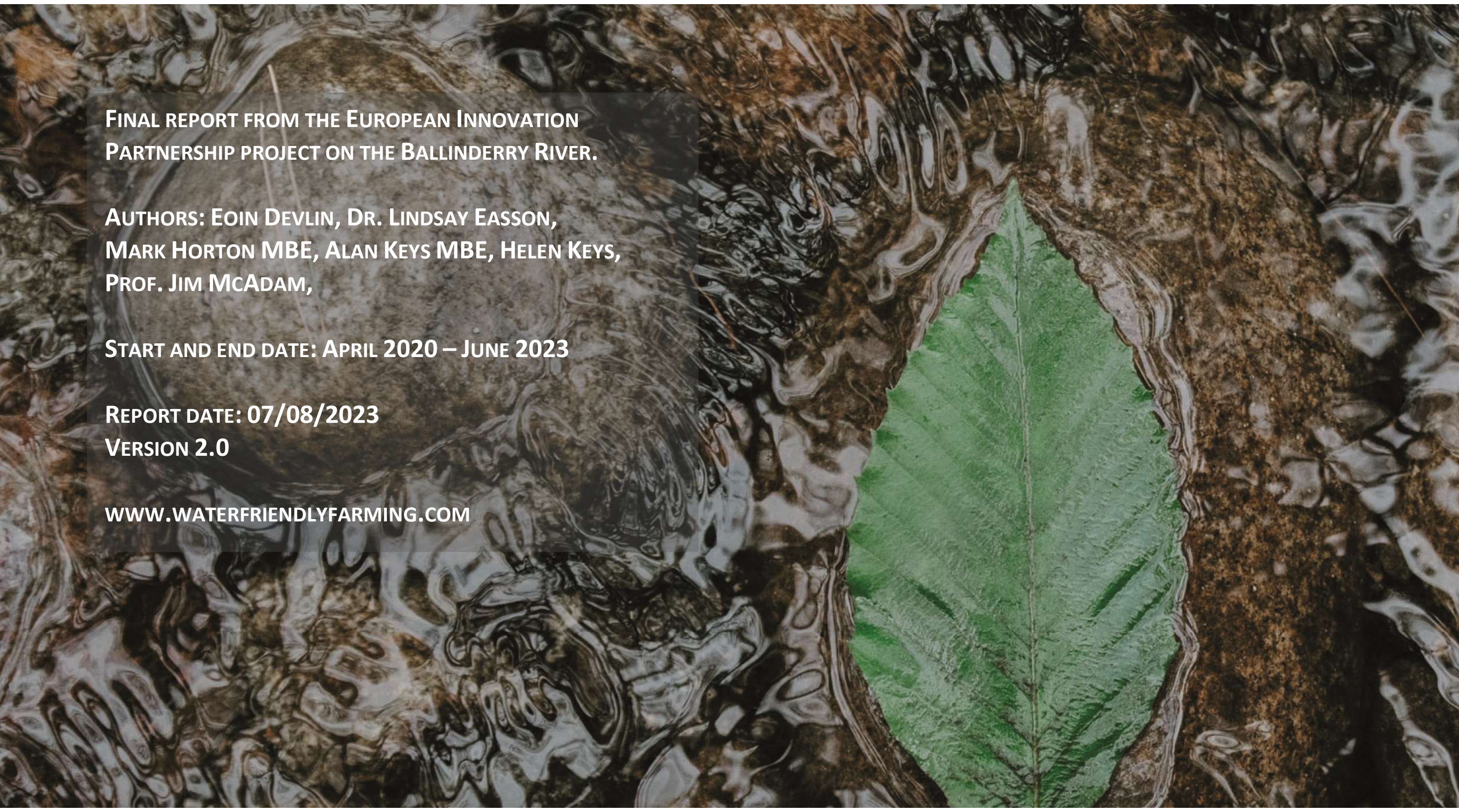
Ballinderry
Rivers Trust

Water Innovation Network

NATURE BASED SOLUTIONS TO BENEFIT BOTH FARMS AND WATERWAYS



FINAL REPORT FROM THE EUROPEAN INNOVATION PARTNERSHIP PROJECT ON THE BALLINDERRY RIVER.

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Abstract

Water poses a constant management problem for farmers in Northern Ireland (NI). On average around 1000mm of precipitation falls on every square metre of NI each year. If not adequately diverted and/or collected, this water makes its way across farms picking up contaminants, such as nutrients, chemicals and soil. Agricultural contamination of watercourses often results in legal action against the farmer, resulting in fines, loss of subsidies and even custodial sentences. In 2017, farming accounted for the largest proportion (30%) of substantiated water pollution incidents investigated by the Northern Ireland Environment Agency, not only impacting the environment but causing reputational damage to the farming sector and NI agri-produce. Water management costs farm businesses time and money, where profit margins are already tight and time is in short supply, especially for part-time farmers.

There are a lot of ideas and technologies on how water pollution from farms could be reduced or prevented, but Ballinderry Rivers Trust's experience in the Ballinderry River over the last 25 years is that, these are often not readily or widely taken up by farmers because they are too costly; require long-term maintenance; inhibit productivity on the farm or they do not provide any benefit to the farm business.

This project is a European Innovation Partnership (EIP) project and is funded by the European Agricultural Fund for Rural Development and Department for Agriculture, Environment & Rural Affairs (DAERA). The project aims to identify and trial solutions to the barriers mentioned above, by developing innovative and integrated win-win solutions for rivers and farm businesses, using nature-based, productive, solutions that protect the water environment whilst maintaining and improving productivity and profitability of the farm business.

We used Design Thinking techniques in a series of workshops with the farmers in our Operational Group. Together we came up with a long list of potential ideas which we investigated further at the feasibility stage of the project.

This led to five on-farm trials of different designs of swales, using comfrey and willow planting for bioremediation. The systems are low cost, don't use up much, if any, productive land and provide a harvestable crop which can be used for feed, fertiliser or biomass.

An unexpected added benefit was that when an accidental slurry spill happened on one of our farms, the swales served as a reservoir, holding the spill and preventing it from reaching the river.

We also tried manufacturing our own soil saving/erosion prevention logs from locally available materials for riverbank stabilisation. These are usually made from imported coir and can be expensive, as well as having a large carbon footprint. We used waste hessian sacks from a local coffee roasting company filled with locally grown and chopped miscanthus. It's early days but so far they seem to be just as effective as the traditional coir logs.

One of the other problems we tried to solve was water management around the farm - our farmers spent a lot of time checking troughs and drinkers, separating clean and dirty water and diverting water around the farm. Our initial idea to use an off-the-shelf sensor-based control system proved too expensive to be viable for most farms, so we looked instead for lower-cost more manual systems which would fit with the farmers daily routine.

The project has yielded a string of spin-off 'satellite' innovation projects; one farm went on to explore the potential for using nettle fibre in textiles and composites with the support of an Innovate UK grant; Ballinderry Rivers Trust worked with the Belfast Met college to investigate lower cost water sensors; two more farms implemented the swale systems at their own cost; and another local farmer has started a comfrey nursery to supply plants for future systems.

Contents

Acknowledgement

We would like to take this opportunity to thank the landowners involved in the project. Without your participation and patience, this project would not have been possible.

To the wider Operational Group, we are thankful for your expertise and support throughout the project and for your contributions in making the project a success.

Thanks to the delivery partners listed in the appendices for their work and contributions to the project.

A special thanks to Nigel Murphy, Russell Forster, Katherine Neeson and Norman Weatherup of CAFRE/DAERA; and Meredith Thompson of NIEA/DAERA.

Thanks also to our own team; Jack McKee – placement student; Rachael McEldowney, Sean McGill and Peter Mitchell of Ballinderry Rivers Trust for planting and assisting with events and to Frank Mitchell for assisting with making and installing the soil saving logs.

Finally, a massive thanks to all the funding bodies of this project – The Department of Agriculture, Environment and Rural Affairs (DAERA), the College of Agriculture, Food and Rural Enterprise (CAFRE), the European Agriculture Fund for Rural Development and the Northern Ireland Environment Agency Environment Fund (NIEA).

1 Project Aims

The Water Innovation Network (WIN) is a group of farmers from the Ballinderry catchment and experts in agriculture, water quality and innovation.

The mission is defined:

"We are seeking WIN WIN solutions – innovative ways to make farms more productive, profitable or efficient that also protect and improve water quality."

"Our project aims to - develop innovative and integrated win-win solutions for our rivers and our farmers, using digital technology and nature-based, productive solutions that protect the water environment whilst maintaining and improving productivity/profitability of the farm business. Our solutions will be accessible, affordable, easily integrated into the farming business, generate win-win benefits and will be scalable to the 2,586 dairy farms and 19,587 beef/sheep farms in Northern Ireland. " From the EIP Stage 2 application.

The table below provides a summary of our objectives at the start of the project - as with any innovation project, things evolved as we learned and designed, and with agreement from our funders we adapted the objectives as we went.

Table 1: Project objectives

Objectives
Project Mobilisation and Management To coordinate the project ensuring full engagement from partners and overseeing the successful delivery and dissemination of the project on time and within budget. Contract to run from - from October 2020 to September 2023
Innovation Scoping and Feasibility To commission: 1. Feasibility Study: Productive Water Management Systems, 2. Feasibility Study: Water Smart Farms, Business Plan: Lower costs - Added profit, Initial reports by June 2021, trials completed by December 2022, final report by March 2023.
Innovation Realisation and Testing To set up test trials: 4 productive water management systems (buffer zones/block planting/ponds), 3 water smart farming systems, 3 new business systems (e.g. new low cost products like rush logs to prevent soil erosion, nursery for low cost plants or trees suitable for agroforestry, system for managing planting or harvesting labour or produce sales.) Trials to run from June 21 to Dec 22
Monitoring and Evaluation To set up monitoring systems (see detailed monitoring framework) and collect data on a quarterly basis. To carry out a mid term and final evaluation
Demonstration and Dissemination Farms To organise 12 farm visits for 240 farmers groups and expert
Communications To build a very large audience of interested farmers and conservationists who will follow the project and tell others about it and then establish the Ballinderry River catchment as a Water-friendly Farming Innovation Test Catchment, to attract further innovations/innovators. Target 10,000 in 12 months.

2 About the Operational Group

For nearly 40 years the Ballinderry Rivers Trust (BRT) has been working with farmers throughout the Ballinderry River catchment, in a non-regulatory capacity, supporting them to deal with issues on their farm that might impact the river. Together they have put up fencing to keep livestock out of the river, stabilised banks, diverted dirty water and other potential pollution risks. Together they have walked the rivers, looked over bridges, and worked to identify where there are problems and what can be done to solve them.

So, there were already existing relationships between BRT and the farmers that joined the Operational Group to deliver this project. Alan Keys has worked for BRT since it was set up, he knew the farmers personally. Although retired, he got involved in the project as one of three advisory experts and was a key player in getting everyone on board. Two other experts were recruited as the project evolved; Dr Lindsay Easson, an agronomist and Professor Jim McAdam, specialist in upland grasses, peatlands and agroforestry.

The project was delivered during the Covid-19 pandemic so the majority of the Operational Group meetings were on zoom.

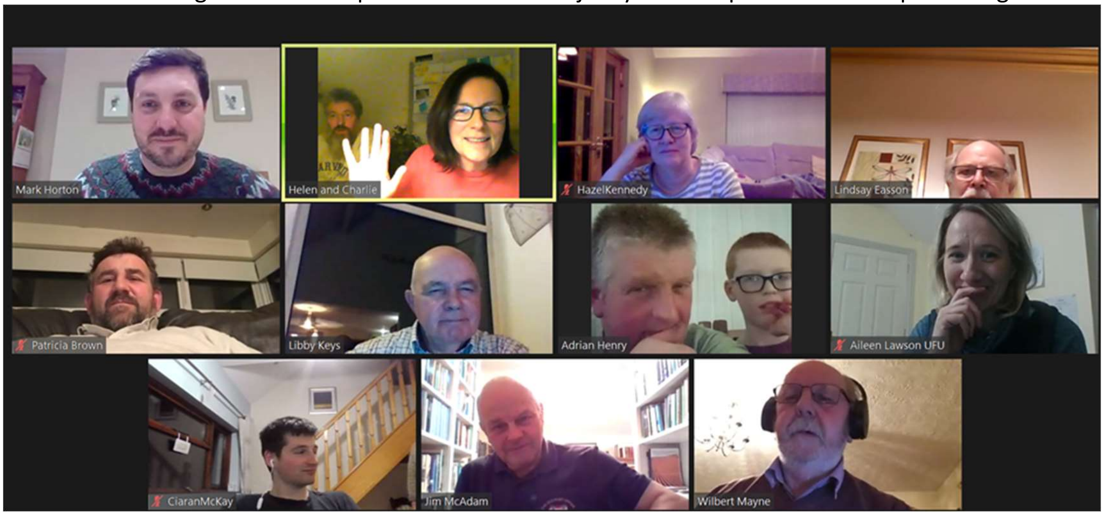


Photo 1: The first of many zoom meetings for the Operational Group

The nature of the European Innovation Partnerships is that groups coalesce around a shared problem or interest and through co-design processes, the project emerges.

The original Operational Group consisted of a mix of farmers from throughout the Ballinderry catchment, supported by an Innovation Broker, a Project Co-ordinator and a panel of advisors.

As the project evolved, it emerged that some farms were more suited to trial projects than others so the Operational Group naturally evolved, with new farms coming on board and other farms taking less of a role.

Ballinderry Rivers Trust took the lead on administration, working directly with the funders to meet the significant procurement and monitoring requirements – freeing the Operational Group members to concentrate on delivery.

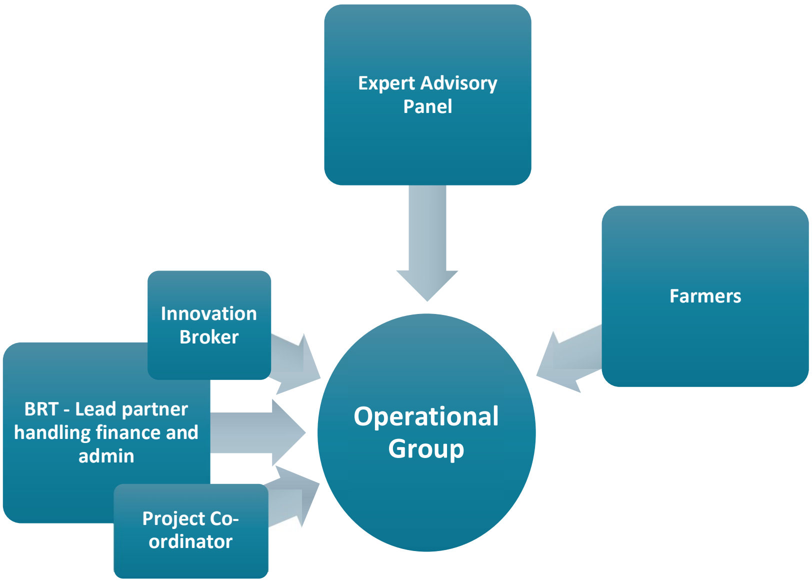


Figure 1: The Operational Group structure

3 Project details

3.1 Overall timeline

The project was delivered over two stages between April 2021 and May 2023. The first stage involved a series of design workshops with local farms to get to the heart of the problem and to fully understand what a good, workable, solution would look like for a farm business. This resulted in a long list of ideas which were prioritised and shortlisted for the Stage 2 application. Once Stage 2 was awarded the ideas were researched further and a Feasibility Study was drawn up. The study identified a range of projects which were costed and the budget agreed with the funder.

Through 2021/22 the projects were delivered on the ground and monitoring systems were set up. From August 2022 we started to bring farmers to visit the new nature-based systems and share results.

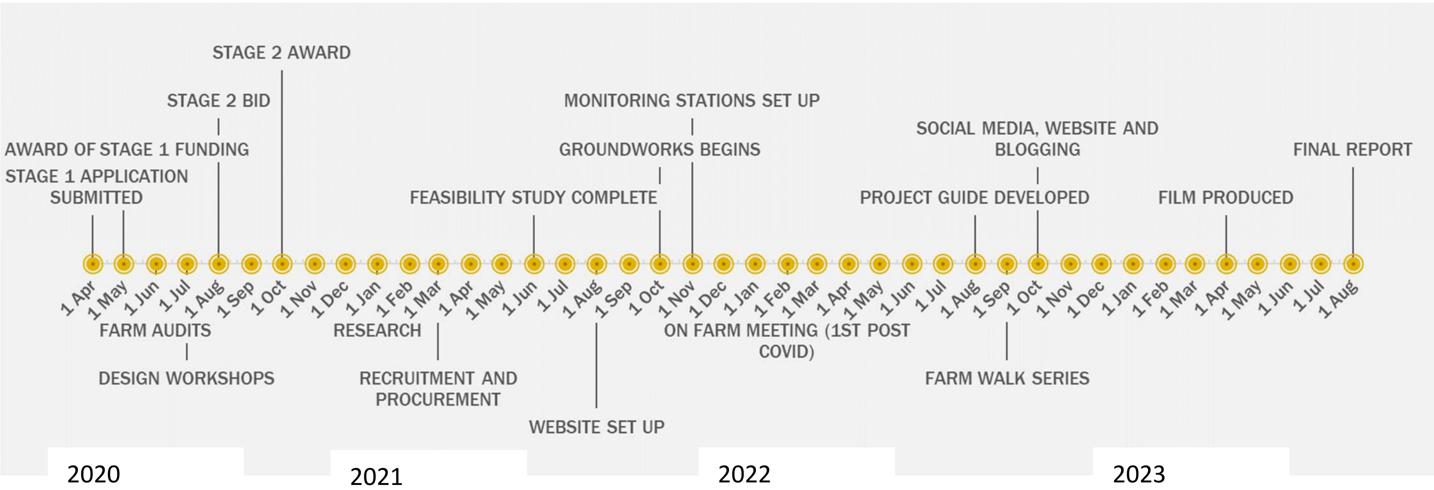


Figure 2: Project timeline

3.2 Design workshops

Venture Folk Ltd is a co-operative which specialises in innovative design processes. Commissioned by the project, they facilitated the first three design thinking workshops, they involved farmers as well as people with relevant expertise but no farming background (chemist, engineer etc). This approach meant the problems had to be fully explored and explained in simple terms before solutions were sought. The overall purpose of this project was to find 'win-win' solutions that would benefit both the farm business and the water environment. With this in mind the design process started by looking at the problems to be solved from both the farm perspective and the river. The table below shows our starting point from the very first workshop.

Table 2: Extract from an initial design workshop

Needs for the farm	Needs for the river
Farmers need to safely store slurry and be able to use it for fertiliser to grow crops but if something goes wrong, they can face fines.	We need to stop slurry reaching the river - when it is spread too liberally on fields or worse when a slurry valve is left open or a store fails.
Farmers need a low-cost way to store grass over the winter that doesn't damage water quality or create recycling charges / waste	We need to stop sileage effluent and plastic sileage wrap from reaching the water
Farmers need to protect their soil against erosion to maintain long term productivity - this means less ploughing, protecting river banks.	We need to stop soil and silt getting into the river
Farmers need to find the right balance in the use of fertiliser, pesticides and herbicides to maintain productivity but protect the long-term health of the soil.	We need to stop pesticides, herbicides and fertiliser getting into the river to protect water quality
Farmers need to collect, store, heat/cool, move and dispose of water to feed to animals, clean buildings and equipment, water crops, mix with slurry.	We need to manage how water is removed and returned to the river to prevent fish being taken up and slurry and other pollutants getting in.
Farmers need to find ways to get value out of the waterways	We need farmers to want to look after the river and know how to do it.
Farmers need to develop their business without creating more ammonia	We need to stop ammonia (from the air and from animal waste) reaching the water because it kills wildlife

Having established this broad overview of the problems from different perspectives we started to delve deeper.

3.3 Farm audits – understanding the problem

The workshops were followed by a series of farm visits. Our team of experts spent time on each farm, talking to each farmer. These visits got to the heart of the problem on the ground. The team looked at how water was flowing around the farm and where it was becoming contaminated. They also got to understand how the farm was being managed and what each farmer was looking for from any solution.

3.3.1 Physical problems

- Farmyards get dirty – animals and machinery moving around the yard will inevitably bring dirt onto the yard.
- Rain falls directly on the yard and also can run off roofs – there it collects the dirt, runs into watercourses and ultimately makes its way to the river. We'll refer to this as Farmyard Dirty Water (FDW)
- In some situations, clean spring water can also join this contaminated water bringing in even more water, even more quickly to the river, and itself becoming contaminated.
- Roof runoff from poultry and pig buildings is likely to be contaminated with minerals.

Photo 1: A typical mucky farmyard – vehicles and animals moving from wet fields onto the yard will bring dirt

- Rain falls on silage pits and if they aren't covered it washes effluent away to the river.
- Rainwater can also find its way into slurry pits and lagoons increasing the volume that has to be dealt with.
- Leaking silage pits can let effluent seep away.
- Slurry lagoons and above ground slurry stores present major threats if they overflow or fail.
- Water control measures which might be OK most of the time can't always cope with intermittent high rainfall periods -which are increasing.
- Unproductive land – most of the farms had areas of poorly drained, boggy land which are difficult to cultivate and hard to make productive.
- As farms expand, more livestock may be kept on yards that weren't designed for the numbers. Where this happens and the receiving waterway is a minor stream the problems are more challenging.

Photo 2: Water on a yard - Unless we roof over the yard completely - there will always be some water accumulating.

3.3.2 Management problems

- There are different types of contamination – extract below is from the Wildfowl and Wetlands Trust


Photo 3: The problem - slurry in the river

Nitrates and ammonia: mainly from fertiliser or manures, are extremely soluble and may be lost in runoff, by volatilisation or absorbed into the soil. Within the soil soluble forms of N become part of the nitrogen cycle and can be taken up by growing plants. Some may pass through the soil profile to groundwater or into rivers through drains or subsurface flow, or be lost to the atmosphere as nitrogen gas.

Phosphorus: is much less soluble and most phosphorus in soils binds tightly to soil particles with only a small proportion available to plants. Where soil particles enter drainage water or are subject to surface run-off they will carry phosphorus with them. This can happen from tramlines, compacted fields and stubbles.

Sediment: Loss can result from soil erosion and run off from fields under poor livestock or soil management and livestock damage to riverbanks.

Agrochemicals: including sheep dip and crop protection pesticides lost through drain flow or soil run off, or from overspray and drift. The Environment Agency (EA) advocates treatment of pesticide washings using a biobed or biofilter.

Microbial pathogens: faecal indicator organisms from manure can be washed into surface waters by rain, or deposition where livestock have direct access to watercourses.

(Mackenzie, 2015)

- The sheer volume of slurry that our livestock farmers are dealing with is a worry for them especially in winter when animals are housed. Slurry can't be spread on fields between October and February.
- A history of high phosphate levels in farm soils resulting from high fertiliser use and imported livestock diets and associated manures, was identified in some cases which was likely to be contributing to particulate runoff into water courses.
- Systems need to be safe for farmers, farm families and livestock.
- Many farmers are working on their own so any system needs to be easily handled.
- Valuable nutrients are being lost to the farm at a time when costs are rising, we need to capture and recycle these nutrients as much as possible.

3.3.3 Barriers – why has it not been solved before?

There are well tested remediation measures available to farmers to prevent pollution; Integrated Constructed Wetlands (ICW's), riparian buffer zones and soil erosion techniques are all proven to work but have not been widely adopted despite the availability of grants through the Environmental Farming Scheme. Talking to farmers throughout the catchment we've found that the potential loss of productive land, the burden of paperwork associated with grants, the high costs of creating constructed wetland ponds and the high cost of planting out have all prevented uptake.

3.4 Solutions

From our very long list of ideas, we narrowed down to a shortlist of ideas that we wanted to develop:

- **Swale systems** - swales are long channels with a shallow gradient which can channel water slowly and filter it as it travels through the system, our idea was to place these in areas of non-productive land and FDW would be channelled to the systems.
- **Plant power** – using plants like willow, miscanthus, nettle and comfrey along the swales and between the swale system and river to 'mop up' nutrients – our thinking was that these crops needed to be productive i.e. harvestable for fodder, biomass or some other purpose that would benefit the farm.
- **Water smart farms** – using sensor systems to alert farmers when water was running where it shouldn't be (e.g. overflowing drains) or not running where it should be (e.g. troughs).
- **Soil saving logs** – replacing imported coir logs used to stabilise riverbanks with our own locally manufactured version.

N.B. The ideas evolved from this initial concept – read on…

3.4.1 Managing the flow of water

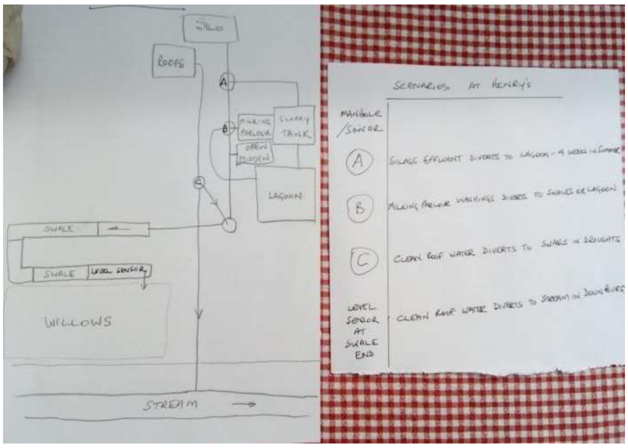


Figure 3: Initial sketches of a system to separate clean and dirty water on the yard.

The team looked first at how to reduce the volume of dirty water heading for the river by diverting clean water, from roofs, rain and springs, before it gets contaminated.

It's important to consider how the farm operates throughout the year and how the volumes might change. Sometimes there will be far too much water, sometimes there won't be enough. Systems need to be designed for all seasons.

On one of the farms there was a huge amount of spring water mixing with FDW, this was increasing the volume and the speed towards the river. Pipework around the farmyard 'caught' the spring water and diverted it away before it could become contaminated. We measured the diverted spring water and found that it could be the equivalent of 11 tankers per day.

The system was designed so that clean water could be manually directed into the swales during dry spells to keep the plants growing or to the river during wet weather.

The FDW could be directed to an existing lagoon or the swale system as required. The team designed some simple systems for diverting water – see section 3.4.5

Before water entered the swale system it was directed through a concrete 'sediment trap' where silt could settle. The trap can be easily cleaned out, based on the build-up so far, the team estimates a maximum of every two years.

Photo 4: Sediment trap between the farmyard and the swale system.

3.4.2 The swale solution

Initial concept

Some of the participating farms had already investigated the creation of Integrated Constructed Wetlands as a means of dealing with waste water. The cost of construction and plants (estimated at about €120,000) and the loss of productive land have stopped them from proceeding.

On the farm visits it was noted that there are areas on the farms which are already unproductive as they are wet, boggy areas sometimes cut-over peatlands and often having a heavy rush infestation.

It was initially considered that a low-cost system of swales (broad shallow ditches) could be used to transfer water from the yard to these 'unconstructed' wetland areas. Dirty farm water, already partly cleaned during its passage along the swales, would enter and pass through a wetland area - planted up with willow for further cleaning (bioremediation) before entering the river.

This would reduce the loss of productive land near the farmyard and the swales themselves could improve the water on the way to the wetland. Both the plots between the swales and the wetland area could be planted with harvestable bioremediating plants (see next section).

Swales are effective in improving water quality of runoff, by removing sediment and particulate pollutants. In wet swales, the effectiveness is further enhanced by providing permanent wetland conditions on the base of the swale. (Mackenzie, 2015)

Four farms were identified which each had FDW to deal with:
1: Dairy Farm
2: Beef Farm
3: Poultry Farm
4: Pig Farm

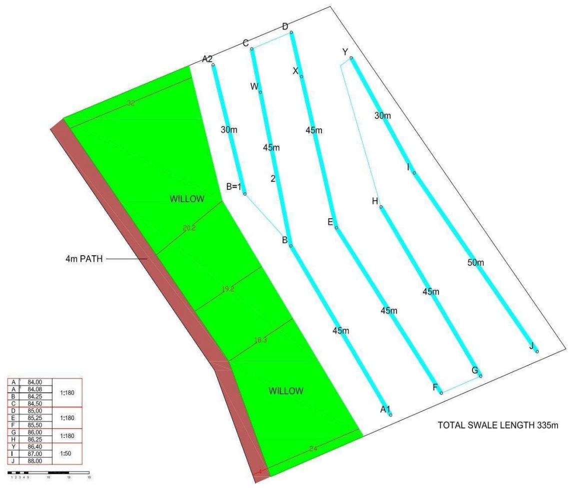


Figure 4: Engineers design showing swale lengths and levels.

The team worked closely with the farmers and brought in external expertise from a surveyor and engineer. The use of swales was considered appropriate for each farm, albeit in different configurations. Different locations and swale designs were proposed and reviewed for each farm.

Location and layout

The main factors considered for location and layout of the swales were:

1. The preferences of the landowner and fit with their operations.
2. Avoiding negative environmental impact e.g. by replacing recovering peatland or valuable biodiversity habitat.
3. Avoiding any potential links or spillover into open drains or pipes which lead to the river.
4. Ease of access for maintenance.
5. Minimising the use of productive land.
6. The cost of creating the swales.
7. Shape and layout of inter-swale plots for optimum nutrient uptake and easier cultivation and harvest

   - 2.5m or greater to allow access for a mower
   - buried pipes to carry water between swales

Photo 5: An open swale

Figure 5: An example of social media posts about the swale systems

Swale designs

The following Design Guidance is provided by the EU Commission Natural Water Remediation Measures Group.

> *'Generally, swales are most efficient, and easier to construct and maintain, if the channel is trapezoidal or parabolic in shape, with shallow sides (between 1 in 3 and 1 in 4), shallow depths (no greater than 600mm) and a shallow gradient (between 1 in 100 and 1 in 300). This promotes lower velocities and increases the wetted perimeter, which in turn minimises erosion, promotes filtration and enhances safety. The base of a swale should be flat and 0.5-2m wide. (CIRIA, 2007)*
>
> *If the natural longitudinal slope is more than 2 in 100, it is possible to use check dams in order to divide the swale into several segments, to reduce velocities and optimise storage volumes.*
>
> *A minimum length of 30m is recommended by CIRIA (2007) to maximise water quality benefits, although it is recognised that this may be constrained by the site (i.e. a site length of less than 30m should not necessarily preclude the use of swales).' (Natural Water Remediation Measures)*

This basic principle, of slowing the water and soaking up the nutrients, was the foundation but as the project evolved the team reviewed each situation and developed the concept further.

- DESIGN 1: OPEN SWALES

The first version incorporated a sediment trap at the top of the system to capture silt, sand and organic material – this can be easily cleaned out (every other year).

The swales were planted with deep rooting Russian Comfrey to boost the bioremediation effect and provide a harvestable crop.

Pipes run between the swales which can be turned up and down to control levels.

Willow was planted at the bottom of the system to 'mop up' any remaining nutrients.

Photo 7: An Open Swale with deep rooting Russian comfrey growing

Photo 6: Willow planted between the swale system and the river

Check dams can be made from cast concrete, these can help to slow the flow of water but can also act as a reservoir for during the dry summer season to keep feeding the comfrey. These were placed at every point where the swale level dropped by 650mm.

The swale system was fenced off for safety.

- DESIGN 2: PEBBLE SWALES

Open swales have a nature value and where the field is already unproductive these are a good solution, however they do need to be fenced off for safety.

In areas where the loss of land is a concern a new system was trialled where the swales were filled with pebbles, covered with topsoil and planted up with comfrey. In this system the plants can be easily harvested and either used for fertiliser or ensiled along with grass. Comfrey leaves are hairy and not appealing to livestock until wilted so these areas didn't need to be fenced which reduced the cost of the system.

Check dams in the swales not only slow the flow of water but they act as a reservoir, holding water during dry periods to keep the plants growing.

Photo 10: Pebble swale under construction 1

Photo 9: Pebble swale under construction 2

Photo 8: Comfrey in bloom in it's first year, planted on a pebble swale system

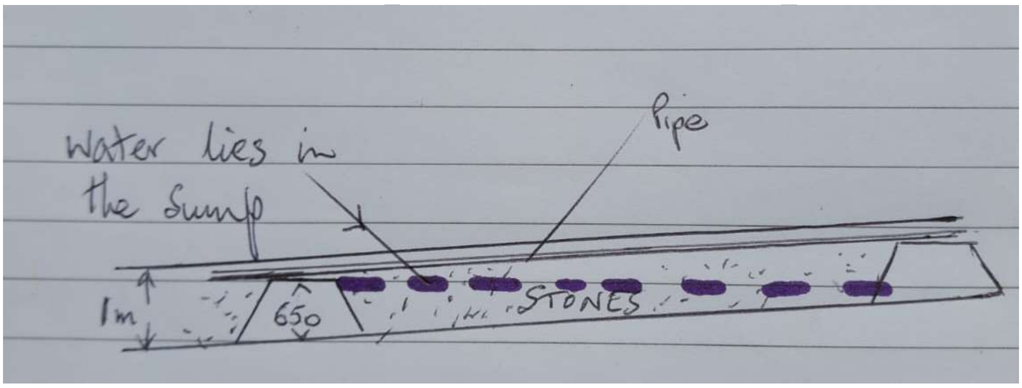


Figure 6: Sketch showing cross-section of a pebble filled swale

- DESIGN 3: LADDER SWALES

After demonstrating the pebble swales as part of this project two other farmers decided to trial similar systems on their farms. These were outside the scope and funding but the design evolved further so we've included them here.

Photo 11: Check dams and pipes carrying water off to a parallel swale when levels get higher.

Photo 12: Parallel swales

These systems made use of existing sheughs and drains. Perforated pipes were used to collect water from the sheugh when it reaches the level and carry it to a system of parallel swales – a bit like a ladder.

During the project one of our trial farms had an accidental slurry spill. They were able to hold the slurry in the swale system, preventing it reaching the river, until they were able to draw it away safely.

In the recent systems this has been incorporated as a design feature – an area dug out, sufficient to accommodate a slurry spill, which can be closed off if necessary to safely contain slurry.

Photo 14: Comfrey being planted at 1m spacings

Photo 13: Slurry trap which can be closed off in the event of an accidental spill.

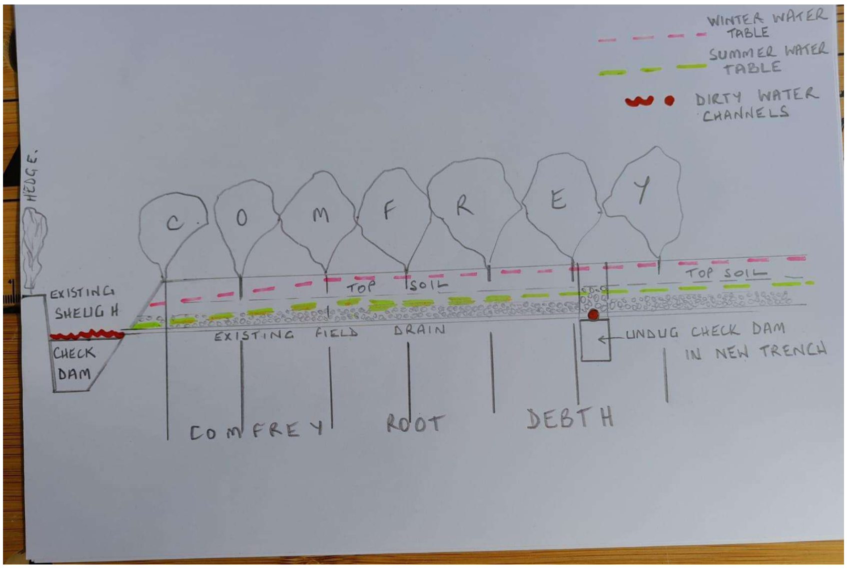


Figure 7: Design sketch for an underground swale system, making use of existing sheughs, no loss of productive land. Comfrey can be cut and ensiled along with grass.

3.4.3 The power of plants

COMFREY

During the initial research a number of plants were considered that could be planted along the swales to boost the bioremediation effect; comfrey, nettle, miscanthus, willow.

Comfrey proved to be the most useful and became the focus of the trials for the following reasons;

- Russian varieties will stay where they are planted (unlike nettles)
- The plants have a very deep root of up to 3 metres which will pull nutrients up from below the water level of the swale into the leaves of the plants.
- Comfrey has been extremely well researched – most notably by Henry Doubleday and Lawrence D Hills, who note the following:
- It can be used in silage, for biomass or to make fertiliser.
- Comfrey can be cut from 2-5 times a year.
- Comfrey provides good ground cover, protecting soil and competing with weeds.
- Comfrey flowers from late May to late Autumn. Pest predators like lacewings, Parasitoid Wasps and Spiders are supported by the plant. Honey and bumble bees can be seen gathering nectar throughout the flowering season.

Photo 15: Social media communication on comfrey

Photo 16: Comfrey beside an uncut strip of silage - significantly more volume

Photo 17: Comfrey in full bloom at one of our trial sites, competing well with weeds and full of pollinators

On two of the trial farms, we set up fertiliser cubes. These are 1,000L Intermediate Bulk Containers (ICBs) which are filled with comfrey leaves. As the leaves break down, they release liquid fertiliser which can be diluted and used on the farm. We used a 'wet' method and a 'dry' method i.e. one using water to dilute and one without.

Below the photo is an extract from Lawrence D Hills research on the value of wilted comfrey leaves compared to compost and manure. (Hills, 1979). It shows high values of Nitrogen, Phosphorous and especially Potassium which helps flowers and fruit to form. Comfrey fertiliser is highly valued by gardeners. A next step for this project will be to do our own analysis of the comfrey fertiliser produced in our trials.

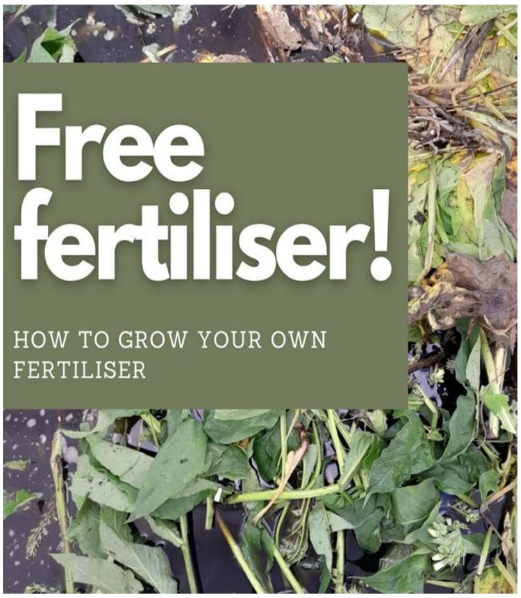


Photo 18: Comfrey roots ready for planting

Photo 20: Our social media posts promoting on farm fertiliser making

Photo 19: Showing local farmers how to make their own fertiliser

	Water %	Nitrogen %	Phospnoric Acid %	Potash %
Rothamstead				
Farmyard Manure	76.0	0.64	0.23	0.32
Haughley Compost	76.0	0.50	0.27	0.81
Municipal Compost	49.4	0.77	0.06	0.09
Wilted Comfrey	75.0	0.74	0.24	1.19

Photo 21: Extract from Lawrence D Hills well-known research on comfrey

WILLOW

Scientific studies carried by Agri-Food and Biosciences Institute (AFBI) and others in the last 20 years have demonstrated that willow stands can be used to receive dirty water from water treatment works *(Use of Short Rotation Coppice -SRC- willow for the bioremediation of effluents and leachates, EU 2014)* and from a farm *(SRC Willow as a bioremediation medium for a dairy farm effluent with high pollution potential, Biomass and Bioenergy, Vol 105, 2017)* (Edward G.A. Forbes, 2017) by irrigation and to clean the water so that it is sufficiently clean to enter a watercourse. One trial conducted by AFBI on a 5-hectare plot over 5 years demonstrated that it provided effective remediation for up to 22 m^3 of FDW per hectare. In addition, the coppiced willows can be harvested every two or three years as a commercial crop thus giving a return from the use of this land. Even during the winter when no growth is occurring the root zone remains active so that there is a remedial effect on the water.

The photo below shows willow planted in one of our trial schemes, the willow in the foreground is growing outside of the swale system, the willow in the background is being fed on nutrients from the swale system. It is growing to three times the height as it utilises the available nutrients, that would otherwise be lost to the river, for growth.

The willow can be used for forage, as tree hay or biomass.

Photo 22: Willow planted at the bottom of a swale system, willow in the background is being fed on FDW and is 3 times the height.

3.4.4 Soil Saving Logs

Coir logs are commonly used as a measure to stabilise banks, prevent soil erosion, and facilitate peatland restoration. Coir is a fibre produced from coconuts and the "logs" are most commonly manufactured in India and imported to the United Kingdom and Ireland. Typical values from an online search show that a 3m long coir roll with stakes costs £52.40/roll, a 1m long coir roll with stakes costs £22.40/roll.

When the logs are planted up with wetland plants the price increases to £100 for a 3m length.

Coir logs protect banks from erosion in three excellent ways throughout their entire lifecycle. They absorb the power of water to reduce the damage it does to banks immediately. Over time the vegetation's roots stabilise the ground, facilitated by coir logs. Finally, when these logs biodegrade, the remaining fibres root into the ground to strengthen to land into the future.

Affordable, effective, and easy to install, coir-logs are a practical and popular solution to both erosion control and slope stabilization. 100% Coir logs are fully biodegradable and help create conditions that are perfect for planting long-term vegetation for a permanent erosion control solution. As the logs decompose, they enrich the soil. In the meanwhile, the vegetation grows stronger and eventually takes over the job of holding the slope and stabilizing the soil.

Even when site conditions are demanding, coconut coir logs are rugged, strong and stand up to the test. Depending on the style you select and the site conditions, plan for coir logs to last from 2-5 years before fully decomposing.

Production & Installation of Soil Saving Logs

Sourcing Miscanthus plants and hessian bags for filling

The miscanthus plants were being grown locally at the CAFRE Loughry College campus. After making enquires with staff members at Loughry college, we were given permission to take the required number of plants to complete the project. Prior to this, the miscanthus had been cut and put into round bales, however we needed to mulch the miscanthus further to a suitable size for bagging. A total of 5 round bales of miscanthus was required for the 3 sites trialled.

Most of our hessian bags were sourced from a coffee shop in Belfast. Having contacted this company, we were able to collect these bags free of charge. We also purchased rolls of hessian material, which we used to sew more bags when needed.

Identifying potential sites for trial

As this was a riverbank stabilisation trial, we wanted to select 3 sites with some variations in depth, width and erosion size. We also wanted to ensure that the 3 sites were easily accessible for the process of installation, monitoring, and future modifications. We decided on two sites located on separate tributaries of the Ballinderry River and one site along the main Ballinderry River. Each of these sites had different characteristics in terms of the river depth, width, velocity etc. However, each with a clear and distinctive bank erosion issue.

Mulching and Bagging

Through the project, we had purchased a wood shredder/mulching machine to shred the miscanthus. However, there were some issues with the machine getting jammed. As the miscanthus came in round bales, the mulching machine was too small scale for the job and therefore didn't work as well as we had hoped. With the help of local landowners, we were able to mulch the round bales of miscanthus using a silage feeder. This process reduced the miscanthus to a suitable size to allow for maximum compaction within the hemp bags.

A stand was designed to fill the hemp bags with miscanthus and a handmade compacter was used for the logs to be filled to maximum compaction. Using buckets, we poured miscanthus into the logs from the stand above and used the compacter frequently to ensure compaction. It was vitally important to make sure the logs were fully compact with miscanthus as this would form a stronger barrier against the forces of the river and ultimately extend the life expectancy of our logs.

Variations of logs used:
3m logs = 4 hemp bags
2.5m logs = 3 hemp bags
1m logs = 1 hemp bag
0.5m logs = 1 smaller hemp bag

It was difficult to obtain the exact log sizes required for each of the sites. As we were required to sew individual hessian bags together to create 'logs', we decided to produce a various range of log sizes based on the measurements at our trialling sites. We found that 3m & 2.5m logs were the most adaptable to our sites with the support of smaller 1m & 0.5m logs to fill in the gaps.

Installing Logs

At each site, we used a series of 8ft wooden fence posts to essentially form a channel for the logs to be fixed in place. The posts were driven into the riverbed and tight to the riverbank using a handheld post rammer. The posts followed the line of the bank in a series and were separated approximately 1 metre apart, allowing the logs to be held securely in place. Having established the foundations (posts) at each site, the logs could be dropped in, stacked to the required height and fixed into place. We used bull wire to tighten the posts together and to help secure the logs in place.

The small gaps between the log structure and the riverbank had also been backfilled with soil, clay, rocks and planted with willows, long rooted grass and other vegetation to help strengthen the bank.

Site 1

Date installed: 17th November 2022
Site Location/Description: Gortin Water, a tributary of the Ballinderry River.

A concrete laneway runs parallel to the river. As the river meanders at this location, the outer bend has suffered from years of bank erosion mainly through hydraulic action during high flow periods. This was beginning to undercut the laneway that runs along the river, which is clear to be seen from the photos provided in the results section. At this site, there was approximately 8 metres of bank erosion on the left side bank looking upstream. We installed a total of 11 logs at this site.

6x 3m logs
2x 1m logs
3x 0.5m logs

The 3m logs establish the main body of the structure, with the smaller 1m & 0.5m logs being used to fill any gaps within the structure.

Site 2

Date installed: 12th December 2022
Site Location/Description: Drumard River, a tributary of the Ballinderry River.

Due to significant bank erosion, the landowner at this site has lost the structure of their field fencing. The landowners fence posts and wire are overhanging the riverbank as the ground beneath has been eroded away. At this site, there was approximately 8 metres of bank erosion on the left side bank looking upstream. We installed a total of 12 logs at this site.

6x 3m logs
3x 1m logs
3x 0.5m logs

The 3m logs establish the main body of the structure, with the smaller 1m & 0.5m logs being used to fill any gaps within the structure.

Site 3

Date installed: 23rd January 2023
Site Location/Description: The main Ballinderry River at Wellbrook Beetling Mill.

As this site was on the main channel of the Ballinderry River within the designated Special Area of Conservation (SAC), our team were required to seek permission from the Northern Ireland Environment Agency (NIEA) to trial this bank stabilisation method. Permission was granted. Unlike the other sites, this site was along the main channel of the Ballinderry River. The river here is much wider, deeper and experiences greater flow rates. This site was a great test to see if these methods would withstand the forces of erosion on a bigger scale. At this site, there was approximately 6 metres of bank erosion on the right side bank looking upstream. We installed a total of 8 logs at this site.

4x 3m logs
4x 2.5m logs

3.4.5 Water Smart Farms – the low-tech way

On each of the participating farms an audit was carried out to investigate where waste water needed to be treated to a higher standard of purity:

- To keep it contained and flowing e.g. prevent dirty water reaching the river, tanks overflowing
- to ensure it was safely contained and running appropriately e.g. through swales, irrigation or to reach animals
- to be able to remotely divert it.

The team worked with Cloud Water Controls to investigate how remote sensor technology could be used in these applications.

Potential sensor functions were identified as follows:

- to manage dirty and clean water and separate it when necessary
- to detect potential for overflow from a lagoon
- to ensure that crops were irrigated
- to detect overflowing dirty water and divert it to a tank.

Costs were established for each of these systems but at more than £10,000 per farm it was decided that this did not meet our 'test' of 'affordable, repeatable, scaleable' and would be unlikely to be generally adopted by farms. The team looked for other ways to solve the same problems, they designed simple systems which can be implemented for a fraction of the cost and provide much the same result. The team also identified an alternative funding source to help develop the sensor idea further. They are currently working with Belfast Met.

Manual diverter systems

In two of the systems Manual Diverters are installed which allow the farmer to divert water to where it is needed. It's a simple design, water arrives and leaves a manhole via pipes, a sluice gate is used to open and close pipes. This allows the farmer to send water to either the lagoon or the swales.

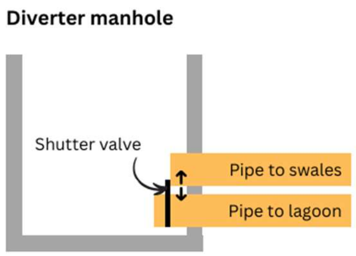


Figure 8: Manual diverter system – not to scale

Automated diverter system

There are times when an automated system is more appropriate. The team designed a system where a float activates a submersible pump when the water reaches a certain level. On one of our trial farms this system was used where a manhole would regularly overflow in heavy rain.

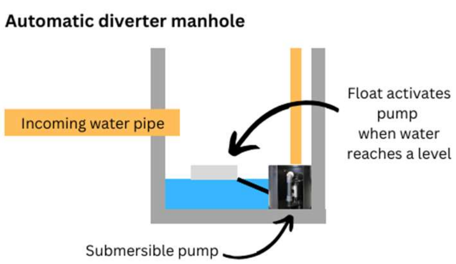
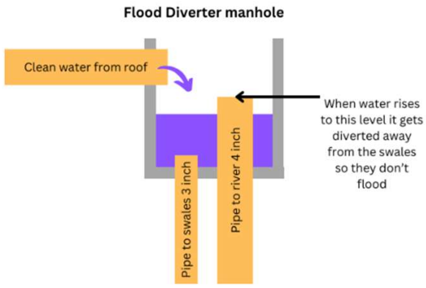


Figure 9: Float and pump system

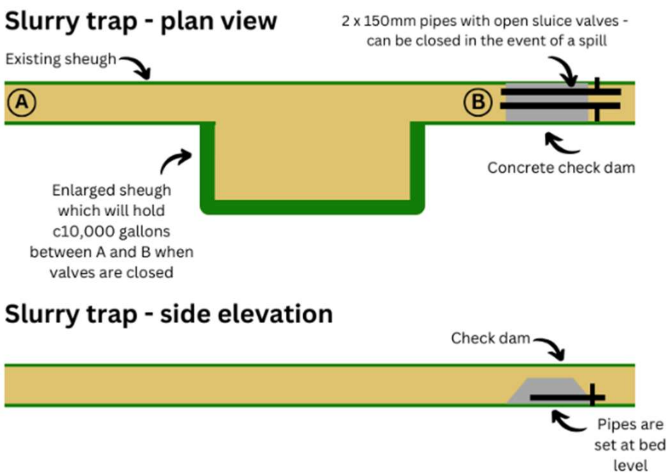
Flood relief diverter

This is another very simple design where clean roof water is directed into a tank and taken to the swale system via a 3-inch pipe. In very heavy rain the water will rise in the tank to a level where it is picked up by a 4-inch pipe which can take it straight to the river – preventing the swales from flooding.



Slurry trap

On one of the farms an accidental slurry spill had been captured by the swale system, the design evolved to include an area capable of holding c 10,000 gallons, which can be closed off in the event of an accident.



3.4.6 Spring-fed local native plant nurseries

The local supply of cost-effective native species for planting in wetland areas, riparian buffer zones and agroforestry schemes is likely to improve uptake.

Through the feasibility study, the team has identified a local nursery that is interested in developing a project around this.

The team also identified that a number of the farms visited had natural springs, particular to the groundwater and geology of the area that were not being utilised on the farm.

The team identified that the spring water could be used to keep nursery plants at a constant temperature and set up a pilot project to examine how this natural resource can be used to grow crops.

The farmer has plants growing on the floor of the polytunnel and plants growing in raised troughs all "warmed" by 10°c spring water. He is going to add piping for overhead irrigation. He intends to reuse the spring water to grow outdoor crops.

He has young comfrey plants, grown in the polytunnel which he will plant out on banks and in corners to become parent plants to provide root cuttings for sale.

On another farm spring water is feeding a polytunnel growing salad for local markets.

Photo 24: Spring water-fed polytunnel at one of the trial sites

Photo 23: Salad and brassicas to supply local markets

4 Funding

Below we have set out the cost associated with the delivery of the project, as well as the funding sources, including other sources outside of the EIP scheme.

Funder	Amount
Stage 1 The Department of Agriculture, Environment and Rural Affairs (the Department) acting through its College, the College of Agriculture, Food and Rural Enterprise (CAFRE) as the managing agent for this element of the NI Rural Development Programme 2014 – 2020, under the European Agriculture Fund for Rural Development.	£4,988.00
Stage 2 The Department of Agriculture, Environment and Rural Affairs (the Department) acting through its College, the College of Agriculture, Food and Rural Enterprise (CAFRE) as the managing agent for this element of the NI Rural Development Programme 2014 – 2020, under the European Agriculture Fund for Rural Development.	£120,000.00
NIEA Environment Fund Water Quality Improvement Strand	£25,410.24 at 85% of eligible costs
Landowner	£4,479.34

A spin off project researching nettles for fibre secured funding of £25,000 from Innovate UK. Another spin off looking at sensors for water control secured £5,000 from Invest NI.

5 Project results and outcomes

5.1 Introduction

The headline project outputs are:

- 5 trial swale systems on farms - infrastructure included:
    - Traditional open water filled swales
    - Underground swales - reducing loss of productive land
    - 'Ladder' swales
    - Check dams
    - Diverter tanks – manual and automatic
    - Sediment trap
    - Fertiliser cubes
    - Fencing and gates
- 2 additional swale systems outside the scope of the project
- 2 spring water fed horticulture systems
- 23 soil saving logs manufactured and installed at two sites to stabilise river banks

Outcome highlights are listed below with more detail in the sections that follow:

- Learning: New designs developed for effective, nature-based, low cost solutions
- Sharing the learning: Farmers learned about how to check their own waterways and saw the new systems in action – see section 6
- Productive crops: Crops grown using the FDW - willow and comfrey which can be used for feed, fertiliser and biomass see 5.2
- Improved water quality in the Ballinderry River see 5.3
- Creation of habitat: Improved biodiversity see 5.4
- Ability to produce soil saving logs at a low cost from local materials 5.5
- Riverbank stabilised – see 5.5
- Project team and external contractors now experienced in the design and implementation of nature based systems
- Spin off projects
    - Nettles for textiles project
    - On farm trials of 2 new swale system designs
    - Work with Belfast Met to prototype low-cost water sensors

5.2 Productive crops

Comfrey and willow are both thriving on the nutrients from the swale system on all but one of the farms where the soil was not as suitable. Over 1,000 plants should produce 5 tonnes of foliage annually.

For fodder
Comfrey can be fed directly to animals but the leaves are hairy and it becomes more palatable when the leaves are wilted. Similarly, livestock will graze on willow leaves, it can also be cut and used as 'tree hay'.

Comfrey can be cut and ensiled along with grass providing valuable food source, some useful research has already been undertaken into the value of comfrey as a food source and there is evidence it can improve intestinal in pigs.

> *"Comfrey leaves show similar values in dry matter as soybean or blue lupine in crude protein content, but much higher levels of calcium and phosphorus. However, in terms of increased efficiency in animal husbandry, comfrey has been displaced by mainly soybean and cereals. Due to its profile of macro- and micronutrients the use of comfrey could have the potential to re-establish local resource cycles and help remediate over-fertilized soils." (Michael Oster, 2021)*

Willow also provides nutritional benefits for livestock:
“The feed value of poplar and willows leaves is 65–70% dry matter digestibility, about the same as lucerne hay. A crude protein level of 15% is well above that required for livestock maintenance. The leaves contain valuable compounds called condensed tannins (CT) and phenolic glycosides (like aspirin) and these have health benefits for stock. Massey University research found that 5–10 year-old trees yield up to 22kg DM per tree of edible forage, and that poplars and willows were similar in nutritive value. Condensed tannin levels are usually higher in willows. Willow leaves are also high in zinc and magnesium, which are important animal health minerals.” (Poplar and Willow Research Trust, 2016)

AFBI is currently researching the potential for willow to reduce methane emissions.

Comfrey for fertiliser
Initial trials have started on making liquid fertiliser from comfrey leaves. The system is straightforward. Leaves are cut and placed in a 1000L tank. We are trialling both wet and dry systems but it is too early to show any results just yet.

5.3 Improved water quality

The swale systems were all monitored monthly and analysed for

- pH,
- Conductivity (uS/cm),
- Ammoniacal Nitrogen as N (mg/l),
- Ammonia as NH_3 (mg/l),
- Nitrate as N (mg/l),
- Total Suspended Solids (mg/l),
- Dissolved Oxygen (mg/l),
- BOD + ATU (5 day) (mg/l),
- Redox Potential (mV),
- Soluble Reactive Phosphorus as P (mg/l)

In most cases the water quality indicators are showing that the swale systems are effective. The high value of nutrients coming from the dirty farm water is being utilised within the systems through the comfrey and willow crops. From the analysis of water quality downstream of the systems, the receiving waterways appear to be unaffected by the systems in most cases. However, some results have indicated that the systems can be put under pressure during the wetter winter months. It is important to note, that with proper landowner management and maintenance of these systems, the wetter months become less of a pressure and therefore less of a concern. More detailed reporting on each farm trial and the water quality results are included in the appendix.

Biotic indicators are a good measure of the health of the river. As well as the monitoring data described above the team have also regularly checked under stones to see what wildlife is surviving. Before the project one of the sections of river downstream of one of the swale sites only contained those invertebrates expected in poorer water quality i.e. leeches, worms, snails. After installing the swale system, subsequent checks found invertebrate assemblages that indicate good water quality include species of mayflies and stoneflies, which are particularly sensitive to pollution.

5.4 Creation of habitat

Biodiversity is improving. After the swales were filled and the willows came into leaf, skylarks and mallard ducks were seen around the sites and probably nested there. Since then, teal ducks come daily to feed in the swales. There are also bees, butterflies and dock beetles feeding on the wildflowers and comfrey. There is evidence of otters around the swales.

5.5 Soil Saving Logs

Site 1 Gortin Water - Outcomes

Out of all the sites that were trialled, this site proved to be the most successful in terms of miscanthus log preservation and bank redevelopment. Although, the miscanthus logs were put in place and the work was completed a month prior to the other sites which gave this site a slight head start. The miscanthus bags have no signs of deterioration at this site. The backfill along the bank has progressed with long rooted grass growing in behind the logs. This process is allowing the plants to develop a strong root system along the riverbank which will help the bank to restabilise itself over time.


Site 2 Drumard River - Outcomes

At this site, the logs remain in place having battled through a wet winter and periods of flooding. The structure here in comparison to 'site 1' seems to be more exposed to the forces of the river with ripples directing the flow towards the structure. There were clear signs of deterioration, particularly with the bottom layer of logs. Some of these logs had been torn, however the wet compacted miscanthus was still holding its shape. Having seen this, we modified the structure by adding a layer of chicken wire to the front of the logs with the intentions of holding the miscanthus in place in the event of further deteriorations. Over recent months, a promising layer of grass has developed on the backfill and therefore beginning to generate a root system which will help strengthen this bank over time.

Direction of ripples/flow towards logs

Evidence of log deterioration

Site 3 Ballinderry River (Wellbrook) Outcomes

As this site is located along the main channel, we expected the structure to be faced with greater erosion pressures from flooding and other factors. The logs remain in place, although much like the findings at 'site 2', there were clear signs of deterioration, particularly with the bottom layer of logs as some of these logs had been torn. However, the wet compacted miscanthus was still holding its shape. Having seen this, we modified the structure by adding a layer of chicken wire to the front of the logs with the intention of holding the miscanthus in place in the event of further deterioration. At this site, the backfill vegetation has been slow to establish. However, this was expected with the poor exposure to sunlight here.

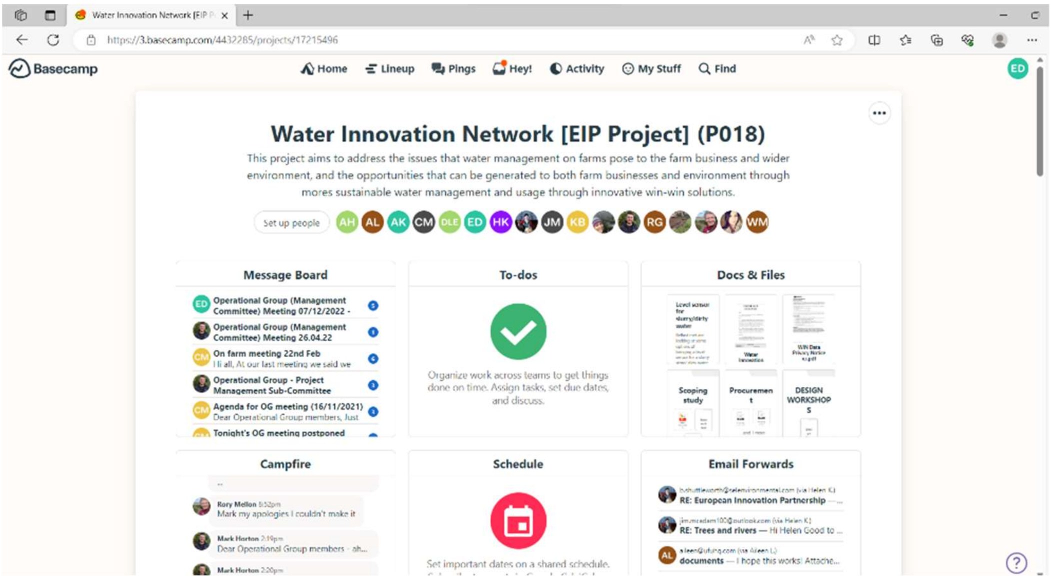
Evidence of log deterioration

In general, it is too early to comment on the success of these methods for bank stabilisation. The structures have only been in place for 6-8 months and therefore there hasn't been enough time to see significant development in the riverbanks. However, we can say that the structures have been preventing further erosion at each of these sites with the evidence of log deterioration. In fact, this proves that the logs are doing their job whilst allowing the riverbank to rebuild itself naturally. However, it is still unknown how much further impact these logs can take or how long they will last. These sites will need to be continuously monitored going forward in order to answer these questions.

6 Communication

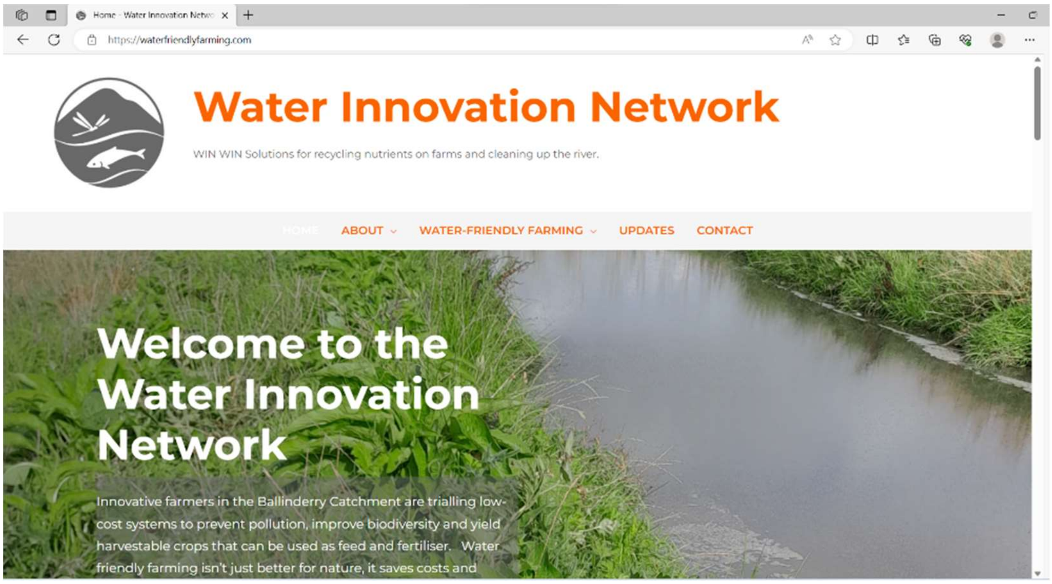
6.1 Message Boards

The operational group used an application known as 'Basecamp', an online message board and communication resource for the purposes of contact and information sharing. Throughout the project, this application was used to organise tasks, arrange meetings and share information on project activities. The operational group had meetings every 3 months, the majority of which occurred via Zoom calls and some on-farm meetings. These meetings provided the best opportunity to bring the operational group members together to discuss the progress of the project and the plans moving forward.



6.2 Website and blog

We set up a website in the early stages of the project and updated this - short blog updates and more substantial overhaul when things were starting to happen on the farm.



[Home - Water Innovation Network (waterfriendlyfarming.com)](https://waterfriendlyfarming.com)

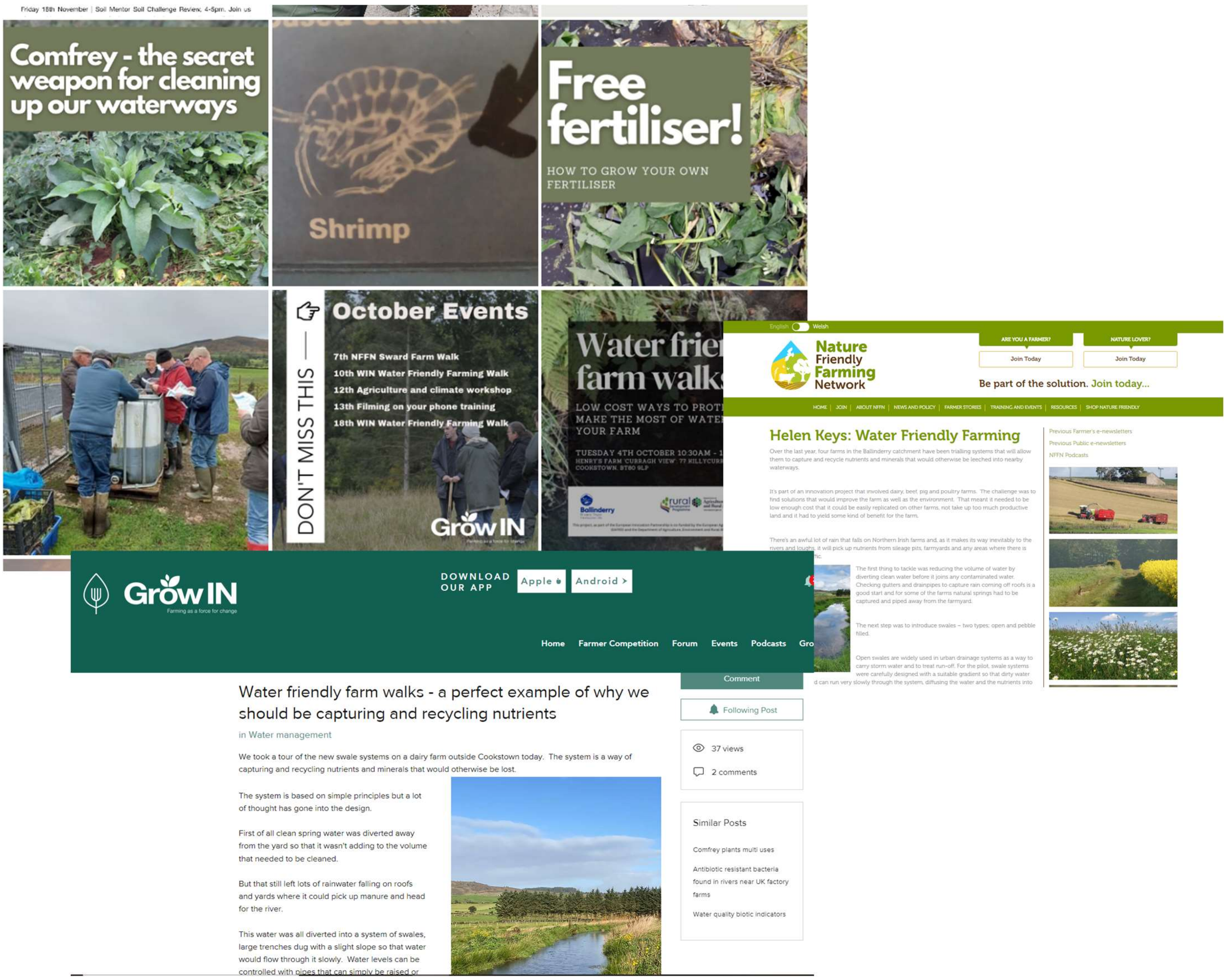
6.3 Social media and networks

We developed a communication strategy and distilled some of the key messages from the project into short 'bite-size' snippets of information. We published these out through our own social channels.

Key messages were:

- How to check the waterways around your farm
- Free fertiliser - making your own on farm
- The low-cost fail-safe device to protect against slurry spills
- Dealing with dirty water using swales
- Comfrey - the secret weapon for cleaning up our waterways.

We also made use of existing farm networks in Northern Ireland, in particular the Nature Friendly Farming Network and the Growing Innovation Network. Both shared events and blog posts about the project.



We got some online interaction from people who had attended events.

Bronagh O'kane
Oct 17, 2022

W

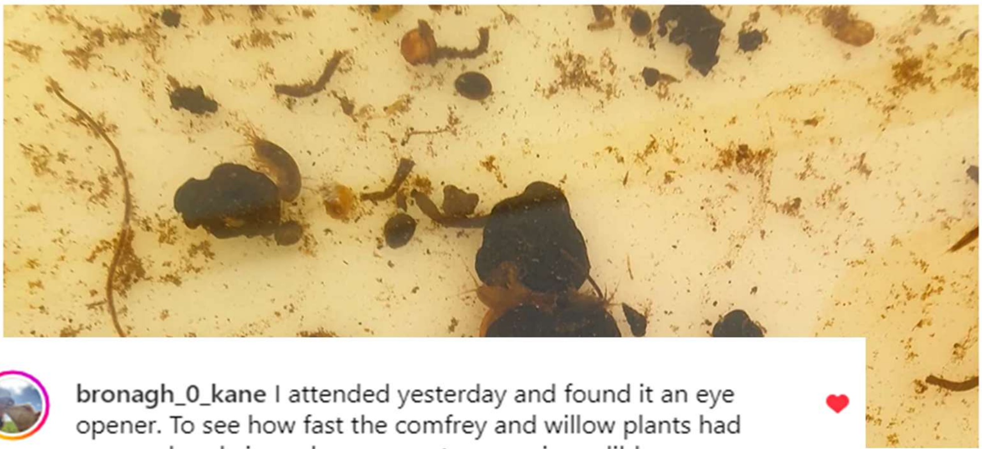
I found this talk really interesting, Alan is super knowledgable. I'm now on a mission to grow comfrey!
Dad and I found it inspiring to see what can be done and he is already thinking of what he can make for our water that runs off the yard/silage/FYM pit. Usually goes into slurry tank but a better method would help

Water quality biotic indicators

in Water management

Great visit at the Water Innovation Network farm walk today. Took the kids out when we got back to check what we could find in one of our burns. And delighted with what we found! Every category covered: mayfly, cased caddis, shrimp, beetles, caseless caddis, leeches, worms...

1 Like



bronagh_0_kane I attended yesterday and found it an eye opener. To see how fast the comfrey and willow plants had grown already in such a new system was incredible.
Learning how the willow can be fed to my cows and sheep and the comfrey made into a liquid fertiliser is just a genius way to close the system with zero waste and free food!
👏👏👏👏

43 w 2 likes Reply ...

The Rivers Trust All-Ireland @RTallireland · Jun 27
Mark & Eoin from Ballinderry Rivers Trust show a solution to clean and dirty water separation on farms that can also host a cash crop & open new revenue streams itv.com/news/utv/2023-... @AgrilandIreland @DiscoverCAFRE @BallinderryRT @DiscoverCAFRE @theriverstrust

itv.com
Anglers urge tougher penalties for river pollution after nearly 1,500 in...
Exclusive figures obtained by UTV reveal there has been 1,371 agricultural river pollution incidents since 2018. | UTV News

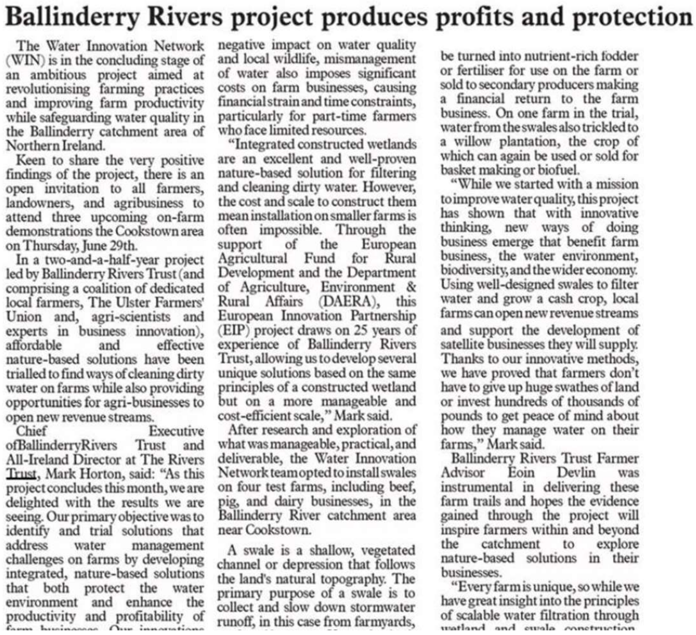
The table below gives an indication of the views and interactions the posts received.

Instagram post	Impressions	Interactions
Comfrey - the secret weapon in cleaning up our waterways	158	13
The Rambo of the waterways	109	7
Free fertiliser	179	11
Free fertiliser 2	158	12
Event listings	152	12
Events	120	6
GrowIN		
Water advice	36	4
Water quality biotic indicators	24	2
Comfrey uses	22	3
Water farm walks - recycling nutrient	37	2
Emailed newsletter	452	NA

6.4 Press

The project attracted attention from UTV who filmed a piece for the news in June 2023.

The story was also picked up by local newspapers Tyrone Courier and Dungannon News.



Ballinderry Rivers project produces profits and protection

The Water Innovation Network (WIN) is in the concluding stage of an ambitious project aimed at revolutionising farming practices and improving farm productivity while safeguarding water quality in the Ballinderry catchment area of Northern Ireland.

Keen to share the very positive findings of the project, there is an open invitation to all farmers, landowners, and agribusiness to attend three upcoming on-farm demonstrations the Cookstown area on Thursday, June 29th.

In a two-and-a-half-year project led by Ballinderry Rivers Trust (and comprising a coalition of dedicated local farmers, The Ulster Farmers' Union and, agri-scientists and experts in business innovation), affordable and effective nature-based solutions have been trialled to find ways of cleaning dirty water on farms while also providing opportunities for agri-businesses to open new revenue streams.

Chief Executive ofBallinderryRivers Trust and All-Ireland Director at The Rivers Trust, Mark Horton, said: "As this project concludes this month, we are delighted with the results we are seeing. Our primary objective was to identify and trial solutions that address water management challenges on farms by developing integrated, nature-based solutions that both protect the water environment and enhance the productivity and profitability of

negative impact on water quality and local wildlife, mismanagement of water also imposes significant costs on farm businesses, causing financial strain and time constraints, particularly for part-time farmers who face limited resources.

"Integrated constructed wetlands are an excellent and well-proven nature-based solution for filtering and cleaning dirty water. However, the cost and scale to construct them mean installation on smaller farms is often impossible. Through the support of the European Agricultural Fund for Rural Development and the Department of Agriculture, Environment & Rural Affairs (DAERA), this European Innovation Partnership (EIP) project draws on 25 years of experience of Ballinderry Rivers Trust, allowing us to develop several unique solutions based on the same principles of a constructed wetland but on a more manageable and cost-efficient scale," Mark said.

After research and exploration of what was manageable, practical, and deliverable, the Water Innovation Network team opted to install swales on four test farms, including beef, pig, and dairy businesses, in the Ballinderry River catchment area near Cookstown.

A swale is a shallow, vegetated channel or depression that follows the land's natural topography. The primary purpose of a swale is to collect and slow down stormwater runoff, in this case from farmyards,

be turned into nutrient-rich fodder or fertiliser for use on the farm or sold to secondary producers making a financial return to the farm business. On one farm in the trial, water from the swales also trickled to a willow plantation, the crop of which can again be used or sold for basket making or biofuel.

"While we started with a mission to improve water quality, this project has shown that with innovative thinking, new ways of doing business emerge that benefit farm business, the water environment, biodiversity, and the wider economy. Using well-designed swales to filter water and grow a cash crop, local farms can open new revenue streams and support the development of satellite businesses they will supply. Thanks to our innovative methods, we have proved that farmers don't have to give up huge swathes of land or invest hundreds of thousands of pounds to get peace of mind about how they manage water on their farms," Mark said.

Ballinderry Rivers Trust Farmer Advisor Eoin Devlin was instrumental in delivering these farm trails and hopes the evidence gained through the project will inspire farmers within and beyond the catchment to explore nature-based solutions in their businesses.

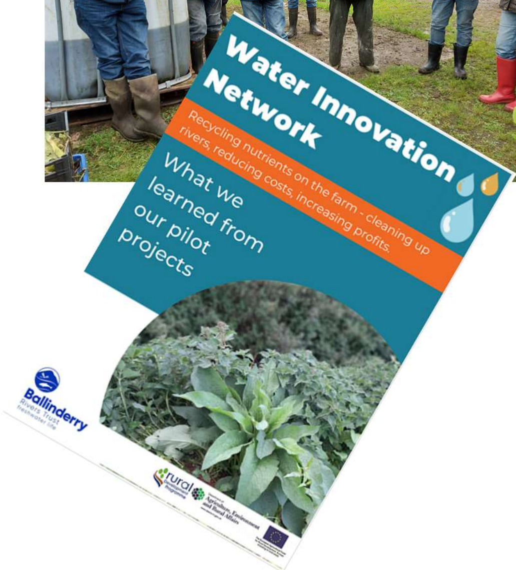
"Every farm is unique, so while we have great insight into the principles of scalable water filtration through

6.5 Farm walks

There was a total of 15 organised farm walks carried out over the duration of the project, with a total of 135 attendees. We promoted these through online channels but also direct contact with farmers we knew might be interested in doing something similar on their own farms. We kept the walks informal and talked about how farmers could check their own waterways and use biotic indicators i.e. Measure water quality by checking what bugs were living there. We created a handout brochure which summarised what we had learnt, guidance on how to check waterways and what to do.

There were several farm walks that were open public events, which allowed for a diverse audience of farmers, agronomists, botanists, conservationists, anglers and so on. From these events, it was interesting to gauge a mixture of views on the project work coming from these areas of expertise. There were multiple farm walks organised as group events, where members from recognised organisations such as the Ulster Farmers Union, DFI Rivers Agency, Lough Neagh Partnership and Queen's University Belfast were in attendance.

Overall, the number of attendees was lower than originally predicted at the application stage. Specifically for the public events, it was difficult to accumulate high numbers of attendees. From this, we have learnt to adjust the promotional techniques for future events in order to target specific groups. For example; with some public events we had to change the messaging from 'water-friendly farm walk' to 'make free fertiliser' in an attempt to attract more people, specifically within the farming community. Going forward, a greater push would be needed with event promotion and selling the events with messaging that attracts your target audience.



6.6 Wider consultation

At the exploratory stage it was important to broker in as much expertise as possible to avoid 'reinventing the wheel'. The range of options being proposed were discussed with people who have a wide range of experience at both a practical and scientific level.

Michael Costello – Horticulturalist
Alan McKeown – Aquaculture and Wasabi grower
Andrew Thompson – CAFRE Water Quality
Chris Johnston – AFBI
Regenerative Farming Ireland Facebook group
Stephane Durand – EIT Food
Michaela Fox – EIT Food
Robert Greer – Contractor
Ian Marshall – QUB
Moira Dean – Institute of Global Food Security
EIP database
Michael Meharg – Lough Neagh Partnership
Simon Grey - Ulster Wildlife Trust
Paul Williams - QUB
Bernard Neeson - Horticulturist
Trevor Hutton - Architect
Kevin McGurk - Surveyor

7 The additional benefits or unintended negative consequences that have arisen from the delivery of the project.

Spin off projects

One of the Operational Group members was interested in our early discussions about nettles and went on to secure a £25,000 grant from Innovate UK to study the potential to grow nettles as a fibre crop.

John McClenaghan, Deputy President of the UFU visited one of the projects and has worked with our team to implement a similar system on his farm. He describes the system in this video https://youtu.be/n70FSOG5qnM

Ian Marshall, a farmer and former president of UFU has also trialled a scheme at his farm. This was one of the lowest cost interventions, it made use of existing sheughs, swales were filled with stone so there is much less loss of productive land. Water quality has improved dramatically.

At 2 farms the swale system has effectively acted as a buffer and has protected the river from unexpected spillages that would otherwise have ended up causing pollution in the river. However, this should not result in the farmer being less vigilant as the systems clearly have their limit about how much pollution they can prevent.

Some lessons from the project:

On the first farm swales were put into use as soon as they were constructed but they need time for plants to bed in before they become fully functional.

On one of our trial farms the soils around swales are sandy/permeable soils, which allows the water to infiltrate and get away. Therefore, the dirty water does not get to fully utilise the system or get to the final swale and willow planted area. Our nutrient hungry plants (Comfrey & Willow) have not been growing particularly well at this site in comparison to the other farms. Percolation tests should have been done initially and represented later to test soil permeability. 1000 grade alkathene/polythene should have been put down on the bottom and sides of the swales to prevent percolation and ensure all swales are half-full of dirty water.

We fenced off swales on all the trial farms but with hindsight this was not necessary except where the water filled swales were exposed and posed a risk to livestock and children. Livestock don’t graze the plants until they are wilted.

The use of perforated pipe caused waterlogging on one farm. The existing solid pipe should have continued until the fence (where the swale system starts) and then introduce the perforated pipe through the system.

8 Conclusions

- Swale systems with some surrounding infrastructure and comfrey/willow planting are a low-cost way to manage dirty water BUT good design, management and monitoring are critical to the system.
- Using plants – comfrey, willow etc for bioremediation can be very effective and yield a useful crop for fodder, fertiliser or biomass.
- The most recent system developed cost just £7,000, it includes a simple in-sheugh stone filter, an emergency slurry trap, four concrete check dams where the sheugh bed falls 650 mm from the dam upstream. Four diverter pipes are located upstream of each check dam. The diverter pipes allow the dirty water to enter 370 metres of stoned swales. Over 1,000 comfrey plants draw nutrients from the swales plus 110 metres of existing sheugh, giving 480 metres of delivery channel. Over 200 square metres of willows are planted downstream of the closed end of the stone swales. The farmer had tried all sorts of measures to deal with FDW without success, now the river scores 10 out of 10 on the biotic indicator measure.
- The nature of the soil will have an impact on design - whether the swales need to be lined, which plants are best suited.
- In planning the project, we need to take account that some farmers are part time, and we need to accommodate evening and weekend working.
- The project was quite short in timescale for a nature-based solution to be designed, implemented, monitored, and evaluated. There is more monitoring work to be done and it is very early to be communicating findings.
- Choosing the right location is critical - the natural instinct is to look for unproductive land but on one farm this proved to be recovering peat bog, any environmental gains would have been outweighed by the loss of important habitat and a carbon sink.
- Water won't flow without a gradient – it is essential to do a survey and get levels so the system can be designed at the right gradient.
- The swale systems can act as an emergency prevention measure for slurry spills, this could be implemented downhill of above ground slurry stores to protect waterways.

9 Recommendations

9.1 Additional research

- A further project to check the fertiliser value of the wet and dry methods of comfrey fertiliser production would be useful.
- Documentation of the systems - Some further testing of the soil should be carried out to determine the optimum growing conditions for the aquatic plants (Sedges, grasses, and rushes) and terrestrial plants (Willow, comfrey) in the systems.
- Alternatives to comfrey should be trialled where comfrey isn't suitable.
- To help inform the scale of the system, the water quality should be recorded using the Biological Monitoring Working Party (BMWP) Score scoring system – in the farm drain before it reaches the receiving waterway and above and below the system in the waterway – in both Spring and Autumn
- Similar projects should be over a longer period of time with a Stage 3 'tail' to the project for monitoring results and communication to the wider audience.
- Detailed guidance and/or training needs to be developed for anyone implementing similar systems.

9.2 System design

- Check the soil type as the design may vary to suit i.e. a percolation test may show that swales need to be lined.
- Check levels on the site to ensure the flow of water.
- Consider where water is needed or could become a problem at different times of the year.
- Consider building in a slurry trap if there is risk of a spill.

On Heavy Soils:

- Swales should be constructed in the summer months.
- Existing land drains should be found and sealed ten metres away on all sides of the swales plot.
- A new land drain should be made along the upstream side of the plot to an exit at the river, downstream of the plot.
- To test the percolation capacity of the swales, they should be pumped full of clean water from a stilling well. The flow in and out should be measured during a dry spell.
- Dirty water from the farmyard should not be introduced to the swales until the plants and trees are growing well, after one full year.
- Comfrey roots must be thoroughly washed to prevent the movement of other invasive weed seeds.
- Hard standing should be incorporated alongside the inflow end of the first open swale. This allows this swale to be emptied in the event of an accidental spillage of slurry.
- A sediment trap should be constructed upstream of the first swale. This allows stones and grit to be removed so that only liquids can enter the swales.

On Light Sandy Soil – all of the above, and –

- If open swales (or pebble swales before they are back filled) allow water to freely percolate into the subsoil, they should be lined with an impermeable membrane to half of their depth.
- Because comfrey and willow are difficult to establish on sandy soils, a 200mm hole should be dug, well rooted plants used, and dilute liquid seaweed sprayed on the compost backfill.

9.3 Government support for water management

- DAERA should consider funding similar schemes under the new Farming with Nature – need to build in design and planning service or at least detailed guidance.
- Options which could be funded:
    - Rain water management – gutters, tanks
    - Swale construction
    - Slurry trap
    - Manual / automatic diverters
    - Sediment trap
    - Comfrey/willow plants
    - Fencing and gates around open swales
- Support may need to be provided to increase stocks of comfrey, multiplier areas could be set up trialling several cultivars of Russian comfrey – potentially working with local farms and nurseries.

9.4 Communications

- Provide farmers with additional guidance on how to check their water ways using biotic indicators.
- Change the messaging around water management to focus on the value of keeping nutrient on the farm.
- Promote the benefits of these low-cost systems.
- Develop guidance on the design of the systems.

10 References

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Michael Oster, H. R. (2021). *Comfrey (Symphytum spp.) as a feed supplement in pig nutrition contributes to regional resource cycles.* Science of the Total Environment, (https://www.sciencedirect.com/science/article/pii/S0048969721040602).
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11 Appendices

11.1 Case studies and detailed results

Farm 1 (Beef Farm)

Original Issues: Beef farm above land leading down to Ballinderry River. Fresh water was leaking into the covered silage pit and leading to unwanted extra yard runoff. Cattle slurry stored in a lagoon. Dirty yard water passes overground to drain in the public road beside the farm entrance, and then passes through a drain to enter a stream carrying spring water down to the river. In the field before the river is a recently naturally developed waterlogged area with rushes and reeds which has become unproductive as farmland.

Recommended solution: A small swale system which would be low maintenance, uses the lowest amount of productive land and can be accessed for mowing.

Outcome: Comfrey is growing well, especially that planted above the pebble swale. A leak, through an old 4" pipe, from the swale to the open sheugh was found. A solid pipe with a sluice valve needs to be connected to the leaking pipe so that the discharge can be regulated and sampled. The farmer allowed his suckler herd to graze the swale area during a dry spell during summer 2022. This did no harm to the young comfrey plants so we see no reason why this should not happen every year.

Farm1 showing the outflow from the pebble swale into the open swale, and the strong Comfrey growth above the pebble swale

Farm 2 (Pig Farm)

Issues: Pig Farm in which the yard receives runoff from a nearby field which can also reach a sump area used when pumping pig slurry into a slurry tank. Runoff from the year goes into a field causing it to become saturated. Not all pig house roof runoff is separated from clean water.

Recommended solution: Slurry and dirty diversion at source in the yard. A small swale system with nutrient absorbing and carbon sequestering vegetation between the swales.

Outcome: The stand pipes that control the water level in each swale had been raised recently but on inspection swales 2 and 3 need to be lowered by 100mm as they may be allowing water to weep through the banks. The water level in the last swale has never reached the outlet pipes so there is no discharge going to the willow area.
The comfrey planted on the inter-swale areas is not growing as well as it is on Farm 1 and Farm 5. So that we can learn the maximum amount from the projects we recommend that soil samples for nutrient analyses and pH be taken from each site. This will be useful information for future projects.

The farmer asked if the swales will grass over and collect sediment and will they need to be cleaned out from time to time. The top swale is the only one that will collect grit and pebbles which pass through the manhole, so the end at the inlet may need to be cleaned out, but probably only after about 10 years. It was agreed to review the growth of vegetation across the swales each 5 years. The floating vegetation uses nutrients but, because it is not being harvested, will return the nutrients to the system each winter.

The only negative comment the farmer made was about the safety of children if they were playing around the swales. The swales are fenced around and the farmer has a lock on the gate from the road. A sign at both gates should be considered.

There were clear otter trails leading into the swales. Mallard ducks were seen on the swales and a Heron had been seen on a recent visit. The site has a good appearance from roadside views.

1st swale at Farm 2 showing strong grass growth within the swale

Farm 3 (Poultry Farm)

Issues: Poultry farm on land which is used for cereal growing and has been shown to have a very high phosphate content. Spring water arising around the farm flows into a stream going down from the farm to the river and passing by, but not entering, an amenity pond area which the farmer has constructed. There are two poultry houses and a run-off area where the hens can free-range. The roof water from the houses is treated as farm dirty water. Ammonia absorption is a priority for this farm.

***Recommended solution*:** New spouting's are needed on a number of sheds around the yard. Only some roofs slope towards the concrete yards, where clean water becomes contaminated, but others turn rain water onto fields where it can't affect water courses. A previous owner piped a continuous supply of spring water through a number of chambers at different levels through the farmyard. These could be used again to deliver spring water to any projects to be developed between the yard and an existing pond sited near a stream. A riparian buffer of mixed shrubs and trees could be planted alongside the lane which runs alongside this stream, to capture phosphate leaking from arable fields on either side. The greenhouse with spring water running through could be used for horticulture production.

The owner has already shown innovation in planting an agroforestry system with free range hens. This will absorb gaseous emissions from the under grazing poultry and help absorb ammonia escaping from the chicken house. It will give added value to the project if this participating farm can also demonstrate the poultry agroforestry system.

Outcomes; There have been good opportunities created which can still be realised. The greenhouse with spring water running through can be used to grow tomatoes and peppers and to propagate young plants from comfrey root cuttings. The farmer has 3 outdoor areas where parent comfrey plants can be grown to provide root cuttings 2 years after planting.

Farm 4 (Horticultural Farm)

Issues: Spring fed plant nursery - If this nursery, based in the catchment area could be developed, it could produce plants for swale bank planting on projects developed on other Farms 1, 3 and 5. The nursery can also service plant requirements for spin-off projects on Farms 2 4 and 6. The nursery manager has previous experience with compost experimentation and this expertise could be utilised within the project. He has experience in landscaping and revegetating river banks. An awareness of the importance of using local provenances of crop and stabilisation plants is vital for the ecological integrity and sustainability of the various revegetation options.

Outcomes: The farmer has plants growing on the floor of the polytunnel and plants growing in raised troughs all "warmed" by 10°c spring water. He is going to add piping for overhead irrigation. He intends to reuse the spring water to grow outdoor crops.

He has young comfrey plants, grown in the polytunnel which he will plant out on banks and in corners to become parent plants to provide root cuttings for sale.

Spring water-fed polytunnel at Farm 4

Farm 5 (Dairy Farm)

Issues: Dairy Farm with large lagoon for slurry and silage effluent. Farm sits on slope down to a tributary of the Ballinderry River. Large unroofed silage pit has effluent catchment to the lagoon, but there is also spring water rising at various places in the silage pit and yards. Some effluent may get into the dirty water system rather than the effluent system. Drainage outflow into the river at times of high rainfall has periodically shown high pollution levels.

Recommendations:
Divert all identified sources of dirty yard water to a low point on the ground just below the Lagoon. Utilise current grassland area between the farm and the river to construct a series of roughly parallel swales totalling about 300 meters mostly on a 1 in 180 gradient, water reaching the bottom swale will percolate into a broad band of willows between the swales and the river. This is a Nature-Based Solution.

Design the system to have potentially harvestable plots in the 2.5m strip between the swales. In this area plant a series of plots of different plant species (produced by the supported native plant nursery) that can uptake nutrients and possibly be of commercial value.

Outcomes: This open swale system coped with the dirty water very well through 2022. Around December 2022 something changed and dirty water began to run across the willow patch to the river. Several measures were tried by BRT and the farmer to deal with the problem and the situation improved for a period.
For example, the site was visited in March 2022 when the swales were working properly and again in October 2022 when the swales were observed to be operating highly satisfactorily (picture below) and the willow and comfrey well established.

Swale system at Farm 5 in October 2022.

During our visit on 5th April 2023 however it was obvious that some dirty water is again getting to the riverbank by surface flow from the swales. With the soil under the willows already water-logged there was no opportunity for this dirty water to be filtered. While it was intended that water would pass from the bottom swale through the soil to the river, there was also some seepage through the banks of the higher swales which contained dirtier water and some of this dirty water was making its way directly to the river. Although the river was not as bad as before, there are a few patches of sewage fungus on the riverbed between the swales and the farm bridge.
The situation on the 5th April was that the slurry lagoon was full and the swales were not capable of dealing with the quantity and quality of yard runoff possibly because some slurry had entered the system that it was not designed to cope with. A review is needed with the farmer to look at:
1. The day-to-day management of slurry and yard runoff.
2. What further work could be done to resolve the problem that occurred over the winter period. For example, could the quantity of yard runoff be further reduced by diverting more spring water.

Swale System at Farm 5 showing excessive presence of slurry solids in the first swale that the system was not designed to handle and also surface flow of dirty water seeping from a swale bank to the river.

White fungal growth in the river at Farm 5.

Farm 6 (Mixed livestock and food processing/butchery)
The comfrey is growing well after having disappeared due to winter frosts.
Although the receiving stream looks pristine there is a slight fungal growth on the bottom of the sampling manhole. This is the first time any flow has been seen discharging into the manhole.
When the project was finished a sheep fence was erected around the pebble swales. Now that the comfrey is established, if the fence was taken away the plot could be grazed with young cattle allowing the nutrients to be redistributed across the field.

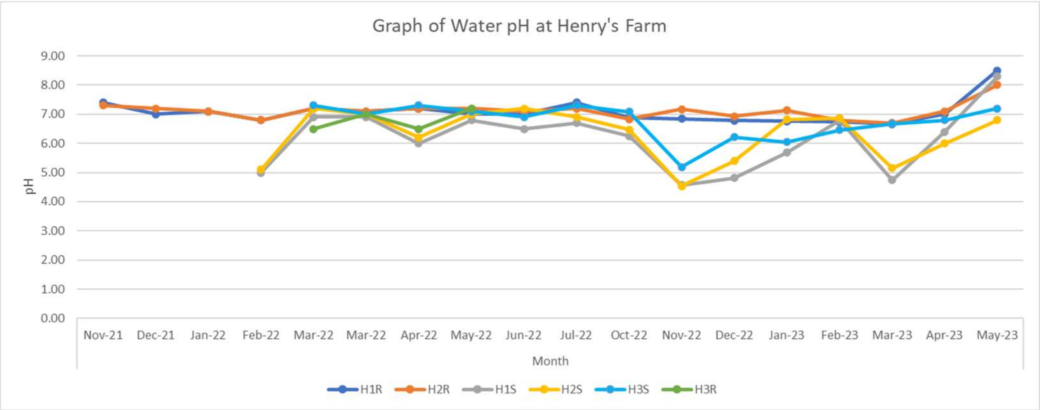
Conclusions from water sample analysis

Dairy Farm

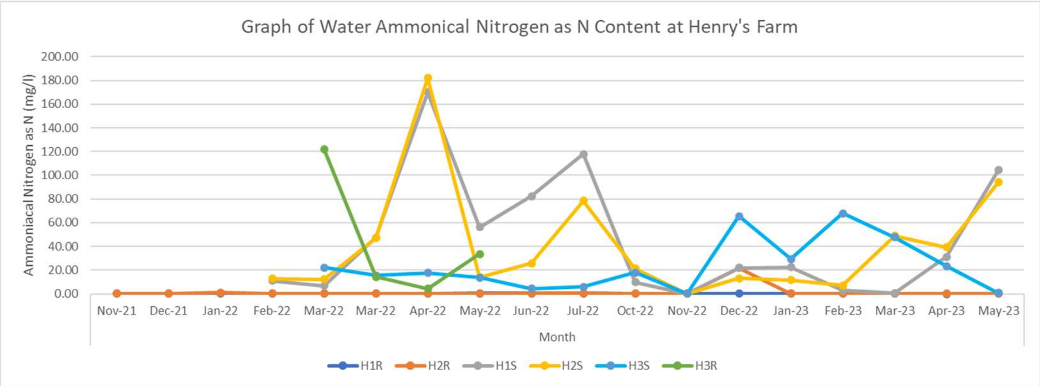
H1R	u/s Project
H2R	d/s Project
H1S	Yard Water Input
H2S	Sed Trap Output
H3S	Swale Output
H3R	d/s Willow

Key: Water Sample locations

- **pH** - Our sample results identified a drop in pH across all sample points over the winter months (Oct 22 onwards). Particularly with the Yard input and Sediment trap output samples. The pH levels were as low as 4.53 in November 2022, which is considered to be moderately acidic. The pH readings from the river (H1R & H2R) have been quite consistent throughout the project period with a slight drop since October 2022. However still consistently between 6.5-7, indicating very slight acidity to neutral levels. The pH results from May 2023 indicated an increase both upstream (8.5) and downstream (8.0) of the project. As the pH increased upstream, this would suggest that the increased pH downstream was not a factor of the swale system. Variation between downstream and upstream of the project is minimal but it would not be expected for the pH to change much over this relatively short time period.

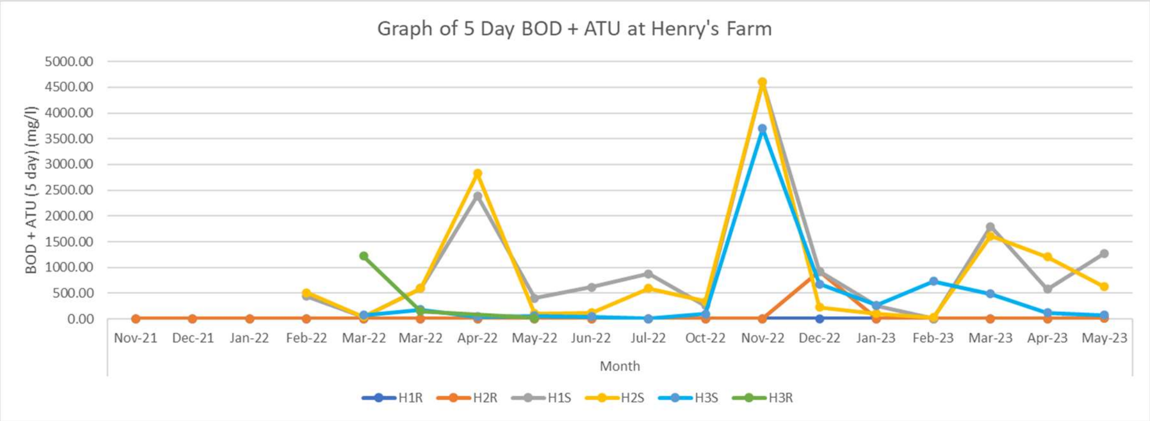


- **Water Ammoniacal Nitrogen as N** - The nitrogen in nitrate form is consistently low in the swales output. This is very positive given the spikes in nitrate release into the water as documented throughout the project. The explanation for the sudden spike in April 23 is discussed in the report (See Section 10.1) and cannot be considered a fault of the system.

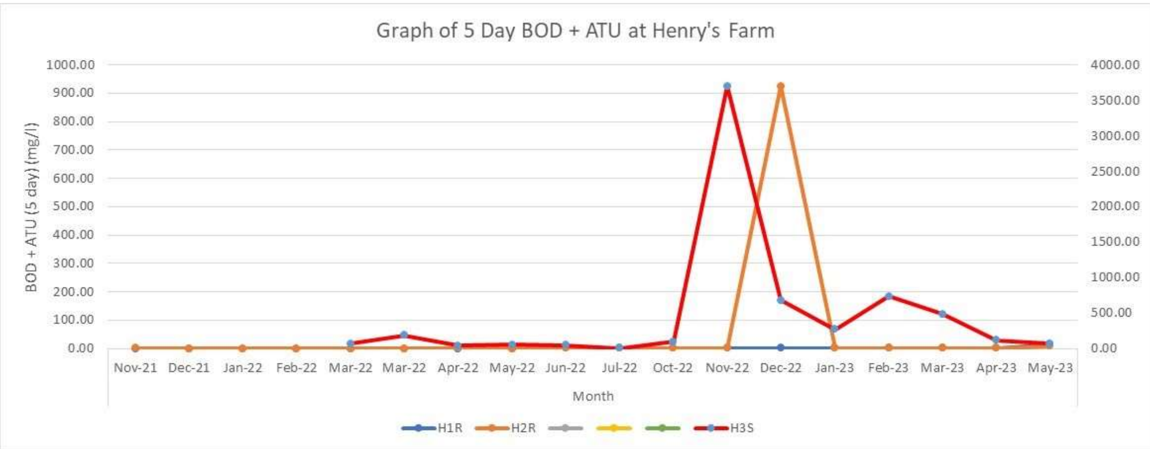


- **Biochemical Oxygen Demand (BOD)** - (Apart from a spike in Nov 22 (explained) the BOD levels are consistently low at the end of the swales run (H3S - Swale Output). Typical BOD levels of pollutants are;

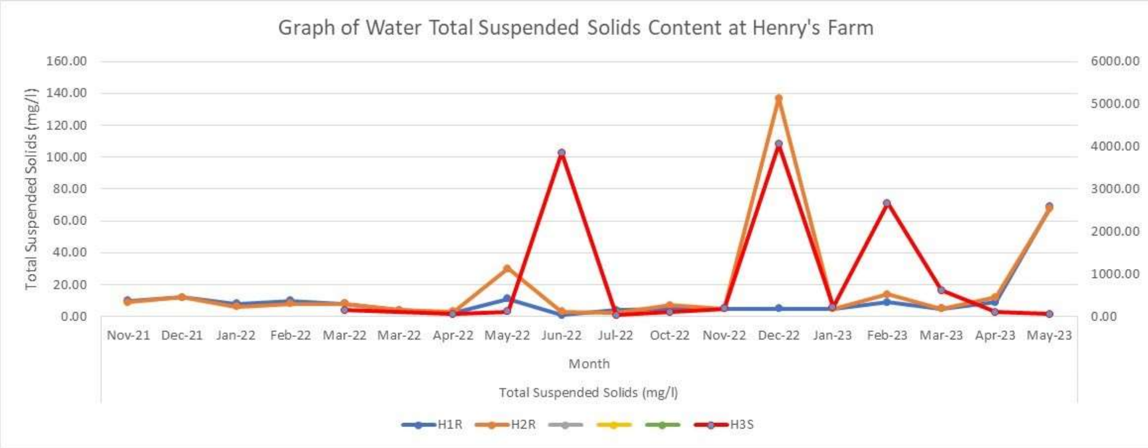
e.g.		BOD
Silage Effluent	-	65,000 (mg l)
Pig Slurry	-	25,000
Cattle Slurry	-	17,000
Dairy washings	-	1,500
Domestic Sewage	-	250 - 440



Most of the values in the swale outputs (H3S) are around 500 mg/l i.e. at the lower end of the scale. In the river, both Upstream and Downstream of the system, BOD levels remain low throughout the majority of the project period. However, when putting the results on a different axis (see below), we do see spikes downstream when they are not present upstream. This also correlates with the swale output readings in November 2022 (3,700mg/l), indicating that the farm has contributed to an increase in BOD downstream (924.80mg/l) December 2022. A similar trend can be seen with Conductivity, NH3, NH3-N, Suspended Solids, and Dissolved Oxygen. With these results, it is clear that the swale system here at Henry's farm had been put under significant pressure over the winter months (Oct 22-Feb 23) and have contributed to some parameter increases in the river over these months.

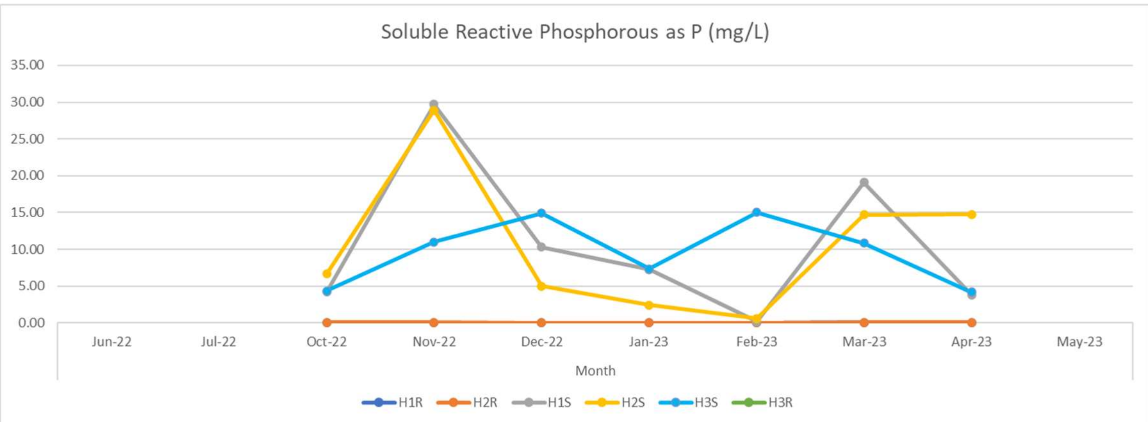


- **Total Suspended Solids** - A spike in December 2022 from the Swale Output (HS3) recorded 4,050mg/l. This reading can be connected to the sudden increase and highest recording identified in the river downstream of the project (H2R) on December 22 at 137 mg/l. Again, this result indicates the pressure put on the system during the wet winter months.



- **Soluble reactive phosphorus (SRP)** - This is one of the parameters used to determine the ecological status of a river. The impact of high concentrations of SRP in rivers includes a shift in the composition and abundance of plant species present, which has an impact on the river's overall ecology. This is one of the most significant causes of water bodies such as rivers not achieving good ecological status under the Water Framework Directive.

  The results here for Soluble Reactive Phosphorus as P suggest that the Tulnacross river is relatively unaffected by the swale system. A very small increase of 0.03 mg/l was identified in December from Upstream to Downstream of the project. However, this difference is extremely minor particularly during the wettest time of year. Within the swale system itself, the levels of SRP are high with peak values recorded in November 2022 (29.70 mg/l). The system seems to be dealing with these nutrients appropriately with the uptake from nutrient hungry plants and there is no evidence of major increases of SRP in the river downstream.



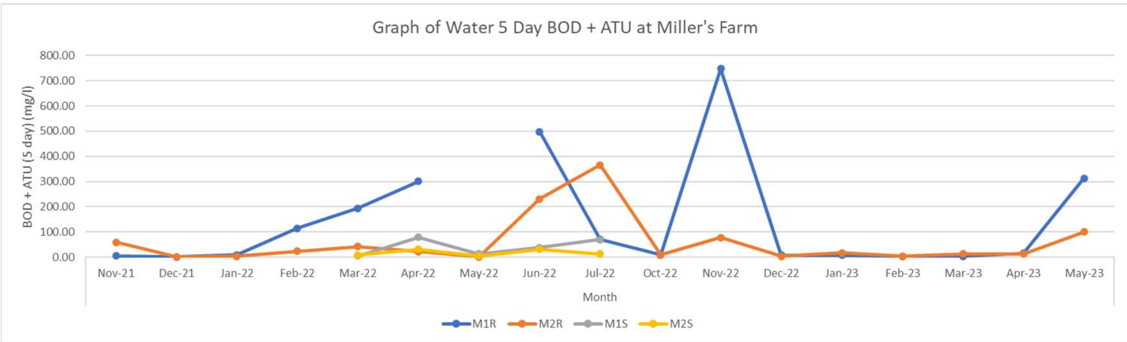
Pig Farm

M1R	u/s Project
M2R	d/s Project
M1S	Yard Water Input
M2S	Swale Output

Key: Water Sample locations

Overall, the system seems to be working well at this site as all water quality parameters below the swales are good.

- **Biochemical Oxygen Demand (BOD)** - There are spikes in BOD recorded upstream of the system (M1R) particularly between January & June 2022. The highest recording was identified in Nov-22 at 748 mg/l. However, these BOD spikes upstream haven't had a significant impact on the BOD levels downstream of the system (M2R), which suggests that the swales are tackling the dirty water nutrients within the system before reaching the receiving waterway. Where there are spikes in BOD upstream, there are evidently small rises in BOD downstream, however the system is doing its job by reducing this significantly and controlling BOD to a harmless level.



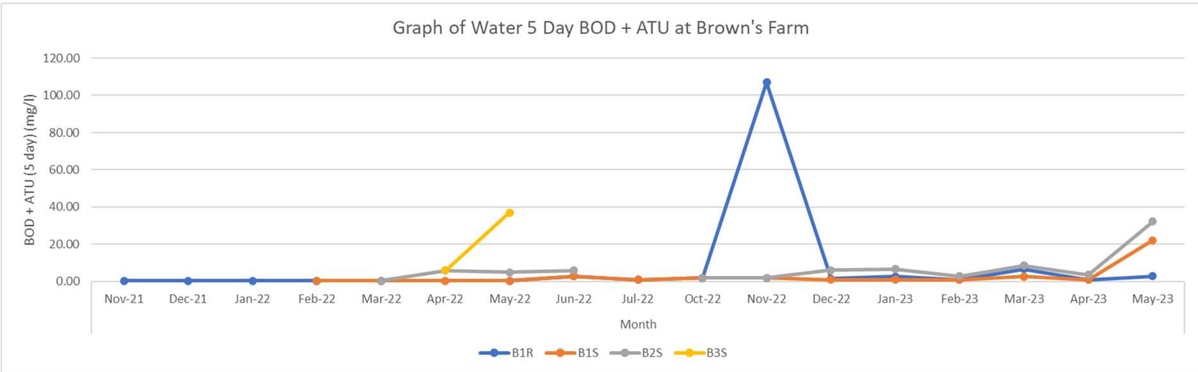
- The results support the observations that water quality is good.
- It is hard to see any obvious reason from the water sampling why the comfrey is not doing well. Reiterates the need for soil testing.
- It is gratifying to see that the spikes in some pollutants in April 23 (flash flooding?) are being removed by the swale system.

Beef Farm

B1R	u/s Project
B1S	Swale Output
B2S	Wetland Area
B3S	Miscanthus Area

Key: Water Sample locations

- **Biochemical Oxygen Demand (BOD)** - Apart from a small spike recorded upstream of the project (B1R) in Nov-22, the BOD levels within this system were extremely low throughout the project period. This would suggest that the system here (a mix of an underground pebble swale, an open swale and a wetland area) was successful at dealing with the dirty water nutrients. Although a less intense farm, the dirty water entering the system will naturally have less harmful nutrients.

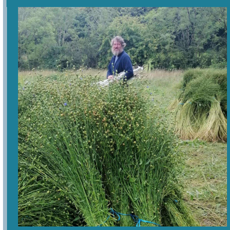


- Large spike in suspended solids and N in the wetland area is probably a good sign -it is trapping those elements

11.2 Operational Group Members

	The Henry Family - Dairy Bill and Adrian own a dairy farm located in the Ballinderry River catchment.
	Kenny Brown - Beef Kenny owns a beef/suckler farm located in the Ballinderry River catchment
	James Millar - Pigs James is a prominent pig and beef farmer, with his farm located in the Ballinderry River catchment.
	Creeve Cottage - Horticulture Bernard and Ciara Neeson run a horticulture business from Ballynagilly, near Lough Fea. They sell chemical free vegetables through Source Grow, local markets and their Honesty Box.
	Robert Greer - Poultry Robert is a part time free-range poultry farmer. The farm is located in the Ballinderry River catchment.
	Wilbert Mayne As a farmer for over 50 years with a farm in the Ballinderry catchment area and current chairman of the UFU Environment Committee Wilbert fully understands and supports the need for win-win solutions for both farmers and the environment. He has supported the work of Ballinderry Rivers Trust for the last 15 years.
	Aileen Lawson Experience of agricultural and environmental policy and management, working with and representing farmers. Member of the DAERA Sustainable Agricultural Land Use Expert Working Group and other EU funded project groups. Experience of sharing information with farmers and facilitating meetings. Experience of challenges and opportunities across the farming and agri-food sector across Northern Ireland.
	BRT CEO - Mark Horton MBE Mark has been working with the Trust since 2004. He is responsible for directing the activities of the Trust and managing the Trust's projects. Mark is passionate about rivers and the conservation of freshwater ecology. He is always looking for ways to keep the community at the heart of protecting our precious freshwater environment. Mark has delivered a range of projects working with farmers to identify and implement win-win

	solutions for both the river and the farm-business. He is also the All-Ireland Director of The Rivers Trust, the umbrella body for the network of rivers trusts across the UK and Ireland, meaning that he is well placed to connect with other projects benefiting both farms and the water environment. The Trust has a trading arm, River Care Ltd that will likely act as the Project Coordinator.
	Project Co-Ordinator 1 = Ciaran McKay Ciaran has worked as a Farm Advisor for the Ballinderry Rivers Trust for several years. He has great experience within the Agri-environment sector having been involved in various other projects/schemes. Ciaran had the role of project co-ordinator through the early stages of the WIN project until 2022.
	Project Co-Ordinator 2 = Eoin Devlin Eoin is a graduate at Queen's University Belfast having studied a degree in Environmental Management. He has been working as a Farm Advisor with the Ballinderry Rivers Trust, with involvement in other Agri-environment projects. Eoin had joined the Operational Group for this project in 2022, replacing Ciaran McKay in a project co-ordinator role.
	Expert advisor = Dr Lindsay Easson Led the agronomy research programme at ARINI, later AFBI, 1977 to 2005, and then led the Environment and Renewable Energy Centre programme there 2006 to 2012. Role: Understanding of crops and land management; constructed wetlands; bioremediation of farm dirty water and of setting up and managing trials. Project design and monitoring
	Expert Advisor = Alan Keys MBE Founder of Ballinderry Rivers Trust (formerly BREA), worked extensively with farms throughout the catchment to identify root causes of pollution and solutions. Pioneered new water quality improvement measures on farms. Role: Identifying suitable farms, liaising with farmers, identifying issues on farms causing damage to the river, designing water management systems.
	Expert Advisor = Prof Jim McAdam Research career specialising in upland grasslands and agroforestry systems. Head of Grassland and Plant Science Branch in AFBI from 2008-2018. Currently an Honorary Professor with QUB. Role: Knowledge and understanding of peatlands and wetlands, role of trees in farming systems, conducting on-farm trials, local knowledge.

	Innovation Broker = Helen Keys Helen is a lecturer in Innovation and Entrepreneurship at both Queen's University Belfast and Ulster University. She works with students in Agricultural Technology, Food and Nutrition and Land Use and Environmental Management as well as the Environmental Leadership Programme. Helen is a member of the Natural Fibre Composite Collaborative Network and a forum developed by EIT Food on the Future of Farming in Northern Ireland.
	Charlie Mallon Charlie operates a low intensity farm of 50 acres just outside Cookstown. He has a small suckler herd and over the last few years has diversified into growing flax, potatoes, cereals and hemp. He is a member of the Nature Friendly Farming Network and a participant in the Environmental Farming Scheme.

11.3 Delivery Partners

The table below shows the list of sub-contractors hired in to deliver various aspects of the project.

Arnold Harkness	Digger Works
RS Greer Contracts	Digger Works
ALS Environmental	Water Sampling
Biosearch	Water Sampling
BlueMonkey	Website Design
Acute Engineering Surveys Limited	Site Surveyor
JourneyFor	Project Filming
Matthew Gould	Drone Footage

11.4 Dissemination Events

Date	Group Involved	Farm Event Location	No. of Attendees
21/09/2022	DFI Rivers Agency Drainage Council	Henry's Farm, Cloughbane Farm	8
27/09/2022	Ulster Farmers Union Environment Committee	Henry's Farm	10
04/10/2022	WFS Farmers	Henry's Farm	10
10/10/2022	Public Event	Henry's Farm, Cloughbane Farm	9
11/10/2022	QUB - Conservation Biology Students	Henry's Farm	28
11/10/2022	Lough Neagh Partnership Group	Henry's Farm, Cloughbane Farm	7
18/10/2022	Public Event	Henry's Farm	6
12/11/2022	The River's Trust (Autumn Conference)	Henry's Farm	4
30/11/2022	Webinar	All Farms	28
16/05/2023	Public Event	Neeson's Farm	7
31/05/2023	Public Event	Millar's Farm	3
31/05/2023	Public Event	Brown's Farm	3
28/06/2023	Public Event	Millar's Farm	4
28/06/2023	Public Event	Brown's Farm	4
28/06/2023	Public Event	Cloughbane Farm	4