Payment by Results

Manual for implementation in the Skell Valley, North Yorkshire

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Chapter 1: Introduction to the Payments by Results Manual

1.1 Executive summary

This manual for the implementation of a nature-based solutions (NBS) payment by results (PbR) scheme is designed to be used in consultation between a landholder and an advisor/ranger. The ideal outcome is a co-developed and agreed costed plan for capital interventions and changes in land management approaches that will be to the benefit of the local catchment, supporting sustainable farm enterprises, as well as positive downstream impacts, over many subsequent years. Every drainage catchment is different, and the interplay of a range of factors need to be considered, including the relative importance of reducing flooding, improving ecosystems, and modifying sedimentation and erosion patterns. Therefore, this NBS PbR manual should be treated as a framework to establish a realistic incentivized plan, with the ability to change monetary values by catchment and by farm. Importantly, although the manual was designed primarily for flood and sediment mitigation interventions, the framework is portable, and readily adaptable to a wider range of NBS.

In practice, PbR frameworks are challenging to develop and implement – they need to be simple enough to be accessible and put into practice on the ground, yet comprehensive enough to account for the complexity of natural systems, the range of interventions, the variability of land use practices, and the restrictions of different funding schemes. An important distinction throughout this manual is the differentiations of payments for short-term capital interventions that might have rapid impacts (a few years), and land management changes where the benefits might be realised over the long-term (decadal). This distinction is practical although not without limitations. Furthermore, the real costs of unlocking NBS investments in a catchment are not completely captured by the numbers generated through using this manual, because an essential component to the successful delivery of these schemes are well-trained farm advisors and park rangers; these costs are not included here.

Despite these non-trivial considerations, an idealised workflow is proposed for the development of NBS PbR schemes (Fig. 1.1). Distinctively, the workflow does not only consider the NBS intervention types and changes in land management practices, but also the types, technological expertise, return period, and type and duration of monitoring, both before and during the lifespan of different interventions. This is a crucial inclusion to the PbR manual as it is a means of demonstrating the environmental benefits of the NBS installations and changes in practices. That interventions are making a positive difference, even if quantification proves difficult, is important in permitting the staged release of payments to landowners over different timescales, and in demonstrating the added value of the NBS to the wider catchment. A baseline might not be possible due to financial and time constraints. However, surveying the landscape prior to installation of infrastructure is a strongly recommended step of the NBS PbR workflow to establish the stacked direct (e.g., reduced flood peak, reduced sedimentation) and indirect (e.g., biodiversity, carbon sequestration) benefits at farm- and catchment-scale. Nonetheless, linking farm-scale NBS interventions to catchment-scale changes in flooding and sediment load is very challenging to demonstrate quantitatively. This might be possible through long-term monitoring before and after installation.

1.2 A message to the landholder

Firstly, many thanks for collaborating with your farm advisor/ranger, and for investigating whether the development of a Payments by Results (PbR) scheme works for you and your land. These frameworks are an essential component for collective environmental improvements in the way our river catchments function over many years.

You know how your land functions, and the local weather and geographic conditions, better than anyone. Nonetheless, there will be opportunities to benefit from the upsurge in the development of many natural flood management installation types, and nature-based solutions, which are mutually beneficial to you, and to the users and inhabitants of the wider catchment.

A major motivation to engage in PbR schemes is financial. These schemes are underpinned by economic incentives to install and maintain interventions and to trial new land management practices. There are multipliers to these schemes that are hard to quantify. Nonetheless, NBS can help reduce the use of fertilizer, reduce soil loss, improve river and floodplain habitats, and maintain and increase productive land through better drainage and less erosion.

1.3 Payments by Results in the Skell

This work has been developed as part of a large-scale conservation project based around the River Skell, which rises in the high moorland of Nidderdale National Landscape and flows eastwards, passing the World Heritage Site at Fountains Abbey and Studley Royal, to the city of Ripon. The Skell River catchment is characterised by a rapid response in river level to precipitation events (i.e., it is classed as a flashy catchment), with high sediment content indicating a large amount of surface run off and erosion, commonly linked to areas of steep slopes. There are also several natural water and sediment stores through the catchment. The emphasis of the Skell Valley Project was on reducing river levels and sediment load during flood periods at a catchment scale – through Fountains Abbey and Studley Royal, as well as in the city of Ripon. This informed the relative importance of benefits arising from the PbR scheme, although this can be readily modified.

A similar physiography and issues are shared by many of the land holdings in the catchment, which were used to underpin opportunity maps with landholders. Nonetheless, at a farm-scale there are important differences. For example, aspect, topography, land use, and connectivity to the River Skell, which meant each farm required separate assessment, and ground truthing proved essential.

1.4 Who is the manual for?

The manual has been developed for an experienced farm advisor or park ranger to work in close collaboration with a landholder to develop a costed installation plan that will benefit the farm, the land, and the catchment. The PbR plan for a farm or land holding should be developed in the presence of the landowner using a tablet/laptop; it should not be used as a 'black box'.

Therefore, some knowledge of natural flood management, and nature-based solutions, is required, as well as a good understanding of the characteristics, and environmental issues, of the wider drainage catchment under consideration. Few individuals will have the collective breadth and depth of experience and expertise to use the manual confidently from the start, and some upskilling might be needed. To help this, there are comprehensive appendices, and links to documents, that detail the types and benefits of NBS interventions, the key sources of information that underpin valuations presented here, and the key stages of development in the PbR plan.

1.5 Manual structure and how to use

The structure of this Payment by Results manual maps onto the steps that an advisor or ranger will take in consultation with a farmer/landowner. **Chapter 2** covers the wide range of different NFM interventions and land management practices open to a typical landowner. This is comprehensive, although no doubt new ideas and techniques will need to be added with time. **Chapter 3** covers the assessment phase prior to any interventions. This covers the desk-based assessment of the catchment as a whole, and individual land holdings. This is followed by an essential ground-truthing assessment of ground conditions. These together, and in consultation with the landholder, will lead to opportunity mapping. We recommend both 'landowner approved' and 'aspirational' maps be developed that reflect a minimum and ideal level of intervention, and that through time a landowner might upgrade their NBS towards the aspirational level as the multiple benefits to their land and their farm business finances are realised. The final step here is to assign responsibilities for installation, maintenance, and monitoring of the different interventions. **Chapter 4** covers the calculation of NFM payments. These will be tied to a particular scheme, and the costs will change through time. Therefore, specific costs/payments are not included in this manual. Chapter 4 is a key step in using the manual, when ideally working with the landholder, the farm advisor/ranger develops appropriate and agreed PbR scenarios. This requires using spreadsheets (Appendices C, D, and E). It is strongly recommended that files these are saved under different filenames before editing begins. **Chapter 5** addresses the crucial aspect of monitoring, which is becoming part of many funding schemes, but the expectations of what technology, and who does the monitoring, is rarely outlined or costed clearly. Here, we link different monitoring approaches to the different interventions, and within that we identify three tiers (user types: landholder, advisor/ranger, expert) of monitoring expertise that cover different expectations and timescales.

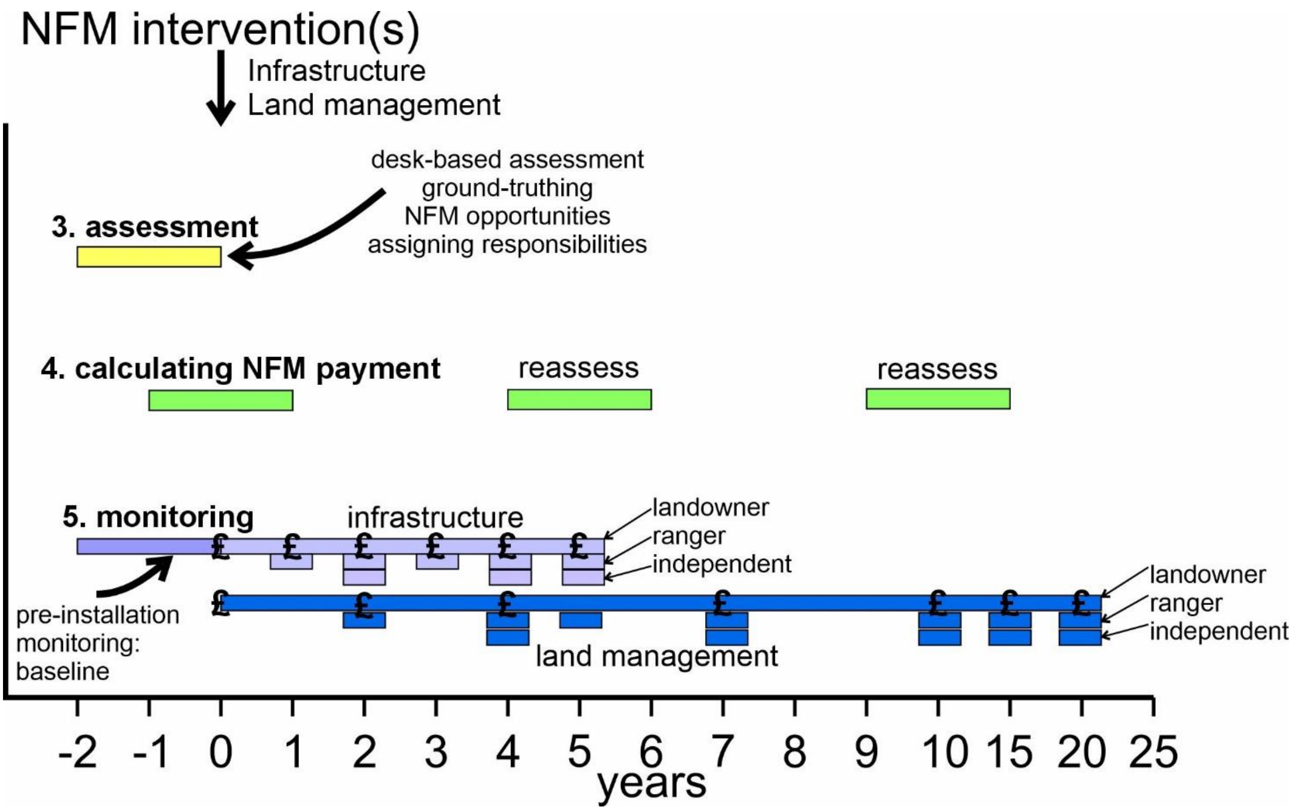

Figure 1.1: Recommended Payment by Results workflow, before and during NFM/NBS interventions. '£' is an indicative timing of landowner payments, although this will vary by scheme.

Chapter 2: An overview of Nature-based solutions

Chapter 2 provides a broad overview of nature-based solutions (NBS), including definitions (2.1), how they contribute to reducing flood risk and sediment erosion (2.2), the different types of NBS used in flood and sediment management (Table 2-1) and general NBS resources (2.3).

2.1 What are nature-based solutions (NBS)?

Nature-based solutions use natural environmental processes to address environmental and societal challenges, including climate adaptation, water management, disaster risk reduction, biodiversity conservation, and urban resilience. There are many different types of NBS, but all work to maintain and improve ecosystem resilience while providing multiple co-benefits (ecosystem services) including reduced sediment erosion, and increased biodiversity, carbon sequestration, improved water quality, habitat creation, and health and social wellbeing.

Subsets of NBS include:

- **Flood Risk Reduction**: e.g., Wetland restoration, Natural Flood Management (NFM), and river re-meandering to store and slow water.
- **Coastal Protection**: e.g., Mangrove forests, salt marshes, and dune restoration to act as natural barriers against storm surges.
- **Urban Resilience**: e.g., green roofs, permeable surfaces, and urban forests to manage stormwater and reduce heat island effects.
- **Water Quality and Supply**: e.g., Riparian buffer zones and constructed wetlands for filtration and groundwater recharge.
- **Climate Change Mitigation**: e.g., Reforestation and peatland restoration for carbon sequestration.

2.2 How does NBS contribute to reducing flood risk and sediment erosion?

As climate change increases extreme weather and flooding, understanding runoff (water flow) generation is crucial for effective flood and sediment management.

Between 2000 and 2019, floods caused 44% of global disasters, impacting 1.6 billion people and costing US$651 billion[1]. Individual events can be especially catastrophic and, in the UK, storms in 2015-16 caused £1.6 billion in damage, prompting significant investment in flood defenses[2]. Flood management strategies fall into two categories: Traditional Flood Management (TFM) and Natural Flood Management (NFM). TFM relies on hard engineering solutions like dams and barriers, which are effective but costly and sometimes environmentally damaging. NFM, in contrast, is a subset of NBS which uses natural processes to mitigate flood risk by slowing, storing and redirecting water within a catchment; its primary goal is to reduce flood peaks and volumes. As a subset of NBS, NFM is recognised to provide additional ecosystem services. NFM is a sustainable and cost-effective strategy which is generally seen as a complement to TFM rather than a replacement.

The success of NFM depends on three key factors:

1. Water storage – Determined by soil depth and geology but can be increased with NFM measures like tree planting and retention ponds.
2. Water transfer – Influenced by soil permeability and surface roughness, which affect how quickly water moves through a landscape. Intensive grazing, for example, can compact soil, reducing absorption and increasing surface runoff.
3. Location – Placing NFM in key areas where water can be effectively stored or slowed enhances flood mitigation.

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[1] Human cost of disasters: an overview of the last 20 years 2000-2019.Centre for research on the epidemiology of disasters & UN office for disaster risk reduction; 2020.
[2] Estimating the economic costs of the 2015 to 2016 winter floods. Bristol: Environment Agency; 2018.

NBS (including NFM) initiatives can also be used to reduce soil/sediment erosion and limit the amount of sediment reaching water courses where it can impact river function. Soils are an important natural resource which underlie many essential services, including delivering 95% of global food supplies[3]. Soil is an essential carbon store; for example, UK soils store ~10 billion tonnes of carbon which equals ~80 years of annual UK greenhouse gas emissions. Despite their value, in England and Wales alone, ~4million hectares are at risk of compaction and ~2million hectares at risk of soil erosion. Intensive agriculture has led to a 40-60% loss of organic carbon in arable soils, and in 2010, soil degradation was calculated to cost ~£1.2 billion per year.

Sediment erosion is driven largely by water runoff. Therefore, NBS works to mitigate erosion through soil stabilization, 'slowing the flow' of water downslope, and trapping sediment before it reaches water bodies. Existing catchment conditions (i.e., antecedent conditions), such as soil saturation, also impact NBS effectiveness for flood and soil erosion mitigation.

The UK Government's 25-year Environment Plan sets out aims to reduce sediment erosion and flood risk using NBS[4]. A combination of nature-based strategies—enhancing storage, improving soil permeability, and increasing surface roughness—is ideal for reducing sediment transfer, and flood peaks and volumes. Table 2-1 lists NBS interventions relevant to the Skell Valley, where flood mitigation (i.e., NFM) and reduction of sediment erosion are the primary aims, alongside photographs and descriptions.

Table 2-1: Types of NBS Interventions

Type of NBS Intervention	Image	Description
Blocking Drainage Grips	  *Credit: Yorkshire Peat Partnership*	Blocking drainage grips entails installing barriers in artificially dug ditches (grips) in moorland or peatland areas to keep water from draining too quickly. This helps to rewet the landscape and minimizes the likelihood of downstream flooding.

[3] The state of the environment: soil. Environment Agency; 2023
[4] A Green Future: Our 25 Year Plan to Improve the Environment. Defra; 2018

Bunds, Swales, and Scrapes	  *Credit: WWT*	Bunds are raised embankments, swales are shallow channels, and scrapes are shallow depressions used to slow down water flow, store excess water, and promote infiltration after heavy rain.
Creating and Managing Buffer Strips	 	Buffer strips are vegetated regions along waterways that trap sediments and pollutants, decrease surface runoff, and increase infiltration, lowering flood risk and improving water quality.
Cross Drains in Farm Tracks		Cross drains are constructed in agricultural tracks to redirect runoff water onto surrounding fields, minimising erosion and the amount of water reaching rivers after heavy rains.
Increasing Soil Permeability / Water Holding Capacity		Improving soil structure by improving permeability allows for more water to be absorbed and stored in the soil, reducing runoff and lowering flood danger. Deep tilling and the use of organic materials are two strategies that can help achieve this.

Leaky Woody Dams		Leaky woody dams are built by placing branches and logs in streams to slow down water flow and temporarily store it. This helps to lower peak downstream flows during storm occurrences.
Livestock Management / Reducing Stock		Managing the number of livestock and their movement can prevent overgrazing and soil compaction, which can lead to increased runoff. Reducing stock density helps improve soil structure and water retention in the landscape.
Mob Grazing		Managing livestock numbers and movement can help to avoid overgrazing and soil compaction, both of which can lead to increased runoff. Reducing stock density enhances soil structure and water retention in the landscape.
Planting and Managing Hedgerows	  Credit: Yorkshire Dales National Park Authority	Hedgerows operate as natural barriers, slowing surface water flow and increasing infiltration. Managing and planting hedgerows in strategic locations reduces runoff and offers habitat for wildlife.
Planting and Managing Trees		Trees intercept rainwater and increase its infiltration into the soil. Planting and managing trees, particularly in upland areas or floodplains, reduces runoff volume and so lowers the danger of floods.

Restoring Meanders		River restoration efforts sometimes involve reintroducing natural meanders into straightened rivers to slow down water flow and enhance storage capacity, hence lessening the speed and intensity of downstream flooding.
Sediment Traps	  *Credit: WWT*	Sediment traps are intended to collect sediment from flowing water, keeping it from entering watercourses and lowering the risk of flooding caused by silt buildup. One type of recommended sediment trap in the Skell valley is brush matting – bundles of small twigs/sticks tied together and placed in a small stream/hillslope runoff channel to intercept all flow. This differs from a leaky debris dam which allows low flow to pass unhindered.
Storage Ponds		Storage ponds are designed to hold extra water during heavy rains, lowering the risk of flooding downstream. These ponds steadily release water over time, creating homes for aquatic life.
Winter Cover Crops	  *Credit: Natural England*	Cover crops are planted during winter to protect soil from erosion, improve soil structure, and enhance its ability to absorb water. This reduces surface runoff and the risk of floods during wet seasons.

Regenerative Agriculture	 *Credit: Fix our Food*	Regenerative agriculture includes practices like crop rotation, reduced tillage, and planting cover crops to improve soil health and enhances its water absorption capacity, reducing runoff and minimizing flooding risks.

2.3 Summary and general NBS resources

NBS provide effective ways to reduce flood and sediment erosion risk while offering environmental benefits such as improved biodiversity, soil health, and carbon sequestration. By working with natural processes and landscapes, NBS interventions can enhance the resilience of landscapes to extreme weather events and contribute to sustainable water management strategies.

The resources listed below provide additional general reading on NBS for flood and sediment erosion mitigation:

- A green future: our 25-year plan to improve the environment. Department for Environment, Fisheries and Rural Affairs, UK Government; 2018.
- Catchment Based Approach website
- International Guidelines on Natural and Nature-Based Features for Flood Risk Management. Bridges, T. S., … R. K. Mohan, eds. 2021.
- Natural Flood Management Design Specification Catalogue. Highways England, Mersey River Trust, Don Catchment Rivers Trust; 2021.
- *Natural Flood Management Handbook*. Scottish Environmental Protection Agency; 2015
- Natural Flood Management Measures – a practical guide for farmers. Yorkshire Dales National Park; 2017
- Natural Flood Management Measures Booklet. Highways England, Mersey River Trust, Don Catchment Rivers Trust; 2021.
- The state of the soil. Department for Environment, Fisheries and Rural Affairs, UK Government; 2023.
- Working with natural processes to reduce flood risk. Burgess-Gamble, L., …Quinn, P; 2017.

  Working with natural processes: Evidence directory update. Pearson, E., …Rose, S; 2025

Chapter 3: Assessing land holdings for NBS opportunities

Chapter 3 presents a workflow designed for assessing flood and sediment erosion mitigation opportunities in the Skell Valley, but it can be applied across multiple catchment types suitable for Nature-based solutions (NBS). The general method is restricted by the availability of data and tools used in desk-based assessment of catchment characteristics; all data for desk-based assessment is openly available for the Skell Valley catchment. Throughout, the term 'landholder' is used to interchangeably describe the owner or occupier (tenant farmer) of the land. Figure 3-1 summarises the NBS assessment process.

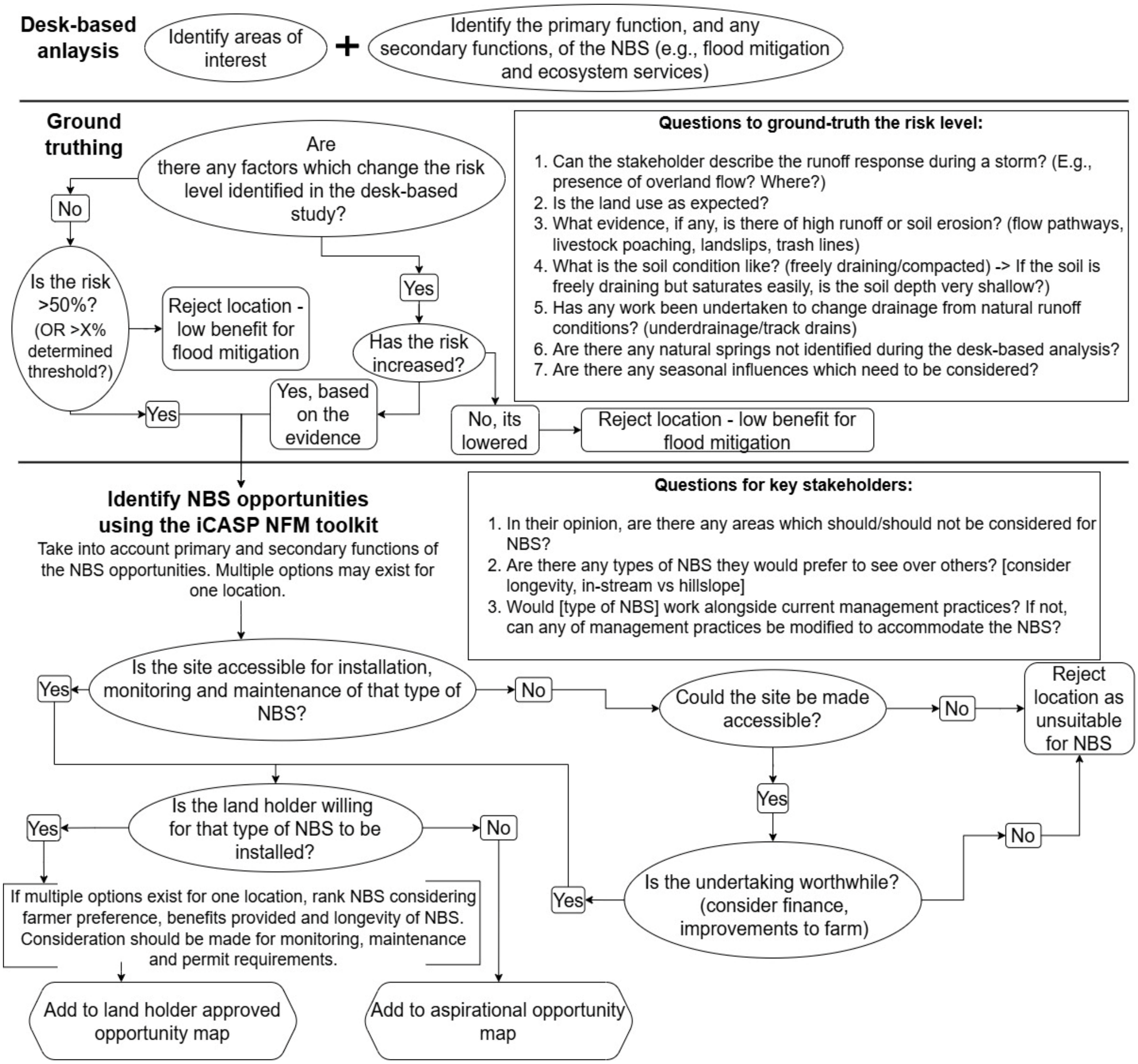

Figure 3-1: Flowchart: Ground truthing NBS opportunities.

The workflow described below has five key elements (links within the manual):

Pre-assessment considerations → Desk-based assessment → Ground-truthing → Assigning responsibilities → NFM opportunities

3.1 Pre-assessment considerations

Prior to any assessment of specific NBS opportunities, key stakeholders should be identified alongside their interest in hosting NBS and restrictions which may inhibit installation. The primary stakeholder groups of interest are: 1) those funding NBS installation, monitoring, and maintenance; 2) organisations who provide permits and/or approval for the work to be undertaken; 3) the landholder on whose land the NBS will be installed; 4) the person, group(s) or organisation(s) responsible for installation, monitoring, maintenance, and evaluation of the NBS installed, and 5) the communities who would benefit from improved flood management. One group may encompass multiple, or all, of the above roles.

Each stakeholder group may be involved in assessing NBS opportunities at different times in the assessment process. This is dependent on limiting factors for NBS installation. For example, funding or permit requirements may restrict the type of NBS which can be installed, such as for installation in locations with environmental or historical designations (e.g., within Fountains Abbey and Studley Park, a World Heritage Site), and without landowner consent NBS cannot be installed. Therefore, prior to assessing a site for NBS opportunities, plausibility for installation and interest for hosting NBS in that catchment must be established. The following questions should be considered (Table 3-1):

Table 3-1: Questions to consider prior to site assessment.

TOPIC	QUESTIONS
REASON FOR NBS ASSESSMENT	1. Why are NBS being considered in this catchment? 2. What is the primary function of the NBS for the catchment? 3. Are there any secondary functions which need to be accounted for? (e.g., enhanced biodiversity, sediment erosion reduction, carbon sequestration, water quality, and drought mitigation) 4. Is there any historical precedence (e.g., storm damage, flood extent, previous NBS schemes) or ongoing NBS schemes in the catchment – or in similar/neighbouring catchments - from which learning can be applied?
STAKE-HOLDERS	5. Who are the key stakeholders? 6. Will the project offer any incentives for joining? 7. Are landholders willing for their property to be assessed for NBS opportunities? 8. Are there any initial conditions to NBS installation which the assessors should be aware of?
FUNDING	9. Has funding been procured? a. If yes, how much is allocated to NBS installation vs maintenance and monitoring? And is there a time restriction on spend? b. If not, which sources are being considered? 10. Does the funding source have associated restrictions or conditions? This may include the type of NBS able to be installed, the organisation(s) who can receive that funding, a time restriction on spend, and the activities which can be funded (e.g., installation vs monitoring and maintenance).

PERMITS	11. Are there any permits which may be required to install and/or maintain NBS in this catchment? Consider: a. Environment protection designations b. Heritage assets, or sites of archaeological interest c. Road or amenity closures for site access d. UK Government | Environmental permits

Once landowners and any associated tenants have been identified, initial contact should be made regarding NBS and potential for site assessment. Preliminary discussions should include reasons why NBS should be considered in the catchment, and gauge interest for the project and any initial concerns or conditions for their involvement. Early engagement is invaluable as it enables local knowledge, site-specific requirements, and management considerations and opportunities to be discussed and incorporated into planning during site assessment; these have been expanded upon in section 3.2.3.

3.2 Desk-based assessment

Following establishment of the locations to be considered for NBS, a desk-based analysis of catchment characteristics should be undertaken to identify areas of interest and establish factors which may influence NBS suitability. Areas of interest primarily include locations at greatest risk of flooding and the flow pathways in which NBS might be placed to mitigate that risk. Ideally, desk-based analysis should also consider locations with potential for improved ecosystem services (see section 3.2.3).

Due to data limitations, including 'no data zones', poor resolution, limited timeseries, and availability from weather 'extreme' years only (e.g., drought), desk-based considerations may be restricted or generalised over a large area (i.e., not farm-specific). Ground-truthing (section 3.3) may be used reduce knowledge gaps where data is limited; ideally, both desk-based assessment and ground truthing will contribute to NBS assessment.

3.2.1 Physical catchment characteristics

Physical characteristics which can be broadly assessed prior to site visitation include geology, soil type, slope, land use and its management, and climate, including prevailing rainfall direction. Key open-access sources are detailed in Table 3-2. [NB: choose 1-2 relevant sources from each category]

Table 3-2: Key open-access sources used to assess physical catchment characteristics globally.

PHYSICAL CATCHMENT CHARACTERISTICS	SOURCE(S)
GENERAL	➢ MAGIC - Datasets (Natural England, 2020) ➢ Maps @ National Library of Scotland (NLS,2025)
CLIMATE & WEATHER	➢ ArcGIS Atlas of the world: weather and climate (ESRI, 2024e) ➢ National Center for Environmental Information (NOAA, 2024) ➢ Worldwide regional climate projections (Copernicus Climate Change Service and Climate Data Store, 2021) ➢ World Meteorological Organization (2024)
GEOLOGY	➢ Macrostat (Macrostrat, 2024, Peters et al., 2018) ➢ ArcGIS Atlas of the world: soils and geology [search by region=United Kingdom] (ESRI, 2024d) ➢ British Geological Society (BGS, 2024b)
HYDROLOGY	➢ UK National River Flow Archive (2024) ➢ European flood awareness system (Copernicus Climate Change Service, 2019) ➢ Aquastat (FAO, 2024) ➢ Global Runoff Data Centre (GRDC, 2024) ➢ Catchment Data Explorer [England only] (DEFRA, 2024)

LAND USE AND ITS MANAGEMENT	➢ WorldCover satellite observation land cover maps (Zanaga et al., 2022) ➢ Dynamic world (Brown et al., 2022) ➢ ESRI land cover explorer (ESRI & Impact Observatory, 2024) ➢ ArcGIS Atlas of the world: land cover (ESRI, 2024b) ➢ Copernicus global land cover viewer (Buchhorn et al., 2020)
SLOPE & ELEVATION	➢ ArcGIS Atlas of the world [search: slope/elevation]: (ESRI, 2024c, ESRI, 2024a) ➢ NASA Shuttle Radar Topographic Mission (CGIAR-CSI, 2006) ➢ Global 30 arc second elevation data (USGS, 2002)
SOIL TYPE	➢ FAO soils portal (2024) ➢ ISRIC-World soil information (2024) ➢ LandIS soilscapes UK (Cranfield University, 2024, Hallett et al., 2017)

3.2.2 SCIMAP assessment of risk factors

Using catchment characteristics, risk factors can be assessed. We recommend use of SCIMAP, an open-source model which enables identification of relative risk (% risk) for diffuse pollution, sediment erosion and overland flow. iCASP have previously published a non-technical method on SCIMAP for Nidderdale Area of Outstanding Natural Beauty which can be found in Appendix A.

3.2.3 Desk-based assessment of ecosystem services

In addition to flood risk management, the potential for ecosystem services should be assessed. Different NBS types are known to enhance biodiversity, promote carbon sequestration, improve water quality, reduce sediment erosion, and/or aid soil health. Stakeholders may have identified ecosystem services of importance in the chosen catchment; where possible, the NBS feature chosen should work towards increased ecosystem services in addition to providing flood mitigation. Ecosystem service requirement may be broadly assessed using the key open-access sources detailed in Table 3-3. [NB: choose 1-2 relevant sources from each category]

Table 3-3: Key open-access sources used to assess ecosystem services in the UK

ECOSYSTEM SERVICE PROVISION	SOURCE(S)
BIODIVERSITY/HABITAT CREATION POTENTIAL	➢ Global Biodiversity Information Facility (2024) ➢ UKCEH-Environmental Information Data Centre (EIDC, 2024)
CARBON SEQUESTRATION	➢ Climate Watch greenhouse gas emissions (Climate Watch, 2024a) ➢ Climate Watch net zero tracker (Climate Watch, 2024b, Levin et al., 2020) ➢ Forest greenhouse gas net flux (Global Forest Watch, 2024, Harris et al., 2021) ➢ Global soil organic carbon sequestration potential map (FAO GloSIS, 2022)
SEDIMENT EROSION, SOIL LOSS AND LANDSLIP RISK	➢ SCIMAP (Reaney, 2022, SCIMAP, 2024) ➢ Global soil erosion (Borrelli et al., 2017, ESDAC, 2019) ➢ Global Landslide Hazard Map (World Bank & Global Facility for Disaster Reduction and Recovery, 2023)

	➢ National Landslide database [Great Britain only] (BGS, 2024a) ➢ UK Soil Observatory (UKRI, 2025)
WATER QUALITY	➢ Global Freshwater Quality Database (GEMStat, 2024) ➢ European Water Framework Directive – Quality Elements map (European Environment Agency, 2024) ➢ Catchment Data Explorer [England only] (DEFRA, 2024) ➢ Water quality data archive [England only] (DEFRA, 2025)
WATER STRESS (DROUGHT MITIGATION NEED)	➢ Aqueduct water risk atlas (Aqueduct, 2024)
NATURAL CAPITAL	➢ Access to Evidence-Ecosystem Services (Natural England, 2025) ➢ Enabling s Natural Capital Approach (DEFRA, 2020)

3.3 Ways and methods for ground truthing

3.3.1 What is ground truthing and why use it?

There are two key limitations to desk-based assessment: 1) GIS-based methods - including SCIMAP - are simplified models based on a limited set of equations which reduce the complexity of catchment ecology-hydrology interactions, and 2) the quality of data, which influences the detail of desk-based assessment made. Data limitations may include zones with limited or no data, poor data resolution, or data only from years in which weather extremes (e.g., drought) were experienced. Therefore, ground-truthing is essential to optimise the location of NBS by confirming on-site suitability and accounting for location-based (section 3.3.2) and management-based (section 0) considerations.

Ground truthing is the practice of verifying information through direct observation or measurement. There are five primary reasons to undertake ground truthing: 1) to account for local heterogeneity in catchment characteristics; 2) to ensure the desk-based assessment is accurate; 3) to assess for features or characteristics (e.g., field drains) which are not visible using desk-based assessment; 4) to gauge practicality of NBS installation which accounts for site accessibility and suitability with current land use practices; and 5) to build relationships with the stakeholders for improved communication and understanding of project needs. Prior to NBS installation, ground-truthing may be used to baseline conditions at the farm and catchment scale.

3.3.2 Location-based considerations

When ground truthing, the primary objective is to establish whether the risk identified during desk-based analysis is reflected by on-the-ground evidence. There are six key questions (Figure 3-1; Table 3-4), which may be asked to estimate location-based risk and aid decision-making, alongside the desk-based analysis. Change in risk is determined by the site assessor using the resources available to them (desk-based analysis and ground truthing). Where risk has changed from the desk-based results due to presence or absence of risk-changing features, the site assessor should make judgement, based on the available evidence, on whether the site in question should be considered as an area of interest for NBS.

Evidence for risk may be obtained via a variety of methods (section 3.3.5) and sources, including from site visits, discussions with key stakeholders who know the catchment well, or via remote means. All evidence should be provided with reference to location, either by marking it on a map, through geo-tagging or provision of grid references, or using open-access software such as what3words (2024).

Table 3-4: Questions to consider during ground-truthing and their associated indicators of high/increased risk.

QUESTION	CONSIDERATIONS	INDICATIONS OF HIGH/INCREASED RISK
1. **CAN STAKEHOLDERS DESCRIBE THE RUNOFF RESPONSE DURING A STORM?**	Does overland flow occur? Where? Does land remain waterlogged for long periods?	Frequent presence of overland flow; Land remains boggy for long periods following a storm event
2. **IS THE LAND COVER/USE AS EXPECTED?**	Are conditions on the day 'usual'? Livestock grazing density; Crop type & rotation; vegetation type	High grazing density (short, cropped grassland); Bare soil; no use of cover crops; close-cropped vegetation
3. **WHAT EVIDENCE IS THERE OF HIGH RUNOFF OR SOIL EROSION?**	Locations of high traffic (vehicles/livestock or human activity)	Soil erosion; incised runoff pathways; landslips; trash lines (high water marks from previous flood events)
4. **WHAT IS THE SOIL CONDITION LIKE?**	Surface and subsurface levels. Use Visual Evaluation of Soil Structure (VESS) method (e.g., AHDB (2024)). Compare to Q1 and Q3.	Surface: poaching; pooling of water; bare soil Subsurface: compaction; close-knit texture; clay soil; shallow freely draining soil underlain by impermeable geology or clay.
5. **HAS ANY WORK BEEN UNDERTAKEN TO CHANGE DRAINAGE FROM NATURAL RUNOFF CONDITIONS?**	Ask landholder if subsurface drains are in place and, if yes, where. Records of drains are often scarce. Track drains; subsurface drains (look for characteristic 'dip' indicating presence of drain)	
6. **ARE THERE ANY WATER SOURCES WHICH HAVE NOT BEEN IDENTIFIED IN THE DESK-BASED ANALYSIS? (IF SOURCES HAVE BEEN IDENTIFIED, ARE THEY PRESENT?)**	Locations of natural springs Locations of high traffic (vehicles/livestock or human activity) Man-made sources (leaky pipes etc)	Bare soil and/or sparse vegetation downslope of the spring Visible presence of soil erosion

3.3.3 Management-based considerations

In addition to location-based considerations, current land-management practice must be accounted for to ensure NBS opportunities identified are practical and promote sustainable, long-term investment in improving catchment flood resilience. The following questions should be considered:

1. Are there any areas which should or should not specifically be considered for NBS?
2. Are there any types of NBS which the key stakeholders would prefer to see over others?
3. Would the proposed NBS work alongside current farming and/or land management practices?
    a. If not, is the landholder willing to modify current practice? For example, implement cover crops, vary livestock access points.

Communication with the landholder, on whose land the NBS will be placed, is essential to understanding how current and future land management may influence the chosen NBS. Introductory or additional meetings may be required to ensure the stakeholder(s) involved have knowledge of what NBS is, and what types of NBS might be used and why. Working with a trusted farm advisor can aid this process, promoting confidence in decision making and ensuring practical conversations regarding NBS suitability where farms have multiple land use needs.

3.3.4 Seasonality

Physical catchment characteristics and land cover management are influenced by seasonality which alters how the catchment responds to storm events. Seasonal influences include vegetation growth and dieback, seasonal vegetation management (e.g., livestock and crop rotations), storm likelihood, and soil conditions. Desk-based assessment may have identified historical 'wet' and 'dry' years which influence flow pathways and volumes. NBS can be used to reduce negative seasonal influences on flood and drought risk. The following should be considered, even if year-round visits to the site are not possible:

Table 3-5: Seasonal considerations for ground truthing NBS opportunities

SEASONAL ATTRIBUTE	DESCRIPTION	ASSESSOR CONSIDERATIONS
SEASONAL VEGETATION GROWTH AND DIEBACK	The density and structure of vegetation 0-5cm from the soil surface influences overland flow velocity (i.e., extent of 'slowing the flow'). In catchments where overland flow is common, NBS with high vegetated surface roughness may be chosen to intercept flow pathways. Vegetation also intercepts rainfall and can store water on its surface (e.g., leaves and branches) which reduces the volume of water reaching the ground. In winter, many vegetation types are less dense than in summer. Generally, moss, which is present all year round, has the greatest ability to 'slow the flow' followed by tussocky vegetation, then woodland, 'light' grassland including hay meadows, and bare soil. Woodland especially has varying understorey vegetation presence and density, and species composition within grassland will influence its ability to 'slow the flow'. Shade is an important influence which can reduce understorey growth but also reduce evaporation.	Where and how often does overland flow occur? What is the current vegetation structure like 0-5cm from the soil surface? (individual species are less important for than the overall body of vegetation which intercepts flow) To what extent is the vegetation present subject to seasonal change?

LAND MANAGEMENT: E.G., GRAZING PRESSURE AND MOWING / CUTTING OF VEGETATION	Grazing pressure year-round will influence the height vegetation grows to, and the species composition present in addition to soil properties. Cover crops, and especially winter vegetation cover, reduce soil erosion and help 'slow the flow'. When vegetation is cut the surface roughness decreases and soil can become exposed.	Are there high-risk areas of the land holding which are also subject to land management? Is the land holder willing to change management practices? (e.g., increased crop / grazing rotations; reduced cutting)
STORM SEASONALITY	Storms in the UK vary seasonally, with summers expected to become drier and winters wetter as climate change progresses. Convection rainfall events (intense rainfall from cloudbursts) are more likely to occur in late summer.	Is there historical precedence for flooding at certain times of year?
SOIL CONDITION	Soils are more likely to be saturated (full of water) during winter. Following long dry spells, soils can become hard and impermeable – this is more likely during summer when higher temperatures evaporate water. Flooding is more likely to occur when rain falls on either saturated soil, or hard, less permeable soil.	Clay soils are especially susceptible to seasonal influences

3.3.5 Methods for ground-truthing

Below, we outline four primary methods for ground-truthing which comprise a mix of in-person (method one) and remote (method 4) approaches, with options for data collection by the NBS assessor or trusted stakeholders (methods 2 & 3). A range of methods should be considered, especially where interventions are planned over large or relatively inaccessible areas. For more information on monitoring methods, including baseline monitoring, see Chapter 5.

Method one: Site visits. Visiting the proposed location(s) for NBS enables the assessor to view local conditions and compare on-the-ground features with results from the desk-based analysis via ground truthing (see section 3.2.3). Often, site visits present opportunity to meet with the key stakeholders involved and discuss NBS opportunities and constraints in context of the site (see sections 3.1, 0 and 3.5). During site visits, methods two and three, below, may also be employed to evidence current (baseline) catchment conditions and justify the need for NBS.

Method two: Photographs. Photographic evidence of catchment conditions may be collated, preferably during or shortly following a storm event. Geo-tagged photographs may include evidence of runoff pathways; soil erosion; land cover, including indication of livestock density, high-traffic areas, and current land uses; trash lines showing the high-water mark from flood events; existing NBS; and soil condition if sample pits are made.

Method three: Quantitative data. Data may be collected to measure baseline conditions in strategic areas, evidencing local need for NBS and potential for improved flood mitigation. The data collected should complement desk-based analysis and maximise evidence available, especially if desk-based analysis identified topics for which there is little information regarding catchment characteristics.

The level of evidence collected will depend on the expertise of the data collector and funding, equipment, and time available for data collection. Two areas of interest are soil properties and river discharge. Soil properties may be investigated using VESS analysis, or through soil samples taken on-site for off-site analysis: key properties include permeability, soil texture and depth of soil horizons. River discharge provides information on the range of flow conditions, including frequency and magnitude of flood events. See Chapter 5: Monitoring protocols and responsibilities of NBS interventions for further details.

Method four: Satellite imagery - if available - may be used to verify flood extent and, in some cases, may be used to verify flow pathways (Tellman et al., 2021, Mason et al., 2021). Where multiple flood events have occurred in the same location, images can be compared to show extent of flooding in response to storms of differing magnitude and duration. Recovery from storms may also be assessed, with possible identification of areas which store water for longer. This method is limited by data availability and satellite return period.

3.4 Identifying NBS opportunities

Following desk-based assessment and ground-truthing, NBS opportunities may be mapped. We recommend two categories of maps to facilitate practical collaboration: 1) landholder-approved, and 2) aspirational. Landholder-approved opportunities are those which the landholder agrees they would be interested to pursue, subject to agreed responsibilities, funding, and formal permissions (see section 3.5). Aspirational opportunities are all opportunities which the assessor has identified as suitable for the catchment and its management, either current or with reasonable adjustments. The aspirational opportunities may present additional or alternative options for NBS which can be considered, or used to advise stakeholders as circumstances change in the short- and long-term (e.g., with increased funding, a change in management, or with knowledge regarding the effectiveness of the NBS installed). Where multiple opportunities exist for one site, they should be ranked considering landholder preference, potential benefits, and longevity of the NBS.

NBS identification tools and peer-review evidenced is available to help an assessor choose NBS opportunities. Some key tools have been identified in Table 3-6.

Table 3-6: Tools for aiding identification of NBS opportunities

TOOL OR EVIDENCE BASE	DESCRIPTION	SOURCE
ICASP NFM MONITORING TOOLKIT	Decision-making flowchart for choosing NFM	Shipp et al. (2021)
THE NATURAL FLOOD MANAGEMENT MANUAL	Overview of NFM types with tips for selection of NFM site/type	Wren et al. (2022) [free to CIRIA members]
NATURAL FLOOD MANAGEMENT HANDBOOK		SEPA (2016)
WORKING WITH NATURAL PROCESSES EVIDENCE DIRECTORY	Evidence review	Burgess-Gamble et al. (2018)
NATURAL FLOOD MANAGEMENT TOOLKIT	Non-technical topic-specific guides, including: • Multiple benefits of NFM • A practical guide for farmers • Flood storage • Moorland restoration • Agricultural land management • Tree planting • Leaky woody dams • River and floodplain restoration	The Flood Hub (2024)

3.5 Responsibilities for installation, monitoring and maintenance

To generate landholder-approved and aspirational NBS opportunity maps, consideration should be made regarding who is responsible for NBS installation, monitoring, and maintenance. Installation and upkeep responsibilities may belong to different stakeholders depending on the type of NBS, willingness to take on the responsibility, and funding requirements or limitations.

Similarly, the level of monitoring required should be considered; is it enough that the feature remains in good condition, or is further data required to monitor effectiveness of the NBS? If detailed scientific analysis are required, who might undertake that and is funding available to support that analysis? It may be that a tiered approach is necessary for each identified NBS measure, suggesting the level of monitoring and maintenance obtainable with different possible resources.

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Chapter 4: Calculating NBS payment levels

Chapter 4 presents a Payment by Results calculator (Appendix C), designed for the Skell Valley but readily adaptable to other catchments suitable for NBS. Section 4.1 defines what a PbR is. Following this, the environmental objectives (4.2.1) and result indicators and payment thresholds (4.2.2, Table 4.-1, 4.2.3) for PbR in the Skell valley are outlined. Finally, the PbR calculation method and spreadsheet (4.2.4, 4.3) are introduced detailing the calculation steps and a worked example. The calculator itself is in Appendix C, and includes a worked example, expected ELMs payments (correct as of November 2024) and input sources.

4.1 Payments by Results

The concept of payments by results (PbR) is more common in health and international aid contexts, however they are increasingly being applied in the environmental sector. For example, within the last 30 years, the EU, and particularly Switzerland, has often used PbR to 'top up' conventional landscape management payments. A general definition of a PbR *is 'payment relating to the achievement of a defined environmental result, and the land manager is allowed the flexibility to achieve that result'*. Payments therefore depend solely on the presence of measurable indicators of the environmental result, examples of which are included in Chapter 5: Monitoring protocols and responsibilities of NBS interventions.

The required steps for designing a successful PbR agri-environmental scheme have been developed by the Institute for European Environmental Policy (Keenleyside et al., 2014). This work has outlined the steps necessary to define environmental objectives, identify suitable result indicators and thresholds, and determine subsequent payment levels. This manual has used the principles laid out by Keenleyside et al. (2014) and briefly outlines the four necessary steps below to help the reader determine their own PbR requirements.

1. **Define clear environmental objectives** which can be used to determine when the scheme has hit the desired target. As an example of objectives relating to farmland birds (Chaplin et al., 2019) suitable objectives included an increase in range (e.g. 50% expansion of home area of a breeding bird), specific population dynamics improvements (e.g. 20% increase in chick survival) or the presence of favourable features (e.g. 10% increase in wetland area). These targets must be based on the most accurate and up to date information available, whereby a strong relationship between the results to be rewarded and the achievement is known.

2. **Choose or select result indicators** which are proxies for the environmental objective and what landowners are paid and encouraged to adopt. This step is arguably the most important aspect of a PbR scheme, as they reflect the definition and measure of success in reaching the objective. These are used as rarely can environmental objectives (e.g. a 20% reduction in overall catchment sediment erosion) be used as a direct indicator of success at field, farm, or landscape level. Simplified or indirect indicators of success must therefore often be used. Examples of result indicators have included ecosystem or habitat attributes of structure (sward height), composition (species richness or diversity) or biophysical attributes (% bare soil, soil condition/infiltration rates). The most suitable result indicators are quantifiable, reliable and of reasonable cost to monitor.

3. **Set suitable indicator thresholds** which are used as the basis for levels of payment or achievements of indicators (proxies) and subsequently, environmental objectives. This step plays an important role in 'tuning' the scheme or outcomes, as the addition of levels or gradations of success can help to prevent degradation or encourage further improvements beyond basic measures of success. Thresholds can be set at single (indicator achieved- payment released), stepped (based on success thresholds- higher payment with each threshold achieved) or without thresholds (payment continues to increase with each increase in indicator) thresholds, as illustrated in Figure 4-1.

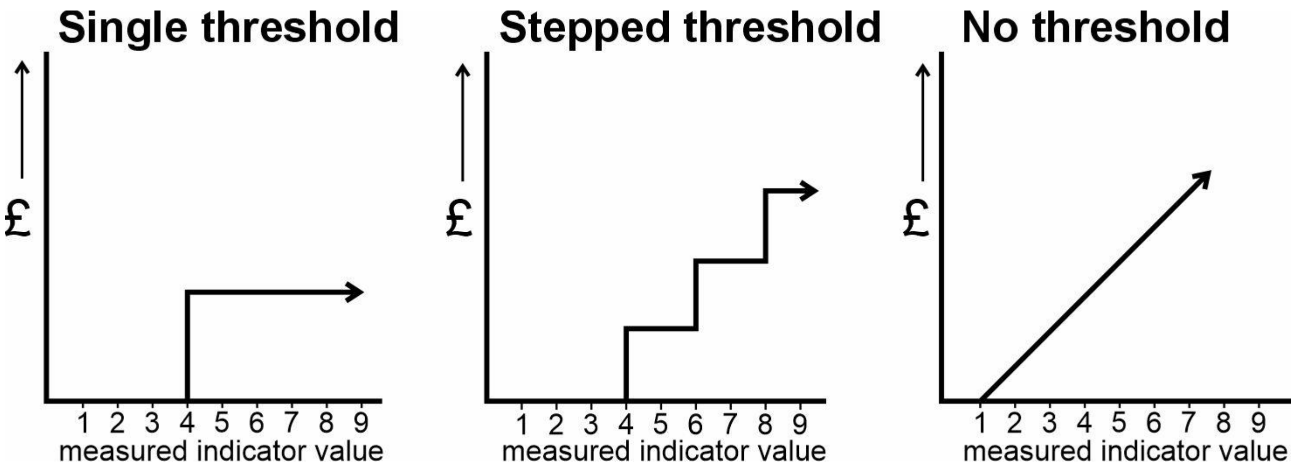

Figure 4-1: Examples of result indicators used as threshold values to 'fine-tune' and encourage results-based payments. Figure from Keenleyside et al., 2014.

4. **Calculate the payment**. Payments are usually calculated with the addition of income foregone and additional costs incurred in implementing any PbR measures. These include:

- Opportunity cost of maintaining current management where environmental results are already present. This is often calculated by comparing the income offered by alternative land management (e.g. ELMS) with the income provided by ongoing beneficial management;
- Income foregone by modifying management (e.g. reduced stocking density) that reduces production or income;
- Additional costs of specific NBS/ PbR management (e.g. direct costs for riparian fencing)

4.2 Determining PbR in the Skell Valley

4.2.1 NBS Objectives in the Skell Valley

The first step in devising a PbR scheme is to define clear objectives which link the result to be rewarded and the achievement that is required. For the Skell Valley, the following objectives were identified:

- Reduce flood impacts.
- Reduce sediment flux.
- Encourage ecological/ additional benefits, including improved water quality (reduced nutrient pollution), provision of habitat and improved soil health.

Reduced flood benefit objectives included decreased flood magnitude, duration, and timing to downstream areas, twinned with sediment control measures to reduce the frequency of dredging of the ponds at Fountains Abbey and to reduce the erosion risk of Fountains Abbey during flood events. Additional ecological benefits were deemed beneficial for farm businesses to promote climate resiliency.

4.2.2 Skell Valley indicators for NBS interventions and PbR payments

Previous research by iCASP (Shipp et al., 2021; Appendix B) identified indicators which could be used to monitor NFM (NBS) outcomes, including slowing, storing and filtering flood water. The research identified potential measurements of success and subsequent monitoring protocol to assess achievement of desired indicators (and subsequent desired environmental outcomes). The most relevant NBS interventions for the Skell Valley are summarised below in Table 4.

Table 4.-1: NBS interventions in the Skell valley, intended measures of success, landowner led monitoring, additional benefits and indicator costs

Timescale of intervention benefits	NBS intervention/ measure	Measurement of success	Landowner led monitoring	Additional benefits* (from iCASP)	Costs** (from YDNP)
Short term benefit returns	Leaky wooden dams/ in channel barriers	• Water pooling behind structure in flood • Sediment accumulated. • Increased infiltration	• Photos of dams 'in action' • Time lapse camera • Logging of water heights from stage board • Monitoring of sediment accumulation/ depths • Monitoring of infiltration in surrounding fields	• Improved water quality • GHG reduction • Habitat provision	• Set up- Low. • Maintenance- low • Certainty- med/ high
	Offline pond	• Should drain within 6-10 hours for storage in multi-day events* • Evidence of stored water • Sediment accumulation	• Time lapse camera • Logging of water heights from stage board • Monitoring of sediment accumulation/ depths	• Improved water quality • Habitat provision	• Set up- high. • Maintenance level- medium • Maintenance cost- low
	Buffer strips	• Provision of rough vegetation and protection from grazing.	• Vegetation height or density • Photos	• Improved water quality • GHG reduction • Habitat provision	• Set up- low. • Maintenance level- low • Maintenance cost- low
	Bunds, swales and scrapes	• Evidence of water storage • Sediment accumulation	• Time lapse camera/ photos • Sediment accumulation monitoring	• Improved water quality • Habitat provision	• Set up- medium.

			• Transition to water loving plants (e.g. rushes)		• Maintenance level- depends on size. • Maintenance cost- medium
	Culvert/ cross drain in farm track	• Evidence of water storage • Sediment accumulation • Increased infiltration	• Visual assessment and associated photos • Monitoring sediment accumulation/depths • Monitoring of infiltration in surrounding fields	• Improved water quality	• Set up- low. • Maintenance level – low • Maintenance cost- low
	Sediment traps	• Evidence of water storage • Sediment accumulation	• Time lapse camera/ photos • Sediment accumulation monitoring	• Improved water quality	• Set up- low. • Maintenance level – low • Maintenance cost- low
Long term benefit returns	Tree planting	• Established woodland. • Good sapling survival • Increased infiltration	• Photos of tree development • Survivorship • Infiltration or soil metrics	• Improved water quality • GHG reduction • Habitat provision	• Set up- medium. • Maintenance level- medium • Maintenance cost- low
	Hedge planting	• Understory vegetation • Increased infiltration	• Vegetation height and density • Survivorship • Photos • Infiltration • Soil metrics	• Improved water quality • GHG reduction • Habitat provision	• Set up- medium. • Maintenance level - high (primarily at planting stage) • Maintenance cost- low

4.2.3 Payment Thresholds

Following consultation with stakeholders during expert and landowner workshops, a stepped approach to payment thresholds was adopted in Skell Valley. Thresholds were applied for the number of, or extent of, interventions, initial cost, initial maintenance cost, potential for loss of income and flood, ecological and sediment benefit. These thresholds are discussed in further detail below.

A full breakdown of the payment threshold scores and calculation, including a worked example, is provided in Appendix C.

4.2.4 Calculation of payment score for NBS interventions in the Skell Valley

We present below a formulaic approach to determining levels of payments for NBS interventions. This approach allows for a bespoke (e.g. catchment, farm or outcome) approach to determining payments via pre-determined priorities. Greater weighting to factors using bespoke priority modifiers can then be changed according to management objectives to achieve and encourage payments relative to the desired objectives.

In the case of the Skell Valley, where reductions in sediment erosion and deposition in downstream locations was a priority, followed by flood peak and volume reductions, the following weighting and calculation categories were initially proposed to calculate payment scores:

Year 1: Payment score = A*Sed + B*Fl + C*Ecol + I + M + L

Year 2+: Payment score = A*Sed + B*Fl + C*Ecol + M + L (+I *if* new NBS added that year)

Where: Sed = Sediment benefits

Fl = Flood benefits

Ecol = Ecological benefits

I = Installation cost

M = Maintenance costs

L = Lost income (potential for)

A, B and C = priority modifiers

Priority modifiers determine the relative importance of each benefit category and are applied per farm. If all categories are equally important, A, B and C = 1; if flood benefits are twice as important as sediment and ecology benefits, A and C = 1, Flood = 1.5. Priority modifiers will stay the same throughout all payment years *unless* monitoring evidence proves an increase/decrease in the NBS net benefit provided, in which case priority modifiers should be amended in-line with benefit change.

Priority modifiers for the worked example of Gabby's Farm provided in Appendix C, for example have been set to 1.5 for flood benefits, 1.2 for ecological benefits and 0.8 for sediment benefits based on the priorities identified for the Skell Valley, as defined in Section 4.2.1. It is expected that these values would be adjusted according to priorities for each PbR scheme or location as required.

Appendix C also provides an alternative calculation:

All years: Payment score = A*Sed + B*Fl + C*Ecol

The alternative calculation may be used where payments for installation, maintenance and potential for loss of income can be calculated outright (i.e., as a defined total) and therefore may exist as additional payments outside of the PbR calculation.

4.3 PbR payment calculation matrix spreadsheet

To ease calculation of PbR payments and to ensure a standardised approach is available for all landowners within the Skell Valley, an Excel spreadsheet was developed to incorporate indicator thresholds and payment calculations. The spreadsheet is designed to allow project managers to adapt the calculations according to their own project needs, and information relating to the Skell Valley project is provided below to illustrate how PbR payments were calculated.

4.3.1 Input key worksheet tab

The first tab in the worksheet *'Input key'* outlines the thresholds used to calculate subsequent modifier values and payments. Values should be defined according to project priorities, and expert input (via stakeholder workshops, published literature etc) and may be updated as monitoring data becomes available. The second tab in the worksheet 'Modifier ID' outlines thresholds for modifier values used in the PbR payment. This tab uses the extent of NBS installations (number, area etc) to modify the payment score where interventions are known to have a positive cumulative effect on desired outcomes or benefits. Table 4 outlines the purpose and value for each of the column headings.

Table 4.4-2: The purpose and threshold value range for each category in the Payment by Results matrix developed.

PbR multiplier tool tab name	Column name	Threshold value	Notes
Input key	Installation cost	1 (low) – 3 (high)	Cost values were determined using YDNPA (2017). Where NBS interventions were not in the YDNPA guide, low-medium-high costs categories were determined by iCASP in consultation with Skell Valley Project team.
Input key	Maintenance level/ cost	1 (low) – 3 (high)	Cost values were determined using YDNPA (2017). Where NBS interventions were not in the YDNPA

			guide, low-medium-high costs categories were determined by iCASP in consultation with Skell Valley Project team.
Input key	Benefit span	Short-term/ long-term	Determined in consultation with National Trust and Nidderdale National Landscape
Input key	Potential for loss of income	0 (unknown); 1 (very low) – 5 (very high)	Triangles indicate perceived loss of income by experts at stakeholder workshop
Input key	Flood benefit	0 (unknown); 1 (very low) – 5 (very high)	Triangles indicate the perceived score determined by experts at a stakeholder workshop. Crosses should be used for assessment until monitoring is established.
Input key	Ecological benefit	0 (unknown); 1 (very low) – 5 (very high)	Triangles indicate the perceived score determined by experts at a stakeholder workshop. Crosses should be used for assessment until monitoring is established.
Input key	Sediment benefit	0 (unknown); 1 (very low) – 5 (very high)	Triangles indicate the perceived score determined by experts at a stakeholder workshop. Crosses should be used for assessment until monitoring is established.
Modifier ID	Modifier for number of, or extent of (successful) interventions	1 (low) – 3 (high)	Some interventions are predicted to work in a cumulative way, whereby increased coverage or number of interventions will increase the NBS benefit where they are installed. This is therefore encouraged.

4.3.2 PbR payment calculation matrix

This section describes how to assign the payment score for the proposed NBS interventions. To enable efficiency of calculation, Appendix C contains pre-inserted formulas which draw upon the data held in the *Input key* and *Modifier ID* tabs. In the PbR score tab, green cells should be edited by the Assessor to produce a PbR score. Yellow cells may be altered annually per farm based on monitoring and/or changes in the number of successful NBS interventions.

The steps to calculate PbR payment are provided below alongside a worked example (Figure 4-2, Figure 4-3, Table 4-3) which is also present in the 'Gabby's farm example' tab of the PbR modifier (Appendix C).

Step 1 - Determine the NBS present on the farm (for worked example, see

Table 4-3 & Figure 4-2). Using the drop-down menu in column C 'NBS interventions', select the required NBS. This will automatically complete columns B, F, and I-M.

Step 2 - Identify whether the NBS is new (i.e., has not received installation-associated payment) or has yearly capital requirements. This will automatically generate a value for column H, installation cost.

Step 3 - Write in the extent of each NBS intervention in column E 'Extent'. The value should be a number (no text), in the units identified in column F. (For worked example, see

Table 4-3 & Figure 4-2)

Step 4 - Using the table in the 'Modifier ID' tab, select the correct modifier value for each NBS extent. Add that value to column G next to the correct NBS.

Step 5 – Assign/double check priority modifier values (red box, columns J-L) to Flood, Ecology and Sediment benefits. These will be specific to each farm, determined using evidence from the desk-based assessment. Priority modifiers will stay the same throughout all payment years *unless* monitoring evidence proves an increase/decrease in the NBS net benefit provided, in which case priority modifiers should be amended in-line with benefit change. Information on how to assign priority modifier values is given in section 4.2.4.

Step 6 – On completion of step 6, a PbR score will be produced. Compare your PbR score to the banding and associated payment using the 'Banding & payment for PbR' tab.

Annual considerations:

On an annual basis, each farm will undergo an NBS maintenance and benefit assessment using the monitoring process described in Chapter 5: Monitoring protocols and responsibilities of NBS interventions. Where NBS has failed, not been maintained, or funding has reached the end of the agreed timeframe, the modifier value (column G) should be set to zero.

As monitoring of the NBS progresses (see Chapter 5), benefit values (columns J-L, PbR score tab in Appendix C) – or the priority modifiers (step 6) – may be adjusted to reward measured NBS success. This may alter payment for the same NBS after initial installation.

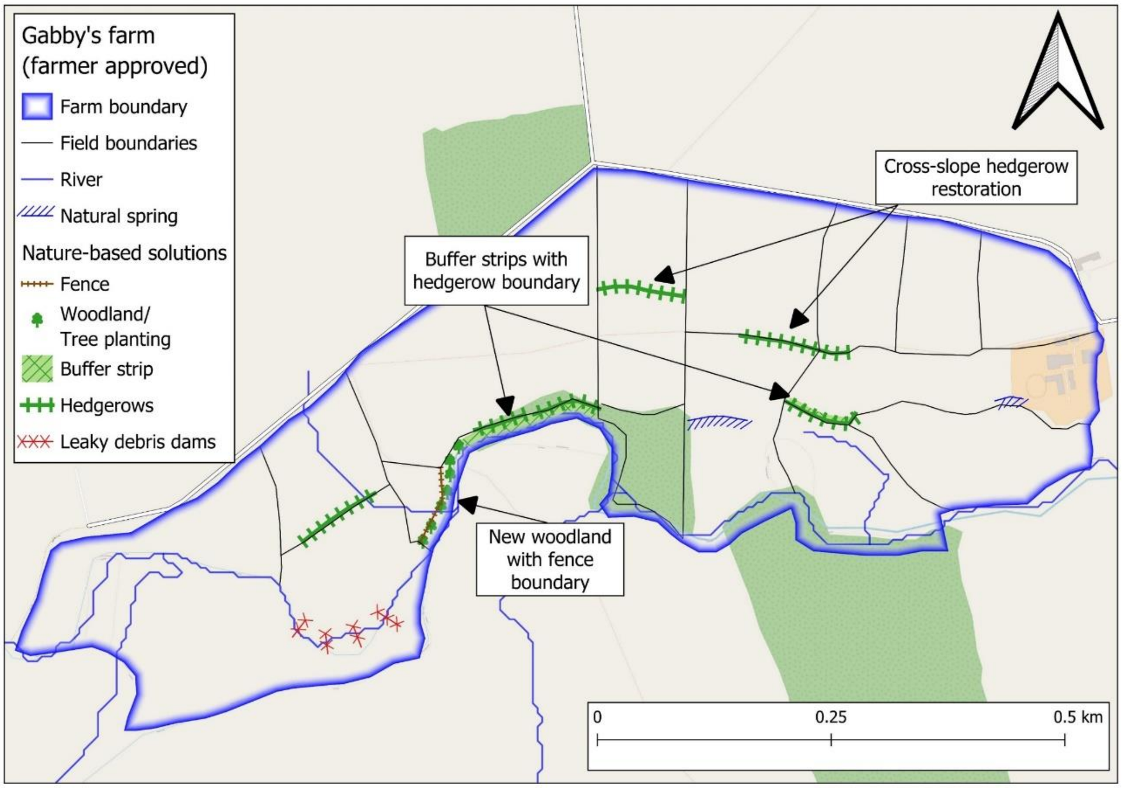

Figure 4-2: Gabby's farm - example opportunity map.

Table 4-3: Gabby's farm - example NBS interventions, their extent, extent units and modifier value. Included at the top of the table: the steps in which these factors should be added to the PbR score calculator.

Step 1	**Step 1**	**Step 3**	**Step 4**
Where to find:	Automatically added to the PbR score table	Determine from opportunity map & interventions agreed with landholder	Table in Modifier ID tab
NBS	**Extent units**	**Extent**	**Modifier value**
Leaky dams	Number of interventions	4	2
Hedgerows	Metres length	511	1
Tree planting/ Woodland creation	Hectares	0.11	1
Buffer strip	Metres wide	6	2

Short or long-term benefit return?	NBS interventions	Is the NBS new or does it have yearly capital costs? (i.e., should installation costs be included in the PbR score?)	Extent	Extent unit	Modifier for the number of - or extent of - interventions	Installation cost	Maintainence cost	Potential for loss of income	Flood benefit	Ecological benefit	Sediment benefit	Total
Step: 1 (auto)	1	2	3	1 (auto)	4	2 (auto)	1 (auto)	1 (auto)	1 (auto)	1 (auto)	1 (auto)	
									Priority modifier - Step 5			
									1.5	1.2	0.8	
Short-term	Leaky dam	Yes	4	Number of interventions	2	1	1	3	4	2.5	2	31.2
Long-term	Hedgerow planting	Yes	511	Metres length	1	2	2.5	3	4	4	3.5	21.1
Long-term	Tree planting / woodland creation	Yes	0.11	Hectares	1	2	1.5	3	4	4.5	3.5	20.7
Short-term	Buffer strip	Yes	6	Metres wide	2	1	1	2.5	4	3.5	4	35.8

Step 6	PbR score	108.8

Figure 4-3: Gabby's farm - PbR score calculation.

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Chapter 5: Monitoring protocols and responsibilities of NBS interventions

Chapter 5 presents an overview of monitoring protocols (5.1) and expected responsibilities for landholders, rangers/advisors, and consultants or university experts per NBS type (editable versions in Appendix D and E). The NBS included are (Ctrl and click on 5.x to jump to the monitoring information):

- Blocking drainage grips (5.2)
- Buffer strips (5.4)
- Bunds, swales and scrapes (5.3)
- Cross drains in farm tracks (5.5)
- Hedgerow planting and management (5.14)
- Leaky woody dams (5.6)
- Livestock: Management/reduction (5.12) and Mob grazing (5.13)
- Restoring meanders (5.7)
- Sediment traps (5.8)
- Soil health (permeability & water holding capacity (5.11)
- Storage ponds (5.9)
- Tree planting and management (Woodland; 5.15)
- Winter cover crops (5.10)

5.1 Monitoring protocols

The integrity of any infrastructure or land management change needs to be assessed periodically to ensure that the intervention is providing the predicted benefits, and that it is in working order. If this is true, the payment can be made to the landholder. There are a range of interventions, ranging from short-term benefits and short lifespan to long-term benefits and long lifespan, which means that many monitoring protocols need to be accessible and practicable. However, sometimes external expert assessment will be needed, especially if quantification of impact or (stacked) benefits is required.

What is success? In most instances, the benefits of NBS interventions on a farm will be hard to quantify at the scale of the catchment. Some NBS intervention is generally better than doing nothing, so the monitoring will be checking that there is some maintenance. However, there are potential outcomes from the monitoring where it can be demonstrated that the NBS interventions do not work or are deemed to be detrimental to the landscape function. For obvious reasons, these are rarely reported, but far from impossible. This occurrence should be considered as a risk to the funding programme. If the farmer/landholder has followed the advice on installation and maintenance from the expert (ranger/advisor) they should not be penalized by having funding withdrawn – the value of their engagement in the process needs to be rewarded.

5.2 Blocking Drainage Grips

Table 5.1: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STORAGE DURATION	• Smart phone with camera • Level board & fixings. • Post to photograph from to ensure comparable field of view. • Internet to send photo	£100s per NBS per site	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Photograph of the level board of presence or absence of water taken from post.

Level board to show depth of water.

Table 5.2: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
FLOW RATE	• Notch weir And either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in drainage grips with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images. Or Time series of water level taken from level sensor. Both height measurements will then need to be converted to flow rate using notch weir equation to demonstrate flow rate is reduced during flood peak (Section 9.1.1 BS3680-4G:1999)
STAGE HEIGHT	Either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in drainage grips with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing a reduction in peak flow and a broadening of flood wave. Or Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.

Level board to show depth of water and trail camera to take timelapse pictures of the board to record changes.

Table 5.3: Monitoring by University/Consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
FLOW RATE OR DISCHARGE	Either • Drone • Computer & software to process data. • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription And/or • Acoustic Doppler Current Profiler (ADCP) • Computer & software to process data. CAVEAT – ADCP suitability is dependent on depth of channel. If too shallow to use ADCP then depth must be recorded using depth gauge to allow for software to turn drone videos into discharge. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£100,000s upfront cost but low ongoing cost	Baseline and then after large event	Changes to discharge measurement from drone or ADCP. This can be used in combination with the techniques from table 5.2 to convert the level data to discharge data.
STAGE HEIGHT	• Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in drainage grips with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.
STORAGE DURATION	• Drone • Computer & software to process data. • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then after large event	3D model of the area surrounding the drainage grips before and after events. Multiple models can be spatially compared to see change in storage.


ADCP in drainage grip to record the depth and flow velocity.

5.3 Bunds, Swales and Scrapes

Table 5.4: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STORAGE DURATION	• Smart phone with camera • Level board & fixings. • Post to photograph from to ensure comparable field of view. • Internet to send photo	£100s per NBS per site	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Photograph of the level board of presence or absence of water taken from post.
REDUCTION IN FINE GRAINED SEDIMENT	• Photograph deposits using smart phone with camera. • Internet to send photo. • Depth of deposit using ruler • Notebook and pen	£100s per farm if buying smart phone	After storm event	Photograph of the depth/areas of sediment deposit within the bund/swale/scrape. Comparison of multiple depths/areas to show cumulative impact.

Level board to show depth of water.

Table 5.5: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
FLOW RATE	• Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in drainage grips with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing water stored during high flow. Or Time series of water level taken from level sensor showing water

				stored during high flow.
STAGE HEIGHT	Either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in drainage grips with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing a reduction in peak flow and a broadening of flood wave. Or Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.
REDUCTION IN SOIL BULK DENSITY	• Soil association bulk density method • 30cm Core • High precision scale • Drying Oven • Computer and software to record and display data.	£1,000s upfront cost	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction of soil bulk density to below the threshold given by soil association for the soil type – Sandy:<1.6g/cm3, Silty:<1.4g/cm3, Clayey:<1.1g/cm3.
REDUCTION IN FINE GRAINED SEDIMENT	• Munsell soil chart to identify sediment source. • Notebook and/or smart phone	£100s	After storm event	Reduction in sediment sources – comparison of sediment stored by NBS after storm event using Munsell soil chart to identify their sources from the sediment deposit. Should see a reduction in sediment from one/multiple sources once NBS established.

Level board to show depth of water and trail camera to take timelapse pictures of the board to record changes.

Table 5.6: Monitoring by University/Consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STAGE HEIGHT	• Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in drainage grips with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.
STORAGE DURATION	• Drone • GPS and ground control points for scaling	£10,000s upfront cost but	Baseline and then after large event	3D model of the area surrounding the drainage

	• SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	low ongoing cost		grips before and after events. Multiple models can be spatially compared to see change in storage.
REDUCTION IN FINE GRAINED SEDIMENT	• Turbidity meter – benchtop • Particle size analyser • Sample bottles	£100,000s	Baseline and then after large event	Reduction in turbidity when comparing data from before and after NBS installation. Reduction in the percentage of fine-grained sediment in water column when comparing data from before and after NBS installation.


Drone to record area of NBS intervention to calculate storage duration.

5.4 Creating and Managing Buffer Strips

Table 5.7: Monitoring by landholder and/or ranger.

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION HEIGHT AND WIDTH	• Tape measure • Drop disc. • Ruler • Notebook and pen	£10s per farm	Annually at mid-summer maximum vegetation height.	Year 1: Presence of vegetation and initial height and width measurement. Year 2 onwards: Maintenance or increase on year 1 volume.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW STRIP	• Photograph above and below strip using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph showing presence of channelized flow with ruler in the image for scale.

Table 5.8: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION AREA AND ROUGHNESS	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Increase in roughness in buffer strip area comparative to surrounding area. This roughness is calculated by creating a 3D model of the buffer strip before and after the intervention and calculating the

				difference in the point clouds.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW STRIP	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Mapping and comparison of channelized flow above/below buffer strip in 3D models before and after intervention. These changes would be identified by calculating the difference between the point clouds.
MOISTURE LEVEL ABOVE AND BELOW BUFFER STRIP	• Moisture probes • Computer & software to process data	£10,000s upfront cost but low ongoing cost	Would give time series data, data download, battery replacement and cleaning frequency dependant on probe	Comparison of time series data above and below intervention to show a reduction in moister levels after the intervention.

Drone to record area of NBS intervention to calculate area, roughness and evidence of channelised flow.

5.5 Cross Drains in Farm Tracks

Table 5.9: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STORAGE DURATION	• Smart phone with camera • Level board & fixings. • Post to photograph from to ensure comparable field of view. • Internet to send photo	£100s per NBS per site	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Photograph of the level board of presence or absence of water taken from post.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW DRAIN	• Photograph above and below drain using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph of presence or absence of water taken from post including the ruler for scale.
SEDIMENT DEPOSITION	• Camera to photograph depth of sediment. • Internet to send photo. • Ruler to measure depth of sediment.	£100s per farm if buying smart phone.	After storm event	Photograph of the depth/areas of sediment deposit within the area. Comparison of multiple photographs to show cumulative impact.
INFILTRATION	• Pipe • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£10's	Annually, set number of days after rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Level board to show depth of water.

Table 5.10: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
HEIGHT OF RETAINED WATER	Either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images. Or Time series of water level taken from level sensor.

	drainage grips with a minimum depth which is dependent on probe parameters.			
REDUCTION IN SOIL BULK DENSITY	• Soil association bulk density method • 30cm Core • High precision scale • Drying Oven • Computer and software to record and display data.	£1,000s upfront cost	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction of soil bulk density to below the threshold given by soil association for the soil type – Sandy:<1.6g/cm3, Silty:<1.4g/cm3, Clayey:<1.1g/cm3.
REDUCTION IN FINE GRAINED SEDIMENT	• Munsell soil chart to identify sediment source. • Notebook and/or smart phone	£100s	After storm event	Reduction in sediment sources – comparison of sediment stored by NBS after storm event using Munsell soil chart to identify their sources from the sediment deposit. Should see a reduction in sediment from one/multiple sources once NBS established.
INFILTRATION	• Double ring infiltrometer • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£100s	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Level board to show depth of water and trail camera to take timelapse pictures of the board to record changes.

Table 5.11: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW CROSS DRAIN	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather;	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Mapping and comparison of channelized flow above/below buffer strip in 3D models before and after intervention. These changes would be identified by calculating the

	flyers need training and A2 Certificate of Competency			difference between the point clouds.
MOISTURE LEVEL ABOVE AND BELOW CROSS DRAIN	• Moisture probes • Computer & software to process data		Would give timeseries data, data download, battery replacement and cleaning frequency dependant on probe	Comparison of time series data above and below intervention to show a reduction in moister levels after the intervention.
WATER QUALITY ANALYSIS	• Bench top turbidity meter. • Computer & software to process data. • Sample bottles CAVEAT - Multiple farms feed into the colour and quality of a watercourse. Hard to untangle results as it may be an upstream issue, and the natural baseline of erosion affects results.	£1,000s upfront cost then low ongoing cost	After storm event.	Comparison between turbidity measured before and after intervention in place indicating a reduction in turbidity after storm events.
INFILTRATION	• Tension infiltrometer • Measurement cylinder/known volume of water. • Level • Sand And either • Notebook and pen to keep record. Or • Datalogger	£1000s and additional £1000s if using datalogger.	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed. This would either by a time series if using a data logger, or single data points if done manually.

Drone to record area of NBS intervention to record evidence of channelised flow.

5.6 Leaky Woody Dams

Table 5.12: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STORAGE DURATION	• Smart phone with camera • Level board & fixings. • Post to photograph from to ensure comparable field of view. • Internet to send photo	£100s per NBS per site	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Photograph of the level board of presence or absence of water taken from post.
SEDIMENT DEPOSITION	• Camera to photograph depth of sediment. • Internet to send photo. • Ruler to measure depth of sediment.	£100s per farm if buying smart phone.	After storm event	Photograph of the depth/areas of sediment deposit within the area. Comparison of multiple photographs to show cumulative impact.

INFILTRATION	• Pipe • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£10's	Annually, set number of days after rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Level board to show depth of water.

Table 5.13: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
HEIGHT OF RETAINED WATER	Either • Level board • Trail camera • Computer & software to process photos into data/video.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing water stored during high flow.

	Or • Level sensor • Computer & software to process data			Or Time series of water level taken from level sensor showing water stored during high flow.
FLOW RATE	• Notch weir And either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in pools with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing water stored during high flow. Or Time series of water level taken from level sensor showing water stored during high flow. Both height measurements will then need to be converted to flow rate using notch weir equation to demonstrate flow rate is reduced during flood peak. (Section 9.1.1 BS3680-4G:1999)
REDUCTION IN FINE GRAINED SEDIMENT	• Munsell soil chart to identify sediment source. • Notebook and/or smart phone	£100s	After storm event	Reduction in sediment sources – comparison of sediment stored by NBS after storm event using Munsell soil chart to identify their sources from the sediment deposit. Should see a reduction in sediment from one/multiple sources once NBS established.

INFILTRATION	• Double ring infiltrometer • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£100s	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Level board to show depth of water and trail camera to take timelapse pictures of the board to record changes.

Table 5.14: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VOLUME OF RETAINED WATER	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-winter minimum vegetation height	Multiple 3D models which calculate the volume of water which could be held by the dams during peak flow. This is impacted by vegetation in the channel.
MOISTURE LEVEL	• Moisture probes • Computer & software to process data	£1000s per farm	Would give timeseries data, data download, battery replacement and cleaning frequency dependant on probe	Comparison of time series data above and below intervention to show a reduction in moister levels after the intervention.
WATER QUALITY ANALYSIS UPSTREAM AND DOWNSTREAM	• Bench top turbidity meter. • Computer & software to process data. • Sample bottles CAVEAT - Multiple farms feed into the colour and quality of a watercourse. Hard to untangle results as it may be an upstream issue, and the natural baseline of erosion affects results.	£1,000s upfront cost then low ongoing cost	After storm event.	Comparison between turbidity measured before and after intervention in place indicating a reduction in turbidity after storm events.
INFILTRATION	• Tension infiltrometer	£1000s and additional	Before intervention (x days after	Reduction in time taken for water to be absorbed by

	• Measurement cylinder/known volume of water. • Level • Sand And either • Notebook and pen to keep record. Or • Datalogger	£1000s if using datalogger.	rainfall) and then annually after x number of days of rainfall	the ground before/after the intervention is installed.

Picture of person next to leaky woody dam with a level board in front of the dam to show the height of the water retained.

5.7 Restoring Meanders

Table 5.15: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STAGE HEIGHT	• Smart phone with camera • Level board & fixings. • Post to photograph from to ensure comparable field of view. • Internet to send photo	£100s per NBS per site	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Photographs showing height of river and maintenance of meander.

Level board to show depth of water.

Table 5.16: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
FLOW RATE	• Notch weir And either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in rivers with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images. Or Time series of water level taken from level sensor. Both height measurements will then need to be converted to flow rate using notch weir equation to demonstrate flow rate is reduced during flood peak. (Section 9.1.1 BS3680-4G:1999)
STAGE HEIGHT	Either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in rivers with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing a reduction in peak flow and a broadening of flood wave. Or Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.

Level board to show depth of water and trail camera to take timelapse pictures of the board to record changes.

Table 5.17: Monitoring by University/Consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
FLOW RATE OR DISCHARGE	Either • Drone • Computer & software to process data. And/or • Acoustic Doppler Current Profiler (ADCP) • Computer & software to process data. CAVEAT – flying drone requires fair weather, flyers need training and A2 Certificate of Competency CAVEAT – ADCP suitability is dependent on depth of channel. If too shallow to use ADCP then depth must be recorded using depth gauge to allow for software to turn drone videos into discharge.	£10,000s upfront cost but low ongoing cost	Baseline and then after large event	Changes to discharge measurement from drone or ADCP. This can be used in combination with the techniques from table 5.16 to convert the level data to discharge data.
STAGE HEIGHT	• Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in rivers with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.


ADCP in river to record the depth and flow velocity.

5.8 Sediment Traps

Table 5.18: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STORAGE DURATION	• Smart phone with camera • Level board & fixings. • Post to photograph from to ensure comparable field of view. • Internet to send photo	£100s per NBS per site	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Photograph of the level board of presence or absence of water taken from post

SEDIMENT DEPOSITION	• Camera to photograph depth of sediment. • Internet to send photo. • Ruler to measure depth of sediment.	£100s per farm if buying smart phone.	After storm event	Photograph of the depth/areas of sediment deposit within the area. Comparison of multiple photographs to show cumulative impact.

Level board to show depth of water.

Table 5.19: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STORAGE DURATION	Either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in pools with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing water stored during high flow. Or Time series of water level taken from level sensor showing water stored during high flow.
REDUCTION IN FINE GRAINED SEDIMENT	• Munsell soil chart to identify sediment source. • Notebook and/or smart phone	£100s	After storm event	Reduction in sediment sources – comparison of sediment stored by NBS after storm event using Munsell soil chart to identify their sources from the sediment deposit. Should see a reduction in sediment from one/multiple sources once NBS established.

Level board to show depth of water and trail camera to take timelapse pictures of the board to record changes.

Table 5.20: Monitoring by University/Consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VOLUME OF RETAINED WATER	Either • Drone • Computer & software to process data. And/or • Acoustic Doppler Current Profiler (ADCP) • Computer & software to process data.	£10,000s upfront cost but low ongoing cost	Baseline and then after large event	Either Multiple 3D models which calculate the volume of water which could be held by the dams during peak flow. This is impacted by vegetation in the channel. Or

	CAVEAT – flying drone requires fair weather, flyers need training and A2 Certificate of Competency CAVEAT – ADCP suitability is dependent on depth of channel. If too shallow to use ADCP then depth must be recorded using depth gauge to allow for software to turn drone videos into discharge.			ADCP survey showing deposition of sediment in pool.
STORAGE DURATION	• Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in pools with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Time series of water level taken from level sensor showing water stored during high flow.
WATER QUALITY ANALYSIS UPSTREAM AND DOWNSTREAM	• Bench top turbidity meter. • Computer & software to process data. • Sample bottles CAVEAT - Multiple farms feed into the colour and quality of a watercourse. Hard to untangle results as it may be an upstream issue, and the natural baseline of erosion affects results.	£1,000s upfront cost then low ongoing cost	After storm event.	Comparison between turbidity measured before and after intervention in place indicating a reduction in turbidity after storm events.

ADCP in river to record the depth and flow velocity.

5.9 Storage Ponds

Table 5.21: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STORAGE DURATION	• Smart phone with camera • Level board & fixings. • Post to photograph from to ensure comparable field of view. • Internet to send photo	£100s per NBS per site	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Photograph of the level board of presence or absence of water taken from post
REDUCTION IN FINE GRAINED SEDIMENT	• Photograph deposits using smart phone with camera. • Internet to send photo. • Depth of deposit using ruler • Notebook and pen	£100s per farm if buying smart phone	After storm event	Photograph of the depth/areas of sediment deposit within the pond. Comparison of multiple depths/areas to show cumulative impact.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW DRAIN	• Photograph above and below drain using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph of presence or absence of water taken from post including the ruler for scale.
SEDIMENT DEPOSITION	• Camera to photograph depth of sediment. • Internet to send photo. • Ruler to measure depth of sediment.	£100s per farm if buying smart phone.	After storm event	Photograph of the depth/areas of sediment deposit within the pond. Comparison of multiple depths/areas to show cumulative impact.

Level board to show depth of water.

Table 5.22: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
FLOW RATE	• Notch weir And either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images. Or Time series of water level taken from level sensor. Both height measurements will then need to be converted to flow rate using notch

	CAVEAT – level sensor can only be used in pools with a minimum depth which is dependent on probe parameters.			weir equation to demonstrate flow rate is reduced during flood peak. (Section 9.1.1 BS3680-4G:1999)
STAGE HEIGHT AND STORAGE DURATION	Either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in pools with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing a reduction in peak flow and a broadening of flood wave. Or Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.
REDUCTION IN SOIL BULK DENSITY	• Soil association bulk density method • 30cm Core • High precision scale • Drying Oven • Computer and software to record and display data	£1,000s upfront cost	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction of soil bulk density to below the threshold given by soil association for the soil type – Sandy:<1.6g/cm3, Silty:<1.4g/cm3, Clayey:<1.1g/cm3.
REDUCTION IN FINE GRAINED SEDIMENT	• Munsell soil chart to identify sediment source. • Notebook and/or smart phone	£100s	After storm event	Reduction in sediment sources – comparison of sediment stored by NBS after storm event using Munsell soil chart to identify their sources from the sediment deposit. Should see a reduction in sediment from one/multiple sources once NBS established.

Level board to show depth of water and trail camera to take timelapse pictures of the board to record changes.

Table 5.23: Monitoring by University/Consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
STAGE HEIGHT	• Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in pools with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.
STORAGE DURATION	• Drone • GPS and ground control points for scaling	£10,000s upfront cost but	Baseline and then after large event	3D model of the area surrounding the pond before

	• SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	low ongoing cost		and after events. Multiple models can be spatially compared to see change in storage.
REDUCTION IN FINE GRAINED SEDIMENT	• Turbidity meter – benchtop • Particle size analyser • Sample bottles	£100,000s	Baseline and then after large event	Comparison between turbidity measured before and after intervention in place indicating a reduction in turbidity after storm events.

Drone to record area of NBS intervention to calculate storage duration.

5.10 Winter Cover Crops

Table 5.24: Monitoring by landholder and/or ranger.

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION HEIGHT AND WIDTH	• Tape measure • Drop disc. • Ruler • Notebook and pen	£10s per farm	Annually at mid-summer maximum vegetation height.	Year 1: Presence of vegetation and initial height and width measurement. Year 2 onwards: Maintenance or increase on year 1 volume.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW STRIP	• Photograph above and below strip using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph showing presence of channelized flow with ruler in the image for scale.
INCREASED SOIL HEALTH	• Soil Association worm counting methodology. • Spade • Mat/tray to place soil. • Sieve • Notebook to record category of worms (epigeic/endogeic/anecic and juvenile/adult).	£10s per farm	Annually – record previous weeks rainfall.	Increase in worm numbers, variety and survival to adulthood

Table 5.25: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION AREA AND ROUGHNESS	• Drone • GPS and ground control points for scaling • SIM card in phone and	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Increase in roughness in cover crop field area comparative to surrounding area. This roughness is

	NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency			calculated by creating a 3D model of the buffer strip before and after the intervention and calculating the difference in the point clouds.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW COVER CROPS	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Mapping and comparison of channelized flow above/below field in 3D models before and after intervention. These changes would be identified by calculating the difference between the point clouds.
MOISTURE LEVEL ABOVE AND BELOW COVER CROPS	• Moisture probes • Computer & software to process data	£1000's per site	Would give time series data, data download, battery replacement and cleaning frequency dependant on probe	Comparison of time series data above and below intervention to show a reduction in moister levels after the intervention.
ORGANIC CARBON CONTENT USING LOSS ON IGNITION	• Coring equipment • Furnace • High precision scale • Crucible • Computer & software to process data	£10,000s upfront cost but low ongoing cost	Annually	Increase in organic carbon content of soil.

Drone to record area of NBS intervention to calculate evidence of channelised flow and area of vegetation cover.

5.11 Increasing Soil Permeability / Water Holding Capacity

Table 5.26: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
EVIDENCE OF REDUCED SURFACE RUN OFF	• Photograph above and below area using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photographs showing less run off after land management changed.

SEDIMENT DEPOSITION	• Camera to photograph depth of sediment. • Internet to send photo. • Ruler to measure depth of sediment.	£100s per farm if buying smart phone.	After storm event	Photograph of the depth/areas of sediment deposit within the area. Comparison of multiple photographs to show cumulative impact.
INFILTRATION	• Pipe • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£10's	Annually, set number of days after rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Level board to show depth of water.

Table 5.27: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
HEIGHT OF RETAINED WATER	Either • Level board • Trail camera • Computer & software to process photos into data/video. Or • Level sensor • Computer & software to process data. CAVEAT – level sensor can only be used in pools with a minimum depth which is dependent on probe parameters.	£1,000s per NBS per site	Every 2-3 months – data download and clean	Either: Time series of water level taken from trail camera images showing a reduction in peak flow and a broadening of flood wave. Or Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.
REDUCTION IN SOIL BULK DENSITY	• Soil association bulk density method • 30cm Core • High precision scale • Drying Oven • Computer and software to record and display data.	£1,000s upfront cost	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Either: Time series of water level taken from trail camera images showing a reduction in peak flow and a broadening of flood wave. Or Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.
REDUCTION IN FINE GRAINED SEDIMENT	• Munsell soil chart to identify sediment source. • Notebook and/or smart phone	£100s	After storm event	Reduction in sediment sources – comparison of sediment stored by NBS after storm event using Munsell soil chart to identify their sources from the sediment

				deposit. Should see a reduction in sediment from one/multiple sources once NBS established.
INFILTRATION	• Double ring infiltrometer • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£100s	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Level board to show depth of water and trail camera to take timelapse pictures of the board to record changes.

Table 5.28: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW AREA	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Mapping and comparison of channelized flow above/below buffer strip in 3D models before and after intervention. These changes would be identified by calculating the difference between the point clouds.
MOISTURE LEVEL ABOVE AND BELOW AREA	• Moisture probes • Computer & software to process data		Would give timeseries data, data download, battery replacement and cleaning frequency dependant on probe	Comparison of time series data above and below intervention to show a reduction in moister levels after the intervention.
WATER QUALITY ANALYSIS	• Bench top turbidity meter. • Computer & software to process data. • Sample bottles CAVEAT - Multiple farms feed into the colour and quality of a watercourse. Hard to untangle results as it may be an upstream issue, and the natural baseline of erosion affects results.	£1,000s upfront cost then low ongoing cost	After storm event.	Measured before and after intervention in place indicating a reduction in turbidity after storm events.
INFILTRATION	• Tension infiltrometer	£1000s and additional £1000s if	Before intervention (x days after rainfall) and	Reduction in time taken for water to be absorbed by the ground

	• Measurement cylinder/known volume of water. • Level • Sand And either • Notebook and pen to keep record. Or • Datalogger	using datalogger.	then annually after x number of days of rainfall	before/after the intervention is installed.

Drone to record area of NBS intervention to record evidence of channelised flow.

5.12 Livestock Management / Reducing Stock

Table 5.29: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VISUAL INSPECTION OF AREAS OF EROSION	• Tape measure • Smart home to take photos of erosion. • Internet to send photo. • Notebook and pen	£100s per farm if buying smart phone.	Annually at mid-summer maximum vegetation height.	Fewer and smaller areas of erosion
INCREASED SOIL HEALTH	• Soil Association worm counting methodology. • Spade • Mat/tray to place soil. • Sieve • Notebook to record category of worms (epigeic/endogeic/anecic and juvenile/adult).	£10s per farm	Annually – record previous weeks rainfall.	Increase in worm numbers, variety and survival to adulthood
SOIL ASSOCIATION % SOIL COVER METHODOLOGY	• Landholder to average % soil cover per month and average per farm per year • Notebook and pen • Map of farm	£10s per farm	Monthly estimates	Increase in average % soil cover of farm.

Table 5.30: Monitoring by ranger

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VISUAL INSPECTION OF AREAS OF ERISION	• Tape measure • Smart home to take photos of erosion. • Internet to send photo. • Notebook and pen	£100s per farm if buying smart phone	Annually at mid-summer maximum vegetation height.	Fewer and smaller areas of erosion
INCREASED SOIL HEALTH	• Soil Association worm counting methodology. • Spade • Mat/tray to place soil.	£10s per farm	Annually – record previous weeks rainfall.	Increase in worm numbers, variety and

	• Sieve • Notebook to record category of worms (epigeic/endogeic/anecic and juvenile/adult).			survival to adulthood
IMPROVEMENT IN SOIL STRUCTURE	• Spade • Mat for hole contents • VESS soil structure analysis table to evaluate structure. • Notebook and pen	£10s per farm	Annual	Improvement of soil structure towards 1 - friable.

Table 5.31: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION AREA AND ROUGHNESS	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Increase in roughness in buffer strip area comparative to surrounding area. This roughness is calculated by creating a 3D model of the buffer strip before and after the intervention and calculating the difference in the point clouds.
ORGANIC CARBON CONTENT USING LOSS ON IGNITION	• Coring equipment • Furnace • High precision scale • Crucible • Computer & software to process data	£10,000s upfront cost but low ongoing cost	Annually	Increase in organic carbon content of soil.

Drone to record area of NBS intervention to calculate area, roughness and evidence of channelised flow.

5.13 Mob Grazing

Table 5.32: Monitoring by landholder and/or ranger.

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION HEIGHT AND WIDTH	• Tape measure • Drop disc. • Ruler • Notebook and pen	£10s per farm	Annually at mid-summer maximum vegetation height.	Year 1: Presence of vegetation and initial height and width measurement. Year 2 onwards: Maintenance or increase on year 1 volume.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW AREA	• Photograph above and below area using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph showing presence of channelized flow with ruler in the image for scale.

INCREASED SOIL HEALTH	• Soil Association worm counting methodology. • Spade • Mat/tray to place soil. • Sieve • Notebook to record category of worms (epigeic/endogeic/anecic and juvenile/adult).	£10s per farm	Annually – record previous weeks rainfall.	Increase in worm numbers, variety and survival to adulthood

Table 5.33: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION AREA AND ROUGHNESS	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Increase in roughness in buffer strip area comparative to surrounding area. This roughness is calculated by creating a 3D model of the buffer strip before and after the intervention and calculating the difference in the point clouds.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW AREA	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Mapping and comparison of channelized flow above/below buffer strip in 3D models before and after intervention. These changes would be identified by calculating the difference between the point clouds.

MOISTURE LEVEL ABOVE AND BELOW AREA	• Moisture probes • Computer & software to process data	£1000's per site	Would give timeseries data, data download, battery replacement and cleaning frequency dependant on probe	Comparison of time series data above and below intervention to show a reduction in moister levels after the intervention.
ORGANIC CARBON CONTENT USING LOSS ON IGNITION	• Coring equipment • Furnace • High precision scale • Crucible • Computer & software to process data	£10,000s upfront cost but low ongoing cost	Annually	Increase in organic carbon content of soil.

Drone to record area of NBS intervention to calculate area, roughness and evidence of channelised flow.

5.14 Planting and Managing Hedgerows

Table 5.34: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION HEIGHT AND WIDTH	• Tape measure • Drop disc. • Ruler • Notebook and pen	£10s per farm	Annually at mid-summer maximum vegetation height.	Year 1: Presence of vegetation and initial height and width measurement. Year 2 onwards: Maintenance or increase on year 1 volume.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW HEDGEROW	• Photograph above and below hedgerow using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph showing presence of channelized flow with ruler in the image for scale.
INFILTRATION	• Pipe • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£10's	Annually, set number of days after rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Table 5.35: Monitoring by ranger.

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION HEIGHT AND WIDTH	• Tape measure • Drop disc. • Ruler • Notebook and pen	£10s per farm	Annually at mid-summer maximum vegetation height.	Year 1: Presence of vegetation and initial height and width measurement. Year 2 onwards: Maintenance or

				increase on year 1 volume.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW STRIP	• Photograph above and below strip using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph showing presence of channelized flow with ruler in the image for scale.
REDUCTION IN FINE GRAINED SEDIMENT	• Munsell soil chart to identify sediment source. • Notebook and/or smart phone • Internet to send photo	£100s	After storm event	Either: Time series of water level taken from trail camera images showing a reduction in peak flow and a broadening of flood wave. Or Time series of water level taken from level sensor showing a reduction in peak flow and a broadening of flood wave.
INFILTRATION	• Double ring infiltrometer • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£100s	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Table 5.36: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION AREA AND ROUGHNESS	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Increase in roughness in buffer strip area comparative to surrounding area. This roughness is calculated by creating a 3D model of the buffer strip before and after the intervention and calculating the difference in the point clouds.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW HEDGEROW	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Mapping and comparison of channelized flow above/below buffer strip in 3D models before and after intervention. These changes would be identified by calculating the difference between the point clouds.
MOISTURE LEVEL ABOVE AND BELOW BUFFER STRIP	• Moisture probes • Computer & software to process data		Would give timeseries data, data download, battery replacement and cleaning frequency dependant on probe	Comparison of time series data above and below intervention to show a reduction in moister levels after the intervention.

WATER QUALITY ANALYSIS	• Bench top turbidity meter. • Computer & software to process data. • Sample bottles CAVEAT - Multiple farms feed into the colour and quality of a watercourse. Hard to untangle results as it may be an upstream issue, and the natural baseline of erosion affects results.	£1,000s upfront cost then low ongoing cost	After storm event.	Measured before and after intervention in place indicating a reduction in turbidity after storm events.
INFILTRATION	• Tension infiltrometer • Measurement cylinder/known volume of water. • Level • Sand And either • Notebook and pen to keep record. Or • Datalogger	£1000s and additional £1000s if using datalogger.	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Drone to record area of NBS intervention to calculate area, roughness and evidence of channelised flow.

5.15 Planting and Managing Trees

Table 5.37: Monitoring by landholder

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION HEIGHT AND WIDTH OF UNDERGROWTH	• Tape measure • Drop disc. • Ruler • Notebook and pen	£10s per farm	Annually at mid-summer maximum vegetation height.	Year 1: Presence of vegetation and initial height and width measurement. Year 2 onwards: Maintenance or increase on year 1 volume.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW TREES	• Photograph above and below trees using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph showing presence of channelized flow with ruler in the image for scale.

INFILTRATION	• Pipe • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£10's	Annually, set number of days after rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Table 5.38: Monitoring by ranger.

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION HEIGHT AND WIDTH OF UNDERGROWTH	• Tape measure • Drop disc. • Ruler • Notebook and pen	£10s per farm	Annually at mid-summer maximum vegetation height.	Year 1: Presence of vegetation and initial height and width measurement. Year 2 onwards: Maintenance or increase on year 1 volume.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW TREES	• Photograph above and below trees using smart phone with camera. • Internet to send photo. • Post to photograph from to ensure comparable field of view. • Ruler for scale	£100s per farm if buying smart phone	After storm event	Photograph showing presence of channelized flow with ruler in the image for scale.
REDUCTION IN FINE GRAINED SEDIMENT	• Munsell soil chart to identify sediment source. • Notebook and/or smart phone • Internet to send photo	£100s	After storm event	Either: Time series of water level taken from trail camera images showing a reduction in peak flow and a broadening of flood wave. Or Time series of water level taken from level sensor showing a reduction in peak flow and a

				broadening of flood wave.
INFILTRATION	• Double ring infiltrometer • Stopwatch • Measurement cylinder/known volume of water. • Notebook and pen to keep record	£100s	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Table 5.39: Monitoring by University/consultant

WHAT WOULD YOU MEASURE?	EQUIPMENT REQUIRED	COST	FREQUENCY	MEASUREMENT OF SUCCESS
VEGETATION AREA AND ROUGHNESS	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription • Computer & software to process data. CAVEAT – flying drone requires fair weather, flyers need training and A2 Certificate of Competency CAVEAT – drone can only fly underneath canopy or above treetops; suitability of method will depend on height of canopy	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Increase in roughness in buffer strip area comparative to surrounding area. This roughness is calculated by creating a 3D model of the buffer strip before and after the intervention and calculating the difference in the point clouds.
EVIDENCE OF CHANNELISED FLOW ABOVE AND BELOW TREES	• Drone • GPS and ground control points for scaling • SIM card in phone and NTRIP subscription	£10,000s upfront cost but low ongoing cost	Baseline and then annually at mid-summer maximum vegetation height	Mapping and comparison of channelized flow above/below buffer strip in 3D models before and after intervention.

	• Computer & software to process data. CAVEAT – flying drone requires fair weather; flyers need training and A2 Certificate of Competency			These changes would be identified by calculating the difference between the point clouds.
MOISTURE LEVEL ABOVE AND BELOW TREES	• Moisture probes • Computer & software to process data		Would give timeseries data, data download, battery replacement and cleaning frequency dependant on probe	Comparison of time series data above and below intervention to show a reduction in moister levels after the intervention.
WATER QUALITY ANALYSIS	• Bench top turbidity meter. • Computer & software to process data. • Sample bottles CAVEAT - Multiple farms feed into the colour and quality of a watercourse. Hard to untangle results as it may be an upstream issue, and the natural baseline of erosion affects results.	£1,000s upfront cost then low ongoing cost	After storm event.	Measured before and after intervention in place indicating a reduction in turbidity after storm events.
INFILTRATION	• Tension infiltrometer • Measurement cylinder/known volume of water. • Level • Sand And either • Notebook and pen to keep record. Or • Datalogger	£1000s and additional £1000s if using datalogger.	Before intervention (x days after rainfall) and then annually after x number of days of rainfall	Reduction in time taken for water to be absorbed by the ground before/after the intervention is installed.

Drone to record area of NBS intervention to calculate area, roughness and evidence of channelised flow.