

Peatland Restoration Guide

Site Preparation and Rewetting



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INTRODUCTION

This booklet in the Peatland Restoration Guide series has been prepared to make available new approaches to site preparation and rewetting¹ that have been developed since the 2003 publication of the *Peatland Restoration Guide, Second Edition*.² It is intended mainly for the horticultural peat industry, but may also be useful for those interested in restoring peatlands that have been drained and where the surface is largely bare peat. It is an update of the 2003 guide section covering site preparation and drainage ditch blocking (pp. 25 to 35 and pp. 60 to 62 of the English version).

This booklet begins with a brief review of the Moss Layer Transfer Technique. It then describes how to prepare the site, manage water flow and retention by building dikes (also known as berms), make sure the restored sector is connected to adjacent land and rewet the site through ditch blocking. The time and resources required for each step are also described.

Rewetting is a critical success factor in peatland restoration, and re-establishing an appropriate hydrological regime is one of the main objectives to reach over the short term. Rewetting techniques have evolved greatly since the publication of the *Peatland Restoration Guide, Second Edition*. The Peatland Ecology Research Group (PERG, Université Laval) also published in 2011 a guide³ that describes in detail the various techniques used to block ditches, based on their size, as well as to fill drainage ditches and cut trees, two other measures that support rewetting.

MOSS LAYER TRANSFER TECHNIQUE

The Moss Layer Transfer Technique (MLTT) developed by the PERG for the restoration of peatlands (bogs, poor fens and moderate-rich fens) is based on active reintroduction of peatland plant species combined with rewetting through hydrological management. This technique has been used in over one hundred restoration projects in Canada as well as in many other countries. It makes it possible to bring back to the restored site over 80% of the species present in the plant material collected from a donor site, and it limits non-peatland plant species to only 3 to 6%. In addition, long-term monitoring of the vegetation (more than 10 years) shows a progressive decrease in these atypical species as the moss carpet develops. A study by PERG in collaboration with researchers

¹ For the purposes of this document, “rewetting” means the actions taken to re-establish the original hydrological conditions, which are characterized by a water table located near the surface, with limited variations in level.

² Quinty, F. and L. Rochefort. 2003. *Peatland Restoration Guide, 2nd edition*. Canadian Sphagnum Peat Moss Association and New Brunswick Department of Natural Resources and Energy. Québec, Québec.

³ Landry, J. and L. Rochefort. 2012. *The Drainage of Peatlands: Impacts and Rewetting Techniques*. Peatland Ecology Research Group, Université Laval, Québec, Québec.

at McGill University demonstrated beyond all doubt that a peatland was once again able to capture and sequester carbon 15 years after restoration.⁴

The success of the Moss Layer Transfer Technique is largely related to how well the restoration work is done, as well as the meteorological and hydrological conditions prevailing while the work is carried out. The MLTT involves the following steps:

- Planning;
- Preparing the sector to be restored;
- Collecting plant material from a donor site;
- Spreading the plant material;
- Spreading mulch;
- Fertilizing;
- Rewetting by blocking the drainage system; and
- Monitoring the restored sectors.

This booklet focuses primarily on the steps involved in site preparation and in rewetting by blocking the drainage system, as part of the restoration of *Sphagnum*-dominated peatlands.

SITE PREPARATION

The goal of preparing a site⁵ is to create conditions that will allow the establishment and growth of plant fragments originating from the plant material that will be spread over the surface. This step has five main goals:

- Refreshing the surface;
- Reprofilling the sector;
- Controlling runoff and improving water distribution;
- Decreasing evapotranspiration;
- Re-establishing connectivity with the adjacent ecosystem.

Selecting the measures to apply and planning the work depend on the site's history and the postextraction residual conditions. This information should have been gathered during the restoration planning step (see the booklet from this series on that topic).

⁴ Nugent, K., I.B. Strachan, M. Strack, N.T. Roulet and L. Rochefort. 2018. Multi-year net ecosystem carbon balance of a restored peatland reveals a return to carbon sink. *Global Change Biology* 24(12): 5751-5768. 2018.

⁵ The term "site" refers to a peat production site, i.e. a peat bog. The term "sector" describes a homogeneous area affected by the same drainage network. It is the scale at which restoration is planned. A sector includes a number of peat fields, which are separated by secondary drainage ditches. However, for ease of reading, the terms "site" and "sector" are both used in this document to designate areas undergoing restoration.

Refreshing and Reprofileing the Surface

Why Refresh and Reprofile

Fields where peat extraction is no longer taking place are generally covered with a loose layer of peat remaining from the last harrowing. The peat fields may be affected by frost heaving, wind or peat oxidation and decomposition. The surface may also be covered by a thin "biological crust," made up of a mixture of cyanobacteria, lichens, algae, mosses and liverworts. All of these can negatively impact plant establishment by creating a barrier between the plant fragments and the compacted peat substrates. The surface of the sectors to be restored should therefore be completely reworked. The oxidized surface layer of loose peat, wood debris and the biological crust must be removed to expose a fresh peat surface. This facilitates contact between the substrate and the introduced plant fragments, enabling them to get water through capillary action as well as from precipitation.

There are several other reasons to refresh the surface. This operation removes any vegetation that has established spontaneously since peat extraction ended and that can prevent the introduced plant fragments from establishing contact with the soil. Also, some fields that had been given a convex profile to allow the drainage and drying needed for peat extraction need to be flattened. And finally, it enables any other surface irregularities to be levelled.

The peat surface that will receive the plant fragments and mulch must be flattened. An experiment comparing flat surfaces to topographies created by ploughing, harrowing or with a crawler tractor showed that flat surfaces provide the best conditions for plant establishment. The other types of microtopography offer favourable conditions in low-lying areas, but, considered overall, not to the extent of flat surfaces. In fact, the highest areas tend to dry out faster and to erode.

Reprofilng domed fields is important because it creates uniformly humid conditions over the entire surface. However, the goal of reprofilng the topography should be to create a flat profile rather than a concave one. While experience has shown that a concave profile improves *Sphagnum* establishment in the lower slopes, it also leads to dry conditions in the upper slopes and to the erosion of peat, plants and mulch by runoff water. In addition, some plant fragments in the depression get buried under eroded material coming downslope.

How to Refresh and Reprofile

The loose peat and everything else found at the surface must be removed, using a grader, screw leveller or bulldozer, until a layer of undegraded peat is reached. Reprofilng may require the removal of a thicker layer of peat to obtain a flat surface. The peat removed in this operation can be used to fill drainage ditches or to construct dikes as discussed later on in the text.

When Not to Refresh and Reprofile

In some cases, the area to be restored may already contain spontaneously established vegetation made of typical peatland species. This is generally seen in sites where hydrological conditions re-establish on their own after the ditches have collapsed. In these cases it is possible to keep this vegetation and not refresh the surface. However, careful attention must be given to the plant communities in place. For instance, dense *Sphagnum* carpets or well-established sedges should be kept, but invasive or very common species, such as cattails or cottongrass, should not. As a general rule, preserving the vegetation in place should be an exception and done only to save peatland plant communities. In all other cases, the surface should be refreshed, as it is essential for successful *Sphagnum* reintroduction.

Should Drainage Ditches Be Filled?

There are benefits and drawbacks to filling ditches. The decision of whether or not to do it should be based on the site conditions.

Filled ditches: When refreshing or reprofiling the site surface, a large portion of the surface peat can be put in the ditches, thereby filling them, at least partly. Even if they are not completely blocked, it will make the blocking of ditches easier later on. Filling ditches allows machinery to move around the site in all directions, which then facilitates other restoration work, especially in sectors that have short fields or dikes.

Open ditches: Leaving drainage ditches open (i.e., not filled with peat) can help create diverse habitats and thereby increase biodiversity on the site. In such cases, the ditches are blocked at the ends, at regular intervals, during the rewetting step. The accumulation of water creates elongated pools between dams. These pools are soon used by a variety of insects and wetland plant species will establish there over time. These ditches can also help collect excess water, potentially decreasing the risk of floods and surface runoff in the peatland. Furthermore, the water stored in the former ditches can help rewet the peat substrate in dry periods.

WHICH TO CHOOSE? Combining both strategies on a single site can provide the benefits of both options. For instance, a few drainage ditches can be kept open, while the others are filled during the surface reprofiling. Ditches can also be filled over a few metres on either side of the dikes to facilitate the movement of heavy equipment.

Controlling Runoff and Improving Water Distribution

While most sites have gentle slopes, this can still create dry conditions upstream and very wet conditions downstream if no corrective measures are taken. After the ditches have been blocked, these slopes can also cause surface runoff that is likely to erode the soil and displace the previously spread plants and mulch.

It would be painstaking to correct this situation solely by reprofiling the surface unless the peat fields are short, with a very gentle slope. Building dikes⁶ is an effective means of controlling runoff and retaining water on the restoration site.

DIKES

In peatland restoration, a “dike” is a low, linear peat construction (30 to 75 cm high) used to retain and control water runoff and to ensure that water is uniformly distributed within a restored sector. Several types of dikes can be built, depending on the site’s conditions and what needs to be corrected. The term “berm” is also sometimes used.

Types of Dikes

Peripheral dikes

Peripheral dikes are mainly used to keep water within a site. As their name suggests, they are built around the sectors to be restored. They are needed when the sectors are bordered by drainage ditches that cannot be blocked or are adjacent to surfaces toward which the water could flow out. That situation is not ideal, and it is preferable to block the ditch if possible. The main ditch can also be moved to allow the sector to be rewetted and connected to the surrounding environments.

Depending on the size of the sectors they surround, peripheral dikes may need to hold back large amounts of water. They therefore have to be resistant and compacted enough to withstand considerable pressure. In the spring, dikes can be good allies in preserving the snow melt because peat’s insulating qualities help maintain an ice core that strengthens the dikes and helps them act as a barrier. Even so, it is strongly recommended that the dikes’ condition and stability be monitored for the first four years following the restoration, until the vegetation is established. Once stabilized, peripheral dikes can better withstand the large amount of water released during the spring thaw.

Dikes perpendicular to the slope

Dikes that are built perpendicular to the slope (Figures 1 and 2) aim to improve water distribution. This technique creates a succession of terraces separated by dikes (like terraced rice paddies) that retain the water and slow its flow. It is recommended that a topographic survey of the site be conducted during the work planning stage to determine the number of dikes required and their location. As a general rule, a perpendicular dike is needed for every 30-centimetre drop in elevation. For example, a 100-metre-long peat field whose change in elevation is one metre from one end to the other will need three to four dikes. The topographic survey will also help determine the layout of dikes that need to be built along lines of

⁶ Underlined words refer the reader to the boxes.

the same elevation. The dikes at the Inkerman Ferry site in New Brunswick were positioned in this way, which helped ensure better water distribution than if they had been built without taking the slope's complexity into account (Figure 2). Given their effectiveness and ease of construction, dikes perpendicular to the slope should be erected on nearly all peatland restoration sites.



Figure 1. Dike perpendicular to the slope at the Saint-Fabien-sur-Mer peatland in Québec, two years after restoration.



Figure 2. Aerial photo of the Inkerman Ferry restoration site in New Brunswick. The dikes were erected along contour lines obtained from a topographic survey.

Checkerboard-pattern dikes

Some situations call for checkerboard-pattern dikes, which create small cells that trap the water. This is useful when large surfaces need to be restored on a flat site, because the cells keep the peat, plant fragments and mulch from being displaced by water and wind. Checkerboard-type dikes are an alternative to dikes built perpendicular to the slope. As an example, the Chemin-du-Lac site in Québec is characterized by complex slopes and short fields. To ensure uniform water distribution, a grader (leveller) was used to form a checkerboard pattern. The cells are approximately 30 metres wide, and the dikes were 30 centimetres high after compacting. The machinery circulating on the dikes during the spreading of the plant material and straw did not cause damage to the point of reducing the dikes' effectiveness.

The Elma site in Manitoba (Figure 3) was covered with checkerboard-pattern dikes to counter the effects of strong winds and the spring snowmelt, which could cause erosion and displace the plant material and mulch. The dikes retain the water and distribute it throughout the entire site. The cells of the checkerboard were made with a bulldozer. They are approximately 10 metres wide, and the dikes were 30 centimetres high after compacting. This was done at the same time the site was levelled.

The bulldozer operator pushed the excess peat over a 10-metre distance with the blade, then built a dike with the gathered material. The operator then compacted the dike with the bulldozer's tracks, before building a new dike parallel to the first, 10 metres farther away. Upon reaching the end of the site, the operator started the process anew, building dikes perpendicular to the ones just created, taking care to lift the blade at each dike encountered. Finally, a tractor was used to compact the perpendicular dikes without damaging the first ones.



Figure 3. Checkerboard-pattern dikes in Elma, Manitoba.

Dike Construction

Dikes are erected using the peat from the refreshment of the restoration site's surface. Any equipment that can move peat can be used to build dikes. Graders and bulldozers are most commonly used.

A dike's width makes a difference in its erosion resistance. The height of the water that will be retained by the dike determines the water pressure that will be exerted on it. Dikes can be reinforced or broadened where water pressure will be strongest. With the exception of peripheral dikes, dikes do not need to be very high. A height of 30 centimetres after compacting is sufficient unless a large amount of water needs to be retained. When dikes are used to counter the effects of wind or to contain a large amount of water, a height of up to 75 centimetres may be needed.

Here are some recommendations to follow to build dikes that are more resistant and watertight and to reduce the risk of having to make corrections later:

1. **Build broader dikes** for greater resistance when a section could be subjected to strong water pressure.

2. **Firmly compact the peat** once it has been pushed into a mound, to make it watertight and more resistant to wind and water erosion. Dikes can be compacted by driving over the top with a tractor. The tractor's repeated trips over the field when spreading the plant material and mulch can be used as an opportunity to compact the dikes.
3. It is important to **remove any wood, branches or other debris** from the peat as they can weaken the dike and cause leaks.
4. **Clean the soil surface before building the dike** to ensure better contact between the dike and the ground surface. This will reduce the risk of water infiltration and leaks. Also, all vegetation must be removed from where the dike will be erected. Scraping the surface will remove the vegetation while ensuring good contact.
5. When building peripheral dikes and dikes perpendicular to the slope, **avoid 90-degree angles** as they will weaken the dike. Rounded dikes are preferable.
6. Dike breach is a rather common problem because peat can erode easily, even when compacted. **Installing devices to remove excess water** helps prevent dike erosion. Many commercial water evacuation systems exist. The simplest involves installing a pipe that crosses the dike and evacuates water out the other side. The height of the intake can either be fixed or adjustable. The outlet should include a protective structure (e.g., a bed of large stones or logs) to dissipate the water's energy and prevent erosion.
7. When there is a marked difference in elevation, it is important to **push the peat upslope** when building dikes rather than down the slope. Pushing it down will steepen the slope (Figure 4) while pushing it up will help create flat terraces.

Recommendations 1, 3, 5 and 6 do not apply to checkerboard-pattern dikes because they are not subjected to as much pressure as peripheral dikes and dikes perpendicular to the slope given the number of cells and dikes created.

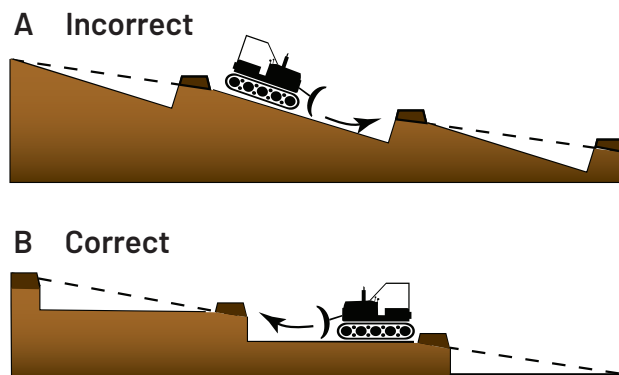


Figure 4. Illustration showing the topography obtained when dikes are built by pushing the peat down the slope (A) and up the slope (B). Pushing the peat up creates terraces, while pushing it down makes the slope steeper.

Re-establishing Connectivity between the Restored Peatland and the Adjacent Environment

The main drainage ditches on a site's periphery affect the adjacent natural environments by lowering the water table. Even after the peripheral ditches are filled, their effect can still extend up to 25 metres into the adjacent natural peatland. These adjacent areas are frequently peatland sectors whose peat is not thick enough or does not have the properties required for horticultural use. They can also be transition areas between the peatland and other surrounding environments.

A lower water table fosters and accelerates the growth of trees and vascular plants. The trees take advantage of the drier conditions to establish and, in turn, lower the water table through evapotranspiration. This cycle leads to forest densification. This effect of drainage is especially pronounced in the first eight metres adjacent to the peatland.

Peat extraction also causes a change in, and even a reversal of, the slope profile between the natural peatland and the one to be restored. As the peat is extracted, the peatland's originally dome-shaped surface is lowered to the point of creating a difference in elevation of up to several metres between the two (Figure 5).

Building and maintaining the drainage network around the peatland also changes the surrounding environment when the excavated material (organic and mineral matter from the bottom of the ditches) is placed at the edge of the adjacent environment. In some places, they form large terraces of compacted substrate that are used to allow machinery to move around the peatland. Similarly, mounds of debris, such as branches and roots from harrowing and cleaning the fields in operation, can also create embankments around the peatland. These can form the ideal environment for undesirable species (often ruderal or invasive) and, inversely, create a barrier keeping diaspores of typical peatland species from reaching the site to be restored.



Figure 5. Significant difference in elevation between the restored sector and the adjacent environment at Moss Spur 2 in Manitoba.

Given all these factors, the peatland in restoration and the adjacent natural ecosystem show different conditions once peat extraction has been completed. During the restoration process, reducing forest density, removing the embankment and restructuring the slope help restore the site closer to its initial conditions and re-establish the connection between the two environments.

Reducing Forest Density

Reducing forest density by tree cutting should be done immediately after ceasing peat extraction activities, to reduce the trees' negative impacts on the hydrology as soon as possible. In practice, all trees within eight metres of the peripheral drainage ditch should be cut. Prompt cutting also makes it possible to clear the land for the subsequent activities that need to be carried out to re-establish connectivity and restore the site.

Coniferous trees can be cut according to the usual forestry practices, but special care must be taken with birch and poplar trees, which establish quickly along drained peatland. Birches tend to grow many stump shoots when cut near the ground. To physiologically weaken the tree, the recommendation is to cut them down in full summer, before cold hardening (accumulation of reserves for winter) begins and to do so at a height of one metre.

Another strategy to reduce forest density is to pull the trees out with an excavator. This makes it possible to select exactly which undesirable trees to remove, even beyond the eight-metre strip. Since the trees are often uprooted, the risk of stump sprouting is minimal. This operation can be carried out while restructuring the slope at the junction between the peatland to be restored and the adjacent environment.

TREE CUTTING

Tree cutting contributes to rewetting because trees play a role in drying out the area by evaporating large amounts of water. Tree cutting can be done in the following locations:

- Sites that have been closed for a long time.
- Natural peatland areas adjacent to restoration sites, where drainage has fostered tree growth.
- Former block-cut sites.
- Restored areas where trees are competing with the *Sphagnum*.

Removing the Embankment

Mounds of material on the periphery of the extraction site keep diaspores from the natural environment from reaching the peatland and are conducive to the establishment of invasive or undesirable species. This material can be completely removed down to the underlying organic soil and used to fill the peripheral drainage ditches, topped with a layer of at least 40 centimetres of peat.

Restructuring the Slope

In order to re-establish ecological and hydrological connectivity, it is recommended that a gradual transition be recreated between the site to be restored and the undisturbed adjacent environment. This operation has two objectives: to fill the peripheral drainage ditch and to create a gentle, regular slope.

Peripheral ditches need to be completely filled, unlike secondary drainage ditches between former peat extraction fields, which can simply be blocked. The most efficient way to fill these ditches is to use the material from the embankment and from digging the ditch, being sure to place the mineral material (if present) at the bottom of the ditch and the peat on top, as the final layer (Figure 6).

There are a few rules to follow to create a gentle, regular slope. The slope should extend at minimum over the entire previously cleared eight-metre strip and should be as gentle as possible. Here too, it is important to respect the rule of building one dike perpendicular to the slope for every 30-centimetre change in elevation. To be sure to create a gradual, regular slope, any big pieces of wood must be removed from the peat when working the surface. For this reason, it is preferable to avoid carrying out this step during winter, as a thick snow cover and frozen pieces of peat will make it difficult to build a regular slope.

When the slope is very gentle, it can undergo the same restoration operations as the rest of the peatland (introduction of plant fragments, mulch, fertilizer, etc.). When the slope is steeper and the top is likely to stay drier, seeding or adding mulch can help stabilize the surface.

Restructuring the slope therefore makes it possible to extend the restored area all the way to the edge of the adjacent environment rather than being limited strictly to the surface occupied by the extraction fields.



Figure 6. Removing the embankment and filling the ditch at Elma in Manitoba.

Situations to Avoid and Problems Encountered during Site Preparation

- **Rapid rise in water level:** Site preparation involves reconfiguring the site (refreshing the surfaces, levelling, etc.) rather than restoring the peatlands' typical hydrological conditions. However, since some of the operations carried out during this step will inevitably lead to at least partial blocking of the drainage ditches and partial rewetting, it is important to make sure that the next restoration steps be accomplished as soon as possible. Otherwise, this partial rewetting could make machinery circulation difficult and compromise the subsequent restoration steps. When dike building requires that the drainage ditches be blocked, short sections can be left open and only be blocked at the very end of the work to avoid saturating the soil, which can cause the machinery to get stuck.
- **Flooding:** The ideal conditions for *Sphagnum*'s establishment is a water level right below the soil's surface (0 to 10 cm). North America's climate is characterized by long winters during which precipitation falls in the form of snow and accumulates on the ground. All this snow usually melts within a short period of time, releasing large quantities of water that can flood the sites. While research shows that short-term flooding will not kill *Sphagnum*, prolonged (> 1 month) or more severe flooding (> 20 cm of water above the surface) has negative effects. *Sphagnum* that is completely submerged can no longer access the carbon dioxide (CO₂) it needs for photosynthesis, which affects its growth. Also, flooding can displace the plant fragments and mulch causing them to float away during the establishment phase. The action of waves over large surfaces and meltwater runoff can cause the dikes to erode and fail. These problems are temporary, however. Once well established, the new vegetation carpets are resistant to the excess water's effects.
- It is very difficult to remodel peat fields or build dikes in the spring because **peat stays frozen a long time** and gets waterlogged when it thaws. It is therefore preferable to wait until summer or fall to prepare the site.
- It is important to **never expose the mineral substrate**, no matter which operation is being carried out. Doing so enriches the surface peat with nutrients and favours the establishment of undesirable species. The best way to avoid this is to leave a sufficiently thick layer of peat in place after extraction to preserve the acidic nature of the peat substrate to be restored (pH < 5.5–5.8).
- Carrying out the work when the soil is saturated with water will lead to an irregular microtopography. Carrying out the work creating an irregular microtopography does not improve the establishment of *Sphagnum* and other mosses. A **flat topography** is preferable.
- Dikes are subject to breaches, notably due to erosion caused by runoff. **Good compaction** of the peat and the installation of an **excess water evacuation system** can prevent this type of problem.

Synthesis of the Site Preparation Options

OPERATION	APPLICATION CONDITIONS	ADVANTAGES
<i>Refreshing the surface of the site</i>	<ul style="list-style-type: none"> • All sites 	<ul style="list-style-type: none"> • Removes the loose peat, biological crust and vegetation to facilitate contact between the plant fragments and the substrate
<i>Removing the vegetation</i>	<ul style="list-style-type: none"> • All sites, especially sectors invaded by trees and undesirable species (e.g., birch trees) 	<ul style="list-style-type: none"> • Facilitates contact between the plant fragments and the substrate • Prevents undesirable species from establishing • Reduces evapotranspiration when trees are present
<i>Keeping the vegetation in place</i>	<ul style="list-style-type: none"> • Very wet, restricted areas colonized by typical peatland species 	<ul style="list-style-type: none"> • Preserves the established vegetation • Prevents the machinery from getting stuck
<i>Reprofiling the peat fields</i>	<ul style="list-style-type: none"> • All fields with a convex profile (dome-shaped) • Sites with an irregular topography 	<ul style="list-style-type: none"> • Favours better water distribution • Flattens the surface
<i>Filling the secondary drainage ditches</i>	<ul style="list-style-type: none"> • Short fields • All sites, as desired 	<ul style="list-style-type: none"> • Facilitates the circulation of machinery • Makes it possible to dispose of the peat resulting from the surface preparation
<i>Filling the peripheral drainage ditches</i>	<ul style="list-style-type: none"> • All sites where it will not affect the sectors in operation 	<ul style="list-style-type: none"> • Improves the hydrological conditions • Contributes to the eco-hydrological connectivity with the adjacent environment

<i>Building peripheral dikes</i>	<ul style="list-style-type: none"> • Sectors in which the primary ditch cannot be blocked • Sectors in which the adjacent environment is lower or still in operation 	<ul style="list-style-type: none"> • Keeps the water within the site
<i>Building dikes perpendicular to the slope</i>	<ul style="list-style-type: none"> • Every time there is a 30 cm difference in elevation • Long fields (> 100 m) • Sites with a risk of the material or mulch being moved by the wind or water 	<ul style="list-style-type: none"> • Favours better water retention and distribution • Prevents flooding of large surface areas • Acts as wind breaks
<i>Building checkerboard-pattern dikes</i>	<ul style="list-style-type: none"> • Sites with complex slopes • Vast or flat sites • Sites with a risk of the material or mulch being moved by the wind or water 	<ul style="list-style-type: none"> • Favours better water retention and distribution • Prevents flooding of large surface areas and the impact of waves • Acts as wind breaks
<i>Reducing the tree density</i>	<ul style="list-style-type: none"> • Sites with a dense forest border 	<ul style="list-style-type: none"> • Reduces evapotranspiration and the interception of surface runoff • Clears the border and facilitates restructuring
<i>Removing the embankment</i>	<ul style="list-style-type: none"> • Sites with a mound of plant debris, mineral material and peat separating the sector being restored from the adjacent environment 	<ul style="list-style-type: none"> • Facilitates water and diaspores circulation between the two environments • Permits a more natural transition
<i>Restructuring the slope at the edge of the restoration site</i>	<ul style="list-style-type: none"> • Sites with a large difference in elevation between the restoration sector and the adjacent area 	<ul style="list-style-type: none"> • Facilitates water and diaspores circulation between the two environments • Permits a more natural transition

DRAINAGE DITCH BLOCKING

There are three types of ditches: **secondary ditches**, which run alongside and separate the extraction fields before spilling into the **primary ditches**, which carry the drainage water into the **peripheral ditches**, which divert all the drainage water out of the peatland.

This section focuses specifically on blocking secondary ditches and primary ditches, which constitute the basis of the peatland drainage network used for peat extraction. This section summarizes the blocking methods presented in detail in the PERG technical guide published in 2011.⁷

Blocking drainage ditches:

- reduces water loss by up to 85%;
- raises the water table closer to the surface and reduces water level fluctuations, which fosters the establishment of peatland plants, including *Sphagnum*, while limiting trees and non-peatland species establishment and growth; and
- increases biological diversity in the restored site by creating diverse habitats.

Building Dams

Secondary Ditches

Peat dams are typically used to block secondary ditches with only a slight slope and low water pressure. Blocking ditches may appear quite simple, but there are certain rules to follow to construct effective, long-lasting dams (Figure 7).

- **Clean the ditch bottom and sides.** Fresh wet surfaces provide a better contact surface for the blocking material and better watertightness. Cleaning removes any vegetation and wood debris that would enable water to flow below the dam and cause erosion.
- **Compact the dam after every addition of peat.** Dams are solidier and more effective when peat is compacted every time it is added. A temporary dam can be installed upstream to dry the area, which improves compaction.
- **Dams must be two to five metres long** to limit erosion and enable machinery to pass.
- **Dams must be approximately 50 centimetres higher than the field surface and extend two to five metres on each side.** This allows extra water to disperse on the surfaces in case of overflow rather than pooling and forming a channel that could erode the dam.

⁷ Landry, J. and L. Rochefort. 2011, op. cit.

- **Use wet, decomposed peat.** Simply filling a ditch with surface peat and then compacting it can cause leaks or dam failure. Dig upstream from the dam site to reach the decomposed peat that is located deeper. Peat from digging and cleaning the ditch can be used to fill in the hole from which the wet peat was removed. The hole can also be left unfilled to create a small pool habitat. In this case, it should have a gentle slope so animals that venture into the pool can get out easily.
- **Do not dig into the mineral substrate** during ditch work, as this can cause water loss if the waterproof barrier is pierced and result in an influx of nutrients and colonization by undesirable species.

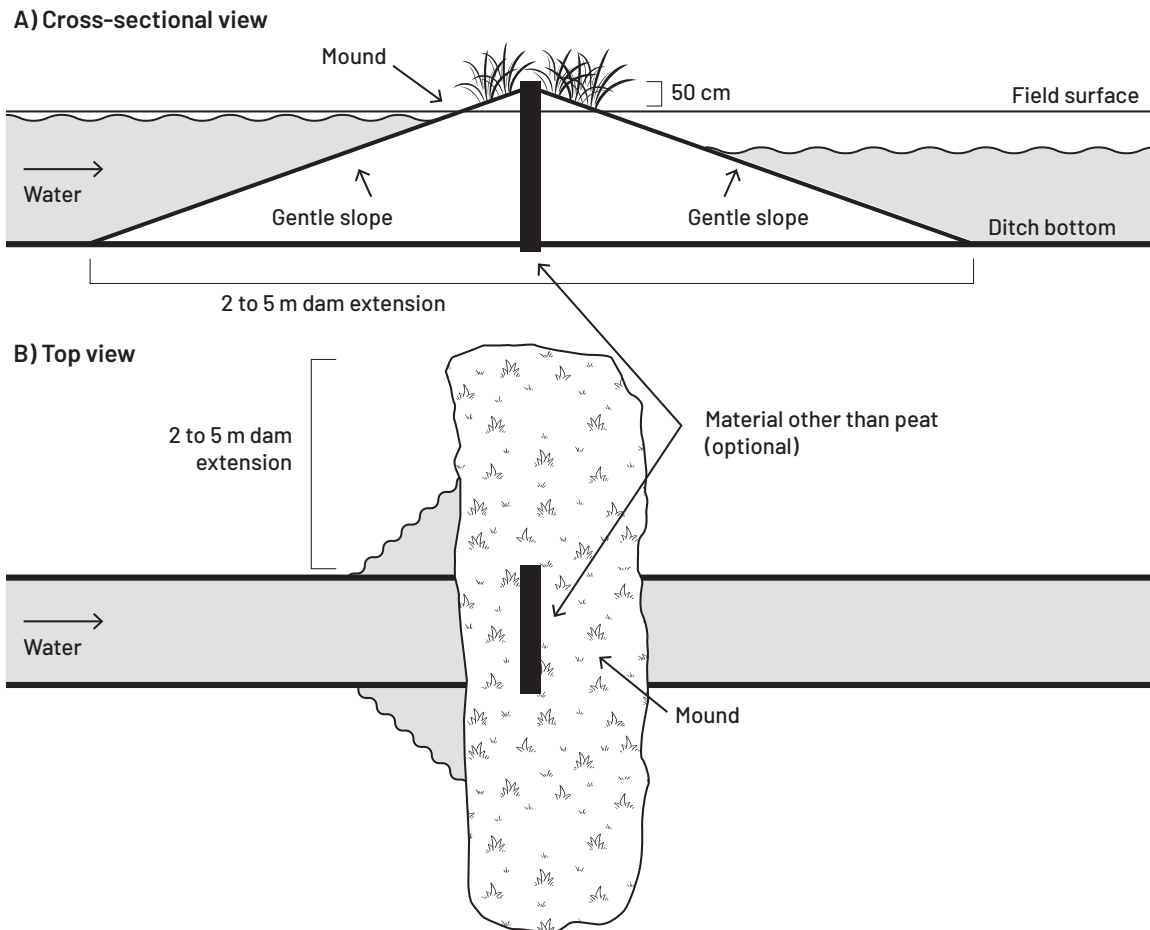


Figure 7. Illustration of a dam in a secondary drainage ditch, in cross-section (A) and from the top (B).

If the slope is too steep or there will likely be high water pressure against the dam, for instance against the last dam downstream a drainage ditch, the dams can be constructed from other materials as is done in primary ditches (see below). In general, however, this is not necessary in secondary ditches.

In most cases, several dams are needed in a secondary ditch to ensure adequate rewetting. The number of dams depends on the slope of the terrain: the greater the difference in elevation between the ends of the ditch, the more dams are needed. The spacing between the dams follows the same logic as for those that are perpendicular to the slope. Spacing should be determined so that the difference in elevation between one dam and the next does not exceed 30 centimetres. Dams could be combined with dikes perpendicular to the slope.

A backhoe is the best type of equipment for dam construction because it can effectively clean the sides and bottom of ditches, especially when overgrown with vegetation (Figure 8). Since the equipment is stationary, it doesn't damage large areas in cases ditches are blocked after placing the plants and mulch. In comparison, a tractor with a front loader pushes the surface peat into the ditch using a back and forth movement, which damages a large area around the dam.

For all sites, it is best to begin working in the higher sections, because blocking the dams in upper areas will create better (dry) working conditions when putting in the lower dams.



Figure 8. Blocking a secondary drainage ditch with peat, at the South Julius peatland in Manitoba.



Figure 9. Blocking a peripheral drainage ditch using a wooden dam covered with geotextile on the upstream side and peat, at the Bic-Saint-Fabien peatland in Québec.

Primary Ditches

Primary ditches collect water running out of the secondary ditches and direct it to the peripheral ditches, which discharge the drainage water out of the peatland. Primary ditches experience greater water pressure and are larger than the secondary ditches. Like the latter, the dams must be about 50 centimetres higher than the field surface and extend out two to five metres on either side. Such measures allow any excess water due to overflow to disperse over the nearby surfaces, rather than gathering and forming a pool, which could erode the dam.

Materials other than peat may be used to increase resistance to erosion. Such materials include wood panels, boards or logs; straw bales; or panels made of other materials (Figure 9). These components must be buried into the soil deeper than the bottom of the ditch and into both sides of the ditch to ensure the dam is strong and watertight. Adding a geotextile or a membrane on the upstream side of the dam will also improve watertightness and resistance to erosion.

As with secondary ditches, the bottom and sides must be cleaned of wood debris and vegetation. In all cases, we recommend creating a gentle slope both upstream and downstream of the dam to mitigate water pressure.

We advise placing the removed clumps of vegetation onto nearby surfaces (Figure 7) to help the dam stabilize faster. To build these dams and larger ones, as needed in peripheral ditches, refer to the PERG guide titled *The Drainage of Peatlands: Impacts and Rewetting Techniques*, which explains in detail when and how to construct them.

Filling Ditches

Ditches are often filled when restoring peatlands, and the advantages and disadvantages of this technique are discussed at the beginning of this booklet. Ditches can be filled when the residual peat is thick enough. A grader or other piece of machinery is used to move the peat and fill the ditch. This technique requires handling much larger amounts of peat and thus involves more work than simply blocking a ditch. On the other hand, filling ditches is a good strategy for using the peat removed during surface preparation. Peat used as fill must be compacted to allow passage of the machinery over former filled ditches during the subsequent work. We recommend adding enough peat to create a mound, after compacting, to compensate for the settling that will occur over time.

Filling ditches is not a replacement for blocking ditches; rather, it is used to fill segments between two dams. It is important to:

- begin with the upstream section.
- compact the peat in the ditches; and
- create a mound approximately 30 centimetres above the field surface to accommodate subsequent settling.

When to Block Drainage

Blocking drainage ditches will inevitably raise the water table and reduce ground support, which could restrict the ability of machinery to move around during other phases of restoration. Even without blocking drainage, some interventions during the site preparation stage will certainly block the drainage ditches, at least partly, causing the water level to rise. As such, it is important to accomplish the post-restoration steps within a short period of time and to **do the final ditch blocking at the right time, generally after all the other work is completed.**

Develop a work schedule informed by staff experience, information about the site and the assessment of rewetting potential conducted during the planning stage. A schedule will ensure that the work is done under the best conditions possible. For example, planning should take into account that an adjacent natural site will likely be a significant source of water.

RESOURCES, TIME AND COSTS

The time needed to **prepare the site** varies considerably, due to the diversity of specific conditions. Preparing fields that have been closed to production for a short period will require less time and effort in terms of refreshing surfaces. Fields that have been closed for a longer time and have loose peat, a biological crust or dense surface vegetation require more planning and resources. The average time needed to prepare a site is calculated at approximately four hours per hectare. A grader is the most suitable and popular type of machinery for surface preparation. It can level off convex fields, move and refresh surface peat, fill ditches and build dikes. It is also best for creating flat, even peat surfaces. A front loader or a bulldozer can be used to fill ditches and build dikes, but their back-and-forth motion can damage wide areas unless they are used on frozen or dry surfaces.

Blocking drainage ditches, however, does not take much time or resources. We estimate that it would take a single operator using the right equipment, for example a backhoe, one hour per hectare to block ditches. If we take into consideration the approximate size of a field (30 m x 330 m), it would take one hour to block several locations in a secondary ditch alongside a field. Sites with a flat surface require fewer blockages than those with a slope, especially knowing that the ideal placement of dams is at each 30-centimetre elevation difference.

SUMMARY

- Refresh and reprofile field surfaces to create a clean, even, regular surface.
- Ensure an even water distribution across the site by building dikes in strategic locations.
- Broader dikes are more resistant to erosion but their height can be limited to 30 centimetres once compacted.
- Restore the ecohydrological connection between the restored site and the adjacent areas by reducing forest density, removing the embankment, restructuring the slope and filling the peripheral drainage ditch.
- Retain as much water as possible on the restoration site, aiming to raise the water table as close as possible to the surface without creating flooded areas.
- Prevent flooding of large areas for long periods (more than one month).
- Clean the sides and bottom of ditches before blocking.
- Block ditches with wet peat over a length of two to five metres, compacting after every addition.
- Build dams 50 centimetres above the peatland surface and with extensions on either side of the ditch, so water can disperse across the surrounding surfaces in case of overflow.
- Never dig down to or expose the mineral substrate.
- Secondary ditches can be filled with surface peat but must still be blocked at regular intervals.



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