The Demonstration Test Catchments Evidence Compendium

March 2020

The purpose of this evidence compendium is to synthesise, translate and disseminate the findings arising from the Demonstration Test Catchments programme to inform the work of policy professionals and groups who engage in catchment and farm management.

Department
for Environment
Food & Rural Affairs

How to use this compendium

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Pages 3–6 provide a background to Defra's Demonstration Test Catchments (DTC) research programme, followed by a summary of the key findings from the research on pages 7–15, with statements which link to detailed pages, indicated by an accompanying page number. Clicking on the tabs at the top of each page in the header bar enables quick navigation to the beginning of each section. It was not possible to include the full wealth of evidence and knowledge accumulated throughout the DTCs within this Evidence Compendium. For additional information on any of the topics, a list of resources have been included in the 'References' section at the end.

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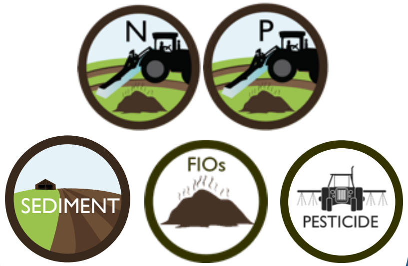

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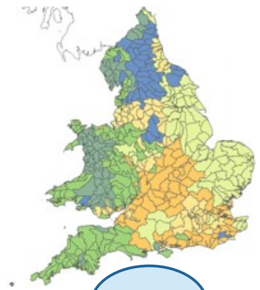

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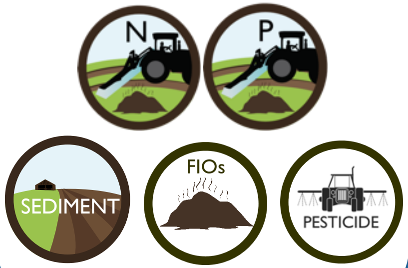

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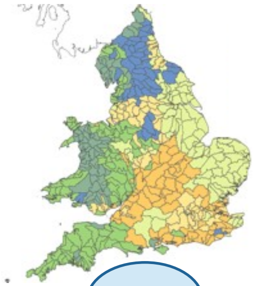
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Background: The challenge of diffuse pollution from agriculture

The different ways in which farmers can manage the land have both positive and negative impacts on the environment. The intensification of farming practices to meet rising demand for food has led to the export of a range of pollutants to both the atmosphere and freshwater systems in agricultural landscapes.

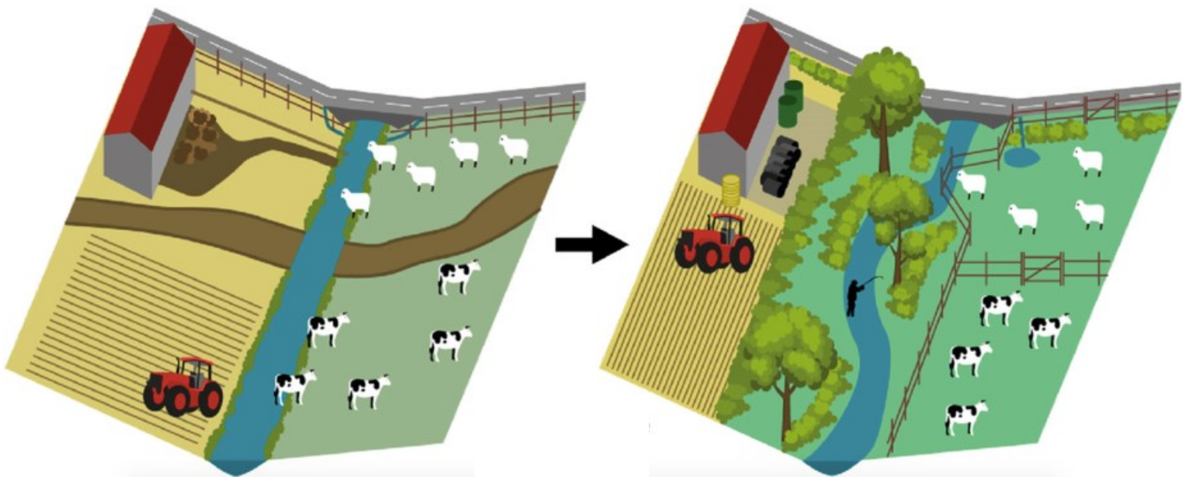
Agriculture is one of many influences on water quality and water-dependent ecosystems. It has an important role to play in meeting the Government's 25 Year Environment Plan goal of achieving 'clean and plentiful water', with 75% of waters close to their natural state as soon as is practicable.

The main agricultural pollutants are nutrients (nitrogen and phosphorus), pesticides and other agrochemicals, faecal bacteria, and soil (sediment). The negative impacts these can generate include eutrophication (the adverse ecological effects of excess nutrients), siltation of river gravels and damage to spawning habitat for fish, increased water treatment costs, damage to tourism and fisheries and impacts on human health.

Achieving reductions in agricultural pollutants whilst maintaining food production requires a combination of changes to the way that land is managed and the implementation of pollution mitigation measures to cost-effectively address the situation.

Historically, the lack of robust empirical evidence, from 1) real working farms and 2) at scales greater than plot trials, on the efficacy of on-farm interventions has been a major constraint on the design of effective pollution mitigation strategies at the landscape scale.

This is the challenge that the Demonstration Test Catchments Programme was established to address.



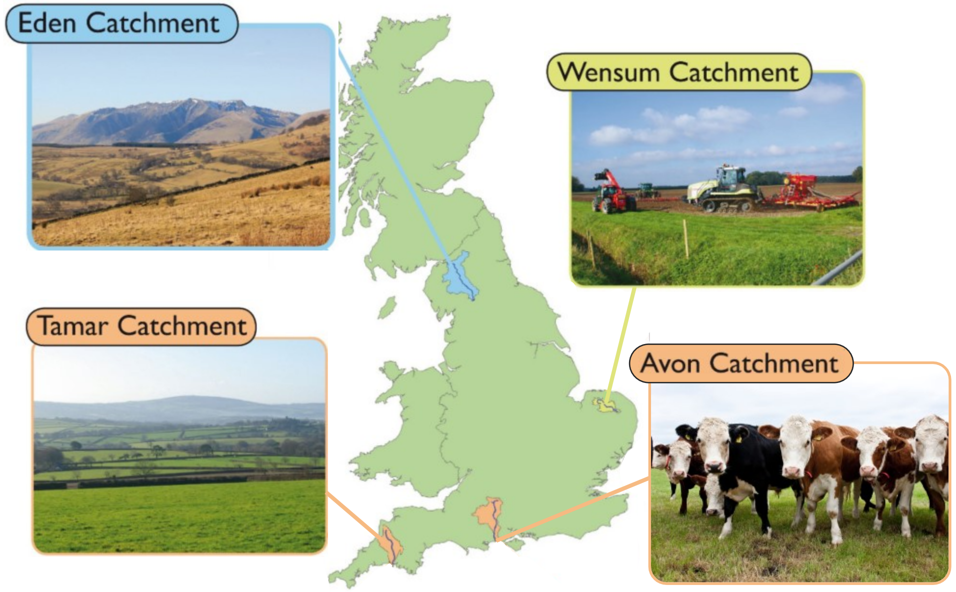
Graphical representation of example land management changes and mitigation measures.

Background: The Demonstration Test Catchments

The Demonstration Test Catchments (DTC) programme was commissioned by Defra with the aim of testing the hypothesis that it is possible to cost-effectively reduce the impact of pollution from agriculture on water body status, whilst maintaining sustainable food production through the implementation of on-farm mitigation measures.

The DTC programme was established to address the gap in empirical evidence on the cost-effectiveness of combinations of on-farm mitigation measures at catchment scales and to explore ways to bring science into stakeholder-led catchment management, demonstrating the use of local expertise to solve local problems.

This nationally coordinated programme of research ran from 2009 – 2019 and focused on four study catchments that represent the major farm types (i.e. arable, livestock, mixed) and the main rainfall and soil combinations across England and Wales.



The four Demonstration Test Catchments, showing their location in England.

	Eden (Cumbria)	Wensum (Norfolk)	Avon (Hampshire)	Tamar (Devon/ Cornwall)
Area/ km^2	2,288	677	1,750	1,800
Geology	Calcareous limestone, new red sandstone, igneous	Chalk, clay, quaternary sediment	Chalk, clay, greensand, gravels. Heavy, medium, sandy and light silty, chalk and limestone soils	Granite, sandstones, mudstones Heavy, medium, peaty soils
Elevation	Lowland - upland	Lowland	Lowland	Lowland
Rainfall (mm)	High (637-3,359)	Low (624-675)	Moderate (714-937)	High (1,000-2,000)
Farms type & avg. size	Lowland livestock; 96 ha	Arable, general cropping; 117 ha	Mixed; 94 ha	Intensive mixed livestock; 62 ha
Main Tenure	Tenanted	Owned	Partly owned and rented	Partly owned and rented
# of farms	2,523	614	1,218	2,602

An overview of the general catchment information (landscape and farm characteristics)

Background: The DTC strategy

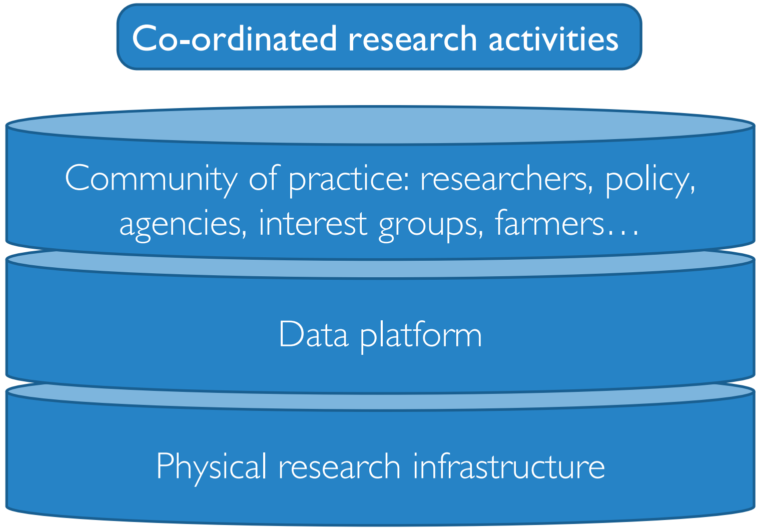
The four catchments were selected in order to build on existing infrastructure, datasets, knowledge and farming contacts developed through a variety of other initiatives, which were not previously well linked. Additionally, these catchments were also undergoing enhanced monitoring through the England Catchment Sensitive Farming Delivery Initiative.

The DTC programme had three main roles:

1. **A programme of linked and co-ordinated research projects:** to provide underpinning research, from farm to catchment scale, that informed policy and practical approaches for the reduction of agricultural diffuse pollution and the improvement of ecological status in freshwaters, whilst maintaining economically viable food production.

2. **A research platform:** to host longer-term collaborative research on diffuse pollution from agriculture, funded by multiple organisations. The aim was to establish a community of researchers and stakeholders enabling short and longer-term policy-relevant research questions to be answered, steering research and translating science into practice.

3. **A demonstration and co-ordination activity:** to demonstrate scientifically robust approaches to diffuse pollution mitigation and explore ways to bring science into stakeholder-led catchment management.



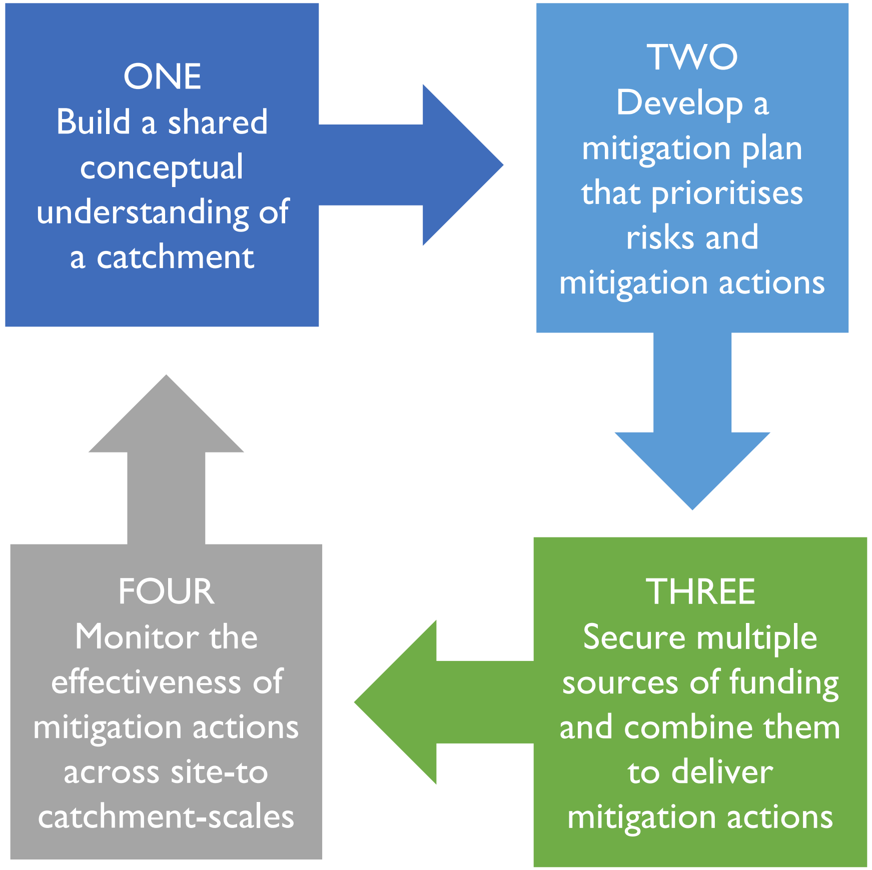
Components of the DTC. The platform consisted of a community of researchers who shared: an understanding of the issues; data; research sites and infrastructure.

Background: The DTC platform

The guiding principle of the DTC was that they should be the foundation for a collaborative 'research platform' upon which other research projects could draw and build.

1

The first phase of the DTC programme (2009–2014) involved establishing a research platform (building stakeholder relationships, finding sites, building conceptual models, installing monitoring equipment, designing on-farm interventions and undertaking baseline monitoring).



2

The DTC network also developed local communities of practice, particularly engaging researchers, farmers and other stakeholders (e.g. farm advisors, CaBA partnerships, Wildlife Trusts) in a process of collective learning about the functioning and management of their catchment systems, as well as providing advice on farm management.

3

The DTC network (2009-19) was supported by approximately £10 million of Defra funding in total. It has also leveraged over £2 million of additional support from other sources (e.g. the Natural Environment Research Council and the British Geological Survey).

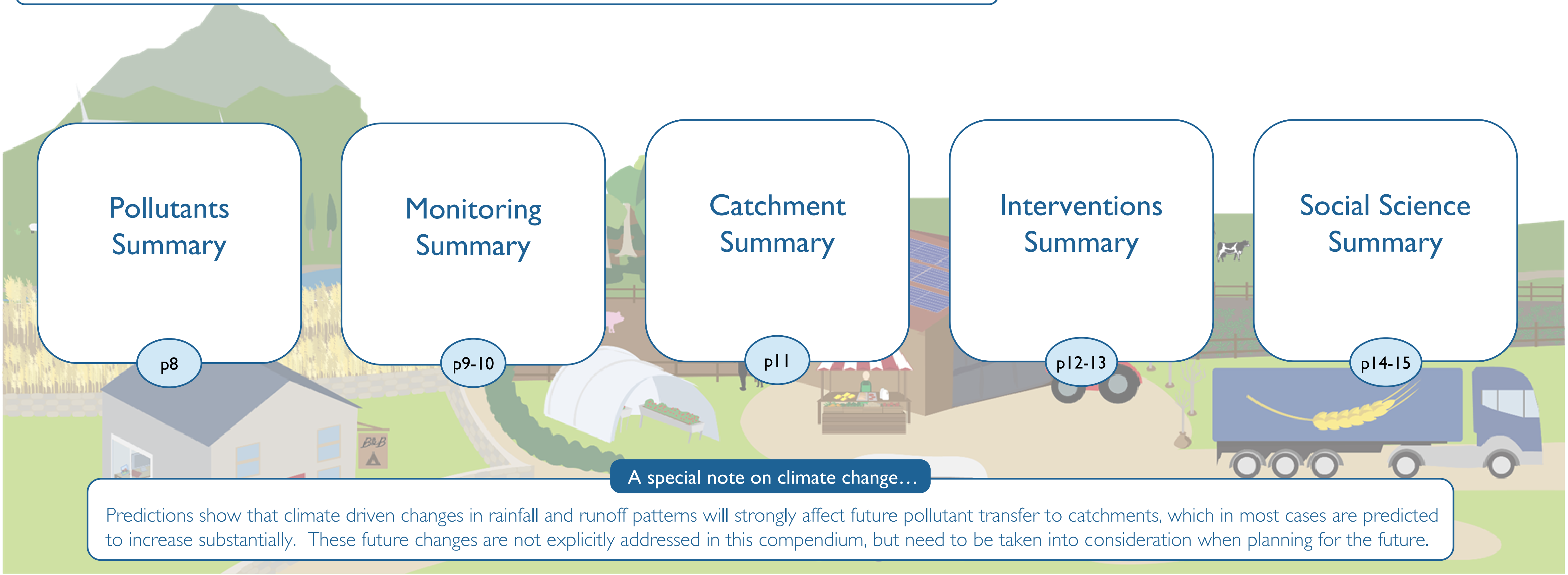
4

The second phase (2014–2017) was concerned with assessing the cost-effectiveness of on-farm mitigation measures at reducing agricultural diffuse water pollution.

Summary

What you will find in this section

This section provides the key messages collated from the entire DTC programme, providing links to the detailed pages.



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A special note on climate change…

Predictions show that climate driven changes in rainfall and runoff patterns will strongly affect future pollutant transfer to catchments, which in most cases are predicted to increase substantially. These future changes are not explicitly addressed in this compendium, but need to be taken into consideration when planning for the future.

Summary - Pollutants

Pollutants overview

The dominant pollution sources for arable farming systems are inorganic and organic fertilisers and pesticides, with farmyard manure being an important factor in livestock systems. Precipitation mobilises pollutants in-field which are transported to streams via overland flow, throughflow and along groundwater flow pathways. Pollutants are also delivered via field drains, roads, and farm tracks, and the voiding of animal wastes or overspray of fertilisers, manures and pesticides directly into watercourses.

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Nitrogen

Nitrogen (N) input into farm systems occurs via the application of nitrogen fertilisers, manure and slurry, and can also be fixed from the atmosphere. Dissolved forms of N are readily transferred into rivers either via leaching through the soil or by entering field drains. Particulate N is mobilised via soil erosion, sediment transport and the entrainment of surface dressed manures and slurries. Key concerns include drinking water contamination and the process of eutrophication.

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Phosphorus

Phosphorus (P) input into farm systems occurs via application of phosphorus fertilisers, manure and slurry application to fields, runoff from hardstanding areas and in some livestock systems, particularly dairy, from feed concentrates. P may be leached from soils, but more commonly is transported to watercourses via overland flow and field drains, attached to eroded soil particles. As with N, excess P in surface water bodies can lead to eutrophication, altering the ecological balance.

p19

Sediment

A wide variety of sediment sources exist across all farming systems. Vegetation, crop cover and soil factors are important influencing agents. Mobilisation occurs during precipitation events where sediment is transported as surface and sub-surface runoff before discharging into rivers where it acts as a major vector for the transport of P. Once the source of sediment is identified specific measures can be implemented to improve management.

p20

Faecal Indicator Organisms

Faecal Indicator Organisms (FIOs) are the key faecal derived pollutant from animal husbandry (directly via livestock effluent entering water bodies, and indirectly from slurry runoff). Channel bed sediment may act as a sink or source of FIOs depending on flow conditions. Turbidity and the time of travel are important to the longevity of FIOs. FIOs are important mainly for bathing water quality.

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Pesticides

Pesticides are potentially important issues in both arable and grassland dominated areas. Pesticides may transfer to rivers via drainage networks, from airborne spray drift, contaminated machinery washings and accidental spillages. They pose a significant threat to river water and groundwater quality. Pesticides are primarily degraded by biological action within the soil over time, unless they are spread directly to watercourses.

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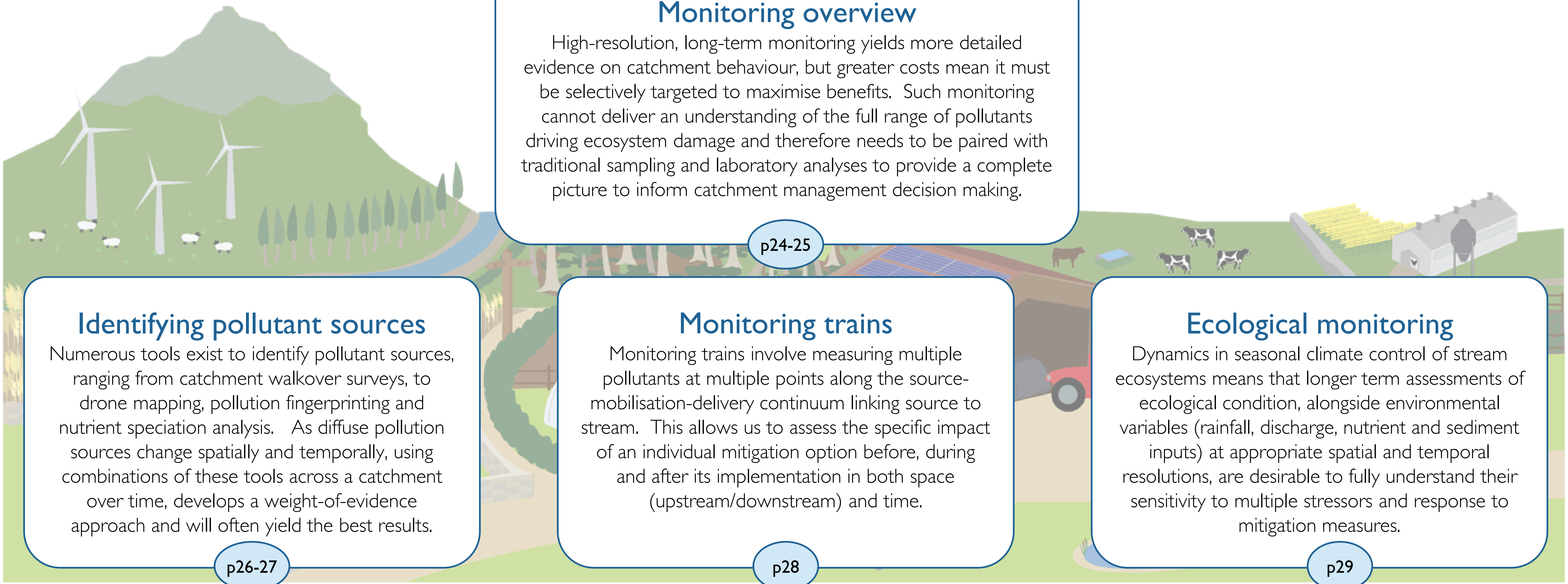
Summary - Monitoring 1



Monitoring overview

High-resolution, long-term monitoring yields more detailed evidence on catchment behaviour, but greater costs mean it must be selectively targeted to maximise benefits. Such monitoring cannot deliver an understanding of the full range of pollutants driving ecosystem damage and therefore needs to be paired with traditional sampling and laboratory analyses to provide a complete picture to inform catchment management decision making.

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Identifying pollutant sources

Numerous tools exist to identify pollutant sources, ranging from catchment walkover surveys, to drone mapping, pollution fingerprinting and nutrient speciation analysis. As diffuse pollution sources change spatially and temporally, using combinations of these tools across a catchment over time, develops a weight-of-evidence approach and will often yield the best results.

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Monitoring trains

Monitoring trains involve measuring multiple pollutants at multiple points along the source-mobilisation-delivery continuum linking source to stream. This allows us to assess the specific impact of an individual mitigation option before, during and after its implementation in both space (upstream/downstream) and time.

p28

Ecological monitoring

Dynamics in seasonal climate control of stream ecosystems means that longer term assessments of ecological condition, alongside environmental variables (rainfall, discharge, nutrient and sediment inputs) at appropriate spatial and temporal resolutions, are desirable to fully understand their sensitivity to multiple stressors and response to mitigation measures.

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Summary - Monitoring 2

Hydrochemical monitoring

Nitrogen, phosphorus and sediment are often essential parameters to monitor in agricultural catchments, although doing so at high-resolution using automated equipment entails considerable costs and maintenance commitments. Sensor systems can only measure a subset of the key variables and have a higher inherent uncertainty associated with the data they generate than quality assured laboratory analyses. A combination of the two is required to generate robust evidence for catchment managers.

p30-31

Hydrological monitoring

The delivery of pollutants to watercourses is closely linked to hydrological activity. It is therefore essential to monitor this in any catchment monitoring programme. The relative importance of overland versus groundwater pathways of diffuse pollutants into water bodies can vary substantially. This has implications for the types of environmental processes that need to be modelled or the sources that need to be addressed in any spatial targeting.

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Soil monitoring

Reliable characterisation of soil health requires measurement of a suite of soil physical, chemical and biological parameters. Soil water nutrient concentrations should also be measured at depth (0-90 cm) to determine rates of leaching into groundwater in permeable catchments and deep throughflow in impermeable catchments.

p33

Meteorological monitoring

High-resolution precipitation monitoring is essential for understanding storm event dynamics and modelling of catchment hydrological response times. Air temperature and net solar radiation data are also valuable for interpreting biotic cycles in fluvial hydrochemistry, calculating evapotranspiration rates and calculating soil moisture deficits.

p34

Social science data

Combining knowledge from both social and physical sciences substantially helps to provide a more robust evidence base for mitigation strategy development. Qualitative data supply rich snapshots of insights which facilitate opportunities to observe behavioural change and effectiveness of new policy mechanisms.

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Summary - Catchments

Catchments overview

England and Wales can be broadly divided into six groups of catchments (five predominantly agricultural, one urban). There are clear differences between groups with: 1) their physical environment, 2) the extent of arable and livestock farming and 3) the importance of agricultural pollutant sources implying that the applicability of mitigation measures is likely to vary.

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Midlands and South Coast

Relatively flat terrain and dry conditions, approximately even share of sand and clay in soils, and elements of both arable and livestock farming. This group is less well-represented by the DTC programme. Likely pollution issues include nitrogen, phosphorus, sediment, pesticides and FIOs where livestock farming is practiced.

p38

Eastern England

Also relatively flat and dry but with sandier soils and a greater presence of aquifers than in the Midlands and South Coast. Over 70% of land is in arable or permanent crops. Likely pollution issues include nitrogen, phosphorus, sediment and pesticides.

p39

Western Lowlands

A wetter climate than the Midlands, South Coast and Eastern England. This group has more pasture than arable land and high numbers of cattle. A multitude of likely pollution issues arise in west lowland catchments: nitrogen, phosphorus, pesticides and FIOs.

p40

Western Uplands

Steep slopes and high rainfall, dominated by poor quality agricultural land, forest and semi-natural land cover. Distinguished by higher proportions of land in designated nature reserves, AONBs and National Parks, and slightly lower farm business incomes. Likely pollution includes nitrogen, phosphorus, sediment and FIOs.

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Upland Northern England

Similar to the Western Uplands on many variables, but with a much greater extent of aquifers, more arable land or pasture and higher numbers of cattle. Likely pollution issues include nitrogen, phosphorus, sediment and FIOs.

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Summary – Interventions 1

Interventions overview

Choosing where and which measures to install is an iterative process of synthesising knowledge and evidence, alongside negotiation with the farmer/landowner. The treatment train approach maximises protection by addressing the key stages in the pollution delivery continuum.

p44

Winter cover crops

Cover crops on arable land can significantly reduce nitrate leaching losses by up to 97%, with the potential for the crop to act as a 'green manure'. Farmer attitudes to cover crops have changed over recent years and uptake is becoming more common. The main disadvantages include additional costs, difficulties in destruction before sowing cash crop and pest problems under certain conditions.

p45

Conservation tillage

Conservation tillage does not appear to significantly improve the short-term environmental sustainability of farming practices in lowland intensive arable systems. However, improvements in farm business performance from operational efficiency savings and improved yields demonstrate land managers can make important financial gains by converting to a conservation tillage system.

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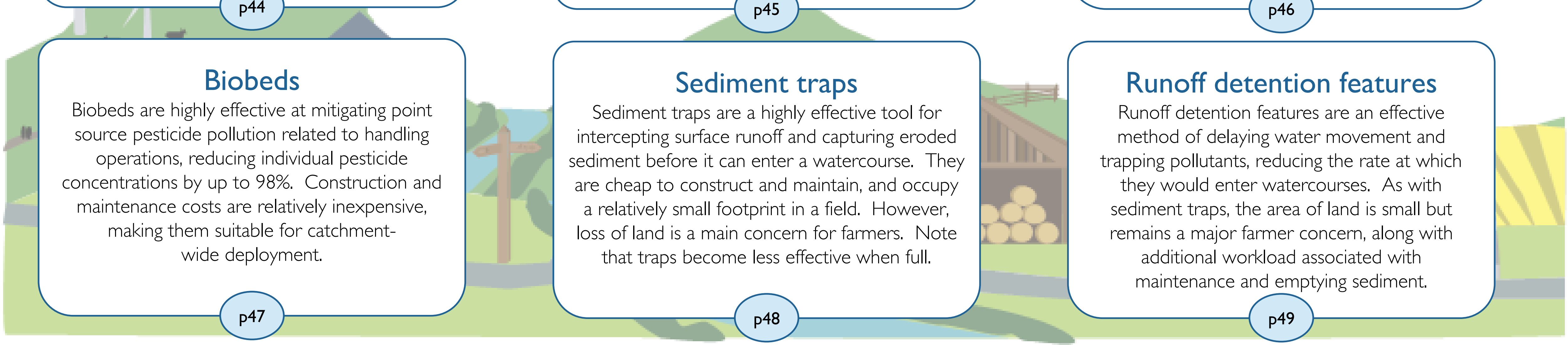

Biobeds

Biobeds are highly effective at mitigating point source pesticide pollution related to handling operations, reducing individual pesticide concentrations by up to 98%. Construction and maintenance costs are relatively inexpensive, making them suitable for catchment-wide deployment.

p47

Sediment traps

Sediment traps are a highly effective tool for intercepting surface runoff and capturing eroded sediment before it can enter a watercourse. They are cheap to construct and maintain, and occupy a relatively small footprint in a field. However, loss of land is a main concern for farmers. Note that traps become less effective when full.

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Runoff detention features

Runoff detention features are an effective method of delaying water movement and trapping pollutants, reducing the rate at which they would enter watercourses. As with sediment traps, the area of land is small but remains a major farmer concern, along with additional workload associated with maintenance and emptying sediment.

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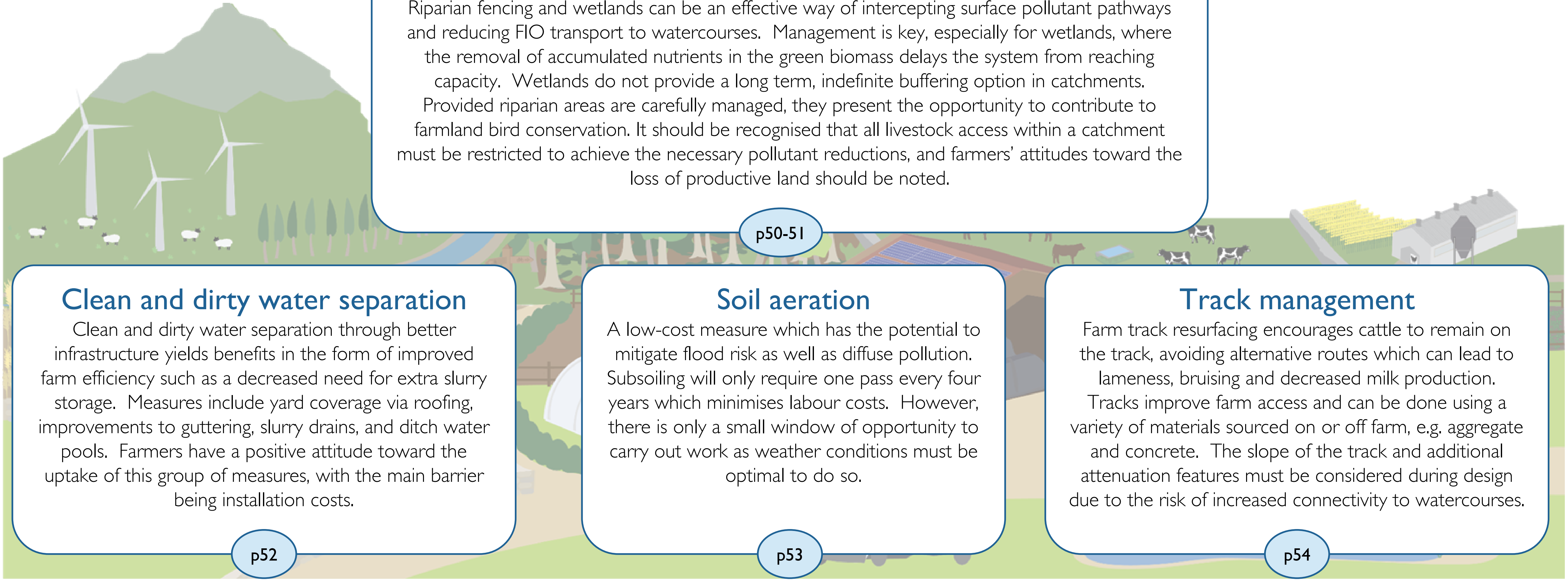
Summary - Interventions 2



Riparian fencing and wetlands

Riparian fencing and wetlands can be an effective way of intercepting surface pollutant pathways and reducing FIO transport to watercourses. Management is key, especially for wetlands, where the removal of accumulated nutrients in the green biomass delays the system from reaching capacity. Wetlands do not provide a long term, indefinite buffering option in catchments. Provided riparian areas are carefully managed, they present the opportunity to contribute to farmland bird conservation. It should be recognised that all livestock access within a catchment must be restricted to achieve the necessary pollutant reductions, and farmers' attitudes toward the loss of productive land should be noted.

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Clean and dirty water separation

Clean and dirty water separation through better infrastructure yields benefits in the form of improved farm efficiency such as a decreased need for extra slurry storage. Measures include yard coverage via roofing, improvements to guttering, slurry drains, and ditch water pools. Farmers have a positive attitude toward the uptake of this group of measures, with the main barrier being installation costs.

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Soil aeration

A low-cost measure which has the potential to mitigate flood risk as well as diffuse pollution. Subsoiling will only require one pass every four years which minimises labour costs. However, there is only a small window of opportunity to carry out work as weather conditions must be optimal to do so.

p53

Track management

Farm track resurfacing encourages cattle to remain on the track, avoiding alternative routes which can lead to lameness, bruising and decreased milk production. Tracks improve farm access and can be done using a variety of materials sourced on or off farm, e.g. aggregate and concrete. The slope of the track and additional attenuation features must be considered during design due to the risk of increased connectivity to watercourses.

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Summary - Social Science I

Social science overview

DTC research paid particular attention to the importance of different types and sources of information, as well as the scope for facilitating social learning amongst groups of farmers, because wider evidence suggests increased understanding, awareness and a shift in social norms are important for increasing uptake of mitigation measures.

p56

Farmer behaviours

Farm practice surveys help improve the reliability of decision support tools as well as guide intervention strategies needed to address low uptake of specific mitigation measures. Behaviours change over time, therefore repeatable surveys are required to capture such alternations.

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Farmer attitudes

There is currently no established norm within the farming community which encourages the proactive adoption of steps to deliver pollution mitigation. A significant shift in farmer identities and beliefs is likely to be required before water pollution mitigation behaviour becomes embedded.

p58

Farmer motivations

Differing complexities of decision processes for the adoption of mitigation measures imply the need to consider each measure separately and take account of the diversity in farming contexts which exist when designing policy interventions. Considering the entire decision process and supporting interventions at multiple stages can help to accelerate adoption.

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Farmer barriers

Barriers vary greatly between farms and mitigation measures. Policy interventions for measures which have internal barriers need to focus on changing social norms and attitudes and will often take a longer time to successfully change behaviours. Measures with external constraints require efforts which alter such restrictions.

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Summary - Social Science 2

Farm advice delivery

Advice must be consistent and delivered from a trusted source. Improvements to communication and co-ordination amongst advisors are required to provide farmers with efficient, clear and effective advice, along with the need for farm advisor continuity.

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Attitudes to advice

To disseminate advice effectively it is essential to appreciate who farmers listen to in each area and why, as farmer attitudes towards advisors varies across catchments, with different attributes being of importance. Ensuring funds are targeted towards organisations with well-established farmer relationships helps deliver government advice through intermediaries.

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Farmer engagement

Providing demonstration sites, training, research platforms, facilitated discussion groups and catchment data engages farmers at a local level. Encouraging farmers to initially change relatively simple measures rather than suggesting complex interventions is likely to result in longer-term receptiveness towards more challenging integrated activity.

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Farmer networks

There is scope to facilitate collaboration between farmers and to aid social learning, but in order to do so, resources are required. An external facilitator is needed, who is known and trusted by the famers and has the ability to organise and run meetings.

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Catchment community

The complexities and trade-offs associated with catchment management require an adaptive management cycle, collaboration between agencies and a 'twin-track' of stakeholder engagement alongside scientific research.

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Catchment governance

The status and role of catchment partnerships needs outlining and reinforcing, with long-term funding available to employ a full-time post in each catchment. Information exchange needs improving, with the sharing of resources and experiences aiding success. Partnerships are helping to facilitate co-operation and social learning to improve catchment management.

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Pollutants

What you will find in this section

This section provides information on the five types of pollutants examined in the DTC programme. For each pollutant, a description is provided regarding 1) the sources, mobilisation and delivery of the pollutant, 2) the environmental concerns associated with it and 3) interventions.

Pollutants overview

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Nitrogen

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FIOs

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Pesticides

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Pollutants overview

What is the problem?

To achieve 'good ecological status' in UK waters under the EU Water Framework Directive, and sustain habitats in favourable condition under the EU Habitats Directive, it is necessary to reduce pollutants entering rivers where agricultural practices are a significant contributory source and pose challenges to meeting compliance targets. The dominant pollution sources and pathways identified across the arable and livestock systems of the DTC programme are shown in the table to the right, highlighting the importance of nitrogen, phosphorus, sediment, faecal indicator organisms (FIOs) from organic manures and pesticides as key pollutants from agriculture.

Across England and Wales, agriculture is estimated to account for 75% of nitrogen export to the water environment, and 20-30% of phosphorus nationally, with significantly higher contributions in rural catchments. The contributions from different sources vary across and within river basins and catchments and for mitigation to be effective it needs to be targeted at the key sources and stressors driving ecosystem damage in the system.

	Arable Farming	Livestock Farming
SOURCES of key pollutants	• Inorganic N and P fertiliser • Organic fertilisers incl. imported slurries • Pesticide spraying • Farmyards & hard standing • Compacted crop fields e.g. maize, sugar beet or potatoes • Damaged road verges • Eroding river channel banks	• Farmyard manure • Slurry/dirty water • Farmyards & hard standing • Damaged road verges • Compacted and poached grassland topsoils • Poached and eroding river channel banks
MOBILISATION of key pollutants	• Precipitation induced leaching through soil (N and pesticide) • Precipitation induced splash detachment and surface runoff (P and sediment) • Solubilisation (N and P) • Incidental losses (e.g. pesticide applications)	• Precipitation induced leaching through soil (N and pesticide) • Precipitation induced splash detachment and surface runoff (P and sediment) • Solubilisation (N and P) • Incidental losses (e.g. pesticide applications)
DELIVERY of key pollutants	• Subsurface field drains • Impermeable metalled roads (P and sediment) • Shallow subsurface quickflow / throughflow (N and pesticides) • Overland flow on compacted soils /tramlines • Groundwater flow (N and P)	• Subsurface field drains (N, P and sediment) • Impermeable metalled roads (P and sediment) • Shallow subsurface quickflow / throughflow (N and P) • Farm tracks • Overland flow on compacted soils • Groundwater flow (N and P)

Nitrogen

Source – Mobilisation – Delivery

- Nitrogen (N) input into intensive arable and grassland systems occurs through the application of inorganic nitrogen fertilisers to crops, primarily during the early growing season (March–April). In livestock systems, N is also added in organic form as manure or slurry amendments to grassland.
- Dissolved forms of N are highly mobile and are readily transferred into rivers either via leaching through the soil matrix (throughflow) or by entering subsurface agricultural field drain networks which act as preferential pathways for the direct discharge of N enriched water into the river system (quickflow).
- Instream nitrate concentrations are commonly diluted during precipitation events, peaking several hours/days post-event as nitrate slowly leaches through the soil (throughflow) into the water course.
- Significant fluxes of particulate organic N (PON) originating from livestock manures and slurries are also mobilised and delivered along overland flow pathways activated during rainfall events.
- N may also enter the environment from direct discharge of organic wastes to streams from slurry lagoons, poorly maintained farmyards and drainage ditches.

Image: EA

Image: Phil Haygarth

Environmental and human health concerns

- Excess N in surface water bodies can lead to eutrophication in estuarine and coastal waters, and some freshwaters (particularly lakes), altering the ecological balance and driving biodiversity loss. N concentrations in excess of 2-4 mg/L Total N are considered to be damaging to freshwater ecosystems, although there are no official standards currently.
- A key human health concern is the leaching of N to drinking water supplies in the form of nitrate. EU Directive 91/676/EEC sets a threshold for acceptable levels of N in groundwater at 11.3 mg/l as nitrate-N.
- Nitrogen in the form of nitrous oxide (N_2O) is a very potent greenhouse gas (GHG) with a warming potential about 300 times that of carbon dioxide. N_2O emissions arise from the breakdown of fertilisers and manures (~33%), and from leaching and runoff (~26%). Improvements in agricultural practice have reduced losses from fertilisers but emissions of N_2O account for for 38% of the agricultural total (CO_2 equivalent) as compared with 36% for ruminant digestive emissions.

Reducing nitrogen pollution

Prevention through reducing N use in farming systems and increases in N use efficiency on farm through modifications to farming practice will reduce the N flux to both environment and drinking water supplies. Nitrogen use efficiency can be driven up by calculating the N balance at farm scale, taking into account N input from fertilisers alongside N in manures and slurries, and N fixed by legumes in crop rotations, alongside accumulated soil N pools. Careful control of frequency / timing will prevent over-application of nitrogen fertilisers in excess of crop requirements.

Phosphorus

Source – Mobilisation – Delivery

- Sources of phosphorus (P) to all farms come from inorganic fertiliser application. In livestock systems, some P also comes into the system with animal feed concentrates. P concentrations in manures and slurries are high.
- Mobilisation of phosphorus can be through physical detachment, solubilisation and incidental losses. Phosphorus binds strongly with clay minerals and metal oxides in soils to form comparatively low-mobility particulate phosphorus (PP) compounds, which are thus commonly mobilised via physical detachment of particles from soils during rainfall. Solubilisation also occurs and is dependant on fertiliser application history and soil pH and chemical-biological conditions. The reactivity of P means it is subject to immobilisation and re-mobilisation processes, such as sorption and desorption. Incidental losses occur when application of manure or fertiliser coincide with rainfall and runoff.
- Delivery of phosphorus varies depending on mobilisation process, but generally fast flows via surface runoff in high rainfall events are important. Slower subsurface delivery via leaching can also be significant in certain hydrogeological conditions. Once instream, P concentrations commonly exhibit a flashy response to storm events with little lag between peak discharge and highest P concentration, a characteristic linked to the rapid activation of surface runoff pathways. Due to its sorption onto soil particulates, riverine PP concentrations are often strongly correlated with sediment concentrations and discharge.

Images: Penny Johnes

Environmental and human health concerns

- P attaches readily to soil particles and enters watercourses via runoff, but slower percolation processes are also significant in the long term and can contribute to P pollution in groundwater.
- Excess P in surface water bodies can lead to eutrophication and a reduction in dissolved oxygen, leading to biodiversity loss. 55% of assessed river water bodies and 73% of assessed lake water bodies in England fail the current WFD phosphorus standards for good ecological status which aim to prevent eutrophication. The damage costs of freshwater eutrophication in England and Wales were calculated to be £75.0-114.3m p.a.
- Unlike nitrate, the amount of phosphate in drinking water is not regulated, though the World Health Organisation has provided a maximum 'safe' level of around 5 mg per litre. High levels (above 100 mg/l) can adversely affect processes in water treatment works.

Reducing phosphorus pollution

As with N, where P originates from agricultural sources, good farm management is key to reducing pollution. Examples include improving nutrient use efficiency by adding P as a fertiliser in balance with the P already accumulated in soil, or added in the form of manures and slurries, and practices which minimise soil erosion and sediment transport.

Sediment

Source – Mobilisation – Delivery

- A wide variety of sediment sources exist in both arable and livestock systems, including but not restricted to: soil erosion of fallow fields with bare ground; heavily poached pasture top soils; runoff from compacted soils; livestock poaching of stream channel banks and disturbance of the streambed; under-maintained poached farm tracks and field gateways; and damaged road verges on narrow rural lanes.
- Evidence suggests most fine-grained sediment is mobilised during precipitation events from source areas (e.g. hardstandings for sugar beet storage/ livestock feeding stations) and is transported as both surface runoff along tramlines, metalled roads, farm tracks or ditches and as sub-surface runoff via field drains before discharging into rivers.
- Once instream, suspended sediment (SS) concentrations are typically positively correlated with river discharge, indicating that quickflow processes dominate.
- Changes in hysteresis behaviour exhibited during precipitation events can indicate whether sediment originates from local (e.g. channel banks or bed) or distal (e.g. poached fields) sources.
- Vegetation, crop cover and the soil type, structure, condition and the way it is managed are important factors for sediment mobilisation.

Image: Adrian Collins

Sediment around the UK, 8th April 2017.
Image by Dundee Satellite Receiving Station

Environmental and human health concerns

- Sediment, suspended in a water course, acts as a major vector for the transport of phosphorus through a catchment, and hence plays a key role in the development of eutrophic conditions and the rate of primary productivity in waterways.
- Sediment also impacts on all key trophic levels in rivers: diatoms; macroinvertebrates; macrophytes and fish, e.g. through choking fish spawning gravels.

Reducing sediment pollution

As the sources of fine-grained sediment problems in river systems are primarily diffuse (but point sources do exist in a distributed manner), it is essential to assemble catchment scale information for informing management strategies. Sediment source tracing procedures have increasingly been adopted in this respect.

Once the source is traced, specific local measures can be targeted and put in place to improve soil management and increase filtration.

For example, sediment ponds can be installed where loss is directly from arable fields, fencing can be deployed where the source is river bankside poaching by livestock and cover crops can be planted to protect soil over winter.

Faecal Indicator Organisms

Source – Mobilisation – Delivery

- Faecal indicator organisms (FIOs) are a group of easily detectable micro-organisms (faecal coliforms and E. coli) that infer the presence of a pathogen in a water body. They are the key faecal derived pollutant from animal husbandry (directly via livestock effluent entering rivers and streams, and indirectly from slurry/manure runoff).
- Channel bed sediment may act as a sink for FIOs under low flow conditions and be a source of FIOs during high flow events. The main controlling factor for FIOs is exposure to sunlight (UV-B), hence, turbidity and the time of travel are important aspects to their longevity.
- Empirical evidence on the relative significance of FIOs derived from direct inputs resulting from livestock access to watercourses versus diffuse sources is poor in the UK.

Relative FIO risk from different agricultural sources

Source	Risk level	Description
Farm tracks (between grazing and milking parlour)	High	High traffic and deposition of fresh excreta. Especially high risk where a direct route to a watercourse exists.
Farmyards and hard standings/heaps	High	High traffic and concentrated fresh excreta. Especially high risk where runoff is not contained.
Grazing livestock	Medium	Distributed fresh excreta, mitigated by die-off. Dependent on drainage/runoff. Risk is low shortly after livestock are removed.
Manure Spreading	Medium	Mitigated by rapid die-off of FIOs in stored excreta. Dependent on drainage/runoff.
Livestock direct access to watercourse	Medium	Mitigated by relatively small input and time spent in river. Regular river crossings are high risk and reflected in farm track risk.
Field storage heaps	Low/ inconsistent	Mitigated by rapid die-off of FIOs. Assumed heaps are sited away from watercourses with no direct entry path.
Roofs	Low	Relatively uncontaminated source.

Environmental and human health concerns

- FIOs are important mainly for bathing waters where they are a major cause of water quality failure in the UK, though the situation is improving. In 2017 only 1.7% of bathing waters in England were designated as 'poor'.
- There are 96 designated Shellfish Waters. Compliance with guideline microbial standard in shellfish flesh has varied between 13% and 23% since 2014. Relationship between microbial pollution in water and in shellfish flesh is extremely complicated.
- The standards are 10,000 total coliforms per 100ml water, and 2,000 faecal coliforms per 100ml water for surface water.

Reducing FIO pollution

Measures to restrict both direct and indirect livestock access to water courses help to reduce the input of FIOs.

Fencing waterways to prevent livestock access and providing alternative drinking water via mains or pump-fed fed troughs is the preferred solution.

Pesticides

Source – Mobilisation – Delivery

- The handling and application of pesticides to crops represents a significant diffuse pollution pressure in intensive arable systems.
- Livestock systems use grassland herbicides and veterinary medicines (e.g. insecticides).
- The dominant diffuse pathways for pesticide transfer from land into rivers during application are via leaching into subsurface drainage networks and from airborne spray drift.
- Agricultural point source pesticide pollution arising from contaminated machinery washings and accidental spillages poses a significant threat to river water and groundwater quality.
- Many pesticides are soluble and applied with water so they can be absorbed by the pest organism. The more soluble the pesticide, the higher the risk of leaching. Herbicides are generally of lower solubility to aid soil binding but are more persistent in the soil.
- Most pesticides adsorb strongly to organic matter in the soil – high organic matter will help to retain the pesticide within the soil. Strongly adsorbed pesticides are less likely to move with drainage water.
- Pesticides are primarily degraded by biological action within the soil over time. This is largely controlled by temperature, moisture and oxygen levels so pesticides are persistent in the winter months or if the soil is waterlogged. Volatilisation and photo-decomposition are generally secondary in importance to soil degradation.

Image: Richard Cooper

Environmental and human health concerns

- Pesticides are targeted at agricultural pests (insects, weeds, fungi etc) that affect both crops and livestock. The use, application and handling of pesticides is therefore strictly regulated.
- Pesticides can contaminate rivers and groundwaters and challenge drinking water treatment processes. The standard for all pesticides in treated drinking water at the tap is 0.1 µg/l.
- Pesticides generally bind strongly to soil and degrade fairly rapidly. If residues enter rivers or especially groundwater they can be much more persistent.

Reducing pesticide pollution

Good agricultural management practices can minimise pesticide pollution. For example, providing an enclosed wash-down facility for cleaning contaminated machinery, biobed and drainage field. Reducing overland flow and trapping sediment can also reduce sediment-bound pesticide pollution in waterways.

Monitoring

What you will find in this section

This section describes the wide variety of monitoring techniques used during the DTC programme to provide a comprehensive understanding of the hydrogeochemical, meteorological, pedological and social characteristics of each of the study sub-catchments.

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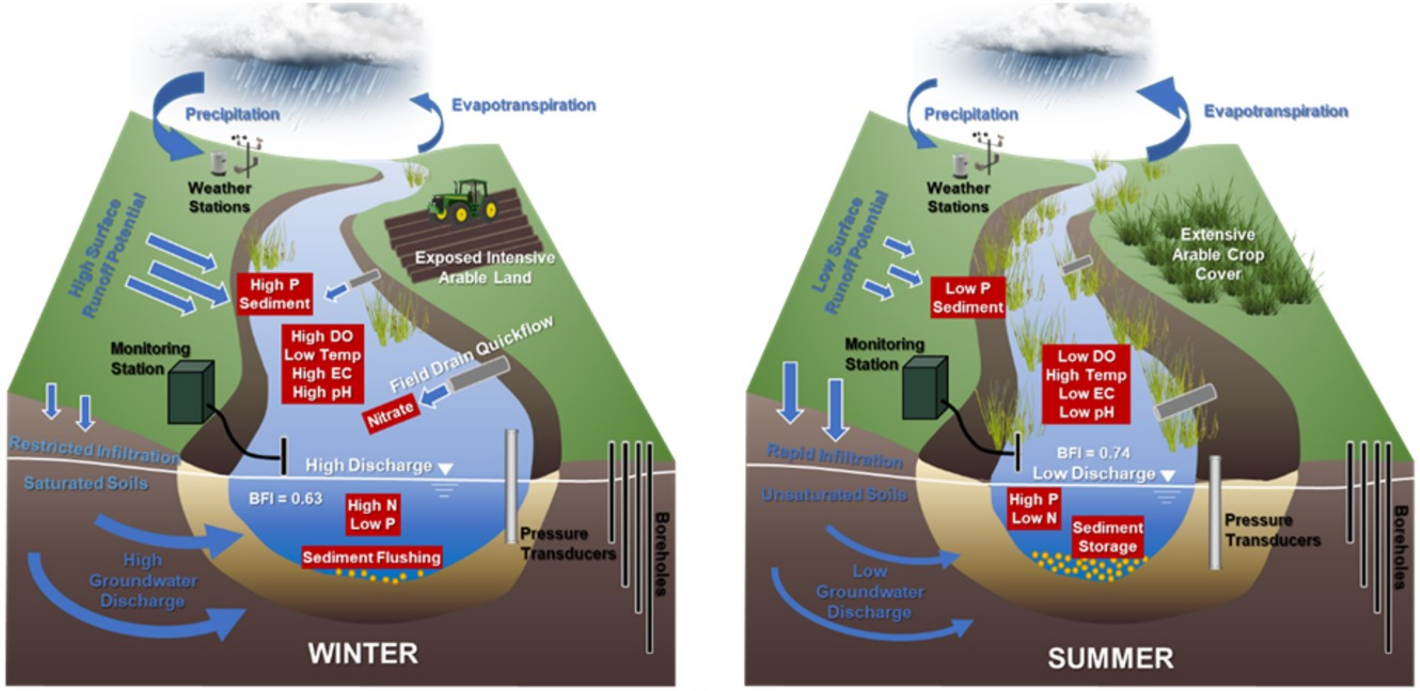
Monitoring overview I

What considerations need to be made when designing a monitoring scheme?

1 **Catchment characteristics** are important to consider as they strongly influence catchment dynamics. Properties such as land use, soil type, topography, geology and climate all influence hydrological functioning.



2 **The purpose of the monitoring** determines the appropriate temporal and spatial resolution required and the parameters to be monitored. For instance, identification of pollution sources and pathways, intervention effectiveness or even just a snapshot of the existing state.

3 Determine parameters of choice

Water quality
- ✓ conductivity
- ✓ pH
- ✓ turbidity or suspended solids
- ✓ pesticides
- ✓ dissolved oxygen
- ✓ nitrate
- ✓ ammonium
- ✓ total nitrogen
- ✓ soluble reactive phosphorus
- ✓ total phosphorus

Hydrology
- ✓ discharge
- ✓ stage
- ✓ groundwater level

Meteorological
- ✓ precipitation
- ✓ temperature
- ✓ relative humidity
- ✓ net solar radiation
- ✓ wind speed
- ✓ wind direction

Soil
- ✓ soil water quality
- ✓ bulk density / infiltration
- ✓ nutrients
- ✓ soil biology
- ✓ erosion

Water ecology
- ✓ diatoms
- ✓ invertebrates
- ✓ macrophytes
- ✓ fish

Monitoring overview 2

What considerations need to be made when designing a monitoring scheme?

4 Monitoring resolution

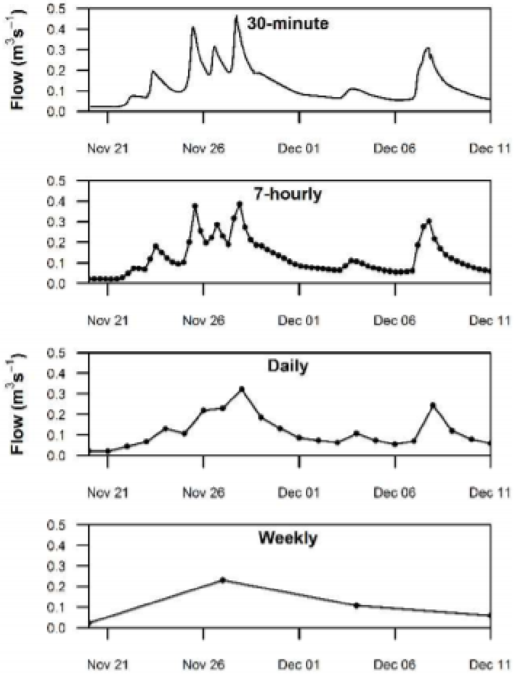
High-resolution

+ Can reveal the intricate dynamics of storm-dependent pollutant transfers.
+ Can identify periods of pollutant mobilisation and storage.
+ Can determine pollution pathways and help to calculate catchment response times.
+ Provides insights into the likely catchment sources contributing to pollutant flux.
+ Potential to develop and help refine conceptual models of hydrochemical processes.
+ Powerful tool for landowner engagement.
- High capital costs of installing, maintaining and running instrumentation.
- Difficult to provide mains power for in situ sensors.
- Can be unreliable leading to data gaps.
- High labour costs of maintenance and data processing (data volume difficult to handle/ interpret).
- Does not include a number of the key water quality parameters of interest.
- Higher levels of uncertainty associated with data compared to quality assured laboratory analyses.

Low-resolution

+ Cheaper than high-resolution monitoring.
+ Quicker to conduct and easier to deploy over a wider geographical area.
+ Lower uncertainties with data when paired with a quality assured laboratory analysis platform.
+ Includes all parameters of interest as not reliant on sensor technologies.
+ Often reliable over the long term.
+ Provides important information on the underlying background state and a useful benchmark with which to compare between sites monitored at a comparable resolution.
- Fails to capture the full range of pollutant concentrations and waterbody conditions, leading to a systematic bias in water quality interpretation.

5 Choice of equipment needed is determined by the purpose, parameters and resolution.



Difference in data from various temporal resolutions

High resolution monitoring

Low resolution monitoring

Key message

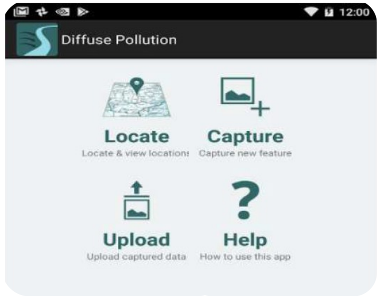
High-resolution, long-term monitoring yields more detailed evidence on catchment behaviour, but greater costs mean it must be selectively targeted to maximise benefits. Such monitoring cannot deliver an understanding of the full range of pollutants driving ecosystem damage and therefore needs to be paired with traditional sampling and laboratory analyses to provide a complete picture to inform catchment management decision making.

Identification of pollution sources I

Which techniques help identify pollution sources?

Catchment walkover surveys are a very simple, yet effective, river corridor assessment which involve walking along the length of a river searching for signs of water pollution and tracing the pollutants back to their source. Surveys need to be repeated as one-offs give biased results in many cases. Issues need to be visible and rivers need to be accessible (often they aren't).

Image: Steve Dugdale

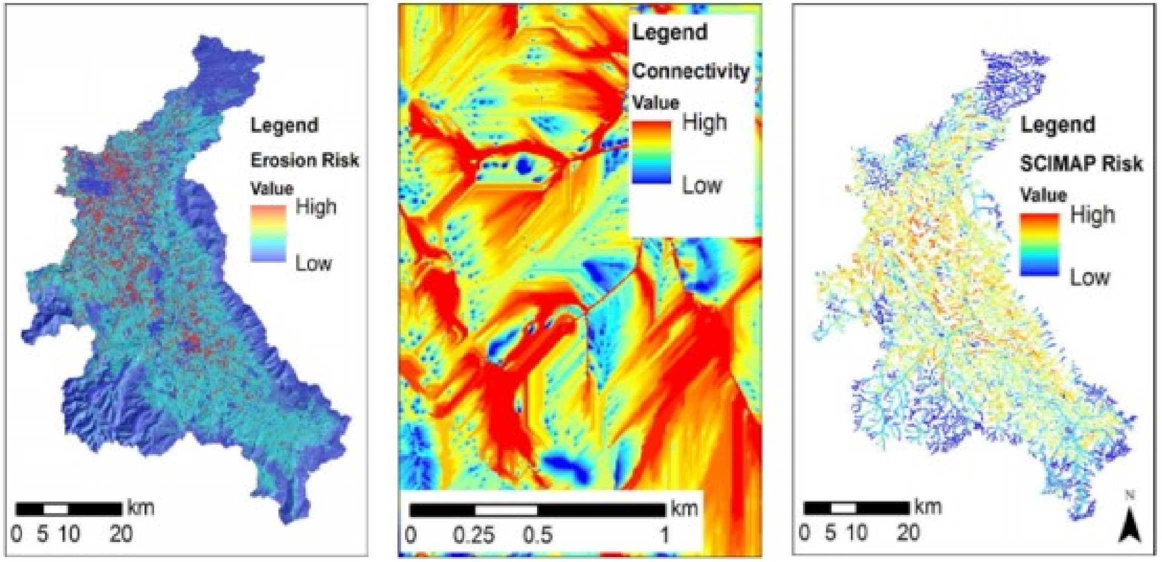


The use of a 'Diffuse pollution' app enables the information gained from walkovers to be captured in an efficient way. Multiple data records may be captured in the catchment and stored off-line, enabling app use in rural areas with little or no mobile network coverage.

Drone mapping produces highly detailed terrain and land cover information (resolution of ~0.01m) to help identify small scale features that may contribute to diffuse pollution risk within a catchment. It also provides an opportunity to produce time series of changing vegetation patterns and associated erosion risk and hydrological connectivity.

Images: Sim Reaney

Risk-mapping tools help predict where within catchments and large landscapes, diffuse pollution is most likely to originate. Two examples include: **SCIMAP** which creates maps by calculating the spatial pattern of erosion risk, based on land cover, rainfall patterns and terrain analysis, and the hydrological connectivity. These datasets are then combined to map the location of the source areas, where there is both a source of pollution and a good hydrological connection to the river channel; **ALERT** which uses the remotely sensed data and high-resolution LIDAR flow routes.

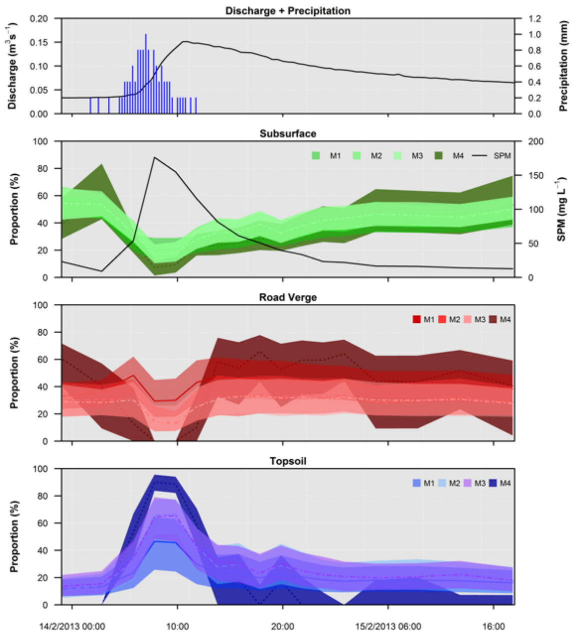


Examples of SCIMAP models

Identification of pollution sources 2

Which techniques help identify pollution sources?

Sediment fingerprinting is a catchment science tool for estimating the contributions from various eroding terrestrial sources to fluvial sediment load via a mixing model approach. The technique relies on selecting appropriate markers or 'fingerprints' that are transported from eroding source areas to the river 'target' in a reliable manner through well understood biotic or abiotic pathways. This technique can help to identify sediment contributions from sources such as arable topsoils, stream channel banks, forests, grassland, road verges, urban areas and contrasting geological zones. If used in combination with high-resolution monitoring equipment, it can help to identify the sources of eroding sediment during the progression of heavy rainfall events.

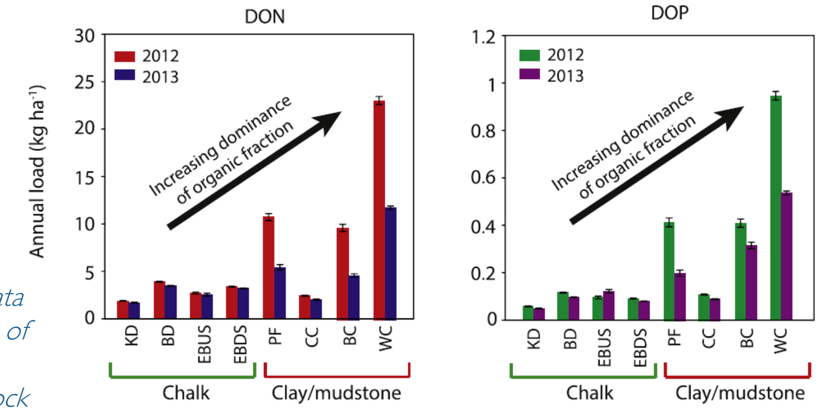


Sediment fingerprinting results for a heavy rainfall event

Nutrient speciation analysis is an approach which allows the catchment manager to estimate the relative proportion of nutrient loading in the river derived from primarily organic, sediment or inorganic solute sources in the catchment.

The inorganic nutrient species are soluble reactive phosphorus (SRP), nitrate, nitrite and ammonium, typically associated with fertiliser applications to crops and grass in a catchment, but also found in manures and slurries. The organic forms are dissolved organic N (DON), and P (DOP), and particulate organic N (PON) associated with the production and management of livestock wastes in the form of manures and slurries stored in yards, or directly voided to grazing land or even to watercourses where livestock have direct access to streams for watering. Particulate P comprises the largest portion of P delivered to most waters in the UK from agricultural land via the process of soil erosion and sediment transport.

Analysis of the balance between these different forms can help to identify the sources of nutrient pollution in any catchment and help target mitigation efforts.



Right: Nutrient speciation data reveal increasing importance of organic nutrient stressors delivered to stream in livestock farming catchments.

Key message

Numerous tools exist to identify pollutant sources, ranging from catchment walkover surveys, to drone mapping, pollution fingerprinting and nutrient speciation analysis. As diffuse pollution sources change spatially and temporally, using combinations of these tools across a catchment over time, develops a weight-of-evidence approach and will often yield the best results.

Monitoring trains

How to establish the effectiveness of mitigation measures?

Monitoring trains involve measuring multiple pollutants at multiple points along a pollutants' source-mobilisation-delivery continuum in order to improve the ability of demonstrating the effectiveness of an individual mitigation option.

An example of a five-stage monitoring train is detailed below for assessing the ability of winter cover crops to reduce nitrate leaching losses.

Stage 1: Conduct cover crop leaf and root analysis to determine the % nitrogen content and enable the calculation of the cover crop nitrogen uptake rate from the soil in kg/ha.

Stage 2: Conduct soil sampling (0-30 cm depth) to determine how much residual soil nitrogen, in kg/ha, is stored in the soil and is vulnerable to leaching.

Stage 3: Install a network of ceramic porous pots at 90 cm depth within the soil across the trial area to capture soil water leaching through the upper soil horizons. Soil water samples can be extracted by vacuum pump and analysed for nitrate concentration, in mg/L in the laboratory.

Stage 4: Sample the outflows of subsurface agricultural field drains which discharge soil water directly into the river at depths of 100-150 cm and analyse nitrate concentration, in mg/L and kg/ha, on return to the laboratory.

Stage 5: Analyse river nitrate concentrations, in mg/L, and nitrate loads, in kg, downstream of the cover crop trial area to determine level of nitrate pollution.

Key message

Monitoring trains involve measuring multiple pollutants at multiple points along the source-mobilisation-delivery continuum linking source to stream. This allows us to assess the specific impact of an individual mitigation option before, during and after its implementation in both space (upstream/downstream) and time.

Example of a five-stage monitoring train to analyse the effectiveness of cover crops, determining nitrate concentrations and loads spatially along the main pollution pathway.

Ecological monitoring

The ecology of a river refers to all plants and animals living within the system including their interactions with each other and the natural environment. Biological monitoring should therefore be conducted across the food web and included key biota (diatoms, macroinvertebrates, macrophytes and fish), as recognised under the Water Framework Directive. Biological monitoring closely matched to hydrological and water quality monitoring provides a complementary assessment of ecological health and water quality to inform on-farm interventions.

Parameter	Sample method and frequency	Reflections
Diatoms	Samples collected monthly Method: **Diatom Assessment of River and Lake Ecological Quality (DARLEQ)**	Diatoms respond to changing conditions in discharge and phosphorus over the previous 18-21 days emphasing the importance of sample frequency. Strong and recurrent seasonal variability in diatom community over 6 years associated with poorer phosphorus conditions during wetter winter periods.
Invertebrates	Samples collected seasonally Method: **River Invertebrate Prediction and Classification System** (RIVPACS)	Good indicator of organic pollution due to their sensitivity to oxygen conditions; can be used with supporting evidence as indicator of other pollutants. Respond rapidly to improvements in pollution. Can quantify variation pre-installation of farm interventions to determine the significance of biological response to subsequent changes in diffuse pollutants.
Macrophytes	Samples collected annually Method: **River LEAFPACS2**	
Fish	Samples collected annually Method: Electric fishing **Fish Classification Tool 2 (FCS2).**	

Images: Iwan Jones

Key message

Dynamics in seasonal climate control of stream ecosystems means that longer term assessments of ecological condition, alongside environmental variables (rainfall, discharge, nutrient and sediment inputs) at appropriate spatial and temporal resolutions, are desirable to fully understand their sensitivity to multiple stressors and response to mitigation measures.

Hydrochemical monitoring

Sensor systems

Parameter	Method/equipment	Description	Reflections
Total reactive phosphorus - TRP Total phosphorus - TP (mg P/L)	Hach Lange Phosphax Sigma AA sampling module	Automated bankside analysis every 30 mins. Automatic calibration once a day. Reagents changed every 3 months.	Costly and time-consuming to maintain. Difficulty in measuring low concentrations <0.05 mg P/L . Downtime = 27%. TRP is not the appropriate variable to monitor. Soluble reactive phosphorus (SRP) is preferable and the international standard measure.
Nitrate (mg NO_3-N/L)	Bankside UV optical sensor - Hach Lange Nitratax Plus SC	Automated bankside analysis every 30 mins. Manual recalibration every 3 months.	Systematic upward drift requires correction after 6 month service. Downtime = 7%
Turbidity (NTU) / suspended sediment - SS	YSI 6600 multi-parameter sonde	Automated bankside analysis every 30 mins. Requires weekly cleaning and monthly calibration.	Can be calibrated against laboratory measured suspended solid concentration to determine sediment loads, but load estimates are unreliable. Biofouling on probe creates 'noisy' data. Downtime = 8-30%
Dissolved oxygen (DO)	YSI 6600 multi-parameter sonde	Automated bankside analysis every 30 mins. Requires weekly cleaning and monthly calibration.	Systematic downward drift requires correction during monthly calibration. Downtime = 24%
Water temperature (°C)	YSI 6600 multi-parameter sonde	Automated bankside analysis every 30 mins. Requires weekly cleaning and monthly calibration.	Produces reliable record with no real issues. Downtime = 5%
pH	YSI 6600 multi-parameter sonde	Automated bankside analysis every 30 mins. Requires weekly cleaning and monthly calibration.	Systematic bias compared with laboratory pH measurements due to sonde drift. Downtime = 20%
Conductivity (µS/cm)	YSI 6600 multi-parameter sonde	Automated bankside analysis every 30 mins. Requires weekly cleaning and monthly calibration.	Produces reliable record that provides good indicator of storm event water input to river. Downtime = 8%

Key message

N, P and SS are often essential to monitor in agricultural catchments, although doing so at high-resolution using automated equipment entails considerable maintenance commitments. Sensor systems can only measure a subset of the key variables and have a higher inherent uncertainty associated with the data they generate than quality assured laboratory analyses. A combination of the two is required to generate robust evidence for catchment managers.

Hydrochemical monitoring

Daily/weekly sampling + laboratory analysis

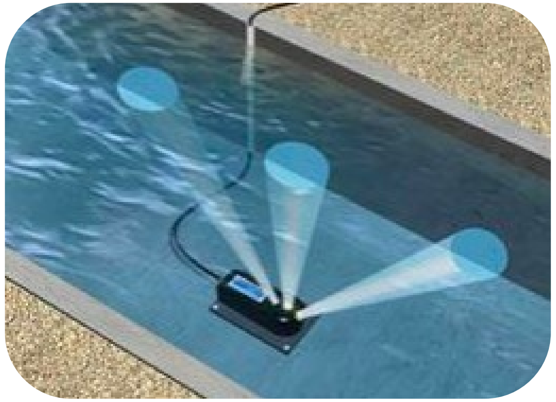
Parameter	Method/equipment	Description	Reflections
Soluble reactive phosphorus - SRP (mg P/L)	Automatic ISCO samplers or manual sampling, daily or weekly	Samples returned to the lab at 4°C in the dark, analysis of fresh samples within 24 hours using quality assured (QA) colourimetric analytical protocol.	Soluble Reactive P is an unstable determinand after 24 hours of sampling. This method allows the reporting of weekly SRP concentrations from the daily sample archive.
Nitrate (mg NO_3-N/L)	Automatic or manual sampling, daily or weekly	Samples returned to the lab at 4°C in the dark, analysis of samples within 24 hours using QA colourimetric analytical protocol.	Nitrate concentrations are stable for up to 1 week. QA in the laboratory assures lower uncertainty than from in situ sensors.
Nitrite (mg NO_2-N/L)	Automatic or manual sampling, daily or weekly	Samples returned to the lab at 4°C in the dark, analysis of samples within 24 hours using QA colourimetric analytical protocol.	Nitrite concentrations cannot be determined in the field. A key determinand indicative of low dissolved oxygen conditions. QA assures low uncertainty in the evidence.
Ammonium (NH_4-N/L)	Automatic or manual sampling, daily or weekly	Samples returned to the lab at 4°C in the dark, analysis of samples within 24 hours using QA colourimetric analytical protocol.	Ammonium is measured as total ammonium (NH_4^++ NH_3). Samples are stable for up to 1 week. QA assures low uncertainty in the evidence.
Total N (mg N/L)	Automatic or manual sampling, daily or weekly	Samples returned to the lab at 4°C in the dark. Unfiltered samples digested using persulphate oxidation and analysed using QA colourimetric analytical protocol.	Total N is determined by persulphate oxidation (simultaneous with Total P), releasing all N in the form of nitrate or nitrite. Analysed colourimetrically using QA protocols. Samples are stable for up to 1 month following collection and storage at 4°C in the dark.
Total P (mg P/L)	Automatic or manual sampling, daily or weekly	Samples returned to the lab at 4°C in the dark. Unfiltered samples digested using persulphate oxidation and analysed using QA colourimetric analytical protocol.	Total P is determined by persulphate oxidation (simultaneous with Total N), releasing all P in the form of SRP. Analysed colourimetrically using QA protocols. Samples are stable for up to 1 month following collection and storage at 4°C in the dark.
Faecal Indicator Organisms (FIOs)	Manual sampling	Collection of samples and water analysis.	Low resolution.
	Cow surveillance cameras	Monitors cattle in-stream activity.	Underestimates pollution impact due to temporal lag. Must be used alongside other methods.

Hydrological monitoring

Hydrological activity is closely linked to the delivery of pollutants to watercourses and therefore any hydrochemical monitoring strategy must also include hydrological measurements. The table below highlights examples of methods to do so.

Parameter	Method/equipment	Description	Reflections
River discharge	Argonaut-SW acoustic Doppler	Automated discharge measurements at 15 min resolution. Plinth mounted on bottom of channel.	Struggles in shallow water (<0.2 m deep). Requires weekly cleaning and consistent channel dimensions free of vegetation.
	NIVUS OCM F ultrasonic Doppler	Automated measurement of velocity and stage at 15 min resolution.	Performs better in low flow conditions. Can be used in pipes or artificial channels.
	SonTek-IQ Doppler	Automated discharge measurements at 15 min resolution.	Can work in shallower water (> 0.08 m) than similar sensors. Requires weekly cleaning and consistent channel dimensions free of vegetation.
River stage	Barometric pressure transducer	Automated water depth measurements at 15 min resolution. Housed in stilling well on channel bed.	Practical, cheap and reliable in shallow water (> 0.01 m). Requires annual recalibration with manual discharge measurements to form accurate stage-discharge rating curve. Downtime = 1.6%.
Groundwater level	Barometric pressure transducer	Automated water depth measurements at 15 min resolution	Practical, cheap and reliable means of borehole groundwater level monitoring. Provides valuable detail on aquifer recharge.

Image: Kevin Hiscock



Key message

The delivery of pollutants to watercourses is closely linked to hydrological activity. It is therefore essential to monitor this in any catchment monitoring programme. The relative importance of overland versus groundwater pathways of diffuse pollutants into water bodies can vary substantially. This has implications for the types of environmental processes that need to be modelled or the sources that need to be addressed in any spatial targeting.

Soil monitoring

Parameter	Method/equipment	Description	Reflections
Soil water	Porous pots	Ceramic pots installed at 90 cm depth at 45° angle with connecting tubes left at surface. Soil water recovered by placing pots under vacuum for 2-8 hours depending on soil moisture content.	Effective means of direct soil water sampling, however generally small sample volumes recovered (< 100 mL). Limited recovery during summer months, and restrictions to application exist due to soil type.
	Field drains	Outflows of subsurface agricultural field drainage can be sampled at point of discharge into river. Typically 100-150 cm deep.	Cheaper and easier to conduct than porous pots if channel is accessible and freeboard has been maintained properly. Drains typically flow October – April, with limited summer recovery possible.
Soil physical	Bulk density; Infiltration capacity	Dry weight of known soil volume measured to determine bulk density; infiltrometer used to determine maximum rate of water infiltration into the soil. Measured annually – seasonally.	Bulk density provides more reliable measure of soil compaction than penetrometer; Infiltration measurements impacted by antecedent conditions.
Soil chemical	N, P, K, S, Mg	Topsoil samples (0-30 cm depth) manually collected with Dutch auger and analysed in laboratory. Measured monthly – seasonally.	Measured soil nutrient concentrations majorly impacted by fertiliser application, so soil sampling prior to application is essential.
Soil biological	Earthworms	Spade full (0.02 m^3) of soil dug up and dissected to locate earthworms. Number, weight and species can be recorded.	Easy to count and effective measure of soil health, but should be done in spring or autumn when worms are most active.
Erosion mapping	Modelling tools	Maps created by calculating the spatial pattern of erosion risk, based on environmental characteristics, see p26 for details. Can be facilitated by drones.	Good for both farm and sub-catchment scales.

Porous pot water sampling

Key message

Reliable characterisation of soil health requires measurement of a suite of soil physical, chemical and biological parameters. Soil water nutrient concentrations should also be measured at depth (0-90 cm) to determine rates of leaching into groundwater in permeable catchments and deep throughflow in impermeable catchments.

Meteorological monitoring

Meteorological parameters, especially precipitation, are closely linked to the delivery of pollutants to watercourses and therefore any hydrochemical monitoring strategy must also include meteorological measurements. The table below highlights the methods to do so:

Parameter	Method/equipment	Description	Reflections
Precipitation	Tipping bucket rain gauge	Automated measurements at 15 min resolution. Limit of detection = 0.2 mm.	Provides the valuable high-resolution precipitation data required for modelling catchment hydrological response times during storm events. Requires weekly cleaning. Downtime = 4%.
	Graduated cylinder rain gauge	Manual measurements at daily to weekly intervals.	Cheap and easy to deploy, but data resolution limits usefulness and requires regular site visits to empty cylinder.
Temperature	Thermometer	Automated measurements at 15 min resolution. Limit of detection = 0.01°C.	Data valuable for interpreting biotic cycles in fluvial hydrochemistry, calculating evapotranspiration rates and calculating soil moisture deficits. Downtime = 7%.
Relative humidity	Hygrometer	Automated measurements at 15 min resolution. Limit of detection = 0.01%.	Can be used for calculating evapotranspiration rates, but less useful than precipitation and temperature data. Downtime = 7%.
Net solar radiation	Net radiometer	Automated measurements at 15 min resolution. Limit of detection = 0.01 W/m^2.	Data valuable for interpreting biotic cycles in fluvial hydrochemistry and valued by arable farmers exploring link between radiation and crop growth. Downtime = 6%.
Wind speed	Anemometer	Automated measurements at 15 min resolution. Limit of detection = 0.001 m/s.	Non-essential parameter. Less useful than precipitation and temperature data. Downtime = 3%.
Wind direction	Weather vane	Automated measurements at 15 min resolution. Limit of detection = 0.1°.	Non-essential parameter. Less useful than precipitation and temperature data. Downtime = 3%.


Image: Kevin Hiscock

Key message

High-resolution precipitation monitoring is essential for understanding storm event dynamics and modelling of catchment hydrological response times. Air temperature and net solar radiation data are also valuable for interpreting biotic cycles in fluvial hydrochemistry, calculating evapotranspiration rates and calculating soil moisture deficits.

Social science data

The implementation of mitigation measures will only be effective with the cooperation of land owners, managers and the wider community. Stakeholder knowledge and engagement is a necessary component of catchment management. Therefore it is vital to learn what behaviours, attitudes, motivations, barriers and priorities are towards different interventions within a catchment in order to evaluate the opportunities and mechanisms required to address water quality issues.

Data collection methods

Method	Advantages	Disadvantages
Face-to-face interview	High quality data and detail Ability to build rapport	Travel time to rural locations Small-scale data collection
Telephone survey	No travel costs Gain further insights	Difficult to build rapport
Postal survey	Low costs and involvement Appropriate for large-scale data collection	Low response rate Risk of low-quality data from lack of engagement or misunderstanding
Workshop (facilitators & note-takers)	Collect multiple responses Useful for broad questions Create a sense of community	Dominant voices may bias results

Design

- All survey/interviews require a comprehensive pilot study to assess duration, wording (not leading/biased), comprehension and engagement.
- Including fun/ interesting activities helps build rapport and increase enthusiasm

Interactive game collecting data on attitudes towards farm advisors

The surveys, interviews and workshops conducted during the DTC programme.

Farm baseline survey
Farmer uptake of interventions and attitudes to future adoption

Farm advisor interviews
Current recommendations of interventions by different farm advisors

In-depth farmer interviews
Motivations / barriers to adoption of specific interventions and attitudes towards advisors

CaBA stakeholder interviews
Lessons for developing effective catchment management strategies as a community

Stakeholder workshops
Identifying mechanisms to encourage intervention uptake and collaborative action

Recruiting participants

- Contacting well-known trusted individuals and organisations within a community can help provide contacts.
- Consider farm businesses rather than holdings as a unit, as holdings in a business are likely to be managed in a relatively uniform manner.
- When making initial contact, clearly explaining the study's objective and the benefits of taking part helps encourage participation.
- Arrange data collection when it is suitable for the participant e.g. after/before milking for dairy farmers (not calving season), breakfast for farm advisors or evenings for community members.

Key message

Combining knowledge from both social and physical sciences substantially helps provide a more robust evidence base for mitigation strategy development. Qualitative data provides rich snapshots of insights which facilitate opportunities to observe behavioural change and effectiveness of new policy mechanisms.

Catchments

Scaling out from the DTC study catchments

Which Catchment Group is my catchment in?
Click here

What you will find in this section

This section describes the characteristics of different groups of catchments, enabling outputs from catchment-specific studies to be translated to other catchments nationally. A summary is given in the Catchments overview of how the DTC Catchment Matcher project assessed and grouped catchments based on their similarities. Click on a Catchment group to be taken to the corresponding page for information on its characteristics, likely pollution issues and relevant mitigation measures. To discover which group an Operational Catchment is in, click on the box in the top right of this page.

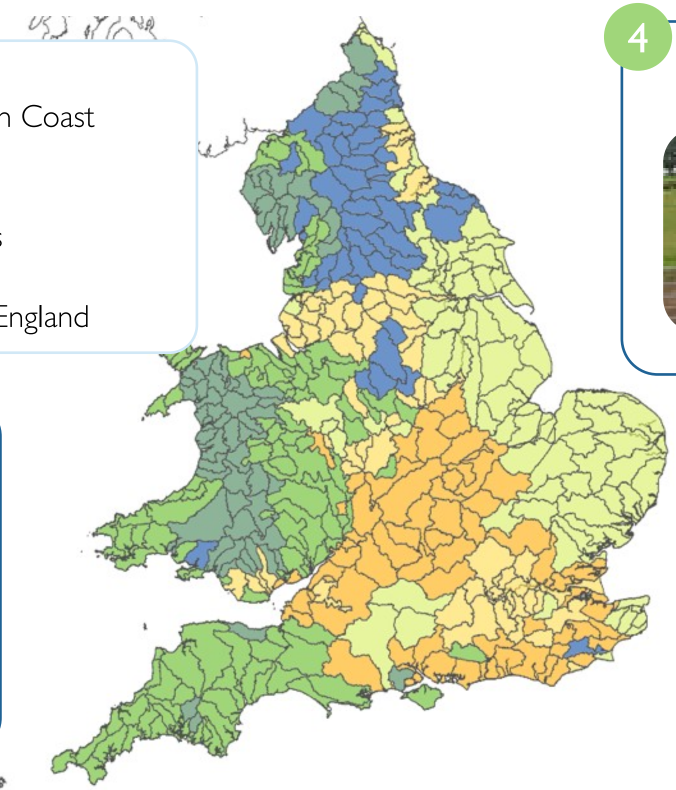
Catchments Overview p37

1 Midlands and South Coast

p38

3 Eastern England

p39



4 Western Lowlands

p40

6 Upland Northern England

p42

5 Western Uplands

p41

*Catchment Group 2 has a high proportion of urban land and the lowest contributions of N and P from agriculture and has therefore been omitted

Catchment overview

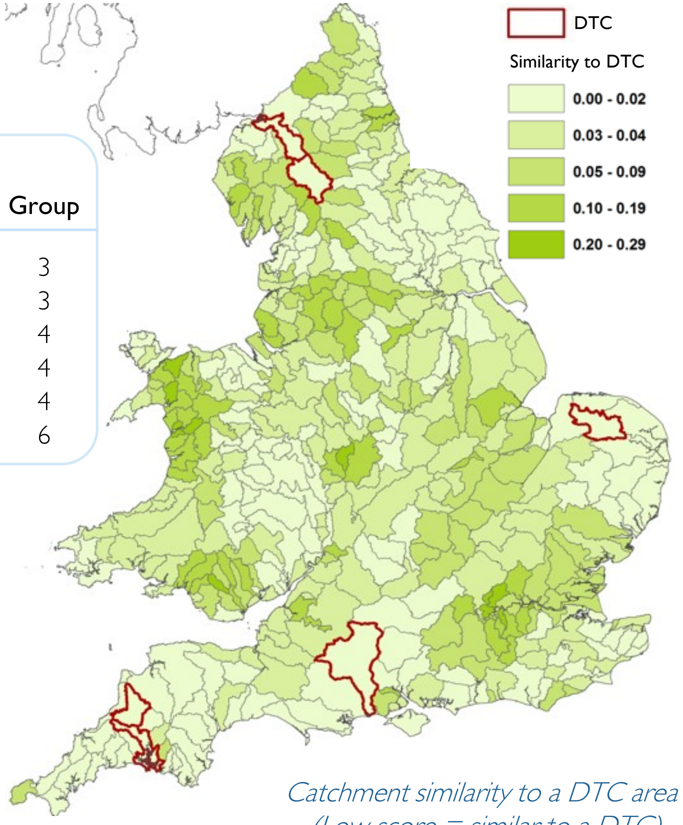
How can catchments be grouped to inform pollution mitigation strategies?

The DTC Catchment Matcher project used a wide range of spatial datasets to run analyses and assign Operational Catchments to distinct groups. Demonstration activities from the DTC programme are well-distributed across groups, suggesting that findings should cover most catchment settings across the country, the main exception being the most urbanised regions and group 1 (Midlands and South Coast).

The Catchment Matcher groups inform pollution mitigation strategies by providing an overview of where certain conditions (e.g. terrain, soil types, aquifers etc.) or activities (e.g. type of farming) occur. Such groupings help:

- Identify the most appropriate modelling or spatial targeting tools to use in different catchment settings,
- Design new mitigation schemes including measures appropriate across different sets of catchments,
- Provide an improved level of confidence when extrapolating findings from one catchment to another,
- Support searches for studies relevant to particular catchments,
- Identify where knowledge gaps exist, indicating where research investment would improve strategic capability.

Operational DTC	Group
Hampshire Avon	3
Wensum	3
Tamar Lower & Inny	4
Tamar Upper	4
Eden Lower	4
Eden Upper	6



Catchment similarity to a DTC area (Low score = similar to a DTC)

Variables used for characterisation

- ✓ Slope Steepness
- ✓ Soil Texture
- ✓ Parent Material & Erodibility
- ✓ Important Aquifers
- ✓ Temperature
- ✓ Precipitation
- ✓ Land Cover
- ✓ Agricultural Land Grade
- ✓ Agricultural Census Data
- ✓ Robust Farm Types
- ✓ Sources of Sediment, N and P

MATCHER CATCHMENT

Key message

England and Wales can be broadly divided into six types of catchments. There are clear differences between catchment groups in: 1) their physical environment, 2) the extent of arable and livestock farming and 3) the importance of agricultural sources of N and P implying that the applicability of particular mitigation measures is likely to vary between the catchment groups.

Catchment group 1 - Midlands and South Coast

Catchment characteristics - Concentrated in central and southern England. Relatively flat terrain and dry conditions, approximately even share of sand and clay in soils, and elements of both arable and livestock farming. **This group is less well-represented by the DTC programme.** Average values for the 66 catchments in Catchment type 1 are summarised below.

Agriculture and environment

14.8 ha wheat
114 cattle
per 2km²

71% N
27% P
Pollution
from agriculture

Farm income £222/ha

6.9% with 1-to-1 CSF advice

68% in NVZs

5.3% WFD Good Status

36% in agri-env schemes

Landscape and land use

4% Designated Nature Reserves

24% AONBs & National Parks

forest / semi-natural
urban
pasture
Arable/permanent crops

37% important aquifers

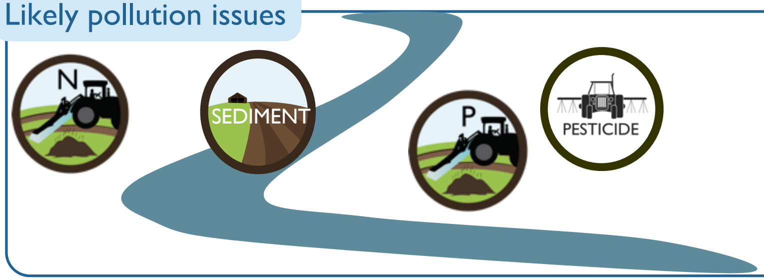
3.7% slope

14% ALC Grades 4 & 5

33% sand

31% clay

Likely pollution issues



716 mm

Climate annual average

9.6°C

Applicable interventions evaluated by DTC

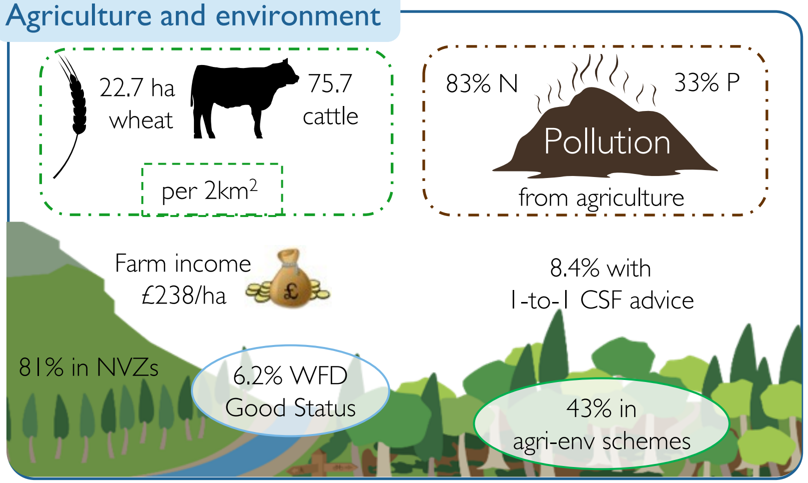
- ✓ Winter cover crops
- ✓ Conservation tillage
- ✓ Biobeds

Designated Nature Reserves = % of area classified as SSSI, SAC, SPA or RAMSAR sites

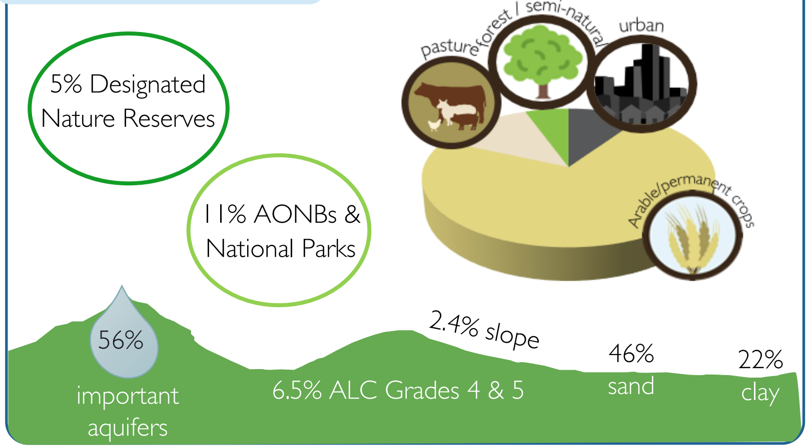
Catchment group 3 - Eastern England

Catchment characteristics – Situated mainly in Eastern England, Lincolnshire and Yorkshire. Sandier soils and a greater presence of aquifers than Group 1, over 70% of land in arable or permanent crops. Average values for the 73 catchments in Catchment Group 3 are summarised below.

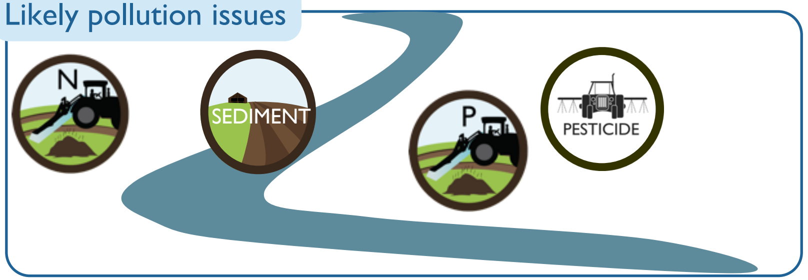
Agriculture and environment



Landscape and land use



Likely pollution issues



Climate annual average

645 mm

9.2°C

Applicable interventions evaluated by DTC

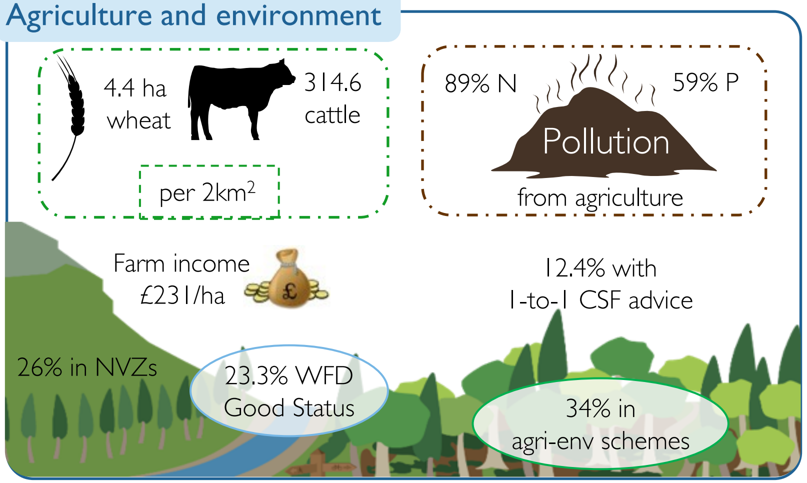
- ✓ Winter cover crops
- ✓ Sediment traps
- ✓ Conservation tillage
- ✓ Biobeds

Designated Nature Reserves = % of area classified as SSSI, SAC, SPA or RAMSAR sites

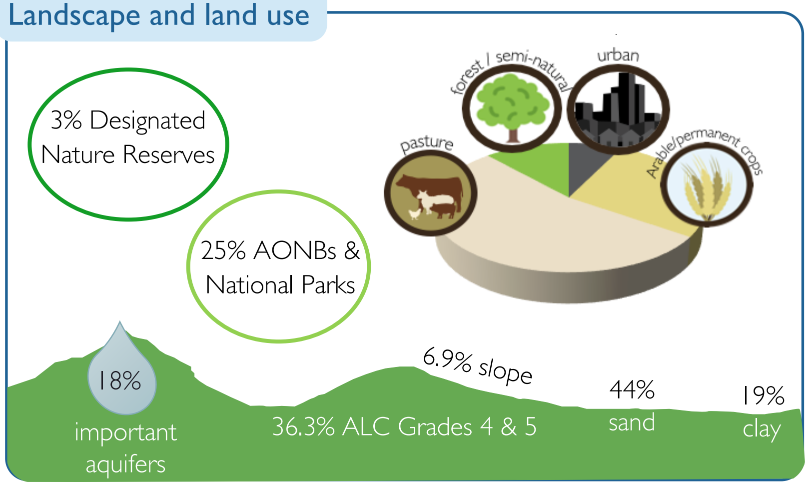
Catchment group 4 - Western Lowlands

Catchment characteristics – Encompasses most of South West England and some parts of Wales, Cheshire and Cumbria. A wetter climate than Groups 1-3, more pasture than arable land and high numbers of cattle. Average values for the 110 catchments in Catchment group 4 are summarised below.

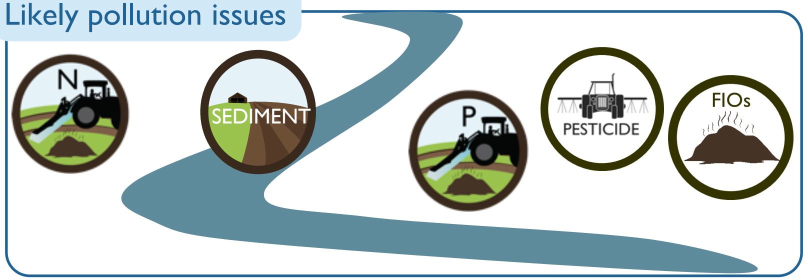
Agriculture and environment



Landscape and land use



Likely pollution issues



Climate annual average

998 mm

9.3°C

Applicable interventions evaluated by DTC

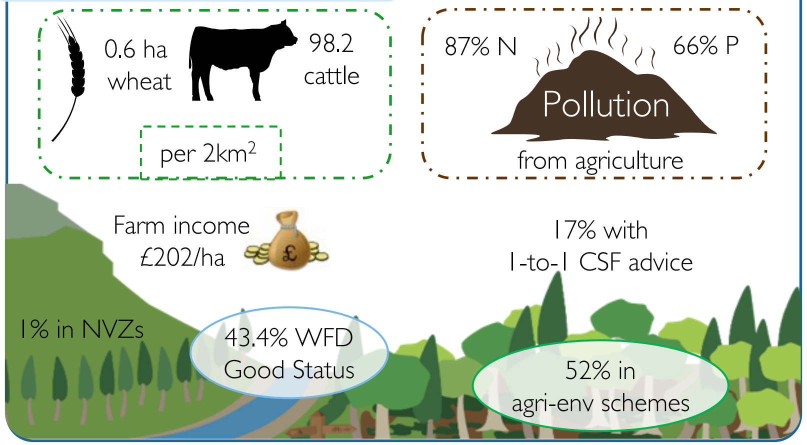
- ✓ Soil aeration
- ✓ Track management
- ✓ Riparian buffer zones
- ✓ Clean & dirty water separation
- ✓ Runoff detention features

Designated Nature Reserves = % of area classified as SSSI, SAC, SPA or RAMSAR sites

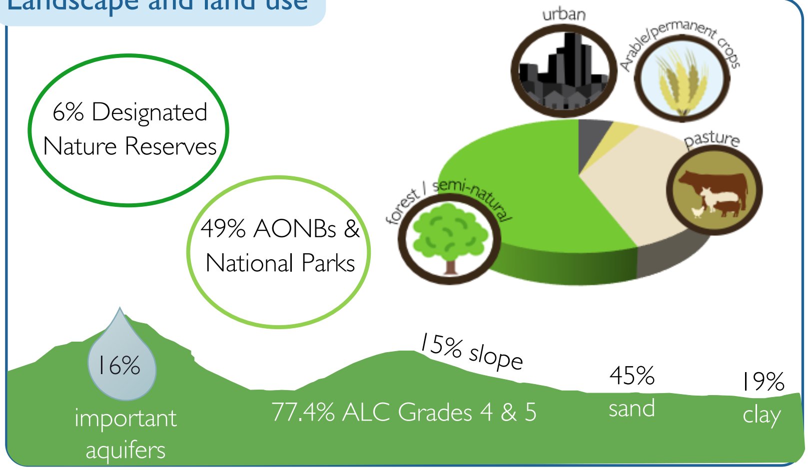
Catchment group 5 - Western Uplands

Catchment characteristics – Largely focused in Upland Wales and Cumbria. Steep slopes and high rainfall, dominated by poor quality agricultural land, forest and semi-natural land cover. Average values for the 61 catchments in Catchment group 5 are summarised below.

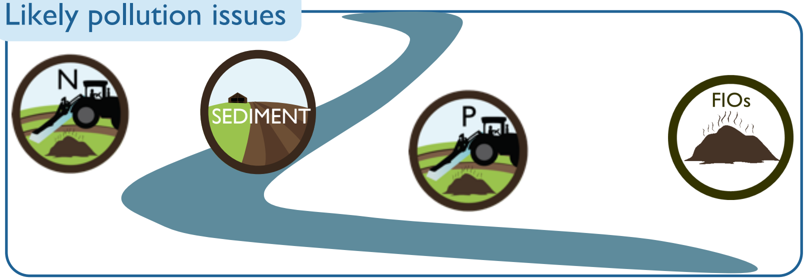
Agriculture and environment



Landscape and land use



Likely pollution issues



Climate annual average

1552 mm

8°C

Applicable interventions evaluated by DTC

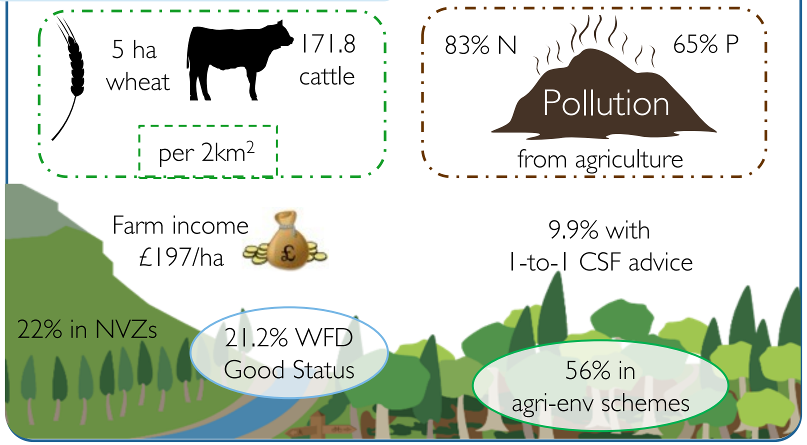
- ✓ Soil aeration
- ✓ Track management
- ✓ Clean & dirty water separation
- ✓ Runoff detention features

Designated Nature Reserves = % of area classified as SSSI, SAC, SPA or RAMSAR sites

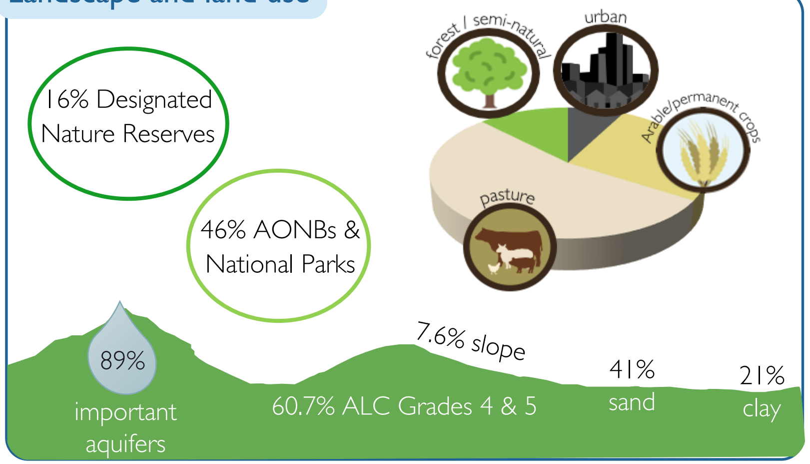
Catchment group 6 - Upland Northern England

Catchment characteristics – Predominantly located in the Pennines and Peak District. Similar to Group 5 on many variables, but with a much greater extent of aquifers, more arable land or pasture and higher cattle numbers. The upland groups (5 and 6) are distinguished by higher proportions of land in designated nature reserves, AONBs and National Parks, as well as slightly lower farm business incomes. Average values for the 50 catchments in Catchment group 6 are summarised below.

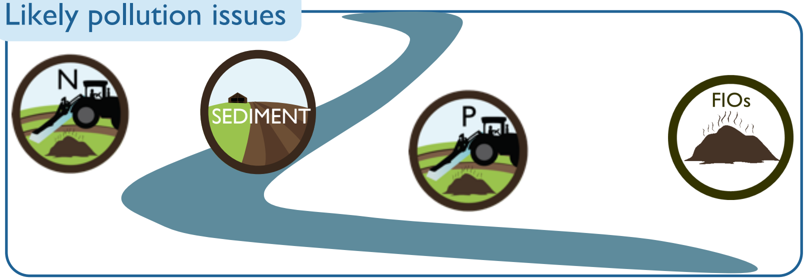
Agriculture and environment



Landscape and land use



Likely pollution issues



Climate annual average

1001 mm

7.7°C

Applicable interventions evaluated by DTC

- ✓ Soil aeration
- ✓ Track management
- ✓ Clean & dirty water separation
- ✓ Runoff detention features

Designated Nature Reserves = % of area classified as SSSI, SAC, SPA or RAMSAR sites

Farm Interventions

What you will find in this section

This section describes the farm interventions tested by DTC work. An overview regarding intervention selection and targeting is provided, followed by each intervention appraised for its efficacy at reducing diffuse water pollution, its cost, and farmers' attitudes toward the intervention. Many of these interventions are applicable to all farm types and are effective for multiple pollutants. The following pages indicate specific farm categories, where appropriate, and list the key pollutants targeted.

Interventions overview: Selecting measures

p44

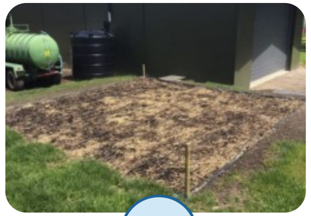
Winter cover crops

p45

Conservation tillage

p46

Biobeds



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Sediment traps

p48

Runoff detention features

p49

Riparian buffers and wetlands

p50-51

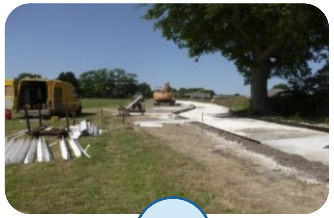
Clean & dirty water separation

p52

Soil aeration

p53

Track management



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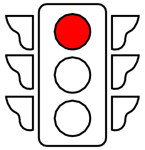
Scaling out

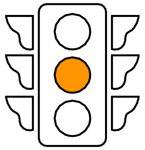
Modelling techniques can be used to scale out experimental intervention efficacy. See references for details.

Traffic light ratings

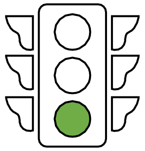
A traffic light rating has been applied to each aspect of the intervention to provide a visual guide.



Focus and attention are required to overcome challenges.



Both challenging and positive characteristics are present.



Indicates a strong positive aspect of an intervention.

Intervention overview

How can measures be targeted effectively within a catchment?

IDENTIFY
...the sources, mobilisation pathways and delivery routes of key pollutants within a catchment through conceptual modelling, targeted monitoring, walkover surveys, and discussions with landowners, advisers, etc.

TARGET
...appropriate measures using evidence from previous research, consultation with catchment scientists and bespoke conceptual models such as SCIMAP and ALERT.

REVIEW
...the selected measures and design criteria in detail with farmers and farm advisers, with particular focus on the practicalities and costs of implementation.

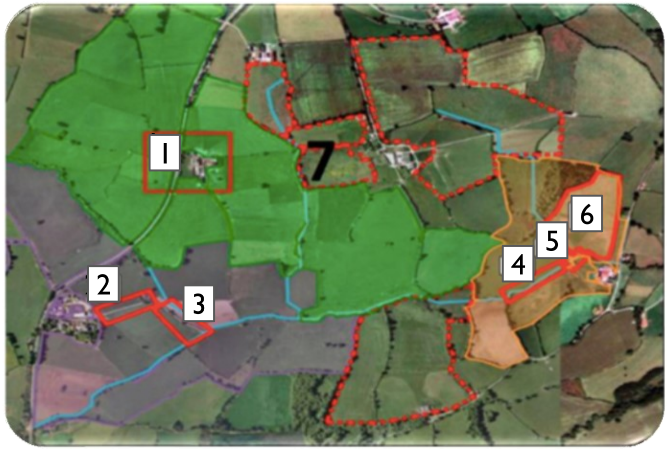
Treatment train

A sequence of multiple complementary measures from farm land to stream

No one individual source of pollution is considered to be responsible for poor water quality within a sub-catchment, and therefore, no individual measure is deemed likely to be wholly effective. A combination of measures to reduce the source and mobilisation of pollutants, intercept their delivery along different pathways, and protect the river/lake is therefore necessary.

Key message

Choosing where and which measures to install is an iterative process of synthesising knowledge and evidence, alongside observation in a negotiation with the farmer/land owner. The treatment train approach maximises protection by addressing the key stages in the pollution delivery continuum.



Map of a trial treatment train. Key to installed measures (1) clean and dirty water separation, (2) track resurfacing, (3) sediment trap, (4) and (5) riparian buffer zones, (6) maize reversion, (7) catchment wide nutrient and soils advice.

Selecting measures – Avon Case Study

Identify

Water quality monitoring used to establish the baseline conditions within the catchment revealed chronic pollution from nutrient, sediment and FIO enrichment from agricultural land.

Target and Review

A catchment mitigation plan was developed using the scientific knowledge available in the DTC team, with the landowners' involvement throughout the process. This comprised a suite of on-farm interventions to address each pollutant individually (see image on the left).

The larger-scale measures selected involved widespread nutrient management and reflect the physical characteristics of the farm as well as the social aspects. The mitigation measures selected serve as a template for developing a comprehensive mitigation plan to tackle agricultural pollution in other catchments.

Winter cover crops

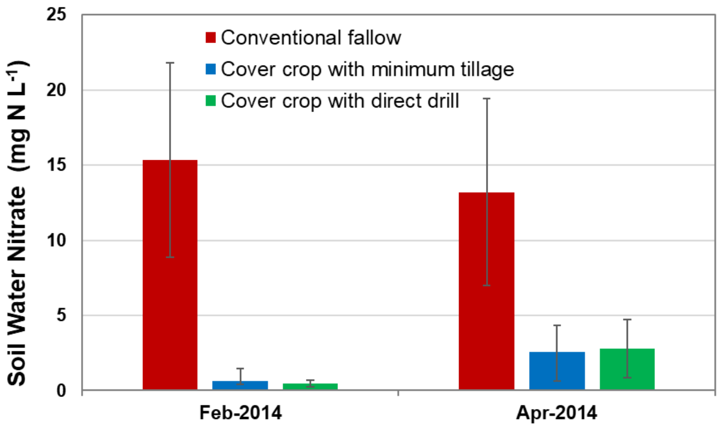
Suitable for Farms: **with spring cropping**

Key pollutant targeted:

A non-cash crop sown in autumn to provide groundcover during winter, reducing the risk of soil nutrient losses from leaching and erosion. The crop is destroyed prior to the cash-crop being planted in spring using herbicide or grazing animals.

How effective are they at reducing diffuse pollution?

Winter cover crops are highly effective at reducing nitrate leaching. In 2014, a 143 ha trial of an oilseed radish cover crop revealed a 75-97% reduction in nitrate leaching losses into subsurface field drainage compared to conventional fallow. However, cover crops had limited impact on either phosphorus or pesticide leaching losses in a lowland arable setting.



Soil water nitrate concentrations under oilseed radish cover crop

What influences farmer uptake?

Motivational factors

- ✓ One-to-one advice
- ✓ Desire to improve long-term soil quality
- ✓ Willingness to experiment

I wanted to start experimenting… and find out what works best on our farm

Barriers

I don't have to!

- ✗ Lack of skills and knowledge
- ✗ Lack of local evidence
- ✗ Cost of implementation
- ✗ Belief the farm has the wrong soil type or rotation
- ✗ Belief cover crops only help with soil erosion

Interferes with rotation

Don't know how to establish them

What are the costs?

The application and variable costs of establishing and managing a cover crop are higher than conventional fallow. However, increased yield in the subsequent cash crop in fields which have had a cover crop offsets these costs and overall results in very similar economic performance.

Winter oilseed cover crop

Key message

Cover crops can significantly reduce nitrate leaching losses by up to 97%, with the potential for the crop to also act as a 'green manure', reducing expenditure on fertilisers. Farmer' attitudes to cover crops have changed over recent years and uptake is becoming more common. The use of herbicides to destroy the crop or control weed populations may increase pollution from pesticide. Mechanical means of destruction such as sheep grazing should be used where possible.

Conservation tillage

Suitable for Farms: **Arable**

Key pollutants targeted: P, SEDIMENT

Soil conservation is a measure under which soil is disturbed to a lesser degree than conventional mouldboard ploughing. Soil is either cultivated to a depth of <10 cm with discs or tines (*shallow non-inversion*) or not cultivated at all (*direct drilling*). The primary purpose is to improve soil structural stability and reduce soil erosion.

How effective is it at reducing diffuse pollution?

A five-year conservation tillage trial was conducted across 143 ha of a lowland arable estate between 2013 and 2018. Results revealed that, over this timescale, conservation tillage did not significantly alter the soil physical, chemical or biological condition relative to conventional ploughing. In addition, conservation tillage did not reduce nutrient leaching losses into field drainage and did not significantly impact upon the neighbouring river water quality, despite the conservation tillage trial area covering 20% of the catchment. It is therefore suggested that conservation tillage may be better suited to catchments with steeper land gradients where the dominant pollution pathway is surface runoff rather than subsurface leaching.

Shallow non-inversion, Salle Park Estate

What influences farmer uptake?

Motivational factors

- ✓ Advice from press and neighbours
- ✓ Regulatory requirements
- ✓ Increased profit margins
- ✓ More cost effective than ploughing

Barriers

- ✗ Negative experiences from trials
- ✗ Fear of reducing yields
- ✗ Fear of encouraging weeds
- ✗ Cost of machinery

Wrong soil type

It really saved us money and increased our profit margin

You can get a good price on second hand machinery

If something works, why change it?

What are the costs?

The machinery and labour costs of conservation tillage methods are similar, or less than conventional plough methods. However, reduced costs and greater operational efficiency make this an attractive intervention to farmers on an economic basis.

Key message

Conservation tillage does not appear to significantly improve the short-term environmental sustainability of farming practices in lowland intensive arable settings where subsurface leaching is the dominant pollutant pathway. However, improvements in farm business performance due to operational efficiency savings and improved yields demonstrate land managers can make important financial gains by converting to a conservation tillage system.

Biobeds

Suitable for Farms: **applying plant protection products**

Key pollutant targeted: PESTICIDE

A moderately sized, lined pit filled with a mixture of 25% compost, 50% straw and 25% topsoil, which can be used to mitigate point source pesticide pollution from accidental spillages, leaking equipment or contaminated machinery washings. Microbial activity within the mixture degrades pesticide residues which are deposited on the biobed.

How effective are they at reducing diffuse pollution?

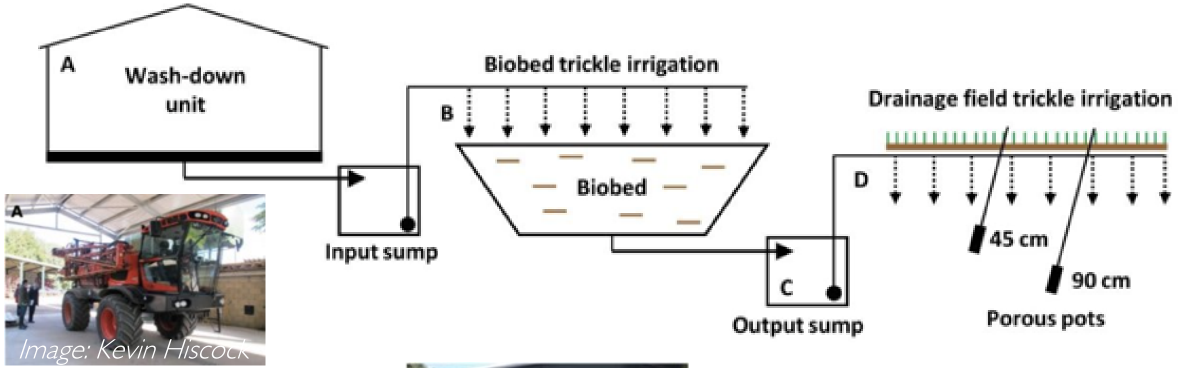


Image: Kevin Hiscock

1) Trials showed a bioded (B) could remove 68-98% of individual pesticides from contaminated machinery washings (A).

Image: Richard Cooper

2) Total mean pesticide concentration reduced by 92% between the biobed input and output sumps (C). However, this level still posed a significant environmental risk.

Image: Kevin Hiscock

3) Drainage field irrigation (D) provided a further reduction of 68-99%, reducing mean pesticides concentrations by 760 times relative to the untreated wastewater. .

What influences farmer uptake?

Nobody recommends them

Motivational factors

- ✓ Regulatory requirements
- ✓ One-to-one and press advice
- ✓ Attending demonstrations
- ✓ Financial incentives
- ✓ Ability to invest in 'luxury infrastructure'

A specialist wrote a very detailed report with all of the information we needed. It was incredible.

Barriers

- ✗ Lack of knowledge
- ✗ Advice against biobeds
- ✗ Belief that alternative methods are more cost efficient
- ✗ Unwilling to invest

Scared of getting it wrong

Not a priority

What are the costs?

The above example pictures a biobed installation with a very high-quality wash down unit. Simpler facilities would be just as effective and could be constructed for £5,000 - £10, 000. An Environment Agency waste exemption licence is also required.

Key message

Biobeds are highly effective at mitigating point source pesticide pollution related to handling operations, reducing individual pesticide concentrations by up to 98%. Construction and maintenance costs are relatively inexpensive, making them suitable for catchment-wide deployment.

Sediment traps

Suitable for Farms: **All**

Key pollutants targeted: P, SEDIMENT, N

Structural mitigation features designed to intercept sediment laden surface runoff by diverting the flow into a static body of water. Entrained sediment settles out of suspension onto the bottom of the trap allowing cleaner water to either discharge into the neighbouring waterbody (*open system*) or infiltrate down into the soil (*closed system*).

How effective are they at reducing diffuse pollution?

A 180 m^3 linear sediment trap was constructed in 2016 to capture sediment entrained in surface road runoff, resulting in suspended sediment load reduction of 58% in the nearby river.

Comparison between two contrasting trap designs – linear (180 m^3) and U-shaped (700 m^3) – revealed that a larger U-shaped design was twice as effective at removing suspended sediment due to the longer flow path improving sediment settling rates.

Pollutant mitigated by linear trap during the first 12 months of operation.

Pollutant	Amount trapped (kg)	Rate (kg/ha/y)
Sediment	7300	305
Organic Carbon	400	17
Nitrogen	30	1.3
Phosphorus	12	0.5

What are the costs?

A linear trap can be created for £19.80 per m^2, including annual maintenance, whereas a U-shaped trap will cost £10.30 per m^2. U-shaped traps are therefore the most cost-effective option.

A large U-shaped roadside settlement trap

Images: Richard Cooper

Smaller linear roadside settlement trap

What influences farmer uptake?

Motivational factors

- ✓ Regulatory requirements
- ✓ Attending demonstrations
- ✓ Attracting wildlife and improving farm aesthetics
- ✓ Receiving advice
- ✓ Financial incentives

Barriers

- ✗ Lack of knowledge
- ✗ Tenancy restrictions
- ✗ Loss of productive land
- ✗ Maintenance requirements
- ✗ Fear of safety issues

Don't know the benefits

Can't be bothered to empty them

I don't have a problem

Key message

Sediment traps are a highly effective tool for intercepting surface runoff and capturing eroded sediment before it can enter a watercourse. They are cheap to construct and maintain, and occupy a relatively small footprint in a field. However, loss of land is a main concern for farmers. Note that traps become less effective when full.

Runoff detention features

Suitable for Farms: **All**

Key pollutants targeted:

Runoff detention features (RDFs) delay water movement across the landscape, offering the potential for sedimentation of particulate matter and other pollutant removal processes to occur.

How effective are they at reducing diffuse pollution?

The table below shows the percentage of pollutant trapped in a trial where seven RDFs targeted around 0.003% of a catchment.

Pollutant	Amount trapped (%)
Average total sediment	1.3%
Average total phosphorus	0.5%
Average total nitrogen	0.03%

Previous research has suggested that RDFs may need to cover 1.5–2% of a catchment to effectively mitigate diffuse water pollution from agriculture. Assuming that similar targeting of RDF location could be replicated over a larger scale, the above figures demonstrate that a very substantial reduction of sediment load could be achieved.

Examples of runoff detention features

What influences farmer uptake?

Motivational factors

- ✓ Financial incentives
- ✓ Desire to attract wildlife and improve farm aesthetics
- ✓ One-to-one advice
- ✓ Attending demonstrations

Brings wildlife to the farm

Barriers

Not needed here

- ✗ Loss of productive land
- ✗ Economic concerns
- ✗ Maintenance concerns
- ✗ Lack of knowledge regarding benefits
- ✗ Fear of attracting pests and weeds

Cost of contractors is too high

What are the costs?

The initial cost of an average RDF is around £1,200, including the opportunity cost of lost land. Annual maintenance costs come to around £200 per feature and include emptying sediment, re-fencing, structural repairs and labour costs.

Key message

Runoff detention features are an effective method of delaying water movement and trapping pollutants, reducing the rate at which they would enter watercourses. As with sediment traps, the area of land is small but remains a major farmer concern, along with additional workload associated with maintenance and emptying sediment.

Riparian buffer strips

Suitable for Farms: **with riparian land***

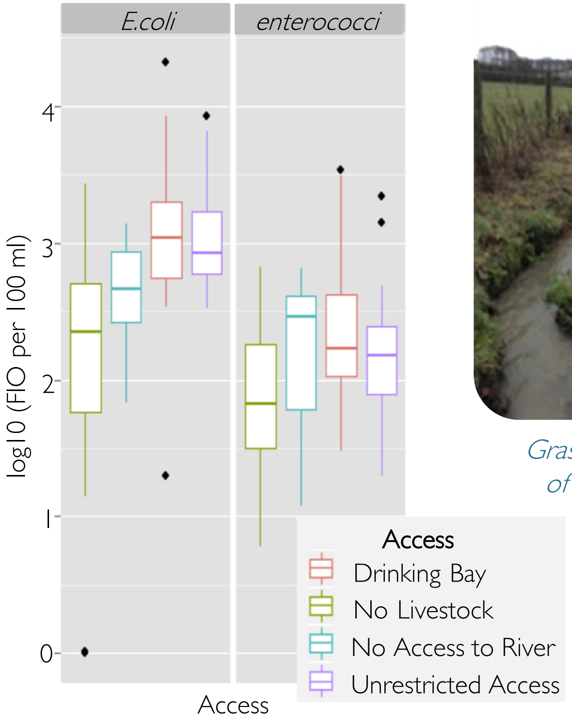
Key pollutants targeted: FIOs, P, SEDIMENT

*results here specifically relate to livestock farms

Riparian land taken out of production. Can be fenced to prevent or restrict access of livestock to watercourses to reduce bank erosion and prevent FIOs from entering watercourses.

How effective are they at reducing diffuse pollution?

Buffers act on surface pathways but are bypassed by field drains and throughflow. Despite this, trials show that riparian buffer zones are an effective measure to reduce concentrations of FIOs in a catchment. The boxplot to the right shows a significant reduction in E. coli and enterococci when livestock are not present or are not given access to the river. The results also indicate that drinking bays may be ineffective at reducing FIO concentrations.



Grass riparian buffer strip (left). Unfenced area upstream of a woodland riparian buffer strip, often poached by cattle (right).

What are the costs?

Construction costs are around £7 per m of fencing. Maintenance costs include the refilling of drinking troughs and will vary according to whether this activity is completed by the farmer (£240 per annum) or a contractor (£400 per annum).

What influences farmer uptake?

Motivational factors

- ✓ Financial incentives
- ✓ Regulatory requirements
- ✓ Desire to improve biodiversity
- ✓ Improved efficiency during pesticide and fertiliser applications

"The fenced-off areas have attracted yellow hammers"

Barriers

- ✗ Takes land out of production
- ✗ Not practical in smaller fields
- ✗ Concerns over weed control
- ✗ Maintenance requirements
- ✗ Aesthetic concerns

"Would lose too much land"

"Pollution is not a problem in this area"

Key message

Riparian buffer strips are an effective way of intercepting surface pollutant pathways and mitigating FIOs in watercourses. Provided they are carefully managed, they also present the opportunity to contribute to farmland bird conservation. It should be recognised that all livestock access within a catchment must be restricted to achieve the necessary reductions and farmers' attitudes toward the loss of productive land should be noted.

Wetlands as buffer zones

Suitable for Farms: **All**

Key pollutants targeted: N, P, SEDIMENT

Wetlands constructed to reduce the rate at which nutrients and sediments are delivered to watercourses from upslope agricultural land.

How effective are they at reducing diffuse pollution?

Wetlands are frequently presented as 'buffer zones' which can remove nitrate, in particular, from water flowing from land to stream. Monitoring results for a semi-natural wetland receiving agricultural runoff for a long period of time, found this 'buffering capacity' is rapidly exceeded.

Wetlands act as a biodiverse system, transforming inflowing nitrate into stored organic N. This slows the rate of delivery, and changes the chemistry. However, once capacity is reached, within 5 years of construction, no additional reduction occurs and during storm events nutrients can be flushed to streams.

These systems effectively trap particulate nutrient forms and sediment but once stored in waterlogged soils, P rapidly desorbs from the sediment particles and is flushed to adjacent waters.

What are the costs?

Significant variability in costs exist based on a host of factors. In grass settings, total costs (capital and income foregone) can be ~£5/ha, in arable settings ~£13/ha.

Example semi-natural wetland

What influences farmer uptake?

Motivational factors

- ✓ Financial incentives
- ✓ Regulatory requirements
- ✓ Desire to improve biodiversity
- ✓ Desire to control flooding
- ✓ Improved efficiency during pesticide and fertiliser applications

Barriers

- ✗ Takes land out of production
- ✗ Not practical in smaller fields
- ✗ Concerns over weed control
- ✗ Maintenance requirements
- ✗ Aesthetic concerns

Would lose too much land

Pollution is not a problem in this area

Key message

Management of wetlands by removing accumulated nutrients in the green biomass is key for delaying the system from reaching capacity. On site management is also important, with grazing observed to generate a substantial increase in N, P and suspended sediment in adjacent waters. Provided they are carefully managed, they can present the opportunity to contribute to farmland plant and animal conservation efforts, but they do not provide a long term, indefinite buffering option in catchments. As with riparian buffer strips, it should be recognised that all livestock access within a catchment must be restricted to achieve the necessary reductions and farmers' attitudes toward the loss of productive land should be noted.

Clean & dirty water separation

Suitable for Farms:

with yard infrastructure

Key pollutants targeted: P, SEDIMENT, N, FIOs

A group of measures with the aim of maximising storage capacity for dirty water and reducing farmyard runoff. Example measures include yard coverage via roofing, improvements to guttering, slurry drains, and ditch water pools.

How effective is at reducing diffuse pollution?

Trials show that improved farmyard infrastructure for clean and dirty water separation has the potential to effectively reduce total concentration of nitrogen, phosphorus and sediment in watercourses in a catchment via reduced runoff.

What are the costs?

As this intervention covers a variety of measures, costs will vary. For example, a trial slurry drain of 30m for draining pig effluent cost £11,500 to construct with annual maintenance costs of £400. Farmyard roofing typically costs around £60 per m^2 to install.

Example farmyard infrastructure for clean and dirty water separation

What influences farmer uptake?

Motivational factors

- ✓ Financial incentives
- ✓ Regulatory requirements
- ✓ One-to-one advice
- ✓ Weather conditions

We wouldn't have been able to afford it without the help…we could stop doing something we didn't want to

Barriers

- ✗ Economic factors
- ✗ Long-term benefits not considered
- ✗ Concerns over the correct design
- ✗ Tenancy restrictions

Not enough grant aid

Unsure about the future

Too expensive

Key message

Clean and dirty water separation through better infrastructure yields benefits in the form of improved farm efficiency such as a decreased need for extra slurry storage. Farmers have a positive attitude toward the uptake of this group of measures, with the main barrier being installation costs.

Soil aeration

Suitable for Farms: **Livestock**

Key pollutants targeted:

Soil aeration is needed because compaction occurs due to the use of heavy machinery and/or stock grazing that can promote surface runoff, which is associated with pollutant export and downstream flood risk. Using machinery (aerators, sward lifters or subsoilers) to loosen compacted soil has the potential to mitigate adverse consequences.

How effective is at reducing diffuse pollution?

An area which had been subjected to subsoiling the previous autumn yielded significantly more dry matter than the control area.

A trial which took place in summer 2016 across four farms examined the effects of using a surface silt aerator. Positive effects were found on total nitrogen content of the grass and in the hydraulic properties at some sites. No positive effects on grass yield were found.

What are the costs?

Hiring machinery rather than purchasing it will significantly reduce costs, making this a low-cost intervention. However, due to wet weather, limited opportunities exist for using the machinery in appropriate conditions, thus resulting in farmers needing machinery at the same time.

Surface aerator used on fields to reduce near-surface soil compaction

What influences farmer uptake?

Waste of time

Motivational factors

- ✓ Desire to improve grass yields
- ✓ Desire to invest in long-term farm viability
- ✓ Attending demonstrations
- ✓ Ability to test machinery
- ✓ Advice, articles and other farmers

I have experienced a third more milk…from better quality grass

Barriers

- ✗ Unsure of results
- ✗ Cost of machinery
- ✗ Unable to access test machinery
- ✗ Fear of damaging drains
- ✗ Wrong soil type

It doesn't work!

Key message

This is a low-cost measure which has the potential to mitigate flood risk as well as diffuse pollution. Subsoiling will only require one pass every four years which minimises labour costs. However, there is only a small window of opportunity to carry out work as weather conditions must be optimal to do so.

Track management

Suitable for Farms: **All**

Pollutants targeted:

A degraded farm track can be a pathway for and source of sediment, nutrient and FIO pollution in watercourses. Track resurfacing reduces it's risk as a source of sediment and can reduce the amount of livestock poaching and soil erosion adjacent to the track. Without additional treatment train features, a track may still be a source of FIOs and nutrients, acting as a key delivery pathway.

How effective is at reducing diffuse pollution?

Track improvements have been shown to be effective as part of a 'treatment train' approach. However, not all degraded farm tracks will be a significant source of diffuse pollution, and experience shows that pre-monitoring is essential to identify the biggest sources of runoff on a farm and inform an intervention strategy which targets these effectively.

What are the costs?

In this example, the track was constructed for £3,000 and annual maintenance costs come to £190. Due to the risk of increased connectivity to watercourses at this site, the track was designed to slope gently toward a grass swale. Without this feature, maintenance costs reduce to £100 per annum for activities such as repairing potholes.

Example track improvement works. Top left shows track before, top right and bottom left, during works and bottom right shows the improved track in use

What influences farmer uptake?

No return for costs

Motivational factors

- ✓ Desire to improve farm efficiency
- ✓ Livestock benefits
- ✓ Regulatory requirements
- ✓ Financial incentives

The dairy industry is changing, so definitely need better tracks

Barriers

- ✗ Cost of undertaking work
- ✗ Belief there are no issues with current tracks
- ✗ Desire to maintain current farm aesthetics
- ✗ Belief it's the landlord's job

Farm is flat, so no runoff

Key message

Farm track resurfacing encourages cattle to remain on the track, avoiding alternative routes which can lead to lameness, bruising and decreased milk production. Tracks improve farm access and can be done using a variety of materials sourced on or off farm, e.g. aggregate and concrete. The slope of the track and additional attenuation features must be considered during design due to the risk of increased connectivity to watercourses.

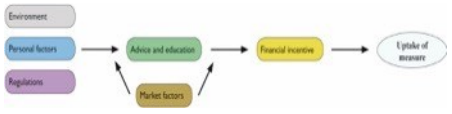
Social Science

What you will find in this section

It has been essential to complement the catchment monitoring and implementation of mitigation measures with stakeholder engagement activities and socio-economic research. This section highlights the key findings from the DTC social science research, supporting the policy design process for influencing an increase in mitigation measure uptake.

Social science overview p56

Farmer behaviours and attitudes



p57-60

Advice delivery

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Farmer engagement and networks

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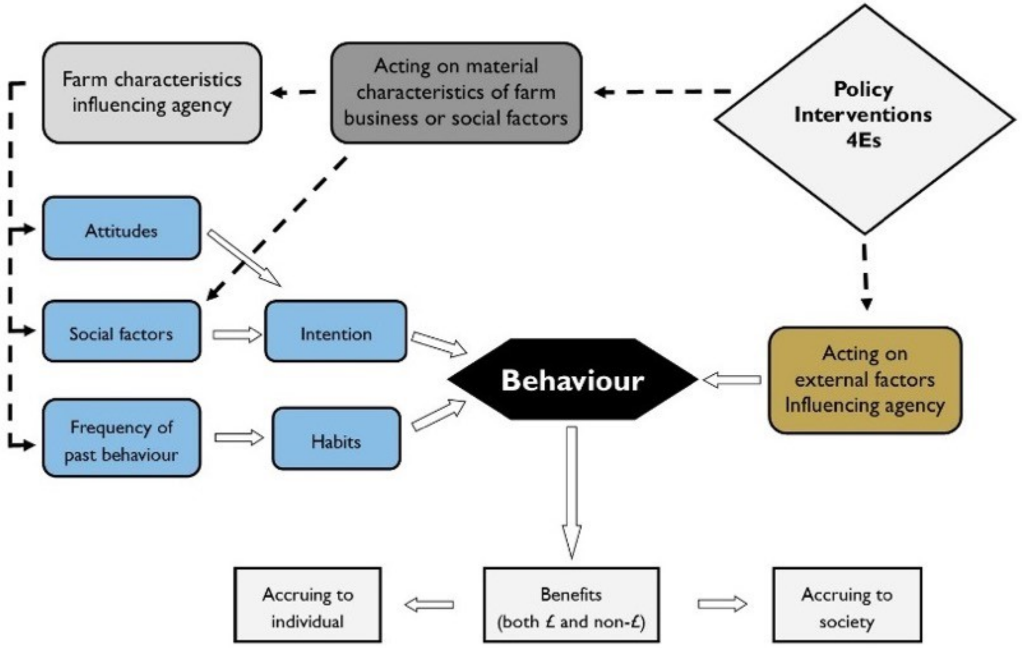
Catchment community and governance

p65-66

Social science overview

To help guide policy mechanism implementation and improve effectiveness, it is vital to understand why certain behaviours occur or particular attitudes exist. An understanding is needed of precisely which elements of the desired behaviours need to be targeted, and most importantly which factors influence behavioural change, otherwise there is a risk that interventions target the wrong elements of behaviour.

The framework below influenced the research design presented in this section by highlighting both the range of potential influences on behaviour and the need for effective policy interventions to address multiple drivers or barriers.



A framework of policy interventions and influences on farmer behaviour (adapted and extended from Pike, 2008)

The adoption of a particular behaviour (i.e. mitigation measure) is considered to be:

- a function of attitudes
- surrounding norms (socially defined expectations)
- habits (frequency of past actions)
- and agency (real and imagined capacities to act).

AND

a series of additional influences, which in an agricultural context can include:

- internal to the farm and farm household (e.g. size, tenure, age of decision makers)
- external such as market conditions or policy.

What has been learnt from social science?

- Baseline 'business as usual' behaviour
- Attitudes to future uptake of interventions
- Priorities amongst farmers
- Interventions recommended by advisors
- Gaps in advisory landscape
- Mechanisms to influence uptake
- Behaviour/attitude changes over time
- Decision process by adopters
- Barriers for non-adopters
- Advice wanted by farmer and from whom
- Partnership successes and limitations

Key message

DTC research paid particular attention to the importance of different types and sources of information, as well as the scope for facilitating social learning amongst groups of farmers, because wider evidence suggests increased understanding, awareness and a shift in social norms are more effective for increasing uptake.

Farmer behaviours

Surveys, consultation with experts and the development of modelling tools are used to document and assess the complexities of farming systems, providing ground truthing regarding farmers behaviours, adoption of different measures and verifying catchment model assumptions.

Data on the uptake of mitigation measures collected alongside other elements of farm business structure and attributes provide a greater understanding of the context in which behaviours occur e.g. data on environmental schemes or agri group involvement can discover potential avenues to encourage uptake of desired behaviours.

Establishing baseline behaviours within a catchment identifies:

1) water polluting practices which can be targeted and addressed,
2) mitigation measures already implemented thus improving accuracy of models and monitoring data,
3) mitigation measures with low adoption rates, highlighting practices which require further interventions to improve uptake (example shown in Fig. 1)

Behaviours change over time

Conducting repeat surveys captures such changes. Examples from two DTC surveys repeated 4 years apart show substantial positive change in uptake.

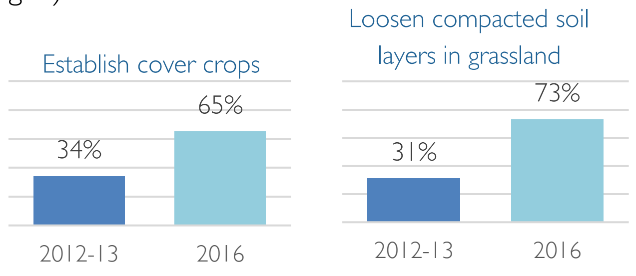


Fig. 2. Change in uptake of establishing cover crops and loosening compacted soil layers in grassland between 2012 and 2016

Adoption of mitigation measures

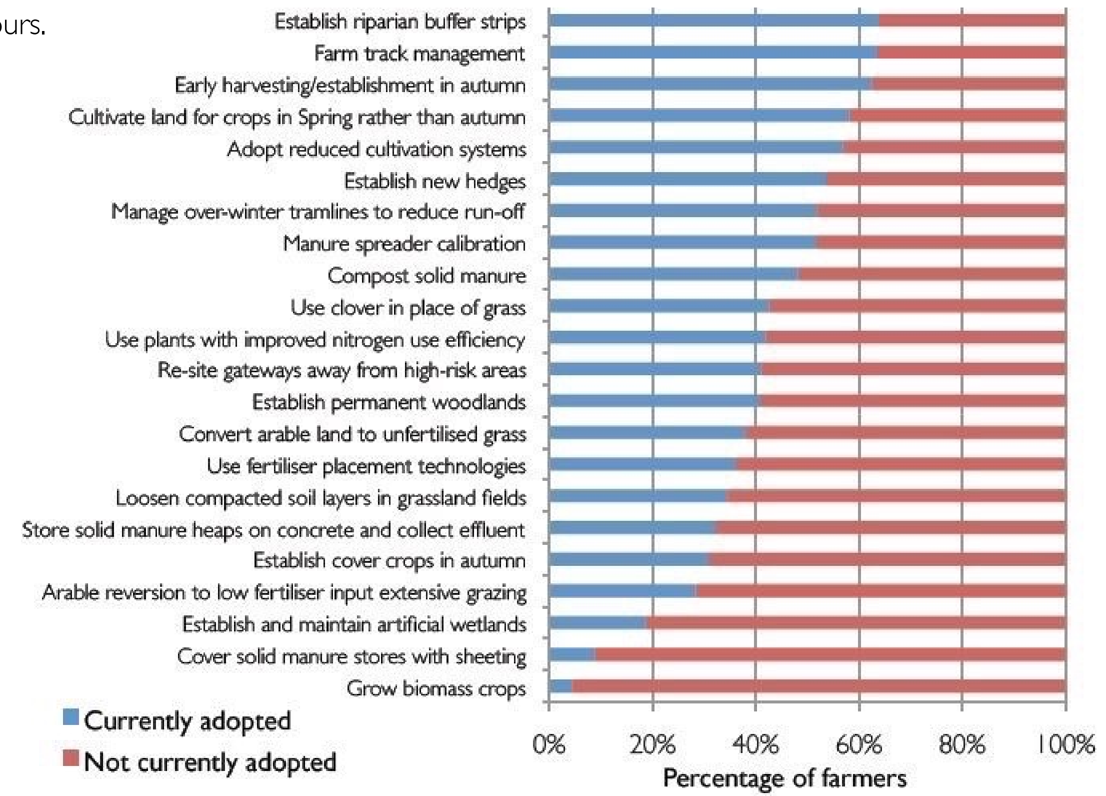


Fig. 1 DTC farm baseline survey results identifying measures with the lowest adoption rate (2012 data)

Key message

Farm practice surveys help improve the reliability of decision support tools as well as guide intervention strategies needed to address low uptake of specific mitigation measures. Behaviours change over time, therefore repeatable surveys are required to capture such alterations.

Farmer attitudes

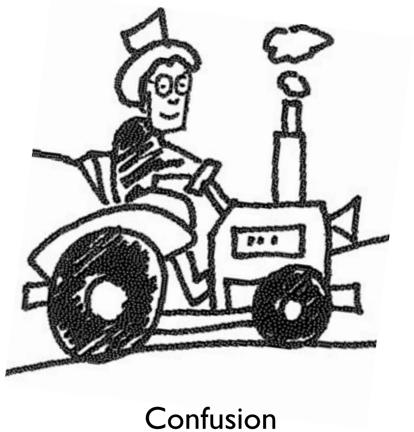
Attitudinal and farm business surveys provide insight into farmers' attitudes and priorities regarding diffuse pollution mitigation measures helping to discover the likelihood of measures being implemented. Attitudes towards specific interventions have been reported in the Interventions section, however, below are the findings regarding more generalised attitudes towards water pollution mitigation.

General attitudes towards water pollution mitigation

Water pollution is an important issue
Farmers generally acknowledged that water pollution is an important environmental issue.

Positive attitudes
Measures which farmers expressed positive attitudes towards adoption but are not currently supported in agri-environment schemes, would be appropriate targets for advisory campaigns or agri-environment scheme support (e.g. re-siting gateways, cover crops, reduced cultivation).

Lack of respect for engaging with the environment
The majority of farmers do not seek recognition from their peers for undertaking mitigation behaviour. The perceived lack of respect from engaging too prominently with the environmental agenda was echoed throughout DTC findings.



Priority measures
Improvements in farmyard infrastructure are a priority for many farmers but radical changes will not occur without substantial financial incentives or regulatory measures.

Compatibility
Measures compatible with current farm practice were more likely to be adopted than those requiring more radical management or change.

Confusion
Confusion over the scale and severity of the problem caused by agriculture

If I were to get the same money as my neighbour, but I'm getting it from the environment whilst he is producing food, I'd feel a fraud.

Key Message

There is currently no established norm within the farming community which encourages the proactive adoption of steps to deliver pollution mitigation. A significant shift in farmer identities and beliefs is likely to be required before water pollution mitigation behaviour becomes embedded.

Farmer motivations

Motivating factors reflect why a person follows their aims and drives them to do something. Due to the wide variety of contexts in which farming businesses exist, differing drivers play a role in determining farmers' willingness to adopt a mitigation measure. The drivers and motivation of **individual farmers' circumstances** are therefore highly important to consider.

Motivational factors

No single motivating factor causes adoption, rather, an evolving combination of influences. Particular motivating factors contribute at different ***stages of the decision process*** to adopt a measure. The general order shown in Fig 1, helps identify what might be required to influence other farmers to adopt and at what stage in their decision it might be needed.

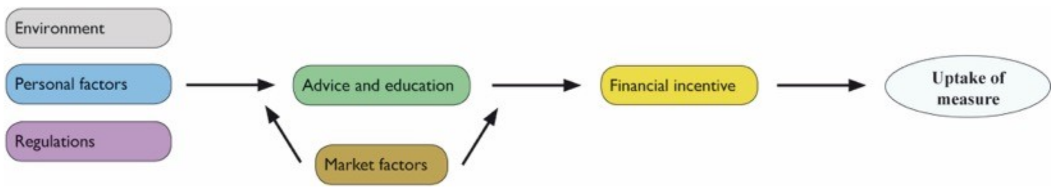


Fig. 1 A generalised set of influencing factors which contribute to the uptake of a measure

Common ***initial factors*** often involved: fear of regulation; farm activities becoming impaired by the environment and wanting to improve the farm's long-term viability. A series of stages then followed in the decision process, varying in number. The ***final stage*** for many involved financial incentives. However, this is not always the case, even when incentives are available, indicating that other mechanisms are effective, such as advice.

Key Message

Differing complexities of decision processes for the adoption of mitigation measures imply the need to consider each measure separately and take account of the diversity in farming contexts which exist when designing policy interventions. Considering the entire decision process and supporting interventions at multiple stages can help to accelerate the process of adoption.

Decision process complexity

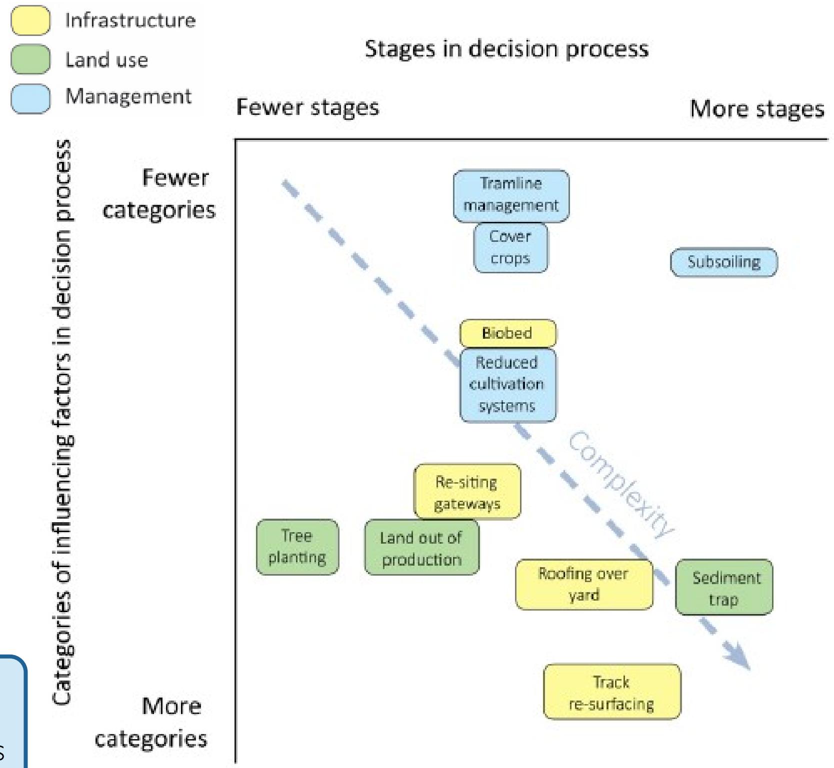


Fig. 2 Measures plotted by complexity of the adoption decision-making process

The more novel measures e.g. sediment traps, regularly required more stages with different sources of advice throughout the process. Whereas other familiar measures, such as taking land out of production and tree planting often merely required two or three stages i.e. having unproductive land or a love of wildlife and receiving a grant.

For some, additional stages in a decision process were needed to add to tip the scales and provide the extra push, with such factors being either secondary benefits (e.g. biomass boiler fuel for tree planting) or knowledge to make a more informed decision (e.g. advice of crop varieties and benefits for cover crop planting).

Farmer barriers

An understanding of the barriers which need to be overcome to increase uptake of mitigation measures helps direct where efforts should be concentrated. Identifying whether internal or external barrier factors dominate or whether numerous different factors act as barriers provides a greater understanding of how mechanisms need to be tailored.

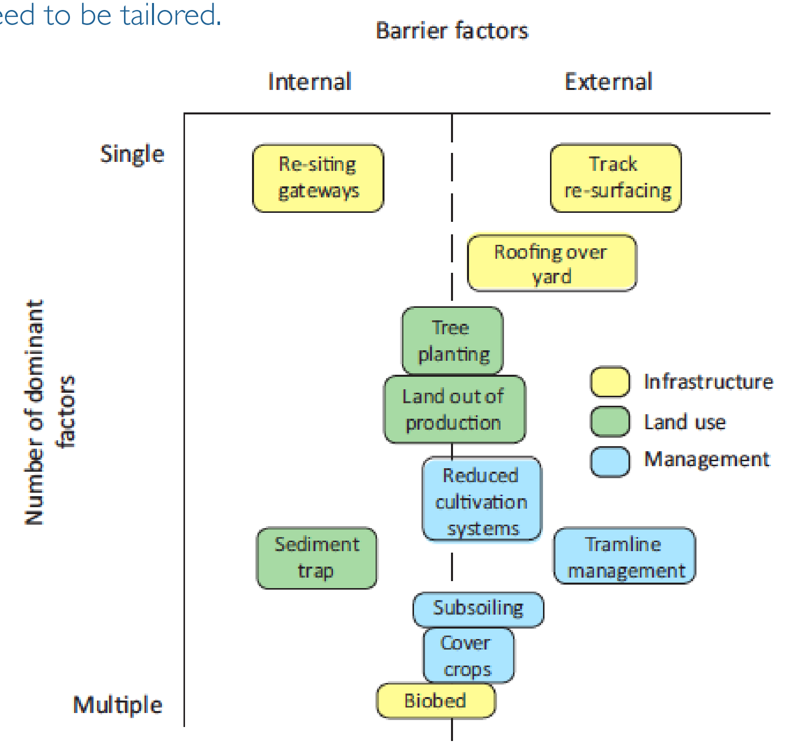
Internal and external barriers for mitigation measure adoption

Internal		External	
Capability	Experience Physical and mental skills Knowledge and awareness Cognitive skills Interpersonal skills	Social/ cultural	Peer pressure Land management ethics Traditions Society trust in government Presence of young farmers
Reflective motivation	Attitude Risk perception Goals and Intentions Optimism Beliefs about outcomes Beliefs about capabilities Identity Attention	Economic	Technology Production factors Farming system Labour Financial factors Incentive schemes/fines Indirect costs – e.g. time
Automatic motivation	Emotion e.g. fear, Habit Routine	Institutional	Infrastructure provided Policies and legislation Incentive schemes Land tenure/property rights Extension services Enforcement mechanisms
Demographic	Gender Level of education Age	Environmental	Climate Soil type Proximity to water Degree of soil degradation Land availability

General barriers

- Strong sense of financial disempowerment
- Lack of time for performing mitigation, attending training events, as well as grant application windows often coinciding with the busiest farming period
- Tenancy arrangements impacting propensity to engage in longer-term initiatives, e.g. soil improvement or infrastructure

Barriers varied for the adoption of different types of measures. Some measures have many different types of both internal and external barriers, while others have only one type (internal or external) as the most common form of barrier.



Examples of dominant barriers for mitigation measures

Key Message

Barriers vary greatly between farms and mitigation measures. Policy interventions for measures which have internal barriers need to focus on changing social norms and attitudes and will often take a longer time to successfully change behaviours. Measures with external constraints require efforts which alter such restrictions.

Farm advice delivery

Advice delivery is used to encourage uptake of mitigation measures, however the farm advice sector has dramatically changed over recent years. Many organisations and businesses now offer advice and there is a risk that the sector has become busy and fragmented. Mapping out the advisor landscape to identify recommendations, gaps and conflicts aids policy interventions.

Conflicts in advice

Different agendas Conflicts in recommendations exist between advisors with differing agendas (environment, government or economic) e.g. the amount of fertiliser to spread and silage cutting times.

Changing regulations
Ever changing regulations causes confusion and difficulties for advisors to keep up-to-date.

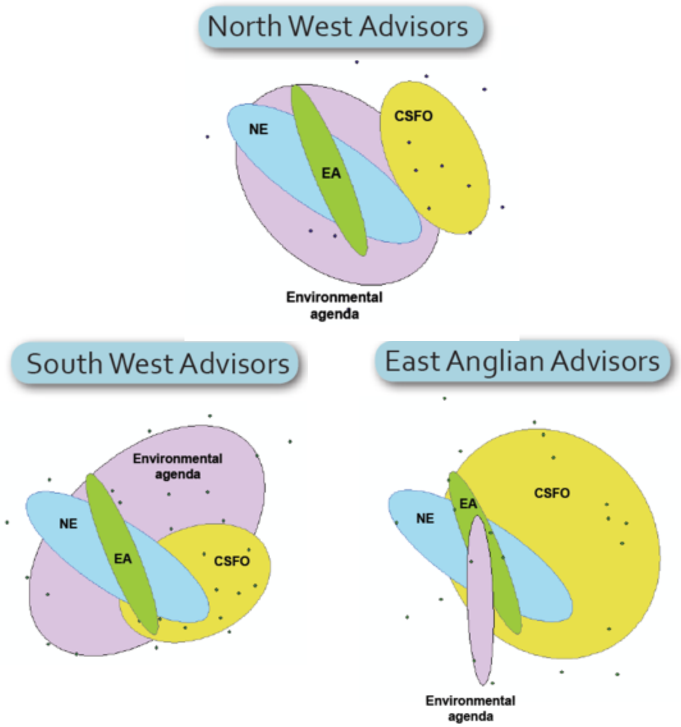
Government Conflicts occur within and between government organisations. Common disagreements involved scheme options and whether they were effectively targeted.

Conflicts indicate that the advice sector could be more efficient, as collectively it does not provide consistent advice

Key Message

Advice must be consistent and delivered from a trusted source. Improvements to communication and co-ordination amongst advisors are required to provide farmers with efficient, clear and effective advice, along with the need for farm advisor continuity.

Advice delivered by different organisations is not homogeneous and some indeed have particular niches within the farm advice sector.



Mapping the advisor landscape in three regions of England

What improvements are needed?

There is scope to better utilise non-government advisors by maintaining communication and providing briefing sessions when new schemes are introduced. This, for instance, is likely to be important for the effective implementation of future agri-environmental policy.

A single one-off transfer of knowledge is insufficient suggesting sustained advice is required as part of an iterative learning process. Efforts should be made to ensure farm advisor continuity and to enhance communication and co-ordination amongst the various actors, aiding knowledge exchange.

Having people on the ground who:

(i) have sufficient local knowledge;

(ii) are accepted and trusted amongst the community;

(iii) fully understand the farmers' contexts and adapt their approach depending upon farmer needs;

(iv) know which stages individuals are at in decision processes, and;

(v) are working to ensure government objectives are met, greatly improves policy efficiency.

Attitudes to advice

Farm advisors are an important communication channel to disseminate information regarding farm mitigation measures. Farmers' attitudes towards advisors influence whether they listen and act upon their advice. Discovering what advice is wanted and from whom helps identify the best channels for disseminating information and engaging farmers.

What advice is wanted?

Generally, farmers want advice for new management and infrastructure change mitigation measures e.g. cover crops, subsoiling, sediment traps and biobeds, with the most advice desired by livestock farmers for management changes. The most preferred format was a visit from a farm advisor, in particular 'hands-on,' practical advice and the least preferred was written communication.

Specific information was requested on:

- Guidance on avoiding waterlogging
- Sustainable slug control
- Rainwater harvesting methods
- Improved bio-bed designs
- Local research being conducted
- Soil management
- Worm density and its impact on soil quality
- Local evidence of benefits

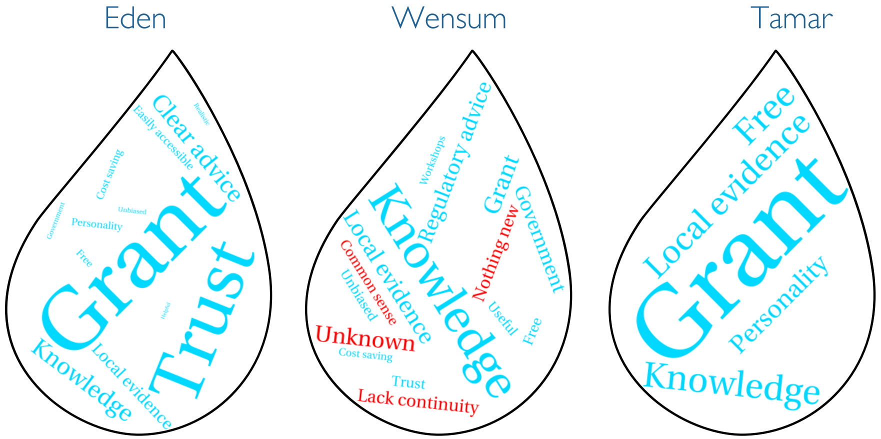
Advice from whom?

Desirable advisor qualities

- ✓ Unbiased
- ✓ Good personality
- ✓ Enthusiastic
- ✓ Knows whole farm
- ✓ Signpost to grants
- ✓ Offer encouragement

The reasons why farmers listen to different advisors vary appreciably. Variations in the reasons farmers listen to Catchment Sensitive Farming Officers (shown to the right) across three catchments highlights the importance of building a trusting relationship through staff continuity and the provision of grants.

Regional differences in attitudes towards advisors



Farmers' comments to describe why they would (blue text) or wouldn't (red text) listen to advice from Catchment Sensitive Farming Officers regarding mitigation measures.

Key Message

To disseminate advice effectively it is essential to appreciate who farmers listen to in each area and why, as attitudes towards advisors varied across catchments, with different attributes being of importance. Ensure funds are targeted to organisations providing advice with well-established relationships, acting as intermediaries for the Government.

Farmer engagement

To encourage best practice amongst farming communities, knowledge exchange activities help disseminate research findings, engage farmers and build a community. Farmers can be engaged in various forms, with examples of some of the methods used throughout the DTC discussed below with recommendations for effectiveness.

Demonstration sites, training and research platforms

Providing opportunities for direct learning from site visits, training and involvement in research platforms helps gain acceptance from the farming community. Raising awareness of issues and potential solutions available, equipping farmers to make informed decisions based on local evidence.


Image: Andrew Lovett

I have become much more aware of the issues of runoff and compaction… allowing us to create a more sustainable farming system… The state of the soil has improved drastically.

Arable farm manager*

We are more aware of the nutrients in slurries and manage them better than we have in the past. We are trying to make better use of that resource.

Upland livestock farmer

Key Message

Provide demonstration sites, training, research platforms, facilitate discussion groups and provide catchment data to engage farmers at a local level. Encouraging farmers to initially change relatively simple measures rather than suggesting complex interventions is likely to result in longer-term receptiveness towards more challenging integrated activity.

Discussion groups

Allowing time for in-depth discussions and providing an opportunity for farmers to meet and debate with fellow members of their industry proved popular. Regarded as worthwhile if 1) Attendees feel they will get practical benefits and 2) opportunities exist for two-way information exchange. When participants were predominantly farmers it was advantageous, giving individuals the confidence to speak freely without judgement from external stakeholders.


Images: Emilie Vrain

Not all farmers will be willing or able to actively participate in discussion groups or site visits….

Therefore, disseminating information from local case studies and demonstration sites helps engage a broader pool of farmers, especially when facilitated by trusted extension workers working closely with innovative respected farmers.

Catchment data

A highly effective method to engage farmers has been the provision of data for their local catchment. When providing such data it is important it can be interpreted and understood by farmers.

Techniques for presenting information to farmers

- Expressing pollution fluxes in monetary value, underscoring the potential benefits to their businesses of pollution control,
- Messages about nutrient losses following rainfall events translated into the cost equivalents in terms of wasted fertiliser,
- Showing storm effects on sediment transport can be a powerful communication tool, as farmers can immediately relate to it in terms of the loss of soil - their most valuable natural resource,
- Making the link between soil health and animal health is an effective method of influencing farmers, especially when delivered by an agriculturally focused advisor, particularly animal nutritionists.

*involved in the DTC research and who has altered the entire cultivation practices of the farm.

Farmer networks

There is currently no established norm within the farming community which encourages the proactive adoption of steps to deliver water pollution mitigation outcomes. A significant shift in farmer identities and normative beliefs is likely to be required before mitigation behaviour becomes embedded and internal barriers to adoption are overcome. Facilitating collaboration between farmers can help this to be achieved.

Establishing discussion groups to initially build a sub-catchment awareness, social capital and trust.

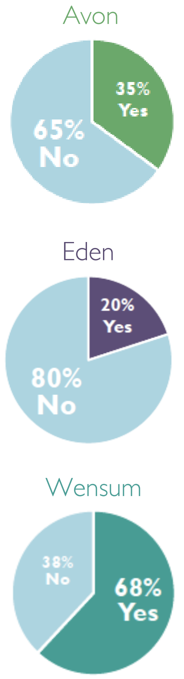
→ Develops closer working arrangements between farmers and may result in formal collaborative endeavours.

↓ Involving other elements of the supply chain could establish positive discussions from which new jointly owned / accepted strategies could emerge.

← Positive experiences of engaging in collective action should be promoted in the farming press. The social benefits emphasised as much as financial benefits.

Initiatives which support farmer collaboration need continuity for the medium to long-term

% of farmers who currently work with others on mitigation measures



Skilled facilitators well versed in rural sociology, farming systems and mitigation interventions (ideally chosen and trusted by the farmers) are needed to aid collaborative or coordinated farmer activities. Such facilitators need job security and to be appropriately trained to distil evidence and data into key messages that resonate with the farming audience.


Image: Richard Cooper

Key determinant of continued farmer buy-in

Supporting more farms to act as demonstration sites, building on the DTC experience that this can be successful for on-going dissemination of local evidence, results and knowledge of good practice.

↓

Communicating the scientific rationale for collaborative or co-ordinated action.

Concerns of working with others

"Damage to machinery"

"A lot of talk and not much action"

"Falling out with friends and neighbours"

"Everyone wants machine at the same time"

"Being penalised for someone else's fault"

Key message

There is scope to facilitate collaboration between farmers and to aid social learning, but in order to do so, resources are required. An external facilitator is needed, who is known and trusted by the famers and has the ability to organise and run meetings.

Catchment community

For the complex challenges of water catchments to be managed effectively, different types of knowledge must be brought together and applied effectively. This will involve making active two-way relationships within and beyond research communities, drawing in the practical expertise of farmers, land managers and other stakeholders to build catchment communities of practice.

Establishing a catchment community with research

It is important to work within, and recognise, the local farming social context by identifying and utilising existing knowledge brokers and building relationships and trust within a catchment.

Starting a process of engagement through meetings and activities from the beginning helps:

1. raise awareness of a research programme
2. identify key stakeholders (both individuals and organisations)
3. develop an underpinning conceptual model of a target sub-catchment
4. inform monitoring strategies
5. identify priorities for the implementation of farm mitigation measures
6. invite collaboration where there are opportunities for the exchange of information and/or joint working.

Key message

The complexities and trade-offs associated with catchment management require an adaptive management cycle, collaboration between agencies and a 'twin-track' of stakeholder engagement alongside scientific research.

Direct involvement of farmers in research adds a sense of reality and credibility to the findings for both local and national level stakeholders

Image: Kevin Hiscock

Transparency is vital regarding the impact of the research collaboration on the day-to-day running of their business, costs, and long-term maintenance of measures.

Build up trust and confidence, to agree change and understand the likely impact on individual farms.

Trust can only be developed through consistency, openness and sound advice.

The DTC experience found the farming community is accepting of evidence and advice from authoritative (non-governmental) sources such as universities and rivers trusts providing this is delivered in a manner **sympathetic to the practicalities of farming** and in a **spirit of co-learning**.

Catchment governance

The Catchment Based Approach was initiated to deliver positive and sustained outcomes for the water environment by promoting a better environmental understanding at a local level; and to encourage local collaboration and more transparent decision-making when planning and delivering activities. The DTC programme conducted an evaluation of the approach through semi-structured interviews with key local and national stakeholders in 2016. Key recommendations arising from the research are summarised below.

Learn from successes

Engagement

People are most engaged at a very local level. Sub-catchment groups work well, with Catchment partnership host acting as the strategic umbrella. Successful involvement of the farming community needs meetings/events to be at suitable times of the day and in accordance with the agricultural calendar. Significant up-front effort may need to be invested by facilitating organisations to successfully recruit hesitant participants.

Host and partners

Having the right host is crucial. Characteristics comprising of highly skilled individuals with facilitation and data management expertise and delivered by a highly competent and committed lead organisation. Having the right partners is also essential. Businesses, local authorities, water companies and farmers involvement shown to be important.

Funding/resources needed for an additional part-time regional funding officer / bid writer helps secure further funding.

Monitoring the success of partnerships through community surveys & annual reviews of the catchment management plans.

Catchment Based Approach

Key message

The status and role of catchment partnerships needs outlining and reinforcing, whilst future funding needs to be long-term and adequate to employ a full-time post in each catchment. Information exchange needs to be improved across the board, with the sharing of resources and experiences aiding success. Partnerships are helping to facilitate co-operation and social learning to improve catchment management.

Overcome frustrations and limitations

Funding/resources

Ensure adequate on-going finance for facilitation and explicitly outline organisational remits and structure funding streams accordingly to avoid competition between entities.

"Can't deliver champagne on a lemonade budget"

Status and legitimacy

The status and role of partnerships needs reinforcing to improve legitimacy and organisational buy-in. An informal agreement was suggested to help know the purpose, help new partners or staff understand and provide a driving force to act.

Data access restrictions to important datasets such as high resolution soil maps and low flows data need to be addressed, providing stakeholders access to data in a format they can understand and scrutinise.

Information exchange needs to be improved between the Government, partnership hosts, partners and the community. Suggested methods include: newsletters, YouTube videos, web portal, farmer steering groups, demonstration sites, data visualisation and map based tools.

Data sources used in this publication (1 of 3)

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If you are unable to locate or access a resource, please contact: water.evidence@defra.gov.uk

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If you are unable to locate or access a resource, please contact: water.evidence@defra.gov.uk

Catchment group proximities

How were these proximities created?

Click here

The Catchment Matcher proximity tables enable practitioners to identify catchments similar to one they are working in, perhaps to ask for advice on a particular issue or search for evidence on the effectiveness of a mitigation measure or other initiative. *Catchment Group* classifications provide an initial means of identifying broadly comparable catchments within the same group and then the proximity indices enable a more refined shortlist to be drawn up. The proximity values could also be used to provide a level of confidence when extrapolating findings from one catchment to another.

Catchments are listed in approximate north to south order within River Basin Districts

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
SEPA	Solway Tweed	3	0.13	0.03
Derwent	Solway Tweed	5	0.27	0.09
Ellen and West Coast	Solway Tweed	4	0.14	0.01
Eamont	Solway Tweed	5	0.28	0.09
Esk and Irthing	Solway Tweed	6	0.11	0.00
Eden Lower	Solway Tweed	4	0.10	0.00
Petteril	Solway Tweed	4	0.16	0.02
Eden Upper	Solway Tweed	6	0.13	0.00
Caldew	Solway Tweed	6	0.12	0.01
Kent	Solway Tweed	6	0.16	0.02
Leven	Solway Tweed	5	0.23	0.07
Greta and Rawthey	Solway Tweed	5	0.30	0.09
Lune Upper	Solway Tweed	5	0.31	0.10
Swale Upper	Solway Tweed	6	0.22	0.04
Ure Upper	Solway Tweed	6	0.21	0.03
Till	Solway Tweed	5	0.12	0.05
Waver and Wampool	Solway Tweed	4	0.16	0.01
Tweed	Solway Tweed	3	0.16	0.02
Rye	Northumbria	6	0.10	0.02
Esk	Northumbria	6	0.13	0.01
Sandsend and Staithes	Northumbria	6	0.11	0.03
Aln	Northumbria	6	0.09	0.02
Berwick to Alnmouth Coast	Northumbria	3	0.16	0.02
Blyth	Northumbria	3	0.12	0.02

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Coquet Lower	Northumbria	6	0.09	0.02
Lyne and Druridge Bay Coast	Northumbria	6	0.14	0.02
Pont	Northumbria	6	0.14	0.03
Coquet Upper	Northumbria	5	0.22	0.06
Wansbeck	Northumbria	6	0.1	0.03
Swale Lower	Northumbria	3	0.14	0.01
Swale Middle	Northumbria	6	0.14	0.01
Wiske	Northumbria	6	0.2	0.02
Leven Northumbria	Northumbria	3	0.09	0.01
Tees Lower and Estuary	Northumbria	2	0.12	0.04
Tees Middle	Northumbria	6	0.09	0.01
Saltburn Coast	Northumbria	6	0.09	0.01
Skerne	Northumbria	3	0.13	0.02
Tees Upper	Northumbria	6	0.24	0.06
Allen	Northumbria	6	0.2	0.03
Derwent Tyne	Northumbria	6	0.13	0.03
North Tyne Lower	Northumbria	6	0.11	0.01
South Tyne Lower	Northumbria	6	0.12	0.00
Tyne Lower and Estuary	Northumbria	2	0.15	0.09
Rede	Northumbria	5	0.23	0.06
Tyne	Northumbria	6	0.09	0.02
North Tyne Upper	Northumbria	5	0.26	0.10
South Tyne Upper	Northumbria	6	0.25	0.06
Browney	Northumbria	6	0.1	0.03

Mean Prx – Mean proximity to all other Operational Catchments
Min Prx to DTC – Minimum proximity to Demonstration Test Catchments

Catchment group proximities

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Gaunless	Northumbria	6	0.11	0.03
Wear Lower and Estuary	Northumbria	2	0.11	0.03
Wear Middle	Northumbria	6	0.11	0.02
Seaham Peterlee Coast	Northumbria	3	0.14	0.01
Wear Upper	Northumbria	6	0.24	0.06
Colne and Holme	Humber	2	0.13	0.05
Aire Lower	Humber	2	0.16	0.09
Calder Lower	Humber	2	0.15	0.09
Aire Middle	Humber	2	0.17	0.10
Calder Middle	Humber	2	0.16	0.08
Aire Upper	Humber	6	0.14	0.01
Calder Upper	Humber	6	0.24	0.08
Derwent Derbyshire	Humber	6	0.13	0.01
Derwent Lower - Derbyshire	Humber	2	0.13	0.06
Derwent Mid	Humber	6	0.11	0.03
Derwent Lower Yorkshire	Humber	3	0.18	0.00
Derwent Middle Yorkshire	Humber	3	0.16	0.01
Derwent Upper Yorkshire	Humber	3	0.12	0.01
Dearne	Humber	2	0.11	0.03
Don Lower	Humber	3	0.15	0.03
Don Middle	Humber	2	0.17	0.12
Rother and Doe Lea	Humber	2	0.1	0.03
Don Upper	Humber	6	0.12	0.02
Churnet	Humber	6	0.13	0.04
Dove Lower	Humber	4	0.13	0.01
Dove Upper	Humber	6	0.16	0.05
Robin Hoods Bay	Humber	6	0.11	0.02
Barmston Sea Drain	Humber	3	0.21	0.01
Burstwick and Eastern Drains	Humber	3	0.27	0.03

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Foulness	Humber	3	0.2	0.02
Gypsey Race	Humber	3	0.21	0.01
Hull Lower	Humber	3	0.18	0.01
Hull Upper	Humber	3	0.23	0.02
Idle	Humber	3	0.19	0.03
Isle of Axholme	Humber	3	0.17	0.02
Croal and Irwell	Humber	2	0.22	0.17
Roch, Irk, Medlock	Humber	2	0.19	0.15
Ancholme	Humber	3	0.19	0.02
North Becks	Humber	3	0.18	0.04
Nottingham Urban	Humber	2	0.16	0.09
Erewash River	Humber	2	0.12	0.07
Trent River	Humber	4	0.11	0.02
South Nottinghamshire B	Humber	1	0.16	0.04
South Nottinghamshire A	Humber	3	0.19	0.01
Trent and Tributaries	Humber	3	0.18	0.02
Limestone Ribble	Humber	6	0.27	0.08
Middle Ribble - Settle to Calder	Humber	6	0.13	0.02
Calder	Humber	2	0.18	0.10
Colne Water	Humber	6	0.16	0.04
Perry Roden & Tern North Shropshire	Humber	3	0.22	0.03
Soar	Humber	1	0.12	0.04
Wreake	Humber	1	0.16	0.05
Penk	Humber	4	0.13	0.03
Blithe River	Humber	4	0.16	0.02
Sow	Humber	4	0.15	0.03
Trent - Source to Sow	Humber	2	0.14	0.06
Trent - Sow to Tame	Humber	3	0.15	0.04

Mean Prx – Mean proximity to all other Operational Catchments
Min Prx to DTC – Minimum proximity to Demonstration Test Catchments

Catchment group proximities

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Foss	Humber	3	0.14	0.01
Nidd Middle and Lower	Humber	6	0.11	0.02
Ure Middle and Lower	Humber	6	0.11	0.02
Nidd Upper	Humber	6	0.17	0.01
Ouse Upper	Humber	3	0.16	0.02
Blythe	Humber	4	0.12	0.03
Tame Lower	Humber	2	0.19	0.12
Mease	Humber	3	0.14	0.02
Sence, Anker and Bourne	Humber	1	0.12	0.02
Trent - Tame to Dove	Humber	2	0.13	0.05
Tame Upper	Humber	2	0.29	0.20
Goyt, Etherow and Tame	Humber	2	0.19	0.09
Avon Rural	Humber	1	0.12	0.03
Avon Urban	Humber	1	0.11	0.03
Dane	Humber	4	0.11	0.01
Weaver Upper	Humber	4	0.16	0.03
Welland Upper	Humber	1	0.14	0.04
Ouse Lower Yorkshire	Humber	3	0.22	0.01
Wharfe Lower	Humber	3	0.15	0.01
Wharfe Middle and Washburn	Humber	6	0.1	0.03
Wharfe Upper	Humber	6	0.31	0.10
Witham Lower	Humber	3	0.19	0.03
Steeping and Eaus	Humber	3	0.2	0.04
Witham Upper	Humber	3	0.17	0.05
Stour Upper Worcestershire	Humber	2	0.2	0.11
Salwarpe River	Humber	1	0.11	0.02
Stour River and Tributaries	Humber	2	0.16	0.07
Worfe River	Humber	3	0.22	0.02
Tidal Thames	Anglian	2	0.13	0.06

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Bure	Anglian	3	0.13	0.02
Waveney	Anglian	3	0.18	0.02
Wensum	Anglian	3	0.18	0.00
Yare	Anglian	3	0.15	0.01
Cam, Rhee and Granta	Anglian	3	0.23	0.02
Lark	Anglian	3	0.19	0.01
Little Ouse and Thet	Anglian	3	0.18	0.01
Lower Cam	Anglian	3	0.17	0.03
South Level and Cut-Off Channel	Anglian	3	0.19	0.02
Wissey	Anglian	3	0.23	0.03
Cherwell	Anglian	1	0.12	0.02
Oxon Ray	Anglian	1	0.15	0.08
Colne	Anglian	2	0.11	0.04
Blackwater	Anglian	3	0.19	0.05
Chelmer	Anglian	3	0.17	0.05
Colne Essex	Anglian	3	0.16	0.03
Crouch and Roach	Anglian	1	0.14	0.05
Stour	Anglian	3	0.19	0.06
Deben	Anglian	3	0.21	0.02
Gipping	Anglian	3	0.18	0.02
Suffolk Coastal	Anglian	3	0.18	0.01
Brampton Branch	Anglian	1	0.14	0.03
Ise	Anglian	1	0.14	0.03
Nene Lower	Anglian	3	0.21	0.05
Nene Middle	Anglian	1	0.17	0.08
Nene Upper	Anglian	1	0.13	0.03
Willow Brook	Anglian	1	0.19	0.11
North Norfolk	Anglian	3	0.2	0.01
North West Norfolk	Anglian	3	0.19	0.01

Mean Prx – Mean proximity to all other Operational Catchments
Min Prx to DTC – Minimum proximity to Demonstration Test Catchments

Catchment group proximities

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Old Bedford and Middle Level	Anglian	3	0.22	0.05
Roding Beam and Ingrebourne	Anglian	1	0.17	0.09
Mardyke	Anglian	1	0.14	0.06
Thame	Anglian	1	0.13	0.04
Bedford Great Ouse	Anglian	1	0.17	0.07
Ivel	Anglian	3	0.15	0.03
Lower Great Ouse	Anglian	1	0.21	0.09
Ouzel and Milton Keynes	Anglian	1	0.15	0.08
Upper Great Ouse	Anglian	1	0.16	0.06
Upper Lee	Anglian	1	0.15	0.04
Glens	Anglian	3	0.2	0.07
Welland Lower	Anglian	3	0.23	0.02
East and West Fens	Anglian	3	0.22	0.04
South Forty Foot Drain	Anglian	3	0.24	0.09
Ouse	Thames	1	0.09	0.02
Arun Upper	Thames	1	0.1	0.04
Rother West	Thames	4	0.09	0.01
Bristol Avon Rural	Thames	1	0.11	0.04
Evenlode	Thames	1	0.12	0.01
Cray and Shuttle	Thames	2	0.15	0.07
Darent	Thames	3	0.11	0.02
Hampshire Avon	Thames	3	0.09	0.00
Kennet	Thames	3	0.1	0.00
Loddon	Thames	2	0.12	0.06
Beverley Brook	Thames	2	0.32	0.26
Ravensbourne	Thames	2	0.23	0.15
Hogsmill	Thames	2	0.24	0.18
Wandle	Thames	2	0.23	0.17
Marsh Dykes	Thames	2	0.32	0.26

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Brent	Thames	2	0.29	0.23
Lower Lee	Thames	2	0.2	0.16
Crane	Thames	2	0.28	0.23
Thames Lower	Thames	2	0.17	0.12
Medway Upper	Thames	2	0.09	0.03
Medway Middle	Thames	2	0.1	0.02
Teise	Thames	1	0.09	0.01
Beult	Thames	1	0.13	0.04
Eden	Thames	1	0.1	0.04
Medway Lower	Thames	1	0.1	0.02
Mole Upper Tributaries	Thames	2	0.14	0.10
Mole Lower and Rythe	Thames	2	0.15	0.10
North Kent	Thames	1	0.11	0.01
Rother Levels	Thames	6	0.1	0.01
Reading, Cradlebridge and RM	Thames	1	0.13	0.02
Rother Upper	Thames	1	0.1	0.04
Chelt, Hatherley and Normans Brook	Thames	1	0.18	0.12
Frome and Cam	Thames	1	0.1	0.04
Gloucester Tributaries	Thames	1	0.14	0.08
Stour Marshes	Thames	3	0.13	0.02
Oyster Coast Brooks	Thames	1	0.11	0.05
Stour Upper	Thames	1	0.11	0.01
Stour Lower	Thames	3	0.1	0.01
Itchen	Thames	1	0.1	0.01
Test Middle and Upper	Thames	3	0.13	0.01
South Chilterns	Thames	1	0.1	0.01
Thames Upper	Thames	1	0.12	0.03
Ock	Thames	1	0.12	0.03
Windrush	Thames	1	0.12	0.02

Mean Prx – Mean proximity to all other Operational Catchments
Min Prx to DTC – Minimum proximity to Demonstration Test Catchments

Catchment group proximities

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Avon - Midlands West	Thames	1	0.11	0.03
Wey	Thames	2	0.11	0.05
Adur	South East	1	0.09	0.03
Teville	South East	1	0.13	0.08
Western Streams	South East	1	0.1	0.01
Arun Lower	South East	1	0.09	0.01
Cuckmere	South East	1	0.09	0.02
Pevensey	South East	1	0.12	0.06
Combe Haven	South East	2	0.11	0.06
East Hampshire	South East	1	0.09	0.02
Isle of Wight	South East	4	0.09	0.01
NF - Hatchet Sowley	South East	1	0.09	0.02
NF - Lymington and Beaulieu	South East	5	0.12	0.05
NF - Urban Coastal	South East	2	0.14	0.08
NF - Bartley Water	South East	1	0.16	0.10
Romney Marsh South	South East	3	0.13	0.01
Brede and Tillingham	South East	1	0.09	0.03
Dour	South East	3	0.11	0.01
North and South Streams	South East	3	0.22	0.01
Little Stour and Wingham	South East	3	0.14	0.01
Test Lower, Southampton Streams	South East	1	0.08	0.01
Axe	South West	1	0.11	0.03
West Dorset Rivers	South West	4	0.1	0.01
Stour Dorset	South West	1	0.09	0.02
Poole Harbour Rivers	South West	4	0.11	0.02
Clyst and Culm	South West	4	0.13	0.02
Creedy and West Exe	South West	4	0.1	0.01
Exe Main	South West	4	0.1	0.02
Lim and Axe	South West	4	0.12	0.00

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Sid and Otter	South West	4	0.13	0.02
Camel	South West	4	0.1	0.00
Fowey	South West	4	0.1	0.01
Gannel Porth and Menalhyl	South West	4	0.11	0.01
Strat, Neet and North Coast Streams	South West	4	0.12	0.00
Seaton Looe and Polperro	South West	4	0.09	0.00
Hartland and Clovelly Streams	South West	4	0.1	0.01
Taw and North Devon Streams	South West	4	0.1	0.01
Torridge	South West	4	0.1	0.01
Parrett River	South West	4	0.12	0.02
Tone River	South West	4	0.1	0.01
West Somerset Streams	South West	5	0.11	0.03
Brue	South West	4	0.15	0.03
Avon, Salcombe and Kingsbridge	South West	4	0.09	0.00
Dart, Start Bay and Torbay	South West	4	0.1	0.02
Erme	South West	4	0.09	0.01
Teign	South West	4	0.09	0.02
Tamar Lower and Inny	South West	4	0.09	0.00
Lynher	South West	4	0.09	0.00
Plym	South West	5	0.17	0.07
Tavy	South West	5	0.12	0.03
Thrushel, Wolf and Lyd	South West	4	0.11	0.01
Tamar Upper	South West	4	0.12	0.00
Yealm	South West	4	0.09	0.00
Fal	South West	4	0.12	0.02
Hayle, Red River, Northern Streams	South West	4	0.11	0.02
Cober and Lizard	South West	4	0.11	0.02
Par, St Austell and Caerhays	South West	4	0.11	0.01
Penwith Peninsula	South West	4	0.17	0.05

Mean Prx – Mean proximity to all other Operational Catchments
Min Prx to DTC – Minimum proximity to Demonstration Test Catchments

Catchment group proximities

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Bristol Avon Urban	Severn	2	0.18	0.12
Severn Lower Vale	Severn	1	0.1	0.03
North Somerset Streams	Severn	1	0.11	0.02
Tywi	Severn	5	0.16	0.02
Dee Upper above Alwen	Severn	5	0.29	0.09
Ceiriog	Severn	5	0.15	0.01
Worthenbury	Severn	4	0.18	0.03
Thaw and Cadoxton	Severn	4	0.1	0.02
Ogmore	Severn	2	0.11	0.04
Afan	Severn	5	0.28	0.12
Neath	Severn	5	0.25	0.10
Tawe	Severn	5	0.24	0.10
Severn Upper Montfort North	Severn	4	0.13	0.02
Severn Upper and Tanat River	Severn	5	0.17	0.02
Severn Upper and Cain River	Severn	4	0.14	0.02
Severn Upper and Vrynwy River	Severn	5	0.21	0.04
Severn Upper Twrch and Banwy	Severn	5	0.17	0.02
Severn Upper and Rhiw River	Severn	4	0.15	0.01
Severn Upper Trannon Clywedog	Severn	5	0.2	0.03
Severn Upper Montfort South	Severn	4	0.12	0.02
Severn Upper Montfort East	Severn	4	0.11	0.01
Cound Brook	Severn	4	0.12	0.02
Morda, Severn North Shropshire	Severn	4	0.14	0.04
Rea Brook	Severn	4	0.12	0.00
Bushley, Longdon, Marlbank	Severn	4	0.14	0.03
Forest of Dean	Severn	4	0.09	0.02
Leadon	Severn	4	0.12	0.02
Malvern Hills	Severn	1	0.1	0.03
Severn River and Tributaries	Severn	4	0.11	0.02

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Telford North	Severn	3	0.12	0.01
Ebbw Sirhowy	Severn	5	0.22	0.09
Rhondda	Severn	5	0.39	0.20
Cynon	Severn	5	0.23	0.08
Taff u s Cynon	Severn	5	0.25	0.09
Ely	Severn	2	0.14	0.05
Taff d s Cynon	Severn	2	0.22	0.16
Rhymney	Severn	2	0.12	0.05
Reens West	Severn	1	0.1	0.03
Teme Lower	Severn	4	0.1	0.02
Clun River	Severn	4	0.1	0.02
Teme Upper	Severn	4	0.1	0.02
Usk Upper Brecon	Severn	5	0.17	0.03
Usk Brecon to Abergavenny	Severn	5	0.24	0.08
Llwyd	Severn	5	0.18	0.08
Usk Lower Abergavenny	Severn	4	0.09	0.00
East Reens	Severn	1	0.11	0.04
Severn River Worcestershire	Severn	4	0.09	0.01
Telford South	Severn	2	0.1	0.04
Shropshire West	Severn	1	0.11	0.01
Trothy	Severn	4	0.11	0.01
Wye H and W d s Lugg	Severn	4	0.09	0.01
Wye H and W - Ithon to Hay	Severn	5	0.13	0.01
Lugg	Severn	5	0.14	0.01
Irfon	Severn	5	0.22	0.05
Wye H and W u s Ithon	Severn	5	0.27	0.09
Ithon	Severn	5	0.15	0.01
Arrow, Lugg and Frome	Severn	4	0.11	0.02
Monnow	Severn	4	0.1	0.02

Mean Prx – Mean proximity to all other Operational Catchments
Min Prx to DTC – Minimum proximity to Demonstration Test Catchments

Catchment group proximities

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Wye	Severn	4	0.09	0.01
Dyfi Lower	Western Wales	5	0.29	0.12
Dyfi Upper	Western Wales	5	0.41	0.18
Teifi	Western Wales	4	0.13	0.03
Ystwth	Western Wales	5	0.18	0.03
Rheidol and Clarach	Western Wales	5	0.25	0.09
Elwy	Western Wales	4	0.13	0.02
Gele	Western Wales	1	0.11	0.03
Clwyd Lower	Western Wales	4	0.1	0.02
Clwyd Upper	Western Wales	4	0.12	0.02
Coastal streams - South Gower	Western Wales	4	0.09	0.02
Coastal streams - North Gower	Western Wales	4	0.08	0.02
Loughor	Western Wales	6	0.13	0.04
Taf	Western Wales	4	0.17	0.04
Gwendraeth Fach and Fawr	Western Wales	4	0.12	0.03
Alwen	Western Wales	5	0.18	0.02
Dee Middle Ceiriog to Alwen	Western Wales	5	0.16	0.03
Alyn	Western Wales	4	0.09	0.02
Dee Estuary	Western Wales	4	0.11	0.02
Soch	Western Wales	4	0.13	0.02
Erch	Western Wales	4	0.12	0.03
Dwyfor	Western Wales	5	0.2	0.05
Glaslyn	Western Wales	5	0.51	0.29
Dwyryd	Western Wales	5	0.33	0.16
Llynfi	Western Wales	5	0.22	0.08
Gwyrfai Seiont	Western Wales	5	0.27	0.11
Ogwen Ddu	Western Wales	5	0.41	0.20
Kenfig	Western Wales	4	0.1	0.04
Coastal streams - South Pembs	Western Wales	4	0.12	0.01

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Coastal streams - North Milford Haven	Western Wales	4	0.12	0.01
Coastal streams – Druidston	Western Wales	4	0.13	0.00
Western Cleddau	Western Wales	4	0.14	0.01
Eastern Cleddau	Western Wales	4	0.13	0.04
Coastal streams and Neverny	Western Wales	4	0.13	0.03
Conwy Lower	Dee	5	0.21	0.05
Conwy Upper	Dee	5	0.4	0.19
Dulas Ganol	Dee	4	0.1	0.02
Dysynni	Dee	5	0.31	0.13
Mawddach Estuary South	Dee	5	0.43	0.22
Wnion	Dee	5	0.42	0.20
Mawddach Estuary North	Dee	5	0.48	0.27
Artro	Dee	5	0.3	0.13
Mawddach	Dee	5	0.38	0.18
Coastal streams – Cardigan	Dee	4	0.14	0.03
Aeron	Dee	4	0.14	0.03
Arth and Wyre	Dee	4	0.14	0.03
Wygyr	Dee	4	0.13	0.02
Alaw Goch	Dee	4	0.14	0.02
Crigyll Caradog	Dee	4	0.12	0.01
Lligwy - Ynys Mon	Dee	4	0.11	0.02
Cefni	Dee	4	0.13	0.02
Braint Cadnant Lleiniog	Dee	4	0.11	0.01
Wirral	Dee	2	0.13	0.07
Clywedog – Dee	Dee	4	0.09	0.01
Dee Lower Chester Weir to Ceiriog	Dee	4	0.19	0.04
Gowy	Dee	4	0.15	0.04
Alt	North West	2	0.2	0.11
Crossens System	North West	3	0.16	0.04

Mean Prx – Mean proximity to all other Operational Catchments
Min Prx to DTC – Minimum proximity to Demonstration Test Catchments

Catchment group proximities

Operational Catchment Name	River Basin District	Catchment Group	Mean Prx	Min Prx to DTC
Cocker	North West	5	0.36	0.15
Douglas	North West	2	0.11	0.04
Yarrow and Lostock	North West	2	0.13	0.07
Bela	North West	4	0.12	0.02
Crake	North West	5	0.36	0.15
Lune - Rawthey to Greta	North West	4	0.12	0.01
Pilling, Ridgy, Cocker and Conder	North West	4	0.14	0.01
Keer	North West	4	0.12	0.02
Wenning	North West	5	0.15	0.01
Ditton	North West	2	0.21	0.16
Glaze	North West	2	0.13	0.07
Sankey	North West	2	0.15	0.07
Big Ribble	North West	6	0.13	0.04
Darwen	North West	2	0.18	0.12
Hodder and Loud	North West	6	0.17	0.01
Savick Brook and Fylde South Drains	North West	4	0.12	0.03
Duddon	North West	5	0.21	0.05
Ehen-Calder	North West	5	0.15	0.03
Irt-Mite-Esk-Annas	North West	5	0.31	0.12
Bollin, Dean, Upper Mersey	North West	2	0.16	0.09
Weaver Lower	North West	4	0.12	0.03
Fleetwood Peninsula Tributaries	North West	4	0.12	0.03
Brock and Tributaries	North West	6	0.18	0.04
Wyre and Calder	North West	4	0.11	0.01

Mean Prx – Mean proximity to all other Operational Catchments
Min Prx to DTC – Minimum proximity to Demonstration Test Catchments