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Natural Flood Management

Natural flood management, defined here as the alteration, restoration or use of landscape features, is being promoted as a novel way of reducing flood risk. This POSTnote reviews the policy drivers of this approach, as well as the scientific basis, and implementation, of inland natural flood management strategies.

Overview

- The Flood and Water Management Act (2010) and Environment Agency Catchment Flood Management Plans promote working with natural processes where possible.
- Natural flood management (NFM) varies in its effectiveness, for example, water storage or flooding land are often more effective than changing land management practices.
- NFM can reduce erosion and benefit water quality, carbon storage & biodiversity. These positive effects may sometimes be more valuable than the reduction in flood risk.
- Collaboration between land-owners and communities is likely to be a key part of the success of NFM. Long-term funding measures or incentives, and better use of local knowledge, will also be important.

Background

Climate projections for the UK suggest that total rainfall will increase in winter and decrease in summer,[1] while individual rainfall events may increase in intensity, especially in winter. These phenomena point to a possible increase in flooding. Flood risk can be expressed as the product of flood probability and resulting flood damage. This means that future flood risk depends on both economic development and environmental change. The UK's current annual estimated flood damage cost is £1.1 billion,[2] and, in 2004, the total value of assets at risk of flooding was around £200 billion for England and Wales.[3] Scenarios, used by the Foresight Future Flooding project, suggested that damage could increase by a further £1–27 billion a year, depending on climate change and social and economic circumstances.[3]

Managing Future Flood Risk

The economic, social and environmental impacts of ways of managing flood risk were also assessed in the different Foresight scenarios. Two of the most "sustainable" ways of managing flood risk were better land use planning and catchment-wide water storage (a catchment is the area of land drained by a water body).[3] Further recognition of the potential of working at the catchment-scale arose from the Defra report, *Making Space for Water* (2005). Limited resources can restrict the use of hard flood defences (typically concrete or metal) because they are expensive to construct. In addition, projects in areas at risk of flooding may not be funded if the assets at risk do not offset the cost. For example, flash flooding is common in the short, steep catchments of the south-west of Britain, such as Holnicote (page 4), but the total value of properties affected may be low.

Combined, these factors have increased interest in 'natural', lower-cost, catchment-scale approaches for flood risk management. Natural flood management (NFM) is the alteration, restoration or use of landscape features to reduce flood risk. Altering features often includes "soft-engineering", which has been defined as engineering with natural materials, such as soil. The "Pitt Review" of the 2007 summer floods highlighted the potential of NFM by recommending "greater working with natural processes". A Pitt Review Working Group on this is due to report at the end of 2011.

Catchment-based Policy and Planning

Using the river catchment to plan flood risk management is not a new idea, but it has come to the fore over the past decade. Integrated catchment management focuses both on reducing flood risk and on delivering wider benefits such as water quality improvements. This is assumed to be an effective way of working towards "good ecological status" for water bodies, as required by the EU Water Framework (2000/60/EC) Directive. The EU Floods (2007/60/EC)

Directive, the Environment Agency's (EA) Catchment Flood Management Plans (CFMPs), (Box 1), and its River Basin Management Plans (POSTnote 320) have all contributed to the development of this method of planning. CFMPs focus on where working with natural processes could help to manage inland flood risk. Shoreline Management Plans deal with coastal flood risk (POSTnote 342), but this type of flooding is not dealt with further here.

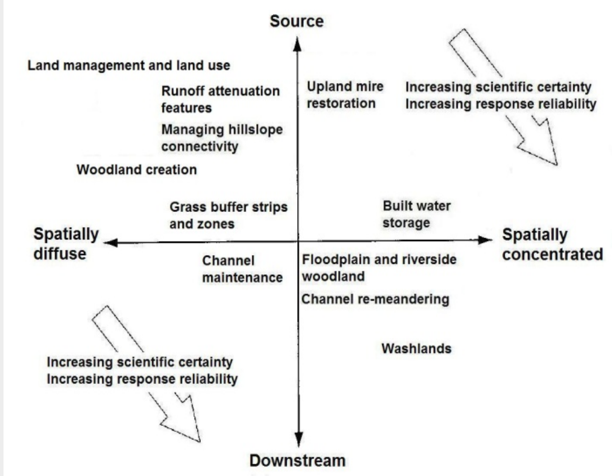
Box 1. Catchment Flood Management Plans
CFMPs are planning tools used to develop flood risk policy, and promote collaborative working between organisations within river catchments. Seventy-seven CFMPs have been created for England and Wales. CFMPs survey the flood risks across a catchment, and consider the potential impacts of climate change on these risks. Catchments are divided into sub-areas, with each assigned to one of six policies. The policies indicate the amount of work required to reduce flood risk in a sub-area to an acceptable level. Within sub-areas particular actions, including NFM, are recommended. River Basin Management Plans are at a larger scale, containing several CFMPs, and address a wider range of environmental issues.

Natural Flood Management in UK Law
The Flood and Water Management Act 2010 establishes primary flood risk management policy for England and Wales. The Act lists "maintaining or restoring natural processes" as a way of managing flood risk, and permits the designation of natural features that can reduce this risk. It also requires the creation of national and local flood risk management plans. The EA's national plan provides the framework for managing flood risk. The local plans focus on surface water, groundwater and small watercourses, and are the responsibility of "Lead Local Flood Authorities". Information about NFM options in the existing CFMPs will inform local planning (Box 1). For Scotland, the Flood Risk Management Act (Scotland) 2009 is the main policy driver. This promotes NFM directly and requires the mapping of "natural features" that contribute to a reduction in flood risk (Section 19), and an assessment of places in which the alteration, enhancement or restoration of natural features could further reduce flood risk (Section 20). The Scottish Environmental Protection Agency and local authorities need to consider these latter features when setting flood risk management objectives.

Strategies for Natural Flood Management
NFM aims to reduce the downstream maximum water height of a flood (the flood peak) or to delay the arrival of the flood peak downstream, increasing the time available to prepare for floods. These aims are achieved by restricting the progress of water through a catchment. NFM strategies can be loosely classified by their likely location and distribution in a catchment (Box 2). They rely on one, or a combination, of the following underlying mechanisms:

- **storing water** by using, and maintaining the capacity of, ponds, ditches, embanked reservoirs, channels or land
- **increasing soil infiltration,** potentially reducing surface runoff, although this can be offset by greater subsurface flows. Free-draining soil will make saturation less likely, and evaporation from soil can also make space for water
- **slowing water** by increasing resistance to its flow, for example, by planting floodplain or riverside woods
- **reducing water flow connectivity** by interrupting surface flows of water, for example, by water storage or planting buffer strips of grass or trees.

Box 2. A Catchment-scale Classification of NFM Strategies[4]
NFM strategies in the figure below are loosely classified by the location of their likely deployment, either near the source of a flood or downstream, and by how the strategy may be distributed on the ground. The classification highlights potential governance issues related to implementation. Diffuse measures may require cooperation between land-owners, or coordinated deployment across a catchment.



An NFM strategy may have different effects in different landscapes, depending on factors such as soil type, geology, topography, climate and the network of water channels. Soil infiltration will depend on prevailing soil moisture conditions. For example, the 2009 winter floods in Cumbria were made worse by saturated ground. NFM will also vary in its effectiveness depending on how rain actually falls across a catchment. Catchment size is another key factor. Recent research suggests that channel networks are the main control on how floods form in larger catchments. These many influences on NFM effectiveness suggest that the more diffuse strategies (Box 2) will often complement, rather than replace, strategies with more reliable responses, such as built water storage or hard defences. A combination of strategies may often be the most effective approach.

NFM Strategies: Evidence and Effectiveness
For NFM to become a standard part of managing flood risk, evidence is required to inform its development and deployment. Quantifying effects is important for designing catchment-wide schemes, and for estimating the cost-effectiveness of an action. Evidence for the effectiveness of particular NFM strategies is summarised below.

Upland Mire Restoration
Uplands often act as sources of flooding. Upland soils tend to saturate rapidly, so water can run off quickly after rain. Management may have an impact on small floods, for example, bog mosses have been found to slow water flow compared with bare peat. Blocking drains in mires can also reduce peak water flow rates, although this may depend on local surface vegetation, variability and slope. Careful planning will be necessary to ensure that drain blocking does not increase the risk of runoff, or synchronisation of drain flows, increasing downstream flood peaks. Multiple benefits,

such as improved water quality, biodiversity and carbon storage, can result from mire restoration. However, conflicts may arise if managing land for recreation affects soil-water interactions. A University of Leeds project (EMBER) is currently researching the impact of moor burning for grouse on soil infiltration and runoff.

Land Management and Land Use
Land management changes can be very effective in dealing with local flooding problems; persistent "muddy floods" in Sussex, caused by runoff from arable fields, were alleviated in some places by grassland buffers and zones that reduced runoff and disrupted water connectivity.[5] Research in upland areas by the Flood Risk Management Research Consortium (FRMRC) has shown that suitably-placed strips of trees can improve water infiltration into soils and reduce runoff. When this effect was modelled at the size of a small catchment (~10 km^2), average flood peak reductions for small and large floods were predicted as 29% and 5% respectively, but with significant uncertainty.[6] However, at larger scales, a Defra project (FD2120) using long-term data on land use change and flooding could not isolate an effect of changing land use from that from climate variability. An FRMRC model predicted that larger catchments (~250 km^2) will be less sensitive to land management affecting runoff compared with small catchments. However, increasing land management change in a catchment, regardless of its size, may still provide some reduction in flood risk.[7]

Woodland Creation
Models examining the water slowing and storage effect of woods at the catchment scale have shown that there can be flood risk benefits, but that these are dependent on the size of the flood and on the distribution and amount of planting. Models suggest that planting the whole of a small catchment (~10 km^2) could reduce flood peaks by an average of 50% and 36% for small and large floods respectively. Targeted planting along watercourses, combined with woody debris dams, was predicted to reduce flood peaks by 8–10% in a ~69 km^2 catchment. Woodlands may also reduce flood peaks by intercepting and evaporating off rainfall. Catchments entirely covered in conifers may have up to 10% less flood water entering streams, but broadleaved trees will have smaller effects.[8] Using tree planting to reduce flood risk and simultaneously to improve water quality is a current focus for research (Box 3).

Sediment Management
Greater runoff can promote soil erosion, raising the sediment supply to water courses. This may increase flood risk if deposited sediment reduces water channel capacity. The current evidence suggests that capacity changes can be very important in the upper reaches of rivers. They may be less important downstream, although some increases in risk may still occur if assets are close to the river. Promoting management that reduces sediment supply (planting riverside trees, for example), and allowing river channels to adjust naturally, can help to maintain channel capacity. These approaches may be especially important for large catchments, where strategies to reduce runoff or surface water connectivity may have less effect on flooding.

Box 3. Flood Risk Management and Water Quality
Forest Research has recently developed "Opportunity Mapping", a method that seeks to identify those areas of a catchment where planting trees could result in multiple benefits. Information from EA River Basin Management Plans and CFMPs is used to identify streams with low ecological status, or that are at risk of flooding. Information from satellite imaging, the modelling of nutrients and sediment, and soil mapping are used, along with knowledge about constraints on planting, to identify priority areas for woodlands. Natural England has also been working with the EA to identify CFMP actions (Box 1) where land management delivered through Environmental Stewardship could reduce flood risk and still deliver its primary objectives, such as natural resource protection. The EA has calculated that 1442 CFMP actions (37%) for England can be met through either Environmental Stewardship or the Woodland Grant Scheme.[9]

Built Water Storage
Modelling of the Parrett catchment in Somerset suggests that using 2–3% of land as storage reservoirs could reduce flood peaks.[10] However, the high costs of land and construction may make widespread built water storage unlikely,[10] but this may change if stored flood water can be used by farmers for irrigation. In Northumberland, a project is using smaller-scale "runoff attenuation features", including storage, near to sources of runoff. Evidence for the efficacy of this approach has emerged (Box 4).

Box 4. Farm Integrated Runoff Management (FIRM) Plans[11]
FIRM plans were developed at Newcastle University. They are based not only on water storage, but also on the slowing, infiltration and filtering of runoff. Other runoff attenuation features include woody debris dams and specially-designed buffer zones. The features require 2–10% of the landscape to significantly affect runoff. Their use in a small catchment (~6 km^2; Belford, Northumberland) delayed the time to flood peak downstream. Newcastle University, with the EA, has now produced a guide to using runoff attenuation at the farm-scale. These features have multiple benefits, including carbon storage and the reduction of water pollution.

River Restoration
Restoring river meanders will increase a river's length and decrease its slope. This may help to slow water and reduce flood peaks and is often used with floodplain restoration. The removal of hard structures, such as culverts and weirs, is sometimes also undertaken. These measures are normally used to improve river ecology to meet EU targets, but they may also help to reduce flood risk (Box 5).

Box 5. In-stream Structures and Flood Risk Reduction
Weir removal may reduce upstream water depth, and so provide greater capacity for storing water at times of flood. Culvert removal may actually exacerbate local flooding, but this has been used in urban river restoration schemes to create local floodplains with amenity and biodiversity value. These can potentially reduce downstream flood risk. Project Kingfisher on the River Cole, Birmingham, removed sheet piling reinforcements from 500 m of riverbank, 150 m of concrete bank reinforcement, and 20 m of concrete channel. The resulting natural channel had ponds and adjacent wetlands with flood storage potential.

Washlands
Washlands are areas of land that are allowed to flood to reduce flooding downstream. This may involve directing water using engineering, or using natural areas such as floodplains. Washlands have been used extensively in flood alleviation schemes throughout Europe,[12] and are well

established tools. The biodiversity benefits of washlands can be large, but will depend on the seasonal management of water levels. The amount of washland created on productive land may need to be balanced against the requirement to maintain the UK's food production capacity. Farming that is compatible with flooding may be feasible in some locations, but the economics will vary between farms.

Future Challenges for Natural Flood Management

A lack of long-term data limits both realistic modelling of NFM over a range of catchment types and knowledge of its true impact. The recent deployment of measuring instruments in catchments trialling NFM is expected to improve both understanding and models. Large-scale soil mapping or soil condition information may also assist in modelling catchments lacking data. Coordinating the deployment of NFM strategies is a key consideration; flood risk may actually be increased if the distribution of strategies in a catchment results in flood peaks from different water courses coinciding downstream. Currently, much of the evidence for the more diffuse strategies (Box 2) suggests that catchment-scale flood risk reduction may be modest compared with other environmental benefits.[13]

Delivering Natural Flood Management

The current EA project appraisal guidance seeks to ensure that "working with natural processes" is considered when evaluating alternative flood management projects, and supporting guidance on some NFM strategies has been issued.[14] New national funding arrangements also mean that smaller projects, and projects with environmental benefits, are more likely to receive at least part-funding from central government.[15] Existing agri-environmental schemes may be able to provide diffuse NFM in some situations (Box 3). For example, the Higher Level Environmental Stewardship handbook has recently been revised to ensure that the flood risk benefits of actions are highlighted. Defra's Catchment Sensitive Farming programme focuses in part on runoff and soil structure, and the EA has suggested flood risk management as an extra objective for this programme. In the Yorkshire and Humber region, the Forestry Commission offers additional contributions on top of the standard Woodland Creation Grant to support planting in areas where this can contribute to flood risk management.

Farmers' Attitudes

A recent survey of 184 Scottish farmers concluded that increased financial or practical incentives that address NFM costs at the farm level would be essential for projects. Trusted local intermediaries between regulators and farmers, and long-term agreements of 5 years or more, were also strongly supported.[16] However, 52% of farmers considered their land to be too valuable for NFM, suggesting some limits to deployment. The Scottish Government is currently researching the variety of agreements or contracts that have been, or could be used in the provision of NFM.

Payment for Ecosystem Services (PES)

PES involves the purchase of a well-defined ecosystem service (such as a reduction in flood risk) by a beneficiary from a supplier, the payment being conditional on the service being delivered. However, flood risk benefits may be hard to quantify in isolation, or be small. One ecosystem services report examined six upland projects, but found flood risk benefits to be minimal, or unquantifiable, with existing data.[17] Benefits will depend on the value of the assets at risk, which may limit the use of NFM as a rationale for land management or restoration projects in some places. The more concentrated NFM options (Box 2) may be more amenable to PES arrangements, as the land involved is likely to be owned by fewer people, and the benefits of NFM strategies such as washlands may be more easily quantifiable.

A catchment management project on the National Trust's Holnicote Estate in Somerset estimated the resulting flood risk benefits. It was found that these alone did not offset the project's costs, but including the values of benefits from other ecosystem services did. PES schemes may be able to use new planning software in the near future. For example, the "Polyscape" software tool, developed by the FRMRC,[6] uses simple rules to assess where flood risk management strategies could also result in other ecosystem service benefits. Future work will integrate more sophisticated models of catchment flooding into the Polyscape tool.

Community Cooperation

As well as land-owner cooperation, community cooperation will be crucial for NFM, especially if a PES scheme is to be implemented. Several projects have found early community engagement to be fundamental to success. A project in Pickering, North Yorkshire, took a radical approach: members of the public were recruited as project advisors. Academics and locals together contributed to a new model, tailored to the catchment. This was found to be more cost-effective than adapting an existing commercial model.[18]

Other Practical Considerations

The potential widespread, and long-term, use of NFM raises various other practical issues, such as: deciding on responsibilities for maintaining NFM features (de-silting water storages, for instance); collecting data to monitor efficacy; the safety regulations for storage features over 10,000 m^3 (Reservoirs Act (1975), as amended); the establishment of local demonstrations for landowners; and, the training of farm advisors to support the take-up of NFM options suitable for a given catchment. The National Audit Office has also raised concerns about the capacity of local authorities to manage new responsibilities for surface water flooding.[2]

Endnotes

1 http://ukcp09.defra.gov.uk/
2 National Audit Office, 2011, *Flood Risk Management in England*
3 Evans, E *et al*, 2004, *Foresight Future Flooding*. OST
4 Adapted from Thorne, C *et al*, 2007, *Future Flooding & Coastal Erosion Risks*
5 Evans, R & Boardman, J, 2003, *Soil Use Manage*, 19: 223–231
6 http://www.floodrisk.org.uk
7 O'Donnell, G *et al*, 2011, *Phys Chem Earth Pt A/B/C*, 36: 630–637
8 Nisbet, T *et al*, 2011, *Woodland for Water*, Forest Research Monograph: 4
9 Burgess-Gamble, L, Environment Agency, pers comm
10 Park, J, Swansea University, pers comm
11 http://research.ncl.ac.uk/iq/Proactive/FIRM.html
12 Blackwell, M & Maltby, E, 2006, *Ecoflood Guidelines*. ECDG Research
13 For example, of 100 catchment management projects in Ofwat's Price Review 2009, only two included flood risk as a motivating factor (K Ridout, pers comm)
14 http://www.environment-agency.gov.uk/research/planning/116705.aspx
15 Defra, 23 May 2011, *Flood and Coastal Resilience Partnership Funding*
16 Holstead, K & Kenyon, W, James Hutton Institute, pers comm
17 Natural England, 2009, *Economic Valuation of Upland Ecosystem Services*
18 Lane, S *et al*, 2011, *Trans Inst Br Geogr*, 36: 15–36

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology.
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