IUCN UK Committee Peatland Programme
*Briefing Note N^{o}**3***

Impacts of Artificial Drainage on Peatlands

Problem

Wider impacts of drains are poorly recognised

Two **common misconceptions are associated with artificial drainage of peat bogs**. The first is that drainage impacts are largely confined to drain margins. In fact they can impact across a much wider area – in some cases, across the whole bog. The second **misconception is that the bog water table should be the main focus of attention** when studying the effect of drainage. Although it is important to measure the water table, the **value of such data is much reduced if surface subsidence is not also measured**. In the long term, surface subsidence rather than the water table is likely to show the greater drainage effect.

Impacts of Drainage

A peat bog is a wetland in which the peat soil is likely to have a **moisture content of greater than 95%** in the undisturbed state – "there are more solids in milk than in peat". Bog surfaces also often have areas of standing surface water. This water-logging is what creates a peatland and allows it to function. Consequently drainage is generally regarded as the first essential activity when attempting to develop the peatland in some way and is thus one of the most widespread forms of human impact on peat bog ecosystems. The effect of such drainage is often disappointing because the anticipated drying effects often appear extremely limited in their extent. Peat just a metre or so from a drain will often still contain more than 80% moisture content by weight. The main effect of peatland drainage is thus frequently described as merely "*more rapid removal of surface water*" rather than deep water-table draw-down.

Main impact of drainage is the re-shaping of the bog system

In fact the main long-term effect of drainage is to re-shape the bog itself, with major implications for water, carbon and biodiversity, yet this re-shaping is rarely recorded or monitored.

Two-layered system, only one layer freely-draining

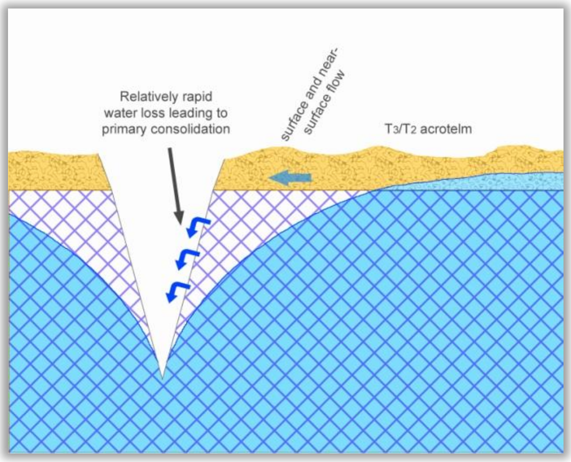
Understandably, **much research into peat bog drainage has focused on the behaviour of the water table**. This is because drainage is largely undertaken to lower the water table and thereby provide a deeper zone of aerated soil for exploitation. However, achieving this in a bog is much more difficult than is the case for most mineral soils because a bog has two layers – the **acrotelm** and the **catotelm** (see ***Biodiversity Briefing Note 2***) - and it is only the thin surface acrotelm which can readily be drained.

The acrotelm layer of a bog offers relatively low resistance to vertical and, more importantly, lateral water movement. Consequently **drainage tends to empty the acrotelm of water fairly readily, sometimes over considerable distances (potentially**

Drainage can affect the acrotelm over hundreds of metres

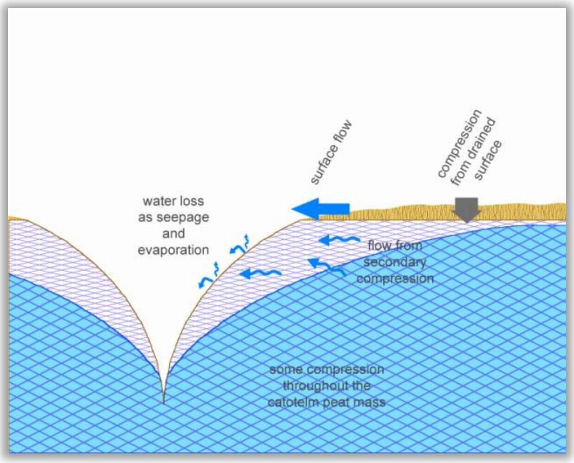
over several hundred metres). With an acrotelm thickness of only 10-20 cm, it is easy to understand, however, why such drainage effects are regarded as 'insignificant' and little more than removal of surface and near-surface water. From the perspective of the bog ecosystem, however, such effects represent a **very significant impact**. Peat-forming conditions exist because the high and relatively stable water table in the acrotelm maintains waterlogged conditions and enables bog species to resist competition from other plant species which are not normally peat forming.

Loss of peat-forming species means loss of peat forming function in the acrotelm



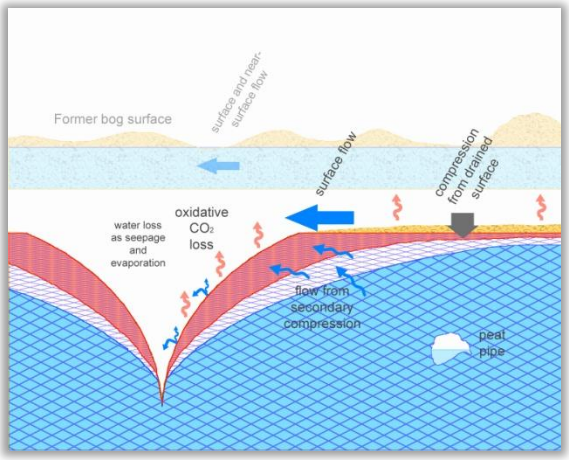
Drying of the acrotelm results in progressive loss of peat-forming conditions and peat-forming species, which means that the acrotelm is no longer capable of providing fresh peat material to the catotelm. Indeed many plant species which typically colonise a dry acrotelm surface **have root systems which further dry out both the acrotelm and the upper layers of the catotelm**, thus enhancing the impact of the drains.

Catotelm resists drying, but responds instead to water loss by collapse and shrinkage



The lower catotelm layer responds to drainage in a completely different way - apparently resisting all attempts to achieve significant water-table draw-down. **Water movement in the catotelm is extremely slow**, up to 1 million times slower than the speed of a snail. It has been estimated that it would probably take **around 90 years for a single raindrop to filter downwards through the 10 m thickness of a raised bog system**. A drain therefore has relatively little *immediate* effect on the water held in the main body of catotelm peat, but *in the immediate vicinity of the drain*, water held in the larger spaces between peat fragments seeps fairly readily into the drain through gravity drainage (visible on the drain walls of the photograph at the start of this Briefing). This water loss results in a draw-down of the water table adjacent to the drain. **This draw-down is often the only *measured* effect of drainage.**

Primary con-solidation is relatively rapid but short-lived



Prior to drainage, water typically occupied as much as 50% of the catotelm peat volume and loss of this water therefore **results in collapse and shrinkage of the peat adjacent to the drain. This process is called *primary consolidation***. Its effects are felt immediately but may continue for some years. The key impact of this primary consolidation is that the drain, in effect, becomes wider because the ground immediately adjacent to the drain subsides.

Secondary compression

This subsided, drained acrotelm and catotelm peat still has significant mass because somewhat more than 40% of its volume consists of water held in large storage spaces within the preserved plant fragments, most notably within leaves of *Sphagnum* bog moss. Consequently once the ‘free’ (or interstitial) water has been lost from the peat, the somewhat drier catotelm peat adjacent to the drain itself becomes a heavy load on the peat beneath because the drained layer no longer floats buoyantly within the bog water table. This load **compresses the peat beneath it and squeezes more water from the peat into the drain, causing the bog surface to subside still further.** Perhaps surprisingly, this downward pressure even forces water upwards into the drain from peat below – with the result that the *entire* depth of catotelm peat experiences some degree of subsidence. The effect is most marked in surface layers but can still be detected even at the base of the catotelm. This type of subsidence is called ***secondary compression***. Secondary compression acts across a steadily widening area beyond the drain, demonstrably over several hundred metres in some cases, and continues as long as drainage is present.

Oxidative wastage

The third catotelm process associated with drainage occurs because drainage allows oxygen to penetrate the catotelm. Under natural conditions the catotelm peat remains permanently waterlogged preventing oxygen-fuelled decomposition – and thus peat material is preserved for millennia. Once oxygen penetrates the catotelm peat store, relatively rapid decomposition can take place. Preserved plant material is thus lost in the form of carbon dioxide gas (CO_2), leading to further subsidence as the peat material itself vanishes into the atmosphere. This process is called **oxidative wastage**.

Secondary com-pression and oxidative wastage are long-term impacts

Unlike primary consolidation, the effects of secondary compression and oxidative wastage continue as long as there is a load caused by drainage and catotelm peat is exposed to the air. For certain locations such as the Holme Fen Post in Cambridgeshire (also Clara Bog’s ‘famine road’ in Ireland and the Donaumoospegel in Bavaria) the effect has been well documented over periods of more than 150 years. Nor is the effect restricted to deep lowland raised bogs; significant subsidence has also been recorded in drained blanket bog. The **three drainage processes – primary consolidation, secondary compression and oxidative wastage** – cause the peat to subside progressively and continuously across an ever-expanding area. Drainage in effect continually widens the dimensions and impact of the drain *even though measurements only a few metres from the drain may still indicate that the water table is close to the bog surface*. Apart from the 2-5 metres immediately adjacent to the drain, the water table *cannot normally be drawn down more than a few centimetres into the catotelm by drainage*.

Limited water-table draw-down does not mean limited drainage effects

The few centimetres of drained catotelm peat will, however, in due course be lost through oxidative wastage in a constant process of drying, subsidence and loss, and so the *entire* peat mass of an area subject to a regular pattern of drains will experience subsidence. In the case of a lowland raised bog (see ***Definitions Briefing Note 1***) large-scale changes to the shape of the bog (the *mesotope* – see ***Definitions Briefing Note 1***) can often be attributed to individual drains which have been continually maintained, while drainage of the lagg fen surrounding the bog - often resulting in a truncated margin to the dome - will bring about long-term subsidence across the entire raised bog dome.

The wetter the peatland the greater the initial response through primary consolidation, but all peatlands exhibit similar long-term effects. Drained areas which appear to support vegetation unaffected by the drainage should be checked for evidence of past vegetation in the recent peat archive. **Areas of deep peat with dense heather and areas rich in lichens or non-*Sphagnum* mosses are often indicators of vegetation change due to drainage**.

Shrinkage causes sub-surface pipe formation

Shrinkage of the peat mass also causes it to deform in other ways. Like mud or clay when they dry, cracks may develop in the peat, particularly along the base of drains or parallel to the drains, and there is evidence to suggest that formation of sub-surface 'peat pipes' is more frequent in drained or drying peat.

If trees then colonise the drained peat, their roots will suck water from the peat and the canopy will prevent rainfall reaching the bog surface, while the weight of the trees further compresses the peat. This combination of effects results in even more dramatic rates of subsidence, even though adjacent areas of open bog may still appear to have high water tables (because these adjacent areas will also be sinking).

Impacts on carbon balance

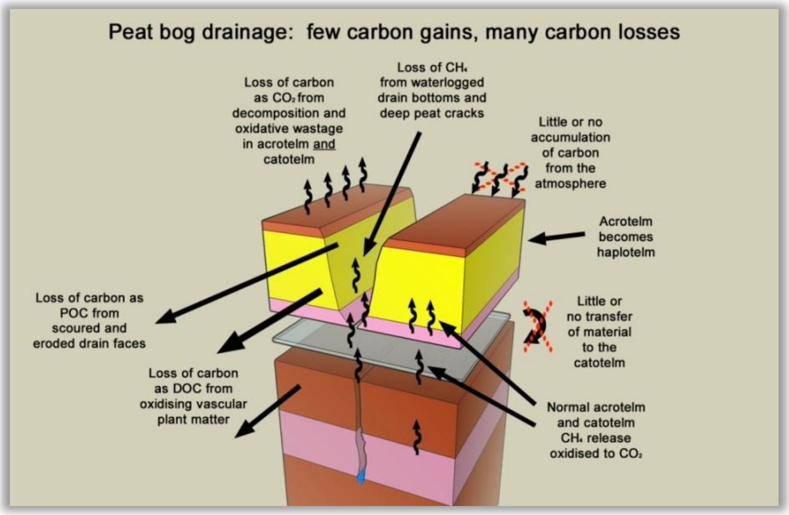
Quantifying the effect of drainage on the carbon balance of a bog is a challenging task because there are several potential pathways of loss. There is also the need to balance methane emissions against carbon dioxide emissions, the extent of drainage impacts may not be evident, and the changes brought about by drainage are expressed over a long period of time.

Oxidative loss

POC
DOC

Methane

In terms of carbon loss, carbon dioxide (CO_2) is released as the dried peat oxidises. This is likely to be most intense close to the drains but the effect may be more widespread during extended periods without rain because the acrotelm may already be largely empty, thus permitting the water table to fall into uppermost layers of the catotelm. Particulate organic carbon (POC) is also washed from the face of the drain, while dissolved organic carbon (DOC) is released directly from the drain sides as well as in water squeezed from the peat by secondary compression. Meanwhile, the drier nature of the peat may reduce methane (CH_4) emissions from the bog surface, particularly if bog hollows or pools are lost, but methane may then be emitted from the drain bottoms, particularly if there are cracks in which water becomes ponded. If shrinkage pipes are also formed, this provides another route by which POC and DOC can be lost. In addition, loss of a functioning acrotelm means loss of carbon-sequestering capacity, diminishing or halting the process of peat accumulation.



There are relatively few reliable figures for oxidative losses from peat bog systems, and even fewer for the balance between methane release in natural bogs compared with its release from drained bogs. Losses of POC and DOC which are directly attributable to drainage have also not been well documented, but if high levels of organic matter enters the water treatment process, chlorination can produce the carcinogen trichloromethane (chloroform). Water utility companies therefore invest heavily to reduce the level of organic matter entering the treatment process.

Subsidence of 1-2 cm/yr, with perhaps 0.5 cm being carbon loss

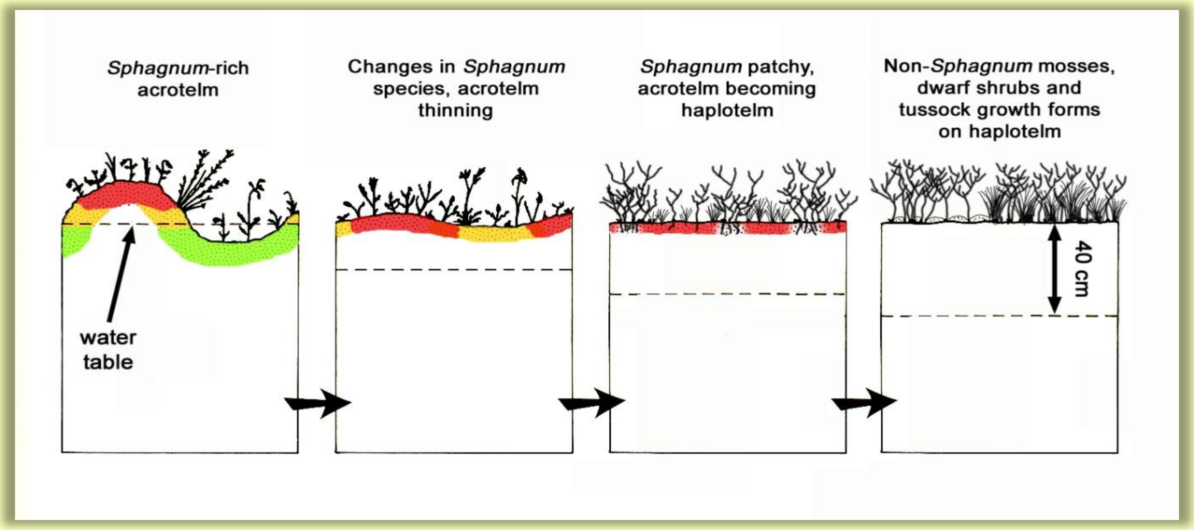
Long-term figures for overall subsidence indicate that, after the initial rapid effects of primary consolidation, long-term subsidence of bog peat is typically around 1-2 cm per year, and measurements of CO_2 emissions suggest that up to 0.5 cm per year of this may be due to oxidative loss. POC losses tend to be greatest when the drains are first dug, but also during periods of heavy rain. Meanwhile DOC release appears to be most intense during heavy rain following a dry period.

Impacts on micro-topography and bog vegetation

Returning to the question of the acrotelm and the apparent high water tables close to drainage, the bog vegetation may *appear* to be largely unaffected by these major changes to the catotelm and gross morphology of the peat, but careful inspection will often reveal that this is not the case.

The vegetation patterns found within the microtopography of a bog (see ***Biodiversity Briefing Note 2***) are adapted to the very stable water table typical of an undamaged bog. Each small-scale vegetation assemblage typically occupies a particular zone above or below the water table. **Such zones are often no more than 10-20 cm in vertical range.**

If the average water table falls by 15 cm, this may represent the entire zonal range for certain vegetation assemblages. Consequently these assemblages may take up new positions within the microtopography, or they may disappear entirely.



A bog surface which before drainage had a **characteristic surface pattern of low ridges and hollows would thus, after drainage, tend to show a shift towards a surface pattern largely dominated by high ridge**. The vegetation may still be rich in peat-forming species, but the *ecosystem diversity* of the bog has changed and diminished. Evidence for such change can often be found by digging into an area which no longer supports peat-forming species. The underlying peat will often have abundant *Sphagnum* remains even though the present surface vegetation contains no *Sphagnum*. Ultimately, if there is continued maintenance of the drainage system, the peat-forming species are likely to be overwhelmed and completely displaced by species of drier habitats such as heather and non-*Sphagnum* mosses.

Reversing Drainage Effects

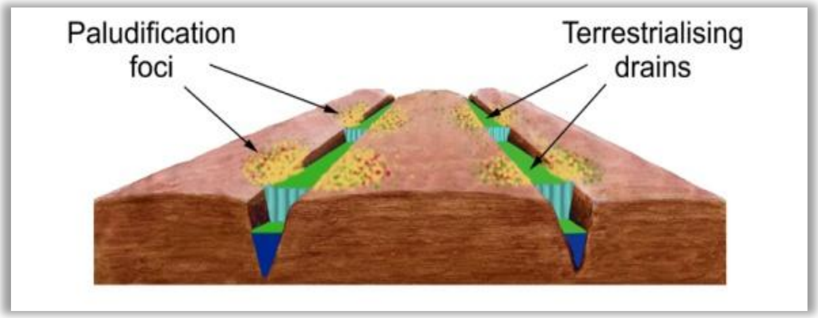
If drains are **not maintained**, they usually begin to choke up with slumped peat and pockets of vegetation, but can be actively blocked through **conservation management to speed up this process**. This ultimately allows **the bog vegetation to re-establish**. Aquatic species infilling the drains (through ***terrestrialisation*** of the open ponded water)

Drain blocking helps re-establish bog vegetation

will contribute relatively little in terms of long-term peat formation because aquatic *Sphagnum* species are poor peat formers. Their **key role is to help stabilise and establish a high water table again across the adjacent bog surface. This wetter bog surface will then be capable of supporting more vigorous peat-forming species through *paludification*.** In the long term, although little can be done about the subsidence which has already occurred, such re-invigorated bog vegetation is capable of laying down fresh peat and ultimately restoring the original shape of the bog, albeit over a long timescale.

Terrestrialis-ation

Palu-dification



Other benefits of re-wetting

The re-establishment of a high, stable water table leads to active bog vegetation and a functioning ecosystem complete with all the associated ecosystem services, including, generally, attenuation of flood peaks, a reduction in POC and DOC release into catchment waters, reduced water-treatment costs and lowered threat of trihalomethane production.

Areas impacted by drainage at risk of being missed

Areas potentially subject to drainage impacts but often not realised to be as such:

- entire lowland raised bog mesotopes where the surrounding lagg fen has been drained;
- areas close to, or distant from, areas of drainage but which still support an 'active' bog vegetation;
- eroded bog where the erosion drainage pattern leads to the head of a drain.

Gaps in Knowledge

Identified gaps are:

- Subsidence is rarely measured when peat bogs are drained. Consequently there are relatively few records, given the extent of drainage, for the scale of subsidence and scale of carbon loss through oxidative wastage.
- The extent of the hydrological footprint of a drain is poorly documented in terms of its impact on both the acrotelm vegetation and the morphological, hydrological and chemical impacts on the catotelm peat.
- Given that the majority of GHG studies undertaken on UK bogs have used degraded sites, there is still a need for data describing the short-term and long-term relationships between drainage and GHG exchange in natural and drained sites and sites undergoing restoration management in differing parts of the UK.
- Given that the majority of hydrological studies undertaken on UK bogs have used degraded sites, the relationship between natural peatland water storage, drainage

and flood-water discharge is not yet well understood. Of particular interest are questions of 'surface roughness' and peat-forming vegetation compared with drainage-induced vegetation which is not peat-forming, and also in terms of the active storage capacity of the natural acrotelm and catotelm.

- In blanket mires, loss of particulate matter and dissolved organic carbon from drained areas also remains relatively poorly documented. Consequently the relationship between drainage in the catchment and levels of trihalomethane production within peat-dominated catchments used for public water supplies merits appropriate examination and monitoring.

Practical Actions

Practical actions:

- Careful long-term measurement of peat subsidence across relevant microtope and mesotope areas, linked to measurements of water-table behaviour, wherever there is peatland drainage.
- Encourage the recovery of peat-forming vegetation, particularly of terrestrial *Sphagnum* species through paludification, by the blocking of drainage ditches, and, where appropriate, erosion gullies. Such actions can potentially be assisted and encouraged by the reintroduction of *Sphagnum*.
- Establish national catalogue of near-natural peatbog sites which can be used as reference sites in GHG and hydrological studies.

More Information

Underpinning scientific report:
http://www.rspb.org.uk/Images/Peatbogs_and_carbon_tcm9-255200.pdf (low resolution)
http://www.uel.ac.uk/erg/PeatandCarbonReport.htm (high resolution : downloadable in sections)

IUCN UK Peatland Programme:
http://www.iucn-uk-peatlandprogramme.org/
Natural England Uplands Evidence Review:
http://www.naturalengland.org.uk/ourwork/uplands/uplandsevidencereviewfeature.aspx
Scottish Natural Heritage Report on peat definitions:
http://www.snh.org.uk/pdfs/publications/commissioned_reports/701.pdf
Peatland Action:
http://www.snh.gov.uk/climate-change/what-snh-is-doing/peatland-action/

This briefing note is part of a series aimed at policy makers, practitioners and academics to help explain the ecological processes that underpin peatland function. Understanding the ecology of peatlands is essential when investigating the impacts of human activity on peatlands, interpreting research findings and planning the recovery of damaged peatlands.

These briefs have been produced following a major process of review and comment building on an original document: Lindsay, R. 2010 'Peatbogs and Carbon: a Critical Synthesis' University of East London. published by RSPB, Sandy. http://www.rspb.org.uk/Images/Peatbogs_and_carbon_tcm9-255200.pdf, this report also being available at high resolution and in sections from: http://www.uel.ac.uk/erg/PeatandCarbonReport.htm

The full set of briefs can be downloaded from: www.iucn-uk-peatlandprogramme.org.uk

The International Union for the Conservation of Nature (IUCN) is a global organisation, providing an influential and authoritative voice for nature conservation. The IUCN UK Peatland Programme promotes peatland restoration in the UK and advocates the multiple benefits of peatlands through partnerships, strong science, sound policy and effective practice.

	We are grateful to Scottish Natural Heritage, Natural England, Natural Resources Wales, the Forestry Commission RSPB Scotland and the Peter de Haan Charitable Trust for funding support.
Authors ***Date***	**Richard Lindsay, Richard Birnie, Jack Clough** **Version Date: 5th November 2014**