BORD NA MÓNA - ESKER BOG

Drainage Management Plan

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Contents

Tables

Figures

EXECUTIVE SUMMARY

Esker Bog is located in Co. Offaly, approximately 3.5km south-southeast of Rhode and c.6km east of Daingean. Esker Bog comprises two main sections, a larger area in the west and a smaller section in the east, that are divided by a stream (the Dogen River). The Esker Stream flows along the southern boundary of the western side with the Dogen River, a tributary of the Esker Stream, flowing north to south and separating the eastern from the western side of Esker Bog.

The rehabilitation measures will generally result in reduced runoff and drainage from the existing peat fields through a mixture of techniques including drain blocking, cell bunding, re-profiling and wetland creation. It is assumed that these measures will not significantly alter the existing topographical catchments and that the spine of the drainage networks, those which the upstream catchments drain through, will be retained by Bord na Móna.

Three potential impacts were considered: the potential to reduce the drainage function to upstream lands, the potential for increased flows downstream and the potential for increased groundwater levels impacting adjacent lands. There is no potential for increased flows downstream and the rehabilitation of Esker Bog, based on evidence from other bogs, will reduce the runoff from the bog by returning the peatlands towards its natural water retention function. The avoidance of reduced drainage function to upstream lands depends on Bord na Móna retaining the drainage routes which traverse the bog upon which drainage of adjacent and upstream lands is dependent.

The potential for increased groundwater levels and to a lesser extent marginal alteration of the topographical catchments has been assessed based on a precautionary approach. With gravity drainage routes retained it is assumed that groundwater levels will reach the surface of the re-profiled peat fields. Standing water may occur in wetland areas which form depressions within the bog landscape. In both scenarios adjacent lands which are at a lower level than the bog could potentially be impacted and the vulnerable area has been defined through a zone of influence approach.

Each of the land parcels has been assessed based on its vulnerability to increased groundwater levels within the bog. In all cases there exists a boundary drain separating the rehabilitation area from the potentially vulnerable lands. Best evidence has shown that these drains provide a positive gravity drainage function and through retaining them they should prevent any groundwater impacts on adjacent lands due to the hydrogeological break / cut-off they provide.

There are some limitations with this approach namely the effect of backwater levels and the lack of detailed survey of the boundary drainage network. Given the low level of risk at Esker it is appropriate in most cases that the DMP measures involve survey, monitoring and continued retention of the boundary drainage network. A suite of measures is identified in order to mitigate any deterioration in the drainage to adjacent lands should monitoring of these lands indicate a groundwater or drainage impact on these lands.

1 INTRODUCTION

Esker Bog is part of the Allen Bog Group. Bord na Móna operated peat extraction within the Allen Bog Group under IPC Licence (Ref. P0503-01) issued and administered by the EPA. Condition 10.2 of this licence requires the preparation of a Rehabilitation Plan for permanent rehabilitation of the boglands within the licensed area.

It is proposed by Government that Bord na Móna carry out enhanced decommissioning, rehabilitation and restoration under the Peatlands Climate Action Scheme on peatlands previously used for energy production. This proposed Scheme will significantly go beyond what is required to meet rehabilitation and decommissioning obligations under existing EPA IPC licence conditions. Improvements supported by the Scheme will ensure that environmental stabilisation is achieved and significant additional benefits, particularly relating to climate action and other ecosystem services, will also be delivered.

A key issue for Bord na Móna is the potential hydrological impact rehabilitation of this bog may have on the bog, surrounding lands and lands downstream which may be hydrologically linked to the bog. Rehabilitation measures generally seek to increase groundwater levels and surface water retention such that they are closer to the surface to encourage peat formation, the associated ecological benefits and carbon sequestration capacity. While in general terms this will reduce the volume of water released from the bog following a rainfall event, the impact on flood run-off is not well understood. Furthermore the increase in the local water table could result in negative impacts to surrounding lands if mitigation measures are not applied (e.g. to agriculture.

This Drainage Management Plan (DMP) for Esker Bog seeks to establish the baseline hydrological performance of the bog and the surrounding drainage network. The plan sets out the characterisation of the bog and surrounding lands, the existing performance of the drainage network and the level of flood risk. The plan identifies the potential hydrological zone of influence of the bog and the objectives, risks and opportunities associated with the rehabilitation of the bog. The plan assesses the potential impact of the various rehabilitation measures which are proposed on the local drainage network and flood risk. It sets out, where necessary, mitigation measures required to reduce impacts to an acceptable level. The plan sets out the measures which are required to be delivered in advance or in parallel with the rehabilitation plan as well as the long term operation and retention of the drainage network and associated infrastructure. The plan assesses the level of residual risk, the potential impact due to climate change and the adaptability of measures in response to these climate change impacts.

1.1 Bog details

Esker Bog is located in Co. Offaly, approximately 3.5km south-southeast of Rhode and c.6km east of Daingean. Esker Bog comprises two main sections, a larger area in the west and a smaller section in the east, that are divided by a stream (the Doden or Leitrim). A third, small, separate area is also included as part of Esker Bog. This is located to the south-east of the other two bog areas. The surrounding landscape is dominated by a mosaic of farmland, largely consisting of improved grassland, an area of conifer forestry to the north-east of the site, and other bogs, many owned and managed by Bord na Móna. The Esker Stream flows along the southern boundary of the western side with the Doden River, a tributary of the Esker Stream, flowing north to south and separating the eastern from the western side of Esker Bog.

Esker Bog is connected via a Bord na Móna rail link to Cavemount Bog, which lies 1.3km to the west-northwest. Ballycon Bog is 700m south of Esker Bog, although the two bogs are not connected, being separated by farmland, the R402 road and the Esker Stream. Cloncreen Bog is located c.200m immediately south of the small section of Esker Bog. Again, these two bogs are separated by some farmland and the R402 road with no direct links (road or rail) between the two Bord na Móna properties.

Esker Bog was in industrial peat production since the early 1970s. The peat was formerly used as fuel peat in Edenderry Power. Industrial peat extraction completely ceased at Esker Bog in 2019. The small, discrete bog section in the south-east of Esker Bog has never been in production.

The proposed Irish Water pipe-line, which will connect Lough Derg to Dublin, is proposed to cross part of this site. This project is in its pre-planning stage.

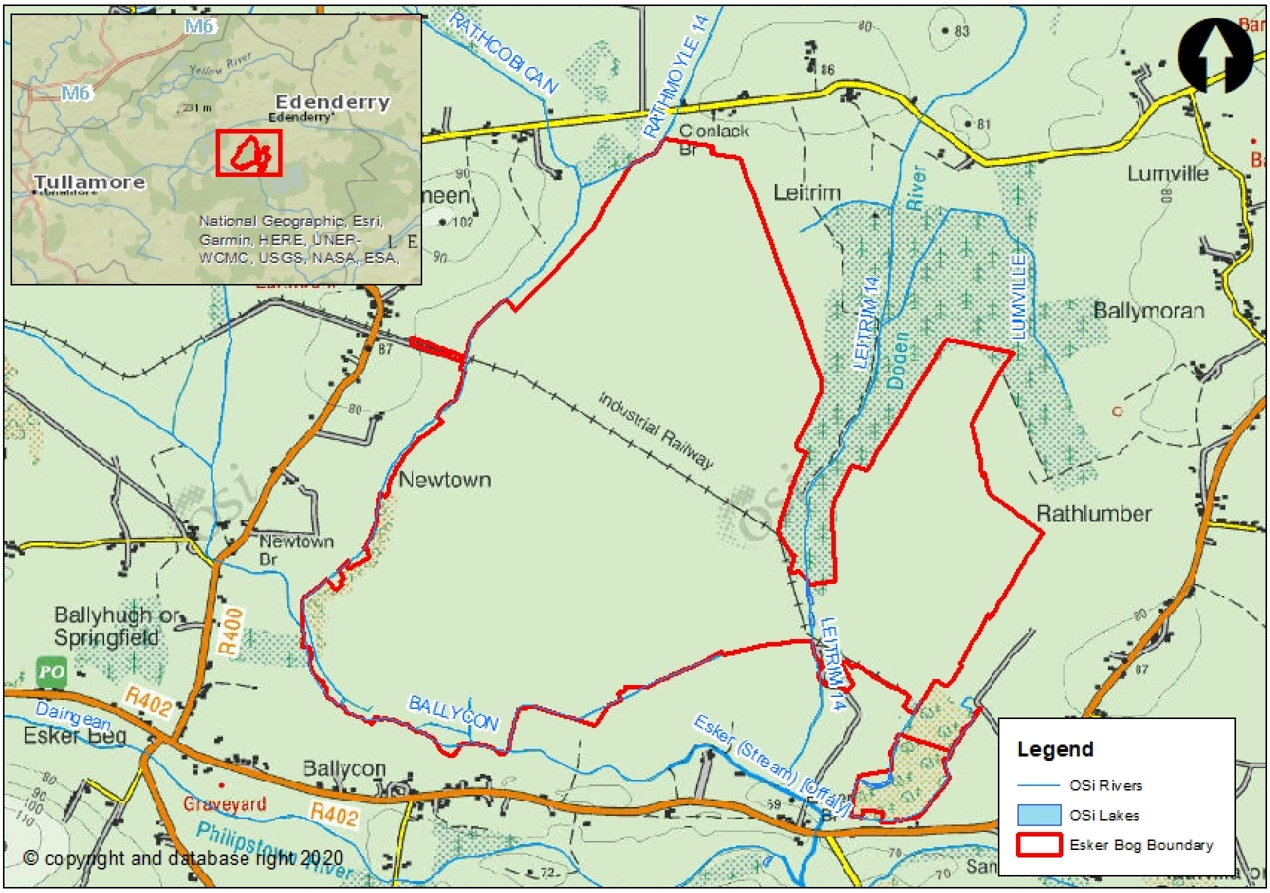

Figure 1.1 Location of Esker Bog

2 BASELINE ASSESSMENT

Through cessation of peat extraction and implementation of the Esker Bog rehabilitation plan there is the potential to impact the adjacent land. The extent of the impact will depend on the existing baseline characteristics of the catchments which drain the bog and the adjacent lands.

The purpose of characterising the catchment area is to develop an understanding of how the catchment currently operates and drains. The characterisation also investigates the risks, constraints and opportunities to the operation and drainage.

2.1 Study Area

To characterise the catchments a study area was determined encompassing the total catchment area draining the bog and adjacent lands through the bog. The drainage under the influence of Esker Bog discharges into external drains, the Esker Stream or the Doden River which discharge to the Philipstown River. In addition to these discharge points there is one inflow location where the adjacent agricultural land drains into Esker Bog. A review was carried out to delineate the external drains around the bog as presented in Figure 2.1 along with their associated hydrological catchment area.

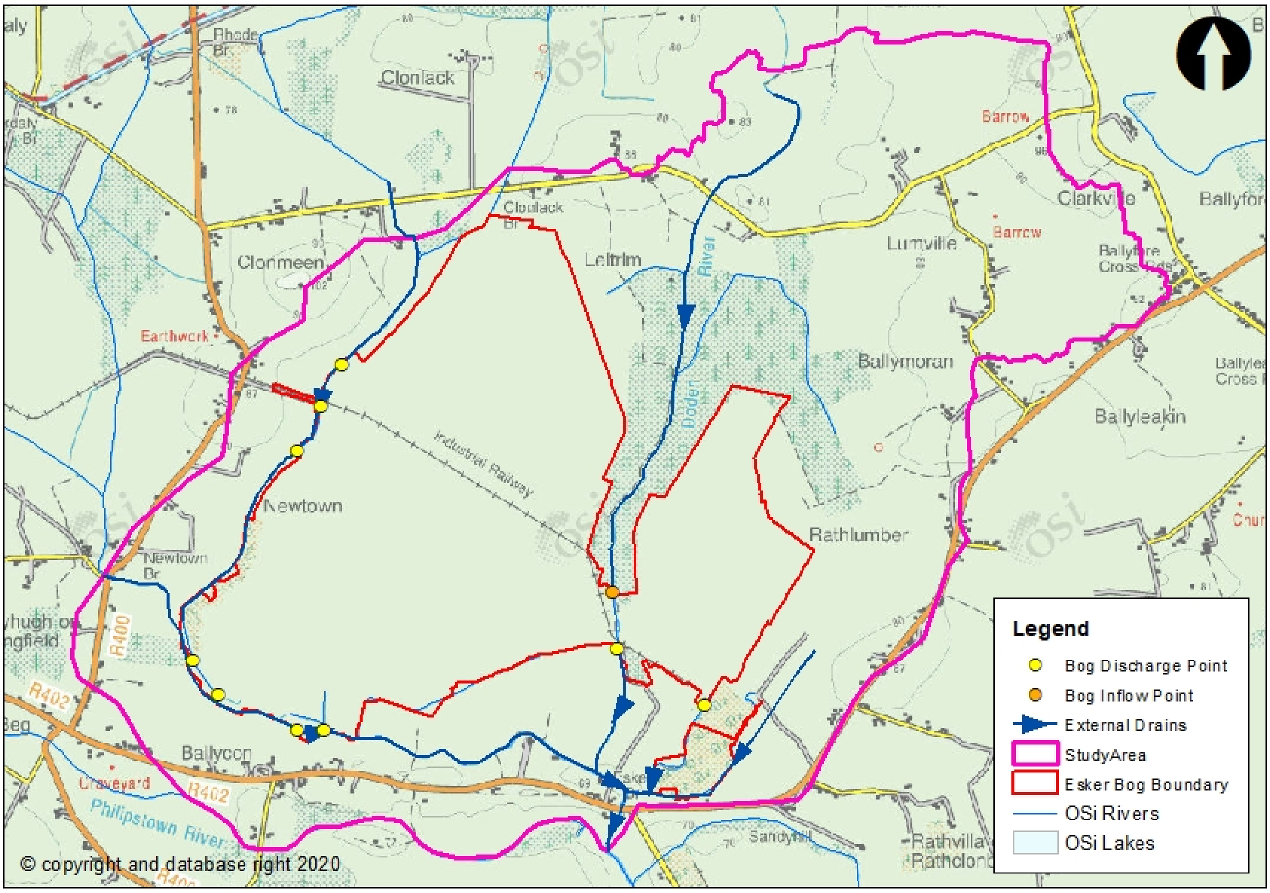

Figure 2.1 Study Area for Esker Bog

2.2 Catchment Runoff Characterisation

A hydrological analysis was carried out within the study area to delineate the sub catchments of the bog drains and the external drains. The recent Bord na Móna drainage survey was reviewed, and the bog sub-catchments confirmed. Sub-catchments of the external drains were identified using ARC GIS tools. The sub catchments are presented in Figure 2.2.

The FSU catchment characteristics provide an overview of how much rain a catchment receives, how impermeable the catchment is and how quickly the water will runoff the catchment due to topography and drainage. Table 2.1 summarises the FSU catchment descriptors for the sub-catchments identified in Figure 2.2.

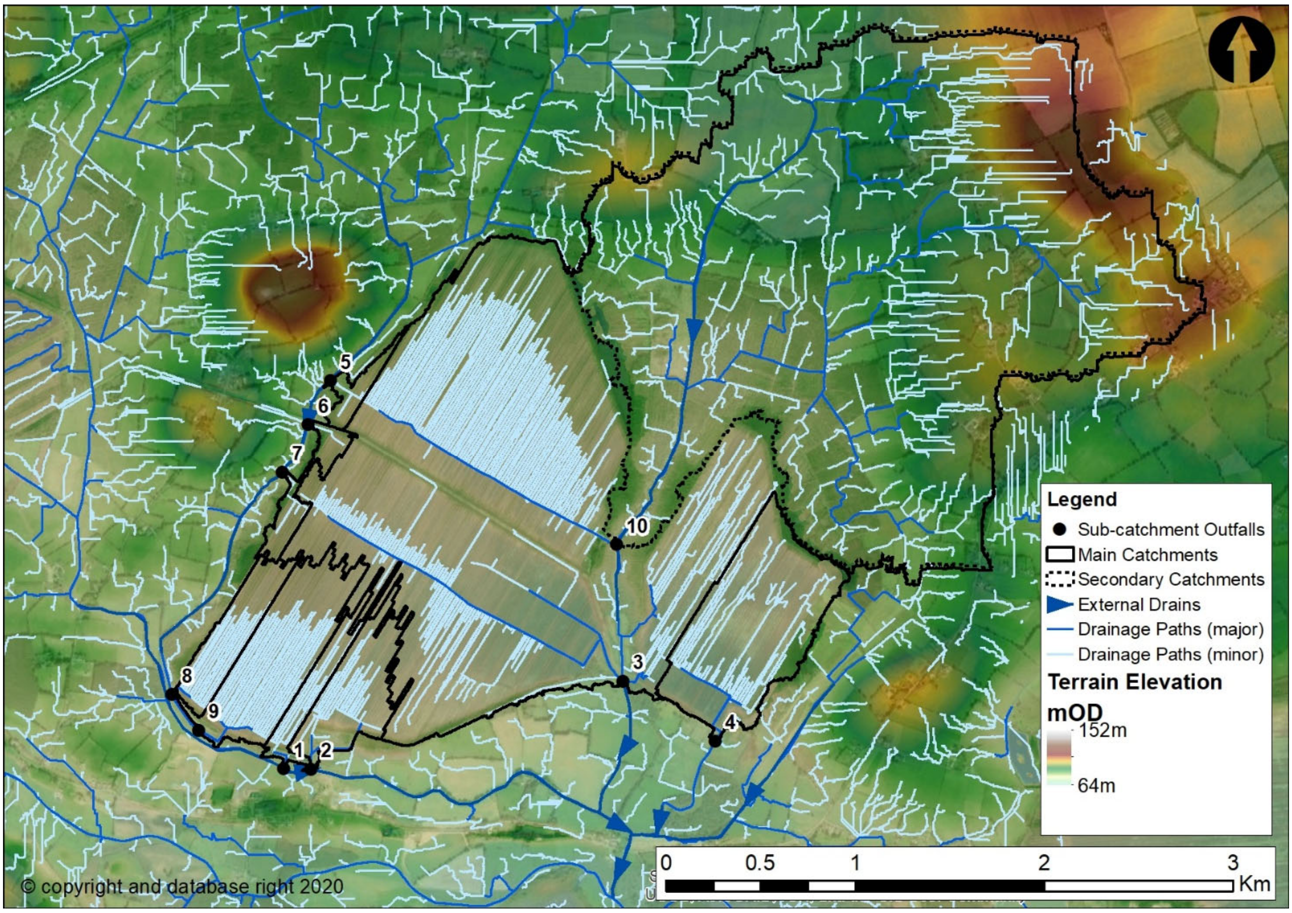

Figure 2.2 Drainage Networks and Sub-Catchments Draining Esker Bog

There are nine main sub-catchments draining Esker Bog and adjacent lands ranging in area from 0.04 km^2 to 9.76 km^2. The catchments are all subject to moderate / low amounts of annual average rainfall. The Baseflow Index for all of the catchments has been taken as 0.643 representing a fairly permeable catchment. The catchments range from very flat to moderately flat.

The Index Flood Flow (Q_{med}) values, which represent the typical peak flood flow which might be anticipated (a 50% chance of being exceeded in any given year), for each of the sub-catchments have been calculated. This is based on two different methods, the Flood Studies Update (FSU) 5 variable equation designed for small and/ or urbanised catchments in Ireland, and the RPS derived Peat Q_{med} equation, derived in support of the Drainage Management Plan project for SAC sites on behalf of NPWS. Both methods result in very similar Q_{med} values where the proportion of arterial drainage (ARTDRAIN2) is assumed to match the proportion of the catchment managed by Bord na Móna (drained).

Table 2.1 Physical Catchment Descriptors of Sub-Catchments Draining the Bog

Sub-Catchment Number	Area (km^2)	SAAR (mm)	BFI	FARL	ARTDRAIN2	PEAT (%)	S1085 (m/km)	FSU5 Q_{MED} (m^3/s)	Peat Q_{MED} (m^3/s)
1	0.11	858.99	0.643	1	1.000	100.0	1.863	0.025	**0.032**
2	0.25	858.99	0.643	1	1.000	100.0	12.640	**0.087**	0.067
3	9.76	855	0.643	1	0.719	71.9	3.079	**1.794**	1.470
4	0.62	855	0.643	1	1.000	100.0	3.439	0.145	**0.146**
5	0.06	858.99	0.643	1	1.000	100.0	7.163	**0.019**	0.018
6	0.04	858.99	0.643	1	1.000	100.0	2.725	0.010	**0.012**
7	0.05	858.99	0.643	1	1.000	100.0	10.694	**0.020**	0.017
8	0.17	858.99	0.643	1	1.000	100.0	31.301	**0.078**	0.049
9	0.40	858.99	0.643	1	1.000	100.0	6.449	**0.113**	0.100

2.3 Hydrogeological & Soil Characterisation

Esker Bog and the surrounding area are underlain by Oolitic limestones bedrock which represents a locally important, moderately productive aquifer. Geological Survey of Ireland (GSI) tracing of karst features has not identified any significant features such as springs, swallow holes or turloughs in close proximity to the bog. Nevertheless the bedrock underlying Esker has potential to facilitate relatively high rates of baseflow. The soils covering the catchments are primarily peat, with some grey brown Podzolics and surface groundwater gleys outside the extent of the bog. These soils would be considered to be relatively impermeable. The sub-soils along the southern margin are limestone-based sands and gravels lain down by the river. Bord na Móna have noted that Grey Marl was exposed in some of the spoil taken from the silt ponds at the southern end of the site Where they are exposed these subsoils would be considered to facilitate transfer of surface water to groundwater and vice versa.

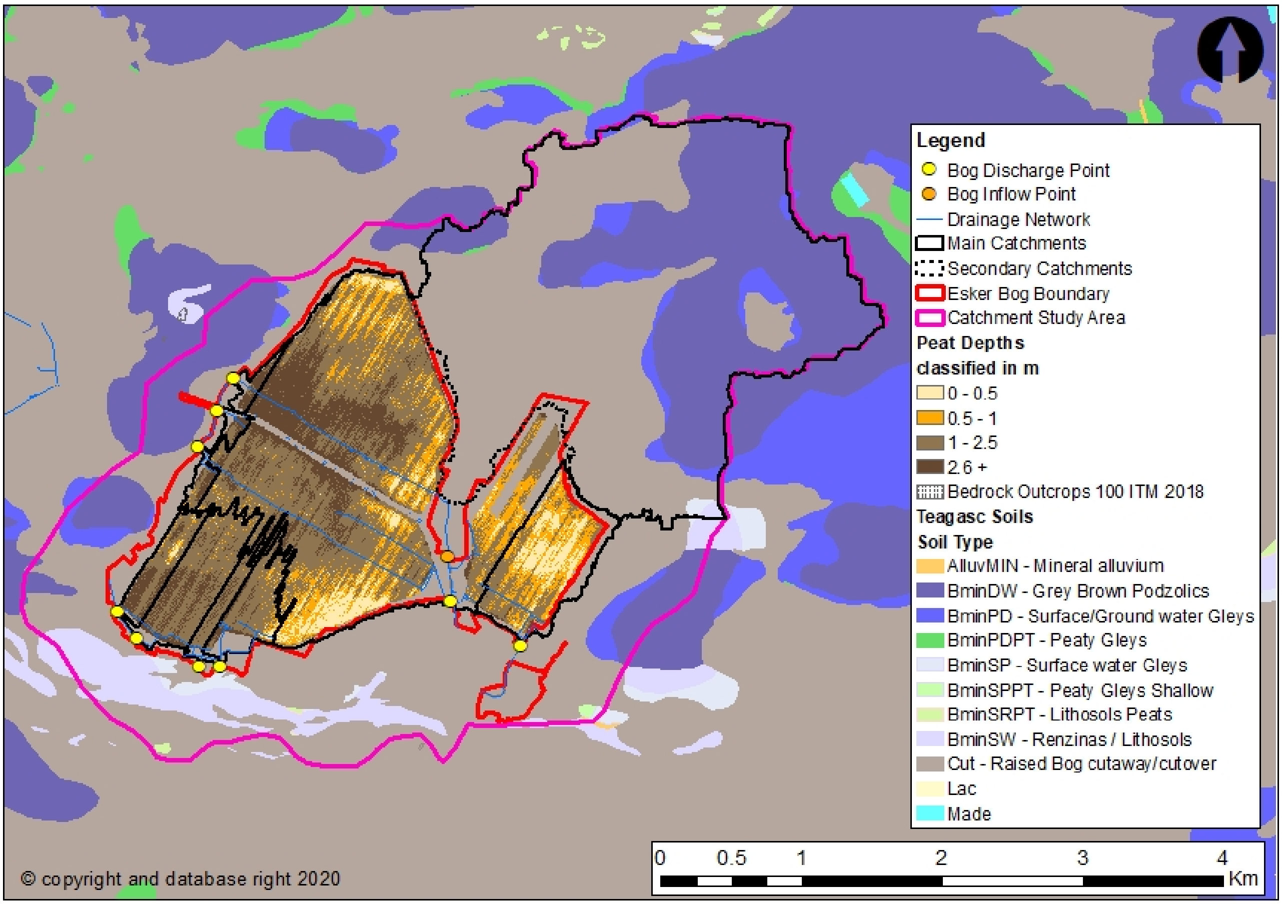

Figure 2.3 Hydrogeological and Soil Characteristics of Esker Bog

2.4 Morphological and Hydraulic Characterisation

A desk top review was carried out of bog drains and external drains. Morphological and hydraulic features were identified.

The external drains and streams are generally small with gentle bed slopes. Aerial photography shows no signs of erosion or deposition however given that the drains are considered small with gentle bed slopes there would be a risk of deposition, and therefore reduced land drainage efficiency. Risk of deposition would occur where there is potential for an erosion or debris source from the surrounding land and where there is potential head loss in the channel due to instream features. Figure 2.4 details the reaches of the external drains where there are potential erosion or debris sources and where instream features may facilitate deposition. The figure shows that due to the location of commercial forests, woodlands and disturbed peat in the surrounding lands there are existing potential sediment sources that could enter the external drains. Given the presence of culverts, sharp bends, channel widening and inflows along the external drains there would be a potential of sediment settling and deposition occurring. The potential for Esker bog being a sediment source to the external drains is considered low due to the presence of silt ponds at all discharge points and that peat extraction activities have ceased.

A review of the bog drains was carried out. The Bord na Móna drainage survey details the open drains, pipes, silt ponds and discharge points. All discharge points have a silt pond located upstream which will reduce the amount of sediment leaving the bog as water is drained. The drains in the bog have very gentle bed slopes and pass through numerous pipes before discharging from the bog. It would be expected that the bog drainage network would be sensitive to drain and pipe alterations and the drain which receives an inflow from the adjacent land, as shown in Figure 2.4, needs careful consideration. A reduction in this drain's capacity has the potential to impact on the agricultural land that drain into the bog.

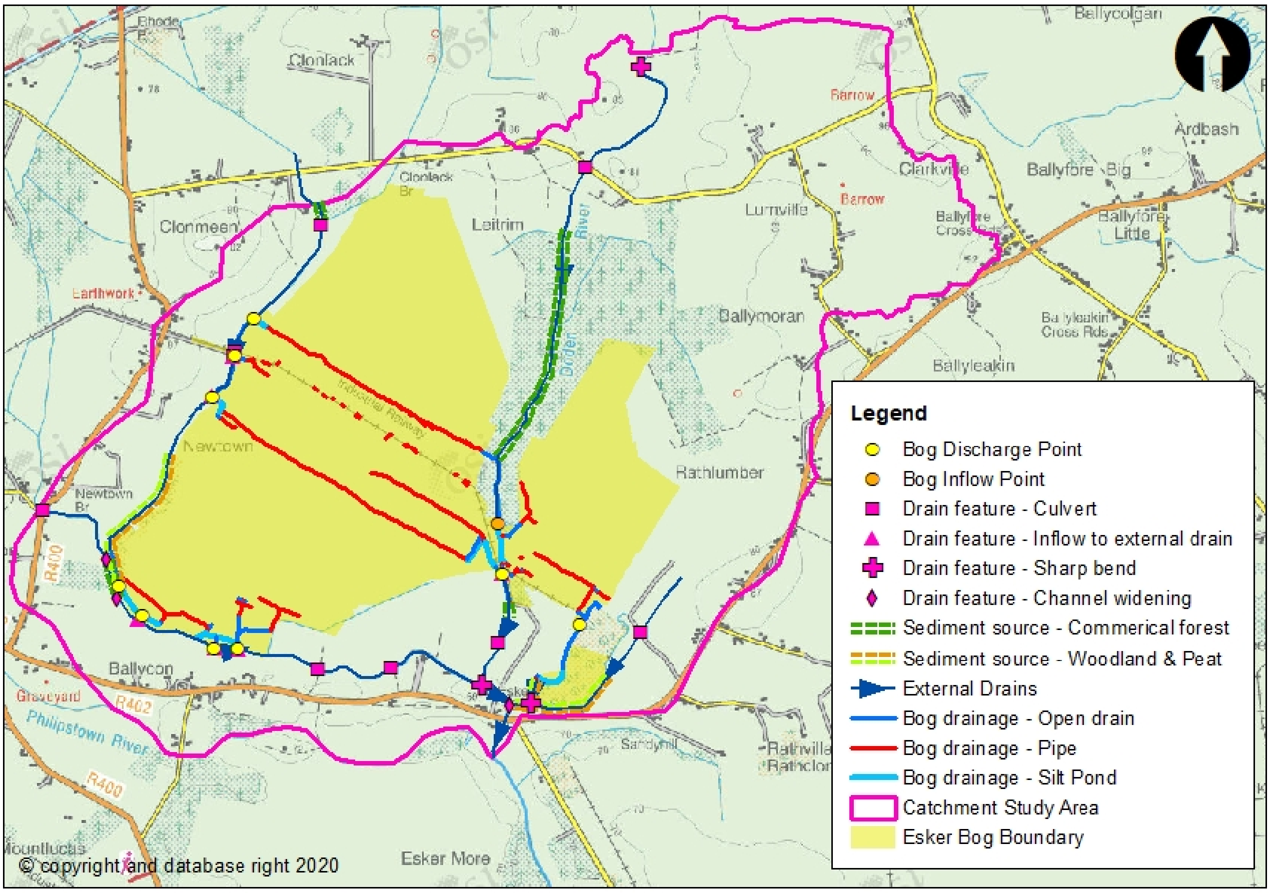

Figure 2.4 Morphological and Hydraulic Characteristics of Esker Bog and environs

2.5 Land use character

The majority of the land within the study area is peat bog and pasture. The remaining areas of the study area consist of commercial forest and transitional woodland. The CORINE land use dataset was used to identify landuse types. This dataset was then reviewed using aerial photography to establish landuse amendments or land use alterations. The review found that additional commercial forests are located in the study areas and some pasture land have been improved. There are some minor roads and properties located in the study area also.

The pasture land is mainly used for livestock which provides food production. The commercial forests provide for timber production. The majority of the peat bog outside the Bord na Móna bog shows evidence of being harvested for domestic fuel production. Other areas of peat bog are undisturbed which contribute to carbon storage and biodiversity. The woodland areas are likewise providing carbon storage and biodiversity albeit as a different habitat to the peat bogs. The minor roads within the study areas service properties and provide access to the pastures, forests and peat bogs.

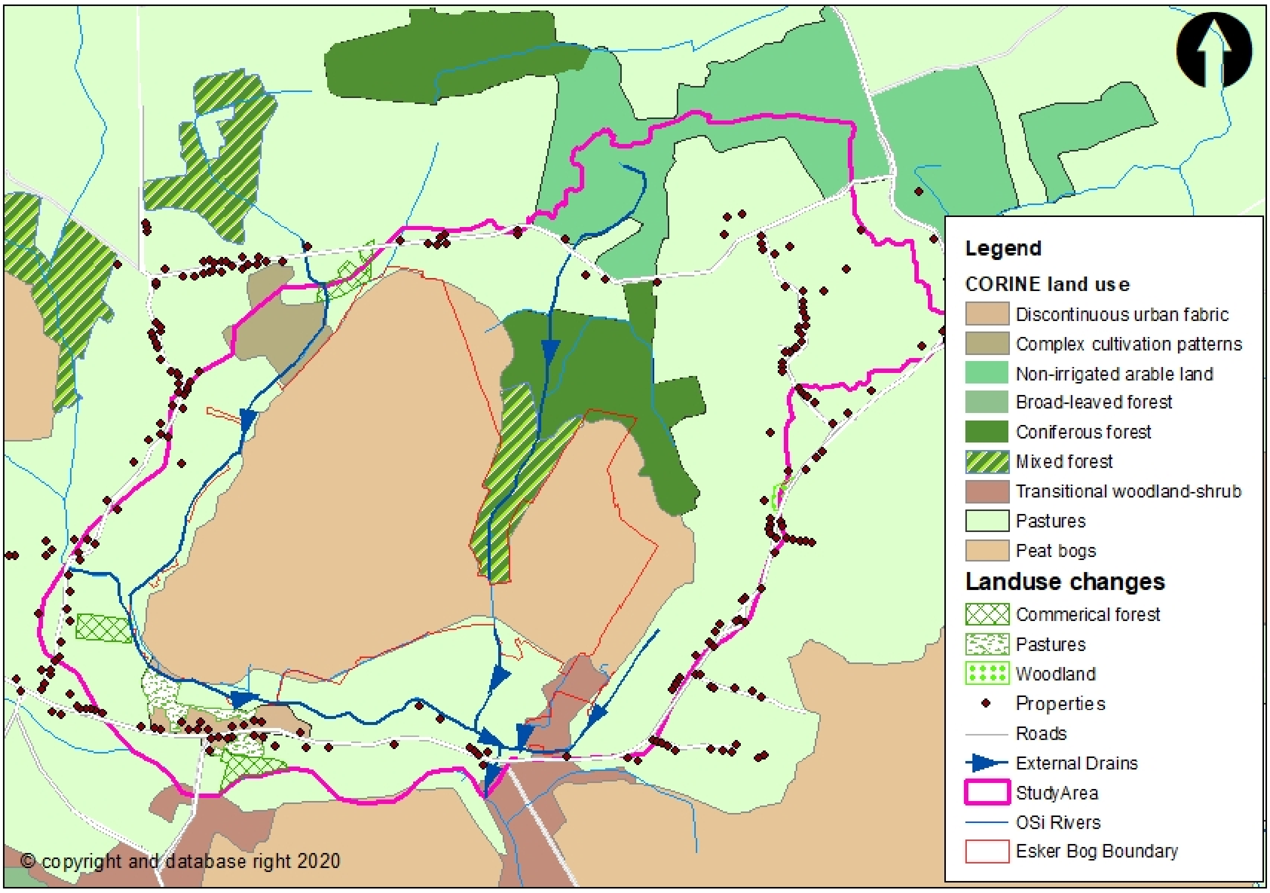

Figure 2.5 Land Use Characteristics of Esker Bog and environs

2.6 Flood Risk

A number of sources of flood risk information are available, both predicted and simulated, in proximity to Esker Bog. These include:

- CFRAM Study maps setting out the predicted fluvial 10%, 1% and 0.1% Annual Exceedance Probability (AEP) fluvial flood scenarios for the Philipstown River.
- GSI predicted groundwater flood maps for high, medium and low probability events
- Mapped flood extents for the 2015 flood event (from Sentinel-1 satellite imagery) and a GSI surface water flooding dataset for the same event
- Anecdotal evidence from Bord na Móna

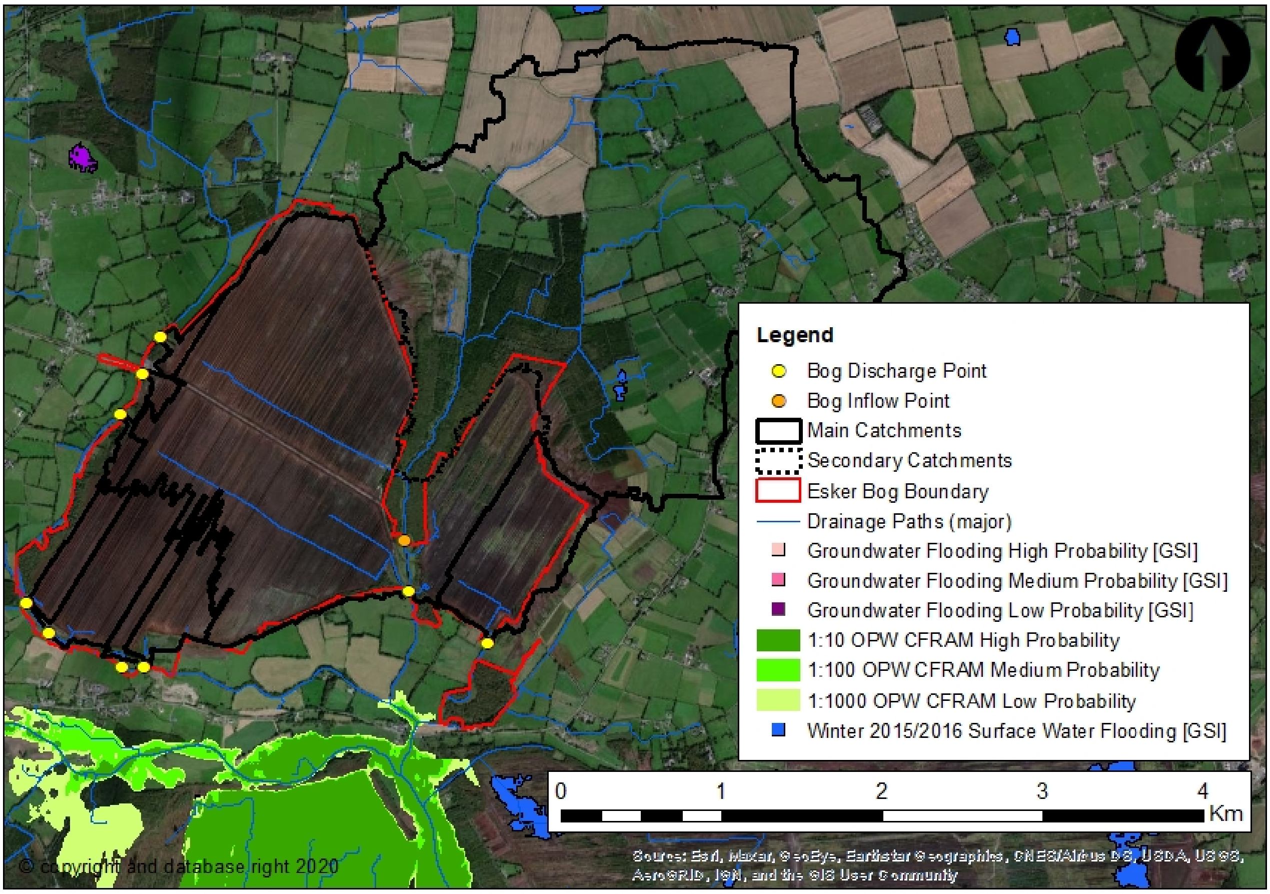

Figure 2.6 Flood Risk at Esker Bog

The CFRAM maps show that the bog is not at risk of flooding although an area to the south of the study area is at risk of flooding from the Philipstown River. It should be noted this analysis did not consider the fluvial flood risk from the smaller watercourses which drain to the Philipstown River through Esker Bog. Historical anecdotal evidence was reviewed to ascertain if there are any known flooding or drainage issues from these smaller watercourses to the bog or adjacent land. No drainage issues have been identified along the Esker Bog boundary drains. Data from the 2015/16 flood event and observations from Bord na Móna do not indicate significant flooding within the bog but some partial flooding south of the bog boundary field which is consistent with what has been observed by Bord na Móna.

There is no predicted groundwater flooding to the bog indicated on the GSI datasets. A smaller area north-west of the bog boundary has a low probability of groundwater flooding.

2.7 Summary

The drainage network sub-catchments within Esker Bog and its environs were used to delineate the study area for the Esker Drainage Management Plan. The overall catchment area was characterised within the context of hydrology, hydrogeology, morphology, landuse and flood risk.

A detailed drainage network delineation was carried out. Drains within the bog and external drains were identified. The assessment showed that the bog discharges to the west to a tributary to the Esker stream, to the South to the Esker stream and to the Boden River to the south east. These are tributaries of the Philipstown River and drain to the south east of the bog boundary.

The catchment area is considered to be relatively small, flat and fairly permeable with a low to moderate annual rainfall. Peak flood flows range from around 0.28 – 0.45 m^3/s per square kilometre (approximately 3 – 5 l/s per hectare) for the Q_{med} event to 0.8 – 1.3 m^3/s per square kilometre (8 – 13 l/s per hectare) for the Q_{100} year plus climate change event.

The bedrock within the catchment is Oolitic limestone, however no karst features were identified in GSI records which could influence groundwater movement and flooding. The soil on top of the bed rock is mainly peat with some other soils in the higher ground. All soil types are relatively impermeable which would restrict groundwater movement however where exposed, the more permeable sub-soils may facilitate transfer between ground water and surface water.

The morphological and hydraulic characteristics of the external drains were assessed. No signs of erosion of deposition could be observed. Areas of deposition risk were identified along each drain. Culverts, sharp bends, inflows and channel widening were identified as potential factors for sediment deposition. Woodlands and bare peat adjacent to the drains were identified as potential sources of sediment. Given that the drains are relatively flat the risk of deposition in the external drains is considered high.

The land use was assessed within the study area. The majority of land is peat bog, some of which has been drained for agricultural purposes. Pasture land makes up a significant proportion of the study area also. The remaining land is made up of commercial forest and transitional woodland. The land provides important services such as food production, timber production, domestic turf cutting, carbon storage, biodiversity and habitat creation.

Table 2.2 summarises the constraints, risks and opportunities identified as part of the baseline assessment.

Table 2.2 Potential Opportunities / Constraints

Land Parcel / Feature	Risk or Opportunity?	Details
Agricultural land	Constraint	It is important to maintain the productivity of agricultural land surrounding the bog

Forestry	Constraint	The area of forestry between the bog sections should not be adversely affected by rehabilitation activities.
Roads	Constraint	Minor roads are located in the study area providing access to properties, agricultural land and peat bogs. Access to these roads should be maintained.
Philipstown River	Constraint	The Philipstown River and associated tributaries run adjacent or close to the bog. No activity should adversely impact this area.
External drains	Risk	Risk of deposition in the drains is considered high due to potential sediment sources in adjacent lands and features within the external drains. External drains may be sensitive to change.
Bog rehabilitation plan	Opportunity	To improve water quality discharging from the bog; stabilisation or improvement in water quality parameters (e.g. suspended solids)
Bog rehabilitation plan	Opportunity	To reduce carbon emissions from the bog and to set bog on a trajectory towards naturally functioning peatlands habitats. Esker has potential to develop embryonic Sphagnum-rich vegetation that has potential to be a carbon sink.
Bog rehabilitation plan	Opportunity	To improve biodiversity by vegetating bare peat and creating more habitat for flora and fauna.
Bog rehabilitation plan	Opportunity	To reduce runoff and restore a more natural runoff regime, thus contributing to flood risk management.

3 BOG REHABILITATION PLAN

The Esker Bog rehabilitation plan[1] consists of the following measures as summarised in Table 3.1 and presented in Figure 3.1.

Table 3.1 Esker Bog rehabilitation measures

Restoration	Description of measures
Deep peat restoration	More intensive drain blocking (max 7/100 m), + field reprofiling + blocking outfalls and managing overflows
	Berms and field re-profiling (45m x 60m cell) + blocking outfalls and managing overflows + drainage channels for excess water + Sphagnum inoculation
Dry cutaway restoration	More intensive drain blocking (max 7/100 m) + blocking outfalls and managing overflows + targeted fertiliser treatment
Wetland creation	Turn off or reduce pumping to re-wet cutaway + blocking outfalls and managing water levels with overflow pipes + Targeted blocking of outfalls within a site + constructing larger berms to re-wet cutaway + transplanting Reeds and other rhizomes
Other	Maintain silt ponds

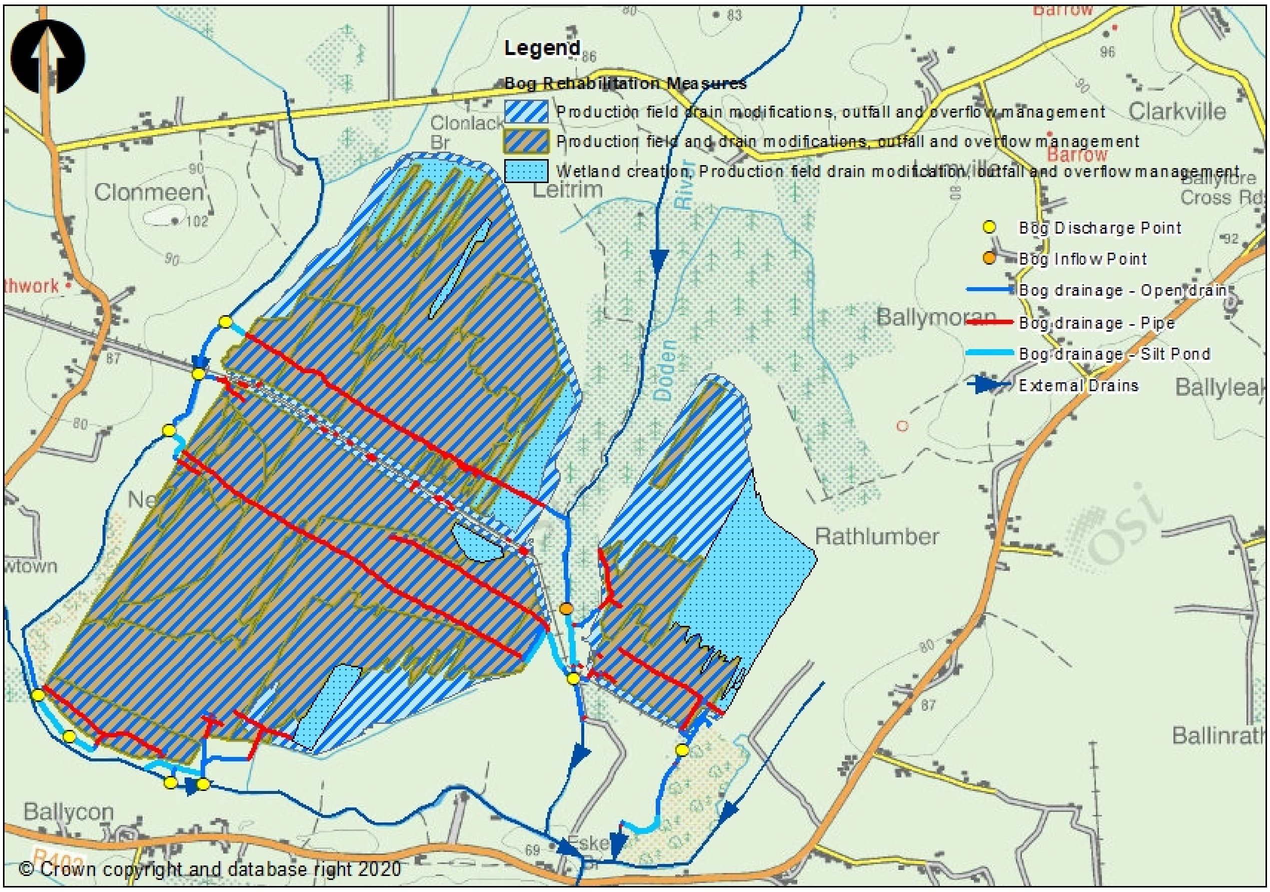

Figure 3.1 Esker Bog Rehabilitation Plan

[1] For further details see Esker Bog Cutaway Bog Decommissioning and Rehabilitation Plan 2021 report

Each measure while designed to promote the rehabilitation and re-wetting of the bog will have a potentially positive and/or negative impact on the adjacent land. This section identifies and assesses these potential impacts.

3.1 Impact Screening

Table 3.2 summarises the rehabilitation measures proposed for the Esker Bog and their potential impact to adjacent land.

Table 3.2 BRP measures proposed at Esker Bog

BnM rehabilitation measure	Description	Potential Impact	Potential Impact Description
Berm construction	A low level berm is proposed across the bog in order to retain water within the bog to help raise groundwater levels. Berms will also be constructed to facilitate wetland creation in designated areas	Negative	Raised groundwater levels to the bog surface will create a hydraulic gradient across the bog into the adjacent land. Land within this hydraulic gradient will potentially rise. The effect will be greatest immediately beside the bog.
Drain blocking, cell bunding, berm and field re-profiling	Existing production field drains within the bog areas that convey surface water away from the former peat production fields towards the bog discharge points will be modified to reduce conveyance or removed altogether by infilling. Surface water runoff through the bog will be slowed allowing the bog to store more water	Positive and negative	Reduced runoff from the bog discharge points resulting in less flow in the external drains located downstream. Reduced conveyance at bog inflow point resulting in increased water volume in external drain located upstream if conveyance channels through the bog are blocked.
Blocking outfalls	Most production field drain systems drain into a headland pipe running perpendicular to the peat field. This intersection is known as an outfall. By blocking the outfalls each production field drain will be prevented from operating resulting in the ditch storing water and raising the groundwater level in the bog. This will allow the bog to store more water and bring the groundwater level to the surface.	Positive and negative	Reduced runoff from the bog discharge points resulting in less flow in the external drains located downstream. Raised groundwater levels to the bog surface will create a hydraulic gradient across the bog into the adjacent land. Ground water levels in lands within this hydraulic gradient will potentially rise. The effect will be greatest immediately beside the bog.
Managing overflows with overflow pipes	This measure is usually combined with blocking outfalls which cause groundwater levels to rise. As the bog fills up it will want to overtop at the	Neutral	The control features will determine the location of the discharge from the bog. However the flow leaving

	lowest part of the bog boundary. Overflow pipes control the location this occurs and where the overtopping water is discharged to.		the bog once it is full will be the same as prior to remedial works. Overall the volume of water discharging from the bog will be reduced but will contribute to raised groundwater levels within the bog and potentially within the zone of influence (subject to mitigation).
Drainage channel for excess water	This measure will work in conjunction with the overflow features. Where suitable drainage channels do not exist or are of insufficient capacity along the bog boundary, a new or upgraded drainage channel will be provided. These drainage channels will convey all flows from the bog to suitable watercourses.	Positive	Drainage channels of sufficient capacity will ensure any overtopping water from the bog does not enter adjacent land. Drainage channels will also act as a hydraulic break in groundwater limiting the impact of bog measures to the groundwater in adjacent lands.
Sphagnum moss inoculation	This measure will propagate sphagnum moss within the bog. Sphagnum moss will cause bog regeneration as it grows and layers.	Positive	Sphagnum moss can hold up to 10 times its weight in water. As such this measure will store water reducing the runoff from the bog into the exterior drains. This will help retain the external drainage efficiency which adjacent land relies on. This measure may also contribute to runoff reduction and wider catchment FRM goals but in a piecemeal way.
Silt ponds	Existing silt ponds will be maintained to store runoff water from the bog and allow any suspended peat to settle out of the water before it is discharge to the external drains.	Neutral	Maintained capacity from the bog discharge points to the external drains and river located downstream. Maintained quality of water being discharged from the bogs into the external drains or river.
Wetland creation	Areas where hydrological modelling suggests suitability have been designated for wetland creation. Shallow water will be allowed to occur resulting in increased water storage. Establishment of reeds and other rhizomes will form part of the wetland creation.	Positive and negative	Reduced runoff from the bog discharge points resulting in less flow in the external drains and river located downstream. Raised groundwater levels to the bog surface will create a hydraulic gradient across the bog into the adjacent land. Land within this hydraulic gradient will potentially rise. The effect will be greatest immediately beside the bog.

3.2 Impact Assessment

Three potential impact sources were identified; groundwater rise, increased runoff from the bog and reduced drainage capacity into the bog. These impact sources have the potential to make the adjacent land wetter and drain less efficiently. An assessment was carried out to delineate the zone of influence resulting from these potential impact sources. Figure 3.2 presents the areas which are at potential risk.

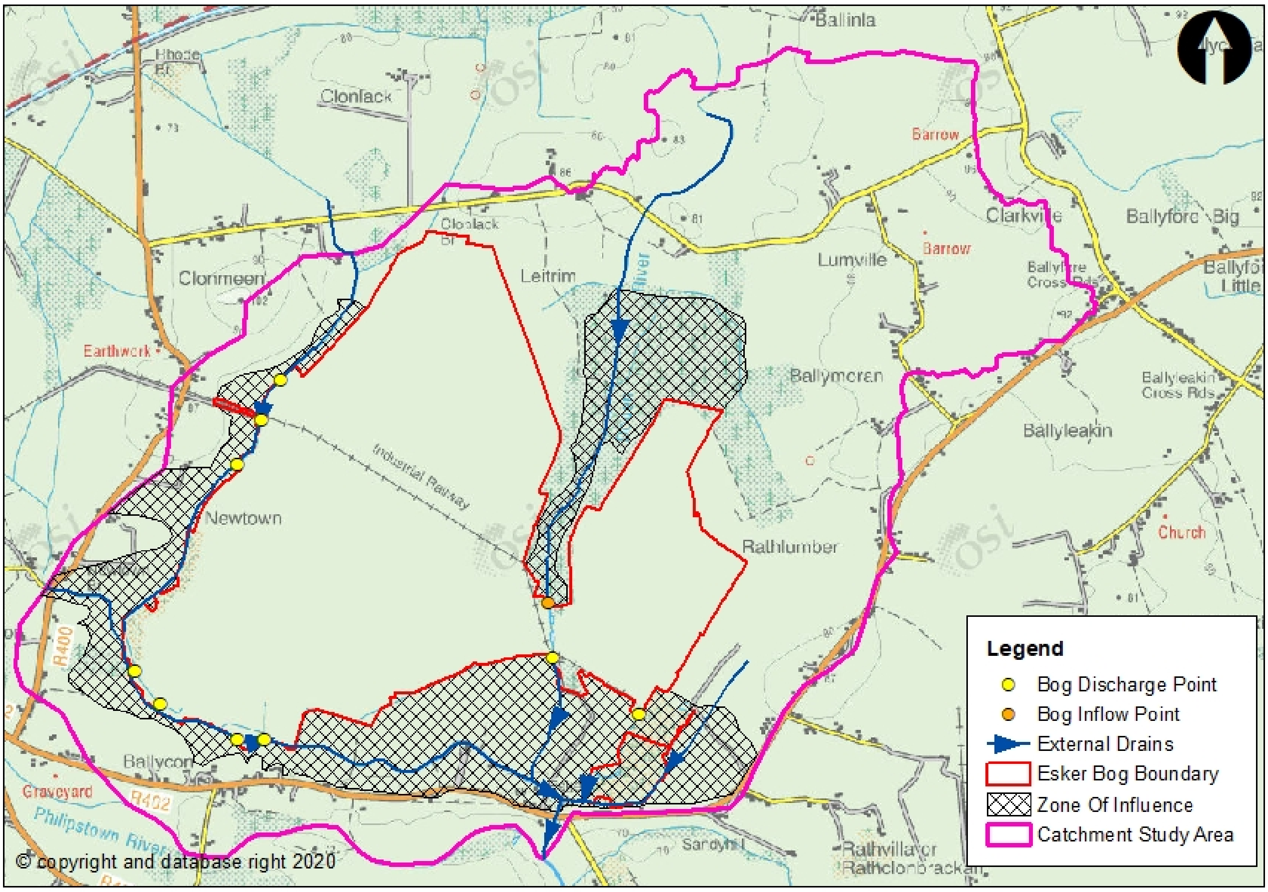

Figure 3.2 Esker Bog Rehabilitation Plan – Zone of influence

3.2.1 Groundwater Impact

The impact of rehabilitation measures on groundwater levels within and adjacent to the bog is difficult to assess quantitatively in the absence of long term monitoring data and hydro-geological models of the bog. Nevertheless it can be assumed that groundwater levels will rise within the bog itself given that this is an objective of the rehabilitation measures – to restore the hydrological conditions for peat formation. It can also be assumed that the maximum level which groundwater will reach outside areas zoned as wetland is the surface of the peat fields post-rehabilitation. This is because topographical flow paths for surface water out of the bog (by gravity) will be retained and the bog is not dependent on a pumping regime to ensure ponding does not occur. For areas zoned as wetland the maximum water level will be above surface level as water ponding is promoted through rehabilitation measures.

Groundwater rise in lands adjacent to the Esker Bog was assessed firstly by estimating the potential rise in groundwater within the bog. The drainage system in the bog is, on average, 1.5m deep. It can be expected that groundwater would rise by 1.5m to bring it to the surface in non-wetland areas. Water level rise in wetland areas is expected to be greater and will be determined by the higher surrounding bog fields or the construction of a berm and by the outlet control to the wetland area. As the groundwater rises in the bog to ground surface level a head water difference will be created between the bog and adjacent land forming a hydraulic gradient (see Figure 3.3a and 3.3b). Groundwater will flow across the hydraulic gradient. This flow will be dependent on the porosity of the ground it flows through and the head difference. This will determine the extent of the zone of influence and the area of potentially wetter ground. Where external drains are located in the zone of influence they will act as a hydraulic break or groundwater cut-off and reduce the zone of influence (see Figure 3.3c). This however is dependent on the drain's ability to convey water away. Drains that are inefficient with high water levels (independent from the bog rehabilitation measures) will also raise the groundwater and the adjacent lands to the bog would be wet (see Figure 3.3d). The avoidance of the drain full condition is dependent on maintenance of a positive gravity drainage function of the boundary drains through monitoring and maintenance.

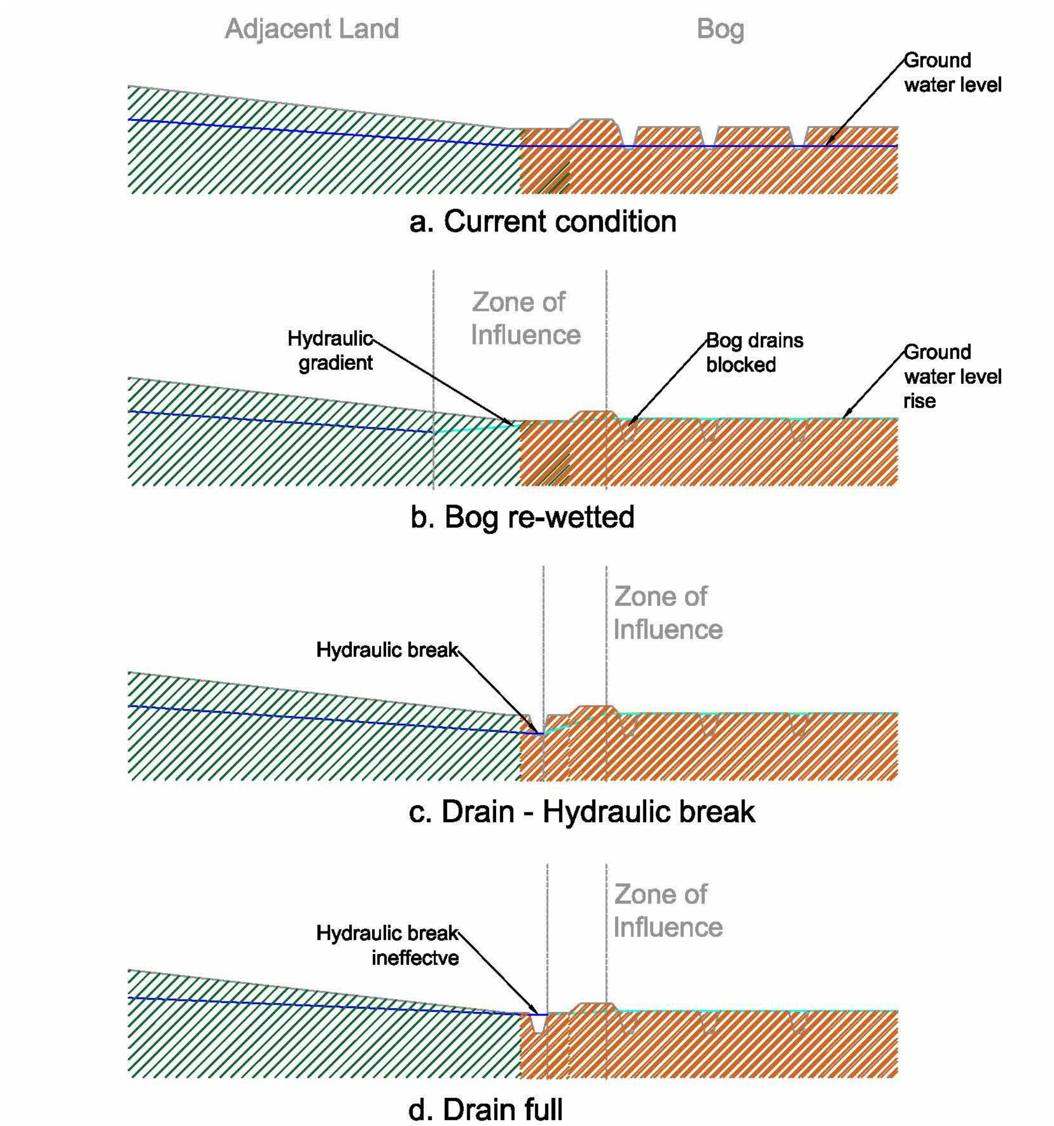

Figure 3.3 Conditions affecting groundwater

A complete survey of the boundary and external drains which provide the groundwater cut-off function to agricultural lands was not available for Esker Bog. It is assumed that these drains would be able to convey Q_{med} (2 year return period) flows under non-backwater conditions which would be typical of natural watercourses in Ireland. Therefore under non-flood conditions it is expected that the external drains identified around Esker Bog will act as a hydraulic break to any hydraulic gradient created by bog re-wetting. However there is a risk that should the flow regime in any external drain be changed post rehabilitation that the land adjacent to the drain would become wetter.

There is also a risk that as the bog fills with water and wants to discharge, that unintended discharge locations would occur. A review of the bog boundary was carried out. No low points were identified, near areas zoned for rehabilitation, that may become an unintended discharge location. The south boundary of the bog discharges directly to the Esker stream or the Boden River. As such there is little risk to adjacent lands should there be increased flows from the bog owing to elevated groundwater levels. However as previously set out this is based on the ability of the existing boundary drainage network, separating the bog from adjacent lands at a lower level, to provide a positive gravity drainage function in relation to groundwater entering the drain. In other words capacity to convey Q_{med} or 2 year return period flows and a free flow (constantly falling) away from the bog.

3.2.2 Insufficient Drainage

It is a significant concern for adjacent landowners that restoration and rehabilitation measures could lead to localised impacts in terms of reduced drainage leading to flooding of agricultural lands upstream of the bog.

There is one inflow location to Esker Bog (Figure 3.2) which connects to a drain which flows south through the bog. Should this drains function and capacity deteriorate, low lying parts of the upstream land may reduce in drainage efficiency. This low lying, wooded land was identified and included in the zone of influence (see Figure 3.2).

3.2.3 Increased Runoff

Evidence from bogs that have previously been the subject of restoration measures demonstrates that the measures proposed at Esker, which are all aimed at reducing runoff and retaining water within the bog, have the effect of reducing the frequency and magnitude of flood events by restoring a more natural hydrological regime. Restoration / rehabilitation has been successfully applied to numerous Bord na Móna bog sites as well as SAC sites such as Clara Bog (East), Raheenmore Bog, Carrownagappul Bog and Lisnageeragh Bog. Elsewhere, the restoration of peatland catchments in numerous sites across the UK, such as Exmoor National Park in Snowdonia, has demonstrated positive flood alleviation following rehabilitation measures. Monitoring found that this occurred as runoff from the moorland was reduced due to increased storage in the peat.

The risk of increased runoff from Esker Bog is low. All rehabilitation measures being proposed will reduce runoff. However there is a potential that if bog re-profiling is carried out as part of the bog rehabilitation measures that the bog sub-catchments will be modified. Changes in sub-catchments could result in certain discharge points draining larger areas. This would result in increased flows that could outweigh the effect of the reduced runoff arising from the rehabilitation. This is a moderately low risk at Esker as the re-profiling of the bog will generally result in the same topographical flow paths, catchment watersheds and discharge locations as in the pre-rehabilitation state. However in the absence of a full pre and post rehabilitation runoff model and in line with a precautionary approach it is prudent that all drainage infrastructure from the bog is fit for purpose and retained such that at a minimum capacity to convey high frequency flood events (Q_{med} or 2 year return period) is provided.

3.3 Potential Risk Areas

The following assets have been identified as being at potential risk from flooding or wetter conditions as described in Table 3.1.

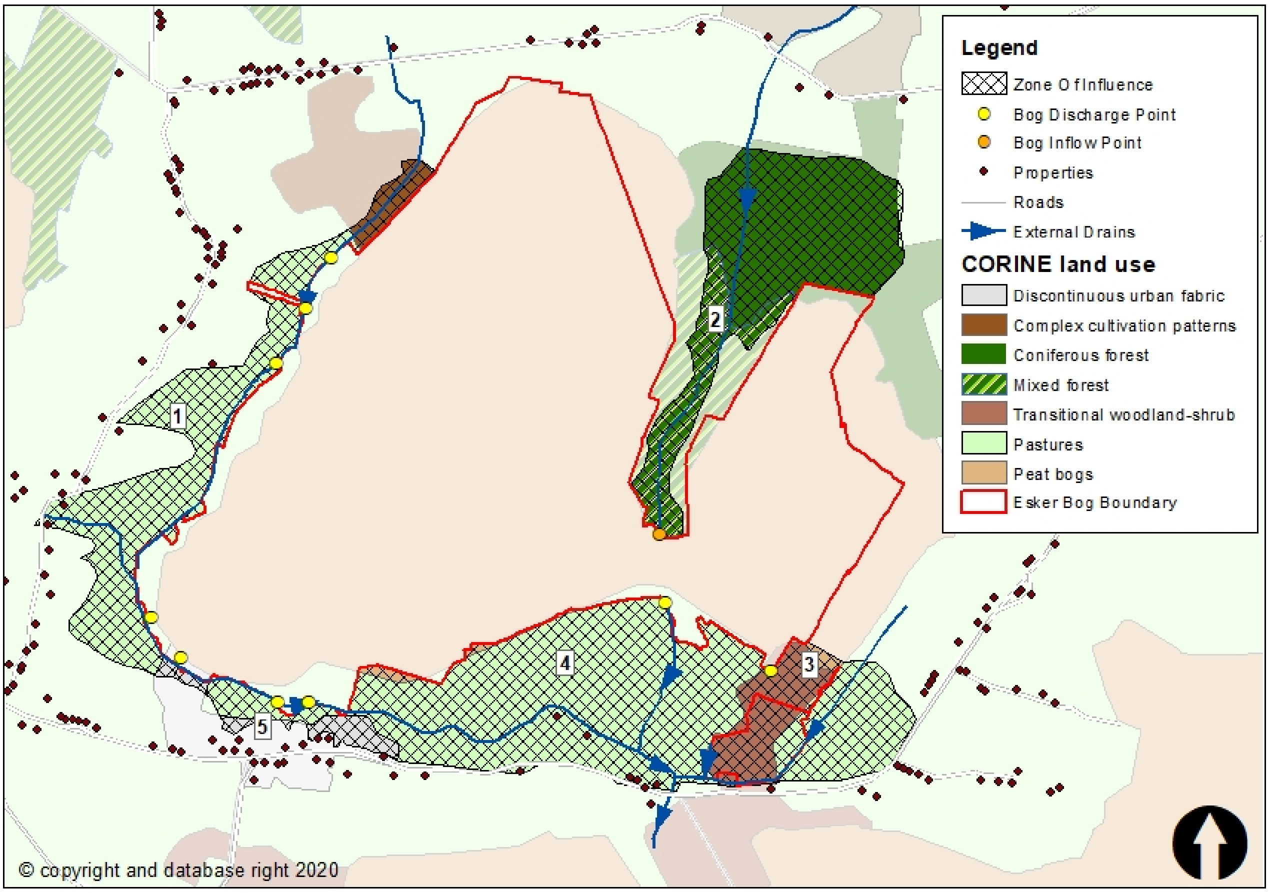

Figure 3.4 Esker Bog Rehabilitation Plan – Assets at risk

The assets at risk are set out in **Error! Reference source not found.** along with the vulnerability, based on the current landuse, of the asset. It should be noted that the appraisal of the assets at risk is considering the consequences of flooding or wetter conditions, not the likelihood of flooding or wetter conditions occurring.

Table 3.3 Assets at risk

Item	Asset	Vulnerability to flooding and/or wetter conditions
1	Agricultural land	High Vulnerability. Land would become less productive should it be made wetter.
2	Woodland and Commercial forest	Low vulnerability. Land adjacent to the bog is woodland which could tolerate wetter conditions. Commercial trees require good drainage. Should the ground become wetter the growth rate of the trees may be reduced. Woodland acts as a buffer between Esker bog and Commercial trees dampening any potential groundwater rise.
3	Woodland and Agricultural land	Low Vulnerability. Land adjacent to bog is woodland which can tolerate wetter conditions. Woodland acts as a buffer between Esker bog and agricultural land dampening any potential groundwater rise.
4	Agricultural land	High Vulnerability. Land would become less productive should it be made wetter.
5	Agricultural land and discontinuous urban fabric	High Vulnerability. Agricultural land would become less productive should it be made wetter. The impact of wet ground conditions or flooding to properties in the urban fabric would be considered high. The road in this area is slightly higher than the surrounding land and risk of flooding is low.
6	Roads	Low vulnerability. Road level slightly higher than surrounding land. Risk of flooding is low.
7	Properties	Moderate – High Vulnerability. Although the impact of wet ground conditions or flooding to properties would be considered high, the location of these properties is mostly away from the bog at the limit of the zone of influence or the level of the property is at a higher elevation than the surrounding land. Properties at low elevations are considered high risk. A number of the properties are agricultural sheds which would be more resilient to any potential flood risk.

In addition to the above risks there is a general low risk that should degradation of the bog boundary occur surface water could be released into adjacent lands.

4 OBJECTIVES

The overarching objective of the Esker Drainage Management Plan is to facilitate the rehabilitation of bog through management of potential adverse impacts to adjacent land and waterbodies. SMART[2] objectives were developed for the Drainage Management Plan that provides direction for the overarching objective. These objectives consider constraints, risks and opportunities that were identified in chapters 2 and 3 and are detailed as follows:

1. To manage potential groundwater impacts between adjacent land and Esker Bog during and after rehabilitation measures.
2. To retain the current drainage capacity of the agricultural land flowing into Esker Bog both during and after the rehabilitation measures.
3. To maintain or reduce flows released from the bog at the discharge locations.
4. To reduce sediment entering the external drains and streams during and after rehabilitation, these measures are to ensure compliance with current discharge limits in IPC Licence.

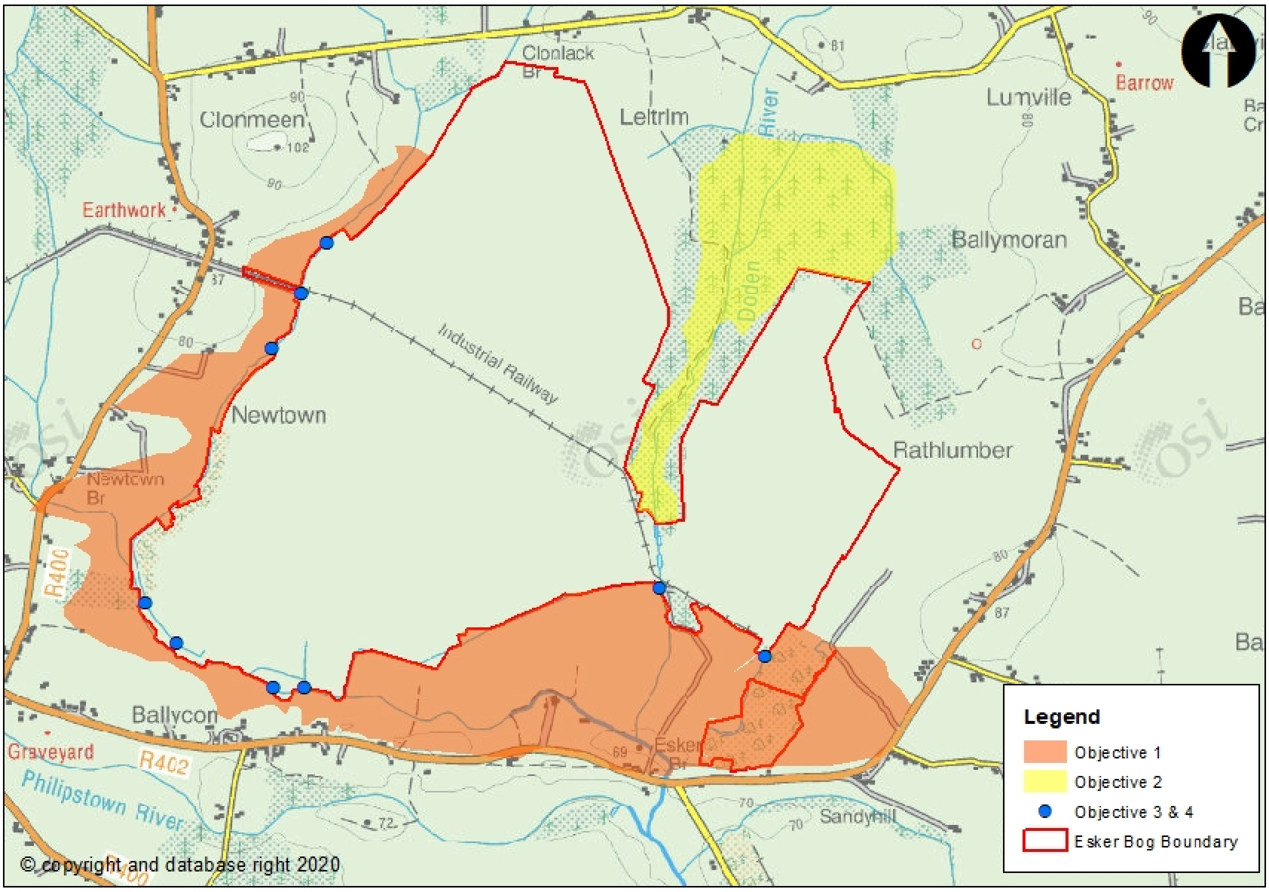

Figure 4.1 Esker Bog DMP objectives

[2] SMART – Specific, Measureable, Achievable, Relevant, Time bound

5 DRAINAGE MANAGEMENT MEASURES

5.1 Key drainage features

Drainage management measures were identified in relation to the objectives set in chapter 4 and are described below. Objectives 1 and 3 consider the potential impact to adjacent land from groundwater rise. Objective 2 considers the existing drainage network flowing into and through the bog. Objectives 3 and 4 consider the control mechanisms to flow discharging from the bog.

An assessment was carried out to identify the key drainage features required to meet the objectives set. Figure 5.1 presents these features. It can be seen in the figure that for groundwater level rise to be managed between the bog and adjacent land that a hydraulic break will be required. To ensure that the land draining into the bog is not impacted the drainage path through the bog will need to be retained. And to ensure that the flow and sediment discharging from the bog is managed the discharge control points will need to be maintained.

Although outside the Bord na Móna bog boundary key external drains were identified. These drains are hydrologically connected to the bog drainage network. While no drainage issues were identified along these external drains, see section 2.4, a risk of sediment deposition was highlighted from sources outside the bog. The maintenance of the existing silt ponds will ensure that the bog will not contribute to an increased risk of sediment deposition arising from rehabilitation. Should this occur drainage from the bog could be impeded and adjacent land could become wetter.

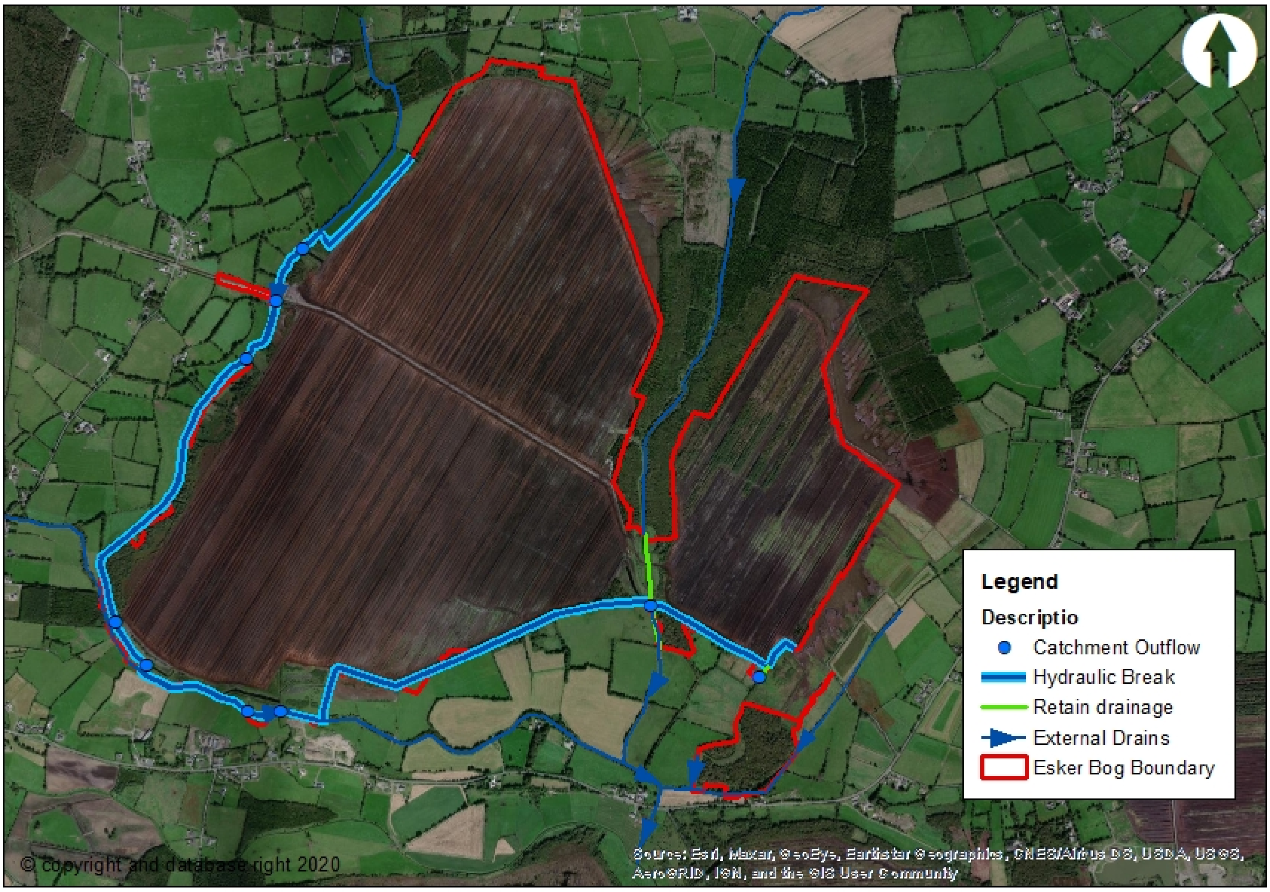

Figure 5.1 Key drainage features for Esker Bog

When identifying measures to provide the key drainage features a review was carried out of the drains. The review found that there is limited data available for boundary drains to the bog and external drains within the adjacent land. While data is available for internal drains this was found to be limited also. It was therefore required to produce a Drainage Management Plan that could offer a suite of measures whereby the most appropriate measures can be selected based on the level of robustness and on-site observations. The DMP would therefore allow the bog to be managed and adapted as the rehabilitation plan progresses and is retained in the future. The following sections describe the suite of measures that can feasibly be implemented for the Esker Bog Drainage Management Plan.

5.1.1 Boundary drains

Boundary drains can provide hydraulic breaks between the bog and adjacent land, see Figure 3.3. In most areas of the Esker Bog there are existing boundary drains. Available information indicate that these drains are suitable to provide hydraulic breaks and can be designated as such and retained in the future. Observing and recording the suitability of the boundary drains is recommended and where they are found to be not functioning as predicted upgrade works will be required. This would involve modification of the drain to make them larger/deeper/wider/steeper. This may be only in specific locations along the drain or an entire reach may require upgrading. Where there is no boundary drain present a new drain can be excavated in order to create the hydraulic break required. In these cases a channel of specified dimensions and slope will be required.

5.1.2 Bog rehabilitation modification

Where a boundary drain is not suitable to act as a hydraulic break or where none exists it may be possible to review the bog rehabilitation plan to provide the required mitigation measure. This can take the form of sacrificing rehabilitation of the last peat field, closest to the adjacent land where an existing field drain could act to provide the hydraulic break function. The field’s drainage network would be retained keeping the groundwater to current conditions and providing a groundwater cut-off in relation to the adjacent land.

5.1.3 Internal drain retention

Drains within the bog that include adjacent land within their sub catchment may need to be designated as key drainage features and retained to ensure that the drainage to the adjacent land does not deteriorate.

5.1.4 Maintenance of silt ponds

Existing silt ponds are located upstream of the bog discharge points. They help regulate the flow and level of suspended peat leaving the bog into the external drains and rivers. Bord na Móna have legal responsibility to maintain these silt ponds and ensure their proper functioning capacity under the existing IPC Licence (Ref. P0503-01).

Where no silt point exists upstream of a discharge point and no subsequent silt pond will be utilised before flow would leave the bog alternative silt control measures will be required. This can include blocking and or diverting the discharge point so that the relevant sub-catchment of the bog drains to a different discharge point with a silt pond. The rehabilitation plan can also be adapted to allow proposed wetlands to act a silt control measure.

5.1.5 Monitoring

As mentioned above DMP measures were selected based on level of certainty and on-site observations. The most appropriate measure was selected from a suite of measures representing varying levels of intervention. Monitoring of the measure and adjacent land will be required prior, during and after the rehabilitation measures. A monitoring programme can be implemented to observe the impact from the bog rehabilitation to the adjacent land. Monitoring would be observational where the condition of the asset in question is assessed in relation to present day conditions accounting for seasonal variability. Where negative impacts are observed other measures can be implemented that will establish a hydraulic break. Otherwise monitoring should continue until environmental stabilisation.

5.2 Drainage assessment

A review was carried out of the existing drainage networks falling within the key drainage features as shown in Figure 5.1. These drainage networks were reviewed to the confluence with streams in order to identify potential downstream control features.

The estimated flood flows were compared with the hydraulic capacity of each of the control features which are important to the effective performance of the drainage network.

Two methods have been considered for the derivation of the Index Flood flow (Q_{med}) as set out in Section 2.2. There is a high degree of uncertainty in the estimation of flood flows at the small catchment scale and therefore the largest of the two estimates has been chosen for each sub-catchment in line with a precautionary approach to uncertainty. Flood flows for Q_{med} (50% AEP) and Q_{100} (1% AEP) peak flows for each sub-catchment have been calculated. A growth curve representing the bog catchment characteristics has been used, whereby a growth factor of 2.4 has been used to scale up the Q_{med} peak flow to determine the Q_{100} event (100 year return period flood event).

The best projections on the effect of climate change have been applied to determine the Mid-Range Future Scenario (MRFS). This represents a 20% uplift over the present day flood flows.

Table 5.1 Peak Flows in Each Sub-Catchment

Sub Catchment	Q_{med} / 50% AEP	Q_{100} / 1% AEP	Q_{100} / 1% AEP MRFS
1	0.032	0.077	0.093
2	0.087	0.208	0.250
3	1.794	4.180	5.017
4	0.146	0.350	0.419

Sub Catchment	Q_{med} / 50% AEP	Q_{100} / 1% AEP	Q_{100} / 1% AEP MRFS
5	0.019	0.045	0.054
6	0.012	0.029	0.034
7	0.020	0.048	0.058
8	0.078	0.186	0.224
9	0.113	0.271	0.325

5.2.1 Assessment Points

Assessment Points have been assigned at key / critical points within the drainage network identified in Figure 5.1 as providing a key drainage management function. The location of the Assessment Points is provided in Figure 5.2.

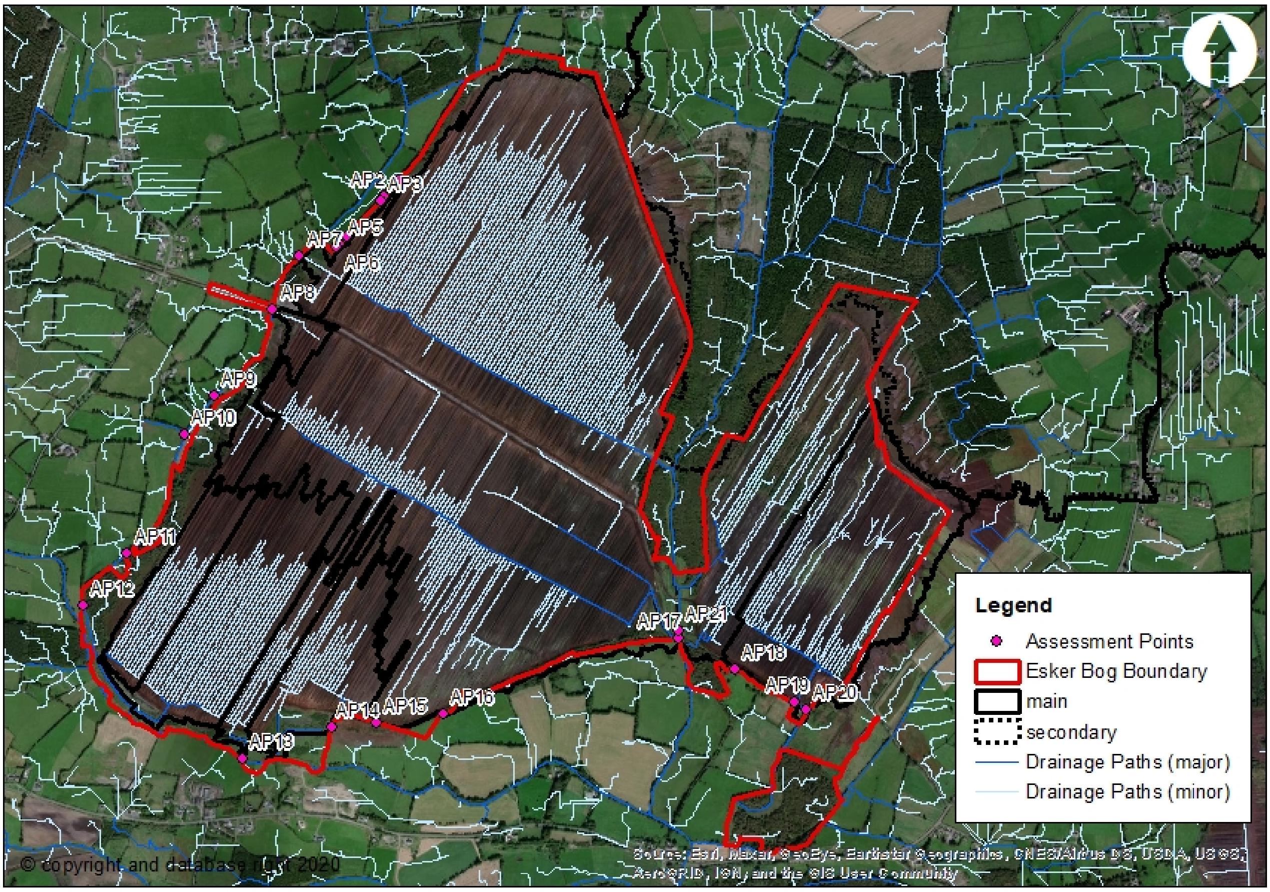

Figure 5.2 Assessment Points at Esker Bog

5.2.2 Hydraulic Analysis

The peak flows at each Assessment Point (AP) have been compared to the estimated hydraulic capacity of each of the features. A summary of the flood flows that may be generated at each AP along with their likely capacity to convey these flows is summarised below in Table 5.2. Note that capacity issues at an AP may have knock on impacts in terms of flooding for the APs upstream which is not captured in this point by point capacity check.

Table 5.2 AP Capacity

Assess. Point	Sub-Catch.	Feature Type	Flood Flow Range (m^3/s)	Capacity & Recommendations
AP_1	3	Pipe	0.043 - 0.121	No data. **Check pipe capacity when conditions allow.**
AP_2	5	Pipe	0.082 - 0.237	No data. **Check pipe capacity when conditions allow.**
AP_3	5	Boundary Drain	0.083 - 0.239	Likely capacity to convey all flood flows.
AP_4	5	Pipe	0.088 - 0.254	No data. **Check pipe capacity when conditions allow.**
AP_5	5	Pipe	0.089 - 0.257	No data. **Check pipe capacity when conditions allow.**
AP_6	5	Pipe	0.090 - 0.259	No data. **Check pipe capacity when conditions allow.**
AP_7	5	Boundary drain	2.098 - 6.042	Capacity to convey QMED. Out of bank flooding during more extreme events.
AP_8	6	Pipe	2.131 - 6.136	No data. **Check pipe capacity when conditions allow.**
AP_9	7	Pipe	0.721 - 2.077	No data. **Check pipe capacity when conditions allow.**
AP_10	7	Pipe	0.782 - 2.253	No data. **Check pipe capacity when conditions allow.**
AP_11	8	Boundary drain	1.046 - 3.013	Capacity to convey QMED. Out of bank flooding during more extreme events.
AP_12	8	Pipe	1.101 - 3.171	No data. **Check pipe capacity when conditions allow.**
AP_13	Esker Stream	Boundary drain	6.317 - 17.434	Capacity to convey QMED. Out of bank flooding during more extreme events.
AP_14	2	Boundary drain	0.045 - 0.128	No clear defined open drain at this location. **Check drain capacity when conditions allow.**
AP_15	3	Boundary drain	0.006 - 0.015	No clear defined open drain at this location. **Check drain capacity when conditions allow.**
AP_16	3	Boundary drain	0.009 - 0.026	Likely capacity to convey all flood flows.
AP_17	3	Internal Drain	0.435 - 1.217	Likely capacity to convey all flood flows.

Assess. Point	Sub-Catch.	Feature Type	Flood Flow Range (m^3/s)	Capacity & Recommendations
AP_18	4	Boundary drain	0.002 - 0.006	No clear defined open drain at this location. **Check drain capacity when conditions allow.**
AP_19	4	Internal Drain Outlet	0.144 - 0.415	Likely capacity to convey QMED away from bog.
AP_20	4	Boundary drain	0.145 - 0.417	Likely capacity to convey all flood flows.
AP_21	3	Pipe	1.143 - 3.197	Likely capacity to QMED flows. Potential constriction at more extreme flood events.

5.3 Identification of measures

The review of drain capacities found that most open drains are likely to have sufficient capacity to convey flow away from the bog. They would therefore be suitable to act as hydraulic breaks provided they are retained with their current estimated carrying capacity. Section 2.6 indicates how all boundary drains appear to be functioning sufficiently with no known drainage issues identified along the drain or in adjacent land. Although there is no survey data for some reaches the anecdotal evidence suggests that the boundary drains identified for retention are functional and can be used as drainage management measures. They would therefore be suitable to act as hydraulic breaks provided they are retained with their current estimated carrying capacity. Table 5.3 and Figure 5.3 details the level of intervention required along each reach of drainage network.

Figure 5.3 DMP measures for Esker Bog

DMP measures 1 & 2 refer to existing drains recommended for retention in order to provide a hydraulic break. It is noted that these drains are inside and out of the Bord na Móna boundary. They do however provide the break between the bog and adjoining pasture land. While Bord na Móna cannot ensure the retention of the reaches of existing drain outside the Bord na Móna bog, monitoring with take place and other measures considered if required.

DMP measure 7 refers to a bog discharge point with currently no silt control measure. It is proposed to block this discharge points and divert the drains to the nearby discharge point to the west via an existing silt pond.

The remaining measures are of low intervention consisting of maintaining the existing features or monitoring lands or features.

Table 5.3 Selection of DMP measures

Measures Item	Feature	Function required	Suite of measures Level of intervention — Low			High
1	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
2	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
3	Internal drain	Drainage of adjacent land	**Retain drain**	Upgrade drain	-	Create new drain
4	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
5	Boundary drain	Hydraulic break	**Retain drain**	Upgrade drain	Maintain outside bog field	Create new drain
6	Silt ponds	Silt and flow control	**Maintain pond**	Upgrade pond	-	-
7	Discharge point	Silt and flow control	Retain discharge	**Block and divert discharge**	Adapt rehabilitation plan	-

5.4 Interaction with monitoring plan

As part of the bog rehabilitation plan groundwater level monitors will be installed at Esker Bog. These monitors will record groundwater levels over the coming months. It will therefore be possible to ascertain if groundwater is rising within the bog following the implementation of the rehabilitation plan.

This data should be considered during the monitoring measures of adjacent land. When groundwater levels are known to be rising within the bog, monitoring of the adjacent land (as described in Section 5.1.5) should take place on a more regular basis to ascertain if impacts to lands outside the bog are observed.

Downstream of the site at Clonbullogue on the Figile River is a long term, flood flow gauging station[3]. Although the gauged catchment (247 km^2) is large, much of it represents Bord na Móna lands which will be subject to rehabilitation. The Esker site represents approximately 11.5 km^2 of potentially rehabilitated catchment and when taken in combination with the other rehabilitated sites within the catchment it would be expected that changes in run-off and flood peaks would be discernible in the gauging station record after a number of years. This represents an opportunity to determine the impact of rehabilitation measures within an existing, robust flood flow record post rehabilitation.

5.5 Residual Risk & Limitations

The level of flood risk to the bog and the surrounding lands has been shown to be low (Section 2.6) generally. The impact of the proposed rehabilitation measures will generally be to reduce runoff from the bog but this will lead to increased groundwater levels and surface water flooding in the bog itself. During flood events no increase in flood risk is envisaged as a result of the rehabilitation measures. During normal flow regime there are unknowns in relation to the post-rehabilitation water levels which will be realised, however the Drainage Management Plan seeks to identify the measures that should provide a hydrological cut off between the bog and the surrounding lands.

As indicated in previous sections there are limitations to the assessments associated with the drainage network both within the bog and outside. Factors such as flow estimations of small catchments, lack of survey data limiting drain capacity estimations and high level definition of soil porosity all contribute to these limitations. Nevertheless the measures recommended represent a pre-cautionary approach based on conservative assumptions.

The DMP measures proposed set a baseline approach however a suite of measures in any given location has been provided. This will allow a reactive approach to be taken if required. Should a measure not be operating efficiently a higher intervention measure can be implemented. This will allow Bord na Móna to identify the most appropriate measure while proceeding with drainage function uncertainties.

[3] https://waterlevel.ie/0000014004/

5.6 Climate Change Adaptability

There is high uncertainty in relation to the effects of climate change, particularly in how it may manifest in terms of small catchment runoff. Ireland is predicted to have drier summers and wetter winters. The most appropriate guidance in an Irish context can be found in the OPW's Flood Risk Management Climate Change Sectoral Adaptation Plan[4]. For the Mid-Range Future Scenario, representing a central emissions estimate on a 100 year time horizon, it is recommended that allowances for peak flow and rainfall are increased by 20%. If such increases in runoff are realised over the timeframe of establishment of rehabilitation measures this could lead to a perception that bog rehabilitation measures at Esker are the cause of increased flood risk.

It is anticipated however that the rehabilitation measures will lead to reduced peak runoff as the water storage function of the bog is increased. This will serve to regulate peak runoff in winter and potentially smooth out the flows in drier periods, essentially acting against the anticipated effects of climate change.

It is therefore anticipated that the bog rehabilitation measures themselves will provide the mitigation of the effects of climate change on runoff and no additional measures will be needed. There are unknowns however in the effectiveness of the rehabilitation measures in this regard and also the severity of climate change impacts. Continued monitoring of the adjacent lands is therefore also crucial to gauge the effectiveness of the BRP measures in mitigating these climate change impacts.

[4] Accessed on 10/12/2020 at https://www.gov.ie/pdf/?file=https://assets.gov.ie/46534/3575554721374f7ab6840ee11b8b066a.pdf#page=1

6 SUMMARY OF DRAINAGE MANAGEMENT PLAN

The Drainage Management Plan for Esker consists of a series of measures to be implemented at different stages of the rehabilitation measures. Drains within the bog and along its boundary were identified as being key drainage paths or hydraulic breaks in order to mitigate against any potential impacts from the bog rehabilitation measures. The effectiveness of all drains acting as hydraulic breaks is dependent on their ability to convey flow which have been outlined in Section 5.3 and deemed appropriate subject to the measures recommended. Factors such as channel size and slope will determine this along with any downstream feature which may control water levels. The external drains which these boundary drains discharge into are also key drainage features that will affect the operation of the drainage network. Measures are generally low intervention and consist of monitoring, retention of existing features and removing an existing feature. Maintenance of measures are proposed to the silt ponds within the bog to ensure that discharge from the bog and sediment is controlled. This is a legal obligation for Bord na Móna and will continue at all existing silt ponds. Monitoring of adjacent land was included in the plan. The monitoring will observe adjacent agricultural land bog and woodland for adverse impacts from the bog rehabilitation. Should these impacts be confirmed, higher intervention measures can be implemented to mitigate the impacts. Monitoring measures will therefore be ongoing during and after the bog rehabilitation measures. Continued retention and maintenance of the key drains and silt ponds will also be required after the bog rehabilitation measures. Throughout the process landowner engagement is recommended to ensure both the rehabilitation plan and Drainage Management Plan are understood and to promote collaborative working to manage impacts as they arise.

Table 6.1 Drainage Management Plan

Measures required PRE bog rehabilitation measures	Measures required DURING bog rehabilitation measures	Measures required POST bog rehabilitation measures
Landowner engagement if required via community liaison	Landowner engagement if required via community liaison	Landowner engagement if required via community liaison
Retention of internal and boundary drains (see section 5.1.1)	-	-
Monitoring external drains	IF REQUIRED – Consideration of need for higher intervention measures	-
Maintenance of silt ponds (see section 5.1.4)	Maintenance of silt ponds (see section 5.1.4)	Maintenance of silt ponds (see section 5.1.4)
-	Blocking discharge point (see section 5.1.4)	-
Monitoring of adjacent land (see section 5.1.5)	Monitoring of adjacent land (see section 5.1.5)	Monitoring of adjacent land (see section 5.1.5)
-	-	IF REQUIRED – boundary drain upgrades (see section 5.1.1)
-	-	Retention of key drains and pipes