Restoring Active Raised Bog in Ireland's SAC Network 2016 – 2020 (LIFE14 NAT/IE/000032)

D2: Vegetation Monitoring Final Report

William Crowley and George F. Smith

3/29/2022

An Roinn Tithíochta,
Rialtais Áitiúil agus Oidhreachta
Department of Housing,
Local Government and Heritage

The results of the vegetation monitoring programme (D2) in The Living Bog project (LIFE14 NAT/IE/000032) is documented and presented in this report. Baseline data collected pre-restoration is compared with post-restoration data both on the high bog and cutover and an assessment of whether or not the project is on target to achieve its Active Raised Bog (ARB) targets is made. Five post-restoration ecotope surveys were undertaken and an expansion of ARB was observed on all five sites. Overall 43ha of new areas of ARB have developed on these sites within just three years of restoration works equating to 19.5% of the long-term target for the development of new areas of ARB on the high bog for all 12 sites. Analysis of the eco-hydrological model indicates that 95% of the high bog target for ARB will be met. Results on the cutover were also positive with 4.7ha of High Sphagnum habitat created across the eight surveyed sites. In addition 5.6ha of shallow (<0.5m) open water areas developed, and it is expected that these areas will be colonised by Sphagnum over time. There was also a notable decline of 15.2ha of Low Sphagnum habitat. Overall, it is estimated that 75-88% of the targets on the cutover will be achieved. The Living Bog also described and defined ARB as occurring on cutover in the Irish context for the first time while acknowledging it will take longer to develop on the cutover than on the high bog. 4.6ha of ARB was recorded and mapped on cutover across the eight sites surveyed post-restoration. Analysis of species changes on the cutover brought about by restoration indicates increases in the cover of Sphagnum cuspidatum, S. palustre, S. auriculatum and Eriophorum angustifolium, and decreases in the cover of Calluna vulgaris and Molinia caerulea. In conclusion, analysis of results shows that sites are on the correct trajectory and analysis of the eco-hydrological model indicates that the project is on course to achieve 91% of its original ARB targets.

Table of Contents

1 Introduction

1.1 Raised Bogs in Ireland

Raised bogs are valuable wetland habitats that have become increasingly rare in Ireland in the last number of decades largely as a result of the mechanisation of turf cutting and the resultant removal of peat on a commercial scale for the production of fuel and horticultural products. They are ombrotrophic environments and composed of accumulations of deep acid peat (typically 3-12m) that originated in shallow lake basins or topographic depressions ca 8,000-10,000 years ago where anaerobic conditions occurred (Cross, 1990). The name is derived from the elevated surface, or dome, that develops as raised bogs grow upwards from the surface (Fossitt, 2000); 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. Exploitation has been extensive and no Irish raised bogs remain completely intact.

Indeed of the original figure of 310,000ha estimated to have occurred in Ireland by Hammond (1979), less than 50,000ha (16%) of near intact (uncut) high bog remains (Fernandez *et al.*, 2014). Approximately 21,500ha (43%) of this is within designated sites (Special Areas of Conservation or Natural Heritage Areas) and within these areas, less than 2,000ha corresponds with Active Raised Bog (ARB). The term “active” indicates that peat is still forming in a significant area (NPWS, 2013), and this living actively growing layer is called the acrotelm. ‘Active raised bog (7110)’ is also a priority habitat listed in Annex I of the EU Habitats Directive (92/43/EEC). Areas of raised bog that are degraded but have the potential to become active raised bog within 30 years of restoration work are also an Annex I habitat ‘degraded raised bog (7120)’.

In addition to the approximately 50,000ha of uncut high bog, there is an estimated 157,500ha of secondary damaged raised bog habitat, which includes intensively drained high bog devoid of vegetation, cutaway bog, cutover bog and some reclaimed agricultural land with peaty soils. These habitats may in some cases have a higher potential for restoration to ARB than some of the uncut high bog and thus may play an important role in raised bog restoration in Ireland.

Irish raised bogs are classified into two sub-types based on phytosociological and morphological characteristics (Schouten 1984): (1) Western or intermediate raised bogs, and (2) True midland or eastern raised bogs. 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 (such as *Pleurozia purpurea* and *Campylopus atrovirens*) which are absent from the true midland raised bogs.

Regardless of the sub-type raised bogs are generally driest at the margins with the wetness generally increasing towards the centre of the peat mass where well-developed pool systems (and indeed ARB) are most likely to occur. 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 species richness (Fossitt, 2000) and comprise species adapted to the biologically harsh conditions. The vegetation is open and treeless, and bog mosses (*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 may also contain soaks and flushes (wet 'active' or dry 'inactive') where there are concentrated surface flows, or where there are links with regional groundwater or the underlying mineral substratum. Slight mineral enrichment and/or increased supply of nutrients from 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 (NPWS, 2016). 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 in a typical situation surface wetness increases 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.

The importance of raised bogs and indeed peatlands in general has not always been acknowledged in Ireland (or worldwide), and starting in the ca 1700s, the raised bogs of Ireland were exploited as a cheap and available source of domestic fuel. Indeed, it is estimated that 50% of Ireland's 310,0000ha of raised bogs were cutover between 1645 and 1946 leaving an estimated 207,089ha of intact raised bog remaining at that point (Foss, 1998). However, the establishment of Bord na Móna in 1946 and the mechanisation of turf (peat) cutting accelerated the exploitation process with approximately 50,000ha of "intact" raised bog now remaining. Other factors which contributed to this accelerated loss of intact bog included the use of turf to fuel electricity power plants, the increased value of peat in the horticultural markets, afforestation programmes commencing in the 1950s and drainage and land reclamation associated with agricultural intensification following Ireland's entry into the European Union in 1973.

Today, the value of intact raised bogs and natural (and semi-natural ecosystems in general) and their role in providing ecosystem services is much more widely appreciated (de Groot *et al*., 2002). In addition to their unique biodiversity and their role in carbon sequestration and storage (Renou-Wilson *et al*., 2019) intact peatlands also contribute to flood alleviation, water storage and purification, and the protection of past environmental and archaeological archives among other services. Furthermore, Anderson *et al*, (2017) highlight that damaged peatlands cannot sustain these services and thus bear a cost to society, which can be alleviated by restoration measures. This has led to growing interest in the concept of natural capital (Bonn *et al*., 2014; Science for Environment Policy, 2017). The growing awareness of the importance of raised bogs and peatlands in general is illustrated by the growing number of bog restoration and rehabilitation projects being initiated and in the decision of Bord na Móna to cease peat production on all of their bogs. However, domestic and commercial turf cutting continues in Ireland today with some illegal cutting still reported even on raised bogs that are designated as SACs (active turf cutting was reported at 22 of the 53 SACs by the NPWS in 2019). Nonetheless, government and EU funding for conservation is increasing as indicated for example by the recently initiated *Peatlands Climate Action Scheme* where works are underway for the rehabilitation and/or restoration of 33,000ha of former cutaway bog across 82 Bord na Móna sites (https://www.bnmpcas.ie/). Ireland has also developed a national peatland strategy to promote bog restoration, and ensure their continued existence and functionality into the future (NPWS, 2015). Furthermore, the NPWS (2018) has published the National Raised Bog Special Areas of Conservation Management Plan 2017–2022 to provide clarity to all parties regarding how Ireland's network of raised bog SACs will be managed, conserved and restored into the future. This plan highlights the need for co-operation with landowners, turf-cutters and local communities while all the time keeping within legal obligations and commitments under the EU Habitats Directive. The plan also sets national targets for raised bog habitats that require the restoration of the national network of raised bog SACs and Natural Heritage Areas (NHAs). These targets are set by a scientific process on both a national and site-specific level, making use of eco-hydrological models (see section 1.4) to ensure targets are achievable. The target for the area of active raised bog in the national raised bog network is set at 3,600 ha. This target is considered to be achievable within the designated raised bog network in the long term, with restoration implemented in the short to medium term. However, it does not take into account any ongoing losses due to damaging activities, and recognises that in order to achieve the national target area for ARB it will be necessary to carry out restoration works on cutover areas as well as on the high bog. It also recognises that restoration of peat-forming habitats on cutover areas is typically more expensive than restoration of suitable high bog areas and more complex due to the range of additional factors that are likely to influence success of restoration such as peat depth, peat permeability, presence of fen peat and mineral-rich groundwater, potential for nutrient rich run-off and the fact that the peat is often much more damaged and exposed to oxidation.

1.2 LIFE and "*The Living Bog*"

The LIFE programme is the European Union's funding instrument supporting environmental, nature conservation and climate action projects through the EU. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental policy and legislation by co-financing pilot or demonstration projects with European added value.

LIFE began in 1992 and to date there have been five phases of the programme (LIFE I: 1992-1995, LIFE II: 1996-1999, LIFE III: 2000-2006, LIFE+: 2007-2013 and LIFE+ 2014-2020). In the first four phases, LIFE has co-financed some 3,954 projects across the EU, contributing approximately €3.1 billion to the protection of the environment (EU-LIFE). Of this, 80 projects focused on peatland restoration with the EU-LIFE nature programme investing €167.6 million (Anderson *et al*., 2017). The most frequent activities undertaken in these 80 projects were tree removal, and ditch and drain blocking with land acquisition and management plan agreements also common features. The ultimate goal was to restore or improve the conditions for over 913km^2 of peatland habitat.

This project, "Restoring Active Raised Bog in Ireland's SAC Network 2016-20" (*The Living Bog*: LIFE14 NAT/IE/000032) is part of the fifth phase of funding. Under this project, twelve Natura 2000 sites [a network of nature protection areas in the EU comprising Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) designated respectively under the EU Habitats Directive (92/43/EEC) and Birds Directive (79/409/EEC)] have been selected for restoration. These sites are 12 of the 53 raised bogs protected in Ireland as SACs for the Annex I priority habitat 'active raised bog' (habitat code 7110). At 3,311ha (2,649ha in the restoration works zone of influence), this is the largest LIFE raised bog project ever undertaken in Ireland, improving over 18% (1,940ha) of the national area of high bog in the 53 raised bog SACs. Furthermore, these 12 sites contain ca. 480ha of ARB, accounting for over 20% of ARB within the Ireland's SAC network.

It is important to note that in Ireland, the current conservation status of Annex I habitat 'active raised bog' is considered to be Bad and deteriorating principally as a result of marginal turf cutting, semi-industrial peat extraction, ongoing associated drainage effects caused by these activities and insufficient implementation of positive management actions (NPWS 2008; 2013; 2019). 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, and climate change is a future threat.

1.3 Previous Ecotope surveys and Restoration Works on Living Bog sites

The 12 sites that are part of *The Living Bog* Project were first surveyed during the 1980's as part of a comprehensive national raised bog survey carried out at that time by O'Connell and Mooney (1983), Douglas and Mooney (1984), and Douglas and Grogan (1985, 1986, 1987). Clara and Raheenmore were then extensively surveyed in the early 1990s by Kelly (1993) in which the raised bog ecotope concept was developed. This system of ecotope classification, which involves grouping and mapping plant community complexes into a number of distinct ecotopes is now well established in Ireland (see Kelly and Schouten, 2002 and Fernandez *et al*., 2014 for further details). Each ecotope has a distinct set of community complexes (homogenous mosaics of stands of different vegetation community types) and a typical associated acrotelm depth and hydrological and hydro-chemical characteristics. The basic system is based on an idealised concentric approach from the centre of a high bog to the margin. However, as a result of subsidence this concentric pattern of ecotopes no longer occurs across many sites. Nonetheless, the characteristics of each ecotope can remain, but now exist in a different pattern across the high bog. The main concentric-type ecotopes range from Central (typically the wettest and indicative of excellent quality active rasied bog) through to Sub-central (also considered ARB), Sub-marginal, Marginal and Facebank, which is the driest ecotope type. Actively accumulating peat conditions (forming ARB) occur within the Sub-central and Central ecotopes only. A further ecotope type exists outside of the concentric system, namely flushes and soaks. These can be either Active (i.e. peat-forming and thus ARB) or Inactive.

Repeat ecotope mapping over time allows even small changes in habitat quality to be measured., and the 12 Living Bog sites have been repeatedly surveyed using the ecotope approach at various times during national monitoring surveys (Kelly *et al*, 2005; Derwin and MacGowan, 2000; Fernandez *et al*., 2005; Fernandez and Wilson, 2009; and Fernandez *et al*., 2014) as indicated in Table 1.1 below.

Table 1.1 Previous ecotope monitoring surveys of Living Bog sites.

Site Code/Name	1994-95	1999-2000	2004-05	2009	2011-13
000006 Killyconny Bog	√		√		√
000572 Clara Bog			√	√	
000575 Ferbane Bog	√		√		√
000580 Mongan Bog	√		√		√
000581 Moyclare Bog	√		√		√
000582 Raheenmore Bog			√		√
000585 Sharavogue Bog	√		√		√
000597 Carrowbehy Bog	√		√		√
000604 Derrinea Bog	√		√		√
000679 Garriskil Bog	√		√		√
001242 Carrownagappul Bog	√		√		√
002341 Ardagullion Bog		√			

Previous restoration works including drain blocking have been carried out on particular sections of all but two of these sites (Ferbane and Derrinea) in the past (See Table 1.2 below). However, these works have largely been confined to the areas of high bog owned by the NPWS. Turf cutting had ceased on all but one (Carrownagappul) of the twelve sites prior to commencement of *The Living Bog*. One plot was cut on Carrownagappul in 2016 and 2017 after which cutting has ceased within Carrownagappul SAC.

Table 1.2 Previous restoration work carried out on Living Bog sites.

Site Code/Name	Physical Restoration Work
000006 Killyconny Bog	Extensive restoration works carried out by the NPWS between 2006-10 including the blocking of some high bog and cutover drains, the grading of facebanks and the installation of a barrier dam parallel to the road on the western cutover. Part of the site was part of a previous LIFE project (LIFE NAT/IE/000121) in which Coillte removed a conifer plantation and blocked the associated drains during the 2004-08 period.
000572 Clara Bog	A joint Dutch/Irish Raised Bog Research project ran from 1989-1993 and formulated management objectives, strategies and possible restoration actions. The series of management measures developed were then implemented under the European Union Cohesion funded Raised Bog Restoration Project (1994-99). This involved an acquisition programme as well as the blocking of high bog drains.
000575 Ferbane Bog	No physical restoration actions.
000580 Mongan Bog	Restoration works undertaken by the NPWS in the 1984-86 period, which involved blocking some of the high bog drains.
000581 Moyclare Bog	Restoration works undertaken by the NPWS consisting of the blocking of some of the high bog drains.
000582 Raheenmore Bog	Blocking of high bog drains and the construction of three dams by the NPWS (assisted by the EU Cohesion Fund) in the 1990's.
000585 Sharavogue Bog	Restoration works undertaken by the NPWS in the 1990's consisting of the blocking of some of the high bog and cutover drains.

Site Code/Name	Physical Restoration Work
000597 Carrowbehy Bog	Restoration works undertaken by the NPWS consisting of tree felling and the blocking of some of the high bog drains across 9ha prior to 2005.
000604 Derrinea Bog	No physical restoration actions.
000679 Garriskil Bog	Restoration works undertaken by the NPWS in 1998 consisting of the blocking of some of the high bog drains.
001242 Carrownagappul Bog	Restoration works undertaken by the NPWS consisting of the blocking of some of the high bog drains on 57.5ha of bog in 2003.
002341 Ardagullion Bog	Part of the site was part of a previous LIFE project (LIFE NAT/IE/000121) in which Coillte removed a conifer plantation and blocked the associated drains during the 2004-08 period.

1.4 Site specific Active Raised Bog Targets

As mentioned above in section 1.1, the raised bog SAC Management Plan has set targets at both a national and site-specific level for the extent of ARB that is considered achievable in the long term through restoration measures being implemented at each site in the short to medium term (NPWS, 2018). These targets are set by a scientific process using an eco-hydrological model. This use of a model to define achievable targets is necessary since unlike ARB, which can be accurately mapped using the ecotope survey methodologies described above in section 1.3, bog that is currently not peat-forming but has the potential to be restored (i.e. Annex I ‘degraded raised bog (7120)’ or DRB) is more difficult to map as, by definition, it includes only those areas that can be restored within a period of 30 years following implementation of restoration measures. In order to quantify such areas of DRB, the eco-hydrological model is necessary and has thus been developed to identify areas on a raised bog where suitable hydrological conditions exist for ARB to be restored. The model is described in detail by Mackin *et al*. (2017), but essentially involves the use of detailed topographic data for each raised bog obtained from LiDAR (Light Detection and Ranging) surveys to assess the potential for the bog surface to support ARB. The potential is largely based on the raised bog’s slope, drainage patterns and rainfall. In this way it is possible to determine the area of each bog that has suitable conditions for the development of active raised bog habitat, whether or not active raised bog currently occurs on that area (NPWS, 2018). Where active bog is absent from such areas, it is assumed that the area must have been impacted by a pressure that is preventing ARB growth. This model, thus, helps quantify the bog’s restoration potential.

The results of the model suggest that national level ARB losses incurred since 1994, cannot be compensated for using high bog restoration measures alone (Mackin *et al*., 2017), generating a need to consider alternative means of restoration, particularly on areas where high bog has already been cut (cutover). In order to identify areas on cutover bog with the potential to develop into peat-forming vegetation an empirical eco-hydrological model was developed based on similar modelling techniques that were developed for the high bog (NPWS, 2018). The modelling process identified areas of gentle surface slopes (≤0.3%) and enclosed depressions that have a contributing catchment area of at least 5000 m^2 as the areas with the greatest potential for maintaining saturated conditions and thus possible peat-forming habitats. These habitats can be broadly divided into two categories, bog peat-forming habitat and lagg peat-forming habitats. Where rainfall and run-off from the high bog is the primary source of water, ombrotrophic dominated bog peat forming habitats are likely to develop. These areas of bog peat-forming habitats may eventually become ARB in the long term (50–100 years) and therefore are considered to contribute to the long-term targets for the habitat. In contrast, where there is significant influence of mineral-rich water (e.g. through upwelling of mineral-rich groundwater or presence of a fen peat layer), lagg or fen vegetation is more likely to develop.

The targets set for each of the 12 Living Bog sites by the eco-hydrological model are presented in Table 1.3 below. These are the targets given by the NPWS (2018) and published in each site's Site Specific Conservation Objectives (SSCOs). It should be realised that the targets for the modeled potential bog forming habitat on the cutover differs slightly (usually lower) from that given in the LIFE bid document (LIFE, 2014). This is due to the eco-hydrological model having been refined in the intervening time. The original targets were provided as part of the LIFE bid prior to the finalisation of the detailed SSCOs and actual targets should be based on the final published version of the SSCOs for each site. See Appendix I for the values given in the LIFE bid document.

Table 1.3 Extent of ARB in ha (according to the most recent ecotope survey up to 2014) and modeled DRB on the high bog, and modeled potential bog-forming habitat on the cutover (NPWS, 2018). The target for ARB across the 12 sites is the sum of these three values. The targets for the modeled potential bog-forming habitat on the cutover differ slightly from that in the LIFE bid document as the model was refined in the intervening time period.

Site Code/Name	Current extent of ARB[1]	Modeled DRB[1]	Modeled potential bog forming habitat	Target extent of ARB
000006 Killyconny Bog	3.9	4.8	4.5	13.2
000572 Clara Bog	111.5	61.3	6.9	179.7
000575 Ferbane Bog	32.6	10.9	0	43.5
000580 Mongan Bog	48.3	10.4	4.1	62.8
000581 Moyclare Bog	21.7	8.3	4.5	34.5
000582 Raheenmore Bog	52.3	16.4	1.3	70.0
000585 Sharavogue Bog	25.8	14.7	0.4	40.9
000597 Carrowbehy Bog	69.9	17.8	4.6	92.3
000604 Derrinea Bog	17.1	6.8	0.8	24.7
000679 Garriskil Bog	50.9	31.6	2.4	84.9
001242 Carrownagappul Bog	28.1	36.5	5.3	69.9
002341 Ardagullion Bog	14.0	2.7	6.3	23.0
TOTAL	**476.1**	**222.2**	**41.1**	**739.4**

2 Objectives

An extensive programme of vegetation monitoring was carried out as part of *The Living Bog*. The principal objective of vegetation monitoring is to track the impact of restoration works on the vegetation of both the high bog and cutover and thus measure and document the effectiveness of the project actions in creating *Sphagnum*-rich vegetation and ultimately ARB as compared to the initial situation, the project objectives and the expected results.

High Bog vegetation has been monitored using the ecotope classification scheme and quantitative vegetation quadrats.

No specific ecotope or vegetation classification scheme exists for cutover vegetation. Thus a specific cutover habitat classification scheme needs to be developed by the project in order to allow assessment of the project results. This classification needs to be readily able to assess the impact on the vegetation (e.g. report on areas changing from low *Sphagnum* cover pre-restoration to high *Sphagnum* cover a number of years post restoration). The recording of vegetation monitoring quadrats will serve a dual purpose on the cutover. Firstly, they will ascertain the different vegetation types present and secondly the quadrats themselves will also be used to assess the impact of the restoration works on the vegetation.

3 Methods

Baseline surveys were carried out in 2016-2018 prior to restoration works being undertaken across the 12 sites to enable the success of these works to be gauged in the future. The methodology employed in carrying out these baseline surveys is described in detail below in sections 3.1-3.2, with the main outputs being:

- An ecotope map produced for the high bog on each site. This was considered to only be necessary where the most recent ecotope map was older than 2011.
- A raised bog cutover habitat classification scheme was developed and published (https://www.npws.ie/sites/default/files/publications/pdf/IWM128.pdf) as an *Irish Wildlife Manual* (Smith and Crowley, 2020).
- A cutover habitat map produced for each site using the newly developed classification scheme.
- A monitoring network established of relevés (236) on the cutover and of quadrats (158) on the high bog

Post restoration work surveys were undertaken in 2020 and 2021, ca. two years after the works had been implemented. The main data outputs of the post restoration surveys were:

- An ecotope map produced for the high bog on five of the sites (Ardagullion, Carrownagappul, Ferbane, Garriskil and Moyclare)
- A cutover habitat map produced for the cutover on eight of the sites (Ardagullion, Carrowbehy, Carrownagappul, Clara, Ferbane, Garriskil, Mongan and Raheenmore)
- 60 (of the 158 baseline) high bog quadrats were resurveyed and 170 (of the 236 baseline) cutover relevés resurveyed

3.1 High Bog

3.1.1 Ecotope Mapping

In the LIFE bid document (LIFE, 2014) a commitment was made to map the high bog habitats on those sites not surveyed in the NPWS monitoring survey of 2011-13 carried out by Fernandez *et al*. (2014). Specifically this meant an ecotope survey of Ardagullion and Clara was necessary. These surveys were carried out in 2016 for Ardagullion and Clara West and in 2018 for Clara East. In addition a full ecotope survey was carried out on Raheenmore, Mongan (both in 2016) and Carrowbehy (2017). Furthermore, the ARB boundary was surveyed and updated for Ferbane in 2017. Here a new survey method was trialled in which the survey was restricted to following and mapping changes in the ARB boundary of the site. This method has limitations in that it may not pick up changes (positive or negative) that are occurring in areas other than along the previously mapped ARB boundary. However, the advantage is that it is quicker than a full ecotope survey and may be useful in instances where a full ecotope survey is deemed unnecessary. The high bog habitats were not surveyed on the other six Living Bog sites as they were surveyed in the 2011-13 period by Fernandez *et al.* (2014), and these maps were considered to be recent enough to gauge any changes brought about by restoration works. Ecotope map data is stored as a shapefile in ArcMap 10.3.

The full ecotope surveys followed the methodology described by Fernandez *et al*. (2014), based on raised Bog ecotope vegetation community complexes developed by Kelly and Schouten (2002). Detailed notes were taken on each community complex and any flushed areas that were present. These included: species lists; estimation of % cover of species; percentage *Sphagnum* cover; evidence of damage (due to burning, peat cutting or drainage); micro-topography; ground firmness; and presence of *Cladonia* species. Mapping was carried out using a GeoExplorer handheld GPS minicomputer (Trimble Geo7x) ensuring sub-metre accuracy so that future changes in ecotope extent can be confidently assessed following restoration works. Data points recorded on this device included the locations of ecotope boundaries, ecotope vegetation complex notes and other points of interest. The GPS positions of these features were logged and stored in K-mobile software and brought into ArcMap 10.3 where the ecotope maps were drawn.

One extra tool that the ecotope surveys carried out by *The Living Bog* project were able to add to the arsenal was the DRB model. Maps relating to the distribution of modeled DRB were uploaded on to the GeoExplorer unit and particular attention was given to these areas during the ecotope survey.

Thus *The Living Bog* ecotope surveys together with those of Fernandez *et al*. (2014) from 2011-13 ensure that there are up-to-date ecotope maps (see Table 5.1 and Appendix IV; Maps 1) available for each site against which future monitoring can be assessed.

3.1.2 Monitoring Quadrats

The LIFE bid document (LIFE, 2014) outlined how in addition to ecotope mapping, it was necessary to establish a number of monitoring quadrats across all 12 Living Bog sites. Quadrats have thus been established on the high bog of 11 of the 12 sites (access to parts of Derrinea has been restrictive), which describe the micro-topographical features and the DOMIN cover scale of indicator species present at chosen locations (see Appendix IV Maps 1 for quadrat locations). The size of quadrats was 4m x 4m, and two geo-tagged photographs were taken at each quadrat location; one from the south-western corner and one more close-up of the vegetation. Opposite corners (SW and NE) were marked with bamboo and a sub-meter GPS location was recorded at all corners using a GeoExplorer handheld GPS minicomputer (Trimble Geo7x). These quadrats can be used in the medium to long term to gauge the success of the restoration works due to be carried out from late 2018 to 2020 as part of *The Living Bog* restoration works. Quadrat data is stored as a shapefile in ArcMap 10.3 and as an Excel spreadsheet.

The criteria used in choosing the location of these quadrats was based on a number of factors:

- The potential development (post restoration works) of peat-forming conditions predicted by the eco-hydrological model (i.e. within the area modeled as Degraded Raised Bog)
- The proximity of a hydrology monitoring point
- The proximity to proposed restoration works (e.g. within 100m of drain to be blocked)
- The development (post restoration works) of peat-forming conditions (ARB) predicted during the ecology survey (based on best expert judgment by the surveying ecologist)
- Established as a monitoring quadrat by Fernandez et al. (2014) during the monitoring surveys of 2011-13
- Selected as a control point

A total of 151 monitoring quadrats were set up across eleven of the twelve sites in ARB, DRB and non ARB/DRB high bog (supporting habitat). See Table 3.1

Table 3.1 Number of Monitoring Quadrats established on the high bog across the 12 LIFE sites.

Site Code/Name	MQ's on non ARB/DRB	MQ's on DRB	MQ's on ARB	Total Number of MQ's
000006 Killyconny Bog	3	4	2	9
000572 Clara Bog	1	3	22	26
000575 Ferbane Bog	4	4	4	12
000580 Mongan Bog	4	4	7	15
000581 Moyclare Bog	7	6	1	14
000582 Raheenmore Bog	0	4	5	9
000585 Sharavogue Bog	3	2	2	7
000597 Carrowbehy Bog	3	5	6	14
000604 Derrinea Bog[1]	0	0	0	0
000679 Garriskil Bog	3	1	7	11
001242 Carrownagappul Bog	4	16	6	26
002341 Ardagullion Bog	1	3	4	8
TOTAL NUMBER OF MONITORING QUADRATS	**33**	**52**	**66**	**151**

[1] due to issues with site access, the high bog at Derrinea has not been surveyed during this project. However, three monitoring quadrats were established in 2012 by Fernandez *et al*. (2014), two of which are in ARB and one in DRB.

3.2 Cutover

3.2.1 Habitat Mapping

In the LIFE bid document (LIFE, 2014) a commitment was made to map the cutover habitats on all 12 sites. It was also acknowledged that no actual specific vegetation classification currently exists for cutover habitats in Ireland and that the cutover surveys would be based on the Fossitt (2000) habitats classification, but that the project team would develop a more specific habitat classification of cutover vegetation.

The cutover habitats of each of the 12 LIFE sites were surveyed largely between August 2016 and November 2017, although further surveys were carried out throughout 2018 and 2019. The objective of the cutover surveys was to:

- Map all habitats within the zones of influence of restoration works of the EU LIFE project *The Living Bog*: *Restoring Active Raised Bog in Ireland's SAC Network 2016-2020* (LIFE14 NAT/IE/000032 on the cutover
- Create baseline habitat maps against which the impact of restoration works on the vegetation can be measured and the effectiveness of the project actions in creating *Sphagnum*-rich vegetation and ultimately ARB can be assessed. Thus, a readily identified metric needs to be embedded in the cutover habitat classification that is to be created as part of the project against which future changes in habitat type can easily be assessed.

The baseline survey of the cutover habitat of each site followed the methods outlined below:

1. A preliminary habitat map of the cutover was created through desktop analysis of the aerial photographs (2012) using ArcMap 10.3. This essentially involved delineating habitat/vegetation boundaries without determining what habitat/vegetation types they were.
2. A field survey was undertaken to check and amend (move, amalgamate and/or create extra) habitat boundaries on the ground using (when available) a GeoExplorer handheld GPS minicomputer (Trimble Geo7x) with sub-metre accuracy (when not available a GPS enabled tablet was used). A minimum habitat area of $400m^2$ as recommended for general habitat surveys by Smith *et al*. (2011), with a minimum habitat width of 4m was used. Any habitat that is smaller than this but considered notable was delineated by a point.

3. Each habitat was assigned a habitat type (using Fossitt, 2000) and described in detail using a species list with cover values (DAFOR). Note that (in line with best practice guidance for habitat survey and mapping; Smith *et al.*, 2011) where possible, the habitat was classified according to the secondary habitat developing, or developed on the cutover bog. Where this was not possible, an indication of the type of cutover bog (PB4) was recorded (e.g. similar to marginal or sub-marginal ecotope and/or with/without *Molinia*). Note also that some areas were mapped as mosaics of different habitats. Particular emphasis was placed on mapping and describing habitats within areas classed

as potentially peat forming by the eco-hydrological model. The full list of the different "working" habitat types of PB4 described across all 12 LIFE sites by *The Living Bog* is given in Table 3.2. These "working" habitat types will be refined after analysis and classification of the cutover relevés recorded. A sample recording sheet used to describe each habitat is included in Appendix II. Most of the data collected is self-explanatory such as *Sphagnum* cover, bare peat cover etc., which are estimates of the percentage cover of *Sphagnum* and bare peat across the habitat being described. However, the following fields require some additional explanation, which is given here:

- Predicted Future Habitat: this is the predicted future habitat that is anticipated to develop within the next number (10-30 years) of years using the best expert opinion of the surveying ecologist taking into account the following factors: current habitat (e.g. if it is currently extremely dry, regenerating bog is less likely), the eco-hydrogical model (e.g. if the model predicts peat-forming habitat, regenerating bog was considered more likely to develop), proposed restoration measures (e.g. if there are no restoration measures in the area, then regenerating bog is less likely to develop), topography (e.g. if it's an enclosed depression, regenerating bog is more likely to develop) and substrate (e.g. fen or bog peat).
- PPF: is the habitat within the area modeled as potentially peat-forming? If yes, is there an obvious difference between the area and the surrounding habitat (e.g. is it in a depression). If yes, and dry is there an obvious reason for it being dry (e.g. deep drains that can be blocked etc.) Finally it needs to be noted here, if there is much tree cover as the model has been found to be less accurate where there is extensive tree cover (F. Mackin, pers. comm)
- Firmness: One of four categories defined as follows:
    1. Firm: ground relatively hard underfoot. Little or no sinking of foot into ground when walking.
    2. Soft: foot sinks approximately 1 to 3cm when walking but little water is released.
    3. Very soft: foot sinks >3cm when walking and a considerable amount of water released in the process.
    4. Quaking: ground bounces or shakes when surveyor gently jumps
- Moisture Levels: One of three categories defined as follows:
    1. Dry: Area appears to be relatively dry all year round (i.e. the water table is below the surface).
    2. Wet: Area appears to be relatively wet all year round (i.e. the water table is above, at or close to the surface for most of the year).
    3. Intermediate: Water table appears to fluctuate throughout the year with indications that it is at the surface for parts of the year and well below the surface at other times.
- Acrotelm depth (cm): this was given as a rapid estimate of the average acrotelm depth over the habitat. The acrotelm was taken to be the living *Sphagnum* layer. One of five categories was chosen: 0cm, 0-5cm, 5-10cm, 10-20cm or >20cm.

- Feature of Conservation/Ecological Interest: This was taken to be the main feature of interest and could be either flora or fauna such as an Annex habitat, regenerating bog, a rare or interesting plant (such as *Eriophorum gracile* or *Frangula alnus*), Marsh Fritillary habitat or a badger sett etc.
- Drain blocking impact: Both negative and positive impacts were included here. For example, if fen or a rare plant was possibly going to be impacted by restoration measures this was highlighted here. On the other hand, if drains were substantial and likely to greatly improve restoration possibilities this too was highlighted.
- Other Management Issues: this included issues such as scrub encroachment, tree regeneration, non-native species, dumping and grazing.

Data from the cutover habitat surveys is stored as an Excel spreadsheet and the header data (i.e. the data minus the vegetation species lists) has been imported into ArcMap 10.3 and stored as a shapefile.

Table 3.2 The "working" habitat types of PB4 used during the baseline cutover habitat surveys.

Cutover Bog (PB4) sub-type	Sphagnum cover
Bare Peat dominated	Low (generally 0-25%)
Facebank-like vegetation on the cutover	Low (generally 0-25%)
Eriophorum angustifolium dominated	Low (generally 0-25%)
Open water with *Eriophorum angustifolium*	Low (generally 0-25%)
Marginal-like vegetation on the cutover	Low (generally 0-25%)
Molinia caerulea dominated and dry	Low (generally 0-25%)
Narthecium and/or *Rhynchospora* dominated	Moderate (generally 25-50%)
Rush (*Juncus effusus* usually) dominated	Moderate (generally 25-50%)
Molinia caerulea dominated and wet	Moderate (generally 25-50%)
Sub-marginal-like vegetation on the cutover	Moderate (generally 25-50%)
Regenerating cutover	High (generally >50%)

3.2.2 Monitoring Relevés

In the LIFE bid document (LIFE, 2014) a commitment was made to record monitoring relevés on the cutover. The objective of these relevés was twofold in that as well as acting as a monitoring point against which the impact of the restoration measures could be measured, the relevés are essential in order to ascertain the different vegetation types present on the cutover, and thus aid the development of a cutover classification scheme.

Relevés were generally recorded at the same time as a cutover habitat survey and were taken in as many habitat types as possible to aid classification of the habitat types present on the cutover. However, particular emphasis was put on placing relevés in areas classed as potentially peat forming (PPF) by the eco-hydrological model. Overall the criteria used in choosing the location of these relevés was based largely on the following factors:

- The potential development (post restoration works) of peat-forming conditions predicted by the eco-hydrological model (labelled as PPF – Potentially Peat Forming – by the model)
- The proximity of a hydrology monitoring point
- The development (post restoration works) of peat-forming conditions predicted during the ecology survey (based on best expert judgment by the surveying ecologist)
- The proximity to proposed restoration works (e.g. within 100m of drain to be blocked)
- Considered necessary for the development of a cutover classification scheme
- Selected as a control point

The locations of the relevés chosen across the 12 sites can be seen in Maps 1 in Appendix IV. Additional fields were added to the standardised field recording card that has been produced by the National Biodiversity Data Centre (see http://www.biodiversityireland.ie/wordpress/wp-content/uploads/NVD-Recording-card.pdf) and uploaded onto a tablet for recording purposes. On completion of field work at each site, all relevé data is imported into and stored in Excel. Locations of the relevés including the four corners were taken using a sub-meter GeoExplorer handheld GPS minicomputer when available and a GPS enabled tablet when not. Two opposite corners of each relevé were also marked with bamboo. Each relevé thus has a full species list and cover value (Domin scale) as well as two photographs (one taken from the south-western corner of the plot and one more detailed of the vegetation). The size of the relevé was 4m x 4m except in woodland areas where the relevés were 10m x 10m. The additional fields added to the standardised vegetation recording form mentioned above were: Predicted habitat, PPF, Firmness, Moisture, Acrotelm depth and total *Sphagnum* cover which are described above under section 3.2.1. In addition the following fields were also added:

- PPF Evaluation: Under this field, an attempt was made on the ground to assess whether a relevé occurring in an area modeled as PPF appeared different to the surrounding non-PPF areas (e.g. in an enclosed depression).
- PPF Moisture: Under this field, an attempt was made to gauge the restoration possibilities of areas modeled as PPF. This field first asked whether the area within the relevé was wet or not and if not was there an obvious reason why the area was dry (such as there being adjacent drains) or why the model may have erred (such as an area being under canopy).
- Pool Depth: the depth in cm of any standing water within the relevé

As detailed above as well as establishing a monitoring network across the 12 sites, the information from the relevés was used to help create a classification of cutover habitats present across the 12 sites (see section 4). Data from the cutover relevés was stored as an Excel spreadsheet and has been deposited in the NPWS database. A total of 236 releves were established across the twelve sites with 174 in areas classed by the hydrological model as potentially peat forming and 62 in areas not classed as such (see Table 3.3).

Table 3.3 Number of MR's established on the cutover across the 12 LIFE sites in areas modeled as Potentially Peat Forming and non PPF.

Site Code/Name	MR's in NON-PPF	MR's in PPF	Total Number of MR's
000006 Killyconny Bog	2	12	14
000572 Clara Bog	2	26	28
000575 Ferbane Bog	6	10	16
000580 Mongan Bog	4	15	19
000581 Moyclare Bog	3	22	25
000582 Raheenmore Bog	6	8	14
000585 Sharavogue Bog	3	15	18
000597 Carrowbehy Bog	6	17	23
000604 Derrinea Bog	2	4	6
000679 Garriskil Bog	3	9	12
001242 Carrownagappul Bog	15	23	38
002341 Ardagullion Bog	10	13	23
TOTAL NUMBER OF MONITORING RELEVÉS	**62**	**174**	**236**

3.3 Monitoring Transects

In addition to the monitoring quadrats and monitoring relevés, monitoring transects have been established at three sites: Ardagullion, Killyconny and Carrownagappul.

3.3.1 Killyconny Transect

An ecological monitoring transect at Killyconny was established on its western cutover in October 2005 by Dwyer and Wann (2005) prior to restoration works being carried out at the site with the intention that it would provide a framework against which vegetation changes can be measured. The restoration works included the blocking of over 5km of drains on the western cutover and the construction of a 1.7km long barrier dam where the western cutover meets an adjoining track.

The transect runs in a SSE direction from the roadway and the peripheral drain at the edge of SAC across an area of extensive cutaway and onto the high bog on the southern lobe. It measures 255m in length with relevés established every 10m resulting in a total of 26 relevés (18 on the cutover and 8 on the high bog). Each relevé was 5m x 5m in extent and all species present within the relevé were recorded and a percentage cover value for each estimated. This transect was resurveyed in October 2018 (and the data forms part of the data manifest of the project detailed in Appendix III). In 2005, the quadrat's south-western corner was marked with bamboo. Not all the bamboo were still visible on the re-survey in 2018, but a sufficient number were found to enable transect to be repeated. Opposite corners (SW and NE) were marked with bamboo in 2018 and a sub-meter GPS location was recorded at all corners using a GeoExplorer handheld GPS minicomputer (Trimble Geo7x). In addition two geo-tagged photographs were taken at each quadrat location; one from the south-western corner and one more close-up of the vegetation.

3.3.2 Ardagullion Transects

In July 2018, two monitoring transects were established on Ardagullion, the details of have been deposited in the NPWS database. One of these (Transect 1) extended out from the western track across a large area of cutover and onto the high bog (in a similar manner to the Killyconny transect) to gauge the impact of the barrier dam that was constructed here in February 2019. The other transect (Transect 2) was located running perpendicular to cutover drains that were blocked on the north-eastern cutover in January 2019. This transect ran across three drains, and through areas that were both modeled as potentially peat forming and not. The objective of this transect was to gauge the impact of drain blocking the accuracy of the eco-hydrological model in this area. The quadrats that these two transects comprised differed to those of Killyconny in that they were not full species quadrats. This was in order to make transects repeatable in a time efficient manner with less bryophyte expertise required. The quadrats are 2m x 2m in extent and recorded the cover for all vascular plants and mosses (liverworts not recorded) present (using the Domin scale) as well as the percentage cover of bare peat, open water and overall *Sphagnum* cover. Opposite corners (SW and NE) of each quadrat were marked with bamboo in 2018 and a sub-meter GPS location was recorded at all corners using a GeoExplorer handheld GPS minicomputer (Trimble Geo7x). In addition two geo-tagged photographs were taken at each quadrat location; one from the south-western corner and one more close-up of the vegetation. The length and spacing of quadrats along transects are as follows:

- Transect 1: Extending south-east from the track (where barrier dam was subsequently constructed in February 2019) through a large area of cutover and onto the high bog. Total length of transect is 300m, with 16 quadrats on the cutover spaced every 10m and 8 quadrats on the high bog spaced every 20m.
- Transect 2: Runs across four former turf plots for 140m. Five quadrats were located at equal spacing within each plot and thus spacing varied slightly between plots, but averaged at every 5m.

3.3.3 Carrownagappul Transect

Concern was expressed by regional management that the drains to be blocked along an internal track through Carrownagappul Bog could result in enrichment of ARB vegetation as the track was constructed using calcareous limestone during the 1950s to provide better access roads for turf cutting. A hydrological report was thus commissioned and the results of this suggested that there would be a negligible risk of minerotrophic water being transported into areas of established ARB communities as a result of blocking the drains along this internal track based on the topography of the site.

The eco-hydrological model highlighted areas of DRB that would likely develop into ARB over time as a result of blocking the drains parallel to this track. A baseline transect was established here in July 2019 in order to monitor vegetation changes over time and thus assess the accuracy of the model (i.e. does ARB develop) and also to gauge whether any minerotrophic inputs from the track can be detected on the high bog vegetation. This transect runs for 110m in a north-south direction from high bog across the track and back onto high bog again with relevés established every 10m resulting in a total of 12 (the data forms part of the data manifest of the project detailed in Appendix III). Each relevé was 2m x 2m in extent and all species present within the relevé were recorded and a percentage cover value for each estimated. Opposite corners (SW and NE) were marked with bamboo and a sub-meter GPS location was recorded at all corners using a GeoExplorer handheld GPS minicomputer (Trimble Geo7x). In addition two geo-tagged photographs were taken at each quadrat location; one from the south-western corner and one more close-up of the vegetation. The details of the transect have been deposited in the NPWS database.

3.4 Historical extent of bog

The historical extent of bog at each of the 12 sites was mapped using ArcMap 10.3 through desktop analysis of the following datasets:

- historic six inch maps from Ordnance Survey Ireland produced from 1829-42 (referred to in this project as the 1840s maps)
- six inch Cassini maps Ordnance Survey Ireland (referred to in this project as the 1910s maps)
- aerial photography from the 1970s
- aerial photography from 2012

The data derived from this analysis is shown in section 5.6. The maps themselves were included in the mid-term report.

4 Cutover habitat classification

The cutover raised bog habitat classification includes open habitats on cutover bog only. Woodland and scrub are excluded as these vegetation types are already well-characterised by the Irish Vegetation Classification (IVC) (NPWS *et al.*, 2019). The classification is divided into four habitat groups that encompass 16 habitat types. For a full description of the cutover habitat classification and its development see the Irish Wildlife Manual (https://www.npws.ie/sites/default/files/publications/pdf/IWM128.pdf) by Smith and Crowley (2020). A summary of that manual is given here.

4.1 Background

When mapping habitats in Ireland, the Heritage Council's *A Guide to Habitats in Ireland* (Fossitt, 2000) is the standard used in ecological surveys, be it in relation to landuse planning or conservation programmes (Smith *et al.*, 2011). Fossitt (2000) can be useful in identifying potential areas of high conservation value, such as those listed in Annex I of the Habitats Directive (92/43/EEC). However, such a broad habitat classification has limitations, because some habitats such as cutover bog are highly variable, as reflected in the description in Fossitt (2000):

> *Cutover bog is a variable habitat, or complex of habitats, that can include mosaics of bare peat and revegetated areas with woodland, scrub, heath, fen and flush or grassland communities. The nature of the recolonising vegetation depends on numerous factors including the frequency and extent of disturbance, hydrology, the depth of peat remaining, and the nature of the peat and the underlying substratum.*

Due to the potential diversity of the recolonising vegetation, the presence of habitats of high conservation value are subsequently not readily identifiable when using Fossitt (2000), except where "the regenerating habitats cover a sizeable area and can easily by fitted elsewhere in the classification". Thus, there is a need for a more comprehensive, specialist classification scheme of cutover bog not only for land-use planning and conservation purposes, but also in relation to carbon cycle and greenhouse gas studies, as there are significant differences in carbon balances (from carbon sink to source) between different types of cutover bog vegetation from bare peat to regenerating bog (Renou-Wilson *et al*., 2019; Swenson *et al*., 2019; Wilson *et al*., 2012). These differences need to be accounted for in calculating national greenhouse gas budgets and in emissions reporting.

4.2 Irish Vegetation Classification (IVC)

The Irish Vegetation Classification (IVC) provides a more detailed classification of most Irish semi-natural vegetation communities, including bogs (NPWS *et al*., 2019). This is an objective classification system based on quantitative analysis of plant cover data from thousands of quadrats recorded across the country. It does not take into account habitat characteristics, such as the history of peat cutting or the overall *Sphagnum* cover.

Prior to developing a new habitat or vegetation classification for cutover bogs, the IVC (NPWS *et al*., 2019) was assessed to determine if that system could adequately describe cutover raised bog vegetation. The data from the 249 surveyed cutover bog relevés were inputted into the ERICA tool (version 4.4; Perrin 2020), which assigned them to 30 different communities.

The correspondence between IVC communities and working cutover bog habitat subtypes assigned in the field was quite poor. For example, the working subtype "PB4/regenerating", which was assigned to areas that were wet with a high cover of peat-forming Sphagnum species, was divided amongst six different IVC communities, mostly in group BG2. Furthermore, many IVC communities included relevés assigned to working cutover bog subtypes representing a wide range of ecological conditions, from *Sphagnum*-rich to dry and Calluna-dominated and from ombrotrophic to flushed.

The main reasons the IVC was found to be unsuitable as a classification system at present for the conservation management of cutover bog include:

- the lack of cutover raised bog data in the IVC,
- the fact that it is a vegetation classification rather than a habitat classification,
- the IVC is still in development.

Firstly, there appear to be few if any relevés from cutover raised bogs used in the development of the IVC classification of bogs and heaths. The technical report for this phase of the classification makes no mention of cutover raised bog relevés (Perrin, 2017), and the number of general raised bog relevés in the analysis was small compared with the number of relevés from blanket bog (P. Perrin, pers. comm.). Secondly, as a vegetation classification, the IVC does not make use of environmental characteristics that are useful for conservation management, such as moisture status and cover of bare peat. Lastly, the IVC is still in development and some communities, such as *Juncus–Sphagnum* flushes, had not yet been included in the classification (P. Perrin, pers. comm.). As a result, affinities between such vegetation and IVC communities were expected to be low. For these reasons, it was considered that a specific cutover raised bog habitat classification would be useful for conservation planning and management.

4.3 Development of the classification

A classification of vegetation based strictly on relative abundances of species was initially trialled; however, the results were unsatisfactory. As with the IVC, the resulting vegetation types generally did not clearly separate out wetter, more *Sphagnum*-rich habitats, but grouped these together with drier habitats of less conservation interest. The decision was then made to pursue a classification where the dataset was initially partitioned according to habitat characteristics after which vegetation classification methods would be used within each habitat group. Use of habitat characteristics was helpful because, firstly, there is only a small pool of species that are common on cutover raised bogs, which makes an ecologically meaningful purely vegetation classification extremely difficult. In addition, much cutover bog vegetation is in a state of flux, recovering from relatively recent disturbance and has not yet reached stable "climax" communities (*sensu* Clements, 1916).

Two of the key pieces of information not used in the vegetation classification were total *Sphagnum* cover and bare peat cover. The former variable provides information on the wetness of the cutover, successional stage of the cutover, and similarity to intact raised bog, including ARB. Cover of bare peat is useful in identifying the younger and more disturbed cutover, and also the drier cutover that is very slow to colonise and thus remains "immature" for a long time. To identify thresholds for partitioning the dataset, *Sphagnum* cover and cover of bare peat were plotted (see Smith and Crowley, 2020) and the literature on *Sphagnum* cover in ARB on the high bog was reviewed.

Previous raised bog research in Ireland indicates that ARB, at least in the midlands, generally supports cover of *Sphagnum* greater than 40% (Fernandez Valverde *et al*., 2005, 2014). In the dataset, cover of bare peat of 10% or more is associated with generally low *Sphagnum* cover on disturbed and young cutover or older, dry cutover with poor vegetation development. *Sphagnum* cover of 10% or less is associated with degraded ecotopes (Marginal and Facebank) on the high bog (Fernandez Valverde *et al*., 2005, 2014) and was found during field surveys to be associated with heath, fen, grassland or other non-raised bog vegetation. Using these thresholds, four habitat groups were defined:

- **High Sphagnum**: Sphagnum cover >40% (regardless of bare peat cover)
- **Bare peat**: Sphagnum cover ≤40% and bare peat cover ≥10%
- **Moderate Sphagnum**: Sphagnum cover 11–40% and bare peat cover <10%
- **Low Sphagnum**: Sphagnum cover ≤10% and bare peat cover <10%

Cluster analyses were performed using the vegetation data for each of the above habitat groups. Bray-Curtis distance was the dissimilarity measure chosen to compare vegetation composition among relevés (Legendre & Legendre, 1998). The cluster method chosen was a version of fuzzy clustering called noise clustering in which each relevé is assigned a degree of membership to each of the clusters formed by the analysis (De Cáceres *et al*., 2010). Membership is also assigned to a 'noise' class, which represents outliers not adequately described by the classification. This method was chosen as it is a well-established method particularly suited to vegetation classification where transitional types and anomalous plant communities are frequent.

Within each habitat group, solutions with different final cluster numbers were evaluated. Silhouette analysis was used to assist in determining the best number of final clusters. This method numerically evaluates the dissimilarity in vegetation composition among all members of a cluster compared with their dissimilarity with members of other clusters. The mean silhouette width of all relevés in a cluster analysis indicates the quality of the classification, and these were compared among classifications with different numbers of final clusters.

For the High Sphagnum group (n=57), a 3–cluster solution was considered best, as it had a higher mean silhouette width than other solutions considered (2–5 clusters). All clusters were easy to interpret ecologically, and adding a fourth cluster provided no additional understanding of the vegetation.

In the Bare Peat group (n=23), the 2–cluster solution was adopted, as it had a higher mean silhouette width than other solutions considered (3 and 4 clusters). The 4–cluster solution included one cluster with only one relevé member. The 3–cluster solution included an *Eriophorum angustifolium* dominated habitat type and two types characterised by *Calluna*. These were not well-distinguished into slightly more or less flushed variants.

For the Moderate Sphagnum group (n=62), a 5–cluster solution was considered best. It had the highest mean silhouette width of the other solutions considered (3–7 clusters), with the exception of the 7–cluster solution. The latter was considered sub-optimal, as it included two very small clusters with n=3 and n=4 and a larger number of noise and transitional relevés. A 6–cluster solution split a *Juncus* dominated cluster to create two flush vegetation types, one of which was difficult to interpret and characterise.

In the Low Sphagnum group (n=71) a 5–cluster solution was considered best. It had the highest mean silhouette width of the other solutions considered (3–6 clusters), with the exception of the 6–cluster solution. The latter was not chosen as it divided a cluster characterised by abundant *Molinia* into poorly defined oligotrophic and more eutrophic types.

When vegetation classifications were obtained for each of the habitat groups, Indicator Species Analysis (Dufrêne & Legendre, 1997) was used to identify the best indicator species for use in describing and identifying cutover bog habitat types. All statistical analyses were performed in the R statistical environment. The Bray–Curtis distance matrix was produced using function `vegdist` in package *vegan*. Noise clustering was performed using function `vegclustdist` in package *vegclust*. Silhouette analysis was performed using function `silhouette` in package *cluster*. Indicator Species Analysis was done using function `indval` in package *labsdv*.

4.4 The Classification

The cutover raised bog habitat classification includes open habitats on cutover bog only. The classification is divided into four habitat groups that encompass 16 habitat types. The classification is outlined in Table 4.1.

Table 4.1 Summary of the cutover raised bog habitat classification (from Smith and Crowley, 2020)

GROUP	HABITAT CODE	HABITAT TYPE
High Sphagnum (>40% cover)	HS1	*Sphagnum subnitens–Erica tetralix*
	HS2	*Sphagnum cuspidatum–Eriophorum vaginatum*
	HS3	*Sphagnum palustre–Molinia caerulea*
Moderate Sphagnum (11– 40% cover)	MS1	*Calluna vulgaris–Sphagnum subnitens*
	MS2	*Eriophorum vaginatum–Sphagnum papillosum*
	MS3	*Molinia caerulea–Polygala serpyllifolia*
	MS4	*Cladonia portentosa–Trichophorum germanicum*
	MS5	*Juncus effusus–Sphagnum palustre*
Low Sphagnum (≤10% cover)	LS1	*Calluna vulgaris*
	LS2	*Eriophorum angustifolium*
	LS3	*Molinia caerulea*
	LS4	*Filipendula ulmaria*
	LS5	*Schoenus nigricans*
Bare Peat (>10% cover)	BP1	*Calluna vulgaris*–bare peat
	BP2	*Eriophorum angustifolium*–bare peat
	BP3	Bare Peat

A description including synoptic tables of each habitat type is detailed in Smith and Crowley (2020). A summary of each habitat type is presented in in Table 4.2. Significant indicator species were determined using Indicator Species Analysis (Dufrêne & Legendre, 1997). Also included are environmental proxy scores for moisture, reaction (acidity) and nitrogen (fertility), generated using ERICA (Perrin, 2020). These are the means of the combined Ellenberg values (Hill *et al*., 2004; Hill *et al*., 2007) for the relevés in a habitat type. The combined Ellenberg value for a relevé is the mean value of each species weighted by its abundance in the plot. Ellenberg values range from 1–9:

- High scores for moisture indicate wetter conditions.
- High scores for reaction indicate more basic conditions
- High scores for nitrogen indicate more fertile conditions

Table 4.2 Summary of the main characteristics of each habitat type in the cutover habitat classification

HABITAT CODE	Significant Indicator Species	Other species that may have some value as indicators	Environmental Proxy Scores (Ellenberg Values)		
			Moisture	Reaction	Nitrogen
HS1	*Calluna vulgaris, Erica tetralix, Odontoschisma sphagni, Eriophorum angustifolium, Sphagnum tenellum, S.*	*Hypnum jutlandicum* and *Trichophorum germanicum*	7.6 ± 0.1	2.2 ± 0.1	1.4 ± 0.0

HABITAT CODE	**Significant Indicator Species**	**Other species that may have some**	**Environmental Proxy Scores (Ellenberg Values)**		
	subnitens, Cladonia portentosa, Narthecium ossifragum and *Rhynchospora alba*				
HS2	*Eriophorum vaginatum, Sphagnum papillosum* and *S. cuspidatum*		7.8 ± 0.1	2.0 ± 0.1	1.4 ± 0.0
HS3	*Molinia caerulea, Sphagnum palustre, Potentilla erecta, Aulacomnium palustre, Calypogeia fissa* and *Polytrichum commune*	*Betula pubescens* and *Juncus effusus*	7.7 ± 0.1	2.6 ± 0.1	1.8 ± 0.1
MS1	*Calluna vulgaris* and *Cladonia floerkeana*	*Sphagnum subnitens*	6.8 ± 0.1	2.2 ± 0.1	1.7 ± 0.0
MS2	*Eriophorum vaginatum* and *Sphagnum papillosum*	*Sphagnum cuspidatum*	7.5 ± 0.1	2.1 ± 0.1	1.4 ± 0.1
MS3	*Molinia caerulea* and *Polygala serpyllifolia*	*Sphagnum subnitens, Aulacomnium palustre, Potentilla erecta* and *Eriophorum angustifolium*	7.6 ± 0.1	2.7 ± 0.1	1.7 ± 0.0
MS4	*Cladonia portentosa, Trichophorum germanicum, Odontoschisma sphagni, Erica tetralix, Sphagnum tenellum, S. rubellum, Rhynchospora alba* and *Kurzia pauciflora*	*Eriophorum angustifolium* and *Carex panicea*	7.5 ± 0.1	2.3 ± 0.1	1.3 ± 0.0
MS5	*Juncus effusus, Kindbergia praelonga, Anthoxanthum odoratum, Agrostis canina, Sphagnum palustre, S. fallax, Dryopteris carthusiana* and *Rhytidiadelphus squarrosus*	*Potentilla erecta* and *Betula pubescens*	7.3 ± 0.1	3.6 ± 0.1	3.1 ± 0.2
LS1	*Calluna vulgaris* and *Hypnum jutlandicum*		6.2 ± 0.1	2.4 ± 0.1	2.0 ± 0.1
LS2	*Eriophorum angustifolium* and	*Erica tetralix, Cladonia*	7.7 ± 0.2	3.2 ± 0.2	1.8 ± 0.1

HABITAT CODE	**Significant Indicator Species**	**Other species that may have some**	**Environmental Proxy Scores (Ellenberg Values)**		
	Trichophorum germanicum	*portentosa, Juncus effusus* and *Sphagnum papillosum*			
LS3	*Molinia caerulea*	*Potentilla erecta*	7.3 ± 0.1	3.1 ± 0.1	2.2 ± 0.1
LS4	*Vicia cracca, Filipendula ulmaria, Mentha aquatica, Anthoxanthum odoratum, Holcus lanatus, Calliergonella cuspidata, Arrhenatherum elatius, Lathyrus pratensis, Rumex acetosa, Festuca rubra, Plantago lanceolate, Agrostis stolonifera, Angelica sylvestris, Kindbergia praelonga, Comarum palustre, Galium palustre* and *Carex rostrata*	*Rhytidiadelphus squarrosus, Potentilla anserina* and *Carex flacca*	7.1 ± 0.5	5.7 ± 0.2	4.1 ± 0.3
LS5	*Schoenus nigricans, Campylium stellatum, Carex lepidocarpa, Ctenidium molluscum, Scorpidium revolvens, Hydrocotyle vulgaris* and *Cardamine pratensis*	*Menyanthes trifoliata* and *Myrica gale*	7.9 ± 0.2	5.0 ± 0.2	2.2 ± 0.2
BP1	*Calluna vulgaris, Hypnum jutlandicum, Cladonia portentosa* and *C. floerkeana*	*Erica tetralix, Eriophorum vaginatum* and *Molinia caerulea*	6.7 ± 0.2	2.5 ± 0.3	1.9 ± 0.2
BP2	*Eriophorum angustifolium*	*Juncus effusus*	8.1 ± 0.1	3.3 ± 0.1	1.4 ± 0.1
BP3	N/A	N/A	N/A	N/A	N/A

The cutover bog habitat classification should be used when carrying out habitat mapping of cutover raised bog. To aid in assigning habitat types to particular areas of cutover bog, a dichotomous key to the classification was prepared. A habitat classification is only a descriptive tool, however, and there will be habitats that will not neatly fit into any of the classified habitat types (Smith et al., 2011). In the case of cutover bogs, especially those more recently abandoned, where the habitats have been highly disturbed and the vegetation is undergoing significant change on the path to a new more or less steady state, areas that are difficult to classify are likely to be especially frequent. In addition, where restoration works have taken place, environmental changes can result in a complete change in successional trajectory. Difficult–to–classify areas can include variant habitat types, transitional habitats, mosaics and anomalous habitats and these are discussed in Smith and Crowley (2020).

The classification is constructed in such a way that it can be used as a metric in post-restoration (and post-LIFE surveys) to assess the trajectory of the cutover habitats and to evaluate the success of restoration in returning a functioning peatland system (e.g. How many hectares of LS habitat develop into HS habitat over time?).

The cutover bog habitat classification should be viewed as an addition to other habitat and vegetation classification schemes, rather than a substitute for them. Advice on applying the two main habitat classification systems used in Ireland, Fossitt (2000) and Habitats Directive Annex I habitats (European Commission, 2013), is provided by Smith and Crowley (2020).

4.5 Assessment of Active Raised Bog (ARB) on cutover

A key characteristic of ARB is that it is wet and “still supporting a significant area of vegetation that is normally peat forming” (European Commission, 2013). As a proxy for assessing peat formation in raised bog monitoring, a general threshold of *Sphagnum* cover of 40% is used as a criterion in determining whether an area of high bog is ARB (Fernandez Valverde et al., 2005, 2014). Accordingly, an area of cutover bog must have *Sphagnum* cover of more than 40%, in addition to the other criteria discussed below, to qualify as ARB. As this is the threshold used for the High Sphagnum habitat group, it follows that an area of cutover should fall into the HS1, HS2 or HS3 habitat types. Given the indicator species criterion (see Table 4.3), most ARB on cutover is expected to be classified as *Sphagnum subnitens– Erica tetralix* cutover bog (HS1) with perhaps a more limited amount classed as *Sphagnum cuspidatum–Eriophorum vaginatum* cutover bog (HS2). Due to the increased values of alkalinity and fertility in *Sphagnum palustre–Molinia caerulea* (HS3) and the influence that has on the species composition, this habitat will not qualify as ARB.

The process of defining ARB on the cutover is detailed in Smith and Crowley (2020). To summarise, in order to qualify as Annex I *active raised bog (7110) (ARB), a relatively homogenous area of cutover bog must meet the following criteria:

- Total *Sphagnum* cover >40%
- Presence of all eight constant species (Table 4.3) within a 100 m^2 plot
- Presence of an additional four indicator species (Table 4.3) within a 100 m^2 plot
- Absence of calcareous fen species, such as brown mosses
- <10% cover of species not typical of ombrotrophic raised bog

Table 4.3 Indicator species of Active Raised Bog

Constant **All eight species required**	**Additional** **Any four species/groups of species required**	
Sphagnum rubellum	*Andromeda polifolia*	*Menyanthes trifoliata*
Drosera rotundifolia	*Cladonia portentosa and/or C. ciliata*	*Sphagnum fuscum* s.l.
Narthecium ossifragum	*Cladonia uncialis*	*Sphagnum auriculatum*
Sphagnum papillosum	*Aulacomnium palustre*	*Sphagnum subnitens*
Eriophorum vaginatum	*Drosera anglica* and/or *D. intermedia*	*Sphagnum pulchrum*
Eriophorum angustifolium	*Leucobryum glaucum*	*Sphagnum magellanicum* agg
Rhynchospora alba	*Vaccinium oxycoccos*	*Sphagnum austinii*
Sphagnum cuspidatum	*Racomitrium lanuginosum, Pleurozia purpurea* and/or *Campylopus atrovirens*	

5 Data

5.1 High Bog

5.1.1 Baseline extent of Active Raised Bog

As discussed in section 3.1.1., a baseline ecotope map is available for each site (see Appendix IV; Maps 1) which future monitoring surveys can be set against. Six of these maps were created during *The Living Bog* project while the other six were created in 2011-13 by Fernandez *et al*. (2014). Ecotope maps detail the extent and type of ARB found on the high bog on each of the 12 sites (see Table 5.1 below for details).

Table 5.1 Total extent (and type) of ARB in ha on the high bog across the 12 sites prior to The Living Bog restoration works commencing.

Site Code/Name	Year of Survey	Sub-central	Central	Active Flush	Bog Wood-land	Total ARB
000006 Killyconny Bog	2011	3.7	0.2	0	0	3.9
000572 Clara Bog	2017	66.7	10.8	23.7	0.9	102.1
000575 Ferbane Bog	2012	30.6	2.0	0	0	32.6
000580 Mongan Bog	2016	18.2	30.9	0	0	49.1
000581 Moyclare Bog	2012	17.1	4.6	0	0	21.7
000582 Raheenmore Bog	2016	44.7	0.6	0.5	0	45.8
000585 Sharavogue Bog	2011	25.8	0	0	0	25.8
000597 Carrowbehy Bog	2017	37.6	32.9	2.3	0	72.8
000604 Derrinea Bog	2012	9.3	7.3	0.4	0	17.0
000679 Garriskil Bog	2011	36.2	14.3	0.4	0	50.9
001242 Carrownagappul Bog	2012	23.9	2.7	1.4	0	28.1
002341 Ardagullion Bog	2016	6.9	0.2	0.1	0	7.2

[1] due to issues with site access, the high bog at Derrinea has not been surveyed during this project. However, three monitoring quadrats were established in 2012 by Fernandez et al. (2014), two of which are in ARB and one in DRB.

5.1.2 Post-restoration extent of Active Raised Bog

Five of the 12 sites had an updated ecotope survey undertaken as part of *The Living Bog* project (see Table 5.2 and Appendix IV; Maps 2; Ecotope changes are illustrated by site in Appendix IV, Maps 3). These surveys took place 1-3 years post-restoration. The remaining sites will be surveyed as part of future NPWS raised bog monitoring programme with four (Mongan, Raheenmore, Derrinea and Clara) due to be surveyed in the years 2022-24.

Table 5.2 Total extent (and type) of ARB in ha on the high bog across the five sites surveyed 1-3 years post-restoration.

Site Code/Name	Year of Survey	Sub-central	Central	Active Flush	Total ARB	Increase in ARB since baseline
000575 Ferbane Bog	2021	34.6	2.3	0	36.9	4.3
000581 Moyclare Bog	2021	18.2	4.6	0.6	23.4	1.7
000679 Garriskil Bog	2021	52.7	15.8	0.4	68.9	18.0[1]
001242 Carrownagappul Bog	2021	41.5	3.0	0.8	45.3	17.2[2]
002341 Ardagullion Bog	2020	8.9	0.2	0.1	9.2	2.0
TOTAL						**43.0**

[1] a full analysis of the increase in extent of ARB will be carried out by the NPWS' raised bog monitoring programme 2022-24. Thus, these figures will be refined. For example, on Garriskil, 10.2ha of the ARB reported in 2021 was on areas of high bog not surveyed in the baseline survey. This 10.2ha is likely to have already been present at that time so that the actual increase in ARB is likely to have been 7.8ha (10.2ha less than that given in table).

[2] a full analysis of the increase in extent of ARB will be carried out by the NPWS' raised bog monitoring programme 2022-24. Thus, these figures will be refined. For example, on Carrownagappul, 5.1ha of the ARB reported in 2021 was on areas of high bog not surveyed in the baseline survey. This 5.1ha is likely to have already been present at that time so that the actual increase in ARB is likely to have been 12.1ha (5.1ha less).

5.1.3 Monitoring Quadrats on the High Bog

58 of the 158 monitoring quadrats (across five of the sites) that were established during the baseline surveys were re-surveyed 1-3 years post-restoration. Detailed analysis has not been carried out, but a summary of the changes in overall *Sphagnum* cover of the plots is shown in Figure 1.

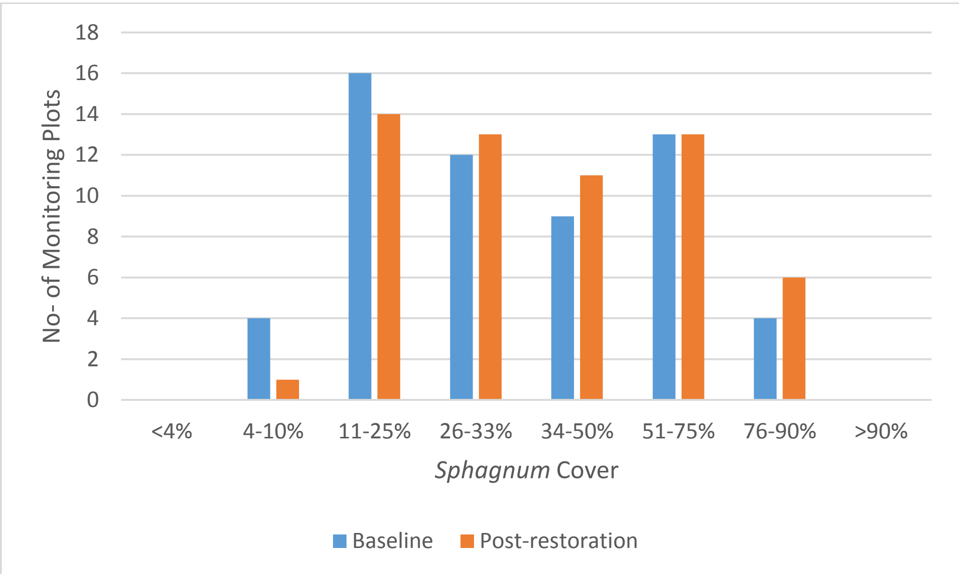


Figure 1 the change in Sphagnum cover in the 58 monitoring quadrats that were recorded in both the baseline and post-restoration surveys.

The mean ± SE of the *Sphagnum* cover in the baseline quadrats is 38.0% ± 2.9 while in the post-restoration quadrats, it has increased slightly to 41.8% ± 2.9. Seventeen of the 58 quadrats are in non-modelled DRB areas with an additional twelve located greater than 100m from any restoration works. These 29 plots can expect limited change. When these are taken out, the increase in *Sphagnum* cover is slightly greater in the remaining 28 plots. These go from a mean of 28.5% ± 2.6 to 33.0% ± 2.6. The very limited time since the works took place can account for the limited increase in *Sphagnum* cover in the quadrat network.

5.1.4 Target future extent of Active Raised Bog

As discussed in section 1.4, the extent of Degraded Raised Bog (DRB) on each raised bog SAC was estimated by the NPWS (2018) using an eco-hydrological modelling process (see NPWS, 2018 for details). As the extent of DRB is essentially the area of high bog that is not currently considered ARB, but which can be expected to become ARB provided steps are taken to repair damage to the bog, the extent of DRB added to the current extent of ARB equates the target extent of ARB on the high bog. It should be acknowledged, however, that the NPWS (2018) also adds to this target, the extent of potential bog peat forming habitat modeled on the cutover (see Table 1.3 above for details). Whether or not the target extent value for ARB will be achieved on a site can only truly be appraised once sufficient time has passed for the vegetation to develop. Meanwhile three factors can be considered to assess the likelihood of realising these targets:

1. Is the site on the correct trajectory, i.e. is ARB expanding and NOT contracting?
2. Has the water table in the peat been increased, at least across parts of the high bog?
3. Have all the drains that were proposed to be blocked actually been blocked? If not, what is the expected impact on ARB targets?

The first question has been answered in section 5.1.2 above, which highlights that ARB is expanding on the five resurveyed sites. The second question is answered by the hydrology report that accompanies this vegetation report and forms part of the final project delivery. The hydrology monitoring network has picked up small but significant increases in water levels in parts of high bog across the network (Cushnan, 2022). Although the water table increases are much lower than that recorded on the cutover, crucially they sometimes have meant that the water table has achieved that which is needed for ARB to be maintained or restored; a water table that is at or within 10cm of the surface year round. The third question can be looked at on a site-by-site basis. A meeting of the Technical Advisory Group (TAG) in November 2019, highlighted where proposed restoration works were not carried out and subsequently an examination of the eco-hydrological modelling estimated what the impacts this would have on achieving the target ARB (see Table 5.3 below). To combat the predicted shortfall in the achievement of ARB, additional restoration works (bunding) were carried out on suitable areas of three sites (Killyconny, Carrownagappul and Clara), and the positive impact that these measures are expected to have was also estimated using modelling techniques. Note that as of March 2022, the installation of the restoration works is being verified by Bord na Móna through an analysis of drone surveys currently being carried out. The results of this analysis may alter the estimates in Table 5.3 slightly.

Table 5.3 The impact on ARB targets from changes in the restoration programme as proposed in the project LIFE bid. Note that the lagg peat forming habitat (PFH) did not form part of the LIFE targets (see Table 1.3), but is included here for interest.

Site Code/Name	DRB at risk (ha)	Bog PFH on Cutover Additional Bog PFH (ha)			Lagg PFH Impacted (ha)
		Negative Impact	Positive Impact	Net	
000006 Killyconny Bog	0	1.5	2.7	+1.2	0
000572 Clara Bog	0[1]	0	0.4	+0.4	2.3
000575 Ferbane Bog	0	0	0	0	1.3
000580 Mongan Bog	0	0	0	0	0
000581 Moyclare Bog	0	0	0	0	0
000582 Raheenmore Bog	1.0[2]	0	0	0	0.9
000585 Sharavogue Bog	0	0.2	0	-0.2	0
000597 Carrowbehy Bog	2.2	0	0	0	0.8
000604 Derrinea Bog	6.8	0.8	0	-0.8	0
000679 Garriskil Bog	0	0	0	0	0
001242 Carrownagappul Bog	0	0	0.8	+0.8	0
002341 Ardagullion Bog	1.2	1.3	0	-1.3	0
TOTAL	**11.2**	(3.8)	(3.9)	**+0.1**	**5.3**

[1] ARB is currently being lost on Clara due to deep-cut drainage on the southern cutover, which has caused changes in the underlying groundwater head (Regan *et al*., 2019). This was not accounted for when setting the targets and is NOT a result of restoration actions not being completed. This issue is being addressed by a separate stand-alone NPWS project.

[2] This includes 0.4ha of ARB, which is under threat from the continued drainage associated with the unblocked drain on the cutover.

In Table 5.3, the DRB column is the only relevant one to consider when assessing the targets for ARB on the high bog. It can be seen that 11.2ha of DRB has been impacted, meaning that 11.2ha of ARB on the high bog are expected NOT to be achieved as a result of certain restoration works not being carried out. The majority of this (6.8ha) is on one site, Derrinea, where permission to carry out the works was not granted by the local landowner. Comparing the figure to the overall area of DRB that was expected to be restored to ARB (222.2ha; see Table 1.3), it can be estimated that 95.0% (211.0 of 222.2ha) of the target ARB can be expected to be achieved. Currently 43.0ha (see Table 5.2) has been restored across the five sites re-surveyed. This equates to 19.5% of the targets having been reached in only 1-3 years post-restoration despite only five sites being surveyed.

On the other hand, it should be noted that the 2016 ecotope survey of Clara noted a decline in the extent of ARB since 2009. This decline has been attributed to changes in the underlying groundwater head due to deep-cut drainage, rather than near-surface peatland drainage (Regan *et al*., 2019). Thus, the achievement of ARB targets on Clara cannot be expected until this issue has been addressed. Indeed, it is likely that the extent of ARB on Clara will continue to decline. The NPWS have researched potential engineering solutions to combat this problem and have drafted a plan to infill a large area of the cutover. The cost/benefit of this plan is currently being reviewed by the NPWS

5.2 Cutover

5.2.1 Baseline habitats on the cutover

In the mid-term report, the baseline habitats recorded in the zone of influence were reported with 408.2ha (47.9% of overall area) mapped as cutover bog (PB4) and 443ha mapped as various other habitats (see Table 5.4). Aside from cutover bog, the most dominant habitat type was bog woodland, which covered 159.9ha (18.8%). Most of this was dry birch dominated, but 5.4ha of *Sphagnum*-rich Annex I 'bog woodland (91D0)' was mapped within this category.

The cutover bog was then mapped according to the cutover habitat classification system devised under this project (Smith and Crowley, 2020). In the mid-term report, the working habitat types were used, whereas in Table 5.5 below the baseline habitats have been reassigned to the new classification system. A map showing the locations of each habitat is presented in Appendix IV, Maps 1. These habitat maps serve as an essential baseline against which future monitoring surveys can be set against and the impact of the restoration works measured.

Table 5.4 Baseline habitat types and their extents in hectares mapped in the zone of influence of the restoration works using the Fossitt (2000) classification system. Where two habitat codes are given, the habitat is a mosaic of the two.

FOSSITT CATEGORY		
CODE	**NAME**	**AREA (ha)**
PB4	Cutover Bog	408.2
WN7	Bog Woodland (Dry but for 5.4ha of 91D0)	159.9
GS4	Wet grassland	60.6
NA	Not surveyed	58.9
WS1	Scrub	49.7
WN6	Wet willow-alder-ash woodland	19.0
GA1	Improved agricultural grassland	18.1
HH3	Wet heath	14.9
WS2	Immature woodland	9.3
HD1	Dense bracken	6.9
FW2	Depositing/lowland rivers	6.0
GS4\WN6	Mosaic of GS4\WN6 habitats	5.0
GS3	Dry-humid acid grassland	4.8
WD4	Conifer plantation	3.3
PF3	Transition mire and quaking bog	2.6
WN1	Oak-birch-holly woodland	2.0
WS5	Recently felled woodland	1.9
HD1\WN7	Mosaic of HD1\WN7 habitats	1.7
FL1	Dystrophic lakes	1.6
ED2	Spoil and bare ground	1.6
GS4\WN7	Mosaic of GS4\WN7 habitats	1.5
PF1	Rich fen and flush	1.5
PF2	Poor fen and flush	1.5

FOSSITT CATEGORY		
CODE	**NAME**	**AREA (ha)**
WD2	Mixed broadleaf/conifer woodland	1.4
BL3\GS1	Mosaic of BL3\GS1 habitats	1.0
GS1\WS1	Mosaic of GS1\WS1 habitats	1.0
GS2\WN7	Mosaic of GS2\WN7 habitats	1.0
HD1\WS1	Mosaic of HD1\WS1 habitats	1.0
GS4\WS1	Mosaic of GS4\WS1 habitats	1.0
WD1	Mixed broadleaf woodland	0.8
PB1\PB4	Mosaic of PB1\PB4 habitats	0.7
GS4\HD1	Mosaic of GS4\HD1 habitats	0.5
FS1	Reed and large sedge swamps	0.5
BL3	Buildings and artificial surfaces	0.4
GS2	Dry meadows and grassy verges	0.4
PB4\PF2	Mosaic of PB4\PF2 habitats	0.3
PF2\WS1	Mosaic of PF2\WS1 habitats	0.3
HD1\WN6	Mosaic of HD1\WN6 habitats	0.2
GS1	Dry calcareous and neutral grassland	0.1
WN2	Oak-ash-hazel woodland	0.1
TOTAL		**851.5**

In Table 5.5., it can be seen that High *Sphagnum* habitat types are relatively rare on the cutover, being the least common of the four broad habitat types, with only 25.2ha (6.2% of PB4 habitat) recorded prior to *The Living Bog* restoration works. Of this, 5.0ha were recorded on the western cutover of Killyconny in which restoration measures were undertaken in the mid-2000's by the NPWS. Thus, less than 5% of cutover habitat across the twelve sites supported High *Sphagnum* habitat types prior to restoration. Low *Sphagnum* habitat types dominated the cutover with 259.6ha (63.6% of total cutover habitat) recorded prior to restoration works. Moderate *Sphagnum* habitat types were the next most common accounting for 93.7ha (23.0%), followed by Bare Peat habitat types that accounted for 29.6ha (7.3%).

Table 5.5 Baseline cutover habitat types and their extents in hectares mapped in the zone of influence of the restoration works using the Smith and Crowley (2020) classification system. Where two habitat codes are given, the habitat is a mosaic of the two.

CUTOVER HABITAT	Area (ha)
HS1	8.8
HS1\LS1	0.2
HS2	9.3
HS3	6.2
HS3\LS1	0.8
Total High Sphagnum habitat	**25.2**
MS1	18.5
MS1\WS1	0.4
MS2	11.0
MS2\FL1	1.5
MS3	22.5
MS3\WS1	0.2
MS4	23.9
MS5	15.6
Total Moderate Sphagnum habitat	**93.7**
LS1	130.8
LS1\HS2	0.5
LS1\HS3	0.2
LS1\PF3	0.5
LS1\WS1	3.2
LS2	4.8
LS3	99.1
LS3\WS1	7.7
LS4	8.9
LS4\WS1	0.2
LS5	3.8
Total Low Sphagnum habitat	**259.6**
BP1	12.1
BP2	15.9
BP3	1.5
TOTAL Bare Peat habitat	**29.6**
TOTAL	**408.2**

5.2.2 Post restoration extent of habitats on the cutover

Habitats were resurveyed on eight of the 12 sites (Ardagullion, Carrowbehy, Carrownagappul, Clara, Ferbane, Garriskil, Mongan and Raheenmore) as part of *The Living Bog* project. The baseline and post-restoration cutover bog habitats recorded on these sites are shown in Table 5.6. Note that this includes only those habitats classed as PB4 using Fossitt (2000) during the baseline survey. The post-restoration surveys took place 1-3 years post-restoration works. Of the remaining four sites, Derrinea had no restoration work carried out while Killyconny had enhanced restoration works carried out in the spring of 2021. Sharavogue and Moyclare were not surveyed due to time constraints, but monitoring releves on these two sites and Killyconny were re-visited. A map showing the locations of each habitat is presented in Appendix IV, Maps 2. These habitat maps can be compared with baseline habitat maps and habitat maps from future surveys to gauge the impact of the restoration works over time.

Table 5.6 Baseline and post-restoration works cutover habitat types and their extents in hectares mapped in the zone of influence of the restoration works in eight of the 12 project sites using the Smith and Crowley (2020) classification system. The change in extent of habitats between the two surveys is also given. Note this table includes only those areas that would otherwise be mapped as PB4, Cutover Bog using Fossitt (2000).

	AREA (HA)		
HABITAT (Smith and Crowley, 2020)	**Baseline**	**Post-Works**	**Change**
HS1	7.0	6.3	-0.7
HS2	4.0	6.7	2.6
HS3	7.6	10.4	2.8
TOTAL HS			**(+4.7)**
MS1	14.8	15.0	0.2
MS2	13.3	16.7	3.4
MS3	37.5	40.3	2.8
MS4	39.6	38.0	-1.7
MS5	11.0	6.4	-4.6
TOTAL MS			**(+0.3)**
LS1	57.4	51.6	-5.8
LS2	6.7	9.9	3.1
LS3	60.7	48.3	-12.4
LS4	5.3	5.2	-0.1
LS5	0.2	0.2	0.0
TOTAL LS			**(-15.2)**
BP1	8.9	12.1	3.2
BP2	8.7	5.6	-3.1
BP3	0.4	3.5	3.1
TOTAL BP			**(+3.2)**
Other habitats (Fossitt, 2000)			
NA (Unknown)	1.1	0.0	-1.1
PF2	0.0	0.7	0.7
WS1	0.0	1.9	1.9
FL (Open Water)	0.0	5.6	5.6
	284.5	**284.5**	**0.0**

Table 5.6 shows that even in these early stages, restoration works on the cutover bog have been successful. The most notable outcomes are the 4.7 ha increase in HS group habitats and the 15.2 ha decrease in LS group habitats. The 5.6 ha increase in open water on the cutover is also notable, and

it is expected that these areas will become colonised by *Sphagnum* over time. The increase in the bare peat (BP) habitat group is a result of machine disturbance during restoration works, and this will be temporary. These changes are illustrated by site in Appendix IV, Maps 3. In these maps, the change in cutover habitat is mapped by assessing improvement (i.e. from a lower to a higher *Sphagnum* group category) or decline (i.e. from a higher to a lower *Sphagnum* group category) in the habitat group categories of Smith and Crowley (2020), using the following coding system:

Table 5.7 Changes in habitat group from baseline to post-restoration surveys. Baseline habitat groups are by row and post-restoration habitat groups are by column (e.g. going from LS to BP= -1, LS to LS= 0, LS to MS= +1 and LS to HS= +2).

HABITAT CHANGES		**TO**			
		Bare Peat (BP)	Low *Sphagnum* (LS)	Moderate *Sphagnum* (MS)	High *Sphagnum* (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low *Sphagnum* (LS)	-1	0	+1	+2
	Moderate *Sphagnum* (MS)	-2	-1	0	+1
	High *Sphagnum* (HS)	-3	-2	-1	0

As indicated in section 4.5, areas of HS1 and HS2 may correspond with the Annex habitat 7110 (ARB). Following the methods of Smith and Crowley (2020), an assessment of whether or not these areas correspond with the Annex habitat 7110 was carried out at each area where these habitats occurred. A total of 4.6ha of the 13ha of HS1 and HS2 mapped corresponds to 7110 and Table 5.8 outlines the total area on each site where 7110 was recorded. The remaining 8.4ha of HS1 and HS2 does not correspond to the annex habitat mainly as a result of having insufficient indicator species present. However, over time these species may colonise the areas so that some of the 8.4ha can expect to develop into Annex I habitat in the future.

Table 5.8 Area in hectares of ARB (Annex I habitat 7110) recorded on the cutover of the eight sights surveyed post-restoration. ARB determined using methods outlined by Smith and Crowley (2020)

Site	**Area of 7110 (ha)**
000572 Clara Bog	1.0
000575 Ferbane Bog	0
000580 Mongan Bog	0.4
000582 Raheenmore Bog	0.2
000597 Carrowbehy Bog	2.2
000679 Garriskil Bog	0.6
001242 Carrownagappul Bog	0.1
002341 Ardagullion Bog	0
TOTAL	**4.6**

5.2.3 Predicted future habitats on the cutover

In Table 5.3 above, the impact of the change in proposed restoration works on achieving the peat-forming habitats (PFH) on the cutover according to analysis of the model is given. Essentially all of the target area for bog PFH is expected to be achieved. However, considering the original targets Appendix I), this amounts to achieving 75.6% of the original cutover targets for bog PFH.

However, during the ecology surveys, the likely future habitat (within ca. 30 years) was also predicted (see section 3.2.1) while considering the proposed restoration works and the eco-hydrological model. The predicted habitats (and their extents) at each of the eight sites surveyed post-restoration are presented in Table 5.9.

Table 5.9 The predicted future cutover habitat types and their extents in hectares on eight of the 12 project sites using the Smith and Crowley (2020) classification system.

CUTOVER HABITAT	Area (ha)
HS1	16.6
HS2	17.8
HS3	15.7
Total High *Sphagnum* habitat	**50.2**
MS1	21.0
MS2	13.5
MS3	37.5
MS4	39.4
MS5	5.5
Total Moderate *Sphagnum* habitat	**117.0**
LS1	50.6
LS2	1.6
LS3	33.1
LS4	3.4
LS5	0
Total Low *Sphagnum* habitat	**88.8**
BP1	0.2
BP2	0
BP3	0.1
TOTAL Bare Peat habitat	0.3
TOTAL	**256.2**
Other habitats (Fossitt, 2000)	
FL (Open Water)	1.7
PF1	0.1
PF2	6.3
WN6	1.3
WN7 (Dry)	7.9
WN7 (91D0)	0.3
WS1	12.7
	30.3

As mentioned in section 1.4, the NPWS (2018) has also used an eco-hydrological modelling process to estimate the extent of potential bog peat forming habitat likely to develop on the cutover. These figures are shown in Table 5.10 for the eight sites surveyed post-restoration, alongside the figures estimated from the ecology surveys for the predicted future extent of regenerating bog on the cutover. Note that the predicted future extent of regenerating bog on cutover excludes the cutover High Sphagnum habitat type HS3, due to the non-ombrotrophic nature of the vegetation in this habitat type.

It is clear from the figures in Table 5.10 that the eco-hydrological model is in general under-predicting the restoration potential of the cutovers with a total of 30.9ha of potential bog peat forming habitat predicted by the model compared to 35.1ha predicted by the ecology surveys. This equates to an underestimation by a factor of 13.6%. If this were to also be true for the three sites not surveyed post-restoration works (Killyconny, Moyclare and Sharavogue, which have a total of 9.4ha of potential bog forming habitat on the cutover), then a total of 10.7ha of regenerating raised bog (and ultimately ARB) can be expected to develop across these three sites. This amounts to a predicted total of 45.8ha overall. In addition as the enhanced measures were drawn up post-survey, the predicated area of regenerating bog habitat from these also needs to be added to this figure. These are; 1.2ha on Killyconny, 0.8ha on Carrownagappul and 0.4ha on Clara, amounting to 2.4ha across the three sites. Thus, the final overall figure for the area of predicted bog peat forming habitat on cutover can be estimated to be 48.2ha, which amounts to 88% of the original target area.

Table 5.10 Current and predicted future extent of regenerating bog on the cutover (the sum of HS1 and HS2 habitat types) from the ecology surveys and the extent of potential bog peat forming habitat modeled on the cutover by the NPWS (2018). Note only the eight sites on which a post-restoration habitat survey was undertaken are included.

Site Code/Name	Current extent of ombro-trophic High Sphagnum habitat on the cutover (ha) (HS1+HS2)	Current extent of non-ombro-trophic High Sphagnum habitat on the cutover (ha) (HS3)	Predicted future extent of regenerating bog on the cutover (ha) from the ecology surveys[1]	Modeled extent of potential bog peat forming habitat on the cutover
000572 Clara Bog	1.9	1.6	7.9	6.9
000575 Ferbane Bog	0.1	0	1.0	0
000580 Mongan Bog	1.2	0.3	1.8	4.1
000582 Raheenmore Bog	0.2	0.7	0.2	1.3
000597 Carrowbehy Bog	2.7	0.7	5.0	4.6
000679 Garriskil Bog	1.8	0.2	4.0	2.4
001242 Carrownagappul Bog	3.4	6.8	10.6	5.3
002341 Ardagullion Bog	1.0	0.5	4.6	6.3
TOTAL	**12.3**	**10.8**	**35.1**	**30.9**

[1] It should be noted that these figures are indicative.

5.2.4 Monitoring Relevés on the cutover

A total of 231 monitoring relevés (MR's) have been established on the cutover across the 12 sites as shown in Table 5.11 below (Appendix IV Maps 1 for relevé locations).

A subset of 170 monitoring relevés were resurveyed following the completion of restoration works on the cutover. The monitoring relevés show similar changes as the habitat data when the baseline data are compared with the post-restoration data. In particular, there has been a dramatic increase in mean cover of open water (Table 5.10). In several relevés, the increase in open water has resulted in a decrease in *Sphagnum* cover, i.e. existing *Sphagnum* patches have been flooded. When these plots – where open water has increased at the expense of *Sphagnum* – are omitted, there is little or no increase in mean *Sphagnum* cover (Table 5.10).

Table 5.11 Mean cover of *Sphagnum* and open water (percent cover ± standard error) pre- and post-restoration

	Baseline	Post-restoration
Sphagnum cover[1]	23.4 ± 2.1	26.4 ± 2.2
Open water cover	0.3 ± 0.09	13.3 ± 2.2

[1] Relevés where *Sphagnum* cover decreased as a result of increases in open water are excluded.

The hydrological model used to predict PPF areas on the cutover was successful in identifying areas that would become wetter post-restoration. The mean increase in open water in PPF relevés was much greater than that in non-PPF relevés (Table 5.12). The fact that open water appears to have increased in non-PPF areas suggests that the hydrological model has under-predicted restoration potential on the cutover. There is little or no overall difference in change in *Sphagnum* cover between PPF and non-PPF relevés.

Table 5.12 Mean change in cover of *Sphagnum* and open water (percent cover ± standard error) following restoration works in PPF and non-PPF relevés

	PPF	Non-PPF
Sphagnum cover change[1]	2.5 ± 1.3	4.3 ± 1.9
Open water cover change	16.6 ± 2.9	4.1 ± 2.1

[1] Relevés where *Sphagnum* cover decreased as a result of increases in open water are excluded.

Although mean changes in *Sphagnum* cover were not large due to the limited time post-restoration, individual relevés did change significantly. The habitat group membership of each relevé mostly remained the same pre- and post-restoration. Of those relevés assigned to the HS group in the baseline survey, six appeared to dis-improve to the MS and LS groups, in part due to loss of *Sphagnum* cover to machine disturbance or flooding, whereas one relevé flooded completely (FL) (Table 5.13). Of the relevés assigned to the MS, LS and BP groups in the baseline survey, more moved to a group with higher *Sphagnum* cover than dis-improved. Most remarkably, four relevés in the LS and BP groups moved directly to the HS group post-restoration (Table 5.13).

Table 5.13 Habitat group changes following restoration works. Shown are numbers of relevés.

Baseline Habitat Group	Post-restoration Habitat Group				
	HS	MS	LS	BP	FL
High Sphagnum (HS)	29	5	1	0	1
Moderate Sphagnum (MS)	8	25	1	3	1
Low Sphagnum (LS)	2	7	41	2	0
Bare Peat (BP)	2	3	9	5	0

Overall vegetation composition changed significantly after restoration on the cutover. A permutational multivariate analysis of variance was carried out on the monitoring relevé vegetation data using the function `adonis` in the *vegan* R package. This found that the vegetation composition of the baseline relevés was significantly different ($F = 2.00$, $p < 0.001$) than that of the relevés after restoration works were carried out. Vegetation composition in in the PPF areas changed more than in the non-PPF areas. Mean Bray-Curtis distance between pairs of relevés pre- and post-restoration was 0.32 in the PPF areas and 0.24 in the non-PPF areas, and this difference was significant ($F = 0.40$, $p = 0.002$).

Table 5.14 summarises the main species that increased and decreased in mean abundance following restoration works. The table shows the species that are present in more than 20 relevés (either in the baseline, the resurvey, or both) with the 10 greatest increases in percent cover and the 10 greatest decreases. The species with the greatest increases are mainly those of wet bog habitats, whereas those with the greatest decreases are largely characteristic of dry bog or heath habitats.

Table 5.14 Mean changes in species abundance post-restoration. Shown are species occurring in more than 20 relevés with the 10 greatest increases and 10 greatest decreases.

Species	n	Percent (%) change ± SE
Sphagnum cuspidatum	56	4.9 ± 0.7
Sphagnum palustre	56	3.9 ± 0.8
Eriophorum angustifolium	142	3.6 ± 1.2
Sphagnum auriculatum	22	3.6 ± 0.4
Juncus bulbosus	28	2.3 ± 0.8
Aulacomnium palustre	66	0.9 ± 0.8
Pleurozium schreberi	23	0.7 ± 0.4
Sphagnum tenellum	58	0.5 ± 0.4
Carex panicea	74	0.5 ± 0.4
Salix cinerea	45	0.5 ± 0.6
Hypnum jutlandicum	156	-1.5 ± 0.8
Kindbergia praelonga	31	-1.6 ± 0.4
Rubus fruticosus agg.	24	-1.9 ± 1.0
Campylopus introflexus	66	-2.0 ± 0.3
Trichophorum germanicum	44	-2.1 ± .0.4
Erica tetralix	137	-2.6 ± 0.4
Pseudoscleropodium purum	67	-2.9 ± 0.8
Sphagnum papillosum	85	-3.6 ± 0.8
Calluna vulgaris	152	-3.8 ± 1.2
Molinia caerulea	136	-4.7 ± 1.2

5.3 Transects

5.3.1 Killyconny Transect and cutover study

As indicated in section 3.3.1, an ecological monitoring transect was established on the western cutover of Killyconny in October 2005 by Dwyer and Wann (2005) prior to restoration works being implemented so that the impact of those works on the vegetation could be monitored. These restoration works pre-dated *The Living Bog*, but offered a great opportunity to assess how the vegetation on the cutover had developed over ca ten years after restoration.

This transect, which comprised 26 relevés (Q1-Q17 on the cutover, Q19-Q26 on the high bog and Q18 on the facebank) was resurveyed in October 2018 (the data forms part of the data manifest of the project detailed in Appendix III). Two of the cutover relevés (Q1 & Q2) were road-side of the barrier dam. The success of the restoration works in this area are indicated in Figure 2 below which compares the percentage *Sphagnum* cover recorded at each quadrat inn 2005 and 2018. A detailed survey of the cutover was also carried out in 2019 and compared with observations of the area from 2005. A scientific paper presenting the results of the before-and-after survey was published in *Biology and Environment* by Crowley *et al*. (2021). The abstract is reproduced below and the full paper is available at https://doi.org/10.3318/bioe.2021.09 .

> **ABSTRACT:** *"Restoration works involving the blocking of drains with peat dams and the construction of a marginal berm along the edge of the cutover on Killyconny Bog in Co. Cavan, Ireland were carried out in the mid to late 2000s. Vegetation change between a pre-restoration baseline and surveys carried out 7–13 years post-restoration are assessed and demonstrate that 5.0ha of Sphagnum-rich regenerating bog vegetation has developed across the 26.9ha study site since restoration works were implemented. Although the restoration measures have triggered Sphagnum regeneration, increased the number of positive indicators species of Active Raised Bog (ARB) and initiated the process of peat-formation, the vegetation still lacks the presence and/or abundance of some critical ARB indicators. Moreover, 56% of the site is still dominated by vegetation with a low Sphagnum cover; 44% by Calluna vulgaris dominated vegetation and 12% by Molinia caerulea dominated vegetation. The key importance of topography in determining restoration potential is highlighted as extremely fine variations in topography appear to have resulted in significant differences in the vegetation that has developed. Any further increase in the area of regenerating bog on the cutover is likely to require enhanced restoration works such as cell bunding and additional marginal berms, the design of which will be informed using the modelling techniques outlined. Although not yet considered ARB habitat, the 19% of the Killyconny cutover that is classed as regenerating is clearly of conservation significance as a peat-forming habitat that supports assemblages of several specialist species and demonstrates how restoration works that raise water levels can initiate Sphagnum regeneration in a relatively short period of time."*

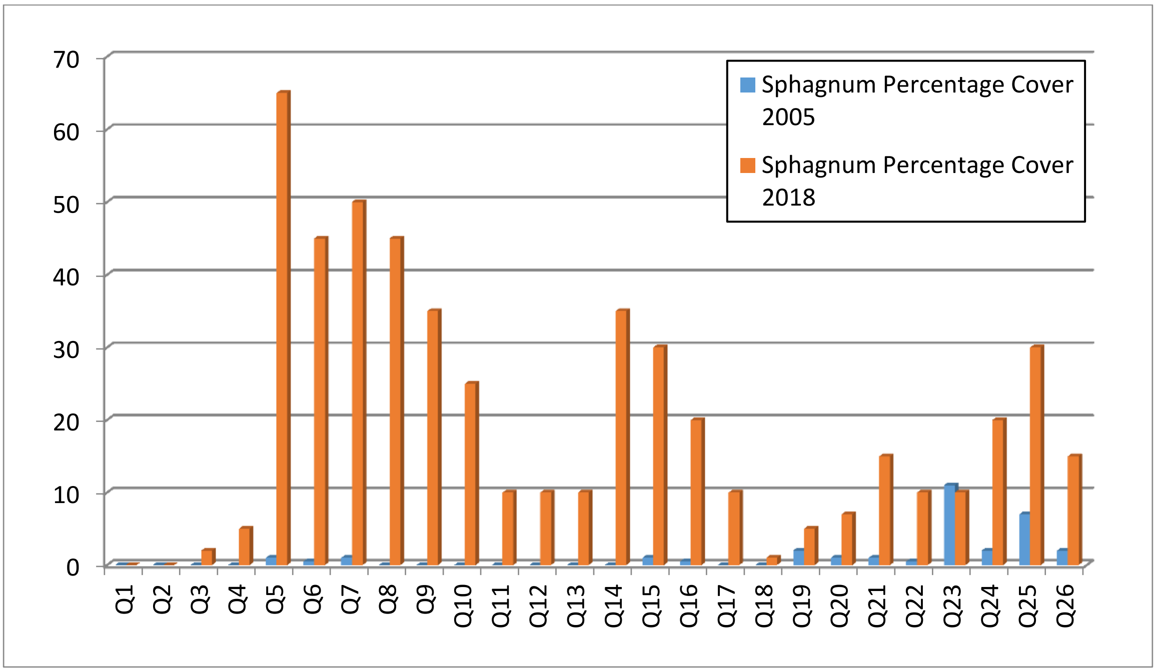


Figure 2 Percentage Sphagnum cover per quadrat in 2005 and 2018.

Ardagullion Transects

As indicated in section 3.3.2, two vegetation monitoring transects were established on Ardagullion in July 2018. This data forms part of the data manifest of the project detailed in Appendix III. Transect 1, runs perpendicularly out from the barrier dam and includes 15 quadrats on the cutover and 9 on the high bog running as far as ARB. Transect 2 runs perpendicularly across drains on the north-eastern cutover and includes 20 quadrats.

These were not re-surveyed post-restoration.

5.3.2 Carrownagappul Transect

As indicated in section 3.3.3, a vegetation monitoring transect was established on Carrownagappul in July 2019. This data forms part of the data manifest of the project detailed in Appendix III. The aim of this transect was to determine if there was any impact on the ombrotrophic high bog adjacent to the track brought about by blocking the drains along the track.

This transect was not re-surveyed post-restoration.

5.4 Interesting species records

A number of new vice-county records of bryophytes were collected during *The Living Bog* vegetation monitoring surveys (Table 5.15). There were also two records of species not seen in their vice-counties since before 1960, known as "debracketers" since old records are bracketed to indicate they may no longer be extant.

Table 5.15 Notable bryophyte records collected during The Living Bog. Status indicates whether the record is a new vice-county record (NVCR) or a debracketer.

Species	Status	Vice-County	Recorded on
Cephaloziella divaricata	NVCR	Offaly (H18)	Mongan
Cephaloziella hampeana	NVCR	North-east Galway (H17)	Carrownagappul
Plagiothecium denticulatum var *denticulatum*	NVCR	Offaly (H18)	Clara
Polytrichum longisetum	Debracketer	Cavan (H30)	Killyconny
Scapania irrigua	NVCR	Offaly (H18)	Clara
Sphagnum contortum	NVCR	Offaly (H18)	Mongan
Sphagnum divinum	NVCR	Offaly (H18)	Raheenmore
Sphagnum divinum	NVCR	Westmeath (H23)	Garriskil
Sphagnum inundatum	Debracketer	Longford (H24)	Ardagullion
Sphagnum medium	NVCR	Westmeath (H23)	Garriskil
Splachnum ampullaceum	NVCR	Offaly (H18)	Sharavogue
Warnstorfia fluitans	NVCR	Longford (H24)	Ardagullion

5.5 Carrownagappul near-intact lagg zone

Lagg zones are wetlands, usually fens, along the margins of a raised bog that form the ecotone between bog and dry terrestrial habitats. No known intact lagg zones exist anywhere in Ireland or western Europe. However, a section of semi-intact lagg zone was recorded in the south-south-western area of Carrownagappul in May 2019 during a cutover habitat survey being conducted to assess the possibility of constructing a short barrier dam in the area. These plans were shelved after the survey (and a subsequent TAG site visit) as much of the area that was expected to benefit from the barrier dam was already regenerating cutover. Furthermore, the sensitivity of the area (to machinery etc.) was highlighted by the presence of the semi-intact lagg and the presence of larval webs of Marsh Fritillary. The semi-intact lagg area was mapped as transition mire (PF3 according to Fossitt (2000), which corresponds to the Annex I habitat 'transition mires and quaking bogs (7140)'), alkaline fen (PF1 according to Fossitt (2000), which corresponds to the Annex I habitat 'alkaline fens (7230)'), marsh (GM1), and wet grassland (GS4). The transition mire vegetation corresponds with the vegetation community FE2F *Menyanthes trifoliata* – *Calliergonella cuspidata* mire under the Irish Vegetation Classification (NPWS *et al.*, 2019).

A list of species recorded in the area includes *Menyanthes trifoliata*, *Equisetum fluviatile*, *E. palustre*, *Caltha palustris*, *Ranunculus flammula*, *Hydrocotyle vulgaris*, *Holcus lanatus*, *Potentilla palustre*, *Anthoxanthum odaratum*, *Cardamine pratensis*, *Galium palustre*, *Mentha aquatica*, *Myrica gale*, *Salix cinerea*, *Angelica sylvestris*, *Lychnis flos-cuculi*, *Briza media*, *Agrostis stolonifera*, *Cirsium dissectum*, *Pedicularis palustris*, *Succisa pratensis*, *Pinguicula vulgaris*, *Dactylorhiza fuchsii*, *D. traunsteinerioides*, *Juncus articulatus*, *J. conglomeratus*, *Carex viridula*, *C. echinata*, *C. pulicaris*, *C. demissa*, *Scorpodium cossonnii*, *Campylium stellatum*, *Bryum pseudotriquetrum*, *Calliergon cordifolium* and *Calliergonella cuspidata*.

A proposal was also submitted to the NPWS (Peatland Issues & Land Designation Unit) to amend the SAC boundary here as part of the lagg zone lies outside of the current SAC boundary. This amendment is not likely to be enacted on until after *The Living Bog* project has ended, but is necessary to protect the hydrological unit of the bog as well as the lagg zone, which is itself of high ecological and scientific value.

A scientific paper of the study of the lagg zone has been accepted by *Biology and Environment* by Crowley *et al*. (2022). The abstract of the paper is given here:

> **ABSTRACT:** "*Despite the importance of lagg zones in the function and restoration of raised bog systems, there have been limited studies on their vegetation communities and environmental characteristics. Given their importance and lack of study, the vegetation in the near intact lagg zone in the south-south-west of Carrownagappul Bog in Co. Galway was sampled along four transects in July 2020. Cluster analysis separated the vegetation, encompassing 97 species, into five vegetation types. There were affinities between these vegetation types and a range of Irish Vegetation Classification bog, heath, grassland and fen communities as well as two Habitats Directive Annex I habitat types, transition mires and alkaline fen. In addition, a population of the Annex II listed Marsh Fritillary (*Euphydryas aurinia *(Rottemburg, 1775)) was recorded from the area. In general, the vegetation communities reflected a gradient of increasing alkalinity, moisture and nutrient status from ombrotrophic raised bog to minerotrophic fen. The diversity of the vegetation over a small area and its near-natural conditions underscores the conservation significance of the lagg zone, and these findings accentuate the hydrological perspective that restoration of the lagg should, where possible, be a key element in raised bog restoration. The current lack of a characterisation of the lagg types found in Ireland is a barrier to developing a sound restoration and conservation management strategy.*"

5.6 Historical extent of bog

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 necessary 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 the ARB and DRB habitats. In addition, 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 extent of bog has been declining at these 12 sites since they were first mapped by the Ordnance Survey Ireland in the 1840s. Table 5.15 below shows the declining extent. These maps were included in the mid-term report. It should be noted that the bog area estimates in Table 5.16 from the 1840s and 1910s do not refer solely to the extent of high bog (i.e. they include some areas that were already cutover), but as the areas reported for the 1970s and 2012 do.

Table 5.16 The historical extent of bog across the 12 LIFE sites

Site Code/Name	**1840s (ha)[1]**	**1910s (ha)[2]**	**1970s (ha)[3]**	**2012 (ha)[3]**	**% of 1840s extent remaining**
000006 Killyconny Bog	227	199	90	86	38%
000572 Clara Bog	925	797	469	451	49%
000575 Ferbane Bog	204	176	121	120	59%
000580 Mongan Bog	305	243	174	134	44%
000581 Moyclare Bog	140	124	81	78	56%
000582 Raheenmore Bog	175	151	131	131	75%
000585 Sharavogue Bog	293	276	160	152	52%
000597 Carrowbehy Bog	662	477	328	255	39%
000604 Derrinea Bog	185	144	122	94	51%
000679 Garriskil Bog	302	272	175	173	57%
001242 Carrownagappul Bog	524	505	355	336	64%
002341 Ardagullion Bog	118	103	64	62	53%

[1] Includes areas that were already cutover bog at that time. Although referred to here as the 1840's extent, the maps of that series span the years 1829-1842.

[2] Includes areas that were already cutover bog at that time. Although referred to here as the 1910's extent, the maps of that series span a longer time frame.

[3] Includes high bog only, but does not include any high bog that was forested at the time. However, it does include isolated areas of high bog that lie outside of the SAC.

6 Results and Discussion

6.1 ARB Targets on High Bog

From the results described in section 5.1.2, it is clear that on the five sites where post restoration ecotope surveys were undertaken, there has been an indication of improvement on the high bog with the area of ARB increasing on all five. The larger increases have taken place on the larger sites and, in the case of Carrowngappul, the site where the most restoration took place. Overall on these five sites, 43.0ha of new areas of ARB have developed within just three years of restoration works. This equates to 19.5% of our long-term target for the development of new areas of ARB (222.2ha) on the high bog for all 12 sites. Thus, it can be seen that these sites are on the correct trajectory to achieve the ARB targets. From an analysis of the hydrological modelling discussed in section 5.1.4, it is estimated that 95.0% of the targets for ARB on the high bog will be met. However, the model does not account for the downward water losses that are occurring on Clara. The last ecotope survey of Clara showed a decline in the extent of ARB on Clara West, and continued declines can be expected until the issue concerning the changes in underlying groundwater head due to deep-cut drainage in the area are addressed. However, an estimate of the continued losses cannot be made using the current eco-hydrological model. The NPWS have researched potential engineering solutions to combat this problem and have drafted a plan to infill a large area of the cutover. The cost/benefit of this plan is currently being reviewed by the NPWS.

Thus, overall although the model is predicting that 95% of ARB targets on the high bog will be achieved, we know that as long as the issues caused by the deep-cut drainage on the cutover on Clara are not addressed, 95% is an over-estimation.

6.2 ARB Targets on cutover

Prior to *The Living Bog*, no ARB (Annex I habitat 7110) was recorded on Irish cutovers. In 2020, as part of *The Living Bog* project, ARB was described (and defined) as occurring on Irish cutover by Smith and Crowley (2020). This was as part of a new cutover habitat classification system developed by *The Living Bog*. It is likely that ARB will take longer to develop on cutover than on high bog as some characteristic species appear to take longer to colonise the cutover than restored areas of high bog. Nevertheless, 4.6ha of ARB were mapped across the eight cutovers that were surveyed post restoration, along with an additional 8.4ha of ombrotrophic High *Sphagnum* habitat (HS1 and HS2) that may develop into ARB within the next ca. 30 years. A further 10.4ha of HS3 *Sphagnum palustre-Molinia caerulea* cutover bog was also recorded. Although this is a flushed habitat type that is unlikely to develop into ARB, it is a high quality poor fen habitat type that may be a net carbon sink or may be developing along that trajectory. As a wet, *Sphagnum*-rich habitat, it too is of high conservation value, and where birch regeneration is significant, it may develop towards the priority Annex I habitat 'bog woodland (91D0)'. Furthermore, High *Sphagnum* (HS) habitats are also present on the four sites not surveyed post restoration works. Killyconny alone has 5.4ha of ombrotrophic High *Sphagnum* habitat (HS1 and HS2), mainly as a result of the restoration works that were carried out there in the mid 2000s.

Post restoration, within just three years and on just eight sites, there has been a 4.7ha increase in High *Sphagnum* (HS) habitats of which 1.9ha is ombrotrophic HS1 or HS2 (Table 5.6). This rapid increase demonstrates the early benefits of cutover bog restoration. Other evidence that points to the sites following the desired trajectory towards wetter conditions includes increases in open water and significant changes in vegetation composition in the monitoring relevés (section 5.2.4). It should be noted that the decrease of 0.7ha in HS1 habitat (Table 5.6) is due to these areas becoming too wet and partially flooded (c.f. Table 5.10). These areas now support shallow open water <0.5m deep and are expected to be colonised relatively quickly by *Sphagnum cuspidatum*. It is likely they will (as will most of the 5.6ha of open water mapped) develop into HS habitat and perhaps ARB within 30 years. Another desired trend observed post restoration is the decrease in extent of Low *Sphagnum* (LS) habitat (15.2ha) with some developing into Moderate *Sphagnum* (MS) habitats, some into HS and some into Bare Peat (BP) habitat types (Tables 5.6 and 5.12). One undesired change was the increase in extent of BP habitats of 3.2ha. This was caused by machinery disturbance during restoration works and would be expected to be reversed the next time out. Although there was almost no change in the extent of MS habitat, it is merely a net balance as some MS developed from LS and some developed into HS.

It is difficult to estimate the extent of ARB that will be achieved on the cutover, and for simplification, it is assumed that HS1 and HS2 habitats will develop into ARB over time. An analysis of the eco-hydrological model in tandem with the restoration works carried out (see Table 5.3) is predicting that 41.2ha of bog forming habitat (or HS1/HS2) will be achieved across the 12 cutovers (0.1ha higher than the refined model target of 41.1ha). This equates to 75.7% of the original target (see Appendix I). However, indications from the ecology surveys are that the eco-hydrological model has under-predicted the amount of ombrotrophic HS habitat achievable on the cutover with a figure of 48.2ha estimated as being achievable from these surveys equating to 88.6% of the original target.

Overall while it is clear that the ARB targets have not yet been achieved, it can be expected that 75-88% of the targets will be achieved with the trajectory clearly on the right path.

6.3 Overall ARB targets

Overall the ARB target to be achieved across the 12 sites was 752.7ha composed of 698.3ha on the high bog and 54.4ha on the cutover. Results in section 5 indicate that there has been an improvement in habitat condition across all eleven sites in which restoration work was carried out. An analysis of the potential impact of the proposed work that was not carried out on the ARB targets indicates that *The Living Bog* project is on course to achieve 728.3ha (687.1ha on the high bog and 41.2ha on the cutover) of the 751.7ha (96.8%) of the original target. This equates to 91.2% of the new ARB (211.0ha of 222.2ha on the high bog and 41.2ha of 54.4ha on the cutover) that was to be created from the project actions.

6.4 Sphagnum transfer experiment

One of the findings of the cutover bog surveys was that some species appeared to take longer to colonise the cutover and thus it was suggested that small scale experiments be carried out on Killyconny Bog to see if this process could be speeded up (Crowley *et al*., 2021). Furthermore, analysis of the western cutover on Killyconny, c. ten years after initial restoration work highlighted a number of areas that require enhanced restoration works if they were to be restored to bog peat forming habitat. These enhanced measures, in the form of bunds, were constructed on the western cutover of Killyconny in February 2021 and soon after these were completed a number of suitable locations were chosen for the transfer of samples of the *Sphagnum* mosses *S. beothuk* and *S. austinii*. These two species are characteristic of good quality ARB in Ireland (Kelly and Schouten, 2002; NPWS, 2019), but were still absent from the cutover on Killyconny over 10 years after the initial restoration works were undertaken (despite their presence on the high bog). These two species were also very rarely found (1.0% of relevés and never together) in the baseline surveys of the cutovers of the twelve *Living Bog* project sites.

The donor site for the *Sphagnum* transfer was the nearby Oristown Bog, which is located 13km to the ESE of Killyconny (Figure 3). Oristown supports ca 40ha of high bog, but is actively cut for turf and has no designated status. Cutting is extensive, and the site is drying out. Conditions are thus no longer optimal for *Sphagnum austinii* and *S. beothuk* and their long term future on Oristown is doubtful. Small samples were judiciously collected from individual clumps of *Sphagnum* and across as wide an area as possible. It was then loosely gathered into one 40cm x 40m shopping bag. Subsequently, a number of potentially suitable locations were chosen on the western cutover of Killyconny for transfer of the samples of *Sphagnum*. A GPS reading was recorded at each of these locations using a Garmin handheld GPS device (See table 6.1 and Figure 4). Transfer took place on 29th June 2021 after the enhanced restoration were carried out. No further monitoring was possible in the timescale of the *Living Bog* project.

Table 6.1 the X, Y co-ordinates of the samples of Sphagnum austinii and S. beothuk transferred to the western cutover of Killyconny.

Sample Number	X	Y
1	667822	782929
2	667820	782921
3	667819	782920
4	667809	783037
5a	667833	782975
5b	667836	782966
5c	667830	782968
5d	667827	782975
5e	667832	782976
6	667430	782294
7	667894	782790

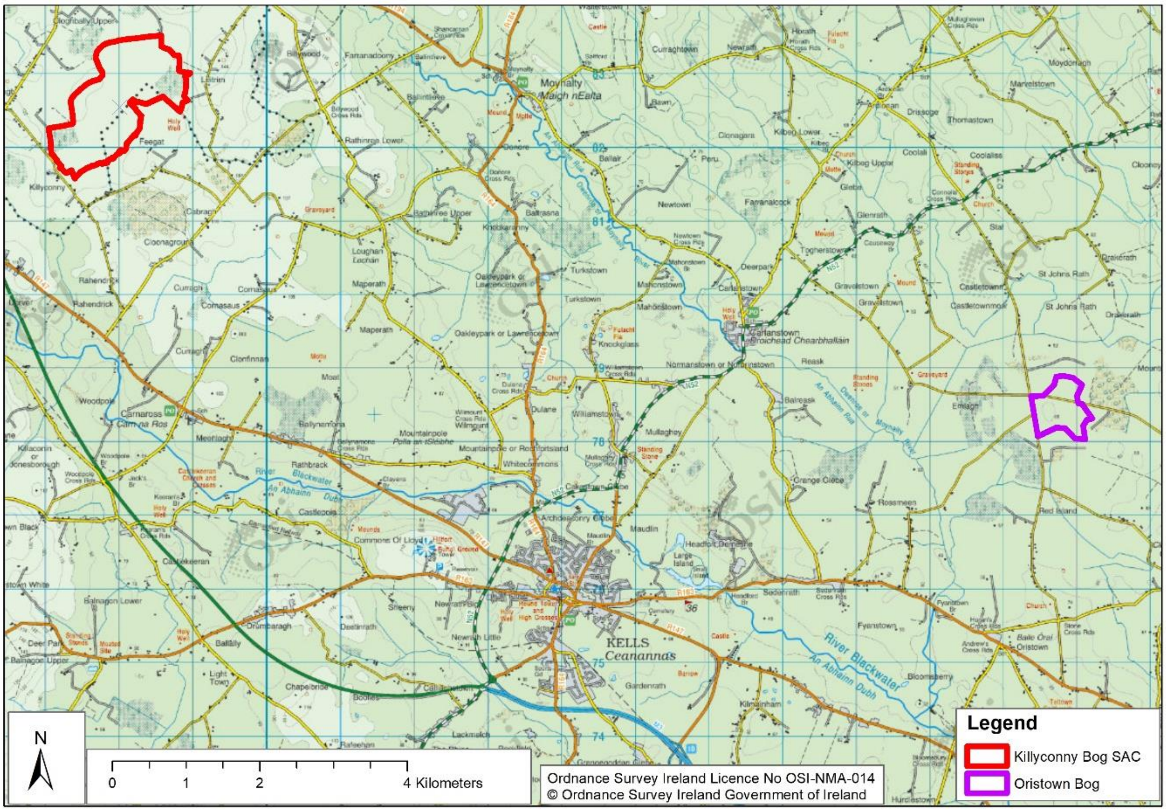


Figure 3 location of the donor site (Oristown Bog) in relation to Killyconny Bog SAC.

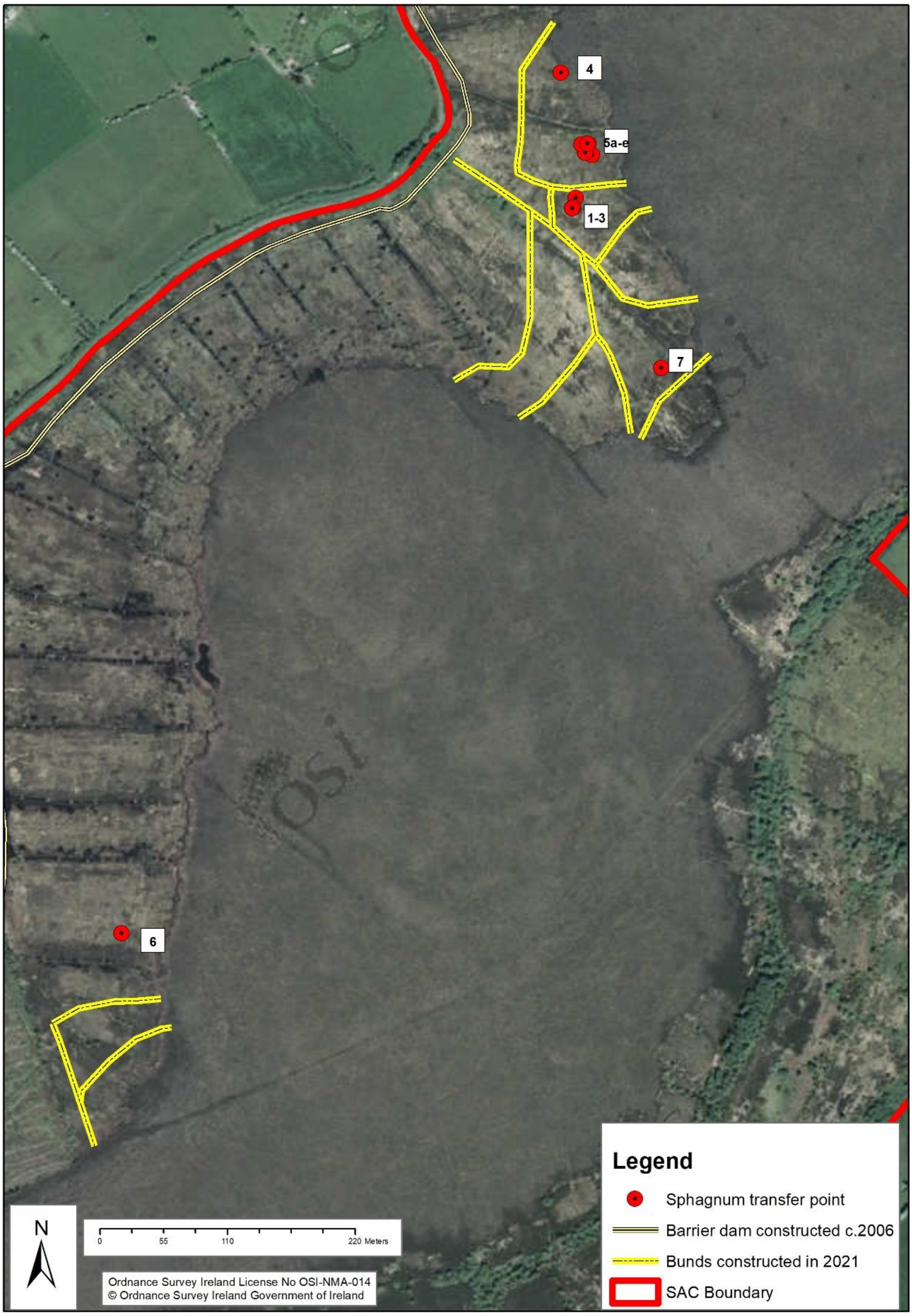


Figure 4 location of the Sphagnum transfers on the Killyconny cutover. Specimens transplanted in March 2021.

6.5 Bird Surveys

No faunal studies were factored in to the original *Living Bog* Project. However late on in the project (2019), the opportunity arose to work with *BirdWatch Ireland* on a number of community engagement issues. Following on from this, a plan was hatched to undertake bird surveys of a selection of *The Living Bog* project sites. Thus, *BirdWatch Ireland* (funded by the Peatlands Community Engagement Scheme of the Department of Housing, Local Government and Heritage, and the Heritage Office of Offaly County Council and Longford County Council) aided by *The Living Bog* carried out census bird populations on five project sites; Ardagullion, Ferbane, Mongan, Moyclare and Killyconny. The aim was not only to understand the current importance of these sites but also to assess how birds may be affected by the inevitable habitat changes brought about by restoration over time. The surveys were carried out 1-2 years post restoration work. Early findings were published in an article in the *BirdWatch Ireland* magazine *Wings* and in a report sent to Longford County Council of the findings on Ardagullion Bog (Kavanagh *et al*., 2021). Analysis of the findings is ongoing and more reports are being prepared with the possibility of a manuscript also being prepared for submission to a scientific journal. In the *Wings* article, Lusby (2022) states the aims of the surveys as to:

- Provide baseline information on the breeding bird species assemblages on raised bogs
- Determine the habitat associations of breeding bird species on raised bogs
- Determine the presence, abundance and densities of open habitat (e.g. Meadow Pipit, Skylark) and raised bog specialists (e.g. Curlew, Snipe, Redshank and Merlin etc.)
- Assess the effects of restoration measures on breeding bird assemblages and abundance
- Establish a baseline of bird species and population data to allow future changes in bird species composition and abundance to be measured

A total of 62 bird species were recorded on the five raised bogs (across the high bog, cutover bog and surrounding scrub and woodland), of which 20 (32%) are of listed on the Birds of conservation concern in Ireland (Gilbert *et al*., 2021); eight on the red list and 12 on the amber list. The following is an excerpt from Lusby (2022):

> *Twenty of these species are on the Red and Amber list on the Birds of Conservation Concern in Ireland, which emphasises the immense conservation value of these sites. Curlew were present on three raised bogs (Killyconny, Ferbane and Mongan) and Redshank on two sites (Mongan and Ardagullion), which given the perilous state of their populations, even these low numbers are of national significance. Snipe occurred on all sites and in higher breeding densities than reported for most other bogs, while Woodcock and Kestrel, two other red-listed birds of conservation concern were also found on all sites surveyed. Meadow Pipit and Skylark were the commonest birds encountered on the high bog, as is expected on relatively intact raised bogs, and both species occurred at breeding densities which compared well to other peatland sites. The habitat associations of breeding breeding birds on the high bog also provides some indications of the potential benefits of the restorations, as the areas of active raised bog which are expected to further expand over time, supported a higher diversity of open-habitat specialists and red-listed Birds of Conservation Concern than the non-active*

raised bog, although the difference was marginal and the non-active raised bog was also important in the species and numbers that it supported.

6.6 Reports and Publications

Two full scientific papers (Crowley *et al*., 2021; 2022) and an *Irish Wildlife Manual* (Smith and Crowley, 2020) were published by *The Living Bog*. These are discussed in sections 4, 5.3.1 and 5.5. The possibility of the preparation of two more scientific papers is also being explored: one on the impacts of the restoration measures on the monitoring relevés and the other a case study of Carrownagappul. A report on the impact of restoration measures on breeding bird assemblages is also being produced by a project running alongside *The Living Bog* and this may also be prepared for submission to a scientific journal.

7 After-LIFE plan

An overall AfterLIFE plan is currently being developed for the *Living Bog* project. This will encompass a variety of elements such as upkeep of visitor facilities as well as continued monitoring of a selection of the hydrology and ecology monitoring network. Restoration works are currently (March 2022) being verified by Bord na Móna through an analysis of drone survey aerial photography. Any proposed works that were not carried out by the *Living Bog* project will be highlighted along with the impacts this had on ARB targets. Future restoration work on these will be prioritised accordingly. One area where future work is certainly necessary is on the southern cutover of Clara West where ARB is currently being lost from the high bog due to deep-cut drainage on the southern cutover, which has caused changes in the underlying groundwater head (Regan *et al*., 2019). An engineering solution has been developed to combat this issue and the cost/benefit of this is currently being reviewed by the NPWS.

In any case, vegetation monitoring of *The Living Bog* sites will continue into the future. The NPWS has a well-established high bog monitoring programme that runs in six year cycles. Four *Living Bog* sites (Clara, Raheenmore, Derrinea and Mongan) are due to be monitored as part of the Raised Bog Monitoring 2021-24 programme in which a total of 31 SAC and NHA bogs are to be surveyed using the standard NPWS ecotope mapping techniques. High bog monitoring quadrats will also be revisited at this time. Additionally these four *Living Bog* sites together with another ten raised bog SACs are to make up the raised bog National Ecosystem Monitoring Network (co-ordinated by the Environmental Protection Agency), sites on which the levels of atmospheric nitrogen deposition will be monitored.

Future NPWS Raised Bog Monitoring Programmes will also now need to include an element of cutover habitat surveying since the conservation objectives of raised bog SACs now include achieving a specific area of ARB (or at least peat-forming habitat) on the cutover. Cutover monitoring plots can be re-visited during these surveys.

However, in the shorter term (ca 5 years) in order to aid the overall understanding of the impacts of the project’s restoration, a number of sites will be selected for full ecotope, cutover habitat, high bog quadrat and full species releves survey with surveys to be undertaken in ca 2025-26. The sites selected are from those that are to have continued hydrological monitoring so that datasets can be combined for a more holistic analysis. The following sites are suggested:

1. Carrownagappul Bog
2. Ardagullion Bog
3. Ferbane Bog
4. Moyclare Bog
5. Killyconny Bog
6. Garriskil Bog

Note that the sixth site (Garriskil Bog) will not have continued hydrological monitoring. Ecotope surveys will follow the methodology described by Fernandez *et al*. (2014), based on raised Bog ecotope vegetation community complexes developed by Kelly and Schouten (2002). Cutover habitat surveys will use the classification system developed by Smith and Crowley (2020). To aid the mapping, high resolution aerial photography of these sites will be undertaken prior to surveys commencing in 2025. The monitoring transects on Carrownagappul, Ardagullion and Killyconny are also to be repeated. The methodology (i.e. survey of 30 vegetation plots) used to describe the western cutover on Killyconny by Crowley *et al.* (2021) should also be repeated to characterise how the restoration of that site is progressing. The number of monitoring plots on each of the sites is shown in Table 7.1 with a total of 208 plots across the five sites. These are 4m x 4m plots. This does not include the monitoring plots along the transects on Ardagullion (44 plots, each 2m x 2m), Carrownagappul track transect (12 plots, each 2m x 2m) and Killyconny (27 plots, each 5m x 5m) or the 30 vegetation plots (2m x 2m) undertaken across the western Killyconny cutover to characterise its vegetation. Thus, the total proposed number of plots to be resurveyed is 321.

Site Code/Name	Monitoring Quadrats on HB	Monitoring Releves on cutover	Total Number of MQ's/MR's
000006 Killyconny Bog	9	14	23
000575 Ferbane Bog	12	16	28
000581 Moyclare Bog	14	25	39
000679 Garriskil Bog	11	12	23
001242 Carrownagappul Bog	26	38	64
002341 Ardagullion Bog	8	23	31
TOTAL NUMBER OF MONITORING PLOTS	**80**	**128**	**208**

8 Acknowledgements

Special thanks to the project team and members of the Technical Advisory Group, Jack McGauley, John Cody, Ronan Casey, Evelyn Slevin, Dr Maurice Eakin, Dr Shane Regan, Francis Mackin, Hugh Cushnan, Fernando Fernandez Valverde, and Jim Ryan for continued support throughout the project and to all members of the Project Steering Group. Thanks to the landowners and particularly to the community members of Carrownagappul Bog (Galway's Living Bog), the Killyconny Bog Committee and Clara Bog for assisting and welcoming *The Living Bog* Project as well as providing local historical knowledge. Thanks to John Derwin and Philip Perrin for providing technical expertise at various stages of the project. Thanks to NPWS staff including Tríona Finnen, Sue Moles, Colm Malone, Noel Bugler and Rebecca Teesdale. Gratitude is also extended to Dr Mark McCorry and Sheila Kelly of Bord na Móna, John Lusby of BirdWatch Ireland and Suzanne Nally of the Peatlands Unit. Thanks also to Robert McCormack and Caroline Lalor for providing fieldwork assistance.

9 References

Andersen, R., Farrell, C, Graf, M., Muller, F., Calvar, E., Frankard, P., Caporn, S., Anderson, P. (2017). An overview of the progress and challenges of peatland restoration in Western Europe. *Restoration Ecology* 25: 271-282.

Bonn, A., Reed M. S., Evans, C. D., Joosten, H. , Bain, C., Farmer, J., Emmer, I., Couwenberg, J., Moxey, A., Artz, R., Tanneberger, F von Unger, M., Smyth, M-A. & Birnie, D. (2014) Investing in nature: Developing ecosystem service markets for peatland restoration. *Ecosystem Services* 9; 54-65.

Bord na Móna (2016) *Biodiversity Action Plan 2016–2021*. Bord na Móna. Dublin. (Accessible at http://www.bordnamona.ie/company/bord-na-mona-story/biodiversity/biodiversity-action-plan/)

Clements, F.E. (1916) *Plant succession, An analysis of the development of vegetation.* Publication No. 242. Carnegie Institution, Washington, DC.

Cross, J. R. (1990) *The raised bogs of Ireland*. Report to the Minister of State at the Department of Finance. Stationery Office, Dublin.

Crowley, W., Smith, G.F. and Mackin, F. (2022) Plant communities in the gradient from raised bog to fen in a near intact lagg zone in Carrownagappul Bog, Ireland*. Biology and Environment: Proceedings of the Royal Irish Academy***122**, No. 1, 1–15*.*

Crowley, W., Smith, G.F., Mackin, F., Regan, S., Fernandez Valverde, F. and Eakin, M. (2021) Recovery of the vegetation of a cutover raised bog in Ireland following rewetting measures. *Biology and Environment: Proceedings of the Royal Irish Academy* **121**, No. 2, 95–121. DOI: 10.3318/ BIOE.2021.09

Cushnan, H. (2022) Hydrology Monitoring (D1) Final Report for *The Living Bog*. Restoring Active Raised Bog in Ireland's SAC Network 2016 – 2020 (LIFE14 NAT/IE/000032)

DAHG (2014) National Raised Bog SAC Management Plan. Draft for Consultation. Main report and appendices. Department of Arts, Heritage and the Gaeltacht.

De Cáceres, M., Font, X. & Oliva, F. (2010) The management of vegetation classifications with fuzzy clustering. *Journal of Vegetation Science*, 21, 1138-1151.

Dufrêne, M. & Legendre, P. (1997) Species assemblages and indicator species: the need for a flexible assymetric approach. *Ecological Monographs*, 67, 345- 366.

de Groot RS, Wilson MA, Boumans RMJ (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* 41:393‑408.

Douglas, C. and Grogan, H. (1985) Survey to locate raised bogs of scientific interest in counties Counties Galway (E) and Roscommon. Part II. Internal report to the Forest and Wildlife Service, Dublin.

Douglas, C. and Grogan, H. (1986) Survey to locate raised bogs of scientific interest in Counties Longford, Westmeath and East Mayo. Internal report to the Forest and Wildlife Service, Dublin.

Douglas, C. and Grogan, H. (1987) Survey to locate raised bogs of scientific interest in Counties Clare and Kerry. Internal report to the Forest and Wildlife Service, Dublin.

Douglas, C. and Mooney, E. (1984) Survey to locate raised bogs of scientific interest in Counties Galway (E) and Roscommon. Part II. Internal report to the Forest and Wildlife Service, Dublin.

Dwyer, R. & Wann, J. (2005) Survey Reports produced for National Parks & Wildlife, Moyne Division for Glen Lough, Fisherstown Bog, Killyconny Bog and Ballinderry & Ballynagrenia Bogs.

EU LIFE Project repository. European Commission website http://ec.europa.eu/environment/life (accessed 12 November 2018).

Fernandez, F., Connolly K., Crowley W., Denyer J., Duff K. & Smith G. (2014) Raised Bog Monitoring and Assessment Survey 2013. Irish Wildlife Manuals, No. 81. National Parks and Wildlife Service, Department of Arts, Heritage and Gaeltacht, Dublin, Ireland.

Fernandez, F., Fanning, M., McCorry, M. & Crowley W. (2005) Raised Bog Monitoring and Project 2004-05. National Parks and Wildlife Service, Department of Arts, Heritage and Gaeltacht, Dublin, Ireland.

Fernandez, F. & Wilson, S. (2009) Clara Bog High Bog Ecological Survey. National Parks and Wildlife Service, Dublin.

Foss, P. (1998) National Overview of the Peatland Resource in Ireland. In O'Leary, G. and Gormley, F. (eds) *Towards a Conservation Strategy for the Bogs of Ireland*, pp 3-20, Irish Peatland Conservation Council, Dublin.

Fossitt, J. A. (2000) *A Guide to Habitats in Ireland*. Heritage Council, Kilkenny.

LIFE (2014) Nature and Biodiversity project application. *Restoring Active Raised Bog in Ireland's SAC Network 2016-2020. Part B – technical summary and overall context of the project.*

Hammond, R.F. (1979) *The Peatlands of Ireland*. An Foras Talúntais, Dublin.

Hill, M.O., Preston, C.D., Bosanquet, S.D.S. & Roy, D.B. (2007) *BRYOATT: Attributes of British and Irish Mosses, Liverworts and Hornworts*. CEH, Monks Wood.

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) *PLANTATT: Attributes of British and Irish Plants - Status, Size, Life History, Geography and Habitats.* CEH, Monks Wood.

Kelly, L. (1993) Hydrology, Hydrochemistry and Vegetation of two raised bogs in Co. Offaly. Ph.D. thesis, Trinity College, Dublin.

Kelly, L., Doak, M. and Dromey, M. (1995) *Raised Bog Restoration Project: An Investigation into the Conservation and Restoration of Selected Raised Bog Sites in Ireland*. Unpublished report, National Parks & Wildlife, Department of Environment, Heritage and Local Government, Dublin.

Kelly, L. & Schouten, M. G. C. (2002) Vegetation. In: M. G. C. Schouten (Ed.), *Conservation and Restoration of Raised Bogs: Geological, Hydrological and Ecological Studies*, pp.110-169, Dúchas – The Heritage Service of the Department of the Environment and Local Government, Ireland; Staatsbosheheer, The Netherlands; and The Geological Survey of Ireland.

Legendre, P. & Legendre, L. (1998) *Numerical Ecology.* Developments in Environmental Modelling, 20. 2nd English edition. Elsevier, Amsterdam.

Mackin, F., Flynn, R., Barr, A., & Fernandez-Valverde, F. (2017). Use of geographical information system-based hydrological modelling for development of a raised bog conservation and restoration programme. *Ecological Engineering*, 106, 242-252.

NPWS (2004). Conservation Plan 2004-2009: Garriskil Bog cSAC & SPA. Draft 2. National Parks and Wildlife Service. Department of the Environment, Heritage, and Local Government, Dublin.

NPWS (2008) The Status of EU Protected Habitats and Species in Ireland. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.

NPWS (2013) The Status of Protected EU Habitats and Species in Ireland. Overview Volume 1. Unpublished Report, National Parks & Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

NPWS (2015) National peatlands strategy. National Parks & Wildlife Service, Dublin, Ireland.

NPWS (2018) National raised bog SAC Management Plan. National Parks & Wildlife Service, Dublin, Ireland.

NPWS (2019) The Status of Protected EU Habitats and Species in Ireland. Volume 2 Habitat Assessments. Unpublished Report, National Parks & Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland. Edited by: Deirdre Lynn and Fionnuala O'Neill.

NPWS, BEC Consultants & National Biodiversity Data Centre (2019) *Irish Vegetation Classification*. National Biodiversity Data Centre, Waterford. http://www.biodiversityireland.ie/projects/national-vegetation-data base/irish-vegetation-classification/

O'Connell, C. and Mooney, E. (1983). Survey to locate midland raised bogs of scientific interest. Internal report to the Forest and Wildlife Service, Dublin.

Perrin, P. (2017) *Irish Vegetation Classification Technical Progress Report No. 3*. Report prepared for NPWS, National Biodiversity Data Centre and the Heritage Council.

Perrin, P. (2020) *ERICA: Engine for Relevés to Irish Communities Assignment. Version 5.1*. BEC Consultants. Accessed 14/04/20. https://biodiversity ireland.shinyapps.io/vegetation-classification/.

Regan, S., Flynn, R., Gill, L., Naughton, O., & Johnston, P. (2019). Impacts of groundwater drainage on peatland subsidence and its ecological implications on an Atlantic raised bog. *Water Resources Research*, 55, 6153–6168. https://doi.org/10.1029/2019WR024937

Renou-Wilson, F., Moser, G., Fallon, D., Farrell, C. A., Müller, C. & Wilson, D. (2019) Rewetting degraded peatlands for climate and biodiversity benefits: Results from two raised bogs. *Ecological Engineering*, 127: 547-560.

Schouten, M. G. C. (1984). Some aspects of the ecogeographical gradient in the Irish ombrotrophic bogs. Proceedings of the 7th International Peat Congress, Dublin, 414-432. Irish National Peat Committee, Dublin.

Science for Environmental Policy (2017)

Smith, G.F and Crowley, W. (2020) The habitats of cutover raised bog. *Irish Wildlife Manuals*, No. 128. National Parks and Wildlife Service, Department of Housing, Local Government and Heritage, Ireland.

Smith, G.F., O'Donoghue, P., O'Hora, K. and Delaney, E. (2011) *Best Practice Guidance for Habitat Survey and Management*. Heritage Council, Kilkenny.

Swenson, M.M., Regan, S., Bremmers, D.T.H., Lawless, J, Saunders, M & Gill, L.W. (2019) Carbon balance of a restored and cutover raised bog: implications for restoration and comparison to global trends. *Biogeosciences*, **16**, 713–731.

Townsend, T. (1811) A Report on the Bogs to the West of District no. 6 Situated in Westmeath and King's County. 2nd report of the Commissioners appointed to enquire into the nature and extent of the several bogs in Ireland and the possibility of draining them.

Tubridy, M. (Ed.) (1984) Creation and Management of a Heritage Zone at Clonmacnoise, Co. Offaly, Ireland. Environmental Sciences Unit, Trinity College Dublin.

Tubridy, M. and Jeffrey, D. (Eds.) (1987). Clonmacnoise Heritage Zone Project. A Portfolio of Management Plans. Environmental Sciences Unit, Trinity College Dublin.

Wilson, D., Renou-Wilson, F., Farrell, C., Bullock, C. & Müller, C. (2012) *Carbon Restore - the potential of Irish peatlands for carbon uptake and storage*. Climate change research programme. Report Series No.17 prepared for the Environmental Protection Agency, Johnstown Castle, Co. Wexford, Ireland by Uni-versity College Dublin.

Appendices

Appendix I: Difference in modeled potential bog forming habitat on the cutover given in the LIFE bid document (LIFE, 2014) and that updated by the NPWS (2018)

/Site Code/Name	Modeled potential bog forming habitat (NPWS, 2018)	Modeled potential bog forming habitat (LIFE, 2014)
000006 Killyconny Bog	4.5	6.85
000572 Clara Bog	6.9	7.82
000575 Ferbane Bog	0	0
000580 Mongan Bog	4.1	4.49
000581 Moyclare Bog	4.5	5.34
000582 Raheenmore Bog	1.3	1.91
000585 Sharavogue Bog	0.4	1.03
000597 Carrowbehy Bog	4.6	7.04
000604 Derrinea Bog	0.8	1.04
000679 Garriskil Bog	2.4	3.70
001242 Carrownagappul Bog	5.3	8.51
002341 Ardagullion Bog	6.3	6.80
TOTAL	**41.1**	**54.53**

Appendix II: Cutover Habitat Recording Form

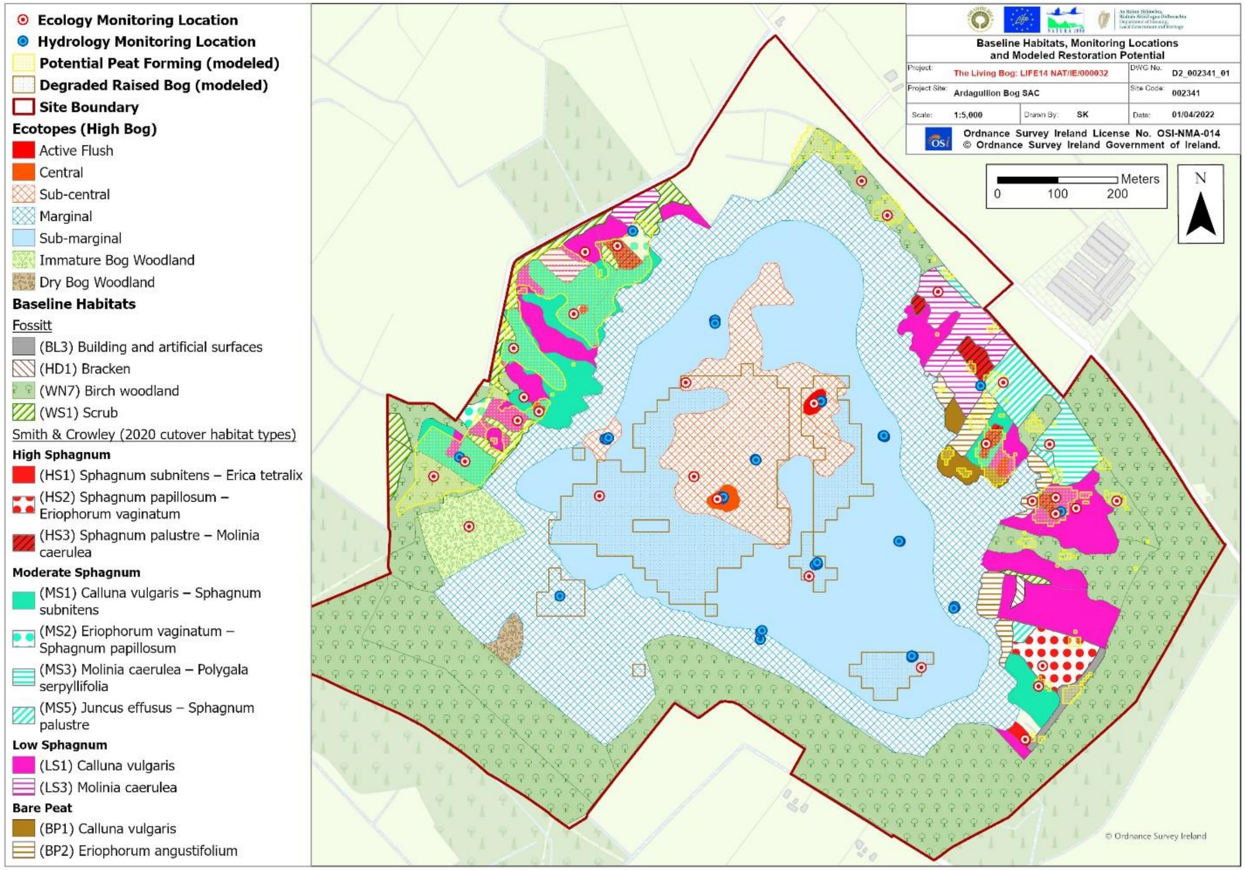
Site		Restoration Zone		Polygon Number	
Current Habitat					
EU Annex Habitat					
Predicted Future Habitat					
Feature of Conservation/Ecological Interest					
Soil Type (Mineral/Fen Peat/Bog Peat)					
PPF (Yes/No/Partially) – if yes describe if/how different to surrounding areas. Is area wet or dry-if dry why? E.g. drains, tree cover (complete or scattered)					
Peat Forming (Yes/No/Potentially)					
Substrate (e.g. check drains for gravel)					
Firmness (Firm, soft, very soft, quaking)					
Moisture Levels (Dry, Intermediate, Wet)					
Sphagnum cover (%)					
Acrotelm Depth (0; 0-5; 5-10; 10-20; >20cm)					
Bare Peat (%)					
Drain blocking potential impact (include negative impacts and suggested changes)					
Other Management issues (e.g. control of scrub/birch/conifers)					
Boundary check (OK/Amended/Need sub-metre update)					
Species Covers (DAFOR)	Dominant				
	Abundant				
	Frequent				
	Occasional				
	Rare				
Photo Numbers/Details					
Relevés					
Comment					

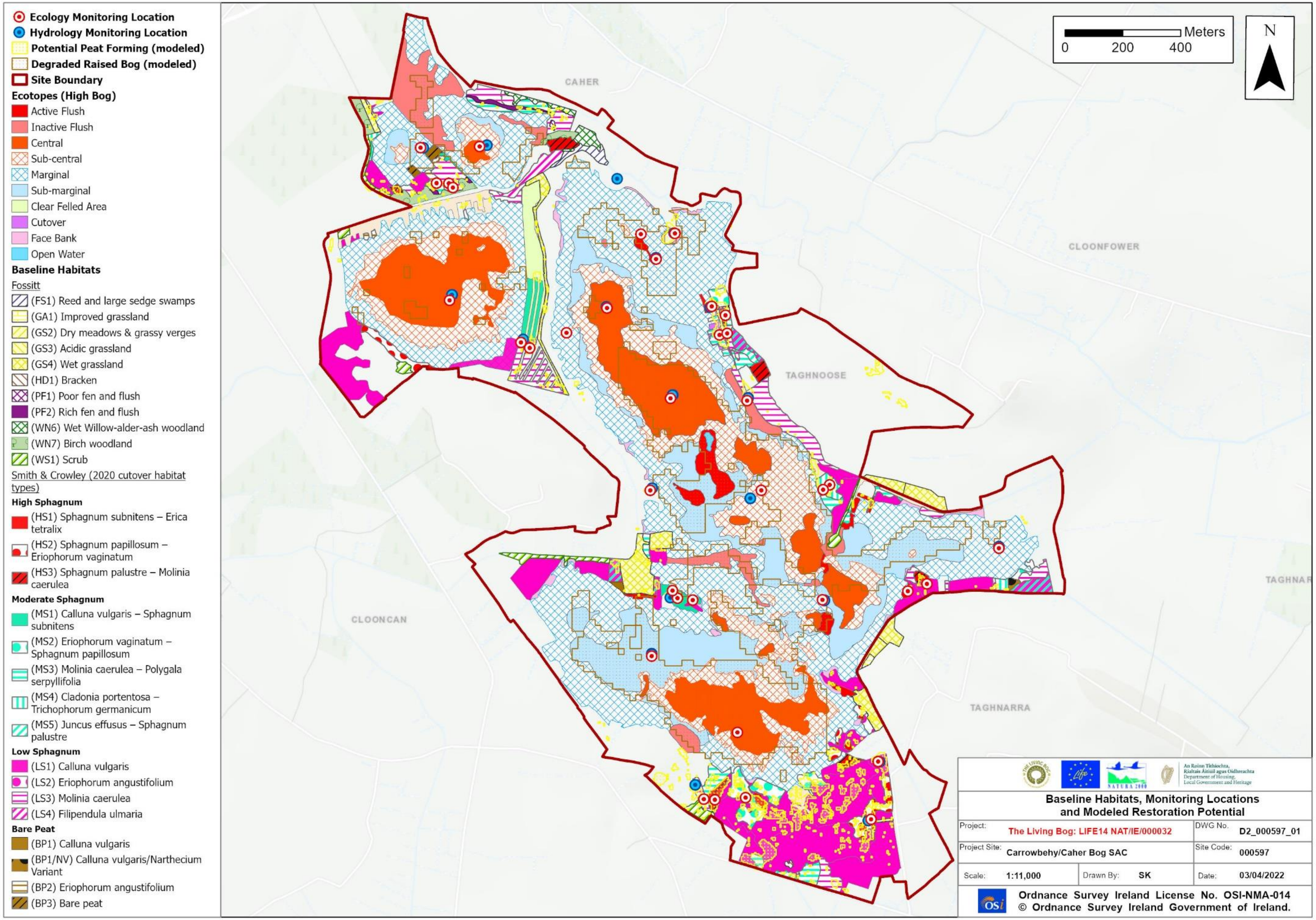
Appendix III: Manifest of vegetation data/reports collected/produced by The Living Bog project and delivered to the NPWS as part of final project delivery

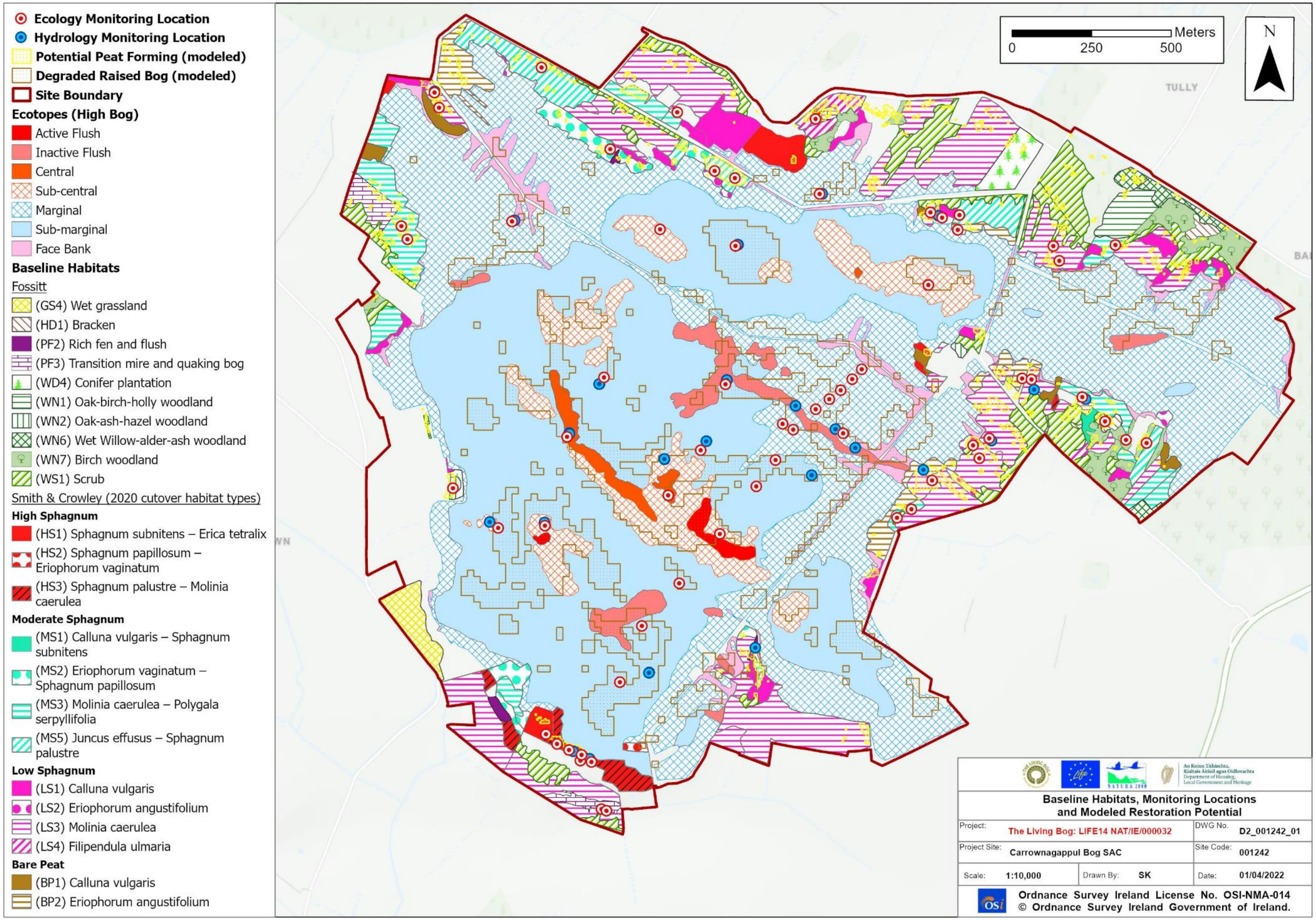
RESOURCE NUMBER	RESOURCE NAME	RESOURCE TYPE
1	RARB16_Baseline_habitats_01a	Shapefile
2	RARB16_Baseline_cutover_habitats_01a	Xcel Spreadsheet
3	RARB16_Cutover_Releves_2016-18_01a	Xcel Spreadsheet
4	RARB16_Transect_Carrownagappul_Lagg_01a	Xcel Spreadsheet
5	RARB16_PLANT COMMUNITIES IN THE GRADIENT FROM RAISED BOG TO FEN IN A NEAR-INTACT LAGG ZONE IN CARROWNAGAPPUL BOG, IRELAND_final_proof	PDF
6	RARB16_Transect_Carrownagappul_Track_01a	Xcel Spreadsheet
7	RARB16_Transect_Killyconny2018_01a	Xcel Spreadsheet
8	RARB16_WesternCutoverPaper_Killyconny_01a	Xcel Spreadsheet
9	RARB16_RECOVERY OF THE VEGETATION OF A CUTOVER RAISED BOG IN IRELAND FOLLOWING REWETTING MEASURES_first proofs	PDF
10	RARB16_Ardagullion_Transects_01a	Xcel Spreadsheet
11	RARB16_Cutover_Releve_Data_2020-2021_01a	Xcel Spreadsheet
12	RARB16_1840s_Bog_Extent_01a	Shapefile
13	RARB16_1970s_HB_Extent_01a	Shapefile
14	RARB16_Ecotopes_01a	Shapefile
15	RARB16_Ecotope_points_01a	Shapefile
16	RARB16_Boundaries_01a	Shapefile
17	RARB16_HB_Quadrats_Baseline_01a	Shapefile
18	RARB16_QuadratCorners_01a	Shapefile
19	RARB16_Habitats_2021_01a	Shapefile
20	RARB16_Ecotopes_2021_01a	Shapefile
21	RARB16_Ecotope_points_2021_01a	Shapefile
22	RARB16_Complex_2021_01a	Shapefile
23	RARB16_Boundary_points_2021_01a	Shapefile
24	RARB16_HB_Quadrats_2021_01a	Shapefile
25	RARB16_ARB_Assessment_cutover_01a	Shapefile
26	RARB16_IWM128	PDF
27	RARB16_D2 Vegetation Monitoring Final Report March 2022	PDF
28	RARB16_Final maps	PDF
29	RARB16_image_catalogue_EcologyBaseline_01a	Xcel Spreadsheet
30	RARB16_Image_catalogue_EcologyPostRestoration_01a	Xcel Spreadsheet
31	RARB16_Vegetation_Monitoring_Photos	Jpgs

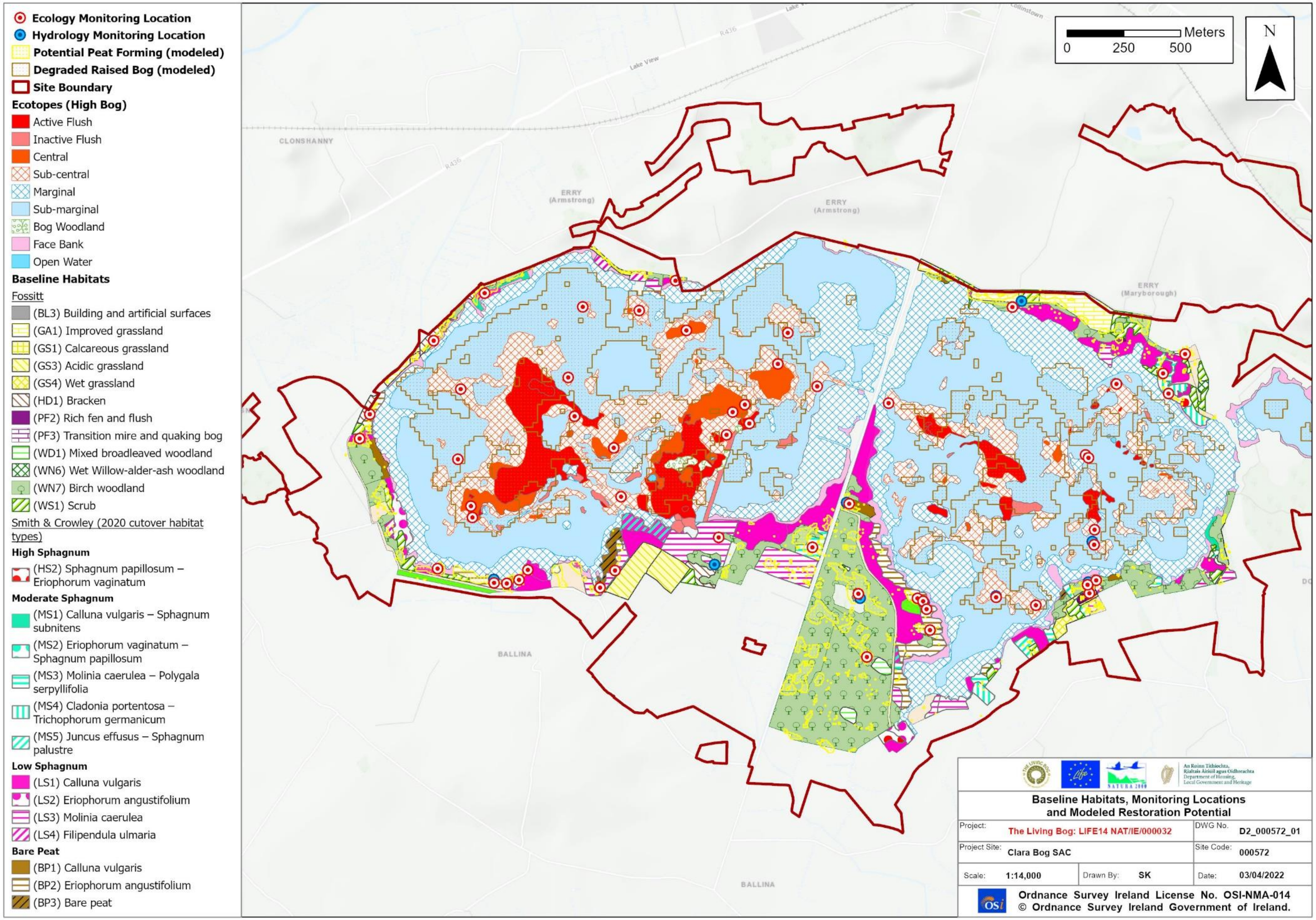
Appendix IV: Maps

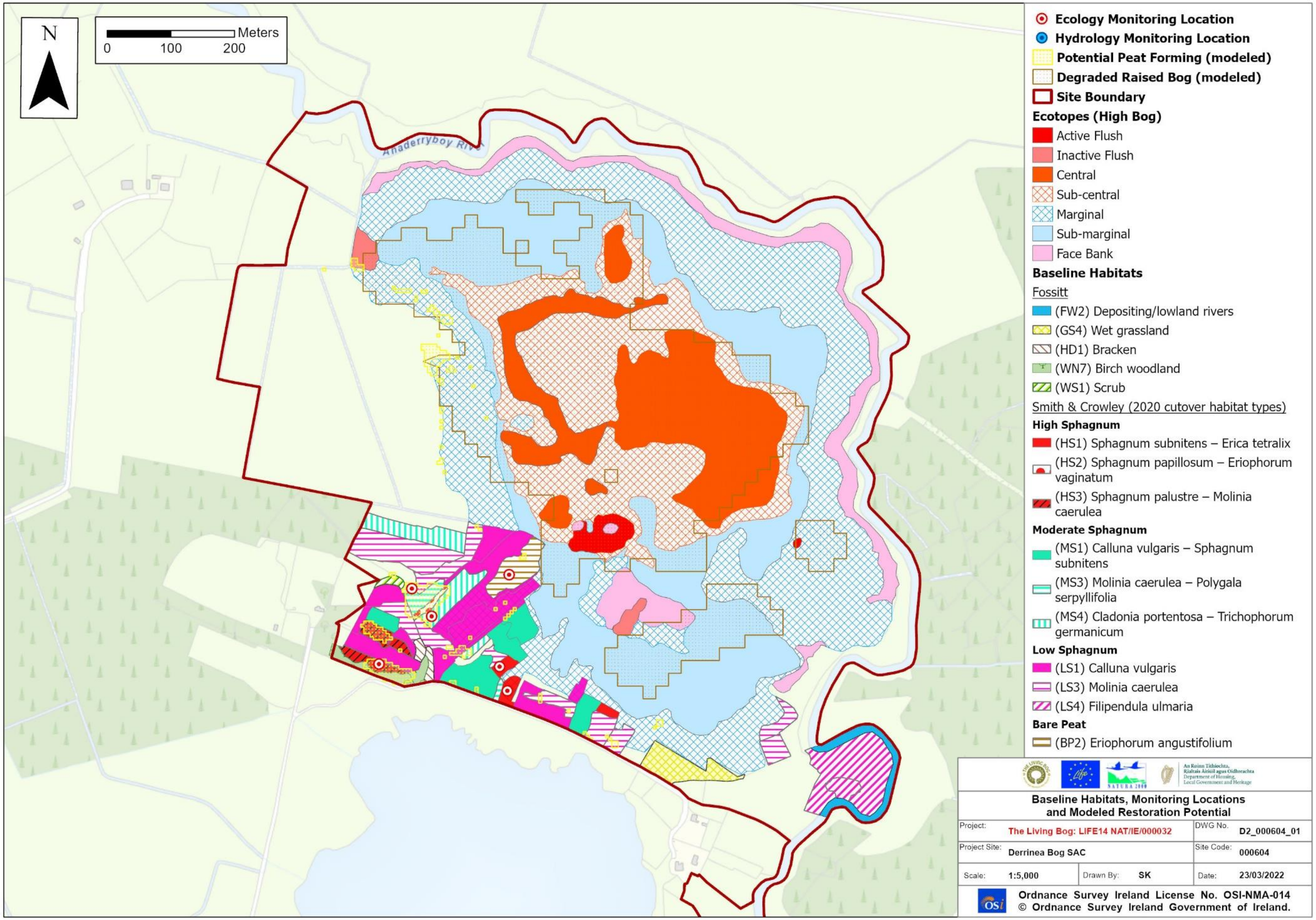
Map 1: Baseline Habitats, Monitoring Locations and Modeled Restoration Potential

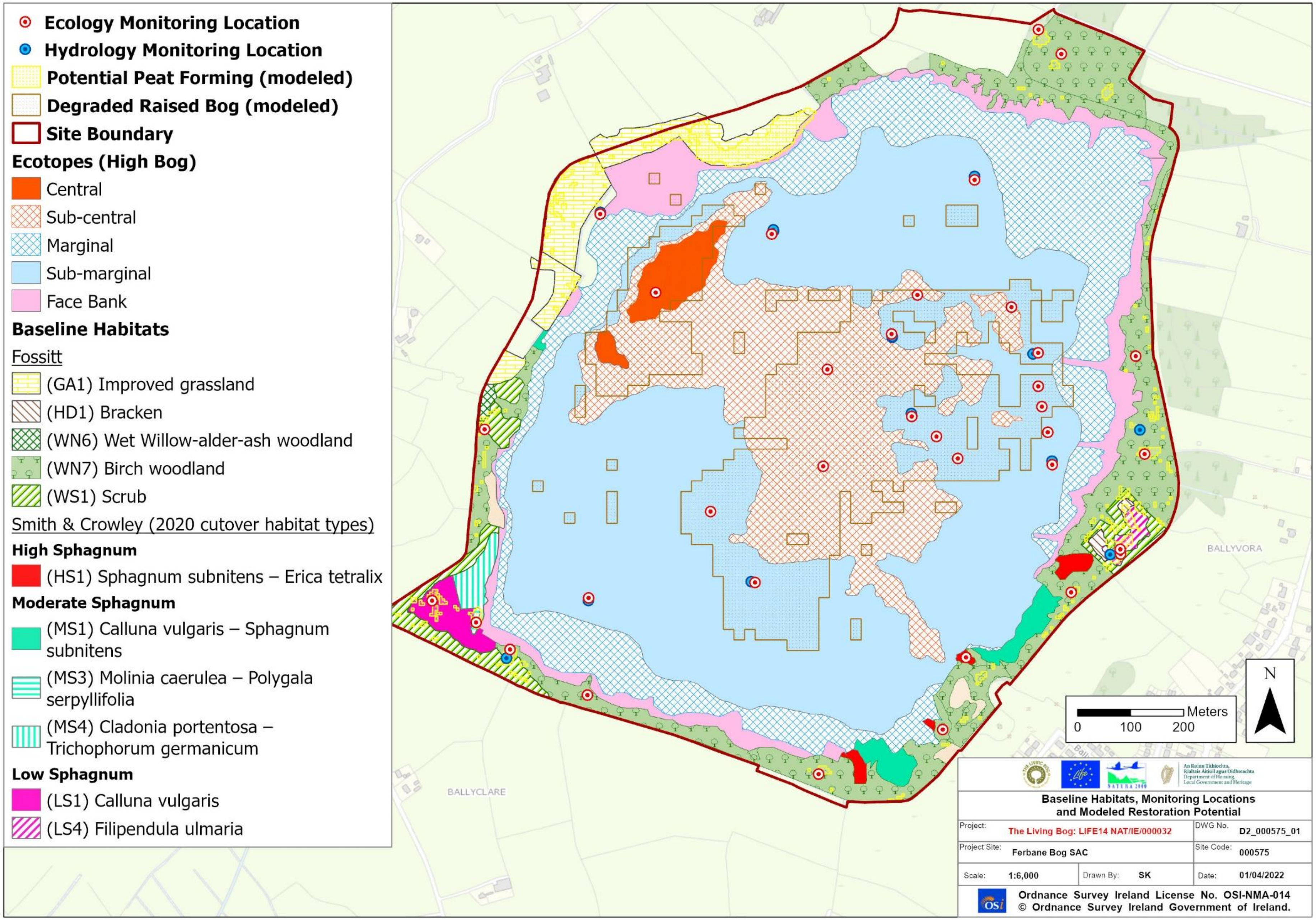


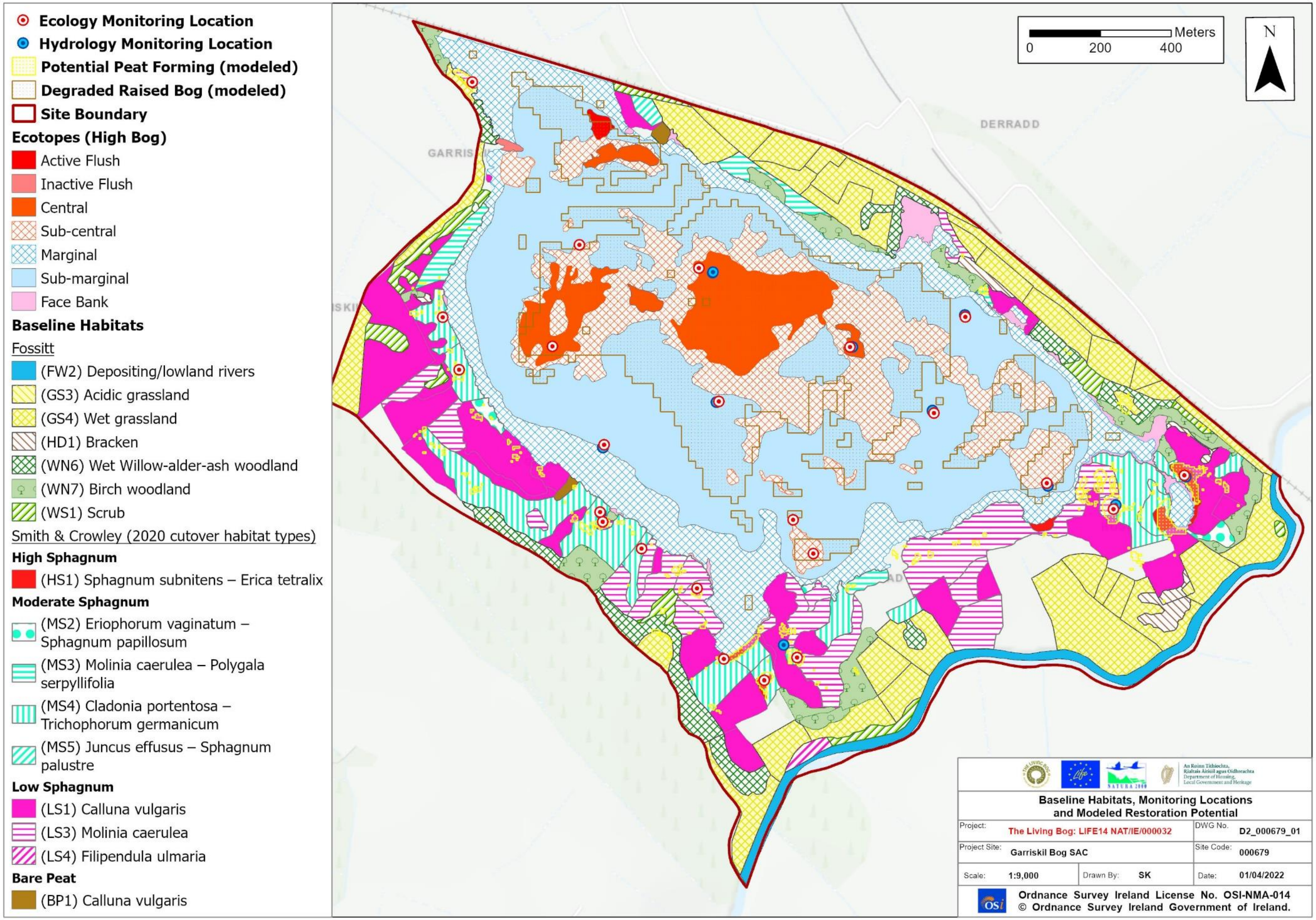

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Clear Felled Area
Cutover
Face Bank
Open Water
Baseline Habitats
Fossitt
(FS1) Reed and large sedge swamps
(GA1) Improved grassland
(GS2) Dry meadows & grassy verges
(GS3) Acidic grassland
(GS4) Wet grassland
(HD1) Bracken
(PF1) Poor fen and flush
(PF2) Rich fen and flush
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS5) Juncus effusus – Sphagnum palustre
Low Sphagnum
(LS1) Calluna vulgaris
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
(LS4) Filipendula ulmaria
Bare Peat
(BP1) Calluna vulgaris
(BP1/NV) Calluna vulgaris/Narthecium Variant
(BP2) Eriophorum angustifolium
(BP3) Bare peat
Meters
0 200 400
N
CAHER
CLOONFOWER
TAGHNOOSE
CLOONCAN
TAGHNARRA
TAGHNAR
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000597_01
Project Site: Carrowbehy/Caher Bog SAC
Site Code: 000597
Scale: 1:11,000
Drawn By: SK
Date: 03/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

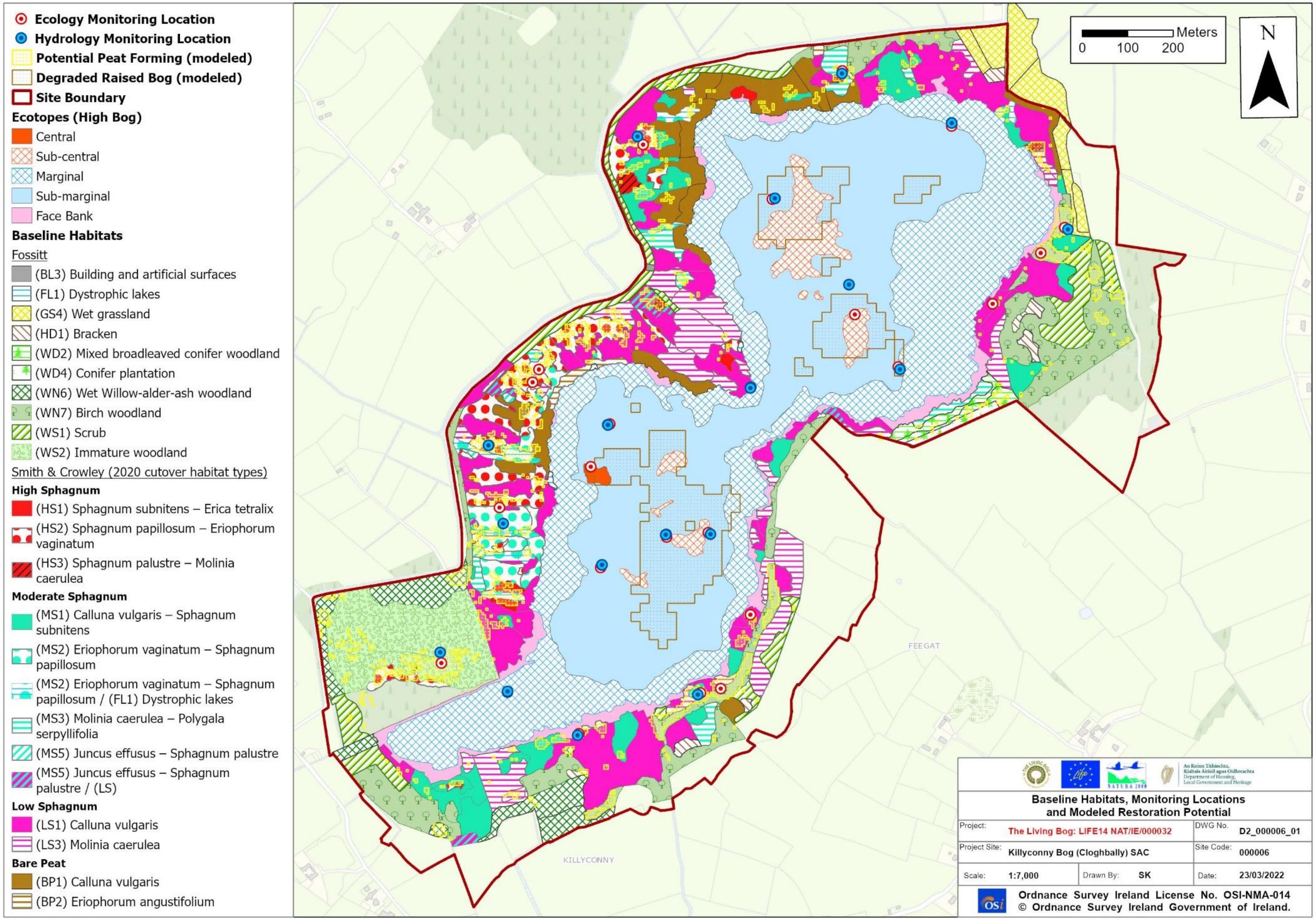

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Baseline Habitats
Fossitt
(GS4) Wet grassland
(HD1) Bracken
(PF2) Rich fen and flush
(PF3) Transition mire and quaking bog
(WD4) Conifer plantation
(WN1) Oak-birch-holly woodland
(WN2) Oak-ash-hazel woodland
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS5) Juncus effusus – Sphagnum palustre
Low Sphagnum
(LS1) Calluna vulgaris
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
(LS4) Filipendula ulmaria
Bare Peat
(BP1) Calluna vulgaris
(BP2) Eriophorum angustifolium
Meters
0 250 500
N
TULLY
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_001242_01
Project Site: Carrownagappul Bog SAC
Site Code: 001242
Scale: 1:10,000
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

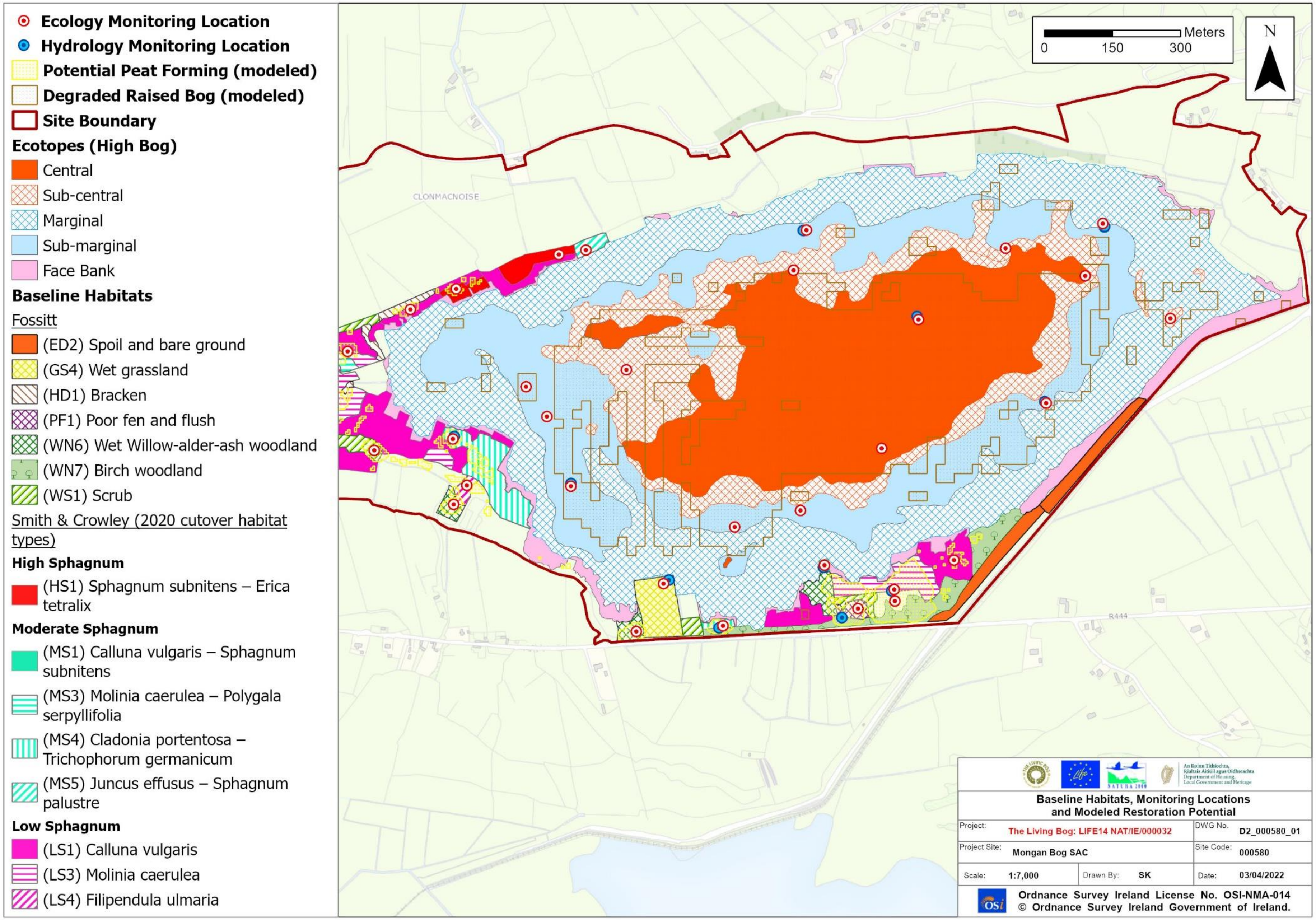

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Bog Woodland
Face Bank
Open Water
Baseline Habitats
Fossitt
(BL3) Building and artificial surfaces
(GA1) Improved grassland
(GS1) Calcareous grassland
(GS3) Acidic grassland
(GS4) Wet grassland
(HD1) Bracken
(PF2) Rich fen and flush
(PF3) Transition mire and quaking bog
(WD1) Mixed broadleaved woodland
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS2) Sphagnum papillosum – Eriophorum vaginatum
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS5) Juncus effusus – Sphagnum palustre
Low Sphagnum
(LS1) Calluna vulgaris
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
(LS4) Filipendula ulmaria
Bare Peat
(BP1) Calluna vulgaris
(BP2) Eriophorum angustifolium
(BP3) Bare peat
Meters
0 250 500
N
CLONSHANNY
ERRY (Armstrong)
ERRY (Armstrong)
ERRY (Maryborough)
BALLINA
BALLINA
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000572_01
Project Site: Clara Bog SAC
Site Code: 000572
Scale: 1:14,000
Drawn By: SK
Date: 03/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

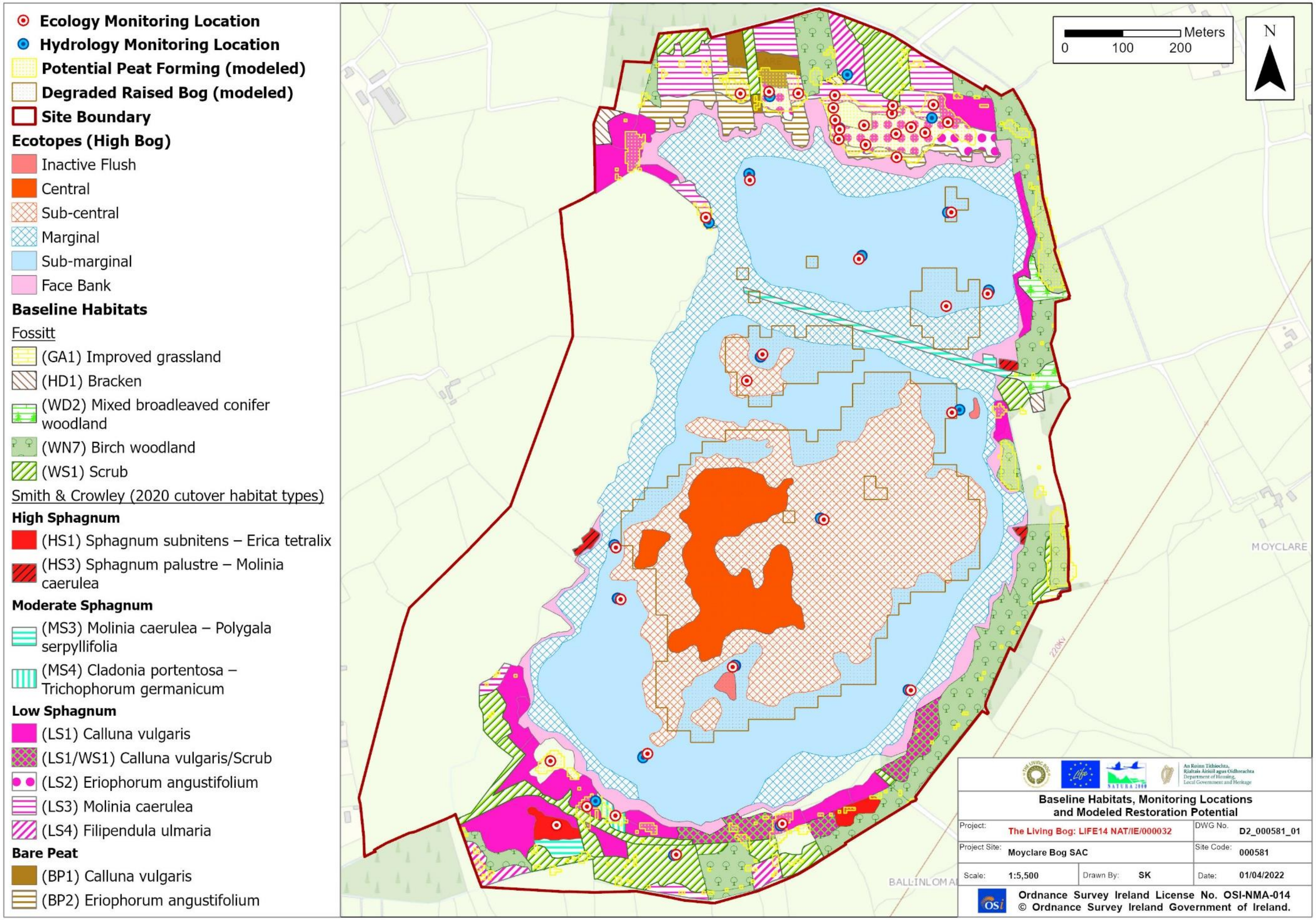

N
Meters
0
100
200
Anaderryboy River
Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Baseline Habitats
Fossitt
(FW2) Depositing/lowland rivers
(GS4) Wet grassland
(HD1) Bracken
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
Low Sphagnum
(LS1) Calluna vulgaris
(LS3) Molinia caerulea
(LS4) Filipendula ulmaria
Bare Peat
(BP2) Eriophorum angustifolium
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000604_01
Project Site: Derrinea Bog SAC
Site Code: 000604
Scale: 1:5,000
Drawn By: SK
Date: 23/03/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

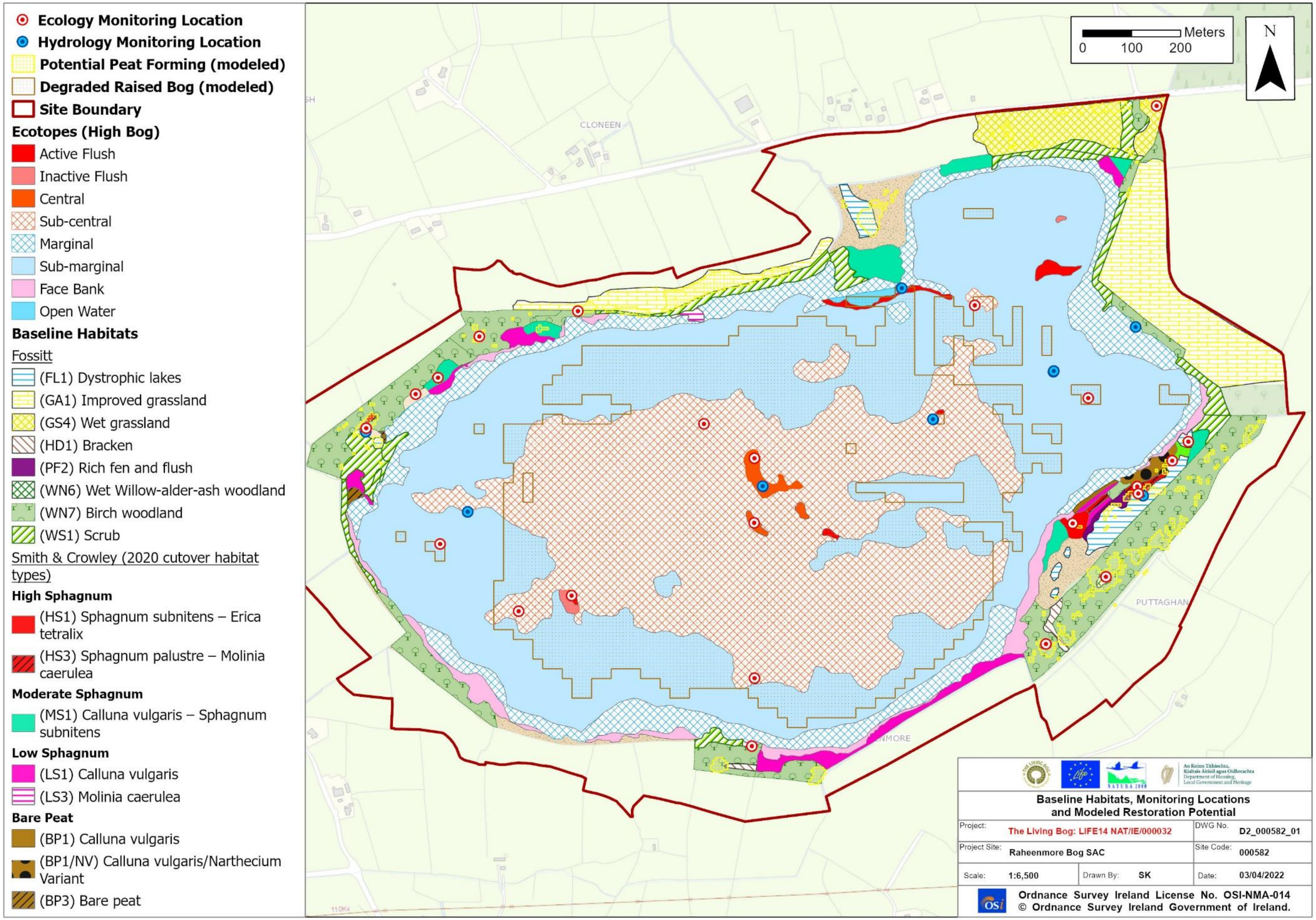

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Baseline Habitats
Fossitt
(GA1) Improved grassland
(HD1) Bracken
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
Low Sphagnum
(LS1) Calluna vulgaris
(LS4) Filipendula ulmaria
BALLYVORA
BALLYCLARE
Meters
0 100 200
N
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000575_01
Project Site: Ferbane Bog SAC
Site Code: 000575
Scale: 1:6,000
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

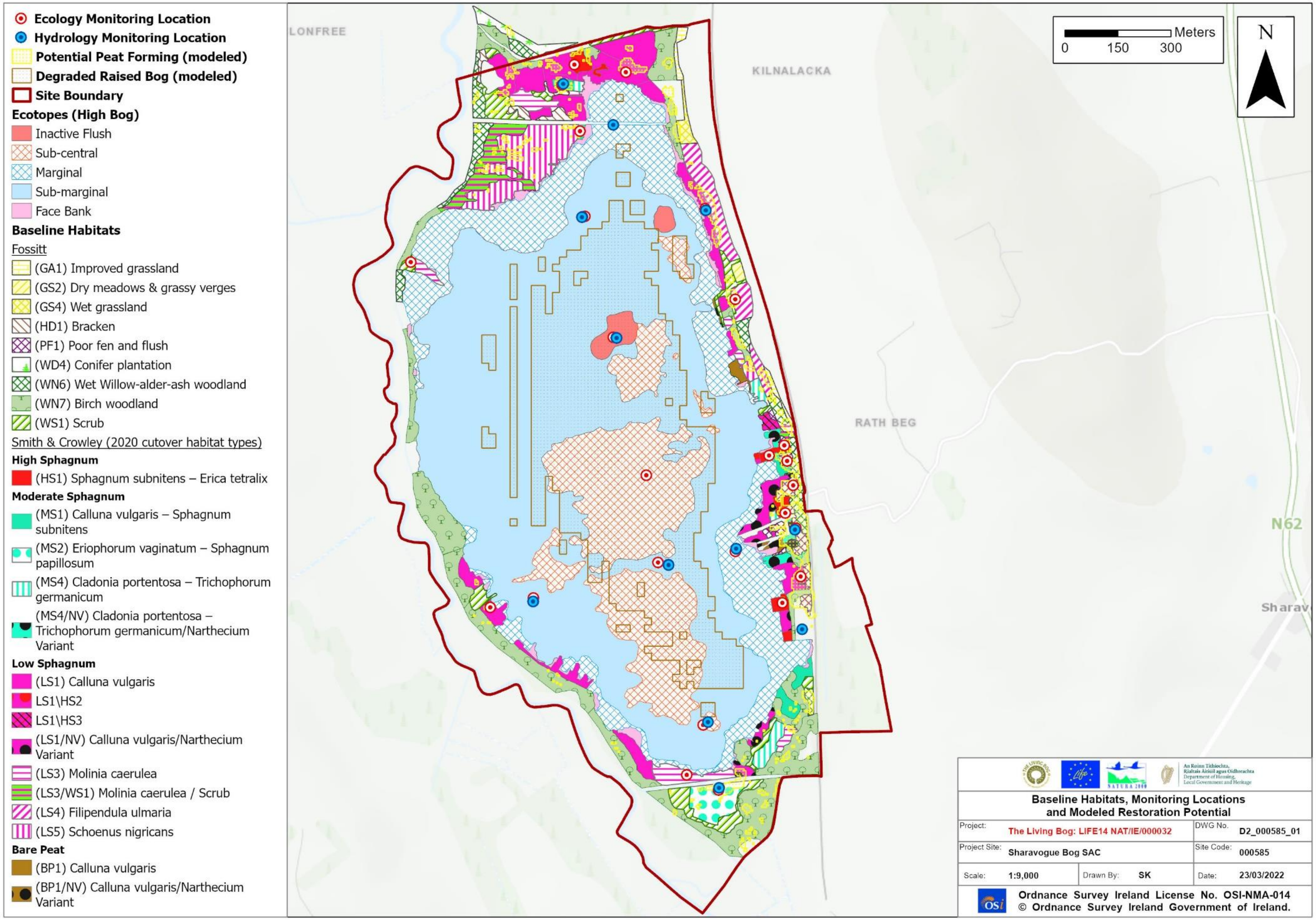

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Baseline Habitats
Fossitt
(FW2) Depositing/lowland rivers
(GS3) Acidic grassland
(GS4) Wet grassland
(HD1) Bracken
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
Moderate Sphagnum
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS5) Juncus effusus – Sphagnum palustre
Low Sphagnum
(LS1) Calluna vulgaris
(LS3) Molinia caerulea
(LS4) Filipendula ulmaria
Bare Peat
(BP1) Calluna vulgaris
Meters
0
200
400
N
DERRADD
GARRIS
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000679_01
Project Site: Garriskil Bog SAC
Site Code: 000679
Scale: 1:9,000
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.


Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Baseline Habitats
Fossitt
(BL3) Building and artificial surfaces
(FL1) Dystrophic lakes
(GS4) Wet grassland
(HD1) Bracken
(WD2) Mixed broadleaved conifer woodland
(WD4) Conifer plantation
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
(WS2) Immature woodland
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS2) Eriophorum vaginatum – Sphagnum papillosum / (FL1) Dystrophic lakes
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS5) Juncus effusus – Sphagnum palustre
(MS5) Juncus effusus – Sphagnum palustre / (LS)
Low Sphagnum
(LS1) Calluna vulgaris
(LS3) Molinia caerulea
Bare Peat
(BP1) Calluna vulgaris
(BP2) Eriophorum angustifolium
Meters
0 100 200
N
FEEGAT
KILLYCONNY
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000006_01
Project Site: Killyconny Bog (Cloghbally) SAC
Site Code: 000006
Scale: 1:7,000
Drawn By: SK
Date: 23/03/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

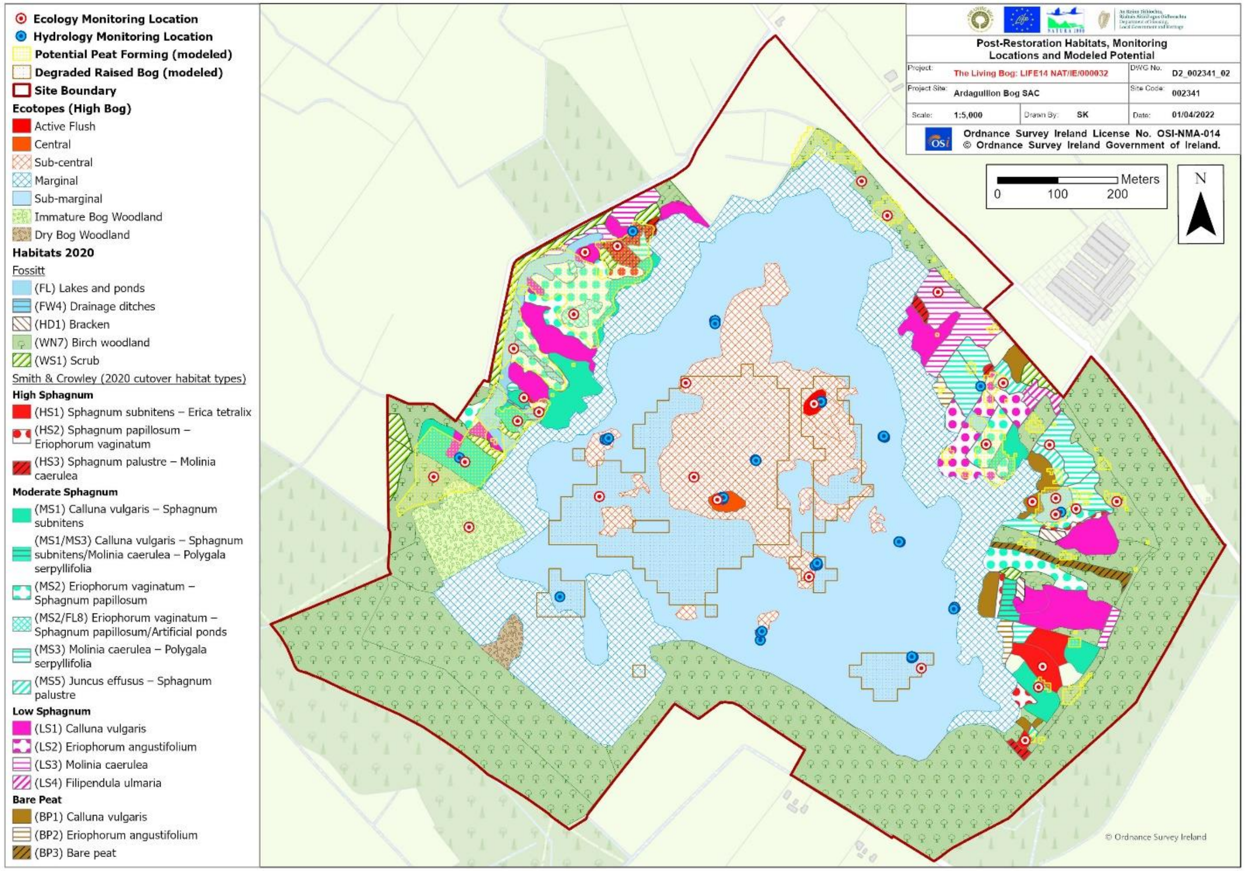

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Baseline Habitats
Fossitt
(ED2) Spoil and bare ground
(GS4) Wet grassland
(HD1) Bracken
(PF1) Poor fen and flush
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS5) Juncus effusus – Sphagnum palustre
Low Sphagnum
(LS1) Calluna vulgaris
(LS3) Molinia caerulea
(LS4) Filipendula ulmaria
Meters
0
150
300
N
CLONMACNOISE
R444
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project:
The Living Bog: LIFE14 NAT/IE/000032
DWG No.
D2_000580_01
Project Site:
Mongan Bog SAC
Site Code:
000580
Scale:
1:7,000
Drawn By:
SK
Date:
03/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

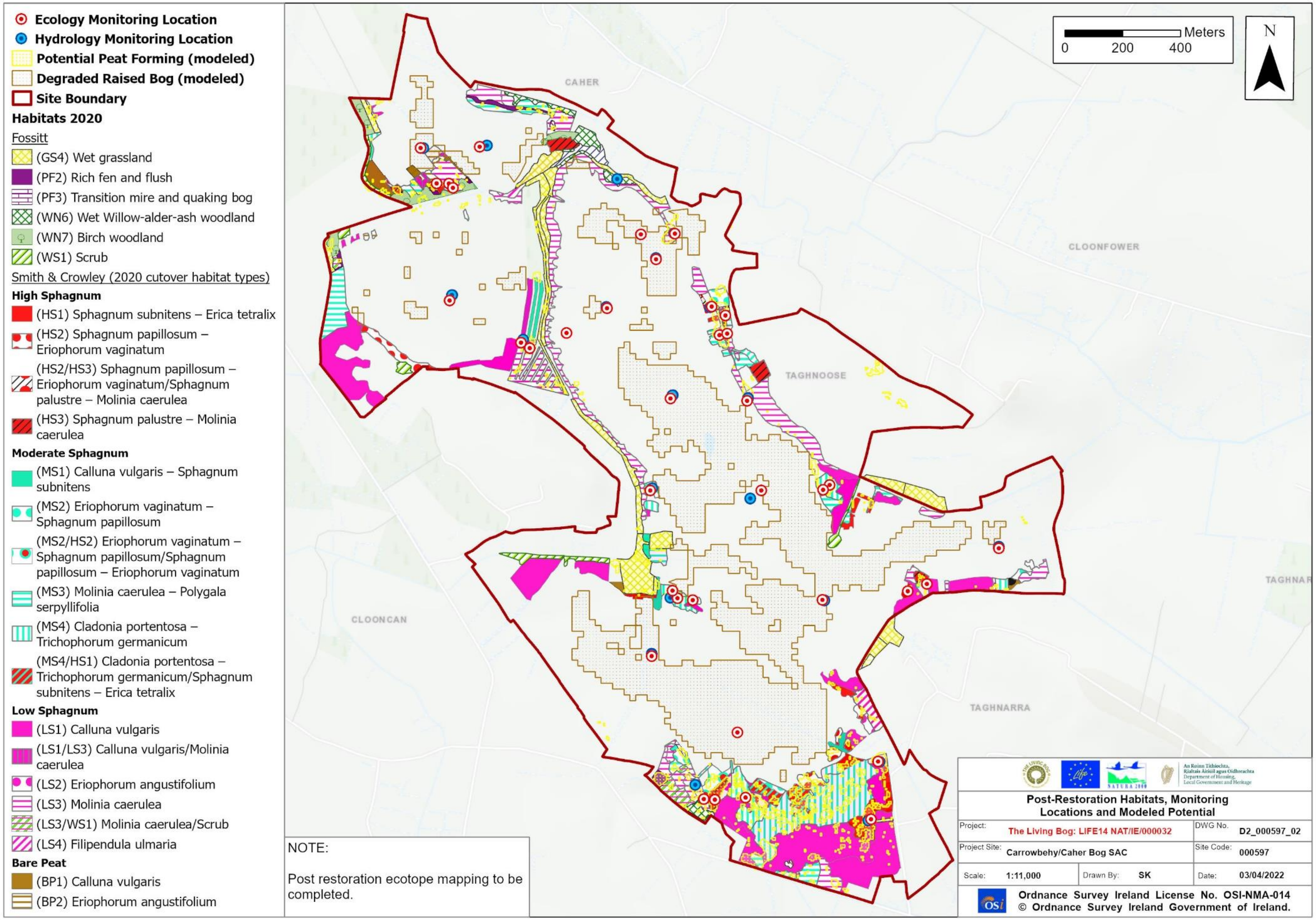

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Baseline Habitats
Fossitt
(GA1) Improved grassland
(HD1) Bracken
(WD2) Mixed broadleaved conifer woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
Low Sphagnum
(LS1) Calluna vulgaris
(LS1/WS1) Calluna vulgaris/Scrub
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
(LS4) Filipendula ulmaria
Bare Peat
(BP1) Calluna vulgaris
(BP2) Eriophorum angustifolium
Meters
0 100 200
N
MOYCLARE
BALLINLOMA
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000581_01
Project Site: Moyclare Bog SAC
Site Code: 000581
Scale: 1:5,500
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

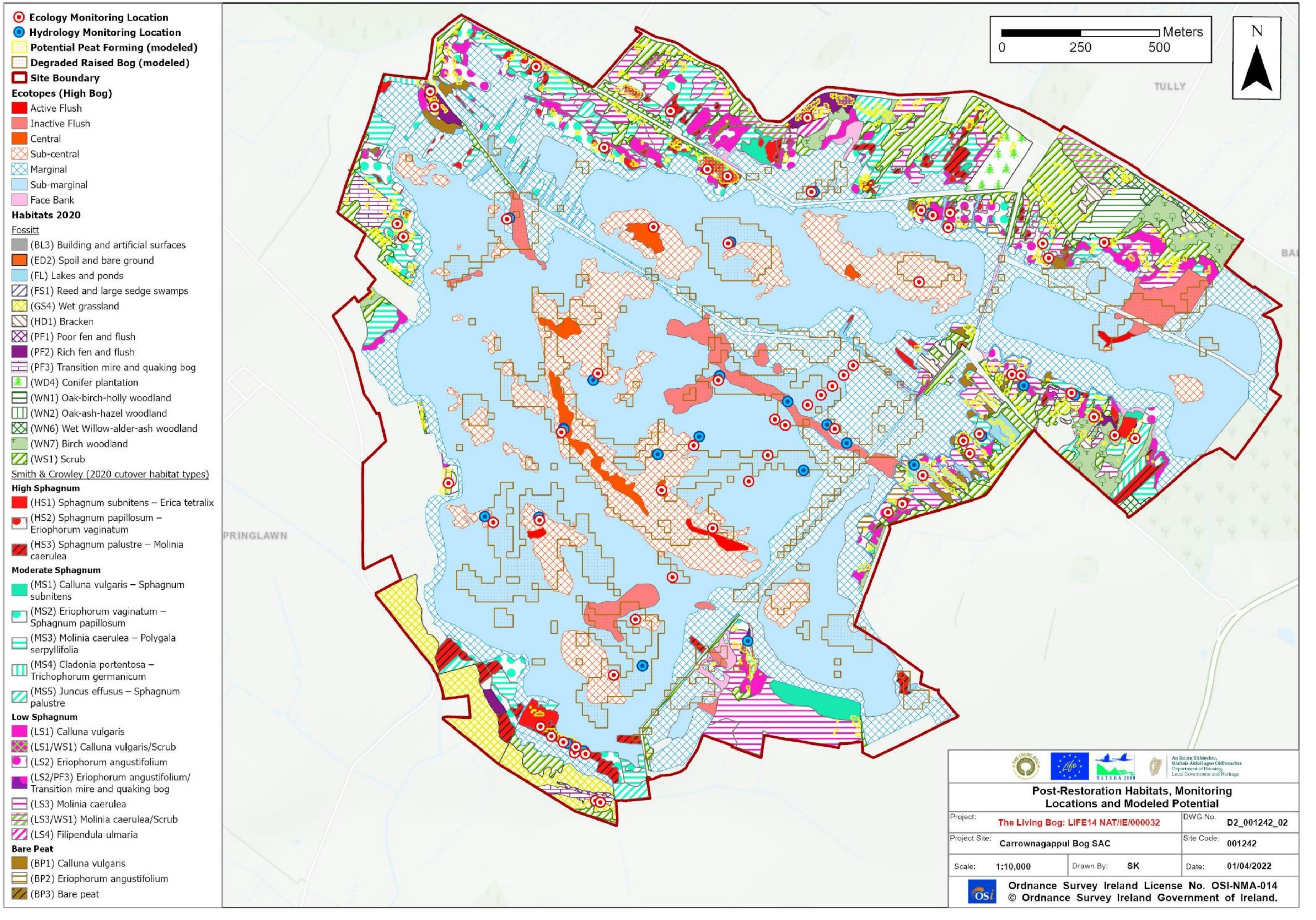

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Open Water
Baseline Habitats
Fossitt
(FL1) Dystrophic lakes
(GA1) Improved grassland
(GS4) Wet grassland
(HD1) Bracken
(PF2) Rich fen and flush
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
Low Sphagnum
(LS1) Calluna vulgaris
(LS3) Molinia caerulea
Bare Peat
(BP1) Calluna vulgaris
(BP1/NV) Calluna vulgaris/Narthecium Variant
(BP3) Bare peat
Meters
0 100 200
N
CLONEEN
PUTTAGHAN
NMORE
110kV
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000582_01
Project Site: Raheenmore Bog SAC
Site Code: 000582
Scale: 1:6,500
Drawn By: SK
Date: 03/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

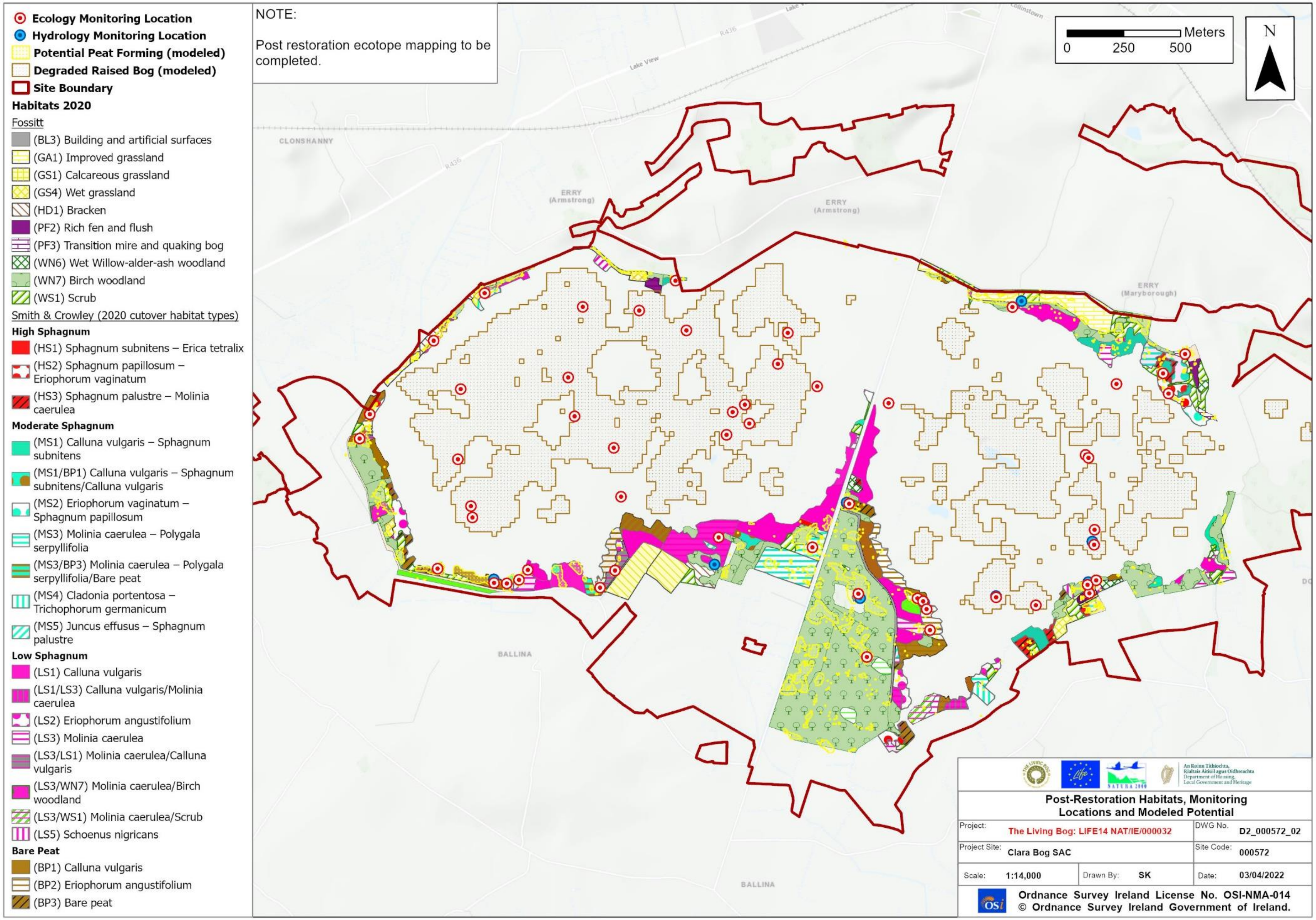

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Inactive Flush
Sub-central
Marginal
Sub-marginal
Face Bank
Baseline Habitats
Fossitt
(GA1) Improved grassland
(GS2) Dry meadows & grassy verges
(GS4) Wet grassland
(HD1) Bracken
(PF1) Poor fen and flush
(WD4) Conifer plantation
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS4/NV) Cladonia portentosa – Trichophorum germanicum/Narthecium Variant
Low Sphagnum
(LS1) Calluna vulgaris
LS1\HS2
LS1\HS3
(LS1/NV) Calluna vulgaris/Narthecium Variant
(LS3) Molinia caerulea
(LS3/WS1) Molinia caerulea / Scrub
(LS4) Filipendula ulmaria
(LS5) Schoenus nigricans
Bare Peat
(BP1) Calluna vulgaris
(BP1/NV) Calluna vulgaris/Narthecium Variant
LONFREE
KILNALACKA
RATH BEG
N62
Sharav
Meters
0
150
300
N
Baseline Habitats, Monitoring Locations and Modeled Restoration Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000585_01
Project Site: Sharavogue Bog SAC
Site Code: 000585
Scale: 1:9,000
Drawn By: SK
Date: 23/03/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

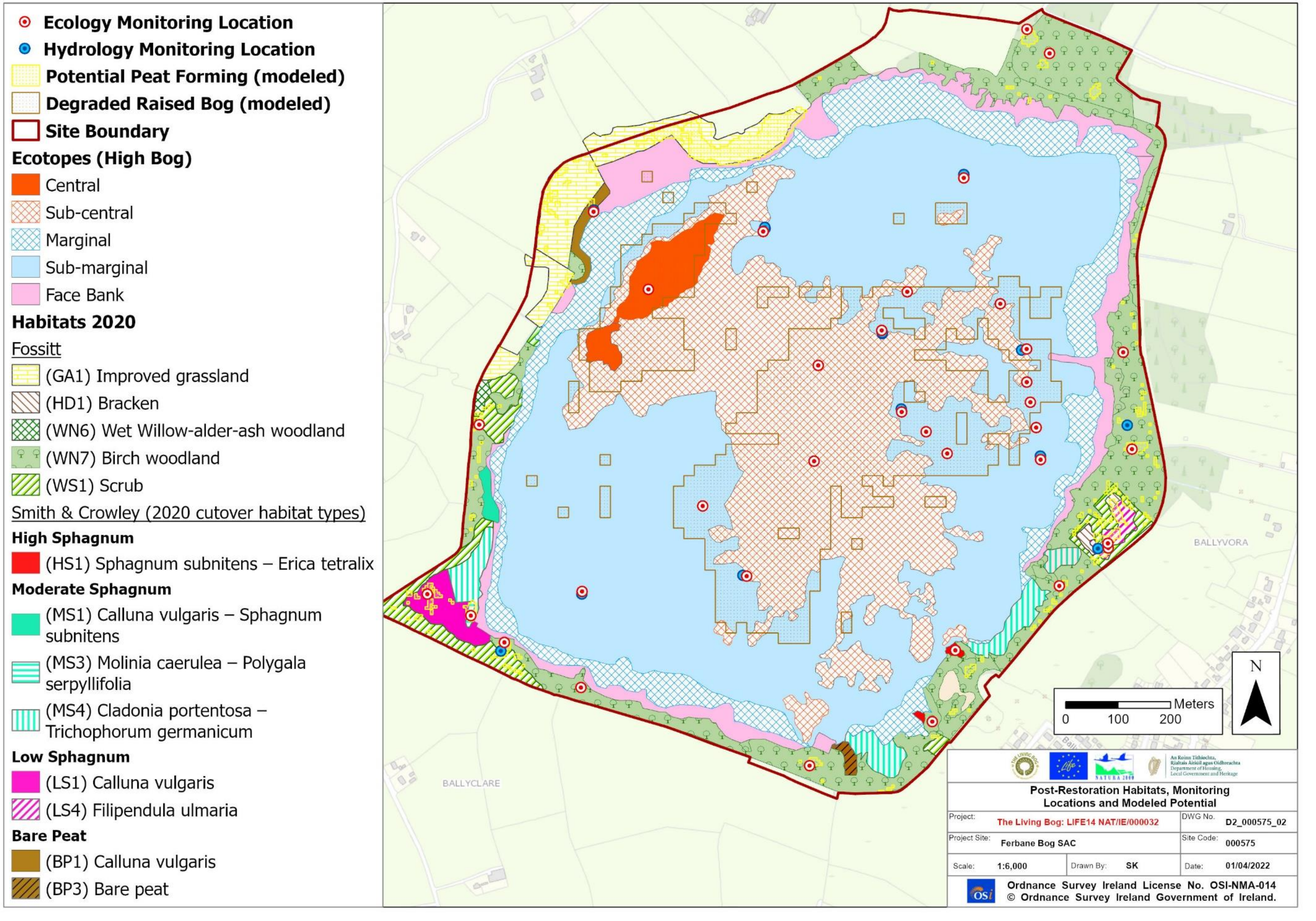
Map 2: Post-Restoration Habitats, Monitoring Locations and Modeled Restoration Potential

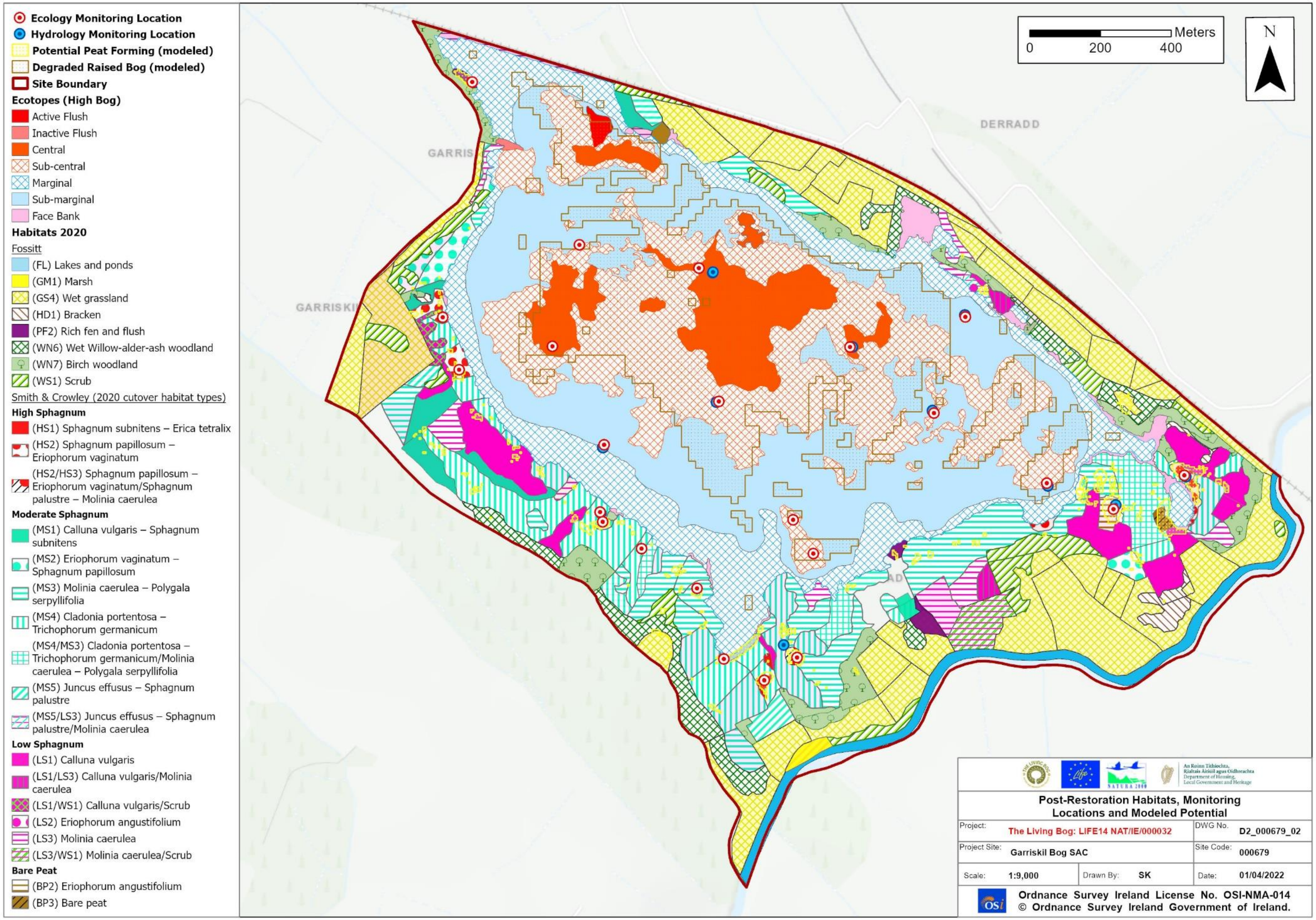


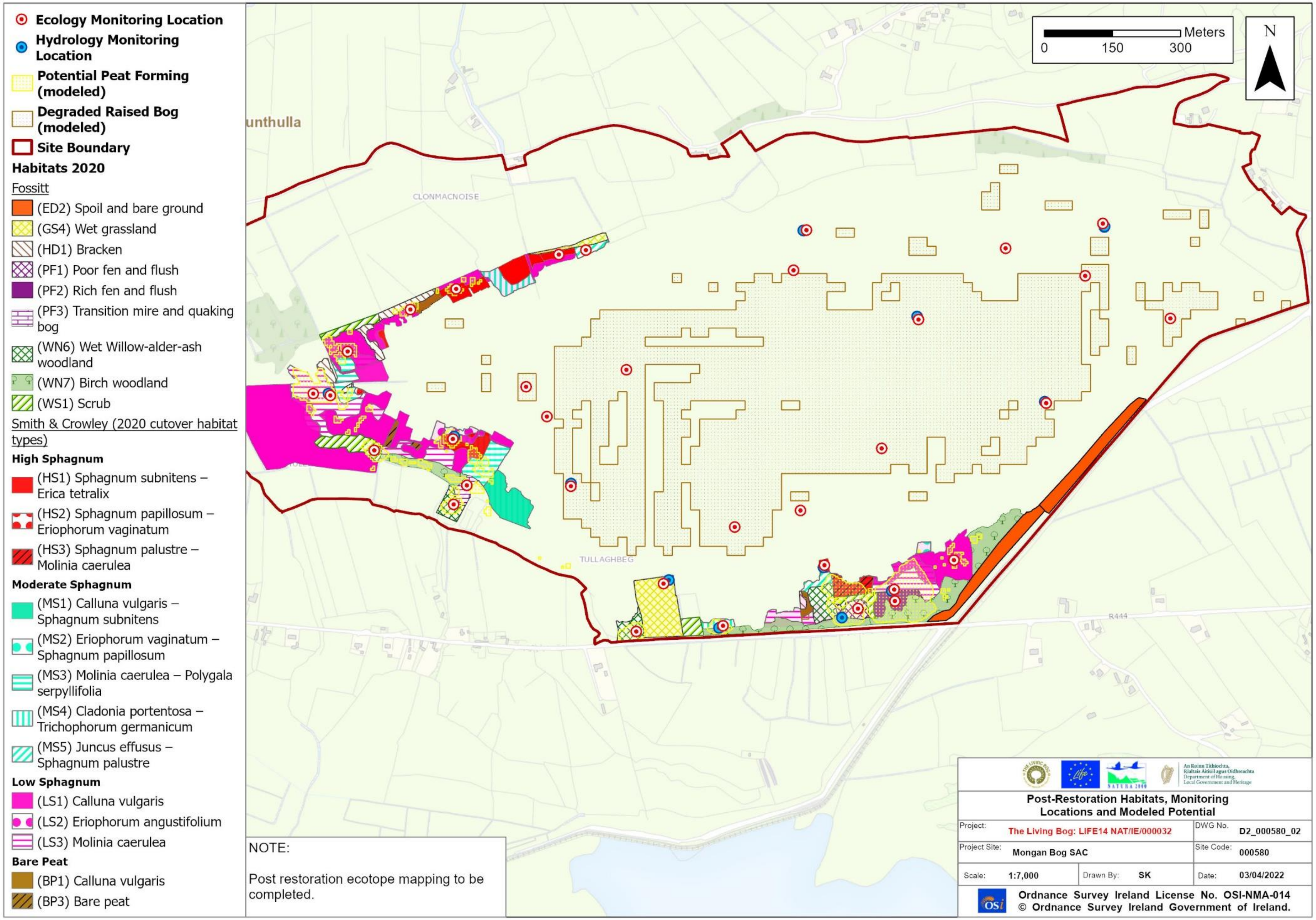

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Habitats 2020
Fossitt
(GS4) Wet grassland
(PF2) Rich fen and flush
(PF3) Transition mire and quaking bog
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS2/HS3) Sphagnum papillosum – Eriophorum vaginatum/Sphagnum palustre – Molinia caerulea
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS2/HS2) Eriophorum vaginatum – Sphagnum papillosum/Sphagnum papillosum – Eriophorum vaginatum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS4/HS1) Cladonia portentosa – Trichophorum germanicum/Sphagnum subnitens – Erica tetralix
Low Sphagnum
(LS1) Calluna vulgaris
(LS1/LS3) Calluna vulgaris/Molinia caerulea
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
(LS3/WS1) Molinia caerulea/Scrub
(LS4) Filipendula ulmaria
Bare Peat
(BP1) Calluna vulgaris
(BP2) Eriophorum angustifolium
CAHER
CLOONFOWER
TAGHNOOSE
CLOONCAN
TAGHNARRA
TAGHNAR
Meters
0 200 400
N
NOTE:
Post restoration ecotope mapping to be completed.
Post-Restoration Habitats, Monitoring Locations and Modeled Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000597_02
Project Site: Carrowbehy/Caher Bog SAC
Site Code: 000597
Scale: 1:11,000
Drawn By: SK
Date: 03/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

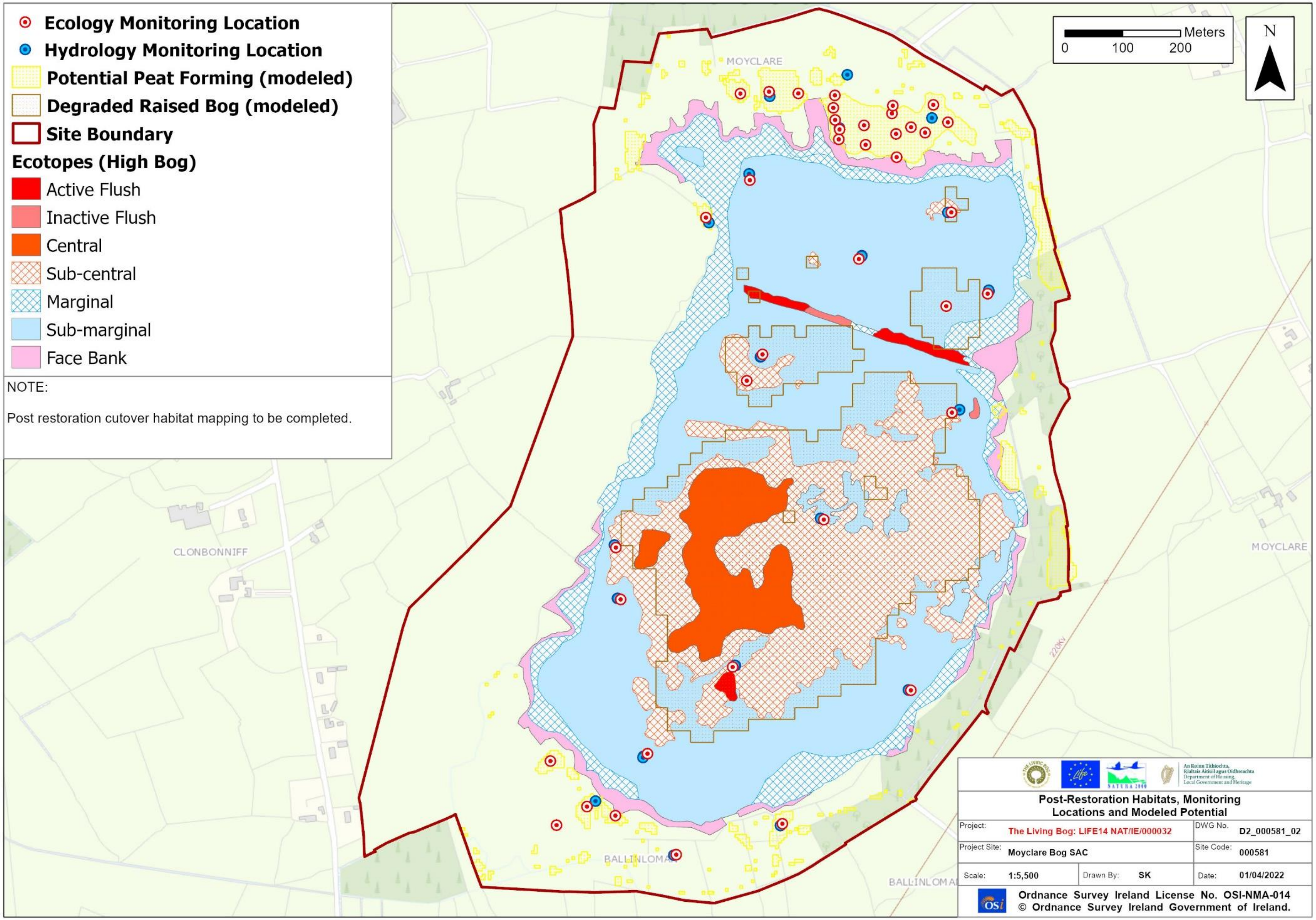

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Habitats 2020
Fossitt
(BL3) Building and artificial surfaces
(ED2) Spoil and bare ground
(FL) Lakes and ponds
(FS1) Reed and large sedge swamps
(GS4) Wet grassland
(HD1) Bracken
(PF1) Poor fen and flush
(PF2) Rich fen and flush
(PF3) Transition mire and quaking bog
(WD4) Conifer plantation
(WN1) Oak-birch-holly woodland
(WN2) Oak-ash-hazel woodland
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS5) Juncus effusus – Sphagnum palustre
Low Sphagnum
(LS1) Calluna vulgaris
(LS1/WS1) Calluna vulgaris/Scrub
(LS2) Eriophorum angustifolium
(LS2/PF3) Eriophorum angustifolium/ Transition mire and quaking bog
(LS3) Molinia caerulea
(LS3/WS1) Molinia caerulea/Scrub
(LS4) Filipendula ulmaria
Bare Peat
(BP1) Calluna vulgaris
(BP2) Eriophorum angustifolium
(BP3) Bare peat
Meters
0
250
500
N
TULLY
PRINGLAWN
Post-Restoration Habitats, Monitoring Locations and Modeled Potential
Project:
The Living Bog: LIFE14 NAT/IE/000032
DWG No.
D2_001242_02
Project Site:
Carrownagappul Bog SAC
Site Code:
001242
Scale:
1:10,000
Drawn By:
SK
Date:
01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.


Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Habitats 2020
Fossitt
(BL3) Building and artificial surfaces
(GA1) Improved grassland
(GS1) Calcareous grassland
(GS4) Wet grassland
(HD1) Bracken
(PF2) Rich fen and flush
(PF3) Transition mire and quaking bog
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS1/BP1) Calluna vulgaris – Sphagnum subnitens/Calluna vulgaris
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS3/BP3) Molinia caerulea – Polygala serpyllifolia/Bare peat
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS5) Juncus effusus – Sphagnum palustre
Low Sphagnum
(LS1) Calluna vulgaris
(LS1/LS3) Calluna vulgaris/Molinia caerulea
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
(LS3/LS1) Molinia caerulea/Calluna vulgaris
(LS3/WN7) Molinia caerulea/Birch woodland
(LS3/WS1) Molinia caerulea/Scrub
(LS5) Schoenus nigricans
Bare Peat
(BP1) Calluna vulgaris
(BP2) Eriophorum angustifolium
(BP3) Bare peat
NOTE:
Post restoration ecotope mapping to be completed.
Meters
0 250 500
N
CLONSHANNY
ERRY (Armstrong)
ERRY (Armstrong)
ERRY (Maryborough)
BALLINA
BALLINA
Post-Restoration Habitats, Monitoring Locations and Modeled Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000572_02
Project Site: Clara Bog SAC
Site Code: 000572
Scale: 1:14,000
Drawn By: SK
Date: 03/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

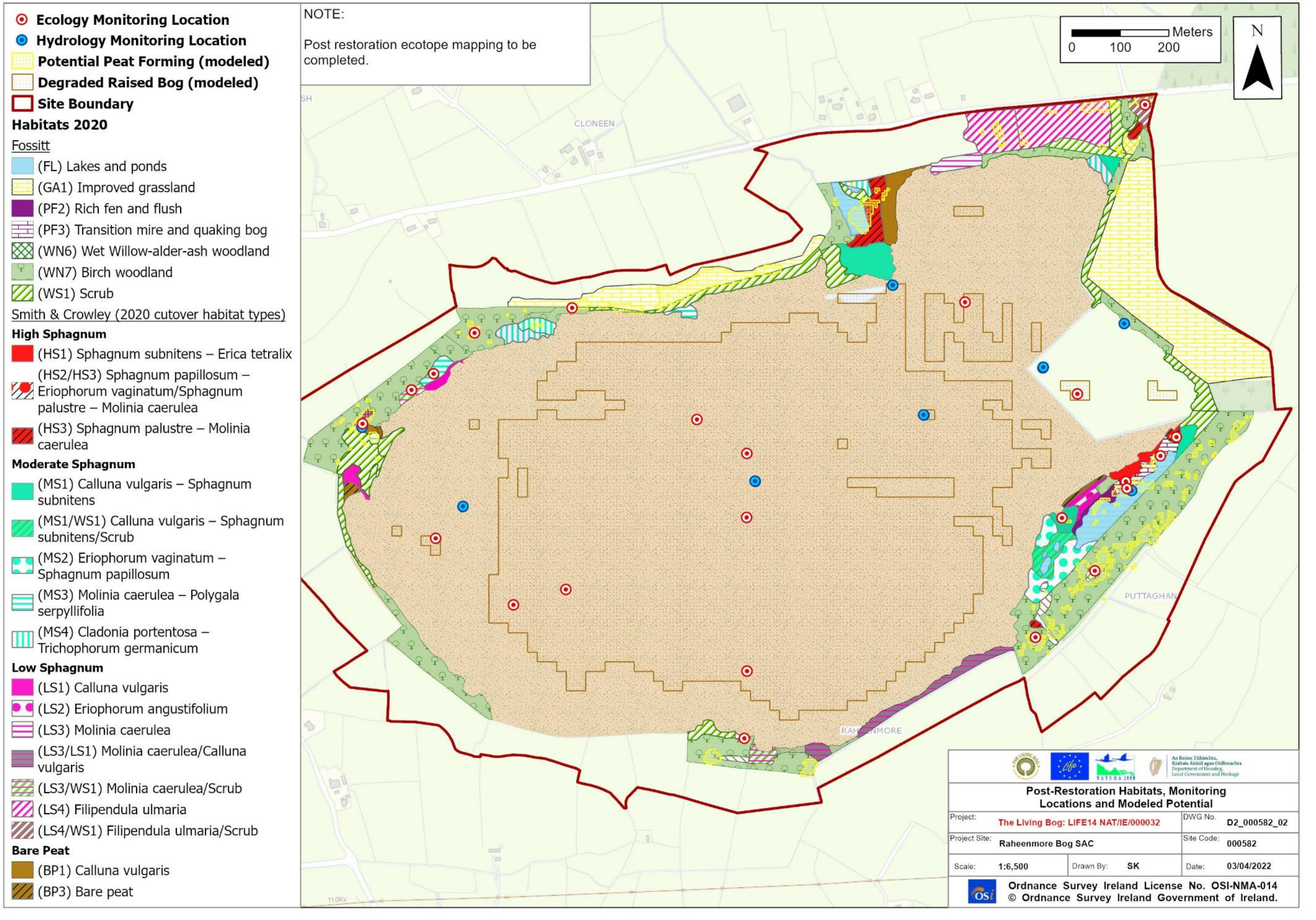

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Habitats 2020
Fossitt
(GA1) Improved grassland
(HD1) Bracken
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
Low Sphagnum
(LS1) Calluna vulgaris
(LS4) Filipendula ulmaria
Bare Peat
(BP1) Calluna vulgaris
(BP3) Bare peat
BALLYVORA
BALLYCLARE
Meters
0 100 200
N
Post-Restoration Habitats, Monitoring Locations and Modeled Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000575_02
Project Site: Ferbane Bog SAC
Site Code: 000575
Scale: 1:6,000
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.


Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Face Bank
Habitats 2020
Fossitt
(FL) Lakes and ponds
(GM1) Marsh
(GS4) Wet grassland
(HD1) Bracken
(PF2) Rich fen and flush
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS2/HS3) Sphagnum papillosum – Eriophorum vaginatum/Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS4/MS3) Cladonia portentosa – Trichophorum germanicum/Molinia caerulea – Polygala serpyllifolia
(MS5) Juncus effusus – Sphagnum palustre
(MS5/LS3) Juncus effusus – Sphagnum palustre/Molinia caerulea
Low Sphagnum
(LS1) Calluna vulgaris
(LS1/LS3) Calluna vulgaris/Molinia caerulea
(LS1/WS1) Calluna vulgaris/Scrub
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
(LS3/WS1) Molinia caerulea/Scrub
Bare Peat
(BP2) Eriophorum angustifolium
(BP3) Bare peat
Meters
0 200 400
N
DERRADD
GARRIS
GARRISKI
AD
Post-Restoration Habitats, Monitoring Locations and Modeled Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000679_02
Project Site: Garriskil Bog SAC
Site Code: 000679
Scale: 1:9,000
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

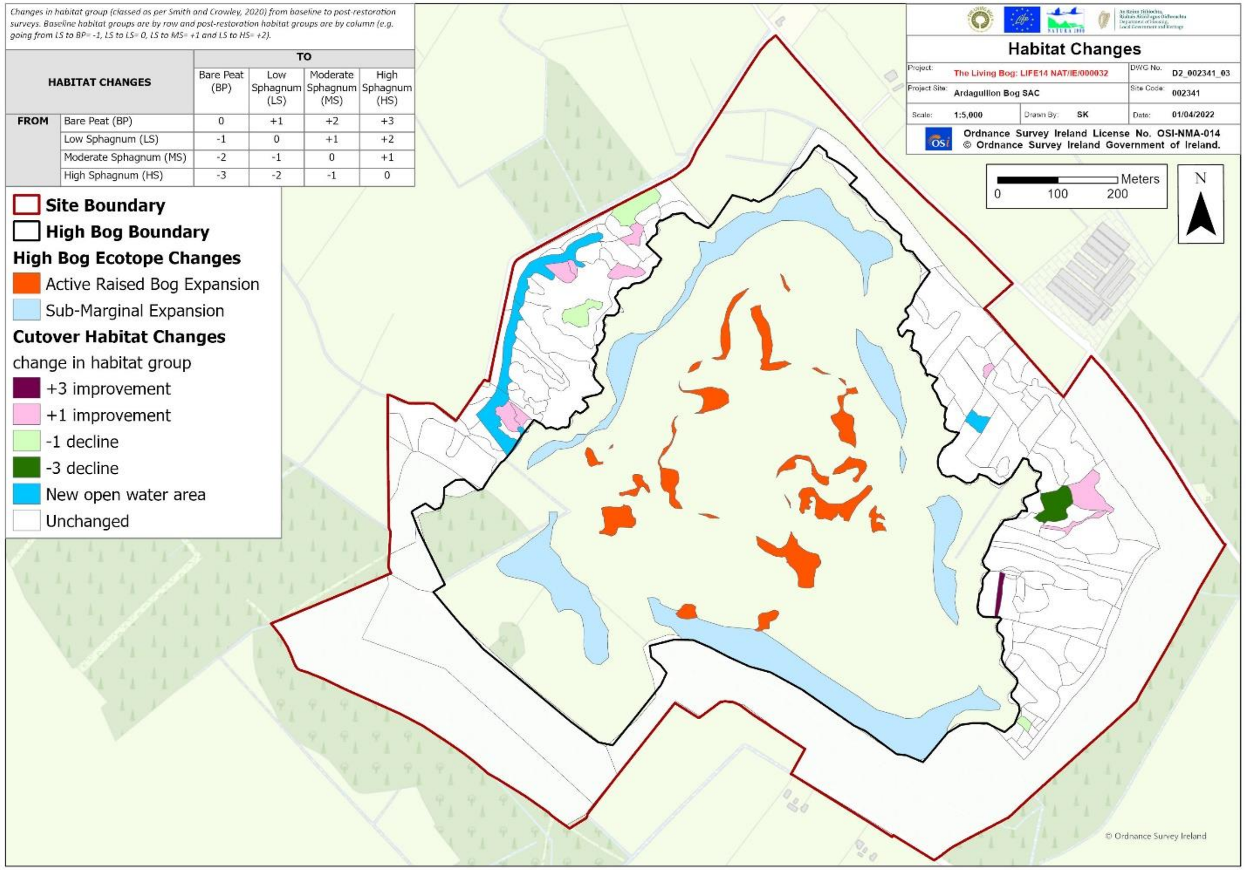

Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Habitats 2020
Fossitt
(ED2) Spoil and bare ground
(GS4) Wet grassland
(HD1) Bracken
(PF1) Poor fen and flush
(PF2) Rich fen and flush
(PF3) Transition mire and quaking bog
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2) Sphagnum papillosum – Eriophorum vaginatum
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
(MS5) Juncus effusus – Sphagnum palustre
Low Sphagnum
(LS1) Calluna vulgaris
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
Bare Peat
(BP1) Calluna vulgaris
(BP3) Bare peat
unthulla
CLONMACNOISE
TULLAGHBEG
R444
Meters
0 150 300
N
NOTE:
Post restoration ecotope mapping to be completed.
Post-Restoration Habitats, Monitoring Locations and Modeled Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000580_02
Project Site: Mongan Bog SAC
Site Code: 000580
Scale: 1:7,000
Drawn By: SK
Date: 03/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.



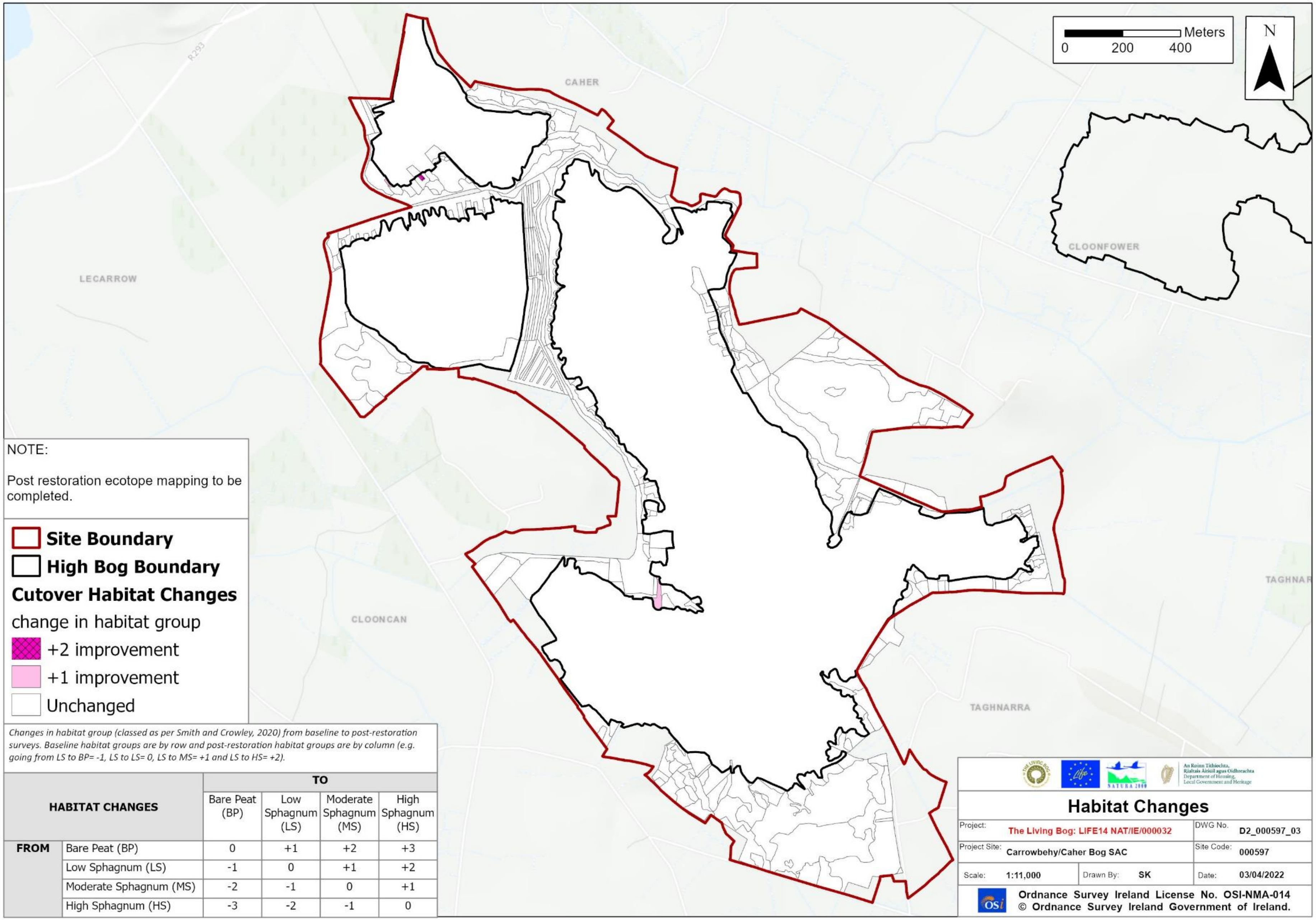
Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Ecotopes (High Bog)
Active Flush
Inactive Flush
Central
Sub-central
Marginal
Sub-marginal
Face Bank
NOTE:
Post restoration cutover habitat mapping to be completed.
Meters
0 100 200
N
MOYCLARE
CLONBONNIFF
MOYCLARE
BALLINLOMA
BALLINLOMA
220kV
Post-Restoration Habitats, Monitoring Locations and Modeled Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000581_02
Project Site: Moyclare Bog SAC
Site Code: 000581
Scale: 1:5,500
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.


Ecology Monitoring Location
Hydrology Monitoring Location
Potential Peat Forming (modeled)
Degraded Raised Bog (modeled)
Site Boundary
Habitats 2020
Fossitt
(FL) Lakes and ponds
(GA1) Improved grassland
(PF2) Rich fen and flush
(PF3) Transition mire and quaking bog
(WN6) Wet Willow-alder-ash woodland
(WN7) Birch woodland
(WS1) Scrub
Smith & Crowley (2020 cutover habitat types)
High Sphagnum
(HS1) Sphagnum subnitens – Erica tetralix
(HS2/HS3) Sphagnum papillosum – Eriophorum vaginatum/Sphagnum palustre – Molinia caerulea
(HS3) Sphagnum palustre – Molinia caerulea
Moderate Sphagnum
(MS1) Calluna vulgaris – Sphagnum subnitens
(MS1/WS1) Calluna vulgaris – Sphagnum subnitens/Scrub
(MS2) Eriophorum vaginatum – Sphagnum papillosum
(MS3) Molinia caerulea – Polygala serpyllifolia
(MS4) Cladonia portentosa – Trichophorum germanicum
Low Sphagnum
(LS1) Calluna vulgaris
(LS2) Eriophorum angustifolium
(LS3) Molinia caerulea
(LS3/LS1) Molinia caerulea/Calluna vulgaris
(LS3/WS1) Molinia caerulea/Scrub
(LS4) Filipendula ulmaria
(LS4/WS1) Filipendula ulmaria/Scrub
Bare Peat
(BP1) Calluna vulgaris
(BP3) Bare peat
NOTE:
Post restoration ecotope mapping to be completed.
Meters
0 100 200
N
CLONEEN
PUTTAGHAN
RAHEENMORE
110Kv
Post-Restoration Habitats, Monitoring Locations and Modeled Potential
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000582_02
Project Site: Raheenmore Bog SAC
Site Code: 000582
Scale: 1:6,500
Drawn By: SK
Date: 03/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

Map 3: Habitat changes from baseline to post-restoration

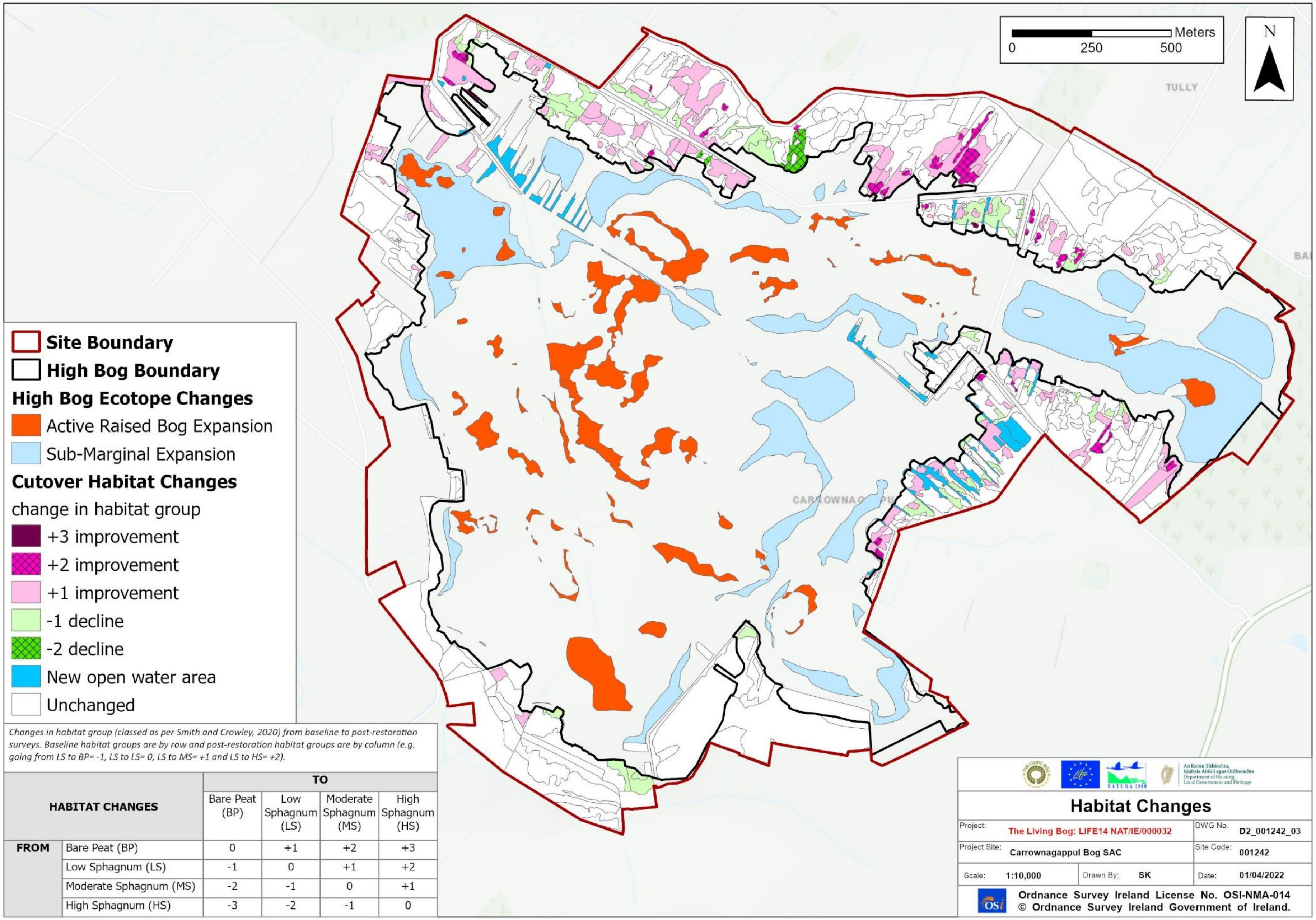


HABITAT CHANGES		TO			
		Bare Peat (BP)	Low Sphagnum (LS)	Moderate Sphagnum (MS)	High Sphagnum (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low Sphagnum (LS)	-1	0	+1	+2
	Moderate Sphagnum (MS)	-2	-1	0	+1
	High Sphagnum (HS)	-3	-2	-1	0



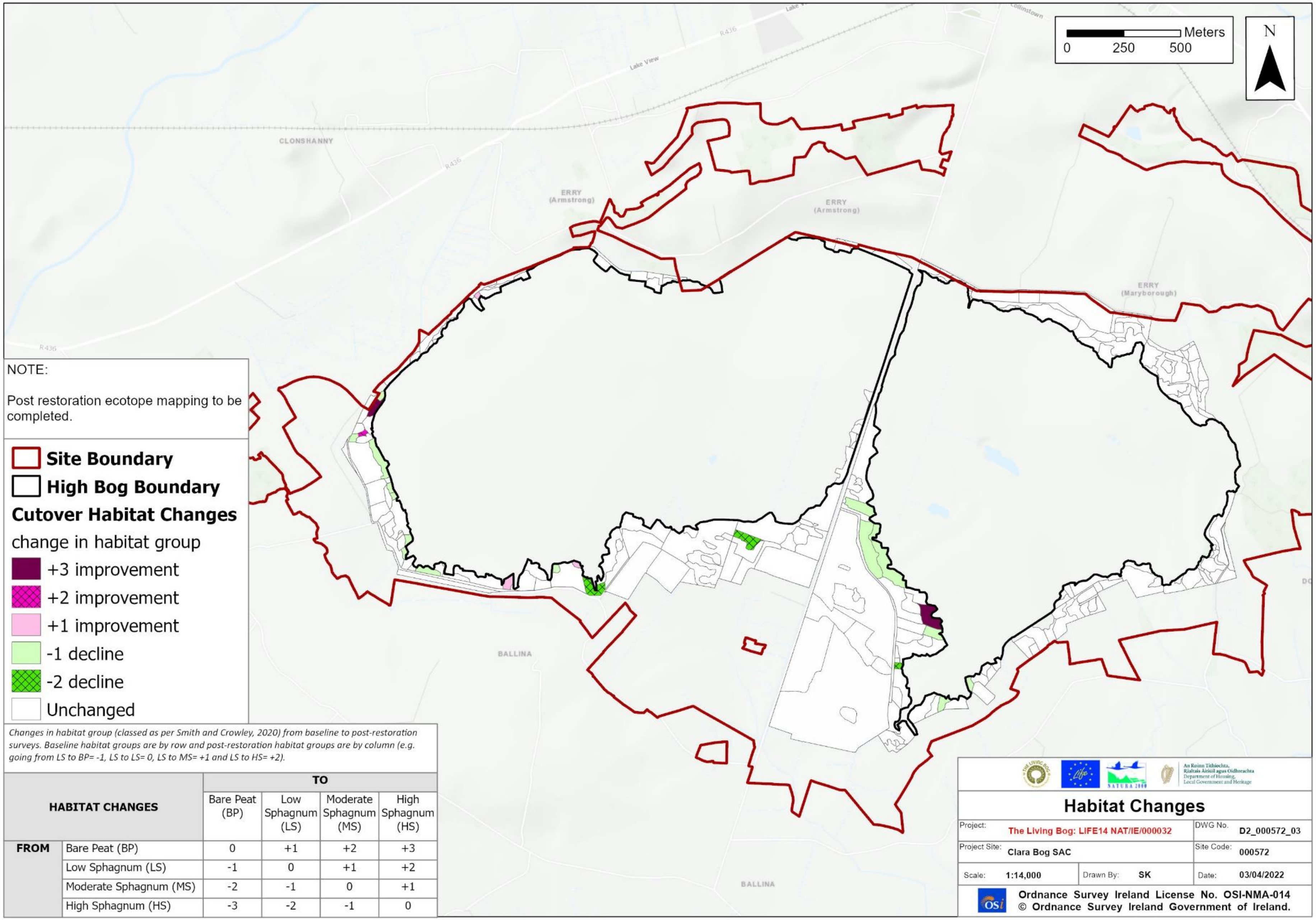
Changes in habitat group (classed as per Smith and Crowley, 2020) from baseline to post-restoration surveys. Baseline habitat groups are by row and post-restoration habitat groups are by column (e.g. going from LS to BP= -1, LS to LS= 0, LS to MS= +1 and LS to HS= +2).

HABITAT CHANGES		TO			
		Bare Peat (BP)	Low Sphagnum (LS)	Moderate Sphagnum (MS)	High Sphagnum (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low Sphagnum (LS)	-1	0	+1	+2
	Moderate Sphagnum (MS)	-2	-1	0	+1
	High Sphagnum (HS)	-3	-2	-1	0

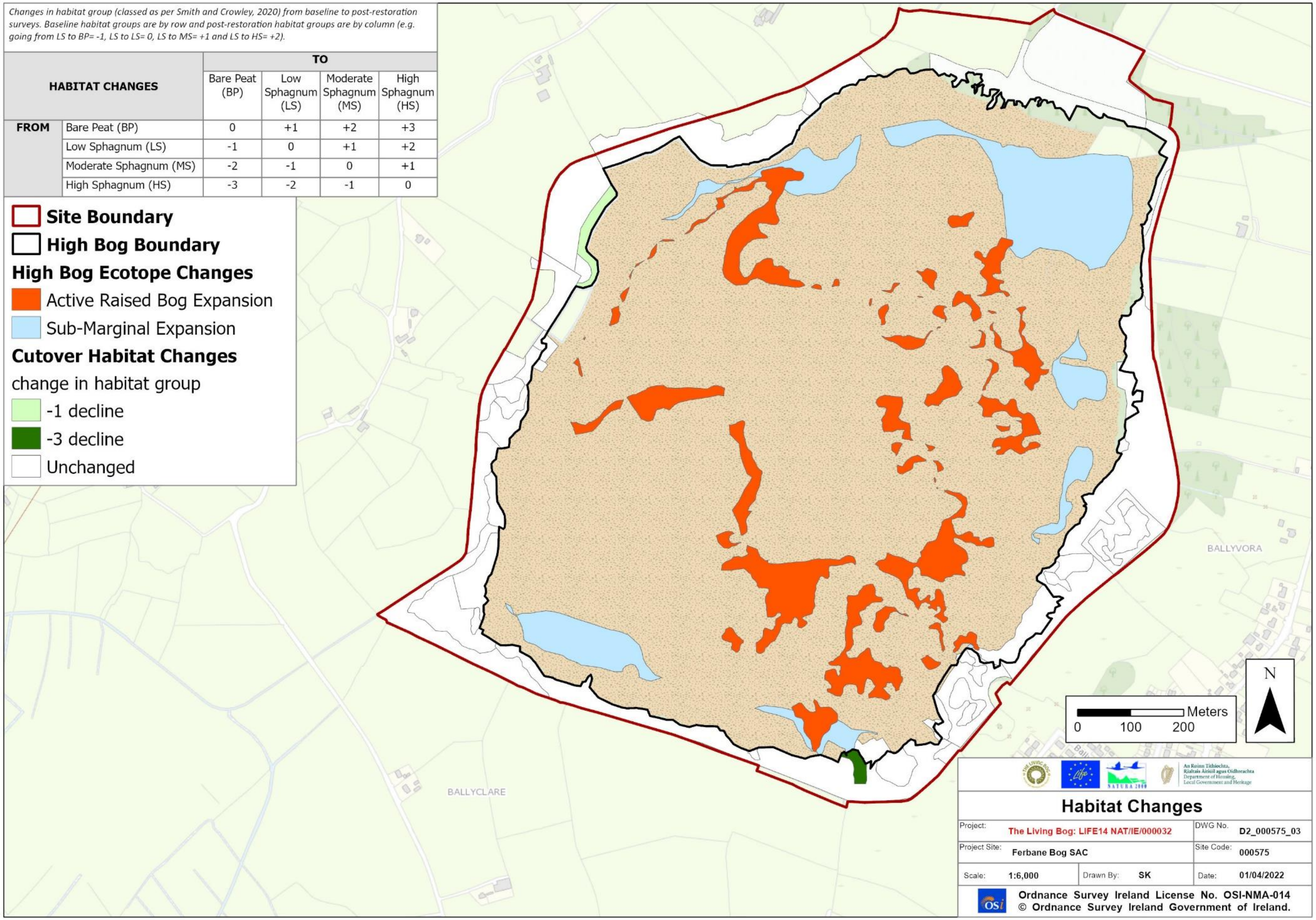


Changes in habitat group (classed as per Smith and Crowley, 2020) from baseline to post-restoration surveys. Baseline habitat groups are by row and post-restoration habitat groups are by column (e.g. going from LS to BP= -1, LS to LS= 0, LS to MS= +1 and LS to HS= +2).

HABITAT CHANGES		TO			
		Bare Peat (BP)	Low Sphagnum (LS)	Moderate Sphagnum (MS)	High Sphagnum (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low Sphagnum (LS)	-1	0	+1	+2
	Moderate Sphagnum (MS)	-2	-1	0	+1
	High Sphagnum (HS)	-3	-2	-1	0

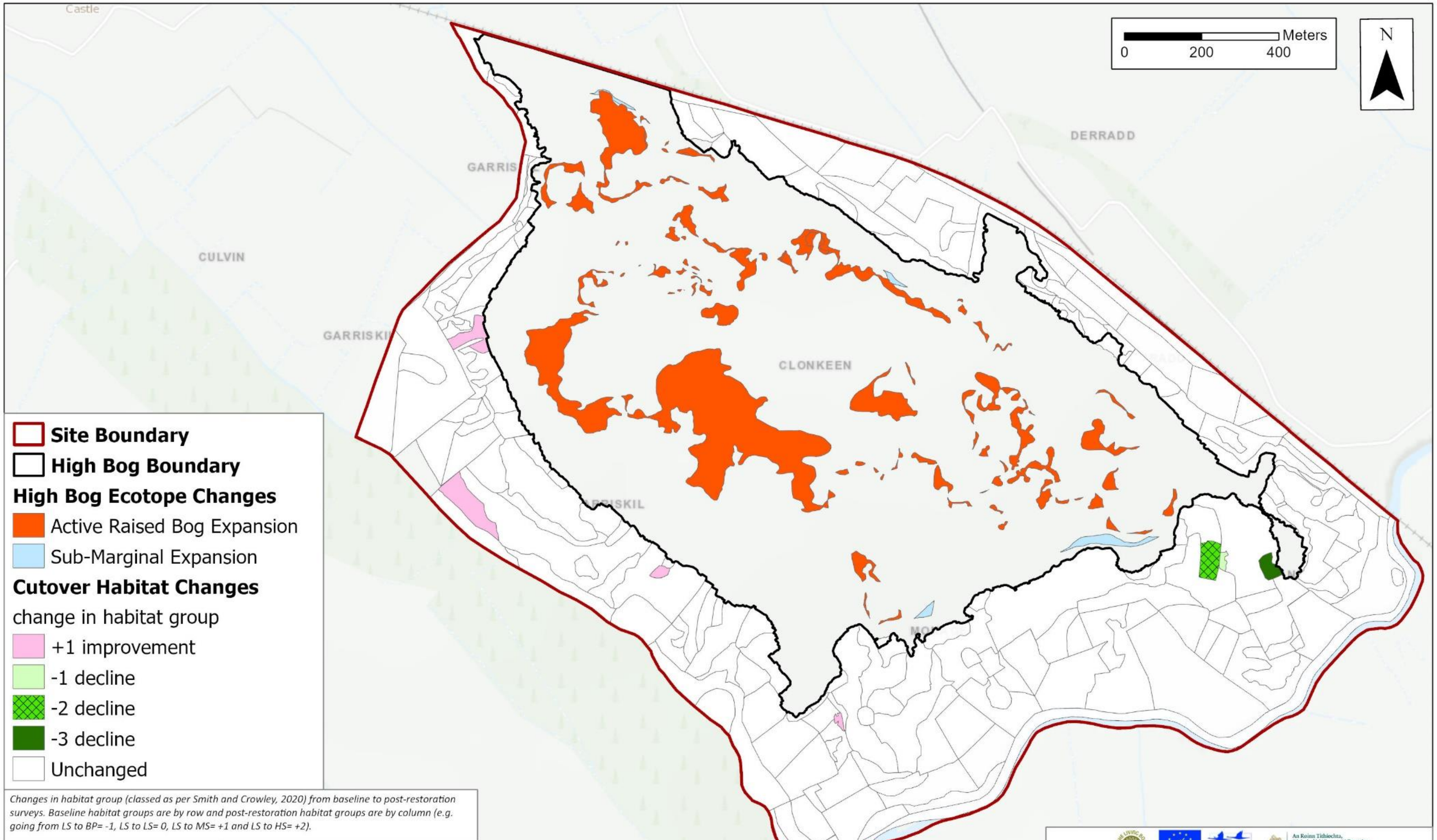


HABITAT CHANGES		TO			
		Bare Peat (BP)	Low Sphagnum (LS)	Moderate Sphagnum (MS)	High Sphagnum (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low Sphagnum (LS)	-1	0	+1	+2
	Moderate Sphagnum (MS)	-2	-1	0	+1
	High Sphagnum (HS)	-3	-2	-1	0


Changes in habitat group (classed as per Smith and Crowley, 2020) from baseline to post-restoration surveys. Baseline habitat groups are by row and post-restoration habitat groups are by column (e.g. going from LS to BP= -1, LS to LS= 0, LS to MS= +1 and LS to HS= +2).

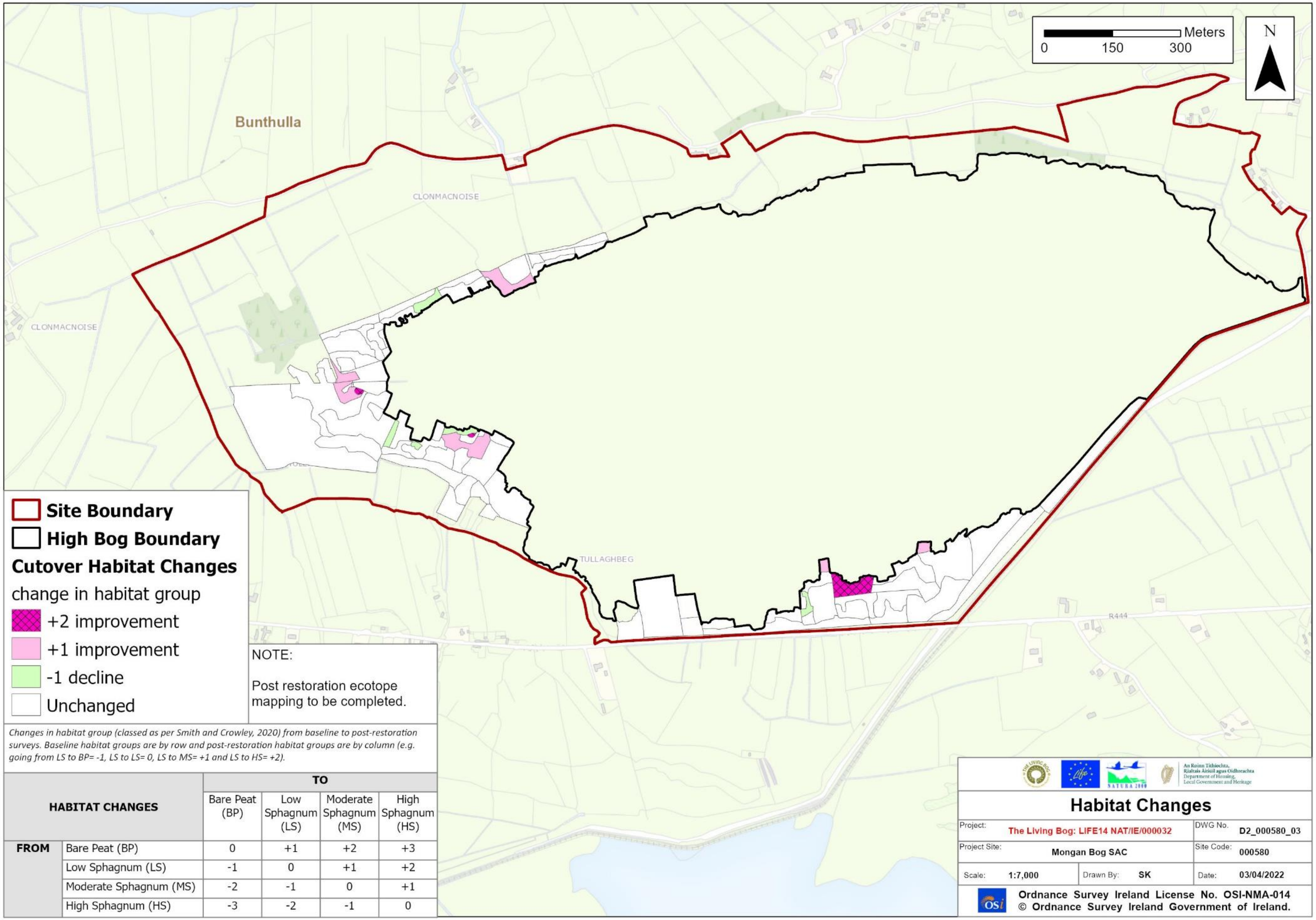
HABITAT CHANGES		TO			
		Bare Peat (BP)	Low Sphagnum (LS)	Moderate Sphagnum (MS)	High Sphagnum (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low Sphagnum (LS)	-1	0	+1	+2
	Moderate Sphagnum (MS)	-2	-1	0	+1
	High Sphagnum (HS)	-3	-2	-1	0

Site Boundary
High Bog Boundary
High Bog Ecotope Changes
Active Raised Bog Expansion
Sub-Marginal Expansion
Cutover Habitat Changes
change in habitat group
-1 decline
-3 decline
Unchanged
BALLYVORA
BALLYCLARE
N
Meters
0 100 200
Habitat Changes
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000575_03
Project Site: Ferbane Bog SAC
Site Code: 000575
Scale: 1:6,000
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

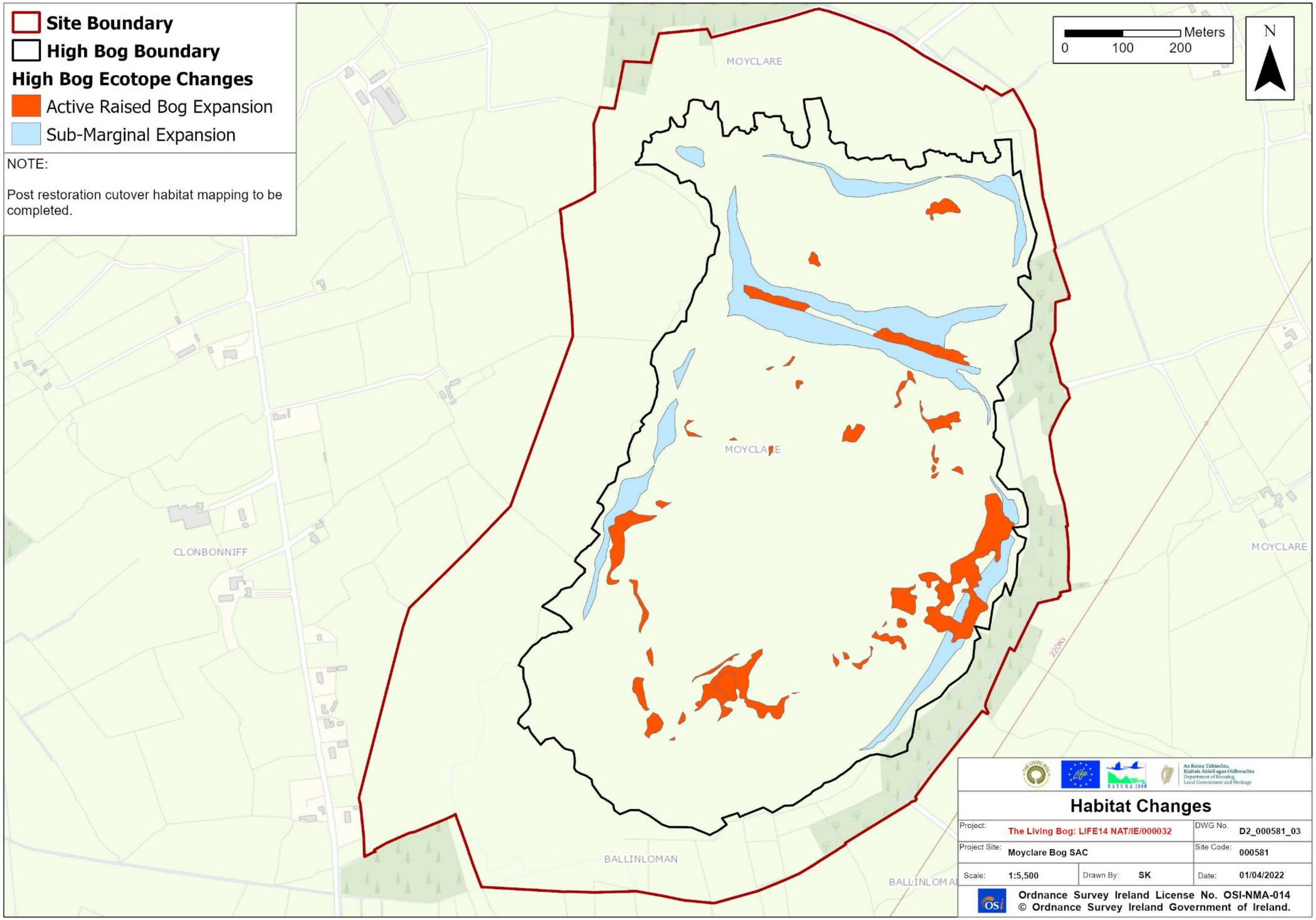


Changes in habitat group (classed as per Smith and Crowley, 2020) from baseline to post-restoration surveys. Baseline habitat groups are by row and post-restoration habitat groups are by column (e.g. going from LS to BP= -1, LS to LS= 0, LS to MS= +1 and LS to HS= +2).

HABITAT CHANGES		TO			
		Bare Peat (BP)	Low Sphagnum (LS)	Moderate Sphagnum (MS)	High Sphagnum (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low Sphagnum (LS)	-1	0	+1	+2
	Moderate Sphagnum (MS)	-2	-1	0	+1
	High Sphagnum (HS)	-3	-2	-1	0



HABITAT CHANGES		TO			
		Bare Peat (BP)	Low Sphagnum (LS)	Moderate Sphagnum (MS)	High Sphagnum (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low Sphagnum (LS)	-1	0	+1	+2
	Moderate Sphagnum (MS)	-2	-1	0	+1
	High Sphagnum (HS)	-3	-2	-1	0


Site Boundary
High Bog Boundary
High Bog Ecotope Changes
Active Raised Bog Expansion
Sub-Marginal Expansion
NOTE:
Post restoration cutover habitat mapping to be completed.
Meters
0
100
200
N
MOYCLARE
MOYCLARE
MOYCLARE
CLONBONNIFF
BALLINLOMAN
BALLINLOMAN
220kV
Habitat Changes
Project: The Living Bog: LIFE14 NAT/IE/000032
DWG No. D2_000581_03
Project Site: Moyclare Bog SAC
Site Code: 000581
Scale: 1:5,500
Drawn By: SK
Date: 01/04/2022
Ordnance Survey Ireland License No. OSI-NMA-014
© Ordnance Survey Ireland Government of Ireland.

Changes in habitat group (classed as per Smith and Crowley, 2020) from baseline to post-restoration surveys. Baseline habitat groups are by row and post-restoration habitat groups are by column (e.g. going from LS to BP= -1, LS to LS= 0, LS to MS= +1 and LS to HS= +2).

HABITAT CHANGES		**TO**			
		Bare Peat (BP)	Low Sphagnum (LS)	Moderate Sphagnum (MS)	High Sphagnum (HS)
FROM	Bare Peat (BP)	0	+1	+2	+3
	Low Sphagnum (LS)	-1	0	+1	+2
	Moderate Sphagnum (MS)	-2	-1	0	+1
	High Sphagnum (HS)	-3	-2	-1	0

Site Boundary

High Bog Boundary

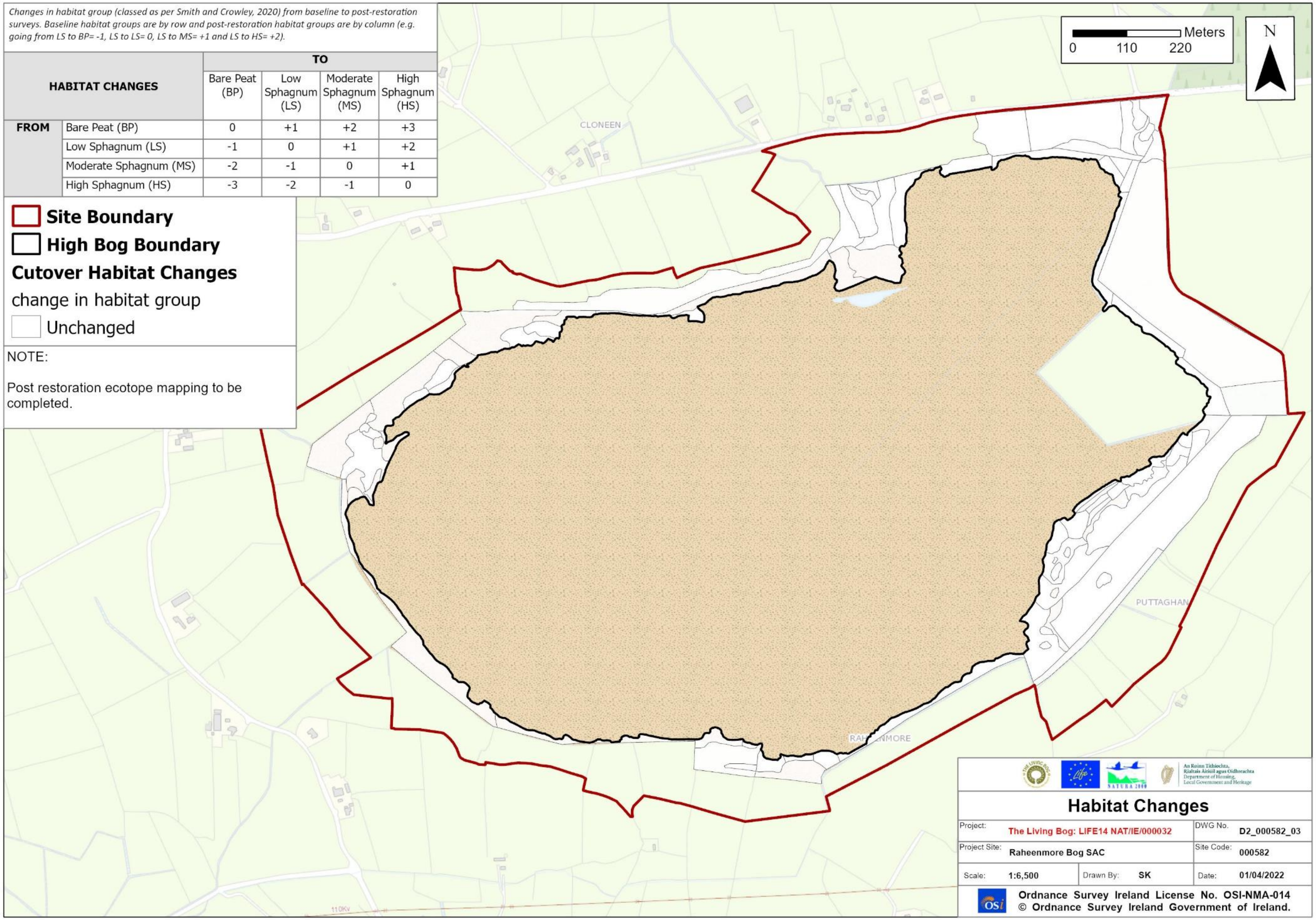
Cutover Habitat Changes

change in habitat group

Unchanged

NOTE:

Post restoration ecotope mapping to be completed.



Habitat Changes

Project:	The Living Bog: LIFE14 NAT/IE/000032	DWG No.	D2_000582_03
Project Site:	Raheenmore Bog SAC	Site Code:	000582
Scale: 1:6,500	Drawn By: SK	Date:	01/04/2022