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The Way Forward for Natural Flood Management in Scotland

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Executive Summary

A more sustainable approach to flood management is being adopted at a policy level by many developed countries. This new approach is leading to an increased need to understand and quantify the methods involved. Sustainable Flood Management (SFM) as a concept is not new, its methods have been practiced on many continents for many years. With increasing scrutiny of the effectiveness of traditional engineered solutions there is a growing realisation throughout the world that there is a huge need for pro-active and sustainable solutions.

SFM as a concept may not be new but, in Scotland, this approach to flood risk management is new. It was incorporated at a legislative level as part of the Water Environment and Water Services [Scotland] Act in 2003. It has been incorporated into recent European legislation and planning guidance under the EU Water Framework Directive and the EU Floods Directive. However, the lack of a detailed explanation of what it is has hindered its development and application.

Natural Flood Management (NFM) is part of a SFM approach and has recently been developed as a series of techniques that involves working with rivers and coasts using natural processes within the framework of land use planning. This type of management is not new and most of the techniques are components of best practices in farming, forestry, river restoration and natural habitat management. A major element is the production of a catchment flood management plan enabling most of the current land uses to continue while introducing flood controls in key areas.

To help fill in the knowledge gap in NFM, this literature review has been carried out to see what can be learned from past studies and experiences in other countries. Please note that this report does not deal with coastal flooding. The issue of coastal management and managed realignment and its benefits for flood risk management in Scotland merits further investigation, but is outside the scope of this report.

Main Findings

- Most hydrological studies of upland forestry have concentrated on the effects on the catchment water yield (the water that flows out of a catchment) and not the effects of flood generation processes.
- Previous river restoration projects have all indicated that there are benefits for flood management but the lack of data fails to quantify how effective this can be.
- Restoration of wetlands and the reconnection of floodplains have been shown to be effective as flood management techniques, and some data exist to quantify how effective they can be. There is a need to sub-divide wetlands, at least in terms of upland and lowland, to better understand their role in NFM.
- There is clear evidence that riparian vegetation will slow down flows in channels and increase local floodwater storage. There is also a need to understand the role of vegetation type over a floodplain and the ability to temporarily hold back water (leaky barriers).
- Several studies have been carried out which show the benefits of some agricultural practices in flood management. These are mostly related to increasing infiltration rates into the soils and reducing the amount of artificial drainage.

Reports from previous land management and river restoration studies in headwater catchments have shown that they are often undertaken only to address a local issue and there is often no quantification of the effects on runoff rates or channel flow rates. There are numerous reports where circumstantial evidence points to the benefits of coordinated land management planning in the uplands for flood management. The work carried out in lower catchments on applied NFM techniques has been more extensive than in other parts of the catchment but there is still little in terms of quantitative output. While there

is a lack of detail in most published reports, there is convincing circumstantial evidence that NFM does work.

The case for NFM in Scotland is based around results from previous studies carried out elsewhere in the UK, Europe and many other countries. The published reports from these studies clearly show that when NFM is applied to a catchment, runoff rates and flow rates in rivers can be reduced. The need to embrace NFM in Scotland is growing, particularly in the face of climate change and over-reliance on traditional flood defences. Legislation now exists to enable NFM to be adopted but there are still gaps in the technical understanding of the NFM processes and the management structures required to implement NFM.

Scotland can learn a significant amount from the other studies but also needs to develop its own strategy for implementing NFM. In the short term, there is a need to focus on hydrologically-based NFM demonstration sites coordinated to focus on specific NFM techniques in functional flood control areas in the catchments. In the long term, there is a need to develop catchment flood management plans to produce management tools for deciding the prescription of measures to be applied, how to involve all stakeholders (particularly the communities) and how to fund the work.

Key Messages

This report produced several key messages that help guide selection of subjects for demonstration sites:

- There is an urgent need to agree a way forward for applying NFM at the catchment level;
- In trying to analyse previous reports there was a distinct lack of detail but conclusive circumstantial evidence to support NFM;
- Most hydrological studies of upland forestry have concentrated on the effects on the catchment water yield and not the effects of flood generation processes;
- The past river restoration projects have all indicated that there are benefits for flood management but most concentrated on the ecological benefits;
- Restoration of wetlands and the reconnection of floodplains have been shown to be effective as flood management techniques;
- There is clear evidence that riparian vegetation will slow down flows in channels and increase local floodwater storage;
- There are benefits from some agricultural practices for flood management particularly in increasing infiltration rates into soils;
- Whole catchment flood management projects have been undertaken but can be prone to failure if the wrong management structure is put in place and if there is a lack of technical understanding;
- Trans-national studies show that even if catchments cross administrative or political boundaries NFM can still be successful.

The Way Forward

The way forward for flood management in Scotland is to produce a robust management toolbox for applying NFM on a catchment scale. This should be done by developing a series of demonstration sites and also a single demonstration catchment. The demonstration sites are needed to develop the techniques involved in NFM and to quantify how effective they can be. The demonstration catchment is needed to produce a method for identifying functional flood control areas, involving all stakeholders, especially the communities, and for deciding how to finance the work.

Recommended Demonstration Sites

The following six demonstration sites should be developed, one for each NFM technique:

- Upland forestry – with focus on the role of forests in attenuating flood generation processes;
- River channel restoration – in particular quantifying the role of meanders in slowing flow rates in rivers;
- Wetlands – examining upland and floodplain wetlands separately to investigate their roles in buffering high energy flows in the uplands and storing water in the lowlands;
- Floodplains – quantifying the effects of reconnecting floodplains to provide storage of flood waters;
- Riparian vegetation – investigating the effects of different riparian vegetation in slowing flood waters and creating leaky barriers;
- Agriculture – focus on increasing soil infiltration rates by different land management practices.

The demonstration catchment should include options for all of the techniques and also a range of land owners, land uses, communities, infrastructure and administrative structures.

The sites and catchment should form a network of NFM demonstration projects which should be coordinated by a group of managers and practitioners. The network should be implemented as soon as possible and operated initially for a three year period. Results should be regularly published and lessons learned throughout the duration of the project. The final product should be the management toolbox for applied natural flood management.

1 Flood management: the sustainable approach

1.1 Why the sustainable approach is needed

It is now becoming widely accepted that in recent years there has been a worldwide increasing frequency of major flood events. Loster (1999) analysed the world's great flood disasters from 1950 to 1998. He found that between 1950 and 1979, there were on average 7-9 major events per decade but the decade of the 1980's experienced 20 major events and in the 1990's there were 34; a threefold increase. Since then the flood events have continued with years such as 2002 when many European countries, including Belgium, Moldova, Russia, Czech Republic, Austria, Germany, Romania, Albania, Switzerland as well as UK, were affected.

It is predicted that these trends will continue. Forecasts estimate that by 2100, climate change could increase river flows by 20% (Werritty *et al.,* 2002). The same report gave details of a comprehensive review of properties in Scotland at risk of flooding and showed that 77,000 inland homes were at risk and the average annual cost of flood damage for Scotland was in the region of £20m. However, floods should not just be considered in terms of their financial cost; there is a substantial human cost to be considered. Goklany (2007) analysed historic records of deaths due to extreme weather events and found that between 1990 and 2006 there was an annual average of over 7500 deaths worldwide due to flooding.

Increased flooding is not just a consequence of climate change. There are established links to human mismanagement of rivers and their catchments. Drainage and land management have reduced the capacity for catchments to hold stormwater and release runoff slowly, producing flashy flow regimes in the river systems. Also demands for floodplain development have meant that rivers have been straightened but constricted within narrow channels, and have been physically disconnected from their floodplains: 90% of the original active floodplain of the Rhine has now been rendered inactive (Schneidergruber *et al*., 2004). Increased floodwaters now have nowhere to go without either overtopping flood defences, or the flood wave is transmitted down the river, increasing the risk further downstream. The traditional response to increasing flood risk in Europe has been to build higher and higher defences; however this has not always proved effective and prevented flooding.

Historically, most developed countries have adopted heavily engineered solutions to flooding problems whereas developing countries tend to lack the economic resource needed to create and maintain them. Natural flood regimes are almost absent in the rivers of industrialized countries as a result of the re-engineering of waterways (Bayley, 1995). Developing countries tend to have rivers with natural flow regimes and they take a more basic approach looking at the source of the problem and how to live with rivers. This fundamental dichotomy in approaches to flood management is described at length in Ogtrop *et al., 2005*.

The increased need for alternative flood management is not only due to inappropriate engineering projects but also because of the degradation of natural buffering systems within the catchment and over development of floodplains coupled with enhanced consideration of the natural environment. Traditional flood management is now being questioned in terms of sustainability.

A more sustainable approach to flood management is being adopted at a policy level by many developed countries. This new approach is gradually leading to an increased need to understand and quantify the methods involved in sustainable management. Additionally it is catalysing more widespread reviews of existing land management practices, many of which might be refined to be applied in the process of Sustainable Flood Management.

1.2 The concept of sustainable flood management

Sustainable Flood Management (SFM) as a concept is not new, its methods have been practiced on many continents for many years. With increasing scrutiny of traditional engineered solutions there is a growing realisation throughout the world that there is a huge and urgent need for pro-active and sustainable solutions.

The notion of sustainability in the context of flood management is still rather ambiguous, but generally embraces economic, environmental and social objectives. Kundewicz (2002) identifies the main indicators of sustainability of a flood protection scheme as: reversibility, flexibility, fairness, risk, consensus, efficiency and synergism e.g. a multipurpose reservoir may have several functions related to sustainability such as flood protection, water supply and hydropower.

SFM as a concept may not be new but, in Scotland, this approach to flood risk management is new. It was incorporated at a legislative level as part of the Water Environment and Water Services [Scotland] Act in 2003, when a new duty to promote sustainable flood management was introduced for the first time. The implications of this duty on flood management were discussed in detail in the report *Go with the Flow* (RSPB, 2003). However, it was soon realised that a lack of understanding of what SFM means, and the unsuitability of existing legislation to deliver SFM on the ground hindered the progress of its implementation, as indicated in the follow up report *Time for a change* (RSPB, 2007). In 2004 the Scottish Government Ministerial Group (the National Technical Advisory Group, NTAG) proposed the following definition of SFM:

"Sustainable flood management provides the maximum possible social and economic resilience against flooding, by protecting and working with the environment, in a way which is fair and affordable both now and in the future."

In a recent consultation, this definition has been accepted but there is still a need for a clear interpretation of its meaning.

SFM has now been incorporated into recent European legislation and planning guidance under the EU Water Framework Directive and EU Floods Directive. The Directive is now ready to transpose in Scotland through primary legislation and provides an opportunity to introduce a new framework within which SFM can operate.

In practice a sustainable approach should mean that plans integrate a range of flood management requirements using best practices and involving the economics of a scheme, good planning, understanding flood generation processes, protecting natural environments and working with communities. This has led to the suggestion that SFM includes the following 8-components (Johnson, 2008a):

1. Floods legislation driven by good science, policy and planning;
2. Flood monitoring networks and warning systems;
3. Flood data for trend analysis and investigating flood generation processes;
4. Protecting, benefiting and involving communities;
5. Engineered flood protection schemes;
6. Economics including capital costs, maintenance costs, environmental and social benefits;
7. Protecting, restoring and enhancing the natural environment;
8. Natural flood management in functional flood control areas involving river restoration and catchment land use planning.

SFM is therefore an integrated set of procedures linked into a physical catchment. Natural Flood Management (NFM) is part of a SFM approach and has recently been developed as a procedure that involves working with rivers using natural processes with systematic land use planning. This type of management is not new and most of the techniques are components of best practices in farming, forestry, river and natural habitat management. The new part is the development of a catchment flood management plan describing flood processes and enabling most of the current land uses to continue while introducing flood controls in key areas.

NFM is a catchment-based approach aimed at reducing runoff rates in the uplands and reducing rates of flow down watercourses. It selects the functional flood control areas within the catchment to modify or restore land uses that together reduce downstream flooding. The key components of NFM comprise the suite of techniques that are used, their spatial distribution around the catchment and the quantification of how effective they will be in the short and long terms.

The techniques that are used in NFM were first described in WWF (2007) and include:

- Reforestation of hillslopes
- Planting dense woodlands in gullies
- Modifying agricultural practices
- Restoring upland wetlands, lowland wetlands and floodplains
- Restoring river channel meanders
- Controlling excessive erosion
- Management of large woody debris in watercourses

These techniques are varied in form, some dealing with runoff rates and some with rates of flow in watercourses. They are all applied using natural processes and are relatively low cost compared to engineered techniques. Some techniques such as blocking drains have an immediate effect while others such as woodland restoration will take years to become effective. Therefore, it is not just about the spatial distribution of NFM techniques but considering their short and long term effectiveness i.e. developing a prescription of measures.

Application of NFM techniques can be considered catchment restoration and, as it is aimed at reducing flood peaks, it is also river restoration. River restoration is more commonly associated with the repair of riverbanks or improvement of habitats; in NFM it is about applying the techniques to restore the natural flow regime of the rivers. NFM should also work with the rivers so that once the flow regime has been restored the river itself will undertake the long term maintenance works.

The prescriptions of measures on the catchment scale needs to be quantified in terms of the changes to the downstream flood hydrograph. The aim is not to reduce the total amount of water in a flood but to reduce the damaging flood peak by extending the length of time when the river is high. Within most catchments there are a number of significant tributaries feeding into the main river. Consideration needs to be given to the magnitude of the flood peaks in each tributary and also the coincidence of peaks.

The planning and implementation of NFM on a catchment scale has to involve the local community. In most situations the proposed work will be on private land, landowners may have alternative uses of the land and situations in the catchment may change. There also needs to be cooperation between neighboring communities. Catchments often cross administrative and national boundaries so there needs to be cooperation between local authorities and governments. NFM should be integrated into other spatial plans so that there are long-term social, environmental and economic benefits for communities and the natural environment. By taking a partnership approach and by using prescriptions for land use planning the flood management will be effective and sustainable.

There is an urgent need to agree a policy for applying NFM at the catchment level. NFM needs better understanding in terms of the methods of implementing techniques and how to quantify its effectiveness. This is likely to involve developing demonstration sites, involving communities and using the lessons learned to develop catchment flood management plans.

2 How could a literature review help to develop NFM

NFM uses a range of river restoration and land management techniques most of which have been used previously in other situations. The new concept is applying them throughout a catchment in the most effective locations and being able to quantify the short and long term effects. Previous studies in river restoration and land management have been undertaken for a range of reasons, by different organizations and in many countries and these results could be useful in the further development of NFM.

The results from previous studies could be of most value in quantifying the effectiveness of individual techniques in terms of flood control but also in assessing their applications in different locations and on different scales. For the techniques there are many examples in the published literature of river channel restoration projects and also many examples of land management changes. However, there are only few examples of either applying techniques to restore natural river flow regimes or where the study has quantified the effect of river restoration on flood flows. But there are previous studies related to selected land management processes. Some of these have quantified the effects on storm water runoff and flood flows however few have applied the results on the whole catchment scale.

In an analysis of previous results there is a need to group studies into an organized framework. This framework could either reflect the location within the catchment or concentrate on individual techniques; both should be useful in the further development of NFM.

Categorising previous works according to the study site location within the catchment could distinguish those studies undertaken either the upper, middle or lower catchment or indeed the whole catchment. The upper catchment studies could be those carried out in that part of the catchment where the rainfall is usually greatest, topography is steep, soils and thin, channel gradients are high. In general this is the zone where floods are generated and so NFM concentrates on techniques to reduce runoff rates and slow flows in river channels. In contrast, the middle and lower catchment studies could be those in the floodplain where river meanders develop, the channel gradients are low and rivers have often been artificially modified. This is the zone where flood risk is usually highest but where NFM concentrates on slowing river flows and increasing flood storage.

Categorising previous works according to the NFM techniques being used could enable the detailed hydrological processes to be better understood and how the techniques could be used to enhance the NFM processes. Ideally the previous works could be categorised by both the techniques and location in the catchment to fully understand the processes in different parts of the catchment.

The review of literature related to NFM found many reports of studies carried out, but relatively few which detailed the changes in hydrological processes. Most of these studies gave little details of the location within the catchment in relation to the landscape and none described the locations in terms of flood generation sites, functional flood control sites or flood storage sites. The framework for classifying the sites therefore could not use the location in the catchment and had to simply use the technique described.

In trying to classify previous reports related to NFM in terms of location within the catchment, there is a distinct lack of detail which insufficiently describes the study location. It was possible to classify the reports into different land management or river restoration processes i.e. into NFM techniques. It is considered a significant hindrance to this analysis that the reports could not be classified in terms of catchment location simply due to lack of details in the reports. This should be addressed as a fundamental component of future NFM studies.

3 An interpretation of published results related to NFM practices

3.1 Upland forestry

In the UK uplands, the effects of commercial forestry has probably been the land use change most widely researched, although most of the research refers to forest management practices which are no longer used (Johnson and Whitehead, 1993). Robinson (1986) concluded that intensive ditching before tree planting can increase the rate of runoff and lead to slightly higher flood flows downstream. Immediately after ploughing across a small catchment, peak flows were observed to increase by 15-20%, though this decreased to only 5% after 20 years. The increase was found to be greatest for moderate rainfall events and tended to decrease in relative terms with increasing storm size. Kirby *et al*. (1991) analysed river flows from Plynlimon in Wales and concluded that a 67.5% cover of mature coniferous forest had no apparent effect on larger flood flows but could slightly decrease the peak flows of smaller floods.

Research has also been undertaken in North America where the general finding was that a 100% cover of mature forest was likely to reduce flood flows, typically in the range of 5-35% (Price *et al.*, 2000). The reduction in flood flows was speculated to be due to drier soil condition under the trees, greater soil infiltration rates, interception losses during the event, and potentially that the rough surface of the forest retains snow. Price *et al.* (2000) also attempted to model the potential benefits for flood alleviation of converting a whole catchment from moorland to forest cover. Winter reductions in peak flow were predicted to be as high as 10-15% for the smaller floods and about half this for the extreme floods.

Most studies of deforestation consider relatively small upland catchments and many are carried out to look at the effects on water resources. Studies at this level generally conclude that deforestation causes an increase in the mean annual discharge. Hibbert (1967) looked at 39 paired catchments studies where significant changes in vegetation cover had occurred, further to this Bosch and Hewlett (1982) added a further 55 catchments studies creating a significant global review. They found almost universally that afforestation decreases annual water yield and deforestation increased it. Effects were not detectable for changes of forest cover of less than 20% but were most pronounced in smaller catchments (<25km^2) in high rainfall areas.

Siriwardena *et al.* (2006) studied the effects of clearing some 16,500 km^2 of natural forest in Queensland. Measured effects indicated that there was a 78% increase in runoff as a result of this. However, some was attributable to general increases in rainfall. They modelled the forest and clearance for this trend and found that even after accounting for the effect of increased rainfall, deforestation increased run-off by 40%.

Most hydrological studies of upland forestry have concentrated on the effects on the catchment water yield and not the effects of flood generation processes.

3.2 River channel restoration

In the UK, the River Restoration Centre (RRC) has been involved in a number of upper catchment projects aimed primarily at restoring river habitats. For instance, the Afon Ogwen River in Snowdonia was described as being severely denuded of habitat for flora and fauna and subject to a decline in salmon fishery outputs. Its restoration included the creation of a shallower and wider profile with many more dynamic features, suitable for enhancing habitat. This work benefited the flood regime in that raising the bed and changing the profile (in line with historic information) has probably reduced the flow rates and causes the water to spill out over the floodplain (River Restoration Centre, 2008a). Unfortunately the river flow changes were not reported.

In another RRC project, this time on the River Quaggy (River Restoration Centre, 2008b), a specific objective was to "reintroduce floodplain as a natural storage area as part of a larger catchment flood alleviation plan". In reality, this meant the deconstruction of an old canalized section to give the river the space to respond in a more natural manner. In addition, the surrounding meadow area was re-vegetated using locally provenance, wetland seed sources. This is another example of a component of a NFM system and the visual assessment of the outputs seems promising, although again there are very little hydrological data to support the project's success.

The following three sites were part of a combined EU-LIFE project termed the River Restoration Project and show the benefits of coordinated studies. In line with other projects carried out by the RRC, they were not conceived specifically as flood management projects. Rather they implemented river restoration techniques with flood management being defined as an objective for that element. The study sites were the Rivers Cole, Skerne and Brede and all had undergone considerable modifications in their lower catchments. The projects were to restore former meanders and one objective was to try and re-create the natural flood regimes. Parts of the former channels were retained as backwaters and wetlands and these are all expected to have benefits during flood events. The RRC final report (River Restoration Centre, 1999) details changes to the hydrological regime on the Cole, whereby the new channel is predicted to increase out of bank flows i.e. use the floodplain more often. In the River Skerne, four new meanders were created and riverbanks strengthened in an open section of floodplain approximately 2km in length. In the River Brede, meanders were restored over approximately 15km of its length which restored seasonal flooding over a 500m wide floodplain. These restoration projects had observable localised effects and also demonstrated that there were benefits to flood mitigation in the lower catchment.

In 1996, the RRC identified the River Glaven, UK, for restoration work (RRC, 2008c). Once again this is an example of a project whose principal rationale was to enhance the ecology of the river system; however one of its three core objectives was to re-connect the river with its floodplain. This was achieved by narrowing the channel and interrupting or slowing flows by introducing woody debris, creating islands and planting riparian woodlands. Whilst this is presented as a case study by the RRC, its successes are assessed qualitatively and focus on ecological benefits. It praises the high degree of community involvement but there is no information about how re-connection of the flood plain has altered floodwater storage or its effects on flood peak values downstream of the site.

The presence of large woody debris (LWD) in the upper River Devon catchment was found to significantly influence the conveyance of water through river channels (McOuat, 2005). Linstead & Gurnell (1999) showed that LWD increases local flow resistance, which in turn induces an increase in the mean flow depth and reduction in mean velocity. In many small woodland streams, log steps and wood accumulations are a major control on the dissipation of the river's energy so the presence of LWD has significant ramifications on flood generation processes.

The past river restoration projects have all indicated that there are benefits for flood management but the lack of data fails to quantify how effective this can be.

3.3 Wetlands and floodplains

Wetlands cover 6% of Earth's surface (OECD, 1996) and in a review of literature on wetlands, Bullock and Acreman (2003) created a comprehensive database of studies that presented evidence about their hydrological functions from 169 quantitative studies. 82% of the studies showed that floodplain wetlands reduced or delayed floods while 45% of the studies showed that wetlands in the upper catchment reduced or delayed floods. Troy *et al.* (2007) also found that for small catchments an increase in run-off over time correlated closely with the reduction of wetland area within the catchments.

In the River Spey catchment, the Insh Marshes is an internationally important floodplain wetland at the confluence of several energetic mountain rivers including the River Feshie and River Tromie. The conservation status of the Marshes relies on the regular inundation of the land but the downstream community of Aviemore relies on the wetland for flood protection. By carrying out a detailed study of the site, a management agreement was entered into involving the partial excavation of downstream sediment accumulations. The work was designed to reduce the extent of flooding while retaining flood water storage over the marshes and maintaining the protection of the downstream community (Johnson *et al.*, 1991). RSPB Scotland now owns and manages the site for the benefit of both biodiversity and flooding. The floodplain regularly floods during winter and spring, acting as a natural flood system with floodwater covering some 1000ha at a depth of 2 metres. Flood risk is reduced to neighbouring settlements including parts of Aviemore, which is an important base for the local tourism economy.

The Middle Creek Flood Damage Reduction and Ecosystem Restoration Project in the Clear Lake watershed in Texas aimed to manage flood risk by reconnecting both the Middle Creek and Scott's Creek to historic wetland areas and areas of disconnected floodplain in the piedmont zone (Lake County Water Resources Division, 2007). This plan was to include 1400 acres of reclaimed wetland some of which would be re-instated by breaching levees. Additionally, significant areas of riparian habitats were restored giving further flood benefits. Unfortunately there are no details given of how effective the work has been.

In 1997 the Daphne Institute for Applied Ecology in Slovakia developed methodologies for large-scale functional floodplain restoration to mitigate flood risk in the lower regions of the Dyje and Morava River (WWF, 2002). These techniques were applied in a region of the lower catchment which acts as a natural buffer against major flood events. During extreme events the Morava backs up from its confluence with the Danube and creates a huge natural ephemeral reservoir, this already effectively protects the town of Bratislava from heightened flood damage. This ability to protect Bratislava was recognized in the 1800's and for this reason the floodplain was protected against development. New areas have recently been added with the principal aim of enhancing this capability.

An EU LIFE funded project to restore the floodplain function of the Upper Drava River in Austria was one of the biggest river based projects in Europe (WWF, 2002). It is located in the piedmont zone (the area in a catchment between the steeper uplands and the gentle lowlands) and had the key aim to "improve the natural flood protection and river dynamic processes". This was to be achieved by widening the main channel and re-connecting the side channels and other storage areas. The ability of the natural landscape to mitigate flood events was to be further enhanced by the restoration of floodplain forests in the same reaches. Initial reports suggest that the work has reduced flow velocity and increased time to flood peak, furthermore it has improved flood storage capacity by up to 10 billion m^3 and reduced bed scouring. The project was heralded as a great success and claimed that this clearly illustrates the effectiveness of river restoration in terms of sustainable flood management. As a result of these successes there are further projects planned which will build on these techniques in this area.

On a much smaller scale the River Lacha is a tributary river in Poland that had previously been deepened and canalized. A project was set up to remediate these actions in order to re-wet grasslands and wetlands in the area. This required substantial land use change which was carried out by purchasing property from various landowners and organizations. During recent large flooding events the flood peak showed a significant reduction, which supports the effectiveness of this work.

The Tweed Forum has recently started another similar project in the River Till, UK where the aim is to get landowners to work on voluntary basis to carry out a wetland restoration project which will re-connect the lower river to its floodplain. At the time of writing this project is in its early stages and there are no outputs describing any measured processes or benefits.

The lower catchment of the River Elbe has been the subject of considerable historical intervention in terms of hard engineered approaches to flood alleviation. Particularly noteworthy are the extensive networks of groins and artificial backwaters created along vast tracts of the bank. However, recently the German Federal Agency for Nature and Conservation has initiated a number of projects that adopt a more sustainable approach to flood alleviation for this system. A principal project is the restoration of floodwater retention areas and the re-connection of the floodplain. This will be achieved utilising NFM techniques such as restoration of native and riparian woodland and the re-integration of abandoned meanders and oxbows into the channel systems.

The Elbe is extensively studied as part of a number of large multi disciplinary research projects (UNESCO-IHE, Flood site, Helmholtz Middle Elbe Platform and others). However it is questionable whether any of these will gather data specific to the effects of these particular project facets or whether the effects will be significant enough at the scale of implementation to be detected.

Restoration of wetlands and the reconnection of floodplains have been shown to be effective as flood management techniques, and some data exist to quantify how effective they can be. There is however a need to sub-divide wetlands, at least in terms of upland and lowland, to better understand their role in NFM.

3.4 Riparian vegetation

It is widely accepted that riparian vegetation and woodland lead to increased hydrological roughness which slows river flows especially during flood conditions (Chow, 1959; Bach and MacKaskill, 1984). Thomas and Nisbet (2006) chose to model the effects of floodplain woodland over a 2.2 km reach of a river in southern England. They predicted reductions in water velocity and increase in local water level for 1yr and 100yr events. Time to peak was increased by 30 and 140min respectively and flood storage increased by 15 and 71%. As a result they conclude that “floodplain woodland offers a means of tackling the increased flood risk associated with climate change”. Anderson *et al*. (2006) modeled vegetation properties and found that channel roughness and hence riparian condition is a significant control on the flood hydrograph with the attenuation of peak discharge substantial in the case of the 100 year flood.

Darby (1999) devised a model to test the effects of flexible and non flexible vegetation on flow resistance. Using factors such as wetted perimeter and vegetation height coupled with stem density on 2, 5, and 20 year simulated events the conclusion was that increases in vegetation height, stem density and percentage cover all lead to an increase in flood attenuation at that locality. This can be interpreted as a potential benefit in terms of flood risk downstream.

Anderson *et al.* (2008) showed that there is much impetus in the USA to restore riparian habitats both for ecological and flood management reasons. In the USA spending on river restoration has been greater than $1 billion per annum since 1990 (Bernhardt *et al*., 2005). Anderson e*t al.* (2008) demonstrated the contribution of riparian vegetation to enhancing local flood generation, while mitigating flood generation in the lower reaches when considered at a catchments scale. It was stated that the detailed planning of vegetation management is essential and they showed that roughness changes according to the stature of the plant and this changes according to the pressure of the water on the plant.

There is clear evidence that riparian vegetation will slow down flows in channels and increase local floodwater storage. But there is also a need to understand the role of vegetation type over a floodplain and the ability to temporarily hold back water (leaky barriers).

3.5 Agriculture

Rural land management has the potential to affect flood generation by influencing the extent to which rain falling on the catchment either infiltrates into the soil profile or runs off as overland flow (O'Connell *et al*., 2004). Robinson (1990) carried out a detailed experiment in six catchments to asses the effects of improved land drainage on storm water run-off. It was found that drainage rate was strongly correlated with soil water status i.e. the antecedent conditions at the time of the storm event. Field drainage was found to increase peak flows from loamy permeable soils. However, where the soils were less permeable and most flow is at or on the surface a drainage network can disrupt the flow pattern and reduce the peak flow. Similarly Howe, *et al*, (1967) showed that field drainage can substantially enhance peak flows by increasing the density of ephemeral streams and inhibiting water infiltration and storage within the soil matrix.

During periods of wet weather the timing of agricultural practices can have a very important bearing on the degree of soil degradation which in turn can exacerbate run-off rates. Sullivan *et al*. (2004) concluded that agricultural developments have led to a widespread deterioration in soil structures, a process which favours soil sealing and crusting, and reduced rates of infiltration and soil storage. Holman *et al*. (2003) found that during very wet years if cultivation practices were poorly timed widespread soil structural degradation would take place and this would result in significant increases run-off rates. In an un-published submission on rural land use, Morris & Hess (2007) state that it is opportune to explore whether, for the recent events, flood risks could be attenuated by the adoption of specific measures that could reduce runoff from and retain storm water on farm land, temporarily 'disconnecting' its flow to the main river system (O'Connell *et al*., 2004). Examples include conservation and contour tillage, retention of crop cover, in-field slope breaks, field margins and hedgerows, ponds and on-farm retention reservoirs. Such measures could positively contribute to the control of flood generation from farm-land.

In response to extreme flood events in the early 1990's, land use practices in the catchment of the River Olsavica, Slovakia, were changed to mitigate flood risks. There was extensive community and stakeholder consultation and this lead to proposals to mitigate flood risk primarily through the sustainable route of land use change (WWF, 2002). Initial results suggest a potential three-fold increase in the level of protection. This process clearly illustrates the value of involving all stakeholders at an early stage, as this appears to have engendered a degree of ownership whereby the community and involved parties were more amenable to changes.

Within the UK there is an example of a community leading a land management project within the upper catchment. The Nant Pontbren is small upland river system situated in Mid Wales. The catchment area for the Pontbren is 18km^2 with the river which forms part of the Upper Severn river basin. Catchment scale flood risk management in this area was catalysed by a farming community initiative to improve the sustainability of their land management practices. Many of the changes in management were implemented for economic reasons, however members of the community noticed that some of the changes were having beneficial effects during flood events. These land use changes included fencing of less productive areas, woodland restoration, shelter belt and coppice woodland planting, restoring hedgerows and wetlands, protecting stream banks and reducing levels of grazing. The commitment and involvement of this community coupled with their blanket control over the catchment meant that there was an excellent opportunity for further studies in this area including the collection of data to support arguments for upland catchment restoration for downstream flood risk management (FRMRC, 2008).

There have already been some outputs for the Pontbren study area. Carroll *et al,* (2004) showed that tree shelter belts significantly improved soil infiltration rates and that these increases occur very rapidly after planting (2-6 years). Marshall *et al*., (2006) studied the effects of manipulations on soil water potential, overland and drain flows at a hill slope scale. Their initial conclusions tend to support reduction of “improved” grassland as a positive flood management measure.

Several studies have been carried out which show the benefits of some agricultural practices in flood management. These are mostly related to increasing infiltration rates into the soils and reducing the amount of artificial drainage.

3.6 Whole catchments

The Wildcat Creek catchment in California, has been positively managed for flooding with a sustainable or natural ethos since the early 1980’s. A number of community groups had formed a coalition to oppose structural flood defence plans and promote the implementation of an alternative flood control plan. One of the key objectives was to “modify existing creek channels to simulate the natural hydraulic shape and processes of undisturbed streams” (United States Environmental Protection Agency, 2008). This objective was set as part of the goal to “safely convey 100-year flood flows past North Richmond using as much of the creek’s natural character as possible”. Detailed components of this plan included the design of a simulated natural channel taking account of geomorphology, sediment transport and flow, the restoration of riparian tree zones using local stock and seed, and changes in land use throughout the catchment such as changing the grazing regime to favour the growth of rough pasture which would slow out of bank flood flows. This particular project has been the subject of a considerable amount of study with the University of California at Berkeley holding an extensive archive detailing the various procedures that have been implemented.

In 2005, as a result of grant funding from HSBC, WWF Scotland was able to set-up a programme of work in the River Devon catchment designed to develop and quantify NFM techniques when applied in the upper catchment. This is one of the few studies in the upper catchment aimed specifically at flood management which includes monitoring networks. The initial findings and results are summarised below, however further details can be found in Flood Planner (WWF, 2007):

- Detailed study of the upper catchment was carried out in order to determine the flood generation processes.
- A suite of techniques for NFM was defined and in order to quantify these techniques four demonstration sites were established. The demonstration sites introduced a range of NFM techniques including woodland restoration, tree planting in a gully, management of tree debris in the watercourse, riparian woodland restoration, erosion control, creation of meanders through a wetland, blocking of artificial drains and planting of tree barriers across a wetland.
- Monitoring stations were established and models developed to quantify the effects on flood water storage and flood flows.
- The results showed that NFM in the upper catchment does work and can make significant differences to run-off rates and the storage of floodwaters. The upper catchment site showed that restoration of steep watercourses can slow down the speed of flood flows and even small wetlands can attenuate floods. A significant difference can also be made to the speed of the water by restoring the natural shape of the channel.

Following severe flooding in 2005 throughout the Scottish Borders region, the NFM option for the Teviot catchment above Hawick was investigated by Scottish Borders Council. It was perceived that the implementation of NFM techniques, particularly in the upper and middle catchment could desynchronise flood peaks and attenuate flood flows such that the extent of flooding during extreme events may be substantially reduced. An upland wetland demonstration site was selected at Craik in the upper Borthwick catchment where the relatively steep tributary burns meet and the gradient of the main river significantly decreases. A model of the site showed that after restoration of riparian woodlands and three former meander channels there would be a reduction in the peak discharge and a delay in the time of the peak even for floods with long return periods (Johnson, 2008b). As a result of the model outputs Scottish Borders Council, WWF Scotland and the Tweed Forum have initiated a programme of work for riparian woodland planting and meander channel restoration. Monitoring stations have been established to measure the effects of this work.

The Parrett Catchment is a relatively large catchment in the UK (1690km^2) with a number of main tributaries including the Rivers Tone, Isle, Cary and Yeo. During 1997 and 1999-2000 the catchment experienced prolonged flooding and due to the high profile nature of habitats present in the catchment there was an enhanced need to address the flooding problems. In 2002 the Environment Agency set out a plan to integrate the whole Parrett catchment in a unified plan at policy level (Environment Agency, 2002). Their strategy aimed to achieve net benefits for flooding and environmental purposes by working with land owners and managers using agri-environment schemes to facilitate change of land use, land swap or land purchase. Arable reversion to grassland proposals aimed to study the potential and physical ability of this land use change to reduce overland flow by changing soil-surface water interactions. They achieved this by developing methods for assessing target areas and recognized that by adopting best practices in soil management, careful timing of planting and harvesting and creating erosion buffer strips, the rate of overland run-off could be greatly decreased.

Two further studies have been carried looking at different aspects of the Parrett Catchments. In 2005 the Forum for the Future carried out a sustainability case study (Somper, 2005) and Land Use Consultants produced their appraisal: Future Organisational Structure for the Levels and Moors and Parrett Catchment (Land Use Consultants, 2005). They both praised the success of the project in creating a high level of public support through the integration of stakeholders and organizations in physical projects.

In the River Enrick catchment in the Scottish Highlands, damaging flooding was experienced in the 1990s resulting in the development of an Integrated Catchment Management Plan (ICMP) (Johnson, 2002). To implement the recommendations the community set up an action group, the Glen Urquhart Land Use Partnership (GULUP). Its principal aims were to ensure the opinions of the local community where voiced. The partnership managed to secure some funding and Forestry Commission took part in an EU funded project (SAFER) which carried out the following work:

- Riverbank stabilisation
- Removal of large debris from river
- Flood-risk assessment
- Establishment of willow tree nursery
- Hydrological survey
- Wetland restoration
- Riparian woodland as buffer-zones
- Blockage of artificial drains
- Ponds & silt traps
- Habitat surveys
- Analysis of flood events

- Erosion modelling
- Flood warning system (CASCADE)

At present there is a number of larger projects that GULUP and partner organisations have identified as priority actions. GULUP have recently updated the ICMP with a proposal for implementing the work (Johnson, 2008). This includes developing detailed plans for channel restoration and sediment removal to reduce the flood risk and to improve aquatic and riparian habitats.

Whole catchment flood management plans are not simple to design and implement, depending on the scale of the catchment. One such example is the Forth Catchment Project (Wise Use Of Floodplains, 2002) which was set-up in 1999 as an EU Life-Environment project. The project carried out extensive consultation to look at how wetlands in the catchment floodplain "could help to provide sustainable solutions to flooding and pollution, now and into the future". It proposed to include the creation of medium and small-scale wetlands, management of headwaters to mitigate flooding and the restoration of riparian buffer zones and river channels and tributaries. One of the core objectives of this project was to "develop local and national action plans to take forward the lessons learned". This project ran for three years from 1999, however since this initial consultation there has been no significant progress to carry any of the recommendations forward.

In 2005, the Environment Agency attempted to set up a demonstration catchment termed the Ripon Multi Objective Project to evaluate the benefits of land use change for flood management. Despite two years with a dedicated project officer and significant funding, the project was not able to get beyond the consultation phase and to date has not really implemented any practices which can be measured in order to fulfil this part of its objectives. This can be starkly contrasted to the relative successes of project like the Parrett Catchment and the Enrick catchment, where community lead projects meant that these early obstacles to practical progress were easily overcome and the projects have progressed to a second phase.

A positive step towards collating and disseminating information has been established by CRUE ERA-NET which aims to introduce structure within the area of European Flood Research by improving co-ordination between national programmes. The vision for the CRUE ERA-NET action on flooding is to develop strategic integration of research at the national funding and policy development levels within Europe to provide knowledge and understanding for the sustainable management of flood risks.

Whole catchment flood management projects have been undertaken but can be prone to failure due to the large scale of the work, the number of individual landowners involved, the extensive consultation which is carried out and the lack of funding focused on flood management. The early involvement of communities is clearly a vital ingredient for success.

3.7 Trans-national river basin studies

Many European river basins cross national boundaries and the advent of the EU Water Framework Directive (2000) and EU Floods Directive (2007) have promoted trans-boundary co-operation and countries are now actively working towards these goals.

The Danube is the second largest river in Europe. It crosses the national boundaries of 19 different countries on its 2780 km route to the sea. A formal agreement: "The Convention on Co-operation for the Protection and Sustainable Use of the River Danube (Danube River Protection Convention, DRPC)" forms the overall legal instrument for co-operation and trans-boundary water management in the Danube River Basin. The signatories to the DRPC have agreed to co-operate on fundamental water management issues by taking "all appropriate legal, administrative and technical measures to at least maintain and where possible improve the current water quality and environmental conditions of the Danube river and of the waters in its catchment area." The International Commission for the Protection of the Danube River (ICPDR) was subsequently set-up as the trans-national body to implement these overarching policies. Two of the ICPDR's goals that relate to NFM are to create or maintain healthy and sustainable river systems and to promote damage-free floods.

The Rivers Rhine and Meuse are both examples of large trans-boundary rivers that have caused considerable flood damage notably in 1993 and 1995. These river systems have a combined catchment area of 191,000 km^2 and flow through heavily populated and industrialised regions and over the years have been heavily modified for land reclamation, navigation and flood management. Historically, flood management has comprised large engineered structures such as dykes and levees. However, as with many other rivers, it is becoming increasingly apparent that the maintenance and enhancement of these structures is not sustainable. As a direct result of the floods in the early 1990's there was unprecedented agreement among the affected states to take part in a collaborative programme of work to mitigate against future flood risk. This programme spawned a considerable number of projects (153 in total), and although the different member states chose subtly different tailored approaches, there was a common thread in that most measures where to have a core focus on "the creation, restoration and preservation of former overflow areas and retention basins".

Despite 365 million euros total budget, there are few specific measured outcomes, the general objectives are valid but component parts are not quantified in terms of their ability to contribute to the success of the whole, indeed the programme website states that "only another emergency situation will test just how effective the programme has been."

The widespread acknowledgement that the Meuse system is predominantly rain fed and there is a need to slow down the responsiveness of the river to extreme rainfall events has meant that attention has turned to the array of tributaries and "capillary" systems in the upper catchment. In 2002, WWF catalysed a project to integrate the management of the upper catchment of the Meuse in an effort to desynchronize and slow flood flows. A recent research study "Storing Water Near the Source" (van Winden *et al.,* 2004) focused specifically on the effects of upper catchment area on the flow regime of the Meuse found that 30% of the water in the flood peak originates in these capillary regions. Further work applied theoretical retardation measures to known contribution values to model the potential flood mitigation that could be derived from manipulations in these upper catchment regions. It claims that there is the potential to decrease flood peak values at Maastricht by as much as $500m^3$.

The trans-national studies add considerable weight to the arguments for NFM. Work has been implemented on the river basin scale which is considered to be reducing flood risk. It argues a compelling case for the integrated role of partners in the upper regions of a catchment who, through grant-supported changes in rural land management can have a considerable positive effect for their counterparts in the lower regions.

3.8 Summary

Reports from previous land management and river restoration studies in headwater catchments have shown that they are often undertaken only to address a local issue and there is often no quantification of the effects on runoff rates or channel flow rates. There are however numerous reports where circumstantial evidence points to the benefits of coordinated land management planning in the uplands for flood management. This is a clear message that NFM in the headwater zone of a catchment can be effective but studies are needed to quantify the effects in terms of flood generation.

The work carried out in lower catchments on applied NFM techniques has been more extensive than in other parts of the catchment but there is still little in terms of quantitative output. Agricultural practices, reconnection of the river with the floodplain, restoration of meanders and riparian vegetation all appear to be effective and there are many examples of this type of flood management being adopted by other countries. While there is a lack of detail in most published reports, there is convincing circumstantial evidence that NFM does work.

4 What mechanisms are in place for NFM implementation

4.1 Existing examples of international and national policies

In recent decades, there has been a significant realisation that catchments must be treated holistically, and this is now reflected in water management policies around the world. Flood management policy is designed to provide a framework, ensuring that work is carried out in a responsible manner without causing problems to downstream areas.

New Zealand was one of the first nations to enshrine integrated catchment management in law and one of the main focuses has been the high degree of devolution away from Central Government (Pyle *et al*., 2001). Traditional, *ad hoc* responses to flooding prior to the 1930's were deemed unsustainable and unsuccessful in preventing flooding, and so, in 1941, the Soil Conservation and Rivers Control Act was produced by Central Government to manage floods and soil conservation. Catchment authorities were established within the jurisdiction of catchment boundaries, with primary responsibility for flood management, and were accountable to local communities through their locally elected boards. Central Government established a system of subsidies to support the catchment authorities.

In 1991 the 1941 Act was combined with other legislation covering water quality, conservation and ecosystem to form the Resource Management Act (RMA). This Act integrates water management with land and air management, with 16 regional councils using catchment boundaries as the implementing jurisdiction. As well as the new legal framework, institutional arrangements were modified to facilitate implementation. For instance, the number of local government agencies tackling natural resource management was streamlined from 622 to 94, and national agencies from 11 to 3. This policy was developed with massive and prolonged open public consultation (Pyle *et al*., 2001). Central Government has the authority to develop national standards and strategies, but plays a very minor role in the day-to-day implementation of the RMA, and rather than command and control the system, they simply guide, assist and supervise regional and local authorities.

Pyle *et al*. (2001) highlighted the barriers experienced to the implementation of the RMA. The introduction of complex, innovative concepts, such as ecosystem management, into law was problematic, due to lack of understanding. Initially, catchment water plans were vague, and lacking in local interpretation of the RMA concepts. Therefore, in 1996, the MfE launched a three-year program of enquiry and policy development, to help fortify implementation of the RMA. The critique concluded that the RMA was a competent piece of legislation, but was hindered by lack of management tools, a lack of data to address current problems, ineffective communication and coordination between sectors of the water management community.

In France, the Agence de Bassin, although only incidentally involved in flood management, provides one of the better examples of integrated catchment management. Policy in France is characterised by centralisation of policy-making combined with decentralisation of decision-making. River Basin Authorities (RBA's) are financially independent, and central government has only limited influence politically and administratively. Together with River Basin Committees (RBC's) and local government, multi-stakeholder participation is promoted by the RBA's, including the water service, environmental NGO's and civic society. RBC's and local government have a very close working relationship, largely due to the fact that taxes raised by RBCs, subsidise local authorities, and local government plays a very active role in policy making, due to the fact that a relatively large number of seats in local government are allocated to RBC members (Lee & Kim, 2008). Another strength appears to be the existence of a catchment 'parliament' made up of major stakeholders, which produces catchment plans. These catchment plans follow a two-tier system already well established in French land use planning. A large-scale, forward planning document is established at the regional (basin) level which identifies broad trends for integrated water management of water resources for 10 to 15 years period. At the local level, a more precise planning document seeks to harmonize the roles and needs of different private and public stakeholders.

In Brazil, water is considered a public resource and community participation is considered key to successful management of water. Watershed management committees are the highest decision-making level. This is viewed as the easiest way to ensure that regional diversities regarding water availability and water user conflicts would be correctly taken into account in the decision making process. Water policies in Brazil are characterised by a decentralised, transparent and flexible management process. Supported by the participation of water users and civil society is the only means available to promote effective implementation of a viable water rights system (Porto *et al*., 1999).

In the UK, the Wise Use of Floodplains initiative aims to demonstrate how sustainable floodplain management can be developed through communication and active involvement of stakeholders. The project is a transnational partnership led by the RSPB, involving government departments, research organisations and NGO's. The Somerset Levels and Moors project was a key component of the scheme, and aimed to demonstrate to policy makers the benefits of a combined approach to multiple sectoral interests. Participatory workshops were held to encourage stakeholders to address issues together, and the project also worked very closely with national and local authorities. The SFM strategies were developed through extensive consultation with stakeholders and organisations involved. Policy opportunities and barriers were identified, together with economic appraisal. The implementation of the Somerset Levels and Moors project generated intensive debate, and has fostered communication and collaboration between many sectors. Stakeholders have prepared a successful integrated catchment management plan, and have demonstrated the importance of stakeholder dialogue to long-term success and sustainability of an SFM project.

Successful policy mechanisms for implementing NFM can be found in New Zealand, France and Brazil. These countries use central Government only in a guidance role and most responsibilities are devolved to a local scale. A local committee needs to involve all stakeholders, including the communities, and need to be financially independent. The committee needs to have management tools available supported by good quality data and most importantly to have specialists involved who can interpret data and results.

4.2 Examples of international and trans-boundary policies

Traditionally throughout the world, flood management has been addressed at a local level and lack of coordination with other river users frequently displaces the risk, without actually decreasing it. Management on a catchment or river basin scale is now fully accepted as best practice however where river basins cross more than one national boundary, numerous practical and political complications arise. Policies facilitating trans-border coordination are therefore a pre-requisite for effective river basin management.

The best example of trans-national policy with the potential to facilitate NFM is found in the EU water policies and legislation, namely the Water Framework Directive (WFD) (2000) and the Floods Directive (FD) (2007). These policies embrace four guiding principles:

1. River basins as the main management unit
2. Principle of solidarity
3. Principle of sustainability
4. Public participation

The WFD is based upon Integrated River Basin Management (IRBM), and aims to achieve 'good ecological and chemical status' on a catchment basis, by 2015. Integration at national and trans-boundary levels is achieved by River Basin Management Plans.

Mitigating the effects of floods and droughts are amongst the objectives of the WFD, however, precautionary flood protection in the form of NFM is not explicitly addressed. It does however provide a structure within which the full range of tools and approaches can be brought together, with multiple sectors working in collaboration, rather than at cross-purposes.

In 2001, in response to the need for a platform for the EC, Member States, candidate countries and stakeholders to share information, experience and expertise, the EU member states and the EC established a WFD Common Implementation Strategy (WFD CIS). Thirteen working groups were set up to establish best practice guidance. In response to major flooding in 2002, the Netherlands and France co-led an initiative on flood prevention, protection and mitigation' in the context of the WFD CIS process (Schneidergruber *et al*, 2004). Ultimately, a document on best practices in flood prevention, protection and mitigation was created. (Meissner, 2003). The document includes an exhaustive analysis of root causes of increased flooding, and makes recommendations for strategy reform. The recommendations highlighted the importance of the integrated river basin approach, public awareness and participation, research, education and exchange of knowledge, retention of water by non-structural methods, land use, zoning and risk assessment, structural measures and their impact, flood measures and prevention of pollution (Schneidergruber *et al*, 2004). Following extensive consultation on this subject, a communication document was published in 2004, which ultimately led to the EU Floods Directive 2007/60/EC. This directive was designed to focus on the assessment and management of flood risks.

European trans-boundary policies for flood management are primarily in the form of the Water Framework Directive and the Floods Directive. Both of these have requirements for international collaboration, exchanges of knowledge and the use of non-structura li.e. non-engineered measures for flood management.

4.3 Financial mechanisms for implementation

In Europe, regional, national and NGO sources of funding are the largest contributors to the implementation of NFM while the EU has supported floods research since the early 1980's through its successive Framework Programmes for research and technological development (Commission of the European Communities, 2004).

There are few published details of the financial mechanisms which have been put in place to support local, regional or national NFM programmes. In the UK, the Flood Risk Management Research Consortium (FRMRC) aim supports an integrated programme of research to support effective flood risk management while in Scotland, the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) has taken a lead role in coordinating discussions into the way forward for flood management in Scotland. Both organisations have made improvements but not yet initiated projects to develop applied NFM.

The EU Framework Programmes aim to facilitate coordination and information exchange on flood protection and the promotion of best practice. European funding streams are complicated, but those which may have relevance to NFM include: the European Regional Development Fund, EU Structural Funds, EU Cohesion Policy, PHARE cross-border cooperation, EU solidarity fund and Special Action Programme for Agriculture and Rural Development (SAPARD). In addition, InterReg is a financial instrument of the EU's cohesion policy, which aims to facilitate trans-national co-operation on flood management. It is an initiative for the support of "cross-border, trans-national and interregional co-operation intended to encourage the harmonious, balanced and sustainable development of the whole Community area" (Schneidergruber *et al*, 2004).

A positive step is being taken through the development of the CRUE website. This is an online database (which is still at prototype stage) coordinating research financed in the EU on flood risk management. This scheme aims to consolidate existing European flood research programmes, promote best practice, and identify gaps and opportunities for collaboration.

Although there have been several successful projects for applying NFM on local, regional and national scales there are little details about the funding structures which supported these works. Funding is clearly a fundamental part of implementing NFM and needs to be put in place for Scotland.

4.4 Key messages

A number of specific findings were made within this report, in summary these were:

- There is an urgent need to agree a way forward for applying NFM at the catchment level;
- In trying to analyse previous reports there was a distinct lack of detail but conclusive circumstantial evidence to support NFM;
- Most hydrological studies of upland forestry have concentrated on the effects on the catchment water yield and not the effects of flood generation processes;
- The past river restoration projects have all indicated that there are benefits for flood management but most concentrated on the ecological benefits;
- Restoration of wetlands and the reconnection of floodplains have been shown to be effective as flood management techniques;
- There is clear evidence that riparian vegetation will slow down flows in channels and increase local floodwater storage;
- There benefits of some agricultural practices in flood management particularly in increasing infiltration rates into soils;
- Whole catchment flood management projects have been undertaken but can be prone to failure if the wrong management structure is put in place and if there is a lack of technical understanding;
- Trans-national studies show that even if catchments cross administrative or political boundaries NFM can still be successful.

5 Conclusions from the review

5.1 The case for NFM in Scotland

The case for NFM in Scotland is based around results from previous studies carried out in the UK, Europe and many other countries. The published reports from these studies clearly show that when NFM is applied to a catchment, runoff rates and flow rates in rivers can be reduced. The need to embrace NFM in Scotland is growing, particularly in the face of climate change and over-reliance on traditional flood defences. Legislation now exists to enable NFM to be adopted but there are still gaps in the technical understanding of the NFM processes and the management structures required to implement NFM.

The role of the Scottish Government should be one of directing and supporting work on a regional scale. Regional scale flood management should operate in river basin or large catchment units, be self-governing with a major role for communities and an independent financial control. This should easily fit into current plans for river basin management planning within Scotland.

5.2 The Way Forward

The way forward for flood management in Scotland is to produce a robust management toolbox for applying NFM on a catchment scale. This should be done by developing a series of demonstration sites and also a single demonstration catchment. The demonstration sites are needed to develop the techniques involved in NFM and to quantify how effective they can be. The demonstration catchment is needed to produce a method for identifying functional flood control areas, involving all stakeholders, especially the communities, and for deciding how to finance the work.

The following six demonstration sites should be developed, one for each NFM technique:

- Upland forestry – with focus on the role of forests in attenuating flood generation processes;
- River channel restoration – in particular quantifying the role of meanders in slowing flow rates in rivers;
- Wetlands – examining upland and floodplain wetlands separately to investigate their roles in buffering high energy flows in the uplands and storing water in the lowlands;
- Floodplains – quantifying the effects of reconnecting floodplains to provide storage of flood waters;
- Riparian vegetation – investigating the effects of different riparian vegetation in slowing flood waters and creating leaky barriers;
- Agriculture – focus on increasing soil infiltration rates by different land management practices.

The demonstration catchment should include options for all of the techniques and also a range of land owners, land uses, communities, infrastructure and administrative structures.

The sites and catchment should form a network of NFM demonstration projects which should be coordinated by a group of managers and practitioners. The network should be implemented as soon as possible and operated initially for a three year period. Results should be regularly published and lessons learned throughout the duration of the project. The final product should be the management toolbox for applied natural flood management.

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Scottish Environment LINK is the umbrella organisation for Scotland's voluntary sector environmental organizations. Operating primarily through its Taskforces – groups formed to address particular policy issue – it is concerned with influencing national policies to ensure sustainable development underpins the government's agenda.

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