Bord na Móna and Coillte

Native Woodland Establishment on Cutover Peatlands

April 2019

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Document version control

Document version	Date	Comment
Bord na Móna Coillte Native Woodlands Establishment Report 26042019 Final	26/04/19	Final copy agreed by all parties
Bord na Móna Coillte Native Woodlands Establishment 24042019	24/04/19	Updated version taking on board Stuart Conaty comments and Ken Byrne update
ZODv7 MK DL KB MMC	15/04/19	Updates to include Mark McCorry edits
ZODv6 MK DL KB	09/04/19	Includes statement pieces from Declan Little (biodiversity) and Ken Byrne (carbon)
ZODv4 KB MK	09/04/19	Copy sent to Declan Little and Ken Byrne for input on biodiversity and carbon respectively. Appendix 4 added.
ZODv3 MK	09/04/19	Revised costs and edits
ZODv2	08/04/19	Restructure format and revise costs
ZOD	07/04/19	Zero order draft

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Summary

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[redacted] The **first** strand was to consider how establishment of new woodlands in the landscape could best be done so that biodiversity enhancement and carbon sequestration potential is maximised. An integrated landscape approach was adopted using the existing Bord na Móna biodiversity plan as a template for design at the landscape level, where woodlands develop in a mosaic of other secondary cutover peatland habitats. Rehabilitation plans already exist for all Bord na Móna bogs under their existing Integrated Pollution Control (IPC) licences and these plans outline measures that will stabilise each bog once peat harvesting has ceased. The primary Bord na Móna rehabilitation strategy is re-wetting peat, where possible. This feasibility study is focussed on accelerating native woodland establishment on drier cutaway peatland areas.

The integrated landscape approach has important consequences on how future environmental impact assessments (EIAs) may be carried out, where the whole landscape should be considered, and not just the new woodland areas. Retention of current and future habitats such as wetlands and regenerating fens was prioritised, based on their biodiversity value and their ability to reduce emissions from peat areas out of production. Native woodland types best suited to these sites were then defined and suitable areas within the landscape habitat mosaic were identified using a geographic information system (GIS) decision support system (DSS). These prescriptions were developed in co-operation with Woodlands of Ireland (WofI), based on their previous experience with the Forest Service Native Woodland Scheme (NWS). [redacted]

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In terms of the proposed woodland types suggested by the GIS study, the vast majority fell into either pioneer birch woodland or birch enriched with Scots pine and other native broadleaves. A very small area (<3ha) was proposed as esker type woodland. This proposed breakdown is tentative for two reasons. Firstly, the actual woodland type to be created will depend on local site conditions which may not be evident from remote sensing or GIS data. Secondly, no peat depth data were available for over 700ha and, for the purpose of this project, these areas have been classified for now as having potential for pioneer birch woodland creation. Ground truthing before and during the establishment phase is therefore a prerequisite if the project goes ahead.

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The value of this project, if successfully established, is potentially very significant. In addition to supporting the Strategy for Native Woodlands, it would complement a number of other important National initiatives such as the National Peatlands Strategy, the National Biodiversity Plan and the National Mitigation Plan. Not only will the project support National climate mitigation targets with respect to carbon (and methane) sequestration, but the acceleration of the creation of large tracts of native woodland (along with the existing naturally-regenerated native woodland already present) in a matrix of other habitat types (developed as a result of Bord na Móna rehabilitation, re-wetting and land use management) - including restored raised bog, wetland, heath and open water, will benefit biodiversity substantially and far more than if it were native woodland alone.

The presence of an array of habitats (from both existing Bord na Móna plans and this project) will, in time, support an increasing number of flora and fauna species. The sheer critical mass of the woodland area in question will potentially support specialist woodland species that require large woodland areas to sustain themselves to become a possibility. In effect, large 'biodiversity restoration' areas will be created and the project will *de facto* become one of the first largescale 'landscape re-animation' project in Ireland. These areas could range from woodland where biodiversity is the primary land use to areas represented by a mosaic of woodland and other land use (e.g. solar or wind farms).

Clearly, the value of these new woodlands should not be looked at in the conventional sense in terms of economic output but in the range of additional ecosystem services provided. [redacted]

[redacted]

In addition to climate mitigation and biodiversity services, other ecosystem services provided by this project include water quality protection and enhancement (through riparian woodland creation), recreation and health. In addition, the proposed woodland establishment (and associated vegetation) will accelerate the stabilisation of the bare peat surface, thereby reducing wind and water erosion. Also limited quality indigenous hardwood (and pine) and firewood production under Continuous Cover Forestry (CCF) is a possibility. [redacted]

The value of the project from a carbon perspective is also explored in the Report. Although any assessment of the potential greenhouse gas balance of the woodland types planned within this project is uncertain (due to lack of accurate greenhouse gas emission factors from the proposed woodland/wetland cutaway peatland mosaic), some reasonable conclusions can be drawn:

1. Woodland creation will accelerate the restoration of the carbon sink function and lead to the development of new carbon stocks in biomass, woody debris and litter.
2. This improved carbon sink function will offset some or all of the carbon loss from peat decomposition and the extent to which it does will depend on the relative balance between carbon uptake and loss.
3. It is uncertain if this balance may move towards carbon neutrality over the medium to long term but the rate of carbon loss will be reduced.
4. At a landscape level, the carbon balance will depend on these and other factors such as the relative extent of different woodland types, wetland ecosystems, future land-use and future climate.

Some other key learnings which were taken on board while putting this proposal together were:

- These lands need to be looked on as a mosaic of different habitat types - wetland, dry woodland, wet woodland, heath, etc. Individual habitat use types should not be looked on in isolation but in the context of the 'habitat mosaic' approach so that their true value will be realised. This is relevant for all the ecosystem services that are pertinent i.e. climate mitigation, biodiversity, amenity/recreation, health and water quality protection.
- Related to that, this project must ensure that existing areas of scrub (not counted in this project) are considered in the overall woodland plan for the cutover peatlands as they complement and inform future establishment and management options and will provide options for biodiversity and management for timber products.

[redacted]

[redacted] this project has a huge potential to support the delivery of National policy initiatives and provide many ecosystem service benefits. The proposed project would also align with the Bord na Móna rehabilitation strategy of re-wetting, where possible, and encouraging the development of habitats, such as birch woodland, that are compatible with underlying naturally drier environmental conditions. The scale of the proposed native woodland establishment has never been carried out in this country before, and it is this scale, in addition to the size of the proposed blocks and the diverse nature of the woodlands planned, that offer so much promise.

Acknowledgements

This project would not have been completed within the tight timetable without the guidance, support and expertise of the following people:

[redacted] Dr. Mark McCorry (Bord na Móna), [redacted] Dr. Florence Renou-Wilson (Earthy Matters), Dr. Catherine Farrell (Bord na Móna), Ciara Byrne (FERS Ltd), [redacted] Sean Lenihan (Kestrel Forestry), Tom Egan (Bord na Móna) and [redacted]

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Future uses of cutaway peatlands

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The wetland will develop mainly over existing peatlands and will form a mosaic with other habitats such as wet woodland, scrub, heathland and wet grassland (Bord na Móna, 2016). The 50% woodland will also be part of a mosaic and will comprise of mainly birch with some willow and pine. Where these woodlands are on wet peat, they will be associated with patches of wetland species, with willow dominant in some instances. On drier sites, the birch can be expected to form dense stands. Whatever the outcome of natural succession post rehabilitation, these processes can take decades to show results, particularly for woodland other than birch/willow.

Creating new woodlands by seeding or planting can potentially speed this process up and offer a wide range of ecosystem services including biodiversity, carbon sequestration and recreational uses. However, it is important that the current habitats need to be identified so that new woodland creation can be considered as afforestation - so that National targets can be addressed. For example, woodlands cannot be said to be created when the current habitat is already classified as forests. According to the National Forest definition, an area with 20% crown cover of trees which have a potential to reach 5m in height is classified as forest. Based on the 2017 National Forest Inventory, there are already 4,000ha of birch dominated woodland which are considered as 'forest cover'on the Bord na Móna estate.

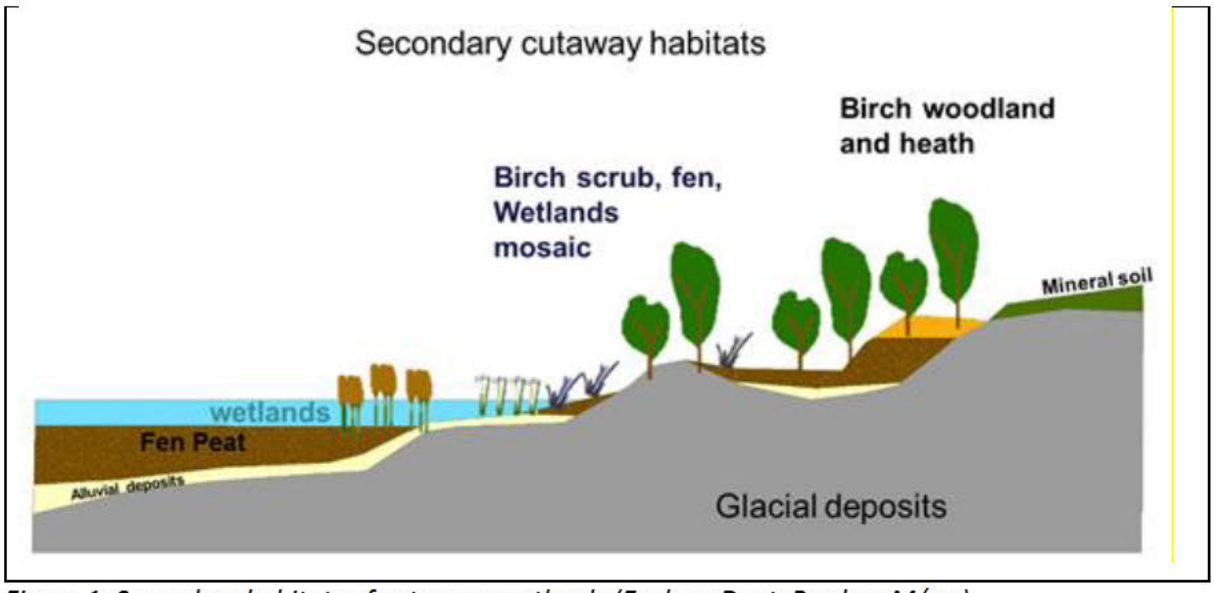

Figure 1: Secondary habitats of cutaway peatlands (Ecology Dept, Bord na Móna)

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Woodland and landscape design guidelines

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High level site requirements for woodland establishment

From lessons learned on previous afforestation programmes on cutover peatlands, initial care in relation to site selection is essential if the programme is to be a success (Black et al., 2017). If inappropriate sites are selected at the beginning, then no amount of care in selecting species or silvicultural regimes will lead to realised objectives. Although the overall objectives of the current project (with an emphasis more on biodiversity attributes) are quite different to previous forest programmes on cutover peatland (which had more emphasis on wood production), some basic requirements remain;

[redacted]

- Sites chosen must contain <250cm of peat over well weathered calcareous sub layer.
- Drainage status of the sites chosen will influence the types of habitat which can be created but overall there should be a mix of well drained areas, periodically water-logged areas and some areas subject to intermittent seasonal flooding. Some water-logged areas are likely to develop as the former drainage breaks down naturally. This approach is quite different to previous commercial afforestation programmes on cutover peatlands which only proposed using sites which were well drained or gravity drainable.

- Only sites containing either bare peat or non-woody vegetation should be selected. Sites which contain woody vegetation are already classified as "woodland" under current NFI criteria.
- Individual sites chosen should be large, and highly fragmented areas should be excluded to reduce establishment cost.
- Sites should contain no bays still in peat production.

[redacted]

In addition to the specific requirements for cutover peatlands, there are also some general requirements when creating new native woodlands (Little, et al., 2009, Rodwell and Patterson, 1994).

- Sites should be as "blocky" as possible, avoiding long narrow strips as they are unlikely to develop a complete woodland flora and are expensive to establish.
- If possible, sites chosen should act as wildlife/habitat corridors between existing habitats.
- At the design phase, new native woodland should include open areas with other habitats. These should be substantial and usually at least 20% of the full area.
- Only sites close to existing seed sources should be selected for natural regeneration. In birch, for example, the majority of seed falls within 50m of parent trees (Worrell, 1999).
- Natural colonisation from adjoining trees is theoretically preferable to planting. In reality, however, planting or seeding may be essential in some areas to accelerate woodland establishment. This is particularly relevant to cutover peat areas as adjoining trees may be long distances away.
- All planting stock should be derived from suitable seed sources, similar to those specified under the Native Woodland Scheme.
- Management practices such as fencing, ground preparation, fertilisation and pesticide use may be required but should be used with care and follow appropriate guidelines.

Integration with the Bord na Móna Biodiversity Action Plan

The current afforestation programme generally works with individual parcels of land of approximately 8-10ha. Identification of large block of cutover peatlands suitable for woodlands is a major limitation given the fragmented nature of the current mosaic of habitats. In addition, creation of individual woodland blocks does not consider biodiversity requirements such as habitat connectivity and creation of a landscape with high structural and functional diversity. The current Bord na Móna Biodiversity Action Plan (Bord na Móna BAP) has identified current and future habitats, which include woodlands (Figure 2).

This project will attempt to integrate the specification and design of the future woodlands using the Bord na Móna BAP as a template. The major advantages of this approach is the potential to increase the scale of woodland establishment from a relatively small area to that approaching a landscape view. In addition to the sheer scale differences, the existing vegetation, underlying parent material and peat

characteristics of abandoned cutaway peatlands will also result in the regeneration of a mosaic of vegetation types as reflected by the Bord na Móna biodiversity habitat map.

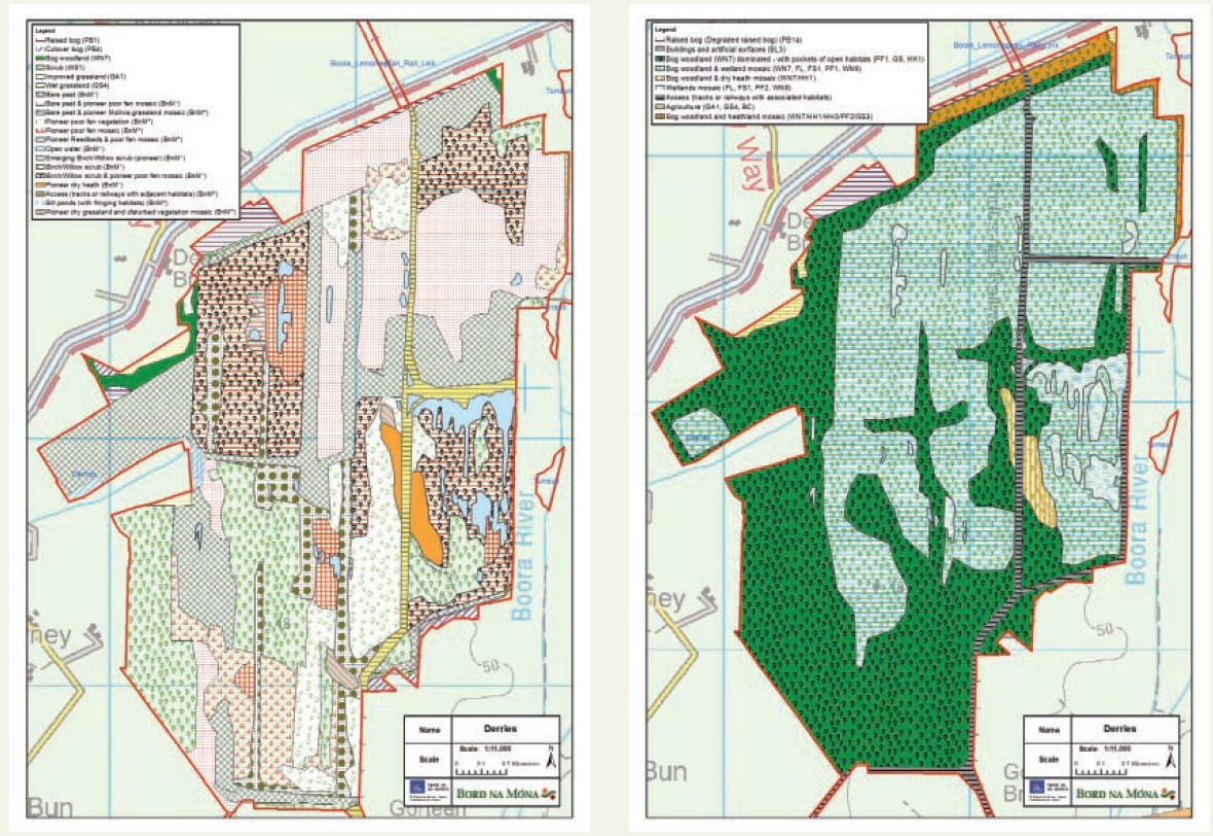

Figure 2: The 2009 habitat map (left panel) and potential future habitat map (right panel) of Derries bog showing development of a birch/wetland mosaic. The project plans to enhance woodland creation, habitat connectivity and biodiversity value to the Bord na Móna BAP (Taken from the Bord na Móna biodiversity action plan (Bord na Móna, 2016)).

The rejuvenation of woodland habitats is an integral part of the Bord na Móna biodiversity action plan (Bord na Móna, 2016). The current project uses this plan as a template for creation of woodland habitats because it already aligns with the project biodiversity and carbon sequestration objectives by delivering:

- A range of different habitats in a landscape mosaic ensuring structural (patchiness and 3D vegetation layers) and functional diversity and enhances habitat connectivity (Noss, 1990).
- Recognition and protection of high value biodiversity habitats such as restoring fens, wetlands and calcareous grasslands (Bord na Móna, 2016).
- New woodlands which will speed up the regeneration process and woodland succession process.
- Planting of native species such as birch, willow, Scots pine, oak, hazel, holly, etc. which will increase species diversity. Without human intervention, this process will eventually take place but it may take decades or centuries for these species to establish to provide full canopy cover.
- Rapid vegetation of the bare peat surfaces, through woodland establishment, may slow peat degradation, enhance nutrient retention and reduce run off (Renou-Wilson et al., 2008b). This in turn encourages further vegetation growth (Renou-Wilson, 2008b, Black et al., 2007a).

- Creation of new cutaway wetlands in suitable areas thereby reducing peat degradation and greenhouse gas emission, relative to a bare peat scenario (Renou-Wilson et al., 2019), but this process may take some time (Rigney et al., 2018).
- Establishment of woodlands will speed up the accumulation of biomass, litter and deadwood carbon pools, which will increase GHG removals, relative to a bare peat which recolonises at a slower rate**.** The emissions from remaining peat layers under afforestation continues, but the precise dynamics remain uncertain. However, it is likely that the net GHG balance of seeded or planted woodlands, relative to a naturally recolonising scrub transition scenario, will become positive more quickly. Conifer afforestation of peatlands has been shown to result in a net carbon sink after 4-12 years (Hargreaves et al., 2003, Black and Gallagher, 2010) but the transition from net emission to net removal of CO_2 depends on site productivity, species and assumptions on the rate at which peat continues to degrade (Black and Gallagher, 2010).

Recommendation:

a) Woodland creation should be undertaken at the landscape level within existing and future Bord na Móna BAP habitats

b) The potential future broad woodland habitats should be defined as specified in the Bord na Móna BAP, including (see Appendix 2 for definition of habitat types):

- **Dry woodlands;** woodlands on dry areas where encroaching scrub develops into birch woodlands. Although birch is considered as a climax vegetation (Feehan et al., 2008) succession species such as oak and pine may eventually dominate in the long term.
- **Woodland-heath mosaics;** similar to dry woodlands (above) but contains patches of non woody heath vegetation. This mosaic has enriched structural biodiversity which will be maintained by not planting already vegetated areas.
- **Woodland-wetland mosaics;** these woodlands are dominated by birch and willow (with some alder) and occur in patches surrounded by wetlands. This again supplements the structural and functional diversity of the landscape.

A review of suitable woodland species

a) Birch

Finnish foresters have been dealing with birch silviculture on cutover peatlands for many decades. Downy birch makes up about 12% of the total growing stock in Finland and the species can constitute almost 100% of growing stock on peatlands forests (Hytönen et al, 2018). Downy birch stands are established by planting, seeding or natural regeneration (Hytönen and Saarsalmi, 2009), but this is generally limited to peat sites where peat depth is 10 to 60cm. However, due to the low amounts of potassium and phosphorus in the residual peat, improvement of the soil nutrient status is usually required for successful afforestation. There is increasing interest in Finland in using wood or peat ash as a fertiliser followed by seeding of downy birch for the establishment of biomass crops (Hytönen, 2019: personal communication).

In Ireland, birch is considered the natural climax vegetation on much of these areas (Feehan et al., 2008) with downy birch (*Betula pubescens*) being far more common than silver birch (*Betula pendula*),

particularly on wetter soils. Silver birch is generally only found as a minor component of woodlands on cutover peatlands and then only on drier, sheltered areas with richer soils (Horgan et al., 2004). Cross (2006) suggests, however, that it is more difficult to predict the regenerated vegetation of cutaway bog. Birch woodland often develops on many drier sites, but we do not know whether this will be replaced eventually by oak-ash forest, or gradually revert to wet heath and subsequently bog. At 47,000ha, the birch genus is currently the third most common (7%) forest genus in this country, after spruce (55%) and pine (11%) (Anon., 2018).

Up to recent years, although valued from a biodiversity and amenity point of view, birch has not been considered a valuable timber tree in this country. It often invades clearfelled areas where seed trees have been left standing, particularly in the midlands. In the past, birch was also sometimes planted on the edges of conifer plantations. In the BOGFOR study, an overstorey of birch provided shelter and improved growth in Norway and Sitka spruce, as well as oak (Renou-Wilson et al., 2008). More recently, the potential for birch to nurse other crops on cutover sites has been demonstrated by Black et al. (2017) who found a 38% increase in productivity in Sitka spruce where the spruce was planted in line mixtures with the birch. The species has other positive qualities too in that it is a valuable firewood or biomass crop and will coppice after harvesting, thus reducing restock costs. Little and Cross (2005) outlined how quality birch can be produced in Ireland under Continuous Cover silviculture in the context of the Native Woodland Scheme.

The potential productivity of birch in this country has been examined by Nieuwenhuis and Barrett (2001, 2002). They found that birch can grow at up to 1m/year but that early height growth peaks before 20 years of age. Stem form was often poor but standing volumes of up to 200m^3/ha could be achieved in 42 years. In parallel, work has also been carried out on a selection and tree improvement programme in birch in this country since the late 1990's (O'Connor, 2006). As a result of this programme, improved seed has been available since 2017 and it is expected that the amount available will increase over time. Under the various DAFM schemes, birch is now a grant-aided species. It can be planted under Grant and Premium Category GPC 8 as a pure timber crop if 'qualified' or 'selected' seed is used or under GPCs 9 and 10 for the Native Woodland Scheme where 'source identified' seed is also allowed.

b) Other species

Although most of the previous work on woodland creation on cutover sites concentrated on growing trees commercially for timber production, some native trees were planted in the BOGFOR trials. Oak has grown well on many fertile cutover sites, particularly where peat depths are less than 1m and drainage is sufficient. The species grows well when grown under a birch shelter. Scots pine has performed well but on some sites was attacked by pine shoot moth. Pines naturally regenerate on abandoned production bays and appear to tolerate deeper and less well drained peats than other conifer species (Black et al., 2017). Common alder grew well initially on all sites. Its subsequent performance varied a lot and it died out on some sites before it reached fifteen years old while, on other sites, it is still growing well. The BOGFOR plot network also contains plots of yew and aspen and these species appear to be suitable as woodland species with enhanced biodiversity value. Willow (various species) is a natural coloniser of cutover peatlands, particularly in wetter sites.

Recommendation: Species selection should be guided by the prescriptions for the various site types (see sections below, Table 1). This will be mostly birch with some Scots pine and other broadleaves where enrichment planting is required.

Definition of woodland types

A number of field visits took place in late February and March where the Bord na Móna Ecology Team member, Dr. Mark McCorry, met with the consultants and Coillte representative ( ). The Team looked at existing representative Bord na Móna sites and some sites already planted under the BOGFOR Programme between 1996 and 2000. For example, discussion on the) suggested that the peat type there, in conjunction with the free draining gravel underneath, hinders the natural colonisation process because of the upper peat layers drying out. Definition of woodland types was done with the objective of retaining most of the current Native Woodland Grant Scheme guidelines, with some modification specific to the site types we investigated. Input on species selection in relation to this project was informed by the previous BOGFOR Programme and discussions with Woodlands of Ireland and Bord na Móna.

Recent (April 2018) changes to the Native Woodland Scheme have included a new Scenario (Scenario 5) that specifically addresses "Highly Modified Peat & Peaty Podzols (Pioneer Birch Woodland)" (Anon, 2018). Although differences between this Scenario and cutover peats are evident, lessons can be learned on the biodiversity potential and species mixes for these modified peat sites. The recommended species mix for Scenario 5, comprising of downy birch, with some Scots pine, sessile oak, rowan, holly & occasional silver birch (with hazel and hawthorn on more fertile areas locally) would work on many cutover sites. For wetter parts, the recommendation of grey willow and downy birch (and occasionally alder, in flushed areas) might also provide options on the cutover sites.

Recommendation: Basic woodland types should be identified depending on peat characteristics and the designated future woodland habitats as defined in the Bord na Móna BAP (Table 1).

Table 1: Woodland establishment decision support system (DSS) and prescriptions . Peat depths should be 0.1-2.5m. Birch refers to downy birch unless stated otherwise and oak refers to pedunculate oak unless stated otherwise.

BnM target habitat*	Current habitat	Peat characteristics	Av. pH (upper 50cm)	Woodland to be created	Establishment methods**	Prescription: species, layout, fertiliser, vegetation control, cultivation, etc.***
1. Dry woodland	Bare peat with gravel sub-soil (esker)	Very shallow peat (<10cm) with limestone or esker subsoil	6-8	Esker type woodland	Birch - natural regeneration, seeding and planting. Other species - planting	Ratio of birch:SP:others should be approximately 60:20:20. Birch should be regenerated in a mosaic, filling in between the planted groups of other species. These planted groups will be made up of SP, rowan, hawthorn, hazel, oak and possibly cherry, blackthorn, buckthorn and spindle.
2. Dry woodland	Bare peat, heath, open pioneer habitats	Peat depth <0.8m, well drained (any anoxic layer must be >40cm deep****)	4-6	Enriched birch with BM1-2 (En_BI_BM)	Birch - natural regeneration, seeding and planting. Other species - planting	Ratio of birch:SP:others should be approximately 60:20:20. Birch should be regenerated in a mosaic, filling in between the planted groups of other species. These planted groups will be made up of SP, sessile oak and possibly silver birch, holly, aspen and rowan
3. Dry woodland	Bare peat	Peat depth < 2.5m and > 0.8m	3.5-5	Pioneer birch (PiBI)	Mostly direct seeding of birch with some planted SP. Willow from cutting located locally	Ratio of birch:SP:rowan:willow should be approximately 70:10:10:10. Birch should be seeded in a mosaic with smaller groups of planted SP, rowan and willow (cuttings – in wetter areas). Some SP direct seeding should be tried
4. Woodland heath mosaics	Bare peat, heath, open pioneer habitats	Peat depth < 0.8m well drained (anoxic layer must be >40cm deep****)	4-6	Enriched birch with BM1-2 (En_BI_BM)	Birch - natural regeneration, seeding and planting. Other species – planting (use locally sourced cutting for willow)	Ratio of birch:SP:others should be approximately 70:10:20. Birch should be regenerated in a mosaic, filling in between the planted groups of other species. These planted groups will be made up of SP, sessile oak and possibly silver birch, holly, aspen, rowan and willow.
5. Woodland heath mosaics	Bare peat	Peat depth < 2.5m and > 0.8m	3.5-5	Pioneer birch (PiBI)	Mostly direct seeding of birch with some planted SP and willow	Ratio of birch:SP should be approximately 80:20. Birch should be seeded in a mosaic with smaller groups of planted SP. Some SP direct seeding should be tried. The SP should be replaced by willow in wetter areas
6. Woodland wetland mosaic	Bare peat	Peat depth <2.5m	4-6	Pioneer birch (PiBI)	Mostly direct seeding of birch with some planted willow (from locally sourced cuttings) and alder. Alder seeding should also be tried.	Ratio of birch:willow:alder should be approximately 70:20:10. Birch should be seeded in a mosaic with smaller groups of planted willow cuttings and alder. The alder should be a combination of planting and seeding.

Notes for Table 1

* See Appendix 2 for habitat definition.
**See Establishment guidelines. Unless stated otherwise, establishment methods for birch should use natural regeneration (where seed source is available) and seeding. Other species should be planted (using cuttings for willow). Seeding techniques should use a combination of hand and mechanical seeding as well as other techniques such as using branches of local birch with heavy seed loads, etc.
*** Fertiliser will only be used where past experience and research on this site type shows that establishment and early growth will not be possible without it. Where *Calluna* is already present on site, it may be better to work in the gaps between clumps rather than removing it entirely. It is not envisaged to use any site cultivation or herbicides on these sites
**** Depth to anoxic layer to be verified at detailed site planning stage.
Note: Mixture percentages are for guidance only and may change. These changes may be influenced by e.g. availability of seed and/or planting stock for specific species at any one time, disease risk (e.g. Scots pine and *Dothistroma*), risk of browsing (hares, deer or goats) or local conditions (e.g. increase in willow in local wet spots).

Establishment guidelines

1. Species and woodland type

The guidelines on woodland and species type is outlined in the DSS provided in Table 1 above.

2. Drainage/Cultivation

[redacted] Under the current project, however, there is a greater understanding that some sites will almost certainly develop as wet woodland. These sites could end up as bog woodland containing some willow and/or birch. [redacted] In our initial site screening, however, sites which are prone to flooding or which are likely to establish permanent wetland cover in the future were removed and were not considered.

Results and recommendations from the BOGFOR Programme on cultivation suggested that, on most sites, cultivation did not greatly improve establishment success. On sites with shallow peats, it did recommend mixing the peat with the sub-peat mineral soil. For the current project, it was decided not to use any form of cultivation, particularly from a carbon emissions point of view.

Recommendation: No additional drainage or cultivation will be used.

3. Seeding

Within this project, the only species being considered for direct seeding is birch (Table 1). On existing cutover sites which have exited peat harvesting for a number of years, the species which normally have seeded successfully are birch and willow with some lodgepole pine, Scots pine, Sitka spruce and, less frequently, rowan (if seed sources exist in the vicinity).

Establishment of birch can be accomplished in a number of ways, ranging from relying on wind borne seeds from trees on or in proximity to the establishment site to planting. The former is less expensive but less reliable than the latter. The former may also be more suited to the site (being a very local seed source) while the latter could allow the landowner introduce trees which may produce faster growing, straighter trees (especially if genetically improved material is used).

There are two basic requirements for successful regeneration from seed: sufficient seed either in or close to the site and suitable microsites that help seed germination and seedling establishment and growth. Seed numbers from established birch trees are estimated to range from 3–530 million/ha of filled seeds (Atkinson, 1992). Most of this seed falls within about 50m of the parent tree but some can be dispersed up to a kilometre or more.

Sitting somewhere between "natural" seeding using on-site trees to sowing seed by hand or tractor, there have been reports of very successful birch establishment where whole trees or branches containing seeds have been brought to and either stuck in or scattered over bare sites. If carried out at the correct time (September/October, depending on season), these techniques can be very successful (Rouine, 1956, Dolan, 2019: Personal communication).

Recommendation: Use 1kg pre-treated (chilling treatment) common birch (certified 481,000 seeds per kg) mixed with 20kg sand (grit size similar to the size of seed). For deeper peats (high bays), increase seedling rate to 600,000 seeds/ha. Application should be carried out in April either manually or by tractor/quad and fertiliser spinner. The spread method depends on fragmentation and size of site. Where the peat type suggests that surfaces will dry out in early summer, use autumn/early winter seeding.

Fertiliser will be required for successful seeding - 125 kg/ha of rock phosphate and 100 kg/ha muriate of potash preferably after germination in June or July.

Seeding can also be carried out by cutting branches of birch trees in the autumn when seed is ripe and sticking the branches in the peat. This system has been tried with success at a midlands Native Woodland Scheme on cutover peatland near Blueball, Co. Offaly but has not been proven from replicated field trials.

No fencing will be used on seeded areas

Expected stocking after 4 years is ca 6,000 seedlings/ha.

Use native or local seed sources

4. Planting & Stocking

Most of the establishment within this project will use direct seeding of birch. Where other species are required on some sites, some planting will be required. It is recommended that Scots pine and broadleaves such as rowan, holly, oak, whitethorn, etc. (See Table 1) are planted in groups as a mosaic within the seeded birch. Where willow and alder are recommended, they should be planted where local conditions suggest they will provide best shelter to other species.

Willow cuttings

Willow is best established using local material (on site or within 5km, if not available on site). They are best taken in the dormant season and should be 50-100cm long.

Cuttings from first or second year material can be used. They should be between 2-6cm in diameter. Approximately 80% of the cutting should be inserted in the peat and it is essential to insert the cutting with the thicker end in the ground to a depth of 15cm minimum. Insert on the same day as the cuttings were taken if possible and certainly within 3 days. Planting of willow should be confined to areas next to drains on either side of the bay or near existing water bodies.

Recommendation: SP and broadleaves (OB) other than alder and willow should be established in clusters at 16 groups/ha (8 of SP, 8 of OB). Each group should be 15X20m – using the existing Bord na Móna bay structure and each group to contain 50 trees, giving a stocking of 800 trees/ha.

Willow and alder should be used on site where they give best shelter with the willow established using local cuttings (as outlined above).

5. Fertiliser

Many BOGFOR trials have shown that neither seeded or planted areas will establish without fertiliser input. The recommended fertiliser rate on cutover peats for seeding is generally lower than that for planting and, as most of the proposed areas will be seeded, it is recommended that the lower rate is used on all sites. These rates are far lower than current Forest Service guidelines for afforestation sites. In addition to normal water protection guidelines, a water monitoring regime will be implemented to trace any nutrient input from the fertiliser application. Nitrogen is generally not required for sites, with the exception of *Sphagnum* peats, where N deficiency may occur before canopy closure in some conifer crops on very poor sites.

Recommendation: Apply 125kg rock phosphate and 100kg muriate of potash/ha at the same time (June/July post seeding or planting) using either manual or mechanical methods.

Nitrogen will generally not be required but will be applied as urea only if foliar analysis confirms N deficiency. The rate of urea to be applied will depend on foliar concentrations of nitrogen.

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7. Crop Protection

Deer populations in most of the proposed project areas are low enough to offer little significant risk. Deer fencing, therefore, should not be required, unless local knowledge or experience suggests otherwise. However, monitoring of the deer population and revision of a deer control plan will be required in the long term. Previous experience from establishment of the BOGFOR trials suggests that protection from hare damage is essential for broadleaf establishment. However, the risk of establishment failure in seeded areas may be low enough not to consider fencing. This risk can be further reduced by increasing seeding rates in higher risk areas. Some areas may be susceptible to grazing by livestock but this is generally localised.

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9. Exclusion zones

Areas within identified woodland heath mosaics, which are covered with existing ground vegetation such as sedges or dense grass cover should not be planted or seeded. This is done to ensure structural and functional diversity of the habitat type.

Other exclusion areas include, bare gravel, areas where machinery traffic is high and areas identified as being subject to flooding or poor drainage. This can be identified by the presence of bog cotton, *Campylopus* or *Sphagnum* moss. These areas should be identified following a site survey.

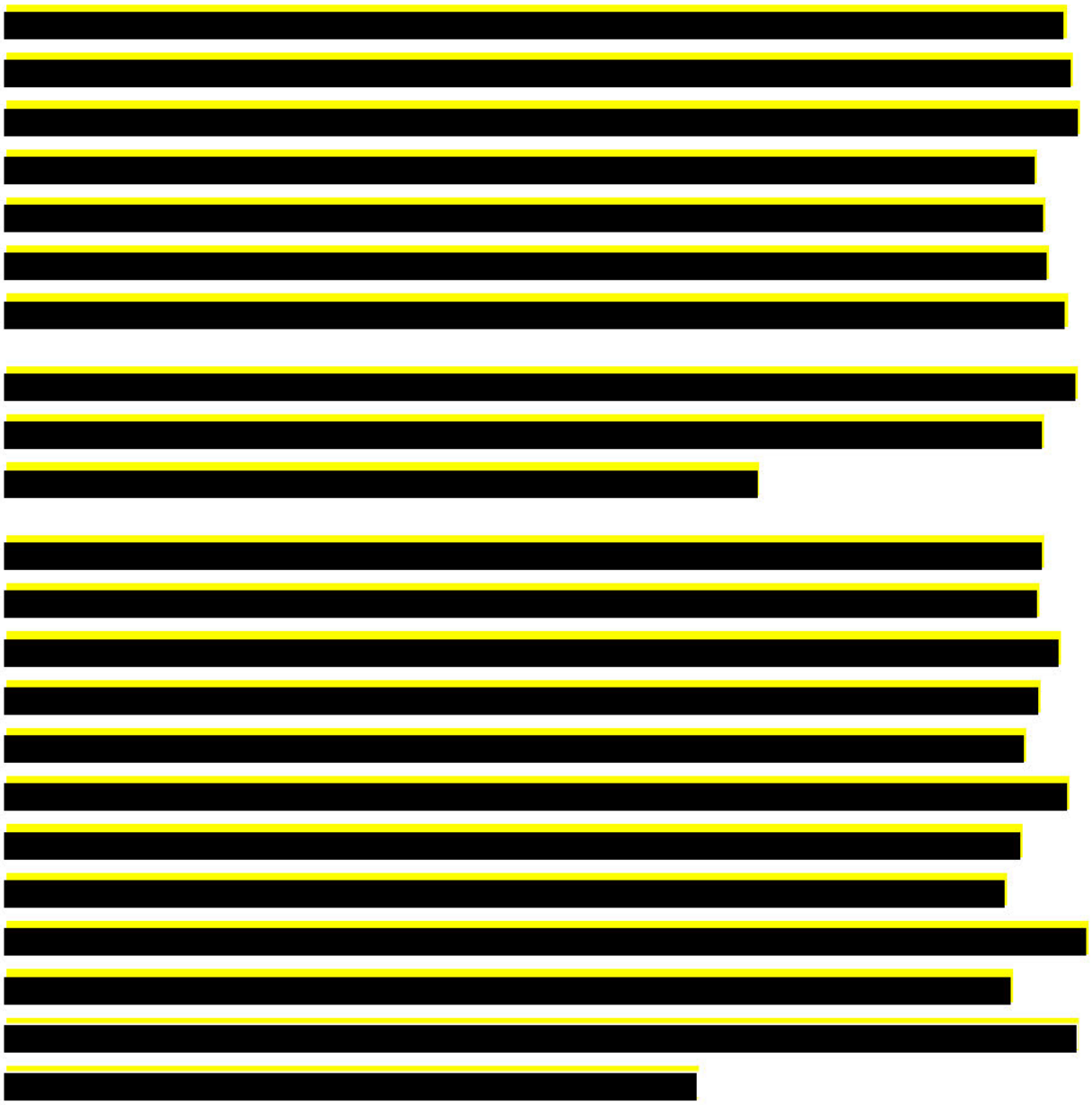
Recommendation: **Only plant or seed suitable areas following site surveys.**

Impact statement on biodiversity

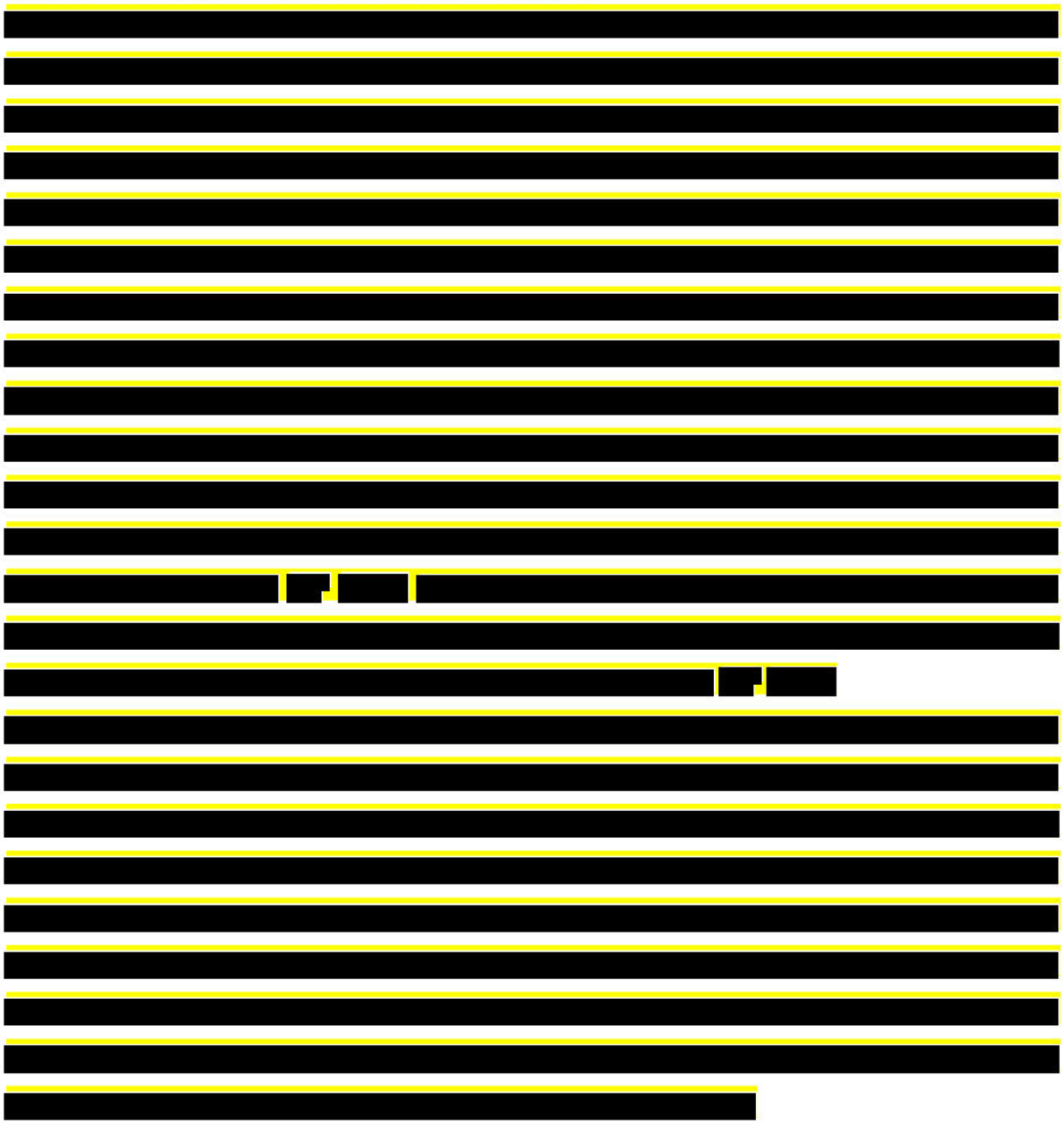
[redacted] If successful, the project has the potential to create large 'woodland biodiversity restoration' areas within a multiple use landscape. [redacted] Woodland restoration and landscape re-animation are relatively new concepts in Ireland and this project offers a real prospect of developing these concepts and learning from their implementation. [redacted].

It can clearly be seen that if the cutaway raised bog woodland establishment project is fully realised that the ecosystem service values of native woodlands would increase substantially. Though carbon (and methane) budgets in cutaway peatlands are subject to ongoing studies to ascertain if woodland mitigates net losses, there is clearly potential to stabilise peatland areas vulnerable to wind and water erosion, whilst potentially locking up and/or slowing down losses of CO_2. Whether these areas are planted or not, native woodland will develop in many areas through natural regeneration as this is currently happening. Hence native pioneer woodland dominated by birch, willow and Scots pine is the natural succession pattern in many areas. Therefore, the biodiversity ecosystem service value will increase substantially if this project proceeds and is successful.

The EU Habitats Directive Annex I priority woodland type 'Bog woodland' [91D0] with *Sphagnum* is a rare and important woodland type (already present but scarce on the Bord na Móna estate) and its development and conservation may also be assisted in this project, where it may develop on the wetter areas that develop naturally with *Sphagnum*. On its own, native woodland biodiversity will increase appreciably, given the proposed range of native woodland types and area proposed. Additionality is provided by the presence of other habitat types and habitat connectivity, creating a biodiversity mosaic that multiplies biodiversity value appreciably, i.e. open freshwater, fens, heath, restored raised bog, wet grassland, etc. As woodlands mature in tandem with these other habitats and species numbers increase (e.g. insects (e.g. dark green fritillary), wildfowl, woodland (e.g. woodcock) and peatland birds, fish, amphibians, otters, badgers, pine martens, etc.) and amenity infrastructure incorporated, the recreation/amenity potential will also increase.



Impact statement on carbon sequestration

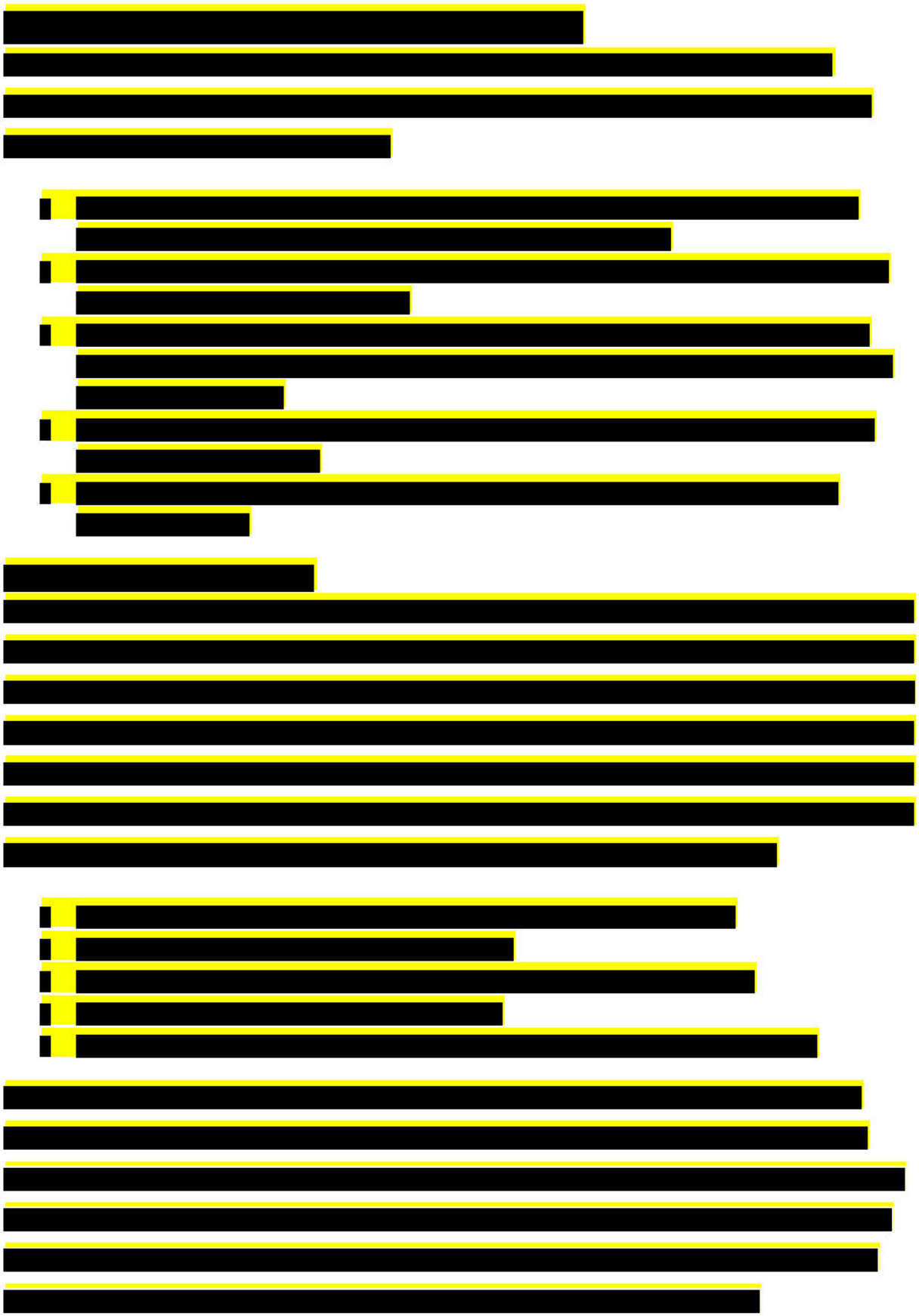


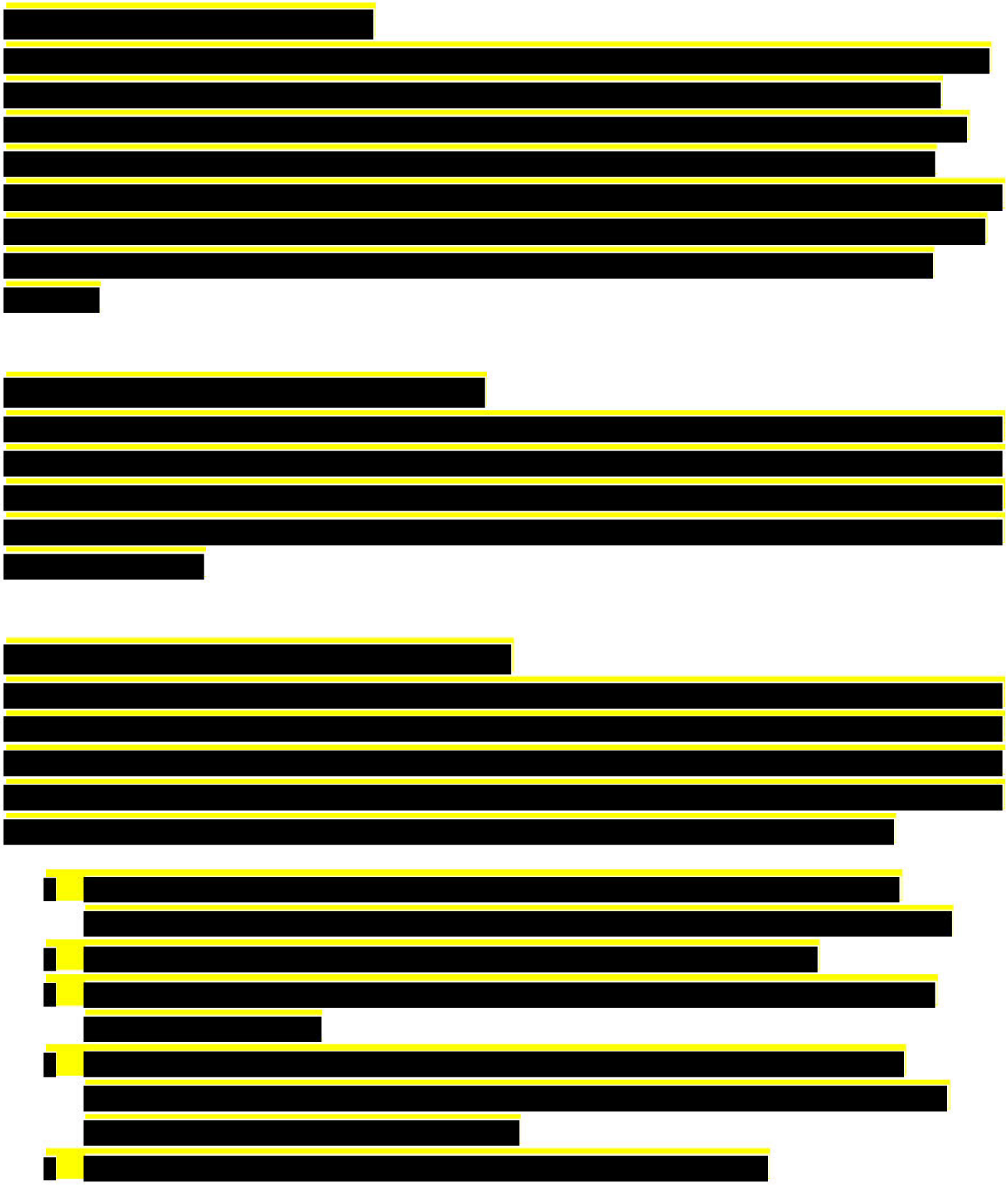
Although there is a significant body of scientific literature on the greenhouse gas balance of peatlands in Ireland, very few studies are applicable to the woodland types envisaged in this report. The only such studies reported to date have been carried out by Byrne et al. (2007b) and Renou et al. (2010). Working at a naturally birch regenerated woodland at Turraun (Offaly), Byrne et al. (2007b) estimated that the rate of respiratory carbon loss due to decomposition of residual peat, root biomass and forest floor was 7.58 t C ha^{-1} $year^{-1}$. Based on biomass sampling, the authors estimated that the rate of carbon uptake by biomass was 2.23 t C ha^{-1} $year^{-1}$. This suggests that the site in Turraun was a net carbon source of 5.35 t C ha^{-1} $year^{-1}$. It should be stressed that these estimates are highly uncertain and limited to one site and that below-ground carbon allocation (which would offset some carbon

losses) are not included. Renou-Wilson et al. (2010) carried out biomass sampling at two naturally regenerated birch crops and estimated that in Ballybracken biomass carbon stocks were 78.1 t C ha^{-1} 20 years after abandonment, while in Turraun the figure was 32.1 t C $^{-1}$, 15 years after abandonment.

Although any assessment of the potential greenhouse gas balance of the woodland types envisaged in this report is uncertain some reasonable conclusions can be drawn:

- In drier areas (where rewetting will not be particularly effective), woodland creation will accelerate the restoration of the carbon sink function and lead to the development of new carbon stocks in biomass, woody debris and litter.
- This new carbon sink function will offset some or all of the carbon loss from peat decomposition and the extent to which it does will depend on the relative balance between carbon uptake and loss. Some of the uncertainty in this area is currently being addressed by results coming from the SmartBOG project.
- It is uncertain if this balance may move towards carbon neutrality over the medium to long term but the rate of carbon loss will be reduced.
- At a landscape level, the carbon balance will depend on these and other factors such as the relative extent of different woodland types, wetland ecosystems and future climate.
- In addition to carbon mitigation, these woodland ecosystems have the potential to provide a range of other, and compatible ecosystem services.
- Research is needed to address information gaps in relation to the carbon balance of woodland creation on industrial cutaway peatland. These gaps include soil respiration across a range of peat types and environmental conditions and the rate of belowground carbon allocation through litterfall and root turnover.





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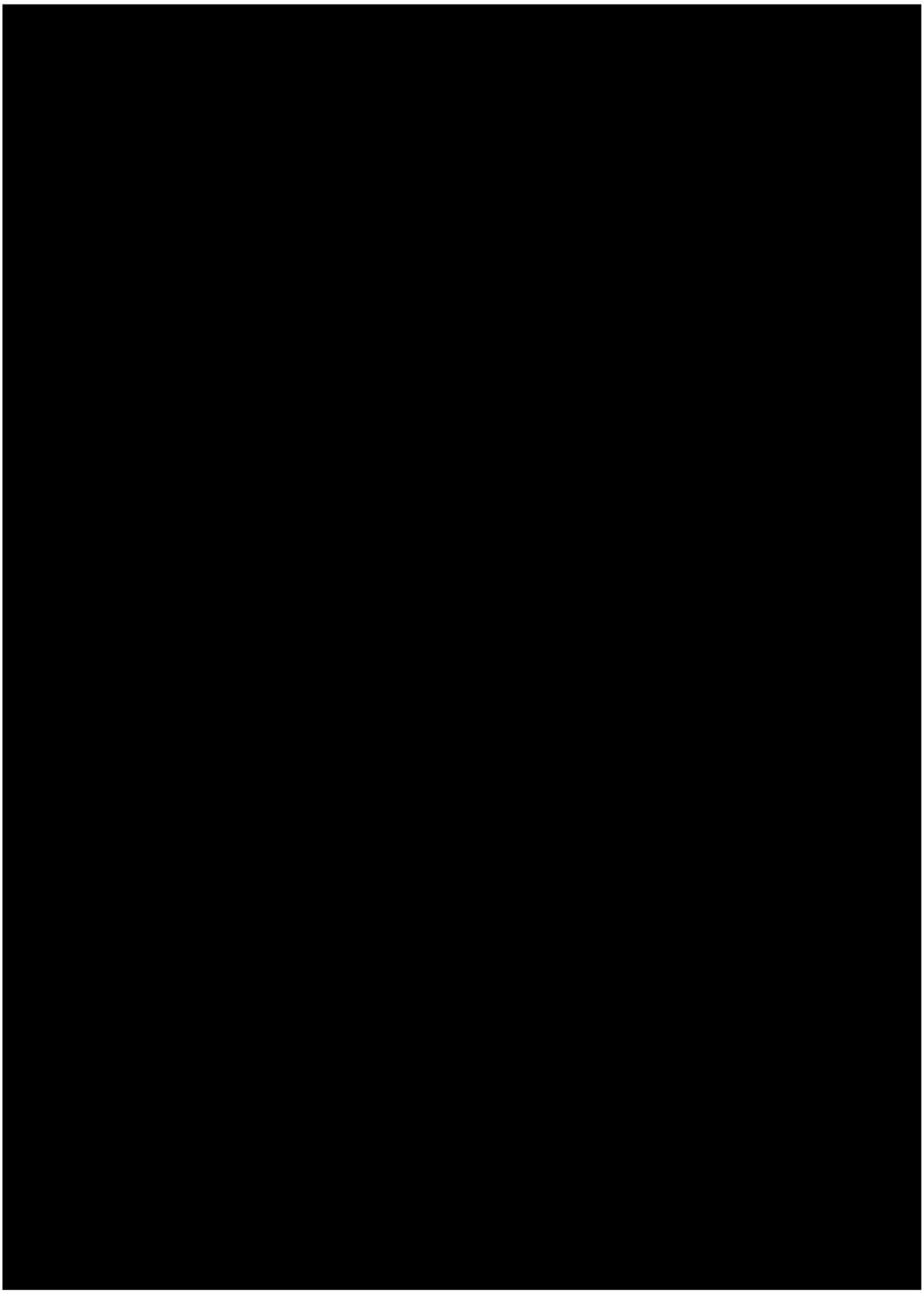

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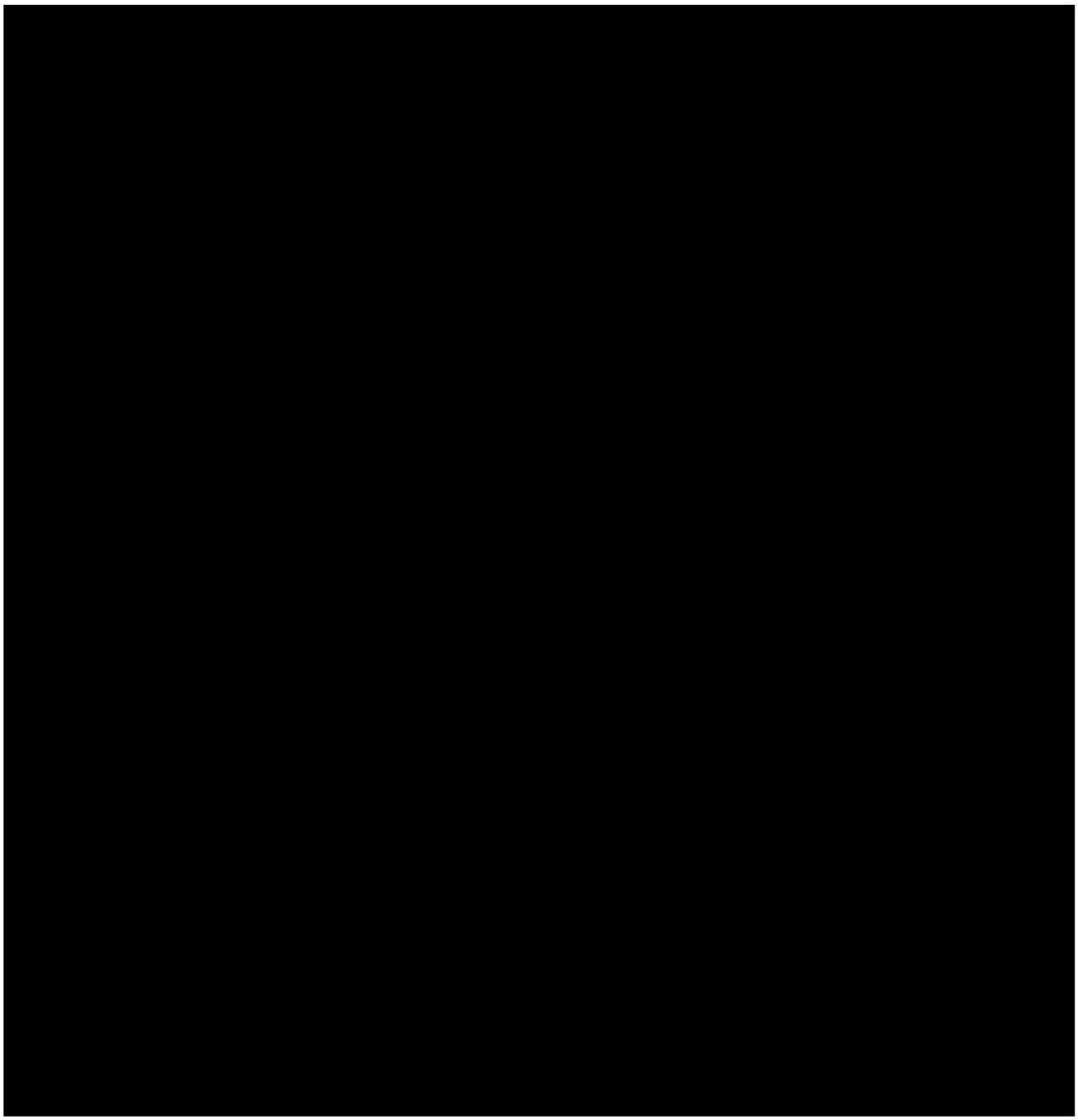

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Conclusions

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The overall value of this project, if successfully established, is potentially very significant. The creation of large tracts of native woodland (along with the existing naturally-regenerated native woodland already present) in a matrix of other habitats (including restored raised bog, heath and open water) will benefit biodiversity substantially and far more than if it were native woodland alone. In addition, the new woodland will assist in reaching National climate mitigation targets with respect to carbon sequestration and provide valuable new opportunities for recreation.

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Appendices

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[3] To be adopted by the Proposal Development Team at project initiation meeting

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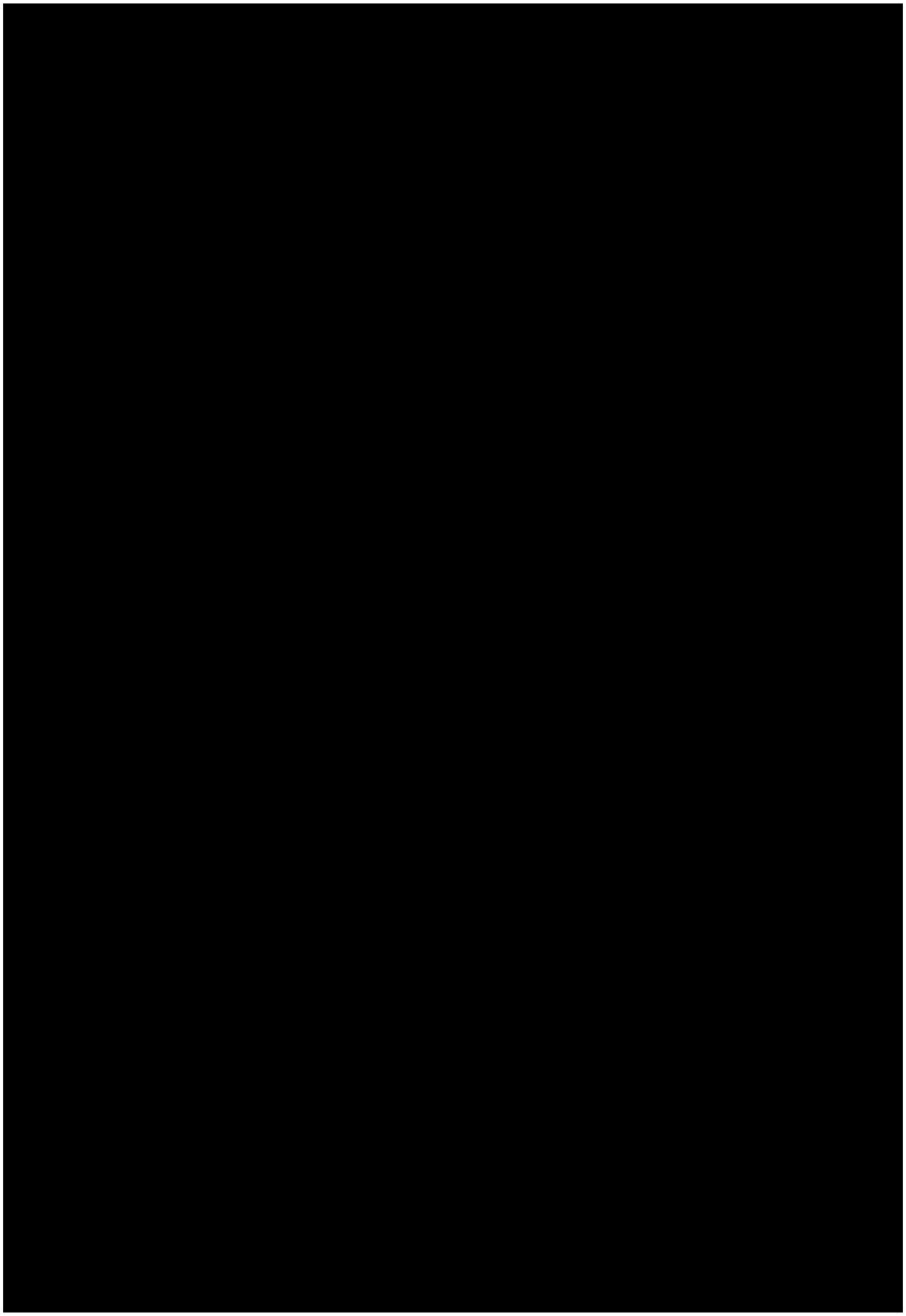
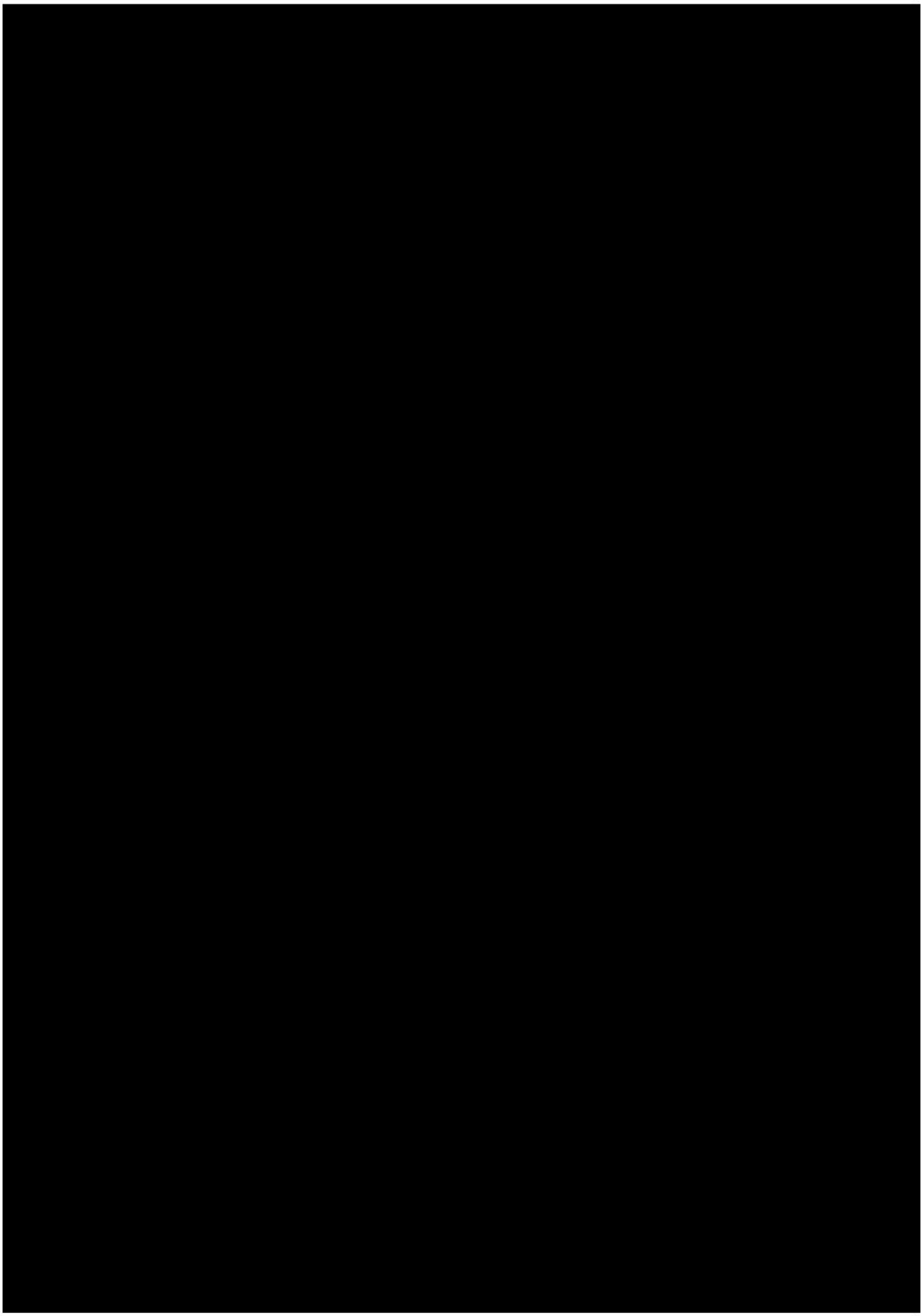
Appendix 2: Definition of biodiversity habitats

Table 2A. Definition of eligible Bord na Móna habitats

Current habitat	Description
Bare peat	Milled peat fields, drained. Very minor vegetation. May be prone to flooding (depending on topography and hydrology). Portion likely to be suitable for rewetting. Areas mapped as bare peat may now have gone out of industrial peat production and have started to vegetate. Habitat mapping on these areas goes out of date quickly e.g. Derries Bog remapped in 2014 but bare peat mapped as part of this baseline survey has now shrunk.
Gravel sub soil	Minor or no peat cover, exposed glacial limestone drift sub-soils (mixed gravel), patchy vegetation. Patchy scrub. Tends to be visible in aerial photos.
Grassland and agriculture	Areas on edges of sites likely to be agricultural grassland (land on margins) and not available for planting as they are not managed by Bord na Móna (property, mapping, boundary issues). Minor agricultural grassland actually owned by Bord na Móna. Areas on cutaway are grass dominated. A portion is calcareous grassland (wetter or drier), a portion is wet grassland, a portion is grassy verges (GS1, GS2, GS4). Cutaway grassland can have a significant cover of Molinia. Real calcareous grassland has patchy vegetation, high, floral diversity and exposed glacial gravel (Cocta Hill – Turraun)
Heath	This includes vegetation that is analogous to dry or wet heath. It generally has heather (dry). It can be on deeper peat (also analogous to Facebank or marginal vegetation on a raised bog) or an indicator of *Sphagnum* peat. It can also be on thin layers of remnant (*Sphagnum*) peat over gravel mounds and ridges ('proper' dry heath). Dry areas tend to have scrub and tree colonisation. Dry areas tend to have patches of bare peat and/or Campylopus moss. Wetter heath indicated by greater proportion of *Molinia* and Bog Cotton. *Sphagnum* may be present but likely to increase in future.
Heath and scrub	Heath with encroaching birch (Scrub Fossitt WS1). Expect some areas to continue to colonise and close canopy. Other more stable areas may stay open (with heath) to some degree for longer.
Pioneer open cutaway habitats	Vegetation cover can be dominated by one of rush, bog cotton, bottle sedge, marsh arrowgrass, horsetails, coltsfoot, reeds. It can be wetter or drier. It can have patchy pioneer vegetation or vegetation cover of > 75%. It can have small birch and willow saplings and scrub already appearing. Marsh arrowgrass and bog cotton are indicators of shell marl and future fen wetland. Soft rush dominance is an indicator of future birch and willow.
Riparian	Edges of deep drains or waterways (area includes rivers and drains). Main Bord na Móna watercourses tend to be channelized in a deep channel with steep vegetated banks on both sides and a row of vegetated spoil or silt that is periodically dredged from the channel. Some of these channels require periodic maintenance.
Scrub and grassland	Grasslands on the cutaway with birch and willow
Scrub and pioneer cutaway habitats	Birch and willow with pioneer ground vegetation. Birch and willow can be scrubby and head height or higher but usually can be walked through.





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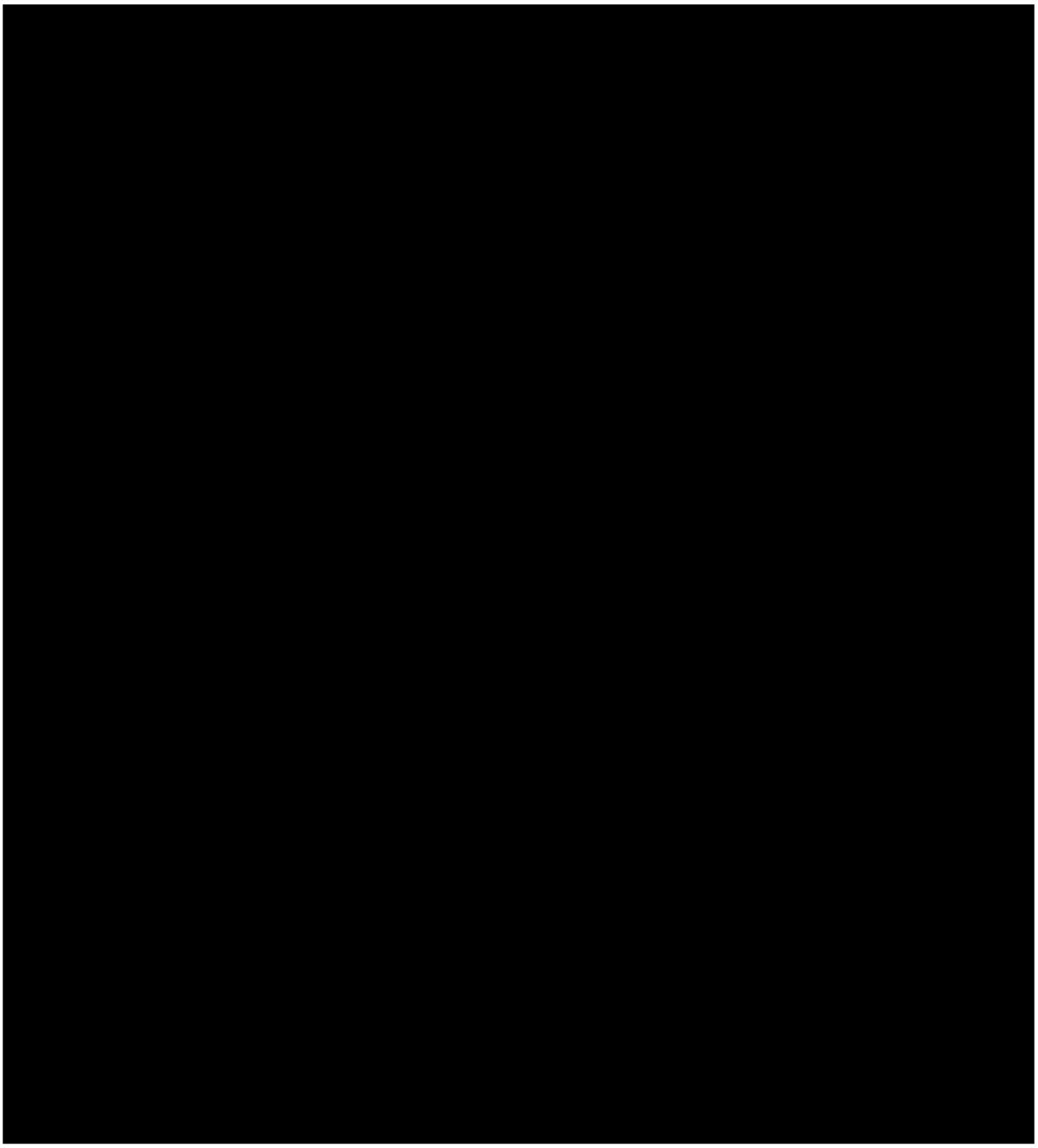

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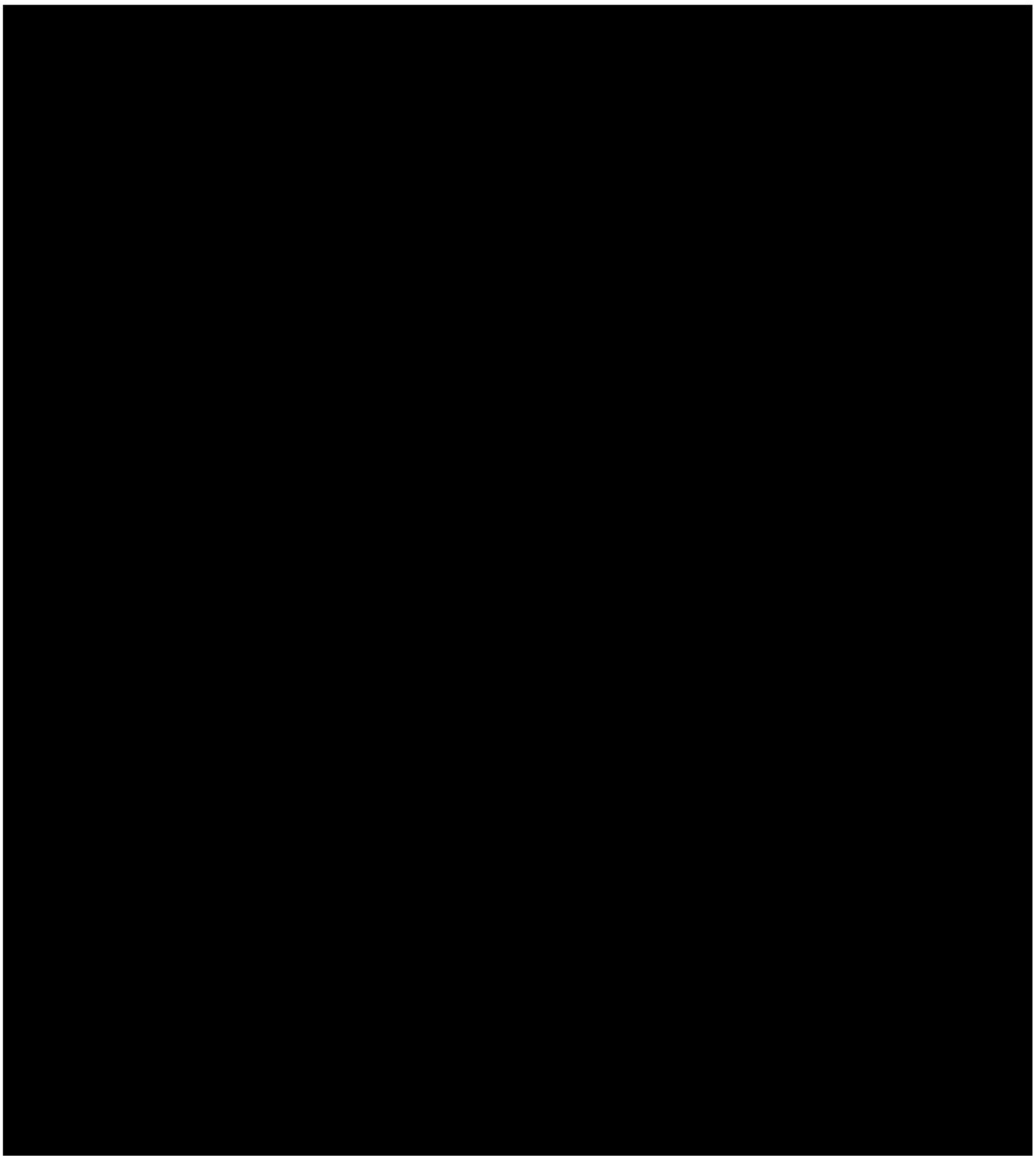

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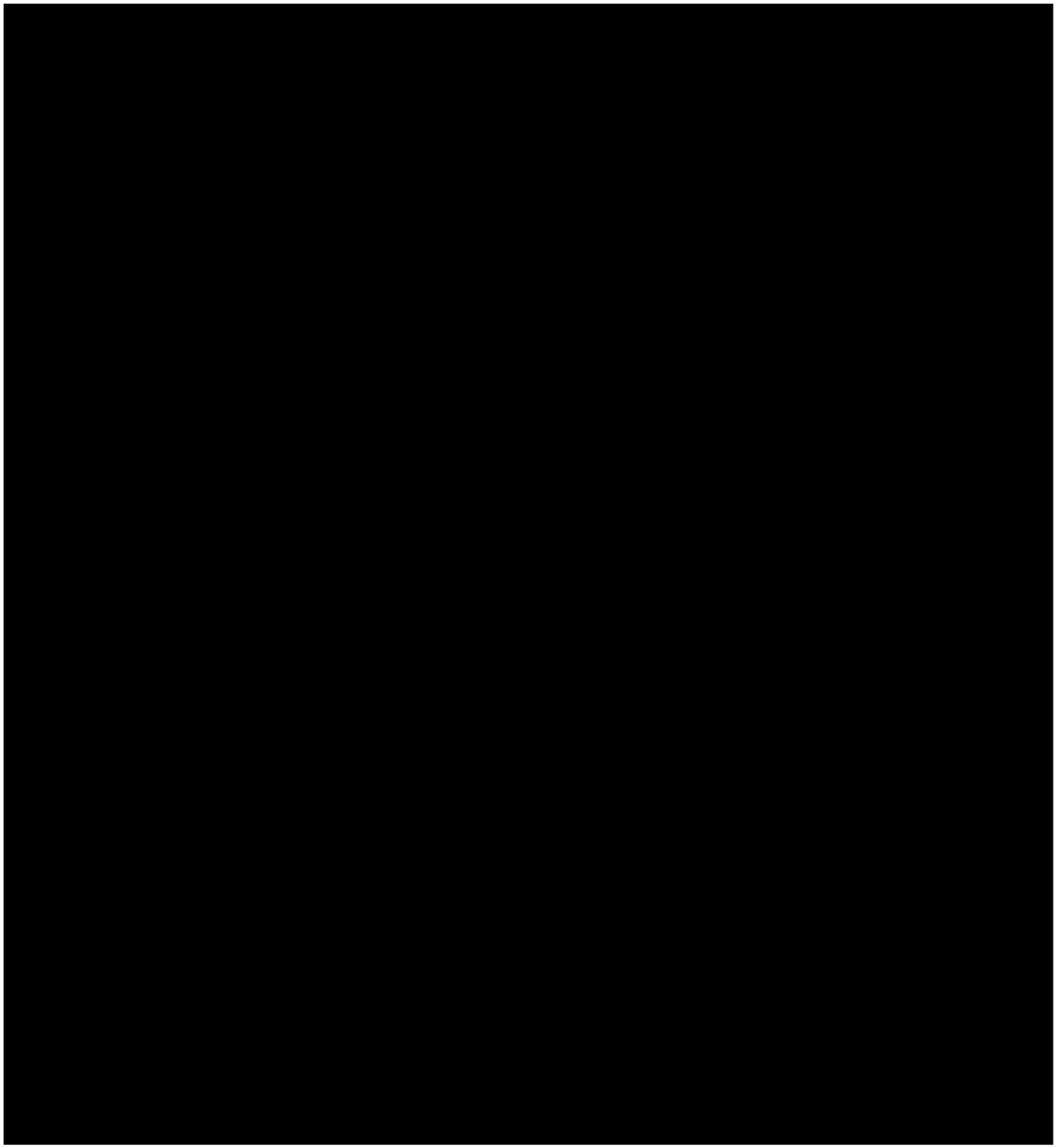

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