# How river catchments can be better managed to control flood risk and provide biodiversity benefits

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A critical discussion of options and experience and suggestions for ways forward

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## Abstract

This paper critically discusses options for farmland, river and floodplain management to resolve flood risk and provide biodiversity benefits. Focusing on the UK context, where there is a call for working more closely with nature. Restoration of natural systems provides the best opportunities for habitat creation and biodiversity, but the benefits to flood risk management can be limited, unless applied at the catchment scale. Conventional hard-engineered approaches offer proven but expensive flood resolution, and there is now a move towards more soft-engineered, multi-purpose, low cost, naturalistic schemes involving the whole landscape. The effectiveness for biodiversity improvements must be balanced by the overriding priority to protect people from flooding. Linking biodiversity and flood risk management is an important step, but does not go far enough.

## Contents

# 1 Introduction

Conventional approaches to flood defence are now often being succeeded by a more holistic, naturalistic approach to flood risk management (FRM). Policies such as 'Making Space for Water' (DEFRA 2005) recognised that flooding cannot be fully prevented, but that the risks can be controlled by widely dispersing flood zones throughout a catchment and by reversing the anthropogenic changes that compound and exacerbate flooding. This approach requires conventional hard-engineered defences be considered only as a last resort, after land, river and floodplain management (constituting a "soft engineered" approach) has been fully explored.

Soft-engineered solutions should be considered across three main categories:

1. Restoring the hydraulic response of the full catchment hydrology in the wider landscape; typically farmland – where changes in farming practice have damaged soil water infiltration, accelerated run-off and intensified evaporation of rainwater (FIGURE 1.1).

2. The re-establishment and restoration of the natural functions of rivers and floodplain environments.

3. Engineering of naturalistic flood alleviation measures as an alternative to technocratic, bureaucratic and costly structures such as dams and walls, with an emphasis on small-scale, locally managed features. This FRM approach aims to attenuate water in suitable areas, or to improve conveyance through areas only where space prevents storage.

A key question is whether management for both flood alleviation and biodiversity is compatible. This paper addresses categories of management for FRM and biodiversity enhancement, and critically evaluates the inherent problems.

*Figure 1.1 Arable field, Painswick. 30cm of topsoil lost in 50 years of arable farming (effects of tillage and chemicals) - agricultural soil degradation typically comprises the biggest single cause of flood and drought in any river catchment, whilst also severely degrading biodiversity here.*

# 2 Restoration of natural systems for flood risk and biodiversity

Despite an increasingly common expressed "knowledge" of the benefits of the use of floodplains and rivers in their natural state to alleviate flooding (e.g. MILLENNIUM ECOSYSTEM ASSESSMENT 2005; MALLEE CATCHMENT AUTHORITY 2010) further examination of the concept is required. The principle is derived logically from the hydrological cycle and traditional methods of water management. Initial hydrological evidence for this working within entire catchments is cautious (ACREMAN ET AL 2001; NISBET 2004; O'CONNELL ET AL 2004), but detailing of the concept in determining catchment hydraulic capacity for additional flood storage (PRETTO 2008) and stored water resource usage and landowner acceptance of this (BROADHEAD 2009) is highly encouraging.

Conventional flood protection, such as canalisation and flood defence walls, tries to keep water in rivers and seeks to improve conveyance downstream (and out of any catchment) in order to prevent flooding on adjacent land. Water must go somewhere however, and thus improved conveyance often increases flooding in unprotected downstream areas, dehydrates soils (worsens drought), degrades habitats and biodiversity. Such an accelerated hydrological cycle ultimately leads to whole cycle environmental degradation with widespread threats to biodiversity.

## 2.1 Agricultural context

Agricultural degradation of soil structure, due to either arable or grazing intensification, leads to a reduction in soil infiltration rates and available soil water storage capacities, increasing rapid runoff in the form of overland flow (O'CONNELL ET AL 2004; WHEATHER AND EVANS 2009) and an increase in evaporation that intensifies rainfall events. In the UK and elsewhere in Northern Europe, farmland typically comprises the major area of any river rainfall catchment and such soil degradation must therefore be considered as a major cause of increased risk of flooding. However, only recently has the role of land use management in enhancing or ameliorating UK flood risk has been identified as an unanswered question by Defra.

*Figure 2.1. Slad Brook. Agricultural sediment (both topsoil and animal manures) in watercourses often comprises a major and persistent pollution; this may be further contaminated with farm chemicals.*

Around 2.2 million tonnes of topsoil is eroded annually in the UK, significantly affecting the productivity of soils and impacting on water quality and aquatic biodiversity through the silting up of watercourses (ENVIRONMENT AGENCY 2004). Soil erosion costs include loss of productivity, water treatment, damage to property and dredging stream channels (ENVIRONMENT AGENCY 2007).

Excess sediment can profoundly affect the biodiversity of a watercourse. The habitat complexity of a stream can be greatly compromised if there is a high sediment supply, which in addition to topsoil and manures, may also include highway runoff and sedimenting sewage (FIGURE 2.1). The negative effects for fisheries typically extend to loss of spawning, egg and alevin survival rates, rearing habitat and adult holding habitat (FIGURE 2.2). A UK strategy for reduction of soil erosion and protection of soil carbon (humus) is now developing (DEFRA 2009).

*Figure 2.2 Salmonid eggs are sensitive to sediments (farm, highways and sewage) and farm chemicals.*

Biological farming methods (biodynamic, permaculture, microbial etc) hold the potential to maintain food productivity while also sequestrating atmospheric carbon to increase soil humus (i.e. Carbon Farming), better infiltrating rain and controlling run off (water and silt). The negation of the use of farm chemicals would not only benefit biodiversity but also, in the longer term, water resource availability. The combined flood, drought and biodiversity benefits for watercourses of biological farming require quantification. Anecdotal claims include typically improved soil rainwater retention of over 500,000 litres per hectare of farmland after just five years of biological farming.

The surest way to manage rivers and floodplains is to encourage positive change on farmland, as the major receiving area of any catchment, by both modifying farming methods and providing space to store floodwater (FIGURE 2.3). The move to a low-carbon economy will increasingly influence land use decisions, settlement patterns and the design of urban environments. Agriculture, forestry and semi-natural habitats will have the potential to play important roles in mitigating the causes and effects of climate change (FORESIGHT LAND USE FUTURES PROJECT 2010). These changing land use perspectives, an increased need for food security, enlarged renewable energy capacity and the role for climate change adaptation will be profound in their implications for our landscape – and biodiversity.

These problems of poor land and river management can be reversed, whilst helping biodiversity by:

1. Encouraging the adoption of soil management practices on farmland that assist retention and infiltration of rainwater.

2. Ensuring there is space for natural flooding.

3. Reducing flooding effects exacerbated by other human actions.

*Figure 2.3 Sustainable highways drainage pond (Gloucestershire County Council), Painswick Stream, provides floodwater buffering and retention of highway sediment while helping biodiversity.*

## 2.2 Urban context

In the urban environment there is a realisation of the need to prevent further development in flood zones and/or implement modifications of rivers to enable flood protection here, as in the Flood and Water Management Act 2010. Planning Policy Statement 25: Development and Flood Risk (PPS25) promotes sustainable development, and aims to, "avoid, reduce and manage flood risk *by taking full account* in (planning) decisions". This is interpreted as a requirement to consider not only the flood risk to proposed developments, but also the *wider implications* of the development on flood risk outside of the bounds of the proposed development. Yet Strategic Flood Risk Assessments only designate areas of flood risk – there is no formal mechanism in place that determines the consequential implications, in cumulative terms, of additional flood risk arising from new developments, or to existing urban areas at risk. Fulfilment of such a planning regime could enable exciting new possibilities for enhancing biodiversity in urban areas.

This interpretation of PPS25 (paragraph 6), requiring consideration as to the effects of any proposed new development on wider flood risk, is backed by the aim to, “reduce flood risk to and from new development through location, layout and design, incorporating sustainable drainage systems (SuDS)...”. PPS25 also suggests that existing flood risk in catchments can be reduced by “using opportunities offered by new development to reduce the causes and impacts of flooding...”, an invitation to planning authorities to make wider flood compensating demands on new developments in order to provide retrospective flood protection (FIGURE 2.4).

*Figure 2.4 Springhill Cohousing, Stroud. High density housing on a steep site, yet SuDS proliferates here, rills and swales collect and store rain water, while benefiting biodiversity (Robert Bray Associates).*

## 2.3 Implications for planning authorities

PPS25 is an integral part of floodplain management, yet new developments often have sustainable drainage systems (SuDS) that still simply convey surcharged surplus floodwater downstream, or in some catchments become submerged and ineffective in major flood inundations, because they are apparently planned without any reference to a wider catchment hydraulic context. Planning conflicts between developers, the Environment Agency and local planning authorities are apparently often unable to enforce the principles sufficiently (e.g. THIS IS GLOUCESTERSHIRE 2008, 2010).

PPS25 encourages planning authorities to “manage flood risk by taking *full account* …”, yet there is apparently no formal attempt in hydraulic terms to fully account here. The Flood and Water

Management Act 2010 furthers the wider principles of Making Space for Water, and defines a Lead Local Flood Authority (LLFA) that now enables a legitimised actor to fulfil this role.

The encouragement of widespread urban implementation of soft (landscape) engineered SuDS could be viewed thus as a unique tool, within an overall catchment hydraulic model (that also allows for wider rural (farmland) flood attenuation), for planners to now achieve important biodiversity and well being benefits in addition to resolving critical flood risks in urban areas.

Soft engineered SuDS schemes thus offer important biodiversity benefits for both the urban and rural environment – improved habitats, qualitative benefits for adjacent watercourses and thermal buffering against temperature extremes.

# 3 Engineering rivers and floodplains

“Roughness” of a stream channel increases due to the presence of rocks, vegetation, and debris. Channelising a stream by doing such things as removing vegetation or lining the stream bed with concrete will reduce the roughness. The roughness factor has a direct impact on how quickly the water will move in the channel and how high the peak flood stage will be. The greater the roughness, the more turbulent the flow. More turbulent flow results in slower runoff and streamflow velocities. This allows more time for infiltration, and it also results in a broader flood wave with lower peak discharges than in rapid runoff situations (FIGURE 3.1).

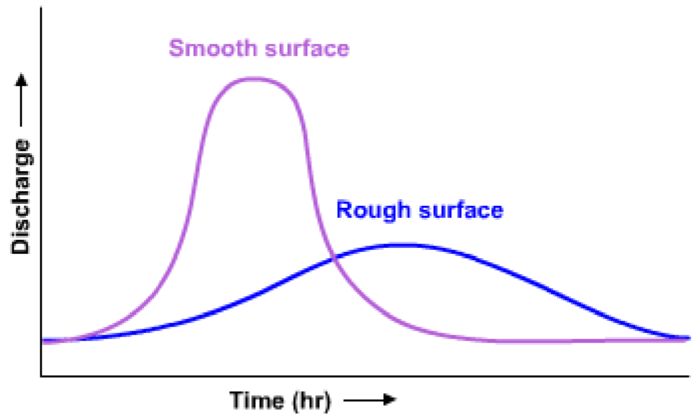


*Figure 3.1 Hydrographic responses to increased flow of rough (natural) watercourse channels vs. smooth (channelised).*

Restoring a ‘natural’ river channel cross-section reduces the channelisation effect of dredging, straightening, and deepening. Natural river channels are hydraulically rough, and woody (or rock) debris in the channel is encouraged (PIÉGAY AND GURNELL 1997) to the benefit of biodiversity. Meso-scale channel restoration is demonstrably compatible with biodiversity, because a hydraulically rough and complex channel contains more hydraulic habitats (NEWSON AND NEWSON 2000). At the catchment scale, this approach is compounded by heavily modified watercourses and urban areas, pointing towards the need to modify such developments in the first place.

Any works on watercourses can sometimes cause pollution through sediment disturbance (KRONVANG ET AL 1998) and this must be weighed against long term benefits. Such measures should only be undertaken within the context of a complete catchment hydraulic model – and be constructed to standards appropriate to the worst case flows that will be likely.

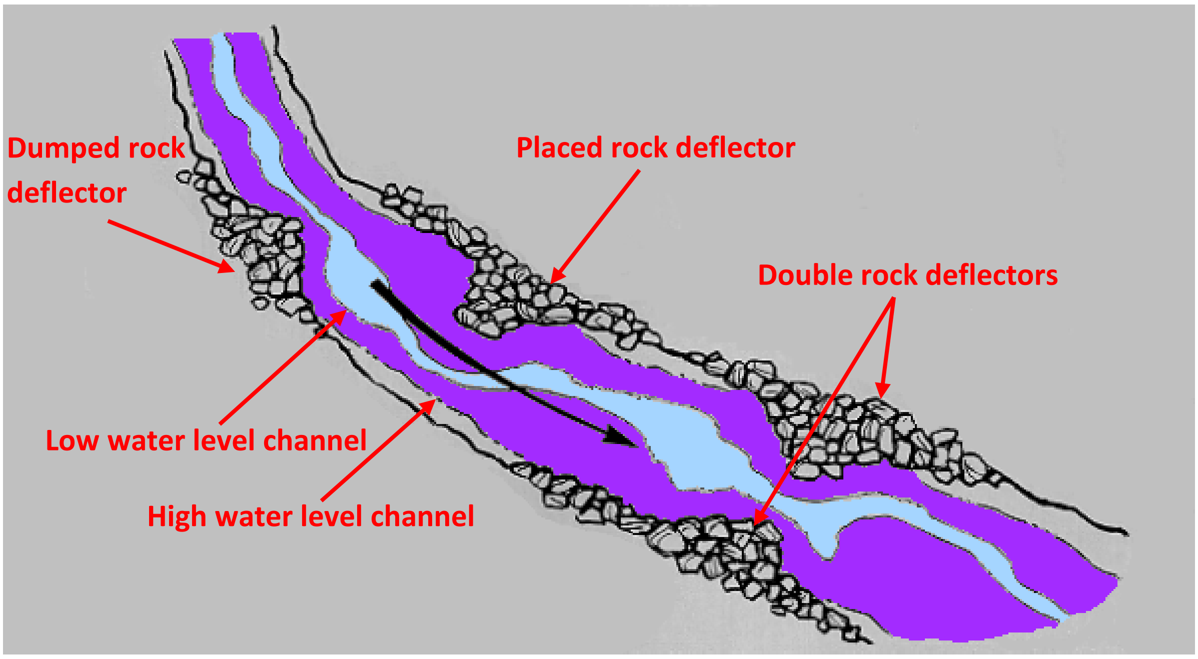


*Figure 3.2 Increasing the roughness of a stream can benefit flood control, biodiversity and other water resource uses, fisheries for example.*

Allowing increasing channel roughness by growth of vegetation, or artificially through placement of rocks and gabions can conflict with outdated regulations, which effectively treat rivers as drains – reinforced in England as a statutory duty of riparian owners to maintain free flow of watercourses by even removing natural vegetation (ENVIRONMENT AGENCY 2007) (FIGURE 3.2).

A recent Gloucestershire study recommended channel vegetation clearance to improve conveyance to alleviate flooding to gardens (GREEN 2009), an £89,000 process (STROUD DISTRICT COUNCIL 2008) which unfortunately accelerated flows through an area of farmland that could safely receive flood events and on into areas unable to deal adequately with further flood risk, while destabilising banks and also severely degrading local biodiversity and fishing.

Floodplain wetlands have been lost across the UK for agricultural and urban development, and embankments created to keep water in rivers. Rivers can be reconnected to their floodplains, restoring frequent inundation to the benefit of pastures. In principle, floodplain storage alleviates flooding in downstream towns by attenuating and slowing the hydrograph.

Reconnection can be made at small scales with water quality and biodiversity as a focus also, even in heavily urbanised areas, such as the Bourne Stream Partnership (2010). Increased runoff from existing developments was partially resolved by restoring banks to reconnect past flood meadows (FIGURE 3.3). However, FRM here was less effective than with potential engineered solutions, because this would compromise biodiversity (ARMITAGE ET AL 1994; AQUILINA 2003).


*Figure 3.3 Bourne Valley Park (before and after construction). Exposing a culverted stream in an urban park to provide flood water storage, leisure and biodiversity benefits (Bourne Stream Partnership).*

At the larger scale, former riverine floodplains are being successfully reclaimed from intensive agriculture by conservation groups, with the intention of restoring floodplain ecology (e.g. BIGGS ET AL 1998) through the Flood Pulse Concept (JUNK ET AL 1989), providing nutrients, flood attenuation and ecological benefits. Although modelling indicates a benefit to downstream flood levels, it is difficult to be certain of the effectiveness of such a system (ACREMAN ET AL 2001; INSTITUTION OF CIVIL ENGINEERS 2001). The biodiversity, leisure and heritage value of managed water meadows in this respect can outweigh the economic benefit derived from their agriculture in modern times (COOK AND WILLIAMSON 2006).

Moreover, restoration of entirely natural systems is limited by lack of pristine reference conditions, the extensive number of heavily-modified watercourses, and the inherent bias in decision-making prioritising flooding over biodiversity. Deeper floodplain inundation is often less beneficial to floodplain ecology – hydrological conditions determine the assemblage (ENVIRONMENT AGENCY 2009). The problem with managing rivers and floodplains for something as critical as flooding in addition to biodiversity, is the inherent trade-off between the effectiveness of the two. Restoration of catchment rivers may thus be beneficial (UNESCO 2009), and cost-effective if achieved through voluntary best-practice, but difficult to rely on compared with hard-engineered or actively managed schemes. Despite calls for working with natural processes, drainage policy recognises many rivers and floodplains as anthropogenic features, and so often promotes conventional solutions (ENVIRONMENT AGENCY 2009). However, there are opportunities to "naturalise" this.

Despite calls to integrate biodiversity earlier in planning hard-engineered FRM schemes (ENVIRONMENT AGENCY 2009), operational experience suggests this may be slow to change. This places a special emphasis on the role of Local Authorities in encouraging such approaches. Conventional hard-engineered solutions (e.g. concrete-lining, channelisation, straightening, and bypass-channels) which effectively treat rivers as drains, afford little biodiversity benefits. But balancing lakes with freeboard storage can provide valuable habitats, for example in Willen Lake, Milton Keynes (FIGURE 3.4). These large-scale engineered reservoirs are built for economy of scale, but can be difficult and expensive to retrofit to existing urban areas, and visually impactful for rural situations.

*Figure 3.4 Constructed lake, Dursley. Now visited by cormorants, egrets, graylag geese and otters (National Rivers Authority, 1990).*

Hard-engineering can be "softened" by mimicking features of natural systems, such as digging ponds in previously dry areas, planting runoff buffer-strips along floodplains to store runoff, and creation of on-line and off-line water storage through agriculturally-engineered earthworks (e.g. STEPHENS 1991). This extends far beyond rivers and floodplains, calling for integrated catchment-scale water and land management.

There is however a move towards integrating flood storage areas (FSAs) with biodiversity to work more closely with nature (PITT 2007; ENVIRONMENT AGENCY 2009). These features store water where alternatives would have improved channel conveyance, increasing flood risk downstream (ACKERS AND BARTLETT 2010). Ecologists now understand the best use of FSAs for biodiversity, such as retaining wetland permanently, with freeboard capacity for flood storage. However, this requires over-engineering of the structure to compensate for lost capacity.

Despite calling for more community participation and working with natural processes (PITT 2007; WADE ET AL 2007), there remains an inherent bias towards expensive technocratic solutions (BOAKES ET AL 2004; OGUNYOYE AND FLIKWEERT 2010), skewing cost-benefit-analysis and thus limiting the flood protection provided.

This presents an opportunity for soft-engineered, small-scale, and dispersed impoundments and wetlands, which realise water resources for landowners, bringing benefits not accounted for in cost-benefit-analysis (FOWLER 1989; BROADHEAD 2009). Flooding can be resolved with a multi-benefit focus as a truly holistic approach, at a scale affordable for individual landowners and communities to fund. This encapsulates the principles of polluter-pays and beneficiary-pays (ENVIRONMENT AGENCY 2009), and communities are brought together in decision-making and ownership of schemes. Elements of this have been applied in parts of Europe (OECD 2008, in MORRIS ET AL 2009).

Socially-embedded river, floodplain and land management also comes from alternative farming practices such as permaculture and biodynamics, and has been used for simultaneously managing drought and flooding, soil health, erosion, biodiversity and carbon sequestration in Australia (YEOMANS 2008; LIFEWORKS FOUNDATION 2009). Environmental engineering can thus deliver biodiversity and other benefits embedded within a holistic approach. However, integrating alternative knowledges into modern academic understanding often limits investigation of realising such multi-benefit, community-funded schemes practically in other contexts.

Additionally, heritage features such as millponds can provide on-line, actively managed flood storage, as was done historically (BROADHEAD 2008). Restored millponds demonstrate an abundance of biodiversity, whilst providing recreational and renewable energy benefits (FIGURE 3.5). However, Environment Agency policies on small-scale hydropower are in practice distinctly negative, but presently being reviewed and so restoration proves difficult. Biodiversity is often prioritised, but the negative impact of fish-kill is overestimated here; experience suggests these issues are not insurmountable, and so biodiversity benefits associated are yet to be realised.

The current lack of information should not be prohibitive to peer-reviewed research to validate alternative or traditional practices in respect of biodiversity; in the same manner, there is not yet a full understanding of the benefits of complete floodplain restoration for flood risk resolution, and yet a precautionary principle prevails.

*Figure 3.5 Online water storage in heritage millponds in the Stroud Valleys, Frampton Mansell, demonstrating biodiversity, but lost opportunities for both renewable energy (hydropower) and active control for flood risk management. Source – author's own picture.*

# 4 Conclusions

This paper has presented a number of options for integrating flood risk and biodiversity in river and floodplain management (TABLE 1). Biodiversity and FRM can be compatible, but there is a trade-off in the effectiveness of the two. The best wins for biodiversity appear to be when this is the priority, through dedicated restoration of river systems (often at small scales), though the reliability for flood alleviation requires demonstration at a catchment scale. The UK priority has therefore always lain with resolving critical flood risk, and despite the increasing guidance on integrating biodiversity with engineered approaches, costly and technocratic FRM appears to remain central to water management and receives funding accordingly – £800 million per year (ENVIRONMENT AGENCY 2009).

Some alternative knowledges indicate that engineered solutions can be considered more holistically than presently interpreted in the UK context. This paper recommends that not only can biodiversity and flood risk objectives be met through management of rivers and floodplains, but that this should be extended to other community-led benefits such as soil health, renewable energy, recreation and fishing. Whether this is practicably achievable is the subject of a forthcoming Water21 study.

| Option | Biodiversity benefit | FRM benefit |
|---|---|---|
| **Restoration** | | |
| • **Avoid development** | ✓✓ | ✓✓ |
| • **Restore channel x-sections, increase hydraulic roughness** | ✓✓ | ✓ |
| • **Reconnect natural floodplains** | ✓✓ | ✓ |
| **Engineering** | | |
| • **Hard engineered** | X | ✓✓ |
| • **Blueing the landscape** | ✓✓ | ✓ |
| • **Greening FSAs** | ✓ | ✓✓ |
| • **Small scale dispersed approach** | ✓✓ (?) | ✓✓ (?) |
| • **Heritage restoration** | ✓ (?) | ✓ (?) |

*Table 1. A summary of options for river and floodplain management to alleviate flooding and enhance biodiversity. There are two broad categories, and there is often a trade-off between biodiversity and flood risk management (FRM). P = can provide a benefit. PP = can potentially resolve the issue on its own. X = often worsens situation. ? = reported benefits, but not yet verified.*

The main conflict is in policy, which often favours the hard-engineering. These have clearly defined physical boundaries and legal responsibilities for construction, ownership and maintenance and the public perceive comfort in the government-assured long-term safety of visible engineered schemes, opening the debate far into human geography of environmental participation. Small-scale dispersed management or catchment-wide floodplain restoration could pose a political problem, as it cannot be effectively policed by the Environment Agency. It would instead rely on society to maintain the landscape for the multi-benefits themselves; this is not fully socially or politically feasible under the current system.

Flood risk management linkage with biodiversity steps in the right direction, and can be achievable, but does not go far enough. A paradigm shift towards truly “making space for water” might re-establish society’s historic involvement in community-funded and maintained water management, embracing a holistic approach. The question is, is society ready?

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