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Floods and Dredging – a reality check

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Foreword

No-one should underestimate the power of flooding. It has shaped our rivers and landscapes for millennia, but can also bring misery to people whose homes, possessions, businesses and land are lost to the water. Indeed, as this report goes to press, communities in the Somerset Levels and Moors have been under water for weeks, with little prospect of relief, while those along the Thames and Severn corridors are experiencing the worst flood in decades.

It is only right that we respond compassionately to the severe difficulties faced by communities. But as water engineers, environmental managers, wildlife enthusiasts and anglers we are uneasy about the lack of science and evidence in public debate that surrounds the recent flooding and what might be done to mitigate future losses. In particular, claims that the widespread use of dredging can act as a flood prevention measure are not only unsupported by both science and evidence, they are a cruel offer of false hope to those living in flood prone communities. That is why we are calling for a 'reality check' on flooding and dredging.

The public debate has of course focussed on the plight of those on the Somerset Levels – a landscape where farming maintains rich wetland habitats and where water level management underpins both. Our review of the Environment Agency's modelling results suggests that dredging of the Parrett and Tone rivers could make a difference in the duration of flooding, but would only have had a limited impact on the extent and height of the floods. That's why the local Internal Drainage Board and others propose such works as part of an integrated package that includes measures to increase resilience and support for those seeking to relocate.[1]

More generally, this report shows that dredging is not a universal solution to flooding. Numerous studies dating back to the 1980's have shown that dredging can speed up flow and potentially increase the risk of flooding downstream and have devastating unintended consequences for wildlife and people's homes and businesses. The ways in which we can get the best from our rivers by working with nature are discussed in an opinion piece accompanying this report, written by Tony Juniper.

That is not to say dredging has no role to play. It can reduce water levels on a local scale and may be critical to flood risk management in key locations; that's why the Environment Agency spent £45 million on channel maintenance in 2012/13.[2] However, dredging cannot hope to prevent flooding caused when heavy rainfall results in flows that vastly exceed the capacity of the river channel.

So we are calling for a more solutions-focused debate. We know that extreme rainfall is the driving force of the flooding we are witnessing: the Met Office's statistics show that Southern England had its wettest January, 200% of its long term average, in records going back to 1766. Climate change is only likely to make such extreme weather events more common. At the same time, development on floodplains puts more people at risk, while compacted soils and damaged uplands channel more water down the catchment at a faster rate. Without a change in approach, it is inevitable that low lying land and communities will be exposed to greater risk of flooding.

But there is an alternative. In recent years many studies and practical schemes have pointed the way to more effective methods for controlling flooding, by slowing the rate at which the landscape drains, and increasing its capacity to capture and store water. Working with nature, rather than against it, is sustainable both in terms of monetary cost and environmental impact. Restoring wetlands, planting wet woodlands, encouraging rivers to meander over the floodplain and creating 'upstream' holding areas and buffer strips are just some of the 'slow water' techniques which allow time for underground reserves to fill and prevent flash flood peaks racing downstream. These approaches also deliver improved habitat for wildlife, better quality water and a range of other benefits that impact positively on people and businesses.

Such solutions – as well as proven 'hard' and 'soft' engineering – must lie at the heart of future strategies for mitigating flood risk. A catchment based approach provides by far the best platform for developing these strategies, in partnership with stakeholders, including local landowners and land managers, and gives us the best chance to respond to the ever increasing threat of extreme floods as our climate changes.

Executive summary

- The term dredging is routinely used to refer to the systematic removal of accumulated material from river or other watercourse channels. In its most extreme form dredging may be used to re-align river channels creating linear, canalised watercourses.
- It would be infeasible to dredge channels with the capacity to carry flood flows of the kind witnessed this winter (2013/14). However, there is significant evidence that dredging can increase channel conveyance, reducing water levels and small floods.
- This is borne out by studies of the Somerset Level and Moors system which suggest that the proposed dredge would have not prevented flooding but could significantly reduce the length of time water stands on the land.
- Numerous studies have pointed to significant unintended consequences of dredging, namely:
    - Increasing flood risk for communities downstream by speeding up the movement of flood water through the river and drainage network.
    - Destabilising river banks, causing erosion and so risking damage to infrastructure.
    - Loss of wildlife and habitats both within the river and across the wider floodplain. These impacts can be significant and permanent.
- It is also important to note that dredging can be a conservation tool, particularly in heavily modified environments where natural processes that maintain ecosystem function are constrained.
- Flood risk management strategies should look to a range of interventions, and include action to reduce runoff by working with natural practices to slow water, and increase infiltration and storage throughout the catchment.
- Strategies will also need to manage the use of naturally flood prone land through a combination of behavioural and engineering options, including flood zoning, warning, changes in land use practices, as well as flood defence structures and operations.
- Land management lies at the heart of these strategies, so the design of farm subsidies and engagement with stakeholders, especially landowners, land managers and farmers is critical to flood risk management. The Catchment Based Approach provides a platform for this engagement.

We conclude that dredging can play an important role in flood risk management in some cases, but is not a stand-alone solution. It should be considered in the context of a range of tools and the origins of different sources of flood water, and comes with significant risks that must be understood at a local and catchment scale.

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1 Introduction

Flooding is a natural process. Rivers and other watercourses regularly exceed their capacity and spill out onto their floodplains, and this process contributes to the diversity and richness of their ecosystems. These characteristics are attractive to farmers making use of fertile soils on floodplains (the result of sediments brought by floods). Floodplains have also attracted settlement, with the people in towns and cities attracted to rivers as a source of transport, food, water and sewerage. As a result, flooding – and society's attempts to control it – has evolved over centuries.

In recent years, there have been a number of high profile flooding events. This flooding has caused, and continues to cause, disruption and damage that interferes with people's lives and livelihoods. Whilst flooding can be short-lived, its impacts can last for months, even years and can extend to health impacts including anxiety and depression, alongside physical damage.

Fluvial flooding (i.e. of rivers) occurs when the flow capacity of a channel is exceeded. When a catchment delivers a flow greater than the capacity of the main river channel water flows onto the adjacent floodplain. Natural rivers form and maintain their own channels and floodplains; the main channel develops to accommodate low flows, medium flows and small flood flows.

Once the channel capacity is exceeded, the floodplain comes into service. Floodplains store and convey all flood flows, from small floods that might typically occur every two to five years, to the extremely large and statistically infrequent flows that fill the whole floodplain to significant depths. A river's channel and floodplain are intimately linked and play a vital role in shaping and sustaining the ecology of rivers, wetlands and the rich diversity of life they support. They function together to deal with the full range of flows delivered from the upstream catchment area.

Floodplains are designed, by nature, to flood fairly often. In recognition of the annual flooding of some rivers, floodplains are known as 'winter channels' in parts of Europe. When water flows onto the floodplain flood energy is dissipated and erosive forces acting upon the bed and banks of the river are relieved. Prevention of floodplain inundation and channel incision through dredging often increases erosion and sediment supply downstream. So any investigation of flooding requires an understanding of all three components of the river system, namely the river, its floodplain and its catchment.

Much reporting gives an impression that flooding is someone's fault – perhaps an organisation's – for not doing what people believe they should be doing, such as managing control gates, building flood defences or dredging rivers to keep the channel wide and deep. This creates a simplified picture that sometimes makes objective analysis of problems and solutions difficult.

In addition to fluvial flooding, coastal, surface water, groundwater, sewer and infrastructure failure flooding can all occur, and all have different characteristics. However, underpinning all of them is extreme weather that is highly variable in its occurrence and potentially linked to climate change.

In the past few years, several major flooding incidents (2007, 2012 and 2013/14) have raised the question of whether flooding is getting worse. Even with the large amount of data that has been collected, it is almost impossible to spot trends in flood data in the UK.[3] Flooding is fundamentally all about extremes, and the variability of flood records means that a trend needs to be very strong if it is to be spotted. Furthermore, flooding is the net result of many physical processes acting on a very varied landscape. The processes, the landscape and the driving forces may all be subject to change over time.

Nonetheless, there is a good understanding of the factors that may make flooding worse. These include changes to the land surface (such as urbanisation), changes to river channels (such as canalisation) and changes to weather patterns. The weather patterns that have triggered the current floods are known to be typical of expected extreme weather events predicted under a changing climate.[4]

The current Government's flood funding rules represent the latest evolution of policies that prioritise the protection of people and property. Recent flooding of low lying areas drained by natural and man-made channels has led to claims that these policies have neglected farmland, especially in relation to a lack of river dredging. With pressure on funding for flood defence, there have been concerns that there could be too great a focus on capital schemes to upgrade and provide new defences, at the expense of maintenance of defences and channels (including dredging).

This report considers the merits of dredging in relation to its impacts, both positive and negative. It also provides a comparison with other options for managing floods and, where that is not feasible, learning to live with flooding. The plight of the Somerset Levels is discussed as a matter of topical concern, and as one of a number of cases that are illustrative of the links between dredging and flooding in low lying areas. The report closes with a brief review of flood risk management approaches and the challenges that lie ahead.

The risk of flooding is predicted to rise and the cost of managing that risk is thus likely to become increasingly expensive. We have to use science and evidence to make the right decisions on how to respond to different types of flooding in the most cost efficient, socially responsible and environmentally sustainable manner.

2 Dredging

2.1 What is dredging?

The term 'dredging' covers a range of activities from the removal of material from the bed and sides of river channels through to the wholesale straightening (canalisation) and/or deepening of watercourses. Works can be undertaken to drain land for agriculture, to improve flood protection and/or for navigational purposes.

Dredging can also be used to create artificial channels that can act as sumps, from which water can be pumped, such as in the Fens and Somerset Levels.

Dredging on rivers often involves the deployment of large, specialist equipment (Figure 1). The working conditions are invariably difficult, such as from a narrow riverbank. Appropriate planning is needed to take account of the numerous hazards and risks to people and the environment. It is therefore an expensive operation.

Dredging is rarely a one-off activity. Rivers carry runoff and silt from the catchment to estuaries, so as soon as dredging is complete, material will begin to re-accumulate. Moreover, the river will seek to re-adjust itself to a more natural form in terms of cross-sectional area, gradient and meanders, with potentially serious unintended consequences including bank failure and erosion (see Section 2.4). As a result, dredged channels require long-term maintenance. Internal Drainage Boards report the need to dredge material from channels about every five to ten years, depending on local circumstances.[5]

Dredgings are frequently deposited close to the river bank – from where they can be carried by rain straight back into the river – or on the floodplain itself. This inevitably reduces the storage capacity of the floodplain and hence its ability to reduce flood peaks. Sediments can also accumulate pollutants over decades; as a result, contaminated silts must also be disposed of in a licensed facility so that these contaminants are not transferred from the soil to the human food chain via agricultural crops.

There are a variety of waste and land drainage consenting regimes that apply to main and non main rivers in England. Compliance with these is a key consideration in mitigating risk to people and wildlife.

Image provided by Middle Level Commissioners

Figure 1: Dredging near Ramsey St Mary

2.2 Can dredging *prevent* all floods?

Dredging is usually deployed to alleviate flooding which originates from a river or its immediate floodplain. It is not usually a tool that can help alleviate or reduce the risk of other kinds or sources of flooding mentioned earlier, e.g. surface water flooding or sewer flooding, though these different types of flood waters can intermingle and thus exacerbate flooding.

A typical cross section through a river and its floodplain is shown in Figure 2, below. Under normal flow conditions, the river is contained entirely within the main channel. The flow capacity of most natural river channels is known as the bankfull discharge. Any flow in excess of the bankfull discharge will result in overtopping of the banks – they only rarely 'burst'. Initially, water tends to lie on the floodplain, which acts as a water store. But as the depth of the water increases, it starts to flow over the floodplain; the speed and depth of that flow is influenced by embankments, hedges and other features.

The *Flood Estimation Handbook*[6] suggests that river flow in the UK typically exceeds the bankfull discharge approximately every other year, although some natural and artificial wetlands flood annually, creating conditions for specialist habitats and species. On that basis, the sight of water on floodplains is actually quite commonplace and is no cause for concern, unless it impacts upon people or property.

It is when the flood flow is sufficiently high and the flood extent sufficiently wide and deep as to impact on the lives and livelihoods of people and businesses that the need for flood management comes into play. For people who live and work on floodplains, flood risk management is a real and pressing issue.

During an extreme flood, the peak river flow may be many times the bankfull discharge.[7] During large events the storage provided by the river channel is typically insignificant when compared to that held in the floodplain as seen, for example, in the flooding of the River Thames in January and February 2014.

It is simply not practical to contemplate dredging of the channel (let alone the floodplain) to the extent that would be required to confine such large and rare flood flows from the wider floodplain, since the storage and conveyance capacity of the channel is a small fraction of that of the wider floodplain. In this respect, dredging cannot prevent flooding.

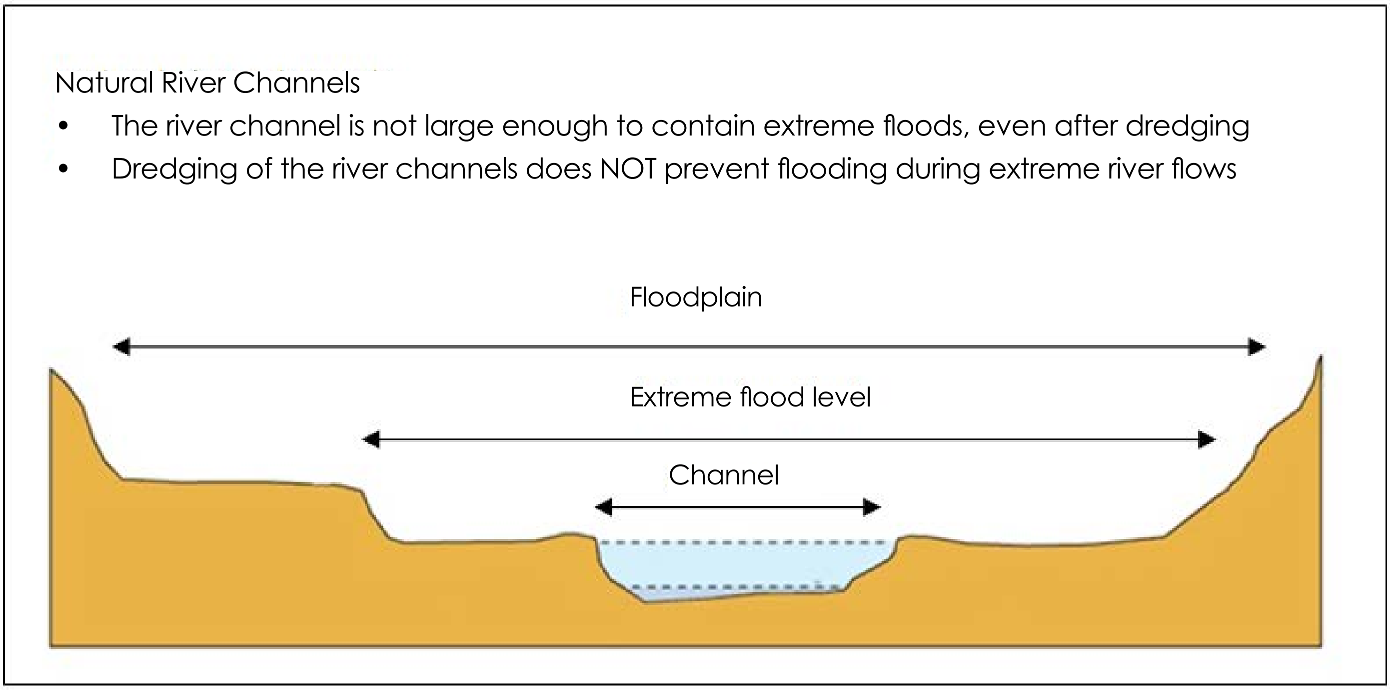


Figure 2: Natural river channels

2.3 Can dredging reduce flooding?

Dredging of a reach (length of channel) results in an increase in the cross sectional area (and hence its volume), as well as a reduction in the roughness of the channel. Where dredging is used to straighten and canalise the river, the effect is to reduce its length and so increase channel gradient. These effects can increase the efficiency of the channel in moving water (increasing the conveyance). Dredging should therefore lead to a reduction in water levels and hence to a reduction in fluvial flood frequency in the immediate area.

When the flow rate is impeded by channel constriction (e.g. by a bridge) or high downstream water levels (e.g. from tide locking, backwater ponding above flow junctions and in-channel structures, or pumping restrictions), dredging may provide no benefit during extreme events.

Moreover, in coastal areas there may be some trade-off between improving conveyance of fluvial floodwaters and increasing risk from tidal floods, as has been modelled on the Parrett.[8]

The Environment Agency has undertaken a pilot study to learn more about the advantages and disadvantages of dredging.[9] Six sites were used in the pilot, which included the use of physical maintenance and computer modelling.

At the Hinksey pilot site, in Oxfordshire, dredging led to a reduction in water level of 120mm when flows were confined to the main channel (Figure 3). However, the reduction in top water level was only 40mm in extreme flows that extended onto the floodplain. This is because in extreme flood conditions, water levels are increasingly controlled by major features like bridges and obstructions on the floodplain, rather than by the capacity and shape of the channel. This is discussed in relation to the Somerset Levels, in section 3.2.

In reference to the dredging pilots in Somerset, the North and South drains are channels whose outflow is limited by the pumping station capacity at the downstream end. These drains are useful examples as they are typical of channels where dredging activity is undertaken by Internal Drainage Boards. The findings are qualitative, but support the view that the work has increased the conveyance within the drains and improved the evacuation of floodwater within the drainage catchment.

Of the three other sites in the pilot, the maintenance of Burstwick Drain increased the conveyance of the drain, though with only small reductions in water levels and no significant reduction in flood risk. The work on the River Windrush was identified as leading to a potential increase in flood risk downstream of the dredged reach, which necessitated further consultations.

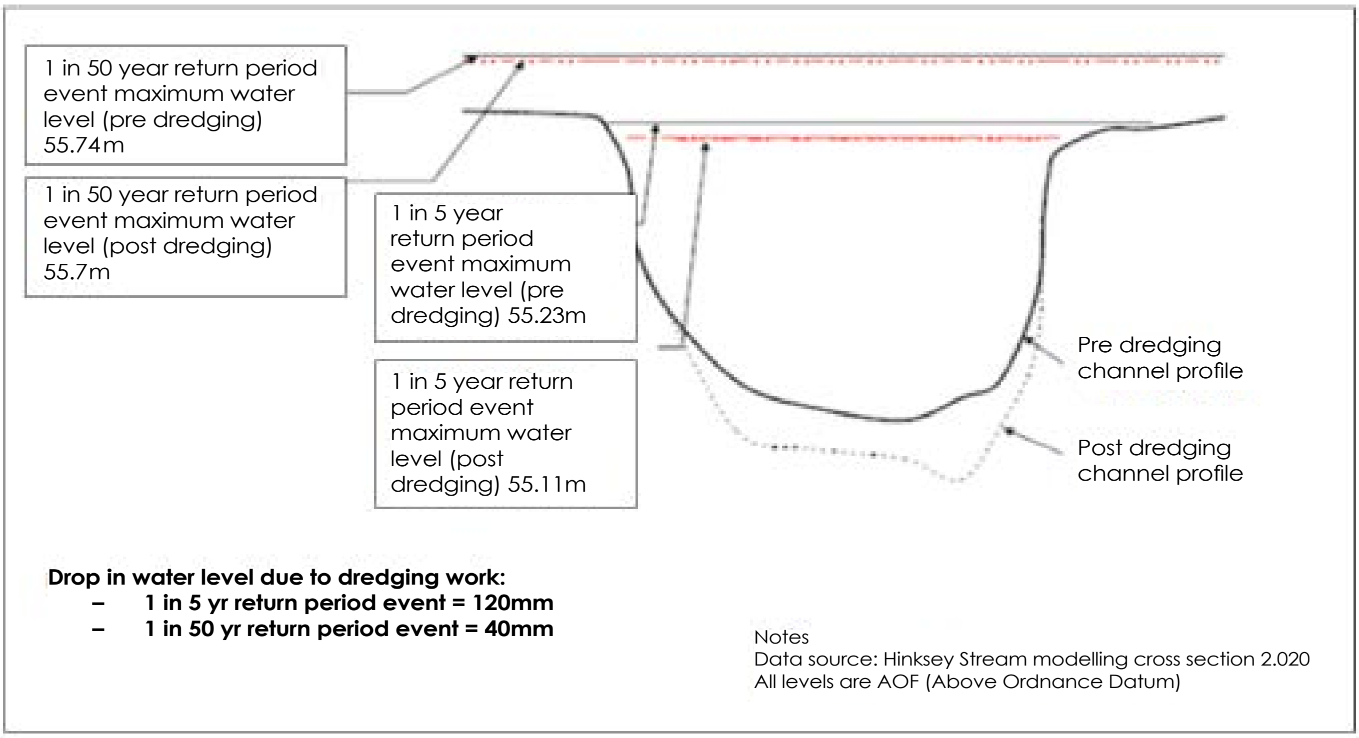


Figure 3: Reduction in flood levels at Hinksey due to dredging

The pilot study highlights the local benefits that dredging can deliver under the lower range of flood flows, but that it needs to be considered on a case-by-case basis. A case-by-case approach will enable an assessment of the flood risk benefits and any negative impacts, for example in relation to water quality and biodiversity.

All of the Environment Agency pilots illustrate the fact that flood problems are often site specific and require individual assessment to determine the right course of action. Targeted dredging can only ever have the potential to reduce flood risk when there is a sufficient understanding of how flood water peaks move through the system. Without an understanding of this very complex picture, there is significant potential to worsen flooding.

2.4 What are the unintended consequences of dredging?

2.4.1 Increased downstream flood risk

As noted above, dredging a channel will increase its potential conveyance while that capacity is maintained. This, accompanied by any straightening of the channel, will increase flow velocity and route floods downstream more quickly. This can lead to an increase in flood risk and sediment supply downstream.

This risk is more commonly associated with the canalisation schemes that were a feature of river engineering works through much of the 20th century. The immediate problem in previous years was one of stormwater disposal, and the construction of rectangular concrete channels was often viewed as the most effective way to do this. However, the consequences of increased flood risk at downstream locations have been reported in many catchments, such as in the River Quaggy, where canalisation led to increased flood risk for Lewisham.[10]

In more rural settings, the impacts of efficient arterial drainage schemes have been well understood for decades: they may lead to increased peak flows downstream, owing to the faster travel time of flood water from the upper catchment.[11,12,13] The impact of arterial drainage on peak discharges and timing depends on the characteristics of the catchment and efficiency of the drainage network. However, they can be significant – as much as 60% higher on rivers that have been arterially drained in comparison with unmodified rivers.[14]

Many parts of these arterial drainage schemes have been neglected in recent decades as government support has dwindled. While it is unlikely we will see an expansion of new major drainage works, it is clear that returning these systems to full efficiency through maintenance dredging could have dangerous unintended consequences downstream.

2.4.2 Erosion

The natural form of a river system is intimately linked to the energy of the water, known as stream power. This energy dictates the erosive power of the flow and the river's capacity to transport sediment. Stream power is dependent upon the channel shape, steepness and flow.

In high energy systems, the greater hydraulic efficiency of dredged channels can significantly increase stream power. This can reach the point where it causes bank failure resulting in significant sedimentation and the need for further maintenance. Alternatively, bank protection works may be engineered into the schemes, destroying the natural ability of the channel to re-adjust in response to changes in flow and sediment rates. Higher stream energy can also lead to coarse sediment, like gravels, being deposited downstream of the dredged river reach. Counter-intuitively, building higher banks can also increase the destructive forces of floodwater by preventing water from spilling onto floodplains and slowing down, dissipating its energy. This exacerbates both the potential for erosion and the damage caused by the interruption of sediment supply.

In low energy systems, the river tends to adjust by accumulating sediment, reducing channel capacity in the dredged river reach and thus requiring ongoing maintenance.

The indirect impacts of dredging on river channels have been understood for decades. For example, the effects can occur upstream of the dredged reach, as the river seeks to return to a more natural gradient. These points are well illustrated in a flume study videoed by the Wild Trout Trust (http://www.youtube.com/watch?v=OAZ_BuyM41s)[15], and in the photographs shown in Figure 4. Erosion can be a major hazard for infrastructure such as bridges, where they become pinch points.

While the impacts are well known they are the result of an extremely complex interplay of factors and difficult to predict.[16]

2.4.3 Damage to wildlife and river ecosystems

Dredging can have significant direct and indirect negative consequences for ecosystems. For example, it can lead to loss and degradation of natural habitats and features such as pools and riffles. It can also impact on a range of protected species.

The removal of vegetation from within channels and along channel banks during dredging operations can increase water temperature by reducing shade: warmer temperatures result in lower oxygen concentrations, making fish and invertebrates in dredged channels more vulnerable to stress during hot weather. Dredging can reduce the diversity and density of invertebrate species, which is likely to have knock-on impacts on fish, and subsequently on top predators such as otters and fish-eating birds like kingfishers.

The impact of dredging on plant communities can extend far beyond the initial physical disturbance. The change in flow and channel characteristics can alter the structure of aquatic plant communities that recolonise, eliminating species – such as water crowfoots – that are well adapted to the flow and shallow water of natural channels. Dredging can also decrease soil stability along banks, leading to greater sediment input and bank erosion. Bare and eroded banks may be readily colonised by invasive non-native plant species, such as Japanese knotweed and Himalayan balsam.

The impact of dredging on fish communities has been the subject of intensive research. Removing gravels can damage vital spawning grounds for species of conservation concern, such as Atlantic salmon, brown trout, European bullhead and lampreys. Even if spawning grounds are protected, the displaced sediment and/or increased sediment load resulting from dredging activities can smother fish eggs and juveniles. Dredging can also lead to the loss of habitat for juvenile flow-loving species such as salmon, trout and grayling, alter fish community and/or population structure and reduce total fish density and biomass compared to non-dredged areas. It may even eliminate all fish for considerable periods of time (e.g. five years).

Other protected species that are negatively impacted by dredging include freshwater pearl mussel and white-clawed crayfish[17], especially where areas of sand, gravel and boulders are removed.[18,19]

Figure 4: Dredging of River Manifold, Derbyshire

River Manifold near Longnor, Derbyshire in October 2007 showing material "excavated" from the riverbed.

(photos: T. Jacklin)

Erosion downstream of dredged and straightened reaches showing deposits of gravel from upstream, dredged sections.

Dredging and channel maintenance can also impact the bankside burrow systems of water voles, and is implicated in their rapid decline.[20] A study from Scotland[21] showed that, immediately following dredging of small ditches, water voles from the entire local population, including those inhabiting untouched sections, showed an increase in mortality.[22]

The reduction in water levels associated with dredging can also dramatically alter the hydrology of the floodplain, reducing the frequency of shallow floods and lowering groundwater levels. The impacts on habitats and species, including birds, can be dramatic. Surveys of floodplain meadows in England and Wales, for example, revealed a large decrease in breeding wading birds like redshank, lapwing and snipe between 1982 and 2002, with snipe declining by 62% and redshank by 29%. Sample surveys since 2002 and the Bird Atlas 2007-11 indicate that these declines have continued, with the remaining birds restricted to a tiny number of suitable sites.[23]

2.4.4 Reduction in water quality

Dredging can also impact on water quality, primarily because of the suspension of sediments during and after the operation. These impacts are generally short-term, and in smaller ditches may be managed by placing physical barriers such as hay bales in the channel to prevent sediment affecting a long stretch.

In larger rivers, which experience flood flows more regularly, impacts may be less significant, since the suspended sediment will mix and flow downstream more quickly. It is also more difficult to put in place physical barriers which might work on smaller watercourses.

In terms of ecological damage dredging is a high risk activity that must take account of environmental legislation on protected species and sites.

Positive impacts of dredging

Sensitive dredging regimes that are undertaken as part of a considered package of measures can have positive impacts on biodiversity. For example, ditches in largely artificial environments like drained fenlands have adapted to exploit niches created by our management of the natural environment, as a partial surrogate for the historic natural processes. Pioneer species in particular rely on a certain level of disturbance. However, disturbance is not the only important factor: water quality and a long history at a particular site are also crucial to sensitive communities. Often, sensitive species rely primarily on being located in areas where they have existed for great lengths of time (e.g. such areas typically formed post-glacially as natural wetlands which were then drained).

Figure 5: Dredging of the River Lowther

(photos: L. Greasley)

The River Lowther in Cumbria, with salmon and trout spawning gravels pulled against the bank for protection and to lower the river bed, while the downstream section was removed to drain the backwater.

3 Flooding

3.1 Recent flooding

The UK has been in a 'flood-rich' period since Easter 1998 (see Table 1 for a summary of some recent flood events). There have been flood-rich periods before, according to compilations such as the Chronology of British Hydrological Events. That said, recent years have also witnessed a succession of droughts, including the deep drought of 2010-2012, illustrating the extremes of weather that are not uncommon in the UK.

For those that have been affected by flooding, or repeated flooding, the experience is often devastating. Whilst not diminishing the plight of those that have suffered flooding, we should not forget that flood risk management has spared millions the costs and stress of flooding that they would otherwise have experienced. For example:

- The North Sea was subject to a storm surge in December 2013, which raised water levels to two metres above Highest Astronomical Tide at Lowestoft and gave rise to the highest surge since the floods of 1953. However, the damage was far less than in 1953, confirming the value of extensive defences along the East Coast and Thames Estuary, including the Thames Barrier.
- Nottingham flood alleviation scheme opened in September 2012, protecting 16,000 homes and businesses.[24]
- Upton-upon-Severn flood alleviation scheme, opened in July 2012 comprises a permanent flood wall with glass panels for protecting the town centre.
- Banbury flood alleviation scheme comprises a major flood storage area that provides protection to 440 homes, 70 businesses and transport infrastructure.[25]

Planning policy has evolved significantly in the past decade[26], but some development does still take place on the floodplains, even where the Environment Agency has objected on flood risk grounds.

Date	Areas affected
Easter 1998	R. Nene, R. Avon, Warwickshire
Autumn 2000	Southern England, Midlands, Yorkshire
January 2003	R. Thames (still only 12th highest in series from 1883 at Kingston)
August 2004	Boscastle
January 2005	Carlisle
Summer 2007	Midlands, Southern England, NE England
October 2008	Ottery St Mary (Devon record 3-hour storm)
November 2009	Cumbria (including record 24-hour rainfall, a total of 316.4 mm)
November 2010	Cornwall
Summer 2012	Extensive surface water flooding in UK
December 2013	North Sea surge (800,000 properties protected)
Winter 2014	Somerset Levels, R. Thames

Note that this is an illustrative list and by no means exhaustive

Table 1: Summary of recent flood events

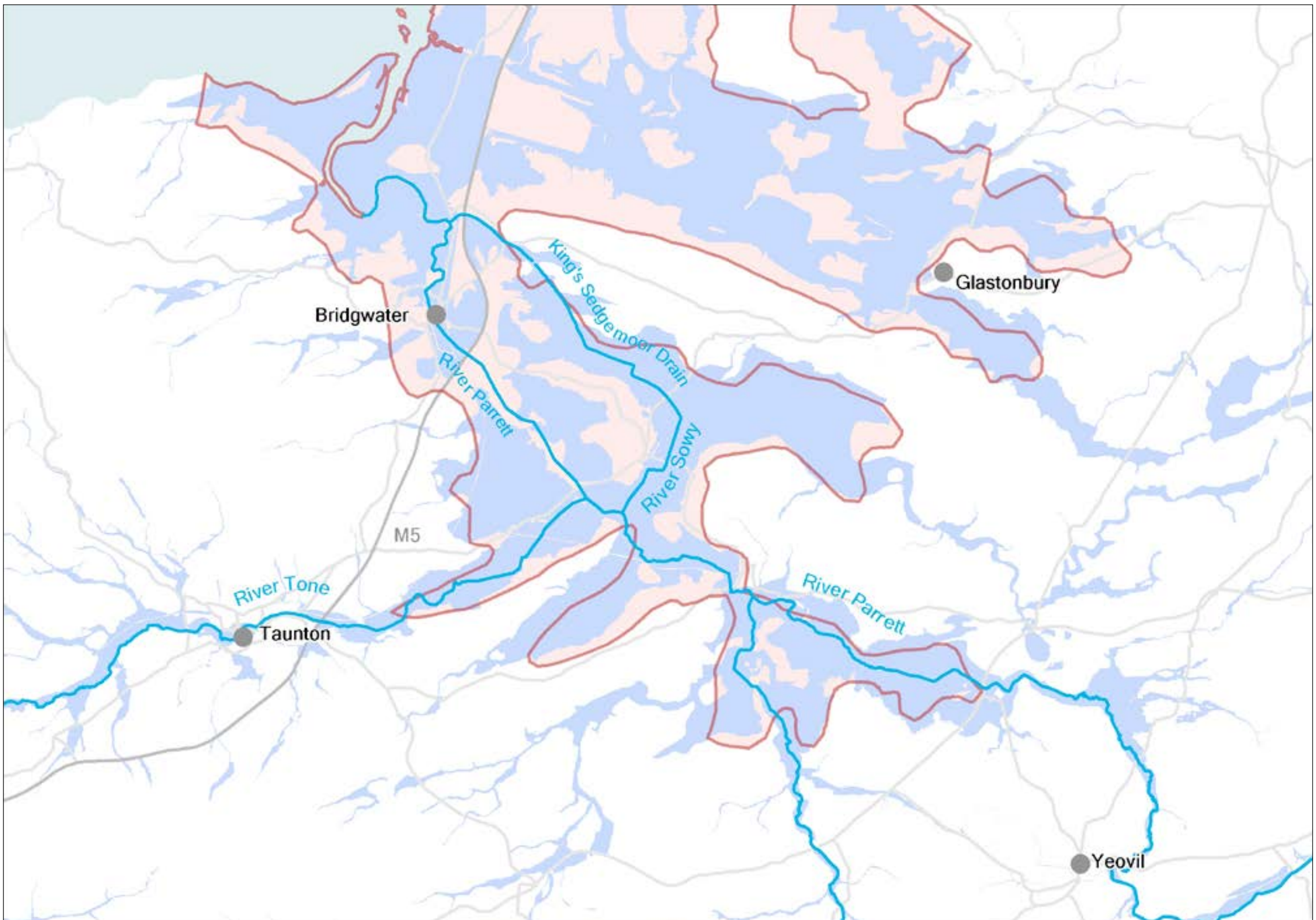
There is an overriding need to address the legacy of existing properties and areas that are at risk of flooding. The Environment Agency's flood risk maps demonstrate the need for urgent action. One of these legacy areas is the Somerset Levels.

3.2 The Somerset Levels

The Somerset Levels are served by four main rivers – the Parrett, Tone, Brue and Axe, which together, drain water from a surrounding catchment of over 200,000ha (Figure 6). The floodplain, which is largely freshwater and covers around 60,000ha, is generally very flat. The River Parrett, for example, falls by only 30cm between Langport and Bridgwater, a distance of about 18.5km. The Parrett and Tone are tidally influenced up to around 30km inland, with tidal sluice gates at Oath Lock and New Bridge respectively. This tidal influence brings a significant amount of coarse silt into the system on each tide.

A flat landscape, tidal incursion and fairly heavy rainfall combine annually to produce extensive winter flooding across many parts of the Levels. Winter rainfall increases soil moisture, leading to diminishing permeability and increasing runoff in the upper and middle catchment, and raising water levels in the main rivers. In time, these may overtop their embankments, leading to flooding on the adjacent, lower-lying moors. High tide levels in the Bristol Channel can also force tidal water farther up the Parrett and Tone, causing overtopping of embankments or reducing the ability of winter river flows to be conveyed out to Bridgwater Bay.

Floodplain water is evacuated into main rivers via pumping stations on many moors. Critically, pumping is only effective when water levels in the River Parrett are low enough to take the additional water. At high tide this can be problematic, since there is a shorter period of time when pumping can occur. The Sowy River flood relief channel, which was designed to provide flood relief to Langport, also takes flows from the Parrett 1,500m downstream of the town. Water in the Sowy is conveyed through gravity drainage



Pale pink with red outline: Somerset Levels and Moors Joint Character Area
Light blue: 1:100 flood extent

Figure 6: Flood risk map for Somerset

into King's Sedgemoor Drain. This then drains into the Parrett Estuary downstream of Bridgwater.

Annual winter floods and high field ditch water levels, managed to provide summer irrigation for livestock, have helped create a rich biodiversity within the Level's floodplain. As a result, the Somerset Levels and Moors have been designated as a Special Protection Area for their winter birds and a Ramsar Wetland of International Importance. Many of the moors are also Sites of Special Scientific Interest. These internationally important habitats depend on regular flooding and high water tables for their conservation.

Major flooding in the catchment has occurred many times since its reclamation, with recent notable events in 1919, 1966, 2000, 2012, and now most recently in 2014. The 1919 floods saw 28,000ha inundated compared to 6,500ha at the time of writing. The second half of December 2013 saw a significant amount of rainfall in South West England, with the Met Office's Hadley Centre recording a maximum of 37mm in a single day on 23rd December 2013. This led to the Parrett and Tone catchments being widely saturated and already conveying significant flows.

The wet weather continued in early January 2014, which coincided with high spring tides in the Bristol Channel. The combination of conditions (i.e. saturated upland and lowland catchments), high river flows, extreme rainfall and high tides, led to the rivers overtopping their banks and water flooding across the moors. Continued wet weather and high tides has seen continuous flooding for six weeks.

3.3 Would dredging have helped to reduce the extent or the duration of flooding?

In recent years, the Environment Agency has undertaken a number of feasibility studies into potential dredging of the tidal sections of the River Parrett and Tone catchments. In particular, it examined a number of potential dredging scenarios for these tidal sections, including assessments of the impacts of dredging different stretches of the rivers, different amounts of sediment removal and comparison of the impacts of agitation dredging verses complete removal of the sediment. The studies included hydraulic modelling, cost-benefit analyses and environmental assessments.

The hydraulic models demonstrated that dredging did not lower peak flood levels significantly for winter storms (e.g. a 140mm drop at Curry Moor for a 1 in 100 year event). This is due to flood levels being determined primarily by the height of the river banks. Therefore, *it is highly unlikely that dredging of the Parrett and Tone prior to the January 2014 floods would have led to a significant drop in the flood levels experienced*.

However, the models do demonstrate that dredging tidal sections of the two rivers would lead to a significant reduction in the duration of flood events. This is because dredging leads to an increase in river conveyance. The main benefit of this is that pumping can remove greater amounts of water from the moors after the flood peak has passed. The modelling studies suggest that if dredging of the tidal sections of the Parrett and Tone had occurred prior to the November 2012 event, then the duration of flooding would have been cut from 54 to 24 days on Curry Moor. Therefore, *it is highly likely that dredging the Parrett and Tone prior to the January 2014 floods would have led to a reduction in the flood duration experienced*.

From Environment Agency studies, it is clear that the geographical extent of any benefits from a dredge vary according to the dredging regime employed. The extent of any flooding experienced at Muchelney, for example, is unlikely to be significantly affected by dredging, although deep flooding is likely to occur for a shorter period. There is a suggestion in the studies that dredging would reduce the frequency at which Athelney Spillway overtops and therefore the flooding of the A361. The relatively large difference in bed levels between the Levels and upstream Taunton mean that dredging will not affect flooding in Taunton.

Improving floodwater conveyance from the Levels floodplain through dredging passes additional water downstream, which can raise flood levels close to vulnerable settlements and infrastructure. For example, the hydraulic modelling suggests that river flood levels would rise in Bridgwater if dredging was to occur. However, the predicted tidal levels for a similar likelihood of event (e.g. annual chance of 1%) are higher than the river levels. Therefore, the argument is made that although river levels in Bridgwater would rise if dredging occurs, the defences are in place to allow this to happen without increasing flood risk in the town. It is not known if exposing defences to high water levels more often will have an impact on maintenance or structural integrity.

It should be noted that the Environment Agency studies demonstrate an increase in tidal flood risk to the Levels from dredging, although flooding associated with these types of events is usually much shorter-lived.

As outlined in this report, dredging has environmental risks associated with the removal of habitats, increased turbidity (i.e. reduced transparency of the water) and potential for contaminant mobilisation. That said, many wildlife groups accept the risks of the planned dredge can be mitigated. However, the dredging does not qualify for significant central government funding under current Treasury rules, due to the (relatively) low benefits obtained compared to investing in flood management schemes elsewhere in the country.

4 Approaches to flood risk management

4.1 A portfolio of responses

Approaches to flood risk mitigation can include a range of interventions, from traditional, hard engineering solutions, including flood defence walls and barriers, through to soft engineering and natural processes (Figure 7).

Hard engineering flood defences typically involve physical disruption of natural processes. For example, traditional flood walls cut floodplains off from the river, reservoirs turn rivers to lakes and tidal barriers restrict the natural ebb and flow of tides moving up the river system. Examples include a relatively new scheme in Nottingham that features considerable lengths of flood wall that isolate the river from its floodplain.

Such approaches will continue to play a vital role in defending people and property. However, there has been a growing interest in softer approaches which seek to mimic or restore natural processes, and in doing so offer a more cost effective and sustainable approach to managing floods. This was reflected in Sir Michael Pitt's inquiry into the widespread flooding of 2007, which recommended that government agencies should work with partners to maximise the use of natural processes to manage flood risk.[27]

In response, the Environment Agency led a stakeholder engagement programme to develop a common understanding of techniques that work with natural processes (see Table 2) along with examples of their implementation.

At Pontbren in Powys, a group of neighbouring farmers have instigated land and soil management to retain and delay surface flows.[28] The practices include:

- Extensive, rather than intensive, land use;
- Planting woodland, shelter belts and hedgerows; and
- Re-establishing farm ponds and wetlands.

In Staffordshire, in the Sow and Penk catchments, a partnership project (Farming Floodplains for the Future) has sought to work with farmers and landowners to implement flood reduction techniques (a report of the outcomes is available online[29]). These include:

- Blocking of ditches to hold back runoff;
- Establishing woodland in floodplains; and
- Constructing flood storage areas to attenuate water.

Hard engineering	Mitigated hard engineering	Soft engineering	Natural flood-risk management
Heavily modified river or coastline	Natural Processes →		(Semi) natural river or coastline

Example interventions

Flood walls, pump drainage, dry washlands (significant intervention)	Green roofs, permeable paving	Wet washlands, balancing ponds, regulated tidal exchange, swales	Managed realignment grip blocking, re-meandering	Natural floodplain/ coastal zone (minimal intervention)

Example outcomes

Floodplain disconnected from channel/ sea, except in exceptional circumstances	*Floodplain connected with channel/sea with high degree of control*	*Floodplain connected with channel/ sea with high degree of freedom*

Figure 7: A Conceptual Model of Working with Natural Processes

Technique name	Technique description
Land and soil management to retain/ delay surface flow	Field scale activities include; tree planting, reduced stocking densities, moving gates and water troughs, planting cover crops, contour ploughing, maintaining soil quality.
Woody debris dams	Naturally occurring or induced in-channel dams of woody debris and vegetation on streams and tributaries.
Moorland grip, field drain and, ditch blocking	Deliberate blocking of previously dug drainage ditches ("grips") to slow run-off rate and allow peat bogs to re-wet and raise water levels and increase field storage / detention potential.
Land use changes	Reversion of arable fields/part fields/buffer strips to pasture to improve soil infiltration rates and reduce surface runoff.
Flood plain woodland	Creating or re-instating floodplain woodland to intercept out of channel flows and encourage infiltration.
Creation or re-instatement of a ditch network	Promoting infiltration (swales, interception ditches, etc). Achieved through maintaining road and trackside ditches to intercept overland flow and detain field and road drainage.
Vegetation management	Alteration or cessation of in-channel vegetation maintenance regimes to selectively promote in-channel vegetation growth.
Floodplain reconnection	Removed or lowered river embankments or new spillways to reconnect river channel to floodplain.
Bed raising/riffle creation	Used to repair damage from over dredging. Mimics a natural process that aligns with the river's natural sedimentation cycle.
Washlands	An area of floodplain that is engineered to flood or deliberately flooded for flood management purposes
Wetland creation	Permanently wet areas where water levels are managed to allow additional flood storage and high flow detention.
On-line flood storage areas	Engineered flood storage that typically involves a structure across a river to restrict flow, causing water to back up and flood out of the channel.
Off-line flood storage areas	Pond, backwater or off-line bypass channel that fills via spillway or pipe when river levels reach critical height. Design can allow for a minimum retained water level within the storage area.
Two-stage channels	Allows additional high flow capacity into a river channel. May involve the creation of wet berms and measures to maintain a narrow low flow channel.
Re-meandering	Reintroduction or reconnection of river meanders of straightened rivers to delay downstream time to peak.
Coastal managed realignment	The deliberate breaching/removal of seawalls/embankments to allow coastal or estuary water to inundate the land behind.
Regulated tidal exchange	Managing existing coastal defences to permit the inflow and outflow of a controlled volume of tidal waters behind a maintained defence. It can be used to raise the elevation of terrestrial habitats as a precursor to managed realignment.
Coastal erosion	Permitting/encouraging coastal erosion in some areas, to supplement sediment supply to coastal frontages elsewhere.
Removal of coastal structures impeding long shore drift	Man-made features may act as impediments to sediment movement and promote sediment starvation. Their removal or modification may allow natural longshore sediment movement to restart creating natural defences.
Manage natural coastal defence features	Saltmarsh regeneration, beach recharge, and dune and shingle ridge naturalisation can dissipate wave energy and act to restrict tidal incursion.
Permeable surfacing	Increased areas of impermeable surfacing affect both the volume and rate of (urban) surface water run-off.
Green roofs / green walls	Vegetation on roofs and walls of impermeable building surfaces intercepts rainfall reducing/ slowing surface water run-off.
Surface water attenuation ponds	Engineered water storage areas designed to detain surface water run-off from roads, housing estates etc. Design may involve a retained water level and will include some control on discharge to an adjacent watercourse.
Removal of in-channel constrictions	Deliberate removal of artificial constrictions to flow and natural hydromorphology. (e.g.de-culverting, removal of redundant bridge supports, weirs, or service pipework).

Table 2: Table of Natural Processes

In the River Quaggy in Sutcliffe Park in London, a local action group influenced the design of a flood alleviation scheme so that it now features:

- Floodplain reconnection and wetland creation;
- Two-stage channels and re-meandering of rivers; and
- Off-line flood storage areas.

The use of processes for slowing the flow have been commonplace in dealing with runoff from urban developments for many years. The use of soakaways, swales and basins for infiltration or attenuation are all used in drainage design to attenuate runoff from developments to pre-development or greenfield rates of runoff. The CIRIA SuDS manual and the WWT/RSPB guidance provide comprehensive guidance for different methods.[30]

4.2 Managing land use

Land is the key resource in any debate over flooding and it is under pressure. Land is in demand for housing, business, agriculture, leisure activity and for broader environmental needs. Land use management via the planning system also provides opportunities for flood risk management, either for storing water in times of flood, or by holding water back to reduce flooding.

The tensions between competing land uses in relation to flood risk are reflected in the land zoning that lies at the heart of national planning policy guidance. Development in areas at high risk of flooding is discouraged through the policy, to protect the proposed development from flooding as well as to ensure that others are not adversely affected by flooding. Despite this, some new development is still undertaken on floodplains where the Environment Agency has objected on flood risk grounds, and it is important that inappropriate development on floodplains is properly controlled.

In Montgomeryshire, the Pumlumon Project[31] is working with local farmers, foresters and tourism businesses across 150 square miles of the Cambrian mountains, changing upland management to reduce flooding, as well as boosting the local economy, improving carbon storage and supporting wildlife, by:

- Blocking ditches that drain peat bogs;
- Restoring acid grassland, hedgerows and upland woodland;
- Improving infiltration by changing grazing regimes, reducing stocking densities and planting broadleaf trees; and
- Buffering rivers and streams.

In the Peak District, the Making Space for Water project[32] is restoring degraded moorland to retain water on the land by:

- Blocking erosion gullies; and
- Re-establishing vegetation on bare soils.

In Pickering, in North Yorkshire, the Slowing the Flow Pickering project[33] is working to reduce the frequency of future floods in Pickering, as well as delivering a range of other environmental and community benefits, by:

- Constructing low level embankments;
- Creating riparian and floodplain woodland;
- Restoring a large woody debris dam;
- Undertaking farm-scale targeted planting and the creation of infiltration basins;
- Blocking moorland drains;
- Establishing no-burn zones along moorland streams; and
- Restoring streamside buffer zones along forest streams.

There is an extensive legacy of historical development in areas at risk of flooding, although most of these areas are protected by defences of some form. The challenges for people living, working and managing flood risk in these areas are often great. In the short term, managing flood risk is all about making communities more 'resilient' to flooding, through warnings, provision of emergency support and use of property and community protection schemes.

However, in the longer term, the strategy is more challenging. Climate change projections indicate that flood risk is likely to increase, due to rising sea levels and increased rainfall. There are also parts of the country where it is considered uneconomic to defend land and property, such as some farmland or small or remote communities. In such locations, resilience to flooding will be vital if their communities still want to live and work there. Shoreline Management Plans by the Local Authorities and Environment Agency, e.g. Suffolk Coastal District Council, present strategies for managed retreat for situations where it is deemed uneconomic to maintain existing defences.[34]

The increased threat of flooding will prompt a call for proactive strategies in more areas of the country. More areas will need to be identified for storage of flood waters and to protect downstream communities (it should be noted that the Environment Agency already owns or operates more than 800 flood storage areas, but this requirement is likely to rise).

The focus is not only on areas that need to be zoned for storing flood water; the management of land in catchments will also need to be reviewed in order to slow the flow of water down. Some of these measures have already been identified in the previous section, including flood storage, less intensive grazing, upper catchment tree planting or ditch blocking, using CIRIA guidance on land use management, flood flows and sediments.[35]

The way that the land is managed is crucial to flood risk management. It is also important to recognise that there are benefits to wider society from flood protection services which may be provided by managing the land in a certain way.

However delivering changes in land management is not straightforward, so engagement with residents, landowners and land managers is a critical element of any strategy.

Having the right tools is also vital. If a more holistic approach is to work we will need clarity over acceptable land use practices to both adapt to and mitigate flood risk. This must include a clear baseline to avoid poor practices leading to increased runoff water and soil washing into rivers, and ensuring good management leading to higher infiltration rates, as well as targeted support for additional action. This could be achieved by requiring higher standards of soil and water protection in return for farm subsidies, and effective use of regulation under the Water Framework Directive. In addition, a new generation of incentive schemes could provide targeted support to farming systems and habitats that increase resilience and deliver multiple benefits from land.

The decisions will not be easy and there will be trade-offs to be achieved, but the kind of initiatives identified (see section 4) provide a model for success while the Catchment Based Approach provides a framework for scaling up initiatives.[36]

Getting the best from our rivers by working with nature – an opinion piece

Tony Juniper, environmental advisor, writer and campaigner

Much of the UK gets a lot of rain, and that is why we have more than 389,000 kilometres of river. Essential for the welfare of people nationwide, over the centuries these watery ribbons of life have become subject to growing pressure, not only because of what we have done to them directly but also because of changes in their catchments.

Our best rivers, those officially recognised for their nature conservation value, are in a worse state than any other kind of similarly designated habitat in the country. Over-abstraction from rivers and ground water, pollution and physical damage are among the reasons. Nutrient input is an especially big problem that is often linked with soil loss.

A consequence of all this is reflected in the biological state of our rivers. With under a quarter in the 'good' condition required by the EU's Water Framework Directive, it is quite obvious that much more needs to be done in bringing our rivers up to scratch so that they can do all the jobs we need them to do.

These include helping to supply water, permitting navigation, recreation, nature conservation and drainage. All of these services have a value in our crowded islands and we need to make sure we can optimize how best to achieve them all. What is evidently not an intelligent approach, however, is to make policies that place any one of the services above the others. But this is exactly what is in danger of happening in the wake of recent floods.

The inundation of farmland, houses and businesses has rekindled calls for more to be done to harness the drainage service provided by rivers through dredging their channels. It's a policy that for many will appear superficially attractive. But tearing out the bed of a river, straightening its channel and de-vegetating its banks could hardly be more destructive, depriving a wide range of aquatic organisms of their habitat and in the process depriving society of many benefits.

Reducing flood risk need not entail this kind of environmental damage, however. An alternative approach is to look instead at how aspects of the water environment can be *enhanced*. Rivers are dynamic and constantly changing systems that are closely linked with other features in the landscape, including their floodplains and wider catchments. There are, in any case, a host of studies that demonstrate that wholesale dredging has many unintended consequences and can often make downstream flooding, more, not less, likely.

When taking this wider view it often becomes clear how flooding is less linked to an absence of dredging and instead damage to the riverine environment. For example building houses or planting crops on floodplains obviously invites increased flood risk. So does the loss of soil from the wider catchment. Caused by cultivation and grazing practices, soil eroding from the land and entering rivers can lead to several environmental problems, including the silting up of riverbeds.

With all this in mind, it seems logical to consider how best to reduce flood risk in the context of the wider state of our river environments and their catchments. By looking at low lying land differently, taking steps to slow down soil loss and through measures to restore river flow in those areas suffering from over-abstraction, it would be possible to harness rivers for the full suite of services and benefits they provide to society, rather than simply seeing them as a drain.

By taking this route, and avoiding the destructive impacts of dredging, it will be more likely that the UK will one day meet the requirements of the EU's Water Framework Directive, and its goal to restore the health of surface waters. It is not a question of looking after the environment at the expense of people's needs. By meeting the objectives in the Directive, not only would we be making an important contribution to conserving wildlife and enhancing the recreational value of rivers, we'd be adding to the nation's water security and reducing flood risk too.

Making this shift toward enhancing the environment rather than causing damage to it will require a more joined up and integrated approach. Simplistic 'solutions' like dredging may command some populist support in the short-term, but going down that road is neither the most intelligent nor optimum course we can take.

5 Glossary

Arterial drainage: a drainage system where different number of drains flow collectively into one main channel.

Backwater ponding: where water levels are influenced by downstream factors – these may include constrictions in the channel, high levels in a tributary river, or the sea.

Bankfull discharge: the flow capacity of natural river channels.

Canalisation: the creation of regular channels often including realignment to increase conveyance.

Conveyance: the theoretical capacity of a river to carry water.

Drain: an artificially created channel or pipe – often for draining agricultural land.

Drainage catchment: an area of artificially drained land – generally defined by the drainage network, but can be affected by local water levels.

Dredging: the systematic removal of accumulated material from river or other watercourse channels.

Desilting: the removal of fine silt and sediment from a watercourse.

Flow rate: the actual flow of water through a river at a given time.

Highest Astronomical Tide: the highest tide level which can be predicted to occur under normal meteorological conditions

Natural catchment: the land drained by a stream or river – generally defined by the topography.

Reach: a length of channel.

Rhyne: a drainage ditch or canal, used to turn areas of wetland at around sea level into pasture.

Sump: an infiltration basin used to manage surface runoff water and recharge underground aquifers.

Stream power: the energy of a river.

Tide locking: the prevention or reversal of normal river flow due to high tidal levels.

End Notes

1. Somerset Drainage Board Consortium, 'Drainage Board's 10-point plan to beat flooding on the levels', www.somersetdrainageboards.gov.uk/notice-board/drainage-boards-10-point-plan-to-beat-flooding-on-the-levels/.
2. Environment Agency (2014) 'Rivers and Coastal Maintenance Programmes 2013-14', www.environment-agency.gov.uk/homeandleisure/floods/109548.aspx.
3. Lancaster University (2008) *Analysis of historical datasets to look for impacts of land use and management change on flood generation*, Defra commissioned report FD2120, http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=13972&FromSearch=Y&Publisher=1&SearchText=fd2120&SortString=ProjectCode&SortOrder=Asc&Paging=10.
4. Met Office 2014 'A Global Perspective on the Recent Storms and Floods in the UK', http://www.metoffice.gov.uk/research/news/2014/uk-storms-and-floods.
5. ADA, *Dredging: the views and experience of Internal Drainage Boards*, www.ada.org.uk/downloads/other/downloads_page/Dredging%20-%20the%20views%20and%20experience%20of%20IDBs.pdf.
6. Institute of Hydrology (1999) *The Flood Estimation Handbook*.
7. Based on typical UK flood characteristics outline in the Flood Estimation Handbook *(The Flood Estimation Handbook*).
8. Environment Agency (2013) *Somerset Levels and Moors Asset Management Strategy Lower Tone and Parrett - Curry Moor and North Moor*.
9. Environment Agency (2011) *Dredging and Pilot Studies Report*.
10. River Quaggy Flood Alleviation Scheme, www.qwag.org.uk/quaggy/flood.php.
11. Newson, M.D.and Robinson, M. (1983) 'Effects of agricultural drainage on upland streamflow: case studies in mid-Wales', The Journal of Environmental Management, 17:333-48.
12. Robinson, M. and Rycroft, D.W., (1999) 'The impact of drainage on streamflow', in: R.W. Skaggs and J. van Schilfgaarde (Editors), *Agricultural Drainage*.
13. Sear, D., Wilcock, D., Robinson, M. and Fisher, K. (2000) 'River channel modification in the UK'. in M. Acreman (Editor), *The Hydrology of the UK, A Study of Change*, pp.55-81.
14. Bailey, A D and Bree, T. (1981) *The effect of improved land drainage on river flood flows, in The Flood Studies Report, Five Years On*, pp. 131-42.
15. 'Unintended consequences of dredging'. www.youtube.com/watch?v=OAZ_BuyM41s.
16. Mathias Kondolf G. (1994) 'Geomorphic and environmental effects of instream gravel mining', Landscape and Urban Planning, Volume 28, Issues 2–3, April 1994, pp. 225–243.
17. P.J. Cosgrovea and L.C. Hastieb (2001) 'Conservation of threatened freshwater pearl mussel populations: river management, mussel translocation and conflict resolution', Biological Conservation Volume 99, Issue 2, June 2001, pp183–190.
18. Stephanie Peay. Guidance on works affecting white-clawed crayfish (2000), Contract Reference: English Nature FIN/CON/139.
19. During the Environment Agency dredging pilot studies, freshwater mussels, found in the North and South Drains in Somerset were removed from the channel bed material and placed back into the drain following dredging.
20. The Water Vole is fully protected under Schedule 5 of the Wildlife and Countryside Act 1981 (as amended).
21. Telfer S (2000) *The influence of dredging on water vole populations in small ditches* (Scottish Natural Heritage commissioned report F99LF13).
22. Good practice guidance is available for mitigating the impacts on water vole of de-silting of small ditches (for example from the Environment Agency, the Association of Drainage Authorities and local Wildlife Trusts) which, at some sites, can be beneficial in the longer-term - for example by opening up previously de-silted ditches to increase water levels and extend habitat. All such works require adherence to the relevant legislation and careful assessment on a site-by-site basis.
23. BTO (2012) *Bird Atlas 2007-11,* www.bto.org/volunteer-surveys/birdatlas.
24. Gov.uk, 'Nation's biggest inland flood defence opened in Nottingham', www.gov.uk/government/news/nation-s-biggest-inland-flood-defence-opened-in-nottingham.
25. Environment Agency, 'Banbury Flood Alleviation Scheme', www.environment-agency.gov.uk/homeandleisure/floods/124750.aspx.
26. Relevant policy documents include Planning Policy Guidance 25: Development and Flood Risk (PPG25) and Planning Policy Statement 25: Development and Flood Risk (PPS25), which have been incorporated into the National Planning Policy Framework (NPPF). Under the NPPF, new development should be directed away from areas at risk of flooding, and developments on the fringes of floodplains should demonstrate at application stage that they are both safe and do not adversely affect the flood risk for others.
27. Pitt M. (2008) *Learning lessons from the 2007 floods*, http://webarchive.nationalarchives.gov.uk/20100807034701/http:/archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html.
28. Pontbren farmers, 'Pontbren farmers', www.pontbrenfarmers.co.uk/.
29. Stafffordshire Wildlife Trust, *Farming Floodplains for the Future*, www.staffs-wildlife.org.uk/sites/default/files/files/Publications/Farming%20Floodplains%20for%20the%20Future%20Final%20Report.pdf.
30. CIRIA (2007) *The SUDS Manual, Report C697*; WWT and RSPB (2013) *Sustainable drainage systems: Maximising the potential for people and wildlife*, www.rspb.org.uk/Images/SuDS_report_final_tcm9-338064.pdf.
31. The Wildlife Trusts Montgomeryshire, *Invest in the Pumlumon Project*, www.montwt.co.uk/images/user/Pum_brochure.pdf.
32. Moors for the Future Partnership, 'Making Space for Water', www.moorsforthefuture.org.uk/making-space-water.
33. Forestry Commission, 'Slowing the Flow at Pickering', www.forestry.gov.uk/website/forestresearch.nsf/ByUnique/INFD-7YML5R.
34. Suffolk Coastal District Council, 'Shoreline Management Plans', www.suffolkcoastal.gov.uk/yourdistrict/planning/coastal-management/engaging-and-enabling/shoreline-management-plans/.
35. CIRIA, *Land use management effects on flood flows and sediments - guidance on prediction* (C719), www.ciria.org/service/knowledgebase/AM/ContentManagerNet/ContentDisplay.aspx?Section=knowledgebase&ContentID=25897.
36. Environment Agency, 'Catchment Based Approach for a healthier environment, www.environment-agency.gov.uk/research/planning/131506.aspx.

About the coalition

The Blueprint for Water coalition is a unique coalition of environmental, water efficiency, fishing and angling organisations which call on the Government and its agencies to set out the necessary steps to achieve "sustainable water".

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For further information and contact details visit:

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