UNIVERSITY OF LEICESTER
UK Centre for Ecology & Hydrology

POLICY BRIEFING NOTE

Infrastructural and societal impacts of water level management on lowland peatlands in England and Wales

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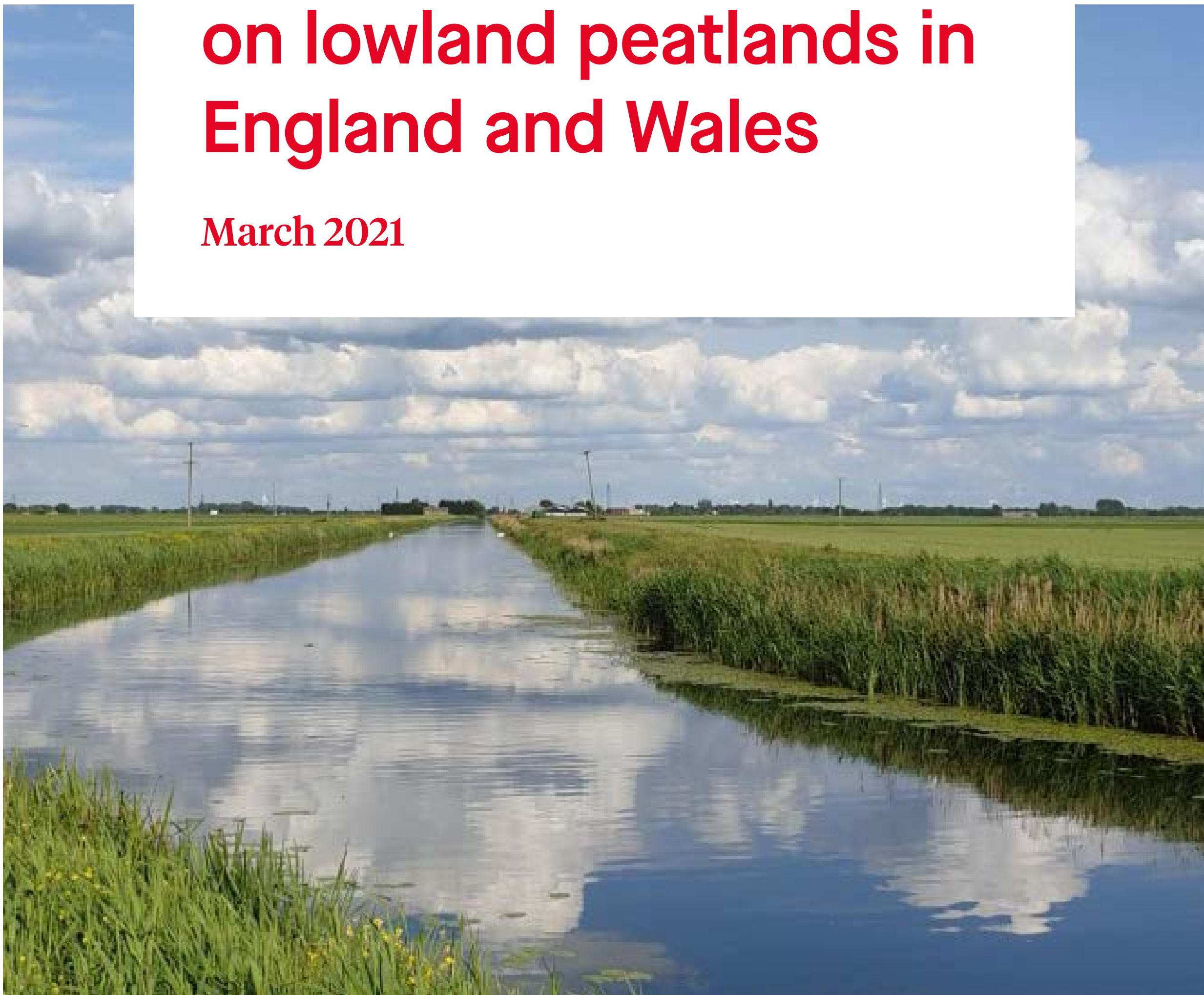

Project Background

This briefing note summarises the findings of a desk-based study undertaken for Defra as part of Project SP1218: Managing agricultural systems on lowland peat for decreased greenhouse gas emissions whilst maintaining agricultural productivity.

We carried out a review of both UK and international literature to assess the benefits and disadvantages arising from historic and current water level management of lowland peatlands in England and Wales. Direct and indirect impacts on hydrology and infrastructure (including transport routes, communication networks and buildings) and societal benefits and costs (agriculture, archaeology, culture, carbon storage and biodiversity) were reviewed to establish the current state of knowledge regarding the extent of these impacts, benefits and costs, their causes and, where appropriate, potential solutions. Key uncertainties and priorities for future assessment were also identified.

Figure 1: The Holme Post at Holme Fen, Cambridgeshire. In 1851, a metal post was driven into the peat so that its top was level with the ground. The top of the post is now 4 m above the land surface. At 3 m below sea level, Holme Fen is the lowest point in Britain. (Photo – S. Page).

Lowland Peatlands

Of the total area of peatland in England and Wales lowland peatlands cover some 44% and 19%, respectively.

They comprise both alkaline/neutral fens and more acidic bogs, with fen peatlands occupying the largest area (2887 km^2 in England; ~200-250 km^2 in Wales).

Only 16% of lowland peats in England still have a depth greater than 40 cm, the threshold that is generally used to define a peat soil. The remaining peat area, a good proportion of which is in the Fens of eastern England, has become 'wasted' (where the peat depth has been reduced through a combination of biological decomposition and wind erosion such that the remaining peat layer is thin and intermixed with the underlying mineral material).

Lowland peatlands, particularly in England, have been subject to a high degree of land-use pressure. Extensive areas of fen peatland have been drained for agriculture, giving rise to some of the most productive farmland in the UK, centred on the Fens. Other large areas of fen peatland, for example in the Somerset Levels and the Norfolk Broads, have also been modified, to varying degrees, by drainage for grazing and other land uses, whilst formerly extensive raised bogs, including the Manchester Mosses and the Humberhead Peatlands have been impacted by agriculture, peat extraction and associated drainage

Figure 2: The Twenty Foot River (Drain) near Whittlesey was constructed in the mid-17th century. Water is pumped 'up hill' into rivers from the lower drains to protect agricultural land and settlements from flooding.
(Photo - S. Page)

What is peat?

Peat is an organic material that contains very little solid matter and, when saturated, is around 90% water by volume.

When saturated peat soils are drained, e.g. to permit agricultural use, a series of events are set in motion, namely peat shrinkage and the oxidation (decomposition) of previously water-saturated organic material under aerobic conditions. These processes result in carbon emissions to the atmosphere, a reduction in peat volume, and lowering (subsidence) of the land surface. Other processes can also contribute to peat loss and subsidence, including wind erosion, peat off-take during crop harvest, peat extraction, and burning. Contemporary rates of subsidence for remaining areas of deep peat under drained arable agriculture in the UK are typically in the range 1 – 2 cm yr^{-1}. At Holme Fen in Cambridgeshire, 128 years of drainage and reduced peat volume have resulted in a subsidence of around 4 m (Figure 1). Wind erosion makes a smaller contribution to peat loss and subsidence, with estimated losses from agricultural land in the Fens translating into a peat surface lowering of 0.03 to 0.25 cm yr^{-1}.

What are the issues?

Hydrology

The most direct of impact of peatland subsidence is a change in hydrology, since subsidence brings the peat surface within the reach of river flood or coastal high tide levels. Large areas of the Fens are below sea level (40% of Lincolnshire; 50% of Cambridgeshire) but drainage provides some of the most fertile agricultural land in the UK, producing a third of England's fresh vegetables. Maintaining agricultural production, whilst also ensuring protection from flood risk, has necessitated significant investment in embankments and coastal flood defences, drainage pumps and sluices, managed by a combination of Internal Drainage Boards (IDBs), the Environment Agency and local authorities. In addition to the costs associated with pumped drainage and flood protection, additional costs arise from the maintenance of watercourses and flood defences owing to peat subsidence, including repairs to embankments that have slumped or deformed and regular deepening/clearance of drains (Figure 2). Some peatlands could also be at increasing risk of coastal flooding and saline intrusion and incursion, both as a result of sea level rise and the increased risk and height of storm surges.

Where drainage by pumping is still feasible, lowland peatlands under agriculture elsewhere in Europe and North America have remained productive, even where the land is now well below sea level. But in some locations, lowland peatlands that were formerly drained for agriculture have now been abandoned or put to other land uses due to decreasing agricultural productivity, the increased costs of drainage and the concomitant risks of riverine and coastal flooding.

Figures 3A & 3B: Damage to road surfaces near Holme Fen, Cambridgeshire. (Photos – S. Page); Figure 3C: Repairs underway on a peatland road in Cambridgeshire during recent summer drought conditions. (Photo – R. Morrison)

Transport Infrastructure

Peat subsidence has a negative impact on transport infrastructure. Roads crossing peat soils suffer regular deformation, cracking and pot-holing, resulting in high repair costs for local authorities (Figure 3). In the Fens, several roads have been constructed on relatively stable mineral ridges, but subsidence of the surrounding peat has left road surfaces well above the adjacent landscape, requiring investment in crash barriers to improve road safety. In general, the costs of repairing and adapting roads due to peat subsidence are not reported separately in local authority or Highways Agency budgets, so it is difficult to quantify these costs, but they are thought to be considerable. As an indication of the scale of the problem, Norfolk County Council have approximately 4,000 km of their road network located on subsidence-prone soils and in Cambridgeshire alone the Department for Transport recently invested £3.5 million towards the repair of subsidence-affected roads.

Reported issues for railway lines crossing lowland peatland include track deformation, resulting in reduced engine power and increased journey times and necessitating regular repairs of the track bed, as well as ground vibration boom from high speed trains, which requires investment in mitigation measures to reduce dynamic amplification.

Buildings

Houses and other buildings may experience cracking, tilting and differential settlement as a result of peat subsidence. There has only been limited urban and rural development on lowland peat soils in the UK, thus subsidence damage to properties appears limited, but effects on individual houses are evident in some areas. In the Fens and the Somerset Levels, most larger settlements are located on mineral islands or ridges, rather than on peat, and have relatively stable foundations.

Figure 4: Subsidence damage to telegraph poles crossing drained peatland near Holme Fen, Cambridgeshire. (Photo – S. Page)

Communication and Energy Supply Networks

Communication and energy supply networks are at risk of damage from peat subsidence, as evidenced by tilting of communication and energy transmission poles (Figure 4) and the differential movement of energy supply pipelines.

Societal Benefits and Costs

Current water and land management practices on lowland peatlands generate a range of societal benefits and costs.

Agriculture

The most important benefits result from the use of lowland peatlands for agriculture and food production: in England, around 2400 km^2 of drained lowland peatland are under agriculture which brings with it benefits for the rural economy, employment and food security. In the Fens, agriculture and food-related industries employ 80,000 people and generate around £3 billion a year for the regional economy. Cultivated lowland peat soils are particularly important for the horticulture sector and generate a substantial proportion of the UK's fresh vegetables (Figure 5). Drained lowland peatlands thus contribute to the UK economy and food security, and reduce reliance on food imports, some of which have high associated CO_2 emissions.

Loss of archaeological interest

Peatland drainage and peat wasting have exposed buried archaeological and historic artefacts to aerobic decay, degradation and loss. Examples of peatland archaeology include the world's oldest surviving trackway in the Somerset Levels as well as human remains (so-called bog bodies). It is estimated that as many as 10,000 archaeological monuments (74% of the total resource) have been destroyed completely in the last 50 years because of peatland drainage and peat loss.

Changing cultural values

Peatland drainage and land use change have resulted in the demise, or in some cases the transformation, of peatland cultural values. Drainage of the Fens led to the loss of a unique cultural heritage associated with the exploitation of the former rich natural resources of this wetland, which supported the livelihoods of local populations who strongly resisted the original drainage of the Humberhead Levels and the Fens (including the so-called 'Fen Tigers', who tried to sabotage their construction). Nevertheless, for today's communities, the unique drainage history of the Fens, along with the transformed landscapes that are important for farming and food production, provide a strong sense of tradition and place.

Carbon storage and greenhouse gas emissions

Peatland drainage facilitates the microbial decomposition of peat organic matter in the aerated zone above the groundwater table. This results in the release of gaseous CO_2 (carbon dioxide) to the atmosphere and, to a lesser extent, of dissolved organic carbon into drainage waters. Methane is also emitted from the drains themselves. Total current greenhouse gas emissions from English peatlands may be as high as 10 Mt CO_2e yr^{-1} (around 3% of UK greenhouse gas emissions in 2019) with lowland peatlands drained for agriculture contributing the majority of this emission.

Biodiversity

The main threats to the biodiversity interests of lowland peatlands are water management, including drainage and excessive water abstraction from underlying aquifers, and pollution from agricultural run-off. In the Fens, peat subsidence has left areas set aside for nature conservation isolated as 'wet' islands perched several metres above adjacent drained fields. This incurs management costs for maintaining an appropriate wetland hydrology. A large proportion of remaining, undrained lowland peatlands are protected as Sites of Special Scientific Interest and both lowland fens and bogs are included as priority habitats in the UK Biodiversity Action Plan. In addition, the network of waterways (rivers and drains) found throughout drained peatlands supports a range of aquatic fauna and flora, including a number of species of conservation interest, and also provides ecological connectivity between remaining wetland habitats.

What options exist for mitigating the impacts of lowland peatland drainage?

Mitigating the risks posed by current water management regimes will require consideration of appropriate actions to reduce hazards, reduce exposure, and reduce vulnerability.

Measures to **reduce hazards** focus on raising the peatland water table to counteract subsidence. This would deliver benefits in terms of

- reduced greenhouse gas emissions;
- reduced maintenance costs for transport routes and other infrastructure;
- protection of archaeological heritage;
- improved hydrological security for wetlands managed for nature conservation.
- improved wetlands

Measures to **reduce exposure** could include

- diverting traffic away from roads without strong foundations;
- strengthening road and rail transport routes that cross peatlands;
- limiting further infrastructure development on peat soils;
- wider uptake and implementation of on-farm soil conservation measures to reduce erosion losses.

Measures to **reduce vulnerability** include

- designing future infrastructure to take account of the low load bearing capacity and subsidence of peat substrates;
- designing future infrastructure to take account of the increased risks of fluvial and coastal flooding under future climate change scenarios.

The magnitude of risks will be determined by

- the characteristics of a particular location (e.g. land elevation, proximity to river/coast);
- vulnerability of assets and people (e.g. presence of high value agricultural land, infrastructure, future impacts of climate change);
- the mitigation and adaptation measures already in place, and their effectiveness.

Implementing appropriate mitigation measures will reduce risks but it will not be possible to offset or eliminate all of them. Measures need to be judged according to their specific costs and benefits (social, economic, environmental) over appropriate timescales. For example, the rate of peat subsidence could be reduced or even stopped by raising water levels. This would provide benefits in terms of reduced costs for water management, reduced greenhouse gas emissions and so on, but would challenge various agriculture-related functions and interests. Taking all lowland peatlands out of agricultural production would significantly impact on UK food production and would have implications for livelihoods and regional economies and could increase reliance on food imports, which would generate CO_2 emissions elsewhere..

The changing climate also needs to be considered in any assessment of the costs and benefits associated with peatland drainage. Climate change projections indicate that the UK is likely to experience hotter, drier summers and wetter, warmer winters. These conditions will promote and possibly enhance current rates of peat subsidence; they could also increase the risk of peat loss by wind erosion and, during extended droughts, increase the risk of damage to infrastructure. In addition, lowland peatlands located at or below sea level, such as the Fens, the Somerset Levels and the Norfolk Broads, could be at increasing risk of coastal flooding and saline intrusion and incursion, both as a result of sea level rise and the increased risk and height of storm surges. This level of increased risk could incur additional costs for the Internal Drainage Boards, the Environment Agency and local authorities with responsibility for land drainage and flood risk management.

Photo: J. Clough

What are the key messages?

Our initial conclusion is that the costs associated with drainage are currently largely 'hidden' and/or are not directly connected to drained peatlands and their management. As a result, it is difficult to model the direct financial and less tangible costs and benefits that could be delivered from implementing the proposed mitigation measures. Some would clearly be challenging to implement without economic or other incentives. For example, permanently raising water tables in peatlands under intensive arable and horticultural production would be problematic given their present-day economic importance. Any such measures would need to consider the implications for food security, along with the interests and livelihoods of those working the land. On the other hand, more sophisticated and dynamic water management systems could avoid over-drainage of agricultural land, reducing (although not halting) subsidence and its impacts, without detrimentally affecting agriculture. New water-tolerant crops could support an alternative and more sustainable form of land-management in some areas (see accompanying briefing note on 'paludiculture').

Uncertainties, costs and priorities for future assessment

The key uncertainties for lowland peatlands in England and Wales relate to costs associated with infrastructure, both in terms of maintenance and higher initial costs associated with construction on soft and subsiding substrates, and for society, particularly in terms of the costs of providing and maintaining land drainage and flood defences. Some infrastructure impacts arising from peatland drainage have been recognised in previous studies, but most of the emphasis has been on identifying and addressing the symptoms of subsidence and little consideration has been given to addressing the causes.

A more detailed assessment of direct and indirect costs would allow:

- an improved understanding of the likely effect of alternative, mitigative water and land management measures on subsidence and greenhouse gas emissions;
- an insight into the key financial values, enabling an accurate modelling of the returns (costs and benefits) delivered from implementing mitigation measures and their practical and economic viability;
- an understanding of what will happen, for example in terms of damage to infrastructure or loss of high value agricultural soils, if nothing is done, thereby providing the basis for a business as usual scenario against which to compare various policy options.

More detailed analysis would also allow regional case studies to be developed (e.g. for the Fens, the Somerset Levels, the Lancashire Mosses and so on), given that there will be geographical variations in peatland type (fen, raised bog), level of flood risk, current and potential future land uses, costs and benefits, and desired economic, social and environmental outcomes.

The full report can be downloaded from:
lowlandpeat.ceh.ac.uk

Glossary

Aerobic
Peatland drainage allows oxygen to enter the peat soil creating aerobic conditions. The presence of oxygen supports microbial and fungal activity which promotes the decomposition of the peat and the loss of carbon (mostly as the greenhouse gas CO_2 – carbon dioxide) to the atmosphere.

Anaerobic
Peat forms under water saturated conditions with little or no access to oxygen. These anaerobic conditions prevent slow down or prevent the break-down of organic material derived from the peatland vegetation.

Bog
A peat-forming system with rainfall as the only source of water. As rainwater is low in mineral nutrients and is also acidic, bog peat is nutrient-poor and acidic.

Fen
A peat-forming system supplied by both rainwater and groundwater. As groundwater can have a variable mineral content, fen peat is usually more nutrient-rich and, compared to bog peat, less acidic, neutral or even slightly alkaline.

Peat
An amorphous organic deposit consisting of semi-decomposed plant (organic) material mixed with varying but small amounts of mineral (inorganic) matter that has accumulated under water-saturated conditions.

Peatland
This term encompasses both ecosystems in which there is active peat-formation and those in which there is a peat soil but owing to changes in site hydrology (e.g. drainage) and loss of the original vegetation cover, the peatland is no longer capable of forming peat. This is the condition of most lowland peatlands in the UK, many of which are now under agricultural land uses.

Peat subsidence
This is a function of several processes, namely peat consolidation, compaction and shrinkage, and the oxidation of previously water-saturated organic material under aerobic conditions. The first three processes lead to an increase in peat bulk density (the weight of peat in a given volume) over time, whereas oxidation results in the loss of stored peat carbon, mostly as CO_2 to the atmosphere.

Wasted peat
Peatland that has been degraded by a combination of oxidation and wind erosion and is increasingly dominated by the underlying mineral material. The remaining peat depth will be less than 40 cm.

UNIVERSITY OF LEICESTER | UK Centre for Ecology & Hydrology

University of Leicester
University Road
Leicester, LE1 7RH, UK

t: 0116 252 2426
w: www.le.ac.uk

UK Centre for Ecology and Hydrology
Environment Centre Wales
Deiniol Road
Bangor, Gwynedd, LL57 2UW

t: 01248 374 500
w: www.ceh.ac.uk

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