Case study 35. Making Space for Water

Evidence on the impact of blanket bog restoration on storm flows

Authors: Jonathan Walker, Mike Pilkington, Alison Baker

Main driver: SSSI condition and flood risk

Project stage: Project is fully set up and monitoring is ongoing

Photo 1: Airlifting heather brash onto Kinder plateau as the first part of the process to stabilise bare peat (source: Moors for the Future)

Project summary:

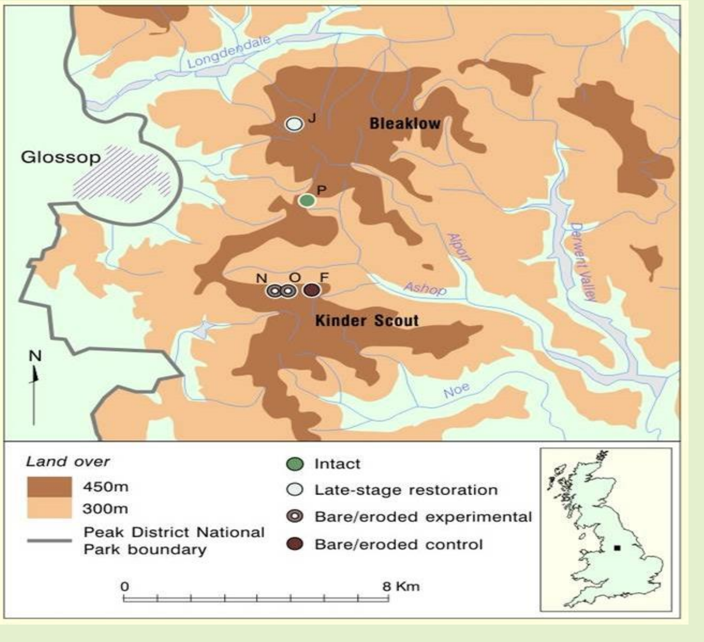
This project is one of 3 Multi-objective Flood Demonstration Catchment Projects funded by Defra in response to the Pitt review of the 2007 summer floods. The project aims to gather evidence on the impact of the stabilisation of bare and eroding peat on upland blanket bog habitat in the South Pennine Moors Special Area of Conservation (SAC). An ecological restoration toolkit used to 'restore' blanket bogs for Natural Flood Management (NFM) benefits was tested within 1ha experimental headwater catchments and attempts were made to identify the mechanisms through which NFM benefits are realised. The restoration method included blocking deep erosion gullies using timber and stone dams and revegetation of bare peat with a facultative grass crop that provided temporary stabilisation of the peat mass. The developing vegetation, in addition to several years of lime and fertiliser, helped to ameliorate environmental conditions and facilitate the subsequent diversification to a community typical of blanket bogs, including Sphagnum mosses. Modelling was carried out in the project both to upscale the results and to indicate how gully blocking techniques could be optimised for NFM benefit. An earlier study had found that water flow velocities were slower through Sphagnum than through grass/sedge vegetation (Holden et al. 2008), meaning that additional benefits are likely to be realised as Sphagnum becomes established. To 'fast track' this evidence, 36,000 sphagnum plants were planted in 2014 into one of the 1ha experimental catchments. Monitoring is ongoing with funding in place to continue until 2021, 9 years post stabilisation and 6 years after Sphagnum application.

Key facts:

Evidence from data collected for 3 years following bare peat stabilisation (involving revegetation with a facultative nurse grass crop) resulted in:

- statistically significant: reductions in peak storm discharge (37%)
- increases in storm-flow lag times (267%)
- increases in water tables (35mm)
- increases in overland flow production (18%)

There were no statistically significant changes in percentage run-off, indicating limited changes to within-storm catchment storage. Although there appeared to be some additional benefits of gully blocking, these were not statistically significant compared with the impacts of revegetation of bare peat alone. Stormwater moved through stabilised catchments more slowly, attenuating flow and storm hydrograph responses. The most important hydrological process response to stabilisation was a reduction in flow velocities associated with increased surface roughness following the establishment of vegetation cover, with these benefits largely realised within one year of intervention.



Map 1: Location of Making Space for Water Project

1. Contact details

Contact details	
Name:	Jonathan Walker
Lead organisation:	Moors for the Future Partnership
Partners:	Environment Agency, Defra, National Trust, Natural England, University of Manchester, University of Durham
e-mail address:	Jonathan.Walker@peakdistrict.gov.uk

2. Location and catchment description

Catchment summary	
National Grid Reference:	SK 08961 89435
Town, County, Country:	The Edge, Kinder Scout, Derbyshire, UK
Regional Flood and Coastal Committee (RFCC) region:	River Trent
Catchment name(s) and size (km^2):	Ashop, 27.8km^2
River name(s) and typology:	River Ashop, mid, small, siliceous
Water Framework Directive water body reference:	GB104028057930
Land use, soil type, geology, mean annual rainfall:	Moorland Blanket bog habitat, deep peat, grit stone, mean annual rainfall for Peak District is 1025mm

3. Background summary of the catchment

Socioeconomic/historic context

High levels of atmospheric pollution were a feature of the South Pennine and Peak District uplands over many decades from the 1850s. This led to an almost complete disappearance of Sphagnum mosses from areas where they were once the dominant vegetation cover. In conjunction with overgrazing, wildfires and climatic factors, this has resulted in significant areas of bare peat (Photo 2) with high levels of erosion and gullying (Carroll et al. 2009). Wide areas of the blanket bogs in this region are classified by Natural England as being in unfavourable condition.

Photo 2: Panorama of bare peat (source: Moors for the Future)

Flood risk problem(s)

Blanket peatlands are naturally ‘flashy’ systems in hydrological terms, with stream flow responding rapidly to rainfall events, relatively short hydrograph lag times and high peak flows relative to total storm run-off volumes (Evans et al. 1999). Peatland degradation, including erosion through loss of vegetation cover or gully development, can further increase the flashiness of stream flow response leading to higher storm flow peaks (see, for example, Grayson et al. 2010). There are several potential mechanisms by which degradation and restoration might alter the characteristics of storm flow run-off and hence influence hydrograph flashiness and peak flows. However, the most important factors relate to:

- potential changes in within-storm catchment storage
- potential changes in the overland flow characteristics of the peatland

Restoration by revegetation could therefore influence water tables, soil water storage and overland flow generation in a number of ways. If the development of a vegetation layer increases, evapotranspiration rates could result in lower water tables and increased soil water storage capacity, particularly after dry antecedent conditions, resulting in less flashy storm hydrograph response. Alternatively, the development of vegetation cover and root penetration could break up the surface of bare peat areas, increasing infiltration rates, raising water tables and reducing soil water storage, thereby increasing flashiness.

In terms of surface cover changes, the establishment of a vegetation cover might also result in increased prevalence of surface depressions between vegetation clumps, increasing surface storage. Importantly, Holden et al. (2008) stressed the role of overland flow in controlling storm hydrograph response, more specifically demonstrating the role of surface roughness as a control on overland flow velocity and travel times, and hence on hydrograph response times. They showed that overland flow velocity is a function of surface cover type, with velocity on bare peat > cotton grass (Eriophorum) spp. cover > Sphagnum spp. cover, indicating that the re-establishment of vegetation on bare peat could be important for reducing downstream flood peaks (Holden et al. 2008, Grayson et al. 2010).

Gully blocking is also potentially important, creating a series of stone or wooden 'dams', which initially result in the formation of pools within the gully systems. Although such pools can rapidly fill with sediment, while they exist they could reduce storm flows through increased within-storm storage, particularly after dry antecedent conditions. Importantly, gully blocks also create barriers to flow within the gullies, initially from the presence of the blocks but on a longer timescale through sedimentation and associated vegetation growth in gully bottoms (Evans et al. 2005). They could therefore reduce flow velocities within gully systems through increased surface roughness, increasing storm water travel times as expressed through hydrograph lag.

Other environmental problems

Condition status

Despite the project area lying within the South Pennine Moors Special Protection Area (SPA), breeding bird densities are suppressed on the site. As a result of the action taken to stabilise and restore the blanket bog habitat, reducing the extent of bare peat from 34% of the 84ha project site in 2009 to 7ha (~4%) in 2014, the condition status of the Site of Scientific Special Interest (SSSI) units covering the project area was assessed as 'unfavourable recovering'. The condition status of the South Pennine Moors SAC is unfavourable due to failing hydrology and morphology, attributable to drainage of the moors. Gully blocking will contribute to restoring the hydrology of the SAC.

Water Framework Directive status

There are issues with diffuse pollution arising from the erosion and transport of peat. Additionally, the peat masses under the blanket bogs of the South Pennine Moors are essentially pollution stores from the Industrial Revolution. In degraded condition, these metals are released from the peat mass in association with particulate organic carbon (POC) and dissolved organic carbon (DOC). In the upper reaches of the catchment, fluvial levels of metals are very high and pH is very acidic, although these are diluted below thresholds at the assessment point at the bottom of the water body catchment.

Drinking Water quality

This project has delivered the practical actions required to address 'at risk' status for colour, which is caused by the levels of POC released by erosion within the Humber Surface Water Safeguard Zone (SWSGZ2301).

4. Defining the problem(s) and developing the solution

What evidence is there to define the flood risk problem(s) and solution(s)

The Floods Directive requires Flood Risk Management Plans to identify areas at significant risk from flooding. In the upland catchment for the Trent, moorland restoration, gully and grip blocking and changes in land management are actions that have been identified. Hydraulic modelling, as part of the Lower Derwent Flood Risk Management Strategy, demonstrated that upstream land management could offset the impact of climate change to benefit Derby, providing benefits during smaller more frequent flood events.

The project area lies within the headwater catchment area of the Derbyshire Derwent river which has a long history of flooding, culminating in the nationwide floods of 2007 and the Pitt review of 2008. The relatively wide areas of bare peat covering these headwater catchment areas have long been associated with increased overland flow and flashy response to rain events, although there was a dearth of strong evidence. The project was initiated specifically to find hard evidence for the beneficial effects of natural land management techniques.

What was the design rationale?

Moors for the Future Partnership, in association with the University of Manchester, developed a before–after–control–intervention (BACI) design on the north edge of the Kinder plateau. This included three 1ha catchments dominated by bare peat, one of which would remain as a bare peat control and 2 of which would be stabilised and revegetated, with one also being treated with gully blocking. Two further 1ha catchments, located on the nearby Bleaklow plateau, were to be used as reference sites, including an intact site and a 10 year-old restoration site. Gully blocks (Photos 3 and 4) were composed of locally sourced grit stone and timber materials. They were located following detailed surveys of gullies, such that the risk of under- and side-cutting would be kept at a minimum.

Photo 3: Gully blocks at Loxley Dipwells (source: Moors for the Future)

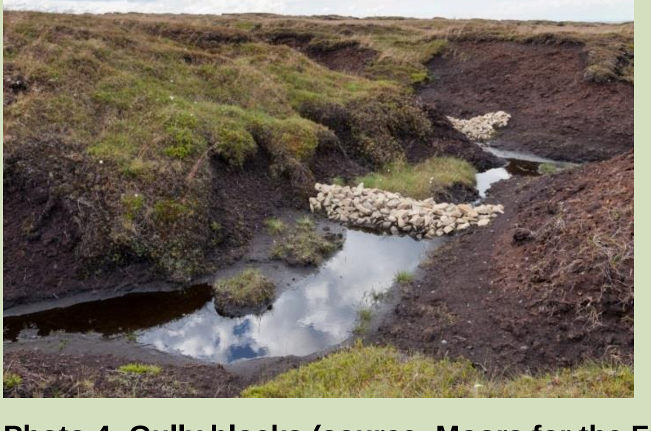


Photo 4: Gully blocks (source: Moors for the Future)

The main aims of the study were to:

- establish the hydrological and run-off characteristics of restored and unrestored peatlands
- evaluate changes in storm flow behaviour following restoration, in particular the key hydrograph variables of hydrograph lag time and peak storm flow, to establish the impact of restoration on flood risk
- establish the causes of any detected change in storm flow behaviour by testing hypotheses of process change associated with restoration

The focus on process explanation is required to permit effective upscaling of restoration effects and the evaluation of downstream flood risk benefits through robust hydrological modelling.

Project summary	
Area of catchment (km^2) or length of river benefitting from the project:	Area of catchment: 27.82km^2 Length of water body benefitting from this project: 9.1km
Types of measures/interventions used (Working with Natural Processes and traditional):	Land cover change involving stabilisation and revegetation of bare peat and installation of run-off attenuation features (gully blocks)
Numbers of measures/interventions used (Working with Natural Processes and traditional):	Bare peat in the project area reduced from 34% of the 84ha project area to 4% (7ha) through revegetation ~2,000 gully blocks installed (~50% stone and 50% timber)
Standard of protection for project as a whole:	Results are attributable entirely to the land management techniques listed above
Estimated number of properties protected:	Unable to quantify

How effective has the project been?

The project has been effective in providing empirical evidence of the NFM benefits of the stabilisation of severely degraded (bare peat) blanket bog habitat. A statistically significant benefit to peak discharge, peak lag times and other hydrological variables was realised within a year of the revegetation and gully blocking interventions. Ongoing monitoring suggested that this benefit would be maintained for up to 3 further years (Shuttleworth et al. 2016); ongoing monitoring should demonstrate whether the establishment and increasing cover of Sphagnum mosses provide additional NFM benefits.

5. Project construction

How were individual measures constructed?

The Moors for the Future Partnership has produced a series of factsheets (http://www.moorsforthefuture.org.uk/factsheets) detailing the landscape scale blanket bog restoration methods tested for NFM benefit within this case study:

- bare peat revegetation
- timber dams
- stone dams (Photo 4)

How long were measures designed to last?

The facultative nurse grass crop is designed to temporarily stabilise the bare peat surface and ameliorate environmental conditions so that the target 'blanket bog' plant species can become established. The grass species only survive as long as top-up treatments of fertiliser are applied. Only one grass species used in the nurse crop mix persists, Wavy hair grass, which is a blanket bog species.

Dwarf shrub heath plants are planted into the nurse crop – cotton grass, crowberry (*Empetrum nigrum*), cloudberry (*Rubus chamaemorus*) and bilberry (*Vaccinium myrtillus*) – and these readily become established.

Sphagnum is also introduced. Replicated trials of the different 'forms' of Sphagnum available to date (wild harvested and propagated Sphagnum in various forms) have been conducted. Ongoing monitoring shows that Sphagnum has become established and cover is increasing on the site. Further monitoring will inform the rate of spread and succession of Sphagnum species on the site.

Stone dams are designed to last in perpetuity, although used to slow water velocities within erosion gullies and trap sediment. These dams do fill with sediment (peat), though these channels become vegetated during this period.

Were there any landowner or legal requirements which needed consideration?

The blanket bog stabilisation/restoration methods tested for their NFM benefit in this project are commonly and widely delivered across the country. The Moors for the Future Partnership has been delivering these works for the last 13 years across the South Pennine Moors SAC. It is a standard method within Higher Level Stewardship plans and approved by Natural England and landowners

6. Funding

Funding summary for Working with Natural Processes (WWNP)/Natural Flood Management (/NFM) measures	
Year project was undertaken/completed:	2009 to the present
How was the project funded:	Defra and Environment Agency funding through Flood Management Multiple Benefit Demonstration Schemes initiative (2009 to 2015) Moors for the Future Partnership's EU LIFE funded project, MoorLIFE 2020, 2016 to 2021
Total cash cost of project (£):	Defra and Environment Agency funding (2009 to 2015): £500,000 MoorLIFE funding (2016 to2021): £75,000
Overall cost and cost breakdown for WWNP/NFM measures (£):	Capital works costs: £556,000 (£112,000 from project funds and £445,000 from Endangered Species Act (ESA) Conservation Plan funds) Monitoring and modelling costs: £377,000
WWNP/NFM costs as a % of overall project costs:	20%
Unit breakdown of costs for WWNP/NFM measures:	Bare peat revegetation and plug planting: £4,300 per ha (excluding Sphagnum application) (2011 prices) Stone dam: £140 per dam (2011 prices) Timber dam: £60 per dam (2011 prices)
Cost–benefit ratio (and timescale in years over which it has been estimated):	Not yet calculated

7. Wider benefits

What wider benefits has the project achieved?

Within the project, the multiple benefits of the land management works have been assessed by monitoring the export of fluvial POC and DOC from the restored and reference catchments. Levels of POC were reduced by 90% following revegetation (Pilkington and Crouch 2015), but there was no evidence up to 3 years after interventions for changes in water colour and DOC concentration in response to revegetation. The latter finding was largely because the before treatment data were limited and the magnitude of the perturbation in the carbon system induced by the 3 years of lime treatments made it difficult to discern long-term changes without further monitoring (Evans et al. 2015).

Vegetation recovery was also monitored with available results showing that by 2014, after 4 growing seasons, bare peat cover had declined by 88%, replaced mainly by a dominant cover of grasses (mainly Wavy hair grass) and acrocarpous mosses. The cover of indicator plant species (that is, species which contribute to a SSSI being classified as being in favourable condition) were relatively low, but increasing, mainly due to the cover of Calluna and pleurocarpous mosses (Pilkington et al. 2015).

The evidence of the wider multiple benefits of bare peat stabilisation has been drawn together through participatory expert workshops (Rouquette 2015).

How much habitat has been created, improved or restored?

Within the project, 84ha of severely damaged blanket bog habitat within the South Pennine Moors SAC, the South Pennine Moors SPA (Phase 1: Peak District), Dark Peak SSSI and the Peak District National Park have been stabilised. Photos 5 and 6 show the revegetated peat and Sphagnum growing naturally, respectively.

Photo 5: Recently revegetated bare peat (source: Moors for the Future)

Photo 6: Sphagnum growing naturally (source: Moors for the Future)

8. Maintenance, monitoring and adaptive management

Are maintenance activities planned?

None are currently planned.

Is the project being monitored?

The project is a monitoring/evidence focused project testing the efficacy of land management techniques for NFM benefit.

Has adaptive management been needed?

As part of the project, modelling has been performed to determine how dam designs could be adapted to provide additional NFM benefits. By default, stone dams are used to trap sediment and do not require any ongoing maintenance. The wooden dams used are designed to hold back water to help restore water tables within the peat mass. The former dams eventually fill with sediment, while the latter are permanently 'full' holding back water. Modelling different dam designs optimised for NFM benefit showed that dams that hold back only storm water flows could attenuate storm flows by up to 34% and, when used in series of up to 6 dams, could reduce peak storm discharge by 46% and increase lag times by 40 minutes across the 1ha experimental catchments (Milledge et al. 2015). The Moors for the Future Partnership is planning to trial this dams design on another site/project.

9. Lessons learnt

What was learnt and how could it be applied elsewhere?

The evidence from the data collected up to 3 years after revegetation and gully blocking showed that catchments became wetter. There was no change in catchment storage during storm events (exemplified by no change in percentage run-off). Storm flow was slowed/attenuated (exemplified by increased lag times, decreased peak storm discharge and reduced HSI Hydrograph Shape Index). Gully blocking had apparent additional benefits for attenuating flow, but these were not statistically significant. The observed changes were consistent with the hypothesis that revegetation and gully blocking had an increased surface roughness effect. Surface revegetation reduced overland flow velocities, and gully blocks and associated gully floor revegetation may also have reduced in-channel velocities. Bare peat restoration by revegetation and gully blocking had benefits for downstream flood risk reduction by ‘slowing the flow’ in peatland headwater catchments, and modelling demonstrated the benefits at larger catchment scale ($9km^2$; up to 12% reduction in peak storm flows; Milledge et al., 2015). This study provides robust empirical data and process analysis to calibrate such models.

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Project background

This case study relates to project SC150005 'Working with Natural Flood Management: Evidence Directory'. It was commissioned by Defra and the Environment Agency's Joint Flood and Coastal Erosion Risk Management Research and Development Programme.