National Parks & Wildlife Service

Ferbane Bog SAC
(site code 000575)

Conservation objectives supporting document - raised bog habitats

Version 1

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Contents

1. Introduction

This document presents a summary of the background information that has informed the process of setting the Site-Specific Conservation Objective in relation to the priority Annex I habitat 'Active Raised Bog' (habitat code 7110) (hereafter referred to as Active Raised Bog (ARB)), for which Ferbane Bog Special Area of Conservation (SAC) has been designated.

Ferbane Bog SAC is also designated for two other related Annex I habitats, namely; 'degraded raised bogs still capable of natural regeneration' (habitat code 7120) (hereafter referred to as Degraded Raised Bog (DRB)) and 'depressions on peat substrates of the Rhynchosporion' (habitat code 7150). Based on the close ecological relationship between these three habitats types, it is not necessary to set specific Conservation Objectives for all three habitats individually. It is considered that should favourable conservation condition for ARB be achieved on the site, then, as a consequence, favourable conservation condition for the other two habitats would also be achieved.

1.1. Raised Bogs

Raised bogs are accumulations of deep peat (typically 3-12m) that originated in shallow lake basins or topographic depressions. The name is derived from the elevated surface, or dome, that develops as raised bogs grow upwards through the accumulation of peat; the domed effect is often exaggerated when the margins of a bog are damaged by turf cutting or drainage, and are drying out. Raised bogs are most abundant in the lowlands of central and mid-west Ireland.

Irish raised bogs are classified into two sub-types (Schouten, 1984): 1. Western or intermediate raised bogs, and 2. True midland or eastern raised bogs, based on phytosociological and morphological characteristics. In terms of overall morphology, the main difference between these two raised bog types is that while eastern raised bogs tended to stay more confined to the depressions in which they were formed, western raised bogs tended to grow out beyond their original basin, presumably a result of the higher rainfall levels (Cross 1990). In terms of vegetation differences the most obvious difference between the two bog types is the presence of a number of oceanic plant species on western raised bogs which are absent from the true midland raised bogs. The liverwort species *Pleurozia purpurea*[1] and the moss species *Campylopus atrovirens* grow on western raised bogs but not on eastern raised bogs; similarly, *Carex panicea* is generally more common on the high bog surfaces of western raised bogs (Schouten 1984). All of these plant species are widespread in the low-level Atlantic blanket bogs and their presence in western raised bogs is presumed to be due to the higher rainfall levels and greater rain-derived nutrient fluxes.

Exploitation has been extensive and none of the remaining Irish raised bogs are completely intact (Cross 1990). It is estimated that less than 10% of the original raised bog habitat in Ireland is in a near intact state (uncut), with less than 0.5% continuing to support ARB (DAHG 2014). Excavated face banks, whether active or inactive, are a common feature around the margins. Any areas where part of the bog has been removed are termed cutover bog, with the remaining area referred to as high bog or intact bog. In a natural state, raised bogs are circled by a wetland fringe, known as the lagg zone, which is usually characterised by fen communities. In Ireland, most laggs have been lost through drainage and land reclamation (Fossitt 2000).

[1] Note on species nomenclature: *In the case of plant species, only scientific names are used throughout the main text while common English names are included in tables. In the case of faunal species, common English names are used throughout the text together with scientific names.*

The surface of a relatively intact raised bog is typically wet, acid, deficient in plant nutrients, and supports specialised plant communities that are low in overall diversity and comprising species adapted to the biologically harsh conditions. The vegetation is open, treeless and bog mosses or *Sphagnum* species dominate the ground layer. Small-scale mosaics of plant communities are characteristic and reflect the complex microtopography of hummocks and hollows on the bog surface. Raised bogs are driest at the margins and wetness generally increases towards the centre of the peat mass where well-developed pool systems are most likely to occur.

Raised bogs may also contain soaks and flushes (wet 'active' or dry 'inactive') due to the increased supply of nutrients over time through concentrated surface flows, or where there are links with regional groundwater or the underlying mineral substratum. Slight mineral enrichment and / or constant through flow of water provide conditions suitable for a range of species that are not typically associated with other areas of raised bog.

When damaged by peat extraction or drainage, the water table in the peat drops and the bog surface becomes relatively dry; pools are rare or absent, cover of bog mosses is greatly reduced and *Calluna vulgaris* increases in abundance. The drop in water table causes the peat to compress under its own weight causing the bog surface to deform. Greater deformation occurs closest to areas where the water table has dropped. This increases the slope of the bog surface causing rain falling on the ground surface to flow off the bog more quickly. The effect is normally greatest around the margins and wetness may increase towards the centre of the bog. Trees such as *Betula pubescens* and *Pinus sylvestris* frequently invade the drier cut margins, but may also occur in flushed areas.

In Ireland, the Annex I habitat ARB is currently considered to be in unfavourable bad conservation status principally as a result of marginal turf cutting, more recent semi-industrial peat extraction, and associated drainage effects caused by these activities (NPWS 2008; 2013). The lowering of regional groundwater levels is also known to have had an effect on some sites. Fires associated with turf cutting, dumping, or agricultural activities may also adversely affect the condition of the habitat.

1.1.1. Raised Bogs Microtopography

Raised bogs are typically treeless and are characterised by a distinctive vegetation dominated by bog mosses (*Sphagnum*), sedges, and dwarf shrubs, all of which are adapted to waterlogged, acidic and exposed conditions. Bog mosses, which have unique properties, are the principal component of peat, and are largely responsible for the typical surface features of hummocks, hollows, lawns, and pools. The wettest bogs, which have extensive pool systems, have the greatest variety of plant and animal life and support a range of specialist species.

The following terms that describe microtopography are generally accepted in the study of mire ecology (Gore 1983). A schematic diagram showing the typical microtopographical divisions is presented in Figure 1.

Pools

Depressions in the bog surface where the water table remains above the surface level all year around or below surface level for only a very short period of time. They are characterised by the presence of aquatic plant species such as *Sphagnum cuspidatum*, *S. denticulatum*, and *Cladopodiella fluitans*. In more degraded scenarios or where high seasonal water fluctuation occurs, the pools contain open water and/or algae. Tear pools are found on bogs where internal tensions, due to mass movement of peat, has taken place

within the high bog and has caused the development of elongated pools. These are frequently found on western bogs and may be natural or anthropogenic in origin.

Hollows

These are shallow depressions (less than 5cm deep) on the bog surface where surface water collects, or where the water table reaches or lies just above ground level, depending on seasonal conditions. They are often filled with *Sphagnum* species such as *S. papillosum* and *S. cuspidatum*. They take many forms but are often eye shaped. Marginal hollows tend to be elongated as they are focused points for surface water run-off. They are often dominated by *Narthecium ossifragum*.

Lawns

These are shallow hollows or flat areas where one species dominates to form a lawn. This is frequently a *Sphagnum* species, such as *Sphagnum magellanicum,* or *S. papillosum* which can completely fill in a hollow to form a small lawn.

Flats

These are more or less flat areas which are intermediate between hollow and hummock communities. They tend to be drier than the above situations.

Hummocks

These are mounds on the bog surface which can range from a few centimetres to more than one metre in height. They are usually composed mainly of *Sphagnum* species, such as *Sphagnum magellanicum, S. capillifolium, S. austinii* and *S. fuscum* but other bryophyte species such as *Hypnum jutlandicum* and *Leucobryum glaucum* are also important, especially as the hummock grows taller and becomes drier. *Calluna vulgaris* is another important element, as it flourishes where the water table is not at surface level (Kelly & Schouten 2002).

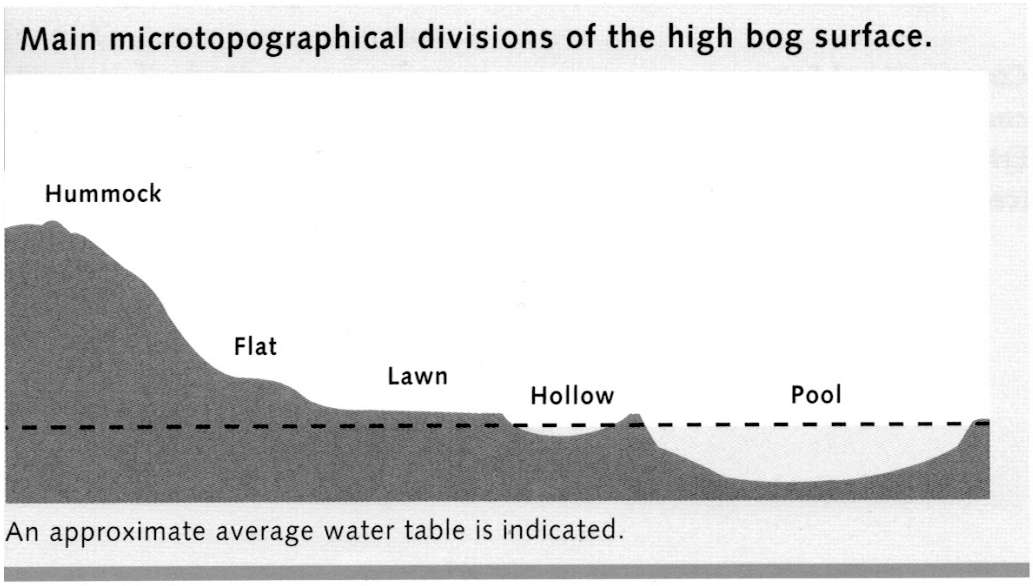

Figure 1 Raised bog microtopographical divisions on the high bog surface (reproduced from Kelly & Schouten 2002).

1.1.2. Typical Flora of Irish Raised Bogs

Raised bogs are characterised by a distinctive vegetation dominated by a variety of mosses (e.g. *Sphagnum spp., Hypnum spp., Racomitrium spp.*), sedges and grass-like species (e.g. *Eriophorum spp., Rhynchospora spp., Narthecium ossifragum, Molinia caerulea* and *Carex spp.*), and dwarf shrubs (e.g. *Calluna vulgaris, Erica tetralix, Vaccinium spp.* and *Empetrum nigrum*). In addition to these groups, a number of other species characterise raised bogs including carnivorous plants (e.g. *Drosera spp., Utricularia spp.*), lichens of both the bog surface and epiphytes on the stems of dwarf shrubs and the occasional trees on bogs (e.g. *Cladonia* spp*., Usnea* spp.). Herbaceous plants are not a significant element on raised bogs and include a few commonly occurring species such as *Menyanthes trifoliata, Pedicularis sylvatica*, and *Potentilla erecta* (Cross 1990).

Drier areas and hummocks usually support *Calluna vulgaris*, *Eriophorum vaginatum*, *Trichophorum germanicum*, *Erica tetralix*, lichens (*Cladonia* spp.), bog mosses (*Sphagnum capillifolium*, *S. austinii*, *S. fuscum*, *S. papillosum*), and other mosses (*Dicranum scoparium*, *Leucobryum glaucum*). Wet hollow areas and pools are characterised by *Eriophorum angustifolium*, *Rhynchospora alba*, *Narthecium ossifragum*, *Drosera* spp., *Menyanthes trifoliata*, bladderworts (*Utricularia* spp.), and bog mosses (*Sphagnum cuspidatum, S. denticulatum and S. magellanicum*).

A list of flora species that are regarded as being typical of ARB habitat in Ireland is presented in Table 1. A number of these typical species would have a restricted distribution and do not occur throughout the range of the habitat in Ireland (see above), therefore only a subset of these species would be expected to be present on any individual bog.

Table 1 Flora species typically associated with active raised bog in Ireland (after NPWS 2013). *Species list is based on vegetation communities defined by Kelly (1993) and Kelly & Schouten (2002).*

Common name	Scientific Name
Bog rosemary	Andromeda polifolia
Bog bead moss	*Aulacomnium palustre*
Bristly Swan-neck moss*	*Campylopus atrovirens**
Lichen	*Cladonia ciliata*
Lichen	*Cladonia portentosa*
Long leaved sundew	*Drosera anglica*
Intermediate leaved sundew*	*Drosera intermedia**
Round leaved sundew	*Drosera rotundifolia*
Common cotton grass	*Eriophorum angustifolium*
Hare's tail cotton grass	*Eriophorum vaginatum*
Large white moss	*Leucobryum glaucum*
Bogbean	*Menyanthes trifoliata*
Bog asphodel	*Narthecium ossifragum*
Purple spoonwort*	*Pleurozia purpurea**
Woolly fringe moss*	*Racomitrium lanuginosum**
White beak-sedge	*Rhynchospora alba*
Austin's bog moss	*Sphagnum austinii*
Red bog moss	*Sphagnum capillifolium*
Feathery bog moss	*Sphagnum cuspidatum*
Cow-horn bog moss*	*Sphagnum denticulatum**
Rusty bog moss	*Sphagnum fuscum*
Magellanic bog moss	*Sphagnum magellanicum*
Papillose bog moss	*Sphagnum papillosum*
Golden bog moss*	*Sphagnum pulchrum**
Lustrous bog moss	*Sphagnum subnitens*
Bladderwort	*Utricularia minor*
Cranberry	*Vaccinium oxycoccos*

*Notes: * Species more typical of western raised bog sites.*

1.1.3. Typical Fauna of Irish Raised Bogs

Raised bogs are extremely nutrient poor ecosystems. Acidic, waterlogged and exposed conditions make them an unattractive habitat for animal life. As a consequence they are relatively poor both in terms of species diversity and population densities. Many species are opportunists, vagrant or temporary rather than specialists, but nonetheless may have an important impact on the ecosystem through nutrient imports and exports or other interactions (Cross 1990). A list of fauna species that would be typically associated with raised bog habitat in Ireland is presented in Table 2. . The species listed are not confined to ARB and most, if not all, will use other areas of the bog and surrounding habitats.

Raised bog is unsuitable habitat for many vertebrates due to the lack of available foraging and suitable breeding places. The Irish hare is the only mammal commonly occurring. The common frog is the most common vertebrate predator.

Although 18 species of birds have been reported breeding on raised bogs (Wilson 1990) many of these species utilise the bog as a nesting habitat only. They are dependent on other neighbouring habitats such as open water bodies, callows and wet grassland particularly for feeding. Just a few species of bird, including meadow pipit (*Anthus pratensis*), skylark

(*Alauda arvensis*) and curlew (*Numenius arquata*) complete their full breeding cycle on the bog and the first two species are the commonest species occurring (Bracken *et al.* 2008). Red grouse (*Lagopus lagopus*) must also be included as a typical bog species, occurring year round as a resident. Red grouse and curlew have declined significantly on across raised bogs in recent times. BirdWatch Ireland have published an Action Plan for Raised Bog Birds in Ireland which lists 13 species of conservation concern that are associated with Raised Bogs (O'Connell 2011). A recent review of birds of conservation concern in Ireland has since added meadow pipit (*Anthus pratensis*) to the red (most endangered) list of Birds of Conservation Concern in Ireland (BoCCI) (Colhoun & Cummins 2013).

Our knowledge of the invertebrate assemblages associated with Irish raised bogs remains incomplete (particularly micro-invertebrate species) with few studies undertaken (Reynolds 1984a; Reynolds 1984b; Reynolds 1985; De Leeuw 1986; O Connor *et al*. 2001; Crushell *et al.* 2008; Hannigan & Kelly-Quinn 2011; Wisdom & Bolger 2011; Nolan 2013). Van Duinen (2013) highlights the importance of structural diversity at various spatial scales (e.g. micro-scale of hummock hollow topography to macro-scale which would include the landscape setting of the bog, see Schouten (2002)) as a prerequisite for hosting the full species diversity of raised bog landscapes.

A recent study of Lepidoptera associated with raised bogs identified two species that appear to be characteristic of higher quality raised bog habitat, namely bordered grey (*Selidosema brunnearia* (Villers, 1789)) and light knot grass (*Acronicta menyanthidis* (Esper, 1789)) (Ciara Flynn pers. comm.).

Recent research on spiders has revealed that a number of species are known to occur in Ireland only on raised bog habitats, all of which are considered local/uncommon or rare across Europe (Myles Nolan pers. comm.). Five of these species that can be considered useful indicators of active raised bog include: *Glyphesis cottonae* (La Touche 1945), *Walckenaeria alticeps* (Denis 1952), *Satilatlas britteni* (Jackson 1913), *Pirata piscatorius* (Clerck 1757), and *Minicia marginella* (Wider 1834) (Myles Nolan pers. comm.).

The information currently available on other invertebrate groups of peatland systems in Ireland is not sufficient to allow a determination of many species that are typically associated with or may be characteristic of higher quality ARB. A selection of invertebrate species and species groups that are known to be typically associated with raised bogs are included in Table 2.

Table 2 Fauna species typically associated with raised bog ecosystems in Ireland (after O'Connell 1987; Cross 1990; Renou-Wilson *et al.* 2011; Bracken & Smiddy 2012).

Common name	**Scientific name**
Mammal species	
Irish hare	*Lepus timidus hibernicus*
Otter	*Lutra lutra*
Pygmy shrew	*Sorex minutes*
Fox	*Vulpes vulpes*
Bird species	
Skylark	*Alauda arvensis*
Mallard	*Anas platyrhynchos*
Greenland white-fronted goose	*Anser albifrons flavirostris*
Meadow pipit	*Anthus pratensis*
Hen harrier	*Circus cyaneus*
Cuckoo	*Cuculus canorus*
Merlin	*Falco columbarius*
Kestrel	*Falco tinnunculus*
Snipe	*Gallinago gallinago*
Red grouse	*Lagopus lagopus*
Curlew	*Numenius arquata*
Golden plover	*Pluvialis apricaria*
Lapwing	*Vanellus vanellus*
Reptiles and amphibians	
Common lizard	*Lacerta vivipara*
Common frog	*Rana temporaria*
Typical invertebrates	
Black slug	*Arion ater*
Large heath butterfly	*Coenonympha tullia*
Marsh fritillary butterfly	*Euphydryas aurinia*
Bog-pool spider	*Dolomedes fimbriatus*
Water striders	*Gerris* and *Velia* species
Oak eggar moth	*Lasiocampa quercus*
Four-spotted chaser dragonfly	*Libellua quadrimaculata*
Fox moth	*Macrothylacia rubi*
Ant	*Myrmica ruginodis*
Emperor moth	*Saturnia pavonia*
Great green bog grasshopper	*Stethophyma grossa*
Other species groups that are well represented on raised bogs include:	Araneae (spiders and mites)
	Ceratopogonidae (biting-midges)
	Chironomids (non-biting midges)
	Coleoptera (beetles)
	Collembola (springtails)
	Diptera (true flies)
	Dytiscidae (water beetles)
	Hemiptera (true bugs)
	Hymenoptera (bees, wasps, ants and sawflies)
	Lepidoptera (butterflies and moths)
	Odonta (dragonflies and damselflies)
	Orthoptera (grasshoppers)
	Syrphidae (hoverflies)
	Tipulidae (craneflies)
	Tabanidae (horseflies)

1.2. Habitats Directive Raised Bog Habitats in Ireland

Four habitat types listed on Annex I of the EU Habitats Directive are typically associated with raised bogs in Ireland, two of which are priority habitats (*):

- 7110 Active raised bogs (ARB)*
- 7120 Degraded raised bogs still capable of natural regeneration (DRB)
- 7150 Depressions on peat substrates of the *Rhynchosporion*
- 91D0 Bog woodland*

The interpretation manual of EU habitats gives the following description for 'active raised bogs': "*Acid bogs, ombrotrophic, poor in mineral nutrients, sustained mainly by rainwater, with a water level generally higher than the surrounding water table, with perennial vegetation dominated by colourful Sphagna hummocks allowing for the growth of the bog (Erico-Sphagnetalia magellanici, Scheuchzerietalia palustris p., Utricularietalia intermedio-minoris p., Caricetalia fuscae p.). The term "active" must be taken to mean still supporting a significant area of vegetation that is normally peat forming, but bogs where active peat formation is temporarily at a standstill, such as after a fire or during a natural climatic cycle e.g., a period of drought, are also included*." (CEC 2007).

DRB should be, according to the interpretation manual capable of regeneration to 'Active Raised Bog' in 30 years if appropriate measures are put in place (i.e. no major impacting activities are present and any necessary restoration works are implemented).

In Ireland, the identification of ARB is made at ecotope level based on the vegetation classification developed by Kelly (1993) and Kelly & Schouten (2002).

Raised bog vegetation communities are grouped into a series of community complexes and these complexes are then amalgamated into a series of ecotopes characterised by different physical characteristics using the approach outlined by Kelly & Schouten (2002).

The main ecotopes that community complexes are grouped into include:

- Central ecotope
- Sub-central ecotope
- Active flushes and soaks
- Sub-marginal ecotope
- Marginal ecotope
- Inactive flushes
- Face-bank ecotope

Actively accumulating peat conditions occur within the sub-central and central ecotopes, which are the wettest on the bog and an indication of good quality ARB. Active flushes and soaks are also dominated by *Sphagnum* mosses and typically have wet conditions. These features are associated with ARB and contribute to the overall diversity of the habitat.

The adjacent surrounding marginal, sub-marginal, and face-bank bog areas typically have a supporting function for the central and sub-central communities but are not peat accumulating. These drier ecotopes may or may not correspond to the Annex I habitat DRB, as it depends on whether they are capable of regeneration to ARB. Other drier ecotopes recorded on the high bog that do not correspond to ARB include 'inactive flushes' which typically have a low *Sphagnum* cover.

The Annex I habitat Rhynchosporion depressions (7150) typically occurs along pool edges and on flats underlain by deep, wet and quaking peat. Typical plant species include *Rhynchospora alba*, *Drosera anglica*, *Narthecium ossifragum*, *Sphagnum cuspidatum*, *S. denticulatum*, *S. magellanicum*, *S. papillosum*, *Menyanthes trifoliata*, and *Eriophorum angustifolium*.

The priority Annex I habitat bog woodland is also actively peat-forming and overlaps with the ARB habitat. Such woodlands are usually dominated by *Betula pubescens* with a characteristic ground cover dominated by *Sphagnum* moss species, which often form deep carpets, and other mosses including species of *Polytrichum*. Woodland areas are occasionally found on raised bogs that have an absence of the characteristic moss layer and are not regarded as peat forming. Such areas do not correspond to the Annex I habitat.

1.2.1. Restoration of Active Raised Bog in Ireland

As already mentioned in the section 1.1, ARB is currently considered to be in unfavourable bad conservation status in Ireland. In addition, according to its definition, DRB should be capable of regeneration to ARB in a 30-year timescale. Thus, it follows that restoration measures are required in order to halt further losses and increase the area of ARB as well as to improve the condition of existing areas of the Annex I habitat.

Most of the restoration works undertaken so far in Ireland have concentrated on the high bog (e.g. Clara Bog, Mongan Bog, Sharavogue Bog and Raheenmore Bog) to prevent further losses as well as to restore areas to ARB. Nevertheless, some restoration works have also been undertaken on cutover areas such as at Ballykenny and Fisherstown Bogs and Killyconny Bog. Such work aims to do one or more of the following (depending on the bog in question): restore ARB on the high bog; reduce further ARB and DRB loss on the high bog; restore peat forming habitats (such as ARB, bog woodland, poor fen) on the cutover.

Works undertaken by the NPWS have indicated that there are significant differences, both ecological and economic, when comparing the effectiveness of works carried out on the cutover with those carried out on the high bog. Positive and significant results (i.e. expansion or development of ARB) can be achieved over a relatively short timeframe (10 years) on favourable areas of the high bog by blocking high bog drains. In contrast, a longer time period (30 years+) is required to achieve active peat formation on cutover areas, and even then the results are generally confined to smaller areas; i.e. flat areas (≤0.3% surface slope) or enclosed depressions that have sufficient water flow (minimum catchment 0.5ha) to maintain wet conditions throughout the year. A longer time period (minimum 50-100 years) is likely to be required for high quality ARB habitat (vegetation structure and species diversity) to develop on such cutover areas. In addition, costs of restoration measures on cutover areas are typically significantly higher than those on high bog areas.

1.3. Ferbane Bog SAC

The SAC includes the raised bog, known as Ferbane Bog and surrounding areas which include a narrow margin of mostly wooded cutover bog, and small areas of agricultural grassland.

The SAC has been selected for the following Annex I habitats:

- [7110] Active raised bogs*
- [7120] Degraded raised bogs still capable of natural regeneration
- [7150] Depressions on peat substrates of the *Rhynchosporion*

Ferbane Bog is a relatively large, domed, midland raised bog located about 10km east of Shannonbridge in Co. Offaly. It is underlain by low permeability Waulsortian limestone and clay-rich tills. The bog is classed as a basin type bog being surrounded by on all sides by low

relief bedrock ridges (Kelly *et al.* 1995).

Much of the surface of the bog corresponds with ARB and is wet and spongy and the cover of bog mosses and lichens is generally high and includes both central and sub-central ecotope. Non-active ecotopes including sub-marginal, marginal, and face bank ecotope occur towards the drier margins of the high bog dome.

The bog is surrounded by a narrow zone of cutover on all sites. Peat cutting has largely ceased at the site (Fernandez *et al.* 2014) and only a single plot to the north-west of the high bog was reported as being cut during a survey in 2003 (Fernandez *et al.* 2005).

There are numerous old drains present throughout the high bog, the majority of which remain functional and continue to have a significant impact on the high bog habitats (Fernandez *et al.* 2014).

The vegetation of the older cut away areas to the west, north and east of the bog is dominated by *Betula pubescens* and *Ulex europaeus*, with areas of *Pteridium aquilinum*, *Salix* sp., *Vaccinium myrtillus*, *Pinus sylvestris* and *Rhododendron ponticum*.

Drainage is extensive at this SAC and has caused significant drying out. Past peat-cutting and some active peat-cutting have also speeded up water loss. However, although the high bog has suffered some water loss, it is still in restorable condition.

1.3.1. Flora of Ferbane Bog

High quality ARB consists of central ecotope featuring interconnecting *Sphagnum* pools and lawns dominated by *Sphagnum cuspidatum* and *Sphagnum papillosum*. *Sphagnum* cover reaches 100% in certain locations. Sub-central ecotope is more abundant and is more variable in quality with the *Sphagnum* cover ranging from 34-75%. Pools are also less common with *Sphagnum* hummocks including *Sphagnum austinii*, but more frequently *Sphagnum capillifolium*, composing a large part of the *Sphagnum* layer.

Outside the ARB areas, the high bog is drier than ARB and supports a lower density of *Sphagnum* mosses. It has a less developed microtopography while permanent pools and *Sphagnum* lawns are generally absent. The high cover of *Cladonia portentosa* across much of the bog suggests that this bog hasn't been burnt for quite some time. Depressions on peat substrates of the Rhynchosporion are found in ARB, DRB and supporting habitat, but tend to be best developed and most stable in the wettest areas of ARB (Fernandez *et al*. 2014). The 2012 survey of Ferbane Bog yielded the following description of the vegetation.

Central ecotope occurs at two locations, both in depressions in the west north-west of the high bog. Two community complexes were recorded, both consisting of low hummocks, lawns, and pools. One complex is extremely wet with inter-connecting pools covering 51-75% that could almost be considered as one very large pool. The *Sphagnum* cover ranges from 76-90% composed mostly of *Sphagnum cuspidatum* and *Sphagnum papillosum* in pools and lawns, respectively. The microtopography is poorly developed with few (and very low) hummocks present dominated by *Sphagnum capillifolium* and *Sphagnum papillosum*. *Calluna vulgaris* and *Eriophorum vaginatum* are frequent on hummocks while *Rhynchospora alba* is frequent on lawns and *Eriophorum angustifolium* frequent in pools. *Sphagnum magellanicum* is also an integral part of the *Sphagnum* lawns. Additional species that are frequent at a low cover throughout include *Vaccinium oxycoccos, Drosera anglica, Cladonia portentosa*, and *Narthecium ossifragum.* The other community complex consist of inter-connecting pools with a cover of 26-33% and the *Sphagnum* cover ranges from 51-90%. *Calluna vulgaris* is frequent throughout and tussocks of *Eriophorum vaginatum* are abundant; *Sphagnum capillifolium* is dominant in the hummock layer with pools dominated by *Sphagnum cuspidatum* and *Sphagnum magellanicum* and lawns dominated by *Sphagnum*

papillosum and *Sphagnum magellanicum*. *Rhynchospora alba* is frequent on lawns and *Eriophorum angustifolium* and *Drosera anglica* frequent in pools (Fernandez *et al*. 2014).

Sub-central ecotope is found in a large area of the centre of the high bog, extending effectively in a north-west / south-east direction. Five community complex types are recorded. The most frequent complex is found to be variable in quality as it grades into and forms a mosaic with sub-marginal community complexes in places, but elsewhere grades into a better quality sub-central complex. Overall, *Calluna vulgaris* and *Eriophorum vaginatum* dominate the vegetation with the *Sphagnum* layer dominated by hummocks of *Sphagnum capillifolium* and *Sphagnum papillosum*. *Sphagnum magellanicum*, *Sphagnum tenellum*, *Sphagnum fuscum*, *Sphagnum austinii* and *Sphagnum cuspidatum* are also present as well as *Dicranum scoparium*, *Vaccinium oxycoccos*, *Hypnum jutlandicum* and *Leucobryum glaucum*. Active hummocks of *Sphagnum austinii* are common in the two best quality complexes and both also support species such as *Dicranum scoparium*, *Pleurozium schreberi* and *Aulacomnium palustre*. *Calluna vulgaris* is abundant throughout both complexes, tussocks of *Eriophorum vaginatum* are frequent and *Narthecium ossifragum* occasional. Another complex is found in the south-east of the central area and has a pool cover generally of 4-10% that is higher in places and a *Sphagnum* cover that ranges from 34-75%. *Sphagnum capillifolium* and *Sphagnum papillosum* are dominant in the hummock layer with pools dominated by *Sphagnum cuspidatum* and very occasional lawns of *Sphagnum magellanicum*.

The pools, however, are variable in quality with some supporting only a patchy cover of *Sphagnum cuspidatum* and a relatively high cover of *Rhynchospora alba*. The pools also support *Eriophorum angustifolium*, *Menyanthes trifoliata*, and *Drosera anglica*. Another complex type is found mainly in the mid-northern section of the central area of the high bog. Although no pools were present, there were 'pool-like' depressions dominated by *Rhynchospora alba*, which supported *Menyanthes trifoliata*, *Drosera anglica* and *Sphagnum cuspidatum*. Tall hummocks which support *Leucobryum glaucum*, *Polytrichum strictum*, *Empetrum nigrum*, and *Vaccinium oxycoccos* were also present. The *Sphagnum* cover ranges from 51-75% dominated by low hummocks and lawns of *Sphagnum magellanicum* as well as hummocks of *Sphagnum capillifolium* and *Sphagnum papillosum*. One complex present in a very small area in the north-east of the central area is dominated by *Eriophorum angustifolium*, *Rhynchospora alba*, *Sphagnum papillosum*, and *Sphagnum magellanicum*. The most inferior quality sub-central complex recorded at Ferbane Bog had some attributes of sub-marginal complexes and graded into and formed mosaics with them. The *Sphagnum* cover ranges from 26-50% and is composed mostly of hummocks of *Sphagnum papillosum*, *Sphagnum capillifolium*, and *Sphagnum tenellum*. *Calluna vulgaris*, *Carex panicea*, and *Narthecium ossifragum* dominate the vegetation (Fernandez *et al*. 2014).

The sub-marginal ecotope features the most developed microtopography within non-active ecotopes. However, pools are absent. Three community complexes (with additional variants) are recorded within the sub-marginal ecotope. The best quality sub-marginal complex had some sub-central characteristics. Only small amounts of this complex are present at Ferbane Bog.

In sub-marginal areas *Calluna vulgaris* and *Eriophorum vaginatum* dominate the vegetation and the *Sphagnum* cover, which ranged from 26-50%, is composed almost entirely of hummocks of *Sphagnum capillifolium* and *Sphagnum papillosum*. Some scattered *Pinus* trees are also present, most of which are <3.0m in height. Another complex covers large areas particularly in the north-west and the south-west of the high bog. The *Sphagnum* cover, which ranges from 11-33%, again is composed almost entirely of hummocks of *Sphagnum capillifolium* and *Sphagnum papillosum*. *Calluna vulgaris* dominated the vegetation along with *Carex panicea*, *Eriophorum vaginatum*, and *Narthecium ossifragum*. The most inferior

quality sub-marginal complex is present mostly in the south-east of the bog. The *Sphagnum* cover ranges mostly from 11-25%, composed almost entirely of hummocks of *S. capillifolium* and *S. papillosum*. *Calluna vulgaris* dominated the vegetation along with *Carex panicea* and *Narthecium ossifragum* (Fernandez *et al.* 2014).

Marginal ecotope is slightly drier than sub-marginal ecotope and is mainly present as a narrow band near the margin of the high bog although there is a wider band in the north-east. The microtopography consists of *Calluna vulgaris* hummocks, low *Sphagnum* hummocks, flats and very occasionally hollows and tear pools. The *Sphagnum* cover is even lower here than in the sub-marginal ecotope (<10%) and the vegetation is characterised by a higher cover of *Carex panicea, Narthecium ossifragum, Trichophorum germanicum*, and *Calluna vulgaris*. *Pinus* is also present in many of the complexes in marginal ecotope particularly in the east, south and north of the site with some trees of up to 8m in height recorded (Fernandez *et al.* 2014).

Face bank ecotope is characterised by firm ground, tall *Calluna vulgaris*, poor *Sphagnum* cover and a flat microtopography. This ecotope occurs as a very narrow band along most of the high bog margin with a wider area recorded in the west-north-west of the bog associated with a large drainage complex in the cutover (Fernandez *et al.* 2014).

Rhynchosporion vegetation is widespread on Ferbane. It is found in both ARB ,DRB and supporting habitat, but tends to be best developed and most stable in the wettest areas of ARB. In these areas, the Rhynchosporion vegetation occurs within *Sphagnum* hollows and along *Sphagnum* pool edges and on lawns. Typical plant species include *Rhynchospora alba*, *Sphagnum cuspidatum*, *S. magellanicum*, *S. papillosum*, *Drosera anglica*, and *Eriophorum angustifolium*.

1.3.2. run-offFauna of Ferbane Bog

The draft Conservation Plan for Ferbane Bog produced in 2005 noted the following species of fauna (NPWS 2005).

The common frog (*Rana temporaria*) is present on the bog as is Irish hare (*Lepus timidus hibernicus*) is common on the bog, with badger (*Meles meles*), fox (*Vulpes vulpes*), and possibly fallow deer (*Dama dama*) also present in the area.

Snipe (*Gallinago gallinago*), skylark (*Alauda arvensis*), curlew (*Numenius arquata*), and meadow pipit (*Anthus pratensis*) are reported to have bred within the site. Pheasant (*Phasianus colchicus*) and woodcock (*Scolopax rusticola*) occur around the margins of the site. Other birds that frequent the site include sparrowhawk (*Accipiter nisus*), kestrel (*Falco tinnunculus*) and merlin (*Falco columbarius*).

The spider fauna of Ferbane Bog has been subject to recent survey (Myles Nolan pers. comm.).

2. Conservation objectives

A site-specific conservation objective aims to define the favourable conservation condition of a habitat or species at site level. The maintenance of habitats and species within sites at favourable condition will contribute to the maintenance of favourable conservation status of those habitats and species at a national level.

Conservation objectives for habitats are defined using attributes and targets that are based on parameters as set out in the Habitats Directive for defining favourable status, namely area, range, and structure and functions. Attributes and targets may change or become more refined as further information becomes available.

National Conservation Objectives for raised bog SACs have recently been published in the Draft National Raised Bog SAC Management Plan (DAHG 2014). The various attributes and the justification of appropriate targets used to define favourable conservation condition for ARB relevant to Ferbane Bog are discussed in the following sections.

2.1. Area

NPWS has commissioned a number of raised bog surveys between 1993 and the present - Kelly *et al*. (1995); Derwin & MacGowan (2000); Fernandez *et al*. (2005); Fernandez *et al*. (2006); Fernandez *et al*. (2014). Mapping from these surveys has been used to derive the area of ARB for each bog as shown in Table 3. More recent surveys have been able to employ more precise and detailed mapping techniques and more standardised ecotope descriptions. NPWS undertook a review of data from earlier surveys in 2014 taking into account these improved techniques with the aim of providing more accurate figures for ARB. This in some cases has resulted in a change in ARB area for these earlier time periods (NPWS, unpublished data).

The national SAC target for the attribute 'habitat area' has been set at 2,590ha (DAHG 2014). This target is based on the estimated area of ARB (1,940ha) and DRB (650ha) present within the SAC network in 1994 (when the Habitats Directive came into effect).

The area of ARB at Ferbane Bog in 1994 is estimated to have been 41.7ha, while the area of DRB is estimated to have been 1.8ha at that time (see Table 3). Using the same approach that has been adopted in setting the national SAC target, the site-specific target for Ferbane Bog would equate to 43.5ha (sum of ARB and DRB in 1994). However, in setting the site-specific target the current hydro-ecological conditions on the bog (including cutover) have been considered in order to ensure that the target being set is based on a realistic appraisal of what is achievable as set out below.

The most recent monitoring surveys of the bog estimated the area of ARB to be 32.6ha (Fernandez *et al.* 2014). This represents a decline of 9.1ha (21.8%) during the period 1994-2012. An additional survey undertaken in 2005 shows that this decline in ARB has been continuous over the period 1994-2012 (see Table 3) (Fernandez *et al.* 2014).

The current extent of DRB as estimated using a recently developed hydrological modelling technique, based largely on Light Detection And Ranging (LiDAR)[2] data, is 10.9ha (see DAHG 2014 for further details of the technique). This represents the area of the high bog, which does not currently contain ARB but has topographical conditions deemed suitable to support ARB (see Map 1 which shows the total area of current and modelled potential ARB). Following an analysis of drainage at the site it is considered that this extent of ARB could be

[2] LiDAR is a remote sensing technology that measures vertical surface elevation by illuminating a target with a laser and analysing the reflected light. This provides much more detailed topographical maps than can be collected by traditional surveying techniques.

restored by blocking drains on the high bog.

Based on the current assessment of the bog above, it is therefore concluded that the maximum achievable target for ARB on the high bog is 43.5ha, which is 1.8ha more than the estimated area at time of designation. However, it is important to note that this assumes no further decline of ARB due to losses of high bog caused by turf cutting and drainage activities associated with same (Fernandez *et al*. 2014). Similarly, should the bog be significantly dependent on regional groundwater levels then any deepening of drains in the cutover could further impact the potential restoration of ARB on the high bog.

Table 3 Area of ARB and DRB recorded on the high bog at Ferbane Bog SAC in 1994, 2005, and 2012 (Source: Fernandez *et al.* 2014).

1994		**2005**		**2012**	
ARB (ha)	DRB (ha)	ARB (ha)	DRB (ha)	ARB (ha)	DRB (ha)
41.7	1.8	36.9	Unknown	32.6	10.9

A recent eco-hydrological assessment of the cutover surrounding the high bog undertaken as part of the restoration planning process suggests that, even by implementing appropriate management, no additional ARB could be restored in this area.

The long term achievable target for ARB on Ferbane Bog is therefore set at 43.5ha, which is the same as the estimated area in 1994 (i.e. 41.7ha + 1.8ha).

In conclusion, the site-specific target for the attribute habitat area is: **Restore area of active raised bog to 43.5ha, subject to natural processes.**

2.2. Range

At a national scale, range represents the geographic range that encompasses all significant ecological variations of the ARB habitat. The national SAC target for the attribute 'range' has been set as 'not less than current range subject to natural processes'.

However, range, in the form of habitat distribution, may also be important at the site level, particularly within larger SACs, including those containing a number of individual bogs (i.e. complexes). The attribute therefore under the parameter of range is 'Habitat distribution'. At the local level, it is important to conserve the variability and distribution of ARB across a raised bog SAC. This will help to ensure the diversity of the habitat is maintained while lessening the impact of localised damaging activities such as fire.

The conservation of ARB within Ferbane Bog as set out in Section 2 above will contribute to safeguarding the national range of the habitat.

The ARB habitat at Ferbane Bog includes central and sub-central ecotope. A map showing the most recent distribution of ecotopes throughout Ferbane Bog is presented in Map 2.

The site-specific target for the attribute habitat distribution is: **Restore the distribution and variability of active raised bog across the SAC.**

2.3. Structure and functions

Structure and functions relates to the physical components of a habitat ("structure") and the ecological processes that drive it ("functions"). For ARB these include attributes such as the hydrological regime, water quality, habitat quality, species occurrence, elements of local distinctiveness, marginal habitats, negative physical indicators, and negative species

occurrence. As several of these attributes are inter-connected, they are all included in order to better define habitat quality in a meaningful way. In some cases, attribute targets are not quantified; however, as more detailed information becomes available (for example through further research), more measurable site-specific targets may be developed. Structure and functions attributes are expanded on in the sections below.

2.3.1. High bog area

On individual raised bogs adequate high bog is required to support the development and maintenance of ARB. Raised bog habitat that is classified as neither ARB nor DRB is still important particularly as a supporting habitat for those listed in Annex I of the Habitats Directive. It is an essential part of the hydrological unit which supports ARB and DRB habitats. High bog is of value in its own right as a refuge for species characteristic of drier bog conditions as well as for providing a transitional zone between the Annex I habitats of the high bog and surrounding areas. Additional values for the maintenance of high bog include the preservation of its record of past environmental conditions and carbon storage. The area of high bog in the entire SAC network in 1994 was 10,740ha. The corresponding area in 2012 is 10,515ha – indicating that there has been a 225ha loss of high bog since 1994.

The national target for the attribute 'high bog' habitat is to ensure no decline in extent of high bog to support the development and maintenance of ARB.

The area of high bog within Ferbane Bog SAC in 1994 was mapped as 120haand the corresponding area in 2012 is also 120ha (based on interpretation of LiDAR and Aerial Photography flown in 2012), representing no loss of high bog habitat (DAHG 2014). The extent of high bog within Ferbane Bog in 2012 is illustrated on Map 1.

The site-specific target for the attribute high bog is: **No decline in extent of high bog necessary to support the development and maintenance of active raised bog.**

2.3.2. Hydrological regime: water levels

Hydrological processes are the key drivers of raised bog ecology. The different raised bog communities, assemblages and species are affected by various hydrological attributes. For ARB, mean water levels need to be near or above the surface of bog lawns for most of the year. Seasonal fluctuations should not exceed 20cm, and water level should be within 10cm of the surface, except for very short periods of time (Kelly & Schouten 2002). Gentle slopes that limit intermittent lateral losses of water (through surface runoff) and encourage sustained waterlogging are the most favourable to achieve these conditions. These conditions may be maintained on steeper slopes in areas of focused flow (flushes).

The traditional view of water flowing across the bog laterally has been recently refined to also consider that water flows vertically through peat into the underlying substrate. Water loss, by this route, depends on the permeability of the material through which the water must flow and the difference in head (water level elevation) in the bog and underlying mineral substrate; larger differences encountered in higher permeability materials will result in greater losses. Although the proportion of water lost in this manner may be small, the sustained loss during prolonged dry periods may be sufficient to impact bog ecotopes. Drains extending into the mineral substrate in marginal areas surrounding the bog can lead to an increased gradient between the head in the peat and the head in the underlying substrate resulting in increased vertical water losses from the bog.

The most recent description of drainage at Ferbane Bog is presented in Fernandez *et al.* (2014). Most of the high bog drains on Ferbane remain functional (7.8km) or reduced

functional (3.1km), meaning there is a total of 10.9km of drains impacting upon the high bog. This dense network of drainage has lowered water levels on the bog surface and continues to dry out the bog, with losses of active raised bog recorded during the latest monitoring survey. Although peat cutting appears to have largely ceased at Ferbane Bog, drains associated with peat cutting occur around most of the site. Several deep perimeter drains run parallel to the bog face bank, including a drain up to 2m deep along the western edge of the bog that is likely to have contributed to subsidence on the north-western side of the high bog. There are no forestry plantations on the bog; however, *Betula pubescens* scrub, and *Betula pubescens* and *Pinus sylvestris* woodland have developed on cut-away peat to the north and east of the site. *Pinus* has also encroached onto the high bog and is likely to be affecting water levels in some areas. To date no physical restoration measures have been carried out at Ferbane Bog.

Much of the knowledge regarding the hydrological requirements of raised bog communities in Ireland stems from the extensive ecological and hydrological work undertaken on Clara Bog since the early 1990s. The only available hydrological study for Ferbane Bog is the work carried out by Kelly *et al.* (1995) who noted that some perimeter drains surrounding the bog intercept the regional water-table. Electrical conductivity measurements of >600µs/cm were recorded in drains along the eastern, southern, and western margins, reflecting highly mineralised groundwater that would discharge from depth. This suggests that groundwater heads in the deposits underlying the peat have been impacted by drainage surrounding the bog. By analogy with findings at Clara Bog, the decline in groundwater head due to upwelling may have contributed to subsidence on the high bog. Geological mapping indicates that the bog is underlain by Waulsortian limestone bedrock (Lower Carboniferous), this is typically a poor aquifer but may be moderately productive in local zones. Subsoil mapping indicates a dominance of limestone till in the surrounding areas. Kelly *et al.* (1995) note the underlying substrate to be clay-rich tills, based on observations within cutover drains. The high proportion of fines in the till suggests that the substrate is likely to have a relatively low permeability. However, it was noted that sections in the drains along the northern cutover indicated that the outer natural boundary of the bog is underlain by stony tills, which would be anticipated to be much more permeable. The shape of the bog would suggest greater subsidence towards the northern side of the bog, which may be as a result of more permeable substrate in this area. Existing drainage in the cutover areas may continue to impact the high bog by reducing groundwater heads, while maintenance of drains presents a risk of further lowering groundwater heads in the underlying mineral substrate.

The site-specific target for the attribute hydrological regime – water levels is: **Restore appropriate water levels throughout the site.**

2.3.3. Hydrological regime: flow patterns

As outlined above, ARB depends on water levels being near or above the surface of bog lawns for most of the year. Long and gentle slopes are the most favourable to achieve these conditions. Changes to flow directions due to subsidence of bogs can radically change water regimes and cause drying out of high quality ARB areas and soak systems.

A map illustrating the slopes and drainage patterns on Ferbane Bog based on a digital elevation model generated from LiDAR imagery flown in 2012 is presented in Map 3.

This map illustrates that flow patterns on Ferbane Bog have been impacted as a result of subsidence and drainage on the high bog surface. Towards the north-west of the bog, flow is directed from the centre of the bog towards the west, before flowing north through the area of central ecotope and towards the northern margin of the bog, where maintenance of cutover drains has been recorded (Fernandez *et al*. 2014). Further south on the western side

of the bog there is an area of converging flow through an area of relatively steep slopes, suggesting subsidence may have occurred in this area. In general the highest point on the bog is located within the southern half of the bog. Further subsidence on Ferbane Bog would be anticipated to have further impacts on flow patterns which may impact on the areas of central ecotope that the bog currently supports.

The site-specific target for the attribute hydrological regime – flow patterns is: **Restore, where possible, appropriate high bog topography, flow directions and slopes.**

2.3.4. Transitional areas between high bog and surrounding mineral soils (includes cutover areas)

Transitional zones between raised bogs and surrounding mineral soils are typically cutover bog and drained lagg zones. The maintenance / restoration of these areas will help to maintain hydrological integrity of ARB and DRB and support a diversity of other wetland habitats (e.g. wet woodland, swamp, and fen), as well as species they sustain. In some cases, these areas may assist in reducing further losses of ARB / DRB on the high bog and in time could develop into active peat forming habitats (including ARB - see Section 2.1 above). These transitional zones, once restored, can provide ecosystem services through flood attenuation and water purification to downstream areas and potentially increase the carbon storage / sink function of the bog. The estimated extent of such transitional areas within the SAC network is 3,000ha (DAHG 2014). The national target for these transitional areas is to maintain / restore semi-natural habitats with high water levels around as much of the bog margins as necessary.

The transitional areas at Ferbane Bog include a range of different habitat types (wet grassland, improved grassland, cutover bog and mixed woodland). The total area of cutover bog within the SAC is estimated to be circa 21ha. The development of habitats within cutover areas depends on a number of factors including prevailing land-use, topography, upwelling regional groundwater, and drainage.

The vegetation of the older cutover areas to the west, north and east of the site is dominated by *Betula pubescens* and *Ulex europaeus*, with areas of *Pteridium aquilinum*, *Salix* sp., *Vaccinium myrtillus*, *Pinus sylvestris*, and *Rhododendron ponticum* also found. Areas of poor-fen vegetation and birch woodland occur on cutover surfaces along the margins of the bog (NPWS 2005).

The site-specific target for the attribute transitional areas is: **Restore adequate transitional areas to support / protect active raised bog and the services it provides.**

2.3.5. Vegetation quality: central ecotope, active flush, soaks

A diverse good quality microtopography on raised bogs consists of *Sphagnum* dominated pools, hollows, lawns and hummocks, which support the highest diversity of species including hummock indicators: *Sphagnum fuscum* and *S. austinii*; pool indicators: *S. cuspidatum*, *S. denticulatum*, and indicators of lack of burning events e.g. some lichen species (*Cladonia* spp.) (Cross 1990).

The national target for the attribute vegetation quality has been set as “to maintain / restore sufficient high quality bog vegetation (i.e. central ecotope and / or flushes / soaks). At least 50% of ARB habitat should be central ecotope and / or flush / soaks.”

A summary description of the vegetation of Ferbane Bog is presented in Section 1.3.1 above. The vegetation and habitats of the bog have been described in more detail by Kelly *et al.* (1995), and Fernandez *et al.* (2005 & 2014).

The ARB habitat at Ferbane Bog comprises central and sub-central ecotope. The central ecotope area at Ferbane features interconnecting *Sphagnum* pools and lawns dominated by *Sphagnum cuspidatum* and *Sphagnum papillosum*. *Sphagnum* cover reaches 100% in certain locations.

The extent of the different ecotopes that correspond with ARB based on the most recent surveys is presented in Table 4 and on Map 2. It can be seen that the proportion of ARB that comprises central ecotope is currently 6.1%. Comparing this to results of surveys undertaken in 2005 indicates that the proportion of each of the component ecotopes remained relatively static.

The target for this attribute is 21.8ha of central ecotope (50% of ARB target area (43.5ha)). This requires an increase from the current area of central ecotope from 2ha to 21.8ha.

Table 4 Extent of ecotopes classified as ARB in 2005 and 2012 (modified from Fernandez *et al.* (2014).

Ecotope	2005		2012	
	ha	% of total ARB	ha	% of total ARB
Sub-central ecotope	34.9	94.6	30.6	93.9
Central ecotope	2.0	5.4	2.0	6.1
Soaks / active flush	0	0	0	0
Total ARB	**36.9**		**32.6**	

The site-specific target for the attribute vegetation quality is: **Restore 21.8ha of central ecotope.**

2.3.6. Vegetation quality: microtopographical features

The characteristic microtopographical features of raised bogs are described in Section 1.1.1 above.

Pool and lawn microtopography is well developed in the central ecotope area of Ferbane Bog with less pools occurring in the sub-central ecotope areas.

The site-specific target for the attribute microtopographical features is: **Restore adequate cover of high quality microtopographical features.**

2.3.7. Vegetation quality: bog moss (Sphagnum) species

Bog mosses, which have unique properties, are the principal component of peat, and are largely responsible for the typical microtopographical features as described in Section 2.3.6 above.

The vegetation of a typical raised bog that is still hydrologically intact is characterised by the dominance of several species of Sphagna and dwarf ericoid shrubs. The most abundant species are *Sphagnum capillifolium, S. austinii* and *S. papillosum* which form hummocks or low ridges. *Sphagnum fuscum* may also form hummocks (Cross 1990). On the flats *Sphagnum magellanicum, S. papillosum, S. tenellum,* and *S. subnitens* are the key species. *Sphagnum pulchrum* may also be dominant in flats on western raised bogs. In permanently waterlogged hollows *Sphagnum cuspidatum* and *S. denticulatum* (western bogs) occur. *Sphagnum fallax* is common where there is slight flushing (Cross 1990). The most commonly occurring *Sphagnum* moss species that occur on raised bogs in Ireland are presented in Table 5 along with a summary of their ecology and typical contribution to peat formation.

Fernandez *et al*. (2014) report that high quality ARB on Ferbane Bog consists of central ecotope featuring interconnecting *Sphagnum* pools and lawns dominated by *Sphagnum cuspidatum* and *Sphagnum papillosum*. *Sphagnum* cover reaches 100% in certain locations. Sub-central ecotope is more abundant and is more variable in quality with the *Sphagnum* cover ranging from 34% to 75%. Pools are also less common with *Sphagnum* hummocks including *Sphagnum austinii*, but more frequently *Sphagnum capillifolium*, composing a large part of the *Sphagnum* layer.

Further information on the occurrence of *Sphagnum* species throughout Ferbane Bog is presented by Kelly *et al*. (1995) and Fernandez *et al*. (2005, 2014).

Table 5 *Sphagnum* species typically associated with raised bog ecosystems in Ireland. Ecology as described by Laine *et al.* (2009) with minor modifications.

Species	Ecology	Peat forming capacity
Sphagnum austinii	Hummock species	High
Sphagnum capillifolium	Forms small hummocks and carpets	Moderate
Sphagnum cuspidatum	Pool and hollow species	Low
Sphagnum denticulatum	Pool and hollow species	Low
Sphagnum fallax	Occurs in lawns and carpets, shade tolerant. Indicative of some nutrient enrichment (soaks and active flushes)	Low
Sphagnum fuscum	Forms dense low and wide, and occasionally high hummocks	High
Sphagnum magellanicum	Lawn species forming carpets and low hummocks	Moderate
Sphagnum palustre	Forms hummocks and dense carpets, often in shaded conditions. Indicative of nutrient enrichment (soaks and active flushes)	Low
Sphagnum papillosum	Lawn , hollow, and low hummock species	Moderate
Sphagnum pulchrum	Grows in lawns and hollows, more typical of western bogs	Moderate
Sphagnum squarrosum	Forms carpets and small mounds. Indicative of nutrient enrichment (soaks and active flushes)	Low
Sphagnum subnitens	Occurs as individual shoots or small cushions and lawns. Tolerant of minerotrophic conditions	Moderate
Sphagnum tenellum	Occurs as single shoots or weak cushions, typically in disturbed patches of the bog surface	Low

The site-specific target for the attribute bog moss (*Sphagnum*) species is: **Restore adequate cover of bog moss (*Sphagnum*) species to ensure peat-forming capacity.**

2.3.8. Typical ARB species: flora

Ferbane Bog supports the full complement of plant species typically associated with a true midland raised bog (see Section 1.3.1 above).

The key typical species that are indicative of high quality raised bog include *Sphagnum fuscum* and *Sphagnum austinii* which are associated with hummocks and *Sphagnum cuspidatum* and *Sphagnum denticulatum* which are associated with pools and hollows. All of these species, with the exception of *Sphagnum denticulatum* are reported from Ferbane Bog (Fernandez *et al*. 2014).

The site-specific target for the attribute typical bog flora is: **Restore, where appropriate, typical active raised bog flora.**

2.3.9. Typical ARB species: fauna

As mentioned in section 1.1.3, a list of typical fauna specific to ARB has not been developed and the table contains species that use the wider raised bog habitat. This may be refined as more information becomes available.

Site specific information on the faunal assemblages associated with Ferbane Bog is limited. It is likely that most species groups referred to in section 1.1.3 occur on the bog.

The site-specific target for the attribute typical bog fauna is: **Restore, where appropriate, typical raised bog fauna.**

2.3.10. Elements of local distinctiveness

A range of features may be associated with raised bogs which add to the scientific, historical, or conservation value of a bog. These can include geological, topographical, archaeological and hydrological features (e.g. soaks, lakes, flushes) and noteworthy species of flora and fauna (Cross 1990). Notable species of flora and fauna include those listed in the Habitats and Birds Directives, Red-listed species and other rare or localised species. For this attribute, features that are particularly associated with ARB are relevant.

2.3.10.1. Site features

Ferbane Bog is a good example of a typical midland raised bog of the basin type.

2.3.10.2. Rare flora

There are no records of rare flora from the site.

2.3.10.3. Rare fauna

As mentioned above, there is a lack of documented site-specific data relating to species that are particularly associated with ARB, including rare species

In conclusion, the site-specific target for the attribute elements of local distinctiveness is: **Maintain features of local distinctiveness, subject to natural processes.**

2.3.11. Negative physical indicators

Raised bogs that have been damaged by marginal cutting and drainage, reclamation for agriculture, forestry activities, fire, surface drainage, or the lowering of regional water tables show a range of negative physical indicators (Cross 1990). Such negative physical features of ARB include: bare peat, algae dominated pools and hollows, marginal cracks, tear patterns, subsidence features such as dry peat and / or mineral mounds / ridges emerging or expanding, and burning evidence.

Fernandez *et al.* (2014) recorded a decrease in the area (4.3ha) of ARB at Ferbane in the 2005 to 2012 period. This loss of sub-central habitat has taken place mostly in the south, south-west and north of the ARB and is thought likely to be associated with high bog and cutover drains that are still drying out the bog. The abundance of *Pinus* sp., particularly in the south, east and north of the SAC also indicate that the bog is drying out.

Peat cutting has now ceased at the site. However, drains associated with past peat cutting are present along the much of the cutover. These drains continue draining the high bog and impacting on high bog habitats (Fernandez *et al.* 2014).

Drainage on the high bog and cutover are the biggest threat to ARB on the bog.

There have been no major fire events reported from the high bog in recent times (Kelly *et al.* 1995; Fernandez *et al.* 2005, 2014).

The site-specific target for the attribute negative physical indicators is: **Negative physical features absent or insignificant.**

2.3.12. Vegetation composition: native negative indicator species

Indicators of disturbance on a raised bog include species indicative of drying out conditions such as abundant *Narthecium ossifragum* and *Trichophorum germanicum*; *Eriophorum vaginatum* forming tussocks; abundant *Sphagnum magellanicum* in pools previously dominated by species typical of very wet conditions (e.g. *Sphagnum cuspidatum*). Indicators of frequent burning events include abundant *Cladonia floerkeana* and high cover of *Carex panicea* (particularly in the true midlands raised bog type).

Fernandez *et al*. (2014) records that *Pinus sylvestris* trees occur quite frequently, particularly in the northern, southern and eastern margins of the high bog where they are quite dense in places. The presence of *Pinus* in these areas was already noted by Kelly *et al*. (1995) and although *Pinus* sp. seedlings and young saplings were recorded during the 2012 survey, they were not frequent. However, *Pinus* was noted to be colonising via drains in the marginal ecotope in the eastern part of the site although the rate of spread has not significantly increased since 2005 and no new areas of the high bog have been invaded (Fernandez *et al*. 2014).

The site-specific target for the attribute negative native indicator species is: **Native negative indicator species at insignificant levels.**

2.3.13. Vegetation composition: non-native invasive species

Non-native invasive species that can commonly occur on raised bog habitats include: *Pinus contorta*, *Rhododendron ponticum*, and *Sarracenia purpurea* (Cross 1990).

Several mature *Rhododendron ponticum* bushes were recorded on the north-eastern margin of the high bog by Kelly *et al.* (1995) and Fernandez *et al*. (2005). These do not appear to be spreading significantly. *Campylopus introflexus* has also been recorded on the high bog. The species is always associated with more disturbed areas such as within the area of the drainage complex in the south of the site (Fernandez *et al*. 2014).

The site-specific target for the attribute non-native invasive species: **Non-native invasive species at insignificant levels and not more than 1% cover.**

2.3.14. Air quality: nitrogen deposition

Peatlands are highly sensitive to air pollution, particularly nitrogen deposition. Reactive nitrogen from fossil fuel combustion or intensive agriculture can contaminate rain and snow, causing soil acidification, nutrient enrichment, and a decline in species that are sensitive to these conditions. There is evidence that the combined impact of elevated nitrogen deposition and a warming climate could exceed the sum of the individual stressors and lead to a dramatic decline in the biodiversity of mosses, sensitive vascular plants, and microbes, potentially leading to catastrophic peat loss (PEATBOG project - http://www.sste.mmu.ac.uk).

Air pollution can change both the species composition and the functioning of peatlands. The primary atmospheric pollutant from the Industrial Revolution to the mid 1970s was sulphur deposition, but levels have since greatly declined. Reactive nitrogen (N) deposition (primarily NO3- and NH4+), which can both acidify and eutrophy, became significantly elevated over a

widespread area in the early to mid-20th century and is now the major pollutant in atmospheric deposition across most of Europe (Fowler *et al.* 2005).

Nitrogen is commonly a limiting terrestrial nutrient and in un-impacted peatlands it is tightly cycled. With long-term elevated N deposition, vegetation composition typically shifts toward species adapted to higher nutrient levels, with an overall loss of diversity (Malmer & Wallén 2005). In peatlands, field experiments with N additions within the current European range have shown significant declines in bryophyte species-richness and productivity, and shifts in composition toward vascular plants (Bobbink *et al.* 1998; Bubier *et al.* 2007). Community shifts toward more nitrophilous bryophytes in N-enriched regions such as parts of the Netherlands are also well documented (Greven 1992). In the UK, both a general survey of peatlands across the country (Smart *et al.* 2003), and a targeted study of *Calluna* moorland (Caporn *et al.* 2007) showed significant inverse relationships between levels of nitrogen deposition and species richness, with bryophytes particularly impacted. Changes in the vegetation also impact below-ground communities and biogeochemical processes.

Moderate increases in N deposition from a low level may increase *Sphagnum* and vascular plant productivity without an equal increase in decomposition rates, leading to enhanced carbon accumulation (Turunen, *et al.* 2004). However, shifts in species composition from bryophytes to vascular plants may increase the production of easily-decomposable plant material, leading to higher rates of decomposition, and reduced carbon accumulation (Lamers *et al.* 2000; Bubier *et al.* 2007).

The particular sensitivity of nutrient-poor ombrotrophic peatlands to nitrogen enrichment is reflected in the low critical load threshold of between 5 and 10kg N/ha/yr for these ecosystems (Bobbink & Hettelingh 2011), a level which is exceeded over a significant portion of their range. An Irish study during the late 1990s undertaken by Aherne & Farrell (2000) concluded that total N deposition shows a strong east-west gradient, with lowest deposition in the west at 2kg N/ha/yr and highest in the east and south-east at 20kg N/ha/yr. Average N deposition over the Republic of Ireland was estimated to be approximately 12kg N/ha/yr. The study also concluded that the Critical Load Threshold for N was exceeded in at least 15% of ecosystems studied. The critical load applied to peatland ecosystems by Aherne & Farrell (2000) was 10kg N/ha/yr. This is in line with the recommendation by Bobbink & Hettelingh (2011) that the critical load should be set at the high end of the range in areas of high precipitation and at the low end of the range in areas of low precipitation assuming that Ireland represents a high precipitation area.

It is recommended in the case of Ferbane Bog that the level of N deposition should not exceed the low end of the range i.e. 5kg N/ha/yr. This recommendation is based on a precautionary approach, as the evidential basis for setting a higher level is not particularly strong as alluded to by Payne (2014). Total N deposition in the vicinity of Ferbane Bog as reported by Henry & Ahern (2014) is 13.4kg N/ha/yr.

The site-specific target for the attribute air quality is: **Air quality surrounding bog close to natural reference conditions. The level of N deposition should not exceed 5kg N/ha/yr.**

2.3.15. Water quality

Ombrotrophic peat waters found on the surface of raised bogs are characterised by low pH values (pH < 4.5) (Moore & Bellamy 1974) and also have low values of electrical conductivity. This is due to the fact that the raised bog system derives its mineral supply from precipitation, which is usually acidic and low in nutrients. Raised bog vegetation exchanges cations with protons to further reduce the pH.

Hydrochemistry varies in the areas surrounding a raised bog. Locally, conditions may be similar to the high bog due to a dominance of water originating from the bog. However, elsewhere in the marginal areas, there may be increased mineral and nutrient content of the water due to regional groundwater influences, runoff from surrounding mineral soils, and the release of nutrients through oxidation of peat resulting from reduced water levels.

Data presented by Kelly *et al*. (1995) suggests a significant contribution of regional groundwater within the drains that occur in marginal areas surrounding the high bog.

The site-specific target for the attribute water quality is: **Water quality on the high bog and in transitional areas close to natural reference conditions.**

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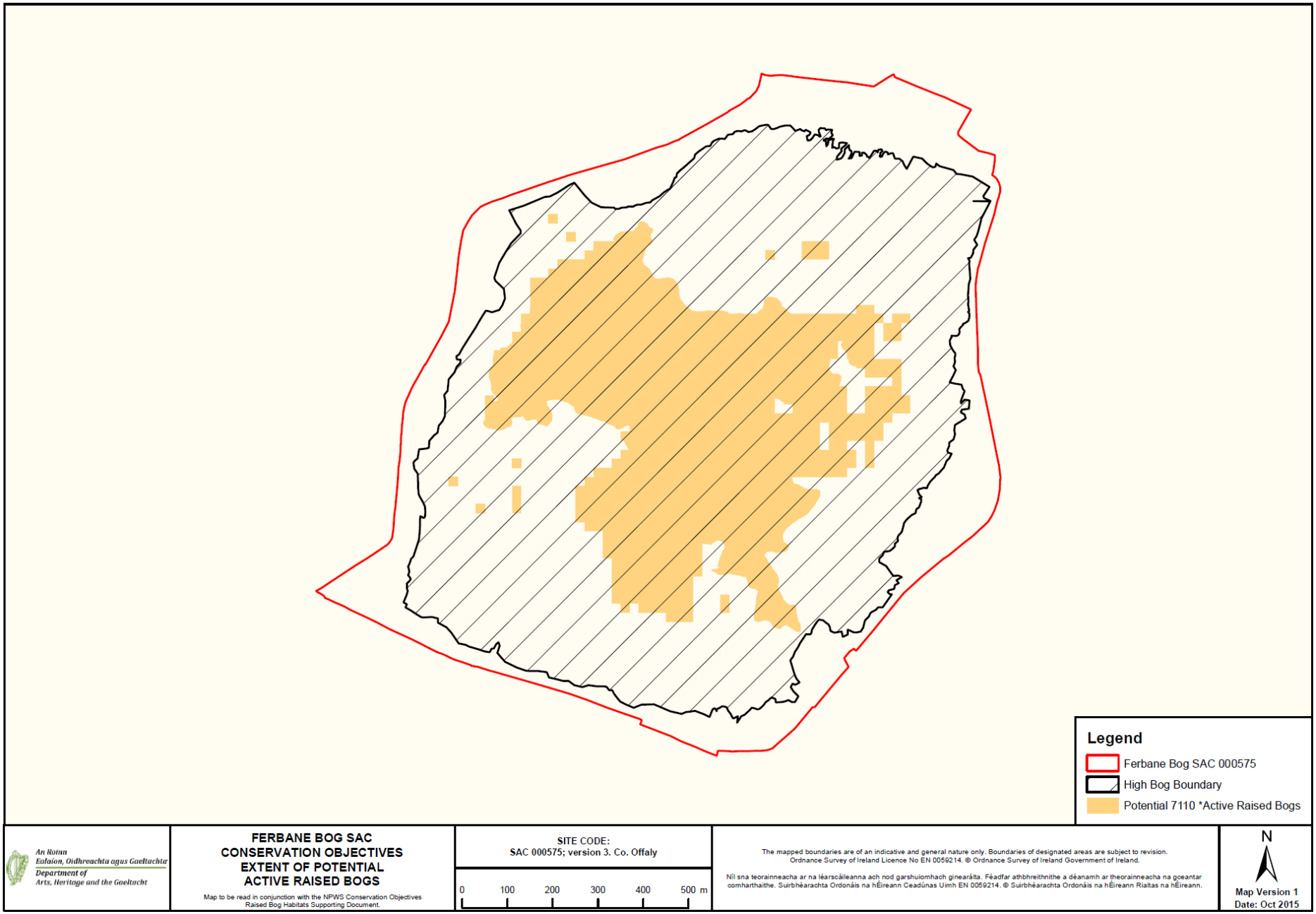
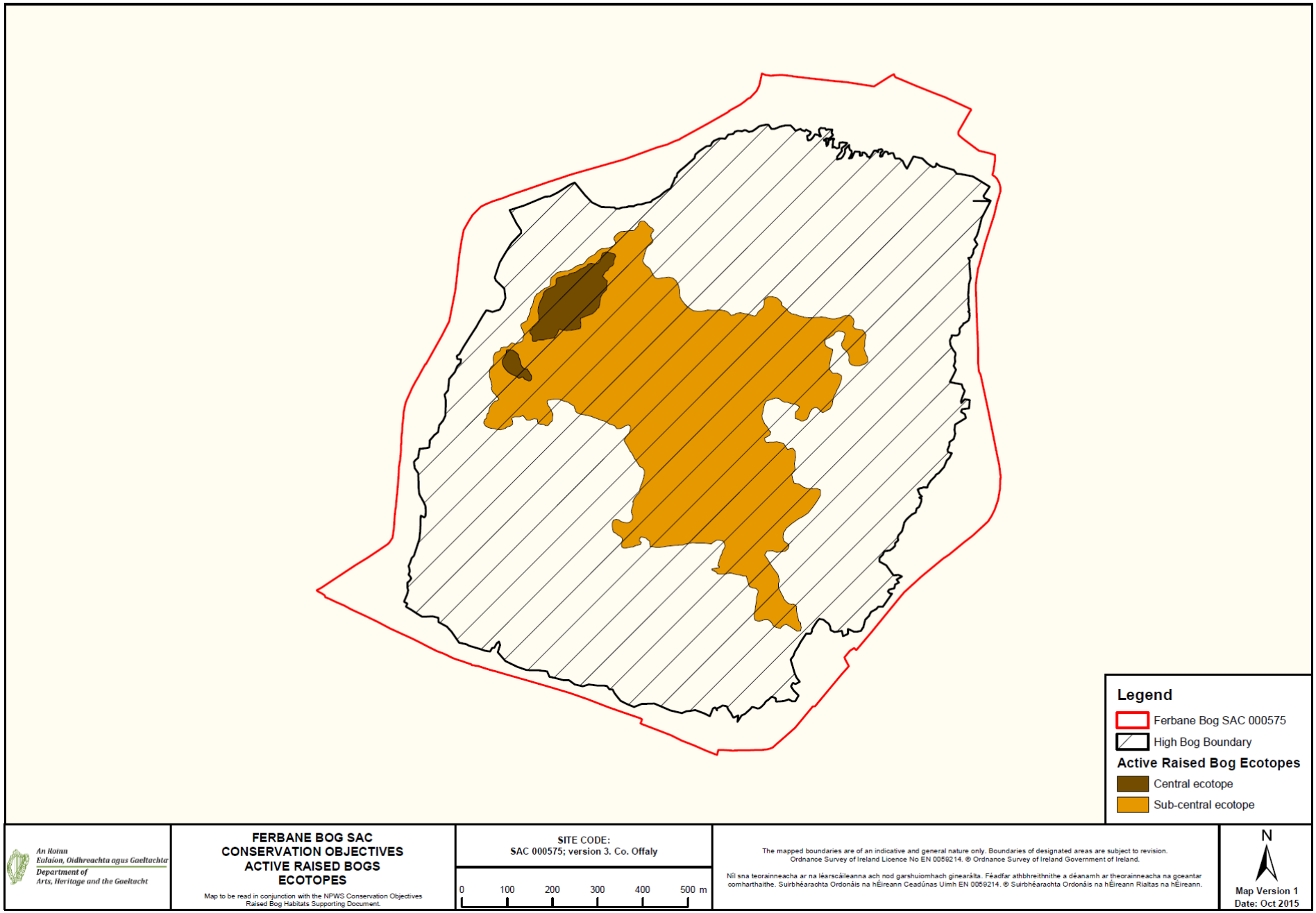
Map 1: Extent of potential active raised bog on Ferbane Bog.



Map 2: Distribution of raised bog ecotopes on Ferbane Bog.



Map 3: Digital elevation model and drainage patterns at Ferbane Bog.