Journal of
Flood Risk Management

# Challenges to enabling and implementing Natural Flood Management in Scotland

K. A. Waylen[1], K. L. Holstead[1,2], K. Colley[1] and J. Hopkins[1]

1 Social, Economic and Geographical Sciences Group, The James Hutton Institute, Aberdeen, UK
2 School of Management, University of St Andrews, St Andrews, UK

**Correspondence**
Kerry Waylen, The James Hutton Institute, Cragiebuckler, Aberdeen, Scotland AB15 8QH, UK
Email: kerry.waylen@hutton.ac.uk

DOI: 10.1111/jfr3.12301

**Key words**
Collaboration; environmental governance; flood risk management; institutional analysis; knowledge use.

## Abstract

We explore factors that constrain implementation of Natural Flood Management (NFM), based on qualitative analysis of interviews with those influencing and enabling flood risk management in Scotland. NFM entails collaboration by multiple individuals and organisations to plan and deliver measures such as re-meandering or buffer strips. Our interviewees identified many interacting issues. They particularly focused on difficulties in securing resources, and evidence gaps and uncertainties associated with NFM. Co-ordination was not simple, often requiring new types of skill, expertise, and resources. NFM is thus outside the 'comfort zone' of many leading or engaged with flood risk management. These experiences echo and elaborate on other studies of attempts to encourage sustainable flood management. To tackle these challenges, practitioners should reflect how pre-existing ideas and practices may shape and constrain new approaches to managing floods, while research is needed on specific strategies that can assist in enabling change.

## Introduction

Many authors have argued that we need to adopt new approaches to flood risk management in the face of future change (e.g. Merz *et al.*, 2010). These arguments also reflect broader trends to open up institutions to new ways of working, away from 'technocratic' decision-making, i.e. top-down management dominated by scientific or technical elites (Stirling, 2008). It is hoped that opening up to new approaches will lead to more sustainable ways of governing and managing flood risk. However, recognising the need for change does not mean that new ways of working are quickly achieved (Washbourne and Dicke, 2001). Many institutional challenges are likely to be encountered, and these must be better understood in order to overcome and enable change (Waylen *et al.*, 2015).

The objective of this paper is to explore and identify the challenges associated with implementing the concept of Natural Flood Management (NFM). NFM aims to slow the flow of water through the landscape, so entails working with new groups for catchment-scale co-ordination of land-use and river management. It is currently of interest in many countries worldwide (Wesselink *et al.*, 2015). We use a case study of Scotland, where there is strong support for new approaches in flood management, but where progress in NFM implementation has so far been slow (Cook *et al.*, 2016). We use this case to identify key underlying issues, and discuss how these may be overcome to enable more sustainable flood management.

### Defining the concept of NFM

Within Europe and beyond, flood management has long been premised on 'technical flood management', i.e. the physical control of rivers and catchments (Cook *et al.*, 2016). The resulting structural solutions – such as concrete flood defence walls and or human-made tidal barriers – have played an important role in reducing the damages from flooding. However, relying solely on these measures is increasingly perceived as inadequate in the face of future climate change and other societal pressures (Merz *et al.*, 2010). Technical measures are very costly, may have unintended consequences, and may not be able to cope with increases in the frequency and size of future flood events (Wheater, 2006). As a result, many have recommended the use of a broader 'portfolio' of measures and approaches (Evans, 2004) and the need to fundamentally reconsider how we conceive, practice, and assess flood management (Lane *et al.*, 2011). This 'Sustainable Flood Management' (SFM) approach is a philosophy which prioritises risk

reduction through a range of measures that can include structural measures, but are more economically and environmentally sustainable than relying on structural measures alone (Cook *et al.*, 2016).

'Natural Flood Management' is part of this new philosophy. Related terms include 'Making Space for the River' (e.g. Warner *et al.*, 2013), 'Ecosystem-based Flood Risk Management' (e.g. Huq and Stubbings, 2015), 'Engineering with Nature' (e.g. Bridges and Walker, 2011), and 'Working with Natural Processes' (e.g. Cooper and McKenna, 2008). NFM can benefit flood management in both catchments and at coastlines. In catchments, NFM entails slowing the movement of water through the landscape by co-ordinating river management and land-use across catchment landscapes so as to (re)-shape hydrological and morphological processes (Rouillard *et al.*, 2015; SEPA, 2016). Measures to achieve this are diverse and range from installing upland wetlands and ponds, through to restoring intertidal habitat, placing woody debris instream, re-meandering river channels and planting trees or other ground cover.

These measures can also potentially benefit other ecosystem services and biodiversity. NFM should therefore support SFM by enabling more economically and environmentally sustainable management of water and flood risks (Iacob *et al.*, 2014; Cook *et al.*, 2016). SEPA (2016) provides a good overview of the range of NFM measures and current knowledge about their effects. However, the evidence base on NFM is relatively young, with many gaps and uncertainties (Spray *et al.*, 2009). NFM measures are thought to reduce flows in floods with small return periods but there is less certainty about their effectiveness in larger flood events (McIntyre and Thorne, 2013).

NFM widens the scope of flood management, as it requires working across all parts of catchments and with a wider range of measures. This also entails widening-out of the set of participants and skills involved (Rouillard *et al.*, 2014). In the past, decisions about flood management have been initiated and implemented by statutory bodies responsible for flood risk management, building on hydrological and engineering expertise. Enabling and implementing NFM requires these same groups and skills, but also requires involvement from other groups who influence land management and use, in particular: public sector bodies, such as agencies charged with water management, but also biodiversity conservation and regional government (local authorities); utilities tasked with providing drinking water and/or sewerage; third sector organisations concerned with conservation and/or catchment management; and various businesses including consultancies providing advice to Local Authorities, farmer extension services, and landowners tasked to carry out or permit actions to be taken on their land. All these groups should be involved in the process of understanding, appraising, deciding, planning, and implementing NFM.

## Potential challenges to enabling and implementing NFM

A review of the wider literature on water governance highlights several ways by which pre-existing ways of working may hinder attempts to adopting such new approaches (e.g. Teisman *et al.*, 2013). Firstly, the quality of communication and collaboration is likely to affect how well networks are able to deliver on environmental goals (Newig and Fritsch, 2009). Those seeking to promote NFM and related approaches have often focused on the challenges of communicating with and motivating land-managers and the wider public (Penning-Rowsell, 1996; Buijs, 2009; van Buuren *et al.*, 2014). This is important, particularly since land-managers are ultimately responsible for implementing or allowing many NFM measures (Holstead *et al.*, 2016a). However, communication and engagement with other groups is also important. A focus on land-managers and local communities needs to be complemented with more attention to the roles of other groups (Cook *et al.*, 2016).

An additional challenge comes when new types of knowledge and uncertainties must be shared and acted upon (Pahl-Wostl *et al.*, 2007). Resistance to new concepts can arise from their misfit with existing ways of understanding, both formal expertise and informal or tacit knowledge. For example, Kirk *et al.* (2007) showed the disciplinary backgrounds of staff in regulating organisations impeded and altered new initiatives to safeguard water quality, in turn exacerbated by resource constraints.

Lastly, challenges of promoting new co-ordination and knowledge use may be worsened by the differing goals and interests of individuals and institutions. Those with power tend to act so as to 'close down' or constrain change so as to favour incumbent interests (Stirling, 2008, 2012). For example, Fischhendler and Heikkila (2010) found transition towards integrated water management is impeded by the practical costs of change, reinforced by the dominance of those whom benefited from the pre-existing system. These effects seem to reinforce each other to impede change (Ingram and Fraser, 2006).

It is therefore important to appraise the effect of existing collaborations, types of knowledge, and interests. Existing studies indicate all these issues may all interact (Lane *et al.*, 2013) to shape flood management. For example, in Germany, Krieger (2013) has shown that existing ideas about floods and risk interact with institutional arrangements to shape the measures chosen for flood management. Also, a philosophy of state-centred regulatory control in Germany is known to conflict with more holistic partnership-oriented approaches (Moss, 2004). Thus both formal and

informal cultures and traditions of managing water hinder attempts to introduce new concepts in flood management (Thomas and Knüppe, 2016). Guerrin (2015) illustrates similar institutional challenges face floodplain restoration in France, with several challenges related to the activities and perceived legitimacy of state bodies, as well as differing understandings of the floodplain system. In the Netherlands, even where individuals and organisations agree with the need to move away from pre-existing modernist approaches to flood risk management, the approaches and assumptions of managerialism tend to persist (Wolsink, 2006) causing a lack of 'deep' institutional change (Wiering and Arts, 2006). Thus, even the influential and high profile 'Making Space for the Water' programme may not fully represent a paradigm shift to sustainable flood management (Wesselink and Warner, 2010).

Similarly, in the UK, two recent studies have highlighted the interaction of pre-existing ideas and institutions for flood management. Huq and Stubbings (2015) suggested that the institutional environment is a key factor explaining the limited implementation of NFM, whilst Cook *et al.* (2016) have shown pre-existing ways of tackling problems with engineered solutions shape how new NFM concepts are assessed and judged. These reports resonate with reports of barriers to floodplain restoration a decade earlier (Adams *et al.*, 2004, 2005) and even earlier reports of how the interaction of interests and institutions has hindered prior attempts to reform UK flood management (Penning-Rowsell, 1996). These studies together identify several issues that further reinforce constraints from ideas and institutions: economic constraints, arising from limited funding but also the profitability of other potential land-uses; the challenges of enabling wider societal participation; limitations and partiality in existing knowledge bases; and the social and physical features of the landscape, particularly land-ownership. Adams *et al.* (2005) noted how such issues could be explicitly cited to justify and reinforce in pre-existing 'conservative' discourses held by individuals and groups that resisted changes in river management. It is important to understand how all these issues may be interacting to shape ongoing efforts to implement NFM.

## The case of Scotland: a policy context evolving to support NFM

Throughout most of the 20th century, approaches to managing flood risk across the UK have been strongly technocratic (Brown and Damery, 2002) with a strong reliance on statutory agencies to design and install hard-engineering measures to minimise the hazards posed by flooding. Only in the last decades has there been support for considering alternative approaches (e.g. Pitt, 2008).

UK flood management is now a devolved matter that is handled separately by England, Wales, Scotland, and Northern Ireland. Of these, Scotland is thought to be particularly supportive of non-structural approaches (Werritty, 2006; Cook *et al.*, 2016). This stance has been reinforced by the European Floods Directive (2007/60/EC) whose supporting documents promote the use of NFM. The transposition of the Floods Directive into national law, through the Flood Risk Management (Scotland) Act 2009, has been identified as 'embracing the spirit of sustainable flood risk management at the catchment scale' (Spray *et al.*, 2009 p.174).

As for other European countries, Scotland has to create and implement Flood Risk Management Strategies and Plans, which are to be reviewed and updated every 6 years. (At the time of this study, this process was ongoing; the strategies were subsequently published in December 2015 and the plans in June 2016.) The Scottish Government recognises that new approaches to flood management need new networks of organisations, and so it requires the formation of formal partnerships to appraise and plan responses to flood risk (SEPA, 2012). Bracken *et al.* (2016) have shown that in the Scotland–England border, excellent networks have already developed that span organisational, administrative, and conceptual boundaries. However, pre-existing statutory agencies retain formal responsibility for planning and ensuring flood risk is managed in accordance with law. Within Scotland, the 'Competent Authority' is designated the Scottish Environment Protection Agency (SEPA) whilst Local Authorities (regional government) and Scottish Water (responsible for drinking water provision and sewerage) are designated as 'Responsible Authorities'.

The adoption – or otherwise – of any new concept is not driven solely by national-level policies. This is especially true for flooding, where formal policy-making has often reflected rather than driven non-policy discourses and commitments (Penning-Rowsell *et al.*, 2006). This is the case for NFM, where policy support was predated by support from non-policy groups, especially environmental organisations (e.g. WWF Scotland, 2007). Given this support, and with the expectation that hazards will worsen yet public budgets for managing these are tightly constrained, one might expect adoption of any such concept that offers a more sustainable approach over the long-term (Monaghan, 2010). However, there have so far been few catchment – scale projects that aim to reduce flood risk through NFM. Within Scotland there are about thirteen examples of NFM projects (JBA Consulting, 2015) such as measures within the Eddleston Water catchment (Perfect *et al.*, 2013). These interventions have often been small-scale, some initially motivated by other goals e.g. for farm diversification, ecological restoration goals and/or research. Similar interventions are ongoing across the UK and

 

Europe.[1] In England, pioneering examples such as 'Slowing the Flow' in Pickering (Nisbet *et al.*, 2015) or the Belford Catchment (Wilkinson *et al.*, 2014) have helped demonstrate the potential effect of tree planting, buffer strips and other measures. Many more plans or trials of measures are currently underway.[2] The 'Room for the River' Programme in the Netherlands offers an example of large scale intervention in catchment management (Rijke *et al.*, 2012), but in most other countries interventions are often small-scale, piecemeal and/or initiated for goals other than flood risk management. Thus, Scotland – with its burgeoning experience of promoting and trialling new approaches to flood risk management – is a good case for understanding the challenges of implementing NFM.

## Methods to explore challenges of enabling NFM in Scotland

To explore the institutional barriers to NFM in Scotland, we used semi-structured interviews with a sample of individuals in organisations relevant to implementing or enabling NFM. We used a qualitative approach to data collection and analysis as this is particularly suitable for exploring individual experiences of complex subjects (Silverman, 2004). The research was funded by the Scottish Government's Strategic Research Programme: this required research into barriers to NFM implementation, reflecting policy teams' support and interest in the topic, but did not specify theoretical framing, methods or subjects.

We identified individuals to interview through a stakeholder analysis of the main organisations and interest groups known to have formal mandates or significant interests in flood management. We carried out semi-structured interviews with 18 individuals over 12 months from January 2014. The first interviewees were selected purposively. Later interviewees were selected based on both emergent issues and suggestions for contacts provided by earlier interviews. We sought to sample from across the private, public and third sectors, and to speak to those with experience of considering NFM, both where this did and did not translate into practical actions.

This is not a study of how to implement a specific policy: however, statutory bodies or public agencies are charged with leading flood risk management for Scotland, and the experts or managers within these agencies have significant influence over flood management processes (Penning-Rowsell and Johnson, 2015). Therefore, over half of our interviewees worked for these bodies. Some agencies lead on flood risk management, amongst other goals (SEPA and Local Authorities) whilst others have different goals but have activities affecting flood risk (Scottish Water and Forestry Commission Scotland). In addition, we sampled consultants (who often are contracted to design or help plan flood alleviation schemes) and representatives of third sector catchment management organisations.

The interviews were steered by a topic guide whose content was informed by the literature on environmental governance and the institutional challenges associated with new forms of water governance, with a special focus on possible co-ordination challenges. Discussion was also shaped by the interests and expertise of the respondent. Every interview was audio-recorded and transcribed. These transcripts, together with field notes, were analysed through thematic analysis aided by Nvivo10. This entailed repeated reading and the application ('coding') of themes describing the content. Our thematic analysis was initially informed by the topics in the topic guide, but was as far as possible inductive in order to allow the identification of new themes and issues that we had not previously considered (Strauss and Corbin, 1998). The process of analysis and data collection was overlapping and iterative, so themes emerging from early interviews were checked and tested in later interviews. Finally, the list of barriers was discussed and refined at a workshop attended by some of the interviewees but also other practitioners and policy makers (Holstead *et al.*, 2016b).

None of our interviewees expressed strongly negative views about NFM. This may reflect our sample strategy, but Bracken *et al.* (2016) suggest the idea of NFM widely receives support in Scotland. Interviewees who were charged with flood risk planning for Local Authorities were often cautious or doubtful that NFM could be prioritised in schemes required to control flood risks, whereas stronger support came from individuals working in policy teams and those representing environmental interests (e.g. NGOs, Fisheries Trusts). All interviewees could identify barriers (experienced or expected) to considering, enabling or implementing NFM. NFM encompasses a family of different options or measures, but we did not find the challenges reported varied greatly by the type of measure considered. This is possibly an indication of the relative inexperience in NFM implementation, or indicates the scope of the challenges dwarf any problems specific to certain types of measures. In our following description of the challenges encountered we therefore do not differentiate between measures. Verbatim quotes are provided below as illustrations of the main themes in our data. These are attributed according to respondent's organisation and their job role, except where the combination would compromise confidentiality.

[1]See for example, the catalogue of case studies at www.nwrm.eu

[2]A useful catalogue of UK initiatives is provided at http://naturalprocesses.jbahosting.com/#6/54.188/-1.945

## Findings: experiences of barriers to enabling NFM

Our interviewees' experiences and expectations identified many perceived barriers to considering or implementing NFM in Scotland. Table 1 describes the main themes reported. Many of these issues interconnect to reinforce each other, as we explain below.

### Difficulties in allocating resources

Significantly, nobody thought that implementing NFM would be cheap, despite part of the rationale being that in the long-term it will prove more cost-effective than relying solely on hard-engineering measures (Crichton, 2011). Interviewees in all sectors worried about lack of funding, citing lack of money as '*the real challenge, the whole thing*' (Consultancy Manager, Local Authority).

The concern may arise from the difference in time perspectives between academic or policy analysts, and those implementing NFM. Analysts can consider multiple costs and benefits likely to be delivered to society over the long-term, a perspective which suggests that overall these measures will be more sustainable. By contrast, those charged with implementing flood risk management must relatively quickly allocate their scarce budgets, with no certainty about future budgets, in order to efficiently deliver reductions in flood risk.

> '*…it's alright putting out these things and saying well this could be done, that could be done … [but]…as you'll know all councils have got to be making savings over the next 3 years again so its……you know,…what you can do with the budget that's there!*' (Flood Risk Management Team leader, Local Authority)

There are presently no funding schemes designed specifically to support NFM in Scotland. Access to funding for measures relevant to NFM may be possible via SEPA's Water Environment Fund, a significant funder of projects to restore river morphology.[3] However, since this was set up to support the goal of 'Good Ecological Status' as required by the Water Framework Directive (2000/60/EC), the priorities of this fund may not always align with those of flood risk management. Furthermore, the Scottish Rural Development Programme may encourage some farmers to adopt certain measures relevant to NFM. However the main opportunities to fund NFM primarily arise from the public funds allocated to managing flood risks.

Choices about how to allocate this funding often depend on the decisions of Local Authorities. These must ensure their choices offer 'best value-for-money' by carrying out a Cost-Benefit Analysis according to a specified procedure (Scottish Government, 2012). This procedure often does not favour the long-term and sometimes imprecisely specified effects of NFM measures. In addition, associated benefits such as biodiversity gains, or recreational improvements can be difficult to account for in a Cost-Benefit Analysis. Furthermore, if the measures cannot mitigate extreme flows with a high degree of certainty, they are unlikely to be prioritised since statutory bodies are obligated to favour measures that are accepted to provide protection against the hazards of severe flood events. NFM schemes typically offer to reduce and delay the peak flows of minor flood events, but cannot guarantee vulnerable areas will be protected during larger flood events, such as after a major storm (McIntyre and Thorne, 2013).

NFM also entails different types of expenditures compared with those required to install hard-engineering measures. Costs arise from the need to collect, model, assess, and present new information in order to understand design schemes and identify their potential effects in specific situations. In addition, significant transaction costs arise from co-ordinating multiple partners, and engaging with new audiences. This may entail resourcing demands that change over time and accrue to a mixture of budget lines, in contrast to issuing a single contract for a large engineering project. For public sector organisations, there are often constraints on moving expenditure to different budget lines or time points. Furthermore, it is often easier to access one-off capital funding than to secure ongoing revenue to support these processes. Thus, some of the issues reported as 'costs' did not arise from the total financial resources needed, but were actually examples of constraints arising from pre-existing ways of working, such as fixed appraisal processes and pre-existing budget allocations.

### Challenges in using evidence and handling uncertainty

Uncertainty was cited as a major barrier by many of those in positions tasked with flood risk management. These included uncertainty about how to select and design measures for specific places, but also uncertainty about the effects of measures on hydrological regimes. For example, it is easier to model the effects of a concrete flood defence on peak flows than it is to model the effects of re-meandering a river.

The scientific evidence base on NFM is known to be incomplete (e.g. Parrott *et al.*, 2009). However, many times when uncertainty was cited, it also seemed to relate to not having confidence or familiarity with the knowledge based on NFM. Flood risk managers often have backgrounds in engineering, and also have practical experience only with

[3]http://www.sepa.org.uk/environment/water/water-environment-fund/

 

**Table 1** Summary of factors acting as barriers to enabling and implementing Natural Flood Management (NFM), as elicited by this study and grouped by underlying themes.

| Theme | Factor | Specific issues acting as a barriers to NFM |
|---|---|---|
| Difficulties in allocating resources | Funding and resources | • Lack of resources available specifically for NFM installation<br>• Lack of resources to fund staff time for collaboration, co-ordination and engagement with other stakeholders<br>• Mismatches in funding and planning cycles by different partner organisations<br>• Payments – for maintenance and/or land-manager compensation – may need to be made in perpetuity |
| | Constraints of place | • Difficult to plan work across larger (sub)catchment scales<br>• Some river systems or parts thereof (coastal, urban) are perceived unsuitable for NFM<br>• Must protect and work around existing infrastructure (bridges, roads) |
| Challenges in using evidence and handling uncertainty | Evidence base on NFM has gaps and uncertainties | • Uncertainty as to how to design NFM measures<br>• Evidence gaps on effectiveness of NFM measures<br>• Worries about possible unintended consequences of NFM<br>• New and complex models required to plan NFM<br>• Perception that NFM may 'only' be useful for small flood events or climate change adaptation |
| | Formal and informal expertise | • Engineering training and backgrounds predominate<br>• Lack of familiarity or first-hand practical experience with NFM<br>• Challenges of partnership working and/or stakeholder liaison |
| | Discomfort with new measures | • New multiple measures appear more complex, with less certainty or confidence that we can deliver them<br>• Public pressure may favour 'hard' structural measures<br>• Time lag between installation of measures and being able to demonstrate their effects |
| Complexities of co-ordination and communication | Potential mismatches between statutory processes, planning and appraisal systems | • Statutory Cost-Benefit assessments rarely favour prioritisation of NFM over structural measures<br>• Flood prevention orders, which give rights to install measures on private land, may be perceived not to apply for NFM<br>• Some 'Flood Risk plan districts' cross boundaries of multiple local authorities<br>• Statutory requirement to reduce risk of severe floods over mitigating more frequent smaller ones<br>• Delivery of NFM not a binding duty on statutory bodies<br>• NFM schemes may need permission under Scotland's Reservoirs Act (2011) |
| | Challenges of collaboration and communication | • Need to co-ordinate within large organisations<br>• Need to work with other partner organisations at multiple levels<br>• Need to co-ordinate multiple measures<br>• Need to reach out to engage, persuade and co-ordinate land-managers<br>• Diffuse and occasionally unclear accountability and responsibility |

designing structural measures. The same depth of knowledge and expertise does not apply to NFM. Therefore, planning and implementing NFM took many beyond their 'comfort zone'.

> *'A lot of local authority flood risk management personnel are engineers – in fact most of them will be engineers. So, this is …kind of woolly biology for them, in a way … you know, it's not something that they've traditionally been brought up with'.* (Policy Officer, SEPA)

Selecting, designing, and monitoring NFM measures seemed a larger and less certain task than when doing the same for structural measures such as a concrete wall. New and complex models could help to plan and predict the effects of measures, but these were expensive and not always well trusted. A fear of additional unforeseen or unintended consequences from some NFM measures also contributed to reluctance in using them. In particular, there were worries that installation of woody debris in a stream could potentially exacerbate rather than reduce flooding, if it were to move downstream and accumulate to cause an obstruction at bridges or vulnerable infrastructure.

The understandings and perceptions of NFM held by the 'general public' at risk of flooding were also cited as a barrier by interviewees in statutory organisations. They stated that those at risk strongly preferred to see structural measures, such as flood barriers. This is interesting as the public does not usually have much direct say in decision-making on flood risk management: their formal involvement is mainly limited to consultation on the flood risk management plans and schemes (Spray *et al.*, 2009).

However, they can put pressure on elected representatives in local government. Flooding is an emotive issue where interacting public and media discourses after flooding events are well known to catalyse national-level policy responses (e.g. Johnson *et al.*, 2005). However, it is unclear exactly if and how such pressures would influence flood risk management planning at the levels and cases considered by our respondents. It is possible that public pressure is cited to account for practitioner discomfort with these types of measures, or other institutional challenges to enabling NFM (Harries and Penning-Rowsell, 2011).

### Complexities of co-ordination

Another requirement needed for NFM – and potentially another new demand on time and skills – is liaison within and between organisations. Flood management has always required some liaison between organisations. However, new partnerships have been needed to satisfy the demands of the Flood Risk Management (Scotland) Act 2009, which requires collaboration to plan for each flood 'district'. These new planning districts cut across pre-existing administrative and spatial boundaries, often entailing multiple new partnerships between SEPA and adjacent local authorities. Other organisations such as third sector organisations may also be collaborating for the first time on this topic. Such new partnerships and processes are intended to aid the adoption of strategic and 'joint working' approaches to planning flood risk management (SEPA, 2012), that should themselves aid consideration of NFM. Setting up the practicalities of co-ordination requires time and skills in partnership working. Bracken *et al.* (2016) have shown that in the Scotland–England border region, different organisations have already made excellent progress in networking. However, forming new partnerships to achieve statutory obligations for flood risk planning consumes much effort, at least in the short-term. This may have constrained opportunities to share and use new knowledge, and so reduced the likelihood of committing to NFM measures within the statutory plans.

Those individuals who lead efforts on flood risk management are often based in statutory agencies or regional government, reflecting the statutory drivers of planning for flood risk management. SEPA retains a strong role as it designated as the 'competent authority' for delivering flood risk management, although interviewees did not always share exactly the same understanding of the extent to which SEPA could and should be responsible for all parts of the process. This and other public agencies are also responsible for the delivery of other policies likely to affect water and catchment management. Many of these policies were designed without reference to the Floods Act, so may conflict with it. As a result, several instruments and legal requirements were perceived as problematic: notably, 'Flood Prevention Orders' authorised by The Flood Prevention (Scotland) Act 1961 give rights to install flood defence measures on privately-owned land, but interviewees often doubted whether these applied to NFM measures; while the Reservoirs (Scotland) Act (2011) may mean NFM projects must seek additional permissions (Wilkinson *et al.*, 2013). Some problems relate to how existing River Basin Management plans take no account of flooding, and these may lessen in future once the Water Framework Directive and Floods Directive planning timescales become harmonised (European Commission, 2015). However, there are potential mismatches in funding and planning cycles related to other policies and goals, even encompassing the organisations' own funding and planning cycles. For example, Scottish Water works on a 6-year investment cycle, whereas Local Authorities plan annually or biannually. Such timing mismatches limit opportunities to jointly plan or share resources that might enable NFM.

Co-ordination could also be a challenge within organisations. For example, one interviewee from a public agency reflected: '*we've quite tight timescales to work in, we needed [another team] to do a review at a certain point … because of other competing work priorities they couldn't do it till four months after they were asked to do it*'. This shows that individuals could be willing to co-ordinate internally, but practically unable to do so because of their other commitments. Internal co-ordination is particularly important for large organisations and where departments, teams, or individuals differ in their specific objectives. This is the case for public sector agencies such as SEPA. Efforts to identify the mismatches and integrate the practical demands of different policies were already being made: significantly, SEPA had already designated a post as responsible for liaising and integrating the goals of the flooding policy with those goals for restoration under the Water Framework Directive. The challenges of co-ordination within one organisation may be less visible than the challenges of co-ordinating between organisations, but may be equally significant.

## Discussion

This study has identified a mixture of challenges are interacting to constrain uptake of NFM in Scotland. This echoes existing observations that a growing discourse valorises and emphasises approaches such as NFM, but technical expertise and structural solutions are still favoured in practice (Wiering and Arts, 2006; Wolsink, 2006; Wesselink *et al.*, 2007; Cook *et al.*, 2016). Our findings build understanding of the reasons why this occurs.

Many challenges relate to difficulties in allocating resources, using new forms of knowledge, and the complexities of co-ordination. These echo challenges reported in

 

studies of closely related concepts in the UK such as ecological restoration (Adams *et al.*, 2004, 2005) and studies from elsewhere, especially the bodies of work in Germany and the Netherlands (e.g. Wesselink and Warner, 2010; Krieger, 2013). We furthermore identify how challenges arise from mismatches in procedures, skill sets and work processes within and between organisations. We also suggest it is important to see these challenges as interconnected (Lane *et al.*, 2013) and to fully interrogate the detail of challenges – e.g. complaints about absent resources may actually relate to pre-existing rules preventing resource re-allocation.

## Implications for enabling NFM

At present, many managing flood risk identify a need for resources to incentivise and enable NFM, and a need for more evidence to demonstrate measures' effectiveness. These are important needs. However, we suggest that the long-term widespread adoption and support for NFM will depend equally on facilitating changes in understandings and cultures of flood risk management. This needs emphasis precisely because it is currently overlooked (van Buuren, 2013). Adoption of NFM, as for Sustainable Flood Management as a whole, requires a paradigm shift (Cook *et al.*, 2016). Without more effort to achieve this, the promise of this and other new concepts is unlikely to be realised (Eden and Tunstall, 2006).

Frustratingly, at present much more is understood about the challenges of change, than about how to achieve it (Pahl-Wostl *et al.*, 2013). However, literatures on 'transformation' (e.g. Abson *et al.*, 2017) and 'transition' (Pahl-Wostl, 2007) are beginning to offer insights about practical techniques and principles that may assist. In particular, it seems important to encourage social learning (e.g. Pahl-Wostl *et al.*, 2007), which can be understood to encompass different 'loops' or levels of learning, achieved through individuals' interaction. Enabling this reflection entails resourcing time, space and skills that can bring together all key stakeholders (e.g. Benson *et al.*, 2016).

It is particularly important to appreciate the role of pre-existing views and understandings about water and flood management (Wesselink and Warner, 2010). Understandings of water systems, risk, and the ability to control change will all affect perceptions of flooding and proposals for specific measures (Hillman, 2009). As modernist expectations for control of nature are still prevalent, even if not recognised as such, they can pose a significant barrier to accepting new forms of flood management (Harries and Penning-Rowsell, 2011). To tackle this challenge, those seeking to facilitate new forms of flood management must find a way to prompt recognition and reflection on pre-existing assumptions and expectations, during the social learning approaches discussed above. This could be enabled by structured interaction with approaches such as scenario-planning to enable participant reflection, learning and planning by discussing future possibilities and priorities (Brown *et al.*, 2016).

If less 'traditional' forms of understanding and controlling floods are encouraged, less 'traditional' ways of organising and co-ordinating may also be entailed (Hillman, 2009). It is thought that institutions connected with flood risk management tend to resist change, albeit often inadvertently (van Buuren *et al.*, 2014). Therefore, we must explicitly discuss and strive for culture change in order to meet the demands of new approaches to flood risk management (Potter *et al.*, 2011). We may ultimately need to reconsider every aspect of conventional approaches to flood risk management (Merz *et al.*, 2010). Literature on adaptive governance may provide useful ideas about potential new governance arrangements (Wyborn, 2015) but the practical implications for flood risk management are not yet clear. It is a priority for researchers to identify and to better articulate these implications. For example, we know that changed understandings about the ability to control floods may need to be accompanied by changes in who is involved and how in the management process itself (Penning-Rowsell and Johnson, 2015). However, more work is still needed to identify the appropriate mix of rights and responsibilities, and how public agencies can continue to best 'steer' such processes (e.g. Garrelts and Lange, 2011).

## Implications for future research

The previous section makes clear that more research is required to inform and enable sustainable flood management. In particular, work is required to interpret how challenges may lead to opportunities for change, and how to interpret and apply abstract concepts. For example, this study exemplifies the idea that legacy can create 'sticking points' (Waylen *et al.*, 2015) or even 'lock in' (Wesselink *et al.*, 2007) to impede new approaches. Although understanding and acknowledging this is important, it is only the first step. The essential second step – identifying how these issues can be tackled to enable change – is more poorly understood. For example, what specific approaches and settings best allow those engaged in flood risk management to recognise and re-examine their views and expectations, and identify how these shape their work practices and collaborations?

To build this knowledge, more comparative studies in water management are needed (Boeuf and Fritsch, 2016). However, even countries sharing a technocratic legacy will still have contrasting governing styles and cultures, affecting how flood risks are appraised (Bubeck *et al.*, 2012). Furthermore, procedures will vary across places and across time. Efforts to generalise across cases must take these

differences and specificities into account. For example, in this study we noted several challenges arising from specific requirements and set procedures such as Cost-Benefit Analysis; another constraint would be eased if planners were able to allocate budgets over a number of years, instead of one-off capital expenditures. It is unknown whether or not these specific constraints are relevant to other places, nor if they will still be cited as important in 5 or 10 years' time. So, although we have observed that policy support for NFM has so far not caused much effect in Scotland, this may yet change. It is possible that as statutory activity shifts to delivering rather than creating the plans required by the Floods Directive, there will in future be more space to consider and deliver NFM. We must therefore track how barriers are perceived to change over time.

It is unclear if such studies of change could be more productively be framed – e.g. Warner *et al.* (2010) identify different types of boundaries as governance challenges. The value of different analytic perspectives should be explored to ensure understanding of flood management can benefit by the insights of multiple literatures, particularly on transitions and transformation (e.g. Pahl-Wostl *et al*., 2010) and working across levels (Newig *et al*., 2015). Relevant insights may also come from studies that are not explicitly or solely about water governance (Evans, 2012), such as the emerging body of work on nature-based solutions (Eggermont *et al*., 2015; e.g. Kabisch *et al*., 2016). However, perceptions of risk and the social impacts of flood events may complicate – or galvanise action – are specific to flood management. Therefore, future work to understand and introduce changes in flood risk management must always remain sensitive to both similarities and differences across time, settings, and with other fields of natural resource management.

## Conclusion

The drive to adopt NFM reflects a general trend to move away from technocratic approaches in natural resource management. However, adopting new concepts is often associated with challenges. Our study indicates that NFM in Scotland is no exception: slow progress is explained by challenges of co-ordination, using evidence and re-allocating resources. These challenges can be quite tangible (e.g. specific statutory requirements but also arise from more tacit issues such as skill sets and pre-existing cultures of organisation and collaboration. These tacit issues need more recognition: a re-examination of existing ways of working and understanding may be required to enable widespread adoption of this and other new approaches. Better links between research, policy, and practitioners are essential in order to share learning and prompt reflection on the changes needed to enable sustainable flood risk management.

## Acknowledgements

We thank all participants in this research, and all who have commented on earlier versions of this manuscript, including Dr M. Wilkinson and Dr K. Blackstock. The research for this paper was supported by the Scottish Government RESAS Strategic Research Programme 2011–2016.

## References

Abson D.J., Fischer J., Leventon J., Newig J., Schomerus T., Vilsmaier U., von Wehrden H., Abernethy P., Ives C.D., Jager N.W. & Lang D.J. Leverage points for sustainability transformation. *Ambio* 2017, **46**, (1), 30–39.

Adams W.M., Perrow M.R. & Carpenter A. Conservatives and champions: river managers and the river restoration discourse in the United Kingdom. *Environ Plan A* 2004, **36**, 1929–1942.

Adams W.M., Perrow M.R. & Carpenter A. Perceptions of river managers of institutional constraints on floodplain restoration in the UK. *J Environ Plan Manage* 2005, **48**, (6), 877–889.

Benson D., Lorenzoni I. & Cook H. Evaluating social learning in England flood risk management: an 'individual-community interaction' perspective. *Environ Sci Policy* 2016, **55**, (2), 326–334.

Boeuf B. & Fritsch O. Studying the implementation of the Water Framework Directive in Europe: a meta-analysis of 89 journal articles. *Ecol Soc* 2016, **21**, (2), 19.

Bracken L., Oughton E., Donaldson A., Cook B., Forrester J., Spray C., Cinderby S., Passmore D. & Bissett N. Flood risk management, an approach to managing cross-border hazards. *Nat Hazards* 2016, **82**, (2), 217–240.

Bridges T.S. & Walker J. *Presentation: Engineering with Nature*, US Army Corps of Engineers, Charleston, South Carolina, 2011.

Brown J.D. & Damery S.L. Managing flood risk in the UK: towards an integration of social and technical perspectives. *Trans Inst Br Geogr* 2002, **27**, (4), 412–426.

Brown I., Martin-Ortega J., Waylen K. & Blackstock K. Participatory scenario planning for developing innovation in community adaptation responses: three contrasting examples from Latin America. *Reg Environ Chang* 2016, **16**, (6), 1685–1700.

Bubeck P., Kreibich H., Penning-Rowsell E., Botzen W., De Moel H. & Klijn F. Explaining differences in flood management approaches in Europe and the USA-A comparative analysis. In: F. Klijn & T. Schweckendiek, eds. *Comprehensive Flood Risk Management. Research for policy and practice, Proceedings of the FLOODrisk2012 conference*, 2012.

Buijs A.E. Public support for river restoration. A mixed-method study into local residents' support for and framing of river

 

management and ecological restoration in the Dutch floodplains. *J Environ Manage* 2009, **90**, (8), 2680–2689.

van Buuren A. Knowledge for water governance. *Int J Water Gov* 2013, **1**, 157–175.

van Buuren A., Potter K., Warner J. & Fischer T. Making space for institutional change? A comparative case study on regime stability & change in river flood management in the Netherlands & England. *Int J Water Gov* 2014, **4**, (3), 81–100.

Cook B., Forrester J., Bracken L., Spray C. & Oughton E. Competing paradigms of flood management in the Scottish/English borderlands. *Disaster Prev Manag* 2016, **25**, (3), 314–328.

Cooper J.A.G. & McKenna J. Working with natural processes: the challenge for coastal protection strategies. *Geogr J* 2008, **174**, (4), 315–331.

Crichton D. 12 International historical, political, economic, social, and engineering responses to flood risk. In: J. Lamond, C. Booth, F. Hammond, & D.G. Proverbs, eds. *Flood hazards: impacts and responses for the built environment*. Boca Raton, FL: CRC Press, 2011, 155–176.

Eden S. & Tunstall S. Ecological versus social restoration? How urban river restoration challenges but also fails to challenge the science ? Policy nexus in the United Kingdom. *Environ Plan C Gov Policy* 2006, **24**, (5), 661–680.

Eggermont H., Balian E., Azevedo J.M.N., Beumer V., Brodin T., Claudet J., Fady B., Grube M., Keune H., Lamarque P., Reuter K., Smith M., van Ham C., Weisser W.W. & Le Roux X. Nature-based solutions: new influence for environmental management and research in Europe. *GAIA* 2015, **24**, (4), 243–248.

European Commission. Communication from the Commission to the European Parliament and the Council on the Water Framework Directive and the Floods Directive: actions towards the 'good status' of EU water and to reduce flood risks, COM(2015) 120 final, 2015.

Evans E. *Foresight: future flooding: scientific summary: volume II: managing future risks*. London: Department of Trade and Industry, 2004.

Evans J. *Environmental governance*. Abingdon: Routledge, 2012.

Fischhendler I. & Heikkila T. Does integrated water resources management support institutional change? The case of water policy reform in Israel. *Ecol Soc* 2010, **15**, 4.

Garrelts H. & Lange H. Path dependencies and path change in complex fields of action: climate adaptation policies in Germany in the realm of flood risk management. *Ambio* 2011, **40**, (2), 200–209.

Guerrin J. A floodplain restoration project on the River Rhône (France): analyzing challenges to its implementation. *Reg Environ Chang* 2015, **15**, (3), 559–568.

Harries T. & Penning-Rowsell E. Victim pressure, institutional inertia and climate change adaptation: the case of flood risk. *Glob Environ Chang* 2011, **21**, 188–197.

Hillman M. Integrating knowledge: the key challenge for a new paradigm in river management. *Geogr Compass* 2009, **3**, (6), 1988–2010.

Holstead K., Kenyon W., Rouillard J., Hopkins J. & Galán-Díaz C. Natural flood management from the farmer's perspective: criteria that affect uptake. *J Flood Risk Manage* 2016a, in press.

Holstead K.L., Colley K. & Waylen K.A. *Tackling the barriers to implementing Natural Flood Management: Summary Workshop Report*. Aberdeen: The James Hutton Institute, 2016b.

Huq N. & Stubbings A. How is the role of ecosystem services considered in local level flood management policies: case study in Cumbria, England. *J Env Assmt Pol Mgmt* 2015, **17**, (4), 1550032.

Iacob O., Rowan J.S., Brown I. & Ellis C. Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective. *Hydrol Res* 2014, **45**, (6), 774–787.

Ingram H. & Fraser L. Path dependency and Adroit innovation: the case of California water. In: R. Repetto, ed. *Punctuated equilibrium and the dynamics of U.S. environmental policy*. New Haven, CT: Yale University Press, 2006, 78–109.

JBA Consulting. Woodland and Natural Flood Management - Lessons Learned, Final Report for the Forestry Commission, Forestry Commission, Farnham, Surrey, 2015.

Johnson C.L., Tunstall S.M. & Penning-Rowsell E.C. Floods as catalysts for policy change: historical lessons from England and Wales. *Int J Water Resour D* 2005, **21**, (4), 561–575.

Kabisch N., Frantzeskaki N., Pauleit S., Naumann S., Davis M., Artmann M., Haase D., Knapp S., Korn H. & Stadler J. Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecol Soc* 2016, **21**, (2), 39.

Kirk E., Reeves A. & Blackstock K. Path dependency and the implementation of environmental regulation. *Environ Plan C Gov Policy* 2007, **25**, (2), 250–268.

Krieger K. The limits and variety of risk-based governance: the case of flood management in Germany and England. *Regul Gov* 2013, **7**, (2), 236–257.

Lane S.N., Odoni N., Landström C., Whatmore S.J., Ward N. & Bradley S. Doing flood risk science differently: an experiment in radical scientific method. *Trans Inst Br Geogr* 2011, **36**, (1), 15–36.

Lane S.N., November V., Landström C. & Whatmore S. Explaining rapid transitions in the practice of flood risk management. *Ann Assoc Am Geogr* 2013, **103**, (2), 330–342.

McIntyre N. & Thorne C., eds *Land use management effects on flood flows and sediments – guidance on prediction*. London: CIRIA, 2013.

Merz B., Hall J., Disse M. & Schumann A. Fluvial flood risk management in a changing world. *Nat Hazards Earth Syst Sci* 2010, **10**, (3), 509–527.

Monaghan P. *Sustainability in austerity*. Sheffield: Greenleaf Publishing, 2010.

Moss T. The governance of land use in river basins: prospects for overcoming problems of institutional interplay with the

EU Water Framework Directive. *Land Use Policy* 2004, **21**, (1), 85–94.

Newig J. & Fritsch O. Environmental governance: participatory, multi-level – and effective? *Environ Policy Governance* 2009, **19**, (3), 197–214.

Newig J., Kochskämper E., Challies E. & Jager N.W. Exploring governance learning: how policymakers draw on evidence, experience and intuition in designing participatory flood risk planning. *Environ Sci Policy* 2015, **55**, (2), 353–360.

Nisbet T.R., Roe P., Marrington S., Thomas H., Broadmeadow S. & Valatin G. Slowing the flow at pickering, final report phase II for the department of environment, food and rural affairs (Defra), Project RMP5455, Defra, London, 2015.

Pahl-Wostl C. Transitions towards adaptive management of water facing climate and global change. *Water Resour Manag* 2007, **21**, (1), 49–62.

Pahl-Wostl C., Sendzimir J., Jeffrey P., Aerts J., Berkamp G. & Cross K. Managing change toward adaptive water management through social learning. *Ecol Soc* 2007, **12**, (2), 30.

Pahl-Wostl C., Holtz G., Kastens B. & Knieper C. Analyzing complex water governance regimes: the management and transition framework. *Environ Sci Policy* 2010, **13**, (7), 571–581.

Pahl-Wostl C., Giupponi C., Richards K., Binder C., de Sherbinin A., Sprinz D., Toonen T. & van Bers C. Transition towards a new global change science: requirements for methodologies, methods, data and knowledge. *Environ Sci Policy* 2013, **28**, 36–47.

Parrott A., Brooks W., Harmar O. & Pygott K. Role of rural land use management in flood and coastal risk management. *J Flood Risk Manage* 2009, **2**, (4), 272–284.

Penning-Rowsell E.C. Flood-hazard response in Argentina. *Geogr Rev* 1996, **86**, (1), 72–90.

Penning-Rowsell E.C. & Johnson C. The ebb and flow of power: British flood risk management and the politics of scale. *Geoforum* 2015, **62**, 131–142.

Penning-Rowsell E., Johnson C. & Tunstall S. 'Signals' from pre-crisis discourse: lessons from UK flooding for global environmental policy change? *Glob Environ Chang* 2006, **16**, (4), 323–339.

Perfect C., Addy S. & Gilvear D.. *The Scottish rivers handbook – a guide to the physical character of Scotland's rivers*, CREW, Scottish Government, James Hutton Institute, Centre for River EcoSystem Science, 2013.

Pitt M. *The Pitt Review: lessons learned from the 2007 floods*. London: Cabinet Office, 2008.

Potter K., Ward S., Shaw D., Macdonald N., White I., Fischer T., Butler D. & Kellagher R. Engineers and planners: sustainable water management alliances. *Proc Inst Civ Eng Eng Sustainability* 2011, **164**, (4), 239–247.

Rijke J., van Herk S., Zevenbergen C. & Ashley R. Room for the River: delivering integrated river basin management in the Netherlands. *Intl J River Basin Management* 2012, **10**, (4), 369–382.

Rouillard J.J., Reeves A.D., Heal K.V. & Ball T. The role of public participation in encouraging changes in rural land use to reduce flood risk. *Land Use Policy* 2014, **38**, 637–645.

Rouillard J.J., Ball T., Heal K.V. & Reeves A.D. Policy implementation of catchment-scale flood risk management: learning from Scotland and England. *Environ Sci Policy* 2015, **50**, 155–165.

Scottish Government. The Flood Risk Management (Scotland) Act 2009: Flood Protection Schemes – Guidance for Local Authorities, Chapter 5: Project Appraisal: assessment of economic, environmental and social impacts, Edinburgh, 2012.

SEPA *Flood risk management planning in Scotland: arrangements for 2012-2016*. Stirling: Scottish Environment Protection Agency (SEPA), 2012.

SEPA *Natural flood management handbook*. Stirling: Scottish Environment Protection Agency (SEPA), 2016.

Silverman D., ed *Qualitative research. Theory, method and practice*. London: Sage Publications, 2004.

Spray C., Ball T. & Rouillard J. Bridging the water law, policy, science interface: flood risk management in Scotland. *J Water L* 2009, **20**, (2–3), 165–174.

Stirling A. "Opening up" and "closing down" power, participation, and pluralism in the social appraisal of technology. *Sci Technol Human Values* 2008, **33**, (2), 262–294.

Stirling A. Opening up the politics of knowledge and power in bioscience. *PLoS Biol* 2012, **10**, (1), e1001233.

Strauss A. & Corbin J. *Basics of qualitative research: procedures and techniques for developing grounded theory*. Thousand Oaks, CA: Sage, 1998.

Teisman G., van Buuren A., Edelenbos J. & Warner J. Water governance: facing the limits of managerialism, determinism, water-centricity, and technocratic problem-solving. *Int J Water Gov* 2013, **1**, 1–11.

Thomas F. & Knüppe K. From flood protection to flood risk management: insights from the Rhine River in North Rhine-Westphalia, Germany. *Water Res Manag* 2016, **30**, (8), 2785–2800.

Warner J., Lulofs K. & Bressers H. The fine art of boundary spanning: making space for water in the East Netherlands. *Water Altern* 2010, **3**, (1), 137.

Warner J.F., van Buuren A. & Edelenbos J. *Making space for the river: governance experiences with multifunctional river flood management in the US and Europe*. London: IWA Publishing, 2013.

Washbourne N. & Dicke W. Dissolving organization theory? A narrative analysis of water management. *Int Stud Manage Organ* 2001, **31**, (3), 91–112.

Waylen K.A., Blackstock K.L. & Holstead K.L. How does legacy create sticking points for environmental management? Insights from challenges to implementation of the ecosystem approach. *Ecol Soc* 2015, **20**, 1–13.

 

Werritty A. Sustainable flood management: oxymoron or new paradigm? *Area* 2006, **38**, (1), 8.

Wesselink A. & Warner J. Reframing floods: proposals and politics. *Nat Cult* 2010, **5**, (1), 1–14.

Wesselink A.J., Bijker W.E., de Vriend H.J. & Krol M.S. Dutch dealings with the delta. *Nat Cult* 2007, **2**, (2), 188–209.

Wesselink A., Warner J., Abu Syed M., Chan F., Duc Tran D., Haq H., Huthoff F., Le Thuy N., Pinter N. & Van Staveren M. Trends in flood risk management in deltas around the world: are we going 'soft'. *Int J Water Gov* 2015, **3**, 25–46.

Wheater H.S. Flood hazard and management: a UK perspective. *Philos Trans A Math Phys Eng Sci* 2006, **364**, (1845), 2135–2145.

Wiering M. & Arts B. Discursive shifts in Dutch river management: 'deep' institutional change or adaptation strategy? *Hydrobiologia*. 2006, **565**, (1), 327–338.

Wilkinson M., Holstead K.L. & Hastings E. Natural Flood Management in the context of UK reservoir legislation, CREW report CD2012/23, Scotland's Centre of Expertise for Waters, 2013.

Wilkinson M.E., Quinn P.F., Barber N.J. & Jonczyk J. A framework for managing runoff and pollution in the rural landscape using a Catchment Systems Engineering approach. *Sci Total Environ* 2014, **468–469**, 1245–1254.

Wolsink M. River basin approach and integrated water management: governance pitfalls for the Dutch Space-Water-Adjustment Management Principle. *Geoforum* 2006, **37**, (4), 473–487.

WWF Scotland *Slowing the flow: a natural solution to flooding problems*. Dunkeld, Scotland: WWF Scotland, 2007.

Wyborn C. Co-productive governance: a relational framework for adaptive governance. *Glob Environ Chang* 2015, **30**, 56–67.