Systems thinking for the Usk: Actors and activities driving the health of Usk catchment freshwaters.

A Cardiff University Water Research Institute report for

Catchment Systems Thinking Cooperative (CaSTCo)

December 2023

Cardiff University | Prifysgol Caerdydd

Water Research Institute | Sefydliad Ymchwil Dŵr

CaSTCo

Making sure that people count at the heart of rivers' recovery

Suggested Citation: Kean EF, Perkins SE, Munday M and Durance I. 2023. *Systems thinking for the Usk: Actors and activities driving the health of Usk catchment freshwaters.* A Cardiff University Water Research Institute report for the Catchment Systems Thinking Cooperative.

Correspondence: durance@cardiff.ac.uk

Cardiff University Water Research Institute

Founded in 1883, Cardiff University is established as one of Britain's leading research universities. The Water Research Institute was launched in 2015 to address the grand challenge of sustainable water management for people and ecosystems in a changing world.

www.cardiff.ac.uk/water-research-institute

Catchment Systems Thinking Cooperative (CaSTCo)

Ofwat funded £7million project led by The Rivers Trust and United Utilities with collaboration between 24+ UK partner organisations. It is creating a radical step-change in the contribution of Citizen Science & Community Monitoring to evidence-based Integrated Catchment Management.

https://theriverstrust.org/our-work/our-projects/castco-catchment-systems-thinking-cooperative

Contents

Glossary* and Acronyms

Actor* A term used to refer to organisations, businesses, groups, and individuals that influence river health, both directly and indirectly within the Usk Catchment.

Catchment* An area of land where water is collected by the landscape and flows to a river system

Information* Data and knowledge that can be shared

Intervention* An intentional activity aimed to protect or improve freshwater health

Knowledge* Understanding and skills acquired though experience, analysis or education.

Network* A network of interactions between actors

Participant* Those actors that we met with or who completed the online survey.

System* A group of interacting or interrelated elements; a complex whole

Systems thinking* A way of understanding complex challenges by considering all the constituent parts of the challenge as a 'whole' rather than focusing on their constituent parts.

BBNP	Bannau Brycheiniog National Park
CU	Cardiff University
DCWW	Dŵr Cymru Welsh Water
NRW	Natural Resources Wales
SAC	Special Area of Conservation
SAGIS	Source Apportionment Geographical Information System
WFD	Water Framework Directive
WG	Welsh Government
WUF	Wye and Usk Foundation

Executive Summary

In 2022 Ofwat funded a consortium of organisations across England and Wales to form the Catchment Systems Thinking Co-operative (CaSTCo). CaSTCo aims to create a radical step-change in the contribution of citizen science and community monitoring to evidence-based integrated catchment management. This report focuses on the Usk catchment as one of ten demonstrator catchments, and systems thinking is used to deepen understanding about how the pressures facing freshwaters might be better addressed. Systems thinking is a way of understanding complex challenges by considering challenges as a 'whole' rather than focusing on their constituent parts.

Cardiff University surveyed a range of organisations, businesses, groups and individuals that influence directly or indirectly the Usk river health. A first assessment of the current monitoring schemes and interventions to improve Usk freshwaters showed a siloed approach to freshwater needs that favours small-scale and fragmented interventions (Section 3). However, it also highlighted a clear will from these different actors in the Usk system to build a different future for the catchment, as for the rest of Wales, one that is more collaborative and ambitious.

A mapping of the information flow between actors in this system (Section 4) revealed a well-connected network despite the dominance of actors such as Dŵr Cymru Welsh Water and Natural Resources Wales. It showed that some actors such as the Wye and Usk Foundation have key roles and responsibilities as 'bridges' linking actors that would otherwise be isolated in the Usk. Despite the well-connected network several significant limitations to information flow were identified (Sections 3.3 and 4.1) that once removed could facilitate a step-change in the functioning of the system towards the goal of freshwater health.

Systems mapping of the many other types of interactions between the broader array of actors linked to the Usk (Section 4.2) also reveals a fully connected system even though the major actors only have a few connections with other actors. Importantly the analysis identifies 'bridge' actors capable of leveraging the resources of actors currently less involved or concerned with the Usk such as food retailers.

Analysis of current challenges and opportunities (Section 5) highlights the risks linked to lack of quality and timely information flow between actors, and lack of inclusion of actors on the outskirts of the network. In practice, this means that some actors might fail to understand freshwater needs or the value of interventions, and thus are unlikely to engage. The recently formed Catchment Partnership could address some of these risks, providing an opportunity for more collaborative understanding and coordinated interventions. Relatively small changes in communication could facilitate further synergies, and there is potential for key actors, the system bridges, to support any conflict resolution. Conflicting policies and lack of resources are also challenges that could be partly mitigated through better information flow and collaboration. However, the survey highlighted that even with resource efficiencies current resources are likely to be insufficient to meet the scale of the pressures facing freshwaters.

Reports such as this are limited in time and reach, and suggestions for next steps are given in the conclusion (Section 6). Understanding of the system and its dynamics is a start to identifying the synergies, trade-offs, gaps, and potential levers that could transform the way the Usk freshwaters are managed. Systems are not static as a report is, they are dynamic, and actors have freedom to change their roles and positions. It is hoped the 'big picture' and opportunities highlighted by the report can be used as a springboard for constructive conversations and effective collaborative interventions towards a shared vision for the Usk freshwaters.

1. Introduction

1.1. Background to CaSTCo

The Catchment Systems Thinking Co-operative (CaSTCo) is a £7.1 million project funded by the regulator Ofwat and led by United Utilities and Rivers Trusts in collaboration with 24+ UK organisations. It aims to create a radical step-change in the contribution of Citizen Science and Community Monitoring to evidence-based Integrated Catchment Management. The Usk was selected as one of ten demonstration river catchments across England and Wales, and the CaSTCo Usk team includes Dŵr Cymru Welsh Water (DCWW) as the lead water utility, the Wye and Usk Foundation (WUF), and the Cardiff University Water Research Institute.

1.2. The Usk catchment

Hydrologically, a ***catchment**** is defined as the area of land from which water flows into a river, lake, or reservoir. However, the boundaries or use of the term 'catchment' vary. Natural Resources Wales (NRW), the environmental regulator for Wales, distinguishes between management catchments and smaller scale operational catchments, but also "opportunity catchments" such as the Central Monmouthshire catchment which partially overlaps both the Wye and Usk catchments. Drinking water catchments, as defined by water utilities, are concerned with the area above the points of drinking water abstraction. Particularly relevant to the Usk, DCWW have also introduced the notion of mega-catchments – in this case the linked catchments that together provide drinking water to a community. The Brecon Beacons mega-catchment includes some of the Usk. For the purposes of this work, we define the Usk catchment as including the main Usk river, its tributaries and the surrounding land that drains into them (Figure 1).

From an ecological perspective, the Usk is designated as a Special Area of Conservation (SAC), primarily designated for the presence of sea lamprey *Petromyzon marinus*, brook lamprey *Lampetra planeri*, river lamprey *Lampetra fluviatilis*, twaite shad *Alosa fallax*, Atlantic salmon *Salmo salar*, bullhead *Cottus gobio* and otters *Lutra lutra* (JNCC, 2015). In terms of water quantity, the Usk is abstracted for public water supply (94% of licensed abstraction), as well as some hydropower generation (non-consumptive – water is returned), agriculture, industrial and amenity/environmental purposes (NRW, 2017). Abstraction of water for the Monmouthshire and Brecon Canal until recently was exempt from licensing. In terms of water quality, the Usk SAC, along with other Welsh SAC rivers, is receiving a lot of attention currently for failing nutrient targets set by NRW. The Usk was assessed in 2021 as having the highest level of phosphate failures of all the Welsh river SACs, with 88% of its water bodies failing their target (Hatton-Ellis and Jones, 2021). This has led to planning guidance issued by Building Regulations Wales which is restricting new developments to prevent further deterioration. The Usk nutrient challenge provides a good illustration of the dependencies between various stakeholders in the catchment, and the increasing need for a more integrated approach to catchment management.

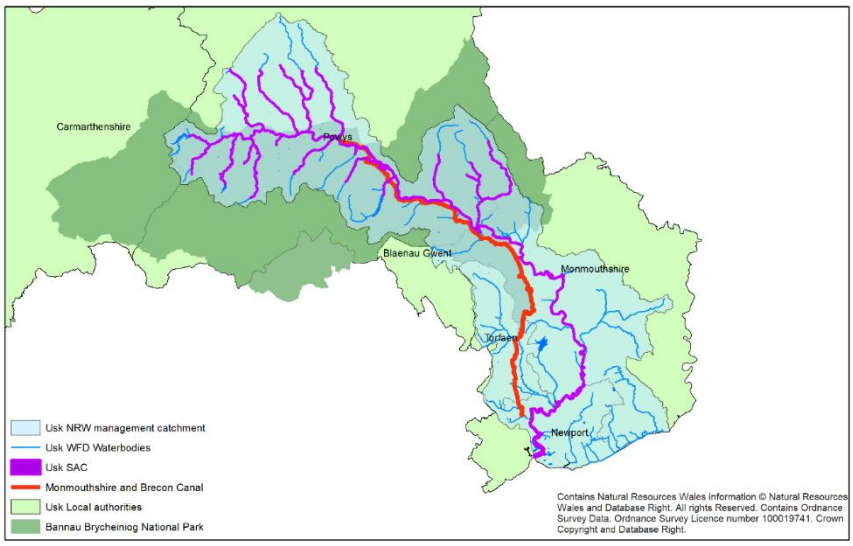


Figure 1. *Administration boundaries in the Usk catchment in south Wales. Starting in Carmarthenshire, the river flows through the towns of Brecon, Crickhowell, Abergavenny, Usk and Newport. The Usk catchment is within the Severn River Basin, draining into the Severn Estuary. The transitional waters around Newport and the Afon Lwyd were not included in this review.*

1.3. Aims

The wildlife and environmental character of the freshwaters of the Usk have been modelled over time by the geomorphology and climatic gradient of the catchment. However, more recent human activities have increasingly played a key role in determining the health of these freshwaters, whether in terms of water quality and quantity or in terms of wildlife. Human activities, within and outside the catchment, involve a range of people which we refer to here as ***actors****. Some directly interact with freshwaters such as anglers and water utilities, others indirectly interact/relate with freshwaters such as homebuilders who depend on clean waters for building permissions.

Some of these activities may have a detrimental impact to freshwater health, others on the contrary, such as restoration measures, are undertaken with the aim to improve freshwater health. Often the interactions between actors, and all their activities, are complicated and hard to conceptualise. This complexity means that many decisions affecting freshwaters are taken without consulting others, or without full understanding of the consequences of these decisions on other activities or on freshwater health.

Given limited resources for interventions to improve the health of freshwaters, efforts need to focus both on reducing detrimental impacts and on enhancing the efficiency of interventions to improve freshwater health.

In this report we propose to use ***systems thinking**** to achieve a step-change in the way we manage freshwaters for future generations. Systems thinking is a way of understanding complex challenges by considering all the constituent parts of the challenge as a 'whole' rather than focusing on their constituent parts.

The aim of this work is to gain a 'systems' understanding of the Usk catchment to improve the health of its freshwaters. In practice, the focus was on understanding: i) the activities that influence freshwaters in the Usk and how these interact, ii) the actors who drive these activities and how they are connected and exchange information. Ultimately the output is a '***systems map***' to understand: a) the barriers to effective interventions in the Usk, b) where better information flows would unlock potential solutions to existing challenges in the Usk freshwaters, and c) where collective efforts would enable synergistic initiatives that yield shared and more efficient outcomes.

2. Approach and method

The overall approach was to test the idea that efficient interventions to improve freshwater health require better interaction or sharing of information between the individuals or organisations that interact with these freshwaters. By ***information**** we mean the data and knowledge to inform understanding, decisions and action. Here, we first provide a generic overview of what a systems understanding of a catchment would look like (section 2.1). We then outline in section 2.2. the principles of system mapping. In section 2.3. we detail the data gathering methods to inform the system mapping. Finally in section 2.4. we briefly explain how we have structured the findings of this report.

2.1. Freshwaters and their catchment as 'systems'

Healthy, functioning catchments provide us with a range of services that we depend on for prosperity and well-being. This includes, for example, resources for basic survival such as clean water or food, or contribution to good health such as healthy environments to live in. River catchments also provide support for a strong economy such as raw materials for industry and agriculture, or natural assets to support tourism consumption. Woodlands, namely along streams also contribute to the regulation of our climate. Lack of understanding on the processes that underpin these services has often led to mismanagement of our river catchments with clear dis-benefits for the economy and social well-being. Improving freshwaters is thus a challenging task, not only because we do not always understand how we can sustain the freshwaters that deliver these sometimes-competing services, but also because there are many actors, individuals or organisations, interacting with freshwaters, and interacting with each other.

In practice, we can identify three broad types of actors (Figure 2), those with a:

- Direct link to Freshwaters (DF) such as anglers or swimmers,
- Direct link to the Catchment (DC) with potential impact on freshwaters such as home builders, or farmers.
- Indirect link to catchments and freshwaters (I) such as retailers who interact with farmers who themselves interact with the catchment.

Together, these actors drive a range of activities in the catchment, that determine freshwater health, but often the interactions between actors, and all their activities, are complicated and hard to conceptualise.

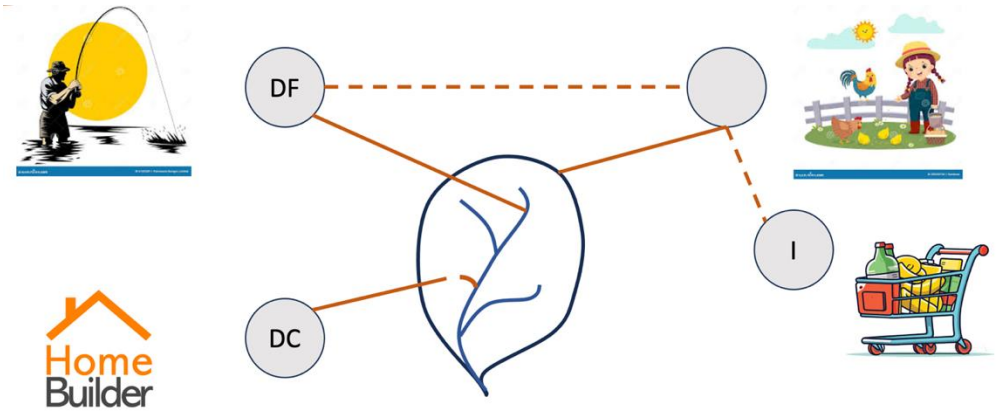


Figure 2. *The actors - individuals to organisations – and activities driving the health of these freshwaters – and how they interact. DF= actors with Direct link to freshwaters, DC= Direct link to Catchment, I =Indirect link to catchments and freshwaters.*

Systems thinking offers one holistic approach to such challenges, that focuses on capturing the complexity of the challenge by looking at its constituent parts (in this case the actors involved and their activities) and the way they are linked. It has been successfully used in an array of sectors to develop effective interventions in complex contexts. The task of improving freshwater health constitutes such a complex challenge.

2.2. Principles of systems mapping (theoretical)

Systems mapping* provides a tool for visualising and quantifying the interactions between multiple different actors, where they could otherwise be too complex to understand. Relationships between actors can be represented on a network, by 'ball and stick' style graphs, with actors represented by a circle (or node) and a line (or edge) connecting them that represents the relationship between them (Figure 3A). As the number of actors in a system increase, networks can be used to gain quantitative insight into relationships. For example, in a more complex network, it is clear to see that 'F' is the most connected (with four connections), while B, D and E are least connected with only one connection each (Figure 3B). Throughout this report we represent networks using 'Kumu', a web-based software platform that specialises in visualising and mapping complex systems, networks, and relationships (Kumu, Relationship mapping software, 2023; retrieved from https://kumu.io.)

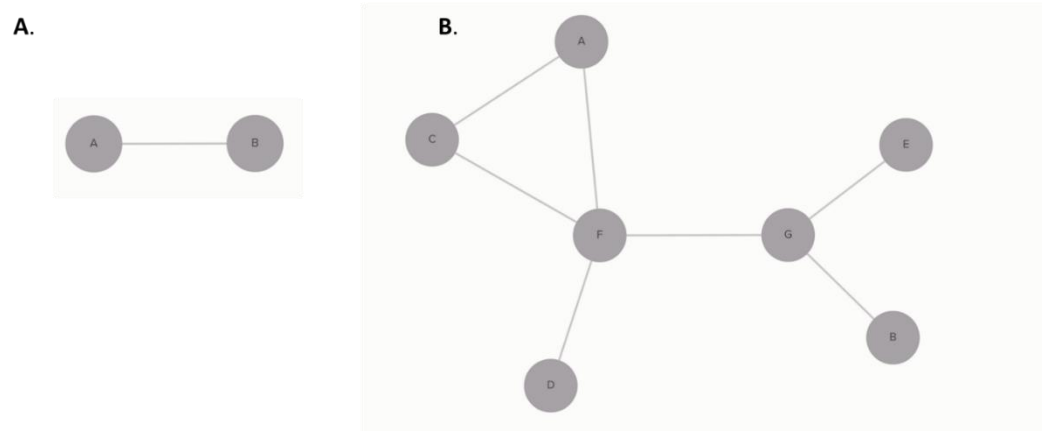


Figure 3. *Simple system (Figure 3A) with interactions between two actors (A and B); and a more complex system (Figure 3B) with seven actors (A-G).*

2.3. Data gathering on actors and their activities

Actors that influence freshwater health, both directly and indirectly, were identified through a combination of CaSTCo Usk Demo partners (DCWW, WUF and CU) workshops and meetings in Autumn 2022. The scope was purposefully broad to include any organisation that influences freshwater ecosystems encompassing water quality, quantity, and wildlife. Catchment and River Basin Management Plans were also reviewed to identify major sectors and industries within the Usk catchment. Mapping layers on DataMapWales online map browser (previously Lle.gov.wales) were used to identify some land uses (e.g. NRW Forest Ownership), and rule out others (e.g. Inventory of Closed Mining Waste Facilities). Bannau Brycheiniog National Park (BBNP) staff also provided comment based on their experience of setting up the Usk Catchment Partnership around a similar time.

A list of 34 actors was selected to represent the array of organisation types that influence the health of freshwaters directly and indirectly, and from all sectors that are interested in, or that are impacted by, the health of the catchment: Government, Environment, Food and farming, Construction,

Recreation, Utility, Research and Education. For all, besides recording their main sector of activity, additional data on the size of the organisation and the extent of their remit (local, regional, national) was collected.

Out of the 34 identified actors, Cardiff University staff surveyed 26 actors through face-to-face or online surveys (Figure 4.). Conversations took place with 1-4 members of each of the 26 organisations (detailed in Appendix 1) between March and May 2023. Meetings lasted between one and one and a half hours. Both the meetings and online survey questions (Appendix 2.) focused around:

i) actor relationship/interactions to the river Usk
ii) interventions and activities to improve freshwater health
iii) interactions with other actors in the Usk and beyond where relevant.

It is important to bear in mind that this type of investigation has some limitations: i) in some cases, such as farming, it is challenging to fully capture the complexity of some actors so the analysis can only be representative rather than comprehensive, ii) the study only provides a snapshot in time, iii) the quality of the relationships and interactions is not accounted for, and iv) surveys of this sort are often answered in the here and now, reflecting what the respondent is currently dealing with. Some information can therefore be biased and miss detail not at the forefront of peoples' minds.

2.4. Overall structure and approach of report

The report is structured around three elements. Section 3 draws from the survey described in section 2 to examine i) what types of interventions are currently in place to improve freshwater health and ii) what information is used to determine freshwater health intervention needs. It then analyses the survey to start understanding what has limited information sharing so far. Section 4 analyses the survey using a systems approach. Information flow on freshwaters between the actors directly interacting with the freshwaters or the catchment of the Usk (see Figure 2) is mapped and assessed to identify key actors and their influence on the system. We then start to capture the broader network of actors by investigating how both direct and indirect (see Figure 2) actors interact and influence decisions and interventions in the Usk. Section 5 reflects on both the qualitative survey analysis (section 3) and the systems analysis (section 4) to identify the barriers and opportunities for improving freshwater health in the Usk.

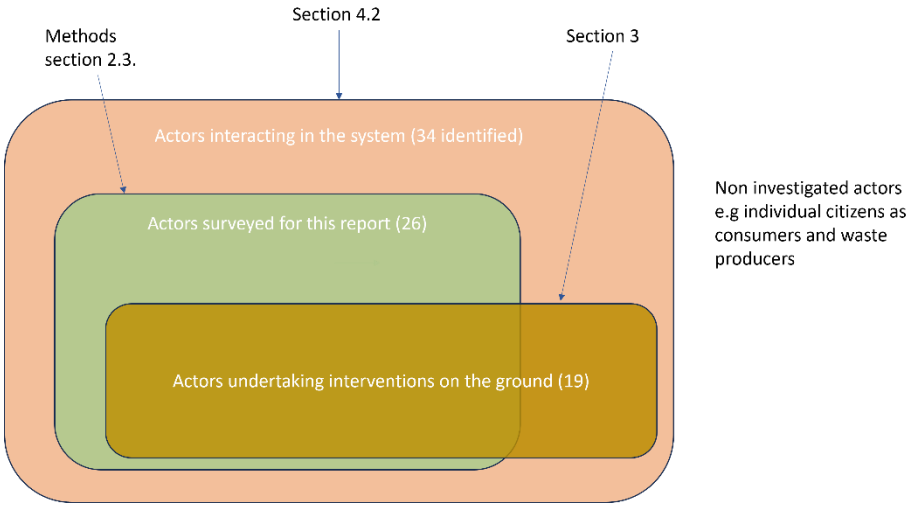


Figure 4. *Schematic diagram of the different groups of Usk catchment actors described in this report.*

3. Improving freshwater health

Freshwater ecosystems are subject to multiple interacting pressures acting at different scales. Pressures can be broadly categorised into diffuse or point source pollution, changes to water quantity, flow and physical character, or alterations to ecosystems. There is good consensus across those working in the freshwater sector in the UK as to the state and trajectory of freshwaters, as well as the nature of the pressures (for UK overview see Water Research Institute (2021) review for the Esmée Fairbairn Foundation). In consequence, this report does not examine activities that negatively impact the Usk catchment but focuses instead on those that aim to improve freshwater health.

In this section we draw upon the answers to our survey detailed in section 2.3 to examine i) what types of interventions are currently in place to improve freshwater health (section 3.1) and ii) what information is used to determine freshwater health intervention needs (section 3.2). We then analyse the survey to start understanding what has limited information sharing so far (section 3.3).

3.1. Interventions in the Usk catchment to improve river health

While there are many interventions by a diverse set of actors in the catchment to improve freshwater health, many highlight that it is challenging to know who is doing what. Focusing on On-the-ground interventions, we recorded 27 projects or schemes current or recently completed (2022 onwards), involving 19 partners. Figures 5a and c. capture this analysis, with further details of locations and timeframes in Appendix 3. Results highlight that:

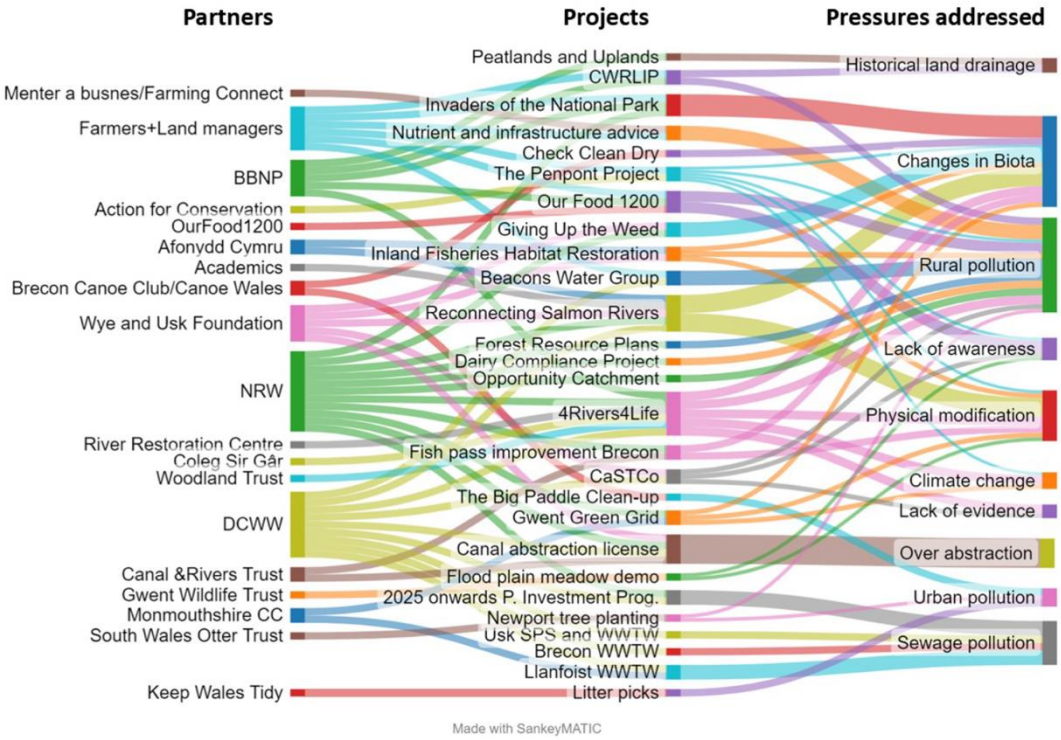
i) actors involved in these in-the-field interventions in the catchment are mostly a range of NGOs, NRW, DCWW (Dwr Cymru Welsh Water), farmers and land managers, local authorities and education/research institutions;
ii) multiple projects are run by a small handful of actors (BBNP (Brecon Beacons National Park), NRW, DCWW, Farmers and Land managers),
iii) focus is dominated on addressing two pressures, 'changes in biota' and 'rural pollution';
iv) although work in partnership is common, most often only a small number of actors contribute to each individual project or scheme.

This analysis of On-the-ground interventions in the catchment revealed two gaps: i) in the partners involved and ii) in the pressures addressed.

Firstly, in the partners involved, the contribution of the food sector beyond individual farmers (e.g. supermarket chains), is unclear, and no projects involving food retailers specifically relating to this catchment were reported to us. Indeed, some actors reported that they felt the supply chain should contribute funds to assist farmers to comply with regulation. It was felt that the wider food system has encouraged the intensification of production (e.g. dairy farms), without adequate support to allow concurrent expansion of farm infrastructure.

Secondly, in the pressures addressed. The analysis highlighted that urban pollution and road run off received little attention. Interventions relating to general run-off and misconnections were not reported to us. However, local authorities, NRW and DCWW do investigate complaints of sewer misconnections, and local authorities are working with new sustainable urban drainage guidance from Welsh Government.

a) On the ground Interventions



b) Information Interventions

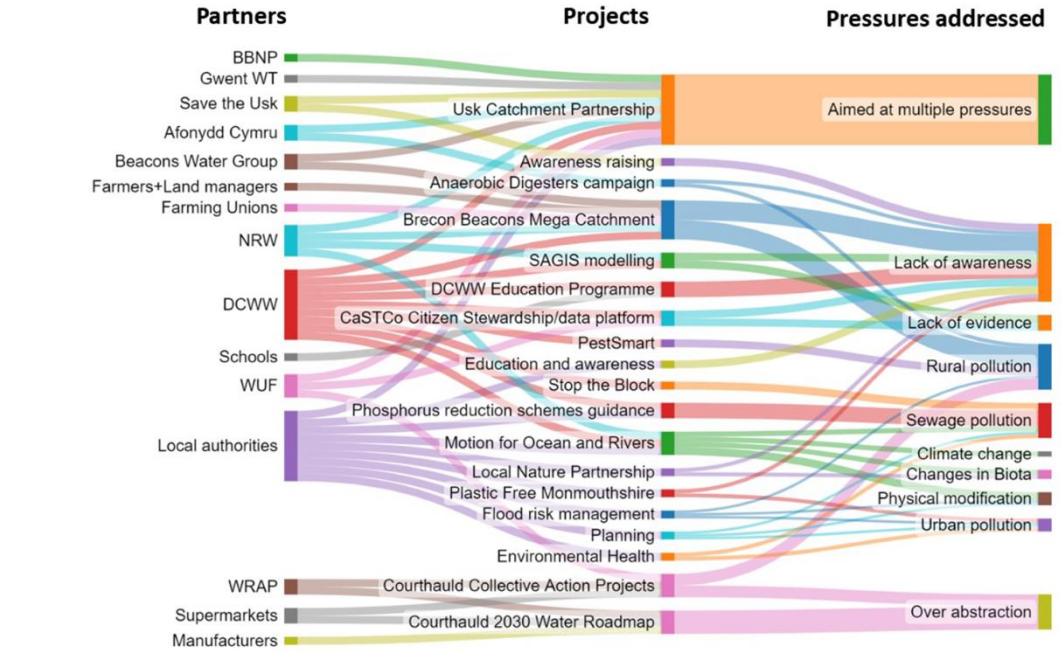


Figure 5 A and B. *Interventions in the Usk catchment that aim to address pressures on freshwaters A) On-the-ground interventions in the water or on the land, and B) Information interventions. Flows from projects were weighted equally between the "pressures addressed" by each project. N.B. Projects may have other partners or subcontractors, but they do not play a role in improving freshwaters in the Usk, or their role was unclear. Actors outside of the catchment (Welsh Government, Ofwat, Charitable funders) who influence actions through funding or setting policy are not represented.*

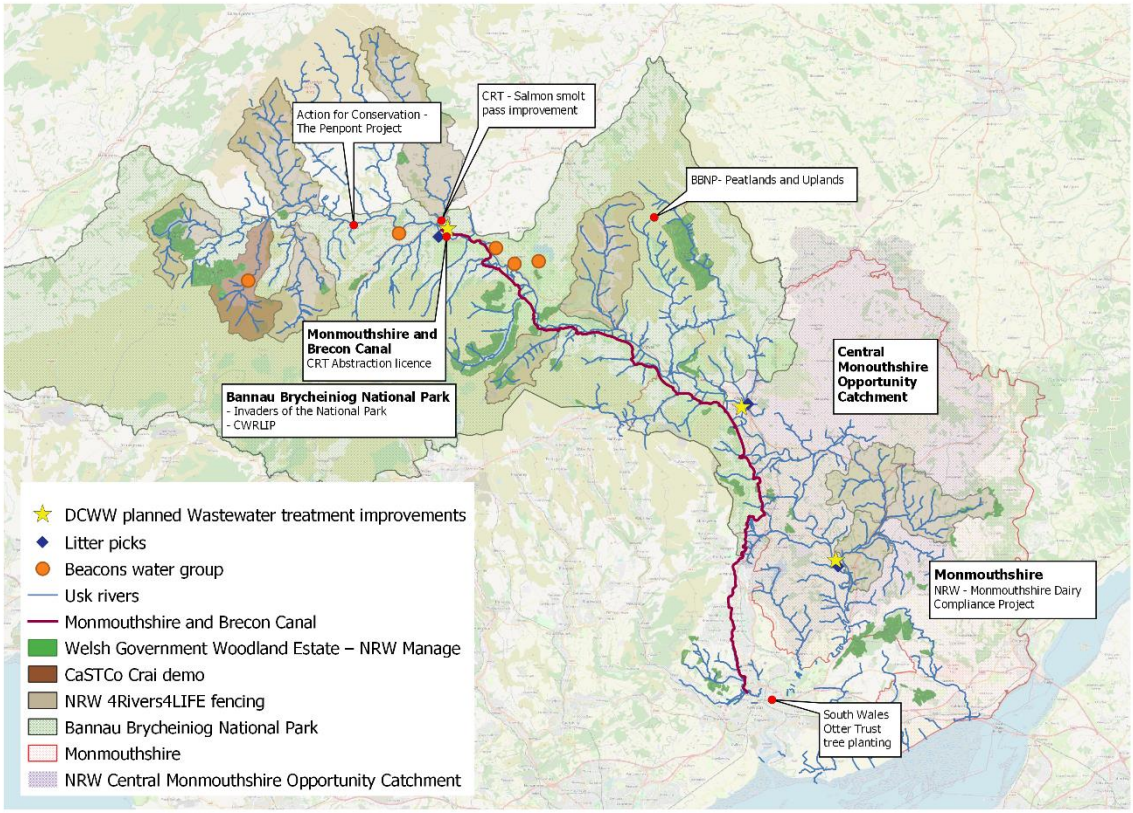


Figure 5 C. *Preliminary spatial map of on-the-ground interventions in the Usk catchment. Interventions that are catchment wide e.g. Farming Connect, or Giving Up the Weed, are detailed in Appendix 3, along with some additional projects where spatial information was not available/provided by those surveyed e.g. non-fencing 4 Rivers for LIFE interventions.*

Those surveyed also suggested that most interventions tended to focus on a handful of practical actions on the land or in the water with high visibility and highly recognised outputs that were often low hanging fruit. For example, many interventions towards addressing 'biota change' had a strong focus on managing invasive species (INNS) through physical removal, or on managing fish populations through barrier removal. Fencing and tree planting have also been the 'go to' solution to address 'rural pollution' such as nutrient issues, to such an extent that it was reported that there is little remaining riverbank that is suitable for fencing, or where farmers/landowners agree.

Sharing information (Figure 5b), mostly through associative projects that aim to educate, inform, co-opt or disseminate information, follows a similar pattern to interventions on the ground. There are multiple actors, with a few dominating, namely DCWW and local authorities, and a plethora of projects, many focused on addressing a lack of awareness of freshwater pressures and their value. One endeavour stands out among these. The recently launched Usk Catchment Partnership brings together multiple partners from different sectors, and while initially set up to focus on nutrients, now also seeks to address multiple pressures in a more holistic way.

This simple overview of interventions overall highlighted that: i) there are many actors involved in improving the health of freshwaters, as well as numerous *On-the-ground* and *Information* interventions to support improvement, ii) there are only however a handful of key actors, with scarce involvement of actors not directly related to freshwaters (Indirect actors, Figure 2), and with relatively low levels of collaboration or consultation with others, and iii) interventions tend to focus on some freshwaters challenges that have well-known solutions, thus leaving some challenges poorly addressed. One exception is the Usk Catchment Partnership which aims to work in collaboration,

across sectors, and to address multiple freshwater challenges. However, the partnership and others reported a lack of comprehensive understanding on freshwater needs in the Usk which currently hinders concerted efforts. It is also not entirely clear through this survey how interventions in the field are spatially distributed (although pre-liminary mapping is given in Figure 5c), and several respondents highlighted how this knowledge could enable better collaborations and synergies. Indeed, the pattern of interventions overall was found by respondents to be fragmented, possibly through lack of information sharing.

3.2. Available information on the health of the Usk

Timely quality information is key to build effective interventions. By ***information****, we mean data that can be analysed to draw conclusions on which to take appropriate action, as well as knowledge in all its forms (expertise, field lore, academic publishing, guidebooks, models) that can be shared to enable rational/informed decisions.

Data to inform interventions in the Usk catchment

Many of the actors in the Usk monitor the river, and produce an array of physical, chemical and ecological data (Table 1). The reasons for collecting data are diverse, including statutory monitoring, regulatory compliance, perceived inadequacy of statutory monitoring, concern for the environment, concern for public health, to inform recreation, and for research purposes (Table 1). This approach results in a large amount of data. For example, NRW have approximately 43 regular water quality monitoring sites in the catchment (number is not static), from which a total of over 2,700 measurements are taken each year. NRW also take approximately 490,560 river level measurements in the catchment each year. In March 2023, Save the River Usk was regularly monitoring 31 locations, and in 6 months had taken 498 water samples. For others there are fewer data points, for example citizen river habitat survey (cRHS) has just one entry within the Usk catchment in 2023.

Owner	Programme/Project	Data type										Availabilty	Frequency	Number of sites (approx.)
		Form/flow	Phys-Chem	Metals	Fish	Inverts	Macrophytes	Microbiol	Chemicals	Habitat	Other			
Local Authority	Drainage - non main river, flooding											Not		
Local Authority	Private Water supplies											Not		
Local Authority	Environmental Health investigations e.g. septic tank soakaways/misconnections											Not		
NRW	River levels											Open	Every 15min	14
NRW	WFD - surveillance, operational and investigative											Summary data = open	Monthly (e.g. pH) , upto every 6 years (e.g. fish)	45 waterbodies
NRW	4Rivers4Life										Diatoms	Request	Before and after interventions	At intervention sites
NRW	Other projects										Species, INNS	Request	Varies	Varies
NRW	Designated sites feature monitoring (SAC, SSSI)										Species	Request		
NRW	Investigations e.g. post pollution incident											Request	Responsive to incidents	Varies
NRW	Compliance monitoring of non DCWW sewage treatment work discharges													
NRW	Fisheries											Request		
NRW/River Restoration Centre	River Habitat Survey (RHS) and citizen RHS (cRHS)											Open	1 cRHS in 2022, pre-2008 multiple RHS sites	1
DCWW	Raw water at abstraction											Request		
DCWW	CSO Event Duration Monitoring										duration	Open	Every 15 min	
DCWW	Treated effluent discharge flow and quality monitoring											Request		
DCWW	Chemical Investigations Programme											Request		
Museum Wales	Diatom surveys										Diatoms	Not		
Canal and Rivers Trust	Monmouthshire and Brecon Canal											Request		
Save the Usk	Citizen science water quality											Request	varies	31+
Cardiff University	Multiple research projects/programmes										Species, INNS	Request	Varies	Varies - fixed sites and ad hoc
Swansea University	Reconnecting the Salmon Rivers of Wales										Fish barriers			
Wye and Usk Foundation	Sondes											Request	Every 15min	3
Wye and Usk Foundation	Electrofishing											Request	Yearly	72
Wye and Usk Foundation/Afonydd Cymru	Barriers and river restoration											Request		
National Park	Invasive non-native species										INNS	Open	Varies	71+
Wildlife Trusts	Projects										INNS	Request	Varies	Varies
Farming Connnect	Farm soil testing											Confidential	273 Nutrient Management Plans and 70 Infrastructure plans, 2015-2023	
Sewbrec and BIS	Biodiversity records										Species, INNS	Open =Low res, Request = high res	Varies	Varies
ERAMMP	ERAMMP National Survey - Headwater streams and ponds													
Wild Trout Trust	Advisory Visits											Open	1 visit in 2012	1 site

Table 1. Data providers of the Usk river system. Form/flow includes river shape and structure, river levels and flow data, and other hydrological data. Phys-Chem includes nutrients, pH, dissolved oxygen etc. Chemicals include metals and organic substances including pesticides. Gaps in the table (Columns: Availability, Frequency, Number of sites) are where we did not speak to the data owner, or the information is not readily available. Additional complementary datasets exist (e.g. weather, soil testing relating to sludge spreading, data collected by discharge or abstraction permit holders, or data collected by consultants and contractors)

Despite the large amount of data produced, users highlight limitations including:

- Limited access: often these datasets can only be obtained upon request, rather than being publicly available to download, or to explore freely on an open access data platform.
- Access requiring additional expertise or tools: for example, the Water Watch Wales website provides access to Water Framework Directive (WFD) monitoring data, and DataMapWales

provides access to a range of datasets (e.g. permitted discharges), but for both these sites, it is not possible to restrict the search to an area (e.g. catchment) and so data download and manipulation in a mapping software is required.

- Data isolation: Most data provisioning sites only provide a specific dataset. This means that GIS skills are required to put the data into context, compare, or to examine any gaps and areas of duplication. Some organisations already share monitoring plans to avoid duplication, for example NRW and WUF share electrofishing plans; but this is unusual.
- Data quantity and/or quality: There was disagreement about the quantity or quality of data available. Some respondents felt there was enough data to make decisions to improve freshwater health in the Usk, whilst others felt more was needed. Reasons for wanting more data include: i) issues of trust in the reliability of existing datasets or providers, ii) more granularity needed to target interventions to locations where they are most needed, iii) disconnected monitoring, where monitoring of some waterbodies is limited to administrative/designation boundaries, with no wider information on waters feeding into them (e.g. some SAC monitoring).
- Data delays: data are sometimes shared years after collection, where they may then be of limited relevance.
- Data interpretability and capacity to inform: Some expressed concern that existing data were not being used to maximum effect because: the data is presented in a raw format or indicator format with no interpretation or interpretation tools, or there is no additional background to understand why the data was collected or how it can be used.
- "Data is power" - some data producers collect their own data so that they can "prove" their contribution, or lack of, to a given problem.

These limitations mean that decisions are often being made based on poor quality information. Importantly, all surveyed suggested that a means to share open accessible data would be very useful, especially as more data is now available from citizen scientists or small groups who do not have the means to share their data more widely and new data types are appearing such as those acquired by sensors like the images from DCWW drones or the sonde (an instrument probe that automatically transmits information about its surroundings from an inaccessible location, such as underground or underwater) records from NRW, DCWW and WUF for example.

3.3. What limits information sharing?

While it is widely recognised that efficient interventions stem from good information, our survey of those intervening in the Usk to improve freshwaters has highlighted that information sharing so far has been somewhat limited, and the following potential causes highlighted:

Informal data sharing mechanisms - Where datasets are available via request (the most frequent of data accessibility, see Table 1), data sharing is often dependent on individual relationships between staff. Such informal data sharing mechanisms are not resilient as they tend break down when staff leave, retire or roles change.

Lack of overview – Some actors may not know what information is held by different stakeholders, and holding organisations might have little knowledge on where their information could have the largest positive benefits on decisions.

Mismatch between administrative and catchment boundaries - Datasets are often collected to administrative boundaries, rather than catchment, limiting accessibility and interpretation. For example, flood risk legislation made it a requirement for local authorities to maintain a register of

structures or features which are likely to significantly affect flood risk, but these potentially key data to inform freshwater management, which are only available upon request, only provide fragmented understanding of the catchment as these are not shared across local authorities.

Privacy issues - There are sometimes privacy constraints to sharing data, for example for data that could identify bad practice on individual land holdings. Farming Connect collect a lot of farm data, as part of consultations to formulate individual farm nutrient management plans and infrastructure plans. These data are not collated or shared due to privacy, however if they were aggregated, they could be valuable in understanding the catchment and informing interventions.

Reputation and trust - How evidence is shared is increasingly important. For example, the reputation of the organisation sharing the data plays a key part in whether the data might be considered for decision making. Closely related organisations, such as NGOs, tend to trust each other's data, and peer groups (e.g. farmers) are readily trusted. Even where there is good broad knowledge base of the success of interventions, locally derived and produced case studies tend to gain better recognition.

Data limitations and uncertainties - While regulatory data that is submitted to rigorous and independent data quality control is the gold standard, there seems to be more caution to utilise data collected by individual actors outside these well understood protocols. Much of the caution seems to stem from lack of accompanying information on how the data was collected, how it was measured, and for what purpose. As such sources of data, namely citizen science data, are increasing, and could fill existing gaps or weaknesses in 'accredited' data, there seems to be a valuable opportunity to devise mechanisms that simply ensure such sources also provide the information on design and protocols that allow data users to assess for themselves associated limitations and uncertainties of the data utilised.

4. A systems approach

This section analyses the survey detailed in section 2 using a 'systems approach'. Information flow on freshwaters between the actors directly interacting with the freshwaters or the Usk catchment (see Figure 2) is mapped and assessed to identify key actors and their potential influence on the system (section 4.1). We then start to capture the broader network of actors by investigating how both direct and indirect (see Figure 2) actors interact and influence decisions and interventions in the Usk (section 4.2).

To gain a quantitative insight into links between actors we used a network approach, where each circle within the network (also called a node in network analysis) represents an actor and the link between actors is represented by a line (called an edge in network analysis). The interactions between actors can then be visualised using a network graph (e.g., Figure 3). Because we have additional data on the attributes of each actor gained from the survey, we can further visualise links. For example, we collated data on whether an actor operated at the national, regional, or local level, and we can colour code nodes according to this attribute so gaining insight into how these actors may interact according to a given attribute.

We used simple network statistics to gain an understanding of the nature of interactions, for example counting the number of links for a given actor, termed *degree centrality*, gives insight into an actors' ***degree of connection***. As an example, in Figure 6, 'B' is one of the least connected actors with degree of 2, whereas 'A' is one of the most connected across with a degree of 4. We also identify '***bridges***', those actors that may link otherwise unconnected parts of the network, by calculating 'betweenness', an actor-level metric that measures the number of times an actor lies on the shortest path between

other actors (Figure 6). In our given example 'B' has the highest calculated betweenness score of all actors because most other actors must link with this one to reach others, and visually we can see that this actor bridges two otherwise unconnected groups of actors (Figure 6).

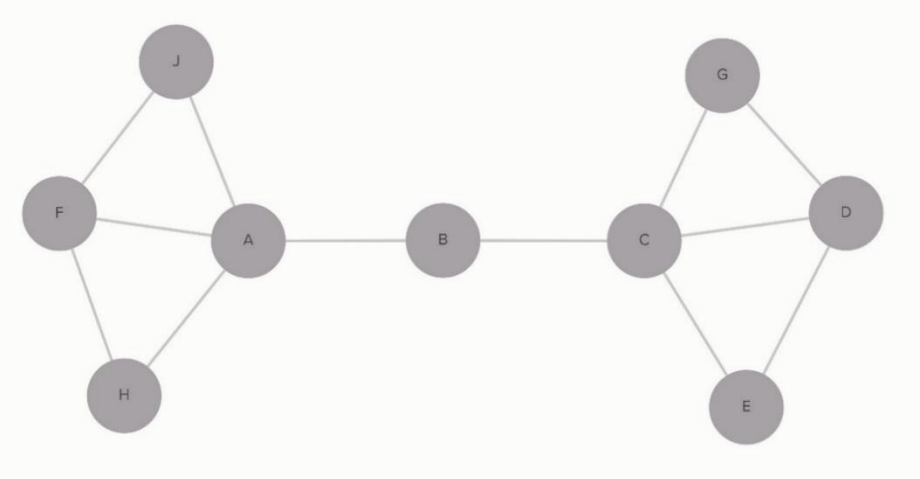


Figure 6. *Theoretical network with actors (circles) and the links between them. The actor with the highest betweenness centrality is 'B', as it links two otherwise disparate groups of actors. 'B', can therefore be thought of as a 'bridge' between groups.*

4.1. Information flow on freshwaters

Out of the 34 actors identified, a total of 24 separate actors within the Usk were involved in ***information flow*** relevant to improving the health of freshwaters in the Usk. We collected data on whether the actor was a provider or user of information (or both). Here, information refers again to sharing of data, or knowledge between actors (see section 3.2). Information flow was represented as a network, with each actor shown with a directed link (arrow) coming from them if they were a data user and a directed link pointing to them is they were a data user.

Outcomes show that information flow between actors in the Usk is represented by a **fully connected** network (Figure 7) – this means that data and knowledge has the potential to be shared amongst all actors currently sharing information within the catchment. As denoted by the direction of the link between actors, a total of 13 actors were information providers, and 11 were exclusive information users, none were an exclusive provider of information. We identified actors that are 'hubs' of information flow by measuring their degree of connections, visualised in Figure 7 by the size of the node, and noted 'NRW', 'DCWW', 'Academics', 'WUF' stood out as '**hubs' of information flow**.

We examined the associated metadata (attributes) of each actor and classified them according to their main sector (Government, Environment, Food and farming, Construction, Recreation, Utility, Research and Education), the size of the organisation in terms of number of staff (small, medium or large) and whether their remit was a local, regional or national level. As regards sectorial provenance, results reveal that no single sector group dominated in terms of connections, and that the actor's sector had no bearing on whether they were involved in information flow (Figure 7). Analysis of information flow relative to organisation size and remit (Figure 8) shows however that large organisations with a national remit were most highly connected in the network. Equally, local organisations tend to be only connected to one or two others. Also, these local organisations tend not to be connected among themselves.

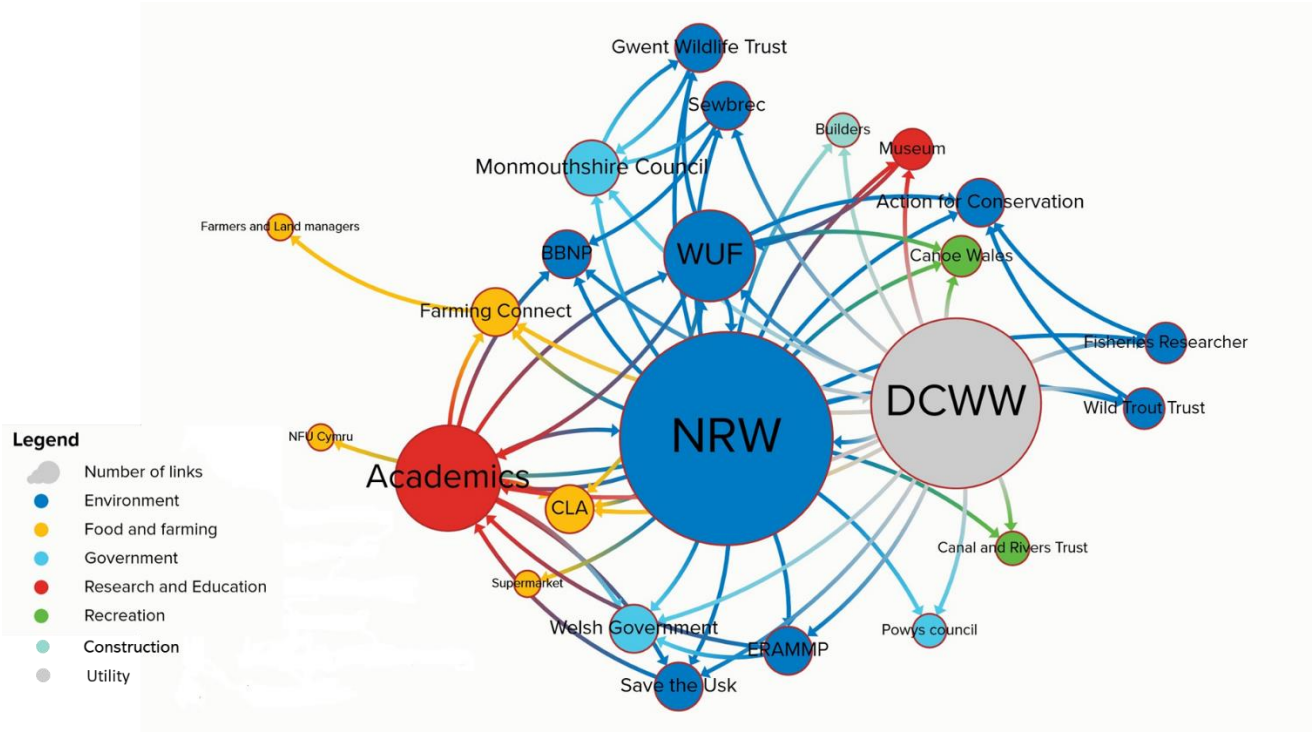


Figure 7. Information flow between 24 actors within the Usk catchment. The size of the circle (node) that identifies the actor is scaled according to the number of connections it has and so identifies 'hubs' of data flow (both incoming and outgoing). Information flow is denoted by the direction of the arrow in the network. Each node is colour-coded according to the given actor's main sector of activity (Government, Environment, Food and farming, Construction, Recreation, Utility, Research and Education). N.B. WUF data are collated with other Rivers Trust data at the national level by Afonydd Cymru.

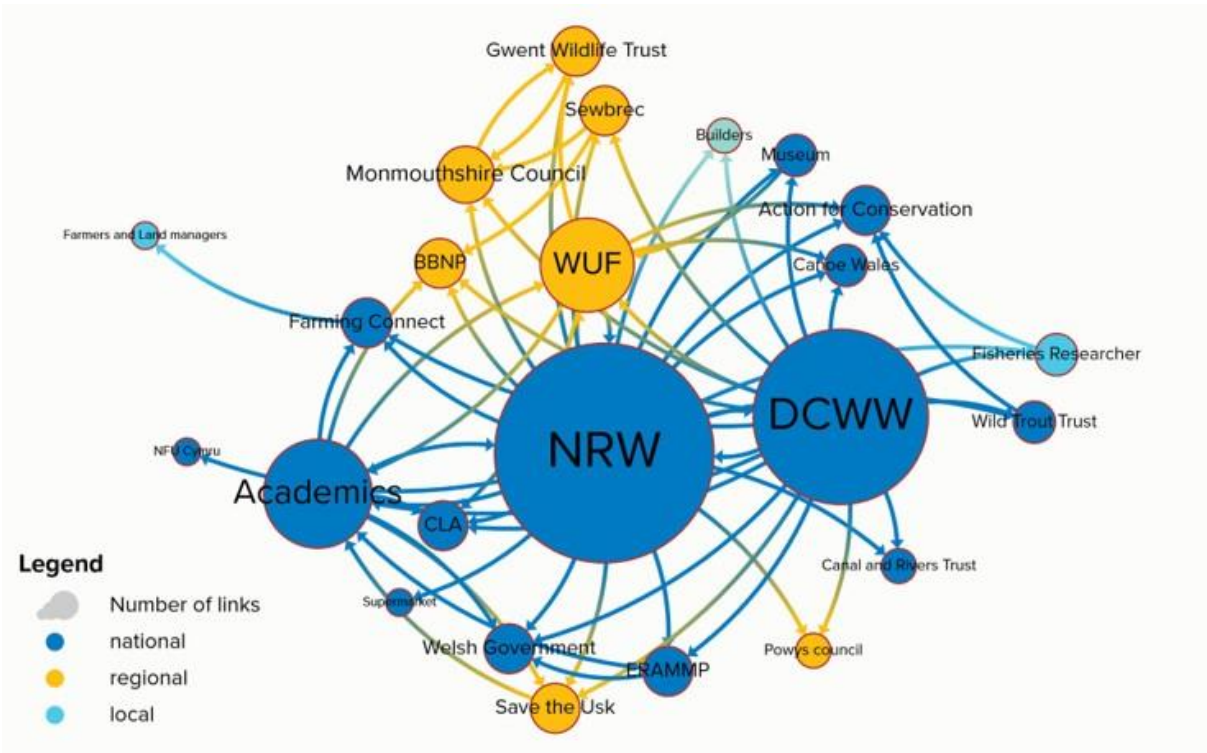


Figure 8. Information flow between national, regional or local actors within the Usk catchment. The size of the circle (node) that identifies the actor is scaled according to the number of connections. Each node is colour-coded according to the given actor's reach.

NRW and DCWW data were the most used data sources (Figure 7, 8), seen by data users a having a high degree of accuracy and reliability, and these organisations have also invested in making datasets publicly available. However, some parties raised concerns about reliance on old data, and the low frequency of some NRW and DCWW monitoring e.g. monthly/quarterly not weekly. In many cases, it seemed as though there was a lack of awareness of other data sources, (here we identify 13 information sources, Figure 7) and indeed this may be due in part to the lack of any mapping of this kind to give an oversight of information sources, and the lack of accessibility of some datasets (see also section 3.2. and 3.3.). Two examples of effective water data sharing were highlighted. It was felt that The Environment Agency Catchment Data Explorer (not operating in Wales) was easy to navigate and collating numerous datasets helped deliver integrated catchment management. Hydrometric data is an example of data that are well shared in Wales, with a real time data exchange portal on an accessible platform.

While the entire information network in the Usk is highly connected (every actor has at least once connection to another) the pattern of data sharing is not random (Figures 7 and 8). Measures of 'betweenness centrality' (how many times an actor lies on the shortest path between two others) reveal that there are actors that can act as key **bridges** within the network (Figure 9). Bridge actors are likely to have more control over the flow of information and act as key linkages within the network, and in this case include 'NRW', 'Academics' and 'WUF'. Importantly, because these actors are bridges of information across the network, they can also be potential single points of failure. Note the contrast in terms of number of connections, especially with respect to DCWW. DCWW are highly connected in terms of information flow but are not a bridge. This means that DCWW tends to connect to other highly connected players – and this makes sense given its national remit. Bridges, as highly connected hubs, are not dominated by a single sector.

These information flow maps do not include a measure of the speed of information flow. Some actors reported frustration at data or analyses taking years to be released (see section 3.3.). Information flow needs to be timely and qualified, i.e. the reliability of the information needs to be reliably understood). Delays within systems impact the functioning of the system, here delays in sharing of information contributes to the poor information flow and thus poor functioning towards the goal of the system: freshwater health.

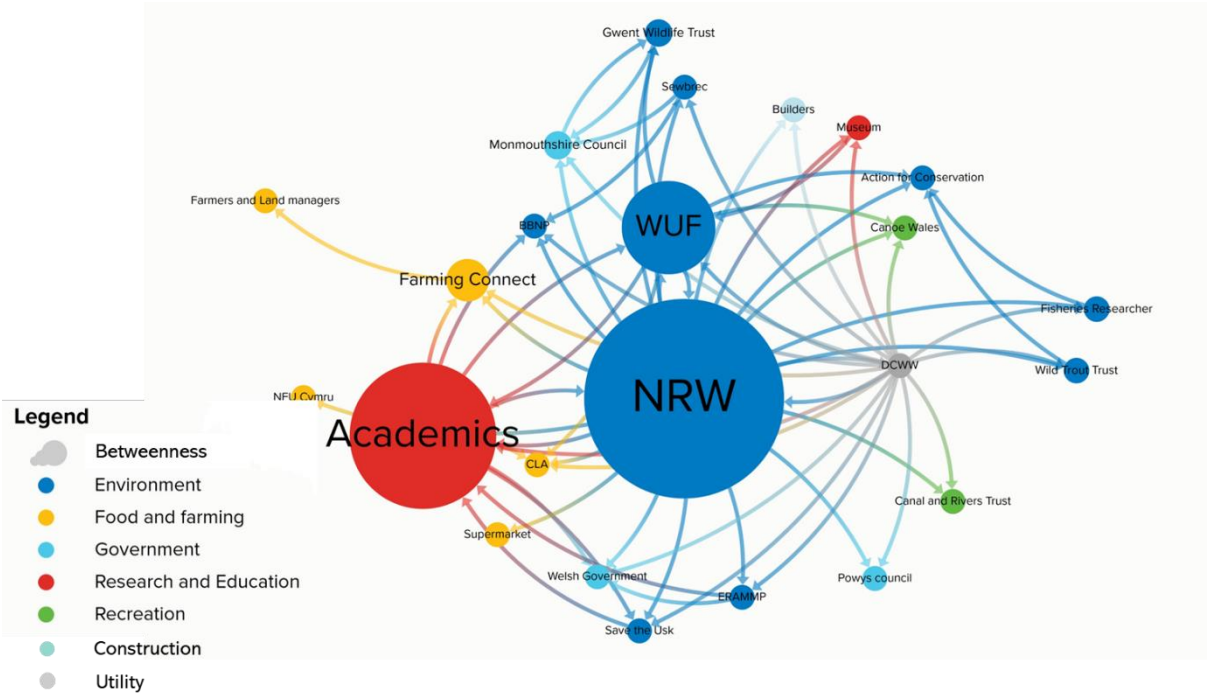


Figure 9. Information flow between 24 actors within the Usk catchment according to betweenness scores. The size of each circle (actor) is scaled according to its 'betweenness' metric and thus identifies bridges of data flow. Information flow is denoted by the direction of the arrow in the network. Each node is colour-coded according to the given actor's main focus (Government, Environment, Food and farming, Construction, Recreation, Utility, Research and Education). N.B. WUF data are collated with other Rivers Trust data at the national level by Afonydd Cymru.

4.2. Broader system interactions

Information flow (described in 4.1.) was limited to 24 of the 34 actors identified, however actors interact in a variety of other ways. Other types of ***interactions*** between all of the 34 actors linked to the catchment were assessed with respect to five different types of interactions: regulation, collaboration, funding, discussions or lobbying about the river Usk catchment. Only those interactions that related to the Usk river catchment were included in the network. Some actors identified relationships with others, that were not included in this network because they did not relate either to freshwaters, or they referred to interactions regarding other catchments, for example, many farmers have diversified their farm business to include income from tourism, however this does not necessarily mean that there is an interaction about river health.

4.2.1. Direct and indirect influences

Outcomes of the analysis (Figure 10) reveals that interactions between all actors in the Usk also represents a **fully connected network**, i.e. all actors are connected to at least one other. The mean number of links within the system was 8.6 (+/- 6.6 St.Dev), ranged from 1-26, and followed a classic skewed (negative binomial distribution) where the majority of actors had few contacts and a minority had many. The top 5 most connected actors include: BBNP (26 connections), NRW (25 connections, DCWW (24 connections), Farmers and Land Managers (18 connections) and Welsh Government (17 connections). The high reach of BBNP could be explained by the fact that since summer 2022, actors from across the catchment are coming together as a Catchment Partnership, set up by BBNP, with consultant facilitators. Welsh Government has provided funding to support the forming of Nutrient

Management Boards to produce nutrient management plans for failing SAC rivers. In the Usk catchment, a decision was taken that a catchment partnership could best deliver these. This accounts in part, for the BBNP having the highest number of connections (Figure 10), but it also highlights the important role that protected landscapes can play. In this interaction analysis, one sector does stand out: the environment sector.

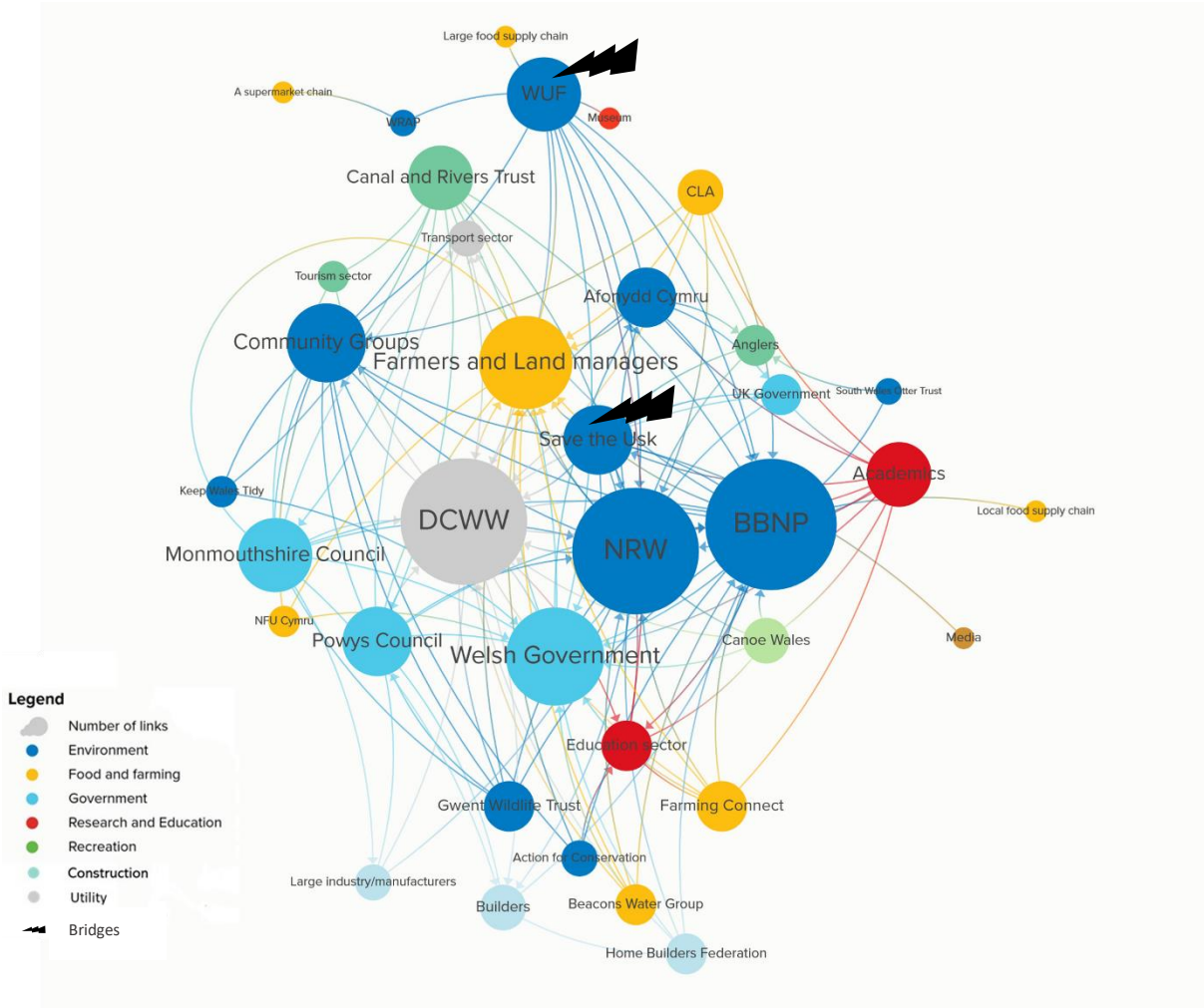


Figure 10. ***Interactions*** *between all the 34 actors linked directly or indirectly to the Usk catchment. The size of the circle (node) that identifies the party is scaled according to the number of interactions. Each node is colour-coded according to the given actor's main focus (Government, Environment, Food and farming, Construction, Recreation, Utility, Research and Education).*

As for the previous analysis, the number of connections is not necessarily the most important metric in a system as some actors can bridge connections between disparate groups. Measures of 'betweenness centrality' revealed that 'WUF' and 'Save the Usk', although not the most connected actors, were significant '**interaction bridges'**. These play a key role in linking up actors that would be otherwise isolated from the network.

4.2.2. Facilitators and influencers

At the broad scale, highly connected national reach organisations (Figure 10) also tend to foster networks and collaborations that facilitate some coordination of approaches and shared learning. As examples: Welsh Government (WG) has set up the Wales Better River Quality Taskforce which brings together NRW, WG, Ofwat, DCWW and Hafren Dyfrdwy with independent advice from Afonydd Cymru and Consumer Council for Water, DCWW has set up an Independent Environment Advisory Panel that

brings together more than 20 stakeholders with an interest in water to regularly discuss collaborative opportunities and challenges, academia has set up the Environment Platform Wales as a means to facilitate evidence sharing with WG and NRW. These actors, mostly highly connected actors with a national remit, play key roles as **information flow facilitators**.

Within the broader scale, our analysis also shows that some indirect actors (for definition see section 2) may have a large influence on the interactions between local actors and their freshwaters. These **influencers** are not reported here but can have significant influence on the way the actors captured here may interact with freshwaters, and each other. For example, governments through the water utility regulator OFWAT and the environment regulator NRW significantly influence (through resource limitation or legislation) how DCWW may intervene to improve freshwater health. Campaigners outside the system can also have a strong effect: for example, WWF through advocacy are altering the way large food retailers such as Tesco consider nature in their supply chain and their consumer advertising, with potential impact on farming practices. In turn, large supermarkets which have a large influence on how land is managed, are also driven by customer choice who want clean rivers but also want cheap food.

5. Challenges and Opportunities

Designing programmes of work across a catchment in a systems thinking way requires the identification of challenges and opportunities. Doing so supports the building of joint understanding, the generation of ideas for problem solving, defining preventative measures and the making of informed decisions. Many of the challenges and opportunities identified here are also relevant to other catchments. Section 5 reflects on both the qualitative survey analysis (section 3) and the systems analysis (section 4) to identify the challenges and opportunities for improving freshwater health in the Usk.

We first reflect on the main perceived causes of lack of collaboration from the survey (lack of shared understanding on issues and lack of shared plans) and outline opportunities offered by the full network connectivity evidenced in our system mapping (section 5.1). We then reflect on the perception among those surveyed that information was not always valued or shared in a way that would enable more efficient interventions and utilise the systems map to highlight some opportunities for change (section 5.2). In section 5.3 we reflect on current sources of conflict among actors in the Usk and discuss how 'bridge' actors and a systems-led collaborative approach might help resolve these. We then investigate the role of policies in enabling or hindering the efficiency of the system (section 5.4), and the role of resources as a key enabler of transformation.

5.1. Coordination and synergies

Efficient interventions require agreement on the issues or challenges that need addressing. In the survey, interviewees perceived a *'lack of a shared understanding about the issues' faced by freshwaters,* namely across different sectors. But it seems disagreement concerned more the source of the issues (e.g. diffuse farming pollution, or urban pollution) rather than the issues themselves – i.e. elevated nutrient or pollutant levels. This review also indicates that multiple actors and their projects were working towards common themes (Figure 5), suggesting many actors within the catchment actually do share understanding of the issues. There are in fact good examples within the catchment of consensus building activities and cooperative working e.g. The Penpont Project or the Beacons Water Group as well as the Usk Catchment Partnership and CaSTCo.

'*Lack of sharing of planned interventions*' was also often mentioned in the survey. Interviewees highlighted that better sharing would avoid duplication of effort in prioritisation, planning and delivery, and avoid landowners being approached by multiple organisations, leading to engagement fatigue, or reduced confidence in the environment sector. Qualitative assessment of community interactions within the Usk catchment seemed to support this: interventions within the Usk were carried out by multiple actors, nearly exclusively on individual projects in a fragmented approach to improving freshwaters (Figure 5). This small-scale fragmented approach is reflected across the UK as our recent review of freshwater needs for the Esmee Fairburn Foundation highlighted (Water Research Institute, 2021).

Our system analysis of interactions between the broader community (section 4.2) provide positive insight on how cooperative activities could be improved. They show that each actor intervening in the landscape is connected to every other, in other words no actors are isolated, therefore cooperative work and information, in theory, can reach every actor. This seems to indicate that small improvements in communication could help to close those final links and facilitate further synergies – leading to larger scale and less fragmentated interventions. As noted, there are already good examples within the catchment of consensus building activities and cooperative working, and the challenge lies here in upscaling these efforts to the whole catchment. There is an opportunity here perhaps to learn from other catchments, nationally or internationally, for example through CaSTCo.

The systems map also highlights an opportunity to expand the network of actors exchanging information on the health of the Usk (Figure 7) –by bringing in some of the actors that currently interact with them or with the Usk but are not directly concerned in improving the health of those freshwaters (Figure 10). For example, food retailers, food processing industries, wholesalers etc do not seem much involved as partners (Figure 5), perhaps because these actors do not fully understand their role or why they should contribute. Some food retailers fund intermediaries to support their supply chain, and partly the associated environment, including water (e.g. Courthauld initiative in the nearby Wye), but are not themselves directly involved as partners. Yet some of these organisations are connected to those directly intervening in the catchment (see Figure 10 connectivity). Clearly their collaboration, and with them that of local consumers, could leverage significant resources and further empower local communities.

5.2. Valuing information

The survey highlighted there was a wealth of data and knowledge within the network but that this information was not always valued or shared in a way that would enable more efficient interventions. Besides the access limitations highlighted in section 3.2 and 3.3, interviewees highlighted areas where the value of information was not realised to its full potential:

- Value of citizen science data: Lack of training opportunities or agreed protocols for citizen scientists, to ensure the outcomes of their efforts are valued and utilised (although projects such as CaSTCo and citizen RHS aim to improve this).
- Value of monitored data: Often data is provided with little explanation or guidance for interpretation. It can thus be challenging for non-specialist practitioners to understand the value of these data – for example data to assess risks associated with some pollutants without additional knowledge provided on safe limits of pollutants. In other cases, the purpose of monitoring is not always clear or seems to result from what is possible (for example in terms of resources, or technologies or field access), rather than what is needed. In such cases the data fails to properly inform on the issue at hand as it only provides part of the answers needed. For example, measures of phosphorous levels in a river might be insufficient to inform

on ecological impact of poultry farms, and similarly measuring sewer spill frequencies might be insufficient to inform on environmental impact from sewer overflow.

- Value of expertise and field experience: Besides the lack of a common data platform signalled in sections 3.2 and 3.3, there is more learning to be gained from successful schemes. This is particularly the case for nature-based solutions, where lack of shared learning can lead to piecemeal approaches with poor before and after design, or sufficient control to rule out context. Note however the 'Mainstreaming nature-based solutions' project, an Ofwat Innovation Fund project led by The Rivers Trust, plans to address that issue.

Our system analysis of information flow across actors in the Usk (section 4.1) highlights that actors on the ground are fully connected. There is thus an opportunity here to focus efforts to: i) enhance the value of data, from a variety or providers, for example through a shared platform that provides a shared data structure/protocol for citizen science data and that contains sufficient metadata on quality assurance and design to fully understand the value (and limitations) of the data; ii) to capture field expertise and best practice from all the actors involved in the Usk, including the actors with currently smaller reach (see Figure 9), and to share it better for more holistic and effective interventions; iii) to bring together the views of all the Usk actors for a shared vision that would enable largescale long term thinking rather than fragmented small scale interventions. Given that the system analysis of interactions across the broader set of actors in the Usk (section 4.2) also highlights that this broader network is fully connected, there is also an opportunity to develop mechanisms and communication tools to help other, perhaps less directly linked actors such as the food sector, or tourism sector, to understand the pressures facing the Usk, why interventions are necessary, and potentially how they can support positive interventions. The latter would require readily available and useful information, but also a better understanding on what information such stakeholders might require to make these decisions.

5.3. Conflicts and trade-offs

Conflicts are an integral part of any socio-ecological system because different actors (wildlife included) have different needs or values (Small et al 2021). Unless these different actors have had a chance to rationally understand the needs/priorities of others, conflicts may be challenging to resolve. The snapshot of the types of conflicts picked up by this survey illustrates that these conflicts can arise between any actor within the system. In part they reflect different uses of freshwaters: recreational users might prioritise aesthetics and water quality, while local authorities might prioritise flood prevention potential. They also reflect different concerns over freshwaters: some eNGOs might be concerned for fish populations and others concerned for the health of swimmers or canoeists.

The quality of information flow in such systems is often correlated to conflict resolution. Our survey highlighted poor information (in quantity and quality), information asymmetries and bounded rationality at the root of many of the conflicts expressed. For example: some felt decisions were made in an unnecessarily precautionary manner in the absence of evidence, some felt decisions were too focused on one pressure (e.g. nutrients) with insufficient awareness for other pressures, some felt evidence was used selectively to fit an opinion, or were sceptic if the evidence did not fit their own opinion or experience. Besides conflictual situations, poor information can lead to feelings of frustration or anger. For example, the survey highlighted that some staff felt disheartened and on the front line of public criticism because of a lack of recognition that they can only work within the confines of their role, and regulations. Likewise, citizen scientists felt their work was not sufficiently recognised.

Such situations have consequences for the system as actors disengage – for example by leaving their job or reducing their efforts, resulting in a loss of expertise.

Organisations that act as bridges, are often the only contacts to some more outlier actors, while also being well connected to all key stakeholders, and then can have a high influence on the narrative. These organisations can therefore play a significant role to reduce unnecessary conflict arising from poor communication. They have the power to push behaviours and responses from the 'emotional realm' into a more 'rational realm' that is conducive to trade-off and conflict resolution. Conversely, for the system to be efficient, such organisations – given their structural position in the information network as 'role model' - will need care in the way they regulate information flow in the network. This is particularly the case with the use of social media, where ideas/concerns may be oversimplified or out of context, and language used can be misleading or misconstrued.

Actors currently in an outlier position, such as farmers, may also feel they are not included in the information network, or only included as a recipient – for example told what they should do or not do. Lack of meaningful exchange can create disengagement from the network and thus resistance to information flow. Given the significant roles that some of these outliers play through their activities in the landscapes that drain into freshwaters, their engagement in the system is key to ensure improvements in freshwater health. This however is only possible if their link to the system is strong i.e. that information is exchanged both ways. For some this may mean that their voice needs to be heard and is given opportunity to contribute to the overall vision and discussion over freshwaters. In some cases, as for any conflict, this may simply mean the opportunity to voice their own needs and concerns, i.e. that their concerns are at least acknowledged. For example, some farming communities have stated they are concerned that nutrient neutrality rules to protect freshwaters are limiting opportunities for farm diversification.

A systems approach can also provide potential solutions to conflictual situations by **bringing in new actors into the conversation**. For example, our survey highlighted the challenge faced by the Canal and Rivers Trust to maintain water levels in the canals during dry periods. The canal is used for navigation, tourism and the goals of the Trust align with the Future Generations Act. However, in drought conditions, abstraction from a SAC river like the Usk to maintain water levels goes against both the Future Generations Act and the Environment Act. The situation arises because unlike other canals, the Monmouthshire and Brecon Canal does not have its own reservoir, and thus relies on abstraction from the Usk river as the principal input. Release from the Usk reservoir could be a solution although DCWW needs in periods of drought to hold back more water for water supply. In this case, the two main actors have already been discussing a catchment solution – involving in the process a wider array of actors from the network such as WUF. This example illustrates well the value of a systems approach to conflictual situations.

More broadly, enhanced information flow between all actors in the system is key to start reconciling multiple but sometimes conflicting values or concerns. Systems thinking can foster cooperation through shared ownership of issues across all actors. There is clearly a need to foster conversations across the whole system, including the more outlying actors, to coproduce and agree a shared vision for the catchment, as well as a menu of prioritised interventions that deliver benefit to multiple actors and address multiple pressures. The recent increase in public engagement and willingness to act, is perhaps an opportunity to broaden the conversation.

5.4. Policies – more than sticks and carrots

Policies, like the rules of a game, should by nature enable systems to function efficiently. Our survey highlighted that while policies could unblock conflicts or enable collaborative interventions, on the other hand, lack of policies where or when needed, lack of resources to enact policies, or conflicting policies could intensify conflicts. Actors involved with policy making (governments, local authorities) hold therefore key roles in enabling or hindering the efficiency of the system.

Existing conflicts highlighted by the survey seem to stem mainly from **conflicting policies** potentially linked to lack of communication within and between national and local government departments – namely when the freshwater issues fall in between the remit of several departments. These incompatible policies tend to impact interventions across sectors. As examples, the PestSmart Pesticide disposal scheme led by Dwr Cymru is limited by highways legislation that does not allow transport of some substances found in pesticides, and the abstraction license conditions to protect the river SAC sometimes compromise the statutory duty to provide safe navigation on the canal. In a similar way, while there is desire for more sustainably produced local food, horticultural developments clash with planning policy for polytunnels, power and water supplies.

The opportunity for **policies to solve conflicts, solve challenges and drive collaboration** was also mentioned several times. For example, in a bid to relieve pressures on SAC river catchments to support delivery of affordable housing, Welsh Government has set up an action plan which includes developing a nutrient calculator to aid planning decisions on nutrient neutrality that will consider catchment-level data and local features and needs (Welsh Government, 2023). In another sector, policies that are currently developed by Welsh Government to ban non-degradable wet wipes are considered key to reducing sewage blockages, and the resulting freshwater pollution incidents that arise from the unintentional overflow of raw sewage into water bodies. This example also illustrates there are a wide array of actors, not considered in this snapshot review -e.g. wet wipe manufacturers, that can have major impacts indirectly on freshwaters – and that systems thinking, which considers all actors that interact with freshwaters, provides an opportunity to develop policies that could have significant positive impact for freshwaters.

In some cases, **the lack of up-to-date policy** was considered as a barrier to collaborative interventions. For example, there was a feeling that some agricultural activities with known adverse freshwater outcomes could continue without a NRW license, thus closing any opportunity for debate around these issues. Similarly, some policies were felt to be out of date because these did not properly factor in global changes like changes in climate - for example closed periods for spreading do not account for recent changes in weather patterns such as flash flooding in summer or warm and dry periods during closed periods, which is particularly relevant for autumn germinating crops. Many expressed concerns at how lags in policy making could create significant risks for freshwaters. For example, novel financing for 'water markets' were seen as an unregulated risk both to freshwaters and through changes in land ownership, to the local communities currently caring for these lands.

5.5. Resources – a key enabler for people and ecosystems

The survey clearly showed a general willingness and desire to 'do things better for freshwaters'. Most however pointed out the overall **lack of resources**. Small organisations, especially those reliant of project staff, and individuals such as farmers or citizen scientists, reported they can struggle to meet the time and cost of involvement in initiatives to improve freshwaters. Those involved in regulatory monitoring and enforcement also felt resources were too low to adequately enforce policies on the ground, namely when it came to pollution incidents which require timely interventions. Similarly,

those in policy-making organisations felt there was limited experienced staff to meet rapidly changing socio-economic contexts. For example, there is concern that private payment for ecosystem service markets or water markets are developing at pace with little headroom for policy decisions.

Collaboration across the system could of course provide economies of scale and synergies to reduce the costs of interventions. Sharing of information – both data and knowledge, for example through a shared digital gateway, was seen as a key tool to enable both **synergies and cost benefits**. Better collation on interventions that worked and those that did not – namely as regards nature-based solutions – was also seen as a key to resource efficiency. Those surveyed highlighted also that more timely academic input on monitoring design, or experimental design in testing interventions, would perhaps contribute to reducing costs given that some freshwaters were over monitored (i.e. simultaneously sampled by different actors) and others under monitored. However, these resource efficiencies alone are unlikely to be sufficient given the scale of the problems for catchments such as the Usk, and additional resources are most likely to be needed.

6. Conclusion – take home messages and further work

Our survey of key actors concerned with improving the health of freshwaters in the Usk highlights that actors on the ground tend to have a siloed understanding of freshwater needs that leads to the small-scale and fragmented nature of interventions. There is also a clear will to build a different future for the Usk, as for the rest of Wales, one that is more collaborative and ambitious.

Systems mapping of the information flow between actors in the Usk reveals that there is a sub-system that is fully connected despite the dominance of players such as DCWW and NRW. It also reveals that no actor on the ground is isolated and that some actors such as WUF have key roles and responsibilities as 'bridges' linking actors in the Usk.

Systems mapping of the many other types of interactions between the broader array of actors linked to the Usk also reveals a fully connected system and bridge actors capable of leveraging the resources of actors currently less involved or concerned with the Usk, such as food retailers.

Analysis of the current conflicts between the actors highlights the risks linked to lack of quality and timely information flow, and lack of inclusion of actors on the outskirts of the network. Among those outliers, citizens are an increasing driver of change that need to be better integrated into the system. It also highlights the potential for key actors such as bridge actors to support conflict resolution and the value of bringing new actors into the freshwater conversation. Conflicting policies and lack of resources are also areas that may lead to conflict, and that could be partly mitigated through better information flow and collaboration.

While there are some obvious caveats with surveys that are limited in time and reach, understanding of the system and its current dynamics – namely as regards flow of information and broader interactions – allows to paint a 'big picture' of the Usk and its freshwaters, and start to identify the synergies, trade-offs, gaps and potential levers that could transform the way the Usk freshwaters are managed.

Building on this stakeholder mapping, next steps include: (1) a comprehensive analysis of the pressures that together shape the needs of the Usk freshwaters, (2) a comparison of these needs to interventions on the ground to highlight future interventions and resources/collaborations required – including leverage from indirect actors. A live online map of interventions, editable by actors, would support this. There is also potential to bring more actors into the interventions space of the system.

The work delivered here for the Usk, as a demonstrator catchment, aligns with wider strategies in Wales for "*an integrated catchment approach focussing on multi-sector co-operation and nature-based solutions to drive water quality improvements*" (Julie James, Minister for Climate Change, 2022). It is hoped the 'big picture' and opportunities highlighted by the report can be used as a springboard for constructive conversations towards a shared vision for the Usk freshwaters.

7. References

DCWW and NRW, 2023. *Phosphorus source apportionment summary: Updating the SAGIS river Usk model.* SAGIS Non-Technical Calibration Report for the Usk

Hatton-Ellis TW, Jones TG. 2021. *Compliance Assessment of Welsh River SACs against Phosphorus Targets.* NRW Evidence Report No: 489, 96pp, Natural Resources Wales, Bangor.

Julie James, Minister for Climate Change (5th July 2022). *Written Statement: Wales Better River Quality Taskforce.* [Online] [Accessed 23rd May 2023] https://www.gov.wales/written-statement-wales-better-river-quality-taskforce.

JNCC, 2015. *River Usk/ Afon Wysg. Designated Special Area of Conservation (SAC)* [Online] [Accessed 23rd May 2023] https://sac.jncc.gov.uk/site/UK0013007

NRW, 2017. *River Usk Abstraction Licensing Strategy.* Natural Resources Wales, Cardiff.

Pye, M. C., Vaughan, I. P., Ormerod, S. J. and Durance, I. 2022. Organic litter dynamics in headwater streams draining contrasting land uses. *Hydrobiologia* (10.1007/s10750-022-05084-4)

Small, N., Munday, M. and Durance, I. 2017. The challenge of valuing ecosystem services that have no material benefits. *Global Environmental Change* 44, pp. 57-67. (10.1016/j.gloenvcha.2017.03.005)

Thomas, S. M., Griffiths, S. W. and Ormerod, S. J. 2015. Beyond cool: adapting upland streams for climate change using riparian woodlands. *Global Change Biology* 22(1), pp. 310-324. (10.1111/gcb.13103)

Water Research Institute (2021) Kean, EF, Crole, DA, Wightman, S, Ormerod, SJ and Durance, I. *Supporting capacity and capability in the freshwater sector.* A Cardiff University Water Research Institute report for Esmée Fairbairn Foundation. Available at https://esmeefairbairn.org.uk/latest-news/supporting-capacity-and-capability-organisations-working-improve-freshwater-environments/

Welsh Government, 2023. *Relieving pressures on Special Areas of Conservation (SAC) river catchments to support delivery of affordable housing.* https://www.gov.wales/relieving-pressures-special-areas-conservation-sac-river-catchments-support-delivery-affordable#118976 accessed 12/07/2023

Appendix 1. Participants

Full list of actors that participated in this study (either spoken to in a meeting, or responded to online survey). Some of the actors that we met with described interactions they had with actors that we did not receive contributions from. Therefore the number of actors in the network map is higher.

Action for Conservation working with Penpont Estate
Afonydd Cymru
Bannau Brycheiniog National Park
Canal and Rivers Trust
Canoe Wales
Cardiff University
Country Land and Business Association
Dŵr Cymru/Welsh Water
Esmee Fairbairn Foundation
Farming Connect
Gwent Wildlife Trust
Home Builders Federation
Individual land manager (chose not to be named)
Keep Wales Tidy
Monmouthshire County Council
Museum Wales
Natural Resources Wales
NFU Cymru
Powys County Council
River Restoration Centre
Save the River Usk
South Wales Otter Trust
Supermarket (chose not to be named)
Usk Catchment Partnership
Welsh Government
Wye and Usk Foundation

Appendix 2. Online survey questions

Section1. About your organisation and connections to the Usk river (main river and tributaries)

1. Optional: If you would like to receive a copy of our report, please provide an email address. Alternatively you can answer these questions anonymously.

2. When answering this survey, what type of organisation are you representing?

- Individual farmer or land manager
- Farming Union
- Food retailer
- Natural Resources Wales
- Water industry
- Local government
- National Park
- Environmental NGO
- Recreation NGO
- Tourism
- Builders
- Other

3. You answered "Other" to the previous question, please describe your group/organisation/business.

4. How does your organisation/business interact with the river Usk?

- Directly - in the water
- Indirectly

5. You indicated that you interact indirectly with the river Usk, please describe how your organisation is linked to the river Usk? It could be though interactions with other organisations.

6. To what extent is the river Usk important to your organisation/business?

0	1	2	3	4	5	6	7	8	9	10
Not at all important										Extremely important

7.What does your organisation/business want from the river Usk? What aspects of the river are important to your organisation? You can select multiple answers.

- Water quality - visible
- Water quality - not visible - chemical
- Water quality - not visible - biological
- Water flow or reduce flood risk
- Aesthetics
- Cultural
- Biota - plants or animals
- None

8. Does your organisation/business have any responsibilities (statutory or other) to the river Usk?

9. Do you interact with others regarding the river Usk?

- No
- Yes

10.Who does your organisation interact with regularly regarding the river Usk? You can select multiple answers.

- Welsh Government
- Dwr Cymru Welsh water
- Natural Resources Wales
- Local councils
- Brecon Beacons National Park
- Farmers and land managers
- Food retailers
- Environmental NGOs
- Community Groups
- Recreation NGOs
- Tourism sector
- Builders
- Academics
- Large industry/manufacturers
- Education
- Transport
- Charitable funders

11.Please tell us about those interactions e.g. do you provide or receive funding or information, work in partnership, lobby.

12.Is there anyone else that you interact with regularly regarding the river Usk?

Section2: Monitoring the health of the river Usk

13. Do you collect or use data collected by others to monitor the river Usk?

- Yes, we collect our own data
- Yes, we use data collected by others
- Both - collect own data and use data collected by others
- No

14. Roughly what proportion of your organisation's time is spent on monitoring the health of the river Usk (include collection, analysis and interpretation)?

0	1	2	3	4	5	6	7	8	9	10

No time spent on monitoring It is our core focus

15. Please describe the data you use to monitor the Usk. Please include what (the type of measurements), where (e.g. fixed point, responsive) and when (frequency - ad-hoc/regular)?

16. What is the purpose of your monitoring/your use of monitoring data collected by others?

17. Do you share your monitoring data with others outside of your organisation?

- Yes, they are open access
- Yes, they are available upon request/under license
- No

Section3: Efforts to improve the health of the river Usk

18. Is there enough data about the river Usk to make decisions?

- Yes
- No

19. You answered no, there is not enough data to make decisions. What do you think is missing?

20. Please rank the following issues in order of the severity for the river Usk, 1 being the most severe

- Changes in biota (biodiversity decline or increase in invasive non-native species)
- Climate change (increased droughts, flood, water temperature)
- Rural pollution from agriculture or forestry
- Sewage pollution
- Physical modifications of water channels
- Lack of evidence
- Over abstraction
- Urban pollution (runoff, misconnections, discharge from industries)
- Historical land drainage
- Lack of resources

21.Does your organisation work to reduce any of those pressures

- Changes in biota (biodiversity decline or increase in invasive non-native species)
- Climate change (increased drought, floods, water temperature)
- Rural pollution from agriculture or forestry
- Sewage pollution
- Physical modifications of water channels
- Lack of evidence
- Over abstraction
- Urban pollution (runoff, missconnections, discharge from industries)
- Historical land drainage
- Lack of resources
- None of the above

22. Are you happy with the current situation? Would you like anything to change? Do you experience barriers or constraints to improving the health of the river Usk?

23. Please use this space to tell us about anything else you feel is important about the health of the river Usk

Appendix 3. Current Usk on-the-ground interventions - locations and timeframes

Lead organisation	Partners	Project/Activity name	Timeframe	Location
OurFood1200	BBNP, farmers	Our Food 1200 – modern regenerative horticulture	Ongoing	across Bannau Brycheiniog, Powys and Monmouthshire
Brecon Canoe Club	Canoe Wales	Glanhad Mawr wrth Badlo / The Big Paddle Clean-up	Annual	Brecon
BBNP	Landowners, NRW, Herbicide contractor	Invaders of the National Park – invasive plant species control	to 2024	BBNP
BBNP	Farmers and landowners, research-based orgs, conservation orgs, policy makers, farming unions, general public	CWRLIP – encourage wet grassland habitat		BBNP
DCWW		Brecon Wastewater Treatment Works improvements - £9m	to July 2024	Brecon
Canal and River Trust	NRW	Salmon smolt pass improvement		Brecon
NRW		Central Monmouthshire Opportunity Catchment – NBS, compliance works		Central Monmouthshire
Monmouthshire CC	Blaenau Gwent, Caerphilly, Newport, and Torfaen local authorities and Natural Resources Wales	Gwent Green Grid – NFM plans	to 2026	Gwent
NRW	BBNP, River Restoration Centre, Coleg Sir Gâr and the Woodland Trust, Dŵr Cymru/Welsh Water, Welsh Government	Four Rivers for LIFE – fencing and tree planting	to2027	Honddu, Cilieni, Mynydd Myddfai, Crai, Senni, Rhiangoll, Crawnon, Olwy, Penarth Brook
NRW	BBNP, River Restoration Centre, Coleg Sir Gâr and the Woodland Trust, Dŵr Cymru/Welsh Water, Welsh Government	Four Rivers for LIFE - Fish barrier removal, flood plain reconnection, gravel reintroduction, INNS removal, Freshwater Pearl Mussel Arc site	To 2027	Various
DCWW	Monmouthshire CC	Llanfoist Wastewater Treatment Works improvements £1.9 m	to March 2025	Llanfoist

Gwent Wildlife Trust		Flood plain meadow demonstration site	Ongoing	lower Usk
NRW		Monmouthshire Dairy Compliance Project	Ongoing	Monmouthshire
NRW	DCWW, Canal and Rivers Trust, WUF	Abstraction licence for Monmouthshire and Brecon Canal	Ongoing	Monmouthshire and Brecon Canal
South Wales Otter Trust	Newport City Council	GGG-Newport Otter Project – tree planting	2022-23	Newport
NRW		Forest Resource Plans	Ongoing	NRW forestry in upper catchment
Action for Conservation	Penpont Estate, landowners, tenants, young people, teachers, foresters	The Penpont Project – restoration, innovative farming and forestry, youth leadership	Ongoing	Penpont Estate
Wye and Usk Foundation	DCWW, farmers, Ofwat, Rivers Trusts, United Utilities,	Catchment Systems Thinking Cooperative (CaSTCo) demo – land management for river health	to 2024	River Crai
NRW	LAs and builders	Nutrient Neutrality		SAC catchment
DCWW	NRW and OFWAT review	Phosphorus Investment Programme	2025 and beyond	TBC
Beacons Water Group	DCWW	Beacons Water Group – farmer led group piloting agric practices	Ongoing	Upper catchment
DCWW		Usk SPS and Wastewater Treatment Works - £10m	to Dec 2025	Usk
Keep Wales Tidy	Community groups	Litter picks	Ongoing	Usk, Abergavenny, Brecon
Swansea University	Affan Valley Angling Club, Afonydd Cymru, West Wales Rivers Trust, Welsh Water, The Wye & Usk Foundation and Natural Resources Wales	Reconnecting the Salmon Rivers of Wales – fish barrier removal	to 2024	Various
BBNP	Welsh Government's 'Sustainable Landscapes, Sustainable Places' fund	Peatlands and Uplands – peatland restoration	2021-22	Waun Fach and Pen Trumau
Canoe Wales	Affiliated clubs, Wildlife Trust,	Check Clean Dry – prevent spread of INNS	Ongoing	Whole catchment

Menter a busnes	Farmers, Welsh Government, Lantra Wales, IBERS, Welsh Innovation Farm Network, ADAS Wales, Kite Consulting, Innovis, Bangor University	Farming Connect – farm advice – nutrient management, water flow and infrastructure	to March 2025	Whole catchment
Wye and Usk Foundation	Natural Resources Wales, Natural England, Beacons Trust and riparian owners	Giving Up the Weed – control of non-native plant species	Ongoing	Whole catchment