Co-UDlabs

Building Collaborative Urban Drainage research Labs communities

D1.2. Roadmap of RI required to support effective UDS transition at EU level

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Background: about the Co-UDlabs Project

Co-UDlabs is a European Union (EU) funded project aiming to integrate research and innovation activities in the field of urban drainage (UD) to address pressing public health, flood risks and environmental challenges. It is a transnational and multidisciplinary "starting community" project, with the aim to influence European regulations and practices to enable a more sustainable management of urban stormwater towards a more resilient cities in the face of climate change.

Bringing together 17 unique research facilities, Co-UDlabs offers training and free access to a wide range of high-level scientific instruments, and experimental equipment, smart monitoring technologies and digital water analysis tools for advancing knowledge and innovation in Urban drainage systems. Co-UDlabs aims to create a network of urban drainage large-scale facilities to provide opportunities for monitoring water quality, urban drainage system (UDS) performance and smart and open data approaches.

The main objective of the project is to provide a transnational multidisciplinary collaborative research infrastructure (RI) that will allow stakeholders, academic researchers, and innovators in the urban drainage water sector to come together, share ideas, co-produce project concepts and then benefit from access to top-class research infrastructures to develop, improve and demonstrate those concepts, thereby building a collaborative European Urban Drainage innovation community.

The initiative will facilitate the uptake of innovation in traditional buried pipe systems and newer green-blue infrastructure, with a focus on increasing the understanding of asset deterioration and improving system resilience.

List of Acronyms

AaU	Aalborg Universitet
ASTEE	Association scientifique et technique pour l'eau et l'environnement
BeST	Benefits of SuDS Tool
CFD	Computational fluid dynamics
CSO	Combined sewer overflows
COST	European Cooperation in Science and Technology
DSS	Decision Support System
EAWAG	Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz
EU	European Union
EJSW	European Jr Scientist Workshop
EWA	European Water Association
IAHR	International Association for Hydro-Environment Engineering and Research
INSA Lyon	Institut National des Sciences Appliquées de Lyon
IWA	International Water Association
JCUD	Joint Committee of Urban Drainage
JRA	Joint Research Activities
NbS	Nature-based solutions
NA	Networking Activities
OTHU	Observatoire de Terrain en Hydrologie Urbaine
PIV	Particle image velocimetry
RI	Research Infrastructure
SuDS	Sustainable drainage systems
SUDS	Sustainable urban drainage systems
TA	Transnational Access
TSS	Total suspended solids
UD	Urban drainage
UDC	Universidade da Coruña
UDMT	Urban Drainage Metrology Toolbox
USFD	University of Sheffield
UWWTD	Urban wastewater treatment directive
WFD	Water framework directive

Executive Summary

This document is the Deliverable 1.2 “Development of a roadmap to identify the role of research infrastructures (RI) to transition to a more sustainable and smart urban drainage systems” of the Co-UDlabs project, funded under the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101008626. The Deliverable is drafted within Work Package 1, “Sectorial Integration and Sustainability Strategy”. The lead beneficiary of the Work Package is GRAIE. GRAIE is the organisation responsible for this Deliverable.

The aim of this document is to collect information from different stakeholders and identify what practices Research Infrastructures need to change or continue doing to help optimise urban drainage (UD) management. Therefore, different sources were considered:

- literature existing within water and environment domains;
- inputs from the academic researchers and scientists involved in the Co-UDlabs project; and
- inputs from other partners who contributed to Co-UDlabs activities.

The evaluation of the different ways of working serves as a blueprint for a further identification of the role of Research Infrastructure to transition to more sustainable and smart urban drainage systems within the project. The aim of this report is to highlight potential ways of working which can enable RI to contribute to effective transitioning to more sustainable and smart urban drainage systems.

1. Challenges and opportunities in urban drainage

There are a number of challenges to overcome when approaching how best to facilitate the transfer of knowledge from research to practice and a significant factor is due to a lack of integration between the two domains (Brown & Farrelly, 2009). This disconnect is in part due to research not being directly applicable to practitioners, but also due to limited interdisciplinary collaboration which slows down adoption of techniques as engineers, policy makers, planners and environmental specialists often stay within their own niche.

Although research is developing innovations, the water industry is generally conservative, risk averse (Cettner, Ashley, Hedström, & Ciklander, 2014), and mainly driven by standards and regulations, preferring to implement established methods over experimental techniques (Kumar Jha, 2023). This is understandable, to a point, as urban drainage systems are critical to society and failure of the systems can lead to problems for the asset owners. Using research infrastructures to test and prove techniques is an important step in applying innovation to the field. In addition to this, urban drainage has to adhere to regulatory standards and the latest innovations may not align with them, with standards and regulation evolving much slower than research outcomes. In addition to this, water utilities have a reputation for being slow at transitioning to new techniques (Cettner, Ashley, Hedström, & Ciklander, 2014) and this could be in part due to existing assets often lasting over 100 years and still functioning, though would potentially not be working to current new environmental standards or flood regulations.

That current policy and advised best practice could be outdated is also an issue. Often it takes time to put policy into practice and it does not necessarily represent the latest research on sustainable urban drainage. This creates a significant barrier for new knowledge to be implemented in practice as there is little presentation of the techniques at the highest regulatory levels. In addition to this, where policy does include innovation, it does not always provide appropriate support for implementation, either in the form of technical information or financial incentives.

These financial constraints pose a problem as creating new systems costs money. Despite strong calls for investment in water (Fayolle & Ovink, 2023; Gottelier, 2013; Voegele, Gouled, & Tafara, 2024; Whiting, 2024) and global water quality declining (Guéguen & Marissen, 2022) municipalities or companies managing urban drainage still need to be able to justify the expense of adopting new methods and need to be able to quantify the benefits of the investment. A lack of comprehensive decision-making support makes these decisions difficult when compared to well evaluated and costed “old” solutions which are implicitly assumed to be satisfactory solutions, when this is not necessarily the case when taking into consideration the new demands upon UD assets due to climate change. This uncertainty is compounded by the impact of climate change as future environmental conditions may exceed the baseline conditions for which the installation was adapted to function (Semadeni Davies, Hernebring, Svensson, & Gustafsson, 2008; Falloon & Betts, 2010).

Knowing how sustainable solutions react to real-world conditions is also a problem to stakeholders who may be interested in adopting the technology (Shaffer, P., CIRIA, 2018). More case studies showing their effectiveness in different contexts is required as sustainable solutions need to be adapted to the local climate and are not as easily generalised. This makes potential adopters hesitant when solutions have not been widely tested, but RI based research could offer data driven evidence in the form of pilot testing and innovation comparison.

Although in certain cases the technical information is available, it is not always well communicated for the intended audience. Research is usually published in academic journals, which are not always accessible or comprehensible to practitioners. Even knowledge shared via conferences or technical reports, the unfamiliar language or complexity of the research can make it unrelatable. Research is mostly published in English, and this is not a universal language for operators in most of Europe. The transfer of digital innovations such as advances in modelling, monitoring, and data-driven decision-making (e.g., digital twins, AI-based flood prediction models) require specific skills, which many practitioners may not possess. Training is often needed, but it can be costly and time-consuming.

Many companies have limited expertise and capacity to engage with and implement new knowledge in urban drainage (Williams, 2024; Water Industry Journal, 2024). The lack of skilled personnel to adopt and manage innovative systems is a significant hurdle. Practitioners are not always exposed to the latest developments during their training and often lack ongoing professional development opportunities (Water by Murray, 2024). This limits their ability to apply cutting-edge techniques or understand the implications of new research.

Whilst lack of capacity is one barrier, the potential lack of motivation is another. Urban drainage professionals often have long-established practices and adopting new methods and ideas can be a slow process, especially if there is no immediate pressure to do so. An effective driver for change are regulatory directives. Two of the most significant directives within the EU that affect urban drainage are the Water Framework Directive (WFD) in 2000 and the Urban Waste Water Treatment Directive (UWWTD), (explored in 1.1 Directives and Strategic Agendas/ Water Governance) which is expected to be updated in November 2024.

1.1. Directives and Strategic Agendas for Water Governance

Two of the most prominent pieces of legislation in the EU that impact UD are the Water Framework Directive (WFD) and the Urban Wastewater Treatment Directive (UWWTD) which outline standards to be upheld to achieve “good ecological status” of Europe’s water systems. This is considered to be that human impact upon the water environment results in minimal deviation from the normal working equilibrium of the system as would be observed in the absence of human intervention or impact. WFD and UWWTD are key drivers to evolution of practices and changes as they impact the research needs but also the operational world thanks to regulations and strategy at the European level and their declinations at the national level.

Even over 20 years later, the WFD is a driving force for water research, and this is reflected in the high number of WFD related papers published. This is mostly within the discipline of water science, with less than 25% combined being related to Governance, Socio-economy, Legislation, or other disciplines (Copetti & Erba, 2023). This could suggest that UD research and UD practitioners are overly driven by regulation.

The appeal of the WFD is not limited to the EU and is considered a source of inspiration for water professionals around the world (Moss, Bouleau, Albiac, & Slavíkova, 2020). How the WFD impacts UD is that combined sewer overflows (CSO) and diffuse pollution can breach ecological and chemical status goals, these events are exacerbated by aging assets and poor governance. However, this gives rise to opportunities to implement sustainable drainage systems (SuDS), nature-based solutions (NbS), upgrade infrastructure, and use smart sensors and data to give better real time control.

The WFD has not been without scrutiny and earlier versions have been accused of “proliferating confusion” due to the lack of coherence in the directive (European Environmental Bureau, 2003). There are still barriers to implementing the WFD with the four main barriers identified in 2020 as:

1. problems related to horizontal intersectoral communication,
2. insufficient land reserves,
3. insufficient staff capacities, and
4. inadequate funding

and the main shortcomings relate to the goals outlined in the WFD and the actual quality of the waters (Zingraff-Hamed, et al., 2020). Also identified as a problem for the WFD is that there are perceived to be conflicts with other EU legislation with the top 4 conflicts being in: Habitats directive, Floods directive, Common agricultural directive, and Nitrates directive.

When considering the future of the WFD, the 4 most popular feedback given for the continuing implementation of the WFD was that:

1. link water with other policies at the European and regional levels,
2. improve cooperation between institutions,
3. promote implementation of nature-based solutions, and to
4. involve the public and communities in planning

The UWWTD is similarly impactful but is also not without its limitations. The goal of current legislation can broadly be summarised as wanting to regulate point-source discharges; however, this does not guarantee the ecological safety of the water environment and it is difficult to quantify these damages in economic terms (Preisner, Neverova-Dziopak, & Kowalewski, 2020).

EU member states are free to apply the effluent standards that are more restrictive than EU guidelines but must adhere to minimum standards. These minimum standards can be either;

- ensuring that discharge does not exceed a maximum level of pollution, or
- that the effluent, after treatment, must have removed a minimum level of pollution based on the total starting level of pollution of that effluent.

This approach can lead to both insufficient treatment of pollution and excessive costs to achieve very high levels of removal depending on how each member state has interpreted the guidelines. An alternative to this is a move away from unitary standards and to link treatment efficiency demands to population, the assimilation capacity of the receiving body, and other locally dependent factors. The assimilation capacity is the ability of a water body to self-purify and return to its normal ecological and chemical equilibrium and this factor does not appear to be a driving element in EU level policy.

Based on comparisons of the approaches to discharge quality globally, “receiver-oriented” policies appear to be most reasonable for mitigating eutrophication and the UWWTD is currently a “unitary-oriented” standard (Preisner, Neverova-Dziopak, & Kowalewski, 2020). This led to a number of suggested improvements for the UWWTD:

1. To use permissible loads of individual pollutants as the main control criteria

2. To not exceed their assimilation capacity of the receiving environment
3. Permissible concentrations and loads of pollution should be specific to the conditions at that location
4. To determine the permissible values of bioavailable forms of pollution
5. To find economic balance between wastewater treatment costs and economic losses due to ecological damage

The updated version of the UWWTD in 2024 included (Halleux, 2024):

- the obligation to set up urban wastewater collecting systems would be extended to all agglomerations with 1000 inhabitants or more (compared to 2000 inhabitants currently);
- stricter standards would be introduced for nutrient removal;
- locally integrated urban wastewater management plans should be established to combat pollution from rain waters (urban runoff and storm water overflows);
- urban wastewater should be subject to additional (i.e. quaternary) treatment in order to eliminate the broadest possible spectrum of micro-pollutants. In line with the 'polluter pays principle', producers of pharmaceuticals and cosmetics leading to urban wastewater pollution by micro-pollutants would need to contribute to the costs of this additional treatment, through an extended producer responsibility (EPR) scheme;
- a binding energy neutrality target would be introduced for the urban wastewater treatment sector, at Member State level;
- new monitoring obligations would be introduced, covering among other things the presence of micro-plastics (including in sludge) and the presence of some viruses like SARS-CoV-2 in urban wastewater.
- Member States would be required to improve and maintain access to sanitation for all, in particular for vulnerable and marginalised people.
- New provisions would be included on information to the public, access to justice, and compensation.

The changes do not significantly address the issues highlighted previously (Preisner, Neverova-Dziopak, & Kowalewski, 2020) and it is unclear as to whether the increased monitoring obligation will lead to increased quality of metrology or whether the changes will lead to changes in practice that will result in more sustainable or smart UD solutions being implemented. Whilst this it does represent progress, it is a “small step” (Wasser 3.0, 2024) and given the known issues that remain unresolved, there was opportunity for more significant reform.

Despite the longevity of the WFD and the UWWTD, a general weakness of both directives is that they give little guidance on how to achieve the demanded impact upon the natural environment. The EU level is very “impact” focused, and it is up to the individual countries to be “directive” at a country level. Not all EU countries had achieved good ecological and chemical water status by 2015 (Voulvoulis, Arpon, & Giakoumis, 2017) and there was little improvement of reducing the number of areas at risk of eutrophication in the EU between 2010 – 2020, both of which can be considered in part due to a lack of standardisation in quality and methodology to determining the sources of pollution (Preisner, Neverova-Dziopak, & Kowalewski, 2020). In addition, there is the challenge posed by shared ownership of water bodies as not all stakeholders involved would necessarily have the same water protections[1] and the solution here is to develop a water sharing arrangement (United Nations Economic commission for Europe, 2015; CADRI Partnership, 2020).

Since the WFD and UWWTD, there are a number of strategic agendas in circulation that are working towards developing and applying solutions to some of the existing needs identified within the water sector. A more in-depth exploration of agendas and roadmaps was established in D1.1 and here a few examples are presented to highlight some key.

On a broader level, the Strategic Research and Innovation Agenda (SRIA) (Water4All, 2022) presented by Water4All, a funding programme for scientific research in freshwater in the EU, has the aim of long-term water security. It hopes to achieve this through funding research and innovation, testing and demonstrating potential solutions, supporting the transfer of science to policy, and by fostering an environment of cooperation, collaboration, and networking. This plan was drafted following a series of consultation with water advisory boards, Water4All representatives, international public consultation and targeted stakeholders. The SRIA document also acknowledges barriers to implementation, touching upon incentives to adopt new solutions, the capacity within the existing economic framework to invest in solutions, and the need for governance with a focus on the environment. Although the SRIA mentions supporting the transfer of science to policy, it appears to be mostly focussed on technical advancement and does not go into depth on how these advancements can lead to a transition in practice or how existing advancements could be better adopted into practice and this seems to be a weak link between the work proposed and the anticipated outcomes.

Like Co-UDlabs, Water Europe has a focus on sustainability and their agenda (Water Europe and UNESCO, 2019) highlights a broad range of 17 sustainable development goals with a strong acknowledgement of how other influences between society, the economy and the environment can influence the rate at which transition towards these goals can be obtained. The agenda is vision shared by the members (SMEs to large corporations, utilities, academia, and technology providers) and has a more comprehensive presentation of how links between different stakeholders can influence transition, providing examples of previous or ongoing projects, and presents a snapshot of how progress is being made (or failing to be made) in respect to existing EU targets, with phosphate in rivers being highlighted as an area of concern. The Water Europe sustainability agenda more effectively prescribes roles to different stakeholders within the agenda, making it more evident how the goals could come into fruition, but it does not clearly outline what barriers could be encountered when pursuing these goals.

An example of the negative effects of integration is from a study in Belarus, Russia, and Ukraine (Shkaruba, et al., 2021) identified that the main barrier for sustainable urban drainage systems (SUDS) in these countries was a lack of strategic foresight for urban development and highlighted that robust governance frameworks are needed and that structural issues are often direct results of governance deficits. In these regions, SUDS are normally promoted by non-governmental organizations (NGOs),

[1] this can be even more difficult when sharing outside of the EU as countries outside of the EU do not measure the same repertoire of pollution parameters

but NGOs and communities are often not connected which results in a significant barrier to SUDS uptake. It is suggested in the study that current regulations result in SUDS installation companies not providing the optimal SUDS solution, with also a lack of successful examples of SUDS in these areas, and that for SUDS to be taken seriously by stakeholders in these areas that SUDS need to feature in their national policy documents. Addressing the barriers to incorporating SUDS are part of the steps to sustainability that are defined in the Water Europe and Water4All agendas.

1.2. Circular Economy, Waste Management and Indigenous Attitudes

A concept that has been gaining increasing traction over the past decade has been that of the "circular economy," a phrase coined by the Ellen McArthur Foundation (est. 2010) and highlighted in Water Europe's 2023 cooperation document (Water Europe, 2023). This principle goes against the linear economic plan which has increasingly dominated since the industrial revolution where fossil fuels supported an economy of consumerism and waste. The circular economy promotes the design of products and processes so that there is no waste and everything is easily re-used or repurposed whilst doing so in a way that stops environmental impacts and regenerates nature – a good set of principles to follow when considering the urban drainage transition to more sustainable practices. Although the Ellen McArthur Foundation has primarily tackled industrial circularity and has widened its reach to touch upon circularity in all domains, the circular economy principles have been applied to water use (Sauvé, Lamontagne, Dupras, & Stahel, 2021) with consideration for quantity, quality and carbon footprint. This approach not only supports sustainability goals but can also help offset the costs associated with meeting the treatment standards set by the UWWTD. The adoption of the phrase "circular economy" across all sectors suggests that it is a principle that could unite stakeholders across disciplines to work towards a common goal.

The circular economy closely mirrors the ethos of Indigenous peoples who promote holistic practices that have been handed down over thousands of years (Horn, 2022; Angarova, 2022). Unfortunately, Indigenous peoples have historically not been given a platform for their knowledge as it has been undervalued and ignored (Wadhwani, 2023) and had been supplanted by Western colonialist practices which often promoted a linear management of resources (van Stam, 2017; Grosfoguel, 2006), with little consideration for future impact. These practices could prove difficult to implement directly in an industrial society where per capita consumption is much higher than that of indigenous peoples. It is only recently that western values have acknowledged "new" ideas such as the circular economy. Indigenous peoples have an advantage transitioning to sustainable practice as these communities have already established economic and ecological values of stewardship (Beamer, et al., 2023), whilst also being strongly impacted by poor water management in their native lands. Whilst Europe is not known for its Indigenous peoples, there are the Sámi people who live in Sweden, Norway, and Finland and also Greenland's Inuit population, who also face water challenges (Giakoumis, Vaghela, & Voulvoulis, 2020; Stockholm International Water Institute, 2019).

A prominent example of Indigenous water management success over western practice is that of the "water bund" or "half-moon" rainwater harvesting technique which is a common restorative practice in West-Africa to transform the somewhat barren Sahel landscape into a more green and agriculturally ready landscape like the regions further south (Partey, Zougmore, Ouedraogo, & Campbell, 2018) and adheres perfectly to the circular economy principles. In Europe, Sámi people have used traditional techniques and contributed their knowledge to rehabilitate rivers in the Inari region of Finland to their natural state (Sapmi & Fofonoff, 2017) suggesting that European Indigenous techniques could be of interest when considering how the urban drainage community could move towards more sustainable practices.

Another important aspect of the circular economy is that of waste management. As previously mentioned, a lot of western practice revolves around linear processes and waste management is no different, often burying waste in landfill sites, though this has been reduced as part of an EU goal to divert waste from landfill (EEA, 2024) or disposal via incineration, which was once seen as a solution, however, the EU now acknowledges that this practice does not contribute to sustainable practice (European Commission, 2021). When waste management is viewed through the lens of resource recovery it presents itself as a domain filled with opportunities and ready for innovation input from RI. In the water domain, advances in sludge management have led to it being used to restore soils and replenish phosphorus (European Commission, 2023), so often depleted from intensive practices, and also research is being done on how to harvest semi-precious metals from sludge, which is often elevated where there are contributions from highway runoff (Varennes, Blanc, Azaïs, & Choubert, 2023; Bezzina, Ruder, Dawson, & Ogden, 2019).

At the waste-water treatment plant, the biomass is being taken advantage of to produce renewable gas via anaerobic digesters installed at the wastewater treatment plant (WWTP), with evidence of boosted production when co-digested with food collected using separate food collection (Cheong, et al., 2022) or transported using the sewer infrastructure using food waste disposers (Evans, Andersson, Wievegg, & Carlsson, 2010; Legge, Jensen, Ashley, Tait, & Nichols, 2022). This demonstrates that there are opportunities for teams at RIs to develop practice in resource recovery and this is very relevant to current issues within the water sector.

1.3. Opportunities for Research Infrastructure

According to the European Commission, RI are facilities that provide resources and services for the research communities to conduct research and foster innovation in their fields, including; major equipment or sets of instruments; knowledge-related facilities such as collections, archives or scientific data infrastructures; computing systems; or communication networks (European Commission, 2024). Development and innovation are a driving force for research within RI. It is possible to develop new approaches and technologies to improve UD management, develop experiments, give support on tests, and help gather results. By filling in knowledge gaps in terms of the parameters and processes occurring, it is then possible to develop models which could have important implications when designing the system to use innovative solutions. This also highlights the need for RI to be designed with flexibility to allow for these new approaches to progress and to ensure that RI remains relevant and useful as best practice within urban drainage develops.

One of the advantages of RI is the ability to collect evidence that a concept works at a pilot scale before it goes to the field. It is not always possible to do tests directly in the field due to safety concerns or due to it being impractical. In a RI, tests can be done under controlled conditions not possible in the field (due to too many variables being present). Whilst field sites can be equipped with sensors, due to the lack of control and difficulty to generate reproduceable conditions, it is very difficult to make valid comparisons of the parameters being examined. Specific characteristics of RI make certain projects possible and proof on concept studies lead to further research to create a useable product which can then potentially be used in the field or commercialised.

Once confidence has been established in a certain technology or practice then it is possible to take this into a field environment. Due to this key link between research and field application, RI can be an essential conduit for information transfer to users. RI gives confidence to an end user that this approach is the right solution for their needs. Once this level of trust is established then it is possible for users to approach RI to find solutions to problems or work towards optimisation and raising efficiency of existing solutions.

2. Achievements and challenges of Urban Drainage Research Infrastructure use within Co-UDlabs

One of the goals of Co-UDlabs is to create a long-term strategy how urban drainage (UD) RI can aid the EU UD community to transition to more sustainable urban water management practices. To identify themes within existing practices that can contribute to the development of the strategy, case studies have been created based on the experience of each Co-UDlabs partner to better understand keys for success in the transition process and need for additional support.

2.1. Case study Methodology

Collecting information on approaches within the project from the Co-UDlabs partners enabled to identify themes or patterns of success and also potential barriers to collaborative efforts or communication. These themes can then be used to give recommendations on how to ensure the success of future collaboration and communication efforts as well as identify further “needs” of the UD community in relation to RI’s aiding the EU transition to better UD management practices.

In a WP1 workshop during the 2024 Co-UDlabs General Assembly in Zurich, it was noted that when partners were asked about their most successful activities, the general trend was that technical achievements were presented, with little “success” value attributed to the dissemination and training activities which are present within Co-UDlabs and for which each partner had at least one example of. The goal of the interviews was to gain a better understanding of the role of RI from proof-of-concept studies all the way to getting innovation into UD systems.

Within Co-UDlabs, different activities were undertaken, and the interviews explored these activities. The pillars of Co-UDlabs included:

- Joint Research Activities (JRA): research-based activities in collaboration with Co-UDlabs partners
- Transnational Access (TA): research-based activities in collaboration with international partners
- Networking Activities (NA), which involve dissemination, training, and capacity building activities

Feedback on the activities within Co-UDlabs was collected using a series of semi-structured interviews. These were done via recorded video call, following a 3-step structure including context, experience, and reflection (based on the "introduction, exploration, reflection" structure outlined by (Bearman, 2019)). The full interview structure is presented in the Appendices (A1 Semi-Structured Interview Plan). Individual interviews were held with the lead from each Co-UDlabs RI.

Activities often overlapped several of the above-mentioned pillars. For the purpose of the interviews, activities were considered as either research or dissemination based. Each institute was asked to present one research activity and one dissemination or training activity undertaken within Co-UDlabs project.

The interviews were supplemented with information from publications, media, follow up questions with a representative from each of the Co-UDlabs RI, and dissemination materials to ensure a holistic presentation of each project.

A source of error within interviews can be due to the interpretation of the response by the interviewer, a mistake when recording the information, or due to an interrogation error such as a badly phrased question, or due to deviating from the structure of the interview plan (Mathers, Fox, & Hunn, 1998). To mitigate these sources of error the interviewees were well informed of the purpose of the interview and were reminded of the purpose and structure of the interview before starting the interview itself (De Gillham, 2005). Questions were prepared and verified in advance to minimize any ambiguity and to avoid leading questions. To detect misinterpretation or mistakes during the recording procedure, interviewees were invited to verify the information used in the case studies. In addition, follow up questions to obtain more detail on the original question were anticipated and prepared in advance of the original interview. These efforts do not completely eliminate error but are appropriate measures to remain as faithful as reasonably possible to each presented case study.

Any deviation from the presented methodology has been noted in the case studies themselves which are presented in the Appendices

2.2. Summary of the role of Research Infrastructure identified by Co-UDlabs members

As part of understanding how RI can help with the transition to more sustainable UD, it is pertinent to know how the users and owners of RI see the purpose of RI. If the role of RI is not harmonised, there is risk of conflicting goals and visions that could mitigate the potential effectiveness of RI.

When getting feedback on the purpose of RI from the Co-UDlabs members, RI was identified as a key focal point, a "binding element" which brings together people involved in and interested in environmental research and hydraulics. Co-UDlabs members consider networking groups to be often established as a result of an RI and that using RI in this way helps to build an international community. There is often good internal knowledge on the use of a specific RI which allows for researchers to capitalise on experimentation and to make research more efficient.

RI empowers teams of researchers, technical industries, and utility companies, often from different disciplines, which may not usually be able to access such practical resources and lets them know the network exists. It is useful to have lots of different perspectives working on the same object as it pushes the boundaries of current knowledge. Similarly, infrastructure which is well adapted to UD research can introduce these RI owners to fields of research that they were not previously involved in.

Access to RI and the collaboration between different teams helps with scientific publishing and dissemination, as it allows for this research to be done in the first place, and it provides a reputable platform. Feedback from Co-UDlabs members suggested that the teams working within RI should be the ones setting standards, creating protocols on equipment maintenance, pushing for the standardisation of data storage, and documenting protocols and how protocols should be followed which allows for eventual harmonisation.

The view of the RI was mostly harmonised; however, each individual had their own slightly different view of the purpose of RI. Whilst this was not considerably different, it can be assumed that each individual approaches the RI with moderately different agenda depending on their specialised interest. Despite the small differences, it can be considered that the owners and users all agree on what RI should be. This common vision will help RI work together and thus facilitate the transition to sustainable systems.

2.3. Summary of needs identified by Co-UDlabs members for RI to effectively help the UD community to transition to better practice

Over the past 20 years there has been a lot of water research funded in the European Union (EU) (Balabanis, Cardós Bon, & Gonzalez, 2022; CORDIS: European Commission, 2024) and it is implied that part of the goal is that there will be a change in practice. Despite this, during discussion in the semi-structured interviews, researchers within the Co-UDlabs project feel that innovations or new knowledge do not always lead to a timely change in practice by end users in Europe (Cooper & Hiscock, 2023), which suggests that there needs to be more efficient transfer to boost the consequence of research investment. As the short-term impacts tend to not be as significant as hoped by researchers, this would suggest that either the outcomes of the projects are not as expected, and the research cannot create a change in practice, or that researchers are potentially making progress but there is dissonance, meaning that the effort required to implement research and result in a change in practice is not being done or is not being done effectively. It would be interesting to know why there is no direct change in practice and what are the problems that are preventing this in the transfer of progress, or whether this is a perceived lack of change due to the time it takes for research outcomes to be adopted in operational applications.

During the above-mentioned interviews, key themes were identified that were raised by Co-UDlabs partners.

2.3.1. Physical Infrastructure

In discussions about infrastructure, much focus has been on the infrastructure within the RI itself. However, it has been identified that there is a lack of forethought in asset design, particularly when considering inspection, maintenance, and repair. Some of the challenges currently being faced involving aging infrastructure could have been avoided or been made easier if more consideration had been applied at the design stage. Circular economy concepts also need to be implemented going forward as it appears that a lot of assets are not designed for re-use or later retrofitting to improve or extend the lifespan. Assets deteriorate but they need to work as designed when needed. Sedimentation causes blockages or lowers the capacity, and these infrastructures should be designed to be accessible and futureproof.

It is not only infrastructure and asset design in the field that needs to be futureproof however, but a repeated theme is also that the RI need to be resilient to future research needs. This means designing facilities that are adaptable, multifunctional, and able to have multiple configurations. This is not exclusive to the field of UD: Sheffield and IKT are able to use their large underground infrastructure test-cells for potable water systems research and Deltares got involved in UD more so due to their existing facilities being well adapted for UD research. Where facilities do not already have this capacity, we need to increase the number of features in, and adapt, the equipment. It is also necessary to update equipment so that it is suitable for the current standards and practices, else it will be obsolete. To not duplicate RI and to better use funds, there needs to be coordination between countries. This targeted investment increases the inherent value of the RI and facilitates research that could lead to a change in practice.

2.3.2. Accessibility

Another way that the value of RI can be maximised is to boost the usage of existing RI. RI needs to be available to multiple stakeholders and to do this, the community needs to develop strategies to include more practitioners. With this approach RI is open to more collaborations, including commercial partners. If there is the possibility to be part of a community and receive value in terms of expertise, then stakeholders will be motivated to get involved. National level re-education of end users on the availability of RI is needed so that the research can be grounded in reality. However, end users also need to be more interested in nascent technologies. Without guidance and support from practitioners, potentially useful technology may never develop to the pilot test-stage, which is often the point where end users start to take notice.

One of the barriers identified in terms of stakeholder engagement is that water operators appear to work in silos and do not have an established RI network. Relationships can be developed between universities and water utilities, but it is still often a relationship between individuals. In addition, universities, and companies like IKT do not have the same social work-network, so it is not without its challenges to make new contacts.

A suggestion on how RI can be more attractive to stakeholders is to get RI projects to focus on the end user and work on the relationship with the people who use the technology. Previously, there has been a disconnect, but we are now seeing researchers get more involved with the practitioners, contractors, manufacturers, municipalities, and network owners by asking them to be involved in steering groups. RI users should adopt this approach and try to have diverse steering groups for each project. This was shown to be helpful in Co-UDlabs as the TA application demands a diverse group and pushes this collaboration/ engagement.

RI usage is very expensive, so stakeholders need a clear plan and know exactly what they want to gain from using them. If it is within a collaboration, then research-wise there will be an outcome, and this can be adapted to the need of the stakeholder. This is not a way of working that all stakeholders have experience in, so support needs to be provided to ensure that everyone’s needs are met on a project. From another perspective, do funding organisations need to change their requirements to say that there needs to be industry involvement?

2.3.3. Dissemination

Relationships can be further improved by providing better communication from researchers; however, the main goal of a research project is to do the research, present the information at a conference and publish a scientific paper. By the time that research is mature enough to be communicated in other formats, the funding and time allocated for the project has been used up and other research projects require investment.

There seems to be a level of disconnection between researchers and the EU funding bodies. Researchers do not always know who to contact in the EU if they wanted to continue some part of a project that has ended. There also seems to be a lot of paperwork, often with unclear demands, which is not related directly to the research itself, and it is unclear to researchers what the EU does with this information or why it is useful to do in the first instance. There is awareness that a better communication and dissemination system is needed, and that the EU needs to provide support for dissemination. There is the suggestion that this could be in the form of an expert whose actions aid dissemination and efficiency. Researchers do not necessarily want advice on how to make a plan for self-dissemination as this is not what researchers are specialized in, and this is not efficient.

Researchers can also give no commitment that they can disseminate during a 2-year period after the project has finished. There is no funding for this, and researchers will be occupied doing research funded by their next project. It is possible to apply for separate funding for dissemination, however this is not well rewarded at a university level, and scientists are not going to spend time getting dissemination funding when their position of employment depends on getting research funding.

There is also a need for research to be presented at industry exhibitions, Pollutec is a big event in France or IFAT in Germany, with lots of industry present, but researchers cannot pay thousands of euros to have a booth at one of these events as they do not have the budget. There are priorities that must be upheld by a researcher and a broader dissemination or networking plan is not always part of it.

The communication barrier in getting research to shape policy in the EU follows a similar pattern of researchers not having the time or funding (or often even the motivation as this genre of information transmission is not interesting or engaging to a lot of researchers) which highlights the need for employing experts in scientific dissemination, communication, and lobbying.

There is a need to try different ways to communicate. Often researchers try to communicate directly with practitioners, but perhaps there is the need to communicate via other organisations such as national water associations. National water associations represent network owners and invest money towards research. Practitioners can give feedback to the European Water Association (EWA) via their national water associations. A new development within the EWA is that it has recently formed a research group. USFD and UDC are now members of this new research group, and the group exists to facilitate collaboration between the different countries and direct changes in policy in Europe.

2.3.4. Language

One of the needs identified in terms of communication was the requirement for information to be disseminated in the native language of each country as, despite there being an idea that “everyone speaks English.” Everyone does not, in fact, speak English. When talking to practitioners, English is not always convenient. The lack of accessible resources and/or ability to communicate in a common tongue means that there is less likely to be uptake from the UD community who do not work within the international community on a daily basis. There is often a paywall for publicised research, and it is also not necessarily in a language in that practitioners can read.

Language is important and an example of this can be seen in the Swiss approach where presentations in different regions of Switzerland would be in different languages. The Swiss wastewater communications was always being done in their respective native languages (ergo, multiple languages as German, French, and Italian have equal status as official languages in Switzerland, though German is dominant). Another example is GRAIE who ensure that the Novatech conference is bilingual with translation in French and English to widen participation and involvement. Similarly, for the UDMT training by UDC, this workshop was done in Spanish to maximise the attendance of Spanish speakers. Another perspective is that in Germany a lot of research results are published in German and not published in international journals, as such reducing the wider accessibility of often high-level work internationally but ensuring that German research remains understandable and accessible to German speakers.

Despite maintaining communication in the recipient's native language being proven to aid communication, it is not possible for researchers to translate into all languages as they do not have the capacity, and they often only have the skills to translate the work into one or two other languages at most (or none in the case of most English speakers). Whilst there has been Urban Drainage Metrology Toolbox (UDMT) training in France & Spain, nothing has been done in the other Co-UDlabs partner countries or other EU countries. This shows that even within the Co-UDlabs group we have not done everything that could have been done. We underestimate the capacity required and amount of time it takes to do this properly. This reinforces the need for employing experts in scientific dissemination, communication, and lobbying – but also highlights that multilingualism could be an essential characteristic of this role.

The linguistic barrier also impacts RI use as technicians within the RI do not always speak a common language with users from outside the RI's home country and people prefer to not speak English where they do not need to. For example, if we look at the TA activities, practitioners rarely speak English outside of the UK and have even less understanding of the technical jargon researchers use. When trying to communicate this can result in a snowball of miscommunication. Whilst no specific solution has been proposed for linguistic barriers to TA at RIs, this is something that needs to be considered when organising TA projects. Similarly, if protocols are not made readily available in the native language of technicians, it is very difficult to establish standard protocols across the EU as lack of understanding is a barrier to uptake.

2.3.5. Policy

At an EU level, there is a gap between what scientists are suggesting to be best practice, and the practices being enforced by policy. However, change in policy often is motivated by the actions of lobbyists, which requires different skills than research. To accomplish policy change, lobbyists need to bridge the communication between scientists and policy leaders to result in effective change.

There is the suggestion that further RI user collaboration with industry, SME's or water utilities could help lead to changes in policy. With the motivation of having a marketable product, industry or SMEs could lobby to have this product be integrated into policy. An example would be the idea that sensing technology needs to be integrated into the water network. However, if there is no legal requirement for a product and if it would not generate revenue for the water utility, then there is no motivator for the water utility to implement it. This means that an innovative technology does not necessarily have a viable market.

So, what comes first, the innovation or the policy? Are problems really problems if there is no policy demand or financial gain to be made? Partnerships going forwards need to try directing the science into policy outcomes. Policy drives innovation, without policy demanding a certain level of working, then no one is going to implement this in practice. Research can provide useful information but if it is not seen as a real problem that needs tackling then it will not be implemented as a policy change and scientists do not have time to lobby for this. Just because the policy is not in place identifying a problem, does not mean that the problem being studied does not have merit and this creativity of problem solving in research should not be stifled.

Another issue is that even once policy is put into place, it is not always enforced and there are no consequences for non-compliance[2]. This suggests there is a gap between policy and the problems people are identifying in the field and RI users and owners need to better communicate with the water associations as they are the ones who lobby at and EU level for policy change. It is organisations like the EWA who tends to scrutinise policy on behalf of network owners. The challenge is that if we want to reach the stakeholders on an EU level then we still need to communicate on a national context.

A motivator for development in Denmark is the large debate on the quality of stormwater which is partly motivated due to changes in EU legislation. Denmark has examples of streams at, or above, the threshold level for further CSO discharge. This means that even if the pollution level is very low in the CSO effluent it is not possible to discharge this to the river as the river is already at capacity. The question is then what is the solution if we are at the river's capacity to take on additional CSO discharge?

However, if science is to contribute to the evolution of the regulation and practice, then there does need to be someone stepping up to ensure that information is transferred. An example of low exchange would be in the development of the UWWTD and the WFD. All partners were asked to get involved, but very few scientists that answered the survey. For the whole of Europe, there were only 18 contributions from scientists to give feedback on the European directive on water. This is probably due to them not having time and even if scientists did fill it out, they are not sure they will be listened to. Beyond this, scientists are not lobbyists, nor do they tend to have anything to immediate interest to protect or to sell or immediate interest in contributing to the regulation. The way things are currently done needs to change as scientific knowledge is useful and valid at a policy level, but it needs to be done efficiently and needs to be done in a way that demonstrates that the time given is valued. This could also signal that the EU authorities are not asking for this information in the right way or giving sufficient information or support. Either way, it is important get scientific knowledge contributes to issues that are policy and politics based.

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[2] Co-UDlabs is working on a specific deliverable report on "Report on smart governance and public access to data". It is expected to be publicly available by December 2024. The document will be available on Co-UDlabs' open-access repository on Zenodo: https://zenodo.org/communities/coudlabs/.

2.3.6. RI Development

A suggested solution would be to use a working group, such as the proposed UDRAIN working group to be established in 2024/2025. UDRAIN is a working group of the Joint Committee of Urban Drainage promoted by IWA and IAHR associations (more details about these water associations are provided in "3.3 Existing Structures within the water sector"). Most Co-UDlabs partners are in academia and are trying to get more impact at an EU level, however the working group could have representatives from each European country whose role it is to transfer the discussions being held in English into their native language so that it can then be effectively disseminated in their home country. The person bridging the gap still needs the scientific knowledge and to facilitate information exchange, but they also need to be motivated to do more lobbying. This position would require individuals to be well versed in Urban Drainage matters, (at least) bilingual and to also have a focus on the transfer and communication of information across the whole spectrum of UD practitioners.

Within individual RI there is not always knowledge about the ecosystem of the water organisations, water lobbyists and what parallel projects are in circulation. There is a need to have some structure bridge the gap. A working group can share the burden and can assist in developing the network. On an EU level, there is new water innovation funding and organisation. What could be suggested is that lobbyists press for UD and water quality to be included in this. These people that are representing the UD community would take an interest in driving the policy, not just scrutinising it. It has been observed that networking groups appear to be often established as a result of an RI that brings them together to work on a project.

Another way this group can be used is to encourage RI owners to make equipment inventories and to do comprehensive RI mapping on a European scale. This task has already been put in motion with T1.3. The main advantage of this is that it raises the visibility of RI to other RI users and to practitioners. A barrier to the increased usage of RI is that a lot of RI have low visibility outside of their own networks. This mapping could be further developed to be used as a catalogue of upcoming projects or spaces in the calendar of the RI so that it is clear where other parties can come in and collaborate. Being aware of upcoming projects can allow for researchers to collaborate on topics that are being worked on in parallel and also will mean that if there is a temporary experimental set up in place that can be adapted to another researchers needs, this can be done so in an efficient manner.

3. Methods of transferring scientific knowledge into practice

3.1. A three-step process to transitioning

When considering barriers to the transfer of knowledge, it is important to account for the actors involved: scientists, practitioners, citizens, and policy makers. Each party involved does not necessarily have a concurrent agenda, nor the same level of motivation when faced with interaction or collaboration with the other actors and this can make it difficult to enact change.

It has been identified that there is a 3-step process to enact change, and this is key for transition. The principles have been outlined in theoretical models (de Haan & Rotmans, 2011) where change has been summarised as a chain of *conditions > patterns > pathways*. This mirrors the *development > engagement > mobilisation* pillars within the circular economy transition outlined by (The Ellen

MacArthur Foundation, 2023) and the concept of regime shift to sewered cities (Geels, 2006) of *niche > niche regime > displaced regime* which has been applied to analyse the transition states of England, Wales and Sweden (Ashley, et al., 2011). However, to better translate this concept to the domain of UD transition, this will be expressed as *diffusion > accompaniment > appropriation* (Figure 1). Diffusion is to be considered the passive step, whereby information is disseminated at a lower level with little follow up or opportunity for applying the knowledge together, despite this, it is still an important step as it lays the foundations to further transition. The second step, Accompaniment, still involves information transfer, but this is at a higher level as it is an active or motivational call to action where there is the opportunity to apply the knowledge to start a new type of practice. Accompaniment elevates the Diffusion step as it could show small scale application of a technology. The third step, Appropriation, is where the most action or implementation occurs and signifies that the knowledge is no longer considered novel as it has been adopted as a standard practice. It is now ubiquitous and is considered a new standard rather than an experimental innovation. This is a continuous process and there is need for ongoing research, development, and feedback loops to ensure continuous improvement in urban drainage practices.

Figure 1. Transition in 3 steps (Flowchart adapted from (Geels, 2006; de Haan & Rotmans, 2011; Ashley, et al., 2011; The Ellen MacArthur Foundation, 2023))

This way it becomes easier to identify which step in the chain is missing for the transition of UD systems to better and more sustainable management practices as current actions can be attributed to one of the 3 steps in the chain. For example, the case studies from INSA Lyon present the Diffusion (A2.2 France, INSA Lyon – The Urban Drainage Metrology Toolbox (UDMT)), with the development and sharing of the Urban Drainage Metrology Toolbox, to Accompaniment (A.3.2 ; A3.4), with the training of others to use the UDMT, which also reinforces the diffusion step. The missing step is step 3: Appropriation. Appropriation could appear as a change in policy that forces users to apply metrology or industry to adopt new standards that necessitate the uptake of metrology by users. These options would also need encouragement of this good practice to ensure compliance.

The concept here is that metrology is the good practice, however this needs to be "good quality" metrology else the data would not be usable. Policy "forcing" good practice by creating standards or using regulation is not always complied with if enforcement is not present or not present to a sufficient degree (e.g. In some places, utilities just pay the fines as it is less inconvenient than solving the original problem) and in this case of non-compliance or partial compliance, encouragement is required to get users to comply. Encouragement can be in the form of educating, but in this example, the benefits (financial cost savings from increased efficiency, more effective in predicting or preventing issues, easier to get useful data from the sensors etc.) of applying metrology techniques could outweigh the costs of not following good metrology practice.

By more easily identifying which step in the transition process is missing, it will be easier to identify where the weak link is in the path to transitioning UD practices in Europe. When considering the state of transition of the Co-UDlabs case studies (A.2; A.3), the majority are only fulfilling the Diffusion criteria, which can be considered where RIs strength lies, with some also making progress to greater or lesser extent on the Accompaniment phase. None of the case studies realise the Appropriation phase which is essential for durable transition.

The 6 needs identified by Co-UDlabs members (2.3):

- physical infrastructure,
- accessibility,
- dissemination,
- language,
- policy, and
- RI development,

highlight several actions that can be matched to a phase of transition. Most of these needs highlight that although there are some Diffusion barriers, there are more significant Accompaniment barriers. Appropriation cannot easily come about without the preceding step, which is a strong level of Accompaniment, and this phase is currently the weakest link in the 3-step transition process for UD.

3.2. Tools to make sustainable decisions

In terms of the environment, sustainability is defined as being "the degree to which a process or enterprise is able to be maintained or continued while avoiding the long-term depletion of natural resources" by the Oxford English Dictionary (Oxford English Dictionary, 2024). The EU promotes an integrated approach and considers "sustainable urban development" to involve education, economic development, social inclusion and environmental protection, which are approached via 3 themes that promote development by being:

- green,
- just and inclusive, and
- productive, smart and connected (European Commission, 2024).

One aspect that has been highlighted as a barrier to more sustainable practice is an uncertainty in the cost and performance of sustainable stormwater management options when compared to piped systems. Current assessment methods can be considered to be either a SuDS model or a Decision Support System (DSS) relying on a SuDS model, with SWMM based models being used in 46% of research publications (Ferrans, Torres, Temprano, & Sánchez, 2022). There are several DSSs available, derived from the domain of impact assessments, however they are not standardised and need to evolve to have consistent criteria. After having made the decision to install SuDS, there are also two significant management issues; that of ownership and of long-term maintenance (Ashley, et al., 2015). Whilst discussing ownership is possibly beyond the scope of this report, long-term maintenance is something that research within RI can, and does, approach.

In the 3-steps to transition (3.1 Three steps to transitioning), DSS are an important part of transition as they are a strong Accompaniment measure or threshold Appropriation tool. The positives to using these tools is that it is possible to account for direct and indirect benefits; they can look at water quantity, quality or both; but what is also significant is that these DSSs can raise awareness of good practices by directing users to other resources that are needed in the context of the DSS (Sun, Sjoman, Blecken, & Randrup, 2024). In any case, users can select a DSS that best suits their needs and focus. One of the recommendations to overcome barriers to implementation is to also acknowledge the multifunctionality of sustainable systems and integrating these “added value” aspects to the decision-making step can lead to sustainable systems being chosen in favour of piped solutions (O'Donnel, Lamond, & Thorne, 2017). In addition, by systemising the decision-making criteria, this can help eliminate bias and can abridge the technical aspects for decision makers who are not necessarily technical users (Ferrans, Torres, Temprano, & Sánchez, 2022).

Better DSS tools could be used to rectify management weaknesses. However, to get to this stage it is necessary to bring the issue of weak decision-making support to teams at RI and encourage a more integrated and harmonious multidisciplinary approach at an economic and social level. Since 1999, the main research focus has been on quality and quantity, with some economic analysis and, in terms of research interest, societal and environmental benefits were only considered since 2015 “boom” in DSS research and makes up only 3% of the papers studied, with research into DSS continuing to be dominated by quantity and quality parameters (Ferrans, Torres, Temprano, & Sánchez, 2022). Interestingly, of all the DSS related research found in this study, only 14% was European based work and of the countries most involved in publishing SuDS DSS literature are not the ones with a big history of investment and implementation.

To make new processes more attractive for investment and adoption, those working in RI need to include information on the economic and societal impact as well as to performance over time to provide the necessary information for the DSS which in turn will allow for informed decisions to be made. Importantly, this information must be presented in a way that is easy to understand and implement. Industry often uses a selection criteria or matrix to determine what options are suitable for the needs of a project. Research questions tend to focus on which SuDS are optimal and where the optimal special allocation of these SuDS could be (Ferrans, Torres, Temprano, & Sánchez, 2022) but are these questions the elements that practitioners want further information on? With insufficient decision support, decision makers are likely to fall back on already established solutions such as piped solutions as they are already well characterised and understood (Sun, Sjoman, Blecken, & Randrup, 2024).

One of the aspects highlighted is to be able to valorise in monetary terms the wider value of sustainable systems. An example of a support tool for this is the Benefits of SuDS Tool (BeST) which facilitates cost benefit analysis by monetising each of the wider benefits not specific to water management (CIRIA, 2015). It has also been suggested that support tools are necessary to support transition in the absence of strong policy (Ashley, et al., 2015).

3.3. Existing Structures within the water sector

Within each European country, there are water organisations in place that disseminate at differing levels. For the purpose of this document, only the countries which are part of Co-UDlabs will be explored and the key EU-Level organizations and networks and it must be noted that this is not an exhaustive list, but those considered most prominent. Each structure participates in activities that can be assigned to one of the 3 steps to transition (3.1).

Table 1. Summary table: what national level structures cover within the countries of Co-UDlabs partners

	Covered National Level Structure						
	Association	Facilitates Collaboration	Water specific Financer	Knowledge broker	Engages with Regulator	Research	# of Structures Highlighted
Denmark	1	3	0	3	1	0	**4**
France	2	5	2	3	4	4	**8**
Germany	2	2	0	2	1	2	**5**
Spain	1	2	0	3	0	2	**4**
Switzerland	2	2	0	2	1	1	**3**
Netherlands	1	1	1	5	1	3	**5**
United Kingdom	1	2	1	3	3	1	**4**

As shown in Table 1 the countries that are part of Co-UDlabs all have a similar set of structures already existing in each country and these existing structures can be further valorised by making stronger links with the group of internal country-level structures (Appendix A4) and at a higher level of exchange with EU level organisation.

All of the countries had at least one association and had at least one structure who contributed to the collaboration between facilities, with Denmark having the highest proportion of its highlighted facilities having a focus on collaboration. Interestingly, of the structures highlighted there is not a lot of water specific finance available at a country level, with France having the most structures offering this. This could be due to countries receiving sufficient financial support from European initiatives specific to water or it could reflect the cross disciplinarity of water resulting in water falling into various different categories (such as farming or ecology) rather than being considered a category on its own, similar to how at an EU level water straddles multiple other categories in Cluster 6: Food, Bioeconomy, Natural Resources, Agriculture and Environment, without possessing its own category within the cluster (European Commission, 2024). Despite water being linked to a Horizon Europe mission area: "Restore our Ocean and Waters by 2030", this is very ocean focussed and not overtly considering inland water (European commission, 2024).

Every country had multiple structures who covered the role of knowledge broker, and the Netherlands seems to have a high emphasis on this aspect as all of its highlighted structures proposed this service. This could be linked to the Netherlands challengingly low topography which has forced them to become innovators and experts in water management, rendering this service essential nationally. In terms of structures that engage with regulators, France seems to have more structures available tackling this point.

When considering the proportion of aspects covered by the total number of structures considered, the UK had the highest average proportion of aspects covered per structure on average across all of the categories and Switzerland was second. This could suggest that there is a lot of overlap in the work done in each structure. Inversely, Germany had the lowest average proportion, suggesting that Germany has less overlap in the work done between structures and has structures with more clearly defined boundaries. Whether this leads to more or less efficiency is unknown and is likely to be unquantifiable due to the variability of the culture and environment within each country. In addition, the structures are the most prominent and this does not mean that they are the most effective. There could be small structures that are highly effective in what they do, but that are not apparent to the foreign observer (in this case, the author) and this unintended bias must also be acknowledged. However, more or less, the countries involved in Co-UDlabs do seem to have similar coverage of the services shown in Table 1 by their most prominent structures, suggesting that there is capacity for RI users to take advantage of the existing structures to promote the transfer of scientific knowledge into practice.

Within the EU there is the European Water Association (EWA) which is a non-governmental organization that promotes sustainable water management practices and helps transfer knowledge between researchers, policymakers, and practitioners across Europe. The EWA organizes conferences, workshops, and webinars focusing on urban water management, including drainage, stormwater, and wastewater.

Water Europe is an industry-driven association that brings together stakeholders from academia, industry, and policymaking to create water-smart societies across Europe and it has a dedicated working group on urban water infrastructure. Water Europe facilitates the transfer of knowledge by organising events, research collaborations, and the publication of policy to promote the adoption of innovative water solutions, including urban drainage systems.

EurEau acts as a representative organisation for drinking water and wastewater service operators across Europe, advocating for policy changes and promoting the implementation of innovative practices. It contributes to knowledge transfer by acting as a platform for water utilities to share best practices, research findings, and experiences in water management, treatment technologies, and sustainability and also by working with EU institutions to shape regulations that encourage the adoption of innovative technologies and research outcomes in water services. In addition, it provides training, workshops, and seminars, helping water operators gain access to the latest knowledge and technologies developed through RI projects. It acts as a link between research institutions and water utilities, ensuring that innovations are practical and scalable for real-world applications.

The JRC, as the scientific and knowledge service of the European Commission, plays a central role in transferring scientific knowledge into policy and practice in various sectors, including water management. Its contributions include supporting research and by providing data reports; developing standards methodologies and guidelines, supporting evidence-based policy development and by participates in technology transfer activities with stakeholders to translate scientific findings into operational solutions.

The JRC and EurEau collaborate on EU research initiatives, where EurEau ensures that research outcomes meet the practical needs of the water industry, and JRC provides the scientific backing and data necessary to inform these initiatives. This collaboration helps ensure that cutting-edge research translates into practical solutions and that water utilities are equipped to implement these innovations efficiently. These two organisations help to bridge the gap between research and practical implementation, ensuring that new knowledge and technologies reach end-users in the water sector, promoting sustainable water management and innovation across Europe.

Also, EU specific, but working more broadly, is Interreg Europe which supports cooperation projects within the EU. The goal is to promote knowledge transfer and shared learning among regions and municipalities by funding and supporting transnational projects that include research-practice collaboration in urban drainage and flood management.

COST (European Cooperation in Science and Technology) Action is similarly not specific to the water sector but works with interdisciplinary research networks to connect scientific communities across Europe and beyond. COST helps to fund collaboration in research projects, knowledge-sharing platforms, and training schools, with a focus on bridging the gap between science and practice.

Although the International Water Association (IWA), is not EU specific as it is a global association, it does have a specific branch dedicated to the European region and is industry inclusive. The IWA connects water professionals and researchers in the field of water and the European branch of IWA organises knowledge exchange and research dissemination in the form of conferences, technical reports, and the promotion of best practices in urban water management, including drainage solutions.

The International Association for Hydro-Environment Engineering and Research (IAHR) also has a European branch and is inherently more research focussed than the IWA. It facilitates the transfer of knowledge from research into practice via conferences that bring together experts from research, industry, and policy, is a respected journal publisher, hosts technical committees where professionals apply research in real-world contexts, encourages collaboration between academia and industry for applied projects and provides training for professional development. It also presents the Project Innovation Awards to recognise and promote excellence and innovation in water management, research and technology. These actions support the application of research.

The IWA, in conjunction with the IAHR, host the Joint Committee of Urban Drainage (JCUD) which supports the transfer of knowledge into practice by bringing together researchers, industry professionals, and policymakers to address urban drainage challenges and promoting international research on sustainable urban drainage systems. The main goal of JCUD is “to promote an ecosystem approach to the planning, design and operation of urban drainage” and has a research agenda that has been developed by the working groups to include; rainfall/runoff processes and modelling, assessment of stormwater and CSO quality and its impacts, role of sewer sediment, stormwater management, CSO control, and hydroinformatics (IAHR, 2024). This information is then shared at JCUD conferences and workshops and in reports and journals, however the audience here is mostly research based with few practitioners and policy makers involved.

UDRAIN is a new JCUD working group that is promoted by Co-UDlabs to coordinate RI globally with a goal of better information sharing across Europe to have a coordinated message to policy makers. The UDRAIN Working Group aims to establish the first worldwide network of large Research Infrastructures (RI) of urban drainage systems to foster cooperation, technical collaboration, and joint initiatives such as transnational access programmes, training activities, and knowledge exchange. This working group will be formalised and presented in the Co-UDlabs deliverable D1.3[3].

Also, not EU specific, but of significance is The World Water Council. This is an international "Think Tank" for Water Policy and its goal is to boost the world water movement for an improved management of the world's water resources and water services.

3.4. Current Stakeholder involvement with RI

RI projects need to consider the current and future needs of industry, network owners and practitioners, and the most effective method of staying connected to these needs is to collaborate directly with these stakeholders.

When RI teams engage with network owners or industry, they must target what issues or needs that network owners are facing and demonstrate that RI teams are hearing their needs by presenting research outputs that correspond. Non-research focussed collaborators have different priorities and prefer for information to be presented to them or categorised as problem orientated or what needs were addressed by a certain technology. The outputs also need to be in a format that fulfils the needs of the partner as well as fulfilling the research criteria. It is not always immediately clear to practitioners when looking at academic research what problem is being solved, and this will mean re-presenting existing research to better present the potential benefits the new discovery and what it can offer stakeholders. This is on the threshold of being Accompaniment (step 2 in 3.1) action that can lead to further valorisation of research as it is being developed into something that is easily actionable by stakeholders.

When considering the applicability of research to practitioners, this can be difficult in case where technology is not yet developed enough to fully address the needs identified. Also, it must be acknowledged that different countries have differing needs, approaches and priorities so there may not be the same level of interest or engagement. Each country needs the freedom to apply the goals they want at a country level. Often engagement on a local level can yield closer working relationships than targeting at a larger scale. Industry needs scalable and adaptable (flexible) drainage solutions that can be customised for different geographic, climatic, and urban contexts due to the varied local climates across the EU. RI researchers could assist by developing modular or adaptable technologies that work across different scales of urbanisation.

The main deterrent for RI researchers and owners getting involved with industry trade fairs is that they are prohibitively expensive with RI level budgets, however it is possible to gain access in alternative ways. It is possible to join up with another organisation who has already paid for a stand or to organise a meet up point for those wishing to learn more about the research from RI. When RI get their own stand for free or reduced costs it is often at the request of the trade fair organiser. In the scenario where booths are not already fully booked, it is also an option approach the organisers directly and propose that if there are spare tables that an RI or RI group could use it to give participants a fuller experience at the fair. An aspect that is important to consider when attending a trade fair is that the

[3] Co-UDlabs is working on a specific deliverable report on " A report on the strategy for delivery of the longterm sustainability of Co- Udlabs". It is expected to be publicly available by March 2025. The document will be available on Co-UDlabs' open-access repository on Zenodo: https://zenodo.org/communities/coudlabs/.

audience are not researchers and will have differing goals and needs from the event. To best engage participants, it is important that presenting researchers adapt the presentation of their work to match the objectives of the trade show and to keep the focus on this narrow theme. This also gives RI users the opportunity to gain direct feedback from practitioners and utilities.

Due to RIs limited visibility at this level within the EU, stakeholders do not always know the best place to find solutions to their problems. A potential solution is that RI expertise is presented in a way that makes it easy to identify and connect with the specialists. Trade associations (e.g. DWA) get benefit from collaborating at RI and this is a good level at which to engage with industry so boosting this relationship could lead to stronger relationships with stakeholders. In return, these organisation bodies are aware of the direction of research and could contribute to a framework of topics that is considered useful to investigate and researchers can then work towards developing solutions to problems within the framework.

Almost every country has a trade association, and it is possible to develop clearly defined project objectives from this. In addition, when RI projects do engage with network owners, it is important to involve network owners during diffusion and accompaniment stages. This helps to boost confidence in RI and create a virtuous cycle to encourage future collaborations. This does require a conscious effort on the part of RI network to involve network owners and for a higher level of engagement RI need to be able to demonstrate the technology.

Something that is of interest to operators is that RI can help model future scenarios and stress-test technologies to ensure they remain effective under changing environmental conditions. Being able to make the right choice is important when trying to apply the best solutions and industry needs independent, research-backed validation of new technologies and “best” practices to ensure they meet performance standards. Research institutions can act as neutral parties to validate the effectiveness of innovative solutions without the influence of the product or technology’s sales team. Also, with better comparison of the performance of different solutions, this provides further information to support decision making (further explored in 3.2). This could lead to more meaningful engagement with practitioners as they currently seem to get too many questionnaires without any significant follow up.

A benefit to RI users better engaging with industry is that it can be a driver for implementing SuDS into legislation (Barbour, 2023) and can be a pathway towards harmonisation via certain practices being adopted as standard.

3.5. Ways that Policy can drive knowledge transfer

There has been awareness of the need to implement the WFD by integrating scientific and technological progress into the policy-making (Quevauviller, et al., 2005). According to Gaventa & McGee (2010), policy spans a number of levels, i.e. international, national, intermediate, or local level. Success of transferring knowledge into practice at a national or international level usually involves the development of policy or law reform. At an intermediate level this means the concept is implemented, or its implementation is improved, and at a local level the knock-on effect is that there is an improvement for the citizens (Gaventa & McGee, 2010). Policy evolution needs to accommodate smart technologies, green infrastructure, and innovative solutions in drainage systems. Changes to legislation, regulations, industry standards or planning guidelines is highlighted as one of the top strategies[4] that can be used to promote and encourage the implementation of sustainable drainage infrastructure (O'Donnel, Lamond, & Thorne, 2017).

Using the EU Nitrates Directive in Ireland as an example (Buckley, 2012), it has been shown that increased knowledge on how to follow policy allowed farmers to better follow policy recommendations. It had been shown in the run up to the directive being implemented that there were gaps in farmers' knowledge of the Nitrates Directives regulations, and they wanted clear, concise information, and this support was given after the directive was implemented. It had also been identified that they were sceptical of management changes required by the regulations, due to a perceived lack of evidence, and that the farmers rarely consider environmental issues beyond the boundaries of their farms, which in turn meant that farmers did not believe that they were responsible for water quality issues.

Increased engagement and education surrounding regulation led to farmers implementing more sustainable management practices and the farmers acknowledges environmental advantages and disadvantages arising from the regulations, whilst some farmers consider there to be sufficient information available to comply and implement the regulations, most farmers seem to be neutral as to whether there is enough information. This suggests that, with the correct support, policy change can lead to better understanding of environmental concerns and result in more sustainable practice. This support is key to implementation as lack of technical knowledge, education and awareness is cited as one of the perceived leading barriers to the implementation of sustainable drainage infrastructure (O'Donnel, Lamond, & Thorne, 2017).

A barrier toward the transition to sustainable practice is that there is sometimes a lack of consultation between those creating policy and those who must implement it, which leads to scepticism. Due to this dissonance, it is necessary to consider how can we better involve governing or regulatory institutions can be more involved and informed by research at RI. Currently, a significant amount of legislation in environmental policy can be summarised as "trying to regulate systems we do not fully understand, driven by discharge limits beyond our command", which inherently has too many variables. There also seems to be an inherent difference in perspective between technical experts and policy makers which has not been resolved and has resulted in a mutual acceptance of the current status-quo, which is that of non-communicating. A lack of communication leads to situations in which discharge limits are set to systems within the water sector and within urban drainage and the discharge limits are not defined in a useful fashion. This results in "creative" solutions to develop systems that adhere to these limits at the lowest possible cost, and this does not automatically result in the reduction of environmental damage as envisaged in the original overall policy.

There has been increased attention towards CSOs spill in rivers and what is considered appropriate usage, and this has been reflected in UWWTD updates, which in part has been driven by public dissatisfaction towards the pollution these overflow events cause in environments increasingly viewed as places for leisure and sport. Design standards and regulation across Europe are not consistent and this can broadly be separated into arbitrary total emissions-based control measures or by the

[4] Identified by Newcastle-based (UK) professional stakeholders with interest in the local urban flood and water management strategies during interviews with researchers as presented in (O'Donnel, Lamond, & Thorne, 2017)

environmental qualify effect upon receiving waters (Blumensaat, et al., 2012). The end-goal is evidently to control the effect upon receiving waters, however this is much more costly to implement, and it is more economically practical to use total emissions as a proxy for the effect upon the health of receiving water bodies – yet CSO emission information alone cannot accurately determine the environmental impact (Schellart, Sharp, Bertrand-Krajewski, & Rieckermann, 2024). This disconnect with the desired outcome of a policy and how policy is implemented by water utilities is a significant issue, suggesting a more pragmatic approach is required.

When striving for effective, realistic and sustainable policy making, the effort to bridge the communication gap between policy makers on the one hand and the technical experts in the scientific and engineering community on the other, there are options available:

- convince scientists and engineers to enter or participate in politics so that experts are the ones directing policy,
- convince policymakers (politicians, lawyers etc.) to acknowledge the key role knowledge and (lack of understanding) can and should have and how to incorporate scientific insights in policymaking.

From the perspective of the Co-UDlabs project, the former option seems to be unrealistic while the latter may be feasible (or at least to a limited extent) by sharing key findings, insights and lessons learned, this so far has not necessarily been used to its full potential. There is scientific evaluation of previous policies through platforms (e.g., national branch organisations) which has been embraced by policymakers and managing organisations and further support of these platforms could lead to a more effective transfer.

A key issue is that in virtually all environmental legislation within the EU, translation to national, or even local level, is a challenge without feasible regulations. It is imperative that regulation maintains a sense of the original goal without degenerating into strictly following (arbitrary) limits quantified. In that respect, the national level branches could organise a regular mutual exchange of insights and the scientific community giving access to research infrastructure on a European level (i.e. Co-UDlabs) might be a first step.

3.6. Public awareness and engagement benefits

Progress can also be made when communicating at a more public level. This attracts attention to the issue, generate awareness and brings public sympathy to the cause. The public, when motivated correctly, can be a powerful tool to bring about change, either within the local community or at a policy level. Initiatives that encourage reducing water consumption, properly disposing of waste, or maintaining household drainage systems can contribute to the broader goals of the WFD and UWWTD. It has been suggested that further study on the importance of community participation on the successful outcome of SuDS is needed to better capitalize on this partnership (Jayasooriya, Ng, Muthukumaran, & Perera, 2020).

Raising awareness of sustainable systems and practice is often Diffusion based (step 1) and implemented using public awareness campaigns, such as raising awareness of climate change so that it can potentially lead to behaviour change. However, there is increasing examples of Accompaniment (step 2) being implemented which will more effectively push transition towards Appropriation (step 3).[5]

Specific guidance exists, such as the "Community engagement for Nature Based Solutions" (Sefton, Hughes, Sharp, Chapman, & Quinn, 2023), to present the benefits and fundamental principles of community engagement. This highlights the benefits of design phase public consultation to ensure that the community needs and aspirations are integrated into the project as this often leads to community stewardship, through a sense of shared ownership, of the site. Successful projects can then encourage additional SuDS measures to be installed in the neighbourhood and lead to a BIMBY attitude.[6] Other publications give examples of how each social niche within the local community can bring different value and perspectives to the project (McEwen, Gorell Barnes, Phillips, & Biggs, 2020).

It is important to highlight the direct, such as flood mitigation, and indirect benefits, such as improved wellbeing or reduction of urban heat islands, of NbS so that the community can support the initiative, but these interactions should be a two-way exchange of information. The local community are experts on their local environment and can offer useful direction on foreseen local challenges for the duration of the project which gives opportunity to develop solutions before it is too late such as an example where local councillors were anxious about safety near open water and the solution of barrier planting and shallow reed planted margins were able to remove this apprehension (CIRIA, 2024). Another example is when community engagement (Greater London Authority , 2024) resulted in better-designed and multi-functional SuDS measures. This empowerment of communities is a good example of how Accompaniment (step 2 in 3.1) can bring about new patterns of behaviour in respect to water management and should thus be seen as an essential action towards Appropriation (step 3 in 3.1).

Risks of community engagement are significant, resulting in the failure of initiatives (Sefton, Hughes, Sharp, Chapman, & Quinn, 2023), however these are valuable lessons as they demonstrate how incorrect engagement can disengage communities and result in resistance to the water management solutions, including NIMBY attitudes.[7] Other risks are that if projects are "over sold" to communities then this can result in unreasonably high expectations and when engagement occurs at the planning stage, there is also the risk of disappointing communities if the project never gets greenlit. To help manage public perception of projects it is important to give clarity and to actively listen to their feedback. Another solution is to give clear and regularly updated timelines of how the project is progressing.

An example of successful citizen action resulting in change is the Ilkley Clean River group who are a group of Ilkley residents that are campaigning to protect the River Wharfe, the first river in the UK designated as a bathing site, from faecal pollution (Ilkley Clean River Group, 2024). This which has resulted in Yorkshire Water investing £75m in improving Ilkley's wastewater treatment plant (Laver, 2024). In this case, residents wanted to bathe in the river and used samples to prove that the swimmers were at risk due to CSO discharges (Karunakaran, et al., 2024). CSO discharges were triggered due to usual rainfall resulting in pollution, when CSOs are intended to be a safety measure for exceptional levels of rainfall exceeding the capacity of the WWTP.

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[5] See Section 3.1 for more detail.
[6] Acronym for *Build In My Back Yard*.
[7] Acronym for *Not In My Back Yard*.

The public can be further engaged and empowered via the promotion and support of citizen science. Stormwater Shepherds, an international not-for-profit organisation, provide resources for citizen scientists, such as the "Investigating pollution from road runoff across your catchment" (Bradley, 2024) but are limited in that they do not know effective this is in changing the actions of polluters or indirectly changing policy as they have not got the capacity to follow up. They also do research on pollution and community cleanups of plastic pollution.

There is also the concept of a Hydrocitizen (Scott-Bottoms & Roe, 2020), a subset of ecological citizenship, which sees transformations in how society works at individual and community levels in respect to engagements with water. Empowering citizens gives them a sense of agency and ensures long term engagement at the community level (McEwen, Gorell Barnes, Phillips, & Biggs, 2020). This highlights that communities are part of our ecosystems and have the power to make sustainable decisions with respect to their water usage. The hope is that a deeper connection to the environment will lead to motivation to support for healthier urban waters and resulting economic and social growth. This links back to understanding, ownership and appreciation of the water system of indigenous peoples (outlined in 1.2 Circular Economy, Waste Management and Indigenous Attitudes) resulting in better stewardship and engagement in sustainable practice.

3.7. The contribution of knowledge to ensuring Compliance

When reflecting on the EU WFD, it is acknowledged that "Compliance with the letter and the spirit of the law are two different things" and are influenced by the motives in each member state and also their willingness to change (Moss, Bouleau, Albiac, & Slavíkova, 2020).

It has been shown that those working under an authority figure will follow their example. In a study investigating the lack of compliance in washing hands in hospitals (Smiddy, O'Connel, & Creedon, 2015) it was noted that junior staff follow the practices of senior staff and that if senior staff do not wash hands, then no one else does either - to the point that junior staff felt like following good practice was futile. However, the inverse is also true, if senior staff do wash hands, then other people follow suit. This suggests that seeing other people following good practice encourages others to follow good practice too, even where there are no laws enforcing the action. In response to partial compliance, including actions incorrectly perceived as a suitable proxy measure, knowledge of the appropriate practice was shared to restore good practice measures.

This suggests that though sometimes good practice is not followed due to lack of knowledge, an effective measure to transition to good practice for all is to target authority figures. For the water sector this would be water companies and industry leaders.

A lot of knowledge is published in academic journals; however, not all of this information is easily accessible as a lot of journals require payment for access. Despite this, a lot of research is now published in open access journals which allow for anyone to read it, which is a significant benefit for those who do not have the funds to pay for access. An example of how RI communities have supported article writing and Diffusion of information is CERN and the success of the Zenodo platform and similarly, there is the HAL platform by the CNRS (and later shared with a number of other French institutions) for sharing research. More informally there is also ResearchGate, which is a social network which allows for researchers to share their work.

When discussing the impact of providing knowledge by publishing outside of academic journals, which is often a source of information sought out by practitioners, authors suspect books with a high price such as the new Institution of Civil Engineers Handbook of Urban Drainage Practice (Ashley, Smith, Shaffer, & Caffoor, 2024) will struggle to sell and make a significant impact when compared to other publications, such as a book on sustainability assessment (Ashley, Blackwood, Butler, & Jowitt, 2004) that the authors insisted be low priced and royalty free. The latter book is still selling even 20 years later showing that it must be helping to provide good information and change practice as people are actively seeking this information.

Some of the most useful knowledge guides in the UK are provided by CIRIA (Construction Industry Research and Information Association). Susdrain was created by CIRIA for the dissemination of sustainable drainage systems (SuDS) installation practice in 2012. In 2014 in England, a common law approach to encouraging SuDS was implemented, but did not result in the needed level of uptake. This is despite the first sustainable drainage installations being installed in the 1990s (CIRIA, 2024) in Scotland. Misunderstandings about costs and technical feasibility were persistent, highlighting a failure to transfer knowledge effectively from research to practitioners, which leads to a lower uptake in SuDS as a solution.

Numerous false assumptions were made as to why SuDS could not be installed in scenarios where, in truth, SuDS would actually be beneficial. As a response to this, a myth-busting sheet with design solutions to the perceived problems was created (Paul Shaffer, CIRIA, 2018) and later, what was also provided were case studies for various types of development, contexts and types of rainwater management solutions (CIRIA, 2024) and also include cost-benefit analysis compared to piped-solutions. Higher uptake is anticipated in the UK due to national legislation being implemented by the end of 2023 to implement SuDS (CIWEM, 2022). This follows resistance since 2010, when the original proposal was made, due to policymakers and practitioners debating whether SuDS were of significance and whether they worked or not. Susdrain is acknowledged as an organisation that has collected and consolidated proof on the subject.

3.8. The Valorisation of water and its impact on water careers

One of the challenges raised is that there is not enough high-level technical talent attracted to the water industry as a whole which results in the limiting factor where practitioners do not have the capacity to adopt innovation. A wide range of practitioners do not have the curiosity to seek out innovations and if innovations are presented, there is not always the skillset established to apply these innovations.

Despite the marked link between sanitation and significantly increased life expectancy (Kesztenbaum & Rosenthal, 2017), the water sector does not have the glamour or prestige (or salary!) associated with other engineering practices and the retained high-level talent are usually only the most passionate for the subject. Engineers are often on the Skills Shortage list within Europe (EURES (EURopean Employment Services), 2024) and globally (CIHT, 2024) so there are no shortage of alternative positions available for existing engineers. This could also be due to the water sector, especially UD, having a reputation of being very conservative offering little margin for experimentation or innovation (Cettner, Ashley, Hedström, & Ciklander, 2014) which also contributes to the sector being unattractive to high-level talent.

A potential way forward for practitioners to better take advantage of existing skilled and creative talents would be to be more open to employing postgraduate graduates across all levels of their organisation. Postgraduate qualification holders are often not considered for roles that they are deemed “overqualified” and also dismissed for technical positions as they are considered too theoretical. Whilst there is some truth that not all postgraduate qualification holders finish the post and can be viewed as at an “operational” level for industry, this is something that could be improved upon and is being increasingly targeted by institutions hiring postgraduate candidates.

This gives utilities better technical staff who are used to more unusual or experimental set ups who can really optimise and adapt existing systems to work to their maximum potential. However, utilities need to broaden their capacity to accept experimentation as to attract and retain high level candidates, there needs to be the offer of an engaging and challenging career path to stimulate and inspire those interested in practice. This is particularly important as there is significant digital innovation being developed and this requires a specific skillset. There is *“a concerning mismatch in training that is hindering innovation and driving engineers into other remits where they feel they have more potential to grow”* (Water by Murray, 2024) and this is a general skills shortage at all levels within the water utility sector.

For the future, a global valorisation and appreciation of the water sector is needed to attract and retain talent. It is not enough to attract only those who are driven by a passion for the water sector. Passion alone is not enough to retain talent when engineers have to be pragmatic regarding their salaries and career progression. That there is such public resistance to pay more for water when “*The price of water almost never equals its value and rarely covers its costs* (Grafton, Chu, & Wyrwoll, 2020)*”,* is strong evidence to the level at which water is disregarded and dismissed as an asset in current society. Whilst water price reform planning is beyond the remit of what users of RI do, price reforms do impact the funding available for research and also what innovations are feasible to install. The bolstering of a healthy water economy will allow for better service delivery (Andrés, et al., 2021), which will help, in an ideal world, to better pay highly skilled practitioners, which in turn creates a virtuous cycle for the water sector.

As the foundation of a sustainable economy, a key step forward is the valorisation of water services within the political and public spheres.

4. Perspectives on how to exploit research infrastructures to transition to sustainable and smart urban drainage systems at an EU level

When applying the methods of knowledge transfer to exploiting RI, then it is imperative that both the long-term and short-term needs are addressed. There is some urgency in improving the valorisation of the work done at RI. This section will present both solutions that can be easily implemented immediately as well as present an aspirational outlook of what the methods can be applied in RI to maximise the transfer of information into the future. These aspirations are proposed beyond the scope of Co-UDlabs and are an initial proposal to raise awareness of the repertoire of options available.

4.1. Summary of the progress and contributions of Co-UDlabs towards transition

In D1.1, “identification of RI users and urban drainage systems community needs” (Tondera, Fontanel, & Brelot, 2022), a number of needs were identified, which did not show significant overlap between country roadmaps, Co-UDlabs researchers and potential users of RI. This suggested that part of this lack of common vision was due to a lack of interaction between stakeholder groups; however, there were a number of needs that also corresponded to needs identified by the IWA and Water Europe. Emerging themes appeared to be on the subject of data management, advanced monitoring and further training in new technologies, and this suggests increased awareness amongst stakeholders. The organisation and legislative structure in the countries evaluated in D1.1 also represent a potential barrier to the implementation of innovation in the urban drainage sector, with integrated planning of the water sector being proposed as a solution that should be implemented within the immediate future.

The impact and contributions of a project that is still ongoing is difficult to quantify. In addition, this progress could be considered marginal in the context of the total history of urban drainage systems, and this is because the Co-UDlabs project spans the relatively short time-period of 4 years. Also, as touched upon in section 2.3.3, it is challenging to fully valorise new knowledge during the research phase, and it is only after this valorisation has become known within the public realm that its true impact can be considered. Due to these factors, it is premature to try to evaluate the true contribution of Co-UDlabs towards transition, as this is only possible to evaluate in the years following the end of the project.

Despite this, the Co-UDlabs project has made steps towards addressing several needs in the short-term via the JRA’s[8] which corresponded well with a portion of the needs identified highlighted in D1.1. In addition, there is the legacy of the Co-UDlabs project which contributes to the longer-term transition of UD, which consists of:

- Establishment of UDRAIN (to be formalised in D1.3[9])
- New partnerships and contacts made because of the Co-UDlabs project
- Increased awareness of the work still required to achieve sustainable UD systems (WP1).

[8] All these reports are publicly available on Zenodo: https://zenodo.org/communities/coudlabs/

[9] Co-UDlabs is working on a specific deliverable report on " A report on the strategy for delivery of the longterm sustainability of Co- Udlabs". It is expected to be publicly available by March 2025. The document will be available on Co-UDlabs' open-access repository on Zenodo: https://zenodo.org/communities/coudlabs/ .

It has also highlighted the need for UD to be more dynamic and open to change as some significant barriers faced appear to be the result of conservative management practices and the loss of respect for water in society (section 3.9).

RI have a critical role and have a lot of potential to contribute to the transition to smart and sustainable urban drainage systems. Already RI allow for the development and testing of new technology and allow for increased understanding of existing structures, which permits science backed decisions to be made when decision makers are considering the value of sustainable options. Moving forward, RI can be further exploited by developing a number of aspects in the short-, medium- and long- term (as outlined in 4.3) and this can result in more effective exchange between RI and the other UD stakeholders, leading to a virtuous cycle of development within the UD system community.

4.2. Specific actions towards transition

What is unanimously agreed upon, during general Co-UDlabs discussion, is that a common council or umbrella organisation is required in future to coordinate the exchange of information between countries in the EU at an EU level and that specialists are required to fulfil a number of tasks (defined below). Whilst maximum efficiency would involve a significant restructure of how each country manages its information sharing to then be effective at exchange at the EU level, this is not practical or efficient in the short-term and can only be considered a long-term option. Each country works differently internally due to significantly different cultures, has different structures, and organises the water sector in different ways with different priorities.

The overarching goals of this future umbrella organisation to start with should be to raise awareness of other studies ongoing in the EU to maximise their impact and also to increase efficiency, such as preventing countries doing the same work in parallel with no exchange and to increase collaboration and transnational access of RI in the EU. Part of the proposed solution is to clearly define the role of representatives put forward by their home country and this new umbrella organization. This would focus on boosting Accompaniment and further valorise existing Diffusion (as outlined in section 3.1), as this seems to be a significant weak link when moving towards transition.

This role could be referred to as a Transition Engineer, a term which seems to have been adopted by the Energy sector (Krumdieck, 2019), or as a Science Communicator or Knowledge Broker, which covers a broad range of sharers of technical information, but this position is often more associated with journalism or teaching, or there is the title of a Technical Communicator, or a more precise title could be created. This expert, or network of experts, would be hosted by existing in-country structures and/or work for the umbrella organisation. Each country should have at least one expert available to represent UD at an EU level.

The tasks of the experts within the organisation would be:

- to be point of reference for policy makers.
- to be point of reference for the public.
- to be the expert to act as a translator between researchers and practitioners.
- to boost the long-term vision of RI: in terms of anticipated problems in the distant future & anticipated skills shortages.

- to direct the writing of research funding schemes as to understand the needs of research and industry.
- to write publications for other media (beyond research publications).
- to help valorise the public and political image of the water sector.

This vision is common across RI users; however, researchers do not have the specific expertise to fulfil the described role (in terms of social, cultural, financial aspects). When scientists are faced with the task of removing these obstacles, they tend to rely on disseminating and communicating, which falls under Diffusion, the first step in the 3 steps to transition (section 3.1) and this is insufficient to bring about changes in practices. The role that has been outlined is not easy, and it is difficult to train people to be suitable for this role (especially when it is not formalised).

One idea would be to use existing IWA/IAHR working groups as recruitment pools as then the representatives from each country are researchers who can speak English and will often already have experience in cross border collaboration and exchange. These individuals can then translate key information and training into their native languages as language barriers are one of the identified needs to be overcome. In the short term, using natives from each country who also speak a common language (which is most likely English as this is almost considered a universal language at this stage) is the most efficient method to exchange information between country level and EU level. Despite this, it has been pointed out that using the proposed experts can cause a bottleneck in the transfer of information if the individual doing so does not transfer all the information due to human error.

This bottleneck can be mitigated by having a number of representatives per country to avoid only one interpretation of the information being transmitted or by also promoting the general learning of other languages at an EU level so that there is less reliance on a small number of people making the transfer. Another point that has been raised is that current technological advances allow for written documents to be instantly translated into another language. Whilst automatic translation of videos is not yet mature enough to rely on completely, it is only a matter of time before this process is perfected, lessening the need for translation of information materials. In addition, regulators can encourage (force) utilities to move forward, first in terms of skills, and then in terms of actions (see sections 2.3.5, 3.5 and 4.3.5).

The question of transition, maintenance, modelling and sensing issues are significant themes within UD, and Co-UDlabs members suggest that these subjects could benefit from EU specific conferences. An alternative could be to support existing conferences and to help develop these at a European level, such as UK's "Sensing in Water" conference and exhibition on sensing by the Sensing for Water Interest Group (SWIG) ((SWIG, 2024), as there are no international or European or equivalent conferences currently available on this topic. In cases where there are international conferences already available, it could be that further support is needed to help Europeans to attend these conferences, such as the Urban Drainage Modelling Conference (UDM) which was organised in the USA in 2022 (International Working Group on Data and Models , 2022). This is an example of an already well-established UD modelling event, but as it is often hosted in Europe, it is unlikely that transport support is a true issue. However, Co-UDlabs members have noticed that recent editions have become much less focussed on modelling, thus possibly losing some of its special interest audience.

In terms of conferences on transitioning, there are limited existing conferences such as the Conference on Energy Transition and Water Resources Management in Water-scarce Areas of China (Global Water Partnership: China, 2024) showing a need to create exchange platforms for this topic. Consequently, a European conference on how to enable transitioning within the water sector could prove successful. Additionally, no dedicated conferences on the maintenance of UD assets could be found in IAHR, IWA or EU level conference lists, although the International Conference on Urban Drainage organised by the Joint Committee Urban Drainage covers these topics partially. As this subject links well with transitioning, mutualised formats could be considered.

4.3. A desired future state of Urban Drainage partnership with RI

4.3.1. Strengthening collaboration between RI and practice

Creating stronger partnerships between researchers, policy makers, water utilities, and industry can help bridge the gap between research and implementation. Although RI plays a crucial role, it is often underutilised. The EU, in general, needs to explicitly suggest that stakeholders use RI. Although RI is at the forefront of innovation in the domain of UD development, it is not always the on the radar of practitioners when they need to find solutions to their problems. Ideally, research institutes should encourage active partnerships with industry stakeholders, offering platforms for co-development, knowledge exchange, and joint projects (such as has been offered within Co-UDlabs).

Development of formal collaboration programs, such as is starting to become more standard within the EU, are currently being pushed to have a stronger focus on industrial competitiveness (European Commission: Directorate-General for Research and Innovation, 2024). More integration between RI projects and practice would mean that researchers are in more regular contact with practice and more aware of needs within the water sector and would also need to justify how the work can be useful. Similarly, Co-UDlabs members feel that it would be useful if there were internship opportunities that embed academic talent within professional settings. One of the comments that researchers hear is that the industry sector feels that researchers do not understand how the industry works and having the opportunity to work in an applied setting would rectify this.

There needs to be more emphasis on policy makers and asset owners getting in contact with research groups handling RI to develop answers to societal needs, which could be more successful in direct interaction. Where scientists offer solutions to problems practitioners are not aware of or feel are not top priority, the challenge is to enhance mutual communication. Overall, development of RI-practitioner relations in this way would ensure that scientific advancements are swiftly translated into practical solutions within urban drainage.

The OTHU field observatory in Lyon, demonstrates long-term collaboration (over 20 years) and is based on concrete objects of study, in a particular geographical area, which are a fundamental element in creating a framework of trust. This encourages exchange, both in terms of formulating questions and listening to proposals and formulating them together. Scientists also learn from practical experiences. These exchanges lead them collectively towards more cross-disciplinary and interdisciplinary approaches. Also, these shared reflections and research produce results that are easier to develop and use. It should be noted that leading this collective and constructive interactions between researchers and practitioners (public and private) is an activity in its own right and highlights the need for a new profession to be developed; the same needs can be expressed to foster the relationship between scientists and legislators, but the difficulty is that the 'common object', the field that brings people together, is a little less identified.

4.3.2. Providing funding and incentives

Currently, funding and incentives for UD are often hampered by limited awareness of the latest innovations. RI, as a hub of expertise, are well placed to provide evidence-based insights to funding bodies and policymakers. Funding agencies would be empowered on the topic of sustainable UD options and also on the long-term benefits. In an ideal scenario, this would lead to incentivising projects that incorporate more sustainable practice. To achieve this, research institutes could publish impact assessments of pilot projects, support the development of policy briefs, and collaborate with financial institutions to develop criteria for grants and subsidies that prioritise sustainable and scalable drainage solutions. This reduction of financial risks for implementing innovative drainage systems can encourage adoption as the initial costs and risks are reduced. As discussed in section 3.9, utilities are quite risk averse and conservative in their decision making.

RI expertise could also be an asset in budgeting the maintenance of sustainable systems. Section 3.2 shows that DSS can help with the transfer of knowledge, but improved DSS can also improve the costing of UD solutions. More accurate long-term maintenance cost estimates will avoid under (or over) budgeting of maintenance projects and reduces once again the risk factor that deters the implementation of SuDS. As pointed out in 3.6, it is possible to also reduce costs through more effective engagement of the local community and fostering collaboration at this level, which also would benefit from RI teams pushing the virtue of community custodianship of certain assets. Overall, this could lead to better allocation of funds towards projects that offer both environmental and economic returns.

In addition, one of the suggestions raised during discussions was that there also needs to be clearer benefits outlined for practitioners to incentivise them to come to RI facilities for investigation of the issues they may be facing and the development of novel solutions. There are currently restrictions on certain RI funding, mandating the involvement of industry partners, so there are increasing pressure and benefits for RI users to collaborate with industry. However, what are the levers encouraging industry to approach RI owners and users? For new or small-to-medium-enterprises (SME), start-up accelerators and incubators are available that can give funding towards pilot tests, which realistically can be also in conjunction with RI. SMEs do not usually have the budget for this scale of development and testing without collaboration and subsidies and the Co-UDlabs TAs, some of which are presented in A.2., have shown that there has been a strong interest from these small, agile companies. A big incentive for large enterprises is that RI offer specialised expertise that they do not possess in-house and the specialised test infrastructure that a lot of large enterprises will not have in-house. Whilst some large enterprises might have enough capital to invest in their own RI, the question is if that is what they want to do as it is often more economical for them to use existing RI specialists and structures to get the work done.

4.3.3. Promoting pilot projects and case studies

Research institutes are well positioned to promote pilot projects and case studies. There is a lack of confidence in innovative drainage techniques, resulting in a lack of implementation if they are not demonstrated at a pilot scale or do not have field-tested examples that stakeholders can use as references (3.7). The optimal situation would involve research institutes actively partnering with municipalities and private companies to design and implement pilot projects, using real-world scenarios (an example of how this could work is outlined in A2.3). To achieve this, users of RI should focus on obtaining funding and partnerships specifically for pilot scale projects and comparisons of technologies (as noted in 3.4). This would not only validate the effectiveness of new technologies, but also inspire further adoption.

These projects must be accessible for others to learn from. Events that could be further taken advantage of to showcase these field-scale application are Novatech or AquaUrbanica, or an event like these national levels could be developed at an EU level. Similarly, existing international conferences, which often move around within the EU region, often organise site visits to innovative sites within the local area could invite additional stakeholders, who are not attending the conference, to the visits. At the local level, stakeholders should be invited to visit demonstrations or existing installations to better understand the benefits.

4.3.4. Developing interdisciplinary education

Urban drainage is inherently interdisciplinary, requiring expertise from, but not limited to, engineering, environmental science, urban planning, and social sciences. Despite this, educational programmes often remain siloed, with limited inter- and multi-disciplinarity. The availability of RI can play a crucial role in developing this approach. A good approach would see universities and technical schools offering more programmes that integrate theory with practice across multiple disciplines, allowing future professionals to approach UD holistically. Research institutes can further collaborate with academia to develop interdisciplinary courses, promote joint degrees, and offer training workshops that combine engineering with sustainability, policy-making, and social impact considerations.

Ensuring that professionals in UD are exposed to the latest developments through interdisciplinary curricula and continuous professional development (CPD) opportunities can improve knowledge dissemination. An example of this is CIWEM[10] in the UK that offers CPD as part of its goal to keep its members up to date with the latest innovations. These sorts of opportunities could be partnered with local RI.

Encouraging partnerships between educational institutions and practitioners in the private sector could lead to more practical, hands-on learning experiences. This increased partnership between RI users and the private sector could lead to more practical internships and also to more higher-level industry focussed qualifications (such as the existing Thèse CIFRE in France, EngD in UK, industrial doctorates in the Netherlands).

4.3.5. Updating regulations in line with development

Reform can remove regulatory barriers and promote innovation. The regulatory framework governing UD systems often lags behind technological and scientific advances, which has a cascade effect on the slow uptake of “best” practice. RI experts can contribute to the debate on updating these regulations in line with the latest developments. Currently, regulations may fail to incentivise the adoption of sustainable technologies due to outdated standards or lack of evidence. Ideally, regulations would be dynamic and be able to adapt in line with the latest innovations while still maintaining public safety

[10] See A4.7 United Kingdom for a general overview on CIWEM

and environmental standards. RI teams can support this by participating in policy discussions, provide expert testimonies, and collaborate with regulatory bodies to review and update existing legislation. By organising forums, publishing position papers, and contributing to technical committees, RI users can help regulations to reflect the latest in scientific knowledge and best practices for urban drainage systems.

As highlighted in section 3.5, there is sometimes a gap between policy and the support provided to implement it. Sometimes, sufficient evidence is needed to have confidence that an innovation or practice is ready to be implemented into policy. At an EU level, which is known to promote science-based policy, there is a nexus between science, practice and the regulation/policy being written, but it is necessary to continue improving these links and promote the availability of RI for consultation. Co-UDlabs has contributed to the discussion by providing further knowledge in the JRAs, which targeted specific needs within the UD community, and there are also members involved at an EU level with the EWA research group (as mentioned in 2.3.3). This can be built upon by further promoting access to RI for policy makers, however, there still remains the challenge of determining the best method to encourage scientists to keep an open dialogue with policy makers and regulators.

5. Lessons learned and next steps

For Scientists

The researchers within Co-UdLabs have learned a great deal from working together at each other's IRs on the JRAs and TAs. The benefits run deeper than just sharing and listening to each other during meetings, they have learnt on the ground by being on-site and are able to better evaluate the differences between their approaches and the added value of their peer's work. The difference between their maternal languages is not a significant barrier, given scientists' culture of using English as a universal language. Even where technicians and local support staff that are in charge of the RI sites do not speak English, which could potentially pose a problem, they are supported by the scientists in a collective approach. Despite this, unless all parties have a very high level of English and are comfortable working in the language, the nuances are often lost when compared to discussion in their native language. These collaborations and the prospect of further networking between RI users as part of UDRAIN offer a great opportunity for European research in UD to become more competent and more robust. This group of scientists could then become a spokesperson for European structures and authorities and use various means of promotion and communication (as outlined in 4.3).

Working on a specific object and site is a strong, stimulating and unifying factor in developing multi- and trans-disciplinary thinking and research at the interface between research and management. Formalising a common problematic upstream of the research and ensuring that it is followed up by the various stakeholders helps to ensure that it is properly disseminated and appropriated. However, these multi-stakeholder approaches remain complex, often requiring multiple and relatively frequent meetings to learn to understand each other where relations are new. It is important that stakeholders listen to each other and share their needs in order to establish a framework of trust and genuine collaboration.

For the EU

The goal of this deliverable was to consider transition at an EU level; however, the foundation of the EU is the work being done within each country. Each country takes and interprets the EU directives and applies it at a local level to suit the local needs and local environment. It is at the local level that the action occurs. The focus has remained on an EU level as this level is deemed more suitable to take advantage of existing structures to progress towards transition and the transition is already being hampered by delays (see 4.3.5) so fast, short-term solutions are needed to get back on track. Despite this, it is important to factor in each country's way of working is more or less effective than their peers, so further development at a country level should be a long-term goal to bolster the foundation that supports EU action.

For Countries

Weaknesses at this level that need to be addressed to better develop the relationship between RI and other stakeholders and each country should actively consider adopting successful structures or strategies from their peers. This highlights the need to not lose sight of the work being carried out at a local level, where work is being done without the language barrier, so nuance is not lost, as it is an important element in making the science-management link. This is not incompatible with a contribution on a European scale, but rather nourishes this international level since this work can provide input for the scientists who will operate as a network. In addition, skills developed by scientists in RI to engage within their own country are always transferrable to engagement at the EU level.

Each county has a viewpoint that is different, even within the EU, as they are coming from different cultural backgrounds. It has been observed that even when researchers think they are working on the same topic with the same viewpoints, they do not always have the same approach due to these differences. These differences could be due to researchers not truly understand the problems faced by the people on the ground in the local environments, but it could also reflect that as each country has varying ecosystems and cultural priorities. Diversity in thought and in practice is an advantage for UD as two scenarios are rarely the same and it is difficult to copy-paste a solution from another project. This is reflected by there are often being multiple practices being derived in response to the same policy due to the varying local environments. This is not to say that each country is already working in the most efficient way and has perfectly adapted to the local ecosystem, it is still important to adopt favourite practices that have perhaps been pioneered elsewhere, but it would be foolish to think UD is a domain where one solution can fix all problems.

For Practitioners

It would be insightful to have further study on the way in which practitioners could feed back into the research systems at European level. As mentioned in the appendix A.4.2, the IWA and IAHR have national secretariats with associations (such as ASTEE in France). These networks could be further valorised by using them as a feedback route for the experiences and desirable developments at the local level. Similarly, encouraging practitioners to engage with RI experts and to feel comfortable enough to consider their local RI a “home-hub” for exchange could offer another avenue for practitioners to give feedback.

For Regulators

Another development could be to raise the awareness of regulators at national level so that they take a more prominent position in negotiations or changes to European regulations. It is important to acknowledge that those working on the ground have few resources and little appetite for lobbying at European level, and that it is important to rely on national intermediaries capable of maintaining a certain neutrality informed by joint research at the science/management interface. In addition to this, during investigation it also became apparent that there is not a lot of information available for how RI, at an institutional level, can engage further at a government and regulatory level as this work seems to be currently done by motivated individuals and is not a goal as such for the owner or users of the RI itself.

6. Summary

During the investigation to support effective UD systems transition at an EU level, clear themes have emerged in terms of RI needs for RI to support transition, what the desired future of RI could look like and potential actions available for this future state to be achieved. These steps to transition need to be encouraged to ensure that the whole system is robust.

Within the Co-UDlabs RI, members highlighted the need for flexible and futureproof RI assets and also using RI to support the application of circular economy concepts when considering the design and maintenance of assets. To further valorise RI, members felt that accessibility of RI is a key, and that stakeholders need to be better engaged and actively encourage to use RI. Dissemination was also identified as another important factor that could be improved and the expectations of funding bodies on the dissemination of research needs to better reflect the limitations of researchers, highlighting the need for dissemination experts. Information needs to better reach the level of industry and practitioners. Language is also a challenge for RI use despite there being a somewhat universal language of English between researchers, not all those involved in RI speak English and this is especially true for technicians. It was recognised that some steps towards disseminating in the native language has been taken in Co-UDlabs projects, but also the limitations recognised. Policy was also highlighted by Co-UDlabs members as having a complex relationship with the science that is driving it, with information not necessarily being applied well and creating difficult to implement restrictions that are not always in the best interest the environment. Future developments to RI including the recent establishment of UDRAIN, a JCUD working group on RI, and the potential to create a map or inventory of EU level UD RI.

Going forward, RI can be better exploited to maximise its impact on the transition to more sustainable UD systems. Specific actions could include the development of EU level specialists for transition in UD, the development of an EU level umbrella organisation to aid transition, and to establish EU specific conferences on the currently under-communicated, but important, themes of transition, maintenance, modelling and sensing. When considering the future state of a number of suggestions were made to strengthen collaboration between RI users and practice, how funding and incentives could remove barriers to transition, and how the increased presentation of pilot projects and case studies could increase confidence in sustainable solutions. To support this interdisciplinary education should be increased in its availability at both the level of initial training for students and also as CPD for existing professionals and there needs to be a real push for regulation to be in line with the latest scientific and engineering developments as policy is currently lagging behind.

The methods of transferring scientific knowledge into practice was explored and broken down into 3 steps to transitioning so that it is easier for RI to identify where in the chain their actions fall and where further future actions could be reinforced. One of the actions that is very important in implementing sustainable solutions is the ability to make the decision in the first place and whilst current DSS are much improved, to make them more effective there needs to be more research and data to support their development into the future. There are a number of existing organisational structures within the EU at both a European level and at a national level and these can be used to transfer knowledge across all levels. Current stakeholder involvement with RI is also an avenue to the implementation of sustainable solutions and RI teams have the opportunity to expand and further solidify these relationships. Policy can also be a vector of information transfer as demonstrated by engagement with European directives, but also gives rise to challenges as those who are making the policy are not always those who have the best knowledge. An often-underutilised avenue for transfer is via the public and engaging the public in meaningful ways can have significant benefits at a number of levels – a powerful option that should not be overlooked. How knowledge is presented and available can also be linked to compliance with policy or current best practice ideals and RI users can take advantage of all the options available to help facilitate transition. The valorisation of water was also briefly examined and how this has a cascade effect on skills availability, the capacity for transition and budgets, which stifle the transfer of knowledge is a limiting factor towards transition.

In the closing remarks, the need to consider how the national level interacts to the European level is also considered and how rapid short-term solutions will still need to be supported by long term development to ensure that the foundation, that is made up of individual.

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Appendices

A.1. Semi-Structured Interview Plan

Semi-structured Interview Plan

Objective: to collect data which will allow us to create a long-term plan which defines what part urban drainage research infrastructures play when helping the EU urban drainage community to transition to better (more sustainable and using smart technologies) urban water management practices

Introductory Questions

- What is your position in relation to the project that we will be talking about today? (project lead, delivering a workshop, laboratory technician etc.?)
- In your experience, using less than 10 words, what is the role of Research Infrastructure?

Research Case Study

1. **Context**
   - What was the title of this activity?
   - Who was involved in this activity?
   - What sort of data was generated as part of the collaboration at your Research Infrastructure?
2. **Experience**
   - How did you prepare for the activity?
   - What was done during the research activity?
   - Were there any follow up activities as a direct or indirect result of this activity?
   - How has this activity increased the development of better urban water management practices?
3. **Reflection**
   - Do you feel that this has created a partnership that could continue into the future? Provide evidence if necessary
   - In your opinion, how easily do you think this new knowledge could be transferred to end-users? And by what means?
   - What do you feel has been done well during the course of your presented research activity?

Dissemination Case Study

1. **Context**
   - What was the title of this activity?
   - Who was involved in this activity?
2. **Experience**
   - How did you prepare for the activity?
   - What type of information was transferred in this activity?
   - What was the target group?
   - Were there any follow up interactions of this activity?
   - How has this activity contributed to better urban water management practices?

3. **Reflection**
   - How do you feel about this as an effective method of transferring knowledge?
   - In your opinion, how easy is it to apply this new knowledge?
   - What do you feel has been done well during the course of the dissemination activity?

<u>Closing Questions</u>

- Are there any additional "needs" that have been identified during the course of either activity that you had not previously considered? Are there any missing infrastructure at your research facility?

- How can we improve communication between Research Infrastructures and other stakeholders in the Urban Drainage community?

- How can we deploy the improved communication ideas at an EU Level?

Thank the participants for taking the time to be interviewed

<u>Question Library (prompts or follow up questions)</u>

- How does Research Infrastructure help us move towards more sustainable drainage systems?
- How do Research Infrastructures help us move towards more "smart" sustainable drainage solutions?
- How has the research activity advanced the role of Research Infrastructures in the Urban Drainage community?
- How do you feel about this as an effective method of transferring knowledge?
- How had this activity increased the development of better urban water management practices?
- How has this activity improved the dissemination of better urban water management practices?
- Did the research activity achieve its technical output goal? What other outputs were there (teaching, seminars, publications)?
- Did your research activity help to establish new Urban Drainage system management techniques? How?
- How easily is this new knowledge transferred to end-users?
- How easy is it to apply this new knowledge?
- What actions have been taken to get good practice to be adopted?
- Are conferences effective in sharing methods, protocols, and good practice? Are there any better ways to transfer knowledge?
- What was the most effective method of sharing information and/ or new knowledge during the project?

- What do you think can be improved?
- What should we be doing in the future?
- What do we need to mobilise to make this happen? Have we already put in place new approaches to make this happen? (research, development of technology, training, teaching tools)
- What Research Infrastructures do we need to make this happen?
- Are there any Research Infrastructures we need to make changes to the approach we currently use when applying solutions to Urban Drainage Systems?
- How did the partnership allow for progression?
- What do we need to improve to take this to the next level?
- How can we deploy this at an EU Level?

A.2. Co-UDlabs Research Case Studies

A.2.1. Denmark, Aalborg Universitet – Hydrodynamic design of stormwater retention ponds

As part of the Joint Research Activities (JRA) Aalborg Universitet (AaU) led a project on the hydrodynamic design of stormwater retention ponds in collaboration with Universidade da Coruña (UDC). The goal of this project was to develop the understanding of hydrodynamics in such a way that it can be used to help improve the treatment of runoff water. In turn, this can allow for stormwater retention ponds to be designed, or existing ponds modified, to maximise their potential for water purification.

Data necessary for the design approach were generated by applying large scale particle image velocimetry (PIV) technology on a stormwater retention pond in Denmark alongside other sensors to measure water levels at the inlet, within the basin, as well as the flow through the facility. This collaboration started within the frame of Co-UDlabs. The main objective was to install cameras and perform surface velocity measurements in the retention pond in order to obtain useful data to calibrate a CFD model and optimize the operation of the installation. Preparations for the activity was done in online meetings. UDC focussed on how to transfer the "indoor" experimental set up out to the field for PIV measurements, a technique that UDC has considerable experience with. This is a common challenge when taking lab equipment into an "uncontrolled" environment. The system had to be modified to better function outside, which resulted in weather protection of the camera and a clear protocol of how it should be installed at the facility.

For the experiments themselves, an expert from UDC came to AaU, Denmark for installation and validation of the setup. One of the challenges of large-scale PIV is that the plastic particles that UDC uses to employ as tracers to be detected by the camera in a laboratory-scale setting cannot be used in a field setting because of their polluting character. Through the experiments, it was found that sawdust could be used as tracer particles, which improved the detection significantly when compared to not adding any particles. Several tests were performed where the surface velocities were measured for different working conditions of the facility and attending at the inflow and outflow area of the facility. Findings have been published on Zenodo in the frame of the Co-UDlabs project and conference abstract on applications of large-scale PIV have been presented at the JIA 2023 Spanish national conference.

AaU aims at future work on the use of the data collected to validate a CFD model to simulate the different operation conditions of the video. In addition to this, UDC is trying to obtain additional information from the videos recording to try monitor online e.g. the water level. It is intended that this joint work will lead to optimize the performance of the facility favouring sediment deposition and reducing the resuspension of particles when emptying, thus reducing the cost of maintaining the pond. This, with the detailed work carried out by AaU on the hydraulic behaviour of the retention pond and on the sediment characterization in terms of its particle size distribution, organic matter content and presence of heavy metals, will contribute to increase the knowledge about the performance of this kind of stormwater treatment solutions.

The partners involved enjoyed working with each other which can result in a sustainable collaboration beyond the scope of Co-UDlabs. Aalborg have also gained a lot of PIV experience as a result of the partnership, so they are interested in continuing using this technique in future. UDC's motivation was to gain more experience in the practical applications of the technology and how can it be deployed outside of the laboratory. All parties got relevant results and benefitted from the partnership. In addition, they consider future projects on this topic, with potential additional industry partners. A challenge that practitioners face is limited space to work in. Due to this constraint, it is important that they, the end user, should be part of developing the solution so that the new technology, when market-ready is practical to use.

A.2.2. France, INSA Lyon – The Urban Drainage Metrology Toolbox (UDMT)

As part of the JRA on "Smart sensing and monitoring in urban drainage" a user tool package was proposed which became the UDMT. At the start of the project all Co-UDlabs partners were asked what features they would like to see in this tool and this initial feedback contributed to about 10% of the ideas going into the tool and about 90% of what was developed was from the initiative of the core team working on this project. Whilst this project was led by INSA Lyon with involvement from Deltares.

An advantage for the project was that almost everyone in the core team knew each other before Co-UDlabs and had already collaborated. This meant that there was a level of trust already established and the team can work with a high level of autonomy as the skillset of each member is well defined and there is an understanding that each member will fulfil their obligations voluntarily. The goal was not to consciously create a group using previously known individuals, but in a small research domain creating a group with specific interests, it is likely that everyone is known to one another just because the candidate pool is so small.

The Toolbox has been developed from previous knowledge and used some pre-existing MATLAB codes which was then revised for creating the UDMT. A part of this was to ensure that the codes can be used with the same format of input-data, as well as improving the code to make it more automated and then an entirely new module was integrated to allow for different formulas to be input values at the user-interface rather than integrated in the code, which would limit the ease of use for the user.

The original WP description was to make the code available with a relatively light task of polishing and annotating the code. However, the WP description evolved to a tool that people can use, with an easy-to-use interface which is available on the web. Then feedback from municipalities and consulting companies indicated that they did not want to put their data on the internet, despite no back up being made. In addition, for security reasons, Greater Lyon has no internet at all on their computers that are dedicated to sewer monitoring, and this is why the downloadable version was created. This WP took a lot more time than originally planned due to the evolution of the tool, if we want to make it accessible to lots of people, it had to change from a list of code to a fully developed software tool with a user interface and online/offline options.

The preparation for this project was relatively easy as 3 of the collaborators had already published a book together on metrology in 2021 (Metrology in urban drainage: plug and Pray (2021) DOI: 10.2166/979178906119) and so was already finished during the start of the Co-UDlabs. The metrology book contains some useful code, but if you are not familiar with MATLAB then you cannot use it easily. Due to this, it was decided that it would be useful if it was available as an autonomous tool so that you do not need knowledge of MATLAB or to download MATLAB to use it.

To follow up, a number of activities were planned (2.5.2a) and the toolbox has been used in MSc courses, training courses and webinars. Participants find it interesting as it is often their first experience of "real" best practice of metrology being applied to real data. The main purpose of the tool is to help disseminate improved practice in metrology and if this can be achieved then that is a good first objective and the team can be happy if this is achieved. Researchers and operators need to be aware of how to work more seriously and rationally with metrology and if this group of people use it, then this is an improvement. However, what is being proposed is just routine work, the toolbox has limitations, for example it cannot save everything in a repository. The UDMT is a good teaching demo and incentive to do better. The code will be available on Zenodo at the end of Co-UDlabs for future users to improve and modify to better suit their needs if they wish to do so.

The impact of this work is the hope that practice will change if people are informed. Working to the UDMT guidelines requires more skills and professionalism compared to frequently observed practice[11] and exposure to the tool highlights to practitioners that they need to do more than what they did in the past. Monitoring is currently a box to tick after the data has been collected, but there are not enough people available to process the data. The observation that they need to do it better and they need to recruit people to work on this data with a higher skillset and movement in this direction must be encouraged.

A limitation is that it is possible to use the toolbox to apply the knowledge, but users need to be motivated and have time to do this. The observation is that people need to develop new skills in metrology, it is not the case of using existing skills and switching software. Most participants need to invest in the development of new skills and in the end, once this is applied, they have added value. An additional issue is that there is feedback from operators saying they have a lot of data, but they do not know what it means or how the system works.

Due to the lack of personnel, no one has time to work on this and when asked why they are collecting the data if they do not know what it means, the response is that the data is collected because it is required by the regulation. The issue is that the objective was not about providing good data, it was to provide a monthly report about self-monitoring. Progress is being made as there is now interest in knowing the content and quality of the data and this drives the need for more skilled people, more people in general and to be given the time to work on this topic. Exposure to the UMDT does not results in instantaneous change, it is a clear observation, there needs to be time given to support this transition.

Transfer of this knowledge from researchers to professionals may not be simple. A barrier here is that scientists often offer solutions to problems that practitioners are not aware of or that practitioners do not consider a top-priority. Research is often considered too far from the practice of professionals, so even if researchers advertise the tool, it is not always easy for the professionals to use this technology, in part due to a lack of trust and a lack of incentives (in regulations, funding etc.). The ideal would be to initially convince the few most advanced operators that this is the way forward, then this community of advanced operators, who already have a proven history of trust within the professional group, can then further disseminate this good practice amongst their colleagues. This is an "early adopters" approach in the innovation theory, but the next steps are not necessarily guaranteed.

[11] Consensus based on observations by a number of people within the UD community

A.2.3. Germany, IKT – Assessment of Inspection tools for Rising mains (AIR)

As part of the TA, IKT worked with Stichting RIONED[12] on the assessment of inspection tools for rising mains (pumped wastewater pipes), also known as the AIR project. This involved the comparison of methodologies for inspecting pressurised pipes (sewer or surface water pipe) for pumping liquid uphill, which is an area that is not very well understood because pressure sewers were not designed with their inspection in mind. Most pressurised systems are aging, and it is necessary to know the remaining pipe-wall thickness because when they fail suddenly it creates unforeseen pollution and results in a lot of disruption locally.

Overall, this project involved IKT, Stichting RIONED, the TA lead (an association for urban drainage in the Netherlands), 4 UK water companies (Wessex Water, Severn Trent Water, Yorkshire Water and United Utilities) who acted as the consulting user group and contributed ideas), a group of suppliers who tested their technologies (1 system from Acquaint, 1 system from ROSEN group, 2 systems from Xylem) and also the UK based Pipebots research project who are developing sewer robots. An inspection system from the University of Bristol and one from the University of Sheffield, which were developed as part of Pipebots, were assessed at IKT. Thus, a total of 6 systems were evaluated at the test setup in IKT´s Large Test Facility (IKT LTF).

The evaluation of the inspection techniques done during the AIR project is relevant for industry in general as pressurised pipe systems are a common asset for any owner at sites where water needs to be pumped up-hill.

This is the challenge that Stichting RIONED face, they would like to know the condition of their pipes and wanted to know what the options are. This project came about as there has been no comparative assessment of available technologies on the market (or soon to be coming to market) and IKT already has their large underground infrastructure test-facility available. The manufacturers of inspection technologies were invited to test their equipment on pipe with known defects with the goal of seeing how accurately the technology could assess the condition of the pipe so that it is possible to know if the pipe soon needs replacing. The current technologies are either run as tethered devices or flow through the pipe or are within a pipe cleaning pig.

The type and quality of the data depended on the technology being tested, however the key result of the project was to evaluate how well the technologies identify the damage within the pipe. The main challenge is getting the instruments into the pipes and this access issue meant that it was difficult to install equipment in the pipes and get the water pressure back up. This TA project acts as a pilot for a larger Stichting RIONED field project where they can assess the technologies in a live pressure sewer provided by one of their member municipalities in Arnhem, the Netherlands. A significant advantage of the TA project is that it identified issues that could be encountered in a live pressurised sewer.

In terms of preparation, IKT benefitted from Stichting RIONED already being aware of Co-UDlabs and being aware of IKT's RI from a previous project (comparing re-lining techniques (Bosseler, et al., 2022)). To prepare the RI for the AIR project, the large underground infrastructure test-facility as set up in a new configuration and it was necessary to design a new length of pipe which was large enough to

[12] Do not confuse: the Dutch Water association "Stichting RIONED" (https://www.riool.net/) was involved and not the Dutch company Rioned (https://www.rioned.com). These are different organisations.

accommodate the bigger technologies being tested. There was some language barrier, but this was managed due to the number of enough bilingual speakers available to facilitate the project.

The large underground infrastructure test-facility was originally offered as the test-pit only, but due to the previous sewer-lining project, there was already a suitable set of pumps etc already installed in the test pit, so this was also offered as part of the TA. The experimental set-up for the AIR project was also used in parallel with a water hammer TA project. This ability to take advantage of previous installations, with small modifications, also helps to make research more efficient and economical. In addition, if ever repeat experiments were needed it is possible to reconstruct the system in the same configuration as all the component parts for the experimental set-up are stored at the IKT laboratory.

A typical day would involve a technology supplier installing their equipment over 1-3 days and using it in the pipes whilst the IKT laboratory engineers managed the hydraulic conditions for the tech suppliers. The distribution of labour, with IKT managing the conditions and the visitors collecting data worked well and the data was shared with IKT afterwards. One of the most time intensive aspects was the installation of the equipment in the pipe. Once installed, there were test trials to get the equipment functioning as intended. Using these results, a methodology for each technology was developed so that anyone using the technology would follow the same procedure and also have troubleshooting suggestions available to have a swift resolution of predictable issues should they be encountered in the field.

The AIR project can contribute to better urban water management practices because it is the first step in what will lead to significant future development. There is currently no single technology that can inspect pipes and give asset holders all the information that they need. Due to everyone facing the same issues when approaching pressurised pipe inspection, there is a lot of interest globally. Currently, multiple technologies are needed to inspect pressurised pipes well, but looking to the future, users would like the technology to advance to the point where only one piece of equipment is needed. By providing data which contributes to understanding of the capabilities and the limitations of the leading technologies on offer, the AIR project allows users to decide which option is most suitable for whatever sort of issue they are facing.

Although IKT are not directly involved in the future Stichting RIONED field project to test the technologies in a live pressure sewer in Arnhem, they will be updated by Stichting RIONED with the results of this study. Stichting RIONED had previously hoped to run tests within a partner municipality's pressure sewer in the past, but it had fallen through due to lack of available data on the technologies being proposed and unknown technologies pose a risk to the municipality's assets. The new evidence from the AIR project gave enough supporting evidence of the use of these technologies that the perceived risk was mitigated and made it possible to find a new site to run field tests.

Stichting RIONED will continue collaboration with the TA technology suppliers and will continue to work with IKT on other projects. IKT had a working relationship with Stichting RIONED and the other UK water companies prior to Co-UDlabs but had not worked with the Pipebots project or the inspection technology companies. Pressure sewer related technologies are a pertinent subject so the new contacts made during the TA would be anticipated to continue their collaboration as this line of research has lots of opportunities in the future.

How applied these technologies end up being depends on dissemination techniques, but as methodologies have been well described, it should be fairly easy to practically apply the techniques researched and described in the TA study. Stichting RIONED have a good reputation which means that anything they publish is well respected by other water associations around the world. This is important for getting technology implemented as the information provided needs to come from a trusted source. An example of this thought process would be the water hammer project. The relining technology protocol established during the project was so good that this is now going to be Aquafins standard protocol for this procedure and as they are globally respected and well known it is likely that this protocol will be adopted by other companies. Harmonisation of standards leads to improved transfer of knowledge and better understanding.

The current dissemination techniques have mainly been word of mouth and via events communications. This is mainly because Stichting RIONED will wait until after the field project is complete before widely disseminating results as the field tests bring a high level of credibility to the TA pilot test results. IKT will be promoting the results of the TA with Co-UDlabs and as the nature of Co-UDlabs means that no data withheld it helps to overcome a big potential barrier as innovation can be withheld from competitors for commercial interest and this prevents dissemination. The technologies are commercially available, apart from those tested by Pipebots, so it is ready to use, therefore there is not any barrier to others using the technologies.

Overall, the TA structure was a success. The documentation on how to be involved in a Co-UDlabs project was thorough and made it relatively easy to find interested partners. The TA developed good relationships with the participants which helped facilitate progress within the project and there was good organisation. There was some challenge in negotiating schedules due to the number of participants collaborating within the laboratory space, but this was not an unexpected difficulty. The project boundaries were well defined by Co-UDlabs so there was no misunderstanding as to what the outcomes of the project was to be, so there was no dissatisfaction that a collaborator's needs were not met.

A.2.4. Spain, Universidade da Coruña – Evaluation of new flow and quality monitoring devices for sewers

The BENS flume facility at UDC was used for one of the Transnational Access (TA) of the Co-UDlabs project. UDC worked with two small-to-medium-enterprises (SME), Ubertone and Photrack who are interested in taking their technology to market, and one university, the Technical University of Cartagena (UPCT), on a partially remote project on the evaluation of new flow and quality devices for sewers. The Photrack cameras are ones that are currently being used in riverain environments, and the Ubertone velocut profilers are used in laboratories and industry, however it is to be determined if the devices are applicable or easily transferrable to the sewer environment.

Before the tests were to start, there was a preparation phase to help the partners draft the proposal and the original CFD modeller was involved at this stage. However, this is a weakness of remote teams as this the original CFD modeller left after the proposal had been accepted, leaving a knowledge gap within the team which was then filled by Photrack. Finally, there were 3 different technologies being tested: an image-based non-contact device to look at surface velocities, an ultrasonic velocity profiler and a "homemade" low-cost spectrophotometer. The use of the first two devices to look at water pollution parameters were also investigated. The spectrophotometer has an IPR protection as they are hoping to exploit the equipment and are currently working with a Spanish WWTP. The equipment had only been tested in the lab prior to being used in the BENS facility and it is these large-scale RI tests that allow for end users to have confidence in the technology. These devices have a commercial status (or are nearly there), so being able to show that they work in the wastewater environment allows for the future users to have confidence in this. The SME are testing the feasibility of that transfer and validating and optimising an already developed technique to sewer pipes.

The preparation for the practical side of the project, to install the equipment being assessed, took around 1 week and was done by the SME and UPCT in collaboration with UDC. After this, there was a series of tests where the devices were tested for different flow conditions changing wastewater flow discharge, slope and the downwards boundary condition, which allows for limitations of the equipment to be identified, and this can then be improved upon before the product gets to market. The practical experiments took 3 months involving UDC personnel and a student from Ubertone who worked at UDC's BENS flume facility for 2 weeks. The BENS system is not the easiest system to work with due to it being inside a wastewater treatment plant which is a difficult working environment, so some anticipated issues with the electronics at the facility stopped experiments for about 2 weeks and resulted in pushing back the end of the experiments one month. However, the experimental plan was successfully completed and the TA group members started to work on the data collected.

Two months after the testing was finished there was a full team meeting with UDC, the two SME's and TUC to share the results and find synergies. Photrack, with depths and flow discharge data from UDC and velocity profiles from Ubertone, is developing a new model to estimate flows from their surface velocities robust for the several flow conditions tested. Ubertone is using the data collected to improve their processing tools and develop the use of the profiler also for estimate turbidity through the echo of the acoustic signal. UPCT has trained and validated model to estimate water quality through the obtained dataset. The preliminary results were presented at the International Conference on Urban Drainage (ICUD 2024). Further work on the data collected is running at its own pace since companies day-to-day prevents them from dedicating the necessary time to it, although they consider these activities are very important and interesting for their mid- long-term development. This fruitful collaboration between researchers and several companies was considered to be a really interesting experience within the Co-UDlabs environment and aligned with its main objectives.

A.2.5. Switzerland, EAWAG – Improving understanding of sewer pollution by hyperspectral imaging

This project started with a JRA, which led to a TA which in turn resulted in an R&D project by Photrack AG (~500k EUR) and collaborative research being taken up with SUEZ in France. Good non-contact water quality monitoring to measure water quality in raw wastewater is a goal for many practitioners. Traditional contact sensors, whilst very good when they work, have numerous weaknesses such as susceptibility to fouling, clogging, drift and build-up which results in a high level of maintenance being required and these issues would be eliminated or vastly reduced if the sensor did not need to be in contact with the water. An additional challenge is that sewers or the inflow to WWTPs often have no power and most technologies need to be powered. The two options to monitor water quality are by using ion selective electrodes like pH electrodes or lab spectrometers modified by companies for use in the sewer, which is quite a basic technology. The company s::can have a submerged spectrometer, aka the Spectro::lyser, which has pressurised air cleaning, but it is still in the water and thus require a lot of maintenance. Ultrasonic level monitors are not in contact with the water so do not need this.

Developing this technology creates improvement in water management practices by allowing for monitoring water levels, water flows and water quality data to be collected with a high data quality. With this it is thus possible prioritise rehabilitation measures and better assess pollutant loads into the environment. There is currently very little information as to what comes out of a stormwater system as it is intermittent discharges and this is very difficult to even monitor the turbidity of the water because the sensor is often dry then wet, it is exposed to insects and dirt and results in a poorly calibrated sensor. Primarily, non-contact sensors help with the monitoring of systems, and secondarily, it is possible to do better full-scale experiments which in turn help improve existing models.

There was a push for non-contact water quality monitoring 20 years ago, but the technology was not accessible at this time. Satellite cameras used to be prohibitively expensive, so this restricted further development, however, now hardware is affordable opening up new opportunities. It was also possible to use the data that was collected 20 years ago as there was a paper, but it was difficult to get hold of the original data and code. In addition, there was no meta data so the information that was available was not well described.

For the JRA (WP6.1) part of this project there was a PhD student, and 2 researchers from INSA; one who provided general support, and a second who was involved due to being very experienced with s::can. The second researcher from INSA provided the training on the Spectro::lyser probes and the experimental design was done by EAWAG with the help of the headwall company who sold them the equipment. This company provided the first camera, the idea came from EAWAG and INSA helped with the initial experiment. These initial results with the PhD student were good and presented at conferences and allowed for enough interest to be generated to create a consortium to submit a TA proposal. This first dataset was lab measurements and is included in a publication.

The TA was submitted by Czech Technical University in Prague. EAWAG supported the application and knew the university prior to Co-UDlabs as they had collaborated with several projects before. Importantly the university also had experience with s::can. In addition to the university, there was a hardware manufacturer involved (headwall company), Geoconcept - the reseller of this technology in Europe (geomatics company, sells drones); Photrack AG, a spin-off from ETH Zurich who use cameras to monitor flows – this project could extend the range of products that they are offering; the German consultant engineering company Dr. Pecher AG, who are using s::can probes in their stormwater-related projects and want to reduce the amount of maintenance required; and the Technical University in Graz was also involved, who have similar expertise to INSA.

Getting the group together for the TA required some work but because the contacts were within the existing network it was more efficient than working with complete unknowns. The end group had a good composition as it has researchers, manufacturers, and users of the technology. Users can help guide the direction of the research (e.g. In terms of how precise the measurements need to be) and the spin off from ETH has a vision of where they want to take their cameras in future. New partners were the headwall company (not part of the UD community); Geoconcept, which is also new; and though the EAWAG Co-UDlabs researchers had not previously worked directly with Photrack AG they knew of them via office colleagues who had collaborated with them before. As the first 2 new partners were not part of the EAWAG Co-UDlabs researchers' network, the contact was made via an optical research hub in Switzerland CSEM who were contacted with the request that EAWAG was looking for a partner to work with on non-contact water quality sensing/ optics and who would they recommended as having the required experience.

Due to the nature of the group, there were not had too many user group meetings as there was the trust already established that the data collection would be done well. Catch ups were done when people were passing through the area or when the TA group were all at the same conference. There were 2-3 online meetings to share progress and data analysis is ongoing.

The additional funds from the TA allowed for tests to be done on live flowing wastewater in the RI and the TA dataset is now being published. This involved a flume experiment with 500 through-samples and lots of absorbance spectra from the Spectro::lyser probes, data from the electrode, catchment information and dynamic mobility information. As the PhD experiments had already been done, it meant that the protocol was established already, making the TA more efficient and it meant that there was labour in place. The PhD student from the JRA was doing most of the on-site work so there was minimal need for extra communication for the internal regulations of using the RI. The TA produced a second dataset which is in process of being published.

SUEZ and the PhD student from the JRA then made a side project (they are both French, so this was fairly easy as there is no language barrier) at SUEZ's experimental research centre near Versailles and EAWAG helped them to set up their own tests (outside of Co-UDlabs). This interest from important stakeholders such as SUEZ shows that the question is relevant, and that the solution currently being investigated is relevant. As a result of the trial done in the TA it was possible to then get an R&D research grant from the Swiss Government (innosuisse funding program) to progress the commercialisation of the technology.

There was a small challenge due to people coming to the labs from outside of the EAWAG collaboration circle as they are more used to collaborating with closer contacts e.g. a lead UDC member within Co-UDlabs did an internship in Switzerland which then facilitated the Co-UDlabs project development, and they have now got about 10 years of collaboration together and publishing papers together so already have that level of trust established. When working with existing contacts, there is the confidence that these people can be invited to come to the lab and trusted do things according to protocol. This may sound small, but there is a build-up of experience such as knowing how to consult with technicians for training or knowing how the facility runs which gives an advantage to collaborators that have been there before which makes getting projects underway more efficient. The big hold up was caused more from the legal side, with legal team at EAWAG not understanding why the EU would give money to Switzerland (which is not part of the EU), and also, when working with unknowns you would want a lot of information in great detail and in writing – so much paperwork is not always needed if the relationship established. EAWAG does not tend to do a lot of contractual experiments, so they do not have the overhead/ infrastructure in place to deal with the legal side as easily as a venue such as Sheffield, who have a lot of capacity for contractual work.

When considering whether this technology will be easy to apply, potential customers will not be used to this as it is a new technology and do not necessarily know how best to apply a water quality sensor. There are sometimes unforeseen challenges as e.g. a UV light in the equipment is dangerous for the eyes so the equipment needs to be installed in such a way that work safety measures are always adhered to. If the sensor is submerged, there is no risk, but if the sensor is open to the air it could pose a risk. If the product is developed successfully then it should be relatively easy to install in existing systems. In terms of maintenance and sensitivity, ion electrodes are not particularly useful on an absolute scale due to drift and membrane fouling so are not particularly precise when measuring unless regularly calibrated and cleaned (Pedersen, Larsen, Thirsing, & Vezzaro, 2020). However, even when not measing the actual value, they can still show the rise and fall of ammonia as measurement degradation is over a long period of time so you can see when the peak is passing through the WWTP as this is over a relatively short time period, so this can be used for control.

When considering channels of dissemination, the spin-off Photrack, who would then work towards commercialising the technology, would also be sharing the results at industry conferences, articles on LinkedIn and other publications. There would also be information in the form of international IP and patents.

A.2.6. The Netherlands, Deltares – Advanced methods for the characterisation and monitoring of sediments in gully pots

This project is a JRA based at Deltares with the collaboration of UDC on the development of advanced methods for the characterisation and monitoring of sediments in gully pots as part of a broader project on the development of monitoring tools based on temperature sensors and heat transfer analysis to estimate sediment build-up processes in urban drainage systems. The precursor to this project involved researchers from UDC and EAWAG, who performed laboratory-scale measurements on the heat transfer processes of sediments reproducing temperature conditions in combined sewer pipes. In addition, the analysis of heat transfer processes in sewers was followed by a Transnational Access project at Sheffield (2.7a).

As a result of the first tests, a monitoring system and a simplified heat transfer model was developed to measure sediment accumulation. The initial methodology was developed for sewer pipes, but the results of the first campaigns indicated the potential application in other urban drainage systems. The application of this methodology to gully pots was studied in the context of the JRA at Deltares. Gully pots are transitional infrastructures between surface runoff flows and the drainage pipes which, at the same time, act as sand traps. Thus, sediment loads in drainage pipes could be reduced during rainfall, avoiding overloading the treatment systems located downstream.

Three experimental campaigns were carried out to understand the heat transfer processes and to apply the temperature-based system to gully pots, including experiments in a 1:1 gully pot model at the research facilities of Deltares and field measurements in the South Holland area (The Hague, Delft and Rotterdam). For the installation of the measuring equipment in the field, the researchers had the collaboration of the company vandervalk+degroot (Poeldijk, Netherlands), responsible for the cleaning of gully pots in The Hague (Netherlands), and the municipality of Rotterdam (Netherlands). The feedback received for the development of the proposed idea was positive by both entities, with which Deltares keeps a continuous communication.

In addition to the temperature-based system, new ideas for the development of monitoring systems and characterization of solids in urban drainage systems emerged during the JRA at Deltares. On the one hand, the development of a TDR (Time Domain Reflectrometry) system was promoted to measure the thickness of the grease generated on the surface of pumping stations. The TDR system consists in an active electromagnetic wave that allows the identification of interfaces between materials by changes in their properties. On the other hand, a research project was initiated to investigate the transport of plastics and urban waste through gully pots. The experimental work was conducted in the same gully pot model at Deltares research facilities and formed part of a Master of Science thesis, which was supervised by researchers from Deltares, UDC and professors from the Institute for Water Education (Delft, Netherlands).

As remarkable results of the JRA at Deltares in terms of scientific production, an article has been published in a scientific journal (Regueiro-Picalloa, Moreno-Rodenas, Clemens-Meyer, & Rieckermann, 2024), as well as the data set of the laboratory tests and field measurements (Regueiro-Picallo, Moreno-Rodenas, & Clemens-Meyer, Measuring heat transfer processes in gully pots for real-time estimation of accumulated sediment depths, 2024) and finally the results have been disseminated in several conferences: Novatech (3-7 July 2023) and JIA (23 and 24 October 2023).

A.2.7. United Kingdom, University of Sheffield - Temperature time series analysis for predicting sedimentation in sewer systems[13]

For this TA there was a user group and a researcher from UDC and 2 project leads in Sheffield, who made sure the annular flume was ready to use and ensuring that the technical staff were available. For this project, a new high resolution temperature measuring system was built. This ended up going overbudget, but the remaining funds were transferred from a different project. The bonus of this investment is that even with the extra costs, the data quality far exceeded what was anticipated. This is a part 2 of an experiment that was done using a non-moving bench-top set up at EAWAG and the goal here was to transfer the principles to allow for sedimentation to be predicted in flowing sewers. There was then a further experiment at Deltares in gully pots (2.3.6).

The user group comprised of 2 European water boards and researchers from Lulea Technical University and TU Delft were involved with the planning of the project and the UDC researcher disseminated the results to them at the end of the TA. There is no immediate funding to apply the technology, but they are enthusiastic to know that the technology is there. Funding to advance innovative technology to get the technology implemented is lacking and this is a limitation for nascent technologies with potential. There at one point was potential to partner with a city council in the Netherlands to work on implementation of the technology, however the opportunity could not be taken as the technology is not yet commercially available, thus it needs a researcher to implement it in the field and there was no research project funding for this. Further funding needs to be found quickly and easily so that these opportunities for implementation are not lost.

There was a significant amount of training for health and safety required for working at Sheffield and experiments would not be allowed to proceed unless risk assessments were filled out in sufficient detail. During busy periods it can take some time to get the risk assessments and COSH forms completed so this should be done well in advance of the allocated experimental time for risk of getting the initial submission refused. Technicians were also a key part of getting the instrumentation installed and the initial tests to ensure that the equipment was working as intended. Due to time being spent

[13] The University of Sheffield presented 2 research-based case studies (2.7a and 2.7b) as at time of writing they had not yet led a dissemination activity.

on this preparatory work, the instrumentation was done very well, and merited the extra time taken to do so as it gave very good data as a result. The system turned out to be very reliable and all the TA contributors were happy with the data produced.

The hope is that with further development that this technology can lead to a change in management practices. Using temperature works well as an analogue for sediment build up and this in turn allows for cleaning campaigns to be better organised. With better maintenance of the system, it is possible to better manage blockage risk, pollutant build up and flood risk. If the technology is installed in locations deemed to be “high risk” then this is also means that maintenance not triggered unnecessarily. It is difficult to get sediment build up data and this technology can potentially be used to better understand the transport and accumulation of sediment and pollutant. This information would allow for mass balances to be done, which can be key when determining the fate of sediment and pollution.

There is potential for future work with the TA team depending on funding. Practicalities are sometimes a barrier to continuing collaboration. As good a technology is in principle, often technology is blocked by the question “is this easy to apply?” No power is a general problem in sewers, and it prevents a lot of promising technologies from being further developed. Lack of power is an issue for more complex monitoring systems which cannot always be powered from a battery unit and also equipment requires ATEX (European Commission, 2013) certification, as of 1994 in Europe, to be permitted in the sewer. In addition, durability of the equipment could also be an issue.

A limitation of the user group within the TA was identified as it is a challenge to get everyone’s signatures to proceed to the next stage. Due to this, the TA did not involve every potentially interested partner as more people involved creates more complexity. This results in more delays so a potential solution would be to give more flexibility of the user group, which would allow for more people to be involved. Another limitation of Sheffield is that the administration system is very slow, and it makes it difficult to add people to the access card system to gain access to the university and laboratory spaces these are essential to unlock doors in many laboratory spaces.

Due to the success of the project, there was a journal paper (Regueiro-Picallo, et al., 2024), a data storage report was made, and the presentation at the ICUD conference 2024 was shortlisted for the Poul Harremoës Award. The next steps for this research would be to apply for innovation funding which would lower the financial risk for a potential developer. It is necessary to further develop this technology to get initial uptake and allow for field tests to be done to give the technology credibility. With field tests and a reputable developer associated with the technology then the technology is ready for a practitioner conference, which is an effective way of disseminating new technologies to practitioners.

A.2.8. United Kingdom, University of Sheffield - Annular Flume studies to test the effect on antibiotic resistant genes and use of CRISPR-Cas in E. coli from sediments affected by sewage pollution

The annular flume facility at Sheffield was also used for another TA led by Universitat Politècnica of Catalunya (UPC) in Spain investigating the effect of hydrological events on the presence of antibiotic resistance bacteria in rivers affected by faecal pollution. Whilst in the domain of urban drainage, this project has a heavy microbiological and genetic focus.

This project had a 2-phase experiment, with part involving the annular flume and part in a bio-laboratory. The annular flume was involved determining if antibiotic resistant bacteria could be transferred between biofilms attached to sediments and river water. Biofilms were developed in the annular flume using water from a local river, and then the presence of the antibiotic-resistant bacteria was characterised in both the water and the sediment at varying levels of shear stress. The bio-laboratory tests involved the evaluation of CRISPR-Cas, a technique for editing genetic material, as a tool to control antimicrobial resistance in freshwater environments. T The studies conducted in the annular flume provided valuable insights into the environmental and health impacts of antibiotic-resistant bacteria spreading in aquatic environments due to hydrological disturbances. Moreover, the research generated crucial data for developing a CRISPR/Cas9-based strategy to effectively target and cleave the CTX-M-1 gene, with the goal of restoring antibiotic susceptibility in ESBL-producing bacteria.

An advantage for this project is that both the lead staff member at Sheffield and the researcher from UPC are Spanish speakers which facilitated communication and the support given by Sheffield for the proposal and also to ensure good communications with technical support on-site.

Preparation for the experiments involved proposal writing, a significant risk assessment and submission of COSHH forms and there was also some level of inter-departmental collaboration required as the Civil & Structural Engineering Department (CIV) provided specialist technical support and the facility being used is managed by the Chemical & Biological Engineering Department (CBE). Whilst this is not insurmountable, the equipment is shared and is used regularly by CIV, the two departments operate on different security systems (so need to be added to the access list for card access to laboratories) and also have different health and safety protocols to adhere to which creates additional barriers as CIV staff members are not as used to working under CBE conditions. Overall coordination was done well between the departments within the university.

The goal would be to do follow up experiments, but this needs additional funding. Molecular biology experiments are very expensive, much more expensive than e.g. COD test kits. Whilst CRISPR-Cas is one of the most efficient and cost-effective gene editing tools, it is still very expensive when compared to basic biochemical testing. There is lots of potential for future work and there is now proof of concept for this work. Although there was enough data to do a conference abstract, with more experiments it would be possible to write a quality paper, but a paper would need repeats of the experiment to show it is replicable as it was only possible to run the experiment once due to the time and budgetary constraints. Potential barriers to continued collaboration is that CRISPR-Cas is expensive and whilst it is easy to do experiments in a controlled lab environment, the real world has a lot more variability. There is still the question of how easy this technology will be transferred to field applications.

During the TA there was high expectations regarding what could be done in 3 months and the workload was very intense. More time and funding are needed to do it properly, but there are already ideas for the next steps if the opportunity arises. The contacts at UPC were pre-existing, but there had never had the opportunity to work together until this TA and due to the success of the collaboration there is a keen interest to further collaborate if funding is secured. To continue, this project will need to get some serious funding to continue, likely at a European level, so the next step is to write proposals.

A problem with this project was that they were quite ambitious, and the proposal demanded too much work within the time demanded. Although it was possible to manage the workload enough to get the experiments completed, it was a very intense period and not at all sustainable to work at this level beyond the short term. When reflecting on the work, the researchers felt that they would have been better to reduce the number of antibiotic tests and to cut some of the genetic work to make the workload more manageable. When writing the proposal for the anticipated next phase of this project, the research will be done on a larger scale, but also be planned to be done in a more manageable and sustainable way.

As already highlighted, there is a difference between the Health & Safety requirements within the CIV and CBE departments at the university, but what was more pronounced is that there are some cultural differences between the two countries. The UK has a lot of safety risk assessment whereas this is much less intensive and time consuming in most Spanish speaking countries such as Spain or Colombia. It can be a challenge to explain the different paperwork required to permit a research project to go ahead in the UK. RI teams need to be able to give more support to countries with different safety infrastructures and be aware of the challenges this may pose to visiting researchers.

Communication of this issue could also be challenging as there is the impression that water utilities do not want to know about what they perceive to be new problems as they already have a lot of problems to solve. Unusual research such as this TA can be viewed as a new problem rather than a new solution. A different outlook or change in attitude is needed to take advantage of this information as large corporations often assume that no knowledge of a solution/problem means no responsibility if left unchallenged. Utilities are very cost motivated a way for research to attract their attention would be if the research could be translated into “cost savings.” A drawback of this approach is that scientists do not always have the experience or expertise in translating research into this sort of information and are not confident in giving cost evaluations. This represents a gap between researchers and their ability to present this as useful, relatable information for the utilities.

Stakeholders need to know that the rivers are contaminated. CRISPR-Cas is a rapidly developing and is being used in lots of different fields due to how flexible and adaptable it is. This technology could in future be used to help stop antibiotic resistance spreading in the environment, but it may be a case of having to wait a while also as time goes on this technology becomes cheaper and, thus, more accessible. The issue is that this is a time sensitive issue if the spread is to be remediated. During the test there were a lot of disease-causing bacteria and antibiotic-resistant bacteria identified in the samples. The samples were not taken from a site that was anticipated to have high contamination levels as it was a recreational site used as a reserve for salmon. Evidently this site is being contaminated and something needs to be done about the way the local infrastructure is managed. To engage the stakeholders, scientists need a specialist to transfer the knowledge.

There is lots of interest from Spain with the knowledge being generated in the UK as they often face the very same problems, however they are not aware of a lot of the work being done in the UK. This could be in part due to not all Spanish speakers using English, but this also highlights the importance of face-to-face dissemination, in the case of this project being between 2 Spanish speakers, but also highlights the importance of researcher mobility in transferring information to and from different RI. However, for more widespread dissemination, there needs to be information dissemination representatives for each country who are part of a working group or who can transfer information more efficiently between countries.

A.3. Co-UDlabs Dissemination Case Studies

All dissemination and training activities were done in English unless otherwise specified

A.3.1. Denmark, Aalborg Universitet – Presentation on Fourier Transform IR spectroscopy (ftr) chemical mapping, online webinar

Aalborg Universitet (AaU) organised an online webinar on the subject of "Fourier transform IR spectroscopy (ftr) chemical mapping" which was planned in the context of Co-UDlabs and presented in English. Aalborg was the only Co-UDlabs member involved in the planning and execution of the webinar, though it was advertised using Co-UDlabs channels with help from Euronovia. To prepare for the workshop it was necessary to arrange these practical aspects.

There was no one specific target audience, but it was made clear that the presentation was focusing on the application of the ftr technique for analysing and detecting microplastics, so focussed on the microplastics community. The 22 participants were mostly researchers, but also there were practitioners in attendance. During the discussion session, there was significant knowledge sharing and after the presentation there was some contact from audience members via email on the subject.

The information being presented provided a technical background for the methods but also experiences with sample preparation and taking samples from the environment. The main challenge is normally separating the plastic from the environmental matrix, which itself is also dependent on the environment the sample was taken from, and experiments on how to do this were also presented.

Presentations such as this are considered to be a fairly effective way of transferring knowledge, which is why it is a persistent dissemination tool. Within Co-UDlabs there is not a big focus on microplastics, but it still provides good context to this knowledge sharing and is a common platform for providing these types of activities.

This is an emerging topic so it is yet unknown how significantly dissemination of this information could contribute to better urban water management practices. What is clear is that there are lots of developments in parallel in different research environments and there is a need to get some alignment of the methods used. All these different branches need to agree on what a good method is and to do this, good communication with other researchers and RI users during method development is a vital step.

When considering how easy the information presented in the webinar is to apply it is not technically easy to run these experiments as it requires specialised equipment and knowledge, and there are a number of difficulties that can be encountered. However, it is relatively easy to access this knowledge and also learn how others are doing similar experiments. The key benefit here would be that the knowledge sharing itself facilitates the alignment of methods.

The event was a success as it gathered this specialised community together, the people were engaged and were eager to discuss the subject. Engagement was high as some audience members knew each other. Also, as it is a specialist topic, it is easy to discuss as everyone has specialist knowledge and assumptions can be made as to what needs explaining or not. Both these factors boost engagement as it allows members to be comfortable and confident asking questions, whereas uncomfortable or unconfident audience members often stay quiet.

A.3.2. France, INSA Lyon – Training and Dissemination of the UDMT, Europe

As part of the JRA, INSA developed the Urban Drainage Metrology Toolbox (UDMT) (A2.2 France, INSA Lyon – The Urban Drainage Metrology Toolbox (UDMT)) which then underwent significant dissemination (Table 1). Training opportunities were organised. The target groups for dissemination were:

- Students, as there is usually a trend with early adopters, they tend to continue in this direction.
- Researchers, because many papers are published without proper description in the method to describe which sensors are used, how they are used, how they are calibrated.
- Practitioners, from cities, companies, water boards and consultancies as they currently do not do these types of analyses but would need to in future if regulations became more stringent.

The workshops involved members from Deltares and GRAIE, who were active in the organisation of the INSA led dissemination activities. There was also UDC led dissemination (). Short online events are good to raises awareness, but this is difficult to evaluate the consequences of these sorts of events as there is little meaningful contact as a result. Covid created a boom for online events, this online trend has continued as they are convenient and cheap. Researchers at INSA do not think that webinars are necessarily the most effective tool to do anything beyond raising awareness, so for a deeper and more durable level of dissemination, other methods must be considered.

Table 22. UDMT Dissemination Events

Type	Event	Leader	Dates	Location
Workshop	UDMT - Urban Drainage Metrology Toolbox (@ 2022 SPN10)	INSA	23/08/2022	Graz, Austria
Training	25th EJSW - European Junior Scientists Workshop on "Monitoring urban drainage systems and rivers"	INSA	15-21/05/2022	St Maurice en Valgodemar, France
Webinar	UDMT toolbox: Routine Uncertainty Assessment	INSA	12/06/2023	Online with GRAIE facilitation
Training	UDMT training course	GRAIE	10/10/2023	Lyon, France
Training	UDMT training workshop	UDC	17/10/2023	Cartagena, Spain
Training	Industrial and water professional workshop on Uncertainty Assessment in UD monitoring data	INSA	6-7/03/2024	Lyon, France
Training	25th EJSW - European Junior Scientists Workshop on "Monitoring urban drainage systems and rivers"	Deltares INSA	26/05-01/06/2024	St Maurice en Valgodemar, France
Training	Applied Course on Urban Drainage Metrology	UDC	6-19/07/2024	A Coruña, Spain
Webinar	Routine data validation in urban drainage, examples of application with UDMT	INSA	10/01/2025	Online with GRAIE facilitation

To INSA, the toolbox is a vector to transmit the key point that the water sector need do metrology in a much better way. Metrology as a real skill is ignored by most people in the water sector and the available education in this field is limited for UD applications. Changes in practice are slow to implement and the tool is there to help people go further in the right direction. Once people have been convinced to go further in urban metrology, they still need to elaborate an action plan to create an environment where the UDMT principles can be used. This requires a big change in attitudes and will be a long-term process which could be further motivated if policy in the water sector reflected what has been shown to be best practice in other domains.

To better engage audiences, it was necessary to adapt the case studies presented depending on the sort of audience that it was being presented to. There are now a number of iterations available to suit various audiences. This likely represents a lot of the continuing work as case study examples demonstrates that the toolbox can be applied to many different scenarios and if you can provide examples relevant to their own practice then the practice is more likely to be adopted as it is considered useful.

The additional contact after the INSA delivered workshops was low, but this is potentially as they did not ask for feedback or prompt for further contact. Next questions are not usually about how to use the tool itself; it is to ask for more information about sensors and calibration to create the right working conditions so that the data generated is of sufficient quality to be useful to apply the UDMT principles to. The INSA researchers find that the best return for follow up contact is always after face-to-face contact. For example, a French face-to-face event ended up with a participant asking for an uncertainty course for their company as they recognised that a relatively short introductory workshop not enough to put into practice the techniques, so this has now been planned for Dec 2024.

Other future activities include writing 2 papers about UDMT, one in French and one in English as well as proposing a workshop for the 2025 ASTEE National Congress on Water (French Water Association), which was not possible in 2024 due to prior commitments at ICUD 2024.

A.3.3. France, GRAIE – International Conference in Urban Water “Novatech” in English & French, France

GRAIE is a non-profit association that acts as the link between research and practitioners in France. GRAIE is the co-ordinator of OTHU, but within the scope of Co-UDlabs it is not classified as an RI holder as all Lyon based infrastructure is under the responsibility of INSA Lyon. GRAIE, however, engages in the Networking Activities (NA) as the lead of work package 1 (WP1) and is responsible for organising the Novatech conference in urban water every 3 years. This conference is of note for it being a mix of academic and practitioners (mainly local services and engineering offices), both in terms of those presenting and in terms of the audience members, but also being a bilingual conference that is fully available in both French and English.

Part of the success of Novatech is that GRAIE already have good contact with technicians and practitioners. The organisation and context of Novatech also leads to its success as it is organised by having a scientific committee and programme committee who support the organisation of the conference. The conference organisation is made up of members of the international scientific network (French and international individuals linked to JCUD) and practitioners (normally French) – both sides are involved in deciding what they want from the conference. By involving both communities in the early stages of the conference development ensures their high engagement, and this makes it possible to organise a programme that focuses on the desired themes based on the proposal submissions.

When preparing for a conference, good organisation and good visibility is key! The goal of the event and resulting impact is to improve the way that professionals can change their practice and to know what research is currently being produced. This in turn will help researchers to adapt their work to the needs of practitioners and improve dialogue between the two groups. To improve on this existing organisation of the conference, the next step would be to involve and encourage attendance from more international practitioners and to boost the number of experiences from countries other than France. A potential solution is to encourage existing scientific contacts to invite practitioners and suggest that they attend. Unfortunately, it is not always easy for practitioners to go to other countries and attend conferences due to time and financial constraints as permission is required from the employer who do not necessarily have budget allocated for these purposes.

A significant contributor to the success of Novatech is the French-English translation by professional simultaneous interpreters of all the sessions during presentations and discussions. It comes at a financial cost, but this is a very important investment for GRAIE as it allows for French practitioners to access global research.

Another benefit from the event is that all papers and presentations are disseminated afterwards. However, the question remains for GRAIE in its other activities (e.g. regional and national practitioners' networks, conferences organisation or speakers etc.) as to how Novatech can further contribute to the diffusion of UD practice and how this knowledge and information can be used to continue the work of transmitting this to practitioners and scientists.

Approximately 20% of attendees each edition are returning attendees, while the majority are new, young researchers and practitioners, as well as employees from the national French ministry and water agencies. This shows that Novatech is always attracting new types of attendees and is widening its impact.

GRAIE shared a summary of findings from Novatech in the French water event "Carrefour de l'Eau" in 2023 that reached a wider audience of French technicians. The goal was to transfer consolidated knowledge and to discuss emerging themes, such as the effectiveness on a catchment scale of rainwater harvesting on a parcel basis. Conferences are generally designed to transfer knowledge, but the real question is how people receive this information and how they take on this information to then make a change in practice. It is important to make the distinction between dissemination and efficiency as efficiency is the true measure of whether the dissemination activities are effective in making this important knowledge transfer

It is difficult to quantify what changes in practice are as a direct result of Novatech (or of any conference event). If you propose a new technology, it is easy to demonstrate whether it has been used or not, however Novatech talks a lot about strategies and is more of a long-term approach in getting sustainable solutions implemented. As this represents a change in thinking, it can be slow in terms of making change because there is no one big moment of revolution. Change in this way means lots of small steps over time which makes it more difficult to track and quantify. GRAIE previously tried to quantify how France has changed their approach to stormwater management, but it is difficult to quantify. Despite this, it is clear that when change is included in the national plans and intervention programmes of the water agencies, with consequences and conditional financial supports, is a major factor in accelerating transition.

During Novatech, and also in the context of the regular work of GRAIE, there is lots of work on technical animation and to raise awareness of themes within urban water. When discussing change with local authorities and engineering companies there is often the argument that there is no demand for change. In part this is because the two parties seem to believe that the other party does not want change, but that they would be willing to change if the demand was there. In truth, this signifies the need someone to take that first step to make progress and this is a global problem for innovation in that consumers are often reluctant to be the first. This reluctance to engage and put themselves at, what is perceived to be, risk is a significant barrier. The question is who should take this risk? Should it be the local authority or the society or the engineer?

When considering needs for the future, one of the emerging demands is how to link between the conferences which only occur every 3 years and how to transfer knowledge based on first meetings. A good example is the JCUD – the aim is to have a themed conference every 3 years and to have working groups in the interim, ensuring that there are annual meetings. Novatech, which is a JCUD conference too, could try to have more activity in-between conferences to improve exchange, however the barrier is that people have too many invitations of events to attend. Due to this it is perhaps more efficient to leave the international level communication to be done via JCUD and then ensure that each country focuses on the dissemination at a national level. The Novatech conference can be used as an in-between, to ensure efficient knowledge transfer between the national and international level.

A.3.4. Germany, IKT – Presentation on drainage good practice and research needs, online webinar

This online webinar on drainage good practice and research needs was done within the first year of Co-UDlabs and had a good turnout with a mixed group of 54 external attendees (audience and speakers) and 74 attendees in total (including the Co-UDlabs community). There is a link between this event and later TA involvement as members of Stichting RIONED took part in the webinar and also applied for TA as presented in A2.3 Germany, IKT – Assessment of Inspection tools for Rising mains (AIR).IKT are known for running these types of events and ran it over 2 mornings rather than for a full day as they had previously found that keeping the sessions shorter boosted audience interaction. It was divided into clear sessions so that people can attend the parts that are most relevant to them. The webinar was split into 3 topics;

- optimising existing UD asset performance,
- valuating assets & deterioration,
- improving resilience,

which are all related to JRAs within Co-UDlabs. For the discussion section, WP leaders were there to listen in and to help with the discussions. During discussions examples were given and research needs identified.

The preparation involved working with the other Co-UDlabs partners (JRA) who were to be the speakers, so there was lots of discussion as to who to include and what could be good examples. This resulted in interesting presentations. This event was advertised quite widely as a global workshop and was circulated by IKT and by Co-UDlabs. IKT´s research and testing are essentially geared towards the target group of asset owners. The asset owners support IKT with ideas and financial resources.

So IKT targeted this existing audience in their event advertising. Due to this many water companies attended the workshop, along with associations that represent water companies. In this respect, organisations like IKT can function as the missing link between research innovations and the network owners.

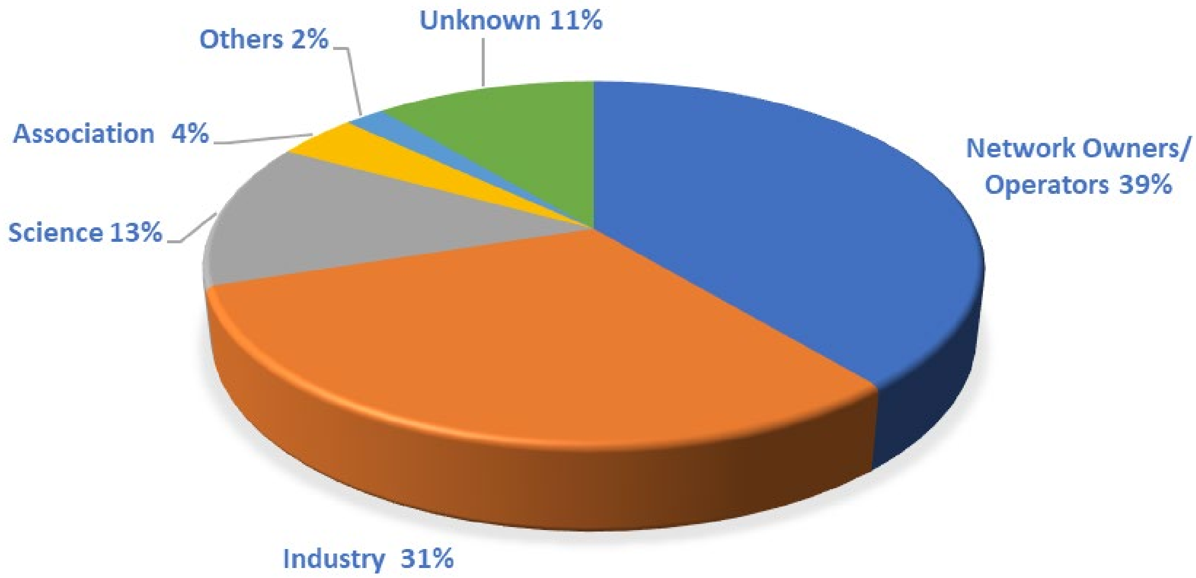

Figure 2. External participants of the Co-UDlabs online practice workshop on Urban Drainage, divided according to affiliation

There were productive discussions and immediate feedback throughout the event. The event, being at the start of Co-UDlabs, acted somewhat as a launch for the project as a whole with attendees being added to the Co-UDlabs mailing list for updates and opportunities throughout the project. The goal was to engage people to determine what matters to them to use this to develop the JRA and shape the direction of Co-UDlabs.

There will be a follow up workshop which will be similar but this time reporting and sharing the JRA outputs and TA outputs: Hopefully, there will be a bigger audience as many people have since engaged with the project and may be interested in seeing the outputs.

IKT found that a limitation of such webinars is that there are now so many available that people are less likely to fully engage and there is now a culture of simultaneously working while party listening to a webinar.

An advantage of webinars is that they are low cost to attend and easily accessible, boosting the transmission of information. This workshop was free, but there is the idea that a payment valorises the item, if it is free there is the stigma that it is not of value. Webinars need to be topical and covering subjects that people are interested in. What IKT has found to not work is anything more sales orientated or if it is not sharing valuable information. In addition, respected speakers from organisations that are of interest need to be invited and the information needs to be sufficiently well circulated.

Consultants, distributors, and manufacturers tend to be interested in what network owners (the potential customer) are wanting or saying. So, with workshops it is necessary to consider who is likely to be interested in using the output and make sure that they are present to take advantage of it.

A.3.5. Spain, Universidade da Coruña - Training and Dissemination of the UDMT in Spanish, Spain

At the 7th edition of the Spanish Water Engineering Conference 2023 (VII Jornadas de Ingeniería del Agua, JIA) at Universidad Politécnica de Cartagena, UDC presented a full day course in Spanish "Course on good practices for flow and pollution monitoring. Analysis and processing of data from water cycle monitoring," which included the UDMT toolbox developed by INSA (2.2). INSA trained the UDC members on the contents of the toolbox and provided resources to UDC for the training (for more details refer to A.3.2).

The workshop was advertised using Co-UDlabs network, internal network, mailing list, and advertised by the conference. The course was free for the conference assistants together with other 4 workshops on different disciplines on water engineering. The Spanish language helped to better reach local authorities and practitioners, highlighting the importance of dissemination in an appropriate language to the target audience. There were 13 attendees at the workshop from a diverse background, 6 from academia, 7 from water administration (practitioners and water boards). This suggests that interactive training could be a good method to engage water administration for those in a more research-oriented background.

The workshop involved presenting the methodology, encouraging the harmonisation of techniques, and highlighting the importance of uncertainty assessment and data analysis, which is something not well implemented in UD. In case of Spain, this could be as Spanish regulations do not require this level of information, so practitioners are not going to exceed the regulation demands without reason. This suggests that regulators need to be the driver for change and that for metrology, to become more widespread in the field of UD, needs to have its value explained to those creating policy and/or those lobbying policy makers. Currently, there is a big investment in sensor technology and smart water systems in Spain, but still, no one is talking about uncertainties which is important in determining the confidence users have in the data and also to make the best use of sensors. Water boards were the most engaged during the training as they deal with real data as a regular part of their profession, and they would want to analyse and/or publish this data following best practice.

The survey by UDC following the training receiving good feedback on the course and there was a special interest on uncertainty analysis and how it can be applied in their daily work. The survey also generated feedback for the UDMT toolbox highlighting what aspects could be further developed in order to adapt to real applications with high amount of data. This, coupled with the feedback from France (A.3.2) suggests that interactive training on how to apply a technique to the audience's systems results in a higher level of audience engagement than a simple presentation of the UDMT software and also, importantly, gain opinions on the future of tools that are in a non-commercial stage of development.

A.3.6. Switzerland, EAWAG – Workshop on acoustic monitoring of suspended solids in natural and engineered systems, online webinar

A workshop on ultrasonic methods for monitoring suspended solids was developed by EAWAG with some input from UDC and with the involvement of the hardware manufacturer, Ubertone. Ubertone were included at this stage so that relevant speakers were used in the panel. This was a Co-UDlab led project, but it was also disseminated through the EAWAG event list as it is common for EAWAG to host these types of events and share events with their supporters.

This event was published on the IAHR page and was branded an official IAHR event. IAHR accreditation helped to disseminate the workshop widely and legitimise the event. Event organisers always want information to be presented in an appropriate manner to the appropriate people and this is the role of the associations. People will often look first on the IAHR website to find workshops and conferences.

The goal of the workshop was to spread the word that the technology exists, and that the ultrasonic monitoring is advancing beyond level and velocity sensing and can now possibly monitor particle concentration as well. The secondary point to transfer is that there are still challenges to this process, so installation location needs to be carefully considered. The reading depends on the particle characteristics. In sewers, , for example, this changes during a runoff event thus giving different readings depending on the material characteristics of material.

There is now hardware being produced which is near maintenance free, which is attractive in UD where maintenance can be costly and disruptive. Knowledge is required to set it up so that it gives useable readings. It is useful in differentiating between low and high pollutant loads, but not necessarily saying what the precise reading is. One could theoretically calibrate to a particular catchment as you are going to expect a similar range of particles each time, however it is still very much specialised lab equipment at this stage.

One of the key aspects of to the longevity of a webinar's success is that it is easy to find later. These events need to be seen as resources to be recorded and uploaded in a way that the information is accessible to all regardless of geographic or social boundaries. It is then also good practice to create a written summary of the event of 4-5 page, so it is searchable and easy to digest quickly. This is especially for students and young water professionals who cannot afford to attend live conferences and watch these events later. However, they still might find the information useful.

Another success was from bringing in specialists for each part of the presentation. Although not everyone knew each other, the thorough planning with previous coordination meeting with the speakers ensured good communication within the group, and that everyone was centred on the key message.

A.3.7. The Netherlands, Deltares France, INSA– European Jr Scientist Workshop (EJSW) on Monitoring Urban Drainage Systems & Rivers, France

The EJSW started in the early 1990's and was initially a less focussed program. Over the years, using feedback from participants, the types of information presented and how it is presented has been modified to optimise the program. One of the aspects that ensures that the workshop remains relevant is that it presents the latest knowledge from the senior researchers and brings in the latest innovations from participants through part of the week involving conference style sessions. Effective knowledge sharing is often face to face and the idea is that you give people knowledge it will end up being applied somewhere, somehow, further down the line.

The presentations are very useful for young researchers as the feedback from peers and the senior researchers is invaluable on research that is often not yet mature enough to go to an international conference or research that needs direction on where to go next. The event has mostly targeted PhDs (preferably first or second year), though it has attracted post-docs and other research professionals. The key element is that it is for people who will do hands on field research and also people making models so that they know where the information is coming from. An aim for the future is to attract more people from industry.

The 5 key elements that make up any EJSW event are:

- Participant presentations on their research (mini conference).
- Presentations on data processing and metrology (key themes of this workshop).
- Activities in the field to gain practical experience of how these technologies work and to understand firsthand how other factors can influence results.
- Environment away from the bubble of the PhD/early-researcher environment (views/opinions of the supervisors) to get outside perspectives and opinions on the direction and perspectives of the work they are undertaking.
- Environment away for the world, ideally with limited internet connectivity, which creates conditions for socialising within the group time and boosts engagement in team building activities.

After a number of years in circulation (first edition of the metrology workshop was held in 2014), the workshop has a good following of researchers who have been to the event or have been recommended the event or who know the organisers. Demand for spaces often exceeds demand and participants are accepted only after submitting abstracts on the work they wish to present. The EJSW workshop is officially linked to the Working Group of Sewer Processes and Networks which is part of the JCUD IWA/IAHR. This also allows for the event to be disseminated using their contact lists as well as personal contacts of the organisers and other UD RI. Although advertised as a European event, the success of this event has led it to include applicants from outside Europe for the 2024 event. This shows that there is not just a need for the event in Europe, but internationally too (in the 2024 edition participants from China, Australia and North America joined in).

Event organisation is successful because the organisers already know each other very well for a sustained period of time. It is already established that they are able to effectively work together for the week and a disadvantage of bringing in new people can sometimes result in tensions (which there is not time for) due to not necessarily having the shared vision of what the workshop is about or not having the prior knowledge of how the other people work. When organising a significant event using a small amount of labour, it is essential that organisers feel able to rely on each other. It is also good to have an organiser who is versed in organising group conversations (e.g. Boy scouts' leader) as it gives the organiser the skills to help conversations get started and it means that they ensure that no one is left out or feels unheard. This suggests that whilst it is important to have event organisers with a good IQ (Intelligence Quotient), a good EQ (Emotional Quotient) is of significant importance to the event's success.

A key concept of the workshop is that it is not a big programme so that it is not too draining. This gives participants space to be creative when discussing research and allows them to make genuine connections. Allowing participants to team-up on a personal level result in comfortable relationships that can be picked up easily in the future if collaboration opportunities arise. Universities are good for making contacts, but what is really needed is for young researchers to make links with people in the same field of interest. This then allows for contacts to be maintained at international conferences (which might not be as inviting an environment to make initial contacts). Trust is key to making durable contacts and EJSW shows young scientists that it is possible to collaborate across institutes.

There are some challenges to find a specific venue to comply with demands. It has to be remote with low connectivity so people talk to each other, no multiple locations so you can all eat and socialise together, and importantly with small river access and sewer access (need contact with the municipality for permission) for the field experiments. The advertising and registration are done by INSA as they have that already in place and the workshop uses Lyon as a travel hub and then take everyone to the venue by a big bus. As with all field work, it can be influenced by the weather, and this means that the schedule needs to have some flexibility built in and potentially a weather dependent option B for the field work.

As part of the 2024 event, opinions were collected from participants. Overall, the feedback is positive. Some participants ask for more practical experience, others for further detail on the theory, however the organisers must make choices due to the time limitation. One of the requirements for the event is limited external connectivity and this was highlighted as an issue for some participants (the venue had a poor WIFI, however 4G is available) so this aspect may be changed for future workshops. The quality of the workshop, transportation, accommodation, and the meals provided was considered to be very good by participants. The length and workload during the event were rated as being “well balanced.” The interaction between participants and the senior researchers organising the event and the working atmosphere as a whole were also very well received. Some participants raised the issue that they were not prewarned that rooms were shared, which will be clearly communicated in forthcoming events.

Some examples of feedback from the event:

> “Great experience for networking, making friends and getting a lot of insights. The informal approach worked great, and we could easily feel welcomed and encouraged to share and receive feedback, thoughts etc.”

> “It’s a great workshop. You get to know the people, as well as their research, and that is necessary to actually collaborate.”

> “EJSW 2024 was a really good course/workshop for both networking and scientific knowledge gaining. The venue is great, and this is the best workshop for meeting other researchers and actually being able to share and discuss opinions.”

> “I can absolutely recommend the workshop. You learn a lot about different monitoring approaches, other research projects and especially you get to learn other junior researchers that you can always contact in the future.”

A.4. Outline of the key structures within each Co-UDlabs member countries

A.4.1. Denmark

In **Denmark** there is the Danish Water and Wastewater Association (DANVA) which represents water utilities and promotes sustainable water management in Denmark. It facilitates collaboration between researchers, policymakers, and practitioners by organizing conferences, workshops, and publishing technical guidelines on urban drainage and climate adaptation.

Spildevandskomiteen (SVK), or the Water Pollution Committee of The Society of Danish Engineers, is a technical committee in Denmark focused on developing and disseminating knowledge about wastewater management, including stormwater, sewer networks, and related environmental technical issues. It is particularly known for publishing technical guidelines, standards, and manuals widely used within the wastewater sector by municipalities, utility companies, consulting engineers, and other industry stakeholders. The committee's work ensures uniform and technically sound solutions for managing stormwater and wastewater across Denmark. This is crucial for protecting the environment and public health, as well as addressing the increasing challenges posed by climate change and urbanization.

More broadly, in Denmark there is also Clean and the Danish Portal for Adaptation to Climate Change (Klimatilpasning). Clean is an innovation cluster for clean technology, focusing on sustainable solutions. An aim is to encourage collaboration between researchers, municipalities, and private companies, to allow for the development and implementation of new drainage technologies, especially in the context of climate adaptation. Klimatilpasning's approach involves integrating scientific research on climate change impacts into urban and rural planning strategies. This knowledge transfer includes partnership between research institutions, municipalities, and private companies. These collaborations help ensure that cutting-edge climate science is rapidly applied to local adaptation projects, often using pilot projects to test new solutions. Danish policies are designed to be flexible, incorporating the latest climate research ensuring that they remain aligned with scientific advancements.

A.4.2. France

In **France**, a number of associations are helping to develop scientific and technical knowledge to help change practices: ASTEE, OIEau and SHF**.**

The main water association is ASTEE (Association Scientifique et Technique pour l'Eau et l'Environnement) which is a scientific and technical association for water and the environment. It promotes sustainable management of water, including urban drainage systems. It facilitates the exchange of knowledge between researchers, water utilities, local authorities, and industry by organizing conferences, seminars, and workshops where the latest research and best practices are shared with practitioners and policymakers; and by publishing technical guides and reports that help translate research findings into practical applications in areas like stormwater management, wastewater treatment, and urban drainage. ASTEE has a strong influence in France, driving innovation in urban drainage and ensuring that municipalities and water management bodies are aware of cutting-edge research and technologies. Its work bridges the gap between research and the practical needs of cities facing challenges such as climate change and urbanization.

ASTEE is the French governing member of IWA, which provides connection to international level. Urban hydrology is worked and discussed in a common working group with ASTEE and SHF. SHF is the société hydrotechnique de France and is the French governing member of IAHR; this common working group is a way to include interdisciplinary approaches of urban drainage (between hydrology and water management).

In addition, there is OIEau (Office International de l'Eau) a French association that supports water resource management internationally and in France, providing training and knowledge exchange related to urban drainage and sustainable water management. It does this by contributing to research programmes, including notable involvement at a European level, the publication and dissemination of research work, the management of water monitoring data on behalf of the French government, and providing technical support to municipalities and water managers to implement urban drainage solutions and through the organisation of stakeholder networks.

GRAIE, a Co-UDlabs partner, is an organisation in France's water sector whose role is to advancing research, boost collaboration, and promote best practices in water management. Its primary focus is to contribute to the advancement of water management technologies and strategies in France, ensuring that urban areas adopt sustainable practices to protect water resources and improve environmental quality. The GRAIE has strong roots in the Lyon Metropolitan Area in terms of stormwater management, but it is increasingly present on a national scale and there are proposals for France to develop local promotion structures to provide support for policy development and to allow for each region to have a local antenna to provide technical expertise and knowledge sharing.

In France, the Ministry of Ecological Transition relies on a number of public bodies to help define and implement water management strategies.

- 6 water agencies, which draw up programmes of measures and collect charges according to the 'polluter pays' principle in each of the major river basins. This enables them to support the main thrusts of local water management strategies: financing local actions by local authorities, industrialists and farmers, as well as research programmes with local operational spin-offs (such as certain programmes in support of the OTHU) and technical coordination (such as Graie). For example, funding is provided for local authority initiatives to manage rainwater at source, disconnect and desilt water, and self-monitor sewage systems. For example, as part of its 12th programme (2025-2030), the Rhone-Mediterranean-Corsica Water Agency is funding actions, studies and works up to 50% or 75% under certain conditions.
- The ministry also relies on the OFB, the French Biodiversity Office, which supports water management research and policy implementation, including urban drainage systems by conducting research, promoting green infrastructure for stormwater management, and supporting collaborative projects. Its importance for UD is that it encourages the integration of ecological and sustainable practices into UD systems in France.
- Cerema is also a state tool for promoting a transition in stormwater management practices, through its involvement in research programmes, in territorial strategies and also the development of a territorial engineering offer at the service of local authorities, including the sustainable management of stormwater. Specifically, the part of Cerema that specialises in

water is TEAM : "Transferts et interactions liés à l'eau" which covers sustainable development, the preservation of water, and adapting to climate change, with a research focus on the hydrological functioning of constructed environments, environmental pollution: water/soil/plant transfers and treatment facilities, and climate regulation processes in urban environments. In partnership with the other structures mentioned previously for France, Cerema also host Eau et ville which is a resource on urban rainwater management.

In France there are also what are known as "Pôles de compétitivité" which are public-private organisations designed to boost innovation and collaboration between businesses, research centres, and educational institutions. The main goal of these clusters is to stimulate economic growth by enhancing the competitiveness of French industries, encouraging research and development (R&D), and creating synergies in specific sectors, but with a mainly techno-centric approach. The Pôles de compétitivité for water are Aqua-Valley and Aquanova (the fusion of "DREAM Eau et Milieux" and "HYDREOS") who both work to improve water management. The AXELERA pole de compétitivité in Lyon has a wider focus but also includes topics dedicated to water, soils and air.

A.4.3. Germany

In **Germany** there is the DWA (German Association for Water, Wastewater and Waste) which plays a central role in setting standards for water management in Germany, including urban drainage. It facilitates knowledge transfer from research to practice by publishing technical guidelines, hosting conferences, and offering training programs for professionals in urban drainage. The DWA's technical rules and standards are widely adopted by municipalities and utilities, ensuring research is effectively translated into practice.

IKT, one of the Co-UDlabs partners, is a German research institute focused on underground infrastructure, including sewer systems and drainage networks. It serves as a critical intermediary between scientific research and practical implementation by providing independent assessments, research, and consultancy services for utilities and municipalities, conducting applied research and by running pilot test projects. It also offers training programs, technical workshops, and publishing reports to ensure that practitioners and asset owners are up to date with the latest technologies and methods. Its work ensures that research findings are directly tested and implemented by practitioners, contributing significantly to innovation in German urban drainage. It also has a branch in the Netherlands.

Another research institution in Germany is KWB (Kompetenzzentrum Wasser Berlin) who focus on applied water research through research projects in collaboration with utilities, developing innovative solutions, and promoting knowledge exchange through workshops. KWB connects research with practice, especially in large urban areas like Berlin.

Of further interest could be the BDEW (Bundesverband der Energie- und Wasserwirtschaft) an association in Germany representing water utilities and energy providers, with a focus on sustainable water management. They provide policy advice, organizes events, and promotes best practices in urban water management to ensure that new technologies and research are effectively implemented by utilities. Similarly, DVGW (German Technical and Scientific Association for Gas and Water) is also a relevant player in Germany as they set technical standards and promote research in water management and also organize training programs, technical seminars, and publishes guidelines to ensure that innovative drainage solutions are implemented in practice across Germany.

A.4.4. Spain

In **Spain** there is the AEAS (Spanish Association of Water Supply and Sanitation) which platform for knowledge transfer between researchers, practitioners, and policy-makers. It is a professional body that promotes knowledge exchange on water supply and sanitation and its main activities are organising conferences, publishing technical guidelines, and conducting studies on urban drainage issues.

In addition, there is the Fundación CENTA (Centre for New Water Technologies) which works with Spanish municipalities and utilities to implement innovative urban drainage solutions. CENTA focuses on innovation in water management technologies, including urban drainage. It acts as a bridge between research and practice by running pilot projects, organizing technical training, and disseminating best practices on sustainable drainage solutions.

CETAQUA (Centro Tecnológico del Agua) is a Spanish water research and technology centre that promotes innovation in urban water management that works on applied research projects in collaboration with universities, companies, and public bodies to develop and implement innovative urban drainage technologies and policies.

Spain also has companies, such as Viratec, that function similarly to the “Pôle de compétivité” in France.

A.4.5. Switzerland

In **Switzerland** the VSA are the leading Swiss association for water management, focusing on sustainable urban drainage, wastewater treatment, and water protection. They organise training programs, conferences, and publishing guidelines on urban drainage and stormwater management with the goal of connecting researchers, practitioners, and regulators to promote the implementation of research-based solutions in urban drainage.

EAWAG (Swiss Federal Institute of Aquatic Science and Technology), a Co-UDlabs member, is a leading research institute in Switzerland focused on water resources and aquatic ecosystems, including urban water systems and drainage and it conducts cutting-edge research on urban drainage, organizes knowledge exchange workshops, and collaborates with municipalities to implement innovative solutions.

In addition to the VSA, there is the SWV (Swiss Association of Urban Water Management) the SWV is the professional association for urban water management professionals in Switzerland, with a focus on urban drainage and sustainable water use. The SWV facilitates networking, organizes training programs, and publishes technical guidelines for urban drainage professionals, supporting the implementation of best practices.

A.4.6. Netherlands

In the **Netherlands** there is KNW (Royal Dutch Water Network) which is a professional association for water professionals in the Netherlands that promotes knowledge exchange between research, utilities, and policy makers. Its main actions contributing to knowledge transfer are organizing seminars, conferences, and workshops where practitioners and researchers can exchange knowledge on innovative drainage solutions and stormwater management.

More research focussed, STOWA (Foundation for Applied Water Research) is a knowledge centre that facilitates research on water management and urban drainage in collaboration with Dutch water boards and municipalities. It conducts applied research, organizing knowledge exchange workshops, and disseminating practical guidelines for urban drainage management, bridging research and practice in urban drainage, particularly in addressing climate resilience.

Stichting RIONED, also known as RIONED Foundation is the Dutch branch organization for urban drainage and sewer management. It supports municipalities and water boards in managing urban drainage systems by providing technical guidelines, training, and supporting research projects, helping municipalities adopt cutting-edge solutions.

Other important structures are RI, such as Deltares, a Co-UDlabs partner, who is an independent research institute focused on water and subsurface management. It conducts research and advises on sustainable urban drainage systems. They provide practical solutions, software tools (e.g., flood models), and applied research in urban drainage and water management. This RI collaborates closely with practitioners and policymakers to implement cutting-edge drainage solutions. There are other RIs such as Marin, KNMI, TNO, NIZO who do research and some consultancy. More broadly there is also RVO (Netherlands Enterprise Agency), that tries to connect the market to theses institutes by issuing subsidies for encouraging co-operation and knowledge transfer.

A.4.7. United Kingdom

In the **United Kingdom**, the Water UK organisation represents the water and wastewater service providers across the UK, influencing policy and promoting innovation in water management and facilitates knowledge exchange through publications, research reports, and partnerships between utilities, researchers, and policymakers.

There is a specific group UKWIR (UK Water Industry Research), that coordinates and collaboratively funds research activities across UK water utilities, focusing on practical solutions for urban drainage challenges and publishes reports that translate research into actionable insights for water utilities, playing a key role in ensuring research outputs are implemented by practitioners in the UK water sector.

More broadly, there is CIWEM (Chartered Institution of Water and Environmental Management) who promotes sustainable water management, including urban drainage, by bridging research and practice in the UK and organizing professional development courses, conferences, and publishing best practice guidelines related to urban drainage and flood management. This acts as a platform for knowledge transfer between researchers, practitioners, and asset owners in urban drainage. In the UK, specialists can become an accredited scientist or engineer through CIWEM’s chartership programme. CIWEM has a specialist working group Urban Drainage Group that is composed of water company representatives, EA staff, academics and consultants and develops code of practice that are used within the UK water industry.

Susdrain is a SuDS specific initiative led by the CIRIA (Construction Industry Research and Information Association) that provides guidance, case studies, and resources for practitioners involved in implementing SuDS, helping bridge the gap between research and practice.