

# Natural Flood Management Pilot

## Lessons Learnt and Way Forward

### National Highways

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# Notice

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# Executive Summary

## The Natural Flood Management Pilot

Natural Flood Management (NFM) protects, restores or mimics natural hydrological processes to store or attenuate flood water in the landscape. It is used to reduce flood risk to assets or improve the resilience of those assets to flooding – most often as a complement to other approaches to flood management such as civil engineering.

This document sets out the findings of a study that piloted using NFM to manage flooding on the Strategic Road Network (SRN) in England. The Pilot tested whether National Highways could work with owners or managers of land ‘off network’ (i.e. land not owned by National Highways) to implement and maintain NFM measures, at locations upslope of known flood hotspots on the SRN. Core activities of the Pilot were a) selecting catchments (Focus Areas) within which to implement the Pilot; b) developing an NFM Fund – a scheme for implementing and maintaining NFM measures on third party land and c) undertaking a trial implementation of the ‘NFM Fund’ in the Focus Areas (parts of the Irwell, Etherow and Little Don in the North West of England).



Leaky barrier in Little Don catchment north of A616

## Outcomes of the Pilot

The Pilot successfully implemented over 100 measures including cross-slope woodland, storage ponds and reducing soil compaction in small rural catchments upslope of flood hotspots on the SRN. All measures are operational and will be maintained until 2025. This implementation was achieved by National Highways, landholders and Rivers Trusts working together.

The governance and payment framework under which the partnership operated is a significant logistical achievement and is a blueprint for future collaborations. The average cost effectiveness of measures delivered by the NFM Fund compared favourably to that of a typical small scale civil engineering flood storage scheme. Measures implemented by the Fund are estimated to have an average cost effectiveness of £166/m<sup>3</sup>. Typically small scale civil engineering flood storage schemes with comparable design lives have a capital (implementation) cost of between £280 and £470 per m<sup>3</sup> water stored.

Whilst the operational framework and cost effectiveness of the Pilot are undoubted successes the cost of this first implementation of the NFM Fund exceeded the monetary valuation of flood damages avoided (and the monetary valuation of the co-benefits it generated were also small). The average benefit cost ratio for



Large woody feature in Little Don catchment north of A616

implementation was just 0.28, with the ratio exceeding unity (2.92) in only one of the catchments in the Focus Areas. In part this was because the flood reduction achieved by the Pilot was modest (it reduced flood risk in only two and increased flood resilience in seven of the 15 sub-catchments that made up the Focus Areas). It was also because the cost of implementing NFM measures were inflated by the experimental, small scale and limited timeframe of a pilot study that was primarily undertaken to prove the concept of the NFM Fund rather than deliver cost beneficial flood schemes.

Future implementations of the NFM Fund (or alternative vehicles for delivery of NFM to protect the SRN) should focus on how to increase the benefits



and reduce the cost of NFM implementation. This is readily done by working at scale to capture more flood water and generating larger co-benefits at lower cost to National Highways. Recommendations on developing vehicles for meeting these requirements and delivering NFM to protect the SRN in a way that is both operable and cost-beneficial are set out in the section headed 'Way Forward' that follows.

## Way Forward

The NFM Fund developed in this pilot provides a sound framework for working in partnership with landholders and River Trusts to implement NFM measures upslope of flood hotspots on the SRN. However, to make that framework cost beneficial (and hence a sensible long term use of public money), **measures need to be more precisely targeted at hotspots on the SRN that suffer most from flood related traffic disruption and in catchments most suited to implementation of effective NFM.**

Two models are proposed for future delivery of NFM by National Highways, as set out below. These are not alternatives; they would run concurrently.

### NFM Fund+ (a National Highways led partnership)

This model is recommended for catchments where National Highways can make a sound business case for funding an NFM implementation independently. Most likely the NFM Fund+ would be applied to small catchments suited to NFM, directly upslope of busy sections of the SRN that are known to suffer from regular flooding. **It is the next generation of the NFM Fund developed in this Pilot, refined to increase benefits generated and reduce the cost of implementation.** In particular the NFM Fund+ would be implemented

- **upstream of flood hotspots where the consequences of flooding are substantial** (busy sections of the SRN that experience regular and substantial disruption from flooding); where flooding is wholly or substantially generated by off-network sources and where the cost of alternative solutions to NFM are high (e.g. culvert replacement).
- **in catchments that are small and physically suited to NFM** (NFM tends to be most effective in headwater catchments); owned or managed by only a few entities (it is a lot easier to rapidly implement NFM widely if you only have a few people to deal with) and those people are receptive to Nature-based Solutions such as NFM.
- **using measures that cost effectively capture a useful proportion of the catchment runoff efficiently and optimise co-benefits.** As a general rule by 'going big', either with extensive measures such as soil decompaction or individual measures that capture a lot of water in one place. This approach drives down the unit cost of capturing flood water. Small measures should only be used if a multiple implementation collectively captures a large volume of flood water. Measures should be designed to optimise co-benefits.



### National Highways as a participant in a wider Catchment Partnership

This recognises that a National Highways led partnership (NFM Fund+) is not an appropriate vehicle for implementation of NFM in all settings. **At hotspots on the SRN where flooding is generated by larger catchments, owned by many entities, of interest to many stakeholders and with the potential to generate many ecosystem services, a broader partnership approach in which National Highways are a participant) is likely to be a more effective vehicle.** National Highways involvement in these partnerships would be appropriate when the multiple benefits they deliver to National Highways justify the investment made by National Highways. National Highways involvement in a partnership will be attractive to other partners when National Highways investment in NFM (and other) measures reduces the flood risk to other stakeholder's assets and can be accounted as a benefit by them. Whilst this broader partnership approach was not a specific focus of this pilot study, it is included for consideration by National Highways when determining a way forward for the use of NFM in managing flooding on the SRN in England.

## Glossary

Term	Explanation
Focus Areas	A geographical unit used in the study. The areas within the Irwell and Little Don catchments in which the Pilot was implemented.
HADDMS	Highways Agency Drainage Data Management System
Implementation Cost	The Year 0 costs of the Pilot comprising a) the landholder price for implementing measures and b) overhead costs of implementing the NFM Fund Pilot. Note the landholder price is sometimes broken down into planning, [measure] implementation and maintenance elements.
Landholders	Owners or managers of land.
Nature based Solution (NbS)	The sustainable management and use of natural features and processes to tackle socio-environmental challenges.
Natural Flood Management (NFM)	The use of various techniques to restore or mimic the natural functions of rivers, floodplains, and the wider catchment. The aim is to store water in the catchment and slow the rate at which water runs off the landscape into rivers, to help reduce flood risk to communities and assets downstream.
NFM Fund	A pilot scheme set up by National Highways to facilitate and fund implementation of NFM measures. The Fund supported measures that aimed to reduce flood risk and increase flood resilience on the SRN.
NFM Fund Pilot	A term used throughout this report to refer to the testing / piloting of the NFM Fund concept in the Focus Areas of Pilot Catchments.
Off-network	Any location outside or beyond National Highways' estate. The National Highways estate is normally restricted to the road network and land immediately adjacent.
On-network	Any location on National Highways' estate.
Pilot catchments	The largest geographical unit used in the study. The areas drained by the Irwell Etherow and Little Don rivers.
Present Value Benefit (PVb)	Total benefits generated by the Pilot, discounted to Present Value over a 25 year period. Assumes measures are maintained and function over a 25 year period.
Present Value Benefit (PVC)	Total costs of the Pilot, discounted to Present Value over a 25 year period. Assumes measures are maintained and replaced as needed over a 25 year period.
Sub-catchment	The smallest geographical unit used in the study. A small hydrological watershed within a Focus Area. These were 0.5 km <sup>2</sup> to 2 km <sup>2</sup> in size.
Sub-Focus Areas	A sub-division of the Irwell Focus Area needed for the of analysis (e.g. estimation of flood risk benefit).
SRN	Strategic Road Network



# 1. Introduction

## 1.1. Context for Pilot

Natural Flood Management (NFM) is a tool to help reduce flood risk and increase flood resilience. Reducing the risk of flooding means reducing the number of times flooding happens. Increasing resilience to flooding means, that when flooding does happen, it causes less harm to people, less damage and life can get back to normal more quickly.<sup>1</sup>

NFM complements other flood risk management approaches and involves working across the landscape to protect, restore or mimic natural hydrological processes that naturally store or attenuate runoff.<sup>2</sup>

National Highways are in the closing stages of a pilot to determine whether they can work with partners to implement NFM in catchments that generate flooding on the Strategic Road Network (SRN). The purpose of the Pilot is to explore whether NFM can a) make a useful contribution to reducing flood risk and / or increasing flood resilience on the SRN. There is also interest in whether NFM can contribute to National Highways' wider environmental commitments. NFM measures offered to landholders under the Pilot are shown in Figure 1-1. They include changes to land management as well as measures applied on flow routes across the landscape or in watercourses. More detail on the NFM measures implemented under the Pilot are listed in Table 1-1.









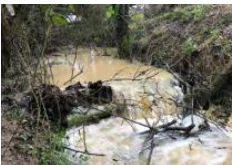
**Figure 1-1 – NFM measures offered as part of the Pilot (from CABA, 2021)**

<sup>1</sup> Definition of flood resilience from 'Using the power of nature to increase flood resilience' (Environment Agency, 2021)

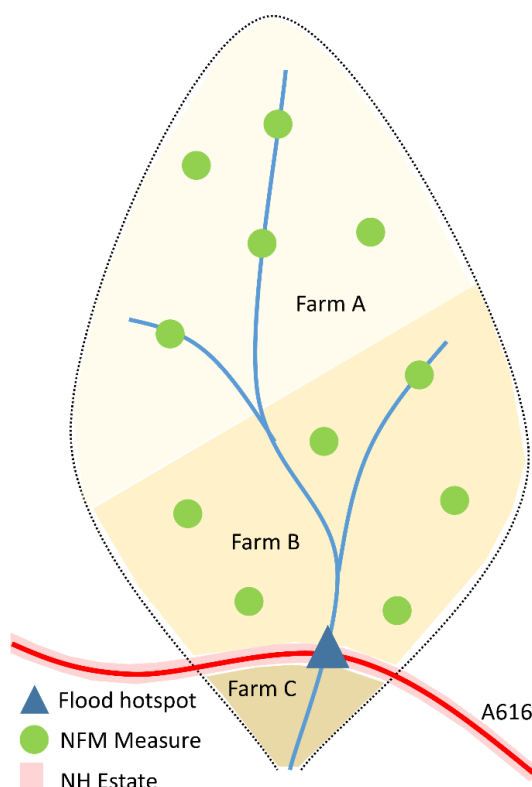
<sup>2</sup> Definition of NFM adapted from the CIRIA Natural Flood Management Manual (Wren et al, 2022)

**Table 1-1 – NFM measures implemented under the Pilot**

Measure	Image	Description
Overland leaky barriers (FR01.1)		Overland leaky barriers are discrete measures that are strategically located and fixed on a floodplain or preferential flow route to intercept and temporarily store water. They are typically constructed from wood, including whole tree trunks laid perpendicular to the flow pathway. They are designed to slow and attenuate the flow of water by roughening the ground surface and providing a barrier that acts to increase the time it takes water to move downstream.
Flow Pathway bund (FR01.2)		Flow pathway bunds are typically made from earth and can be located catchment-wide to target known overland flow pathways. These measures are also termed 'contour bunds', 'cross-slope bunds', 'flow-route bunds' or simply 'bunds'. Overland flow can occur following periods of heavy or prolonged rainfall, directing water (and sediment) rapidly downslope towards a watercourse. Constructing bunds across these pathways aims to capture, slow and store water strategically in the landscape.
Online storage pond (FR02.2)		Online storage ponds provide additional water storage areas incorporated into existing watercourse alignments, or adjacent to them. Online ponds are hydraulically connected to the drainage network, which can be via pipes or open cut channel connections. They are designed to provide additional storage capacity within a channel or to intercept water heading towards a watercourse via the existing drainage network. Both approaches act to attenuate flow and reduce the flood peak. Once the event has passed, the connection/s between the storage ponds and the watercourses facilitates emptying of the pond so that storage is available for the next event.
Landowner Innovation (LI01.1)		The landowner innovation option was an opportunity for landholders to present alternative measures, which could contribute to NFM through mechanisms such as increasing infiltration, reducing water runoff and storing water. The innovation needed to provide a nature-based solution that delivered measurable benefits in term of reducing flood risk.
Vegetated Buffer Strips (LM01.1)		Buffer strips are areas of land that are permanently vegetated. Mixed species buffer strips are typically planted with grasses, herbs and wildflowers along field boundaries or adjacent to watercourses and ditches. They provide a physical boundary between arable land or improved grassland and the drainage network, acting to reduce the amount of water and sediment runoff to watercourses, as well as reducing bankside livestock poaching.

Cross-slope Woodland & Vegetation (LM01.2)		Cross-slope woodland & vegetation (principally hedgerows) involves the planting of trees or hedge species in strategic locations to intercept overland flow. The measure is designed to reduce flooding by slowing the movement of water downslope towards and into watercourses. This occurs through the interception of rainfall and overland flow, encouraging evapotranspiration, increasing infiltration through soil improvements (due to enhanced root growth), and increased surface roughness which can slow overland water flow.
Reducing soil compaction (LM02.1)		Soil compaction can occur across whole fields but is often most focused around vehicle access routes, gateways and areas such as livestock troughs, where high pressures exerted on to the soil surface by machinery and livestock reduces soil pore space. The compaction reduces the infiltration which can lead to an increase in overland flow and flooding during a storm event. Reducing the compaction of soils through aerating, subsoiling or sward lifting can be a very effective technique. Other ways to reduce soil compaction include crop and livestock rotation, mob grazing and avoiding the use of heavy machinery on wet soils. A collection of these techniques were used within this measure bundle by landholders.
Mixed Species Herbal Ley (LM02.2)		A mixed species herbal ley aims to increase water infiltration. Through the establishment of a diverse range of species, including deep rooting species, the soil can be enhanced with greater amounts of carbon, soil organic matter and therefore greater water storage potential. Developing root systems will also aid with reducing soil bulk density (compaction).
In-channel leaky barriers (WC01.1)		In-channel leaky barriers are constructed in small permanently, or intermittently flowing channels (typically 2 - 3 m wide), through the placement and securing of woody material such as sections of tree trunks or large branches or boards. These measures are also frequently termed 'leaky dams', 'woody dams' or 'in-channel barriers'. Leaky barriers can be installed and secured individually, or as a series of barriers with the exact design and location dependent on factors such as channel form, flow character and proximity to local assets (bridges/culverts). They are designed to temporarily impound and hold back flood water within the channel, which then leaks away once the flood peak has passed.
Headwater woody bundles (WC01.2)		Headwater channel woody bundles are of a similar concept to in-channel leaky barriers (WC01.1). However, they are more typically associated with temporarily (ephemeral) flowing channels/gullies in the upper catchment and only become active during or following rainfall events. The purpose of these measures is to roughen the flow route within temporarily flowing narrow channels/gullies.

The Pilot investigated use of NFM to manage flood risk and resilience on the SRN from runoff generated up-catchment or upslope of a road, as illustrated in Figure 1-2. The Pilot tested whether National Highways could work with owners or managers of land 'off-network' i.e. third party land (Farms A and B in the figure, but not the National Highways' Estate) to implement NFM measures in a way that could usefully reduce flood risk, or increase flood resilience at flood risk hotspots on the SRN. NFM is rarely the sole solution to flood risk at hotspots on the network. Its role is to complement existing flood risk management measures (e.g. hard engineering and maintenance activities on the road network), and to increase the resilience of the network to flooding, for instance as a tool for managing the effects of climate change.



**Figure 1-2 –Using NFM on off-network land to manage flood risk at hotspots on the SRN**

## 1.2. Purpose of report

This report uses information gathered during the Pilot and feedback from participating organisations and individuals to answer three questions.

- **Is there likely to be a viable business case for National Highways to invest in implementation of NFM off-network on third party land?** This case needs to consider the benefits of reducing flood risk at hotspots on the SRN. It may also be supported through co-benefits that NFM measures generate – for instance by increasing biodiversity and landscape connectivity and natural sequestration of carbon.
- **How could National Highways invest in NFM at a scale sufficient to make a useful contribution to their business objectives?** This would require a substantial increase in scale of operation from the Pilot. In which catchments and how should NFM measures be implemented? The majority of measures are likely to be implemented on third party land, so how would National Highways partner with owners of this land? What other organisations would need to be involved? Any investment in NFM would be for the long term, so clear agreement on the management of the NFM measure and attribution of the benefits it generated would be essential.
- **What are the wider lessons learnt from the Pilot?** On matters of process, engagement and governance, what lessons have been learnt from the Pilot? How could these be shared and applied to future phases of work?



## 1.3. Drivers for participation in Pilot

### 1.3.1. Introduction

The Pilot was implemented as a partnership between National Highways, the owners or managers of the land on which the NFM measures were implemented and Rivers Trusts for the local catchments.

National Highways funded the Pilot. They also provided local knowledge on the location and severity of flooding at flood hotspots on the SRN in the Focus Areas. To protect their investment National Highways developed a process for implementation of the Pilot.

Landholders provided the land on which measures were implemented on a five-year agreement with National Highways. They implemented the measures (in 2021 / 22) and will continue to maintain them until 2025.

The Rivers Trusts were National Highways' Catchment Partner. As an established local presence trusted by landholders in the catchment, and knowledgeable about implementation of NFM, the Trusts acted as a bridge and intermediary between National Highways and local landholders.

The success of the Pilot and sustainability of any future investment in NFM by National Highways depends on there being substantial common ground in the interests of these three parties – and very likely other catchment stakeholders. This section summarises the key drivers for each, with a focus on those influencing National Highways.

### 1.3.2. National Highways

#### Strategic vision

National Highways are currently developing an Environmental Sustainability Strategy for Road Investment Strategy (RIS) Period 3 (2025 to 2030). This will define a long term environmental sustainability vision (to 2050) and set out the priorities of this vision for delivery in RIS 3. The strategy is being developed under the strapline “a connected country, a thriving environment”. This recognises the needs to deliver a Strategic Road Network that underpins a healthy economy by moving people and goods efficiently. It also sets the challenge of delivering this road network in an environmentally sustainable manner.

At the core of this sustainable approach will be improving the operation and capacity of the existing network. The intent is only to construct new roads when all other options have been exhausted. National Highways are already committed to net zero emission of carbon from the network by 2050 (National Highways, 2021a). The Strategy also sees the road network as an integral feature of the landscape. It intends that future works should be implemented in this context: creating and restoring biodiversity appropriate to the landscape and improving connectivity between habitats at a landscape scale.

NFM measures can support delivery of this vision. Implementation of NFM upslope or up-catchment of flood hotspots can increase the resilience of existing drainage systems, for instance to the effects of climate change. Measures generate more ecosystem services than flood risk management alone. Appropriately designed they store carbon, enhance biodiversity and improve water quality and hence contribute to the wider objectives of the Strategy. Rivers and streams are natural connections within the wider landscape. Local improvements to a watercourse therefore have potential landscape scale effect. Implementing measures off-network requires conversations between National Highways, local communities and landholders - creating stronger connections between National Highways and its neighbours.

Whilst there is a strong logical case for landscape scale implementation of the Strategy, a key challenge will be translating this strategic goal into reality through a business case.

#### Operational metrics

Road Investment Strategy projects delivered by National Highways are routinely monitored by government against a set of performance measures (National Highways, 2021). Metrics relevant to implementation of NFM are presented in Table 1-2.

Whilst the primary purpose of these metrics is to monitor the environmental performance of road improvement schemes, they have been developed to reflect the core principles of National Highways and, as such, are often used in assessing wider activities within the organisation. For instance, they are used as assessment criteria in applications made to National Highways' Designated Funds (National Highways, 2022).



**Table 1-2 - Operational metrics**

Metric (technical note reference, Highways England, 2021)	Performance Indicator	Key Performance Indicator	Description
Drainage resilience (3.4)	✓		The percentage length of carriageway that does not have an observed significant susceptibility to flooding.
Biodiversity (4.2)		✓	No net loss of biodiversity, measured using an industry standard referred to as the biodiversity metric.
Water quality (4.7)	✓		Length of watercourse enhanced through the mitigation of medium, high, and very high-risk outfalls as well as through other enhancements such as river retraining / rewilding

Implementation of NFM measures contributes to the drainage resilience metric by reducing the volume of runoff and peak flow generated by the catchment upstream of a flood hotspot or culvert on the SRN. This can reduce the frequency of traffic disruption due to flooding. It can also increase the resilience of the road network to flooding (allowing the network to 'get back to normal' more quickly after a flood event). Sometimes small changes to flood risk or resilience can delay or avoid the need for expensive 'on-network' works to increase the capacity of drainage systems.

NFM measures have benefits beyond their primary purpose of flood risk management. Many measures (for instance tree and hedgerow planting) generate biodiversity. Measures such as moorland grips and gully blocking will improve habitat condition and water quality in a catchment as well as reducing runoff.

### 1.3.3. Landholders

Around a third of landholders participating in the National Highways NFM Fund Pilot were commercial farmers running holdings in which agricultural production was the principal form of income. Whilst many of these participants had a particular interest in environmentally sensitive farming practices, all were necessarily driven by the commercial needs of their farm business. Measures were mostly selected because they either integrated with the farming system (e.g. making use of marginal or non-productive land); they benefitted the farm (e.g. reinstating a hedge) or they were an opportunity to share the cost of experimenting with an alternative land management operation or use (e.g. herbal leys or soil decompaction).

Around two thirds of participants were landholders with a primary source of income that was not agriculturally based. Holdings were either diversified from agriculture to other businesses (e.g. horse livery) or run as a secondary business. For these participants environmental sustainability was a very important driver and they saw NFM or Nature-based Solutions as a key service provided by their land.

### 1.3.4. Rivers Trusts

The strapline for the national umbrella organisation 'The Rivers Trust' is "wild, healthy, natural rivers, valued by all". Their mission is to bring together the people, knowledge, data and intelligence to help rivers thrive again, for current and future generations. They work with farmers, government, communities and businesses to achieve this goal by providing advice and resources (Rivers Trust, 2022).

Local Rivers Trusts, of which there are 65 in the UK and Ireland, are driven by the same broad objectives as their umbrella organisation. They see rivers and waterways as central to the local landscape and communities. The Trusts work to facilitate a strengthening of the connection between the two. Local Trusts will be focussed on the particular issues and opportunities of their own catchment.

Rivers Trusts get involved in all aspects of river and catchment management and monitoring including matters of biodiversity and water quality as well as cultural and historical heritage. Most have a strong interest in Nature-based Solutions, one strand of which is NFM.

As such, the Rivers Trusts are primarily driven by an aim of protecting and enhancing rivers and their catchment. They are a local presence, wanting to connect communities to their natural environment. That connection is long term - so integrity and trust amongst everyone who lives and works in a catchment are very important.

Trusts tend to be funded through relatively short term grants. This a huge challenge to the long term sustainability of an organisation. Trusts tend to be relatively small organisations - so taking on big new projects takes time (to plan and recruit resources).

### 1.3.5. Other stakeholders

There are other stakeholders with drivers likely to align with the National Highways NFM Fund Pilot.

Within the Pilot catchments land is owned by strategic non-agricultural landholders with common interests to National Highways. For instance, water companies such as United Utilities and Yorkshire Water have similar regulatory drivers on carbon, biodiversity and application of Nature-based Solutions as National Highways. These water companies own land in the Irwell and Little Don catchments. Other potential strategic landowners in upland catchments include large private estates, Ministry of Defence, National Trust and the Forestry Commission. Farmer groups (e.g. Farmer Clusters, 2019) and catchment based projects (e.g. iCASP, 2022) have potential links and established relationships with many landholders. Engagement with these strategic landowners and partners in a catchment can be a route to implementation of measures across extensive areas, when challenges are shared and interests align.

There are stakeholders potentially aligned to the National Highways NFM Fund Pilot through common thematic interests. These include fellow linear infrastructure providers (e.g. Network Rail, HS2, East West Rail), (Flood) Risk Management Authorities and national government programmes including the Defra £15M NFM pilot programme (e.g. FCRIP, 2022 and Environment Agency, 2018 and 2021) are also grappling with delivery of Nature-based Solutions. Membership of the steering group for the recently published Ciria NFM Manual (Wren et al, 2022) gives a feel for the breadth and diversity of this stakeholder group.

**Table 1-3 - Membership of CIRIA NFM Manual steering group**

Department for Infrastructure Northern Ireland	Anglian Water
Environment Agency	Network Rail
Forestry Commission	Severn Trent Water
Herefordshire County Council	United Utilities
Kent County Council	
London Borough of Hillingdon	AECOM
Natural Resources Wales	Arup
Natural England	Atkins
National Highways	HR Wallingford
Scottish Environmental Protection Agency	JBA Trust
Sheffield City Council	Kier Group
	WSP
Associated of Drainage Authorities	
The Rivers Trust	
Tyndall Centre of Climate Change Research	
National Farmers Union	
National Trust	

## 1.4. Other land management schemes with NFM components

National Highways' NFM Fund is just one of many land management schemes in which landholders can participate. Each scheme is different. Each has its own objectives, rules and timings. This variety, complexity and lack of clarity can be confusing and off-putting for potential participants.

Most well established are the government funded agri-environment schemes. These are in transition, with the old Countryside Stewardship schemes closing in 2023 to be replaced by new Environmental Management schemes before 2027 (Defra, 2021). The concept behind this transition is a move away from area based subsidies to a new system investing public money for public good. Other examples of government led initiatives are the England Woodland Creation Offer (Forestry Commission, 2021), Woodland Creation Planning Grant (WCPG) and Woodland Creation and Maintenance (WCM) schemes.

Many organisations with an interest in how catchments are managed have been experimenting with land management schemes in recent years. As an example, Water Companies such as Thames, Severn Trent, United Utilities and Wessex all have catchment management programmes, or have run pilot schemes, often through catchment partnerships (e.g. Smarter Water Catchments – Thames Water, 2022). Whilst these schemes are often targeted at reducing nutrient loads or pesticide concentrations in the natural environment, measures they implement will also reduce flood risk (e.g. wetlands).

A growing but largely undeveloped market in land management support is private investment – often collectively termed Green Finance. There are now many initiatives in the UK that aim to develop high integrity markets for nature-based environmental services (e.g. Broadway Initiative, 2021). The aspiration is that these markets will allow landholders to routinely supply nature-based projects to investors. Most practical applications for these markets are at early stages of development, for instance piloting how to make provision of environmental services 'investment ready' (e.g. Wyre NFM Investment Readiness Project, Green Finance Institute, 2021) or trading systems such as the Landscape Enterprise Network (LENs, 2022).

The NFM Fund would be just one of many land management support options open to landholders. The marketplace is in huge transition with the traditional agri-environment schemes undergoing a radical overhaul and new entrants / technologies entering the market place. Some potential new entrants have the means to make substantial investments in Nature-based Solutions. National Highways needs to understand where its offering sits within this market - or alternatively - how this market could service its needs.

## 2. Description of Pilot

### 2.1. Phase 1 - scoping assessment

An initial desk based GIS assessment was undertaken to locate and prioritise those parts of the SRN in England where NFM has potential to reduce existing flood risk or increase resilience to flooding. This assessment was carried out between 2018 and 2020.

GIS based analysis was undertaken to locate places where a) off-network sources of flooding (principally surface water flow paths) crossed the SRN and b) National Highways records indicated flooding has occurred in the past. Information on the sources of flooding came from the Environment Agency's spatial flood risk and Working with Natural Processes (WWNP) data sets. Records on the location and frequency of flooding on the SRN came from the Flood Hotspot database on National Highways' Drainage Database Management System (HADDMS), and affiliated datasets.

These flood source and record data sets were further analysed to identify the priority 100 locations for the Pilot (the locations where flood risk could be most confidently linked to off-network sources of flooding). These 100 priority locations on the SRN were in turn linked to 55 Water Framework Directive Operational Catchments as a means of defining the watersheds within which flood risk to the SRN was generated. The 100 priority locations are shown in red and the 55 priority catchments are shown in dark blue (scoped catchments) in Figure 2-1.

### 2.2. Phase 2 - opportunity assessment

#### Desk based opportunity assessment

This was an investigation to locate catchments in which there was greatest opportunity to implement and pilot use of NFM measures to address flood risk on the SRN. The work was carried out in 2020 and 2021.

The opportunity assessment started with the 100 priority locations on the SRN and the associated 55 WFD Operational Catchments identified in the scoping assessment. It identified 10 catchments in which the flood risk management needs of National Highways were strongest and aligned most closely with the goals of potential partners in the catchment. These 10 catchments are shown in light blue (opportunity catchments) in Figure 2-1. National Highways strategic needs were determined by review of existing and proposed schemes in the Road Investment Strategy within the catchment.

Further quantitative analysis of the NFM potential in these 10 catchments was undertaken using a strategic NFM modelling tool (NFMStudio, Appendix C.1). This determined the types of NFM measures suited to each of the 10 catchments and estimated the potential volume of water that could be stored by these measures.

#### Selection of Pilot Catchments and Focus Areas

Following engagement with local National Highways Operations teams and local Rivers Trusts, three catchments were selected to pilot implementation of NFM measures: the Little Don, Irwell and Etherow.<sup>3</sup> These are shown in green in Figure 2-1. These three catchments were selected because: a) they generate runoff that is known to contribute to flooding of the SRN; b) desk study and engagement with local Operations teams confirmed off-network sources as a contributing cause of flooding on the SRN and c) a strong and viable relationship had been established with local Rivers Trusts.

Further GIS analysis and discussion with local National Highways Operations teams identified Focus Areas within each of the three catchments to implement the Pilot. These are shown using red hatch in the inset diagram in Figure 2-1, and in the context of the Flood Hotspots they are associated with in Figure 2-2. The hotspots targeted by the Focus Areas are also listed below. These are locations where Operations teams are aware that flooding regularly occurs each year.

- Little Don: Hotspots 1023 (A1), 1846 (A1), 1904 (A)
- Irwell: Hotspots 124 (A1), 1502 (A1), 1595 (A), 1449 (A), 1798 (A), 59 (A1), 1621 (A1), 1865 (B), 1799 (C)
- Etherow: Hotspots 1033 (D), 1034 (A), 1035 (A), 1041 (A), 1042 (A), 1043 (D), 1327 (C), 1888 (B)

<sup>3</sup> Note that the Etherow was added to the Pilot on the request of local Operations teams. It was not one of the 10 catchments identified in process described above.



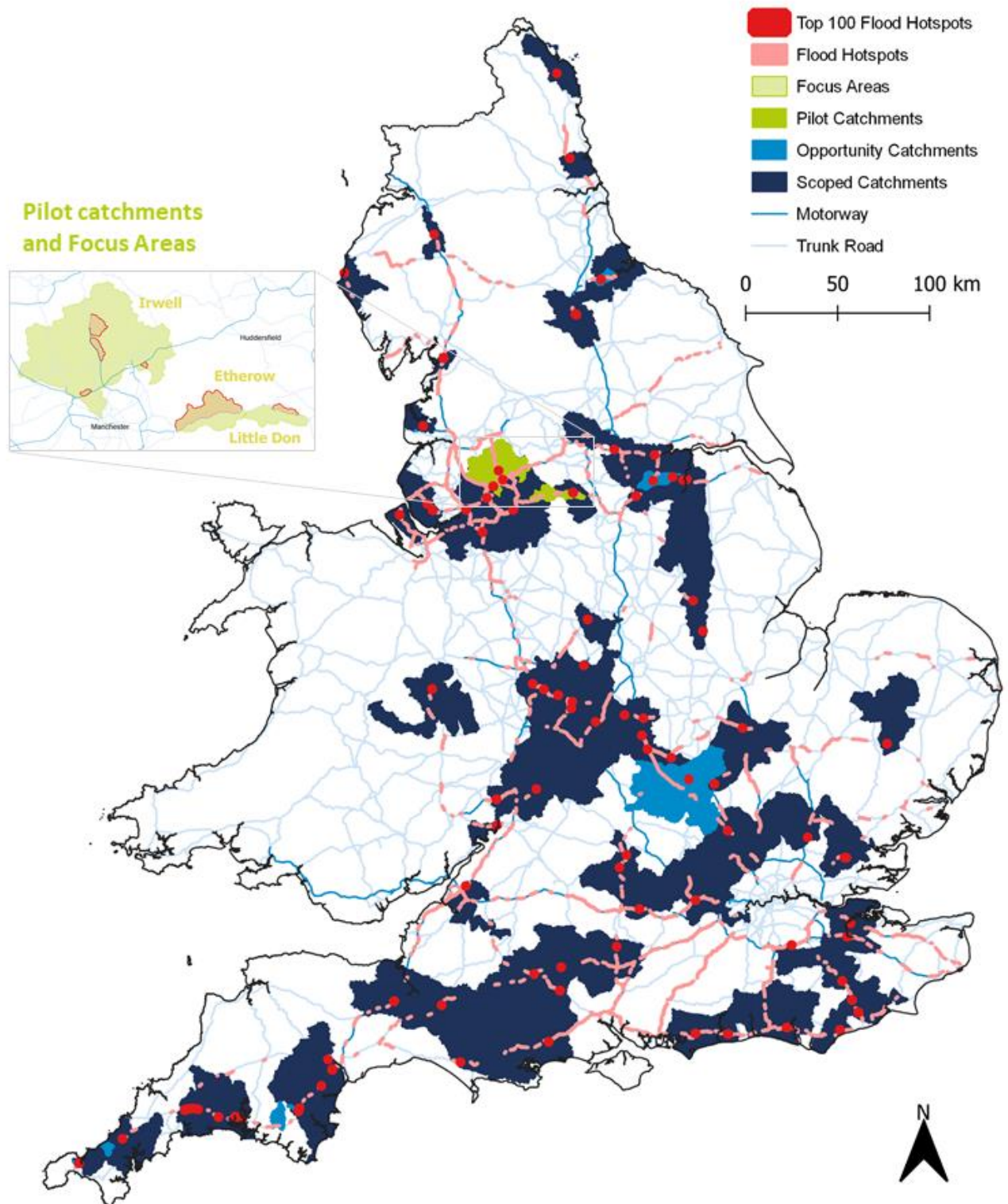
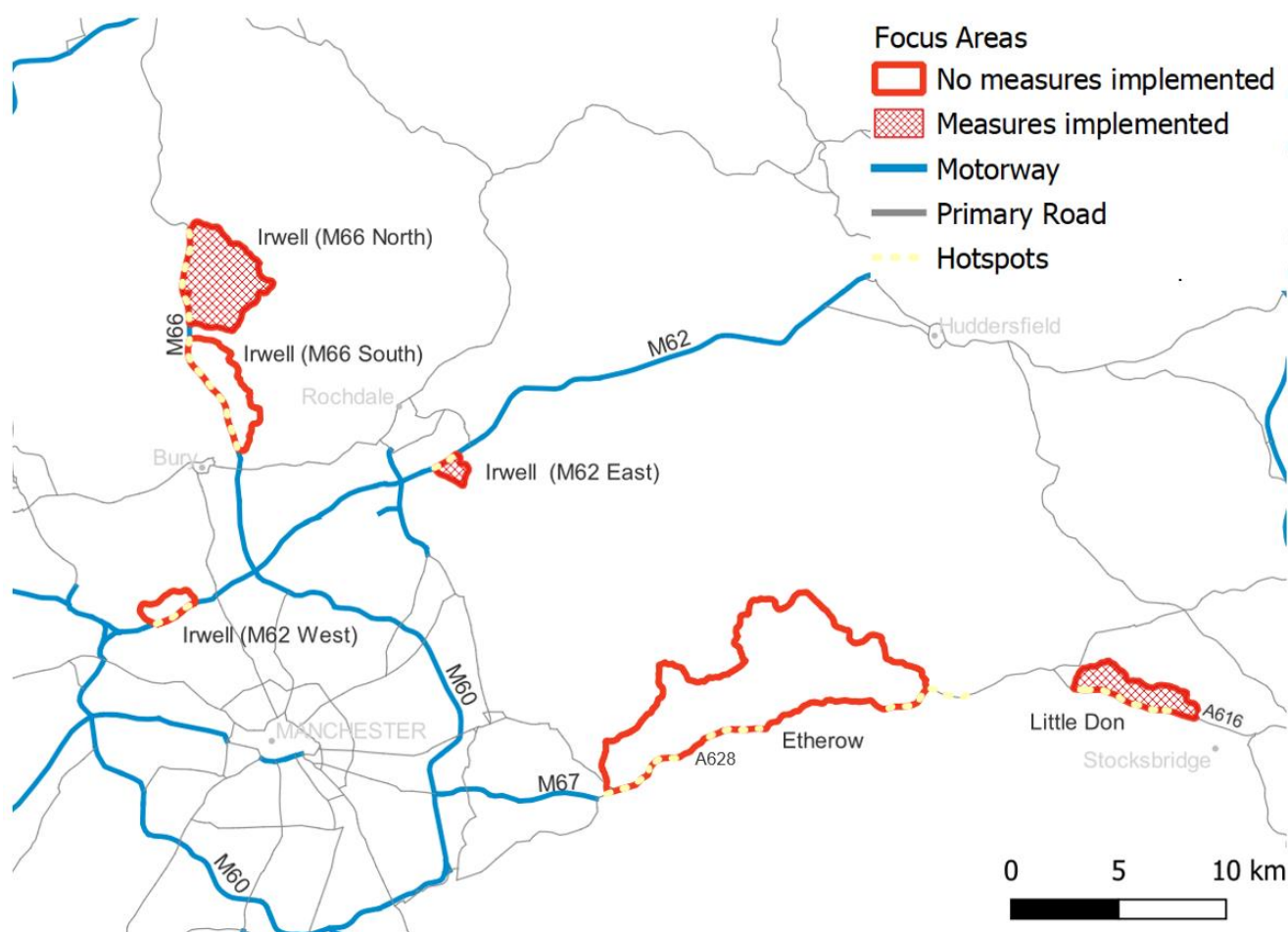


Figure 2-1 – Pilot catchments, Focus Areas and associated flood hotspots





**Figure 2-2 – Focus Areas and flood hotspots in the Pilot catchments**

## 2.3. Phase 3 - developing framework for implementation of NFM Fund Pilot

### 2.3.1. Introduction

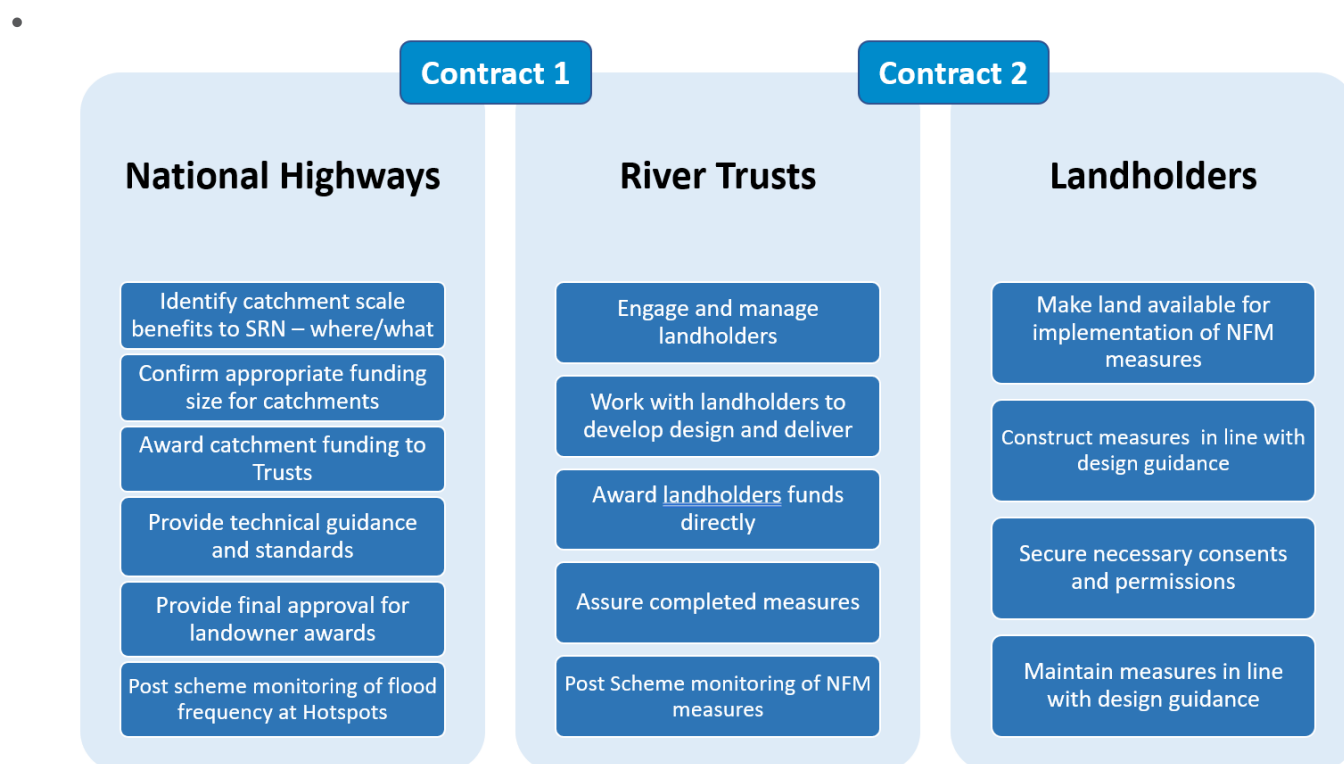
The 'NFM Fund' was set up as a vehicle to pilot a 'National Highways led partnership' for implementing NFM measures in some or all of the Focus Areas shown in Figure 2-2. The Fund was conceived as a competitive grant based scheme supporting implementation of NFM by local landholders. The measures offered by the Fund would be selected for their effectiveness in the flood environment of the Focus Areas. The components and activities of the delivery framework for the NFM Fund are set out below. This framework was developed over the period 2020 to 2021.

### 2.3.2. Setting up of Catchment Partnerships

A partnership was formed between National Highways, the local Rivers Trusts<sup>4</sup> and landholders to deliver NFM in the Focus Areas of the Pilot Catchments. A clear simple organisational structure was formed, with key roles set out in Figure 2-3. The Trusts formed a vital bridge between a national organisation and landholders. They are a well-known and trusted presence in their catchments. The success of the Pilot was ultimately dependent on the willingness and enthusiasm of landholders to participate and provide land on which measures could be implemented. By making use of these existing strong local links, National Highways were able to fund

<sup>4</sup> The Mersey Rivers Trust (2022) covered both the Irwell and Etherow pilot catchments. The Don Catchment Rivers Trust (2022) covered the Little Don pilot catchment.

measures where they were needed to reduce flood risk and increase flood resilience on the SRN: off-network on third-party land outside of their ownership.



**Figure 2-3 – Roles within the catchment partnership**

### 2.3.3. Preparation of resources

A set of digital resources were prepared to support implementation of the NFM Fund. These comprised an:

- *NFM Fund Handbook* which summarised the grant application process for landholders looking to apply
- *NFM Measures booklet* which detailed what landholders could apply for in the Pilot
- *NFM Design Specification Catalogue*, to support landholders in developing measure designs
- *NFM Fund 'How To' Guide* to provide step by step instruction for applications

All of these resources can be found at CABA (2021).<sup>5</sup>

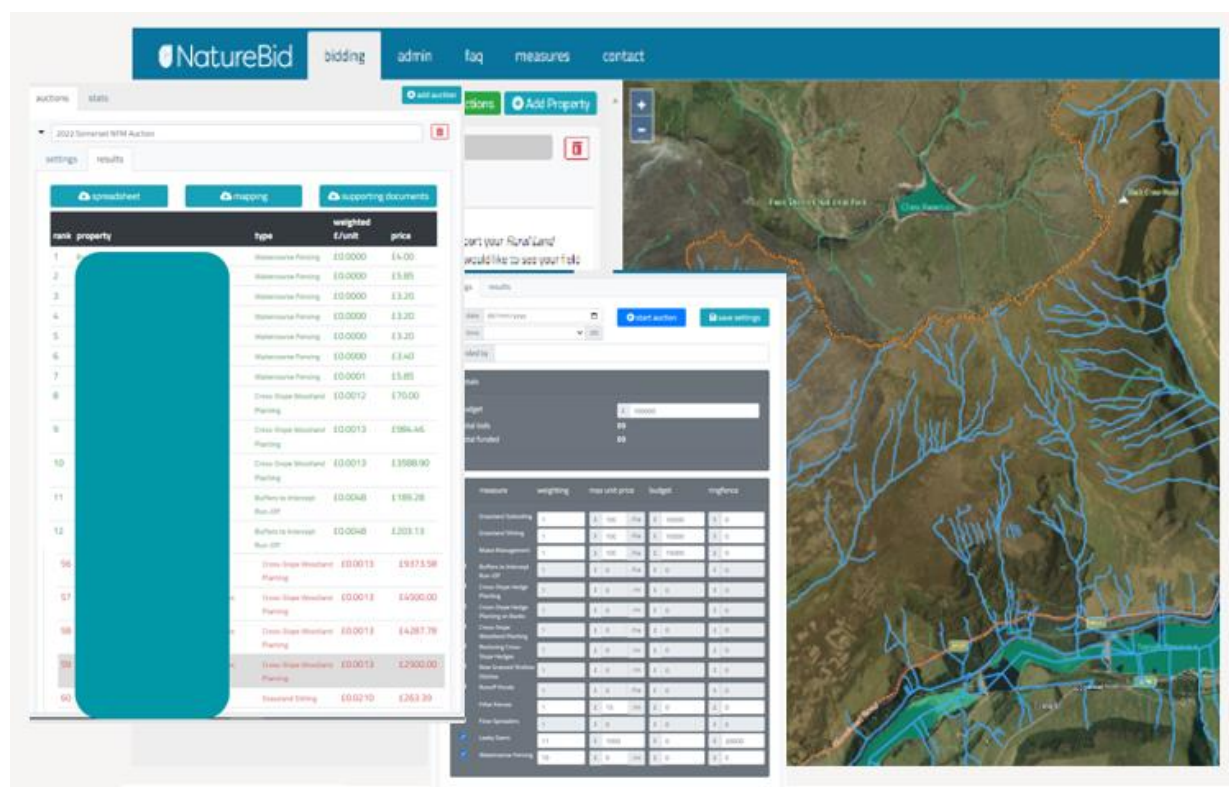
### 2.3.4. Development of a bidding platform

A web based bidding platform was developed for landholders to submit proposals to the NFM Fund (NatureBid, 2021). The platform captured key information on each bid (applicant details as well as the type, location and price of each measure an applicant proposed).

The platform is novel. It's thought to be the first time in the UK that a bidding process (a reverse auction) has been implemented based on 'live' use of environmental modelling data. The platform used a) modelled estimates of the volume stored by NFM measures and b) prices bid by applicants to rank competing bids based on a cost effectiveness (price per volume of water stored, £/m<sup>3</sup>) metric. The volume stored information came from a pre-populated geographical database generated by a strategic NFM modelling tool (NFM Studio, Appendix C.1).

The platform was designed to be intuitive and easy to use for applicants. It output a database of ranked bids ready for assessment.

<sup>5</sup> <https://catchmentbasedapproach.org/learn/he-nfm-fund/>



**Figure 2-4 – Examples web pages from the NFM Fund bidding platform**

### 2.3.5. Early engagement by Rivers Trusts with landholders

The Rivers Trusts invested considerable effort in engaging with landholders in the Pilot catchments to promote the NFM Fund amongst potential participants prior to the Pilot being formally launched. Early engagement activities to promote the Fund prior to its launch included letter drops introducing the Fund and publicity via web sites and social media. Note that only landholders within the Focus Areas of each Pilot catchment were contacted (shown in red in Figure 2-1).

### 2.3.6. Technical assessment of applications

The technical assessment was a structured process undertaken collaboratively by key stakeholders in the project team: National Highways Project and Operations teams, the Rivers Trusts and National Highways' Technical Advisors (Atkins).

The majority of the assessment was an evaluation of proposed NFM measures against the technical specifications in the NFM Fund Design Specification Catalogue (National Highways, 2021b) by both the Catchment Advisors and the Technical Advisors. A minority component of the assessment were 'wildcard' criteria. These represented secondary factors that could influence whether an application was funded<sup>6</sup>

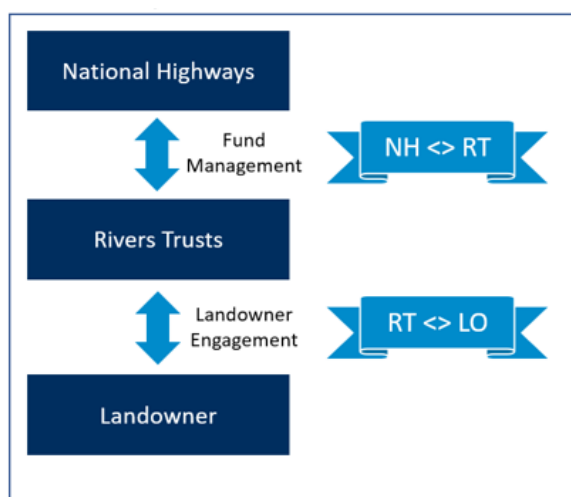
Each application was assessed using the same process and criteria. The outcome was recorded in a template. In this way consistent, transparent, and auditable recommendations on the technical merits of an application could be made to the Funding Body.

### 2.3.7. Development of contractual framework

The interests of all parties were ultimately protected by contract terms (Figure 2-5). Two template contract documents were set up for the operation of the Fund

- Highways England and the River Trusts - to manage the release of block grants to the Trusts
- River Trusts and landholders - to manage the implementation of NFM measures by landholders on the ground.

<sup>6</sup> Strategic value, multiple benefits, monitoring feasibility, value to the pilot.



**Figure 2-5 – Contractual hierarchy**

### 2.3.8. Development of a payment governance framework

A framework covering payment for measures implemented by the NFM Fund was developed and agreed with HM Treasury. Payments would flow in two steps. First a block advance payment by National Highways to each of the Rivers Trust and subsequently payments to each landholder by a Rivers Trust. Payment in advance to the Rivers Trusts was required to enable an efficient management of the NFM Fund grant process and to protect the River Trusts' very limited working capital. It would also facilitate timely payment of landholders on milestones by the Rivers Trusts. Payment to landholders would need to be highly flexible to work around the agricultural and weather cycles; even delays of a few days or weeks could be enough to discourage landholders from participating in the Pilot. In addition, it would reduce the administrative burden in National Highways of having to make multiple small payments across the project cycle.

This expenditure would be clearly tracked against the grant specification in the contract schedules to ensure funds were allocated appropriately. The contract would include completion and monitoring assurance certificates which the River Trusts would be required to provide to National Highways to demonstrate the successful implementation of measures by landholders.

Payments to Rivers Trusts included a contingency for management of scope changes in landowner contracts. As a final step, a reconciliation would be undertaken and any un-allocated funds returned to National Highways.

## 2.4. Phase 4 - implementation of NFM Fund Pilot

### The application process and associated activities

Two rounds of the NFM Fund application process were run in June and November 2021. The process is shown as a flow diagram in Figure 2-6. A full description of the application and implementation process can be found in the NFM Fund Handbook (National Highway, 2021c).

Building on early engagement activities (section 2.3.5) the Rivers Trusts worked closely with landholders within the Focus Areas (red areas in Figure 2-2) to help them prepare for and make applications to the NFM Fund. Often this required re-engagement with landholders who were already aware of the Fund. The publicity of the NFM Fund 'going live' and further door knocking / following up leads also attracted fresh interests in each round.

Farm visits were made by the Rivers Trusts' Catchment Advisors to develop ideas and work up initial designs for applications to the Fund. Advice on pricing was often sought by landholders. Catchment Advisors supported landholders to ensure applications were made. A lot of support was given by Advisors with submitting applications on the bidding platform (section 2.3.4) – this included running a drop in session in the Little Don Focus Area.

Applications were assessed (section 2.3.6) and successful landholders notified. Successful landholders were primarily responsible for preparing designs, consent applications and implementation of measures. However support was available from Catchment Advisors, for instance recommending contractors and providing 'ad hoc' advice when needed. The Rivers Trusts were responsible for paying landholders at two milestones (receipt of

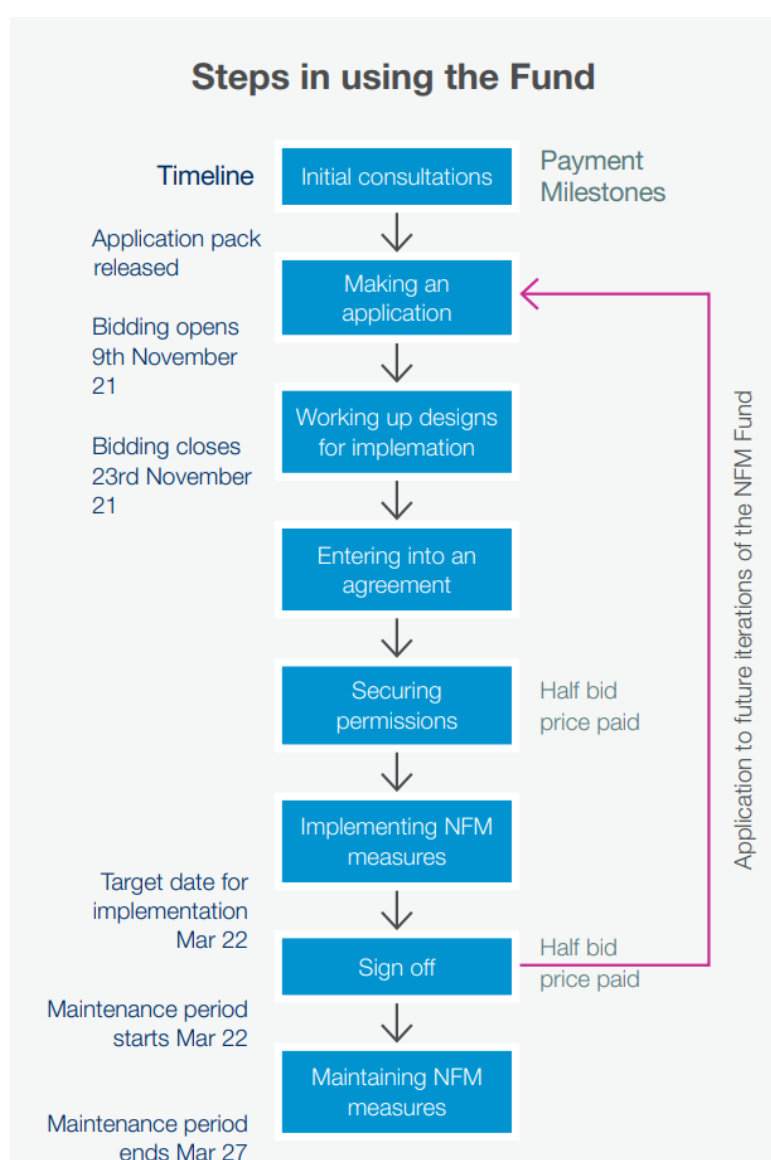
consent and completion). They were also responsible for assuring and signing off landholder measures on completion.

### Measures implemented under the Pilot NFM Fund

The NFM measures implemented are summarised in Table 2-1.

The location of implemented NFM measures are shown in Figure 2-7 (Irwell Sub Focus Areas – M62 East), Figure 2-8 (Irwell Sub Focus Areas – M66 North) and Figure 2-9 (Little Don Focus Area). No measures were implemented in Irwell Sub Focus Area (M62 West), Irwell Sub Focus Area (M66 South) or the Etherow Focus Area. This distribution of measures was primarily driven by a) the location of applications made to the Fund and the location of measures selected by the Technical Assessment process. Whilst a few measures were proposed by landholders in the Etherow Focus Area these offers were not taken up by National Highways. This was because the cumulative runoff reduction estimated to be generated by these few measures was judged to be insufficient to make a useful change to flood risk or resilience on the SRN.

In total across both auctions £1.2M of applications were received from landholders, of which £652,000 was awarded amongst 19 landholders in the Little Don and Irwell Focus Areas. Implementation of all measures was started by March 2022.



**Figure 2-6 – Implementation of the of NFM Fund (with November 2021 auction timeline)**

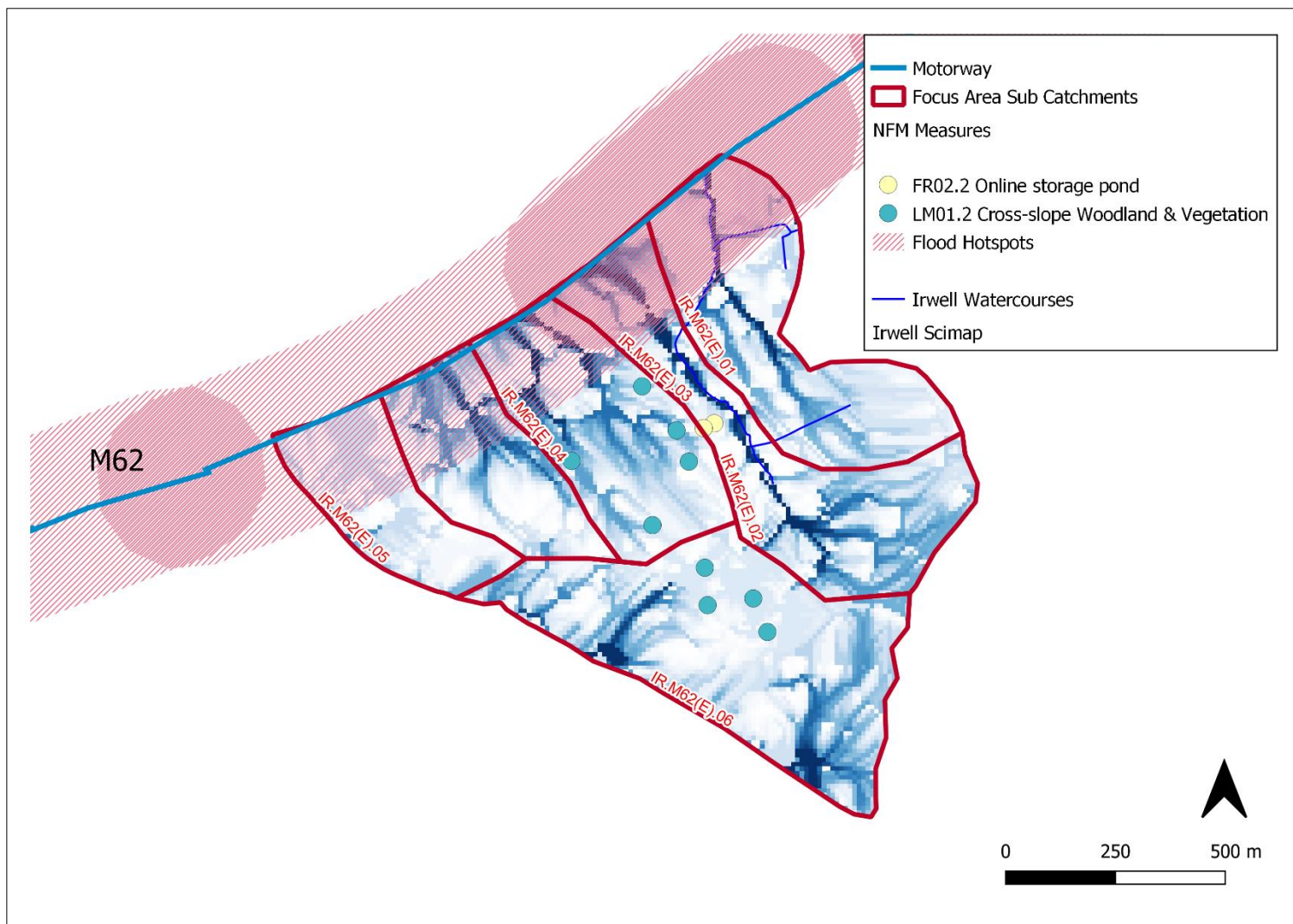


**Table 2-1 – Summary of NFM measures implemented as part of the NFM Fund Pilot**

Measure type	Irwell Focus Area			Little Don Focus Area			Whole NFM Fund Pilot			
	No. measures	Volume stored (m³)	Cost (£)	No. measures	Volume stored (m³)	Cost (£)	No. measures	Volume stored (m³)	Cost (£)	% Cost
FR01.1 Overland leaky barrier	31	340	36,700				31	340	36,700	6%
FR01.2 Flow Pathway bund	1	2	400	1	14	2,500	2	16	2,900	0%
FR02.2 Online storage pond	4	1775	73,000	6	1765	97,500	10	3540	170,500	26%
LI01.1 Landowner Innovation				1	2	2,250	1	2	2,250	0%
LM01.1 Vegetated Buffer Strips	3	41	12,500				3	41	12,500	2%
LM01.2 Cross-slope Woodland & Vegetation	25	430	225,922	16	182	74,598	41	613	300,520	46%
LM02.1 Reducing Soil Compaction	1	115	43,500	8	1609	45,000	9	1724	88,500	14%
LM02.2 Mixed Species Herbal Ley				2	57	9,135	2	57	9,135	1%
WC01.1 In-channel Leaky Barriers				14	19	23,025	14	19	23,025	4%
WC01.2 Headwater Woody Bundles				3	2	5,800	3	2	5,800	1%
<b>Total</b>	<b>65</b>	<b>2703</b>	<b>392,022</b>	<b>51</b>	<b>3651</b>	<b>259,808</b>	<b>116</b>	<b>6,354</b>	<b>651,830</b>	

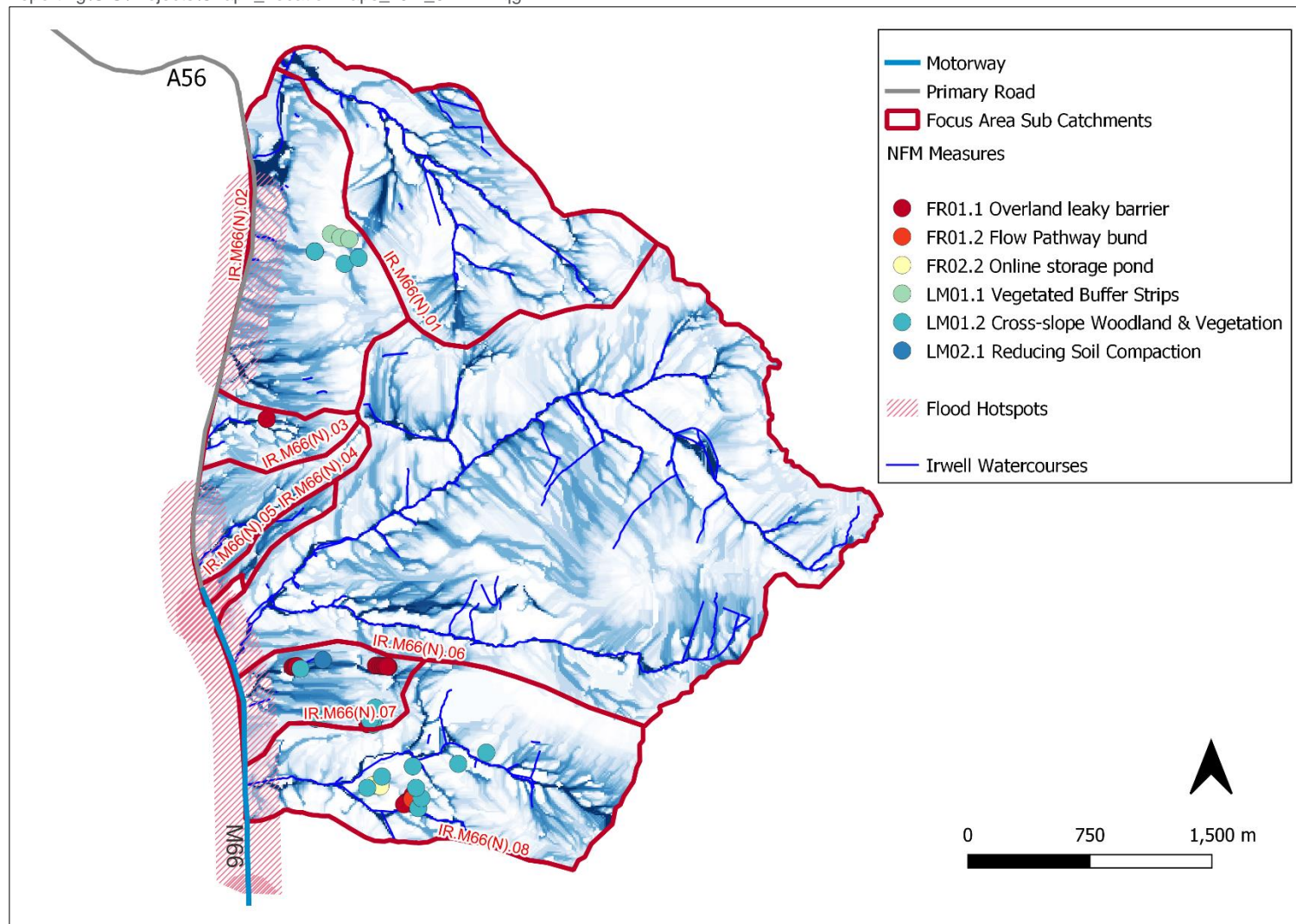
Note – The values presented for the Irwell Focus Area are for measures implemented in Irwell Focus Area (M62 East) and Irwell Focus Areas (M66 North). No measures were implemented in Irwell Focus Area (M62 West), Irwell Focus Areas (M66 South) or the Etherow Focus Area.

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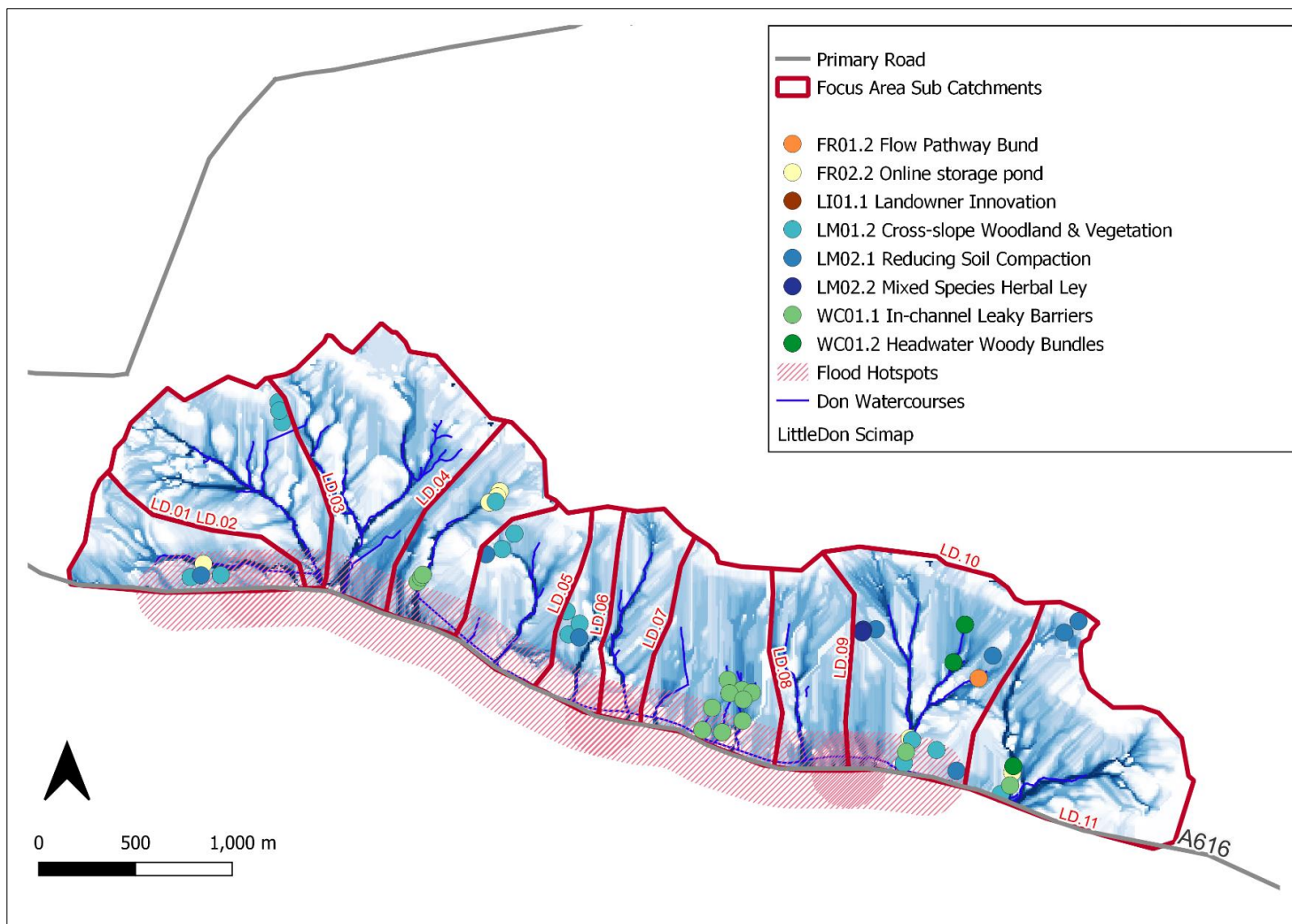


**Figure 2-7 – NFM measures implemented in Irwell Sub Focus Areas (M62 East)**

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**Figure 2-8 – NFM measures implemented in Irwell Sub Focus Areas (M66 North)**



**Figure 2-9 – NFM measures implemented in Little Don Focus Area**

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## 2.5. Phase 5 - monitoring

Monitoring is ongoing and will continue to 2027.

The River Trusts are currently undertaking field scale monitoring of selected measures to help assess their effectiveness. National Highways will also assess flood records on their HADDMS database to determine if measures have reduced the number of incidents at flood hotspots, when these are normalised by rainfall intensity during an incident.



## 3. Assessment of NFM Fund Pilot

### 3.1. Introduction

This section assesses the NFM Pilot implemented in the Irwell and Little Don Focus Areas. For information on the framework under which this Pilot was run refer to section 2.3. A brief description of the implementation of the Pilot is provided in section 2.4.

The assessment is broken down as set out in Table 3-1.

**Table 3-1 - Assessment of NFM Fund Pilot**

Section	Purpose
Effect on flood risk	A simple volume-based assessment of the reduction in runoff generated by NFM measures implemented in the NFM Fund Pilot. Considerations on the context of NFM in flood risk management for the SRN.
Costs	Summary of the implementation costs and Present Value costs (PVC) for implementation of the NFM Pilot.
Flood risk benefits	Assessment of the reduced traffic disruption on the road network resulting from the NFM Fund Pilot.
Co-Benefits	Assessment of the co-benefits generated by measures implemented in the NFM Fund Pilot. Examples include carbon sequestration and biodiversity gain.
Value for money	An assessment of the value for money generated by the NFM Fund Pilot – based on a) cost effectiveness of NFM measures and b) the benefit-cost ratio of the NFM Fund Pilot.
Engagement	A review of engagement activities carried out during the NFM Fund Pilot.
NFM Fund framework	A review of the NFM Fund delivery framework.
Governance	A review of the Governance framework used to manage the NFM Pilot.
Working in partnership	A review of the benefits derived from working in partnership during the NFM Fund Pilot – and the ‘hooks’ that attracted partner organisations to the project.

### 3.2. Effect on flood risk

#### 3.2.1. Introduction

The three areas in which measures were implemented under the NFM Fund Pilot (the Little Don Focus Area together with the Irwell (M62 East) and Irwell M66 (North) Sub Focus Areas) are all in the uplands of north west England. Each area is built up of a series of small catchments that drain often steep hillslopes. The Motorway or Trunk Road on which the flood hotspots are located are typically at the base of the hillslope, close to the valley floor of an arterial river. The vast majority of these sub-catchments have an area of less than 1 km<sup>2</sup> in size. Typically they are between 0.1 km<sup>2</sup> and 0.6 km<sup>2</sup>.

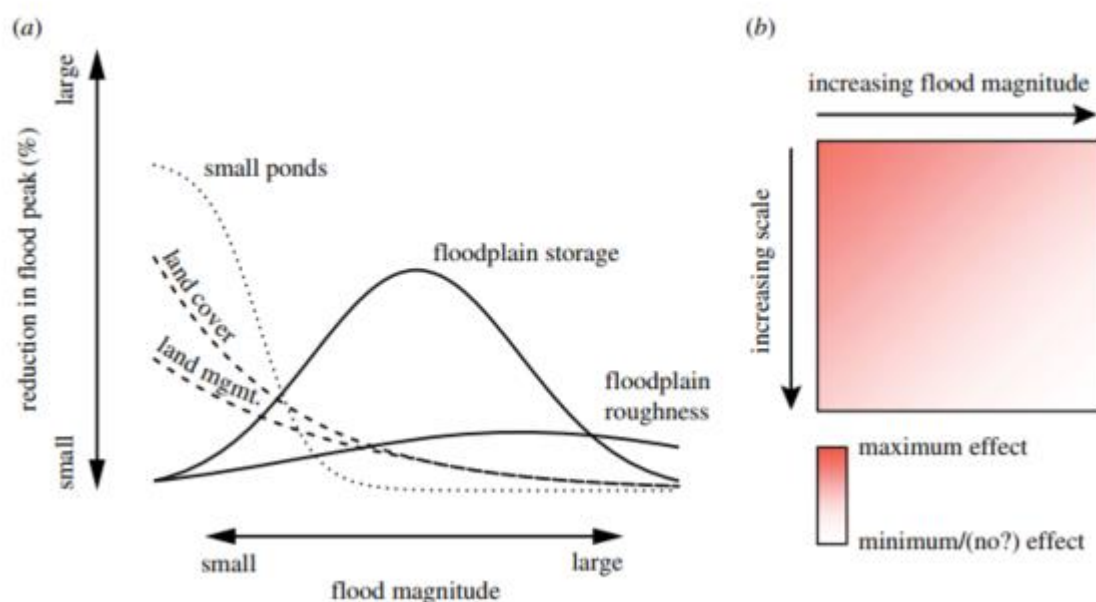
Measures are designed to hold back and temporarily store rainfall in the catchment either on the surface or by infiltrating into the soil, this runoff then makes its way to the watercourse minutes, hours or days later. This reduces the peak level of a flood in most intense rainfall periods. The effect can be modelled by estimating the surface storage provided by a measure or the increase in infiltration rates. Some measures will also reduce flood risk by increasing the roughness of the surface so slowing the rate of runoff without actually storing it, these are more difficult to model as they are dependent on the local conditions.

A useful context for considering the likely effectiveness of measures implemented under the NFM Fund Pilot is a review carried out by recognised leaders in the field of flood risk management (Dadson et al 2017). This identified small ponds, land management (change) and land cover (change) as measures particularly suited to small catchments, such as those in the Focus Areas, particularly for management of low magnitude events (Figure 3-1). Over 95% of the measures implemented in the NFM Fund Pilot fall into these three categories (Table 3-2). There is therefore a sound conceptual basis for the measure types implemented by the NFM Fund

Pilot. If implemented in sufficient density across the Focus Areas they should be effective at reducing flood risk and increasing flood resilience.

**Table 3-2 - Use of measures effective in small catchments in NFM Fund Pilot**

Measure Type (Dadson et al 2017)	Comparable measure type in NFM Fund Pilot	Volume water stored in NFM Pilot (m <sup>3</sup> )
Small ponds	Overland leaky barrier [FR01.1] Flow Pathway bund [FR01.2] Online storage pond [FR02.2]	3896
Land cover (change)	Vegetated Buffer Strips [LM01.1] Cross-slope Woodland & Vegetation [LM01.2]	648
Land management (change)	Reducing Soil Compaction [LM02.1] Mixed Species Herbal Ley [LM02.2]	1782
Total		6292 (>95% of total storage)



**Figure 3-1 –Relative effects of catchment-scale interventions on flood peaks**

Note - Figure a) shows effect of different types of intervention on flood peak reduction b) shows combined effect of catchment based NFM interventions with flood magnitude and catchment scale. Note that the effects achievable in practice will depend on the details of the particular intervention and the context in which it is deployed. From Dadson et al., 2017.

## 3.2.2. Measures implemented in catchments in Focus Areas

### Volume stored by measures implemented in the NFM Fund Pilot

A full summary of the volume of water stored by each measure type implemented in the NFM Fund Pilot is shown in Table 2-1. For storage type features, the physical dimensions available in the design of measures were used to determine storage (e.g. online storage ponds, FR02.2). Volumes associated with other measures, particularly those reliant on a change in infiltration rates (cross-slope woodland & vegetation [LM01.2] and reducing soil compaction [LM02.1]), rely on estimates from NFMStudio based around a 1 in 2 year flood event. Since NFMStudio is a strategic catchment scale modelling tool, there will be uncertainty associated with applying these catchment scale approaches at the 'measure scale'. Also, this pragmatic volume based approach does not explicitly represent the attenuating effect on the runoff hydrograph of the land surface and channels. As a consequence this volume based approach is likely to under-represent the effects of measures such as woodlands, hedgerows and buffer strips. Whilst these measures do store some water, their majority effect on the flood hydrograph can be from the roughening effect they have on the landscape and the resulting attenuation of surface and in-channel flows. We believe that this simplified method is most suited to the kind of near source pluvial flood risk addressed in this pilot, while for catchment wide approaches to address fluvial flooding and floodplain inundation should use models that include 2D overland flow and channel dynamics.

The largest volume of water stored in the Pilot is attributed to online storage ponds (FR02.2) and reducing soil compaction (LM02.1). Reducing soil compaction was effective because it was implemented over a relatively large area (122 ha), Online storage ponds were effective because they were located on a flow pathway and captured a large volume of runoff.

Modest storage volumes were allocated to overland leaky barriers (FR01.1) and cross-slope woodland & vegetation (LM01.2). Both were popular measures and hence implemented at scale.

Relatively small storage volumes were estimated for measures LI01.1, FR01.2, LM01.1 and LM02.2. Only a few of these measures were implemented by the Pilot. The small storage volumes allocated to watercourse features (WC01.1 and WC01.2) are valid (these are estimates of the volume of water in the backwater wedge of these features). However, they are conservative because no account is given to the floodplain storage or attenuation effects generated by these measures.

Note that the estimates for cross-slope woodland & vegetation (LM01.2), vegetated buffer strips (LM01.1) and in channel leaky barriers (WC01.1) were validated (Appendix C.2). Whilst this process did increase volume estimates, the changes were modest. These measures are more reliant on increases in roughness slowing flows rather than creating storage.

### Distribution of measures across the catchments

Measures implemented during the NFM Fund Pilot are not evenly distributed across the Focus Areas.

No measures are implemented in the Etherow Focus Area because insufficient applications to the NFM Fund were made to warrant investment by National Highways in this catchment. The measures that were proposed were considered insufficient to generate any useful change to flood risk at Flood Hotspots on the SRN. No measures were implemented in the Irwell Focus Area (M62 West) or Irwell Focus Area (M66 South) because none of the applications to the NFM Fund satisfied the technical assessment.

Measures were also not evenly distributed across the areas in which implementation did take place (Irwell M62 (East) Sub Focus Area, Irwell M66 (North) Sub Focus Area and Little Don Focus Area (Figure 2-7, Figure 2-8, Figure 2-9). This is because the location of measures was primarily determined by the willingness of landholders to participate in the NFM Fund Pilot.

Measures were most evenly distributed within the Little Don Focus Area, with a reasonable spread in sub-catchments, LD.01, LD.06, LD.08 and LD.10. However, even in this Focus Area, measures are sparse or absent in the remaining seven sub-catchments.

## 3.2.3. Effect of measures on runoff from catchments in Focus Areas

Our assessment of the effectiveness of measures implemented in the NFM Fund Pilot is based around the concept of a target volume of water that measures need to capture to have a useful effect through either a) reduction in flood risk b) increase in flood resilience at hotspots on the road network.

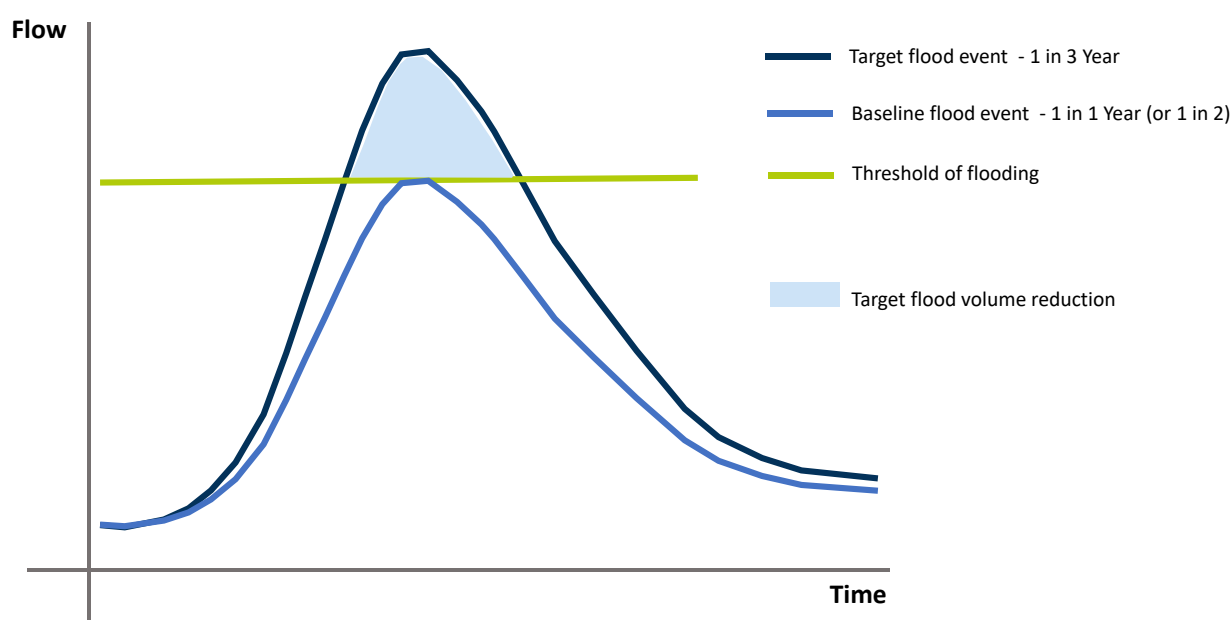
The target was set as the volume of flood water that needed to be stored to achieve an onset of road flooding of once in 3 years. This relatively modest return period goal reflects the likely operational range of NFM measures. We know NFM is most effective in smaller events (section 3.2.1) because measures tend to be

overwhelmed in larger events. We chose once in 3 years as a pragmatic and conservative goal. Note these assumptions were also used in the economic analysis (see section 3.4.2).

Consultation with National Highways' local Operations teams established that flooding of the M62 and M66 currently occurs at least once a year and flooding of the A616 occurs once every couple of years. This information was used to define the current baseline threshold of flooding in each Focus Area. Table 3-3 summarises these target and baseline conditions for each Focus Area in which measures were implemented as part of the Pilot. Figure 3-2 illustrates the target volume as the volume between the current baseline threshold of flooding and the 1 in 3 year hydrograph.

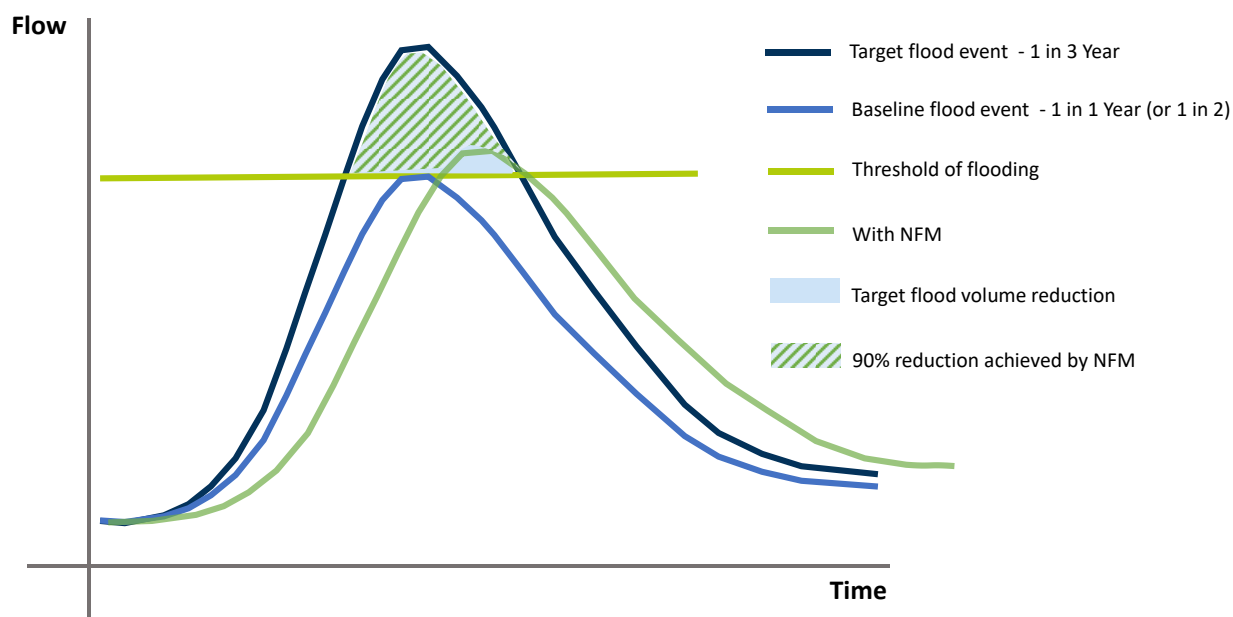
**Table 3-3 – Baseline and Target Events used to estimate target volume**

Location	Baseline flood event / threshold (return period)	Target flood event (return period)
Irwell M62 (East) Sub Focus Area,	1 in 1 year	1 in 3 year
Irwell M66 (North) Sub Focus Area	1 in 1 year	
Little Don Focus Area	1 in 2 year	



**Figure 3-2 – Target flood storage volume estimation**

- The NFM measures implemented in the Pilot will store some of this target volume. Increases in catchment roughness will delay the arrival of the flood peak such that the flood volume will be reduced as illustrated in Figure 3-3 for say a 90% reduction.



**Figure 3-3 – Target flood storage volume achieved with NFM**

A target flood volume was calculated for each sub-catchment in which measures were implemented (locations of these sub-catchments shown in Figure 2-7 onwards). A comparison to the cumulative volume of water estimated to be stored by the measures in each sub-catchment generated the ‘% target flood volume captured’ column in Table 3-4.

We used the ‘% target flood volume captured’ to assess the effect that NFM measures in a sub-catchment had on flood risk and / or flood resilience as follows

- If measures captured more than **75%** of the target flood volume, measures were assessed as having a useful effect on **flood risk**. It would be reasonable to expect a noticeable change in the frequency of road flooding. These are highlighted **green** in Table 3-4.
- If measures captured more than **10%** of the target flood volume, measures were assessed as having a useful effect on **flood resilience**. It would be reasonable to expect less harm to people, less damage and life getting back to normal more quickly as a result of the measures being in place. This can also represent balancing some of the likely impacts of climate change. These are highlighted **orange** in Table 3-4.

This approach is very different from the 2D hydrological and hydrodynamic modelling approaches used in some other NFM studies (e.g. JBA, 2016)<sup>7</sup> which used much larger storms (1 in 10 to 1 in 30 years) to look at reductions in peak stream flow and flood plain inundation levels to assess benefits of NFM. This is because the flood risks at the NH SRN Hot Spots are more related to near source overland flows (pluvial) rather than river levels (fluvial) flooding and on higher return periods. The fluvial flooding models tend to be more sensitive to increases in catchment roughness from large scale tree planting and upland vegetation / peatlands restoration compared to the pluvial storage modelling approach used here.

<sup>7</sup> Rivers Trust Life-IP Natural Course Project: Strategic Investigation of Natural Flood Management in Cumbria  
<https://naturalcourse.co.uk/uploads/2017/04/2016s4667-Rivers-Trust-Life-IP-NFM-Opportunities-Technical-Report-v8.0.pdf>



**Table 3-4 – Estimated reductions in runoff resulting from NFM in sub-catchments**

Sub-catchment	Area of Sub-catchment (km <sup>2</sup> )	Water stored by NFM Measures (m <sup>3</sup> )	Count of Measures in Sub-catchment	Volume over the 1:1 year peak flows (m <sup>3</sup> )	% target flood volume captured
<b><u>Irwell M62(E)</u></b>					
IR.M62(E).02	0.23	975	2	1,246	78.27%
IR.M62(E).03	0.19	75	5	1,013	7.41%
IR.M62(E).06	0.31	34	4	1,684	2.02%
<b><u>Irwell M66(N)</u></b>				<b>Volume over the 1:1 year peak flows (m<sup>3</sup>)</b>	
IR.M66(N).02	1.47	112	11	7,983	1.40%
IR.M66(N).03	0.29	26	5	1,576	1.65%
IR.M66(N).07	0.51	526	22	2,778	18.93%
IR.M66(N).08	1.95	955	16	10,583	9.02%
<b><u>Don</u></b>				<b>Volume over the 1:2 year peak flows (m<sup>3</sup>)</b>	
LD.01	0.41	264	4	1,377	19.17%
LD.02	0.73	14	3	2,442	0.57%
LD.04	0.43	1,187	7	1,445	82.16%
LD.05	0.4	157	3	1,361	11.54%
LD.06	0.23	364	5	781	46.59%
LD.08	0.58	9	9	1,937	0.46%
LD.10	0.89	1,401	14	3,011	46.53%
LD.11	0.85	254	6	2,849	8.91%

Table 3-5 summarises the indicative effect of implementing NFM in the Pilot. It shows the number of sub-catchments in which a reduction in flood risk or increase in flood resilience may result from the implementation of NFM. Field scale monitoring of selected measures is currently being undertaken and records of flooding at hotspots are being maintained with the purpose of verifying this information.

**Table 3-5 – Indicative effect of NFM measures on flood risk and resilience**

	Number of catchments
Reduction in flood risk	2
Improvement in flood resilience	7

### 3.2.4. Integrated flood risk management

Both Rivers Trusts and National Highways' Operations team have pointed out that off-network runoff is unlikely to be the majority contributor to road flooding, even in locations identified as susceptible to this source of flood risk. A key cause of flooding will be issues with drainage infrastructure or maintenance of that infrastructure.

This suggests that the most effective way of managing flood risk to the SRN is an integrated approach in which improvements to the network drainage system are implemented where necessary and NFM is targeted at off-network flood sources where this makes a useful contribution to reducing flood risk or improving flood resilience. This approach requires close collaboration between the people managing the network drainage infrastructure and those siting and developing off network NFM solutions.

### 3.2.5. Key Points

- There is a sound conceptual basis that suggests the measures implemented by the NFM Fund are appropriate and, if implemented in sufficient density across the Focus Areas, should be effective.
- Estimates of volume stored by measures implemented in the Pilot are based on best available information and are considered likely to be conservative.
- We present a quantitative method for assessing a reduction in **flood risk** to the SRN at a sub-catchment scale. A useful reduction in flood risk is achieved when **greater than 75% of a target flood volume is captured by NFM**. The target volume is calculated as the difference between the 1 in 3 year hydrograph and the current (baseline) threshold of flooding on the road.
- A similar approach was used to determine when NFM measures in a sub-catchment were considered to have a useful effect on **flood resilience**: when **greater than 10% of the target flood volume** was captured.
- This simple volume based assessment indicates that storage of flood water by NFM measures has the potential to reduce flood risk in two and increase flood resilience in seven of the 15 sub-catchments in which measures were implemented by the Pilot.
- The practical limitations of a) landholder willingness to participate in the NFM Fund and b) the large number of landholders within each Focus Area has strongly influenced the distribution of implemented measures. Working in catchments in which land is divided into fewer holdings, continuing to target small catchments and potentially being even more specific in which small catchments to target would increase the likelihood of achieving a more even and dense distribution of measures in critical catchments.
- Whilst National Highways' Operations team were regularly involved in the scoping of the Pilot and also took part in the assessment of proposals by landholders, future implementations of the NFM Fund may benefit from closer interaction between Rivers Trusts and Operations teams. Closer cooperation would better use local knowledge when determining where NFM is likely to be useful as a means of managing off network flood sources to reduce flood risk or increase flood resilience at known hotspots on the network. In this way NFM becomes an integrated component of future flood risk management on the SRN.

### 3.3. Costs

#### 3.3.1. Cost of implementing NFM Fund Pilot

A summary of the implementation cost of the NFM Fund Pilot is presented in Table 3-6. The NFM Fund Pilot cost just over £1M, with 60% of this value paid to landholders to plan, implement and maintain measures over a 5 year agreement period and 40% assigned to Rivers Trusts and consultants to manage the implementation of the Fund (as described in 2.4).

Table 2-1 on page 24 provides a breakdown of the landowner element of the implementation costs of the Pilot (planning, implementation [of measures] and maintenance) by NFM measure. Just under half of these costs were allocated to cross-slope woodland and vegetation (LM01.2); just under a quarter on online storage ponds (FR02.2) and 14% on Reducing Soil Compaction (LM02.1). The remaining 14% of costs were distributed amongst the other seven measures taken up by landholders.

The experimental nature and small scale of pilots inflates costs. In the case of the NFM Fund Pilot implementation costs were increased by:

- Inefficiencies associated with doing things for the first time - additional effort applied to developing teams and processes for getting the NFM Fund off the ground in the Focus Areas
- Effort applied to review activities (e.g. workshops to review the success of the Pilot)
- Absence of economies of scale from a small scale implementation
- Limited competition amongst scheme participants on cost (price) - costs were largely determined by recommendations on market rates for materials and labour proposed by Catchment Advisors at the Rivers Trusts.
- Measure selection – some measures were selected for inclusion in the pilot to understand / test their implementation and broaden the range of measures included in the Pilot. Cost effectiveness was not the only driver.

In future applications of the NFM Fund we would expect greater cost efficiencies, with the proportion of cost attributed to scheme management and advice falling and more competitive pricing of measures by participants in the NFM Fund.

**Table 3-6 - Summary of NFM Fund Pilot implementation costs**

Activity	Party	Irwell	Little Don	Total for NFM Pilot	% of Total
Planning, Implementation and Maintenance of Measures	Landholders	£392,022	£259,808	£651,830	60%
Scheme Management	Rivers Trusts	£202,887	£164,113	£367,000	34%
Advice	Consultant	£35,101	£35,101	£70,202	6%
<b>TOTAL</b>		<b>£630,010</b>	<b>£459,022</b>	<b>£1,089,032</b>	

\\WS Atkins.com\Project\GBOXA\Water\Water\WENV\Projects\5158157 HE NFM\7 WIP\Phase 5 - Lessons Learnt and NCA\3. Lessons Learnt\3.4 Reporting\Cost benefit summary v0.1 191022.xlsm

### 3.3.2. Present Value Cost for NFM Fund Pilot measures over 25 years

A Present Value Cost (PVC) for a projected operation of the measures implemented in the NFM Pilot over a 25-year period was calculated for the purposes of economic analysis. This is presented in Table 3-7, broken down by measure/activity. It is also presented in section 3.6.2 (Table 3-10), broken down by geographical unit.

**Table 3-7 - 25 year Present Value Cost of NFM Pilot, by NFM measure / activity**

Activity or Measure	Total (£)
NFM Fund Management (Rivers Trusts)	367,000
Technical Advice	70,202
FR01.1 Overland leaky barrier	63,380
FR01.2 Flow Pathway bund	3,033
FR02.2 Online storage pond	223,507
LI01.1 Landowner Innovation	3,575
LM01.1 Vegetated Buffer Strips	44,304
LM01.2 Cross-slope Woodland & Vegetation	327,898
LM02.1 Reducing Soil Compaction	311,342
LM02.2 Mixed Species Herbal Ley	36,518
WC01.1 In-channel Leaky Barriers	37,529
WC01.2 Headwater Woody Bundles	10,029
Sub Total (Measure implementation, excluding management and technical advice costs)	1,061,116
Total	1,498,318

Calculation of PVC assumed the following:

- **Year 0** - Cost of scheme setup (Rivers Trusts and Atkins). Planning activities (e.g. design and consenting) by landholders. Implementation costs for all measures. Up-front payment to landholders covering 5 years for maintenance.
- **Year 5** - No scheme setup or planning costs. Repeat implementation of operational measures (buffer strips, reducing soil compaction and herbal leys). Up-front payment to landowners covering 5 years for maintenance.
- **Year 10** - as Year 5
- **Year 15** - No scheme setup or planning costs. Repeat implementation of operational measures (buffer strips, reducing soil compaction and herbal leys). Replacement of overland leaky barriers. Up-front payment to landowners covering 5 years for maintenance.
- **Year 20** - as Year 5
- Note woodland and storage ponds both assumed to have at least 25 year design life.
- Start-up cost distributed by area (total area of sub-catchments in which measures were implemented).

The PVC for operating the measures implemented by the NFM Fund Pilot are presented in Table 3-10. The PVC is presented for various geographical scales, ranging from the Pilot as a single unit down to sub-catchment.

### 3.3.3. Key points

- The pilot nature of the project will have substantially inflated costs. Lower overhead costs associated with economies of scale, more targeted application of measures and increased competition amongst applicants all have potential to reduce the unit cost of future roll outs of the NFM Fund.

## 3.4. Flood risk benefits

### 3.4.1. Approach

The benefits of implementing NFM to management of flood risk on the SRN were assessed using a simplified 'avoided disruption cost' approach developed by WEBTAG (Department for Transport, 2021). This approach attributes a monetary value to disruption in traffic flow caused by flooding of a road. The monetary value attributed to reduced disruption resulting from a flood risk management measure is taken as a benefit.

A two-step approach has been applied to calculating the 'avoided disruption cost' of the NFM Fund Pilot:

- First, we have undertaken an assessment for an 'at scale' implementation of NFM. This step is summarised in section 3.4.2 below and is described more fully in Appendix A.
- Second, we have scaled the benefit value attributed to the 'at scale' implementation to represent the benefits generated by the measures implemented in the NFM Fund Pilot. This scaling is necessary because the Pilot was not a full scale implementation of NFM. Our approach to this scaling is set out in section 3.4.3.

### 3.4.2. Flood risk benefits generated by 'at scale' implementation of NFM

We applied the WEBTAG approach to the Irwell Sub Focus Areas M66 (North) and M62 (East) and the A616 adjacent to the Little Don Focus Area (see Figure 2-2).<sup>8</sup> We assumed NFM measures could be applied at a sufficient scale across these three areas to change the onset of flooding on the

- M62 and M66 Irwell from once every year to once every 2 years
- A616 Little Don from once every 2 years to once every 3 years

Note that these are the same basic assumptions used to calculate target flood volumes in the runoff calculations presented in section 3.2.3. The summary results of this assessment are presented in Table 3-8. These are quoted as a Present Value benefits (PVb) for a 25-year evaluation period.

This 'at scale' implementation of NFM is greater than that achieved in the NFM Fund Pilot. Further scaling is required to generate benefits attributable to the Pilot. This second stage of assessment is set out in section 3.4.3 below.

**Table 3-8 – Estimated benefit of reduced traffic disruption ('at scale' implementation)**

Road	Focus area	Benefit (£ PVb, discounted over 25 years)
M62	Irwell (M62 East)	£1,065,200
M66	Irwell (M66 North)	£10,302,700
A616	Little Don	£89,000

### 3.4.3. Flood risk benefits generated by NFM Fund Pilot

To scale the benefit value (PVb) attributed to the 'at scale' implementation to represent the benefits generated by the NFM measures implemented in the Pilot we have undertaken another two-step analysis

- First, the PVb values presented in Table 3-8 have been distributed amongst their constituent sub-catchments in proportion to the area of each sub-catchment
- Second, the PVb value for each sub-catchment has been scaled based on the effectiveness of NFM measures in that sub-catchment. This effectiveness is taken to be directly proportionate to the '% of target flood volume captured' reported in Table 3-4. In sub-catchments where NFM measures capture all the

<sup>8</sup> Assessments were not made for the Etherow Focus Area or for Irwell Focus Areas M66 (South) and M62 (West) because no measures were implemented in these areas.



runoff needed to deliver the target change in the frequency of onset of flooding it is reasonable to assume that the total flood risk benefit for that sub-catchment will be realised. In sub-catchments where NFM measures capture less than the target volume, the benefit is attributed based on the proportion of runoff captured.

The PVb calculated from this analysis is presented in Table 3-10. This PVb is presented for various geographical scales, ranging from the Pilot as a single unit down to individual sub-catchments.

### 3.4.4. Key points

- The benefits of implementing NFM to manage flood risk to the SRN was assessed using a simplified 'avoided disruption cost' approach based on conservative assumptions.
- Our assessment of an 'at scale' implementation of NFM generates benefits orders of magnitude different between the three Focus Areas where measures were implemented. This substantial difference comes about because of differences in the number of vehicles that use each road and the length of diversion required (particularly for HGVs). The high benefit estimated for the Irwell (M66 North) results from a very busy motorway and long diversion route for HGVs. The substantially lower benefit for the A616 is because this road is a much less busy single carriageway trunk road.

## 3.5. Co Benefits

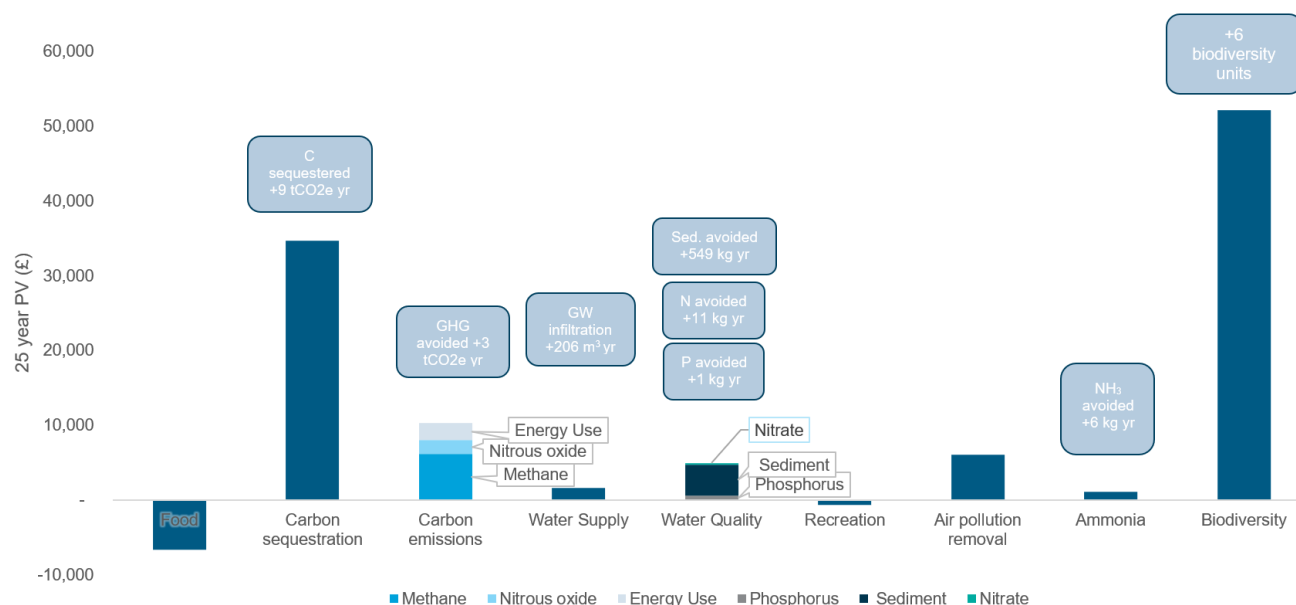
### 3.5.1. Background

Whilst the primary aim of the NFM Fund is to reduce flood risk, measures benefit other ecosystem services (benefits provided to people by the natural environment) such as biodiversity, climate regulation (for instance through natural carbon sequestration, air quality, water supply and water quality. Establishing the value of these benefits demonstrates the wider contribution of the Pilot NFM Fund. It could also unlock co-funding within National Highways, particularly from biodiversity and carbon sequestration interests. Partnership funding of co-benefits from interests outside of National Highways is also possible.

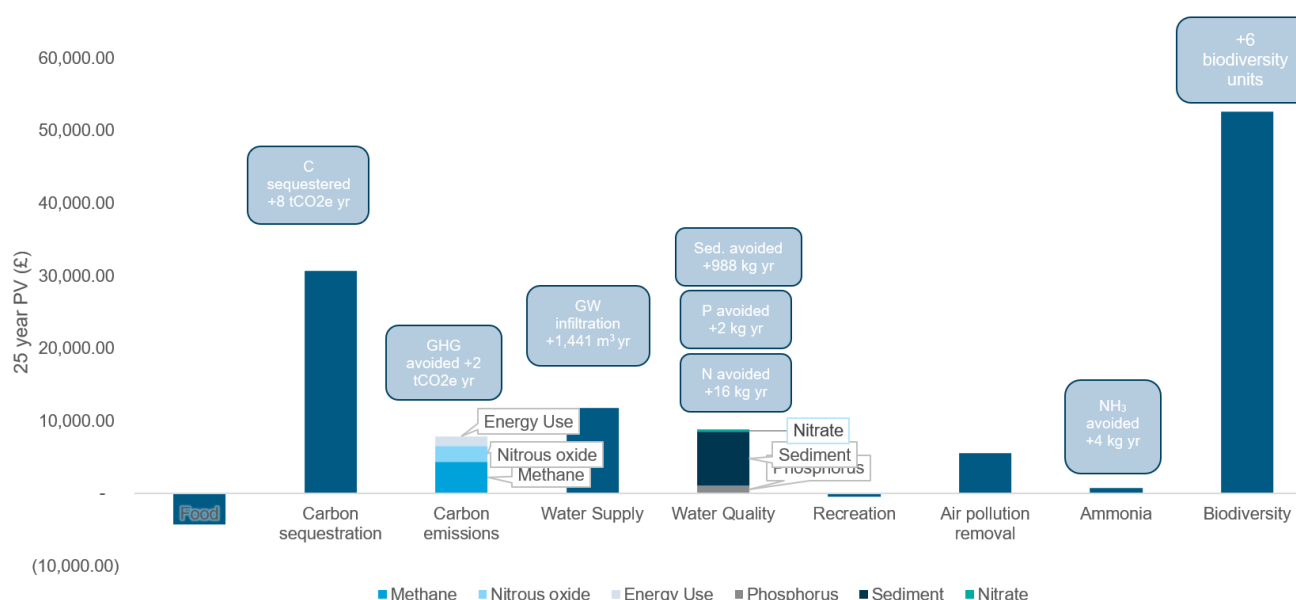
Assessment of these ecosystem services was undertaken using Atkins' rapid valuation tool, Natural Capital Studio (NCS). The tool is aligned with latest best practice and industry guidance, and uses a value transfer approach, adopting estimates from other sites as reported in authoritative government datasets and scientific literature. Combined with GIS mapping and site-specific data provided by National Highways, ecosystem services were quantified to compare pre- and post-scheme land management scenarios. Further details on the assessment (and insight into the potential value of co-benefits for wider roll out of NFM) can be found in Appendix B.

### 3.5.2. Results

Even at the relatively small-scale of the NFM Fund Pilot, the enhancement of natural capital achieved by NFM measures would provide **co-benefits of £103,524 in present value over 25 years for the Irwell Focus Area, and £113,309 in present value over 25 years for the Little Don Focus Area.**



**Figure 3-4 – Irwell– 25 Year PV impact of the change in ecosystem service provision**



**Figure 3-5 – Little Don– 25 Year PV impact of the change in ecosystem service provision**

### 3.5.3. Interpretation

The largest estimated increase comes from the climate regulation service, due to increased sequestration of carbon in cross-slope woodland and hedgerow measures relative to the semi-improved grassland baseline. Specifically, we predict a net annual carbon sequestration increase of 9 tCO<sub>2</sub>e in the Irwell and 8 tCO<sub>2</sub>e in the Little Don. Additional value comes from reductions to greenhouse gas emissions (methane, nitrous oxide, and carbon dioxide), and water pollutant loading relative to the previous agricultural land use. The increase in tree cover would also add value by increasing absorption of long-range air pollutants. We also predict an increase in biodiversity value as measured in Biodiversity Units post the interventions. Across the Irwell, 6 additional biodiversity habitat units would be created, as well the creation of 23 biodiversity hedgerow units. In the Little Don, we also estimate 6 additional biodiversity habitat units and the creation of 3 new biodiversity hedgerow units. Note that the monetised value for co-benefits (section 3.5.2) includes a monetary value for Biodiversity Habitat units, but not hedgerow units).

The environmental gains predicted, including the carbon sequestration and Biodiversity Units increases, are estimations and would need habitat survey and further ground-truthing to verify against carbon and biodiversity

market standards. However, the predictions are encouraging and demonstrate that NFM measures implemented by National Highways have potential to deliver Biodiversity Net Gain (BNG) and contribute to Net Zero ambitions.

### 3.5.4. Key points

- Co-benefits generated by NFM measures implemented in the NFM Fund Pilot are significant when compared to the flood risk benefits. In the Irwell Focus Area monetised co-benefits are 25% of flood risk benefits. In the Little Don Focus Area monetised co-benefits are 720% of flood risk benefits.
- The Present Value of monetised co-benefits generated by measures in the NFM Fund Pilot indicate that co-benefits represent a
  - 25% of the Present Value estimates estimated for the Irwell Focus Areas
  - Three times greater than the flood risk benefits generated for the Little Don Focus Area
- Carbon sequestration and biodiversity are the most substantial co-benefits generated by the NFM Fund Pilot. These predictions demonstrate that NFM measures implemented by National Highways have potential to deliver Biodiversity Net Gain (BNG) and contribute to the organisation's Net Zero ambitions.
- The methodology presented is for the quantification of co-benefits using a Natural Capital Accounting framework. The landowners themselves may assign greater co-benefits to certain measures for improvement of their landscape or providing improved recreational potential for their land which is not fully captured in the Natural Capital tools. There is evidence of this in the high levels of applications for cross slope woodlands and hedgerows, despite these having lower NFM benefit by the measures used for this pilot.
- Measures implemented in the NFM Fund Pilot were principally designed for flood risk management function. Less attention was given to the function of co-benefits. There is potential to optimise the design of measures across a wider range of functions.

## 3.6. Value for money

### 3.6.1. Cost effectiveness

#### Introduction

Cost effectiveness of NFM measures has been calculated as the average 25 year Present Value Cost (PVC) of storing a cubic metre of water by measure type. This £/m<sup>3</sup> of water storage metric is used as one way of assessing the value for money of measures implemented as part of the NFM Fund Pilot. Its typically used to compare value for money across measure types.

This section is a discussion of the cost effectiveness of measures implemented in the NFM Fund Pilot. It looks at the cost effectiveness of the Pilot from various perspectives:

- As a comparison to the cost effectiveness of traditional small scale flood storage schemes
- Comparing cost effectiveness of different measure types
  - implemented across the NFM Fund Pilot
  - between Focus Areas

Table 3-9 provides a summary of the cost effectiveness of measure types implemented in the NFM Fund Pilot, together with a short commentary and useful contextual information.

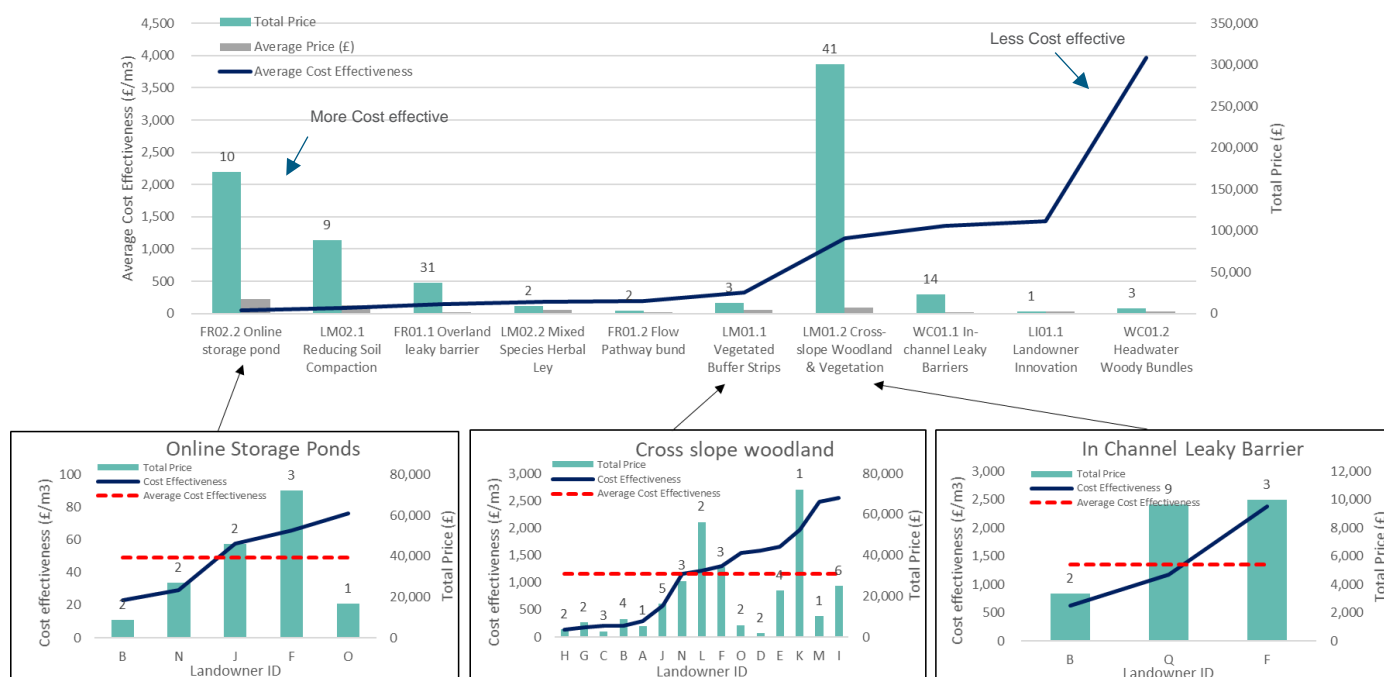
#### Comparing cost effectiveness of the NFM Fund Pilot and traditional small scale flood storage schemes

Assuming comparable asset lives (25 years) the cost effectiveness of the NFM Fund Pilot compares favourably to that of a typical small scale traditional flood storage scheme (e.g. a flood retention pond or embankment). The Present Value Cost (PVC) of implementing, replacing and maintaining measures funded by the NFM Fund Pilot over 25 years is estimated as £1.061M (Table 3-7). These measures are estimated to store 6,354 m<sup>3</sup> of flood water (Table 2-1). This gives the NFM Fund Pilot as a whole a cost effectiveness of £166/m<sup>3</sup>. Typically small scale traditional flood storage schemes have a capital (implementation) cost of between £280 and £470 per m<sup>3</sup> water stored (Environment Agency, 2015).

#### Comparing cost effectiveness of different measure types implemented by the NFM Fund Pilot

This comparison (and all subsequent comparisons in this section) is made based on the implementation cost of measures by the NFM Fund Pilot (£651,830) and the estimated volume of water they stored (6, 354 m<sup>3</sup>).

The upper panel of Figure 3-6 compares the cost effectiveness of the measure groups implemented by the NFM Fund Pilot. It also compares total and average price (cost to National Highways) of the groups. The lower three panels examine the cost effectiveness of implementations by individual landholders for three of the measure groups.



**Figure 3-6 – Cost effectiveness comparison between and within NFM measure types**

Lines represent the cost effectiveness and bars the total and average spend by National Highways on each measure type. The higher lines represent lower cost effectiveness - as the measures were more expensive to store each m<sup>3</sup>.

Comparison of cost effectiveness between the measure types allows for some patterns to be drawn out from the data.

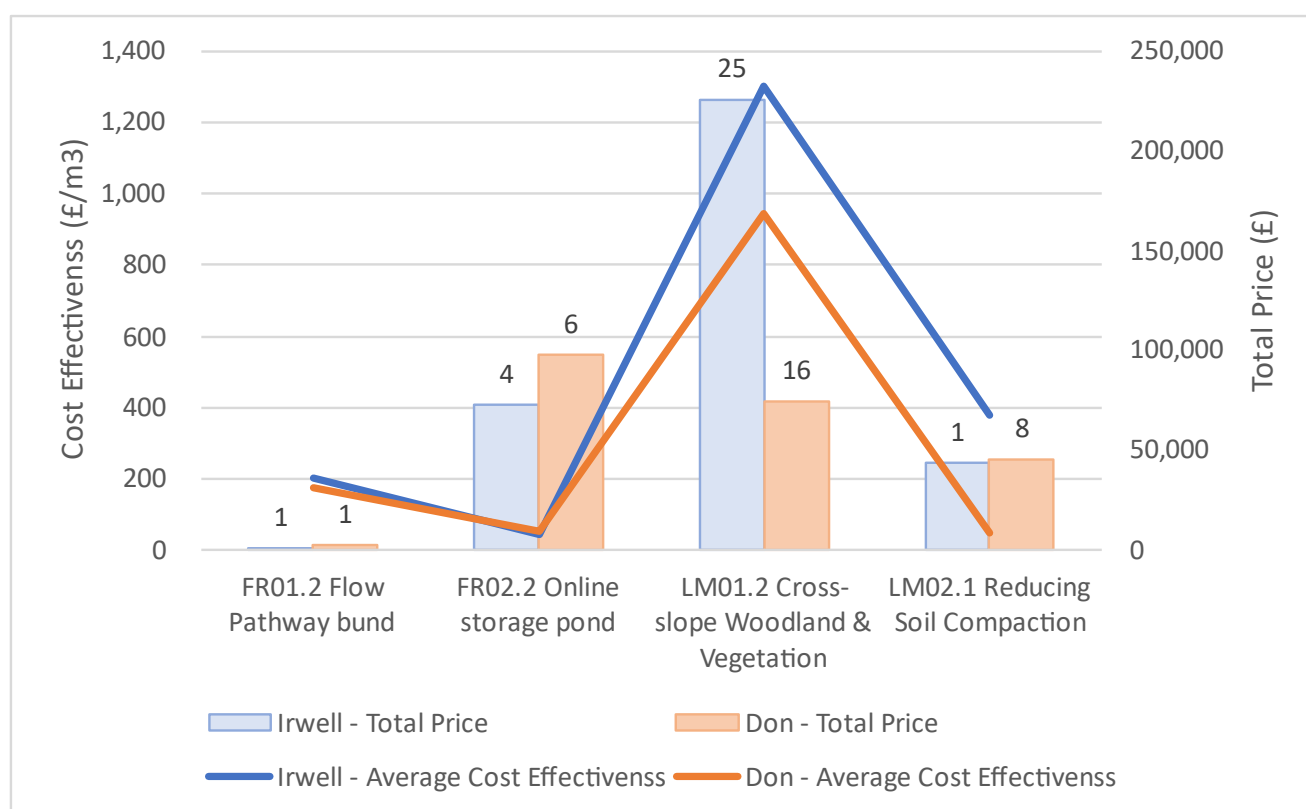
- With the notable exception of cross-slope woodland & vegetation (LM01.2), total spending on measures decreases as they become less cost effective. This suggests that the auction and technical review generally functioned to fund the measures that provided the most benefit to National Highways. Cross-slope woodland was by far the most popular measures: 68 applications were made of which only 41 were accepted for funding. So, in part, the high uptake of this measure is simply a result of its popularity amongst landholders. The relatively low cost effectiveness of cross-slope woodland is attributed to a) the comprehensive specification required to ensure trees established (e.g. fencing) (National Highways, 2021b); b) potentially conservative assumptions used to estimate the volume of water stored by this measure and c) recognition of the wider benefits woodland provides within the landscape, particularly as a habitat and a connection between habitats (see Section 3.5).
- The average price for each measure awarded to individual landholders (grey bars) is fairly consistent across all the measure types, indicating that there were no large outliers in the prices accepted and funding awarded. However, the cost of each application was an element of the technical assessment, which was scored against the outline costs provided in the design specification documents. Any overpriced applications were likely to have been screened out during that technical assessment stage.
- The lower cost effectiveness of the in-channel measures<sup>9</sup> is not a true reflection of the value of this measure type. It is largely explained by the uncertainties and conservative modelling approach applied in the project. This has resulted in the volumetric benefit of this measure type being undervalued, partly due to the function of in-channel barriers being to attenuate and slow flows rather than store water.
- The measure type to rank the most cost effective was the online storage pond (FR02.2). This assessment was driven by the storage efficiency of this measure type. In the Irwell in particular, measures funded effectively used local expertise to identify efficient options which adapted existing features to provide greater storage potential.
- Reducing soil compaction (LM02.1) is also reported as particularly cost effective. This measure increases infiltration to ground and the volume of water stored in the soil. Although the measure only captures a small

<sup>9</sup> In-channel leaky barriers (WC01.1) and Headwater woody bundles (WC01.2).



volume of water per unit area, it is applied across a large area, generating a useful large volume of storage efficiently.

The three graphs in the lower panel of Figure 3-6 break down the cost effectiveness assessment of three measure types by individual applications. These plots indicate that cost effectiveness ranged quite widely between applications – most often because of local circumstances. Individual landholders able to achieve greatest value for money are those that have a lower line, indicating being more cost effective, as well as a high total price bar, indicating that more money was spent on the most cost-effective measures, as is the case for some of the landholders who were awarded funding for cross-slope woodland and in channel leaky barrier measures.



**Figure 3-7 – Comparison of cost effectiveness of measures funded in both catchments**

Lines represent the cost effectiveness and the bars the total spend.

### Comparing cost effectiveness of different measure types between Focus Areas

From the inter-catchment comparison shown in Figure 3-7 we can see that cross-slope woodland was the most popular measure in both catchments. The cross-slope woodland funded in the Don catchment was marginally more cost effective, likely due to local circumstances and possibly more competitive contractor prices for fencing.

In the Don catchment the most funded measure in monetary terms was online storage ponds, despite it not being the most popular measure. Whereas in the Irwell the most funded measure was cross-slope woodland.

The landowner innovation measure type was included in the NFM Fund Pilot to give landholders the opportunity to propose innovative practice and measures for implementation as part of the Pilot. All applications of these measure types underwent technical review. There was only one landholder innovation measure awarded funding. This was in the Little Don Focus Area. This innovative measure was designed to remove cattle from accessing the riverbank to allow for restoration of the riverbank and regenerative land management, alongside the implementation of solar powered water pumps and drinking troughs to provide an alternative drinking source for the livestock. Overall, this measure type ranked second least cost effective. However, this is not unsurprising given the cost of capital items for this measure and being the only measure in this category.

The high uptake of cross slope woodlands and was driven by these being the most popular measure with landowners. They are clearly seen as providing significant benefits to the landowner in addition to their NFM function.

**Table 3-9 - Summary of cost effectiveness of measure types implemented in Pilot**

Measure Type	Count of Measures	25-yr Present Value Cost (£)	Implementation costs (%)	Total Water Stored (m³) *	Asset Life **	Time to effectiveness	Average Cost effectiveness (£ / m³)	Comment
FR02.2 Online storage pond	10	223,507	71%	3540	10 years	Immediately	63	High cost effectiveness is driven by high storage volumes, despite high costs
LM02.1 Reducing Soil Compaction	9	311,342	86%	1724	2–3 years	Immediately	181	High water storage as implemented over a large area (122 ha), however is a measure type that has to be repeated every 2–3 years
FR01.2 Flow Pathway bund	2	3,033	97%	16	30 years	Immediately	185	Medium cost effectiveness linked to relatively high industry standard costs for the capital items for this measure, however despite high upfront costs this measure type has a long lifetime and produces lots of co-benefits
FR01.1 Overland leaky barrier	31	63,380	90%	340	5–10 years	Immediately	186	Cost effectiveness is driven by the low cost of these measures
LM01.2 Cross-slope Woodland & Vegetation	41	327,898	94%	613	20 years	5–30 years	535	Mid-range cost effectiveness due to moderate costs and water storage
LM02.2 Mixed Species Herbal Ley	2	36,518	100%	57	4 years	Immediately	637	
LM01.1 Vegetated Buffer Strips	3	44,304	88%	41	3–5 years	Immediately	1,074	
WC01.1 In-channel Leaky Barriers	14	37,529	54%	19	5–10 years	Immediately	2,004	Conservative modelling approach and primary function of attenuation results in a lower water storage volume which drives lower cost effectiveness
LI01.1 Landowner Innovation	1	3,575	67%	2	-	Immediately	2,265	Bank restoration through the implementation of cross-slope woodland for the exclusion of livestock
WC01.2 Headwater Woody Bundles	3	10,029	43%	2	5 years	Immediately	5,492	Low cost effectiveness is driven by conservative approach to estimating the volume of water stored by these measure types

\* Greyed cells present the measures that the volume stored is based on a conservative modelling approach

\*\* Taken from the measure specification document (National Highways, 2021b)

### 3.6.2. Benefit – cost

Monetised flood risk benefits and costs of the NFM Fund Pilot are compared in Table 3-10. These are shown as Present Values (PVb) and Present Value Costs (PVc) over 25 years. The benefits (PVb) do not include the co-benefits presented in section 3.5.

The comparisons are made at various geographical scales (Whole Pilot Area, Focus Areas, Sub Focus Areas and sub-catchments). At each of these scales only the geographical units in which measures were implemented by the NFM Fund Pilot are compared (for information, these areas are shown as green in Table 3-11).

Key assumptions and the approaches to calculating the streams that generate PVb and PVc can be found in sections 3.3.2 and 3.4.3.

**Table 3-10 – Comparison of 25 year Present Value Benefits and Costs for Pilot**

Geographical unit	Name / Code	Present Value (PVb) (£)	Present Value Cost (PVc) (£)	Benefit-Cost Ratio
Whole Pilot Area	Whole Pilot	426,485	1,498,318	<b>0.28</b>
Focus Area	Irwell	410,763	683,878	<b>0.60</b>
	Little Don	15,721	814,440	<b>0.02</b>
Sub-Focus Area	M62 (East)	179,319	121,424	<b>1.48</b>
	M66 (North)	231,444	562,454	<b>0.41</b>
Sub-catchment	IR.M62(E).02	161,277	55,315	<b>2.92</b>
	IR.M62(E).03	12,414	39,320	<b>0.32</b>
	IR.M62(E).06	5,628	26,788	<b>0.21</b>
	IR.M66(N).02	15,984	132,530	<b>0.12</b>
	IR.M66(N).03	3,719	23,652	<b>0.16</b>
	IR.M66(N).07	75,220	148,171	<b>0.51</b>
	IR.M66(N).08	136,520	258,101	<b>0.53</b>
	LD.01	1,137	52,700	<b>0.02</b>
	LD.02	60	44,181	<b>0.00</b>
	LD.04	5,113	114,288	<b>0.04</b>
	LD.05	676	77,765	<b>0.01</b>
	LD.06	1,568	92,558	<b>0.02</b>
	LD.08	38	50,661	<b>0.00</b>
	LD.10	6,035	307,063	<b>0.02</b>
	LD.11	1,094	75,225	<b>0.01</b>

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Commentary on the benefit-cost ratios presented in Table 3-10 is provided below

- The high benefit-cost ratios for the Irwell M62 East Sub Focus Area are driven by a) a substantial benefit value attributed to the hotspots on the M62 (c. £1M) b) a reasonable proportion of target runoff being captured by measures and c) a single very cost effective implementation of storage ponds within sub-catchment IR.M62(E).02.
- The benefit attributable to the Irwell M66 North Sub Focus Area is very high (c £10M). However, the benefit-cost ratios for this geographical area are pulled down below one by a combination of a) a very low proportion of target runoff being captured by measures and b) measures with a relatively high cost.

- Very low benefit-cost ratios for the Little Don Focus Area and all of its sub-catchments are driven by a very low flood risk benefit value derived for the hotspots on the A616 (< £100,000).
- Benefit-cost ratios at the Focus Area and Whole Pilot Area scales are products of the factors set out in the above bullets.
- The above benefit-cost ratios do not account for the co-benefits generated by NFM measures.

**Table 3-11 - Geographical areas in which measures implemented in Pilot**

Whole Pilot	Focus Areas	Sub-Focus Areas	Sub-catchments
✓ Whole Pilot	✗ Etherow	✗ Etherow	ET.01 ✗
	✓ Irwell	✓ Irwell M62 (East)	IR.M62(E).01 ✗
			IR.M62(E).02 ✓
			IR.M62(E).03 ✓
			IR.M62(E).04 ✗
			IR.M62(E).05 ✗
			IR.M62(E).06 ✓
		✗ Irwell M62 (West)	IR.M62(W).01 ✗
		✓ Irwell M66 (North)	IR.M66(N).01 ✓
			IR.M66(N).02 ✓
			IR.M66(N).03 ✓
			IR.M66(N).04 ✗
			IR.M66(N).05 ✗
			IR.M66(N).06 ✓
			IR.M66(N).07 ✓
			IR.M66(N).08 ✓
		✗ Irwell M66 (South)	IR.M66(S).01 ✗
	✓ Little Don	✓ Little Don	LD.01 ✓
			LD.02 ✓
			LD.03 ✗
			LD.04 ✓
			LD.05 ✓
			LD.06 ✓
			LD.07 ✗
			LD.08 ✓
			LD.09 ✗
			LD.10 ✓
			LD.11 ✓



### 3.6.3. Key points

- Cost effectiveness of the NFM Fund Pilot compares favourably to that of a typical small scale traditional flood storage scheme. Measures implemented in the Pilot are estimated to have an average cost effectiveness of £166/m<sup>3</sup>, calculated from a 25 year Present Value Cost (PVC). Typically small scale traditional flood storage schemes with comparable design lives have a capital (implementation) cost of between £280 and £470 per m<sup>3</sup> water stored.
- The most cost effective measures implemented by the Pilot NFM Fund were online storage pond (FR02.2) (£63/m<sup>3</sup>) and reducing soil compaction (LM02.1) (£181/m<sup>3</sup>). Ponds are a very efficient way of storing large volumes of water. Soil decompaction applied to a large area will cumulatively capture a lot of flood water.
- In channel measures were calculated as least cost effective. This is largely explained by the conservative modelling approach applied to these features in the project. Their effect on flood risk was simply represented as the volume of channel within the backwater of a feature. This pragmatic approach does not account for their effect on floodplain storage or attenuation of flood flows and how that may impact flood risk on the SRN.
- The cost effectiveness of the most popular measure of the NFM Fund Pilot (cross-slope woodland & vegetation, LM01.2) was calculated at around £535/m<sup>3</sup> (i.e. less cost effective than a small traditional engineering scheme). This may in part be explained by relatively conservative assumptions used when modelling the runoff captured by these measures. High implementation costs definitely had a role. Note that woodland provided the highest co-benefit value of all measures implemented under the Pilot, which will offset some of the high implementation cost.
- Benefit-cost ratios have been calculated across various geographical scales. These only account for flood risk benefits and do not include monetised values for co-benefits (e.g. carbon sequestration). Overall, the NFM Fund Pilot generated a benefit-cost ratio of 0.3. There was considerable variation across the scheme, with some sub-catchments generating benefit-cost ratios around 3 and others generating ratios of close to zero. Key reasons for these differences included a) the 'order of magnitude' (c. £10M, c. £1M and c. £100k) difference in flood risk benefits attributed to each of the Sub Focus Areas; b) the variation in cumulative runoff capture across sub-catchments (used as a scaling factor for attributing benefits to sub-catchments) and c) substantial variation in the cost effectiveness of measures.
- The low overall benefit-cost ratio and variation in benefit-cost ratios across sub-catchments must be considered in the context of the pilot nature of this project. Lessons learnt during implementation of the Pilot can be used to target catchments and measures more effectively. Substantial increases to the value for money NFM delivers to National Highways are very achievable at larger scales of implementation.

## 3.7. Engagement

### 3.7.1. Introduction

Connecting with stakeholders and building relationships was a vital component of the NFM Fund Pilot. It informed selection of Pilot Catchments and Focus Areas. Critically it facilitated the implementation of NFM measures on third party land not owned by National Highways. In addition, engagement was a vehicle for collaboration within National Highways, bringing teams together to address flood risk issues and laying the ground for future potential collaborations.

This section sets out key lessons learnt about engagement on the project.

### 3.7.2. Within National Highways

The Pilot project team engaged with National Highways Operations team during the scoping assessment, opportunity assessment and implementation phases of the project. The Operations team were a highly knowledgeable source of information on flood risk to the local road network, particularly those who had been responsible for the same part of the network for many years. Operations teams were also interested in the potential of NFM as a complementary tool for management of flood risk. The knowledge and opinion of the Operations team strongly influenced the selection of Focus Areas and supported decisions on which measures to implement as part of the NFM Fund Pilot.

Four key lessons were learnt.

- Earlier engagement with the Operations team in the scoping assessment and opportunity assessment would have identified Pilot catchments more efficiently (and the same would be true if additional catchments are brought into the project in the future).
- Closer collaboration between the National Highways Operations team and River Trust Catchment Advisor during the period when landholders were being engaged and measures located would have allowed more effective siting of measures and ensured a more focussed approach to engagement (Catchment Advisors would have been able to work upslope from particular flood issues identified by the Operations team).
- A working collaboration between the Operations team and Catchment Advisors is also likely to lead to true integration of hard and NFM based flood risk management solutions for the network.
- The information on flood risk generated by surface water on HADDMS, a database of National Highways assets, was of variable quality. A standard of service for reporting of surface water runoff in HADMS may address this issue

### 3.7.3. With Landholders

#### A single point of contact

A consistent single point of contact is essential to engagement. For the NFM Fund Pilot this was a Rivers Trust Catchment Advisor. The advisor needs to be easy to get hold of and, ideally, quick to respond. Simple things, like providing a phone number and name, can make the difference between a potential participant responding to or ignoring a letter or flyer.

The Catchment Advisor must be knowledgeable about NFM but also local farming and land management systems. This will allow them to give sound advice on how to integrate NFM into a farming business as well as the landscape. The advisor needs to inspire confidence amongst landholders that NFM measures are useful to their farming systems and will serve the wider community through flood management and provision of wider ecosystem services.

Whilst a wide range of measures were implemented in both the Irwell and Little Don Focus Areas, the emphasis of the measures selected did reflect the specialisms of the advisors in both catchments. As an example, far more soil management measures were implemented in the Little Don and more cross-slope woodland in the Irwell. Whilst the single point of contact is the “friendly face” of a scheme, they need access to technical support and a sounding board for their ideas to ensure the opportunities for NFM on a holding are most effectively exploited. This peer support could come from other Catchment Advisors, the Umbrella Rivers Trust organisation or technical consultants.

### Building relationships

It takes time to build relationships with landholders. The credibility of the NFM Fund amongst local farmers was enhanced by the involvement of local Rivers Trusts in the project because this allowed the NFM Fund to “piggy back” on existing relationships in the catchment between landholders and a trusted organisation. However, it still takes time to establish a working relationship with individual landholders, who will need time to consider what the NFM Fund can do for their landholding and business. Face to face meetings, particularly site visits were vital in building this rapport and developing an effective package of NFM measures for a holding. More than one face to face contact is very often needed.

### Recognise that every person and business is different

Everyone is different and no two land holding businesses are the same. Engagement approaches and expectations need to be tailored to reflect this.

Early adopters of the NFM Fund in the Pilot tended to be agile small holdings and progressive larger landholders with a strong interest in environmental sustainability. Often, they came from younger generations. More conventional farmers were often slower to respond or didn't take up the NFM Fund in either of the two auction rounds. In most catchments or areas there will be landholders who are held in particular respect by other farmers. Identifying these key influencers, and investing effort in working to implement measures on their land, is likely to encourage others to take up the scheme.

None of the larger non-agricultural landholders (e.g. water companies and quarrying businesses) took up the NFM Fund in either catchment. This was because the timeframes of the NFM Fund did not align with their business and project cycles. They could not develop a proposal within the relatively short time period the NFM Fund was available. This missed significant opportunities on large landholdings within the Focus Areas. If the NFM Fund is to be run again in the future long lead times on engagement is required with these organisations.

### Keep the scheme simple and make it attractive to participants

A simple scheme process with terms that favour participants makes uptake more likely. Short ‘bite size’ scheme resources based on examples were also favoured by participants. Some of the NFM Fund resources were considered too wordy by landholders – in particular the design specifications.

Payment terms that avoided long periods of negative cashflow for participants made the NFM Fund much more attractive. The absence of a performance based specification also made the NFM Fund Pilot much more appealing. Participants were only required to meet a physical specification (National Highways, 2021b), and were not responsible for whether measures reduced flood risk).

### Have examples and data to hand to demonstrate how and why measures work

Farmers are inherently practical people. Many have a scientific background. As a group they tend to respond well to real world examples and evidence-based approaches. They are more likely to adopt a measure if they can see it has worked elsewhere. Short, visual, example based documents are often the most effective ways of engaging with this community on paper. Workshops and site visits to places where measures have already been implemented or equipment can be seen operating also tend to be an effective engagement approach.

## 3.7.4. With the wider stakeholder community

The NFM Fund Pilot is part of a wider NFM and catchment-based stakeholder community. The catchment and thematic members of this community are summarised in section 1.3.5.

There has been engagement with many of these organisations during the NFM Pilot, by both National Highways and Rivers Trusts, to share learnings on technical detail, the form and geographical location of the Pilot NFM Fund, and the future direction of the Pilot.

Wider roll out of the NFM Fund, in whatever form it takes, will benefit from continued engagement with the wider stakeholder community and potentially strategic alliances with catchment partners (for instance water companies such as United Utilities and Yorkshire Water) to optimise coverage of NFM and realise / monetise the full ecosystem service generated by NFM. There is also significant opportunity to co-develop scheme resources and processes with stakeholders who have similar interests in the application of NFM.

The NFM Fund Pilot was a useful engagement vehicle for the Rivers Trusts. It was an opportunity to meet people in the catchment and discuss related land management matters.

### 3.7.5. Key points

- Regular engagement with the National Highways Operations team is needed in any future development or roll out of the NFM Fund. Their knowledge of the location and cause of local flood hotspots is a key input in deciding on Focus Areas and, more specifically, siting NFM measures to optimise their beneficial effect on the network. Collaboration between Catchment Advisors and the National Highways Operations team is required during periods of landholder engagement to focus the siting of NFM. Collaboration will deliver a much more integrated approach to management of flood risk on the SRN.
- Engagement with landholders is most effectively achieved through a single point of contact that is seen as a trusted and knowledgeable advisor. This advisor cannot work in isolation and needs a support network – for peer review, as a sounding board and for technical advice on matters outside their area of expertise. It takes time to build relationships with landholders. Although engagement with the NFM Fund can be accelerated by ‘piggy-backing’ existing landholder relationships in a catchment (such as those with Rivers Trusts), an allowance for developing relationships with individual participants in any future roll out of the NFM Fund needs to be built into its programme.
- Every landholder and every land management business is different. Engagement strategies need to account for this diversity. Note that some landholders (particularly larger strategic operations) will take a long time to engage and partner.
- Landholders and farmers are inherently practical people. Effective engagement, particularly on paper, should focus on real world examples and evidence.

## 3.8. NFM Fund framework

### 3.8.1. Delivery Framework

#### Delivery process

The overall process for the NFM Fund Pilot (Figure 2-6) was generally received well. As a sequence of steps very similar to a traditional agri-environment scheme (e.g. mid tier) it was a familiar and comfortable high level framework for both participants and the Rivers Trusts.

#### Delivery programme

A much longer lead-in time (shown as initial consultation in Figure 2-6) would have increased uptake. The initial consultation periods before the June 2021 and November 2021 auctions were adequate to engage with responsive landowners but were far too short to align with business cycles of larger strategic landowners (see section 3.7.3). This missed significant opportunities on large landholdings. Potentially a different strategy is needed to engage with these long burn opportunities.

The auction period (generally around two weeks) was appropriate. It was enough time to allow applications to be made, but not so long for interest to wane. In the event, the majority of applications were made in the last 48 hours.

Landholders would have appreciated clearer and more regular communication on the dates when they would hear about the outcome of their applications to the Pilot NFM Fund.

The periods allowed for planning and implementation of measures needs to coincide with quiet periods in the agricultural calendar. In general, the periods allowed in the Pilot NFM Fund (5 to 6 months) were adequate for implementation of simple measures not requiring consent from a Regulator. However, they fell well short of the period needed for implementation of more substantial interventions requiring consent and input from a specialist contractor.

Many participants in the NFM Fund Pilot would be keen to extend their maintenance agreement beyond the current 5 year period of the Pilot. Few, if any, are expected to actively remove their measures at the end of the maintenance period.

#### Written resources

More pictures and less words was the general feedback from landholders on the written resources supporting the NFM Fund Pilot. They also wanted more real world visual examples of NFM implementation and clearer sign-posting of information to allow more rapid navigation between and within documents. When supplied as hard copies documents were more well used than digital versions. Specific requests included

- House everything on a single website (a digital one stop shop).

- Provide a catalogue of photographic examples of good and bad implementations of NFM, showing measures in different seasons.
- Promote the benefits to landholders of implementing measures, rather than just the flood management purpose. These will be the hooks that will draw a landholder into a scheme. For instance a hedge is a shelter belt as well as a means of trapping flood water.
- Land use management changes (e.g. herbal leys) appeared to have a low profile or secondary status in the overall presentation of the Pilot NFM Fund. These are measures that integrate most closely with existing farming systems – a more positive presentation could have increased uptake.

The Rivers Trusts were the principal users of the design specifications (as a reference manual). Crucially, this document also acted as the specification under the contract between the Trusts and the landholders – and so ultimately protected the financial investment being made by National Highways.

Landholders at the Rivers Trusts felt that the documentation could have provided more advice on when consents (e.g. Flood Risk Activity Permits) were required and what information was needed to support applications for consent.

### Delivery team

An appropriately resourced team, which is resilient to changes in staffing was crucial to the successful implementation of the NFM Fund Pilot. NFM was a new concept to many landholders. So they often relied heavily on the Rivers Trusts for support in the design of measures, preparation of applications to the Pilot NFM Fund, and sourcing of specialist support (e.g. contractors). In turn, the Rivers Trusts often relied on specialist advice from consultants (e.g. Atkins) on more complex issues of design and construction. In general, there was a shortfall of specialist consultant and contracting skills available to the Pilot suggesting a register of suitably qualified contractors, equipment suppliers and design consultants would have been of benefit.

## 3.8.2. Bidding platform

### System function

A bespoke web-based bidding platform was developed in the NatureBid application (NatureBid, 2021). Landholders submitted applications to the NFM Fund through this platform. The NatureBid application is very flexible and able to accommodate multiple combinations of funders, buyers and measures. It has been used in many different projects, both as an auction platform and as a simple 'proposal generator'. Its application in the NFM Fund pilot was novel, because a price per volume of water stored metric was used to rank bids live during auctions.

### Proposal generation

The platform required landholders to enter key information on the location, type and extent of measures through a map-based interface. It proved a very effective way of capturing proposals made by landholders to the Pilot NFM Fund. These proposals were stored in a spreadsheet database that could be readily interrogated during the period when proposals were assessed. As such the platform proved to be a highly effective 'proposal generator' for the NFM Fund Pilot.

This automatic proposal generation process was very useful for those assessing applications to the Pilot NFM Fund. It did away with the traditional written or pdf application form, and the sometimes lengthy interpretation process needed to translate information into a consistent digital dataset in order to make an informed comparison between different proposals.

### Competition through auction

Landholders did not actively participate in an auction using the platform. This was because

- Landholders were unfamiliar NFM measures and had limited knowledge of their likely cost. They often relied heavily on information provided by the Catchment Advisors to determine price. Many bids were therefore similarly priced.
- Engagement with landholders was restricted by the COVID epidemic. This is likely to have significantly reduced the number of applications made to the NFM Fund Pilot.
- Minimising cost was not the only objective of the bidding process. Auction ceilings were also set to ensure enough participants to thoroughly test the NFM Fund Pilot process and implementation of a wide range of measures in different flood environments.



- In many instances, information was entered into the platform by the applicant and the Catchment Advisor together. Landholders may have been reluctant to go back into the system and change a bid because they were unfamiliar with its operation (see 'User Engagement' below).

In reality it was the formal technical assessment of applications (see 3.8.3) that most strongly influenced the selection of proposals. The technical assessment weeded out non-compliant or inappropriate applications to bring the total value of bids to below or equal to auction ceilings.

### User engagement

Despite the bidding platform being intuitive and easy to use, there was reluctance amongst landholders to invest time in learning how to use it. Many landholders relied on Catchment Advisors to help enter applications. This may well reflect the pilot nature of this project – landholders may have been unwilling to engage with a new piece of software that they would only ever be using infrequently.

Some landholders were put-off using the platform because it was tricky to use on a mobile phone.

### Auction budgets

Pitching the budget (setting the auction ceiling) needs to be considered carefully. It will strongly influence the success and interest in a bidding process.

- Budget is a key factor in generating competition. A budget that is too small will put potential applicants off bidding because of a perceived excess of competition. A budget that is too large will discourage applicants from submitting a keen price, in belief that a 'slightly higher' bid will probably be successful.
- The budget needs to be scaled to the desired outcome. There needs to be sufficient money to pay a 'fair' price for the number and scale of NFM measures required within a catchment
- Substantial variation in the ceilings set on sequential auctions can generate uncertainty.<sup>10</sup> Consistency is preferred.

Auction budgets also have implications for the engagement process. Large budgets will require more applicants, which in turn sets the scale of the engagement process. Catchment Advisors will need to promote the scheme more actively and are likely to deal with a large number of queries.

## 3.8.3. Technical assessment of applications made to Pilot NFM Fund

A summary of the assessment process is provided in section 2.3.6.

The process generally worked well. It screened out applications for schemes with low NFM potential and picked up potential technical issues with measures requiring clarification and revision to applications.

Potential future applications of the process should consider a) a separate independent assessment of the siting of measures by the National Highways Operations team to improve targeting of measures on known surface water flood sources to the network; b) a quantitative assessment of co-benefits of different measures to weight against their NFM benefits.

## 3.8.4. Contract framework

The two model contracts were prepared by Atkins, based on similar previous projects for landholder natural capital land-use schemes and from a model contract from National Highways for use with the Rivers Trusts. Wordings were established and agreed with National Highways involving considerable discussions before the bidding processes started. During implementation there were no issues raised with either the contract between National Highways and River Trusts nor that between the Rivers Trusts and landholders.

## 3.8.5. Key points

### Delivery process

- In general a longer lead in time to auctions would have increased uptake. Whilst the programme gave sufficient time for agile landholders to participate in the scheme, it was inadequate for many larger strategic landowners to engage. This missed significant opportunities on large landholdings within the Focus Areas. Potentially a different strategy is needed to engage with these long burn opportunities.

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<sup>10</sup> A particular issue in the Little Don Focus Area, in which the ceiling set on a second auction with 10% of the ceiling on the first auction.

- The general feedback on the manuals supporting the NFM Fund Pilot was more pictures and less words. Landholders wanted more visual real world examples of NFM implementation and clearer signposting to allow navigation within and between documents. The Rivers Trusts were the principal users of written technical information. These specifications also protected National Highways interests in the contracts. More information on consenting was requested by all – however this is challenging to provide, given the diversity of sites and consenting authorities.
- An appropriately resourced team, which is resilient to changes in staffing is crucial to delivery. The face or focal point of this team is the Catchment Advisor, a well-known and respected presence in the catchment. The advisor will need support from others both in the form of a sounding board for ideas / peer review and specialist advice on technical matters beyond their area of expertise.

### Bidding platform

- The NatureBid bidding platform proved to be an excellent proposal generator for the NFM Fund Pilot. It produced a comprehensive database of applications immediately ready for assessment. As such it streamlined and rationalised the proposal assessment process. The cost effectiveness metric also proved an effective initial screening tool, by rapidly identifying outliers. By contrast there was reluctance to engage with the platform amongst landholders.
- The bidding process generated limited competition amongst applicants. There are many likely reasons for this, centring on the pilot nature of this project and the unfamiliarity of many applications with the 'going rates' for NFM. This should be seen in the wider context of farmers being very familiar and comfortable with auction and competition in many other aspects of their enterprises.
- Whether it is used just as a proposal generator or as an auction platform NatureBid, or similar technology, is an efficient way of collating, processing and potentially evaluating applications. It also allows more careful management of personal data.

### Technical assessment of applications made to Pilot NFM Fund

- The process generally worked well. It screened out applications for schemes with low NFM potential and picked up potential technical issues with measures requiring clarification and revision to applications.
- Potential future applications of the process should consider a separate independent assessment of the siting of measures by the National Highways Operations team to improve targeting of measures on known surface water flood sources to the network.

### Contract Framework

- A robust and effective contract framework was established for the operation of the scheme which can form a good model for future schemes for NFM and other Natural Capital measures by other stakeholders.

## 3.9. Governance

### 3.9.1. Governance structure

#### Overview

Table 3-12 describes the roles of the organisations participating in a) development of a Framework for the NFM Fund and b) delivery of the NFM Fund Pilot. The table focuses on just these two phases of the project (phases 3 and 4 as described in section 2) because these would be the core activities of any wider roll-out of the NFM Fund that might take place in the future. The bullets below summarise the contribution organisations made to each of these activities:

- **Developing a Framework for implementation of NFM Fund** – key players were National Highways Policy team and their Technical Advisor, who developed the framework, associated business case, governance agreements and bidding platform. Other parties provided advice on the development of the framework, for instance the local knowledge of National Highways Operations team was critical in selecting the Focus Areas in which the NFM Fund was piloted.
- **Implementation of NFM Fund Pilot**
  - **Application to NFM Fund Pilot** - key players were a) Rivers Trusts - who engaged landholders and then supported them in making their applications and b) landholders who developed and submitted applications to the NFM Fund. Multiple parties were involved in the assessment of applications. Running parallel to these application activities a payment structure was also put in place and implemented. National Highways Policy team paid the Rivers Trusts up front for their services and set up the necessary agreements with the Treasury to facilitate early payment of landholders (further details in section 3.9.3)
  - **Delivery of measures** under NFM Fund Pilot -
    - **Planning** – key players in this phase were landholders (who prepared designs and, where necessary, consent applications for NFM Measures) with support from the Rivers Trusts and ad hoc advice from the Technical Advisors (Atkins and other specialists in the design of NFM Measures). Consenting authorities granted the necessary permissions.
    - **Implementation** - Implementation of measures was principally the responsibility of landholders, supported by substantial project management (payment and change control) as well as quality assurance effort by the Rivers Trusts. Specialist contractors were responsible for delivery of some of the more complex measures
    - **Maintenance** - landholders are responsible for operation and maintenance of measures to specification over a 5 year period to 2027. The Rivers Trusts and National Highways Operations team are undertaking monitoring. National Highways' Policy team are evaluating the pilot with support from their Technical Advisor.

#### Key points

The framework and delivery structure summarised above has allowed measures funded by National Highways to be implemented up-slope or catchment of flood hotspots on the SRN and on third party land. This is a significant logistical achievement. However, this framework and delivery structure will need developing if the NFM Fund is to be rolled out more widely. In particular, other parties need to be involved, roles need to be more clearly defined and a governance structure needs to be developed that defines the inputs from and outputs to each party involved. Some initial points are bulleted below.

- Securing the NFM function (and co-benefits) of NFM measures throughout the maintenance (operational) phase of the NFM Fund. The NFM Fund Pilot incorporated a relatively short maintenance period (2022–27) in which landholders are responsible for maintaining the function of measures. Wider roll out would require many more measures to be implemented and maintained over a much longer operational phase (say 30 years). A clear definition of roles and responsibilities is required. Clarity on whether participants would be willing to enter into such long term agreements is required.
- If co-benefits (e.g. natural carbon sequestration and biodiversity gain) are to form an important part of the business case for the roll-out of the NFM fund) a transparent, credible process is needed to quantify these benefits and clearly attribute them amongst partners in any implementation. Put simply, how much are the co benefits worth, how can they be kept secure, and who owns them? (see section 3.9.2).

- Closer co-operation with partners within National Highways is going to be necessary to fully realise the potential of a wider roll out of the NFM Fund
  - Operations team – to advise on a) locations on the SRN where flooding generated by surface runoff is a critical issue and b) to support the locating of NFM measures.
  - Parties with interests in capturing and realising the co-benefits of NFM
- Even at the pilot scale, securing people with the right skills to deliver the NFM Fund has sometimes been a challenge. Wider-roll out will exacerbate this issue. How best manage the greater number of people and wider range of skills needed to resource wider roll out of the NFM Fund? Long term resilience of these teams to change in staff also is critical.
- National Highways cannot implement the NFM Fund alone. Wider roll-out is likely to only be possible through greater partnership working. As a minimum those implementing a National Highways NFM Fund in a catchment need to understand the wider flood and catchment management context in which the Scheme is being implemented. Finding the right level of partnership will be key.

Table 3-12 - Roles in development of framework for NFM Fund and delivery of Pilot

		Organisation	National Highways Operations team	National Highways Policy team	Rivers Trusts	Landholders	Technical advisor	Catchment stakeholders
		Overview of role	<i>Tailor measures to requirements of flood hotspots on SRN</i>	<i>Direct NFM Fund</i>	<i>Facilitation and management of NFM Fund</i>	<i>Operation of NFM Measures</i>	<i>Provision of specialist technical advice</i>	<i>Regulatory and advisory inputs</i>
Project phase (as used in Section 2 (Description of Pilot))	Phase 3	Development of Framework for NFM Fund	Advise on location of Pilot Catchments and Focus Areas	Develop governance and technical frameworks for NFM Fund Select Pilot catchments and Focus Areas Develop business case for NFM Fund & secure funding Secure governance agreements for release of funds to Rivers Trusts	Advise on NFM Fund technical and governance frameworks Recruit Catchment Advisor for NFM Fund Pilot		Support setting up technical and governance frameworks for NFM Fund Prepare resources for NFM Fund	Advise on development of technical framework (EA, Rivers Trust)
	Phase 4	Application to NFM Fund Pilot	Support assessment of applications to NFM Fund	Pay Rivers Trusts Assess applications Block sign off of payment to landholders	Engage landholders with NFM Fund Pilot Support landholders through applications to NFM Fund Pilot Support assessment of applications to NFM Fund	Engage with Rivers Trusts Prepare and submit applications to NFM Fund Pilot	Manage assessment of applications to NFM Fund Pilot	Host NFM Fund resources on Web site (Rivers Trust)
		Delivery of measures under NFM Fund Pilot	Planning		Support landholders in design of measures	Design NFM Measures Secure consents for NFM Measures	Provide ad hoc technical advice for design	Specialists in design of NFM Measures Consenting of measures (e.g. LLFA, EA)
			Implementation	Transfer block payments to Rivers Trusts	Pay landholders (2 stages) Manage change during implementation of NFM measures Quality assure implemented NFM measures	Provision of land for NFM Measures Construction of NFM measure in accordance with specification		Specialists in construction of NFM Measures
			Maintenance (5 year period)	Monitor flood hotspots on SRN for change in flood severity	Evaluate and report outcome of NFM Fund Pilot	Monitor effectiveness of NFM measures	Maintenance of NFM Measures in accordance with specification	Support evaluation of NFM Fund Pilot



### 3.9.2. Co benefits - securing and attributing

#### Overview

National Highways need NFM measures to deliver long term improvements to flood resilience and long term increases in natural capital (co-benefits). A useful lifetime of an NFM measure to National Highways is likely to be around 30 years. This is also a likely minimum period for substantial realisation of co-benefits such as natural carbon sequestration or biodiversity gain. The delivery of these outcomes at the end of this asset lifespan will need to be **secured** if National Highways' needs are to be realised. Measures will need to be implemented and operated to an effective specification to ensure that these assets deliver their expected outcome. This requires a clear implementation specification and maintenance programme. A monitoring programme is also likely required to determine whether assets are functioning and developing in accordance with the expected outcome.

At least two parties will be involved in the delivery of an NFM measure: a provider (landholder) and a buyer (National Highways). There will need to be a clear understanding about how the expected benefits of an NFM measure will be attributed between these parties and how each party might use these benefits. A key question for National Highways is whether their requirement is limited to simply securing the flood risk protection or natural capital an asset will generate, or do they also require any financial benefit that may result from the accrual of natural capital (e.g. 'ownership' of a carbon credit or biodiversity unit).

Initial discussions within National Highways on biodiversity co-benefits of NFM measures indicated that National Highways agreed metric for biodiversity gain is the Biodiversity Net Gain (BNG) unit. So implementation and maintenance specifications would need to ensure assets complied with the requirements of the BNG system. For instance this requires a clear definition of baseline (pre improvement) conditions.

#### Key points

- NFM measures will need to deliver flood resilience and natural capital through and at the end of their anticipated asset life (say 30 years). This performance and outcome will be secured through a) definition of common goals with landholders and b) most likely, implementation and maintenance / operation specification and monitoring.
- A clear understanding between contributing parties (e.g. landholders and National Highways) on the attribution of benefits generated by NFM measures will be required. National Highways need to be clear on whether their requirement is simply for the flood risk protection or natural capital an asset will generate, or whether they also require ownership of any financial benefit that may result from the accrual of natural capital.

### 3.9.3. Advance payment

#### Overview

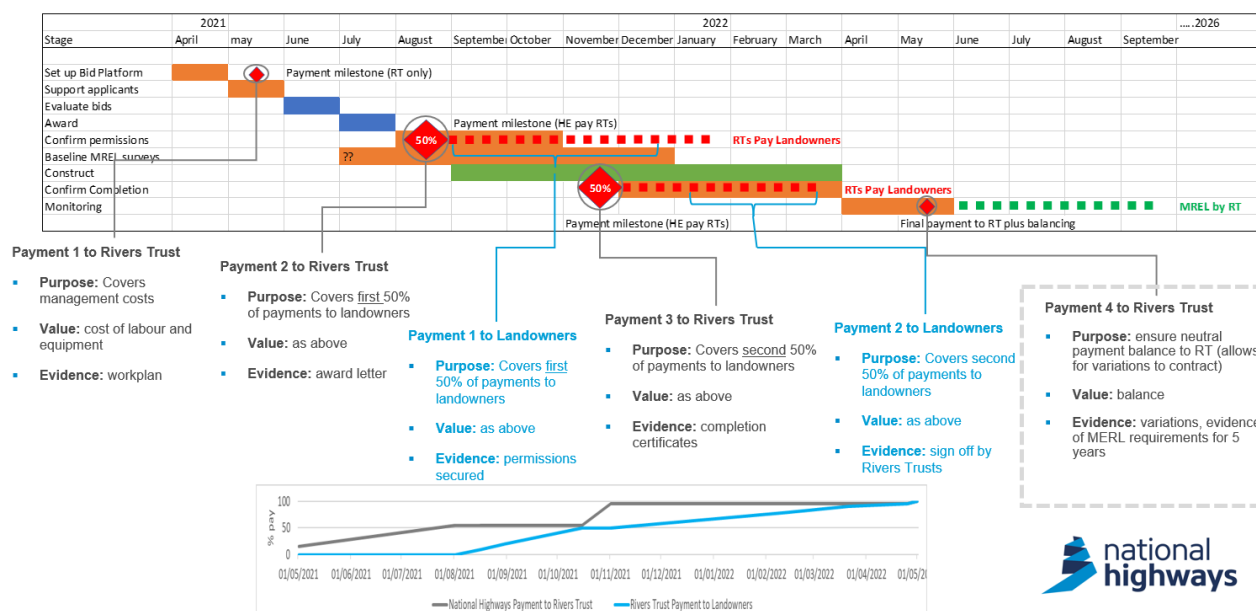
During the NFM Fund Pilot payments in advance were made to Rivers Trusts by National Highway and then by the Rivers Trusts onto landholders. This was a progressive and novel aspect of the NFM Fund. It is believed to be the first time that the Treasury has sanctioned release of funds in advance to a third-party outside of the government community. Figure 3-8 illustrates the flow of payments between project partners.

Advance payments were made to enable an efficient management of the NFM Fund grant process. Payments were not made in advance of need, but were necessary to enable partners to deliver the NFM Fund on behalf of National Highways. In particular advance payments were made to protect the limited working capital of the Rivers Trusts. They also incentivised landholders to participate by limiting periods in which their accounts experienced negative cashflow.

The NFM Fund needed to be highly flexible to work around agricultural and weather cycles, and therefore grant payments needed to be made promptly, which was facilitated by advance payments to the River Trusts so the funds were on stand-by; even delays of a few days or weeks could be enough for loss of interest from a landholder in participating, reducing the effectiveness of the pilot project in reducing flood risk. Therefore, the benefits of paying across the funds in advance increased the likelihood of a successful pilot, as it allows greater flexibility in grant payments to landholders, which is key to uptake. In addition, this reduced the administrative

burden in Highways England of having to make multiple small payments across the project cycle, with the River Trusts being set-up to work with small payments. Note that the interests of all parties were ultimately protected through terms of contract.

## Typical payment schedule



**Figure 3-8 – Flow of payments between partners in the Pilot NFM Fund**

The grant contract set-up included a mechanism to allow funds to be recovered where not utilised. Expenditure was clearly tracked against the grant specification in the contract schedules to enable controls to ensure funds were spent correctly.

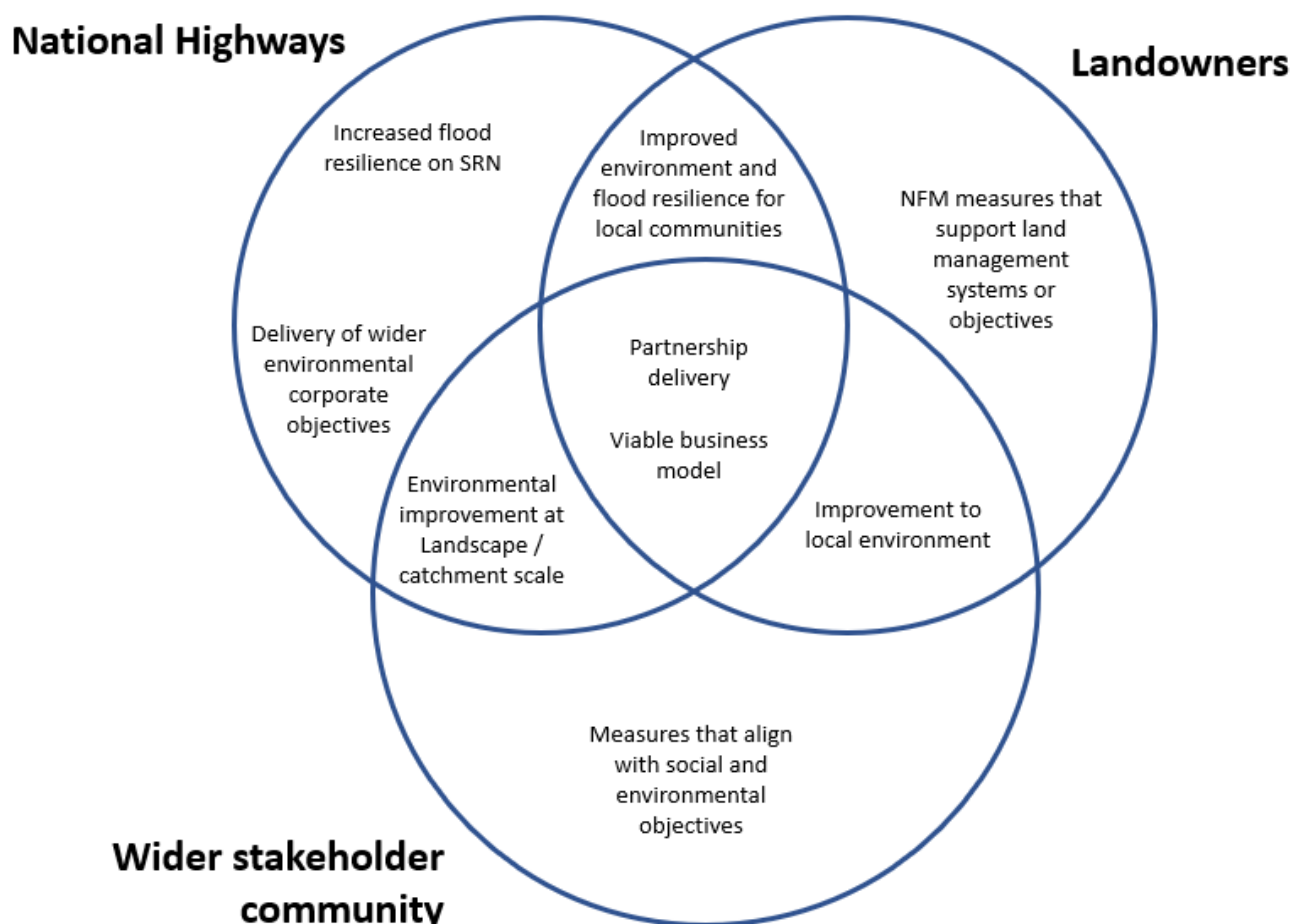
### Key points

- Advanced release of funds to Rivers Trusts (and subsequent favourable payment terms for landholders) were central to a viable business model. Payments were not made in advance of need but early enough to avoid or limit periods of negative cashflow in either the Rivers Trust or landholder accounts. Proper management of public funds was ensured through clear specifications and contract terms as well as monitoring of expenditure.

## 3.10. Working in partnership

### 3.10.1. Overview

A successful partnership will achieve more than the sum of its parts. By working together organisations deliver more than by operating in isolation. The Venn diagram in Figure 3-9 sets out how the NFM Fund Pilot delivered mutual ambitions of its partner organisations. The discussion of this partnership below focuses on what attracted or ‘hooked’ each organisation into the partnership.



**Figure 3-9 – The NFM Fund as a partnership**

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The Pilot NFM Fund allowed National Highways to test implementation of NFM on third party land at locations targeted to increase the resilience of the SRN to flooding. As such it was an alternative or complementary flood risk management approach to the hard engineering traditionally implemented within the often limited spatial constraints of the road corridor. The Pilot NFM Fund was also a vehicle for National Highways to test delivery of commitments made in its forthcoming Environmental Sustainability Strategy, for instance on specific matters of carbon net zero and biodiversity - but also on the role the organisation could play in improving landscape, habitat and habitat connectivity (section 1.3.2).

National Highways has a shared interest with the wider stakeholder community in the NFM Fund as a vehicle for delivering environmental improvement at a landscape or catchment scale. This is not only about geographical extent of change but also the benefits of connecting habitats across a landscape. The linear nature of National Highways' estate makes it an excellent vehicle for this connecting role. Common ground between National Highways and landholders is focussed on the flood resilience and environmental benefits the NFM Fund could provide to local communities. Closer collaboration between Catchment Advisors and the

National Highways Operations team in managing flood risk on and in the vicinity of the SRN also has the potential to yield significant mutual benefits (see section 3.2.4).

The wider stakeholder community in general engaged with the Pilot NFM Fund as a potential vehicle for delivery of their varied environmental and social objectives. Specifically, the Rivers Trusts have taken part in the Pilot NFM Fund to facilitate improvements to flood resilience, land management and the environment within their catchments. The Pilot has also been a vehicle for the Trusts to engage with landholders about wider catchment issues - for instance improving soil health and river water quality. Knowledge on different types of NFM measures has been shared between partners.

The stakeholder community is broader than just the Rivers Trusts (see Table 1-3), with some groups connected to the Pilot catchments geographically (e.g. Lead Local Flood Authorities, Environment Agency) and others to the Pilot from a thematic perspective as organisations facing similar challenges or implementing similar or related land management schemes (e.g. Network Rail, Natural England). Engagement on thematic themes has mainly been about sustainable flood risk management, flood resilience and the co-benefits these deliver (biodiversity, carbon).

Landholders were attracted to NFM measures that support their land management system and business. They tended to focus on the agricultural or environmental co-benefit of measures. Landholders were most open to measures that

- could be implemented within, and without adversely affecting, an existing land management system
- complemented existing land management practices
- made use of unproductive or marginal land
- supported transition to alternative land management approaches

As environmental managers and members of the local community landholders also share an interest with National Highways and the wider stakeholder community in improving the local environment and the flood resilience of local communities. Some were motivated wholly by this aspect of the scheme.

Whilst the partnership is brought together by its common goals it must also operate as a viable business model. For National Highways this business case needs to be founded on a) value for money for investments coming from the public purse and b) the benefit of the investment to the SRN. For both Rivers Trusts and landholders, participation in the NFM Fund Pilot was made particularly attractive by favourable payment terms that avoided extended periods of negative cashflow. Working together should increase the value of deliverables (by recognising and realising the full range of benefits they produce). It should also provide opportunity to reduce costs by sharing overheads between partners (e.g. sharing the cost of scheme resources such as manuals or bidding platforms) partners sharing the capital cost of investments (e.g. funding of projects based on agreed benefit attribution).

### 3.10.2. Key points

- The Pilot NFM tested and proved the partnership delivery of NFM measures at locations targeted to increase the resilience of the SRN to flooding. Critically these measures were sited on land not owned by National Highways.
- The partnership succeeded because it was an attractive delivery model to each participant, providing
  - National Highways with a vehicle to implement NFM on targeted third party land and to deliver against wider corporate environmental objectives
  - Landholders a funding route to implement measures that aligned with their land management system
  - Rivers Trusts a vehicle to support the implementation of sustainable flood risk management practices within their catchment and the opportunity to promote good catchment management practice more widely
  - Wider stakeholders the opportunity to learn and engage with an alternative NFM delivery model
- The partnership was strengthened by testing how common mutual goals could be delivered. These goals focussed on both local and landscape / catchment scale environmental improvement
- The complexity of the partnership was considered broadly appropriate. Involvement of many more organisations could have convoluted the process with different agendas.

## 4. Way forward

### 4.1. Introduction

#### 4.1.1. National Highways' ambition for NFM

National Highways is keen to understand the viability of wide scale roll out of NFM as a vehicle for reducing flood risk and improving flood resilience on the SRN. The NFM approach is attractive because it fits closely with the core objectives of the organisation's emerging Environmental Sustainability Strategy. First, NFM offers the potential to address a key threat to the operation of the SRN (traffic disruption due to flooding). Second, as a Nature based Solution (NbS), NFM has the potential to address that threat in a way that enhances and enriches the environment adjacent to the road network. NFM helps integrate the SRN into its local landscape.

Early stages of this Pilot identified 100 priority hotspots where NFM could support the reduction of flood risk or improve flood resilience on the SRN (Figure 2-1). These priority hotspots are a useful starting point for understanding the potential scale and geographical distribution of a roll-out of NFM beyond the initial Pilot locations in the Irwell and Little Don catchments.

#### 4.1.2. Key Lessons from NFM Fund Pilot

##### Achievements

The NFM Fund Pilot has demonstrated that National Highways can make NFM work for the SRN. Crucially it has shown that National Highways can collaborate effectively with local landowners to implement NFM on land not owned by National Highways upslope of flood hotspots on the SRN. This is where NFM must be located if it is to be effective at addressing flood risk on the SRN. The Pilot has also shown that NFM can be an effective vehicle for reducing flood risk and improving flood resilience on the SRN – if enough effective measures are implemented in the 'right' locations upslope of a hotspot.

##### Issues

However, the Pilot has also revealed that there are issues with, and potential limitations to, a National Highways led delivery model like the NFM Fund. Crucially, more needs to be done to turn the NFM Fund into a viable business model for delivering NFM. We believe the solution to this lies in optimising the pairing of hotspots and catchments to which the NFM Fund is applied. Further work is also required on the selection and application of measures. An effective combination of these factors is set out in the three bullets below.

- **Hotspot** – The greatest traffic disruption generated by a flooding incident will be at hotspots on a busy motorway where drivers need to take a lengthy diversion route if a road is closed. It is these circumstances that yield the greatest benefits for measures that reduce the severity of flooding. Also, NFM is most effective if it can be targeted to reduce flood peaks at specific drainage assets known to be under-capacity.
- **Catchment** – the ideal catchment for application of NFM is one in which a sufficient coverage of measures can be implemented in a relatively short period of time (say a 5 year RIS period) to effect a useful reduction in flood risk or improvement to flood resilience. This is most likely to be a) a small predominantly rural catchment (< 5km<sup>2</sup>) with b) a limited number of landholdings and c) a catchment community with a progressive attitude towards NbS and implementation of NFM on their patch.
- **Measures** – These need to be either cost effective on flood risk grounds alone, or where they generate wider co-benefits, these additionalities need to be fully accounted for in the business case.

We believe this optimisation can be achieved by refining the existing NFM Fund delivery model run under a National Highways led partnership. We have called this the NFM Fund+ model. Further details are provided in section 4.3.

##### Limitations

There will be an upper limit to the size of catchment, scale of flood issues and complexity of stakeholder interactions for a National Highways led partnership like the NFM Fund+. To effectively address these larger more complex flood risk challenges is likely to require a more collaborative approach in which the requirements of multiple stakeholders are fully considered, and, importantly, the value of multiple benefits are fully accounted. In these circumstances we suggest the most effective solution lies in National Highways contributing as a participant in a wider catchment partnership. The complexities of this bigger challenge is discussed in section 4.4.



## 4.2. Overview of Way Forward

We suggest National Highways considers two forward pathways for wider roll out of NFM to reduce flood risk and improve flood resilience on the SRN.

- **National Highways led partnership.** This is the NFM Fund+ delivery model discussed above.
- **National Highways as a participant in a wider Catchment Partnership.** – Also discussed above. An approach appropriate to larger more complex flood risk challenges demanding greater collaboration in which the requirements of multiple stakeholders are fully considered, and importantly, the value of multiple benefits are fully accounted.

Figure 4-1 is a visualisation of the delivery pathways for these two models:

- The X axis represents the aspiration of National Highways' emerging Environmental Sustainability Strategy to scale up implementation of NbS (including NFM) across the network to support delivery of corporate and project environmental targets. It also recognises the complexity of moving from a simpler flood risk focused approach toward the challenges and complexities of realising multiple benefits by working in partnerships.
- The Y axis uses volume of water stored to represent a wider group of success factors that determine the effectiveness of NFM implementation at a catchment scale.

One blue arrow leads to the yellow box. This represents a 'National Highways led partnership' NFM Fund+ approach. The trajectory and end point of the arrow suggest this approach will only be applicable to some of National Highways' priority catchments, but that where it is applied it should be effective.

The other blue arrow leads to the green box. This represents an approach in which National Highways is one participant in many wider catchment partnerships. This way forward realises more multiple benefits across a larger number of catchments, but only some of these benefits will directly meet National Highways' needs.

These two approaches are presented as parallel pathways, not as alternatives.

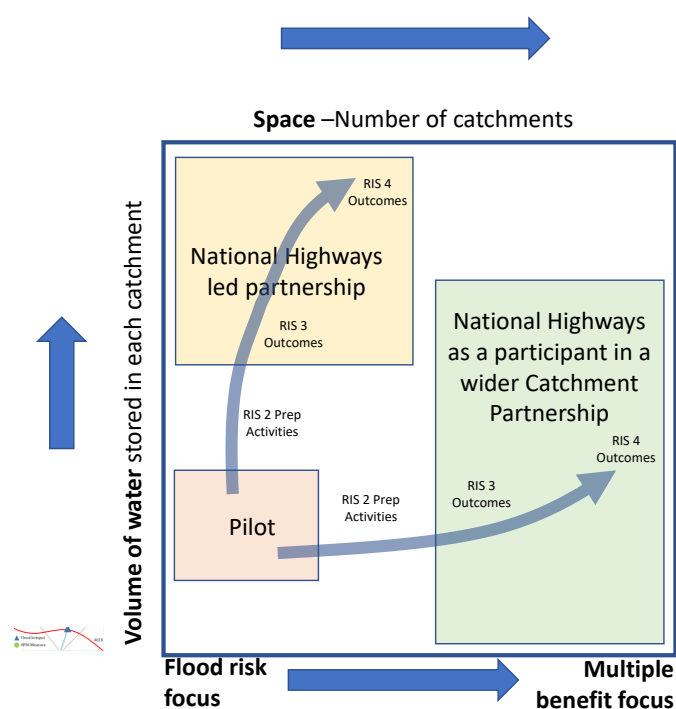


Figure 4-1 – Way Forward

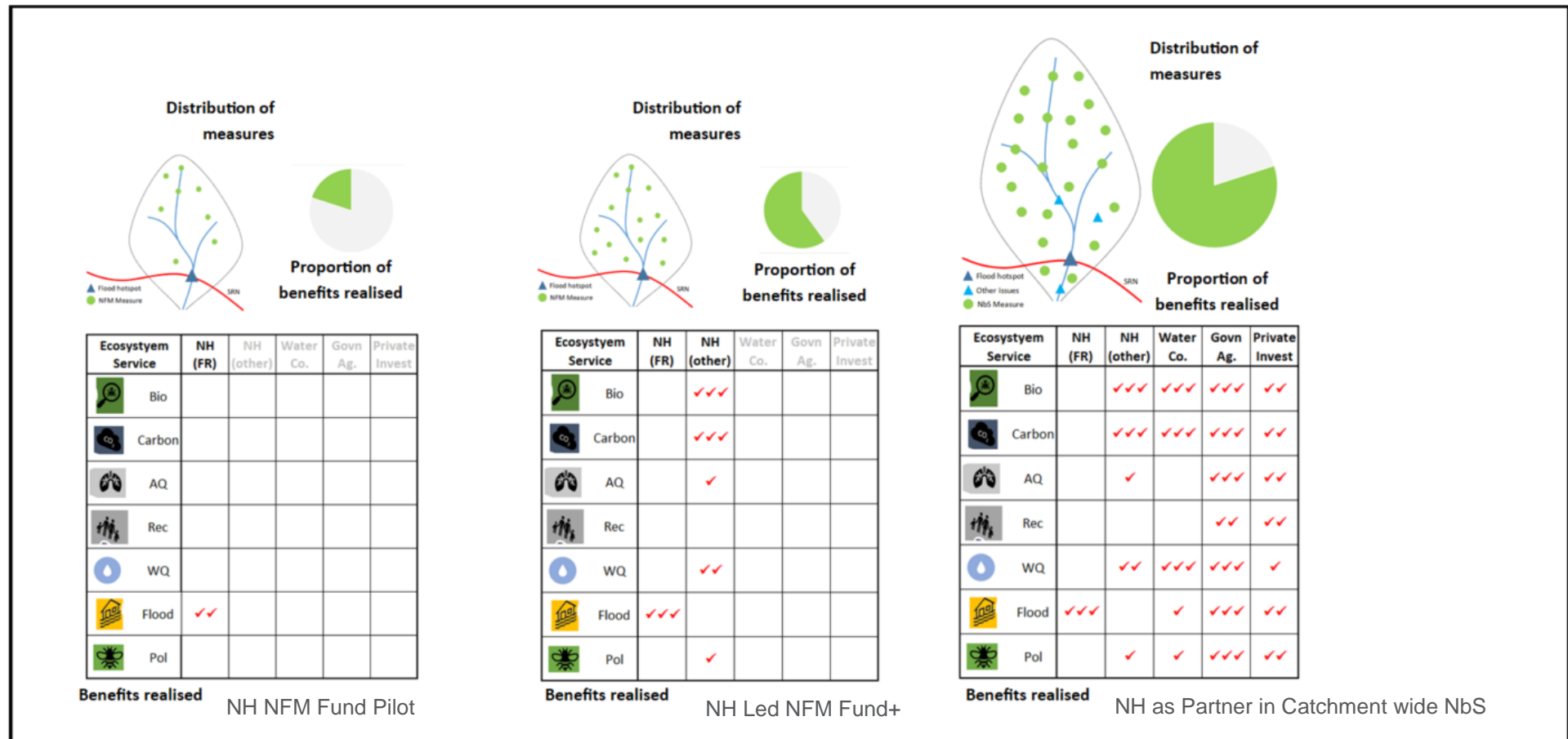


Figure 4-2 – Concept diagram – benefits realised by three different delivery models

## 4.3. National Highways led partnership

### 4.3.1. Overview

This delivery model is an update to the model used in the NFM Fund Pilot, based on lessons learnt from the Pilot and the wider experiences of the project team and stakeholders. It would be rolled out at a regional scale at the start of Road Investment Strategy (RIS) Period 3 (2025), with a view to multi-regional implementation in RIS 4 (2030–35). Development of a Proof of Concept would be required in the remainder of RIS 2 (2022–2025). More detail on these stages is set out below.

### 4.3.2. Proof of concept (2022–25)

We propose a phase of works within the remainder of the RIS2 to develop the existing NFM Fund delivery model based on lessons learnt during the Pilot. The purpose of this would be to target NFM measures, based on the factors discussed above to deliver more cost effective and cost beneficial measures that support a more robust business case for wider roll out. An initial list of tasks is set out below.

#### Technical proof of concept

- Review and rationalisation of cost base
  - Cost effectiveness of measures
  - Opportunities for rationalising overhead costs
  - Generating competition by pitching auction ceilings and engaging auction participants with platform
- Review of measure locations with National Highways Operations team – linkages to specific assets
- Exploring methods for increasing measure implementation in selected Focus Areas / sub-catchments
  - Engaging with strategic landowners (e.g. United Utilities, quarrying interests)
  - Expression of Interest (EoI) / additional round of auctions in selected Focus Areas / sub-catchments to test propensity for increasing density of measures
  - Closer collaboration between National Highways Operations teams and Rivers Trust to target measures
- Measure review, technical specification review to optimise value for money delivered by measures offered under the Fund (say 30 years)

#### Selection of region / catchments to implement regional roll out

- Starting point – priority catchments identified in Phase 1 (scoping assessment) of Pilot (Figure 2-1)
- GIS based analysis to filter through to catchments most conducive to implementation of NFM
- High level traffic disruption analysis to identify hotspots where reduction in flood severity would generate the largest benefits
- Engagement with external stakeholders to support region and catchment selection. Looking for local intelligence on catchments most conducive to implementation of NFM, as well as catchments with progressive landholder groups and active NbS communities
- Engagement with National Highways internal stakeholders to support region and catchment selection.
  - Commonalities between NFM Fund and other National Highway projects, schemes and drivers
  - Operations team – interpretation of HADMMS to understand specific assets adversely affected by surface water flood risk

#### Development of a delivery framework and governance structure for regional roll out

- Preparation activities
  - Explore approaches for ensuring adequate resourcing of regional roll out (skills and number of people) e.g. setting up national resource pool through National Rivers Trust
  - Explore protocols for long term NFM management and attribution of co-benefits to NFM measures. Develop NFM asset management and benefit attribution agreements / protocols for full asset life of measures offered under the NFM Fund (say 30 years)
- Develop programme of works for regional roll out

- Develop governance framework for regional roll out. Specify roles and success criteria for key stakeholders (consider validating these role descriptions with national bodies such as National Rivers Trusts)

#### Preparation of funding application

- Preparation of application and supporting business case for regional roll out.

### 4.3.3. Regional roll out (2025–30)

- Regional roll out depending on and informed by proof-of-concept phase.

### 4.3.4. Multi-regional roll out (2030–35)

- Multi-regional roll out depending on and informed by regional roll out phase.

## 4.4. National Highways as a participant in a wider Catchment Partnership

The Pilot focused on use of NFM measures to reduce flood risks at flood hotspots on the SRN. The NFM measures delivered under the Pilot also provided co-benefits to natural capital. Other stakeholders may implement land-use change schemes with landholders in the same vicinities to reduce runoff that is threatening their assets (e.g. local councils, developers industrial facilities, other utility infrastructure e.g. power grid, water treatment) or primarily for the delivery of other benefits such as BNG, Carbon Sequestration, soil protection, water quality management, water resources management, recreation and residential land values etc (e.g. Defra, forestry commission, water companies, or charitable organisations) that will have co-benefits for NFM. Farmers may also undertake major changes in land-use as part of their core farming and food production which may have impacts on runoff and other natural capital measures e.g. changing between arable and pastures, adding forestry, energy production (solar or biomass) or switching between organic, regenerative and conventional farming systems. These may be positive or negative in terms of flood risk downstream. The National Highways (NH) NFM Fund measures may be considered as part of a system of multiple measures for multiple stakeholders.

The coordination of multiple stakeholders' multiple benefits could be part of the next logical step forwards for this NFM pilot, however, there are some quite serious complications that will need to be resolved if it is to work.

Reducing flood risk at hotspots on the SRN may be achieved by implementing measures on 3 main levels:

1. On network infrastructure: Measures in the immediate vicinity of the highway flood area (hotspot) – e.g. additional storm gullies and drains, drainage channels, balancing ponds, flood walls – generally engineered structures on NH land as a component of NH assets constructed by NH which address risks from both pluvial and fluvial flooding. Not normally NFM based.
2. Off network NFM for Flood Hotspots: Measures beyond the NH estate but in the local vicinity of a flood hotspot, generally pluvial flooding – NFM measures which will retain flows on the land so reducing the peak flood response and lengthening the time of concentration of runoff from landfall to flood risk area either by overland flows or stream flows for medium sized storms occurring every year or two. Constructed by the landholders. This approach is generally suited best to small catchments. It was the focus of the NFM Fund Pilot and would also be the focus of the NFM Fund+ delivery model discussed in section 4.3.
3. Off network Catchment level NFM: Measures over the whole catchment, further from the flood hotspot which will reduce the flood peak in rivers where these are a contributory factor to the flood risk at the hotspot or a threat to asset integrity. Generally fluvial flooding in large storms – 1 in 10 to 1 in 100 return period. Constructed by the landholders.

Only a subset of NH flood hotspots will be responsive to nearby NFM measures (level 2 above), section 4.3 addresses expanding NH led partnerships for the delivery of these. Many others will require the flood levels in watercourses to be reduced (level 3) or are a result of problems with the infrastructure in their immediate vicinity (level 1).

NFM and flooding is particularly complex because two identical landholder measures with the same storage volume in different locations will have very different benefits in relation to different flood hotspots depending on distance and type of flow path. This will also be different in relation to the flood risks of different stakeholders (e.g. local authority buildings at risk). The flood risk level, and risk reduction affecting different stakeholders' assets at different distances can be complex to quantify.

Going through each of these levels 1 to 3, the benefit of the measure to the level of flood risk at the NH hotspot becomes less direct but the costs to NH of implementing NFM measures may become lower and co-benefits higher with greater opportunity to share costs with others.

NFM can contribute to this level 3 catchment flood management but only if implemented across large proportions of the whole river catchment. NH would not be able to directly incentivise or fund such measures on such a scale, however other measures that are being implemented for other stakeholders may deliver co-benefits of catchment runoff reduction which NH may be willing to contribute towards funding as a percentage of the overall cost.

The ideal of a future scheme would be that multiple stakeholders cooperate to run a system that allows landholders to bid for funding / to sell benefits in actions that will increase natural capital including flood risk reduction, or potentially to have to pay into the scheme if undertaking activities that will reduce natural capital; all quantified over multiple benefit metrics for multiple stakeholders. Stakeholders would contribute in accordance with their interest in attaining specified benefits.

Such a system could be extremely complex and difficult to manage. It could only work if facilitated by a digital twin of land-use, natural capital and operational benefits and stakeholders' interests in receiving those benefits. The NFM Fund Pilot did have the basic components required for this but with very limited scope around NFM benefits on specified sensitive receptors of SRN flood hotspots.

Building an all-encompassing multi benefit system cannot be done in a single step, it will need to be built up in incremental stages, adding new features and new partners to a system, implementing, resolving issues, learning and then taking next steps.

The interactions operate in multiple directions and between multiple participants e.g. between measures and receptors; upstream and downstream; stakeholders in natural capital services and landholders providing such services; between different stakeholders; and between natural capital services and landholder food or other agricultural product values. Developing a multi stakeholder scheme will involve gradually building capability in each of these, and many other parts, then gradually bringing these together.

Some of the steps to consider in the development of catchment wide multi-stakeholder schemes:

- Catchment wide NFM potential impact on NH assets: Identify NH flood hotspots across a catchment and which of these are at risk due to flood waves on main river reaches (fluvial flooding rather than local pluvial runoff). Estimate the runoff reduction and resultant flood risk reduction that might be achieved by catchment wide NFM measures and thereby the benefit that might be allocated regarding NH assets.
- NH willingness to pay: Develop metrics of the value of a given level of flood risk reduction and what NH might be willing to pay to other stakeholder led schemes to achieve this.
- Other stakeholders' willingness to pay: Estimate the co-benefits of NH NFM fund schemes and the value of these to other stakeholders in the catchment (use Natural Capital Studio). What would be their willingness to pay?
- Clarify the different modelling approaches for catchment wide, fluvial, flood risk reduction compared to local fluvial flood risk reduction.
- Look at the negative natural capital impacts of some changes in farmland use and if there is scope to incur levies or require compensation for the removal of natural capital and ecosystem services which are of value to others.

It is a huge challenge to make such a system workable and not just a complex nightmare that adds friction to anything that anybody tries to do on their land. However, it could also be a part of facilitating the major changes in attitude to land use that will be required if we are to transition to a net-zero society.

The technologies of farming have changed massively in the last 70 years or so with mechanisation, chemical enhancement, genetic selection and a dramatically reduced rural population. Yields have increased and new ways have been found to extract value from land through leisure, recreation, and commercial activities in rural settings. There is also a need to increase residential development in rural areas. The next stages of rural development will likely involve a branching between greater intensification with greenhouses, indoor vertical



farm systems and synthetic processes applying high energy and capital to produce orders of magnitude greater yields of crops from any climate in any location at any time of year at low enough costs to feed growing populations; and at the same time de-intensification of the rest of the land to produce high quality produce in a manner that regenerates the ecosystem services that support us and most importantly protects and regenerates the soil. The way that we develop land for residential purposes could also transition to allow the lines between urban and rural to become less distinct, such that people can live in active rural settings as participants. Currently the danger is that people move to sub-urban compounds next to barren monoculture fields they only see through their window and have no connection with.

The land-use change is one half of the climate change adaption / mitigation and net-zero journey that we are now on. If we are to succeed not only must we change our industry, energy use, transport, and urban infrastructure we must change the way that we manage land to build natural capital and resilience. This will be a great challenge, requiring us to extend from our current sets of prototype models of land use change impacts in different sectors to an operational digital twin system that can facilitate multiple stakeholders to work together and direct investment in the most efficient manner.

A small part of the how to build the layers of such systems can be informed by the lessons from this NFM pilot. We have demonstrated some of the elements of such a system but there are far more parts yet to bring together.

## 4.5. Key points

- National Highways' emerging Environmental Sustainability Strategy presents Nature-based Solutions (NbS) as an essential component of delivering the organisation's corporate and project environmental targets. NFM is recognised as a key component of this approach. However, investment in implementation of NFM needs to be supported by a credible business case. This case can consider wider non monetised benefits, but does require a sound economic footing.
- Two models are proposed for delivery of NFM by National Highways, as set out below. These are not alternatives; they would run concurrently.
  - **National Highways led partnership.** This model is applied to catchments where National Highways can make a sound business case for funding an NFM implementation in its own right. It is the next generation of the NFM Fund (NFM Fund+) that focuses on
    - Hotspots where
      - flood issues at specific assets are generated by off-network flood sources
      - substantial traffic disruption results from flooding
    - Catchments
      - that are small and physically suited to NFM
      - with landholders and landholder groups that are particularly receptive to implementation of NbS and NFM
    - Measures that optimise
      - co-benefits
      - cost effectiveness of the stored volume
  - **National Highways as a participant in a wider Catchment Partnership.** This recognises that a viable business case for application of the next generation of the NFM Fund cannot be developed for all catchments where benefit to the SRN can be derived from application of NFM, especially where the risk arises from fluvial flooding and requires measures over a wide area distant from the flood hot spot. For these catchments a broader partnership approach will need to be developed in which National Highways are a participant (rather than the lead).
    - Hotspots where
      - flood issues at specific assets are generated from off-network flows leading to higher river or flood plain water levels
      - substantial traffic disruption or threat to asset integrity results from flooding
      - Co-benefits from NH participation in schemes with partners can justify investment by NH.
      - NH investment in NFM measures can also reduce the flood risk to other stakeholder's assets and be accounted as a benefit by them.
    - Catchments

that are large, rural and have potential for NFM  
with landholders and landholder groups that are receptive to implementation of NbS and NFM

- Measures that optimise  
co-benefits  
Reduction in peak runoff and attenuation of large storms

## 5. Conclusions

### 5.1. Conclusions

Is there likely to be a viable business case for National Highways to invest in implementation of NFM off-network on third party land?

#### Partnership Delivery

National Highways has successfully worked in partnership with landholders and Rivers Trusts to improve flood resilience and reduce flood risk on the Strategic Road Network (SRN) using Natural Flood Management (NFM). Over 100 NFM measures have been implemented on 19 landholdings outside of National Highways' estate, upslope of known flood hotspots within the Pilot Catchments.<sup>11</sup>

**The governance and payment framework under which the Pilot has operated is a significant logistical achievement that has allowed the partnership to function with clear roles and fair commercial terms.** In particular each participant has benefited from the collaboration. National Highways achieved implementation of NFM on third party land where measures were needed to reduce flood risk and increase flood resilience on the SRN. Landholders were paid to implement measures on favourable commercial terms and with minimum disruption to their business. The Rivers Trust were able to promote sustainable flood risk management and wider good environmental practice in their catchments.

#### Flood risk and flood resilience on the SRN

A simple volume based assessment indicates that storage of flood water by the measures implemented by the NFM Fund Pilot has the potential **to reduce flood risk in two and increase flood resilience in seven of the 15 sub-catchments** in which measures were implemented. Reducing the risk of flooding means reducing the number of times flooding happens. Increasing resilience to flooding means, that when flooding does happen, it causes less harm to people, less damage and life can get back to normal more quickly.

#### Benefits generated by the NFM Fund Pilot

The benefit of NFM to road users is the reduced disruption of traffic that comes from less frequent flooding of the SRN. Industry standard techniques were used to estimate the change in disruption that could occur to the M62, M66 and A616 adjacent to the three Focus Areas measures were implemented. Even modest changes in the frequency of the onset of road flooding (e.g. a reduction from once every year to once every two years) had the potential to generate substantial benefits on the M62 (£10M in present value over 25 years) and M66 £1M in present value over 25 years), but much smaller benefits on the single carriageway of the A616 (£100k in present value over 25 years). **Only a small proportion of this benefit was attributed to the measures implemented by the Pilot (£179K, £231k and £16k respectively) however with careful selection of future measures and by using an additive approach to enhance the coverage of NFM in Focus Areas the benefits would be expected to increase.**

**The enhancement of natural capital achieved by NFM measures implemented in the Pilot is estimated at £104k (in present value over 25 years) for the Irwell Sub Focus Areas combined, and £113k in present value over 25 years for the Little Don Focus Area.** This value includes an estimate of biodiversity gain from woodland (but not hedgerows).

Enhancement of natural capital makes a significant contribution to benefits of the Pilot in the Irwell Focus Area, particularly accounting for the non monetised components of biodiversity benefit. It is the majority benefit in the Little Don Focus Area.

#### Cost of the NFM Fund Pilot

The Present Value Cost (PVC) over 25 years of the NFM Pilot was £121k for the M62 (East) Sub Focus Area, £562k for the M66 (North) Sub Focus Area and £814k for the Little Don Focus Area. The high cost for the Little Don reflects an extensive use of NFM measures requiring re-application on a regular basis.

<sup>11</sup> Irwell Sub Focus Area (M62 - East) , Irwell Sub Focus Area (M66 - North) and the Little Don Focus Area (A616).

## Value for money

**Cost effectiveness of the NFM Fund Pilot compares favourably to that of a typical small scale traditional flood storage scheme.** Measures implemented in the Pilot are estimated to have an average cost effectiveness of £166/m<sup>3</sup>, calculated from Present Value Cost over 25 years. Typically small scale traditional flood storage schemes with comparable design lives have a capital (implementation) cost of between £280 and £470 per m<sup>3</sup> water stored. There is significant variation in the cost effectiveness across the measures implemented in the Pilot with online storage ponds costing £63 /m<sup>3</sup> and the most popular measure (cross slope woodland) costing £535/m<sup>3</sup>.

Benefit-cost ratios were calculated for implementation of the NFM Pilot at Pilot Wide, Sub Focus Area and sub-catchment scales. The benefit side of these ratios only account for flood risk benefits and do not include monetised values for co-benefits. **This analysis reveals a very mixed picture. Implementation of NFM in one sub-catchment generated a benefit cost ratio of just below three. However, the ratio for most catchments was well below unity and, in most sub catchments in the River Don Focus Area, close to zero.** The Pilot as a whole generated a benefit-cost ratio of 0.28. Key reasons for this variation include a) the substantial difference in flood risk benefits attributed to each of the Sub Focus Areas; b) the variation in cumulative runoff captured by NFM measures across sub-catchments (used as a scaling factor for attributing benefits to sub-catchments) and c) substantial variation in the cost effectiveness of measure types. Catchments generating higher benefit cost ratios were those where cost effective measures captured a significant proportion of the total runoff upslope of a busy, heavily used motorway where the impact of reducing disruption from flooding is greatest.

The pilot nature of the study will have pulled down benefit cost ratios. Lower overhead costs associated with economies of scale, more targeted application of measures (taking account of both flood risk and other environmental benefits) and increased competition amongst applicants all have potential to reduce the unit cost of future roll outs of the NFM Fund. However, if the Fund is to be rolled out further, more needs to be done to secure a sound investment.

**The Pilot has demonstrated, in a small number of sub-catchments, that careful targeting of hotspots, catchments and measures can generate a more attractive investment case. These target conditions comprise** locations where cost effective NFM measures directly address a surface water flooding issue, on a heavily used motorway. They are in catchments physically suited to NFM on holdings managed by landholders who are receptive to implementing nature-based measures such as NFM. **The NFM Fund delivery model needs to be refined to identify and target these types of opportunity.**

## How could National Highways invest in NFM at a scale sufficient to make a useful contribution to their business objectives?

We suggest National Highways considers two forward pathways for wider roll out of NFM to reduce flood risk and improve flood resilience on the SRN.

- **National Highways led partnership.** This approach uses a refined version of the NFM Fund to target catchments, hotspots and measure combination that are particularly receptive to the application of NFM.
- **National Highways as a participant in a wider Catchment Partnership.** An approach appropriate to larger more complex flood risk challenges demanding greater collaboration in which the requirements of multiple stakeholders are fully considered, and importantly, the value of multiple benefits are fully accounted

### National Highways led partnership

More needs to be done to turn the NFM Fund into a viable business model for delivering NFM. We believe the solution to this lies in optimising the pairing of hotspots and catchments to which the NFM Fund is applied. Further work is also required on the selection and application of measures. Table 5-1 sets out key factors for targeting these catchments / measures and operating effective NFM measures over their 25–30 year asset life.

We believe this optimisation can be achieved by refining the existing NFM Fund delivery model run under a National Highways led partnership. We have called this the NFM Fund+ model.

**Table 5-1 – Factors influencing effective implementation of NFM**

	Factor	Explanation
Hotspots	Substantial traffic disruption results from flooding	<ul style="list-style-type: none"> <li>Target hotspots at which flooding causes the greatest disruption to traffic. These are the parts of the SRN that flood and where traffic flows are greatest and diversion routes are longest.</li> </ul>
	where flood issues at specific assets are generated by off-network flood sources	<ul style="list-style-type: none"> <li>Focus NFM upstream of specific highway drainage assets that a) local operations teams identify as vulnerable to flooding and b) flooding is linked to off network flood sources. HADDMS gets some of the way on this, but understanding of local drainage systems is key</li> <li>Recognise NFM as part of an integrated flood management solution for the SRN. Its main role will be to complement the existing drainage system, creating resilience to flooding on the road network</li> <li>Closer collaboration with the National Highways Operations team is needed in any future development or roll out of the NFM Fund. Their knowledge of the location and cause of local flood hotspots is a key input in deciding on Focus Areas and, more specifically, siting NFM measures to optimise their effect on flood risk and resilience</li> </ul>
Catchments	that are small and physically suited to NFM	<ul style="list-style-type: none"> <li>From a purely pragmatic perspective it is easier to implement NFM in smaller catchments with fewer landholders where there are clear opportunities to implement substantial measures. These factors all facilitate quicker implementation of measures that capture a useful proportion of the runoff generated by a catchment</li> </ul>
	with landholders and landholder groups that are particularly receptive to implementation of NbS and NFM	<ul style="list-style-type: none"> <li>NFM is as much an attitude towards land management as it is an engineering approach. Working with landholders who have a progressive view on Nature-based Solutions and the role of their holding the wider landscape is likely to yield more effective NFM measures</li> </ul>
Measures	that are reasonably cost effective	<ul style="list-style-type: none"> <li>Go big. Substantial measures, or changes to land management / use across larger areas, store more volume and tend to be more cost effective</li> </ul>
	that optimise co-benefits	<ul style="list-style-type: none"> <li>Design measures that optimise across both flood risk and wider benefits. A little more investment to optimise, say, the biodiversity function of a measure has the potential to substantially increase its value</li> </ul>
	Know who owns what / who is responsible for what. Test landowner appetite for longer term agreements and measure performance specifications	<ul style="list-style-type: none"> <li>Clear agreement on attribution of co-benefits between partners is essential. National Highways need to understand the benefits they own or have rights to, and hence can legitimately include in their business case</li> <li>The anticipated design life of NFM measures is 25–30 years. Clear agreement on who manages and maintains all functions of an asset over the period is required. Specifications and monitoring will be necessary</li> </ul>

### National Highways as a participant in a wider Catchment Partnership

This recognises that a viable business case for application of the next generation of the NFM Fund cannot be developed for all catchments where benefit to the SRN can be derived from application of NFM, especially where the risk arises from fluvial flooding and requires measures over a wide area distant from the flood hot spot. For these catchments a broader partnership approach will need to be developed in which National Highways are a participant (rather than the lead).

### What are the wider lessons learnt from the Pilot?

Key wider lessons learnt from the Pilot are summarised in the tables below.

**Table 5-2 - Summary of lessons learnt – engagement**

Topic	Lessons learnt
With landholders	<ul style="list-style-type: none"> <li>- Key to successful engagement with landholders is</li> <li>- a single point of contact (see 'Catchment Advisor' below)</li> <li>- allowing time to build relationships with landholders</li> <li>- recognising that every person and business is different, and adapting the approach accordingly</li> <li>- keeping the scheme simple and making it attractive to participants</li> <li>- having examples and data to hand to demonstrate how and why NFM measures work</li> </ul>
With National Highways	<ul style="list-style-type: none"> <li>- Closer co-operation with partners within National Highways is going to be necessary to fully realise the potential of a wider roll out of the NFM Fund</li> <li>- Operations team – to advise on a) locations on the SRN where flooding generated by surface runoff is a critical issue and b) to support the locating of NFM measures.</li> <li>- Parties with interests in capturing and realising the co-benefits of NFM</li> </ul>
Central role of the Catchment Advisor	<ul style="list-style-type: none"> <li>- Catchment Advisors are a well-known and respected presence in the catchment. They are a crucial link between National Highways and local communities / landholders. They need to be an advocate of NFM and other Nature-based solutions. Landholders relied on them heavily throughout the NFM Fund Pilot as a source of knowledge on effective implementation of NFM and on the NFM Fund process. Rapid implementation of the NFM Fund Pilot was largely attributable to the existing long term relationships established by the Rivers Trusts in the Pilot catchments.</li> </ul>

**Table 5-3 - Summary of lessons learnt – NFM Fund Framework**

Topic	Lessons learnt
Delivery process	<ul style="list-style-type: none"> <li>- A longer lead in time to auctions would have increased uptake. In particular it was too short to engage with strategic landowners such as Water Companies.</li> <li>- The general feedback on the manuals supporting the NFM Fund Pilot was more pictures and less words. Landholders wanted more visual documents. The Rivers Trusts were the principal users of written technical information. The design specification in particular served as a contract specification, and as such needed to contain sufficient detail to unambiguously define deliverables.</li> <li>- More information on consenting was requested by all.</li> <li>- An appropriately resourced team, which is resilient to changes in staffing is crucial to delivery. The face or focal point of this team is the Catchment Advisor. The advisor needs support from others – as a sounding board and specialist advice on technical matters beyond their area of expertise.</li> </ul>
Bidding platform	<ul style="list-style-type: none"> <li>- The NatureBid bidding platform proved to be an excellent proposal generator for the team assessing applications. It produced a database ready for analysis. However there was some reluctance to engage with the platform amongst landholders.</li> <li>- The bidding process generated limited competition amongst applicants.</li> </ul>
Technical assessment	<ul style="list-style-type: none"> <li>- The process generally worked well. It screened out applications for schemes with low NFM potential and picked up potential technical issues with measures requiring clarification and revision to applications.</li> </ul>



of applications	- More engagement with National Highways Operations team at this stage would have potentially targeted funding better
Contract Framework	- A robust and effective contract framework was established for the operation of the scheme which can form a good model for future schemes for NFM and other Natural Capital measures by other stakeholders

**Table 5-4 - Summary of lessons learnt – Governance**

Topic	Lessons learnt
Governance Framework	- Successful implementation of the NFM Fund, and delivery of NFM measures on third party land is a significant logistical achievement. However, this framework and delivery structure will need developing if the NFM Fund is to be rolled out more widely. In particular, other parties need to be involved, roles need to be more clearly defined and a governance structure needs to be developed that defines the inputs from and outputs to each party involved.
Long term management and maintenance of measures	- Securing the NFM function (and co-benefits) of NFM measures throughout the maintenance (operational) phase of the NFM Fund. The NFM Fund Pilot incorporated a relatively short maintenance period (2022–27) in which landholders are responsible for maintaining the function of measures. Wider roll out would require many more measures to be implemented and maintained over a much longer operational phase (say 30 years). A clear definition of roles and responsibilities is required. Clarity on whether participants would be willing to enter into such long term agreements is required.
Resources and skills	- Even at the pilot scale, securing people with the right skills to deliver the NFM Fund has sometimes been a challenge. Wider-roll out will exacerbate this issue. How best manage the greater number of people and wider range of skills needed to resource wider roll out of the NFM Fund? Long term resilience of these teams to change in staff also is critical.
Co-benefits, securing and attributing	- If co-benefits (e.g. natural carbon sequestration and biodiversity gain) are to form an important part of the business case for the roll-out of the NFM fund) a transparent, credible process is needed to quantify these benefits and clearly attribute them amongst partners in any implementation. Put simply, how much are the co benefits worth, how can they be kept secure, and who owns them?

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# Appendices



# Appendix A. Flood Risk Benefit Assessment

# Technical Note

Project:	National Highways Natural Capital Assessment		
Subject:	Transport disruption damages – flood risk		
Author:	[REDACTED] - originator, [REDACTED] – checker , [REDACTED] - reviewer		
Date:	01/09/2022	Project No.:	5198557

## Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
1.0	For inclusion in overall project reporting as appendix	PE	AB	CNS		01/09/2022

## Client signoff

Client	National Highways
Project	National Highways Natural Capital Assessment
Project No.	5198557
Client signature / date	



# 1. Introduction

Traffic disruption has been calculated for the:

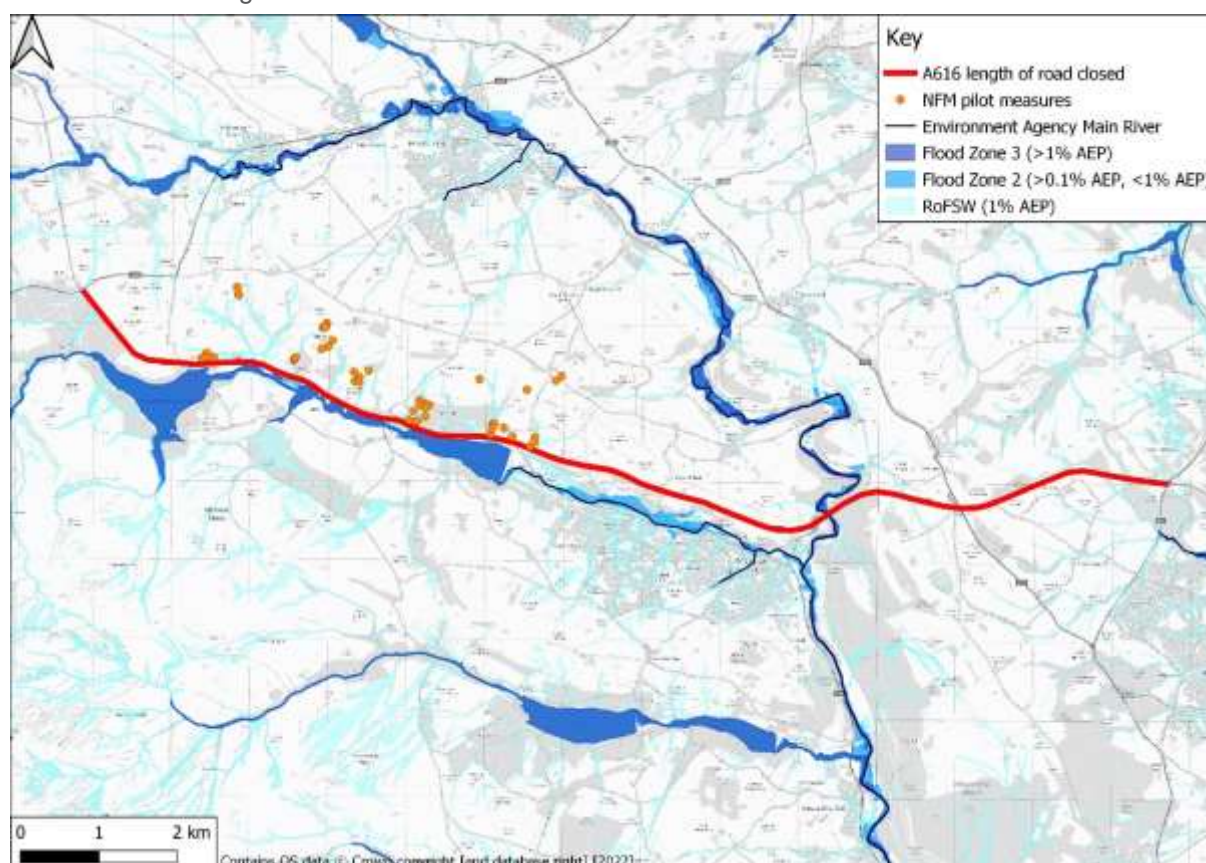
- A616 in the Little Don catchment;
- M62 in the Irwell catchment; and
- M66/A56 in the Irwell catchment.

Traffic disruption has been calculated for both the baseline (i.e., the existing flood risk to the roads presently) and also with the implementation of Natural Flood Management (NFM). NFM has not been modelled and therefore the theoretical potential reduction in flood risk to the network has been demonstrated through sensitivity testing of a range of design flood events which have been presented.

Figure 1-1 shows the flood risk from the Little Don to the A616. In the event of a flood, the A616 would be closed from Flouch roundabout to the west to Westwood roundabout in the east. The length of road closed is shown in the figure.

Figure 1-2 shows the flood risk from the Irwell to the M62. In the event of a flood, the M62 would be closed from Junction 20 to Junction 21. The length of road closed is shown in the figure.

Figure 1-3 shows the flood risk from the Irwell to the M66. In the event of a flood, the M66 would be closed from Edenfield Roundabout to the north, to the junction with the A56 east of Nuttall to the south. The length of road closed is shown in the figure.



**Figure 1-1 - Flood Risk to the A616 from the Little Don**

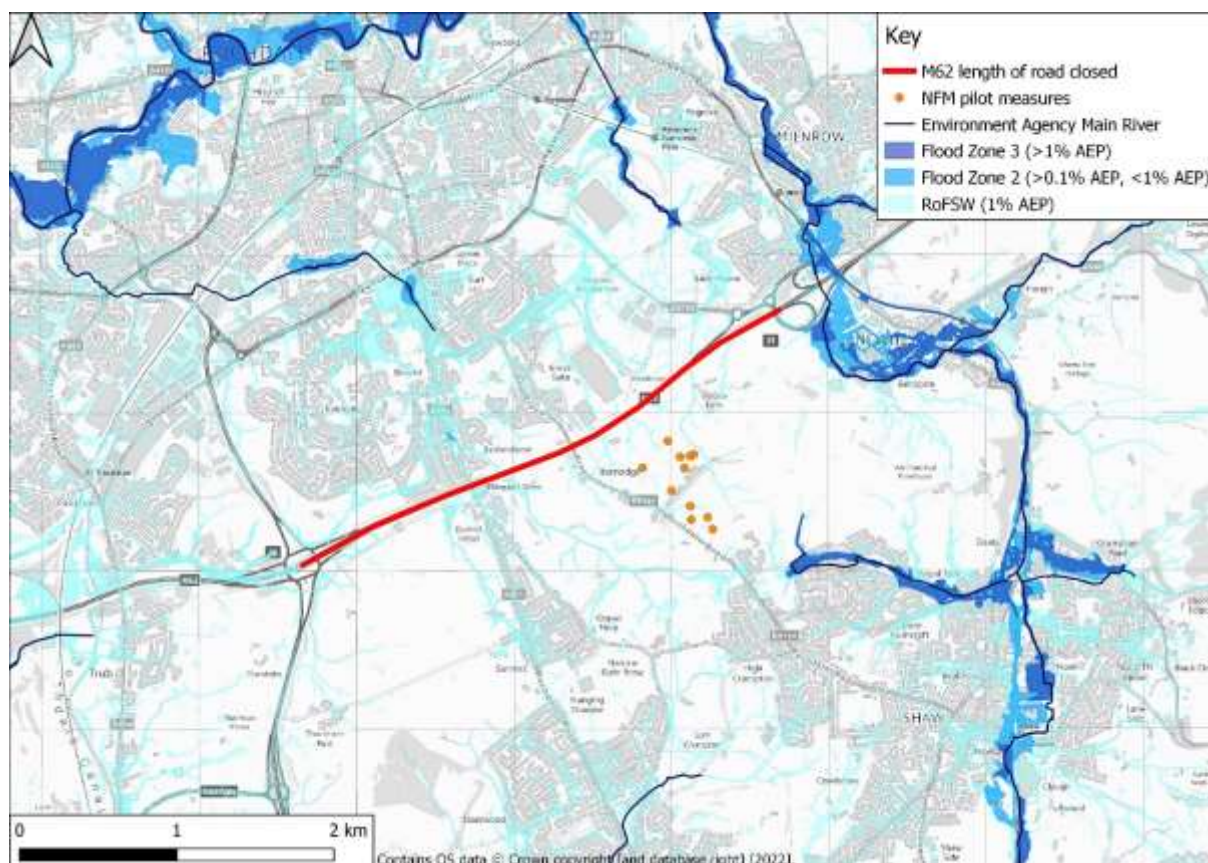


Figure 1-2 - Flood Risk to the M62 from the Irwell

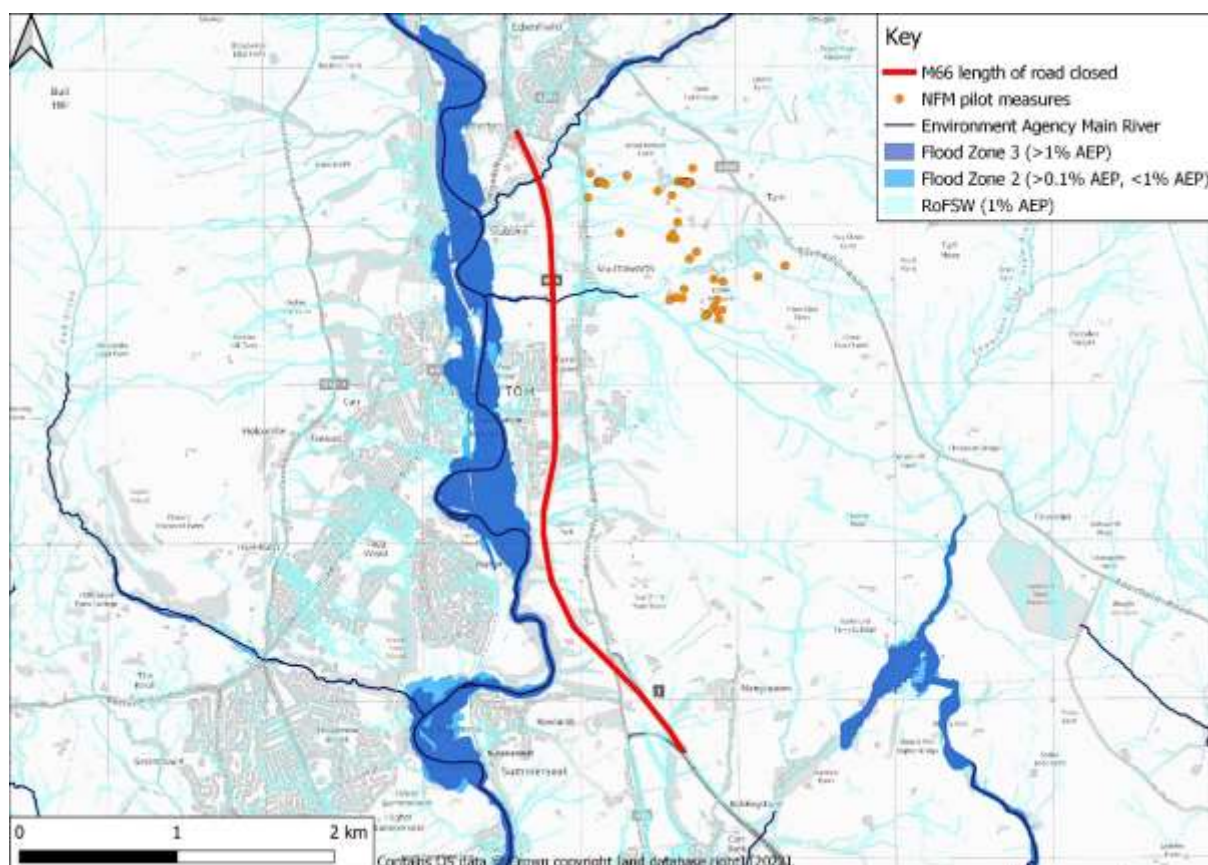


Figure 1-3 - Flood Risk to the M66 from the Irwell



## 2. Methodology

Traffic disruption has been calculated using a simplified WEBTAG (Department for Transport, 2021) approach. This calculation is based on the value of time, fuel and operating costs of each vehicle and generates a single traffic disruption damage value per flood event.

Traffic count data was taken from the Department for Transport (DfT) regional statistics for Rural A Roads in Yorkshire and the Humber, and Motorways from the North West.

The method is outlined below. The impact of climate change was not investigated as part of this appraisal.

### 2.1. Flood occurrence

Flood frequency was derived a number of ways. For the A616 National Highways were able to provide an indication that the road was flooded approximately once every 2 years from on the ground experience. For the M62 flood frequency information was not provided by National Highways but instead based on anecdotal local knowledge from Mersey Rivers Trust and for the M66 only anecdotal news reports online were available to inform how frequently flooding impacts the road.

#### 2.1.1. A616 Little Don

For the A616, traffic disruption and road closure due to road flooding is assumed to last for 0.5 days (12 hours) and first incurred in the 50% (1 in 2) Annual Exceedance Probability (AEP). It is assumed this affects both carriageways. This was then altered to represent the potential impact of NFM features, assuming that the flooding was first incurred in the 33.3% (1 in 3) AEP, the 20% (1 in 5) AEP and the 10% (1 in 10) AEP.

#### 2.1.2. M62 Irwell

For the M62, traffic disruption and road closure due to road flooding is assumed to occur twice per year with each incident lasting for 0.125 days (3 hours) and first incurred in the 100% (1 in 1) Annual Exceedance Probability (AEP). It is assumed only the westbound carriageway is impacted as per local knowledge gained from Mersey Rivers Trust. This was then altered to represent the potential impact of NFM features, assuming that the flooding was first incurred in the 33.3% (1 in 3) AEP, the 20% (1 in 5) AEP and the 10% (1 in 10) AEP.

#### 2.1.3. M66 Irwell

For the M66, traffic disruption and road closure due to road flooding is assumed to occur twice per year with each incident lasting for 0.25 days (6 hours) and first incurred in the 100% (1 in 1) Annual Exceedance Probability (AEP). It is assumed this affects both carriageways. This was then altered to represent the potential impact of NFM features, assuming that the flooding was first incurred in the 33.3% (1 in 3) AEP, the 20% (1 in 5) AEP and the 10% (1 in 10) AEP.

### 2.2. Diversion routes

#### 2.2.1. A616 Little Don

There are two diversion routes in place if the A616 is closed as shown on Figure 2-1. This information was provided by National Highways on 24/06/2022.

The first diversion route is suitable for HGVs and is diverted along the A628, the M1 and the A61.

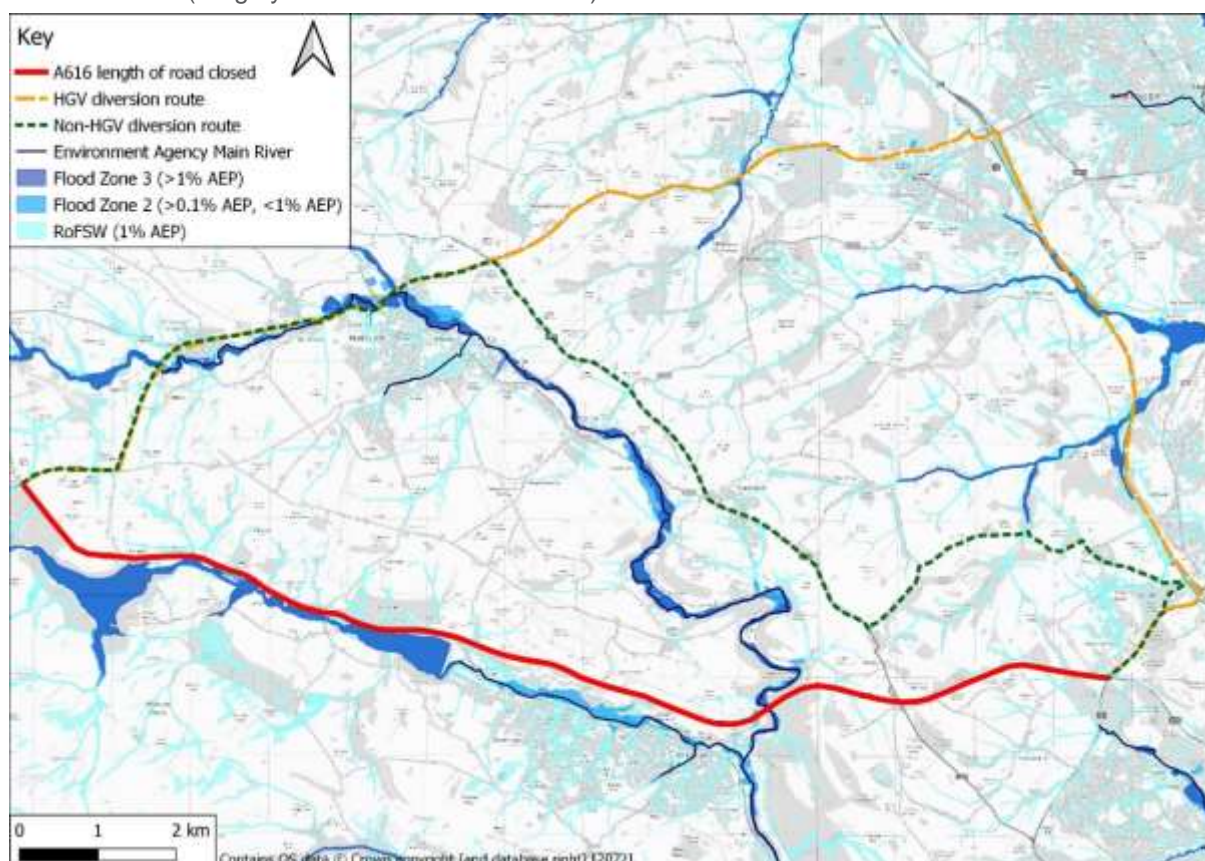
The second diversion route is diverted along more rural roads and is suitable for all other vehicle types. The roads within the diversion include the A628; the A629; rural connector roads between the A629 and A61; and the A61.

The length of each diversion, time taken, and average speed is shown in Table 2-1. The routes have been assumed to have some level of traffic, and all journey times have been taken from Google Maps.

**Table 2-1 - Diversion routes**

Route	Diversion route (km)	Time (minutes)	Average Speed (km/hr)
Normal	14.8	16	55.5
HGV	23.3	44*	32.0
Non-HGV	20.9	35	35.8

\* Time given by Google Maps was 35 minutes but applied a 25% uplift due to HGVs driving slower on the A628 portion of the route (roughly half of the diversion route).



**Figure 2-1 - Traffic diversion routes for the A616**

### 2.2.2. M62 Irwell

There are two diversion routes in place if the M62 is closed as shown on Figure 2-2. This information was based on anecdotal information from local knowledge of past flooding from Mersey Rivers Trust and professional judgement.

The first diversion route is assumed to be suitable for HGVs and is diverted along the A627(M); the A62; and the A672.

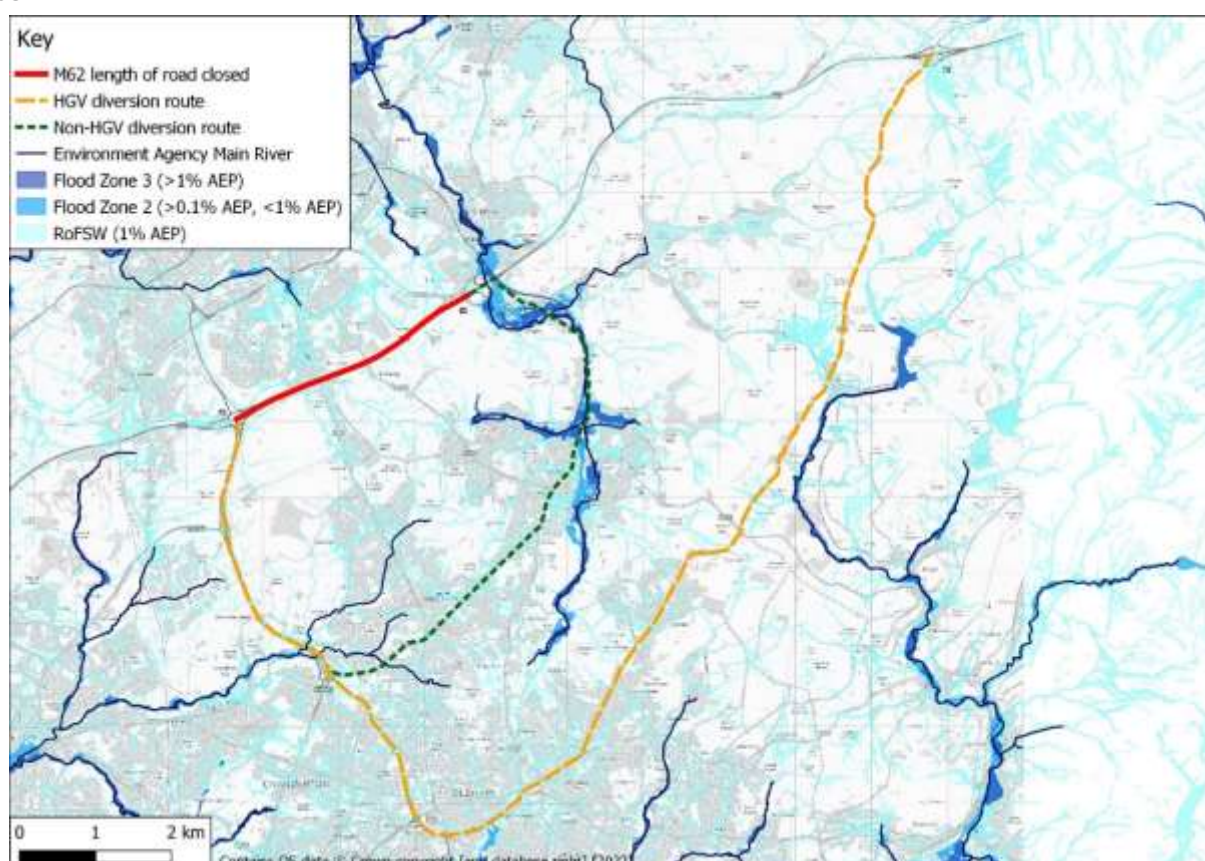
The second diversion route is diverted along more local roads and is assumed to be suitable for all other vehicle types. The roads within the diversion include the A627(M); the A663; and the A640.

The length of each diversion, time taken, and average speed is shown in Table 2-1. The routes have been assumed to have some level of traffic, and all journey times have been taken from Google Maps.

**Table 2-2 - Diversion routes**

Route	Diversion route (km)	Time (minutes)	Average Speed (km/hr)
Normal	3.4	3	67.6
HGV	19.8	50	23.8
Non-HGV	11.7	30	23.5

\* Time given by Google Maps was 40 minutes but applied a 25% uplift due to HGVs driving slower on the A-roads.



**Figure 2-2 - Traffic diversion routes for the M62**

### 2.2.3. M66 Irwell

There are two diversion routes in place if the M66 is closed as shown on Figure 2-3. This information was based on anecdotal information from media coverage of past flooding and professional judgement.

The first diversion route is suitable for HGVs and is diverted along the A56; the M65; the A666; and the A58.

The second diversion route is diverted along more local roads and is suitable for all other vehicle types. The roads within the diversion include the A56; the B6232; Broadhead Road; Bury Road; the B6212; and the B6213.

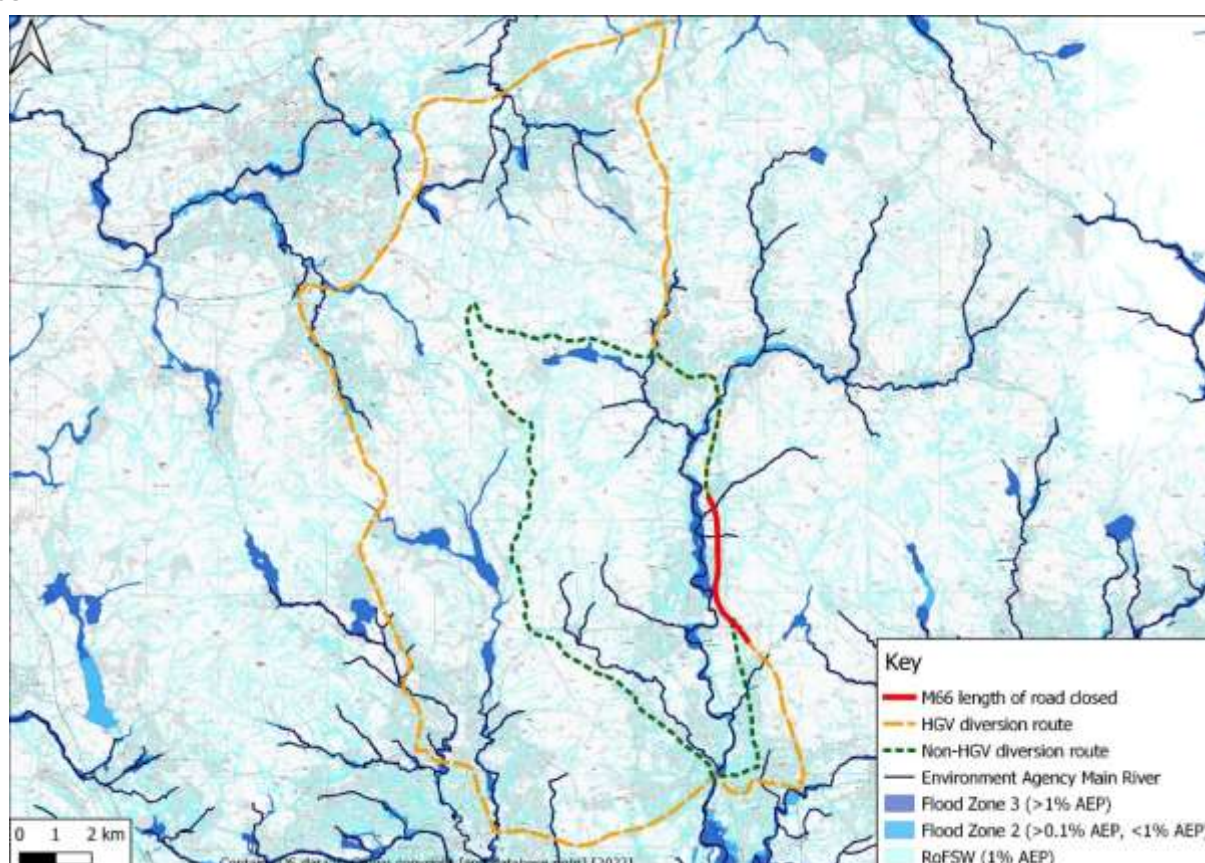
The length of each diversion, time taken, and average speed is shown in Table 2-1. The routes have been assumed to have some level of traffic, and all journey times have been taken from Google Maps.



**Table 2-3 - Diversion routes**

Route	Diversion route (km)	Time (minutes)	Average Speed (km/hr)
Normal	3.5	3	70.8
HGV	62.3	138	27.2
Non-HGV	33.3	55	36.3

\* Time given by Google Maps was 110 minutes but applied a 25% uplift due to HGVs driving slower on the A-roads.



**Figure 2-3 - Traffic diversion routes for the M66**

## 2.3. Time

The appraisal assessed costs associated with the time delay vehicles would incur due to the diversion routes. The calculation of time costs has used AADF counts, separated out for diversion routes. The traffic counts have then been multiplied by the market price of time per vehicle from the TAG data book (uplifted from the 2010 values using the GDP deflator) to establish the costs of time for both the basic and diverted routes. The increased cost per day for each of the diversions is then calculated by subtracting the time cost of the normal route from the diverted route.

## 2.4. Fuel Costs

The appraisal assessed fuel costs based on the additional distance travelled on the diversion routes. The calculation of fuel costs has used AADF counts, separated out for diversion routes. The traffic counts have then been multiplied by the fuel costs, calculated in line with the TAG data book (uplifted from the 2010 values using the GDP deflator) to establish the costs of fuel for both the basic and diverted routes. As with the time costs, the increased cost per day for each of the diversions is then calculated by subtracting the fuel cost of the normal route from the diverted route.



## 2.5. Non-Fuel Costs

Non-fuel vehicle operating costs include oil, tyres, maintenance, depreciation, and vehicle capital saving. These have been calculated in line with the TAG data book (uplifted from the 2010 values using the GDP deflator) to establish the non-fuel costs for both the normal and diverted routes. The non-fuel costs have been multiplied by the AADF and the distance travelled on both the normal and diversion routes. As with the time costs, the increased cost per day for each of the diversions is then calculated by subtracting the fuel cost of the normal route from the diverted route.

## 2.6. Generation of Present Value Losses

Losses have been established for each of the options. Under current Treasury guidance, a variable discount rate was then applied to the losses detailed above to generate the Present Value Losses (PVL) for each option over an appraisal period of 25 years which is the assumed design life of the NFM assets.

# 3. Results

## 3.1. A616 Little Don

Table 3-1 outlines the damages incurred by closing the A616 due to flooding. It also shows the damages, and benefits of testing the AEP of when flooding is likely to first occur, thereby testing at a high level, the potential impact of installing NFM measures within the Little Don catchment.

**Table 3-1 - Little Don traffic disruption results**

Traffic Disruption	Baseline	NFM test 1	NFM test 2	NFM test 3
	Flooding first occurs in a 50% (1 in 2) AEP	Flooding first occurs in a 33.3% (1 in 3) AEP	Flooding first occurs in a 20% (1 in 5) AEP	Flooding first occurs in a 10% (1 in 10) AEP
PV Damage (£K)	262.4	173.4	103.3	51.4
PV Benefit (£K)	-	89.0	159.1	211.0

## 3.2. M62 Irwell

Table 3-1 outlines the damages incurred by closing the M62. It also shows the damages, and benefits of testing the AEP of when flooding is likely to first occur, thereby testing at a high level, the potential impact of installing NFM measures within the Irwell catchment.

**Table 3-2 - M62 traffic disruption results**

Traffic Disruption	Baseline	NFM test 1	NFM test 2	NFM test 3
	Flooding first occurs in a 100% (1 in 1) AEP	Flooding first occurs in a 33.3% (1 in 3) AEP	Flooding first occurs in a 20% (1 in 5) AEP	Flooding first occurs in a 10% (1 in 10) AEP
PV Damage (£K)	1,283.9	218.8	130.3	64.8
PV Benefit (£K)	-	1,065.2	1,153.6	1,219.1

## 3.3. M66 Irwell

Table 3-1 outlines the damages incurred by closing the M66. It also shows the damages, and benefits of testing the AEP of when flooding is likely to first occur, thereby testing at a high level, the potential impact of installing NFM measures within the Irwell catchment.

**Table 3-3 - M66 traffic disruption results**

	Baseline	NFM test 1	NFM test 2	NFM test 3
Traffic Disruption	Flooding first occurs in a 100% (1 in 1) AEP	Flooding first occurs in a 33.3% (1 in 3) AEP	Flooding first occurs in a 20% (1 in 5) AEP	Flooding first occurs in a 10% (1 in 10) AEP
PV Damage (£K)	12,418.7	2,115.9	1,260.8	627.2
PV Benefit (£K)	-	10,302.7	11,157.9	11,791.5

### 3.4. M66 Irwell - Sensitivity Testing

The levels of confidence in the assumptions for the input data to the assessment are lower for the M66 disruption than for the other two roads as the sources of information have not been able to be verified or provided by National Highways. The assumptions that have been made, based on anecdotal media reports available online, have a significant impact on the results of the assessment. The impact on the results is shown in Table 3-4 and Table 3-5 below.

**Table 3-4 - M66 traffic disruption results – sensitivity test for duration of road closure from 6 hours twice per year to 3 hours twice per year**

	Baseline	NFM test 1	NFM test 2	NFM test 3
Traffic Disruption	Flooding first occurs in a 100% (1 in 1) AEP	Flooding first occurs in a 33.3% (1 in 3) AEP	Flooding first occurs in a 20% (1 in 5) AEP	Flooding first occurs in a 10% (1 in 10) AEP
PV Damage (£K)	6,209.3	1,058.0	630.4	313.6
PV Benefit (£K)	-	5,151.4	5,579.0	5,895.8

**Table 3-5 - M66 traffic disruption results – sensitivity test for frequency of flooding from a 1 in 1 to a 1 in 2**

	Baseline	NFM test 1	NFM test 2	NFM test 3
Traffic Disruption	Flooding first occurs in a 100% (1 in 2) AEP	Flooding first occurs in a 33.3% (1 in 3) AEP	Flooding first occurs in a 20% (1 in 5) AEP	Flooding first occurs in a 10% (1 in 10) AEP
PV Damage (£K)	4,680.2	2,115.9	1,260.8	627.2
PV Benefit (£K)	-	2,564.2	3,419.4	4,053.0

## Appendix B. Co-benefits assessment



# Natural Flood Risk Management Pilot Scheme

Natural Capital Assessment Report

National Highways

October 2022

# Notice

This document and its contents have been prepared and are intended solely as information for the Natural Capital Assessment of National Highway's Natural Flood Management Scheme and is for information only.

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## Client

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# Introduction

Welcome to the Natural Capital Assessment for the National Highways pilot Natural Flood-Risk Management (NFM) scheme in the Irwell and Little Don catchments.

This booklet summarises the findings of a desk study to understand how interventions funded by the scheme affect the value of ecosystem services, which are the benefits provided by the natural environment to people. The assessment considers wider benefits including climate mitigation, water quality, biodiversity and more.

The work demonstrates how the benefits of NFM can be quantified and monetised using a natural capital approach. The results can be used to inform National Highway's business plan and to help secure funding for NFM in future land management schemes.

Assessment of flood-risk benefits was undertaken using a simplified WEBTAG (Department for Transport, 2021) approach to assess traffic damages, this is reported in the separate Transport Disruption Damages Technical Note. The assessment of other ecosystem services such as carbon sequestration and biodiversity was undertaken using Atkins' rapid valuation tool, Natural Capital Studio (NCS). The tool is aligned with latest best practice and industry guidance, and uses a value transfer approach, adopting estimates from other sites as reported in authoritative government datasets and scientific literature. Combined with GIS mapping and site-specific data provided by National Highways, ecosystem services were quantified to compare pre- and post-scheme land management scenarios. Seven ecosystem services were identified as being most material to National Highways' catchment management and wider company priorities, and these were "screened in" for assessment.

A complete description of the approach, datasets and assumptions made are provided in this report alongside the results of the assessment.



Background

Natural Flood Management (NFM) measures emulate or enhance natural processes to store water in, or reduce flow through, the landscape. Typical measures include managing land to encourage infiltration of rainfall into the ground and slowing or storing runoff, either as it flows across the ground or in watercourses.

National Highways (NH) have developed a NFM Fund, to support farmers and landowners in the implementation of measures that work with natural process to reduce flood risk to A Roads and Motorways (the strategic road network). The Fund is part of £936M of designated funding made available over the next five years to deliver lasting benefits to the environment and communities. As part of a pilot scheme designed by Atkins and implemented by Sylva and the Rivers Trusts, NH awarded £650,000 to 26 landholders to implement a set of measures across focus areas within the Irwell and Little Don catchments. The focus areas within the catchments are shown in **Error! Reference source not found.** below (credit: National Highways).

The supporting technical note, ‘*Transport Disruption Damages – flood risk*’, appraises the impact of the set of measures if they were applied at scale across the whole of both catchments. Under a conservative assumption, flood frequency would reduce from a 1 in 1 year to 1 in 3 years (M62, M66) and from 1 in 2 years to 1 in 3 years (A616). In this scenario the avoided traffic disruption would be worth £1,065,200 (M62), £10,302,700 (M66) and £89,000 (A616) in present value (2021) over a 25-year evaluation horizon. The note also considers avoided disruption costs under different flood frequency and duration assumptions.

Whilst the primary aim of the scheme is to reduce flood risk, these interventions are also have known to benefit a range of other ecosystem services (benefits provided to people by the natural environment) such as water quality, air quality, climate regulation and biodiversity. As such, the interventions, to varying degrees, will contribute to the overall enhancement of natural capital, which is the stock of natural assets from which people derive ecosystem services. Revealing the value of these benefits helps demonstrate the wider contribution of the pilot NFM scheme and could potentially identify and unlock co-funding, which would be important considerations for a wider NFM scheme rollout.

The report assesses, quantifies, and monetises the likely ecosystem service value enhancement of a sample of five of the measures included within the pilot, but does not consider the costs of implementation or maintenance of the NFM measures. To do this, the study quantified and valued the ecosystem services provided at the intervention location before (baseline) and after (future scenario) the measures had been implemented. The difference between the ecosystem services provided under the baseline and future scenario was used as an estimate of the measure’s benefit.

The selected measures are:

- Cross-slope hedge and woodland
- Reducing soil compaction
- Online storage ponds
- Overland leaky barriers
- In-channel leaky barriers

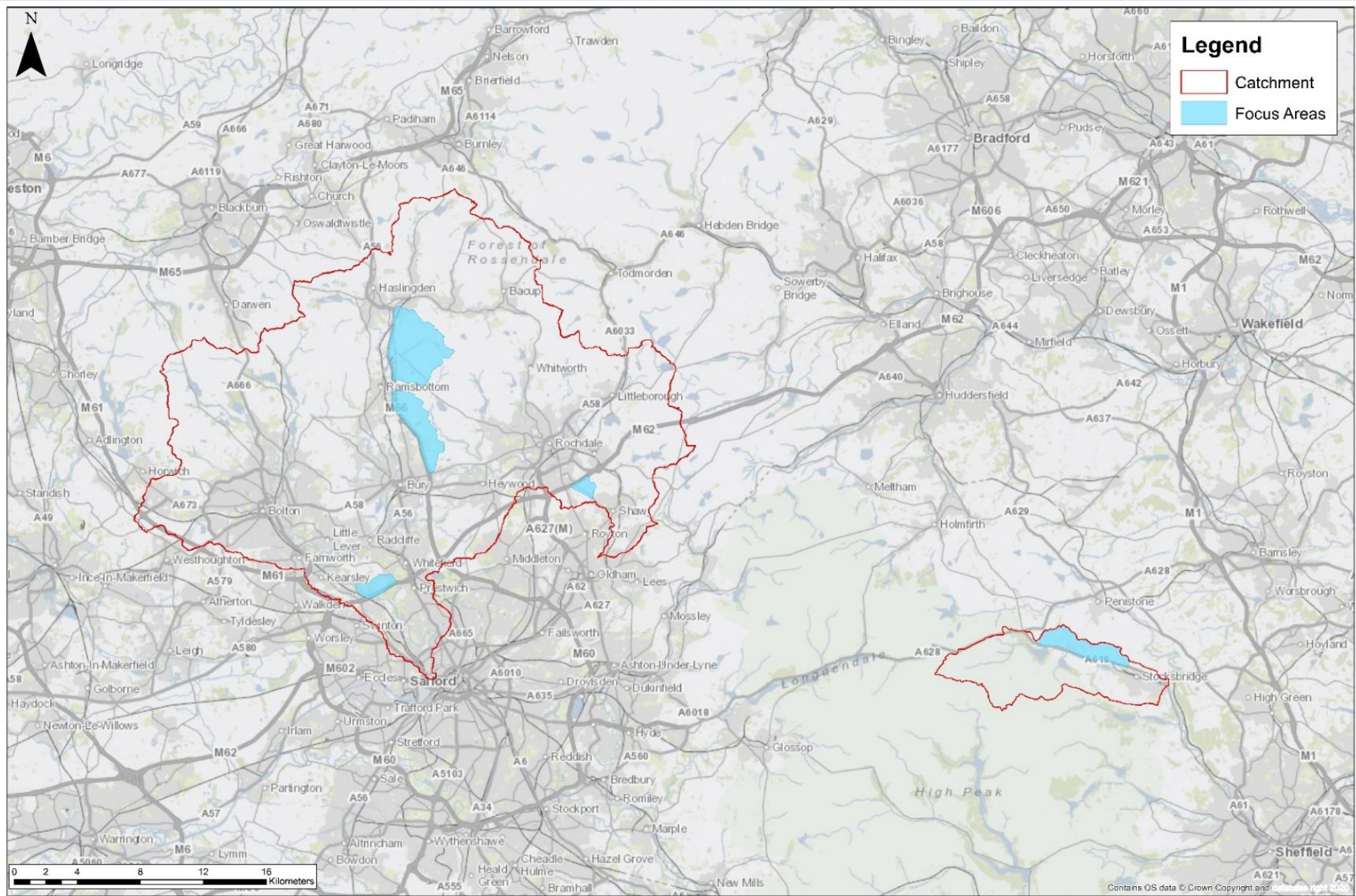



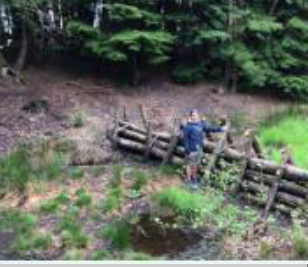
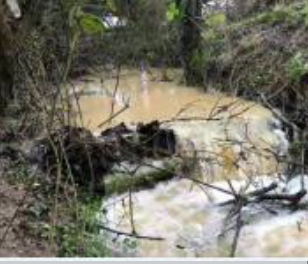


Figure 1 Location of the Focus Areas for the pilot scheme

Measure by Measure description

From the 14 available measures within the NFM Fund, a sub-sample of five was chosen to be assessed within this Natural Capital Assessment. These were selected based on an exclusion criterion which excludes the least popular options (less than 5% uptake by volume or area), focusing the assessment on the top five most popular options. A short summary of each measure is given in the table below. Descriptions in the table below are taken from The NFM Measures handbook (Highways England, 2021).



Measure	Image	Description
Cross-slope Woodland & Hedgerows		Cross-slope woodland & hedgerows involves the planting of trees or hedge species in strategic locations to intercept overland flow. The measure is designed to reduce flooding by slowing the movement of water downslope towards and into watercourses. This occurs through the interception of rainfall and overland flow, encouraging evapotranspiration, increasing infiltration through soil improvements (due to enhanced root growth), and increased surface roughness which can slow overland water flow.
Reducing soil compaction		Soil compaction can occur across whole fields but is often most focused around vehicle access routes, gateways and areas such as livestock troughs, where high pressures exerted on to the soil surface by machinery and livestock reduces soil pore space. The compaction reduces the infiltration which can lead to an increase in overland flow and flooding during a storm event. Reducing the compaction of soils through aerating, subsoiling or sward lifting can be a very effective technique. Other ways to reduce soil compaction include crop and livestock rotation, mob grazing and avoiding the use of heavy machinery on wet soils. A collection of these techniques were used within this bundle by landowners / farmers.
Online storage ponds		Online storage ponds provide additional water storage areas incorporated into existing watercourse alignments, or adjacent to them. Online ponds are hydraulically connected to the drainage network, which can be via pipes or open cut channel connections. They are designed to provide additional storage capacity within a channel or to intercept water heading towards a watercourse via the existing drainage network. Both approaches act to attenuate flow and reduce the flood peak. Once the event has passed, the connection/s between the storage ponds and the watercourses facilitates emptying of the pond so that storage is available for the next event.
Overland leaky barriers		Overland leaky barriers are discrete measures that are strategically located and fixed on a floodplain or preferential flow route to intercept and temporarily store water. They are typically constructed from wood, including whole tree trunks laid perpendicular to the flow pathway. They are designed to slow and attenuate the flow of water by roughening the ground surface and providing a barrier that acts to increase the time it takes water to move downstream.
In-channel leaky barriers		In-channel leaky barriers are constructed in small permanently, or intermittently flowing channels (2 - 3 m wide), through the placement and securing of woody material such as sections of tree trunks or large branches or boards. These measures are also frequently termed 'leaky dams', 'woody dams' or 'in-channel barriers'. Leaky barriers can be installed and secured individually, or as a series of barriers with the exact design and location dependent on factors such as channel form, flow character and proximity to local assets (bridges/culverts). They are designed to temporarily impound and hold back flood water within the channel, which then leaks away once the flood peak has passed.




**Baseline: ecosystem services being delivered by natural capital assets before scheme**

This section provides a qualitative summary for the baseline level of ecosystem services provided by the fields within the scheme, prior to the implementation of the NFM measures by landowners and farmers.

The set of ecosystem services assessed was based on Defra’s guidance within the Enabling a Natural Capital Approach (ENCA), and after a qualitative screening process undertaken by Atkins subject matter experts, who identified those ecosystem services that are of value to the catchment areas and are likely to be impact by the sample measures.

The table below and overleaf describes the ecosystem services considered in the assessment and how they were quantified. Full details on quantification and valuation methodologies are provided in the appendices (with an overview provided in Appendix B

The flood risk service associated with the scheme at baseline and post-NFM scheme was not quantified and monetised in the same measure and uptake specific method as the other ecosystem services as a hydraulic model was not available to link volumetric reductions with flood extent and frequency reductions at hotspots on the strategic road network. Instead, a high-level assessment of scheme potential (if extended from a pilot to a full implementation across each catchment) was carried out. This is described in the accompanying Technical Note and summarised in the Conclusions section of this report.

Provisioning	Food production		<p><b>Description:</b> the ability of various ecosystems to produce food.</p> <p><b>Quantification:</b> based on CORINE land cover data and the location of the measure implementation, all baseline land areas were assumed to be semi-natural grassland, which provide a stable level of food production value.</p> <p><b>Baseline:</b> All arable, grassland or rough grazing areas within the assessed boundary (14.41ha of the Irwell and 112.70 ha of the Little Don) are assumed as providing food production value. The magnitude of the value was determined with reference to the agricultural gross margin for these land cover types calculated with reference to the most recent (2019) Farm Business Survey farm productivity data for the North-West region.</p> <p><b>Relevance:</b> the implementation of the measure may reduce the available land for food production.</p>
	Water supply		<p><b>Description:</b> Waterbodies are natural capital assets and water companies rely on them to provide supply. Other natural capital assets (e.g., grassland, woodland) affect the supply of water by influencing interception, infiltration, and runoff.</p> <p><b>Quantification:</b> using the Daily Based Morgan Morgan-Finney (DMMF) model which utilises site specific infiltration and runoff data parameterised for the study area.</p> <p><b>Baseline:</b> the study parcels are all located within the Irwell and Little Don WFD management catchments. Land is steeply sloped with watercourses in proximity and supplying a moderately productive aquifer. There are major commercial (Little Don and Irwell) and reservoir (Little Don only) abstractions downstream of the study locations in the catchments. Any water infiltrating into the soil is assumed to be able to travel freely into the point of abstraction.</p> <p><b>Relevance:</b> land management changes have the potential to influence infiltration to groundwater via root growth and evapotranspiration from leaf surfaces, thus affecting the quantity of water resources available for abstraction.</p>
Regulating	Air quality		<p><b>Description:</b> air pollution is a human health risk. Management of natural capital helps to lessen these impacts by reducing direct pollution (e.g., NH<sub>3</sub> emissions) and by absorbing background pollution (NO<sub>x</sub>, O<sub>3</sub>, SO<sub>2</sub>, PM) in vegetation (particularly woodland), depending on proximity to an affected population. This air quality measurement considers the avoided NH<sub>3</sub> pollution from land use change.</p> <p><b>Quantification:</b> The FARMSCOPER tool predicts NH<sub>3</sub> emission figures associated with fertilizer use and livestock waste for a representative farm.</p> <p><b>Baseline:</b> A farm was created in FARMSCOPER using the tool's default parameters and Defra Agricultural Census data to represent the agricultural land use in and associated with the parcels affected by the NFM scheme. Baseline NH<sub>3</sub> emission figures were then taken from the tool's output.</p> <p><b>Relevance:</b> land management changes that reduce fertiliser use and livestock waste could influence the production of NH<sub>3</sub></p>

	<div>Air pollutant removal</div> <div></div>	<p><b>Description:</b> air pollution is a human health risk. Management of natural capital helps to lessen these impacts by reducing direct pollution (e.g., NH<sub>3</sub> emissions) and by absorbing background pollution (NO<sub>x</sub>, O<sub>3</sub>, SO<sub>2</sub>, PM) in vegetation (particularly woodland), depending on proximity to an affected population. This air pollutant removal service considers the absorption of air pollutants by vegetation.</p> <p><b>Quantification:</b> based on CORINE land cover data and the location of the measure implementation, all baseline land areas were assumed to be semi-natural grassland, with measures mapped to new UK Habitat types based on their specification.</p> <p><b>Baseline:</b> Jones et al (2017) determines indicative £ / ha / yr values for different habitat types across the UK, with semi-natural grassland assessed to provide a stable, but low baseline value.</p> <p><b>Relevance:</b> land management changes that increase vegetation cover and/or woodland area could increase air pollutant removal although the rural setting of the scheme and distance from any air quality management areas (AQMA) means such changes are likely to be limited.</p>
	<div>Water quality</div> <div></div>	<p><b>Description:</b> nutrients and sediment from agricultural run-off or leaching are a source of water pollution (eutrophication, turbidity, reduced clarity). Different types of agricultural land management or changes of land cover away from agriculture alter or remove rates of run-off and leaching. Vegetation (e.g., riparian buffer strips) can also intercept surface run-off and protect watercourses.</p> <p><b>Quantification:</b> Pollutant losses, from the fields, for nitrate (NO<sub>3</sub>-N), phosphorus (P) and sediment (SS) are taken from FARMSCOPER as described above.</p> <p><b>Baseline:</b> A farm was created in FARMSCOPER using the tool's default parameters and Defra Agricultural Census data to represent the agricultural land use in and associated with the parcels affected by the NFM scheme. Baseline emission figures were then taken from the tool's output.</p> <p><b>Relevance:</b> this report investigates how NFM measures change the quantity of nitrate, phosphorus and sediment lost from fields as a result of land cover change or land management change.</p>
	<div>Climate regulation (carbon sequestration)</div> <div></div>	<p><b>Description:</b> a natural function of ecosystems is to sequester carbon dioxide from the atmosphere and store it as below or above-ground carbon. This varies between broad habitats and specific land management regimes.</p> <p><b>Quantification:</b> literature review of carbon sequestration factors by habitat and land management interventions; N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> emissions values from FARMSCOPER. Emissions and removals are combined in terms of CO<sub>2</sub> equivalence (CO<sub>2</sub>e) to provide a net carbon position (but the breakdown of sequestration vs. avoided emissions is shown).</p> <p><b>Baseline:</b> the baseline habitat within the boundary is assumed to be semi-natural grassland, which sequesters carbon at a rate of 0.98 tCO<sub>2</sub>e per annum. Associated emissions from land management, machinery use and fertilisers are also present in the baseline,</p> <p><b>Relevance:</b> any change in land use or management can affect the quantity and in some cases the balance of GHG emissions and removals.</p>
	<div>Climate regulation (GHG emissions)</div> <div></div>	<p><b>Description:</b> Different farmland management regimes also influence emissions of carbon dioxide (CO<sub>2</sub>) associated with machinery use as well as nitrous oxide (N<sub>2</sub>O) and methane (CH<sub>4</sub>) from fertiliser and livestock pathways respectively. In the context of valuation, the benefit is the contribution to meeting national GHG targets to avert damaging climate change.</p> <p><b>Quantification:</b> N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> emissions values from FARMSCOPER. Emissions and removals are combined in terms of CO<sub>2</sub> equivalence (CO<sub>2</sub>e) to provide a net carbon position (but the breakdown of sequestration vs. avoided emissions is shown).</p> <p><b>Baseline:</b> A farm was created in FARMSCOPER using the tool's default parameters and Defra Agricultural Census data to represent the agricultural land use in and associated with the parcels affected by the NFM scheme. Baseline emission figures were then taken from the tool's output.</p> <p><b>Relevance:</b> any change in land use or management can affect the quantity and in some cases the balance of GHG emissions and removals.</p>
Supporting	<div>Biodiversity</div> <div></div>	<p><b>Description:</b> Biological diversity is ‘the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part’ (Convention on Biological Diversity). Biodiversity underpins to varying degrees all ecosystem services.</p> <p><b>Quantification:</b> Biodiversity unit quantification is done in units using Natural England's Biodiversity Metric 3.1 for the various types of land cover in the scheme area.</p> <p><b>Baseline:</b> Within the Irwell and Little Don catchments there are a variety of land covers. Each land cover is classified in the Metric 3.1 according to the most similar UKHab category, see 1.1.1.1.1.Appendix D for detailed biodiversity metric categories in the baseline. Given the desk-based study approach conservative assumptions on habitat condition are used in selecting ‘moderate’ across all habitats.</p> <p><b>Relevance:</b> the chosen NFM measures, may impact the habitat category, or the habitat condition and may therefore lead to an increase or decrease in biodiversity compared to the existing baseline.</p>
Cultural	<div>Recreation</div> <div></div>	<p><b>Description:</b> the recreational value of green spaces is significant. This value reflects both the natural setting and the facilities on offer and often has a strong non-market element. It varies with the type and quality of habitat, location, local population density and the availability of substitute recreational opportunities. The wider tourism and outdoor leisure sector is also dependent upon nature to varying degrees.</p> <p><b>Quantification:</b> The UK ONS Natural Capital Accounts quantification and metrics for recreation are applied on a pro-rata basis according to the hectares of UK Habitat's classified in the study area. Values reflect the aggregate predictions for visitor rates and travel costs derived from the OrVAL model.</p> <p><b>Baseline:</b> The focus areas are near to Manchester (Irwell) and Sheffield (Little Don) and the Little Don focus area intersects the Peak District National Park. They may there attract visitors from their respective close urban city areas looking escape the city for the countryside. However recreational use associated with the land parcels specifically is forecast to be fairly modest with 74,967 recreational visitors estimated per year, before the measures are implemented.</p> <p><b>Relevance:</b> Enhancements or interventions to land within existing recreational sites or adjacent to public footpaths can change the attractiveness of the site or footpath to visitors and thus change the number of annual visitors and hence the recreational value.</p>
Land cover summary		
<p>The National Highways Pilot NFM scheme was implemented across focus areas within the two catchments (as shown in <b>Error! Reference source not found.</b>). The total catchment areas for the Irwell and Little Don are 55,218 ha and 4,596 ha respectively, whilst the total areas of the measures achieved via the pilot are smaller in nature at 14.41 ha and 112.70 ha for the Irwell and Little Don. Figure 2 and Figure 3 highlight the scale of the catchment, the CORINE land cover types of the catchments, and the sites where the NFM measures were implemented.</p>		



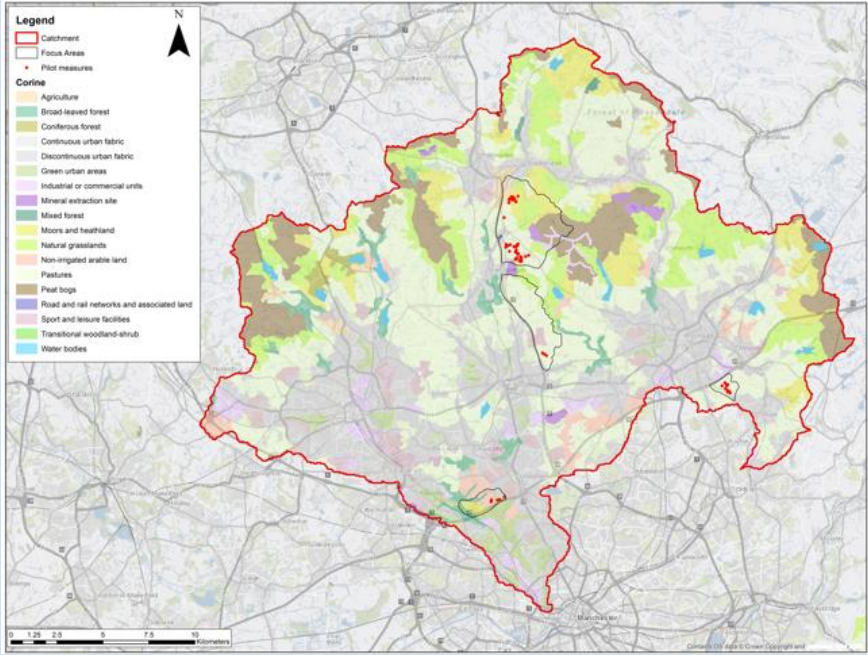


Figure 2 Irwell Baseline Landcover Map with the intervention sites

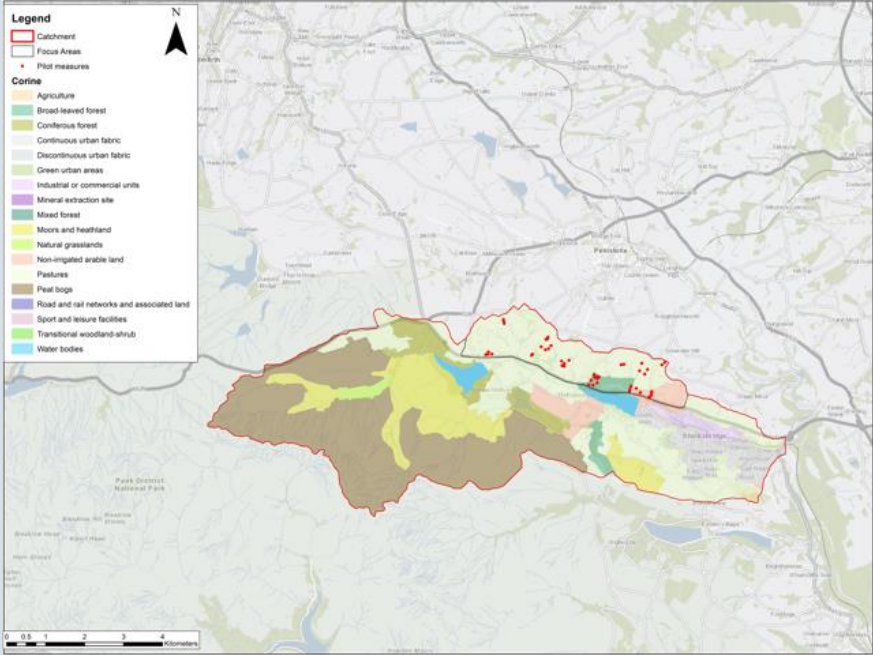


Figure 3 Little Don Baseline Landcover Map with the intervention sites

The Irwell and the Little Don catchments baseline landcover, and especially those located nearer to the measure sites, were predominantly pastureland, modified grassland, and moorland. The table shows the split area of the measures implemented between the sample of measures.

The main NFM measure implemented in both catchments was the “Reducing Soil Compaction” measure with 11.5 ha in the Irwell catchment and 111 ha in the Little Don catchment. The scale of the implementation in the Little Don, means that there were significantly more hectares of land included within the Pilot for the Little Don. The next most implemented measure was “Cross-slope Woodland and Vegetation (Woodland and Hedgerows)” with 2.6 ha and 1.7 ha in the Irwell and Little Don catchments respectively.

Ha for point interventions (overland and inland leaky barriers) were converted into area equivalent values via GIS analysis of the width and backwater associated with each intervention to calculate an average area of impact across each intervention.

Total Hectares of measures implemented		
	Area Irwell (ha)	Area Little Don (ha)
Cross Slope Woodland and Hedgerows	2.6	1.7
Reducing Soil Compaction	11.5	111
Online Storage Ponds	0.1	0.0
Overland Leaky Barriers	0.2	0.1
Inland Leaky Barriers	0.0	0.007
Total	14.4	111.3

Natural Capital Valuation

Methodology overview

The assessment provides an aggregated assessment of the combination of measures applied across the Irwell and Little Don catchments, as well as an aggregated assessment of the impact of each measure. The assessment has considered only land where the measures have been implemented, and the impact on ecosystem services and natural capital that these measures may have.

Atkins’ rapid natural capital valuation tool, Natural Capital Studio (NCS), was used to assess the change in ecosystem service value provided by this area of land under two scenarios:

- Baseline value before the implementation of the sample set of measures
- Future scenario value post the implementation of the sample set of measures

NCS facilitates a natural capital approach aligning with and building upon best practice guidelines including:

- HM Treasury Green Book<sup>1</sup>
- Defra’s ENCA<sup>2</sup> guidelines

NCS uses a value transfer approach, adopting quantification and value data from other sites in published studies alongside any local data available. The tool is applied within a GIS mapping framework to quantify and monetise up to 15 standard ecosystem services. NCS has a well-established track record and has been previous use on NFM projects including the National Highways A14 project, in catchment management schemes, and site-specific studies for local governments, infrastructure schemes and water companies. It has a large library of unit impacts and values covering a range of habitat types and interventions but can also use open source and other site-specific data sets It also interfaces with other industry standard tools such as FARMSCOPER and ORVal to provide flexibility in assessing specific services in greater detail. In this application of the tool, standard impacts and values were not available for hedgerow creation so a short literature review was undertaken to populate NCS accordingly for this intervention.

Of the 15 standard ecosystem services that NCS can quantify and monetise, 9 were ‘screened in’ for assessment in discussion with National Highways. These services were considered most material to the catchments, and most likely to be impacted by the measure implemented. Those selected are detailed in the baseline table above. Biodiversity was quantified using Natural England’s Biodiversity Metric 3.1 and a proxy ecosystem service value attributed based on a £ / habitat value from a recent Defra consultation<sup>3</sup>

A series of technical appendices outline the approach in full, including a summary of how each of the services were estimated (Appendix B ), a detailed review of the methodology for the more complex quantification and monetisation approaches (Appendix C to Appendix F ), the sources of information and data used throughout the report (Appendix G ) and the assumptions made as part of this assessment (Appendix B )

Figure 4Figure below shows the different steps used as part of the assessment. For this assessment, natural capital has been evaluated using...

<sup>1</sup> [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/938046/The\\_Green\\_Book\\_2020.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938046/The_Green_Book_2020.pdf)

<sup>2</sup> [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/869801/natural-capital-enca-guidance\\_2\\_March.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/869801/natural-capital-enca-guidance_2_March.pdf)

<sup>3</sup> Net gain Consultation proposals (defra.gov.uk)



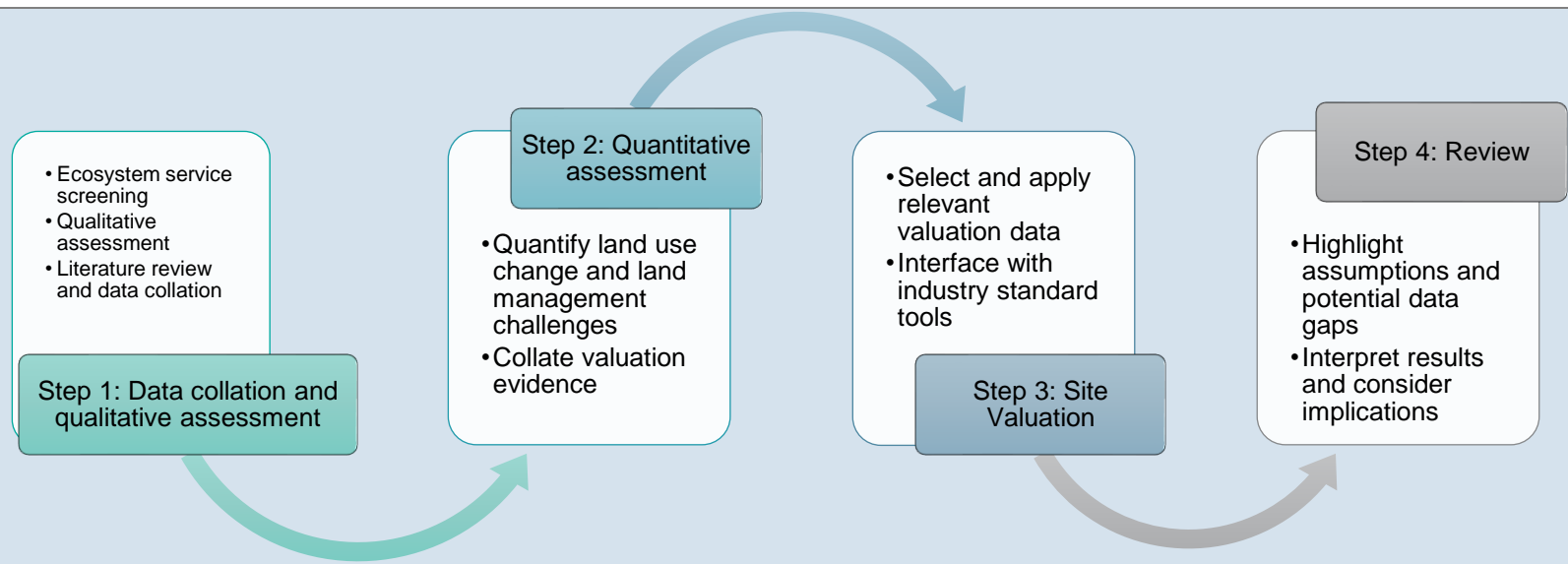


Figure 4 - Summary of process in this application of the natural capital assessment approach

### Project-specific detailed methodologies

The natural capital assessment included the application of a series of models to ensure they were as site-specific as possible and to extend and expand the functionality of NCS to enable the full natural capital assessment of the measures.

Certain ecosystem services were quantified using specific tools, in order to provide greater location specific granularity and enable more site-specific information to be incorporated to generate results, these are as follows:

- GHG Emissions
  - Methane, nitrous oxide, energy use were calculated using FARMSCOPER, detailed in Appendix C
- Air quality was calculated using FARMSCOPER, detailed in Appendix C
- Water quality was calculated using FARMSCOPER, detailed in Appendix C
- Biodiversity using Natural England’s Metric 3.1 was used to assess biodiversity, detailed in Appendix D
- Water Supply is assessed using The Daily Based Morgan Morgan-Finney (DMMF) model as detailed in Appendix E **Error! Reference source not found.**

### Catchment Scale Results – a summary

Table 1 and Table 2 set out the results at a pilot scale for the Irwell and Little Don respectively. They show both the physical flow and monetary flow accounts, representing the baseline, future scenario and change across each of the eight ecosystem services assessed aggregated across all measures, for both the Irwell and Little Don catchments. Figure 5 and Figure 6 illustrate the change in ecosystem service value delivered by the measures across the pilot areas.

The physical flow account records, where appropriate, the baseline and subsequent increase or decrease in the environmental metrics for the study area. For example, when looking at the carbon sequestration contribution, the physical flow reports the tCO<sub>2</sub> sequestered. For ecosystem service where no environmental metrics was assessed ‘na’ is recorded. This occurs when valuation of an ecosystem service is calculated through a £/ha basis, without an intermediate environmental metric step. The monetary flow account records, where appropriate, the baseline and subsequent increase or decrease in the monetary value attributed to each ecosystem service within the study area.

#### Irwell Highlights

- The assessment estimates that the combined measures deliver a total ecosystem service value increase of £3,137 per year, or £51,443 over 25 years.
- Carbon sequestration (net removals of carbon dioxide from the atmosphere) is assessed to increase by 8.59 tCO<sub>2</sub>e per annum, from 2.59 tCO<sub>2</sub>e to 11.18 tCO<sub>2</sub>e per annum, driven largely by the cross-slope hedgerow and woodland measures. Further GHG emission benefits are also estimated via the reduction in GHG emissions from land-use changes totalling 2.54 tCO<sub>2</sub>e /yr.
- Biodiversity habitat units are assessed to increase from 7.74 units to 13.5 units, again driven by cross-slope woodland measures. (Note this does not include the hedgerow or river units). Calculated using a conservative £/unit value of £9,000<sup>4</sup> a proxy ecosystem service valuation of £52,080 is calculated over the 25 year period (assumed paid upfront at the point of implementation).
- There is a reduction in the value of food production by -£402 per year, or -£6,620 over 25 years. This is caused by the replacement of agricultural land with the NFM measures, thus decreasing the agricultural productivity of the land and reducing the ecosystem service. It is noted this is a small loss given the low baseline food production value calculated for these areas.

#### Little Don Highlights

- The assessment estimates that the combined measures deliver a total ecosystem service value increase of £3,702 per year, or £60,731 over 25 years.
- Carbon sequestration (net removals of carbon dioxide from the atmosphere) is assessed to increase from by 7.60 tCO<sub>2</sub>e per annum, from 1.69 tCO<sub>2</sub>e to 9.29 tCO<sub>2</sub>e per annum, driven by the cross-slope hedgerow and woodland measures. Further GHG emission benefits are also estimated via the reduction in GHG emissions from land-use changes totalling 1.95tCO<sub>2</sub>e /yr
- Biodiversity habitat units are assessed to increase from 7.5 units to 13.3 units, again driven by cross-slope woodland. Calculated using a conservative £/unit value of £9,000<sup>5</sup> a proxy ecosystem service valuation of £52,578 is calculated over the 25 year period (assumed paid upfront at the point of implementation).
- There is a reduction in the value of food production by -£262 per year, or -£4,314 over 25 years. This is caused by the replacement of agricultural land with the NFM measures, thus decreasing the agricultural productivity of the land and reducing the ecosystem service. . It is noted this is a small loss given the low baseline food production value calculated for these areas.

The prediction that the scheme provides considerable additional value above and beyond the primary objective demonstrates an important advantage of natural flood management measures, in contributing to other key objectives for NH such as Net Zero and Biodiversity Net Gain. The benefit and importance of this in future decision making and establishing a viable business case and funding source for large enrolment of the Pilot is discussed in the conclusions and recommendations section.

<sup>4</sup> [Net gain Consultation proposals \(defra.gov.uk\)](https://www.defra.gov.uk/net-gain/consultation-proposals/)  
<sup>5</sup> [Net gain Consultation proposals \(defra.gov.uk\)](https://www.defra.gov.uk/net-gain/consultation-proposals/)

Measure Scale Results – a summary

Table 3 to Table 7 – shown in 1.1.1.1.1.Appendix H - set out the results on a measure-by-measure basis, combined for both the Irwell and Little Don respectively. This allows for a detailed analysis on the relative benefits of each measure. Again, these show the physical flow and monetary flow accounts, representing the baseline, future scenario and change across each of the eight ecosystem services assessed. Figure 8 - Figure 12 illustrate the impact of each measure on the monetary value across all the ecosystem services.

Highlights

The table below provides a summary of the monetary increase estimated for each measure on a per hectare basis per annum. Due to the challenges in translating point interventions (overland leaky barriers and in-channel leaky barriers) into hectares, the ‘per hectare’ values for these measures are not provided here.

Irwell and Little Don combined	£ / ha (GBP 2021 prices)	£ / barrier (GBP 2021 prices)
Cross Slope Hedge and Woodland	£3,223	-
Reducing Soil Compaction	£7	-
Online Storage Ponds	£26	-
Overland Leaky Barriers	-	£0.74
In-Channel Leaky Barriers	-	£0.09

- Cross slope hedge and woodland is estimated to have the greatest benefit, largely driven by the increased carbon sequestration associated with both woodland and hedgerows and the proxy ecosystem service value attributed to the biodiversity unit increase.
- For online storage ponds, overland leaky barriers, and in-channel leaky barriers the main ecosystem service contribution / ha is a result of the water supply improvement, and an increase in the level of water quality – namely the reduction in sediment.
- Ecosystem service disbenefits are rare throughout the measures and are generally only seen in the food ecosystem service. Here, when the measures are implemented, land which was estimated to provide a small food production value is replaced. It is key to note that the land area change for these benefits is relatively small and thus can co-exist alongside existing and significant food production.

Table 1 - Natural capital valuation results for the Irwell Catchment– Annual & 25-Year PV (total aggregate catchment account)

\*For detailed information on each ecosystem service look in Appendix C to Appendix F

Ecosystem service	Change in service provision**	Metric	Physical Flow Account			Monetary Flow Account (Annual)			Monetary Flow Account (25-year PV)		
			Baseline	Scenario	Change	Baseline	Scenario	Change	Baseline	Scenario	Change
Food production	↓↓	£ / across UK Hab types	na	na	na	£2,191	£1,789	-£402	£36,107	£29,487	-£6,620
Water supply	↑	m³ of water infiltrating to groundwater per year	197,361	197,566	206	£97,618	£97,720	£102	£1,608,893	£1,610,571	£1,678
Recreation	↓	£ across UK Hab types	na	na	na	£1,931	£1,893	-£38	£31,829	£31,203	-£625
Air quality	↑	kg NH3 lost per year	59	53	-6	-£514	-£463	£51	-£10,650	-£9,585	£1,065
Air pollutant removal	↑↑	£ across UK Hab types	na	na	na	£229	£625	£396	£3,693	£9,736	£6,042
Water quality	↑↑	kg N loss per year	134	123	-11	-£151	-£139	£13	-£2,490	-£2,283	£207
		kg P loss per year	7	6	-1	-£248	-£209	£39	-£4,084	-£3,437	£646
		kg Sediment loss per year	2,846	2,297	-549	-£1,290	-£1,041	£249	-£21,259	-£17,159	£4,100
GHG emission reductions (inc. carbon sequestration)	↑↑	tCO2 sequestered per year	3	11	9	£634	£2,739	£2,104	£10,456	£45,138	£34,682
		tCO2e of CH4 emissions per year	15	14	-2	-£3,763	-£3,387	£376	-£62,027	-£55,828	£6,199
		tCO2e of N2O emissions per year	4	4	-0	-£1,042	-£932	£111	-£17,177	-£15,354	£1,823
		tCO2 emissions per year due to energy use	6	5	-1	-£1,363	-£1,227	£136	-£22,469	-£20,221	£2,248
Biodiversity	↑	Number of biodiversity units	8	14	6	na	na	na	£69,696	£121,776	£52,080
		Number of hedgerow units	na	23	na	na	na	na	na	na	na
		Number of river units	na	na	na	na	na	na	na	na	na
Total value		-	-	-	-	£96,994	£100,131	£3,137	£1,666,045	£1,769,569	£103,524

\*\*based on the 25 year PV change values

Figure 5 – Irwell natural capital valuation results – 25 Year PV impact of the change in ecosystem service provision

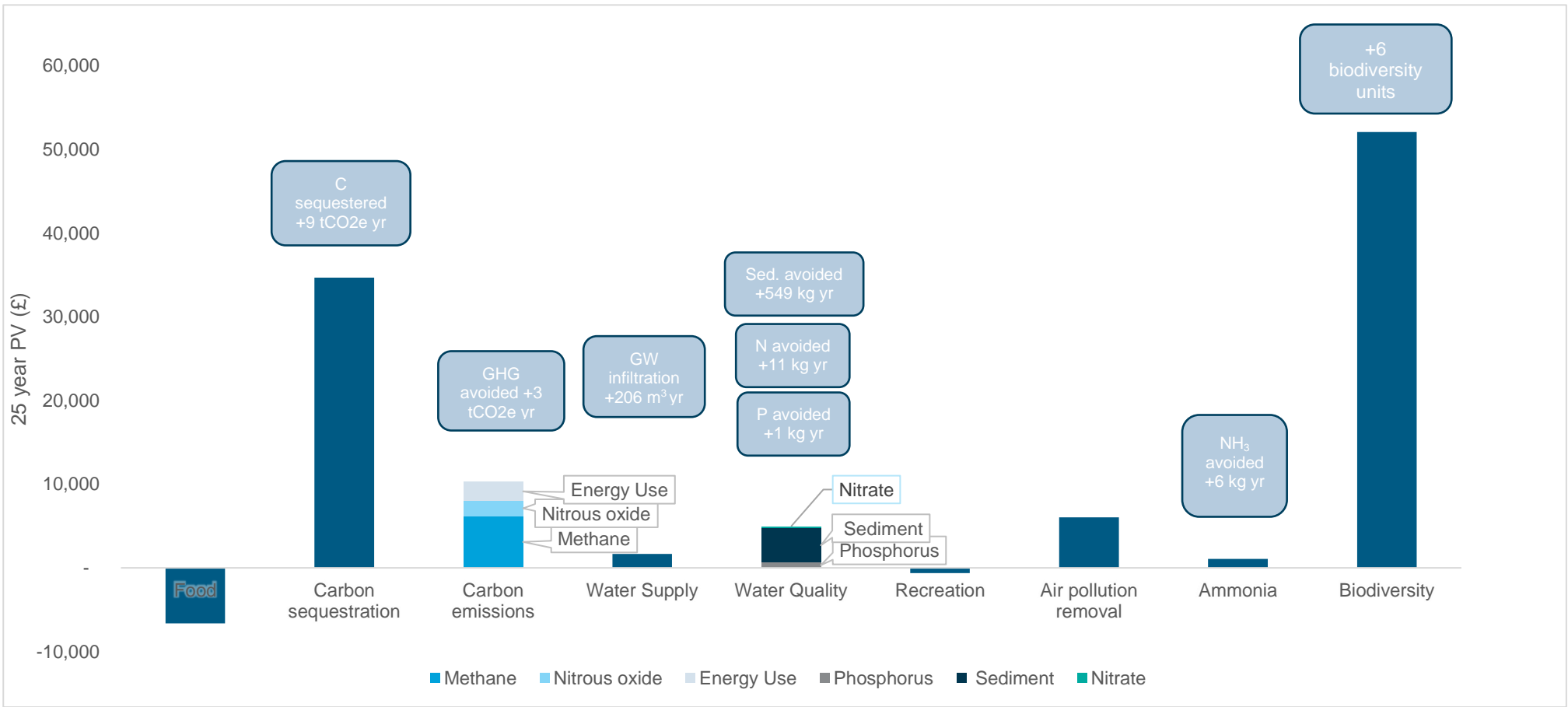


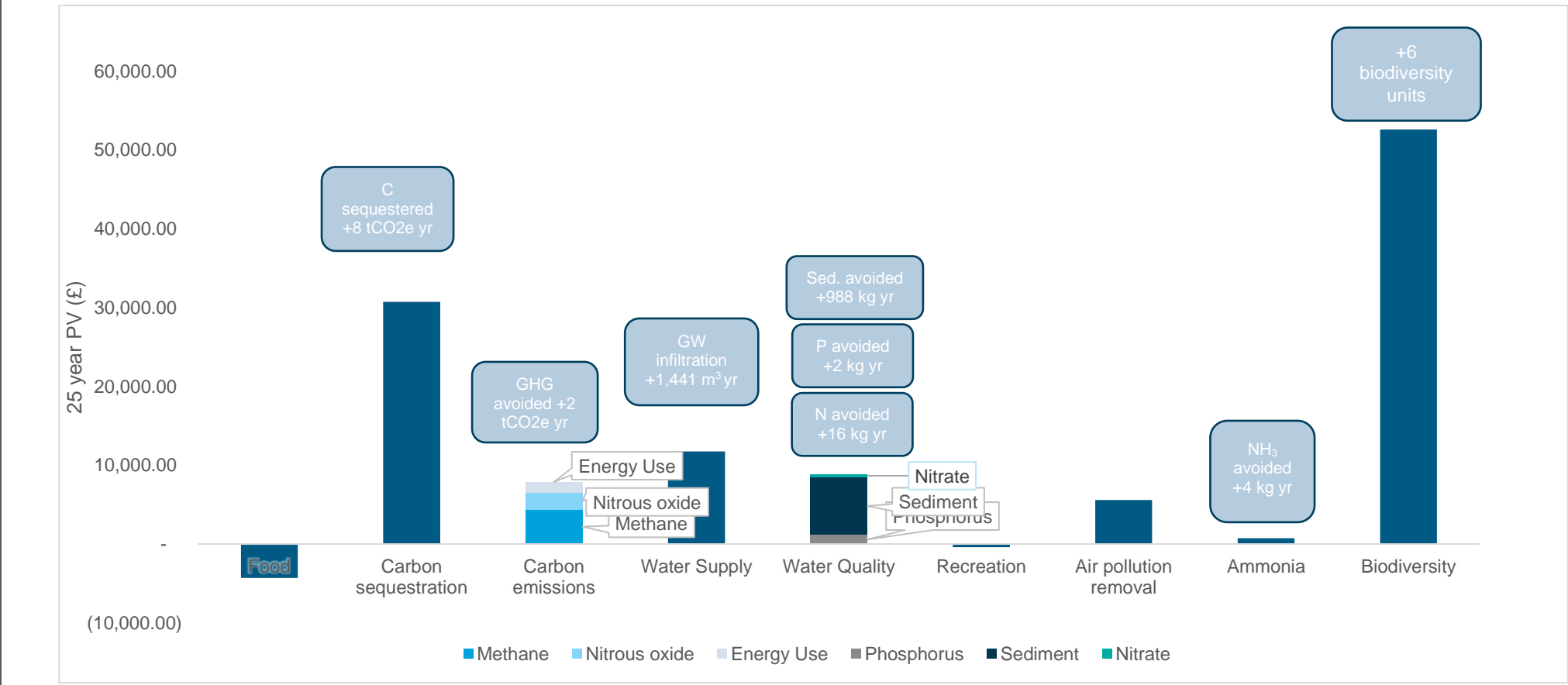
Table 2 - Natural capital valuation results for the Little Don Catchment– Annual & 25 Year PV (total aggregate catchment account)

\*for detailed information on each ecosystem service look in Appendix C to Appendix F

Ecosystem service	Change in service provision**	Metric	Physical Flow Account			Monetary Flow Account (Annual)			Monetary Flow Account (25-year PV)		
			Baseline	Scenario	Change	Baseline	Scenario	Change	Baseline	Scenario	Change
Food production	↓↓	£ across UK Hab types	na	na	na	£17,132	£16,870	-£262	£282,365	£278,051	-£4,314
Water supply	↑↑	m³ of water infiltrating to groundwater per year	459,981	461,422	1,441	£227,515	£228,228	£713	£3,749,790	£3,761,535	£11,745
Recreation	↓	£ across UK Hab types	na	na	na	£15,368	£15,344	-£25	£253,296	£252,889	-£407
Air quality	↑	kg NH3 lost per year	435	431	-4	-£3,780	-£3,744	£36	-£78,318	-£77,579	£739
Air pollutant removal	↑↑	£ across UK Hab types	na	na	na	£1,822	£2,188	£365	£29,390	£34,972	£5,582
Water quality	↑↑	kg N loss per year	1,068	1,052	-16	-£1,204	-£1,186	£18	-£19,845	-£19,545	£300
		kg P loss per year	33	31	-2	-£1,264	-£1,195	£68	-£20,831	-£19,702	£1,128
		kg Sediment loss per year	13,354	12,366	-988	-£6,052	-£5,604	£448	-£99,739	-£92,362	£7,377
GHG emission reductions (inc. carbon sequestration)	↑↑	tCO2 sequestered per year	2	9	8	£413	£2,276	£1,863	£6,813	£37,519	£30,706
		tCO2e of CH4 emissions per year	123	122	-1	-£30,084	-£29,817	£266	-£495,825	-£491,434	£4,391
		tCO2e of N2O emissions per year	29	29	-1	-£7,188	-£7,055	£133	-£118,468	-£116,280	£2,188
		tCO2 emissions per year due to energy use	26	26	-0	-£6,377	-£6,298	£79	-£105,101	-£103,804	£1,297
Biodiversity	↑	Number of biodiversity units	7	13	6	na	na	na	£67,085	£119,663	£52,578
		Number of hedgerow units	NA	3	NA	na	na	na	na	na	na
		Number of river units	0	1	1	na	na	na	na	na	na
Total value	^	-	-	-	-	£232,921	£236,624	£3,702	£3,889,317	£4,002,626	£113,309

\*\*based on the 25 year PV change values

Figure 6 – Little Don natural capital valuation results – 25 Year PV impact of the change in ecosystem service provision



# Conclusions and Recommendations

## 1. The sample of NFM measures assessed generate multiple ecosystem service benefits in addition to flood risk mitigation

If applied at scale such that NFM reduced flood frequency from a 1 in 1 year to 1 in 3 years (M62, M66) and from 1 in 2 years to 1 in 3 years (A616), an NFM scheme in the Irwell and Little Don catchments has the potential to avoid traffic disruption which would be worth £1,065,200 (M62), £10,302,700 (M66) and £89,000 (A616) in today's money over a 25-year evaluation horizon. However, even at the relatively small-scale of the National Highways pilot scheme, the enhancement of natural capital achieved by the measures would provide wider environmental benefits (ecosystem services) worth £3,137 per year or £51,443 in present value over 25 years (£103,525 including the biodiversity unit-linked credit upfront lump sum) for the Irwell, and £3,702 per year or £60,731 in present value over 25 years (£113,309 including monetised biodiversity) for the Little Don.

The largest estimated increase comes from the climate regulation service, due to increased sequestration of carbon in cross-slope woodland and hedgerow measures relative to the semi-improved grassland baseline. Specifically, we predict a net annual carbon sequestration increase of 9 tCO<sub>2</sub>e in the Irwell and 8 tCO<sub>2</sub>e in the Little Don. Additional value comes from reductions to greenhouse gas emissions (methane, nitrous oxide, and carbon dioxide), and water pollutant loading relative to the previous agricultural land use. The increase in tree cover would also add value by increasing absorption of long-range air pollutants. We predict an increase in biodiversity value as measured in Biodiversity Units post the interventions. Across the Irwell, 6 additional biodiversity habitat units would be created, as well the creation of 23 biodiversity hedgerow units. In the Little Don, we also estimate 6 additional biodiversity habitat units and the creation of 3 new biodiversity hedgerow units.

The environmental gains predicted, including the carbon sequestration and Biodiversity Units increases, are estimations and would need habitat survey and further ground-truthing to verify against carbon and biodiversity market standards. However, the predictions are encouraging and demonstrate that NFM measures implemented by National Highways have potential to deliver Biodiversity Net Gain (BNG) and contribute to Net Zero ambitions.

## 2. Understanding NFM measures' natural capital impact can influence future decision making

Both the scale of implementation and the type of measures implemented influenced the natural capital enhancement for each catchment. The soil decompaction measures has the lower per unit contribution but was a popular measure with a wide uptake, especially in the Little Don (111.0 ha). The Cross-slope woodland and hedgerow measure has the highest per unit contribution to wider environmental benefits (especially carbon sequestration and biodiversity) but had a more modest uptake. Individually, overland leaky barriers and in-channel leaky barriers are more limited in their contribution to wider environmental benefits but if applied at scale they could provide important water supply and water quality benefits. Storage ponds have only limited wider benefits because they are not deemed to be true wetland habitat. Increasing the uptake of cross-slope woodland / hedgerow in future schemes would help deliver more in terms of wider benefits. Where tree planting is not appropriate, creation of wetlands and restoration of peatland habitats (e.g., grip and gully blocking) would be alternative approaches that would contribute significantly to wider benefits. Measures that create or restore semi-natural grassland would also deliver value in terms of biodiversity units. Mixed species herbal leys and cover crops are not applicable to the two catchments which are mostly grassland but would be potentially valuable if applied in more arable or mixed farming contexts.

Per hectare and per barrier monetary and physical benefits across each of the measures – combined across the Irwell and Little Don							
Irwell and Little Don combined	Units	£ / ha (GBP 2021 prices) / yr	Carbon sequestration improvement tCO <sub>2</sub> / ha	BNG Units Biodiversity / River / Hedgerow Units	Phosphorus avoided / ha / yr (kg P)	Nitrogen avoided / ha / yr (kg N)	Sediment avoided / ha / yr (kg sed)
Cross Slope Hedge and Woodland	Per hectare	£3,223	6.104	4 biodiversity units per hectare 8 hedgerow units per km	0.4	6.23	216.09
Reducing Soil Compaction	Per hectare	£7	0	N/A	0.01	0.07	8.06
Online Storage Ponds	Per hectare	£26	0	0.6 biodiversity units per hectare	0.00	0.05	2.64
Overland Leaky Barriers	Per barrier	£0.74	0	6 biodiversity units per hectare	n/a	n/a	n/a
In-Channel Leaky Barriers	Per barrier	£0.09	0	0.01 river units per barrier	n/a	n/a	n/a

## 3. Upscaling the pilot measures could deliver significant natural capital benefits across both catchments

The current pilot was targeted at a combined 2,997ha of focus area across both catchments, with 127 ha of measure implemented (4.2% of the combined focus area). Assuming a linear relationship, if the focus areas were increased to cover 75% of the catchment (a crude assumption) and the same rate of measure implementation was seen then the result would see 883 ha of implementation.

If the mixture of measure was to remain consistent with the pilot, this would total a natural capital benefit of £58,826 across the Irwell and £21,359 across the Little Don per year. Given the size of the Irwell catchment, and the relative size of the focus area vs. the catchment, the greatest opportunity for future increase lies in this catchment.

Whilst based on high level assumptions, these calculations are intended to give a sense to the potential scale of the opportunity for the catchments if the pilot scheme were to be expanded more widely in these catchments. Such assumptions could be refined, and a more detailed analysis on future scaling up could be undertaken as a follow up to this study.

Not reported in the table, but assuming the proxy biodiversity ecosystem service value (£9,000 x habitat units delivered), was split equally amongst the 25 year period, then the annual natural capital benefits would be £5,220 and £5,805 for the Irwell and Little Don. Scaled up across both catchments this would generate total ecosystem service value of £97,887 and £33,492 respectively.

Illustrative scaled up natural capital benefits, carbon sequestration impact and BNG improvements across the Irwell and Little Don									
	Focus Area (hectares)	Measures as a % of Focus Area	Focus Area as a % of Catchment	Annual Natural Capital Benefits (2021 £GBP)	Scaled up Annual Natural Capital Benefit (2021 £GBP)	Carbon sequestration (tCO <sub>2</sub> )	Scaled up carbon sequestration (tCO <sub>2</sub> )	Increase in biodiversity units	Scaled up increase in biodiversity units
Irwell	2,385	0.6%	4%	3,137	58,826	8.59	161.04	5.79	108.50
Little Don	613	18.4%	13%	3,702	21,359	7.60	43.87	5.84	33.70
Total	2,997	4.2%	5.0%	6,840	80,185	16.19	204.91	11.63	142.20



## 4. The wider natural capital benefits of NFM contribute to environmental and social objectives and present opportunities to secure future funding

This study has highlighted benefits across a wide range of ecosystem services. This presents opportunities for National Highways across two major themes, whilst simultaneously delivering flood risk benefits from the NFM: **broader sustainability targets** and **additional funding schemes**.

- **Sustainability targets:** although NFM measures are aimed at reducing flood risk, our study demonstrates that they potential for benefit across climate regulation, recreation, water quality, and water supply. NFM therefore could contribute to multiple sustainability targets and objectives, including the National Highways initiative, Net Zero highways plan and the commitments to protect biodiversity. We should caveat that the assessment is a desktop indication and would need to be ground-truthed with appropriate survey methods to meet the criteria required to claim BNG or net zero contributions.
- **Revenue Streams:** the study has indicated the potential for BNG, C sequestration and nutrient loading reduction. These are all ecosystem services where there are established or nascent environmental markets for 'credits' (Woodland Carbon Code, Biodiversity Credits, Nutrient Neutrality) or where there are other 'buyers' with a regulatory driver (Water Companies). In future, rather than funding the entire scheme themselves, NH could potentially collaborate with these buyers to co-create a scheme in which they could achieve the same avoided flood risk benefits for lower direct cost, or where they could increase funding rates to incentivise the uptake of more ambitious measures (e.g., woodland) which require higher payment rates to incentivise uptake. The ELM scheme, funded by Defra, would also be a potential co-buyer of ecosystem services.

## 5. The proposed next steps for National Highways

### USE

- **Adopting a natural capital approach** ensures that the wider environmental benefits of natural flood management are embedded into National Highways strategic planning. Quantification and valuation of ecosystem services helps better inform decision-making, scheme design, stakeholder engagement, nature positive business planning, and can help identify innovative funding sources.
- The findings within this report can be a key **communication toolkit** across the National Highways business that will increase natural capital and ecosystem service knowledge and inspire cross-cutting projects to deliver on key initiatives such as Net Zero and Biodiversity Net Gain.
- Disseminating this knowledge to landowners can help them appreciate the potential wider value of different NFM measures, which may **incentivise** greater uptake of more challenging but effective measures, especially if payment rates or scheme budget can increase.

### IMPROVE & EXTEND

- **Further deep dive analysis** could be completed to capture the information required at implementation and the long-term management agreements needed to meet the standards required to make Biodiversity Net Gain or Net Zero claims. This would also help future attract co-funding from developers and carbon market buyers.
- The approach used in this assessment is **transferrable** and could be applied to the other measures within the pilot scheme. This would allow for impacts and benefits to be compared across the whole range of measures. Excluded due to the relative level of uptake, understanding the wider benefits of these measure may drive increased focus towards these measures especially in other geographic contexts where they might be more applicable.
- This assessment has focused on the natural capital impact of a selected number of measures applied in specific locations. National Highways could look to **establish baseline natural capital data** across the whole of the Irwell and Little Don catchments (or more widely across catchments with high road flooding risk) to gain greater understanding of current contribution of land cover to wider environmental benefits. This would potentially help target interventions towards areas which deliver the greatest wider benefits as well as contributing to flood risk alleviation.



# Appendices



# Appendix A Natural Capital Approach Summary

The table below shows the ecosystem services that were assessed. The table describes how the ecosystem services have been assessed in the scheme, identifying key metrics and approaches and data used to calculate them. Natural capital valuation is an evolving discipline and detailed data describing individual services on every site may not always be available. As a result, there may be gaps in metrics for specific site settings and services. A detailed methodology for specific ecosystem services is provided in Appendix C Appendix F Where assumptions have been necessarily made, these are clearly stated in Appendix B Appendix B to help focus themes for future investigation, research and/or monitoring across the scheme study area. In the table below, a confidence score for each ecosystem service has been presented, reflecting on data availability and the assumptions made to value them.

Ecosystem Service	Metric	Approach	Methodology	Confidence* (Key below)
Food production	Value of agricultural production (Yield in tonnes/yr)	Farm Business Survey value transfer approach	Based on the values provided within Defra Farm Business survey, which provides financial, physical and environmental performances of farm business across England, Atkins have been able to attribute a gross margin value to each hectare of land included within the boundary. By mapping the appropriate farm value per region onto the appropriate land cover categories (in this case dairy, lowland grazing and less favoured area grazing values to semi-natural grassland), we have been able to calculate a gross margin per ha.  This value is calculated at £151.90 / ha and is applied to the whole area of land included within the assessment boundary. Only cross slope woodland and hedgerow are adjudged to impact future food production, and for these measures, there is a full expected loss in food production value due to the land-use change.	
Water supply	Volume of recharge (m³)	The Daily Based Morgan Morgan-Finney (DMMF) model	The volume of water infiltrating to groundwater was estimated for the baseline and scenario conditions, based on DMMF modelling outputs. Values were monetised using the cost per cubic meter of water is calculated by using the ENCA recommended ONS (2020) value of £0.46 per cubic meter.	
Air quality	Pollutant emission reduction (tonnes per ha)	Value transfer approach	Air quality figures were calculated by mapping the changes to the fields before (Baseline) and after each of the five interventions, in both the Irwell and Little Don catchments. FARMSCOPER was used to quantify the changes to the pollutant emissions for the baseline and intervention scenarios. Values were monetised using the damage costs of ammonia from the air quality appraisal: damage cost guidance <sup>6</sup> .	
Air Quality	Air pollutant removal	Value transfer approach	Based on mapping of land cover before (the baseline) and after (future scenario) the implantation of the measures. Figures used from the literature are from Jones et al (2017) for ONS, which produced a natural capital account for air pollution removal by vegetation across the UK for a range of pollutants. Estimated health costs from reduced concentration of air pollutants are attributed to UK vegetation on a £ / hectare basis. Jones provides £/ha values in 2012 prices, for the two years, 2015 and 2030. A straight line assumption was made between these values and utilised for the starting point of this assessment (2021)  2021 projected £ / ha values, in 2012 prices, which are later inflated to 2021 are as follows: <ul style="list-style-type: none"> <li>- Semi-natural grassland: £14</li> <li>- Rural woodland: £203</li> </ul>	
Water quality	Nutrient losses avoided (kg)	Value transfer approach	Nutrient losses avoided were calculated by mapping the changes to the fields before (Baseline) and after each of the five interventions, in both the Irwell and Little Don catchments. FARMSCOPER was used to quantify the changes to nitrate and phosphorous volumes for the baseline and intervention scenarios. Values were monetised using damage costs per kilogram of phosphorous and nitrate were based on values used in FAMSOCOPER.	

<sup>6</sup> <https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance>

Ecosystem Service	Metric	Approach	Methodology	Confidence* (Key below)
Climate regulation (inc. carbon storage and climate sequestration)	Carbon sequestered and emissions reduced (tonnes)	Value transfer approach	<p>Based on mapping of land cover before (the baseline) and after (future scenario) the implantation of the measures. Figures used from the literature are for tonnes of carbon sequestered by semi-natural grassland (the baseline) and woodland and hedgerows (future scenarios). Values are either ENCA recommended figures (woodland), the ENCA methodology applied to ONS data (semi-natural grassland) or taken from a literature review (hedgerows). Values:</p> <ul style="list-style-type: none"><li>- Woodland: 5.75 tCO<sub>2</sub>e (ENCA – taken from ONS data)</li><li>- Semi-natural grassland: 0.98 tCO<sub>2</sub>e (calculated by Atkins using ENCA methodology)</li><li>- Hedgerow: 1.43 tCO<sub>2</sub>e (additive tCO<sub>2</sub>e – see assumptions section for summary of the literature review)</li></ul> <p>FARMSCOPER outputs are used to quantify CO<sub>2</sub> emissions, N<sub>2</sub>O emission and CH<sub>4</sub> emissions under the baseline and future scenarios, with the values for N<sub>2</sub>O and CH<sub>4</sub> converted to CO<sub>2</sub> equivalent values. All greenhouse gas sequestration emissions were monetised using the UK Government's latest figures for valuation of greenhouse gas emissions (BEIS, 2021),</p>	
Biodiversity	Habitat units  Proposed biodiversity tariff rates	Net Gain methodologies	<p>The Biodiversity Metric 3.1 was used to assess the impact of the change in land cover on the biodiversity, for each intervention. A BNG assessment was completed using Natural England's Biodiversity Metric 3.1. In line with the guidance, biodiversity benefits were reported in terms of change in biodiversity.</p> <p>In providing a proxy biodiversity ecosystem service value, a tariff rate of £9,000 was used for £ / unit in line with the lower range recommended as part of a Defra consultation<sup>7</sup>.</p>	
Recreation	Number of visitors / £	ORVal	Recreation values were calculated using a value transfer approach, using the ENCA recommended monetary values from ONS (2021) which were themselves determined by aggregating ORVal results to national scale. The modelling is based on the change of the land cover from the baseline land cover recreation value to the measure land cover recreation value.	

Confidence Category definitions*	Confidence level*
We may have used some assumptions or estimation but these are in line with current industry standard approaches.	
We have used some assumptions or estimation and some of these would benefit from additional data collection.	
We are confident that the number is in the right order of magnitude. Order of magnitude implies that for an estimate of 5 that we are confident that the real figure is within the range 0.5 to 50.	
We can't offer a number which is likely to be in the right order of magnitude. This is due to unquantifiable uncertainty in the science, valuation, or the relationship between them. What we do know, and our confidence, is discussed qualitatively.	

\*Adapted from the Environment Agency confidence category definitions.

<sup>7</sup> [Net gain Consultation proposals \(defra.gov.uk\)](https://www.defra.gov.uk/net-gain/consultation-proposals/)

# Appendix B Key overarching assumptions of the natural capital valuation approach

There are several uncertainties linked to the valuation of ecosystem services that are relevant to this study. The table below outlines the main uncertainties and identifies the assumptions that have been made to address them as part of the National Highways Natural Flood Management Pilot Scheme assessment.

Theme	Uncertainty	Explanation and mitigation
General*	The approach used relies on value transfer.	Whilst we have sought to use the best available data and studies at the present time, there are inherent uncertainties associated with transferring values from a primary study to the site in question. The results should therefore be considered as indicative approximations of the value of the measures ecosystem services benefits.
	The interconnections between ecosystem services may lead to double counting.	Where possible we have used conservative figures and sought to identify the potential for and avoid double counting; for example, by only attempting to value 'final services' that provide direct benefits to people. Furthermore, the calculation does not seek to identify all benefits and therefore is not the final or total figure but an estimate using the available information.
	Ecosystems are dynamic, and the valuation approach does not take full account of the changes that may occur over time.	For the purposes of the study, it has been necessary to assume that land cover will remain fixed over the duration of the assessment time horizon, assessed both annually and for a 30-year period. It is important to recognise that the values generated represent high-level estimates of the economic value of each service.
	The approach assumes values are comparable.	The advantage of assigning a monetary value to as many ecosystem services as possible is that this helps to enable trade-offs to be explored and evaluated. However, it should be borne in mind that although impacts have been converted to a common currency where possible, this does not mean that there is always full comparability between different values.
	The valuation does not include intrinsic values and some decisions must draw on information beyond the bounds of economics.	An ecosystems valuation approach does not fully capture the ethical and moral arguments for protecting and enhancing ecosystems and should not be seen as replacing or negating these; the arguments should be considered as complementary.
Carbon sequestration	Hedgerow carbon sequestration figures are uncertain and will vary based on size, age, and the level of maintenance (trimming).	It is assumed that hedgerows sequester 1.43 t CO <sub>2</sub> e ha <sup>-1</sup> yr <sup>-1</sup> as a mid-range estimate from a review of the literature. The value is a combined value of soil organic carbon (SOC) (below ground) sequestration and above ground carbon (AGC) sequestration from hedgerow planting. SOC is assumed to be 0.49 t CO <sub>2</sub> e ha <sup>-1</sup> yr <sup>-1</sup> (Biffi et al., 2022 and Ford et al., 2019) and AGC is assumed to be 0.94 t CO <sub>2</sub> e ha <sup>-1</sup> yr <sup>-1</sup> (Ford et al., 2019 and Fallon et al., 2004). The figure used in this study is also in line with the estimates provided within the Natural England Research Report NERR094 (2021).
FARMSCOPER	NFM measures may not be exactly equivalent to FARMSCOPER mitigation methods. The true impact on water quality, air quality and GHG emissions may be different.	All due care has been applied to represent NFM measures as closely as possible by cross-referencing FARMSCOPER's user guide and the NFM measure description.
	We assume no prior uptake of other mitigation methods. The impact on water quality, air quality and GHG emissions may be slightly overstated	Our values represent the likely opportunity for pollution abatement. If the pilot were to be scaled up to a full catchment management scheme with a nutrient loading element (e.g., funded by water company or developer) a more detailed baseline farm practice assessment is recommended.
Biodiversity Net Gain (BNG)	It is unknown what the condition of the habitat types of all farms are within the Irwell and Little Don catchments.	It is assumed that habitat types which need a condition input into the model are 'Moderate' condition.
	The 'strategic significance' of the study area is unknown.	It is assumed that the 'strategic significance' of habitats is 'Area/compensation not in local strategy/ no local strategy' which has a multiplier value of 1.
	Hedgerow area is unknown as the BMT 3.1 tool gives these values as biodiversity units/km.	It is assumed that there is no baseline data available for the hedges as this study focuses on establishing new hedgerows.
	The baseline habitat for the site of each intervention.	Given a lack of baseline data, we have instead established an estimate of the baseline for habitat units for the Irwell and Little Don respectively. This was generated by taking an average of the CORINNE land cover data around the measure sites.
Food Production	Farm gross margins are based on regional statistics. Local profitability in the catchment may vary.	Catchment level profitability data is not available. Regional statistics are the closest readily available dataset.
	Attribution from farm type to land cover type is assumed based on agricultural census data	The conversion from farm level to land cover level is based on the same assumptions used by the ONS to calculate food production values in the UK's national accounts.
Water Supply	Water table level	The soil water conditions do not represent the impact of raised water table levels across a wider area, just the impact to the soil immediately under the measure.
	Width of the channel	To get the volume of water stored in in-channel leaky barriers, the width of the stream is needed, as we do not know the width of each channel in the study area, there is an assumption made that the width of the channel is 3m.

\*The general limitations outlined are applicable to all transfer value studies, and therefore all of the ecosystem services assessed in this study.

\*\*Not all ecosystem services have specific limitations associated with the approach used to value them, therefore are not listed individually, but the general limitations are applicable to these.



# Appendix C Water Quality, Climate Regulation and Air Quality: detailed methods and results

Losses of nutrients, air pollutant emissions and climate regulation

Methodology

The baseline and scenario losses of nutrients (phosphorus (P) and nitrate (NO<sub>3</sub>-N)), climate regulation and air pollutant emissions from the fields included in the measures were estimated using FARMSCOPER (version 5.0). FARMSCOPER is a DEFRA published, peer-reviewed decision support tool, developed by agricultural specialists ADAS, that can be used to assess a variety of ecosystem services on a farm and quantify the impacts of various farm mitigation methods on these ecosystem services. FARMSCOPER was used to generate results for water and air pollutant emissions/losses and climate regulation. This appendix considers the outputs for water pollutant losses, climate regulation and air pollution emissions, the methodology for generating these values was the same. This approach offers a more site-specific assessment than the Natural Environment Valuation Online (NEVO) tool which has a low spatial resolution (catchment or 2km grid square).

Baseline P and NO<sub>3</sub>-N, for water pollutant losses, CH<sub>4</sub>, N<sub>2</sub>O and Energy Use for climate regulation and NH<sub>3</sub> for air pollutant emissions, were estimated using FARMSCOPER. The baseline was established using the FARMSCOPER Upscale tool. For each catchment an 'LFA Grazing' farm type was selected as this mapped most accurately to the farms in the Pilot.

The total areas for grazing, and each crop type were included in the baseline, as well as the soil types (free draining and drained for agriculture) and average rainfall (in mm per year). FARMSCOPER was run twice with the model set up once for a free draining farm, and then for a drained farm. A weighted average of the outputs was calculated based on the quantity of both free draining and drained agricultural farms in each of the two catchments, according to the Census data within the FARMSCOPER Upscale tool.

For example, in the Irwell catchment the Census data shows that out of a total of 60 farms there were 39 free draining and 21 drained, therefore the weighted average value for each soil type is 0.65 and 0.35, respectively. Annual rainfall for all fields was assumed to be between 900 and 1200mm, based on the Met Office's average annual rainfall mapping for the area<sup>8</sup>.

As the functionality of the tool would not directly permit a comparison of the baseline and interventions in a single run, we confirmed the following approach with the authors of FARMSCOPER: key nutrient losses, climate regulation and air pollutant emission metrics were estimated in multiple stages, firstly the interventions were applied to both the Irwell and the Little Don baselines, separately. The interventions were applied to a free draining and a drained farm in both catchments. Secondly, a weighted average of the change, in the key metrics, from the baseline values was calculated for the corresponding free draining and drained agricultural farms, so our results are representative of both soil types within each catchment. Finally, the per ha values calculated in the previous step were multiplied by the number of ha each intervention was applied to within each catchment, to generate the final per catchment values for the Pilot scheme.

Details of the baseline set up in FARMSCOPER are below:

- Baseline (Irwell):** This was generated using the FARMSCOPER upscale tool. The farm type is assumed to be LFA grazing, within the Irwell catchment.
- Baseline (Little Don):** This was generated using the FARMSCOPER upscale tool. The farm type is assumed to be LFA grazing, within the Upper Don catchment.

Details of the methods set up in FARMSCOPER are below:

- Cross-slope woodland and vegetation (Woodland):** A farm with 100% woodland land cover is created for this intervention, the outputs from this farm are then compared to the baseline to generate the change in pollutant losses/ emissions. It is assumed that there is a 4m x 10m strip of hedge within each field this measure is applied in, therefore 40m<sup>2</sup> of this area uses the results from Hedgerows (see intervention below).
- Cross-slope woodland and vegetation (Hedgerows):** FARMSCOPER method 80 'Establish new hedges' was applied to the baseline farm to generate the change in pollutant losses/ emissions.
- Reducing soil compaction:** FARMSCOPER method 15 'Loosen compacted soil layers in grassland fields' was applied to the baseline farm to generate the change in pollutant losses/ emissions.
- Overland leaky barriers,** FARMSCOPER method 114 'Management of grassland field corners' was applied to the baseline farm to generate the change in pollutant losses/ emissions.
- Online storage ponds,** FARMSCOPER method 114 'Management of grassland field corners' was applied to the baseline farm to generate the change in pollutant losses/ emissions.
- In-channel leaky barriers.** FARMSCOPER could not be appropriately applied for this intervention, therefore key nutrient losses, climate regulation and air pollutant emission metrics are not quantified.

A schematic showing the steps used to generate results from FARMSCOPER is shown below.

1. Baseline farm created in FARMSCOPER based on typical LFA grazing farms in the Irwell and Little Don catchments.

2. Interventions applied to the baseline farms using a mix of FARMSCOPER methods and comparing different FARMSCOPER set ups (woodland only), to give the change in pollutant losses/ emissions of each intervention.

3. Weighted average (free draining and drained agricultural) of the changes in key metrics from the interventions calculated.

4. Outputs from step 3 (weighted average nutrient losses/ air pollutant emissions) are multiplied by the area of each intervention in the Little Don and Irwell catchments.

Baseline crop types within FARMSCOPER

Irwell baseline crop type (FARMSCOPER)	Irwell proportion of total land cover (%)	Little Don baseline crop type (FARMSCOPER)	Little Don proportion of total land cover (%)
Grazing types		Grazing types	
Permanent Pasture	80.6	Permanent Pasture	42
Rotational Grassland	0.8	Rotational Grassland	1
Rough Grazing	14.9	Rough Grazing	54
Crop types		Crop types	
Winter Barley	0.8	Winter Barley	0.4
Spring Barley	0.8	Spring Barley	0.4
Bare Fallow	0.8	Bare Fallow	0.4
Woodland	1	Woodland	1.2

<sup>8</sup> <https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcpwxz1ey>

Contains sensitive information  
Natural Capital Assessment report\_v1.0

	<p>Monetisation of water quality benefits used water treatment costs (for nitrate) and damage costs for nutrient losses from agricultural land (for phosphorous). Damage costs per kilogram of phosphorous were derived from Chadwick <i>et al.</i> (2006) as used in FARMSCOPER. Costs for nitrate were also based on values used in FAMSCOPER.</p> <p>The damage costs of ammonia (air quality) are calculated using the air quality appraisal: damage cost guidance<sup>9</sup>, which was updated in 2021. Methane, nitrous oxide and energy use quantities (climate regulation) were converted to tCO2e and monetised using the UK Government's latest figures for valuation of greenhouse gas emissions (BEIS, 2021).</p>
Results and Interpretation	<p>The greatest reduction P losses in the Irwell catchment are from the cross-slope hedgerow creation intervention, whereas in the Little Don catchment the greatest losses are within the reducing soil compaction intervention. The cross-slope hedgerow creation and reducing soil compaction intervention are also the interventions which reduce the N losses the most in the Irwell and Little Don catchments, respectively. It is likely that in the case of the Little Don catchment the highest P and N losses are due to the large area within the catchment which undergoes the reducing soil compaction intervention (110.86ha). The per ha values for losses of P and N confirm the cross-slope hedgerow scenario is the intervention with the largest reductions in both P and N, thus explaining why this intervention has the largest P losses in the Irwell catchment.</p>

Estimated baseline and scenario losses of phosphorus						
	Irwell Phosphorous (P)			Little Don Phosphorous (P)		
	Area of land (ha)	Baseline- Total P losses across scheme area (kg/P)	Scenario- Total P losses across scheme area (kg/P)	Area of land (ha)	Total P losses per ha (kg/P/ha)	Total P losses across scheme area (kg/P)
Cross-slope woodland and vegetation (Hedgerows)	1.17	1	1	0.13	0	0
Cross-slope woodland and vegetation (Woodland)	1.47	1	0	1.60	0	0
Reducing soil compaction	11.50	5	5	110.86	32	31
Online storage ponds	0.18	0	0	0.11	0	0
Overland leaky barriers	0.09	0	0	Not assessed	Not assessed	Not assessed
In-channel leaky barriers	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
Baseline to Scenario overall change	-	-	-1	-	-	-2
Estimated baseline and scenario losses of nitrate						
	Irwell Nitrate (N)			Little Don Nitrate (N)		
	Area of land (ha)	Baseline- Total N losses across scheme area (kg/P)	Scenario- Total N losses across scheme area (kg/P)	Area of land (ha)	Baseline- Total N losses across scheme area (kg/P)	Scenario- Total N losses across scheme area (kg/P)
Cross-slope woodland and vegetation (Hedgerows)	1.17	11	11	0.13	1	1
Cross-slope woodland and vegetation (Woodland)	1.47	14	4	1.60	15	6
Reducing soil compaction	11.50	107	106	110.86	1,051	1,044
Online storage ponds	0.18	2	2	0.11	1	1
Overland leaky barriers	0.09	1	1	Not assessed	Not assessed	Not assessed
In-channel leaky barriers	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
Baseline to Scenario overall change	-		-11	-		-16

<sup>9</sup> <https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance>



Appendix D Biodiversity: detailed methods and results

Ecosystem Service Case Study – Using the net gain methodology to quantify biodiversity benefits						
Methodology	Biodiversity benefits were quantified using Natural England’s Biodiversity Metric 3.1.					
	Indicative Biodiversity Units representing the baseline condition of the fields where interventions were applied within the Irwell and Little Don catchments were determined as the product of ‘habitat area’ (ha), ‘habitat distinctiveness’ and ‘habitat condition’, based on the habitat categories and guidance accompanying Biodiversity Metric 3.1. The following assumptions were made when calculating the biodiversity units within this study:					
	<ul style="list-style-type: none"><li>To give a per ha value for the purposes of this assessment, the habitat area (ha) will total 1 ha which was a representative hectare of the average percentage of land cover for each habitat type</li><li>Where habitat types required the ‘habitat condition’ a central value of ‘Moderate’ is assigned, in all cases.</li><li>Where habitat types required the ‘Strategic significance’ the following condition was chosen in all cases ‘Area/compensation not in local strategy / no local strategy’.</li></ul>					
	The habitat types within the baseline fields were taken from the CORINE land cover and UK NEA data. CORINE data was used in this assessment as it provides a suitable resolution land cover dataset. Where the habitat types did not directly map between the Biodiversity Metric and the data sources, the nearest match was used, based on advice given from an ecological specialist. For example, the “Pastures” land cover type in CORINE has been assumed to be “Modified grassland” within the Biodiversity Metric tool based on the understanding that this catchment is predominantly semi-natural grassland used for pastoral agriculture.					
Methodology	Details of the Biodiversity Metric Tool inputs and the assumptions for the baseline are below:					
	<ul style="list-style-type: none"><li><b>Baseline (Irwell):</b> The baseline in the Irwell catchment is composed of the following habitat types (% cover of the total area where measures were applied in the catchment); Modified grassland (84%), cereal crops (3%), Other neutral grassland (13%).</li><li><b>Baseline (Little Don):</b> The baseline in the Little Don catchment is composed of the following habitat types (% cover of the total area where measures were applied in the catchment); Modified grassland (86%), cereal crops (3%), other woodland; broadleaved (11%).</li></ul>					
	Indicative Biodiversity Units for each of the measures were calculated in the same way to the baseline. Details of the Biodiversity Metric Tool inputs and the assumptions for each measure are below:					
	<ul style="list-style-type: none"><li><b>Cross-slope woodland and vegetation (Woodland):</b> The woodland creation scenario assumes that 100% of the area dedicated for woodland creation will be ‘Other woodland; broadleaved’. The broadleaved category has been assumed because most of the existing woodland in these catchments is deciduous, therefore the measure interventions should match.</li><li><b>Cross-slope woodland and vegetation (Hedgerow):</b> The cross-slope hedgerow scenario was calculated within the “Hedge Baseline (B1)” section of the Biodiversity Metric tool. The biodiversity units are calculated by combining the score for ‘Native Hedgerow with trees’ and ‘Native Species Rich Hedgerow’ these best represent the cross-slope hedgerow. The units for hedgerows are given in as a per km value rather than an area (ha) value, therefore they cannot directly be compared alongside the other interventions.</li><li><b>Reducing soil compaction:</b> Biodiversity has not been quantified for this method as it is assumed to have very little impact since it does not result in a land-use change.</li><li><b>Overland leaky barriers:</b> The overland leaky barriers measure scenario assumes that the habitat type under this intervention is 100% ‘Other neutral grassland’ which reflects a slight improvement from the modified grassland type in the baseline.</li><li><b>Online storage ponds:</b> The online storage ponds measure scenario assumes that the habitat type under this intervention is a mixture of ‘Ponds (Non- Priority Habitat)’ (25%) and ‘Sustainable urban drainage feature’ (75%). The ‘Sustainable urban drainage feature’ is deemed the most representative habitat for the attenuation ponds which have been created as part of this study, which will likely not be filled with water throughout the whole year. The ‘Ponds (Non- Priority Habitat)’ is representative of those areas where pig slurry pits have been converted to ponds and will be filled with water all year round.</li><li><b>In-channel leaky barriers:</b> The in channel leaky barriers measure was calculated within the “River Baseline (C1)” section of the Biodiversity Metric tool. For this intervention it has been assumed that the ‘Other Rivers and Streams’ habitat type is representative of the surface water flow pathways where the measures were applied, and that this will move from a baseline condition of ‘Moderate’ to a ‘Fairly Good’ condition.</li></ul>					
Results and interpretation	Biodiversity benefits were reported as change in biodiversity units, and then via a proxy biodiversity ecosystem service value, by multiplying the biodiversity units provided with a £9,000 £ / units value for Biodiversity Credits provided by Defra in a recent consultation.					
	The BNG assessment highlights that the intervention which is likely to have the greatest percentage increase in biodiversity in the Irwell is the overland leaky barriers, whereas in the Little Don catchment the greatest biodiversity net gain is likely to be from the cross-slope woodland and vegetation (woodland) intervention.					
Estimated change in Biodiversity Units for each intervention						
	(a) Baseline Irwell	(b) Scenario Irwell	Irwell biodiversity net gain potential	(a) Baseline Little Don	(b) Scenario Little Don	Little Don biodiversity net gain potential
Cross-slope woodland and vegetation (Hedgerows)*	Not assessed	23.44	Not assessed	Not assessed	2.52	Not assessed
Cross-slope woodland and vegetation (Woodland)	6.57	11.78	79%	6.99	12.76	83%
Reducing soil compaction	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
Online storage ponds	0.79	0.89	12%	0.47	0.53	14%
Overland leaky barriers	0.39	0.86	124%	Not assessed	Not assessed	Not assessed
In-channel leaky barriers*	Not assessed	Not assessed	Not assessed	0.67	0.78	16%
*Biodiversity units per km of hedgerow and rivers (e.g., considered as a linear feature), therefore unable to compare to a baseline or to the other measures.						



Appendix E Water Supply: detailed methods and results

Impacts of Natural Flood Management on water supply

Methodology	<p>Each of the five measures is likely to have an impact on water flow regulation and water supply is through regulating the amount of runoff a soil surface will generate and its influence on infiltration to groundwater. There will be a change in the land cover and thus the vegetation with each measure implemented in the Irwell and Little Don catchments.</p> <p>The Daily Based Morgan Morgan-Finney (DMMF) model<sup>10</sup> was used to calculate the volumes of infiltration and runoff from the fields included in the measure implemented. A schematic of the DMMF model is provided below.</p> <p><b>Figure 7 Schematic of the DMMF model.</b> Q=run-off. IF= interflow, SW = soil water budget, ini = initial, R eff= effective rainfall, ET= evapotranspiration, SW c= surface water infiltration capacity, FC = field capacity, K= saturated soil lateral hydraulic conductivity.</p> <p>The DMMF model is a gridded model and was run for both catchments, the Irwell and Don. The gridded outputs were clipped to the areas representing the location of the individual measures. The Inputs into the DMMF model are:</p> <ul style="list-style-type: none"><li>• Soil parameters – Porosity, bulk density, hydraulic conductivity and depth. This information is taken or derived from the BGS Parent material model using the Saxton Equation<sup>11</sup></li><li>• Slope – Derived from Terrain 50 digital terrain model</li><li>• Rainfall – We have used average SAAR rainfall data 1961-1990 and event rainfall for design rainfall events as calculated by FEH.</li><li>• Land cover – Assumptions on the land cover have been made to model the effects of cover crops (see below) for a nearby catchment for which we had already obtained catchment descriptors. The catchment descriptors, scaled to the area of the fields, were then used to calculate hydrographs and the volume of rainfall in each event.</li></ul> <p>Assumptions made in the DMMF model are as follows:</p> <ul style="list-style-type: none"><li>• <math>\Theta_{ini}</math> (soil water initial volume) was calculated by matching the total runoff generated by the DMMF model to the total runoff expected from FEH hydrographs. The step calibrates the DMMF model outputs to the industry standard FEH methodology.</li></ul> <p>The DMMF model was used to quantify the effects of the five measures implemented on the water supply ecosystem service. The water supply ecosystem service is estimated using the following methodology:</p> <p><b>Water supply:</b> Within the model, the amount of infiltration is largely driven by soil and bedrock characteristics and is also affected by initial soil water content. The outputs for infiltration are therefore less dependent on rainfall event size. Infiltration was scaled up based on the length of the modelled rainfall event (60.6 hours). The amount of infiltration occurring over the 60.6 hour time period was assumed to represent an average rate of infiltration for each grid square and was scaled to provide annual values for infiltration in mm. These values were then converted to m<sup>3</sup> of infiltration across the entire scheme area. This calculation was completed in the following ways for each of the measures:</p> <ul style="list-style-type: none"><li>• For the <b>Cross-slope woodland and vegetation</b> the difference in soil water storage (SW) was calculated by comparing to baseline and the woodland creation option in the DMMF model, this gives mm of water storage for converting the baseline land cover to woodland.</li><li>• For the <b>Reducing soil compaction measures</b> the difference in soil water storage (SW) was calculated by comparing to baseline and the soil recovery option in the DMMF model, this gives mm of water storage for implementing soil aeration practises that are modelled by reducing the bulk density.</li><li>• For the <b>overland leaky barriers, in-channel leaky barriers and online storage pond measures</b> types the difference between initial soil water conditions and saturated soil (ie the soil water capacity) was calculated. It was assumed that under each water storage measure the soils are going to become saturated.</li></ul> <p>For monetisation of water supply benefits, it was assumed that all infiltration to groundwater will reach an aquifer for public water supply. The cost per cubic meter of water is calculated by using the ENCA recommended ONS (2020) value of £0.46 per cubic meter.</p>
Results and Interpretation	<p>The estimated volume of water infiltrating into the groundwater once the measures have been implemented in the Irwell and Little Don catchments are shown in the table below. Reducing soil compaction is the measure which has the largest infiltration increases into the groundwater, in both the Irwell and Little Don catchments. The particularly large increase in the Little Don, under the reducing soil compaction measure, is likely to be caused by the large areas of the reducing soil compaction measure implementation within the catchment. Although, the largest increase in volume of water infiltrating into the groundwater is also seen, for reducing soil compaction, in</p>

<sup>10</sup> Choi, K., Arnhold, S., Huwe, B. and Reineking, B., 2017. Daily Based Morgan–Morgan–Finney (DMMF) Model: A Spatially Distributed Conceptual Soil Erosion Model to Simulate Complex Soil Surface Configurations. Water, 9(4), p.278.

<sup>11</sup> Saxton, K. and Rawls, W., 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Science Society of America Journal, 70(5), pp.1569-1578.

	the Irwell catchment, thus highlighting that this method is also a particularly effective method for water supply ecosystem service improvements.					
Estimated change in volumes of water infiltrating to groundwater for each of the NFM measures implemented in both the Irwell and Little Don catchments						
	Irwell			Little Don		
	Baseline-annual volume of water infiltrating to groundwater (m³)	Scenario- annual volume of water infiltrating to groundwater (m³)	Change in annual volume of water infiltrating to groundwater (m³)	Baseline- annual volume of water infiltrating to groundwater (m³)	Scenario-annual volume of water infiltrating to groundwater (m³)	Change in annual volume of water infiltrating to groundwater (m³)
Cross-slope woodland and vegetation	100,434	100,468	34	7,139	7,157	18
Reducing soil compaction	95,677	95,821	144	451,763	453,152	1,389
Online storage ponds	519	532	13	1,015	1,046	31
Overland leaky barriers	731	749	15	N/A – this measure type wasn’t implemented in this catchment		
In-channel leaky barriers	N/A – this measure type wasn’t implemented in this catchment			64	66	3

# Appendix F Water Flow Regulation (Flood Risk Alleviation)

Please see technical note ‘Technical Note - Traffic Damages v1’ for the Flood Risk Alleviation report.



# Appendix G Sources of data and information used in natural capital valuation

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Appendix H Individual measure results

Table 3 – Natural Capital Benefits: Combined Benefits of the Cross Slope Hedgerows and Woodland Measure										
*for detailed information on each ecosystem service look in appendix Appendix C to Appendix F										
Ecosystem service	Change in service provision**	Metric per year	Physical Flow Account				Monetary Flow Account (Annual)			
			Baseline	Scenario	Change	Change per ha	Baseline	Scenario	Change	Change per ha
Food production	↓↓↓	£ across UK Hab types	na	na	na	na	£663	£0	-£663	-£304
Water supply	↑	m³ of water infiltrating to groundwater	107,573	107,625	51	12	£53,208	£53,233	£25	£6
Recreation	↓	£ across UK Hab types	na	na	na	na	£596	£533	-£63	-£29
Air quality	↑	kg ammonia loss	17	7	-10	-3	-£152	-£65	£87	£28
Air pollution removal	↑↑↑	£ across UK Hab types	na	na	na	na	£71	£832	£761	£280
Water quality	↑↑↑	kg N loss	41	22	-19	-6	-£46	-£25	£21	£7
		kg P loss	2	1	-1	-0	-£66	-£23	£43	£15
		kg sed loss	726	176	-550	-216	-£329	-£80	£249	£98
GHG emission reductions (inc. carbon sequestration)	↑↑↑	tCO2 sequestered	4	20	16	6	£1,048	£5,015	£3,967	£1,496
		tCO2e of CH4 emissions per year	5	2	-3	-1	-£1,150	-£507	£643	£209
		tCO2e of N2O emissions per year	1	1	-1	-0	-£301	-£129	£172	£56
		tCO2 emissions per year due to energy use	1	1	-1	-0	-£347	-£130	£217	£71
Biodiversity	↑	Number of biodiversity units	14	25	11	4	£4,880	£8,835	£3,956	£1,289
		Number of hedgerow units	na	26	na	na	na	na	na	na
		Number of river units	na	na	na	na	na	na	na	na
Total value	^	-	-	-	-	-	£58,074	£67,490	£9,415	£3,223

\*\*based on the 25 year PV change values

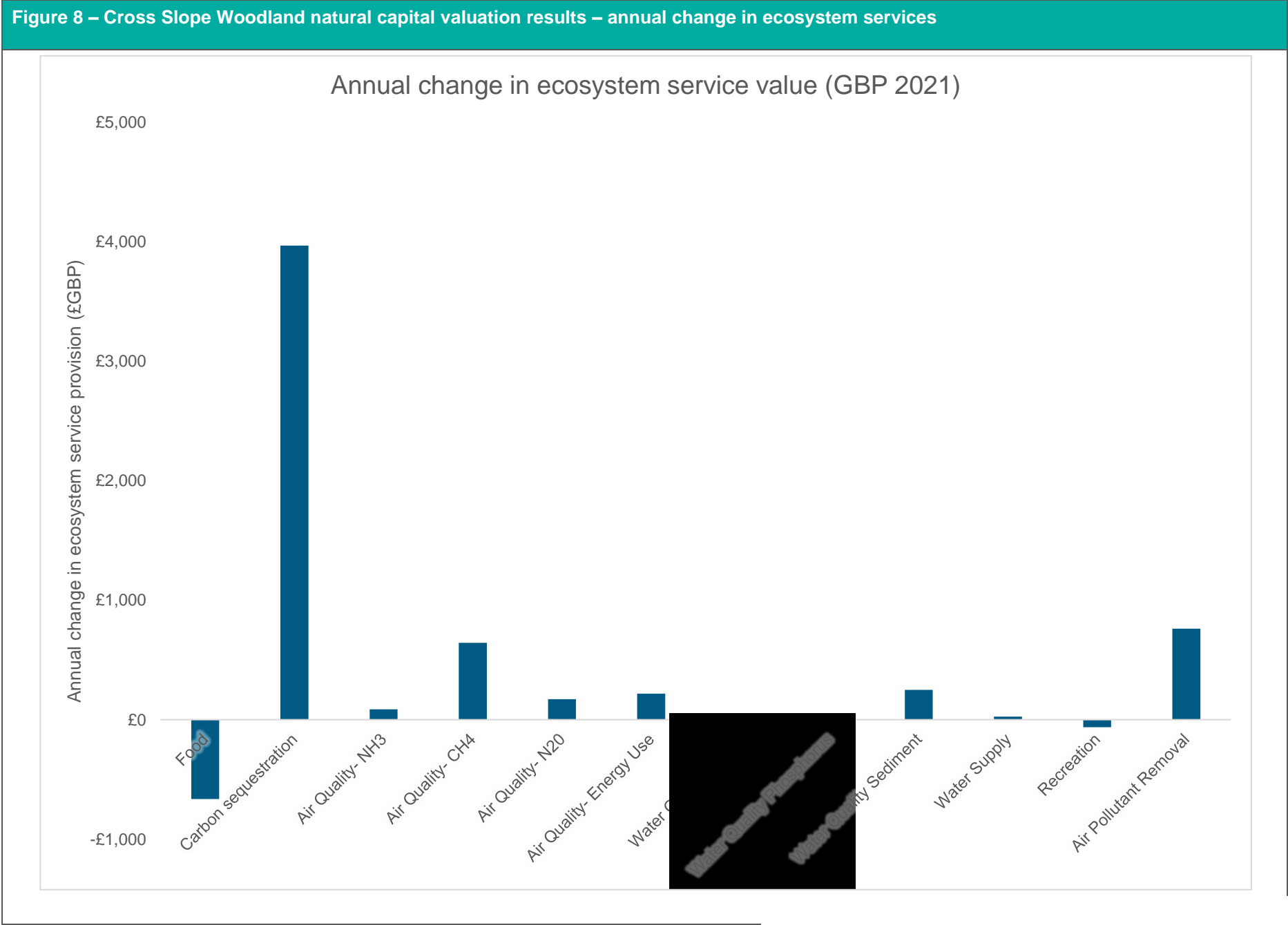


Table 4 – Natural Capital Benefits: Combined Benefits of the Reducing Soil Compaction Measure										
*for detailed information on each ecosystem service look in appendix Appendix C to Appendix F										
Ecosystem service	Change in service provision**	Metric per year	Physical Flow Account				Monetary Flow Account (Annual)			
			Baseline	Scenario	Change	Change per ha	Baseline	Scenario	Change	Change per ha
Food production	-	£ across UK Hab types	na	na	na	na	£18,602	£18,602	£0	£0
Water supply	↑↑	m³ of water infiltrating to groundwater	547,440	548,973	1,533	13	£270,774	£271,532	£758	£6
Recreation	-	£ across UK Hab types	na	na	na	na	£16,704	£16,704	£0	£0
Air quality	-	kg ammonia loss	475	475	0	0	£-4,129	£-4,129	£0	£0
Air pollutant removal	-	£ across UK Hab types	na	na	na	na	£1,981	£1,981	£0	£0
Water quality	↑↑	kg N loss	1158	1150	-8	0	£-1,305	£-1,296	£9	£0
		kg P loss	37	36	-2	0	£-1,445	£-1,380	£65	£1
		kg sed loss	15409	14424	-986	-8	£-6,983	£-6,536	£447	£4
GHG emission reductions (inc. carbon sequestration)	↓↓	tCO2 sequestered	0	0	0	0	£0	£0	£0	£0
		tCO2e of CH4 emissions per year	133	133	0	0	£-32,600	£-32,600	£0	£0
		tCO2e of N2O emissions per year	32	32	0	0	£-7,903	£-7,832	£71	£1
		tCO2 emissions per year due to energy use	30	30	0	0	£-7,362	£-7,832	£-470	£-4
Biodiversity	-	Number of biodiversity units	na	na	na	na	na	na	na	na
		Number of hedgerow units	na	na	na	na	na	na	na	na
		Number of river units	na	na	na	na	na	na	na	na
Total value	^	-	-	-	-	-	£275,713	£276,595	£881	£7
**based on the 25 year PV change values										
Figure 9 – Reducing soil compaction natural capital valuation results – annual change in ecosystem services										

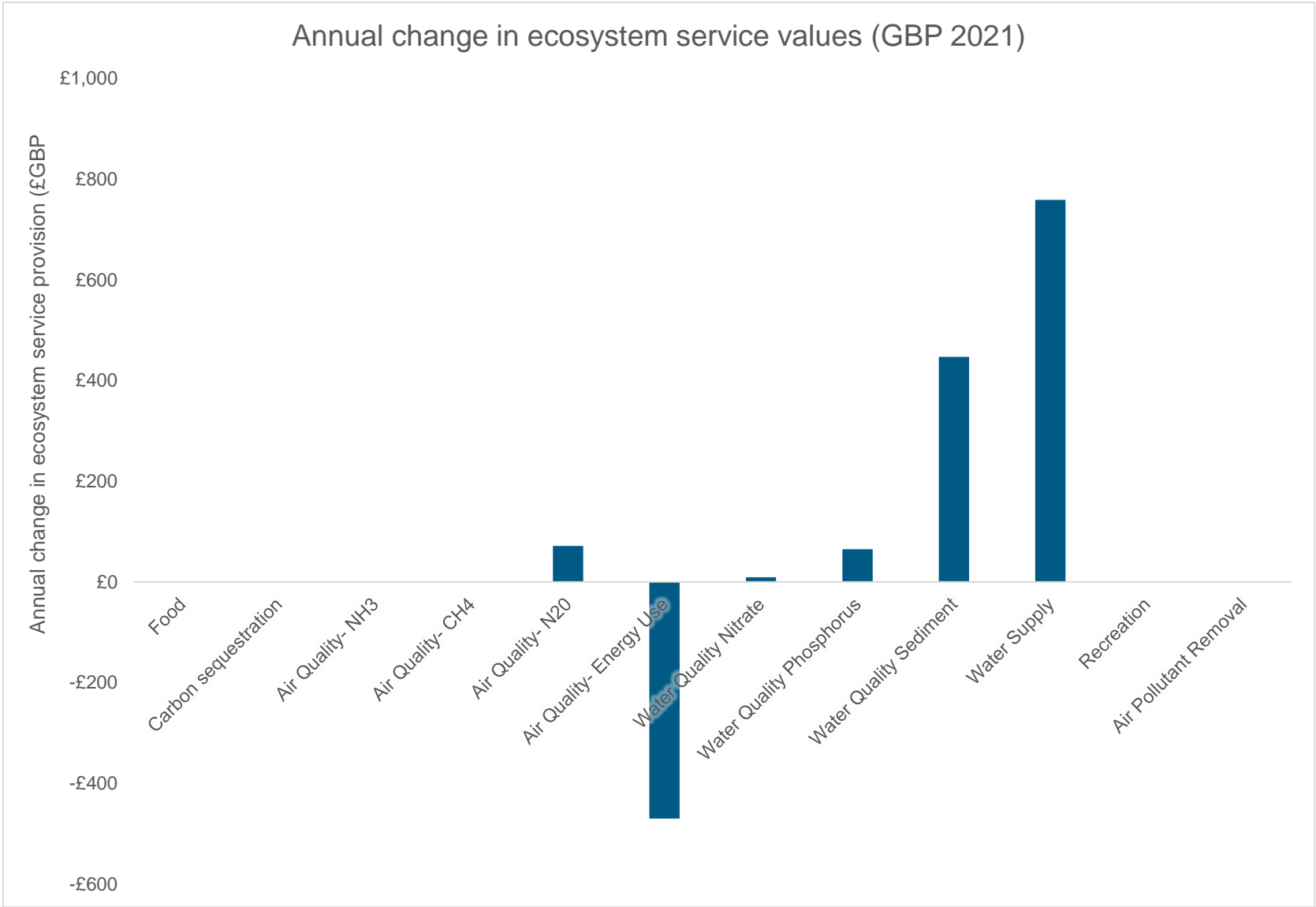


Table 5 – Natural Capital Benefits: Combined Benefits of the Online Storage Ponds Measure

\*for detailed information on each ecosystem service look in appendix Appendix C to Appendix F

Ecosystem service	Change in service provision**	Metric per year	Physical Flow Account				Monetary Flow Account (Annual)			
			Baseline	Scenario	Change	Change per ha	Baseline	Scenario	Change	Change per ha
Food production	-	£ across UK Hab types	na	na	na	na	£43	£43	£0	£0
Water supply	↑	m³ of water infiltrating to groundwater	1,534	1,547	13	46	£759	£765	£6	£23
Recreation	-	£ across UK Hab types	na	na	na	na	£0	£0	£0	£0
Air quality	-	kg ammonia loss	1	1	-0.004	-0	-£10	-£10	£0	£0
Air pollution removal	-	£ across UK Hab types	na	na	na	na	£0	£0	£0	£0
Water quality	↑	kg N loss	3	3	-0	-0	-£3	-£3	£0	£0
		kg P loss	0	0	-0	-0	-£1	-£1	£0	£0
		kg sed loss	48	47	-1	-3	-£22	-£21	£0	£1
GHG emission reductions (inc. carbon sequestration)	↑	tCO2 sequestered	na	na	na	na	na	na	na	na
		tCO2e of CH4 emissions per year	0	0	-	-	-£75	-£75	£0	£0
		tCO2e of N2O emissions per year	0	-0	-0	-0	-£20	-£19	£0	£0
		tCO2 emissions per year due to energy use	0	0	-0	-0	-£23	-£23	£0	£1
Biodiversity	↑	Number of biodiversity units	1.3	1.4	0.2	0.6	na	na	na	na
		Number of hedgerow units	na	na	na	na	na	na	na	na
		Number of river units	na	na	na	na	na	na	na	na
Total value	^	-	-	-	-	-	£649	£656	£7	£26

\*\*based on the 25 year PV change values

Figure 10 – Online storage ponds natural capital valuation results – annual change in ecosystem services

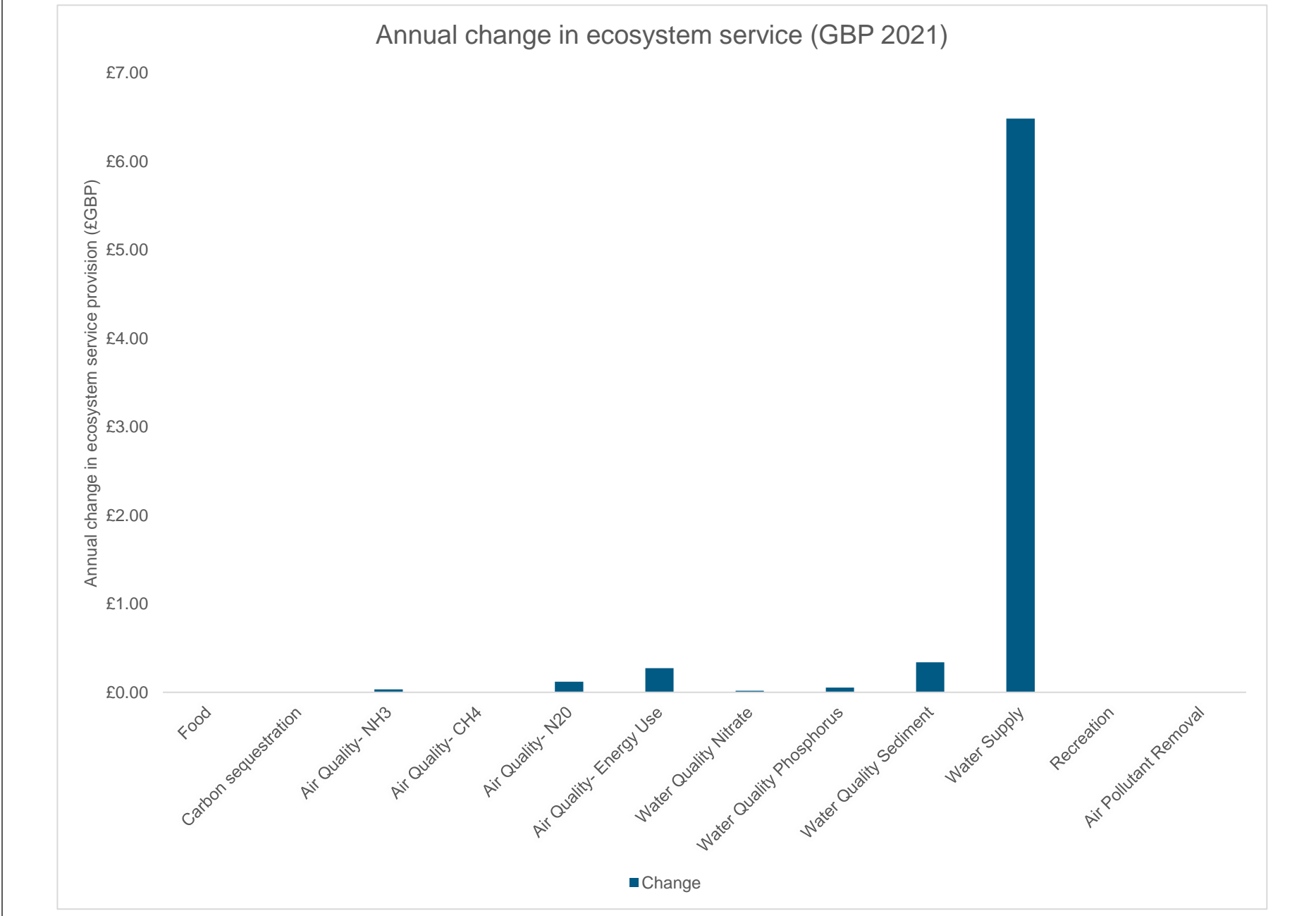


Table 6 – Natural Capital Benefits: Combined Benefits of the Overland Leaky Barriers Measure										
*for detailed information on each ecosystem service look in appendix Appendix C to Appendix F										
Ecosystem service	Change in service provision **	Metric per year	Physical Flow Account				Monetary Flow Account (Annual)			
			Baseline	Scenario	Change	Change per ha	Baseline	Scenario	Change	Change per ha
Food production	-	£ across UK Hab types	na	na	na	na	£13	£13	-	
Water supply	↑	m³ of water infiltrating to groundwater	731	777	46	532	£361	£384	£23	£263
Recreation	-	£ across UK Hab types	na	na	na	na	£0	£0	£0	£0
Air quality	-	kg ammonia loss	0	0	-0	-0	-£3	-£3	£0	£0
Air pollution removal	-	£ across UK Hab types	na	na	na	na	£0	£0	£0	£0
Water quality	↑	kg N loss	1	1	-0	-0	-£1	-£1	£0	£0
		kg P loss	0	0	-0	-0	£0	£0	£0	£0
		kg sed loss	17	17	-0	-3	-£8	-£8	£0	£1
GHG emission reductions (inc. carbon sequestration)	↑	tCO2 sequestered	na	na	na	na	na	na	na	na
		tCO2e of CH4 emissions per year	0	0	-	-	-£23	-£23	£0	£0
		tCO2e of N2O emissions per year	0	0	-0	-0	-£6	-£6	£0	£1
		tCO2 emissions per year due to energy use	0	0	-0	-0	-£8	-£8	£0	£1
Biodiversity	↑	Number of biodiversity units	0	1	0	6	na	na	na	na
		Number of hedgerow units	na	na	na	na	na	na	na	na
		Number of river units	na	na	na	na	na	na	na	na
Total value	^	-	-	-	-	-	£326	£349	£23	£267

\*\*based on the 25 year PV change values

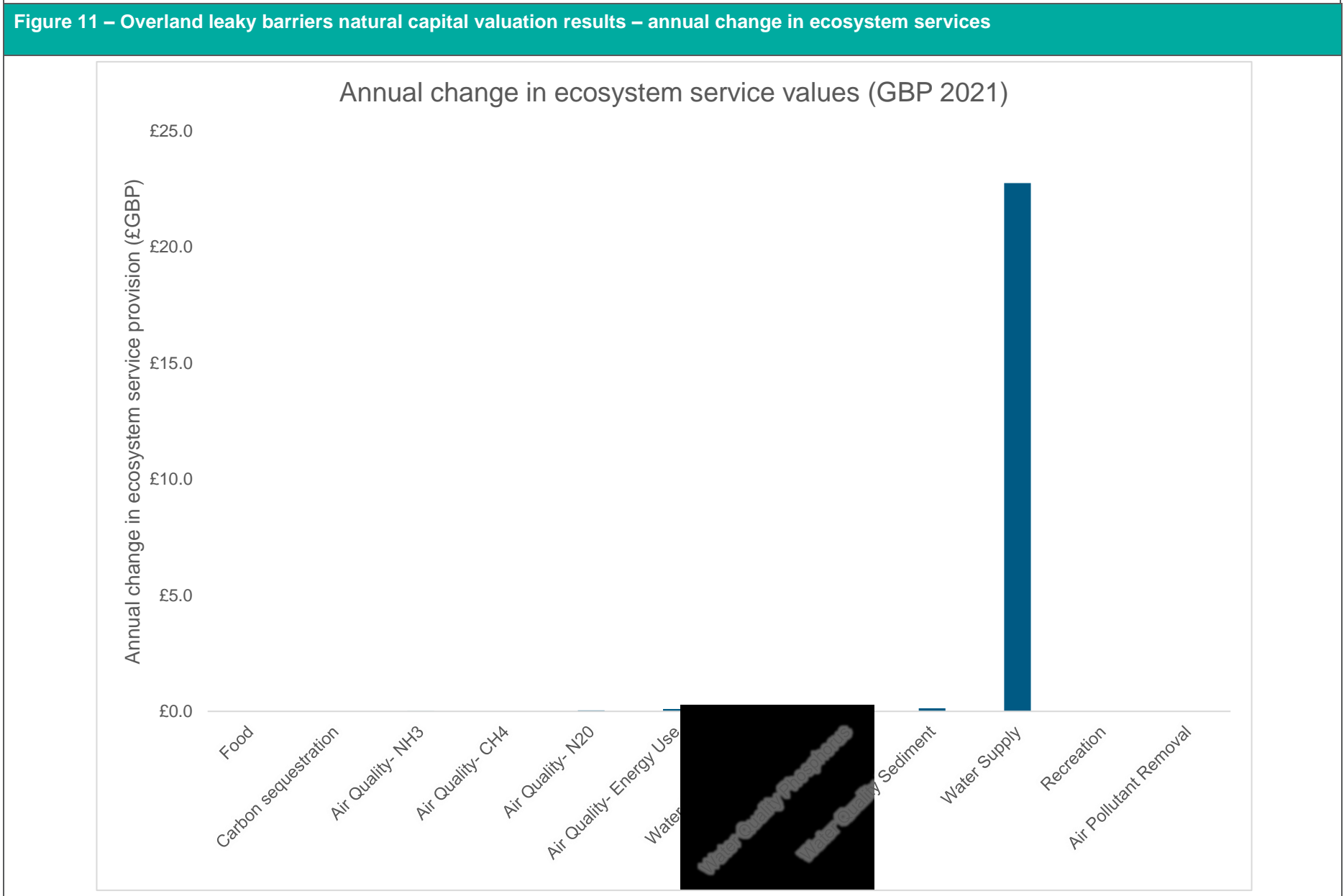




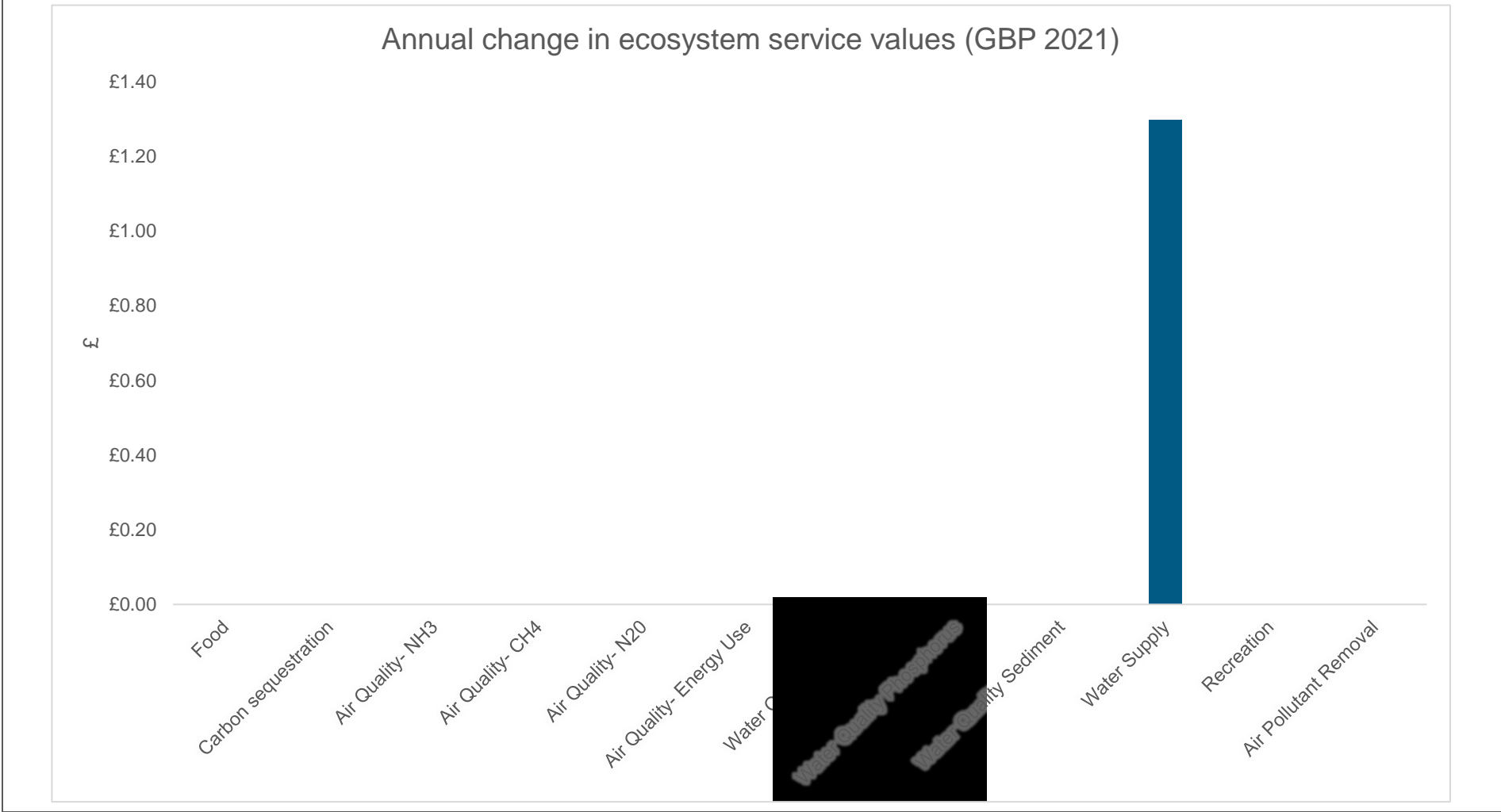
Table 7 – Natural Capital Benefits: Combined Benefits of the In-channel leaky barriers measure

\*for detailed information on each ecosystem service look in appendix Appendix C to Appendix F

Ecosystem service	Change in service provision*	Metric per year	Physical Flow Account				Monetary Flow Account (Annual)			
			Baseline	Scenario	Change	Change per ha	Baseline	Scenario	Change	Change per ha
Food production	-	£ across UK Hab types	na	na	na	na	£0.99	£0.99	-	£0.00
Water supply	↑	m³ of water infiltrating to groundwater	64	66	3	403	£31	£33	£1	£200
Recreation	-	£ across UK Hab types	na	na	na	na	£0	£0	£0	£0
Air quality	-	kg ammonia loss	na	na	na	na	na	na	na	na
Air pollution removal	-	£ across UK Hab types	na	na	na	na	£0	£0	£0	£0
Water quality	-	kg N loss	na	na	na	na	na	na	na	na
		kg P loss	na	na	na	na	na	na	na	na
		kg sed loss	na	na	na	na	na	na	na	na
GHG emission reductions (inc. carbon sequestration)	-	tCO2 sequestered	na	na	na	na	na	na	na	na
		tCO2e of CH4 emissions per year	na	na	na	na	na	na	na	na
		tCO2e of N2O emissions per year	na	na	na	na	na	na	na	na
		tCO2 emissions per year due to energy use	na	na	na	na	na	na	na	na
Biodiversity	↑	Number of biodiversity units	na	na	na	na	na	na	na	na
		Number of hedgerow units	na	na	na	na	na	na	na	na
		Number of river units	0.67	0.78	0.11	0.01	na	na	na	na
Total value	^	-	-	-	-	-	£32	£34	£1	£200

\*based on the 25 year PV change values

Figure 12 – In-channel leaky barriers natural capital valuation results – annual change in ecosystem services



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## Appendix C. Hydrological Methods

## C.1. Overview of NFM Studio

**ATKINS**

Member of the SNC-Lavalin Group

# NFMStudio description

April 2022







# NFM Studio

## Summary of the tool

NFM Studio is a decision support tool that helps catchment managers find the best places to implement NFM within the landscape. It is a strategic tool - its purpose is to inform decisions on NFM at a catchment or landscape scale. To date, NFM Studio has been used at a number of locations for a number of organisations.

At the core of NFM Studio are three assessment streams:

- Opportunity mapping:** to identify places in a catchment that are physically suited to NFM and where interventions might be easiest to implement from a practical and stakeholder perspective.
- Hydrological assessment:** to estimate the volume of water stored by NFM interventions and how this attenuation changes the shape and the peak of the hydrograph at a catchment outlet.
- Natural capital and multiple benefits:** to estimate the ecosystem service benefits generated by NFM. This provides a complete picture of the overall benefits of these nature-based solutions in the catchment.

The information generated by these three streams are integrated to produce as spatial NFM database of the catchment. They also form the basis for the overall structure of this report. Outputs from the hydrological and opportunity streams are combined to identify those parts of the catchment that are best for NFM i.e. those places that are particularly effective at storing flood water and most suited to implementing interventions. The natural capital assessment provides context by estimating the total benefits to ecosystem services generated by interventions – an essential consideration for catchment managers wanting to develop integrated catchment management (ICM) solutions.

All assessments are carried out using open-source data, a key ethos of NFM Studio. Use of open-source data enables the tool to be applied to any catchment or catchments in England without the need for data purchase. Outputs can be readily shared without the need for data sharing licenses.

The spatial NFM database generated by the three assessment streams is presented in this report as a suite of maps. These show the best places to implement NFM and estimate of the flood risk benefits interventions are likely to deliver. A hydrology calculator (provided as a spreadsheet) allows the interactive manipulation of the catchment outlet hydrograph by changing assumptions on how NFM is implemented. An additional suite of maps consider the wider ecosystem service benefits NFM can provide such as water quality amelioration, carbon lock-up, biodiversity and recreation amongst others.

All outputs are generated based on field boundaries defined by Ordnance Survey MasterMap data. Whilst data are produced at this scale to allow flexibility in presentation and analysis, outputs are intended for interpretation at landscape or catchment scale.

## Measures Considered by NFM Studio

The NFM intervention types considered and mapped by NFM Studio are grouped as shown in the figure below and include:

A. Land use (and management) change	Including measures such as: <ul style="list-style-type: none"><li>Land use change along successional steps</li><li>Woodland planting and plantation management</li><li>Land use management improvements for example increasing soil health, reducing compaction and stocking densities</li><li>Peatland and moorland restoration including re-introduction of vegetation, gully blocking etc.</li></ul>
B. Flow pathway interventions	Including measures such as: <ul style="list-style-type: none"><li>Bunds including leaky barrier, cross slope bund</li><li>Offline and online storage ponds</li><li>Cross slope woodland and hedge planting</li><li>Track and overland flow path cross drains and grips</li></ul>
C. In-channel and floodplain attenuation	Including measures such as: <ul style="list-style-type: none"><li>In-channel woody structures</li><li>Headwater channel woody bundles</li><li>Floodplain reconnection measures</li></ul>

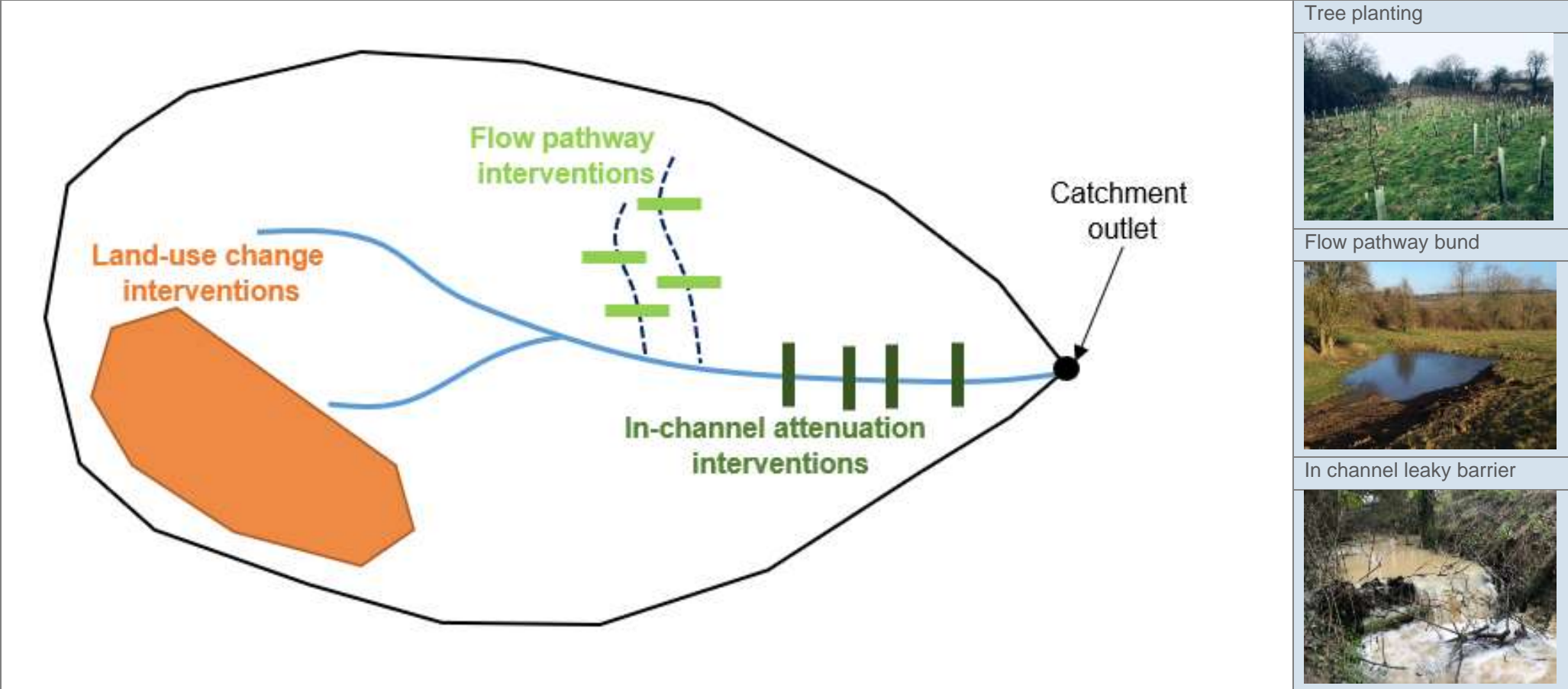


Figure 1. NFM interventions considered in NFM Studio

# Opportunity mapping

Opportunity Maps

Opportunity-constraint metrics are used in NFM Studio to assess the opportunity for NFM at the field scale. The benefits of implementing NFM in these locations are considered separately by the volumetric and natural capital calculations.

The opportunity-metrics are developed through one or a series of opportunity workshops that make the outputs catchment specific, but are based on a series of standardised open source data sets describing the landscape from which the suitability for implementing NFM is inferred (see Appendix D). For the purposes of mapping, opportunity scores for each of the three NFM measure types are normalized and displayed in a numeric scale from 0 to 1, where a score of 0 is the least appropriate field and 1 the most appropriate field for the implementation of a given NFM measure.

The opportunity assessment in NFM Studio considers the NFM potential of individual fields based on enablers and constraints identified by open-source datasets included in the NFM Studio tool (see Appendix D). The opportunity assessment can also be moderated using the outcome of opportunity workshops where stakeholders are engaged to provide catchment specific intelligence and knowledge. Opportunity metrics provided for each field are summed and normalised to produce an opportunity score between 0 and 1. The opportunity assessment is performed for each of the NFM intervention types summarised as follows:

- **Land use change measures** – All areas of the catchment are scored for suitability for land use change NFM, with the exclusion of urban areas.
- **Flow pathway measures** – All areas with risk of flooding from surface water are scored for suitability for catchment Storage NFM, with the exclusion of urban areas.
- **In-channel and floodplain measures** – All areas bordering a river are scored for suitability for in-channel NFM, with the exclusion of urban areas.
- **In-combination** – A combination of all the above NFM intervention types

# Hydrological assessment

## A. Land runoff measures

The methodology used to estimate changes in infiltration and runoff for different land use and management options in NFM Studio is the Daily Based Morgan–Morgan–Finney (DMMF) Model. The DMMF model outlined by Choi *et al.* (2017) is a widely used field scale surface water runoff and soil erosion model, which has been incorporated into NFM Studio to simulate runoff under different land-use, land management and rainfall scenarios. The figure below presents a schematic of the DMMF model in the NFM Studio tool, showing the different processes it considers and the range of parameters that can be adjusted. A number of model parameters control how each of these processes are calculated in each land use scenario and are highlighted in yellow. For example, the initial soil conditions ( $\theta_{ini}$ ) are used to derive the Soil Water Initial conditions ( $SW_{ini}$ ), the bulk density and soil depth are used in the calculation of the soil water store ( $SW$ ), the hydraulic conductivity is used in the calculation of the interflow ( $IF$ ) and an interception coefficient is used to derive effective rainfall ( $R_{Eff}$ ).

Rainfall under different storm return periods is input to the model which considers catchment conditions such as baseline hydrology, soil characteristics, land cover and slope in calculating the volume of infiltration and run-off. The soil hydrological conductivity and infiltration rates of the soil and parent material are inferred from an open-source soil characteristics dataset developed as part of the tool, and the land-use determines the permanent interception factor. The DMMF model is run under baseline conditions and for three Infiltration NFM intervention options detailed below.

**Baseline:** The DMMF runoff model is utilised to calculate superficial runoff in 50x50 m grids for a single timestep. Land, soil and catchment characteristics (i.e. land use, soil characteristics, sub-soil, slope, etc.) are processed from a number of physical, environmental and socio-economic spatial datasets. Initial conditions in the model are calibrated to match the total superficial runoff calculated from the Flood Estimation Handbook (FEH). The runoff generation calculated with the DMMF model is then assigned to the fields within the catchment and calibrated against ReFEH hydrographs.

**Return periods assessed:** Commonly, the DMMF model is run for four return period events. The 1:2, 1:20 and 1:100 return period events are run as standard within NFM Studio.

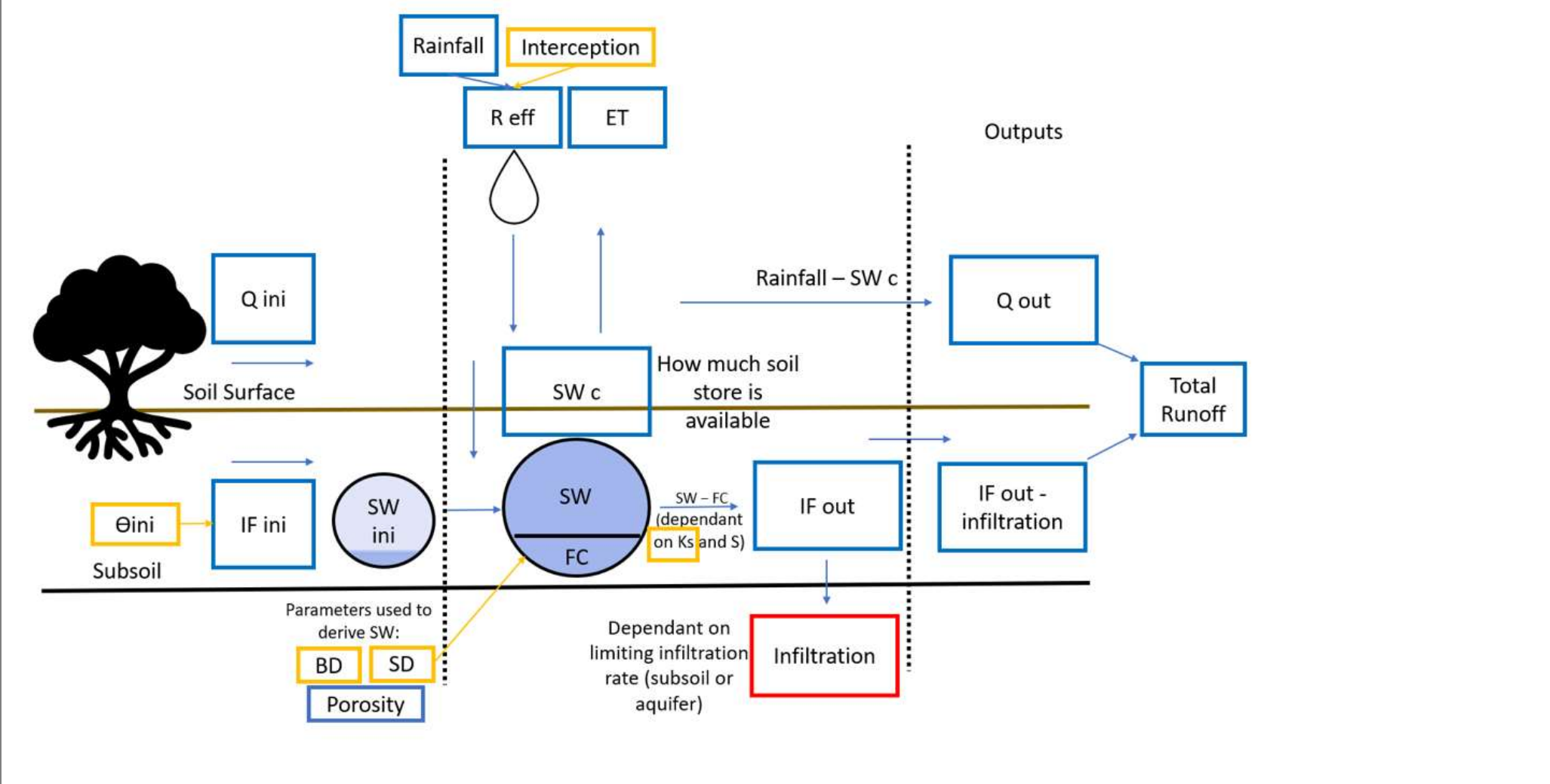


Figure 2 Schematic of DMMF model.  $R_{eff}$  is the effective rainfall,  $ET$  evapotranspiration,  $Q$  superficial runoff,  $IF$  interflow,  $SW_c$  soil water capacity,  $FC$  field capacity,  $SW$  soil water. Yellow boxes identify soil parameters that drive how different processes are calculated in the DMMF model.

## Land Use Scenarios

- NFM Studio considers the effects of land use and management on land runoff based on three standard scenarios as follows:
- **Scenario 1 - Land use change and management:** This option assumes that arable land in the catchment is transformed into pastures; pastures into natural grasslands and natural grasslands to woodland. Within NFM Studio, these changes are simulated by altering interception factors and bulk density values (shown in yellow in Figure 2).
  - **Scenario 2 - Woodland creation:** This option assumes that all arable land, improved grasslands and natural grasslands are converted to woodland. As for option 1, within NFM Studio this change is simulated by altering interception factors and bulk densities (see Figure 2).
  - **Scenario 3 - Soil recovery:** This option simulates the potential improvements in soil health that arise from soil recovery measures such as aeration. Within NFM Studio, this option is simulated by maintaining existing land use but altering bulk densities to simulate for example increased aeration or soil organic matter.

To assess the effects of different land use scenarios, it is assumed that the calculated and calibrated baseline initial soil moisture/antecedent conditions are the same in the baseline condition and each of the scenarios. This assumes that the initial/antecedent conditions associated with a given return period flood is the same regardless of the land intervention applied. However, the initial conditions do change for different return period events. Another important point to note is that the inputs to the DMMF models represent average conditions over the year and therefore provide an estimate of annual average runoff. For example, the interception rates of a vegetation canopy growing above a soil surface will vary seasonally over the course of a year, especially for deciduous woodlands and crops.

Current/Baseline Land Cover	Scenario 1 – Land-use change	Scenario 2 – Woodland creation	Scenario 3 – Soil Recovery
Arable	Improved grasslands	Woodland	Arable*
Improved grasslands	Natural grasslands	Woodland	Improved grasslands*
Natural grasslands	Woodland	Woodland	Natural grasslands*
Woodland	Woodland	Woodland	Woodland *

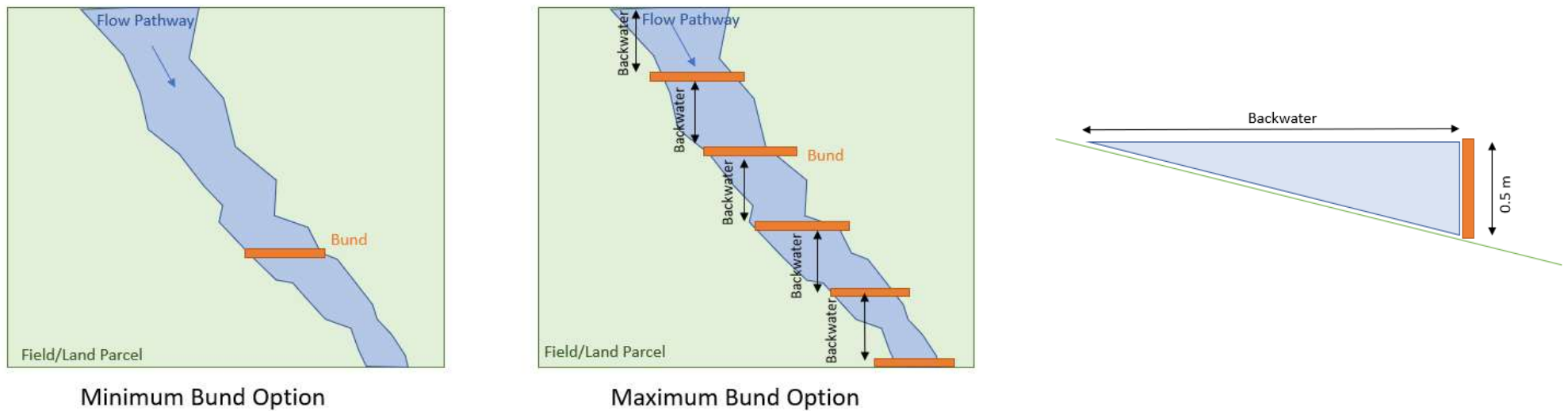
\* with reduction in soil bulk densities



## B. Flow Pathway Measures

The methodology used by NFM Studio to estimate the volumes of water that might be stored along flow pathway NFM measures uses the Environment Agency's Risk of Flooding from Surface Water (RoFSW) dataset. These data are first mapped for the catchment. Areas prone to fluvial flooding are excluded and hence the flow pathways identified are the areas that convey flow within the catchment excluding watercourses and their floodplains. Small areas which are ponds and don't have a flow pathway attributed to them are also excluded. Once the location of the flow pathways in the catchment are identified, the volume of water store behind a bund is calculated to assess the potential volumetric storage. The total volume stored in each field is then calculated as the sum of the water behind the bunds.

The total volume store behind the bunds is calculated for two scenarios which reflect the minimum number likely to be applied in a field (a single bund) as well as the maximum number of bunds that could be applied along the flow pathway in any given field. In both cases, NFM Studio assumes that bunds are 0.5m high. The figure below presents a schematic of the flow pathway model in the NFM Studio tool.

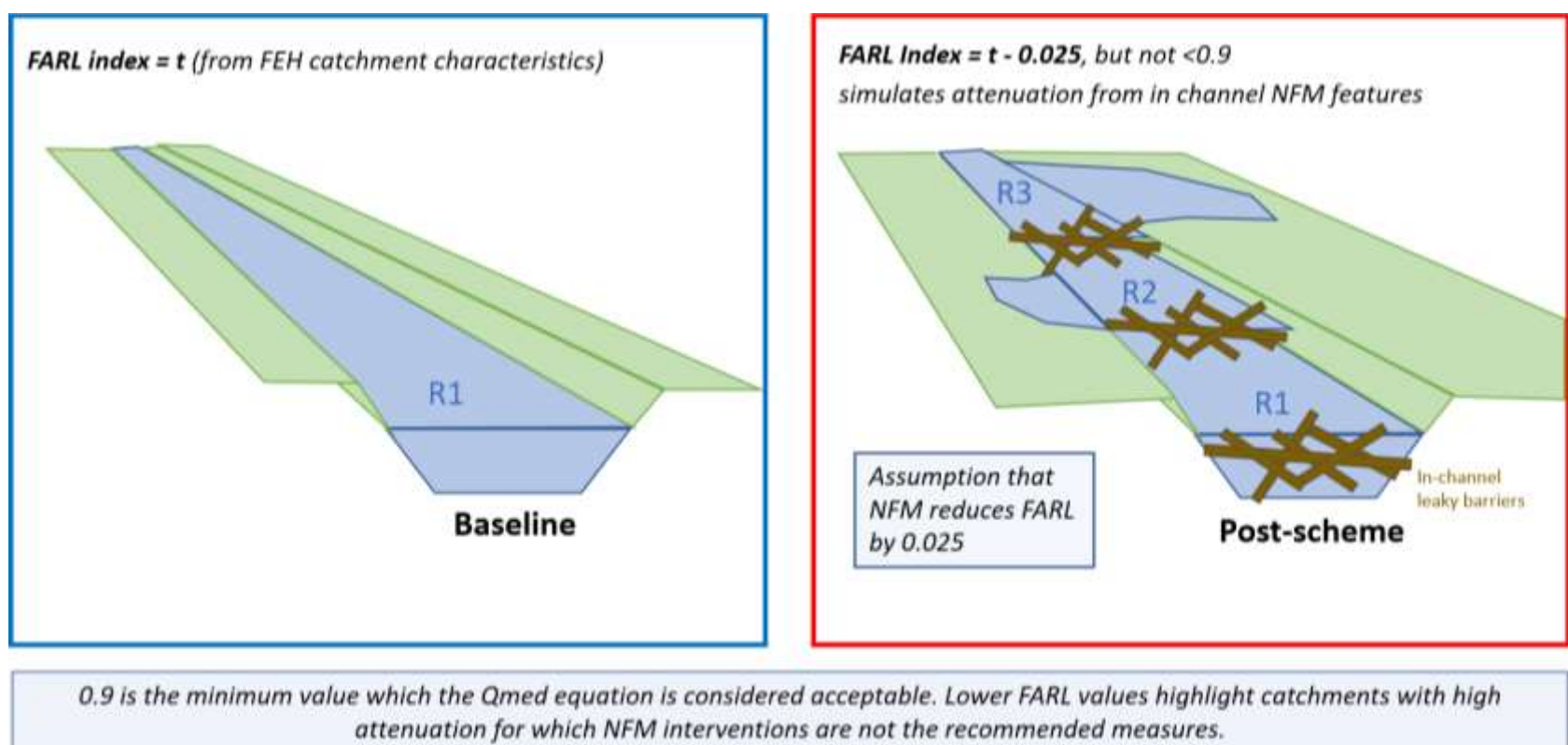


## C. In-channel and floodplain attenuation measures

In-channel and floodplain attenuation measures refer to actions that reduce flow velocities within watercourses and reconnect floodplains in rural areas, for example woody features in a watercourse. The methodology used to estimate the in-channel attenuation of watercourses in NFM Studio uses the FARL index in the industry-standard Flood Estimation Handbook (1999)<sup>1</sup>. The FARL index is a catchment descriptor that identifies the flood attenuation provided by online reservoirs and lakes. To calculate the effect of in-channel measures, NFM Studio uses the upstream river length, sub-catchment area, total catchment area and characteristics data from the OSMM water dataset for watercourse reach. NFM Studio assumes that the effect of in-channel attenuation measures such as woody features reduces the FARL index by 0.025, to a minimum value of 0.9.

The hydrograph is re-calculated to account for the updated FARL and the difference in total volume under the hydrograph (m<sup>3</sup>) before and after the change in FARL is considered the temporary volumetric storage for the catchment. The hydrograph for the 1 in 2yr event is used for the in channel volumetric assessment as it is representative of approximately bank full conditions. The Muskingum flow routing method is used to route the adjusted Qmed to generate the attenuated hydrograph and account for the attenuation of any in-channel interventions.

Within NFM Studio, the total catchment attenuation potential is proportioned out to individual watercourse reaches depending on the upstream catchment area and watercourse width, with wider reaches lower in the catchment having more attenuation potential. The Environment Agency's WWNP 'floodplain reconnection potential' dataset is also incorporated into the calculation, to account for the potential floodplain reconnection capacity of each watercourse reach. Therefore, the resulting in-channel attenuation volumetric output estimates the total potential storage across the river corridor. .



<sup>1</sup> The Flood Estimation Handbook Centre for Ecology & Hydrology, 1999 <https://www.ceh.ac.uk/services/flood-estimation-handbook>



# Appendix A. Assumptions and limitations of NFM Studio

The NFM Studio assessment includes a series of assumptions that are necessarily made to simplify the calculations the tool performs, and to fit the availability of data describing catchment character, hydrological responses, the effectiveness of different NFM measures, their implementation costs and natural capital benefits. The table below summarises the main assumptions and associated limitations that should be considered when interpreting NFM Studio outputs.

	Assumption or limitation	Commentary
General	NFM Studio uses Corine (2018) land cover data. It is likely that some land cover changes have occurred in the catchment since these data were produced.	Corine 2018 remains the most current open source land cover dataset available and any undocumented land cover changes are likely to be a small percentage of the overall catchment area.
	Standard Percentage Runoff (SPR) values may not identify the heterogeneity of catchment soils at small spatial scales.	SPR values are estimated from both the BGS Soil Parent Material Model and BGS 625k superficial geology layer to improve granularity of model outputs. Whilst local variations in the soil may not be represented, in the absence of licenses for or more detailed soil data, this approach remains the best open-source approach to estimate soil properties.
Opportunity	Land holder engagement considerations are not included in the assessment	Coverage of environmental stewardship across the catchment is used as a proxy for likely overall engagement in an NFM scheme. CLAD landownership map issued alongside other reporting products.
	Multi-criteria decision analysis (MCDA) is a standard tool used across multiple industries but can often be a subjective and biased process.	Where this is used, the risk of subjectivity is addressed in NFM Studio by using the Analytic Hierarchy Process (AHP) developed by Saaty (1994).
	Opportunity mapping is a subjective part of the NFM assessment, where opportunity scores developed during workshops are applied. This information represents the perceived opportunities for NFM only and does not consider the volumetric potential for NFM.	The workshop enables local knowledge and catchment intelligence for any catchment to be collated to make the assessment as catchment specific as possible.
Land runoff	In NFM Studio, the total runoff generated by land runoff (estimated by a Daily based Morgan Morgan-Finney model, DMMF for the catchment) is cross-checked by comparing outputs with ReFH hydrographs.	Checking and matching DMMF outputs to ReFH increases confidence in model outputs. ReFH is an industry standard approach.
	The initial soil moisture antecedent conditions are the same for baseline and scenario NFM Studio runs. This assumes that soil conditions at the beginning of a modelled flood are the same regardless of the intervention applied.	This approach enables direct comparison between estimated runoff under the baseline and scenario model runs to estimate reductions in runoff.
	The parameters applied within the DMMF model of the catchment consider ‘average’ conditions over a year and therefore provide a generalised view of a catchment that does not account for the dynamic and temporal variability of environmental variables.	The DMMF model is routinely run for a range of return periods, altering the amount of rain applied to the model to replicate different catchment conditions. Different scenarios can be designed and run through the model if required.
Flow pathway	Flow pathway storage two scenarios; (a) one bund per field or (b) maximum number of bunds possible in a field. The maximum bund option assumes that the entire length of the flow pathway in a field can accommodate a number of bunds in series. The number of bunds that can be accommodated is calculated based on the back water length and the total flow pathway length.	By providing an estimated minimum and maximum volumetric estimate, a no constraints assessment of what may be possible is provided. In reality, the number of bunds that might be implemented as part of an NFM scheme is likely to be somewhere in between, and will also depend on the size of the bunds.
	Each bund is assumed to be 0.5m high.	It may be possible to implement bunds higher than 0.5m but this is the maximum practical height without the need for engineering design.
	For both flow pathway scenarios, it is assumed that no water infiltrates into the soil when stored within the bunds.	It is assumed that the bunds slowly release the water stored after the flood event. Under intense rainfall conditions which generate over land flow, the soil is already likely saturated, resulting in the overland flow, therefore any infiltration is likely to occur after the rainfall event.
	The effects of bunds on flood hydrographs is achieved by removing storage volumes from the rising limb of the hydrograph and do not directly affect the flood peak.	Bunds are assumed to be empty at the start of the event and once full remain so during the flood event.
In-channel	It is assumed that after the in-channel interventions within the catchment are applied, FARL can be reduced by 0.025 down to a minimum value of 0.9.	Qmed is therefore re-calculated with the updated FARL and the difference in total volume (m3) before and after the change in FARL for the 1 in 2yr event (which is approximately bank full) is considered the temporary volumetric storage.
	In Channel measure types that are considered by the tool include in channel leaky barriers and measures that encourage floodplain reconnection.	Stage 0 assessments are completed for the catchment to increase the granularity of the in-channel intervention types considered in NFM studio.
Hydrology	Shallow interflow infiltrates to baseflow and there are no losses/recharge into the groundwater system.	Implies assumption that there is no or limited recharge to groundwater aquifers during flood generation, that will apply for most clay-dominated catchments
	Standard hydrographs for chosen return periods are generated using ReFH to provide indicative flood volumes and visualise the impact of NFM across the catchment.	Aligned with standard return periods used in most flood risk management studies
	All measures can be applied simultaneously, and all measures are applied across the whole catchment, in every land parcel	NFMStudio provides a catchment scale assessment of NFM. However, the data provided alongside it can be used for more granular assessments if required
	Volumetric reductions are calculated for each individual land parcel separately and are applied to the hydrograph without considering implications of connectivity between individual fields and watercourses	Implies assumption that most of the catchment will have an influence on flood generation during the event, that will apply for most clay-dominated catchments that are likely to have additional elements of artificial drainage
Natural capital	See Appendix G for further detail	
Outline Costings	For costing flow pathway bunds, the width of a bund is assumed to be the same as the width of the flow pathway, according to the RoFSW layer	Costings have been taken from the <a href="#">National Highways Design Specification</a> document where possible. These are capital costs only and exclude operational costs such as project development, design and management of implementation. For other NFM projects, operational costs are assumed equivalent to capital costs.
	For costing in channel measures, the spacing of leaky barriers is assumed to be 5 time the channel width. The channel widths have been taken from OSMM Water layer. Where channel widths are missing (for smaller watercourses), an assumed width of 3m has been used.	
	Where multiple cost estimates for individual measures have been identified, the upper range of costings has been adopted to provide a conservative costings approach.	

# Appendix B. Datasets used by NFM Studio

The datasets used in the NFM Studio tool are presented in Table 1. Note that the majority of the datasets are implicitly considered in the natural capital metric outputs since the metric uses outputs from the hydrology and opportunity-constraint metric datasets. Therefore, only datasets explicitly applied in deriving that metric are reported in Table 1.

Table 1 - Datasets included in the metrics (hydrology, natural capital and opportunity)

Dataset	Hydrology	Natural Capital	Opportunity	Summary of how the Dataset is Applied
FEH Catchment descriptors	✓			Catchment descriptors are utilised to calculate peak flows and obtain hydrographs with ReFH.
Agricultural Land Classification (ALC)			✓	Land quality and ease of removing land from productive agriculture can be inferred from the grades.
OS Greenspace	✓	✓	✓	Used to exclude greenspaces where NFM interventions are very unlikely to be applied (i.e. golf course, tennis courts, etc.).
BGS 50k, 625k and soil parent material data	✓		✓	Used to derive standard percentage runoffs and soil characteristic in the runoff modelling.
Enhanced Corine Land Cover 2018	✓	✓	✓	Describes land-use / landcover in each metric. The dataset has been enhanced and extended using Priority Habitat Inventory data.
Environment Agency Floodplain Woodland			✓	Catchment with floodplain woodland potential used to target areas of land-use change.
Environment Agency Floodplain Reconnection	✓		✓	Target areas of floodplain reconnection next to the river and increasing volumetric storage attenuation potential.
Soil Characteristics e.g Standard Percentage Run-off (SPR)	✓		✓	SPR provides information about the runoff generation. Interventions can be targeted according to high/low runoff percentages.
Risk of Flooding from Surface Water (RoFSW) 1 in 1000 years and 1 in 100 years	✓		✓	Areas at risk from flooding used to target NFM intervention types, and also to identify flow pathways for volumetric calculations.
Runoff Attenuation			✓	Areas with runoff used to target NFM intervention types.
Manmade Features in the Floodplain			✓	Areas around manmade features are less suitable for NFM interventions as may increase local flood risk.
Countryside Services Stewardship			✓	Countryside Stewardship areas may infer that the landowner is likely to be receptive to and capable of implementing NFM interventions depending on the prescriptions being applied.
Environmental Services Stewardship			✓	Environmental Stewardship areas may infer that the landowner is likely to be receptive to and capable of implementing NFM interventions depending on the prescriptions being applied.
Conservations sites (i.e. SSI, LNR, SAC, SPA, PHI, etc.)		✓	✓	These datasets identify the conservation sites and how they influence the likelihood of interventions being implemented. They are also flagged up in the natural capital metric to steer intervention types.
Scheduled Monuments		✓	✓	Dataset that indicates where the monuments in the catchment are and how they constrain intervention delivery.
Historic Landfill and Waste sites		✓	✓	Dataset that indicates where the waste management issues in the catchment are and how they constrain intervention delivery.
Source Protected Zones (SPZ)		✓	✓	SPZ 1 (not 1c) are used to identify potential constraints to NFM intervention delivery.
Flood Zone 3	✓	✓	✓	Used to differentiate between flow pathway and in-channel intervention types in the assessments.
OS MasterMap	✓	✓	✓	Used to divide up and summarise the metric outputs into land parcels (denoted as fields in this report).
Terrain 50 – Slope	✓			The slope is calculated with terrain 50 data and utilised in the Infiltration and flow pathways calculations.
Standard Annual Average Rainfall (SAAR)	✓			SAAR data identifies the variability of rainfall across the catchment and is used to develop spatially variable rainfall statistics in the hydrology metric outputs.
Nitrate Vulnerable Zones and Environment Agency Aquifer Designations		✓		Used to identify potential constraints to NFM intervention delivery in the natural capital metric.
Defra (2021). Air quality appraisal: damage cost guidance		✓		Air quality monetisation
BEIS (2021). Valuation of greenhouse gas emissions: for policy appraisal and evaluation		✓		GHG emission and C sequestration monetisation
National Water Environment Benefits Survey		✓		Channel intervention monetisation
Woodland Trust by Europe Economics 2017 report		✓		Raw materials monetisation
Christie, M. et al (2011): Economic Valuation of the Benefits of Ecosystem Services (BAP)		✓		Biodiversity value monetisation

Dataset	Hydrology	Natural Capital	Opportunity	Summary of how the Dataset is Applied
Woodward and Wui (2001) Water flood control and storm buffering value of wetlands		✓		Flood risk management value monetisation
Hanley & Craig (1991). Wilderness development decisions and the Krutilla-Fisher model: the case of Scotland's flow country. Ecol Econ 4, 145-164		✓		Recreational value monetisation (peatland)
ONS UK natural capital accounts: 2019		✓		Groundwater resources monetisation Recreational value monetisation
Agriculture in the UK 2020		✓		Food production value monetisation
iCASP (2019). A user guide for valuing the benefits of peatland restoration		✓		Peatland restoration carbon sequestration estimation
Farmscoper: ADAS		✓		Estimate impacts of scenarios on reduction of diffuse pollution (water quality, air quality, greenhouse gas (GHG) emissions)
ONS (2021). GDP Deflators		✓		Adjustment of historic monetary values to reference year (2020).

## C.2. Validating volume estimates

### C.2.1.1. Introduction

Estimates of the volume of flood water stored by NFM measures were validated for three measure types (as presented below). This was done to double check outputs from the NatureBid platform that, in the opinion of our flood specialists, appeared potentially conservative.

Whilst the alternative methods used to check these volume estimates generated slightly higher volumes than the originals, the revisions did not materially change the outcome of the assessment. They confirmed the original estimates to be sensible but conservative.

The updated estimates were used in the analysis presented in this report.

### C.2.1.2. Cross-slope Woodland & Vegetation (LM01.2) and Vegetated Buffer Strips (LM01.1)

The volumes of water stored by the cross-slope woodland and buffer strip measures took values from Atkins' NFM Studio modelling tool, we were aware that this was potentially under valuing the water stored by these measures as it only considers the runoff reduction and increase to infiltration over the footprint of the measure and has no consideration of the impact to intercepting overland flows. Additional analysis was undertaken to assess the contributing area the cross-slope woodland and buffer strips are likely intercepting overland flows for. This geospatial analysis was undertaken by using the SciMap and lidar data alongside the OSMM to delineate the upslope catchment of the woodland and buffer strip measures. The following principles were applied in delineating the upslope area:

- The area extended upslope until a near-by ridge or topographic divide was reached
- Or, until the area extended to the next woodland feature upslope
- Or, until the area extended to the length of the upslope field. The maximum the impacting area could be the entirety of the field the measure sat within, as it was assumed the upslope field boundary would be intercepting the upslope runoff.

Once the extended areas for the cross-slope woodland and buffer strips were calculated, a sensitivity analysis was undertaken to calculate the best estimation of the runoff intercepted. Firstly, the NFM Studio storage volumes were scaled to the updated areas as this would be a consistent methodology and consider the ability for the soils to infiltrate the runoff volumes. Secondly, the total runoff from the 1 in 2 ReFH2 hydrographs for the donor catchments in the Don and Irwell were scaled to the adjusted areas of the measures. Using the ReFH2 runoff values was chosen as the preferred method as it most accurately calculates the likely runoff volumes to be generated from the areas upslope of the measures. A factor of 25% was then assumed to be the storage impact of the measures, this is based off expert judgement and average calculations of storage per m of cross-slope woodland.

### C.2.1.3. In channel leaky barriers (WC01.1)

Similar to the cross-slope woodland and buffer strip measures, the conservative modelling approach for the in-channel leaky barrier measure type results in the volumetric storage being undervalued. Following a literature review and comparison with other NFM studies a factor of 7.5 was applied to the In channel leaky barrier storage volumes to increase the modelled storage volumes to be consistent with other studies. However, the storage volumes of this measure type remain low in comparison to the other measures in the pilot as the primary function of this measure is to attenuate flows rather than store them.

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