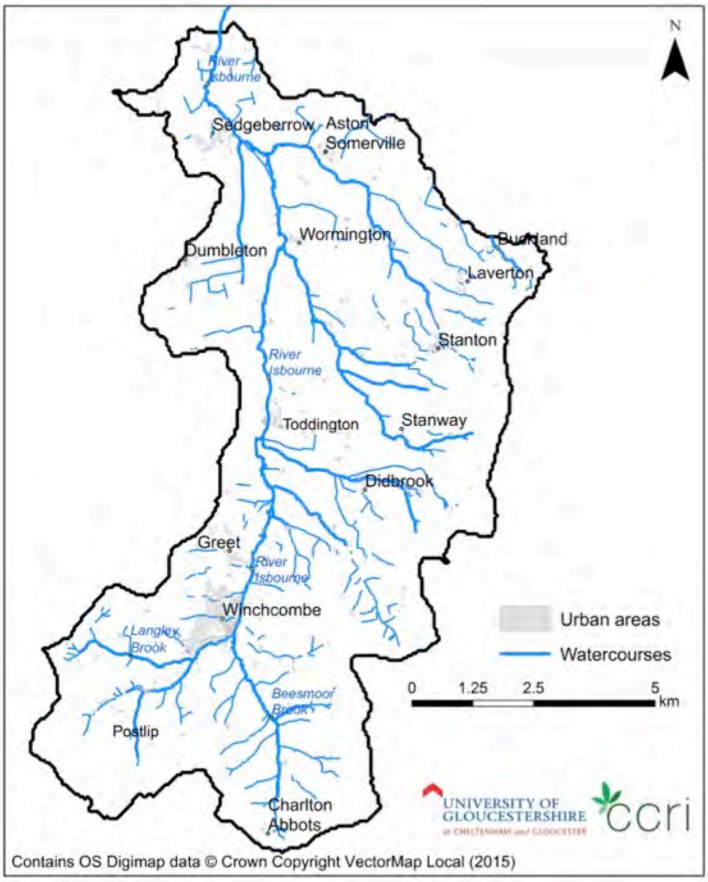
Isbourne Catchment Community Report: Potential for Natural Flood Management in the Catchment



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Date of Report: January 2017

When quoting this report use the following citation:

Clarke L and Short C (2016) Isbourne Catchment Community Report: Potential for Natural Flood Management in the Catchment (Final). Report to the Isbourne Catchment Group. School of Natural and Social Sciences, University of Gloucestershire & CCRI: Gloucestershire, UK.

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1. Introduction

1.1 Aim of the report

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 Isbourne Catchment Group (ICG) and the Environment Agency (EA) to undertake an initial assessment of the River Isbourne to determine the feasibility and potential benefits of applying natural flood management (NFM) techniques across the Isbourne catchment. Other engineering options had been considered in an analysis of the catchment in 2010 (Haycock 2010) and some minor changes have been made by the EA in the last few years. However, most significant engineering options were not considered to be cost effective whilst soft engineering options such as land use change and natural flood management were recommended for further investigation, which is the focus of this report – no assessment of hard engineering possibilities are made in this report as it is beyong the remit of the investigation.

1.2 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 EA, Gloucestershire County Council, Haycock Environmental Consultants Limited, Tewksbury Borough Council, Worcestershire County Council, and 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.

1.3 Natural flood management

NFM consists of a range of techniques that aim to reduce flooding by working with natural features and characteristics to store or slow down flood waters, the key to successful implementation of NFM is to install multiple interventions over a wide area which cumulatively achieve catchment-wide reduction of peak flows.

NFM involves soft-engineering methods that include drainage techniques (that could be classified as Rural Sustainable Drainage Systems (RSuDS)), land management changes to 'slow the flow' and increasing the availability of temporary water storage areas. Within a river catchment these aim to reduce the rate or amount of runoff (water running over the surface of the ground), reduce the speed of water within water bodies and/or improve the ability of rivers and their floodplains to manage flood water. The techniques associated with NFM 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 and numerous interventions need to be used to have any measurable impact. Nevertheless, NFM also has a number of other benefits such as improving water quality, enhancing local biodiversity and amenity as well as offering a more direct opportunity for the involvement of local communities to assist in 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.

There are a range of NFM designs and potential locations designed to reduce the initial flood peak, which include:

In-channel: these are features that are placed within a river channel to divert and slow the flow of water during high flow events. Many of our rivers and streams have been deepened and straightened, becoming disconnected from their natural floodplain. This means floodplains only provide their natural flood storage in extreme conditions. Carefully placed and individually designed leaky barriers, woody debris dams and deflectors can be used to direct water into preferential areas, increasing temporary water storage and slowing water passage. They are low cost, and utilise natural materials and processes.

In the Isbourne catchment this could involve adding and preserving existing natural vegetation and introducing new semi-natural features (e.g. woody debris deflectors, dams and tree root encroachment) along wooded and scrubby river sections. 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). Multiple in-channel interventions are required to have a notable impact on flood flows.

Barriers: cause water to pond introducing sedimentation and increasing infiltration (water soaking into the ground).

Photograph taken from Avery (2012)

Grip/gully blocking: grips are drainage ditches that have been used in managed peatlands to lower the water table to improve the land for grazing. Blocking grips may help reduce runoff through increased water retention, although the main aim is to minimize dissolved organic nutrient concentrations.

Photograph taken from Avery (2012)

Online pools/ponds: ponds and pools designed to permanently retain some water at all times and provide temporary storage above it, through an allowance for large variations in level during storms.

Photograph taken from Avery (2012)

Sediment traps: retention ponds that attenuate (hold up) water and allow sediment to build up.

Photograph taken from Avery (2012)

Woody debris: woody dams slow the passage of water downstream, increasing sediment retention. Logs or boards (untreated) can be used across ditches and small streams to help slow and disconnect the drainage network, channeling water into preferential storage areas and increasing infiltration.

Photograph of woody debris in the Slad Valley, Stroud by author

Floodplain and land areas: Land-based designs to intercept overland flow pathways (i.e. runoff) could be applied to steeper areas on the edge of the escarpment. These are limited in the Isbourne catchment 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 bunds, swales, deflectors and land-based flow barriers (hedgerows and shelter belts), ponds, basins.

Buffer strip and headland options: medium width, dry, bands of natural or naturalized vegetation situated alongside waterbodies.

Photograph taken from Avery (2012)

Hedgerow planting/ management and construction of dry stone dykes across erosion prone slopes to intercept runoff and reduce the concentration of animals or machinery operations in these vulnerable areas.

Photograph taken from Avery (2012)

Ponds: normally dry basins designed to temporarily store and slowly release runoff water during high flows.

Photograph taken from Avery (2012)

Shelter belts: planting mixed woodland to produce a belt which will primarily reduce wind speeds, but also encourages infiltration and prevents soil erosion.

Photograph courtesy of Gandhiv Kafle

Swales: broad and shallow vegetated open channels, designed to convey runoff, reducing its volume and velocity and removing pollutants.

Photograph taken from Avery (2012)

Wetlands: creation of a small linear wetland feature within a ditch, increasing sedimentation, water attenuation and nutrient utilization.

Photograph taken from Avery (2012)

Farmyard areas: techniques can be applied to manage surface water flows and improve water quality released from farmyard 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 farmyards and treating dirty water before it enters water bodies might be available through the Countryside Stewardship Scheme, although the Isbourne catchment is not a priority catchment under the Catchment Sensitive Farming initiative. Some potential options could be:

Cross drains: a cross drain is a system to convey water across a path or route and away from a watercourse. A cut-off drain is a more durable form of cross-drain and can also be used to collect run-off from a vulnerable area (e.g. tracks) that provide a significant transport pathway for water and sediment.

Photograph taken from Avery (2012)

Rainwater harvesting: rainwater is collected from roofs and impervious hard standing areas and diverted from surface waters. It can be stored and used around properties and farms.

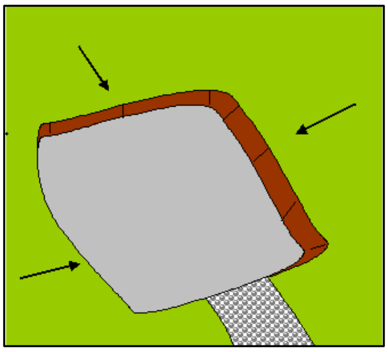
Photograph taken from Avery (2012)

Green roof: a multi-layered system covering the roof of a building with vegetation cover or landscaping over a drainage layer. They are designed to intercept and retain precipitation, reducing run-off volume and attenuating peak flows.

Photograph taken from Avery (2012)

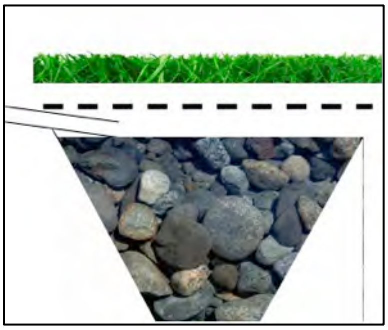
Permeable surfaces: pavement or hard standing constructions or other pervious surfaces that allow rainwater or run-off to infiltrate through the surface to an underlying temporary storage area.

Photograph taken from Avery (2012)



Sediment trap: contaminant area where sediment-laden runoff is temporarily detained, allowing sediment to settle out before the runoff is discharged.

Photograph taken from Avery (2012)



Soakaways: an infiltration drain. Often square or circular excavations (may also be trenches) filled with rubble, lined with brickwork, pre-cast concrete rings or similar where rainwater and run-off is collected and infiltrates directly into the ground.

Photograph taken from Avery (2012)

Swales: broad and shallow vegetated open channels, designed to convey runoff, reducing its volume and velocity and removing pollutants.
Photograph taken from Avery (2012)

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. Such changes reduce the surface roughness and therefore the potential to increase surface runoff rates rises. Grants are available through the Countryside Stewardship for targeted woodland planting in suitable locations and for the appropriate management of existing woodland. Small copses (groups of trees) should also be considered; the location, choice of species and future management should be an important consideration, with the aim both to create an effective NFM feature and also benefiting biodiversity.

Land and soil management that contribute to NFM could be applied to the large areas of arable land in the catchment, these will help to increase infiltration rates (i.e. encourage more water to soak into the ground), reduce surface runoff (i.e. reduce the amount of water flowing over the ground surface), increase vegetation cover and retain soil coverage on the fields. 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 Farm Estate practices zero tillage and regularly plants green manures so there is vegetation on the land all year round; the farm manager regularly has visits to show other farmers the practicalities of this approach. Some possible considerations could include:

Contour ploughing: ploughing along the contours of the land in order to minimize soil erosion helps to reduce the amount of water flowing downslope.

Photograph courtesy of Frans Kwaad

Converting arable land to species-rich grassland: this will increase the surface roughness and also ensure a year-round vegetation cover to both reduce surface runoff and increase the water taken in by plants.

Photograph taken by author

Decreasing soil compaction: aerating the soil increases the infiltration capacity (the ability of the soil to soak up water) and allows more water to be absorbed into the soil rather than running over the surface.

Photograph taken from Avery (2012)

Reduced or zero tillage: ploughing (tillage) disturbs the soil surface and can lead to an increase in sediment mobilization and runoff, but reducing or eliminating ploughing from agricultural practice will help to mitigate against these impacts.

Photograph taken from MethodFinder.net

1.4 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 watercourses.

This report reviews the physical nature of the River Isbourne catchment and assesses the current impacts of flooding and environmental pressures caused by diffuse pollution (sediment, nutrients and other pollutants). The study then reviews the applicability of NFM across the Isbourne catchment and evaluates whether they could have a positive effect on the main study objectives. The justification for this approach is that previous investigations (e.g. Haycock 2010) have ruled out large-scale hard engineering solutions in the Isbourne catchment.

2. River Isbourne catchment characteristics

2.1 The catchment

The River Isbourne catchment lies to the north of Cheltenham and has a total catchment area of 88 km^2 which flows in a northerly direction and drains into the River Avon at Evesham. It forms part of the Warwickshire Avon management catchment that is a subset of the wider Severn River Basin District (Figure 1). The River Isbourne is the only main river (managed by the EA) 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 2a). At the lower reaches of the River Isbourne it meets with the lower River Avon catchment near Evesham.

Figure 1: Management catchments in the Severn River Basin District showing the Warwickshire Avon that the River Isbourne is contained within (source: Environment Agency, 2015)

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

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.

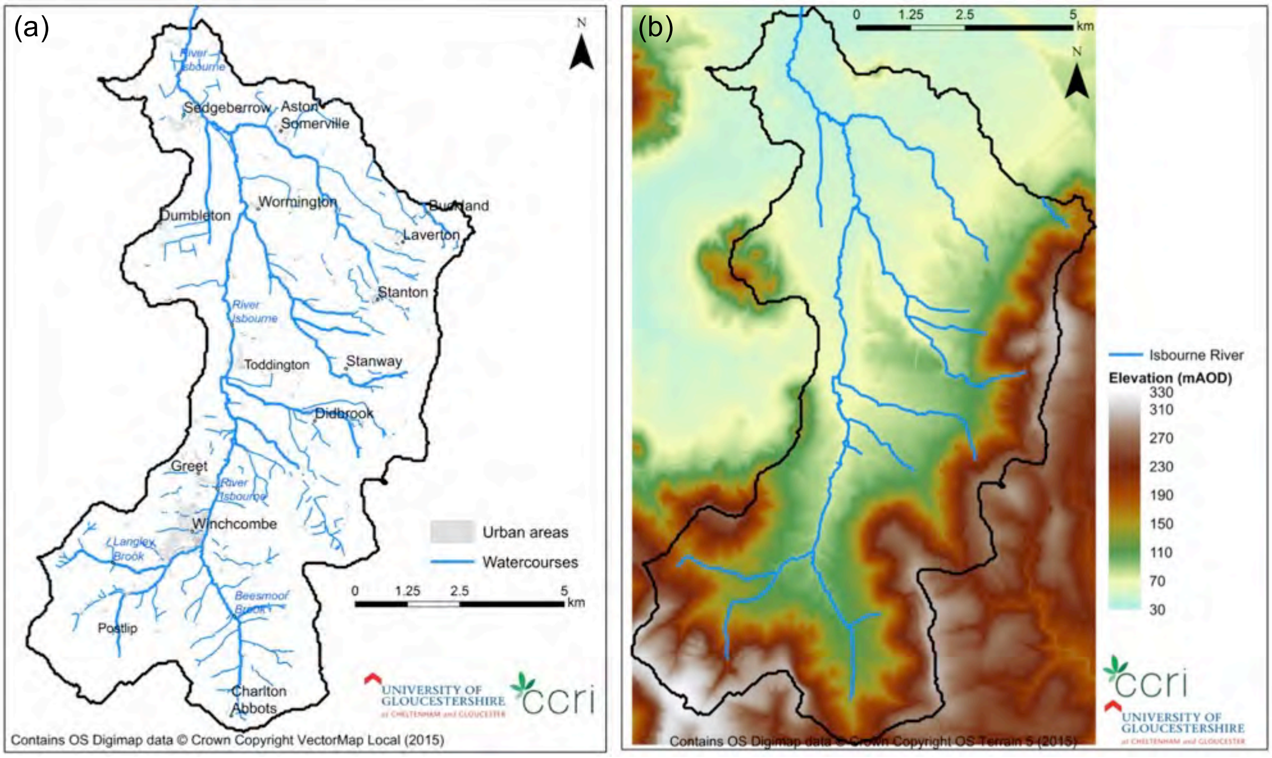


Figure 2: (a) River Isbourne catchment area overview map, and (b) catchment topography map

Figure 2b provides a colour-coded representation of the catchment's topography from upland areas to the valley floor. The catchment can be divided into three distinct landscape types:

- **Upland areas:** elevated between 150 – 300m Above Ordnance Datum (AOD), generally flatter ground areas above the edge of river valleys but including some steep sides;
- **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 for the river to spread over when high flow occurs; and,
- **Floodplain river valleys:** where channel slope and valley bottom opens out to form wide, permanent floodplains to allow flood water to spread across adjacent land areas when bank top levels are reached. In many of these areas, because of the flat ground areas available, there is typically a greater density of development, industry and human settlement.

The proportion of these landscape types in the Isbourne catchment is shown in Figure 3.

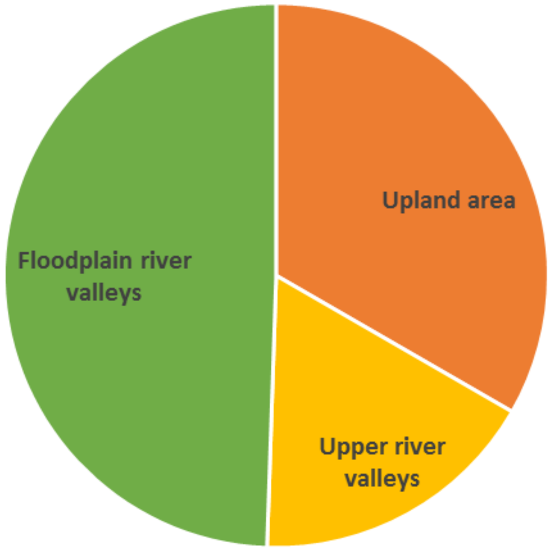


Figure 3: Proportion of area in the Isbourne catchment taken up by the three main landscape types

2.2 Geology

The topography of the Isbourne catchment reflects the underlying geology, with a permeable (allowing water to drain through) Inferior Oolite limestone forming the upland areas and escarpments. This then transitions into more mudstone dominated bedrock towards the lowland and southern end of the catchment with a more open valley landscape, which is less permeable. Ground slope also flattens out form the steep, narrow valley's of the upper catchment as the Isbourne geology becomes less permeable but with a lower gradient as they transition into Lias Clay (Figure 4). 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.

2.3 Hydrology

The hydrological and hydrogeological behaviour of the Isbourne catchment is dominated by the influence of the underlying geology. The River Isbourne is linked to groundwater (water held underground in the soil) resources, with some of its flow being derived from limestone aquifers, either from spring discharges at the interface between the limestone and clay or from groundwater rising up and interacting with the river bed. These springs 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.

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. Nevertheless, there is some evidence from other Cotswold estates that in the clay lined “dry” valleys infiltration had reduced and benefits of aerating the soil were noticed on the flatter areas.

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. The numerous springs also progressively add more water to the main channels along the whole length of all watercourses in the catchment. However increased infiltration in the Upland areas will slow the flow of water downstream and the emergence from the springs will spread the flow over a longer period.

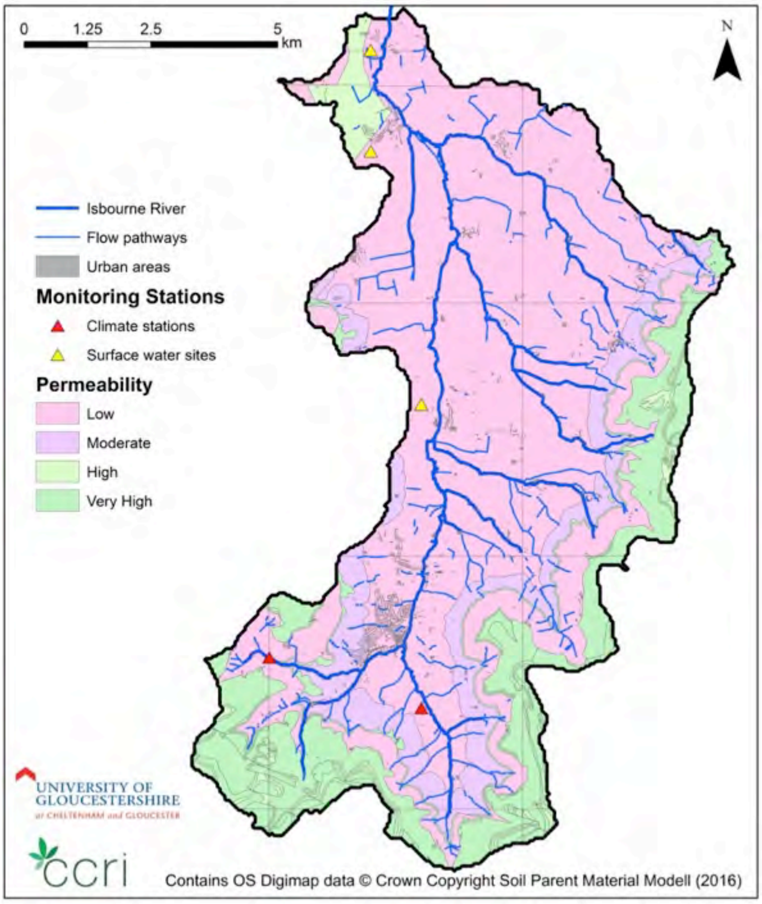


Figure 4: Levels of permeability across the Isbourne catchment

2.4 Flow monitoring data

There is one active gauge station with continuous flows on the River Isbourne at Hinton on the Green (see Figure 4 for location) which has been in operation since 1973, as well as newly installed flow gauges at Toddington and Sedgeberrow that do not have data sets available yet. This gauging station is situated at the downstream end of the catchment which has animpermeable geology and here river levels are almost entirely driven by river flows received from upstream. Calculated mean annual flow from the gauging station is 0.67 m^3/s, and Figure 5a shows the variation in mean annual flow data over the period of record. The variation in annual flow patterns is apparent, with the years 2001, 2007, 2008, 2013 and 2014 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 5b).

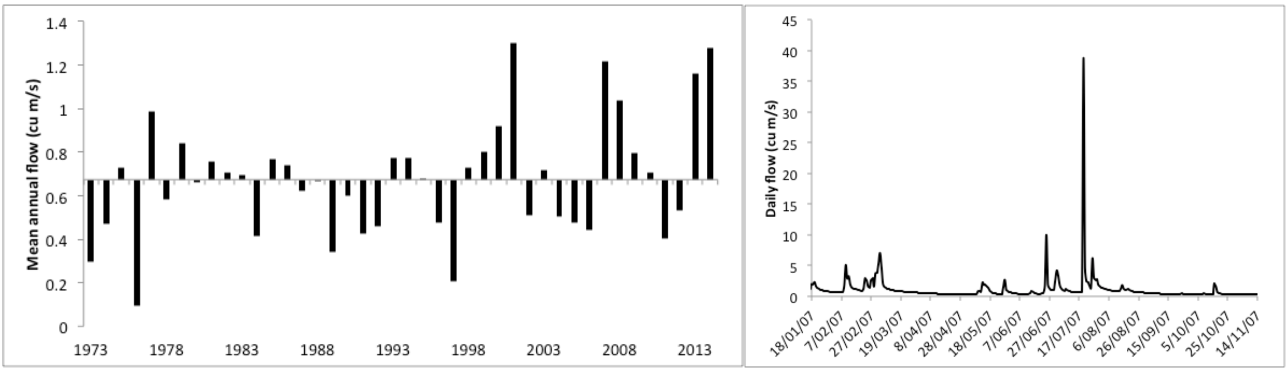


Figure 5: Mean annual flow at Hinton on the Green gauging station between (a) 1973-2014, and (b) 2007, showing the magnitude of the July 2007 floods (data sourced from the NRFA website)

A review of the 2007 flow data at Hinton on the Green (shown in Figure 5b) 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.

The application of NFM may therefore be best applied to intercept any ephemeral (seasonal flows of water) overland flow routes initialized during high rainfall, maximize infiltration into the ground, and slow the speed of surface flows (by vegetation interception) across Upland Areas, as well as ensuring land management practices that encourage reduced runoff. Upper River Valley NFM designs need to attenuate (store water) 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, but the concept of NFM is that many interventions working together across the catchment will benefit all areas within it by reducing the volume of water travelling down the catchment and reduce the magnitude of the flood peak.

2.5 Flood history

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, 1979 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 (Figure 5b) and had substantial damage associated with it. The most widespread flooding occurs after sustained periods of rainfall, in which river levels are raised and combined with increased runoff response from land areas leads to elevated river levels. Both the 1968 and 2007 flood events were caused by extended heavy rainfall under a pronounced low pressure system over the area. Figure 6 shows where the EA has measureable records of flooding along the Isbourne since the 1960s.

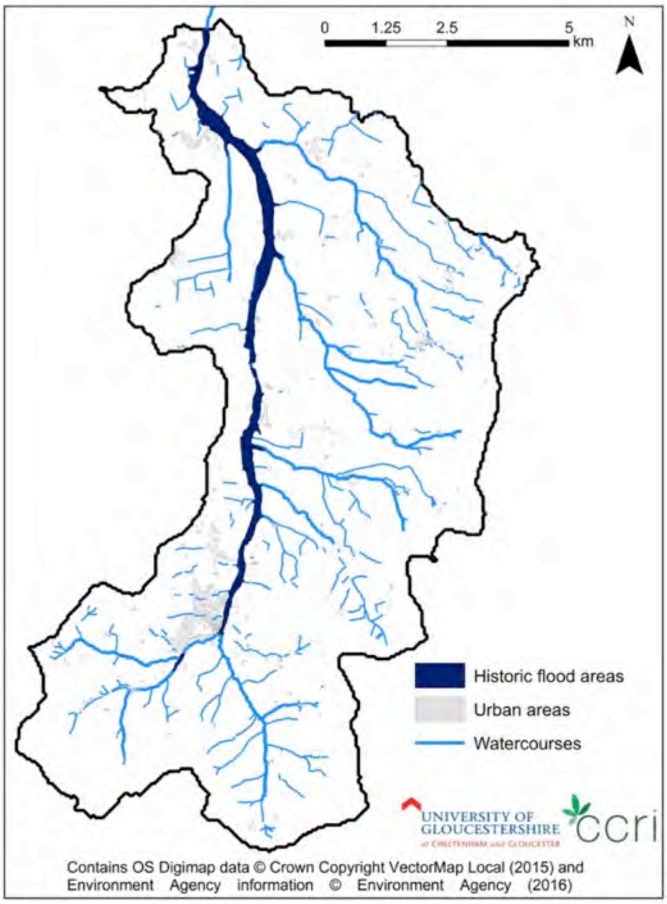


Figure 6: Historic flood map – post-1960 flood extents from Environment Agency flood data

2.6 Land use change

Measured land use across the catchment from the 1930s until 2012 (Figure 7a and 7b) reveal changes in vegetation cover, agricultural practice and urban influences. The most notable change is that arable areas have increased substantially across the catchment, and there has also been a reduction in orchards and natural grasslands, the latter being replaced by pasture (where the land is cultivated and more productive grass species planted) (Figure 8). Trees reduce the roughness of the surface and therefore the amount of runoff, therefore reducing the amount of wooded areas can increase the volume of water entering river channels during rain events. Although urban areas make up a small proportion of the overall catchment, this has increased since the 1930s, resulting in a further expansion in the amount of impermeable surfaces.

Changes in land use will have undoubtedly changed the hydraulic behaviour within the catchment over an extensive period of time (Figure 8). The work by Haycock (2010) suggests that rainfall which would have resulted in a 1:100 event (i.e. statistically has a 1-percent chance of occurring in any given year) in the early 1970s 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 (water evaporation from plants);

- arable crops will take up water whilst growing but during ripening their water uptake will be less;
- large proportions of the catchment therefore contribute runoff directly into the river systems during rainfall events 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 and hedgerows that were important for livestock are no longer needed and fall into disrepair or have been removed – reducing potential runoff 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.

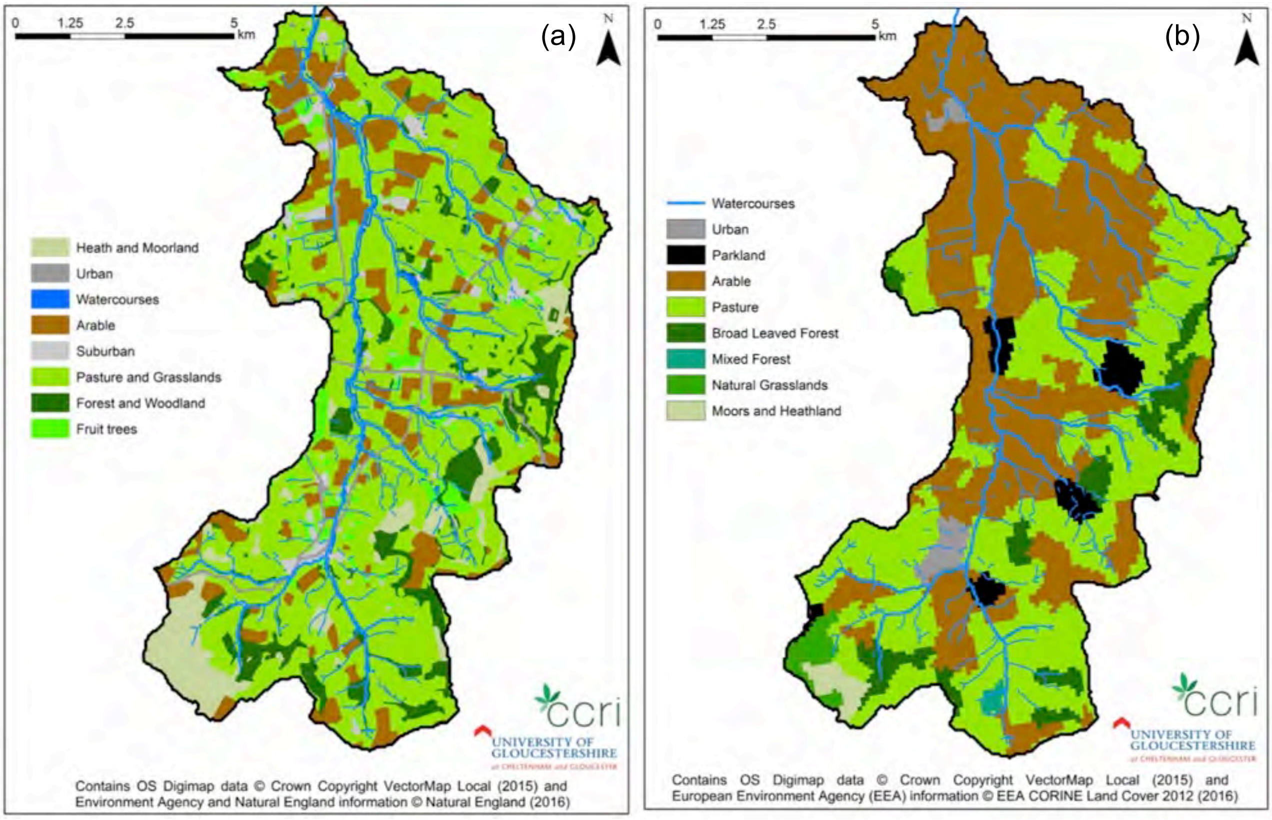


Figure 7: Land use in the Isbourne catchment in (a) 1930 and (b) 2012

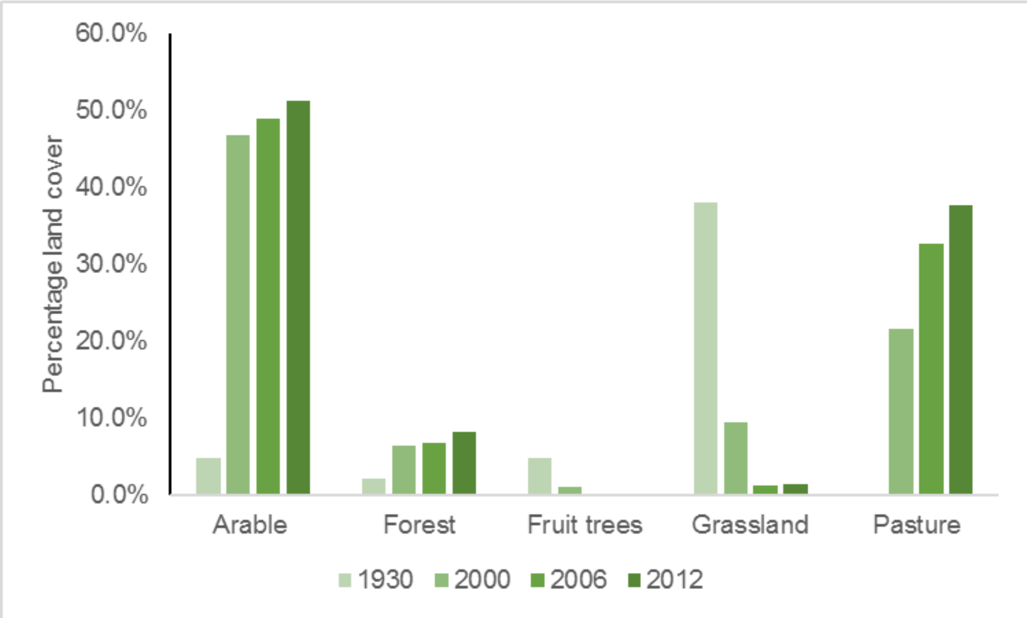


Figure 8: Percentage land cover for arable, forest, fruit trees, grassland and pasture for the Isbourne catchment between 1930 and 2012 using the data from Figure 7

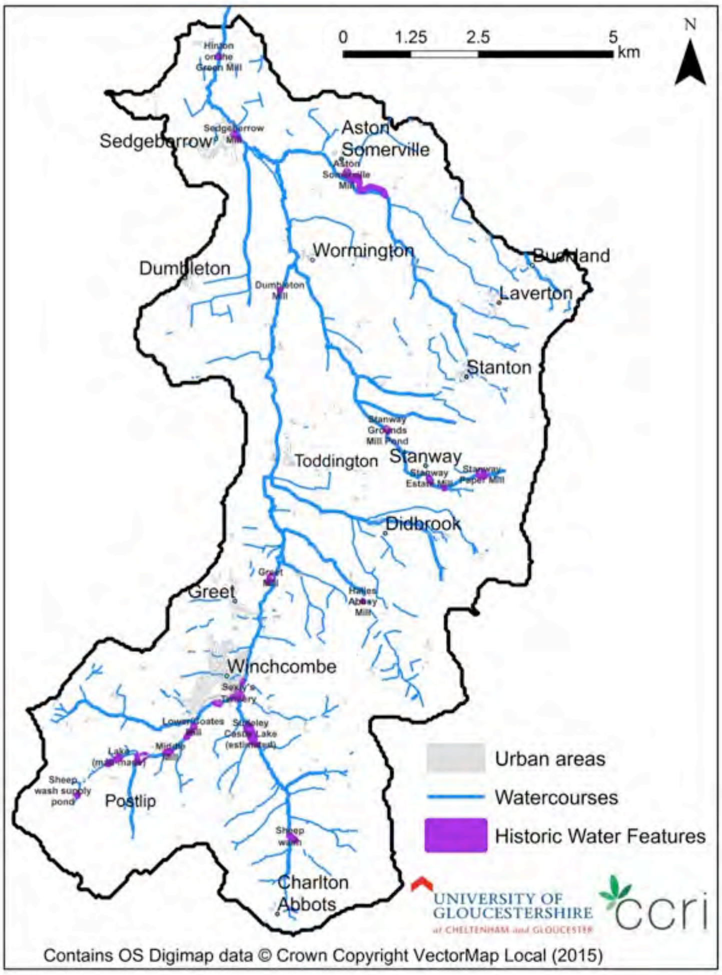


Figure 9: Historic water features in the Isbourne catchment (mapped from Lovatt, 2012)

2.7 Water use change

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 9). 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 are now derelict and provide potential additional water storage capacity following appropriate investigations.

2.8 Water Framework Directive (WFD)

The WFD is a European Directive which provides a strategic planning process for managing, protecting and improving the water environment. The condition of water quantity, quality and environment are of key consideration for the UK's responsibilities under the WFD. Water bodies, which includes rivers, canals and lakes, reservoirs or lochs and aquifers (groundwater sources), have been classified to identify their current condition in terms of their ecological condition (i.e. fish, invertebrates and aquatic plants), chemical condition (i.e. dissolved oxygen, pH, temperature, phosphates, nitrates, ammonia. copper, zinc) and physical condition (i.e. quantity and dynamics of flow, and channel shape and modification).

In the future there is to be 'no deterioration' from the classified current status of all water bodies (as established during baseline assessments undertaken in 2009). Where a water body is currently achieving Moderate, Poor or Bad condition, improvement or enhancement measures must be implemented as each identified water body has been given targets to achieve Good Ecological Status (GES) or Good Ecological Potential (GEP) by 2027. Failure to achieve this will result in an infraction of the WFD and fines will be imposed by the EU.

The River Isbourne lies within the Severn River Basin District for implementation and management of the WFD. There are 10 river management catchments identified within the Severn River Basin Management Plan (RBMP), the River Isbourne is contained within the Avon-Midlands West Operational Catchment in the Warwickshire Avon management catchment (see Figure 1). The current overall status for the River Isbourne is 'Poor' (EA Catchment Data Explorer updated March 2016), with the objective to reach Good Status by 2027. The catchment is not designated as heavily modified (HMWB) and is therefore predominantly natural in its form, and the chemical status is classified as 'Good' but the water body is failing on Ecological Potential, Phosphate, Biological Quality Elements and Fish. NFM therefore has the potential to improve the WFD status by contributing to improving water quality so that these strategic targets are met.

2.8.1 Water quality

Water quality aspects that are important under WFD include target conditions for Dissolved Oxygen (DO), pH, Ammonia, Phosphate and water temperature. With the exception of Phosphate, these data have been modelled for the Isbourne catchment by the EA as part of the 2015 update to the WFD assessment (presented in Table 1), 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 (aquatic plants that have the capacity to improve the water quality by absorbing nutrients) 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 2021 with no barriers cited to impede this improvement and a very certain projection by the EA. 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 1. Water quality/chemistry results for the Isbourne catchment (2015 WFD by the EA)

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

2.8.2 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 since the 1930s. 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 for livestock 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.

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

2.9 Designated sites and wildlife areas

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 Isbourne catchment lies within the Cotswold Areas of Outstanding Natural Beauty (AONB), and has a range of Special Areas of Conservation (SAC), Sites of Special

Scientific Interest (SSSI), Ancient Woodland sites, Scheduled Ancient Monuments sites and Local Wildlife Sites (LWS) across the catchment (shown in Figure 10). 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 and the Gloucestershire/Worcestershire Wildlife Trust. 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.

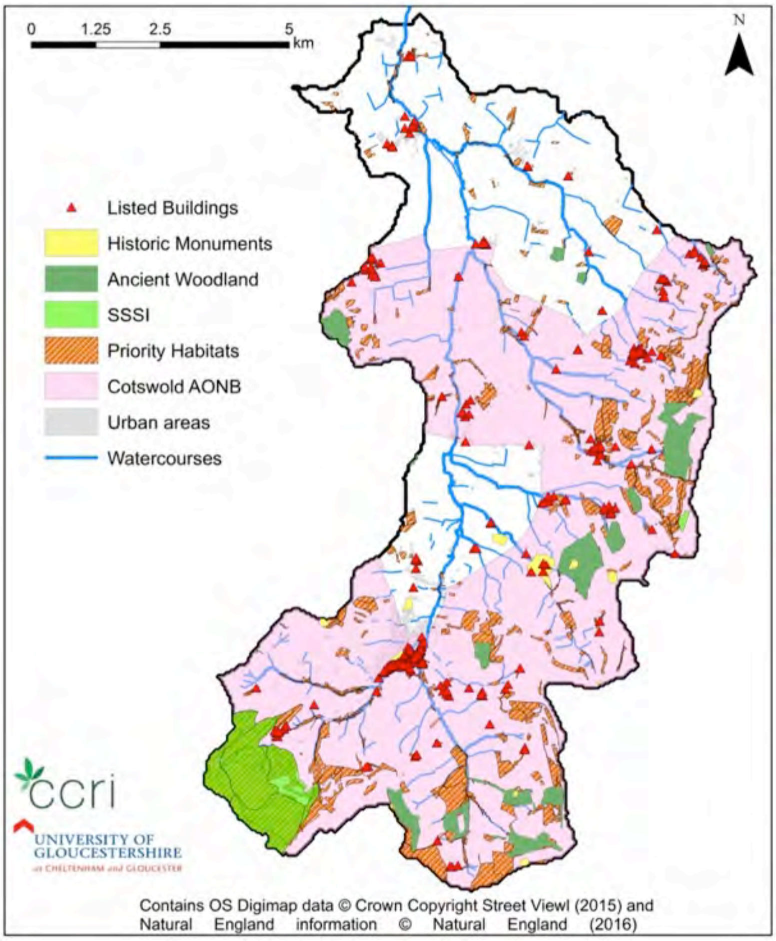


Figure 10: Main designations in the Isbourne catchment

2.10 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 (covering three quarters of the area), with Wychavon covering the northern 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 11a The catchment is also made up of 20 parishes, although some of these only cover a small area, these are shown on Figure 11b.

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 forums (formed after the devastating floods of 2007) and residents of the catchment.

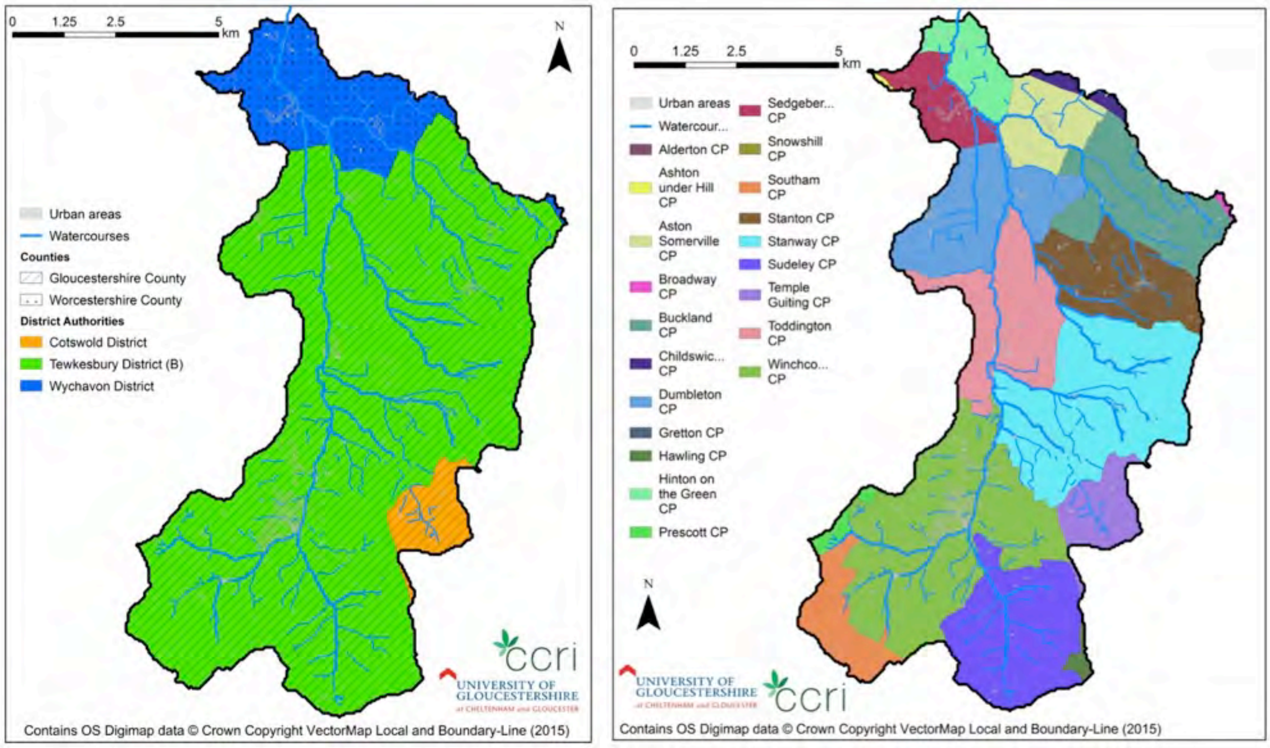


Figure 11: Isbourne catchment (a) country and district authority boundaries, and (b) parish boundaries

3. Natural flood management options in the Isbourne catchment

3.1 Defining the NFM drivers within the Isbourne Catchment

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.

3.2 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 these areas should be to ensure that the permeability of soils across these upland areas is retained and enhanced wherever possible. This may involve testing aeration of the soil in the dry valleys and potentially 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 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 structures that are installed will require careful management of ephemeral surface water flow routes; focussing these in scrubby and partially wooded areas will help to enhance the effectiveness and multiple benefits.

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 flows 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 functioning effectively. Other open areas may be of local importance for wildlife or form valuable wetland habitats, and these could possibly be adapted 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 habitats and 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 and steep also requires any NFM features to be carefully considered. However to be effective a large number of NFM interventions would need to be spread across all upper reaches of the Isbourne catchment.

Single-site large-scale storage is not practical in the sub-catchment Upper River Valleys. NFM works most effectively by installing a large number of small interventions across the catchment, which cumulatively serve to slow the flow, reduce runoff and increase infiltration rates benefitting all areas of the catchment. This would also assist with meeting of WFD objectives. Likewise the insertion of NFM should seek to enhance all existing local habitats, which are likely to be positioned within the Cotswold AONB and should conform with landscape guidance (Cotswold Conservation Board 2015).

3.3 Measurability factors

Specifying potential measurable improvements to flood risk reduction, diffuse sediment pollution or water quality 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 existing projects (such as those highlighted in the recommended reading) that there are 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/or constructing woody debris dams in watercourses. However, recommendations for which NFM can be applied and where across the catchment, along suggestions for the next steps towards planning and implementation, can be made (see Sections 4 and 5).

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 nearby Stroud SuDS project has shown that NFM projects align well with meeting WFD objectives. For this to be the case it is important to note all existing local habitats and where possible should seek to enhance natural features through sensitive management practices.

The installation of small-scale NFM in isolation tend to have little measureable impact on the catchment hydrological processes, however they can provide local benefits to farmyards, field areas and in-channel areas. Within a single watercourse, if other potential influencing factors could be accounted for, it may be possible to measure environmental changes. Only the extensive application of numerous NFM interventions across the whole catchment in as many locations as possible will achieve a measurable impact. 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.

3.4 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 multiple NFM interventions 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 SuDS project;
- Any larger works, such as the excavation of storage areas, will need to be assessed 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 to assess the impact of the NFM interventions.

3.5 Catchment characteristics

The Isbourne catchment is considered a single entity for the WFD, however, for the purposes of this study, the watercourses in the catchment have been split into 9 areas (see Figure 12):

- **Langley Brook, including water body flowing from Cleeve Common to Winchcombe:** highest area of catchment and characterised by the presence of Cleeve Common and other natural grassland areas. 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. There is evidence of historic milling 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.
- **Beesmoor Brook, flowing from Charlton Abbots to Winchcombe:** 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 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 watercourse that could potentially be utilised for storage and their current state needs to be reviewed.

- **Didbrook and tributaries, flowing in to the Isbourne below Greet:** 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 watercourse is primarily situated on moderately permeable mudstone 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.
- **Stanway tributaries, flowing into the Isbourne at Wormington:** The majority of the watercourse 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 being 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 watercourse. 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 watercourse that have potential for re-instatement.
- **Stanton and Laverton tributaries, flowing into the Isbourne above Sedgeberrow:** lowland Floodplain Valley Area, under 100m AOD with most of the watercourse 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.
- **Dumbleton tributaries, flowing into the Isbourne above Sedgeberrow:** lowland Floodplain River Valley that has a relatively low elevation, with most of the watercourse 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 watercourse is pasture with some forest, while the lower reaches are arable. There are no designations in the lower parts of the watercourse, but the upper area is within the Cotswolds AONB and have some areas of priority habitat and some ancient woodland.
- **The Upper Isbourne from Winchcombe to join with Didbrook tributaries:** 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 watercourse has seen a growth in impermeable urban areas and a reduction in the number of fruit trees and woodland areas along the river channel since the 1930s. There are some mill ponds located in close proximity to the watercourse. 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 watercourse.
- **The Mid Isbourne from Didbrook join to Stanton and Laverton tributaries:** 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 pond on the Toddington estate that will be

considered as a potential area of attenuating flood water during the catchment walk throughs. There has been a transition from pasture and reduction in the amount of woodland area/fruit trees along the watercourse since the 1930s. This area is within the Cotswold AONB and there are some priority habitats. Flood risk is high along this watercourse.

- **The Lower Isbourne from Stanton and Laverton to the downstream end of the catchment:** 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. 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 watercourse. The area is not within the Cotswold AONB but there are some priority habitats along the river channel. Flood risk is high along this watercourse.

The recommended NFM options for these areas are summarised in Table 2 and on Figure 12 (with close up maps of the areas in Appendix B).

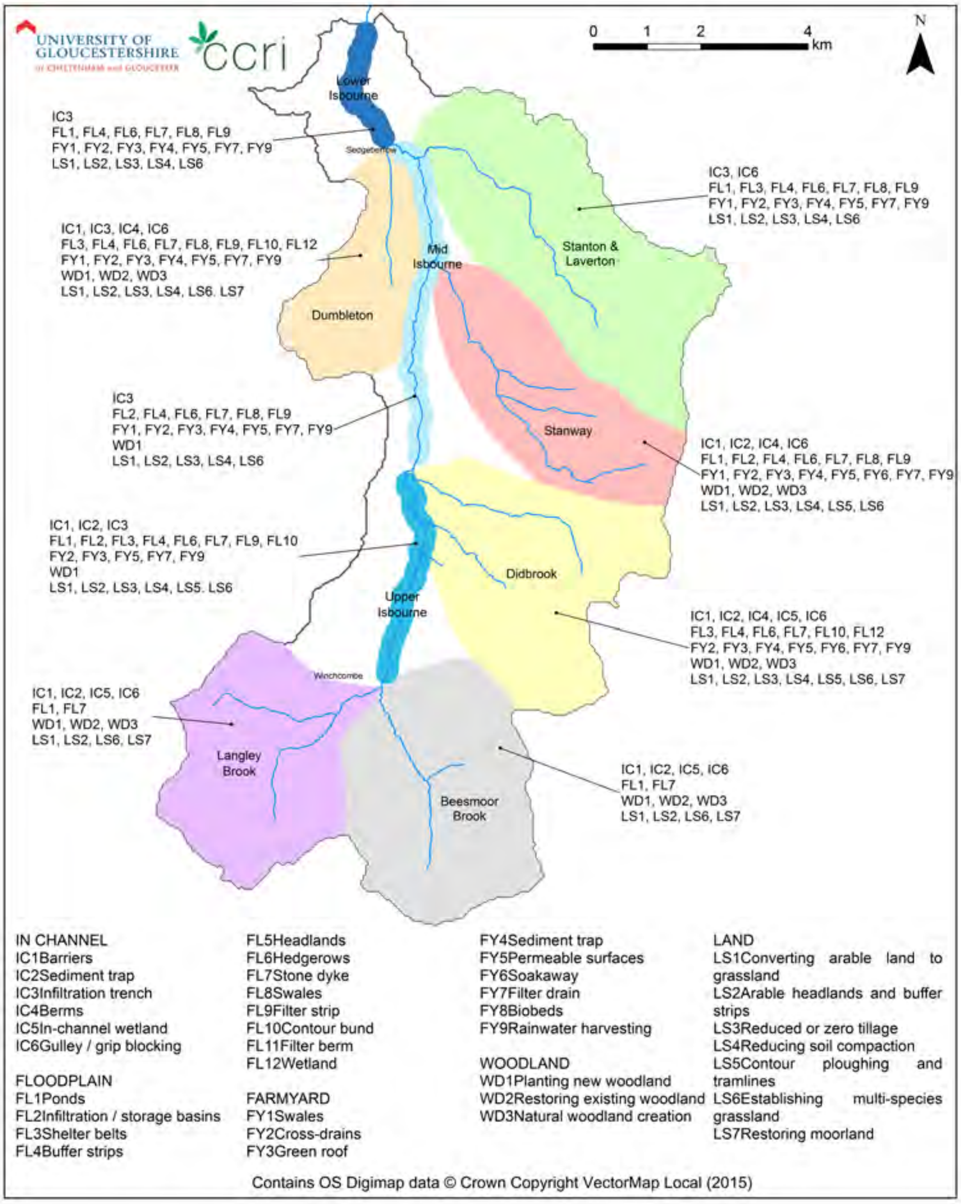


Figure 12: Summary of natural flood management options for the Isbourne catchment

Table 2. Possible NFM options for the watercourses in the Isbourne catchment (blue: RSuDS methods, green: land management methods)

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 2 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									

4. Recommendations

The opportunities presented 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, 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 ICG shows the level of interest and willingness to implement the findings of this report.

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 the 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. Such a pragmatic approach has worked well in the Stroud SuDS 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, 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. 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, and there is therefore potential to address this through land use management changes.

The potential of currently overgrown and redundant structures along the lower part of the catchment, such as the relict pond at Toddington, 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 as part of 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 EA, landowners, District Authorities, County Councils, Gloucestershire/Worcestershire Wildlife Trusts, Farming and Wildlife Advisory Group (FWAG), 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 SuDS project suggests that any impact on WFD objectives is positive, notably in 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.

5. 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 possible 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 interventions applied;
- this would then enable identification of the potential scale of NFM interventions that could be applied within each of the watercourses in the catchment and identify the potential extent to which they could begin to address the key issues for flood risk, water quality and sediment transfer;
- determination of initial pilot study watercourses 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.

6. Reading

6.1 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
- Stroud RSuDS project (2016): https://www.stroud.gov.uk/rsuds

6.2 References

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

Cotswold Conservation Board (2015) Landscape Strategy statements.

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 (2015) River Basin Management Plan, Severn River Basin

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

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

Appendix A

Glossary

AOD	Above Ordnance Datum
AONB	Area of Outstanding Natural Beauty – a landscape protected due to its distinctive character and natural beauty
AWB	Artificial Water Bodies – a defined WFD water body which has been constructed for a specific use (e.g. a reservoir)
CCRI	Countryside and Communities Research Institute, University of Gloucestershire
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 (see definitions in this table) – 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 – main archive for hydrometric data in the UK
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
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 establishing a framework for the European 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.

Key terms and 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
Floodplain	Area of low-lying ground adjacent to a river, formed mainly of river sediments and subject to flooding
Fluvial flows	Flows of water in a watercourse that run all year round
Impermeable	Not allowing fluid to pass through – soil and geological properties that prevent water absorbing into the ground and promoting runoff
Infiltration	Downward movement of water into soil
Main river	Statutory watercourse in England/Wales that is managed by the 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
Permeable	Allowing fluid to pass through – soil and geological properties that allow easy absorption of water into the ground and minimising runoff
Runoff	The draining away of water from the surface of an area of land, creating surface overland flow
Surface flows	Overland flow paths of water, potentially those that have failed to infiltrate to groundwater systems

Appendix B

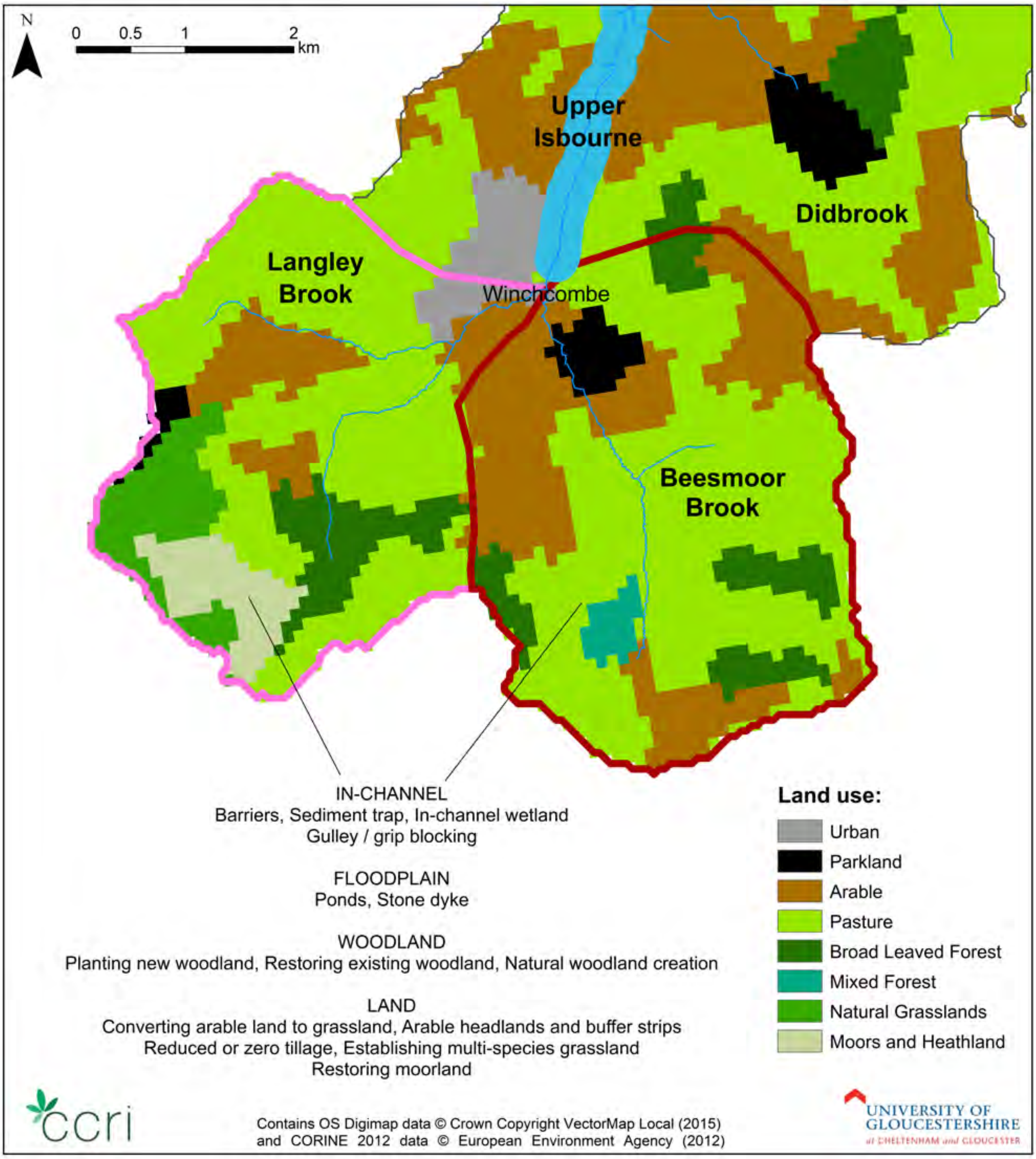


Figure 13: Summary of natural flood management interventions for the Langley Brook and Beesmoor Brook areas of the Isbourne catchment

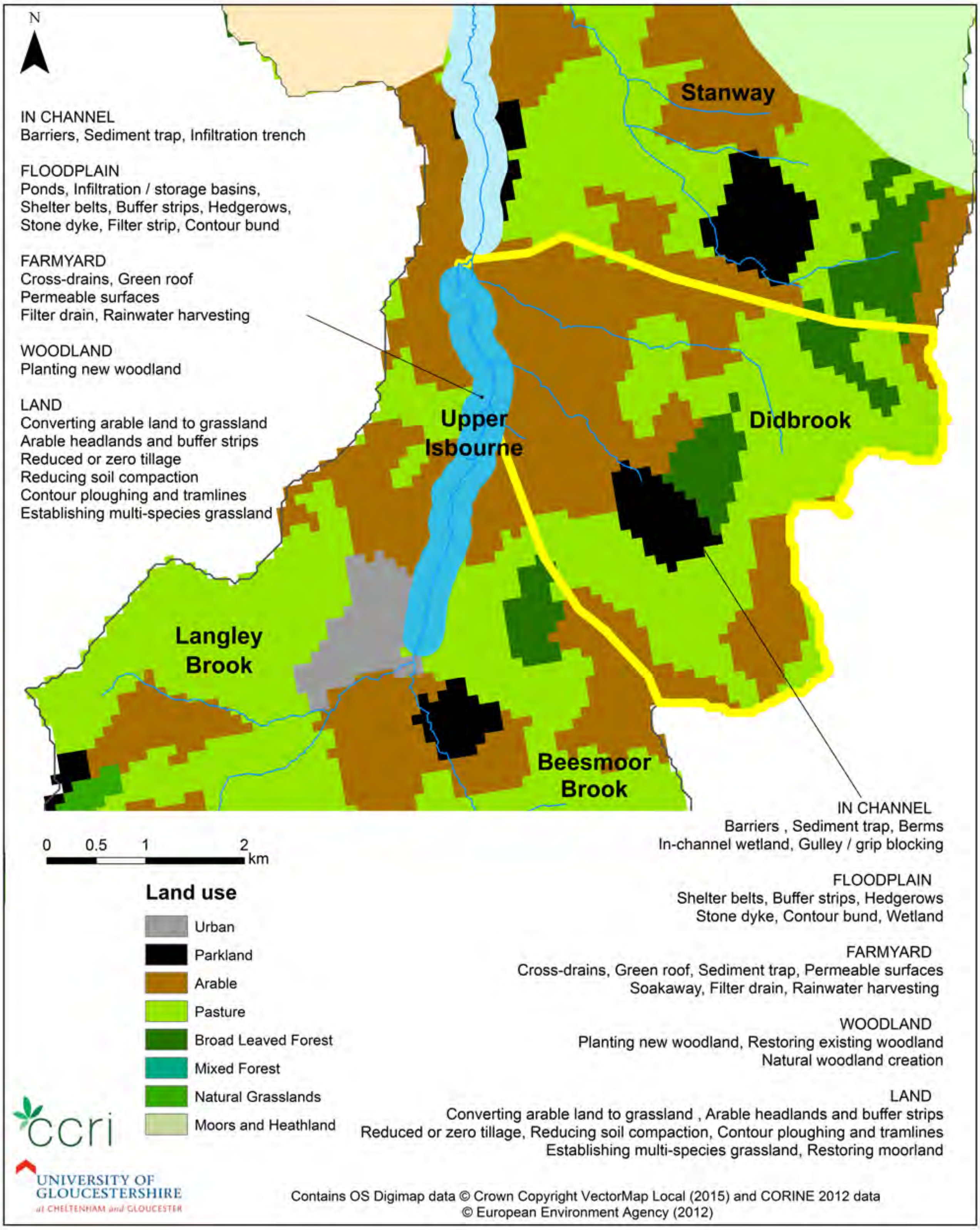


Figure 14: Summary of natural flood management interventions for the Didbrook and Upper Isbourne areas of the Isbourne catchment

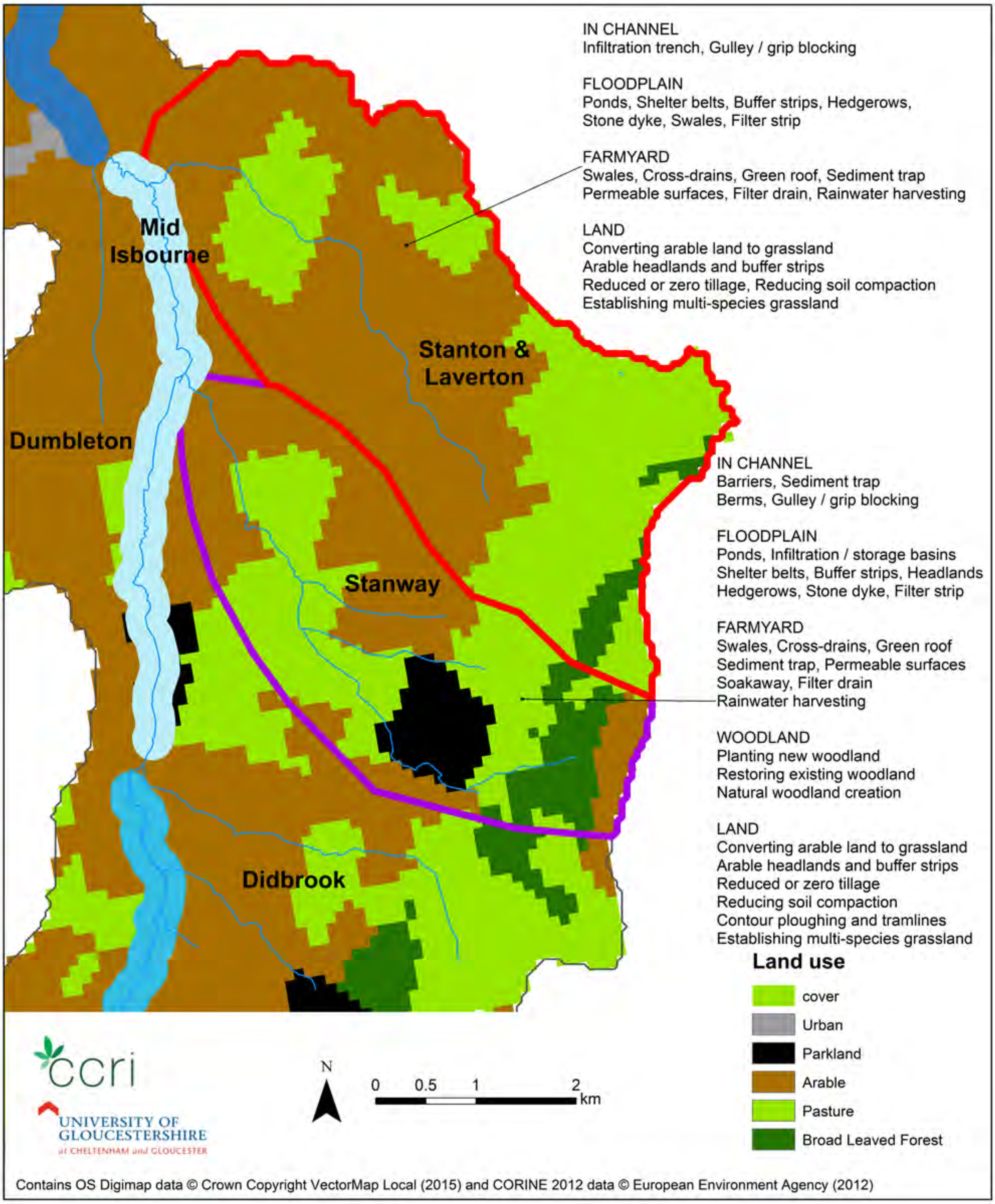


Figure 15: Summary of natural flood management interventions for the Stanway and Stanton & Laverton areas of the Isbourne catchment

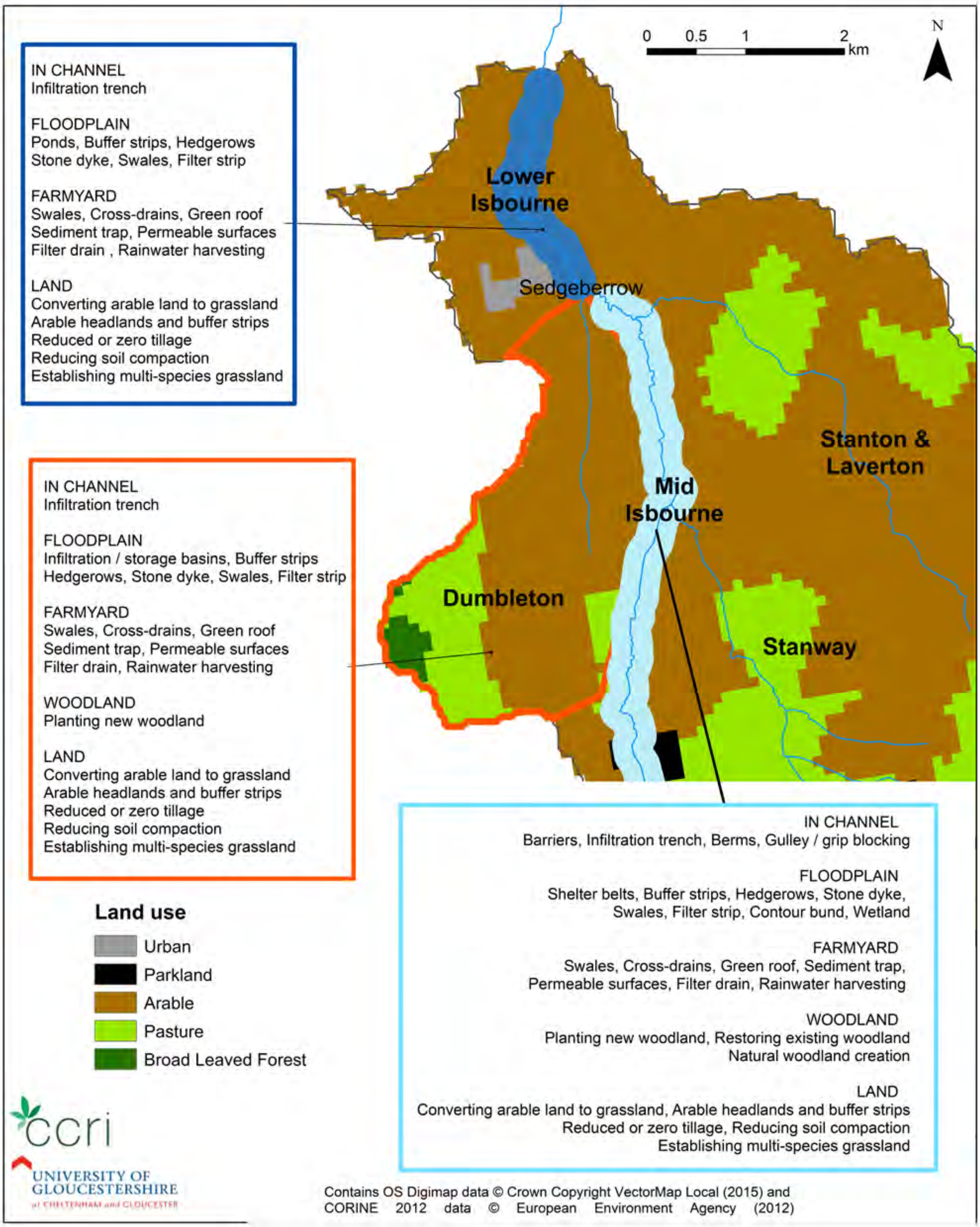


Figure 16: Summary of natural flood management interventions for the Dumbleton, Lower Isbourne and Mid Isbourne areas of the Isbourne catchment