Isbourne Catchment Project

Scoping Study (Final Report)

To

Isbourne Catchment Partnership & Environment Agency

By

School of Natural and Social Sciences, University of Gloucestershire

&

The Countryside and Community Research Institute

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Project Manager (Research Team)

Chris Short

Research Team:

Lucy Clarke, Rob Berry

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University of Gloucestershire
Francis Close Hall Campus
Swindon Road
Cheltenham, GL50 4AZ
www.ccri.ac.uk
www.glos.ac.uk/sciences

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Glossary

AOD	Above Ordnance Datum
AONB	Area of Outstanding Natural Beauty – a landscape protected due to its distinctive character and natural beauty
AWD	Artificial Water Body – WFD classification of a water body that has been constructed by man and is therefore 'artificial' and includes flood relief channels, canals (not canalised rivers), reservoirs
BAP	Biodiversity Action Plan - addressing threatened species and habitats and is designed to protect and restore biological systems
CCRI	Countryside and Communities Research Institute
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
FWAG	Farming and Wildlife Advisory Group – an organisation that works with farmers to assist them in understanding the environmental value of their land and make the most of the agri-environment options available
GEP	Good Ecological Potential – classification of the 'potential' ecological status for a defined WFD water body which incorporates biological, chemical and physical assessments within an AWB or HMWB (distinguishes water body from an unmodified, more natural water body – see GES)
GES	Good Ecological Status – classification of the ecological status for a defined WFD water body which incorporates biological, chemical and physical assessments within a natural or semi-natural water body
HMWB	Heavily Modified Water Body – WFD classification of a water body that has been significantly altered from its natural state (i.e. bed and/or bank alterations, reinforcement, canalisation, impoundments and flow controls)
ICG	Isbourne Catchment Group
NFM	Natural Flood Management – the alteration, restoration or use of landscape features to reduce flood risk
NRFA	National River Flow Archive
NVZ	Nitrate Vulnerable Zone – areas where the EA has identified where land drains into nitrate polluted waters/groundwater or where waters/groundwater may be sensitive or at risk of becoming polluted by nitrates. Introduced by the UK government in response to the EU mandate that all EU countries must reduce the nitrate in drinking water to a max of 50mg/l. Good Agricultural Practice should be applied to activities within these areas by farmers
RBMP	River Basin Management Plan – report published by the EA to outline the current and target conditions for water bodies as required under the EU WFD

RsuDS	Rural Sustainable Drainage Systems – a suite of drainage techniques and designs that can be applied to rural areas to enhance natural drainage pathways
SAC	Special Area of Conservation – site designated under the Habitats Directive. They are internationally important for threatened habitats and species.
SSSI	Site of Special Scientific Interest – conservation designation denoting a protected area in the UK.
SFRA	Strategic Flood Risk Assessment – document produced by Cheltenham Borough Council and Tewkesbury Borough Council to document recorded flooding within the area
SNSS	School of Natural and Social Sciences, University of Gloucestershire
SuDS	Sustainable Drainage Systems – artificial drainage designs that mimic natural drainage processes that can be applied across urban developments and other areas to manage runoff and water quantity, improve water quality and enhance local biodiversity
WFD	Water Framework Directive – European Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. Published in the Official Journal (OJ L 327). Covering all aspects of water management (quantity, quality and environment) including groundwater and surface water bodies.
WWNP	Working with Natural Processes – a joint Defra/EA research programme. Working with natural processes means taking action to manage fluvial and coastal flood risk by protecting, restoring and emulating the natural regulating function of catchments, rivers, floodplains and coasts.

Key terms & definitions

Ephemeral watercourses	Seasonal flow paths of water that do not flow all year round, most likely dry during summer months.
Field drainage systems	Underground drainage systems installed in agricultural fields to facilitate water reaching drainage channels at field edges and into fluvial flow.
Fluvial flows	Flows of water in water course that run all year round.
Main river	Statutory watercourse in England/Wales and is managed by EA. Is a watercourse marked as such on a main river map.
Ordinary watercourse	Ordinary watercourses include every river, stream, ditch, drain etc (other than a public sewer) and passage through which water flows and which does not form part of a main river. Managed by a local authority.
Surface flows	Over land flow paths of water, potentially those that have failed to infiltrate to groundwater systems.

Executive Summary

The School of Natural and Social Sciences (SNSS) and the Countryside and Communities Research Institute (CCRI) at the University of Gloucestershire were commissioned by the Environment Agency (EA) and the Isbourne Catchment Group (ICG) to undertake a Scoping Study of the River Isbourne to assess the feasibility and potential benefits of applying natural flood management (NFM) techniques across the Isbourne catchment. Other options had been considered in an analysis of the catchment in 2010 (Haycock 2010) and some minor changes have been made. However, most significant engineering options have been ruled out and not considered to be cost effective whilst soft engineering options such as land use change and natural flood management were recommended for further investigation.

Natural Flood Management (NFM) involves soft-engineering techniques that include drainage techniques that could be classified as Rural Sustainable Drainage Systems (RSuDS), land management changes and increasing the availability of water storage areas. These are becoming an increasingly popular option to reduce flood risk as the opportunity for hard engineering options diminishes. However they remain novel and cutting edge and are considered most effective when working in tandem with other conventional approaches of flood risk management. Nevertheless NFM also has a number of other benefits such as improving water quality and enhancing local biodiversity and amenity as well as increasing the role of the local community in contributing directly to reducing the flood risk of the catchment. Once fully operational across the catchment, NFM will reduce the number of total flood events but on its own it would not erase the flood risk from major flood events, such as those that occurred in the Isbourne in 2007.

NFM designs and typical locations for application include:

- **In-channel:** barriers, bunds, sediment traps, berms, on-line pools, woody debris;
- **Floodplain and land areas:** ponds, basins, wetlands, swales, stone dyke, hedgerows, headlands and buffer strips, contour bunds, shelter belts;
- **Farmyard areas**: rainwater harvesting, cross-drains, swales, green roof, sediment traps, permeable surfaces, soakaways, filter trenches and drains;
- **Woodland**: planting new woodland, restoring existing woodland, natural creation of woodlands;
- **Land and soil management**: converting arable land to species-rich grassland, arable headlands and buffer strips, reduced or zero tillage, decreasing soil compaction, contour ploughing and tramlines.

This Scoping Study reviewed the physical nature of the River Isbourne catchment and assessed the current impacts of flooding and environmental pressures caused by diffuse pollution (sediment, nutrients and other pollutants) that are important considerations under the Water Framework Directive (WFD). The study then reviewed the applicability of NFM across the Isbourne catchment and evaluated whether they could have a positive effect on the main study objectives. The justification for this approach is that previous investigations have ruled out large-scale hard engineering solutions in the Isbourne catchment.

It is important to note that at this stage the estimation of predicted, measurable benefits that could be expected from NFM is very difficult to provide with any confidence. The use of NFM is a relatively new process and published data on achieved flood risk or water quality benefits from other catchments or sites are as yet unavailable. Further work is required to quantify their application across any site or catchment. As a result, this scoping study cannot provide estimations of potential measurable benefits for flood risk or water quality improvements across the Isbourne catchment. Nevertheless it is clear from projects such as those highlighted in the Appendix C that there a number of significant benefits from introducing NFM features. Where natural and local materials are used there appears to be a significant biodiversity benefit both within the water body and the surrounding area. Linked to this there are benefits in meeting WFD objectives. The soft engineering approach means that members of the local community can feel directly involved, either through changing farming practices, allowing the placement of features on their land, planting of the trees specifically for flood risk management and constructing woody debris dams in water courses. However, recommendations for which NFM can be applied and those areas most suitable across the catchment, along with suggestions for the next steps towards planning and implementation can be made.

Key catchment drivers

The key drivers for this study involve the consideration of:

- **Flood risk:** localised flooding has occurred along the River Isbourne;
- **Diffuse sediment pollution:** land use and management change can release large quantities of sediment into watercourses;
- **Water quality and pollution:** phosphate and nitrate levels in river water impact on the biodiversity of the water courses.

A desk study of the catchment provided an understanding of the baseline geology, topography, land use, environmental condition and flood risks.

Catchment characterisation

The Isbourne catchment is considered a single entity for the WFD, however, for the purposes of this study, the water courses in the catchment has been split into 9 areas:

- Langley Brook, including water body flowing from Cleeve Common to Winchcombe
- Beesmoor Brook, flowing from Charlton Abbots to Winchcombe
- Didbrook and tributaries, flowing in to the Isbourne below Greet
- Stanway tributaries, flowing into the Isbourne at Wormington
- Stanton and Laverton tributaries, flowing into the Isbourne above Sedgeberrow
- Dumbleton tributaries, flowing into the Isbourne above Sedgeberrow
- The Upper Isbourne from Winchcombe to join with Didbrook tributaries
- The Mid Isbourne from Didbrook join to Stanton and Laverton tributaries
- The Lower Isbourne from Stanton and Laverton join to joining river Avon.

NFM opportunities for the Isbourne catchment

Whilst there are local characteristics within each water course that may mean some NFM are more / less applicable when considered independently, a range of NFM that are typically applicable can be identified for use within the Isbourne catchment.

- **In-channel designs** involve adding and preserving existing natural and introducing new semi-natural features (e.g. woody debris deflectors, dams and tree root encroachment) along wooded and scrubby river sections. These sections should be used as a template for application in other sections that lack these features. Along the sections of the River Isbourne it should be ensured that in-channel designs such as woody debris (deflectors, natural dams) do not increase local flood risk during larger scale events.
- **Land-based designs** to intercept overland flow pathways such as stone dykes, interception ponds, leaky timber walls, headlands, hedgerows, buffer strips, contour bunds, shelter belts and woodland creations could be applied to steeper areas at the edge of the escarpment. Land-based designs are limited by a lack of floodplain area but could be applied across short open river valley floor areas to enhance in-channel attenuation by carefully designed throttled outflow controls, deflectors, bunds and land-based flow barriers, ponds, basins.
- **Farmyard designs** can be applied to manage surface water flows and improve water quality released from yard areas, livestock and storage buildings, manure / silage / materials / equipment storage areas and improve sediment management of farm sites, tracks and gateways. Capital grants for enhancing run off from yards and treating dirty water before it enters water bodies might be available through the Countryside Stewardship Scheme provided the area concerned was within the Catchment Sensitive Farming designation.
- **Woodland:** the Isbourne catchment has undergone a reduction in tree cover over the last 80 years and wherever possible, woodland or shelter belt plantations should be considered. Grants are available through the Countryside Stewardship for targeted woodland planting and the appropriate management of existing woodland. Small copses should also be considered, the choice of species and future management should be an important consideration with the aim being a dual aim of creating an effective NFM feature and benefiting biodiversity.
- **Land and soil management practices** that contribute to NFM should be applied to the large areas of arable land in the catchment; the introduction of buffer strips, contour ploughing and practices to encourage increased organic matter in the soil and a reduction on soil compaction, such as reduced or zero tillage should be encouraged. The conversion of arable land to species-rich grassland in selected areas could also serve to reduce runoff and increase rates of infiltration. The Countryside Stewardship scheme provides incentives for some land and soil management practices but this is a competitive scheme that is targeted to certain areas. Practices that specifically benefit soil management, such as increasing organic matter and reducing soil erosion, also have benefits for the farmer and land manager in terms of increasing productivity and reducing pest burdens, so might be attractive without government incentives. The nearby Overbury estate practices zero

tillage and regularly plants green manures so there is vegetation no the land all year round. The farm manager regularly has visits to show other farmers then practicalities of this approach.

Principles for NFM application across the Isbourne catchment:

- Permeability of soils across upland areas needs to be retained and enhanced wherever possible.
- A lack of surface water features in upland areas will require careful management of ephemeral surface water flow routes;
- A lack of substantial floodplain features in the Lower River Valleys means that NFM will need to maximize the potential for smaller floodplain features and the potential re-use of mill structures;
- Development across the lower part of the River Isbourne means that any NFM features in the Lower River Valley will need to be carefully located to avoid increasing flood risk;
- Multiple spring sources adding water to rivers along all watercourses means that NFM will need to be spread across all upper areas of the Isbourne catchment;
- Correct siting of NFM barriers and management to increase infiltration will enhance WFD objectives, as indicated by the Stroud project;
- Any larger works, such as the excavation of storage areas, will need to be assessed in order to ensure they meet WFD objectives;
- Insertion of NFM must not damage or cause a deterioration in the existing local habitats, but should where possible seek to enhance natural features;
- As with other NFM projects, for the Isbourne catchment it is inevitable that a significant number of NFM structures and techniques would need to be applied to have a measurable benefit;
- Time is always a constraint and, even with limited resources, a pragmatic decision should be made to begin engaging with the community regarding the installation of NFM features where there is a willingness to do so.
- To measure potential NFM benefits, specific pre-installation, baseline condition, flow and water quality monitoring should be considered, to be followed by continued monitoring after installation as such data has not been collected.

Recommendations

These opportunities and the subsequent principles provide a sound basis on which to take forward a NFM project in the Isbourne catchment. The next step would logically be, following the acceptance of this report, it has already been agreed that there will be a collective review of land use across the catchment. This will build on and ground truth the GIS mapping through a series of catchment walk throughs. The keenness of the local community and in particular the Isbourne Catchment Group shows the level of interest and

willingness to implement the findings of this report. This has become increasingly clear as the project has progressed.

In order to secure some quick gains, which will be important in maintaining and building on the local interest, we recommend that two areas are targeted in the first instance, aimed at reducing the speed at which rainfall travels down the catchment, namely:

- Langley Brook, including water body flowing from Cleeve Common to Winchcombe
- Beesmoor Brook, flowing from Charlton Abbots to Winchcombe

These two areas provide the largest areas of extensive grassland and woodland and significant land owners are supportive of nature conservation and the NFM approach.

The recent, extensive conversion of grassland to arable could be significantly contributing to diffuse sediment pollution in the upper reaches of watercourses. Even if much of this is potentially filtered out before it reaches lower valley areas by many on-farm features such as ponds, there is considerable scope for adjustments in farming practice. The recently secured Facilitation Fund for the Carrant and Isbourne area under the Countryside Stewardship Scheme will be able to facilitate this using the Overbury Farm Estate as a knowledge exchange hub. The wider applied research across the UK would also be beneficial, notably the Allerton project in Leicestershire (see Appendix C4). The change from woodland and natural grassland to arable and pasture has simplified vegetation cover diversity across the catchment and rainfall interception and catchment 'roughness' is much reduced.

The potential of currently overgrown and redundant structures, such as the line mill pool at Toddington, along the lower part of the catchment need to be fully evaluated in terms of their capacity, suitability for storage and likely effectiveness. The first step would be to include a visit to Toddington on the catchment walks and to determine the current state of the feature and its capacity in order to determine the potential contribution of this site.

In terms of flood risk, runoff and erosion control, woodland cover has been estimated in studies in other areas to intercept and prevent up to 40% of rainfall reaching the ground (Dixon *et al.*, 2016). Increasing and maximising woodland cover within a sub-catchment is likely to have a considerable, measurable impact on river flows and flood risk in downstream areas. Whilst catchment-wide woodland re-creation is unlikely to be possible or practicable across the Isbourne catchment, all potential opportunities for increasing general woodland areas, shelter belt or hedgerow cover should be explored. The 'next best' application would be the enhancement of riparian woodland cover wherever it is lacking or damaged by grazing to reduce sediment release and increase in-channel roughness as well as absorption of rainfall. Other techniques could provide localised benefits for site-specific issues such as ephemeral flows or springs that arise after heavy rainfall events.

Many of these potential opportunities will only be achievable with extensive liaison, cooperation, engagement and partnership working between stakeholders including the Environment Agency, landowners, District Authorities, County Councils, Gloucestershire/Worcestershire Wildlife Trusts, Natural England and Defra. In a difficult economic climate it will be important to explore potential funding opportunities and align

WFD and flood risk objectives for the Isbourne catchment to provide a more effective, catchment-based approach.

Application of NFM across the Isbourne catchment must be considered alongside WFD objectives, although the experience of the Stroud project suggests that any impact on WFD objectives is positive, notably in improving reducing sediment loads and improving water quality. Where existing heritage features or natural and semi-natural habitats are concerned a similar approach to enhance should be taken.

Future plans

With the above in mind, the key next steps for NFM across the Isbourne catchment will involve:

- A series of catchment walk throughs to identify specific runoff problems, potential water retention areas and potential sites for NFM where remedial action could be taken on farmyards and where woodland/shelter belts can be inserted and riparian woodland can be enhanced and any other NFM applied;
- This would then enable identification of the potential scale of NFM applications that could be applied within each of the water courses in the catchment and identify the potential extent to which they could begin to address the key issues for flood risk, water quality and pollution management measure;
- Determination of initial pilot study water courses with the potential for a wide range of NFM applications to begin implementation of measures within the catchment. We recommend the Langley and Beesmoor Brooks as the most sensible starting points;
- Exploration of partnership opportunities and identification / alignment of sources of potential financial support for NFM and catchment management approaches;
- Secure funding for a project officer for the catchment. A shared role across two local authorities, Tewkesbury and Wychavon, would be ideal provided the necessary arrangements for cross boundary working, in terms of budget, lines of reporting and communication, can be satisfactorily secured for all parties.
- To devise and undertake baseline assessments and future monitoring programmes to produce measureable outcomes to quantify the impact of any NFM implemented. This may include the installation of more monitoring points in the headwaters of the catchment.

Applying the principles of restoring or enhancing natural drainage pathways and improvements to runoff management across the whole Isbourne catchment can only have positive effects. A catchment-wide, collective consideration of sediment and nutrient sources and drainage pathways is certainly to be recommended.

1. Introduction

1.1 Study Brief

In 2014, the Environment Agency published a report on the Working with Natural Processes (WWNP) to reduce flood risk, outlining a suite of natural flood management (NFM) designs and considerations to restore the natural regulating function of catchments to develop a more resilient approach to flooding (Barlow, 2014). The proposed soft-engineering techniques included drainage techniques that could be classified as Rural Sustainable Drainage Systems (RSuDS), land management changes and increasing the availability of water storage areas.

The School of Natural and Social Sciences (SNSS) and the Countryside and Communities Research Institute (CCRI) at the University of Gloucestershire were commissioned by the Environment Agency (EA) and the Isbourne Catchment Group (ICG) to undertake a Scoping Study of the River Isbourne to assess the feasibility and potential benefits of applying these natural flood management (NFM) techniques across the Isbourne catchment. The applicability of these practices in any location depends on the physical characteristics of the catchment and the potential benefits they can provide in terms of water quality, water quantity and flood risk reduction. There is also an element of whether they provide cost-effective, affordable and sustainable solutions. The justification for this approach is that previous investigations have ruled out large-scale hard engineering solutions in the Isbourne catchment. Other more conventional options had been considered in an analysis of the catchment in 2010 (Haycock 2010) and some minor changes have been made. However, most significant engineering options have been ruled out as not being cost effective whilst soft engineering options such as land use change and natural flood management were recommended for further investigation.

The findings of this Scoping Study will be based on understanding the physical characteristics of, and issues of concern within, the catchment. In particular, it focuses on impacts involving flood risk and sources of diffuse pollution (sediment and chemical) within the Isbourne catchment. Understanding how the catchment functions allows this scoping report to provide a professional judgement of what NFM techniques are applicable. Also, given the physical characteristics and main water-related issues within the catchment, to make recommendations for the next steps with regard to planning and implementation of NFM techniques across the catchment and identify where further monitoring is required to help focus future efforts.

The main drivers identified within the catchment that NFM may be able to address are:

- **Flood Risk** – the Isbourne catchment has been affected by several incidents of river and surface water flooding. Conventional flood risk management structures / flood defence options are not economically viable in such a rural catchment as relatively few properties are affected and flood defence schemes are very costly. The Environment Agency is, however, keen to work with local communities to assess the potential for NFM to provide a contribution to local flood reduction;

- **Water quality management** – many rivers across England and Wales are subject to excessive nutrient loading from point and diffuse sources. Target water quality conditions of both surface waters (rivers) and groundwaters (underground aquifers)

are affected by a range of pollutants including elevated nutrients (nitrates and phosphates), pesticides (insecticides, herbicides, biocides), organic matter (such as manures, sewage, organic litter) dissolved metals and other polluting substances from agriculture, industry and urban development. The EA has obligations to work towards delivering water quality in catchments that can deliver good ecological status under the European Water Framework Directive (WFD);

- **Sediment management** – Excessive sediment loading to rivers can and does have adverse affects on our watercourses and the species and habitats they support. Increased sediment can affect river plants by reducing water clarity and light penetration, by directly smothering plants and animals living on the river bed and can influence the physical nature of rivers and how they function. River bed gravel areas can also become clogged which then prevents some fish from spawning. All of these features are criteria for measurement of river health and must be protected and, where possible, enhanced under the WFD. The steepness of the Isbourne catchment and extent of land use change over hundreds of years will have impacted the catchment in terms of sediment pollution.

The main reasons behind these drivers being identified for assessment within the Isbourne catchment are discussed in greater detail in Section 4.1 and a summary of the WFD and how it has been applied across the Isbourne catchment is provided in Appendix A.

1.2 Study Approach

To engage with the local community through the Isbourne Catchment Group (ICG) to understand the wants and needs of the local population in the Isbourne catchment, to lead to local governance and stimulate an interest in creating a local approach for managing flood risks and reduce vulnerability to flooding.

To assess which NFM techniques could be applied across the catchment and to estimate the benefits that they may have for the area, the catchment character was reviewed. A desk study of available information was conducted, gathering information and data from the EA, the relevant District and Borough Councils and speaking with people with knowledge and understanding of the catchment.

Further desk-based studies of catchment information used available GIS mapping data. Soil and land use data were provided by and are under license to the EA through their Geostore data system and the Ordnance Survey through their Digimap system. This information was combined with review of geological, topographical, land use and hydrological information to provide a series of maps (provided in Appendix E) to help explain the catchment characteristics and enable a better understanding of the applicability of different NFM types.

Records of fluvial (river) flooding and general policies relating to water within the catchment were identified by reviewing the Strategic Flood Risk Assessments (SFRA) for the Isbourne area (see Appendix B for summaries of these documents) and from primary data supplied by Gloucestershire County Council and Worcestershire County Council.

The range of NFM techniques are then considered for their applicability within the Isbourne catchment and according to the landscape types identified within each of these areas relative to land use, topography, geology and drainage characteristics.

1.3 Consultations

Various stakeholders and statutory organisations were contacted to gain an insight of catchment characteristics and knowledge of the hydrological nature of the catchment and any known flood risk locations; these included the Environment Agency, Gloucestershire County Council, Haycock Environmental Consultants Limited, Tewksbury Borough Council, Worcestershire County Council, Wychavon District Council. There was also external consultation with those involved in other NFM schemes across the UK to discuss their experience, where they are best applied and any measurable benefits expected or realised.

1.4 Report Structure

Section 2 provides background information on what NFM options are.

Section 3 provides a characterisation of the River Isbourne catchment. These studies include reviews of its watercourses, topography, soils, hydrology, hydrogeology, flooding as well as land and water use across the catchment and identify designated sites for landscape and wildlife. The accompanying maps and figures for this section are presented in Figures E1-E16 in Appendix E.

Section 4 defines the key environmental drivers for reviewing the applicability of NFM within the catchment. The identified catchment are reviewed to understand how different NFM techniques could be applied to segments across the study area.

Section 5 then summarises the main findings of the catchment characterisation and outlines which NFM are potentially applicable across the Isbourne catchment. Potential NFM opportunities and constraints are then discussed and recommendations for potential next steps to take NFM further within the Isbourne catchment, with references for suggested further reading.

2. What are natural flood management options?

2.1 Introduction to natural flood management options

The following sections within this chapter set the context of what natural flood management (NFM) are, and outlines how the objectives of the WFD need to be considered for all surface water and groundwater bodies. and land Appendix A provides a more detailed outline of how the WFD is being implemented for water management and how it has been applied to the River Isbourne. The chapter looks at two broad categories of NFM:

- Rural Sustainable Drainage Systems (RSuDS) (Section 2.2)
- Land management changes (Section 2.3)

NFM involves the utilisation or restoration of 'natural' land cover and channel-floodplain features within catchments in order to increase the time to peak and reduce the height of the flood wave downstream. This may involve altering multiple elements of a catchment water balance by promoting interception, infiltration and groundwater storage, enhancing water losses through evapotranspiration, lengthening hydrological pathways and increasing flow resistance (Iacob *et al*., 2014).

Traditional drainage systems, particularly within urban areas, have been designed to transfer rain water away from the point of ground contact as rapidly as possible, usually to underground systems via impermeable, clay or concrete pipes that rapidly discharge to sewer, other artificial drainage system or watercourse. Coupled with ever-expanding impermeable surface areas, the speed, quantity and quality of the water being drained in urban areas can, and does, have significant impacts on natural flow regimes, wetland habitats and flood risk. This is further exacerbated when climate change is considered, with predicted heavier, intense rainfall events but generally drier summers and increased winter precipitation (Atkins, 2013).

Within rural areas, which are relatively undeveloped, land use changes and agricultural intensification means that open field areas are drained more rapidly than ever before. Impacts in rural areas include deforestation, land use change (e.g. insertion of artificial drainage, change from grassland and orchards to arable), soil compaction and degradation (through the use of heavy machinery, cultivation and livestock trampling). Consequences for land drainage include reducing infiltration, increased runoff and erosion of top-soils. Since the 1960s the insertion of artificial land drains has also rapidly increased sub-surface drainage speed across most agricultural areas of the UK, with peak flows and high volume consequences for receiving watercourses (Atkins, 2013).

A review of available information on other NFM schemes under way across England (see Appendix C for case studies for NFM in other catchments) helps to support growing evidence that inclusion of NFM alongside best land management practices, across a drainage catchment can potentially combine to deliver reductions in flood risks and reduce sediment transport into watercourses. Unfortunately at present, published facts and figures that provide quantitative evidence of the improvements that NFM can create are still unavailable or unmeasured.

However, the principles of restoring natural drainage pathways and slowing downstream transfer of water through NFM designs is in line with sustainable practices that will be vital

for future environmental management and could help to mitigate the impacts of climate change. Additional benefits of NFM systems are the creation of a variety of habitats for wildlife to colonise, many of which are Biodiversity Action Plan (BAP) habitats (e.g. wet woodland, wetlands, moorland, peatlands, ponds, hedgerows).

2.2 Rural Sustainable Drainage Systems (RSuDS)

Rural Sustainable Drainage Systems (RSuDS) comprise individual or multiple linked component structures replicating natural processes, designed to attenuate water flow by collecting, storing and improving the quality of run-off water within rural catchments.

The EA published a document describing existing drainage management methods and drainage designs that fit within the definition of RSuDS (Avery, 2012). The document reviewed their cost and effectiveness in helping to meet the objectives of the WFD, to reduce flood risk and adapt to climate change.

General principles for the implementation of RSuDS in rural areas are to:

- Maximise interception of rain and surface run-off by vegetation;
- Increase surface roughness (vegetation, woody debris, rough substrates);
- Provide water attenuation / retention systems that also allow settlement of sediment and bio-treatment of pollutants;
- Maximise spread of water over floodplain areas;
- Improve / allow local infiltration.

RSuDS include permanent / semi-permanent designs, which will collect, store and treat water, resulting in a slower release into the environment. Designs tend to have a low cost, low energy input with low maintenance costs and result in positive impacts on the environment. They are typically located in three main locations depending on their design: in-channel; across floodplain and land areas; across farmyard areas as detailed in Table 1.

Table 1. Typical locations for RSuDS designs (adapted from Atkins, 2013 & SEPA 2015)

Typical Location	RSuDS Design
In-channel sites	Barriers (steps, weirs, woody debris) Sediment trap Infiltration trench / drain Berms In-channel wetland Gulley / grip blocking
Floodplain and land areas	Ponds Basins (infiltration or storage) Shelter belts

	Buffer strips Headlands Hedgerows Stone dyke / leaky timber walls Swales Dry / wet vegetated filter strip Contour bund Filter berm Wetland
Farmyard areas	Swales Cross-drains Green roof Sediment trap Permeable surfaces Soakaway Filter drain / trench Biobeds Rainwater harvesting / re-use

While NFM measures associated with land management seek to reduce flood water generation, in-channel NFM seek to improve the ability of rivers to manage those flood waters. This is achieved by restoring a more natural hydrological response and regime, for example, by slowing flows (e.g. remeandering or the use of instream structures) and reducing excessive supplies of fine sediment (e.g. bank stabilisation) or by increasing the potential for the floodplain to store water (e.g. by decreasing the confinement of the river and reconnecting the floodplain) (SEPA, 2015). Restored areas often have stock fences added to them to protect the river environment as it naturally develops.

Another in-channel NFM is the introduction of woody material or boulders to a natural channel to slow the flow, increase in-stream water levels during moderate to high flows, and thereby increase water storage on the floodplain. This can either be in the form of leaky dams (permeable structures of wood that allow water through at a moderated rate) or in-channel woody debris that deflects and delays the water flow. These can significantly delay flood peak travel time, with a study on a tributary of the River Usk in South Wales (Thomas and Nisbet, 2006) finding that individual woody debris dams could delay the downstream passage of a 1-in-100 year flood peak in tributary streams by an average of 2-3 mins.

In areas around farmyards and tracks key NFM techniques include increasing the amount of permeable land surface through provision of soakaways and ensuring that there are sufficient culverts to allow removal of water from hard standing areas. Rainwater harvesting (the collection, storage and use of rainwater from roofs and hard surfaces for domestic use) can also reduce the volume of runoff generated. Overland sediment traps are a containment area where sediment laden runoff is detained to allow sediment to settle out, these are primarily located on a surface runoff pathway. These are effective in retaining water during

flood events, and over a long-term by storing excess sediment and preventing this entering the channel system they maintain the capacity of rivers to convey flood waters.

A runoff attenuation feature is defined as a man-made landscape intervention that intercepts and attenuates a hydrological flow pathway. Simply, the design philosophy is to create features that 'slow, store and filter' runoff in the rural landscape (EA & University of Newcastle, 2011). This approach advocates the use of many features located throughout the landscape, with the benefits accrued by the network of features rather than one large scale / dominant intervention. An earth bund can also be used to retain water coming off the land. Bunds are particularly useful on sloping fields where the runoff tends to exit the field at a particular point, such as a valley bottom, where slopes converge, or the low corner of a field (SEPA, 2015).

More information about each RSuDS design is summarised in Appendix D and further information on the designs, benefits, advantages and disadvantages for each of these can be found in the Environment Agency RSuDS report (Avery, 2012). The beneficial impacts of these systems on a site or across a larger area depends on the scale of the issue of concern (e.g. flood risk, pollution source) and the size and / or number of RSuDS that can be applied to the site and an understanding of any other factors that may influence the cause or response of the problem. More than one design can be used for a given drainage site and they can be linked together to maximise their effectiveness.

2.3 Land management changes

Land management measures are land-based techniques and practices that seek to influence flood generation by reducing the amount of surface runoff reaching the river network. They achieve this primarily by improving soil structure (e.g. making it more porous), increasing infiltration, and ultimately increasing the capacity of the land to store water. In addition to reducing runoff, these measures can also reduce soil erosion and the transfer of sediment and pollutants to rivers.

The SEPA handbook on NFM (2015) and the EA position statement on NFM (2016) outline a range of land management techniques that are aimed at reducing the rate and amount of runoff from land into the river network and thereby reducing the downstream maximum flow and delaying the resulting flood peak. These documents review the effectiveness and potential locations for these techniques and the role that that they can provide in terms of meeting WFD objectives, to reduce flood risk and as an adaptive response to climate change.

General principles for the implementation of land management options are to:

- Reduce flood water generation;
- Minimise the surface run-off from rainfall;
- Maximise the infiltration by vegetation;
- Improve / allow local infiltration.

The effectiveness of NFM measures will be site specific and depends upon many factors, including the location and scale at which they are used. NFM measures within a catchment

are associated with varying levels of certainty in terms of their effect on flooding. The evidence collected by the EA suggests that those situated at the headwaters of a catchment have the greatest degree of uncertainty due to the other factors in the catchment between them and the areas at risk. However, collectively across a catchment they can have a significant impact on how a river behaves in extreme weather events. The two main types of land management options are outlined in Table 2.

Table 2. Typical locations for land management options (SEPA 2015, EA 2016)

Typical Location	Land management option
Woodland	Planting new woodland Restoring existing woodland Natural creation of woodland
Land and soil management practices	Converting arable land to species-rich grassland Arable headlands and buffer strips Reduced or zero tillage Reducing soil compaction Contour ploughing and tramlines Establishing multi-species grassland Restoring extensive grassland, moorland

Adapted from SEPA (2015) and (2016)

The key aim of land management options in reducing the generation of floods is achieved by creating diversity in the landscape that absorbs water to a greater extent than is currently the case. It does this by increasing the areas of woodland, which when placed inappropriate places absorb water before it enters the river network. Similarly soil management practices reduce the surface run-off and increase infiltration. The type of vegetation and the way it is managed can impact on water retention, also having a wide range of plant species, especially if some are deep rooted, will increase infiltration rates. Natural or extensive areas of grassland will also be better for reducing flood risk.

Farming practices such as reduced or zero tillage cut the amount of cultivations and minimise the time that land is left without a cover of vegetation. This reduces run off and increase the natural absorption of water by vegetation. Land management actions such as contour ploughing or positioning tramlines according to contour is a way or reducing run off within arable crops from establishment through to harvest. Research at the Loddington Estate in Leicestershire (Deasy *et al*., 2008) has shown that as much as 80% of the run off from arable fields occurs via the tramlines, which are responsible for about 2% of the land area. In essence they act as water channels, which at times of high rainfall create high volume run off channels, so by removing or minimising the use of these it can help to reduce the amount of runoff from agricultural fields. The work at Loddington (see Allerton Project in Appendix C4) has highlighted a number of adjustments to existing farming practice across a

range of soil types that help address some of the main concerns regarding meeting WFD objectives, that would also contribute to a NFM project (see Appendix C).

The planting and management of trees can be used as part of a water management plan. Trees have the potential to manage the sources and pathways of flood waters in a number of ways. Field-based evidence shows that they can reduce water yield by improving the infiltration rates of woodland soils and by 'sponging up' water through the process of evapotranspiration. In a recent study, Dixon *et al*. (2016) found that forested floodplains have a more general impact upon flood hydrology, with areas in the middle and upper catchment tending to show reductions in peak magnitude at the catchment outflow. The most promising restoration scenarios for flood risk management are for riparian forest restoration at the sub-catchment scale, representing 20–40% of the total catchment area, where reductions in peak magnitude of up to 19% are observed through de-synchronization of the timings of sub-catchment flood waves.

Some land management practices are available through options available through the current Countryside Stewardship scheme offered by Natural England. This scheme has been developed so that it incorporates delivery of the Water Framework Directive as one of two key objectives. As a result there are options that are relevant to farmers and landowners covering arable reversion, headlands, margins, buffer strips and a range of woodland planting opportunities. The nearby Overbury estate practices zero tillage and regularly plants green manures so there is vegetation no the land all year round. The farm manager regularly has visits to show other farmers then practicalities of this approach.

As part of this initiative a successful application has been made to the Countryside Stewardship Facilitation Fund for a Carrant Catchment Restoration Project. This has an extension clause to cover the Isbourne catchment. The project will focus on innovations in cultivation techniques, soil health, organic matter, soil biology and water attenuation as contributory to sustainable farming and reducing diffuse water pollution from agriculture. This will help to deliver Good Ecological Status (GES) of fluvial and ground waters under the EU WFD, underpinning ecological recovery and rare species protection. It will also focus on the practical learning of riparian management and improving the ecology for fish habitats and channel diversity for other target species. Woodland restoration and tree planting will be a key focus of the project through woodland management plans and strategic woodland planting to reduce run off and flooding.

3. River Isbourne Catchment Characterisation

The following text describes the main character of the Isbourne catchment and reviews its watercourses, geology, hydrology, soils, water and land use. The maps to accompany the text (Figures E1 to E16) are provided in Appendix E.

3.1 The Catchment

The River Isbourne catchment lies to the north of Cheltenham and has a total catchment area of 88 km^2 (as measured from the National Flood River Archive catchment boundary) which flows in a northerly direction and drains into the River Avon at Evesham. Contained within the catchment are the towns and villages of Winchcombe, Greet, Toddington, Wormington, Sedgeberrow and Hinton on the Green. Other outlying villages across the wider catchment area include Aston Somerville, Buckland, Charlton Abbots, Didbrook, Dumbleton, Hailes, Langley, Laverton, Postlip, Stanton and Stanway.

The Isbourne catchment supports a **main river** (for which the Environment Agency is the managing authority), **ordinary watercourses** (under Lead Local Flood Authority [County Council or Unitary Authority] management) and **lakes and reservoirs** (under private management).

Figure E1 (Appendix E) shows the Isbourne catchment area. The catchment has been identified by the Environment Agency as a single distinct 'water body' for catchment management and assessment as part of its responsibilities under the WFD, the details are listed in Table 3.

Table 3. River Isbourne catchment WFD water body summary

Water body	Reach name	WFD ID	Area (km^2)	Length (km)
Isbourne	Source to conf R Avon	GB109054039631	87.991	30.05

The WFD requires that all water bodies (including rivers, reservoirs, lakes and canals) should be assessed for their current, baseline condition and that there should be no measurable deterioration in the ecological or physical condition of these water bodies in the future and, where possible, their quality and condition should be improved (see Appendix A for more detailed information on the WFD). Each water body is regularly monitored by the Environment Agency to assess its ecological (biological and chemical) health as well as its physical condition as part of the WFD. Table A1 in Appendix A presents the key WFD baseline conditions for the River Isbourne as assigned by the Environment Agency within the River Basin Management Plan for the Severn River Basin District.

For the purposes of this scoping study, the River Isbourne water body will be considered in its entirety as it is characterised in the WFD.

3.1.1 Main river

The **River Isbourne** is the only main river in the catchment. It is 30.05 km in length and flows from its source near Postlip on the Cleeve Hill escarpment through Winchcombe, Greet, Toddington, Wormington, Sedgeberrow and Hinton on the Green (see Figure E1, Appendix E). At the lower reaches of the River Isbourne it meets with the River Avon at Evesham. For details of the current and target WFD conditions for this water body, see Appendix A.

3.1.2 Ordinary watercourses

Other tributaries of the River Isbourne that are classed as ordinary watercourses (not main river) include Beesmoor Brook, Didbrook, Langley Brook and Merry Brook. There are also a number of smaller tributaries joining the Isbourne throughout its course northwards.

The ordinary watercourses will form part of the NFM review of the Isbourne Catchment undertaken later in the report, and will be referred to in more detail in Sections 4.2 and 4.3.

3.1.3 Lakes and reservoirs

The Isbourne catchment historically was a milling area and many mill ponds and artificial water retention areas have been built in the area. Large lakes or ponds within the catchment include Aston Somerville, Beesmoor (Beesmoor Brook), Charlton Abbots (Beesmoor Brook), Hayles, Manor Farm, Postlip, Toddington Manow, Sedgeberrow, Waterhatch (Beesmoor Brook) and Wormington. None of these are included in the current WFD water body assessments (Appendix A).

3.1.4 Groundwater bodies

There is one groundwater body identified in the Severn River Basin District RBMP which covers underlying ground areas larger than the Isbourne catchment as they are based on bedrock geological formations rather than surface water drainage features. The Warwickshire Avon – Secondary Mudrocks groundwater is currently (i.e. 2015 WFD cycle) classified as Good WFD Status but is at risk from pressures including urbanisation, nitrates and pesticides.

This groundwater body is important as a source of drinking water and is under the Nitrates Directive so the control and reduction of the chemicals affecting them is of great importance.

3.2 Topography

Figure E2 (Appendix E) provides a colour-coded representation of the catchment's topography from upland areas to the valley floor.

3.2.1 Upland Areas

The upland areas are the interfluves, or flat ground areas between river valleys which are generally elevated above valley sides and are flat or gently sloping towards the valley edge. These areas are the remnants of the original Oolitic limestone 'platform' (Bathonian Age, Middle Jurassic 167.7-164.7 million years ago) that existed before the rivers began to cut into the landscape. The upland areas typically lie at the highest ground levels within the catchment (at up to 300m Above Ordnance Datum (AOD)) and fall to around 150m AOD

where they meet the valley edge where the rivers have cut into the limestone landscape. Most of the upland area has been converted for agricultural use as arable or pasture fields (see Section 3.6 below), with some areas of woodland and small settlements and farm buildings.

3.2.2 Upper River Valleys

The Upper River Valleys are characterised as areas where the spring flows and headwater streams have cut deeply into the landscape, forming valleys with very steep slopes that are a narrow or a wide 'V' shape which is characteristic of limestone catchments. The river channel has little or no floodplain area over which the river can spread when high flows occur, some of which are very steeply-sided. The steepness of these valley sides mean that cultivation has not been possible in many locations and they have retained semi-natural broad-leaved or mixed plantation woodland. Some of these woodland areas are still accessible for grazing by cattle, sheep or horses, which can often lead to soil and river damage through trampling.

3.2.3 Floodplain River Valleys

The floodplain river valleys begin where the steepness of the upper river valley begins to flatten and the valley sides are less steep and much more open. Within these areas a flatter, wider valley bottom exists to allow flood water to spread across adjacent land areas when bank top levels are reached – creating a permanent floodplain feature along the valley floor. In many of these areas, because of the flat ground areas available, there is typically a greater density of development, industry and human settlement.

3.2.4 Proportion of landscape type within the Isbourne Catchment

Using GIS mapping, each of the three main landscape types were plotted in the Isbourne catchment and an assessment made of their proportional cover. Table 4 below shows the proportion of Upland Area, Upper River Valley and Floodplain River Valley identifiable within each the catchment. The data reveals that there is a relatively small proportion of the catchment that supports Floodplain River Valley areas, with the majority of ground areas supporting Upper River Valley landscapes.

Table 4. Proportion of area within Isbourne catchment that falls within the three main landscape types used for this study

WFD Reach	Upland Areas	Upper River Valleys	Floodplain River Valleys
River Isbourne – from source to conf with River Avon	33.3%	17.2%	49.5%

3.3 Geology & Soils

The topography of the Isbourne catchment reflects the underlying geology with the Inferior Oolite limestones (of Jurassic origin) forming the upland areas and escarpments. Deep incisions into the limestone have been formed within river valleys that penetrate into the underlying impermeable Lias Clay beds and forming spring-fed streams draining from the limestone.

Figure E3 (Appendix E) shows the main geological structure of underlying bedrock across the Isbourne catchment. The escarpment of the Isbourne catchment are underlain by a permeable Inferior Oolite limestone, this then transitions into more mudstone dominated bedrock towards the lowland and southern end of the catchment with a more open valley landscape. The Lias Mudstone Group formation consists of Whitby Mudstone Formation, Bridport Sand Formation, Dyrham Formation and the Charmouth Mudstone Formation (moving in a downslope direction). Ground slope also flattens out form the steep, narrow valley upper catchment as the Isbourne geology becomes less permeable but with a lower gradient (Figure E2 in Appendix E).

The soils of the Isbourne catchment reflect the underlying geology. Table 5 provides a review of the characteristics of soils in the Isbourne catchment in support of the following descriptions and the geology (Figure E3, Appendix E).

Table 5. Soils of the Isbourne catchment and their characteristics (Data source: Cranfield University, 2016)

Location	Soil Type		Description	Behaviour	Crop/Land Use	Sand, Silt, Clay %
Upland	343a	ELMTON1	Shallow loam over limestone	Shallow well drained fine loamy soil	Cereals, sugar beet & potatoes, winter cereals	34, 38, 28%
River Valleys	411a	EVESHAM	Deep clay	Slowly permeable calcareous clayey soils	Dairying on permanent & short-term grassland	20, 35, 45%
	511i	BADSEY 2	Freely draining loam over limestone	Well drained calcareous fine loamy soils over limestone gravel	Cereals, sugar beet, potatoes & field vegetables	-
	572i	CURTISDEN	Silty over sandstone	Silty soils over siltstone with slowly permeable subsoils & slight seasonal waterlogging	Dairying on permanent & short-term grassland; cereals, field vegetables & potatoes where drier; woodland on slopes	19, 66, 15%
	712b	DENCHWORTH	Loam and clay	Seasonally waterlogged clayey soils with similar fine loamy over clayey soil	Winter cereals & short-term grassland in drier lowlands; dairying on permanent grassland	-

3.4 Hydrology and hydrogeology

The hydrological and hydrogeological behaviour of the Isbourne catchment is dominated by the influence of the underlying geology, particularly the Oolitic limestone, that underlies much of the upper reaches of the catchment, and its interplay with the low permeability deposits along the river valley floors. The River Isbourne is linked to groundwater resources, with some of its flow being derived from aquifers in the Oolitic Llimestone, either from spring discharges at the interface between the Jurassic limestone and Lias Clay layers or from groundwater rising up and interacting with the river bed, especially where they flow over permeable strata such as the Bridport Sand Formation and Limestone Oolites in the upper catchments. The springs form distinct geological boundary spring lines along the sides of the valleys and flows are dependent on seasonal fluctuations in groundwater levels and recharge. In lower areas, wet flush and seepage zones are formed at aquifer outflow points which are often of importance for wetland ecology features. This is demonstrated in the Winchcombe area where a recent study (Murray 2016) shows the extent of the springs above Winchcombe on the Langley and Beesmoor Brooks (see Figure 1 below).

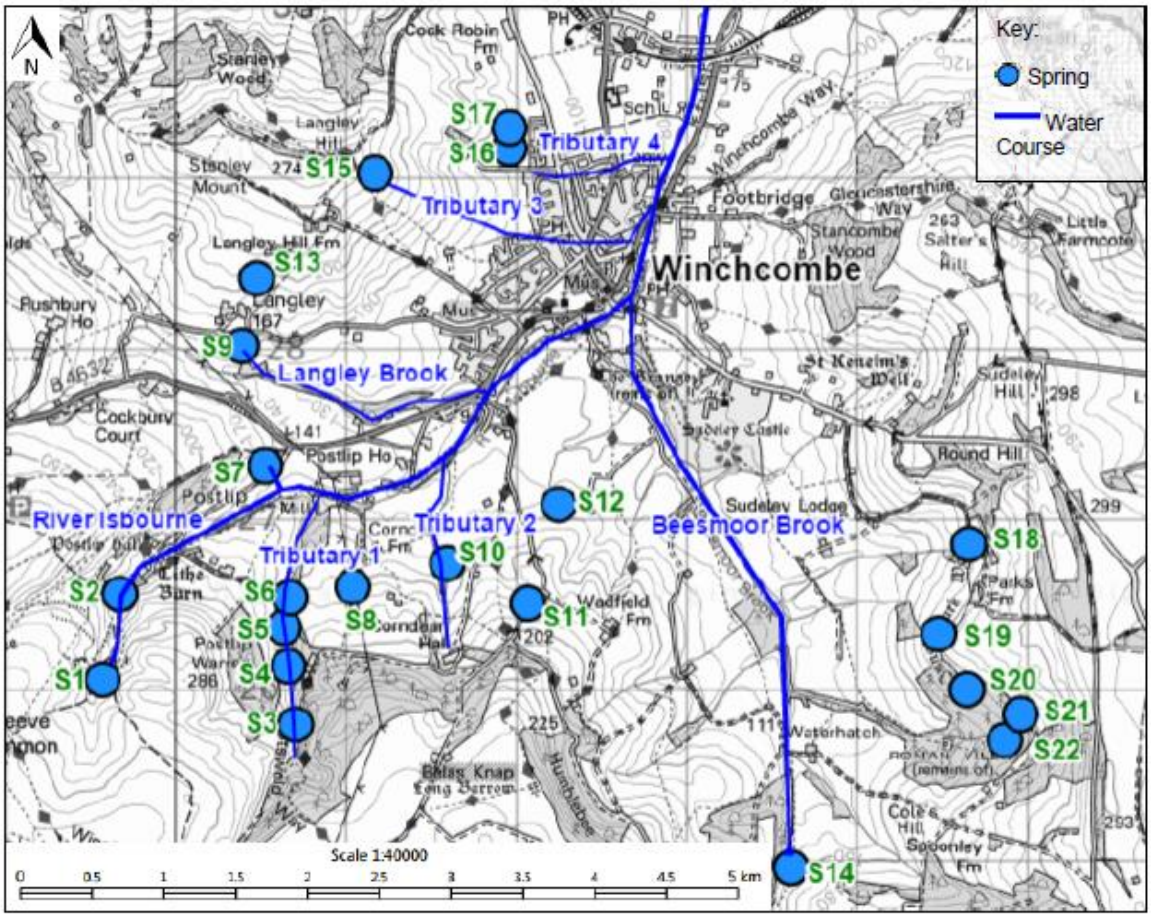

Figure 1: Map showing the location of springs in the headwaters of the River Isbourne, the fourteen springs which contribute directly or indirectly to the River Isbourne are marked. Source: Murray (2016)

In terms of drainage pathways and potential applications of NFM, the thin topsoil layers across the upland areas and fracturing within the underlying limestone bedrock create conditions that allow rapid infiltration of rainfall through soil layers and rapid water transport down into the bedrock aquifer, rather than keeping rainfall above ground. This condition provides free-draining soils and the need for artificial drainage (i.e. ditches or artificial

drainage) across arable is much less extensive in the Upper Isbourne catchment than for other catchments across the UK that have poorly-draining soils (Murray 2016). Nevertheless, there is some evidence from other Cotswold estate that in the clay lined “dry” valleys infiltration had reduced and benefits of aerating the soil were noticed on the flatter areas, even though the bed rock was close to the surface. The aim is to maintain and increase infiltration as this would help reduce the peak flow at times of heavy rainfall as water entering the ground water system would be significantly delayed in terms of its route through the catchment.

The presence of clay layers in the river valley bottoms prevents infiltration and maintains water flows above ground within the Upper River Valleys and Floodplain River Valleys. Numerous spring flows enter all watercourses along the Upper River Valley sides flowing from points close to the boundary between the limestone and less permeable Lias Clay deposits. These features progressively add more water to the main channels along the whole length of all watercourses in the catchment. Spring contributions are less frequent along the Floodplain River Valley sections and flows are mostly surface-water, with less influence by groundwater due to the increasingly impermeable nature of the geology. Flows in the Lower River Isbourne therefore reflect the combined volumes of both fluvial and groundwater interactions released by the upper catchment areas.

The Upper River Valleys are the first major site of overground flows (fluvial flows) as water flows out of spring points and is held above ground by impermeable clay in the valley bottom.

Figure E4 (Appendix E) presents the drainage pathways for sub-surface and fluvial flows across the catchment, including the locations of sites where river flows are monitored.

3.4.1 Flow monitoring data

There is one active gauge station with continuous flows on the River Isbourne at Hinton on the Green – National River Flow Archive (NRFA) station ID 54036 (as annotated on Figure E4, Appendix E) – which has been in operation since 1973. This gauging station is situated at the downstream end of the catchment which is comprises impermeable geology and here river levels are almost entirely driven by fluvial flows received from upstream.

Calculated mean annual flow from the gauging station is 0.67 m^3/s, and Figure 2 below shows the variation in mean annual flow data from NRFA over the period of record. The variation in annual flow patterns is apparent, with the years 2001, 2007, 2008, 2013 and 2014 are all notable for the high mean flows. The summer floods of 2007 do not record as the highest mean annual flow, but this is because of the contribution of the flow conditions in the remainder of the year, to explore this in more detail it is necessary to look at the daily flows for 2007.

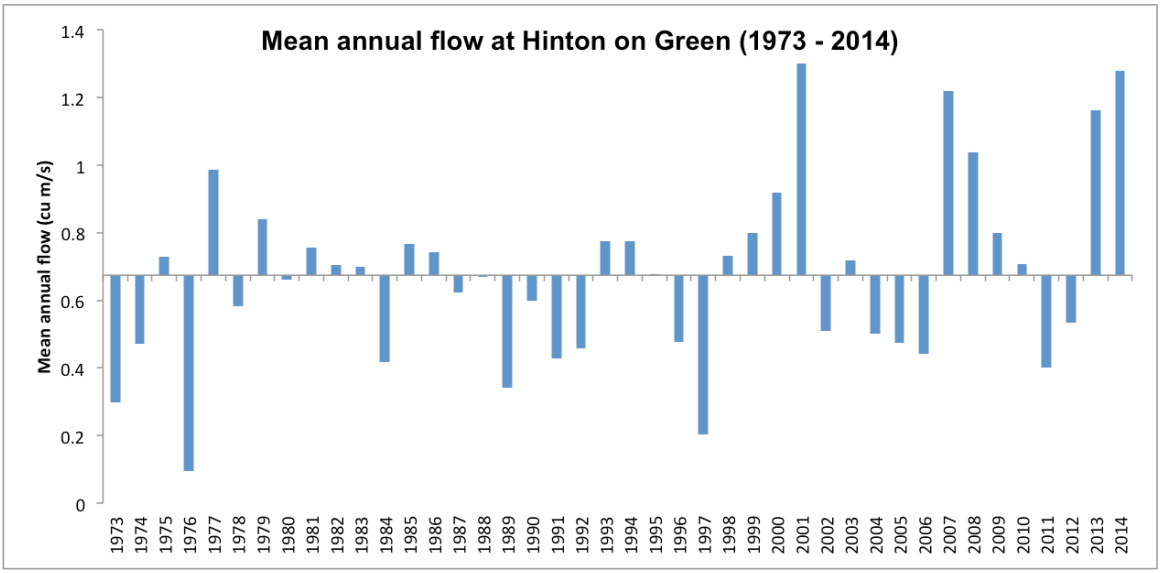

Figure 2: Mean annual flow at Hinton on the Green gauging station between 1973-2014 (data sourced from the [NRFA website](#))

Further analysis (Haycock 2010) examined trends in water flow since the 1970s (Table 2). The analysis shows an upward trend in the peak flow for any given return periods was not associated with an increase in the magnitude of rainfall. Haycock (2010) concludes that the changes in the characteristics of the catchment are most likely caused by changes in the rate of runoff, this is most likely the result of land use changes in agriculture; the increase in arable areas since the 1970's (see Section 3.6.2 for further detail on this) which will have increased soil compaction and consequently reduced infiltration. Additionally, the removal of hedgerows which act as brakes for fast moving runoff, increased impermeable areas and cause an increase in peak flows further downstream.

Table 6. Peaks over Threshold analysis for the Hinton on the Green gauging station (1973-2007) – the data was split into 8 year sets. Taken from Haycock, 2010.

Return period (years)	Peak flow (cumecs)			
	1972-1980	1981-1989	1990-1998	1999-2007
10	28.9	33.1	35.2	38
20	33.5	38.7	41	43.7
30	36.2	41.9	44.4	47
40	38.1	44.2	46.8	49.4
50	39.5	46	48.7	51.2
60	40.7	47.5	50.2	52.7
70	41.8	48.7	51.5	54
80	42.6	49.8	52.7	55.1
90	43.4	50.8	53.7	56
100	44.1	51.6	54.5	58.9
150	46.8	54.9	58	60.2
200	48.7	57.2	60.4	62.6

Note: the 1:100 year peak flows shift from 44.1 cumecs in the 1970s to 56.9 cumecs in 1999-2007

Precipitation patterns in the Isbourne catchment are influenced spatially by orographic impacts of the Cotswold Escarpment (Figure E1, Appendix E). Looking at the annual rainfall over the same period (1972-2012) a recent report by Murray (2016) found that there was a significant difference between monthly precipitation across the forty year time period (Figure 3). Precipitation patterns on the River Isbourne display standard UK seasonality, where winter values are lower than summer because summer months display higher variability. Figure 3a below shows the outliers as small circles and the July 2007 floods are displayed as a significant outlier, and also apparent is that more outliers generally occur in the winter months over this forty year period.

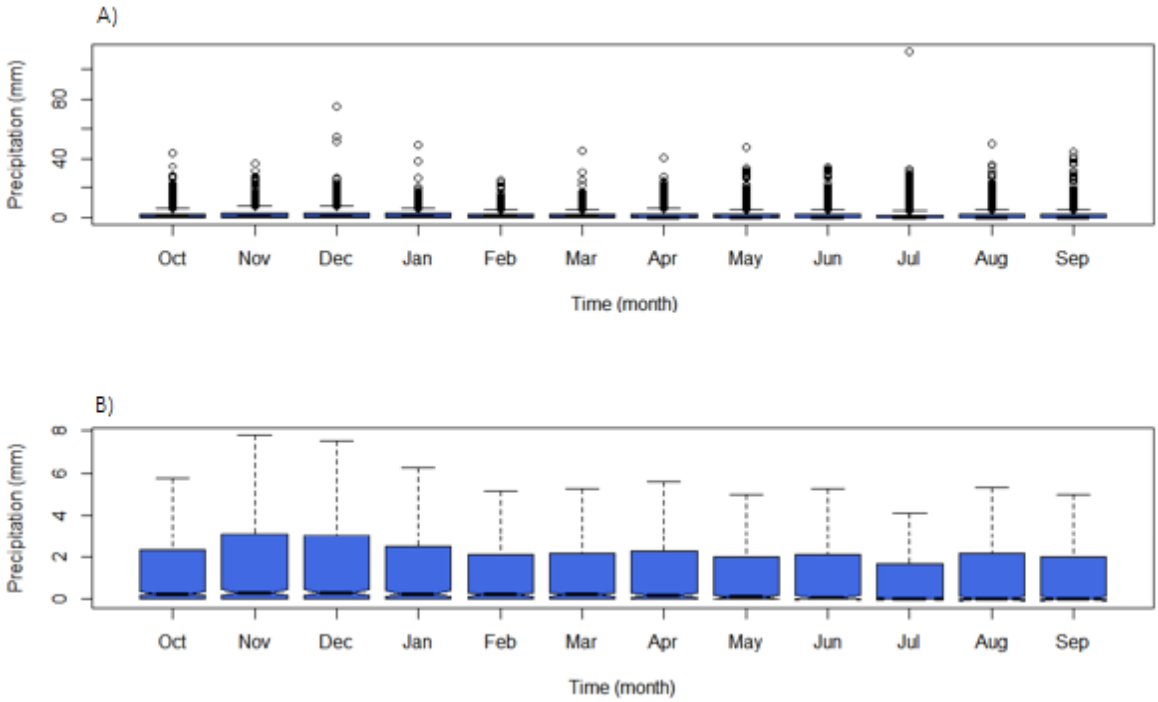

Figure 3: Monthly variation in precipitation for the period 1972-2012 showing (a) a plot of all of the data and (b) a plot of the 1972-2012 data with outliers removed (Source: Murray, 2016)

A review of the 2007 and July 2007 flow data at Hinton on the Green (shown in the Figures 4 and 5 below) demonstrate the 'peaky' or flashy flow as river levels rapidly responded to high volumes of rainfall-runoff flowing over impermeable land areas and combined surface water flows released from watercourses in the catchment. The peak flow was recorded as 38.8 m^3/s on 20 July 2007 – the maximum recorded daily flow over the period of record.

River levels return to normal levels relatively quickly after the main peak flows had been reached (Figure 5 below), highlighting that the main cause of high water flows was from surface water caused by rainfall

Flood risk is considered low in the Upland Area and Upper River Valleys but the resultant fluvial and groundwater flows combine to create much greater flood risk in the Floodplain River Valleys.

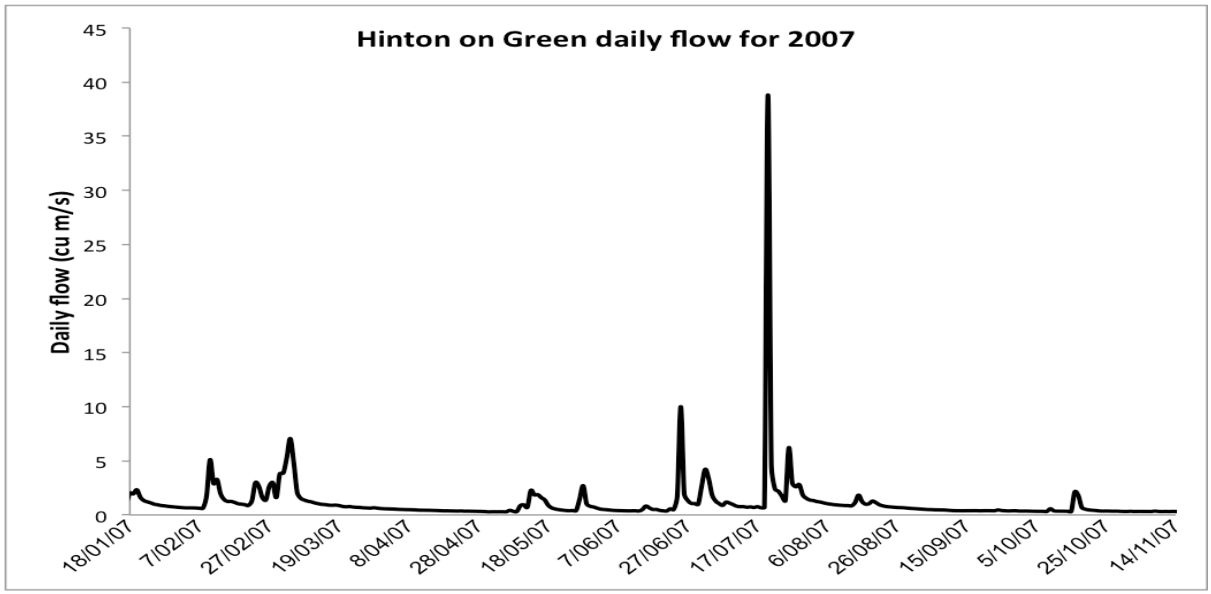

Figure 4: Flow data from the Hinton on the Green gauging station for 2007 – showing the magnitude of the July 2007 floods (data sourced from the NRFA website)

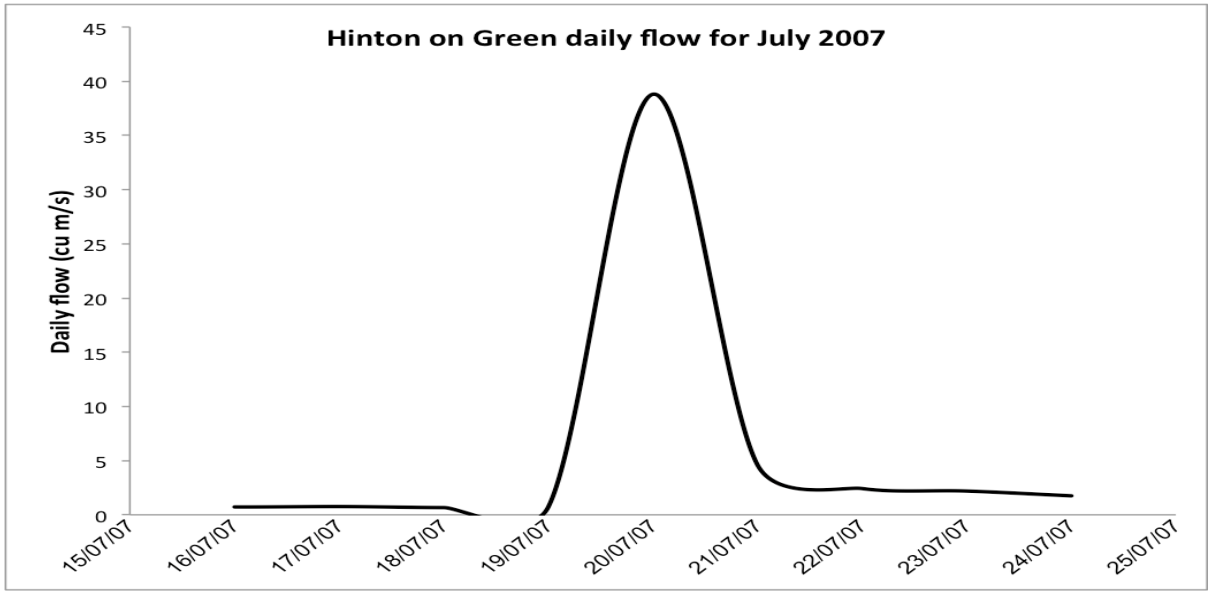

Figure 5: Flow data from the Hinton on the Green gauging station for July 2007 flood event (data sourced from the NRFA website)

The application of NFM may therefore be best applied to intercept any ephemeral overland flow routes, maximize infiltration into groundwater flows, and slow the speed of surface flows (by vegetation interception) across Upland Areas, as well as ensuring land management practice to reduce potential runoff. Upper River Valley NFM designs need to attenuate and slow flows they release into the Floodplain River Valley sections. Application of NFM in the Floodplain River Valleys will have a reduced benefit in terms of flood risk in the lower catchment as these landscape areas are too far down the drainage system and too constrained by development.

3.5 Flood events in the Isbourne Catchment

Two primary flood processes affect the Isbourne catchment:

- Fluvial flooding: involving the River Isbourne and its tributaries
- Surface water flooding: artificial drains, overland flows and water collection points across low-lying ground.

There is very little documented data on historic flow events on the River Isbourne, although verbal history suggests that there is a history of flood events along the catchment. The River Isbourne flooding in 1947, 1968 and 1998, with a number of properties in the catchment and along the River Avon impacted. The largest flood to have impacted the catchment is associated with the summer 2007 event, which was the most sizeable individual flow event recorded on the River Isbourne and has substantial damage associated with it. The most widespread flooding occurs after sustained periods of rainfall, in which river levels are raised combined with increased runoff response from land areas. Both the 1968 and 2007 flood events were caused by extended heavy rainfall under a pronounced low pressure system over the area.

Figure E5 (Appendix E) reveals where the Environment Agency has measureable records of flooding occurring within the study area from the 1960s to the current time (previous events do not have sufficient detail to include on flood event mapping). The Isbourne catchment flooded during 2007, with residential and commercial properties affected in Winchcombe, Greet, Toddington, Sedgeberrow and Hinton on the Green. Properties in Winchcombe were also reported flooded during winter 2012.

The majority of fluvial flood events have occurred in the Floodplain River Valley areas, which is where the majority of settlements in the catchment are positioned. The urban settlements in the lower (northern) catchment and those located around ‘pinch points’ (restrictions) are most at risk from flooding. Runoff from the steep-sided escarpment and low permeability of the lower catchment geology and soils, often results in flooding across the slopes and the lower valley bottoms. These problems can be exacerbated by mill streams, culverted sections, restrictions caused by bridges and complex urban drainage arrangements.

Most of the flood risks within the Isbourne catchment are dependent upon the antecedent conditions. Flood risk is likely to be more severe if the ground areas and groundwater system is already saturated by previous rainfall events which reduces the catchment’s ability to absorb any further heavy rainfall events and results in a more rapid river response with a prolonged duration of high river levels.

3.6 Land and water use (past and present)

3.6.1 Water use

The watercourses of the Isbourne catchment have a long history of use and alteration by humans to provide drinking water, improve land drainage, provide water power for milling (mainly to support the woollen industry and agriculture) and for use in industrial processes. Obstructions and water control systems include weirs and mill flow control structures. Derelict and operational buildings, leats, weirs and other features of the Isbourne’s historic

function as an important source of water power are commonplace along all watercourses (Figure E6, Appendix E shows the location of these features). Many of the storage ponds, pools and reservoirs are still in place, forming either on-line systems (where the river flows directly through the pool area) or off-line systems where the river water needs to be abstracted or overtop to fill the pool. However, there are a number of these features that have been filled and provide potential additional water storage capacity.

A recently-published book on the historical uses of the River Isbourne (Lovatt 2012) was used to identify and map a number of these features. A total of 22 watermill sites and other features including former swimming and tanning pools were digitised using historical Ordnance Survey maps and added to the GIS database (Figure E6, Appendix E). A basic analysis was conducted using modern Ordnance Survey mapping and aerial photography in order to determine which features (with an emphasis on mill ponds) are still in existence today.

Mill sites include: Postlip Mill, Stanway Mill, Town Mill, Dumbleton Mill, Sedgeberrow Mill, Aston Somerville Mill, Castle Street/Coates Mill, Greet Mill, Hailes Abbey Mill, Hampton Mill, Middle Mill and Sudeley Mill (see Figure E6, Appendix E). There is also an old lake site on the Toddington estate that is worthwhile investigating for water storage potential.

3.6.2 Land use

Historically, the Isbourne valley was renowned for its grazing pastures and most of the land that was viable for agriculture was converted to improved grassland and arable farming. This linked closely with the extensive woollen milling industry for which many of the mills and mill pools were constructed. Some remnants of this land use remain, notably at Toddington and the potential for this and other structures to act in a positive capacity for flood risk relieve will be explored.

Using information obtained from the OS Digimap Store and the European Environment Agency Geostore, land use mapping data is available from 1990 up to 2012. This was compared to a map of land use from the catchment from the 1930s Dudley Map Survey. At this point it is important to note that the data is likely to have been gathered using different techniques and criteria and there are likely to be some errors in the data whilst the diversity of land uses recorded varies between different surveys. Digitised data collected in 1990 results in coarse mapping outputs compared to earlier maps. Despite these differences there are some clear trends in how land use has changed. Unfortunately similar data is not available prior to this period.

Figure E7 (Appendix E) presents land use records for the 1930s across the whole Isbourne catchment, Figure E8 presents data from the 1990 Land Cover Map of Great Britain, with Figure E9 for 2000, Figure E10 for 2006 and Figure E11 presents land use coverage for 2012 based on data from the CORINE surveys (a European land cover map produced by the European Environment Agency). The dominating extent of the grassland across the catching can be seen in the 1930s, with arable land use confined to small patches generally corresponding to land within upland areas and patchy woodland cover along steeper river valley sections and headwater areas. It is also noticeable that orchards accounted for

approximately 5% of the catchment area in the 1930s, with sizeable orchards around the Floodplain Valley Area around Greet and Toddington.

By 1990, although the categories being recorded are more complex and the level of detail on a much coarser scale, the expansion of arable land cover is quite evident, particularly in Floodplain Valley Areas and Upland Areas. Much of this change is likely to have occurred in from 1970s onwards as the area of land arable cultivation expanded. There has been a disappearance of the orchards ('fruit trees') in the Floodplain Valley Areas, although the last of these located close to Hailes persisted until the mid-2000s. By 2000 and through to 2006, small grassland gaps between Upland arable land use areas have been converted to arable. Large portions of north-eastern section of the catchment (around Laverton and Stanton) and southern catchment edge were converted from pasture to arable and natural grassland to pasture, respectively. There is some variation in forest cover in terms of areas and locations, with the forest cover at the southern of the catchment becoming discontinuous and the emergence of moors and heathland in the south-west. The 2012 land use map showed the expansion of urban areas, with Sedgeberrow showing as a sizeable urban area, there was also some loss of woodland coverage and moors and heathland. The percentage land use change of arable, forest, fruit trees, grassland and pasture for the Isbourne catchment have been calculated from figures E7-E11 and are displayed in Figure 6 below to demonstrate these patterns more visually.

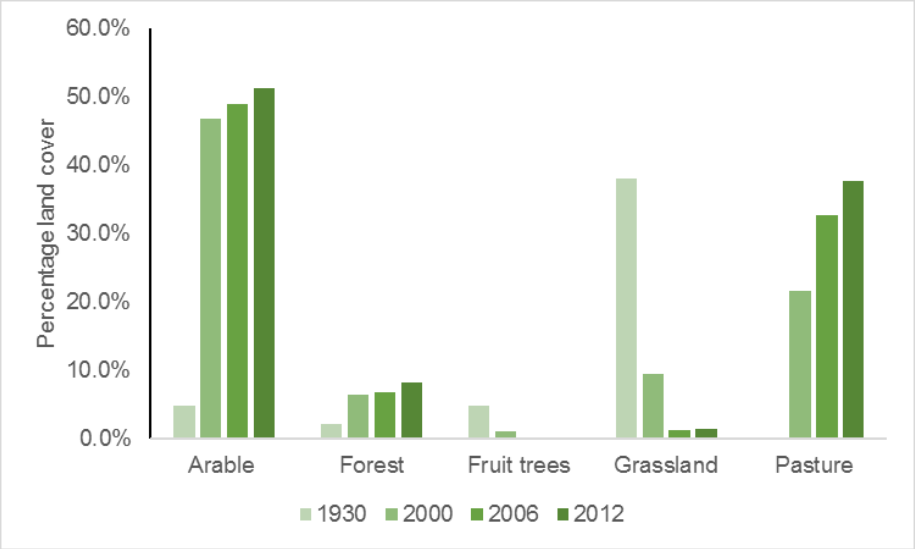

Figure 6. Percentage land use cover for arable, forest, fruit trees, grasslands and pasture for the Isbourne catchment between 1930 and 2012 (created from land cover data presented in Figures E7-E11)

3.6.2.1 Implications of land use change

The most notable land use change over the last 80 years is the expansion of arable land use. The work by Haycock (2010) suggests that rainfall which would have resulted in a 1:100 event in early 70's would now be closer to a 1:40 year event due to the change in responsiveness across the catchment as a result of land use change. Atkins (2013) and Haycock (2010) note the following changes in catchment drainage function:

- For much of the year there is sparse or no vegetation cover across arable landscape areas;
- There is no permanent vegetation cover to intercept rainfall, absorb it and return any of it to the atmosphere through transpiration;
- Arable crops will take up water whilst growing but during ripening their water uptake will be less;
- Large proportions of the catchment therefore rapidly absorb rainfall directly into the groundwater systems rather than have this process slowed by vegetation absorption;
- With temporary or less dense vegetation cover, there is also increased risk of soil surface erosion, particularly during heavy rainfall events and where fields are located on steeper sloping ground;
- Field boundary walls, headlands and hedgerows that were important for livestock are no longer needed and fall into disrepair or have been removed – reducing potential overland flow interception systems;
- Over the past 80 years land drainage has increased, resulting in direct drainage to the watercourses, even where infiltration is secured
- Climate change may lead to wetter winters and although summers may be drier there could be heavier summer rainfall events – these coincide with reduced vegetation cover or absorption in arable crops.

Figure E12 (Appendix E) indicates locations in the catchment where soil erosion is greatest, the highest risk areas coincide with many land areas that are now under pasture and the steep Upland Areas. Chapter 5 also outlines the role that land management options such as zero tillage, overwintering crops, cover crops and buffer strips can make in reducing the impact of these land use changes. Such a correlation between soil erosion risk and land use change will be important when considering adjustments to land management practices, such as the introduction of field margins, conservation headlands, planting of hedges, establishment of herbal grasslands or arable reversion.

3.6.3 Designated sites and wildlife areas

As well as identifying the key physiological characteristics of the catchment, it is important to note that there are numerous environmentally important sites across the catchment that must be considered as part of any scheme if works are planned within or near to designated sites and areas.

The majority of the catchment lies within the Cotswolds Area of Outstanding Natural Beauty (AONB). This covers the upper catchment to Winchcombe, the area from Toddington to Wormington and the eastern side of the catchment.

Special Area of Conservation (SAC): Dixton Wood

Sites of Special Scientific Interest (SSSI) include: Beckford Gravel Pits, Bourton Down, Cleeve Common, Hornsleasow Roughs, Jackdaw Quarry, Puckham Woods

Ancient Woodland sites include: Bespidge Wood, Congrove Wood, Dumbleton Wood, Hailes Wood, Humblebee How, Lidcombe Wood, Limehill Wood, Spoonley Wood, Stancombe Wood, Thrift Wood, Williss Coppice, Wormington Brake and Wynniatts Brake.

Scheduled Ancient Monuments sites include: Greet Roman Villa, Hailes Abbey, Milhampton Roman Site, Spoonley Wood Roman Villa, Tithe Barn at Postlip Hall, Toddington Manor, St Barbara's Church, St Marys Church, Village Cross at Stanton, Wadfield Roman Villa, Winchcombe Abbey

Local Wildlife Sites (LWS) are located all over the catchment area and include woodland areas, grassland fields and several sites lies along woodland sections of the watercourses.

Figure E13 (Appendix E) shows the locations of many of these sites and should any works be proposed within or near to these sites it will be important to liaise with the appropriate managing authority, such as Natural England, English Heritage, Gloucestershire/Worcestershire Wildlife Trust.

Existing habitats could be enhanced by NFM, whilst others could present a constraint. For example, it would be inappropriate to promote tree planting or regeneration of tree planting on species rich grasslands or wetlands, whilst the integrity of other habitats could be enhanced by expansion, such as woodland.

Careful consideration of the natural and semi-natural features at a potential NFM site will be very important, whether designated or not, with appropriate liaison undertaken with stakeholders at an early stage.

3.7 Current governance and institutional framework

The Isbourne catchment is complex in terms of governance. It is divided between two counties; Gloucestershire making up over three quarters of the area, and Worcestershire comprising the remaining area to the northern end of the catchment. There are three district authorities; the majority of the land area is under Tewkesbury Borough Council, which covers three quarters of the area, with Wychavon covering the north part and a small area on the eastern edge falling into Cotswold District Council. The County and District Authority boundaries for the Isbourne catchment are shown on Figure E14 (Appendix E). The catchment is also made up of 20 parishes, although some of them are only cover a small areal, these are shown on Figure E15 (Appendix E).

In terms of other designations, it is worth noting from Figure E13 (Appendix E), that approximately two thirds of the catchment falls within the Cotswold Area of Outstanding Natural Beauty.

Locally, the catchment coordination is led by the Isbourne Catchment Group, which is a recently formed community group focussed upon the entirety of the catchment of the River Isbourne. The membership of the group includes members of local flood forum, formed after the devastating floods of 2007, and residents of the catchment.

4. Natural flood management options for the Isbourne

4.1 Defining the NFM drivers within the Isbourne Catchment

Investment in NFM will necessarily be driven by the need to deal with local pressures on the water environment. Key considerations for this scoping study have been identified to include:

- Flood risk alleviation for locations along the lower end of the catchment or in 'pinch points';
- Sediment management for WFD and general environmental improvements;
- Water quality improvements for WFD and general environmental improvements.

4.1.1 Flood risk

Figure E5 in Appendix E indicates where the maximum extend of flooding recorded across the Isbourne catchment since the 1960s. As discussed previously in Section 3.5, there are no records of flooding in the Upper River Valleys or Upland Areas. However, the topography and geology means that these areas have a strong influence on flooding in the Floodplain River Valley areas, to which the water is rapidly transferred via both fluvial and groundwater pathways.

Flood events in the Isbourne catchment typically occur following short but extraordinarily heavy rainfall events where water drains rapidly off the Upland Areas and into ephemeral and fluvial water flows across the steep Upper River Valleys. The Upper River Valleys have limited floodplain areas and steep bed-slope which means that water reaches lower lying Floodplain River Valley areas at speeds and volumes too great for the culverts and urbanised channels (that have been built within what would have been the natural floodplain area at the valley bottom). Where flooding does occur it is often located upstream of a culvert structure, indicating that the culvert is too small or that it became blocked at the time of the flood incident. Careful management of mill pool levels and weirs can and does help to reduce local flood risks.

The key application for NFM for flood alleviation would be to maximize the amount of rainfall soaking into the ground, and to retain and slow the surface water flows down the watercourse before reaching the low-lying urbanised areas at the downstream end of the catchment. The key application of NFM in these areas is to slow surface flows and implement soil de-compaction measures to encourage greater groundwater infiltration. NFM structures would also be needed to slow fluvial flows in the upper catchment. NFM structures are not being considered along urbanised reaches as these areas lie too far down the drainage system to have any impact on flood risks within the majority of settlements. Flood risk reduction in these areas could be managed by reviewing potential flood protection measures, culvert enlargement or removal and prevention of culvert blockages. The continued maintenance of these artificial drainage and flood protection systems is vital as remedial works to remove culverts or increase connectivity in these locations is often not a viable alternative option.

4.1.2 Sediment

The volume of soil transferred to the river valleys when woodland was first cleared many hundreds of years ago is likely to have been immense and further quantities of topsoil are likely to have been lost since then through agricultural intensification after the Second World War. Overgrazing and trampling within riparian corridors does occur in the upper reaches of the catchment. Here there should be a strategy of moving drinking access up the slope and away from the valley bottom. A second source would be the continuing arable cropping regime which leaves soils bare over late summer after harvest and through the winter period following cultivation and planting. These are likely to be contributing to a continued degree of sediment transfer from upland areas towards the river valleys.

Application of the standard Defra methodology of sediment erosion risk to the catchment suggests most of the catchment is at low risk of soil erosion (Figure E12, Appendix E). However, there are numerous hotspots of medium and high risk, particularly in the upland areas and Upper River Valleys around the edge of the catchment where arable ground, sandier loamy soils and steep slopes coincide. Many of these hotspot areas coincide with more recent land use changes from grassland to arable crops and the removal of orchards and trees within the catchment (see Figures E7-E11), therefore the risk of soil erosion and diffuse sediment pollution are high.

There are numerous relict and active mill pools along the Isbourne and its tributaries that could potentially influence the impacts of diffuse sediment pollution entering the watercourses. Suspended sediment can settle out in these areas before leaving the Upper River Valley areas, leaving little silt accumulation within the slower sections of the river. The extent to which this occurring will need to be quantified with a catchment walk-through.

Whilst the weir and pool system could potentially have a positive impact on diffuse pollution by reducing the downstream transport of fine sediment, barriers and mill pool structures can also have parallel adverse affects on water body condition under the WFD by interrupting natural geomorphological processes and blocking the migration of fish.

4.1.3 Water quality

Water quality aspects that are important under WFD include target conditions for Dissolved Oxygen (DO), pH, Ammonia, Phosphate and temperature. With the exception of Phosphate, these data have been modelled for the Isbourne catchment by the Environment Agency as part of the 2015 update to the WFD assessment (presented in Table 6 below), rather than directly measured in the catchment so there could be some errors associated with these values.

The overall chemical status of the River Isbourne water body is classified as Good, with only Phosphate and macrophytes (these have capacity to improve the water quality by absorbing nutrients, while at the same time decay of the macrophytes increases nutrient concentration leading to eutrophication) being classified as Moderate. Phosphate levels could be accounted for by diffuse sources from agricultural sources or discharge from septic tanks. Phosphate has improved from Poor classification in the initial baseline WFD assessments in 2009, and is predicted to be Good by 2012 with no barriers cited to impede this improvement and a very certain projection by the Environment Agency. Macrophytes are predicted to be Moderate by 2021 and Good by 2027 due to the ecological recovery time associated with

this process. The remaining water quality variables have been modelled to be Good or High classifications and therefore exceed the acceptable levels for the WFD and need no further attention.

Table 7. Water quality/chemistry results for the Isbourne catchment (2015 WFD)

Year	Ammonia	Dissolved Oxygen	Invertebrates	Macrophytes	pH	Phosphate	Temp
2015	High*	High*	Good	Moderate	High*	Moderate	High*
Predicted 2021	High	High	Good	Moderate	High	Good	High
Predicted 2027	High	High	Good	Good	High	Good	High

* Values based on modelling rather than direct measurements

4.1.4 Other WFD impacts and considerations

The overall ecological status of the Isbourne catchment is classified as Poor in the 2015 WFD re-assessment, which brings the overall catchment classification down to Poor at present. In particular the River Isbourne is failing on fish (classified as Poor) due to the large number of barriers and on-line mill pools along the Isbourne which are a major barrier to fish and eel passage. The Environment Agency have predicted that the classification for fish will remain Poor by 2021, as there would need to be routes around all of these structures for all species in order to meet Good in terms of the WFD, and this is considered unfeasible due to the disproportionate expense this would cost.

The Isbourne catchment is not designated as artificial or heavily modified and the hydrological regime and hydromorphology (i.e. the physical characteristics of the shape, boundaries and content of a water body) ‘support good’ in the 2015 WFD re-assessment, however no data have been collected on this. To create a diverse habitat under the WFD and to promote an increase in the number of macroinvetebrates and fish species, as well as to slow the flow during flood events, it is important to have a range of channel and in-channel forms and features within a water body, so assessment of the hydromorphology of the Isbourne could be a valuable contribution to this and to help highlight where NFM measures would be most appropriate.

In terms of flood management, water storage designs can take the form of large-scale storage basins or reservoirs, formed by insertion of a flow restrictive structure at the downstream end to throttle and hold water behind in times of high flows. The excavation of large basins or the insertion of new barriers to flow is generally unacceptable under the WFD for many reasons, including fish passage, but also for the interruption to the natural dynamics of river flow and for interruption of natural downstream transfer of river sediment and migration of plants and animals. Such large-scale structures would be deemed a modification to the existing condition of the river and would need careful design consideration.

Alternative barriers for slowing flow speeds and deflecting flows could involve the insertion of woody debris and deflectors, which if placed in appropriate locations and positioned carefully can deflect and slow flows whilst not significantly impairing continuity of flow, sediments or migration. The limitations are the scale of water that can be slowed or stored by these structures as they tend to have small-scale effects and would only function during in-channel, pre-overbank flood events.

4.2 NFM application to water courses in the Isbourne

The ordinary water courses in the Isbourne catchment can be divided into 6 separate tributaries, whilst the River Isbourne itself can be separated into three sections. These are:

- Langley Brook, including water body flowing from Cleeve Common to Winchcombe
- Beesmoor Brook, flowing from Charlton Abbots to Winchcombe
- Didbrook and tributaries, flowing in to the Isbourne below Greet
- Stanway tributaries, flowing into the Isbourne at Wormington
- Stanton and Laverton tributaries, flowing into the Isbourne above Sedgeberrow
- Dumbleton tributaries, flowing into the Isbourne above Sedgeberrow
- The Upper Isbourne from Winchcombe to join with Didbrook tributaries
- The Mid Isbourne from Didbrook join to Stanton and Laverton tributaries
- The Lower Isbourne from Stanton and Laverton join to joining river Avon.

The above divisions are shown on Figure E16 (Appendix E). The next section will outline the characteristics of each area and show which NFM options might be best placed on each of these water courses.

4.3 Water body reviews for applicable NFM

This section will look at the main water bodies where NFM might be applied using the distinctions made in Section 4.2 and outlined in Figure E16 (Appendix E) and Table 7.

Langley Brook

Langley Brook is characterised by the presence of Cleeve Common and other natural grassland areas. It is the highest area of the catchment at over 330m AOD and includes the steep Cotswold scarp. There is also the largest area of Inferior Oolitic limestone. The high areas are very permeable and it is important that this is maintained and improved where appropriate. There is some ancient woodland and only a small area of arable but this is likely to be at risk from soil erosion. This water body has the largest area of SSSI and the woodland is a priority habitat. The evidence of historic milling is evidence with lots of mill ponds, relict and active, along this stretch of river. Flood risk is low in the upper reaches of

the watercourse, but increases as it joins the main River Isbourne. The recommended NFM options for this area are summarised in Table 7 and on Figure E16 (Appendix E).

Beesmoor Brook

Beesmoor Brook is a natural combe and the land falls from around 300m AOD down the Cotswold scarp to about 120m AOD on three sides. The scarp is mostly Whitby mudstone and Dyrham formation and as a result is moderately permeable and at relatively high risk of soil erosion. There is some arable at the very top of the catchment but most is on the lower slopes. The main slope areas are grassland and woodland. There are also areas of ancient woodland and priority habitat. There are some large mill ponds in the lower reach of the water course that could potentially be utilised for storage and their current state needs to be reviewed. The recommended NFM options for this area are summarised in Table 7 and on Figure E16 (Appendix E).

Didbrook and tributaries

The source of the Didbrook is at the base of the Cotswold escarpment at around 250m AOD falling to 70m AOD at the confluence with the main River Isbourne. The water course is primarily situated on mudstone, which is moderately permeable in the upper reaches and with a high risk of soil erosion, but becomes low permeability as it turns to Lias Clay in the lower reaches. The land use is pasture and ancient woodland in the top sections, with the majority of the region being arable as well as the managed parkland around Hailes Abbey. There are some priority habitats and the upper reaches falls within the Cotswold AONB. The recommended NFM options for this area are summarised in Table 7 and on Figure E16 (Appendix E).

Stanway tributaries

The majority of the water course is under 110m AOD, with only the source originating at the base of the Cotswold escarpment (approximately 250m AOD). The area is low permeability with a band of moderate permeability along the Inferior Oolitic limestone in the upper reaches. The reach has moderate soil erosion risk in the upper areas with the remaining area low soil erosion risk. The majority of the area is pasture, with some forest (of which some is ancient woodland) in the upper reaches and arable along the lower water course. There is also the Stanway House parkland, which is a managed section of land along the channel. This falls within the Cotswold AONB and there are some priority habitats. There are a number of mill ponds in the upper stretches of the water course that have potential for re-instatement. The recommended NFM options for this area are summarised in Table 7 and on Figure E16 (Appendix E).

Stanton and Laverton tributaries

This area is lowland Floodplain Valley Area, under 100m AOD with most of the water course under 50m AOD elevation. All of the area is low permeability on the Lias Clay. The land use is primarily arable, with some areas of pasture. There is a low risk of soil erosion. The area does not fall within the Cotswold AONB but there are a small number of priority habitats,

patches of ancient woodland and some mill ponds in the lower reaches. The recommended NFM options for this area are summarised in Table 7 and on Figure E16 (Appendix E).

Dumbleton tributaries

This is an area of lowland Floodplain River Valley that has a relatively low elevation, with most of the water course under 70m AOD with the source area rising to approximately 120m AOD. The area is covered by Lias Clay and has a low permeability. The upper water course is pasture with some forest, while the lower reaches are arable. There are no designations in the lower parts of the water course, but the upper area is within the Cotswolds AONB, have some areas of priority habitat and some ancient woodland. The recommended NFM options for this area are summarised in Table 7 and on Figure E16 (Appendix E).

The Upper Isbourne River section

This is an area of Floodplain River Valley under 120m AOD elevation. It is primarily low permeability Lias Clay formation. The land use is arable and pasture, with some urban areas; this water course has seen a growth in impermeable urban areas and a reduction in the number of fruit trees and woodland areas along the river channel. There are some mill ponds located in close proximity to the water course. The area is at medium risk of soil erosion. The area is within the Cotswold AONB and there are some priority habitats in the upper reaches. Flood risk is moderate to high along this water course. The recommended NFM options for this area are summarised in Table 7 and on Figure E16 (Appendix E).

The Mid Isbourne River section

This is an area of Floodplain River Valley which is under 50m AOD in elevation. The base geology is Lias Clay formation and has low permeability. The land use surrounding the watercourse is primarily arable with limited pasture, as well as the managed parkland at Toddington Manor and areas of urbanisation. This includes the former mill pond that will be considered as a potential area of attenuating flood water. There has been a transition from pasture and reduction in the amount of woodland area/fruit trees along the water course since the 1930s. This area is within the Cotswold AONB and there are some priority habitats. Flood risk is high along this water course. The recommended NFM options for this area are summarised in Table 7 and on Figure E16 (Appendix E).

The Lower Isbourne River section

This is an area of Floodplain River Valley, it is a flat low permeable area which is under 30m AOD in elevation, other than the eastern edge of the lower watercourse with is Blue Lias and has a high permeability. The area is entirely arable in land use with some urban areas. The area has undergone significant change from pasture and fruit trees since the 1930s, and there are some historic mill ponds along the water course. The area is not within the Cotswold AONB but there are some priority habitats along the river channel. Flood risk is high along this water course. The recommended NFM options for this area are summarised in Table 8 and on Figure E16 (Appendix E).

Table 8. Possible NFM options for the water courses in the Isbourne catchment

NFM Options		Langley Brook	Beesmoor Brook	Didbrook	Stanway	Stanton & Laverton	Dumbleton	Upper Isbourne	Mid Isbourne	Lower Isbourne
In-channel sites	Barriers (steps, weirs, woody debris)									
	Sediment trap									
	Infiltration trench / drain									
	Berms									
	In-channel wetland									
	Gulley / grip blocking									
Floodplain and land area	Ponds									
	Infiltration / storage basins									
	Shelter belts									
	Buffer strips									
	Headlands									
	Hedgerows									
	Stone dyke / leaky timber walls									
	Swales									
	Dry / wet vegetated filter strip									
	Contour bund									
	Filter berm									
	Wetland									

Table 7 cont.

NFM Options		Langley Brook	Beesmoor Brook	Didbrook	Stanway	Stanton & Laverton	Dumbleton	Upper Isbourne	Mid Isbourne	Lower Isbourne
Farmyard areas	Swales									
	Cross-drains									
	Green roof									
	Sediment trap									
	Permeable surfaces									
	Soakaway									
	Filter drain / trench									
	Biobeds									
	Rainwater harvesting									
Woodland	Planting new woodland									
	Restoring existing woodland									
	Natural woodland creation									
Land and soil management practices	Converting arable land to species-rich grassland									
	Arable headlands and buffer strips									
	Reduced or zero tillage									
	Reducing soil compaction									
	Contour ploughing and tramlines									
	Establishing multi-species grassland									
	Restoring moorland									

N.B. Blue: RSuDS methods, Green: land management methods

4.4 Potential measurable benefit factors

Measuring the benefits of natural flood management is complex due to the number of other factors and an inability to single out the impact of NFM structures from these other factors. The concept of NFM and RSuDS is relatively new and implementation of designs is still at a very early stage (outlined in Atkins, 2013 and SEPA 2015). Although there are several catchments where pilot studies and installations are under way (see Appendix C), there is little published information about measurable benefits. Baseline data is either still being collected or has proven difficult to interpret due to complex catchment character, limiting accuracy of measuring beneficial impacts driven by NFM techniques that have been installed. Many designs will take time to mature (i.e. woodland-based systems) and monitoring data is as yet unavailable.

Nevertheless it is clear from projects such as those highlighted in Appendix C that there a number of significant benefits from introducing NFM features. Where natural and local materials are used there appears to be a significant biodiversity benefit both within the water body and the surrounding area. Linked to this there are benefits in meeting WFD objectives. The soft engineering approach means that members of the local community can feel directly involved, either through changing farming practices, allowing the placement of features on their land, planting of the trees specifically for flood risk management and constructing woody debris dams in water courses.

However, the nearby Stroud RSuDS project (see Appendix C for background information) has been able to compare historical flows under a given rainfall event with flows and levels before and after the installation of NFM measures. Here a single example was found that permitted comparison. In the Slad valley, where a number of flow gauges have been collecting data over a reasonable time period before work was carried out, and report these by Stroud District Council (2016). On March 9th 2016, the Stroud Valleys had approximately 35-40mm of rain over 12 hours, this is roughly half the monthly total expected for March. The EA were able to compare this event with a similar one that occurred in November 2012, before the Stroud RSuDS project started. Account was taken not just for an event of similar magnitude and intensity, but importantly, also the level of ground saturation before the rainfall occurred. In both cases the soil moisture deficit is zero, indicating full saturation.

The comparison of the two events is shown in Figure 7 below, this shows the two peaks aligned in the 10 hours over the event and shows a very substantial reduction in peak level in the 2016 event demonstrating the influence of the NFM structures. The EA have checked the gauges to ensure that there were no technical errors or problems and also compared the 2012 data with other events pre-construction, and the data has been deemed reliable for both events. However, it is important to note that the base flow level for 2012 was higher, indicating greater preceding ground saturation, and therefore potential run-off. Also, the total rainfall over the 10 hours prior to the peak was higher in the 2016 event.

Comparisons of this nature need to be treated with a high level of caution, as no two events will ever be identical. But by choosing two rain events that were closely comparable in terms of total rainfall, duration, intensity, preceding conditions and seasonality, it is likely that the difference that has occurred is due to the benefits of NFM. Therefore, at least in part the reduction in peak flow is, as far as it is possible to tell, the result of the more than 50 structures that have been installed in the Slad Valley. The other factor to consider is that as

the total capital and revenue expenditure for this reduction came at a cost of only £75,000 (approximately £1,500 per structure).

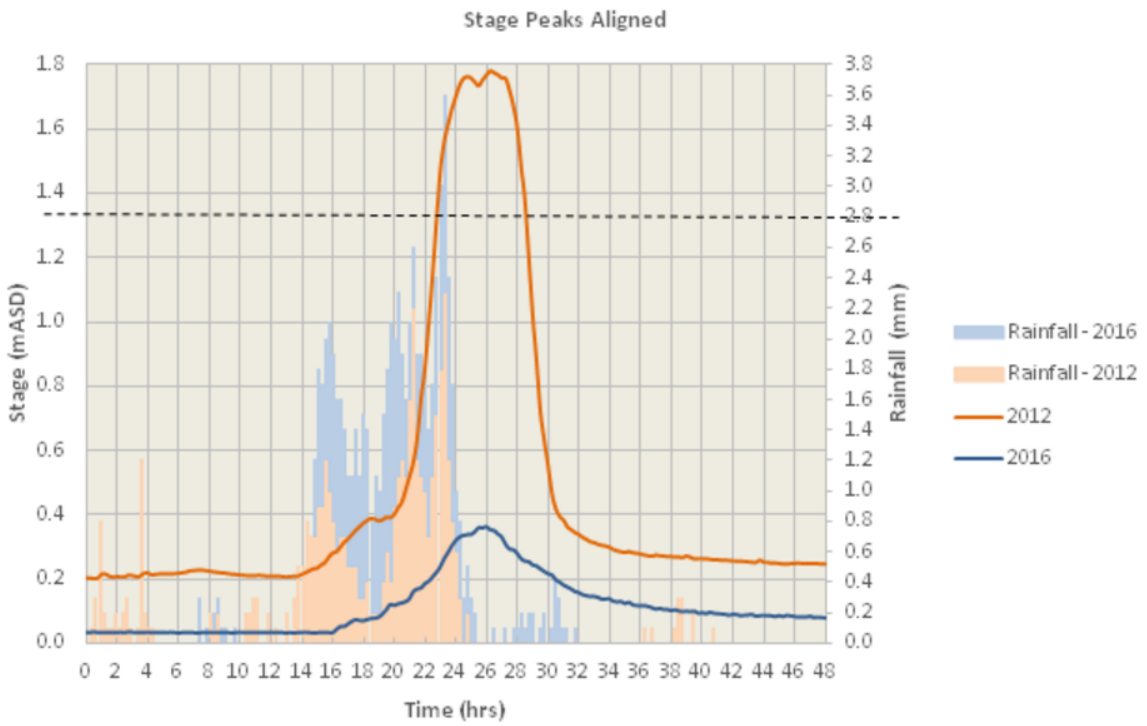

Figure 7. Comparison of water flow in Slad Valley pre- (2012) and post-NFM (2016) (Source: Stroud District Council, 2016)

4.5 Suggested governance arrangements (local and institutional)

The crucial aspect in terms of any governance arrangement is the connections between the local catchment group and the national agencies and authorities. Given the complex local administrative arrangements noted in Section 3.7, this is not straightforward for the Isbourne. However, the advancement of the NFM will depend upon an officer to drive the project forward, with the support of the ICG. Should a responsible district authority be allocated, the most appropriate local authority would seem to be Tewkesbury Borough Council. However as they only cover three quarters of the land area, this could create funding restrictions to cover the remaining catchment area. A shared role across two local authorities, Tewkesbury and Wychavon, should be seen as the ideal way to proceed, provided the necessary arrangements for cross boundary working, in terms of budget, lines of reporting and communication, can be satisfactorily secured for all parties.

Another alternative would be the Cotswold AONB, who would also have an interest in terms of the landscape and biodiversity benefits of the NFM techniques. However, these would be largely focused on the Cotswold scarp areas where the AONB have a number of projects, such as Magnificent Meadows and the Cotswold Scarp Nature Improvement Area.

The other option would be for another organisation to host the catchment NFM officer. The most likely options would be a farm advisory organisation, such as the Farming and Wildlife Advisory Group (FWAG) which would be regionally-based (the FWAG South-West group), or

a river-based group such as the local Rivers Trust (for the Isbourne this would fall under the Severn Rivers Trust).

What is key is for the ICG to be integrated into the consultation and decision-making so that they agree with the proposed option, as well as to be involved in the implementation and overall governance of the project.

4.6 Other potential flood risk solutions

There is the potential to explore opportunities to increase potential storage within the mill pool and reservoir systems that already exist in within the River Isbourne. Throughout the Isbourne catchment, open valley floor areas within both the Upper and Floodplain River Valleys have often been adapted for storage of large volumes of water for milling and water power (see Figure E6, Appendix E). These features already hold a significant volume of water but, when maintained at full or current capacity, provide little or no further storage capacity for river water during high flows as they are already full. As other sites for creating new storage areas are generally lacking across the catchment, given the topography and potential adverse impacts on flood risk and WFD criteria, the adaptation of the existing mill pool systems to increase storage capacity is an option that could be considered.

The main methods by which storage in mill pools could be increased are by either lowering normal water levels (either permanently or temporarily) to increase available storage within the existing structure or by raising surrounding ground levels or bunds to increase storage capacity above existing water levels (Atkins, 2013).

Further assessment would be necessary to identify viable sites and to demonstrate that there are measurable flood risk benefits by taking such options further, though the size and number of pools that could be adapted may not be sufficient to provide a significant flood risk reduction. It is understood that some discussions have taken place around the former mill pond close to Toddington Manor and this would be a sensible place to start to determine the potential impact and feasibility of this option. In all such investigations it is important to understand the risks and responsibilities associated with any changes to these structures, and potential impact on the wider catchment.

5. Summary, natural flood management opportunities & recommendations

5.1 Summary of main findings

NFM involves soft-engineering techniques that include drainage techniques that could be classified as RSuDS, land management changes and increasing the availability of water storage areas. These are becoming an increasingly popular option to reduce flood risk as the opportunity for hard engineering options diminishes (see examples in Appendix C). However they remain novel and cutting edge and are considered most effective when working in tandem with other conventional approaches of flood risk management. Nevertheless NFM also has a number of other benefits such as to improve water quality and enhance local biodiversity and amenity as well as increasing the role of the local community in contributing directly to reducing the flood risk of the catchment. Once fully operational across the catchment, NFM will reduce the number of total flood events but on its own it would not erase the flood risk from major flood events such as those that occurred along the Isbourne River in 2007.

5.1.1 Key catchment drivers

The key drivers for consideration for the application of NFM across the River Isbourne and its catchment involve:

- **Flood risk:** most flooding occurs in the Lower Isbourne; steep slopes and rapid runoff in the upland areas of the catchment channel water down to the lower areas where it exceeds channel capacity;
- **Diffuse sediment pollution:** land use change has released large quantities of sediment into the upper reaches of watercourses, however sediment is not considered a significant impact in the Lower Isbourne, potentially due to storage in active and relict mill ponds and water storage features;
- **Water quality and pollution:** most water quality aspects are of good quality in the Isbourne with the exception of Phosphates and macrophytes being classified as moderate.

The River Isbourne has been split into 9 water course areas for this study which comprise:

- Langley Brook, including water body flowing from Cleeve Common to Winchcombe
- Beesmoor Brook, flowing from Charlton Abbots to Winchcombe
- Didbrook and tributaries, flowing in to the Isbourne below Greet
- Stanway tributaries, flowing into the Isbourne at Wormington
- Stanton and Laverton tributaries, flowing into the Isbourne above Sedgeberrow
- Dumbleton tributaries, flowing into the Isbourne above Sedgeberrow
- The Upper Isbourne from Winchcombe to join with Didbrook tributaries
- The Mid Isbourne from Didbrook join to Stanton and Laverton tributaries
- The Lower Isbourne from Stanton and Laverton join to joining river Avon.

5.1.2 Catchment character

The river flows across the Isbourne catchment are driven by a combination of interactions between rainfall, the underlying geology and the topography of the catchment.

Geology: The escarpment of the Isbourne catchment are underlain by a permeable Inferior Oolite limestone, this then transitions into more mudstone dominated bedrock towards the lowland and southern end of the catchment with a more open valley landscape. Ground slope also flattens out form the steep, narrow valley upper catchment as the Isbourne geology becomes less permeable but with a lower gradient as they transition into Lias Clay.

Hydrology: Springs sources and baseflows fed directly by the groundwater system dominate water supply in upland area watercourses within the Isbourne catchment and are also reliant upon direct surface water (runoff) contributions. Normally rainfall rapidly soaks into soil in upland areas and is released as spring flows in Upper River Valley areas, this delays the path of water down the catchment over a two week period. At times of excessive flow there is excess water and this surface water joins ephemeral water flows and continues over-land downstream. The springs and smaller tributaries progressively add more water at many points along all the river valleys until the Floodplain River Valley is reached.

The Lower Isbourne differs considerably in geology, topography, landscape type and hydrology. Soils are less permeable, flatter and mainly form Floodplain River Valley landscape types where the river can spread over extensive adjacent land areas. The majority of flows in the Lower Isbourne are as a result of the fluvial flows released from the four upstream sub-catchments, as the impermeable Lias Clay geology beneath results in minimal groundwater contributions or interactions with water levels.

Topography: Geology, hydrology and topography combine to create three distinct landscape types present in each sub-catchment that help summarise landform character:

- **Upland Areas:** elevated, generally flatter ground areas above the edge of the river valleys;
- **Upper River Valleys:** steep river valleys cut into the landscape with steep or shallow 'V' forms, steep channel slope and relatively little or no permanent floodplain area;
- **Floodplain River Valleys:** where channel slope and valley bottom opens out to form wide, permanent floodplains.

Land use change: Measured land use across the catchment since the 1930s and up to 2012 reveals changes in vegetation cover, agricultural practices and urban influences. The most notable change is that arable areas have increased substantially across the catchment. There has also been a reduction in orchards and natural grasslands, the latter being replaced by pasture. Although urban areas make up a small proportion of the overall area their coverage has also increased since the 1930s, resulting in a further increase in the amount of impermeable surfaces.

Changes in land use will have undoubtedly changed they hydraulic behaviour within the catchment over an extensive period of time.

5.2 Opportunities for NFM

Whilst there are local characteristics within each water course that may mean some NFM are more / less applicable when considered independently, a range of NFM that are typically applicable can be identified for use within the Isbourne catchment.

- **In-channel designs** involve preserving existing natural and introducing new semi-natural features (e.g. woody debris deflectors, dams and tree root encroachment) along wooded and scrubby river sections. These sections should be used as a template for application in other sections that lack these features. Along the sections of the River Isbourne it should be ensured that in-channel designs such as woody debris (deflectors, natural dams) do not increase local flood risk during larger scale events. It is not recommended to install permanent in-channel structures (steps, weirs).
- **Land-based designs** to intercept overland flow pathways such as stone dykes, interception ponds, leaky timber walls, headlands, hedgerows, buffer strips, contour bunds, shelter belts and woodland creations could be applied to steeper areas at the edge of the escarpment. Land-based designs are limited by a lack of floodplain area but could be applied across short open river valley floor areas to enhance in-channel attenuation by carefully designed throttled outflow controls, deflectors, bunds and land-based flow barriers, ponds, basins.
- **Farmyard designs** can be applied to manage surface water flows and improve water quality released from yard areas, livestock and storage buildings, manure / silage / materials / equipment storage areas and improve sediment management of farm sites, tracks and gateways. Capital grants for enhancing runoff from yards and treating dirty water before it enters water bodies might be available through the Countryside Stewardship Scheme provided the area concerned was within the Catchment Sensitive Farming designation.
- **Woodland:** the Isbourne catchment has undergone a reduction in tree cover over the last 80 years and wherever possible, woodland or shelter belt plantations should be considered. Grants are available through the Countryside Stewardship for targeted woodland planting and the appropriate management of existing woodland. Small copses should also be considered, the choice of species and future management should be an important consideration with the aim being a dual aim of creating an effective NFM feature and benefiting biodiversity.
- **Land and soil management practices** that contribute to NFM should be applied to the large areas of arable land in the catchment; the introduction of buffer strips, contour ploughing and practices to encourage increased organic matter in the soil and a reduction on soil compaction, such as reduced or zero tillage should be encouraged. The conversion of arable land to species-rich grassland in selected areas could also serve to reduce runoff and increase rates of infiltration. The Countryside Stewardship scheme provides incentives for some land and soil management practices but this is a competitive scheme that is targeted to certain areas. Practices that specifically benefit soil management, such as increasing organic matter and reducing soil erosion, also have benefits for the farmer and land manager in terms of increasing productivity and reducing pest burdens, so might be attractive without government incentives. The nearby Overbury estate practices zero

tillage and regularly plants green manures so there is vegetation no the land all year round. The farm manager regularly has visits to show other farmers then practicalities of this approach.

5.3 Principles for the use of NFM

5.3.1 Applicability factors

In the highest areas of the catchment the soils are very permeable, but some land use changes can reduce this through compaction, poor land management and cultivation of soils in this area. The principle in this area should be to ensure that the permeability of soils across these upland areas is retained and enhanced wherever possible. This may involve the testing of some aerating of the soil in the dry valleys and may be some of the flatter tops in areas of permanent pasture or seeking to increase the diversity of vegetation through plants that are more deeply rooted. Where there is arable land some permanent green cover should be considered alongside some soil improvement approaches.

The lack of surface water features across the Upland Areas places some restrictions on the NFM designs which can be applied in these areas. All those structures that are installed will require careful management of ephemeral surface water flow routes. Focusing these in scrubby and partially wooded areas will help to enhance these.

The lack of open floodplain areas and urbanization along the valley bottom of the main River Isbourne sections and high degree of groundwater interactions (via springs and baseflows rising through the river bed) also restricts the use of land-based NFM in these areas. Open valley bottom areas have often already been developed for mill pools and associated mill structures so storage may potentially already be fully utilized, this needs to be explored further looking for areas that are not function effectively. Other open areas may be of local importance for wildlife or form valuable wetland habitats, but these may be possible to adapt for attenuation if ecologically-sensitive systems can be designed.

Many springs flow from valley sides and enter watercourses on both sides of all watercourses in this catchment. It is not feasible to create attenuation on spring systems as they form important natural features and habitats, form water supplies. However some NFM options would be possible at source, provided they could be secure and not increase risk for properties downstream. The fact that the terrain is also usually inaccessible, steep also requires an NFM features to be carefully considered,. However to be effective they would need to be spread across all upper reaches of the Isbourne catchment.

Single-site large-scale storage is not practicable in the sub-catchment Upper River Valleys. Whilst the impact of hundreds of springs entering all along the valley sides mean that the only option is multiple NFM features across the upper reaches of the catchment in order to slow the flow into the lower end of the Upper River Valleys. This would also benefit the meeting of WFD objectives. Likewise the insertion of NFM should seek to enhance all existing local habitats, all of which are likely to occur within the Cotswold Area of Outstanding Natural Beauty and note is taken of the landscape guidance (Cotswold Conservation Board 2015).

5.3.2 Measurability factors

Specifying potential measurable improvements to flood risk reduction, diffuse sediment pollution or chemical pollution as a direct result of implementing NFM is not yet possible as published and verified data on such results is still lacking. At this time, pilot studies in other drainage catchments have not published data from their findings, although initial qualitative observations show multiple benefits. Nevertheless it is clear from projects such as those highlighted in Appendix C that there a number of significant benefits from introducing NFM features. Where natural and local materials are used there appears to be a significant biodiversity benefit both within the water body and the surrounding area. Linked to this there are benefits in meeting WFD objectives. The soft engineering approach means that members of the local community can feel directly involved, either through changing farming practices, allowing the placement of features on their land, planting of the trees specifically for flood risk management and constructing woody debris dams in water courses. However, recommendations for which NFM can be applied and where across the catchment along with recommendations for the next steps towards planning and implementation can be made

Quantities of water attenuated and baseline data is often unavailable or requires lengthy pre-construction monitoring as well as continued post-installation monitoring. There are also site-specific, local ground condition factors and sub-catchment complexities (geology, topography, vegetation, grazing) that mean many factors other than NFM structures could cause change in flows, water quality and suspended sediment loadings.

Collecting evidence to confirm catchment-wide benefits of NFM is likely to be difficult as measurable changes would be influenced by many other external factors. However the experience of the Stroud project (see Appendix C) has shown that NFM projects align well with meeting WFD objectives. However, in order for this to be the case it is important to note all existing local habitats and where possible seek should seek to enhance natural features through sensitive management practices.

The installation of small-scale NFM in isolation tend to have little impact on the catchment hydrological processes to be measurable, particularly where the degree of groundwater influence is high. However they can provide local benefits to farmyards, field areas and in-channel areas.

Only the extensive application of NFM approaches across the whole catchment in as many locations as possible will make it possible to achieve a measurable impact. Within a single watercourse which could be specifically monitored pre- and post-works and, if other potential influencing factors could be accounted for, it may be possible to measure environmental changes. However, time is always a constraint and, even with limited resources, a pragmatic decision should be made to begin engaging with the community regarding the installation of NFM features where there is a willingness to do so.

5.4 Recommendations

Following the acceptance of this report, it has already been agreed that there will be a collective review of land use across the catchment. This will build on and ground truth the GIS mapping through a series of catchment walk throughs. The change from woodland and natural grassland to arable and pasture has simplified vegetation cover diversity across the catchment and rainfall interception and catchment ‘roughness’ is much reduced.

In order to secure some quick gains aimed at reducing the speed at which rainfall travels down the catchment we recommend that two areas should be targeted in the first instance, namely:

- Langley Brook, including water body flowing from Cleeve Common to Winchcombe
- Beesmoor Brook, flowing from Charlton Abbots to Winchcombe

These two areas provide the largest areas of extensive grassland and woodland and significant landowners are supportive of nature conservation and the NFM approach. Such a pragmatic approach has worked well in the Stroud project in both starting the project work and showing the local community, especially landowners and farmers, what is required.

The recent, extensive conversion of grassland to arable could be significantly contributing to diffuse sediment pollution in the upper reaches of watercourses. Even if much of this is potentially filtered out before it reaches lower valley areas by many on-farm features such as ponds, there is considerable scope for adjustments in farming practice. The recently secured Facilitation Fund under the Countryside Stewardship Scheme will be able to facilitate this using the nearby Overbury Farm Estate as a knowledge exchange hub. The wider applied research across the UK would also be beneficial, notably the Allerton project in Leicestershire (see Appendix C).

The potential of currently overgrown and redundant structures, such as the line mill pool at Toddington, along the lower part of the catchment need to be fully evaluated in terms of their capacity, suitability for storage and likely effectiveness. The first step would be to include a visit to Toddington on the catchment walks and to determine the current state of the feature and its capacity. .

In terms of flood risk, runoff and erosion control, woodland cover has been estimated in studies in other areas to intercept and prevent up to 40% of rainfall reaching the ground and river channel (Dixon *et al*., 2016). Increasing and maximising woodland cover within a sub-catchment is likely to have a considerable, measurable impact on river flows and flood risk in downstream areas. Whilst catchment-wide woodland re-creation is unlikely to be possible or practicable across the Isbourne catchment, all potential opportunities for increasing general woodland areas, shelter belt or hedgerow cover should be explored. The ‘next best’ application would be the enhancement of riparian woodland cover wherever it is lacking or damaged by grazing to reduce sediment release and increase in-channel roughness as well as absorption of rainfall. Other techniques could provide localised benefits for site-specific issues such as ephemeral flows or springs that arise after heavy rainfall events.

Many of these potential opportunities will only be achievable with extensive liaison, cooperation, engagement and partnership working between stakeholders including the Environment Agency, landowners, District Authorities, County Councils, Gloucestershire/Worcestershire Wildlife Trusts, Natural England and Defra. In a difficult economic climate it will be important to explore potential funding opportunities and align WFD and flood risk objectives for the Isbourne catchment to provide a more effective, catchment-based approach.

Application of NFM across the Isbourne catchment must contributing to the meeting of all WFD objectives and the enhancement of any existing heritage features or natural and semi-natural habitats.

5.5 Next steps

With the above in mind, the key next steps for NFM across the Isbourne will involve:

- A series of catchment walk throughs to identify specific runoff problems, potential water retention areas and potential sites for NFM where remedial action could be taken on farmyards and where woodland/shelter belts can be inserted and riparian woodland can be enhanced and any other NFM applied;
- This would then enable identification of the potential scale of NFM applications that could be applied within each of the water courses in the catchment and identify the potential extent to which they could begin to address the key issues for flood risk, water quality and pollution management measure;
- Determination of initial pilot study water courses with the potential for a wide range of NFM applications to begin implementation of measures within the catchment. We recommend the Langley and Beesmoor Brooks as the most sensible starting points;
- Exploration of partnership opportunities and identification / alignment of sources of potential financial support for NFM and catchment management approaches;
- Secure funding for a project officer for the catchment. A shared role across two local authorities, Tewkesbury and Wychavon, would be ideal provided the necessary arrangements for cross boundary working, in terms of budget, lines of reporting and communication, can be satisfactorily secured for all parties.
- To devise and undertake baseline assessments and future monitoring programmes to produce measureable outcomes to quantify the impact of any NFM implemented. This may include the installation of more monitoring points in the headwaters of the catchment.

Applying the principles of restoring or enhancing natural drainage pathways and improvements to runoff management across the whole Isbourne catchment can only have positive effects. A catchment-wide, collective consideration of sediment and nutrient sources and drainage pathways is certainly to be recommended.

5.6 Suggested further reading

The application of NFM across river catchments is not only about flood risk management or control of diffuse pollution sources it is also about best drainage and land management practices as well as enhancing biodiversity within the landscape. Some recommended sources of information to help with further planning and understanding include:

- Allerton project (2016) Water friendly farming https://www.gwct.org.uk/allerton/
- Avery, L. (2012) Rural Sustainable Drainage Systems (RSuDS). Environment Agency, Bristol.
- Environment Agency (2016) Working with Natural Processes Evidence Base. Environment Agency, London
- SEPA (2015) Natural Flood Management Handbook. Scottish Environmental Protection Agency, Stirling.

6. References

Atkins (2013) Rural SuDS – River Frome Catchment (Stroud Valleys) Scoping Study Final Report. Environment Agency, Bristol.

Avery, L. (2012) Rural Sustainable Drainage Systems (RSuDS). Environment Agency, Bristol.

Barber, N.J. & Quinn, P.F. (2012) Mitigating diffuse water pollution from agriculture using soft-engineered runoff attenuation features. Area, 44.4, 454-462.

Barlow, J., Moore, F. & Burgess-Gamble, L. (2014) Working with natural processes to reduce flood risk. Environment Agency Report SC130004/R2. Environment Agency, Bristol.

Carrick, B. & Welton, P. (2007) Belford Catchment Solutions: Plant a tree today (and reduce peak flows). Environment Agency, Northumbria.

Cotswold Conservation Board (2015) Landscape Strategy statements, available at http://www.cotswoldsaonb.org.uk/planning-management-advice/landscapestrategy/

Cranfield University (2016) The Soils Guide. Available: http://www.landis.org.uk. Cranfield University, UK.

Deasy, C., Quinton, J.N., Silgram, M., Jackson, R.J., Bailey, A.P. & Stevens, C.J. (2008) Field Testing of Mitigation Options. Final report to Defra for contract PE0206. Lancaster University & Defra.

Dixon, S.J., Sear, D.A., Odoni, N.A., Sykes, T. & Lane, S.N. (2016) The effects of river restoration on catchment scale flood risk and flood hydrology. Earth Surface Processes and Landforms, 41, 997-1008.

Environment Agency (2016) Working with Natural Processes Evidence Base. Environment Agency, London

Environment Agency (2015) Severn River Basin District River Basin Management Plan. Final Report. Environment Agency, Bristol.

Environment Agency (2014) The Avon Warwickshire Management Catchment. Environment Agency, Bristol.

Environment Agency & Newcastle University (2011) Runoff Attenuation Features. A guide for all those working in Catchment Management. Partnership Project for work carried out for the Belford Catchment Solutions Project.

Environment Agency (2010) Working with Natural Processes to Manage Flood and Coastal Erosion Risk. A Guidance Document. Environment Agency, Bristol.

Environment Agency (2009) River Basin Management Plan: Severn River Basin District. Final Report.

Gloucestershire City Council (2015) Gloucestershire SuDS Design and Maintenance Guide. Gloucestershire City Council, Gloucester.

Halcrow (2012) Strategic Flood Risk Assessment for Local Development Framework. Level 2. Final Report. Tewksbury District Council.

Halcrow (2008) Strategic Flood Risk Assessment for Local Development Framework. Level 1, Volume 1 – Final. Tewksbury District Council.

Haycock, N. (2010) Isbourne catchment hydrological study following 2007 floods, confidential report to the Environment Agency.

Iacob, I., Rowan, J.S., Brown, I. & Ellis, C. (2014) Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective. Hydrology Research, 45.6, 774-787.

JBA Consulting (2009) South Worcestershire Joint Core Strategy Level 1 and Level 2 Strategic Flood Risk Assessment. Wychavon District Council.

Lovatt, M. (2012) The River Isbourne: In the Service of Mankind. Amberley Publishing, Stroud.

Murray, V. (2016) A baseline hydrogeological study of the River Isbourne catchment: Flood assessment and green engineering mitigation recommendations for the town of Winchcombe, UK. MSc Dissertation submitted to the School of Geography Earth & Environmental Sciences, University of Birmingham.

Nicholson, A.R., Wilkinson, M.E., O'Donnell, G.M. & Quinn, P.F. (2012) Runoff attenuation features: a sustainable flood mitigation strategy in the Belford catchment, UK. Area, 4, 463–469.

Nisbet, T.R., Roe, P., Marrington, S., Thomas, H., Broadmeadow, S. & Valatin, G. (2015) Slowing the Flow at Pickering – Phase 2. Defra FCERM Multi-objective Flood Management Project RMP5455. Defra, London.

Nisbet, T.R., Marrington, S., Thomas, H., Broadmeadow, S. & Valatin, G. (2011) Slowing the Flow at Pickering – Phase 1. Defra FCERM Multi-objective Flood Management Project RMP5455. Defra, London.

Pitt, M. (2008) Learning the Lessons from the 2007 Floods. (The Pitt Review). Secretary of State, London.

Quinn, P.F., O'Donnell, G., Nicholson, A., Wilkinson, M., Owen, G., Jonczyk, J., Barber, N., Hardwick, M. & Davies, G. (2013) Potential Use of Runoff Attenuation Features in Small Rural Catchments for Flood Mitigation. University of Newcastle and Environment Agency, Newcastle.

SEPA (2015) Natural Flood Management Handbook. Scottish Environmental Protection Agency, Stirling.

Thomas, H. & Nisbet, T.R. (2006). An assessment of the impact of floodplain woodland on flood flows. Water & Environment Journal, 21, 114-126.

Welton, P. (2010) Finding Solutions for Belford. Reducing flood risk through catchment management. Environment Agency.

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

7. Appendices