head at existing riffle.
16	161050	177657	Installation of a stone weir, with pool head at existing riffle.
17	161166	177710	Installation of a stone weir by adding to the existing boulders at existing riffle.
18	161194	177757	Remove rhododendron and install bank protection upstream of confluence with minor stream
19	161157	177779	Installation of a stone weir and development of a plunge pool.
20	161128	177847	Installation of a stone weir, with pool head at existing riffle. Cut willow on RHS bank and bank protection
21	161111	177864	Build up a large secure stone weir to yield a high drop into plunge pool. Cut willow at riffle.
22	161091	177906	Pool suitable. Cut willows on RHS bank
23	161103	177948	Existing river bed ideal. Selective tree removal at both sides of channel
24	161022	178011	Remove fallen tree from river to restore flow to centre of pool and deepen same. Remove sycamore from RHS bank. Possible head increase with boulders / stone weir
25	190974	178103	Remove ash branch across pool and various other light branches
26	160908	178097	Remove lateral branches and some trees
27	160779	178079	Incomplete boulder bar across the river: fill gap at LHS with boulder(s) to develop a plunge pool. Eradicate rhododendron
28	160755	178067	Move large boulders ca. 5m downstream and create a stone weir
29	160757	178065	Cut large willow tree trunks and remove fallen branches
30	160661	178028	Move instream at boulder riffle ca. 2m downstream to increase head. Remove dead tree
31	160627	177997	Remove branches and trees on both sides with the exception of ash trees
32	160611	177959	Build on 2 existing boulders at riffle by using those in river just downstream and additional boulders. Remove branches
33	160508	177956	Possibility of deepening pool by removal of rock. Some minor branch clearance
34	160419	178013	Some minor branch clearance at RHS of channel
35	160276	177941	Some minor branch clearance
36	160223	177914	Move instream boulders downstream to main riffle. Clear lateral branches and dead pine on LHS bank. Remove whitethorn trees on LHS bank.
37	160157	177918	Create stone weir at narrowest part of stream ca. 4m upstream of large Sitka spruce tree
38	160060	177897	Move instream boulders downstream to main riffle to create a stone weir. Clear lateral branches and dead wood. Grade RHS bank and protect as it is undercutting, and protect with rock armour/logs, as available.
39	159963	177979	Move instream boulders to primary riffle to direct flow to centre. Clear lateral branch.
40	159891	177952	Straighten the existing boulder arrangement at riffle to direct flow to centre as undercutting LHS bank. Remove fallen tree
41	159840	177954	Introduce boulders from LHS bank
42	159774	177988	Straighten the existing boulder bar to direct flow to centre as undercutting at RHS bank. Remove fallen tree
43	159710	177967	Reintroduce rocks to river to create stone weir where there are 2 existing embedded rocks near lower end of riffle. This reach has been modified
44	159647	177944	Reintroduce rocks to river to create stone weir. Remove scrub at both sides. Bank protection on LHS bank

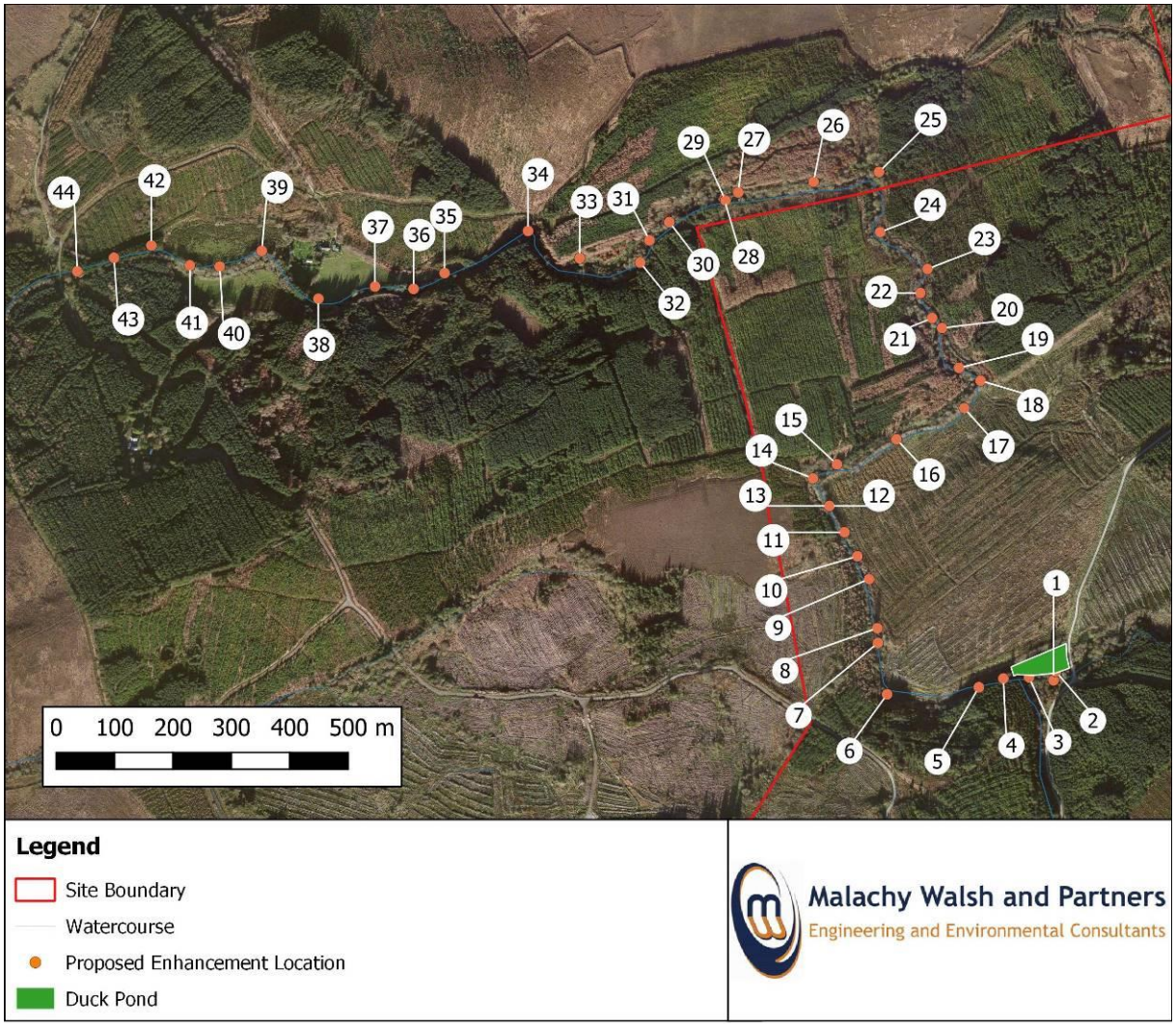

Figure 1 Location of proposed enhancement works on the Owenogarney River and Coumnagun Stream and environs.

2.1 POOL CREATION AND ENHANCEMENT

The subject watercourses are high gradient channels, with some reaches comprising cascades over bedrock and large boulders. Substrates on these reaches are currently quite stable due to their large size and position. They are classified as B-type channels, after Rosgen (1996).

Proposed pool creation and instream enhancement on these higher energy reaches is not recommended due to a number of factors including difficulty securing materials, instability that may be caused to existing substrates, potential washout of installed structures and difficult access in some areas.

Some reaches are relatively flat and less erosive. These reaches are deemed suitable for pool creation and enhancement works. Many of these medium gradient reaches have been modified in the past by apparent removal of larger boulders and rocks from the river to create river retaining, and flood prevention walls. Lands around these areas were farmed in earlier times but these lands have been long abandoned by local farmers. These lands are now used for commercial timber production. Riffle-pool sequences usually associated with such reaches are weakly defined and are considered to reduce the ecological carrying capacity of the stream. This feature has been exacerbated along some heavily shaded reaches, where the channel has become wider and shallower, with pool depths reduced, a process described in O'Grady (2006) as tunnelling. With reduced levels of sunlight reaching the stream bed, this

leads to diminished primary instream production. This in turn leads to a loss of macroinvertebrates in terms of biomass and diversity and usually means a change in trophic status with an associated decline in juvenile salmonid feeding.

There is scope for development of riffle-pool sequences along many parts of the river. Notch weirs are recommended at most of these locations. These would function in creating head upstream and depth in pools downstream. It may be possible to remove boulders from the riverbed downstream of these weirs and use these to build upon the substrates (boulders and bedrock) at the head (top) of these areas. See **Photographic Plate 6 Appendix 1** as an example of an area proposed for such enhancement. **Plate 9** shows a naturally developed pool with a steep fall over bedrock at the head (top) of the pool. The aim of stone weirs is to replicate such features and therefore increase physical diversity. Vortex stone weirs and single notch stone weirs are recommended where there is potential for erosion of banks downstream of the installed feature. Aprons may be required to prevent scouring in plunge pools. It is essential that any installed features are stable and would not be scoured out during floods.

2.2 BANK PROTECTION

Some banks along the enhancement reach were seen to be eroding or undercut. The worst case was at Location 1 (**Figure 1**), on the Coumnagun Stream. Bank revetment and stabilisation with stone or logs is recommended here. This could take the form of rip-rap with willow trees planted at the landward side. Directing flow away from eroding banks by appropriate positioning of features would help limit erosion in areas such as Location 6. Some banks should be regraded, and then protected as they are severely undercut e.g. Location 38. At Location 12 a combination of bank protection and riparian management is required to prevent further soil loss to the river. Use could be made of both logs and boulders for bank protection works.

2.3 NURSERY ENHANCEMENT

Physical diversity could be improved along many reaches where flow is laminar, primarily due to low gradient and substrate homogeneity, as **depicted in (Plate 13 Appendix 1).** Random boulders could be placed instream where a thalweg[1] is likely to develop post works. The placement of random boulders should not necessarily restricted to areas identified, especially in areas where there are ample boulders forming disused walls along the river, noting that some of these were likely sourced from the river.

3 ENHANCEMENT MEASURES FOR RIPARIAN HABITATS

As documented in O'Grady (2006), a balanced riparian zone can perform specific functions:

- Provide bank stability and prevent excessive erosion.
- Partially shade the channel. This provides a camouflage effect for fish and helps to reduce high summer temperatures.
- Provide decaying vegetation in the channel which is a food source for certain macroinvertebrates.

The physical enhancement recommendations based on a literature review and field study are outlined below.

3.1 EXISTING RIPARIAN HABITATS

In areas where existing land management has modified naturalness, the enhancement measures will be focussed on returning the existing riparian woodland to a more natural state, including:

- Reduction of any grazing pressure from deer, mainly through fencing.

[1] The line defining the lowest points along the length of a river bed, section of river conveying the most flow.

- Removal of any non-native species, such as rhododendron.
- Blocking of existing drains.

3.2 NEW RIPARIAN HABITATS

Where riparian habitats are not well established or absent from the Carrownagowan site, the following measures will be carried out:

- Setback areas will be established and allowed to re-vegetate naturally, with native seed bank
- Set-back areas slow to re-vegetate will be planted with native species, such as heathers (including ling heather), purple moor-grass, gorse, and willow species.

3.2.1 Establishment of set-back areas

A river set back zone will be created to provide a buffer between the watercourses and conifer plantation. Refer to **Figure 2,** below, for map of set-back areas. The water setback zone will be designed to create an intact and permanent buffer of natural vegetation alongside the aquatic zone[2].

Table 2. Aquatic setback distances

Slope leading to the aquatic zone	Minimum set back (meters)
Flat to Moderate (0-1 in 7/0-15%)	10m
Steep (1-in-7 to 1-in-3 / 15-30%)	15m
Very Steep (1-in-3 / >30%)	20m

- The water setback will be strategically widened at key locations onsite, where site hydrology and slope increase the vulnerability of receiving waters.
- Based on ground conditions, and topography, the width of the setback will be varied to avoid artificial lines and to create a naturally undulating forest edge.

3.2.1.1 Bank stabilisation and shading within set back areas

- Along stretches of sheltered, or high gradient areas planting of native species within the setback areas will be carried out, which will aim to enhance bank stabilisation, provide cooling, and shading, and nutrients into the aquatic ecosystem. This measure will create further habitat diversity within the setback. Enhancement measures will include:
  - Planting of single or small irregular groups (5-10 individual stems) of native trees, such as willow (*Salix cinerea*), gorse (*Ulex europaeus*), hazel (*Corylus avellana*), and occasional alder (*Alnus glutinosa*) at strategic areas along the riparian setback.
  - This planting will not be greater than 20% of the area of the water setback.
  - Trees will be pit-planted and protected from grazing, as necessary. This will involve individual tree shelters and small fenced-off exclosures, as deer use the site.
  - Where trees will be planted as groups, this will be done using trees with similar growth rates.
  - Trees within set back zone are to be pit-planted. No cultivation will be permitted within the water setback, but, if required, soil can be imported from outside the setback, and deposited to create individual planting positions.
  - No fertiliser application will be permitted. Post sapling trees will be planted that will not need to compete with ground flora.

[2] (* An aquatic zone is defined as "Any natural river, stream of lake (but not an artificial drain) illustrated on an Ordnance Survey 6 inch map." Other water features are also protected under the Environmental Requirements for Afforestation, i.e. relevant watercourses, hotspots and drinking water abstraction points (See Forest Service Circular 12/2017 for details.)

- For the management of vegetation within set back zones, herbicide use will be prohibited. Management measures can include trampling, mulching, and mats.

3.2.1.2 Silt control within set back areas

Within the set-back zones, sediment trapping will be facilitated by blocking drains, and by slowing the overland flow of water, allowing for infiltration and filtering through vegetation before entry into aquatic zone. This enhancement measure will significantly reduce the potential for any sediment release into the rivers and streams, increasing in-stream biodiversity, especially for fish.

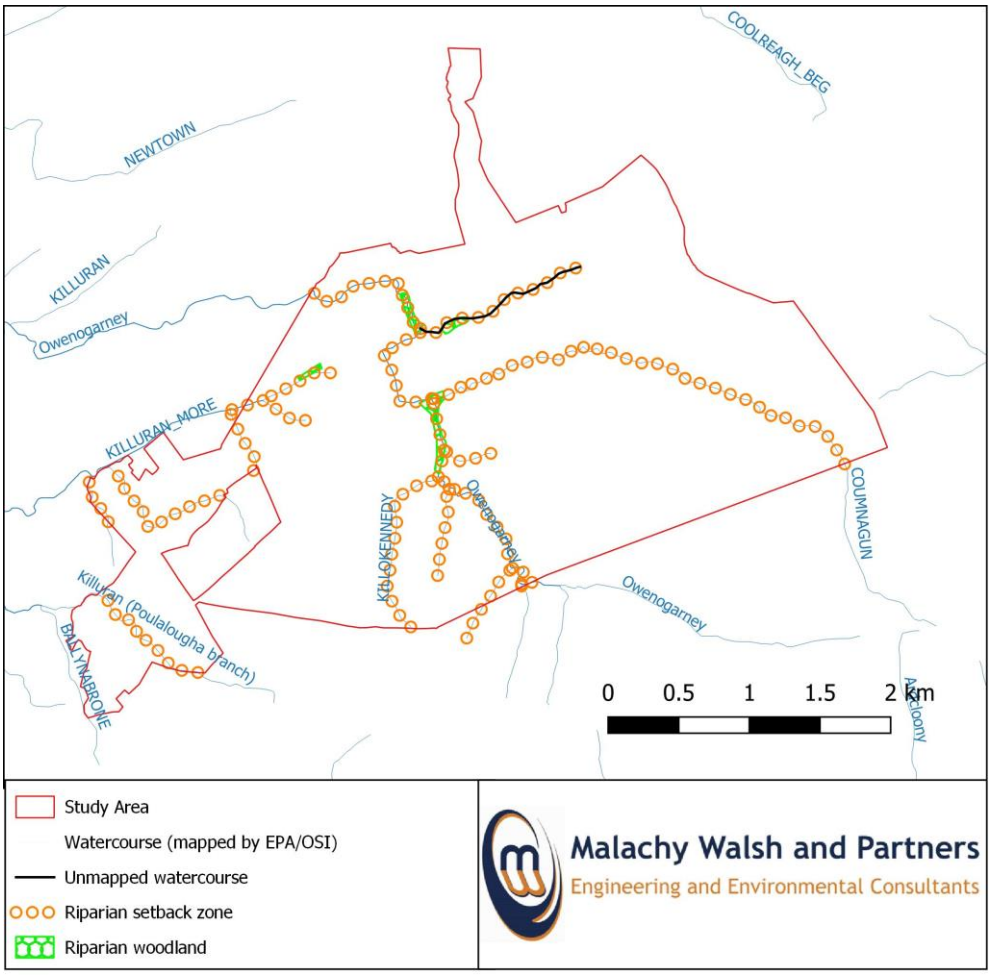

Figure 2. Riparian habitat set back areas

4 ENHANCEMENT MEASURES FOR PEATLAND HABITATS

Peat habitat restoration will be in line with guidance in 'Best practice in raised bog restoration in Ireland' (Mackin et al., 2017) and the National Peatlands Strategy (NPWS, 2017). The main objectives of the enhancement measures outlined below are to raise and maintain the water levels, and to exclude these peatland habitats from future forestry operations, and any future development. Enhancement measure are;

- Exclude sections of peatland habitats from planting and any future development.
- Block drains, to slow down water, rewetting peatlands. This will be carried out in drains that occur along the perimeter as well as any internal drainage;

- Drains can be blocked with mechanically installed peat dams where possible, and plastic dams where plant cannot access, such as wetter areas.

- Fencing will be installed to prevent trespassing and grazing animals.

4.1 UPLAND BLANKET BOG AND WET HEATH

This habitat type was likely one of the main habitat types that occurred on level or lower lying areas throughout the Carrownagowan site, prior to conifer plantation. Currently, this habitat type occurs mainly towards the centre of the site (see **Figure 3** below). Drainage ditches have been installed along the perimeter of these sections of bogland. Dominant species include ling heather (*Calluna vulgaris*), purple moor-grass (*Molinia caerulea*), some deergrass (*Trichophorum caespitosum*), cotton grass (*Eriophorum* spp.), and bilberry. Some cover of *Sphagnum* mosses occur towards the central areas, and less damaged areas, but cover of *Sphagnum* is significantly reduced towards the margins. Wet heath occurs in mosaic with the blanket bog habitat where it is present within the Carrownagowan site.

The following **Figure 3 and Table 3** show and describe the four locations of Upland blanket bog and Wet heath habitats where drain blocking will be undertaken.

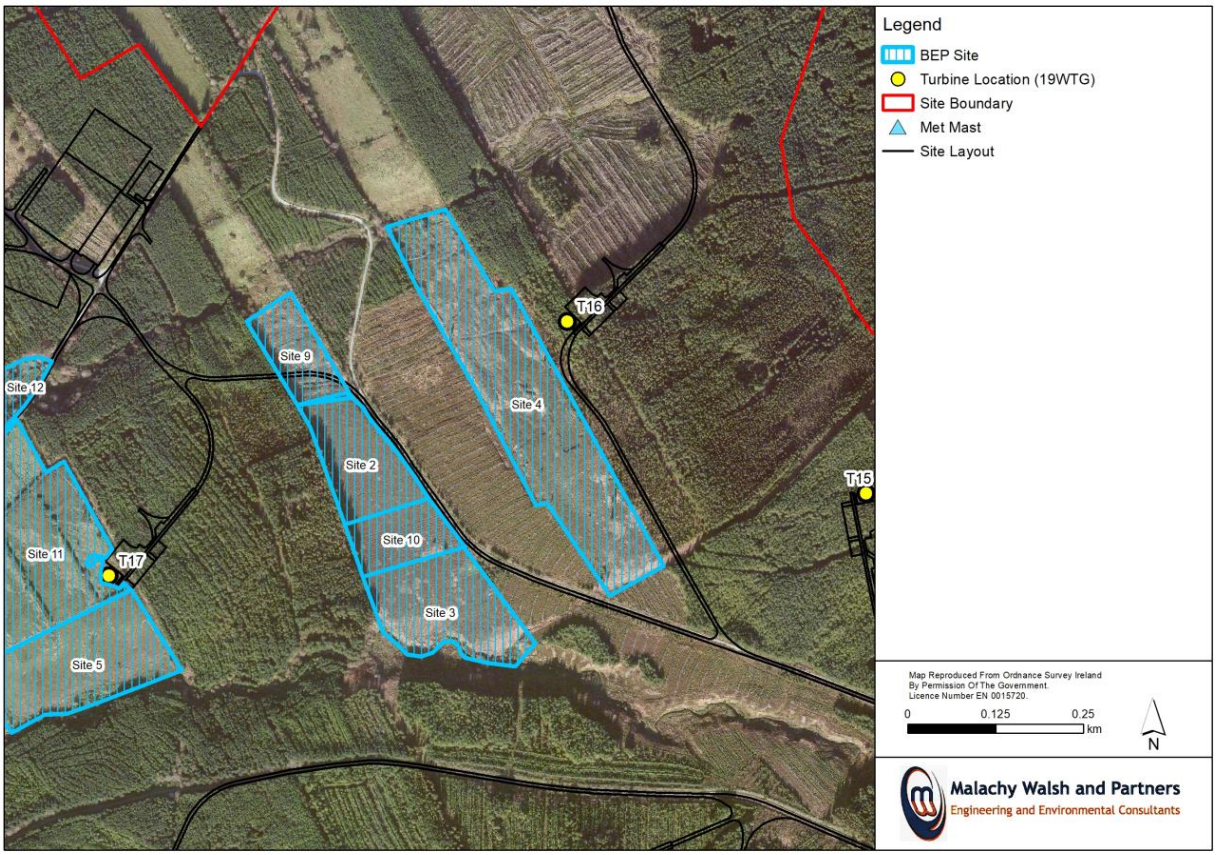

Figure 3. Upland Blanket Bog and Wet Heath Habitats (Sites 2, 3, 4, 5)

Table 3. Upland blanket bog and Wet heath habitats

Site	Area (Hectares)	Description
2	2.158	Degraded blanket bog. Drained by perimeter drainage ditches.
3	2.174	Degraded blanket bog. Wet heath towards southern steeper area. Drainage ditches along northern, western and eastern margins.

Site	Area (Hectares)	Description
4	5.312	Wet heath and blanket bog mosaic. Degraded by perimeter drainage ditches. Some drains and cut away towards north centre.
5	2.88	Wet heat, reverting from some improvement. Degraded by drainage ditches along northern, eastern and western margins.

4.2 RAISED BOG (PB1)

This habitat occurs towards the west central part of the site. This habitat would have developed from the accumulation of peat originating from a shallow lake, or basin, or the topographic depression in the area. Dominant species towards the margins, on dryer areas include: ling heather (*Calluna vulgaris*), cross leaved heath (*Erica tetralix*), and deergrass (*Trichophorum caespitosum*). Species in wetter areas included bog asphodel (*Narthecium ossifragum*), bogbean (*Menyanthes trifoliate*), and *Sphagnum* mosses. Drainage ditches have been installed towards the perimeter of this habitat. The conifer forestry has been planted up to the verge of this habitat, sometimes encroaching onto this habitat type. The area of conifer around this habitat has poor growth for a stretch of c.25m, most notably extending away from the northern part of this habitat type.

The following **Figure 4 and Table 4** show and describe the location of Raised bog habitat where drain blocking will be undertaken.

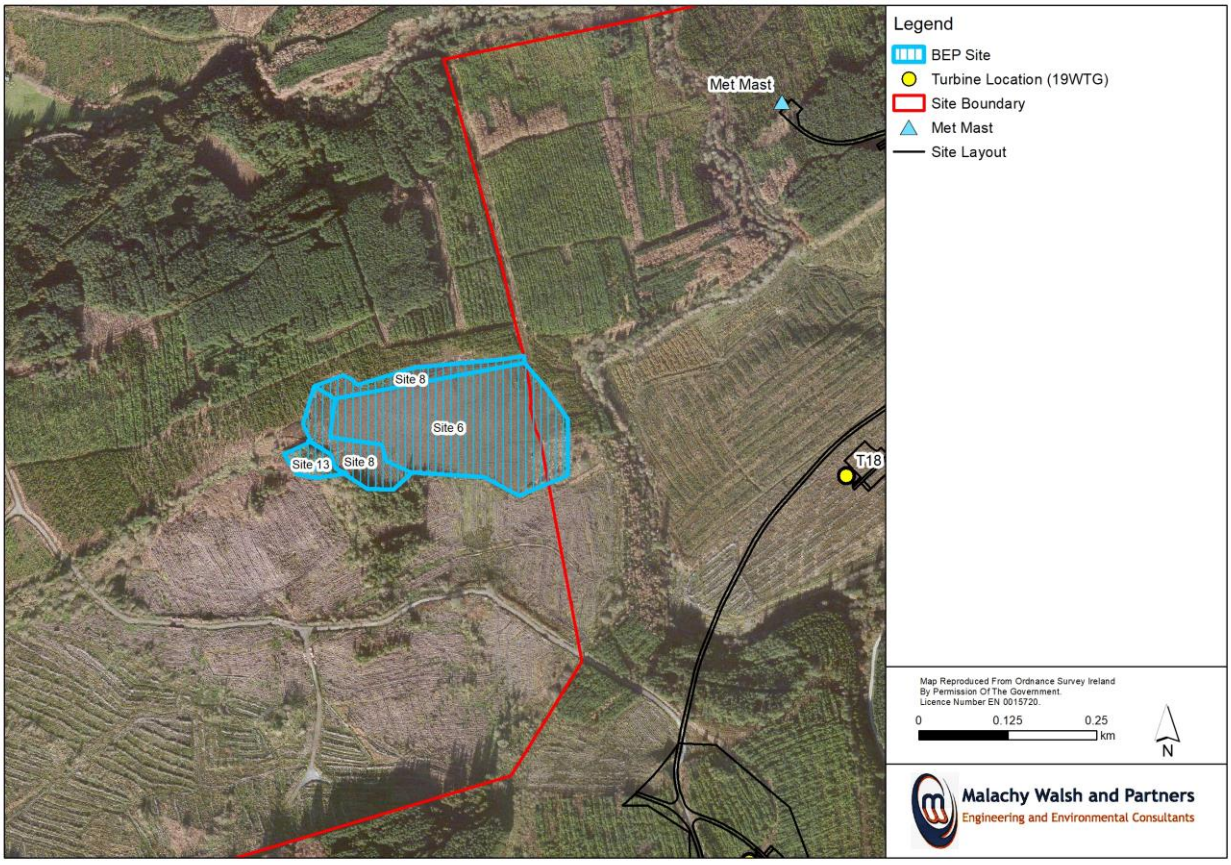

Figure 4. Location of raised bog (Site 6)

Table 4. Raised bog

Site	Area (Hectares)	Description
6	4.21	Degraded by drainage ditches towards margins of this habitat type.

4.3 CUTOVER BOG

Sections of this habitat type occur throughout the site, mainly occurring in areas of one time blanket bog that was drained for forestry, or cutaway as a result of peat harvesting. **Figures 5 to 7** below illustrate the locations of this habitat type throughout the site. This habitat occurs towards the south western end of the site (site 7). Conifer plantation extends way. At this location the cutover has re-vegetated to some extent, however the anthropogenic impact has compromised the original blanket bog. At this location (site 7), the ground area rises towards the north, with the wetter area mostly at the south of the habitat. As can be seen in **Figure 5** below, peat harvesting has been carried out throughout this area, with peat banks clearly visible. The site has largely re-vegetated with ling heather (*Calluna vulgaris*) and purple moor-grass (*Molinia caerulea*).

The following **Figure 5 to 7, and Table 5** show and describe the five locations of Cutover bog habitats where drain blocking will be undertaken.

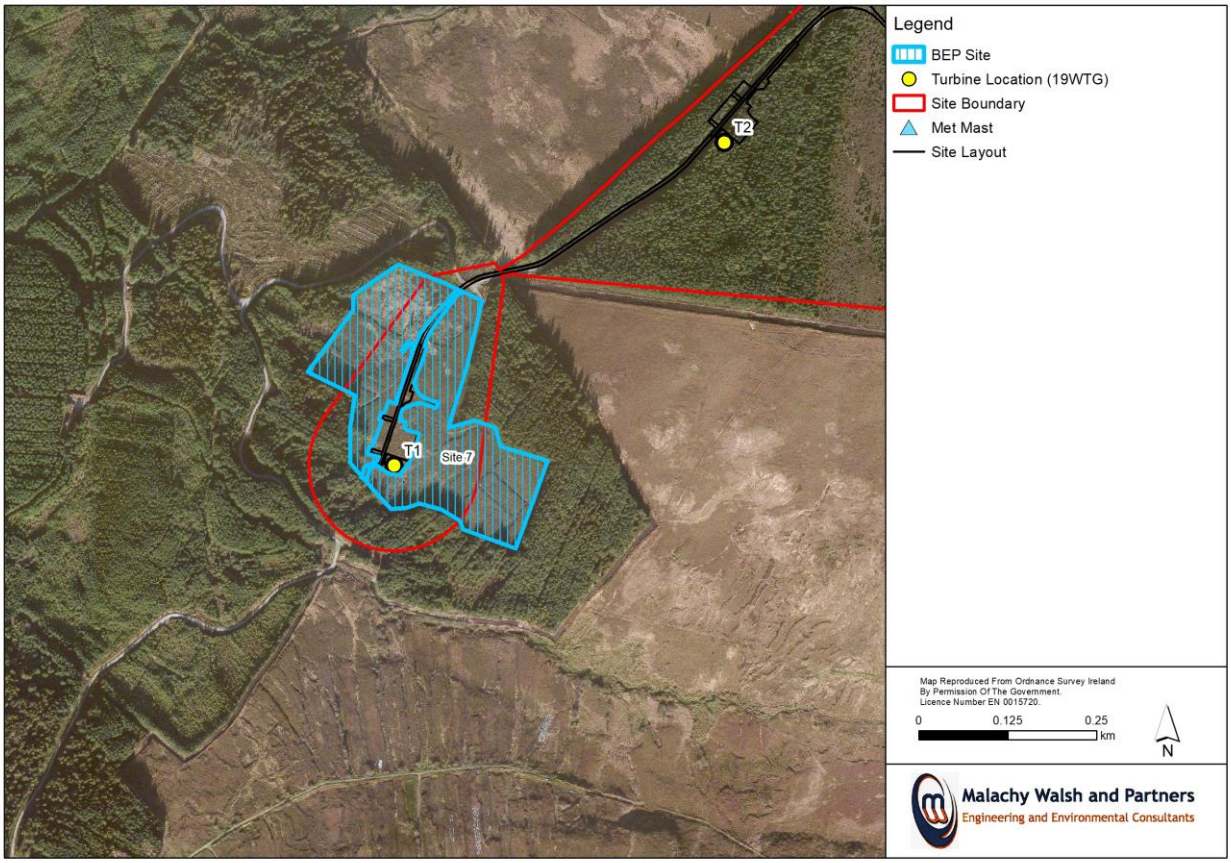

Figure 5: Location of cutover bog (Site 7)

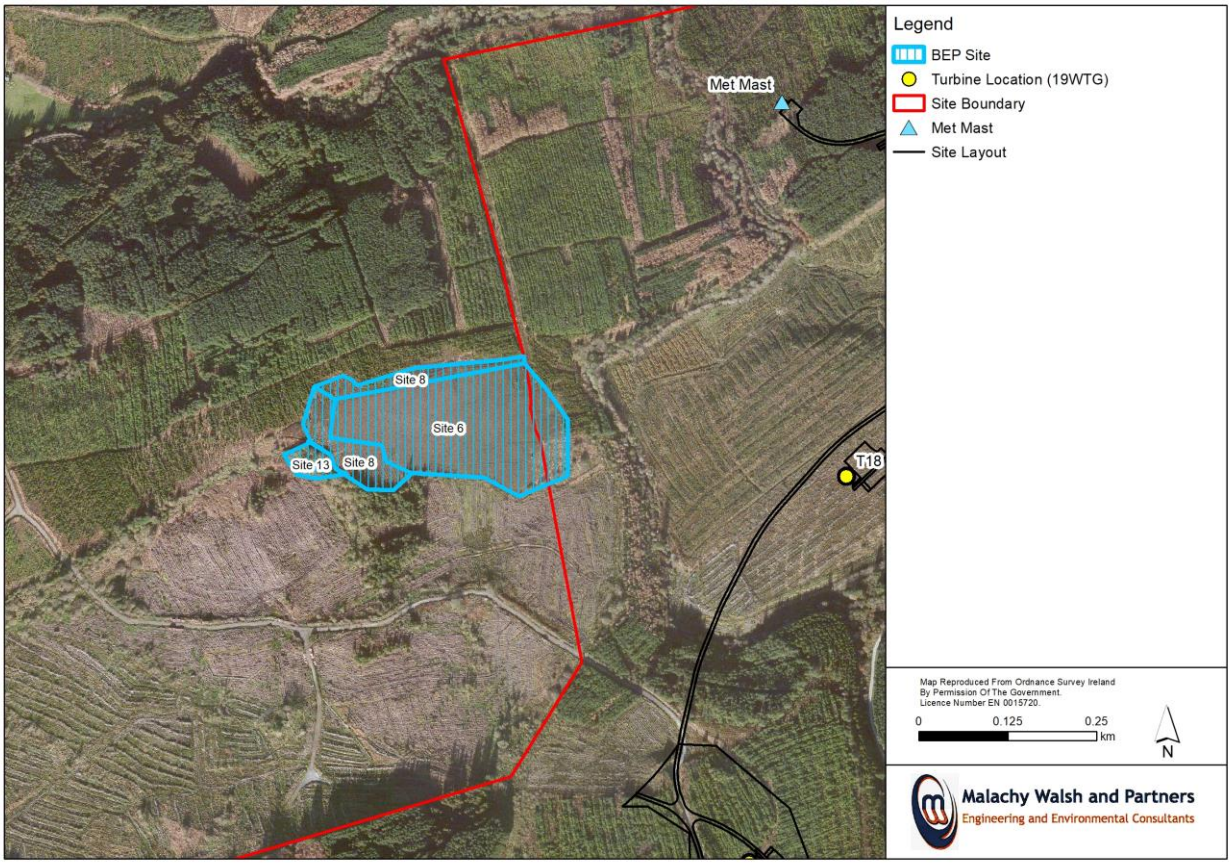

Figure 6: Location of cutover bog (Site 8)

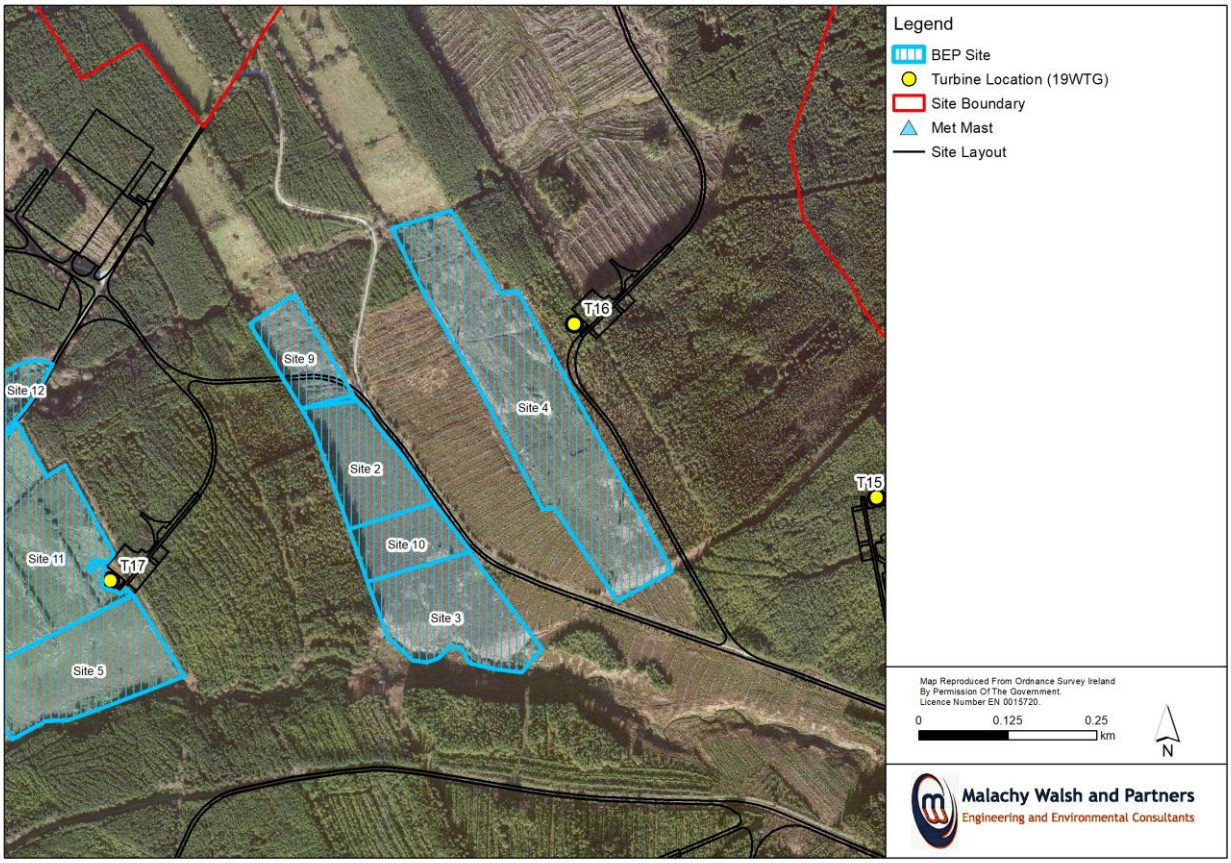

Figure 7: Location of cutover bog (Sites 9 and 10)

Table 5. Cutover bog

Site	Approx. Area (Hectares)	Description
7	5.718	Cutover bog. Bog banks throughout. Peat harvesting has not been carried out at this location for some time, and the area has largely re-vegetated with ling heather, and purple Moor-grass.
8	0.526	Cutover bog along the margins of raised bogland (Site 6).
9	1.377	Cutover bog. Bog banks and drainage ditches throughout. Margins are scrubby, with willow (salix spp.), bramble and gorse.
10	0.750	Network of drainage ditches, generally draining from east to west. This ground area separates site 2 and site 3 above.

5 ENHANCEMENT MEASURES FOR GRASSLAND HABITATS

The aims of the enhancement measures for wet grassland are to provide a dense cover of grass species, and other plants to support species such as invertebrates (such as butterfly species), small birds and mammals. The grassland habitats will provide food and shelter for a range of insects and other invertebrates, which in turn provide food for fauna including birds. The grassland habitat will benefit species such as meadow pipit, and skylark, which will in turn provide prey items for birds of prey such as hen harrier.

- Exclude sections of wet grassland from planting and any future development
- Install fencing to prevent trespassing and grazing animals.
- The parcels of land can be periodically grazed

5.1 WET GRASSLAND

This habitat occurs in a number of plots towards the centre of the site. This habitat type is reverting back from improvement for agriculture. Grass species included: Yorkshire fog (*Holcus lanatus*), purple moor grass (*Molinia caerulea*), and pockets of fox tail (*Alopecurus geniculatus*). Other species included rushes (*Juncus* spp.), meadow sweet (*Filipendula ulmaria*) along the periphery, marsh bed straw (*Galium palustre*), horse tail (*Equisetum arvense*), and yellow flag iris (*Iris pseudacorus*). Some infrequent devil's bit scabious (*Succisa pratensi*) was recorded in this habitat type. Hedgerows bound the margins of fields, emerging for the most part from vegetated mounds. Dominant hedgerow species included willow (*Salix* spp.), bramble (*Rubus fruticosus* agg.) and gorse (*Ulex europaeus*). Stands of Rhododendron (*Rhododendron ponticum*) are scattered throughout Site 11. At site 12 (see **Figure 8** below), sections of scrub have encroached from the boundary, and are maturing to semi natural woodland.

The following **Figure 8 and Table 6** show and describe the two locations of wet grassland habitat where grazing and natural re-generation of species will be encouraged.

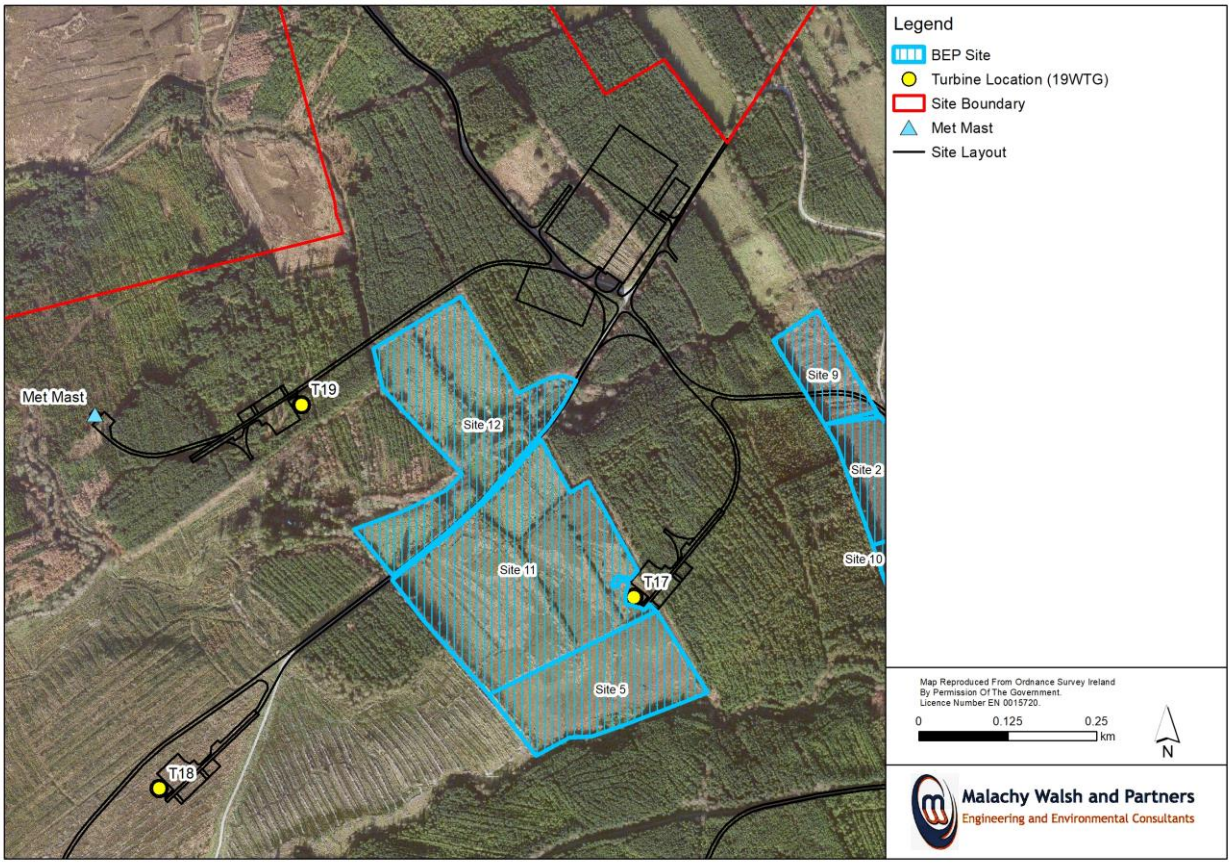

Figure 8. Wet grassland (Sites 11 and 12)

Table 6. Wet grassland

Site	Area (Hectares)	Description
11	5.544	Grassland occurring on southern side of existing coillte access track. Reverting back from improvement. Grazed by foraging deer.
12	3.526	Grassland on northern side of existing Coillte access track. Grazed by foraging deer.

6 ENHANCEMENT MEASURES FOR WOODLAND HABITATS

In order to prevent degradation of the semi-natural woodland habitat within the Carrownagowan forestry site the following will be undertaken;

- Exclude from planting and any future development
- Install fencing to prevent trespassing and grazing animals.

6.1 BOG WOODLAND

A small stand of bog woodland occurs to the western margin of the section of raised bogland. Some historic drainage occurs at this general location. Species include birch (*Betula* sp.), willows (*Salix* spp.), and ash (*Fraxinus excelsior*). Ground cover includes some scattered ling heather (*Calluna vulgaris*), bilberry (*Vaccinium myrtillus*) and purple moor grass (*Molinia caerulea*).

The following **Figure 9 and Table 7** show and describe the location of the bog woodland habitat where access and disturbance will be prevented.

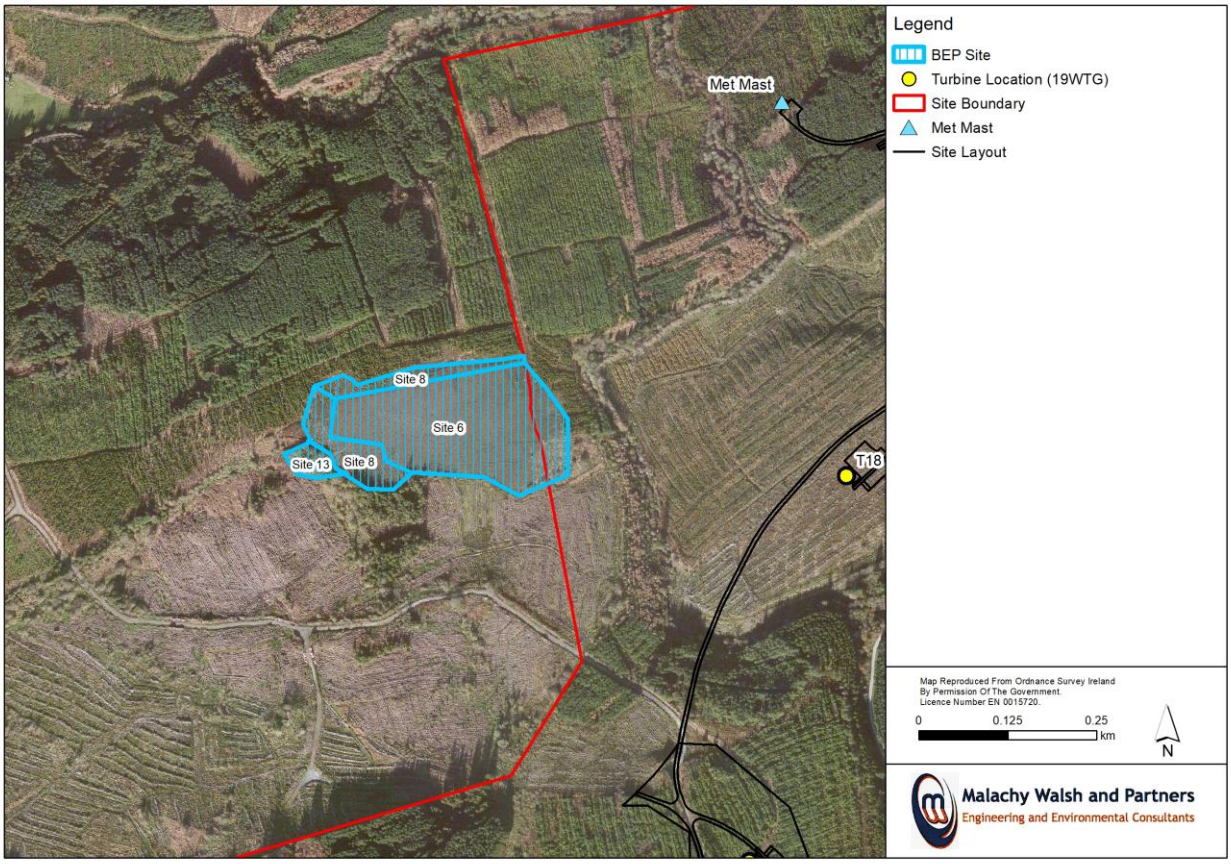

Figure 9. Bog woodland (site 13)

Table 7. Bog Woodland

Site	Area (Hectares)	Description
13	0.608	Small section of woodland on western margin of raised bog

7 ENHANCEMENT MEASURES FOR THE DISUSED BORROW PIT

In order to allow natural succession at this habitat and to encourage more diversity of species the following measures will be undertaken;

- Exclude from planting and any future development
- Fencing and signage will be installed to prevent accidental encroachment

7.1 DISUSED BORROW PIT

A pool has formed at a location of a disused quarry. During heavy rain, the pool is fed from natural run off from bogland to the south, with outflow to the forestry access track drainage. Species using the pool include beetles, dragon flies, and frogs, algae, and pondweeds. The once disturbed ground around it and old spoil heaps are vegetated with species such as yellow flag iris (*Iris pseudacorus*), dandelion (*Taraxacum* spp.), rushes (*Juncus* spp.), Yorkshire fog (*Holcus lanatus*), and willow herbs (*Epilobium* spp.).

The following **Figure 10** shows the location of the unused quarry habitat which will be closed off and allowed to function as a wildlife pond.

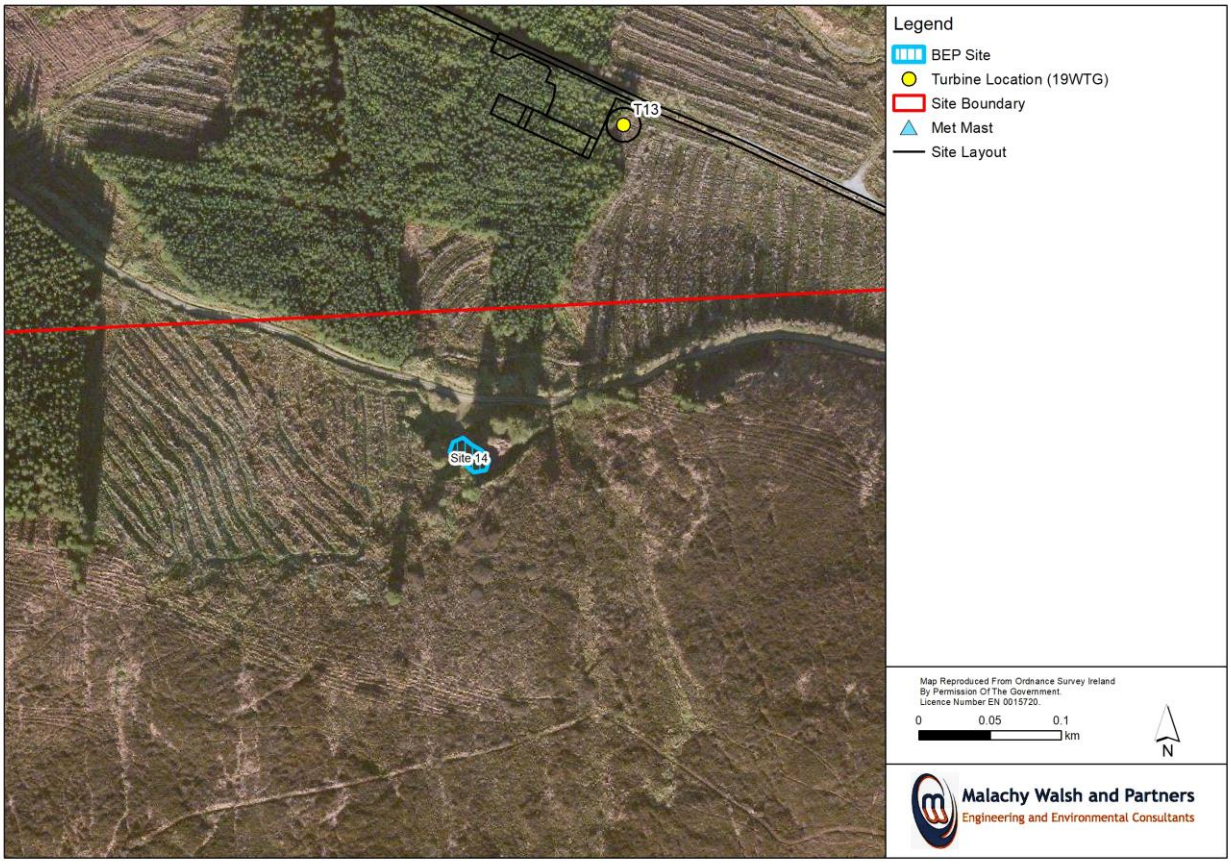

Figure 10. Wildlife pond (Site 14)

An overview map showing the location of the habitat enhancement sites in the context of the proposed wind farm is illustrated in the following figure.

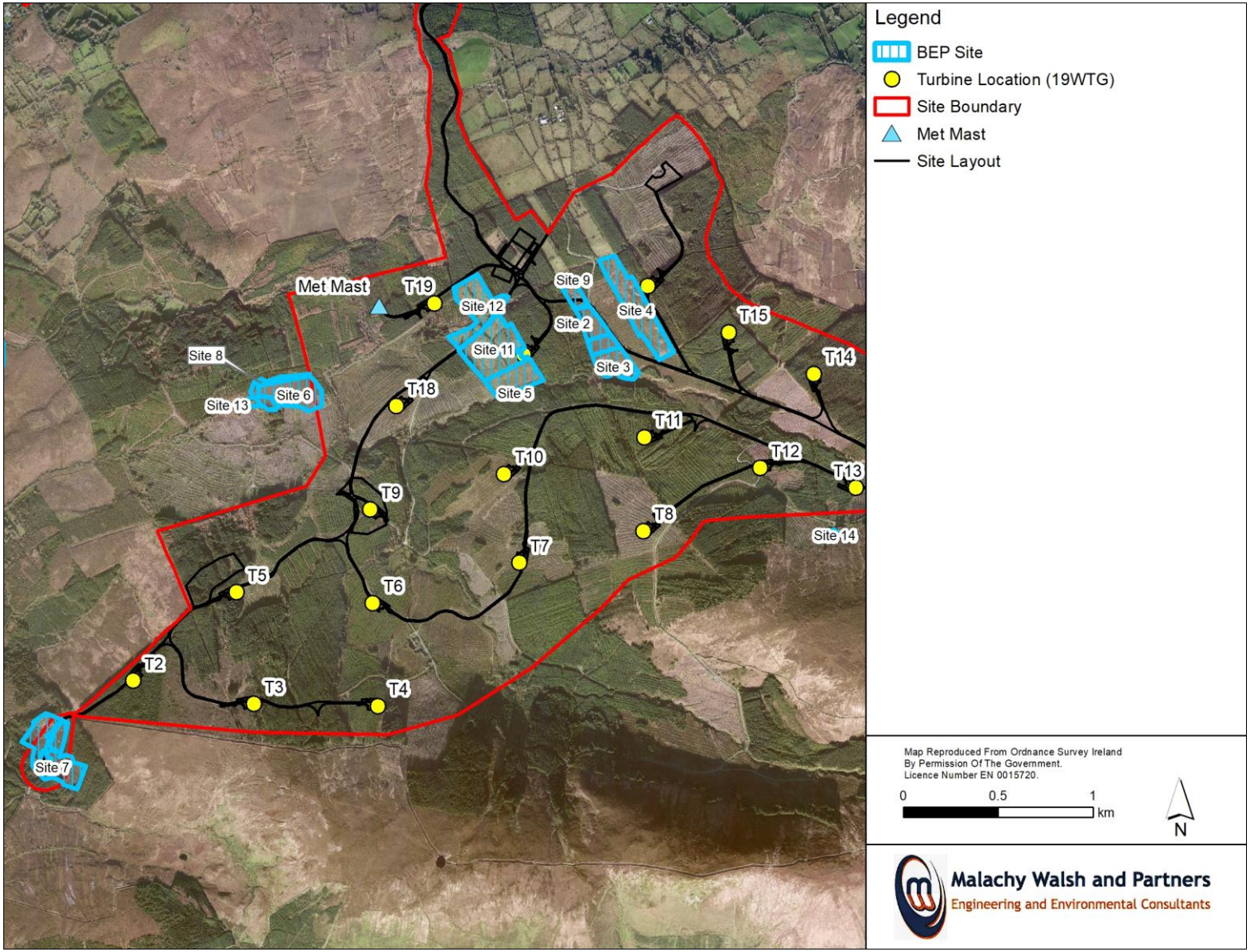

Figure 11: Overview map of habitat enhancement sites

8 REFERENCES

The "River Continuum Concept" by Vannote et al. (1980) describes the ecological function of rivers as linear ecosystems and the effects of interruptions of their connectivity. The current river enhancement proposals were considered with regard to the river continuum concept.
In formulating enhancement measures, the physical requirements of macroinvertebrates and salmonids were considered with reference to the following:

- Trout and Salmon. Ecology, Conservation and Rehabilitation (Crisp, 2000)
- Quantitative Ecology and the Brown Trout (Elliott, 1994)
- The habitat of the Brown Trout (*Salmo trutta L.)* in watercourses (Haury et al., 1999)
- Growth and Food of Brown Trout *Salmo trutta (L.)* in Irish waters (Kennedy and Fitzmaurice, 1971)
- Use of Habitat Assessment in Evaluating the Biological Integrity of Stream Communities (Barbour and Stribling, 1991).

The following guidance was consulted in relation to stream enhancement:

- Channels and Challenges - the enhancement of salmonid rivers (O'Grady, 2006).
- River Enhancement Programmes in Ireland (O'Grady et al., 2017)
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Appendix 1

Photographs of Proposed Enhancement Locations

Plate 1 Location 1 on the Coumnagun Stream: placement of random boulders instream and stone weir (left).

Plate 2 Mass bank wastage on the Coumnagun Stream (left): bank protection works. Source of logs for bank protection in adjacent woodland/duckpond (right).

Plate 3 Coumnagun - Owenogarney confluence: notch stone weir on both watercourses to create plunge pool.

Plate 4 Location 4 Installation of notch stone weir and removal of Rhodendron. Downstream view (left) and upstream view (right).

Plate 5 Riffle glide sequence at location 5: install notch weir (left). Underwater view, showing suitable habitat for juvenile trout (right).

Plate 6 notch stone weir to direct flow to right away from eroding left bank. View downstream (left) view upstream (right).

Plate 7 Remove boulders bedrock to deepen and place boulders at upstream limit of pool to create plunge. View downstream (left) view upstream (right).

Plate 8 Remove mature Sitka's from Island as they risk eroding island if they fall and get uprooted.

Plate 9 Natural plunge pool below a rapid: trimming of bankside trees/shrubs. Pools of this type are used by adult trout for resting and for spawning (pool tail).

Plate 10 Narrow the flow to pool by placing a boulder at both side of the sill. Boulder bar across RHSof riffle at end of pool. This may result in the loss of the two vegetated clumps at downstream end of pool.

Plate 11 Create pool using notch weir between 2 relatively shallow rock boulder at riffles ca. 16m apart.

Plate 12 Bare banks along this reach with associated erosion of soils beyond the grip of conifer roots (left). Tunnelling effect on this reach along with past removal of large substrate from the channel has reduced instream heterogeneity and ecological value (right).

Plate 13 Heterogenous reach with scope for enhancing physical diversity (left): Introduce random boulders and stone from wall to river where the bed comprises gravels and silt only. Cut back some Hazel.

Plate 14 Undercut banks here would benefit from hydrodynamic alteration: redirecting thalweg to the centre of channel (left). Bank reprofiling also recommended. Source of stone nearby (right).

Plate 15 Pool creation here by installation of a notch weir. Source of stone adjacent (right).

Plate 16 Installation of a notch weir, with pool head at existing riffle. View upstream (left) view downstream (right).

Plate 17 Installation of a notch weir by adding to the existing boulders at existing riffle. View upstream (left) view downstream (right).

Plate 18 Remove rhododendron and install bank protection upstream of confluence with minor stream.

Plate 19 Installation of a notch weir by adding to the existing boulders at existing riffle. View upstream (left), view downstream (right).

Plate 20 Installation of a notch weir by adding to the existing boulders at existing riffle. View upstream (left), view from instream (right).

Plate 21 Build up a large secure notch weir at primary riffle to yield a high drop into plunge pool. Cut willow at riffle. View upstream (left) view from instream (right).

Plate 22 Pool suitable. Cut willows on RHS bank

Plate 23 Existing river bed/morphology ideal. Selective tree removal at both sides of channel. View upstream (left) view from RHS (right).

Plate 24 Remove fallen tree from river to restore flow to centre of pool and deepen same (left). Remove sycamore from RHS bank (right). Possible head increase with boulders / notch weir.

Plate 25 Remove branches across pool. View upstream (left), view downstream (right).

Plate 26 Remove branches across pool. View upstream (left), view downstream (right).

Plate 27 Incomplete boulder bar across the river: fill gap at LHS with a boulder(s) to develop a plunge pool. View from RHS bank (left), view upstream (right).

Plate 28 Move large boulders ca. 5m downstream and create a notch weir. View upstream (left), view downstream (right).

Plate 29 Cut large willow tree trunks and remove fallen branches to expose pool.

Plate 30 Move instream at boulder riffle ca. 2m downstream to increase head. Remove dead tree.

Plate 31 Remove branches and trees on both sides of channel with the exception of ash trees.

Plate 32 Build on 2 existing boulders at riffle (view from RHS bank on left). Remove branches to open channel to additional light (view upstream, right).

Plate 33 Waterfall and pool (view downstream, left). View upstream (right). Possibility of deepening pool by removal of rock. Some minor branch clearance required.

Plate 34 Some minor branch clearance at RHS of channel.

Plate 35 Minor branch clearance

Plate 36 Move instream boulders downstream to main riffle. Clear lateral branches and dead pine on LHS bank. Remove whitethorn trees on LHS bank.

Plate 37 Create notch weir at narrowest part of stream ca. 4m upstream of large Sitka spruce tree (left). Upstream view (right).

Plate 38 Move instream boulders downstream to main riffle to create a notch weir (left, background). Grade RHS bank and protect as it is undercutting, and protect with rock armour/logs, as available.

Plate 39 Move instream boulders to primary riffle to direct flow to center. Clear lateral branch.

Plate 40 Straighten the existing boulder arrangement at riffle to direct flow to centre as undercuting LHS bank.

Plate 41 Introduce boulders from LHS bank to create notch weir.

Plate 42 Straighten the existing boulder bar to direct flow to centre as undercuting at RHS bank. Remove fallen tree.

Plate 43 Reintroduce rocks to river to create notch weir where there are 2 existing embedded rocks near lower end of riffle. This reach has been modified.

Plate 44 Reintroduce rocks to river to create notch weir. Remove scrub at both sides. Bank protection on LHS bank

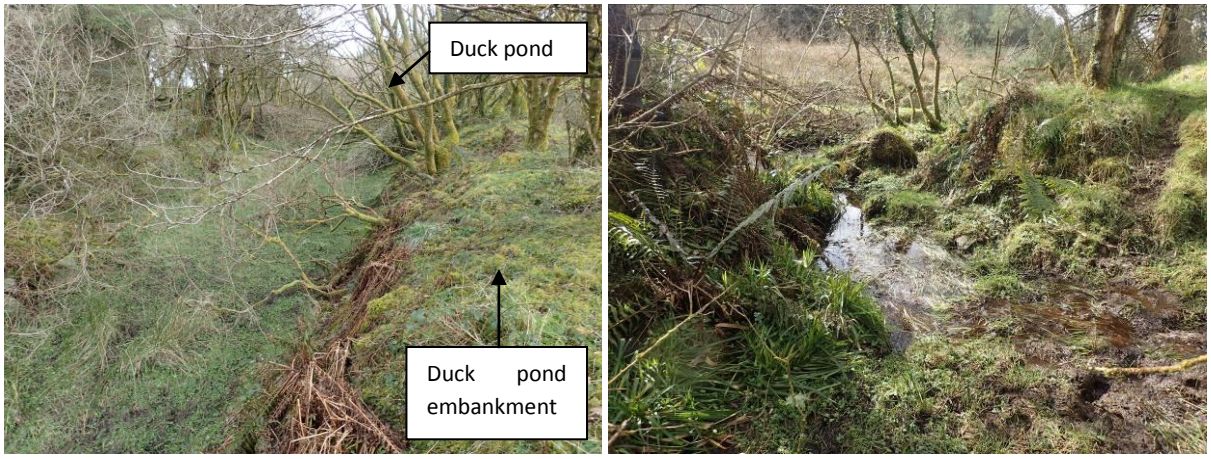

Plate 45 Embankment along the Coumnagun Stream formed to create the 'duck pond' (left). Cut in the embankment (right).