Interreg North-West Europe
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Rural Roadwater Rescue

Strategy for
Rural Roadwater Rescue

Opportunities for co-creation of
Climate Adaptive Water Hubs (CAWHs)
along the network of highways
in North-West Europe

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1 Introduction

Climate change is increasingly disrupting the **balance between water supply and demand**, with extreme weather causing both surpluses (flooding) and shortages (drought). The **RRR-project (pronounce: triple-R) or "Rural Roadwater Rescue"-project** addresses this challenge by developing a transnational strategy to **transform existing roads and highways into systems that collect rainwater (runoff from roads) for treating, storing, reuse and infiltration**. The website can be found here: https://rural-roadwater-rescue.nweurope.eu. This final deliverable integrates the results of the RRR-project.

The partnership developing this integrated, cross-sectoral approach consists of:

- Rijkswaterstaat (RWS, NL),
- Coöperatie Kloostersland (CK, NL),
- Vlaamse Milieumaatschappij (VMM, BE),
- DVGW-Technologiezentrum Wasser (TZW, DE),
- Centre d'études sur l'environnement, la mobilité et l'aménagement (CEREMA, FR),
- Interuniversitair Micro-Electronica Centrum vzw (IMEC, BE).

This document contains a comprehensive **strategy for Climate Adaptive Water Hubs (CAWHs)**, a **mapping of opportunities** in North-West Europe, and two **action plans**. It describes an **implementation pathway and a sharing platform** for replicating and exchanging best practices. The strategy will go beyond existing solutions and will deliver a more comprehensive, integrated, multi-sectoral and multi-level, close-to-practice approach. For the mapping of opportunities, possible locations will be identified, where the strategy could be applied, taking into account the technical, social, ecological, local and legal context. Two concrete action plans for locations near Eindhoven (NL) and Leuven (BE) are presented. An implementation pathway for up-scaling and replicating to other areas in North-West Europe is proposed and a sharing platform is offered here: https://cloud.waterhubs.eu.

The partnership is **committed to both practical realisations as well as extensions to other areas** in North-West Europe. The RRR-project lays the foundation for further work beyond its lifespan towards implementations, including **inspiring others to join** and acquiring further (financial) support on regional, national and EU-level.

2 Vision

The vision of the Rural Roadwater Rescue (RRR) project is to transform the role of roads and highways in a way that they actively contribute to local water systems. By integrating rainwater collection, treatment, storage, reuse and infiltration into existing and future infrastructure, roads can become valuable assets in restoring and maintaining the local water balance. Rather than swiftly draining rainwater into sewage, canals or rivers, these networks can help to store and distribute water where it is needed most, especially in rural areas affected by both drought and water surplus due to climate change.

Changes are needed across several dimensions. Not only **technical** adaptations to infrastructure are needed, but also shifts in **institutional** roles, involvement of the **community** and introduction of alternative **value and funding models**. The transformation requires collaboration across sectors and levels of government, business and society. A common understanding of the value of roads to water resilience is essential. Each of these dimensions plays a critical role in enabling the integration of water functions into road infrastructure. This paragraph outlines the challenges and opportunities within each domain and sets the foundation for a comprehensive, actionable strategy.

Technical

Roads, especially highways, are designed to go fast and safe from A to B by car. Too much water can hinder this mobility, which is why water is diverted from the roads as quickly as possible. Because roadwater is heavily polluted, it is cleaned technically, mainly by filtering it through a sand filter, and biologically (nature-based solutions) for instance with reed or willows. Storage allows roadwater to be used in times of water shortage.

A relatively new development is the use of tunnels to capture and store water in times of water overflow (also an effect of climate change). This technique is used in Antwerp in the Oosterweel project. In this case, the tunnel is closed for traffic for a short period. After the heavy rain fall, the surplus of water is given back slowly to the environment.

As a big change, we envision roads contributing to the challenges of the areas they cross. They become serving assets that support the water challenges in the environment. Not only via collecting, cleaning and storing roadwater, but also by constructing the road with locally grown plants (bio-based materials) that support a healthy living soil that stores water and contributes to the biodiversity and liveability of the region.

Up until now, roads have been designed as mono-functional systems, mostly taking into account safety and maximal circulation for traffic. With the recent and ongoing renovations of former roads it is clear that other aspects, part of the environmental impact assessment and new innovations, are addressed by design: i.e. ecoducts, sound walls, solar energy, charging stations, etcetera. Roads are not merely bringing people from point A to B, but are an integrated part of their surroundings. Improved infrastructural technical designs could turn water from waste into a valuable asset for restoring and maintaining the local water balance.

Institutional

Government bodies often operate based on policy frameworks that emphasize targets, quality, and budget constraints, primarily the rational aspects of a project. However, since these policies are ultimately designed to serve society, it is equally important to actively engage with the community and align the project's objectives with societal needs. Achieving this balance between rational and societal considerations requires flexibility from all stakeholders and a collaborative mindset throughout the process.

Community

When developing a new highway or renovating an existing one, it is essential that the responsible authorities involve local stakeholders in the process. This ensures that the diverse needs of the surrounding community are taken into account, creating most local value, and that the design of the highway can be adapted accordingly. The community plays an important role in identifying and realising possible water reuse, retention and infiltration opportunities.

For example, when people living close to the highway get the opportunity to sell local (food) products at serving stations (currently exploited by oil companies), highways will contribute both to local value creation and to living water-retaining soils.

Value and funding models

As a result of local stakeholders working together and being involved in the development and implementation of roadwater solutions, new opportunities for shared value creation (beyond mobility) and funding can emerge. Instead of relying solely on government budgets or isolated contributions from individual stakeholders, collaboration allows for a more efficient allocation of resources. By aligning interests and bundling efforts, value can be created collectively—both in financial terms and in the broader societal impact—while reducing the financial burden on any single party. An example of others similarly leveraging roads for value creation is found here: https://roadsforwater.org/.

3 Pragmatic steps in involving the community

3.1 Introduction

We define the **local community** as the collective of (subgroups of) stakeholders with an interest (stake) in the local area, such as residents, farmers, landowners, organisations and authorities. The local community must not be confused with the municipality.

The **reasons for involving** the local community in (an early phase of) the project are:

1. **Impact**: Local initiatives may already exist that can be connected and leveraged,
2. **Knowledge**: Local people and organisations have a lot of knowledge about the specific local context,
3. **Support**: Early involvement of the community will strengthen support and understanding for solutions,
4. **Co-investments**: Solutions, relevant and matching local demand, will provoke co-investments from the local community.

We distinguish **steps in the process** (elaborated in the next paragraphs) that have a different character, described below and illustrated on the next page:

1. **Identification** of promising locations and stakeholders,
2. **Exchange** with the local community through bilateral talks, meetings, online interaction and questionnaires to examine the local context,
3. **Design** practical solutions with the local community (co-creation) that are realistic and adapted to local needs, values, interests and constraints,
4. **Implementation** of solutions requires arranging local governance (lead and ownership), finding appropriate places, suppliers and investors for realisation.
5. **Maintain, Sustain and Use** requires a stable organisation to sustain and support facilities and services to (or from) the community, collect feedback and regularly assess (if needed adjust) the business and value case.

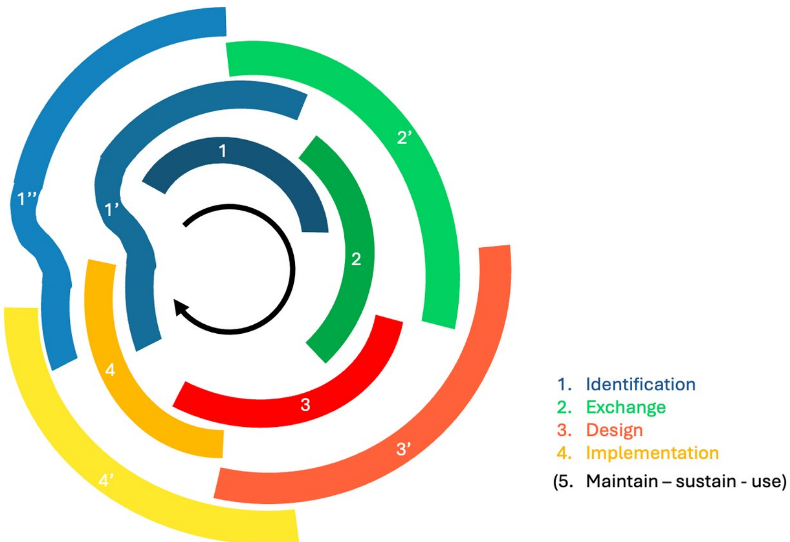


Figure 1: Impression of the cyclic, partially overlapping steps in the process of involving the local community.

3.2 Identification

3.2.1 Approach

The communities we want to involve in water management are typically location-based. This raises the question of what comes first: Selecting the community or determining the location? And, regarding community and location, what size or area do we have in mind or seems logical? Within this community, who should be involved and how do we get to know them? We actually don't know and we can't in advance formulate the right questions. There is no logical order in progressing and the only way to find out is to look at promising locations and communities and to talk to them.

In the next two paragraphs, we will look at an approach in determining what could be promising in terms of community and location, allowing to determine an initial scope for further examining the local context. We draw from examples of how the process of identification actually went in different locations, showing that many triggers and routes are possible and there is no such thing as a one-size-fits-all solution. Another source of inspiration is the participation guide around water, developed by VMM (in Dutch).

3.2.2 Locations

When identifying locations, we look for places with chances or problems. Chances may also rise as a spillover from solving problems. One might do better than just solve the problem. Chances can be discovered by taking different perspectives on places: geological, hydro-logical, landscape layout, assets and infrastructure, motivation and (land)ownership, institutional/governmental jurisdiction and scale. We will now further explain these.

When reviewing the **geological, hydrological and landscape layout** situation of a location, one could assess the quantity and quality of water bodies (lakes, rivers, streams and canals), types of soil (more or less water-absorbing, prone to erosion or landslides), groundwater levels (increasing/decreasing), differences in landscape (flat/hilly, urban/rural, vegetation, nature, agriculture), weather and climate conditions causing heavy rains, mudslides and flooding, problems of drought and salinisation (at the seaside).

We have seen flooding of highways in Germany, diverse urban areas with (canalised) rivers overflowing their banks (throughout Europe), man-made canals blocking the natural groundwater flow and tunnels leaking and draining groundwater (NL), and problems arriving with the rising of groundwater levels around a former coal mine (Bergheim, DE).

Periods of drought have resulted in water restrictions and mandatory reporting of smaller, shallower groundwater wells to local water authorities (NL, no new ones allowed) impacting agriculture and forcing changes in farming practices. We see adaptations to existing homes and buildings, such as removing pavement (increase infiltration), installing rainwater collection systems (conserve water) and redirecting stormwater away from sewage systems (preventing sewage dilution and overflow of the system).

The discharge of pollution to rivers and streams has a huge impact on the water quality. This may, for example, come from the process industry (chemicals, PFAS), agriculture (pesticides and fertilizers) and road runoff (e.g. microplastics, salt and oil). Where possible, pollution should be prevented at the source. We have also seen situations, especially in dry periods, where rivers carry less water and the concentrations of pollution become so high, that they lead to massive dying of fish. Or drinking water companies, that use raw water from rivers and that more often need to temporarily stop the intake of water due to high concentrations of pollution.

Existing and planned **assets and infrastructures** in an area also provide chances for water hubs. These *assets might be leveraged* and used to contribute to better water management. For example, roads can be leveraged to not only provide mobility, but also act as large collectors of water. Roadwater can provide a valuable contribution to the water supply at moments of water scarcity, when collected, buffered and cleaned, and at the same time this prevents polluting the environment and surface water. In times of heavy rainfall and flooding, buffering roadwater can help to prevent it from causing problems in other locations, such as agricultural land, built environment/sewers and in drainage canals, streams and rivers.

Another way of thinking is that *assets can be combined or extended* to serve similar purposes. An example of this is a waste water treatment facility near the highway (Aachen, DE), that might also be used to clean roadwater that is currently discharged into a stream untreated.

Assets may be relieved, such as the drinking water production facilities or pumping installations. Some drinking water companies (NL) do not have enough (capacity) sources to provide water during dry periods or to extend to new neighbourhoods. Offloading the tap water and groundwater use, by providing alternatives for households (to water the garden) and for farmers (to water the fields) will relieve the drinking water infrastructure.

Finally, a location might be very appropriate for the *introduction of new (water hub) assets* that help balancing the water system, such as providing a large area for buffering water.

Motivation, sense of urgency and (land)ownership are other factors that increase the chances of successfully introducing water hubs, where ownership can be both understood as problem ownership and land ownership (we will come back to that).

Typical questions to be asked are:

- What are locations that have experienced problems, where people and governments are aware of water issues and are willing to take preventive measures?
- In which places is community involvement required because the government is no longer able to solve the issues alone?
- In which areas do individuals need each other's help because they cannot (efficiently) solve the problems by themselves any more?

Important is the need for collective action. If an individual is able to solve a problem single-handedly, then there is no incentive to work together. However, this *collective-problem-ownership* is required but not enough. The local community must also be able to influence possible solutions, raising questions such as “Who owns the land?” and “Who owns important assets?” In other words: Is the local situation *community-ownership-aligned*?

It is important to find out **what organisations or governments have jurisdiction** in a certain area and at what level they operate (local, regional, national, EU). The “further away” these organisations stand from the specifics of the local situation, the more difficult it will be to involve them in customized local solutions. Typically, higher governments also work on different (larger) time scales with respect to developing and realising. However, if you happen to succeed in involving a higher government, this may very well provide leverage to your project and to other organisations required to participate. In short, organisations and governments with jurisdiction in the area can both increase or decrease chances of success.

The appropriate **size or scale** of an area is much debated. We suggest finding a balance between keeping it “small, simple and easy for decision making” and “large enough to allow economies of scale and to have access to the required diversity to achieve multiple-value creation”. Too small and you will lose the aspect of collective-problem-ownership as discussed, too large and the decision making, the number of parties and the complexity will take away any chance of success within a reasonable time frame. We found that keeping the scale limited leads to a closer involvement of the local community and to easier decision making, while it still allows to work together with other initiatives on joint topics. However, it doesn’t come with the difficulties of a large organisation and it accommodates different speeds and timelines for initiatives, not holding each other back, but inspiring each other.

To conclude: Promising locations for water hubs can be found by taking different perspectives on chances and problems, such as the ones described above, and see if they strengthen each other. It will be a creative process of connecting the dots, weighing the pros and cons and making educated guesses.

3.2.3 Stakeholders

When identifying a community, we look for persons and organisations that are connected to and have an interest (stake) in the local area. We are especially interested in what drives them, individually, but even more in what emerges from their interactions, togetherness and community sense. We want to learn more about how the community is organised, how they connect to each other, what fabric keeps them together. Below, we will suggest an approach to take and what subgroups of stakeholders to look for.

By far the most important thing to do is start talking to people from the local community. Start with an open conversation and less of an agenda. In this early stage, being referred to other persons (enthusiasts, esteemed/key persons, experts) is the most important. Most people in a community will know to whom you should talk and are willing to bring you into contact with them. Although you might ask anyone on the street, typical entrances can be local initiatives, clubs, neighbourhood representatives, village councils, associations and municipality representatives. Meetings with local people should not resemble sermons or interrogations, but should rather bring forth dialogues and reflect genuine interest. Not only the content matters, but also the development of trusted relationships, essential for later steps. Gradually, it will be possible to gain insight into how the community operates, who are the community leaders and what is the level of awareness and knowledge within the community. Furthermore, it will become clear whether the community has the spirit, the motivation, the willingness and the energy to address the water challenges together and in collaboration. Then, it's time for the next step ("exchange"), described in paragraph 3.3.

On the topic of water-challenges, certain subgroups of stakeholders are recognised as relevant for inclusion in the identification process. We want to describe them in general terms because we noticed that the way in which responsibilities are allocated may differ throughout North-West Europe. For example, we've seen water authorities being part of a ministry or organised as an independent entity, but regionally bound, or somewhere in between. In the Netherlands, for example, large water bodies, rivers and canals are managed by Rijkswaterstaat, which is a separate "executive organisation", accountable to the ministry. We classify such stakeholders all under the subgroup of "water authorities". For different areas, this requires "translation" to the local context.

We can think of the following relevant subgroups of stakeholders:

- residents
- companies
- schools and clubs
- livability groups (neighbourhood/village)
- associations
- landowners
- farmers
- nature conservation organisations
- water authorities
- road authorities
- drinking water companies
- sewage treatment companies
- government (local/regional/national/EU)
- regional development companies
- property developers
- research institutes

The list is not complete and in every area you may encounter other relevant stakeholders. However, whether a stakeholder considers itself part of the local community and is willing to provide commitment is not necessarily clear or straightforward. Sometimes an organisation needs independent minds, persons that can think out-of-the-box or color-outside-the-lines, to make participation and innovation possible.

To conclude: Promising communities for water hubs are found where stakeholders strengthen each other, are willing to collaborate and are prepared to give and take in service of the common good. Again, it will be a creative process of connecting the dots, estimating the chances of involving certain stakeholders and making educated guesses.

3.3 Exchange

The goal of this step is to make sure that the members of the community recognise the location-based challenges and opportunities as **a shared point of departure**, making use of the provisional input from the identification step. They interactively form a general, shared picture of the situation, of the common water challenges that the community faces, now and in the future, of the relevant stakeholders in the area and what elements in the area are relevant to take into account.

An effective exchange among the members, aimed at reaching the broadest consensus on challenges and opportunities and boundary conditions, will need skilled and well prepared orchestration and a well-thought-out methodology. We will first look at orchestration and then discuss the methodological approach.

Orchestration is about taking the right initiatives, at the right time, activating the right group of members with the right techniques. The “orchestrator” is a person or small team with certain qualities. Members of the orchestrator team are familiar with the content, know the area, have a broad network, can weigh different interests, have a feel for how one interacts with stakeholders who are strongly emotionally involved, can delve into the relevant aspects of the challenge, are good at process management in direct link with the relevant content. They take and further develop an integral and independent view on the challenge, by continuously asking questions and integrating things into the overall picture. Sticking to its role is crucial for the orchestrator (team) to remain a trustworthy discussion partner for the members of the community. The orchestrator (team) might already be part of the fabric of the community or must be willing to become so.

We propose a **methodological approach** that makes use of successive techniques to interact with members of the community to initiate and promote interaction, building and strengthening relations and exchanging views:

1. **Bilateral in person conversations:** Get initial information and build relationships.
   It is important to start these bilateral talks with very diverse members of the community in order to explore and diverge as widely as possible at this stage and to ensure that everybody in the community feels that they can be involved in the process. The conversations focus both on making an inventory of the common challenges and goals as well as on the personal challenges, goals and interests that stakeholders have, without zooming in on the tensions that can exist between the interests of different stakeholders. This works best in bilateral conversations where people feel they can talk more freely than in group meetings.

2. **Broadcasting**: Communicate to the broader community that you will be working on water challenges with the community. Members of the community then know about the project and where to find you when they want to contact you or want to get involved. This allows you to reach out to persons and stakeholders that you might otherwise overlook.
3. **Meetings in small groups**: These meetings aim at strengthening the social fabric and creating common understanding within the group. First, stakeholders with similar interests are brought together. This enables them to clarify their shared interests in an environment where they feel safe to speak out. At the same time, the discourse can move away from possibly too rigid preferred solutions, personal interests and personal opinions.
4. **Meetings in mixed settings:** These meetings will bring together participants with different or complementary interests in order to be able to unite and balance these interests, so that the first scope/vision is developed: problem definition and possible solutions, with some concrete examples. During these meetings the long-term perspective is emphasised and methods are used to think about the common good (being in the same boat), to stay away from short-term interests and pressures.
5. **Broader validation and reflection:** This step is to challenge the first scope/vision and get feedback, possibly physically or online, in a broader meeting (webinar) or via questionnaires. It ensures a correct scope and vision with broad support and provides an invitation and teaser for community members to participate in upcoming phases.

3.4 Design

The **point of departure** at the beginning of the co-creation process must be very clear, especially the purpose of the design, the reason and “why”-question behind it. Furthermore, the focus and preliminary, tentative scope must be defined. The concrete subject of design may still evolve over time.

Co-creation requires the involvement of various stakeholders throughout the entire design process. It's not about one party 'working it out' based on the input from all stakeholders. On the other hand, not all stakeholders may be able or willing to collaborate on all subjects. It should therefore align with the energy and engagement of the different stakeholders. A good approach may be to delegate certain topics to working groups, but to discuss their results and make final decisions in plenary sessions. Still, this does not mean that all stakeholders need to be included, but the mix must be such that it allows different angles to be taken into account. It is recommended to jointly formulate some design principals.

The design should address **local needs and requirements**, such as the availability of drinking water, the possibility to connect new residential areas to the drinking water system, the availability of water for agricultural use, the prevention or mitigation of flooding and water nuisance. It is important that the design and its later implementation align with the DNA of the local environment, e.g. regarding landscape, architecture and embedding.

It’s important for the design to **align with local values**. Make sure to be aware of elements of cultural or historical significance. Other local values may include: landscape preservation, livability, fairness and justice, social inclusion. For example: Is a privatised swimming lake accessible to all members of the community or only to those who can afford it? Can we trust a privatised sewage treatment to prevent pollution from ending up in the local water system? These aspects may seem to only be related to the business and value case, but they are important to design choices too. Local values often influence the “how”.

Creating a design **in service of local interests** adds to the value for the local community. We will explain this by drawing a comparison with the energy market. At first, energy was cheap and nobody seemed to bother. Then, in Europe, scarcity drove gas and electricity prices high as a consequence of geopolitical tension. Many households ran into trouble. Something similar could happen to the drinking water system that, just like energy, cannot prioritise between users and purposes of use. If scarcity occurs in the future, prices will rise rapidly, making no distinction. It’s in the local interest to prevent this from happening and take precautionary measures, since water is a primary necessity for life. A similar argument applies to flooding and water nuisance. They involve a risk that may not occur often, but can incidently lead to significant damage.

Long-term, robust solutions are best secured by leveraging local strengths and in turn reinforce the local fabric and living environment. For example, involving local suppliers for design, construction, and maintenance ensures that local capabilities and motivation are reinforced, as opposed to choosing the cheapest supplier from other regions, which could lead to a loss of local value and autonomy. Even in situations where an external contractor works with local subcontractors (which is already better), it remains vulnerable. Therefore, direct involvement is preferable. Importantly, a local supplier has a reputation to loose as part of the community and cannot hit-and-run. This may seem to limit competition, but it should be clear that the community itself, especially if organised as a cooperative, acts as both client and contractor. Thus, there is no risk of harming the "consumer interest". The government (including municipalities) and the community can act as partners in this regard. Before any tendering process begins, the community should have the opportunity to present a proposal, similar to the European right of households to share energy among themselves without intervention of ‘the market’, either directly or through a collective entity.

The design must be **optimised within the constraints** that apply. This may concern means such as money or resources, as well as boundary conditions such as time restrictions, regulations, maintainability and local support. From a sustainability perspective, reuse and local sourcing of materials is recommended (low energy, low emission). For the same reason, it seems logical to make use of available local production chains, value chains and competences. Last but not least, the environmental constraints of landscape, geology and hydrology must be taken into account.

3.5 Implementation

In the implementation step, various aspects need to be addressed, including participants and users, suitable locations, governance, finances, and realisation factors. We will address each of these in turn.

For **participants and users**, a clear offer must be formulated. It is not enough that a water hub serves the general interest; there must be a distinct benefit for individual participants. This benefit should be one that cannot be achieved by an individual participant acting alone but must be realised through collaboration. Additionally, it should not be possible for an individual participant to block a collective implementation in order to negotiate personal gain. Participants should feel they would miss out on a significant advantage if they do not participate (fear of missing out effect). Lastly, some form of personal investment or recurring contribution from participants is necessary because little value is attached to a free proposition and participants might easily withdraw at the slightest inconvenience. To enhance collective involvement, participation, and engagement, decision-making power should come to rest with the participants, in a good balance among them.

Suitable locations must be identified within the area for equipment, installations, infrastructure, nature-based solutions, and/or spatial improvements. The search conducted during the identification step will also prove useful here. Crucial infrastructure should preferably not be placed with individual parties who might develop different interests in the future. Such infrastructure may be protected through contracts with landowners, clearly arranging ownership, accessibility, modifications, first-right-to-buy, etcetera. Preferably, the owners of locations are also participants in the collaboration, whose interests durably align with those of the other participants. Locations for crucial infrastructure can best be owned by a joint legal entity, accommodating the collaboration.

It is important to establish proper **governance**. Initially, this involves shaping the project organisation. The project lead could emerge from the previous orchestrator. Depending on the activities, a legal entity may need to be established for this purpose, and a board be appointed. We prefer the cooperative form due to its democratic control. Participants and users become members and help determine the direction. Decisions are made by (enhanced) majority to prevent vetoes and blockades. A daily management team will need to execute the policy. Crucial components of the water hub should fall under this collective governance. The same holds for value exchange agreements, such as mutual tariffs for demand and supply. Consideration must be given to government organisations or certain companies that, due to their structure, may find it difficult to become members of a cooperative. For them a collaboration agreement with the cooperative would suffice.

There are many different ways to **finance** an implementation. However, it is important to align the financing with the governance. Generally, those who contribute financially will also expect a say (who pays the piper calls the tune). Therefore, it makes sense for participants and users to contribute capital (i.e. invest) or pay an (annual) fee themselves. Additionally, bonds can be issued with a certain return but without voting rights. With a strong business and value case, regional development companies and banks may also be willing to provide loans. For certain risks, a government might be willing to act as a guarantor. One-time subsidies and donations can also help secure financing. For example, a water authority could save costs as a result from the implementation and donate this cost advantage to the cooperative. We do not recommend attracting external investors, as their ultimate interest is always in returns rather than locally added value.

Careful consideration is required for a number of **realisation factors**. During the realisation step, a choice must be made between using: (1) volunteers, (2) professional participants within the collaboration, or (3) external professional parties. We advise not to involve volunteers for realising infrastructure due to aspects of insurability, required guarantees, quality, and continuity. If realisation can be done by professional participants within the collaboration, it is wise to always compare their offer with those from external parties. With a market-conforming offer, preference should be given to a participant within the collaboration. In paragraph 3.4, we already discussed the advantage of involving local supply chains. Furthermore, it is important to select a party that can do both realisation and maintenance for the initial period. In such setting, this party will less likely take shortcuts during realisation, knowing it will be confronted with the resulting problems during maintenance. Carefully and wisely selecting and contracting suppliers and service providers, also looking at their DNA/company culture, is crucial for successfully realising, maintaining, and managing solutions. Whether everything runs smoothly during the operational phase will heavily depend on the choices made in this step.

3.6 Maintain, sustain and use

To maintain, sustain and use water hubs, a stable organisation is required to support facilities and deliver services to (or obtain them from) the community, to collect feedback and to regularly assess (if needed adjust) the business and value case.

For a stable, strategically aligned organisation, the board members are best sourced among (employees of) the participants, in a good mix, representing all participants. We suggest a lean and mean organisation where most of the executive tasks are outsourced. This again calls for good contracts and work arrangements with suppliers, contractors, service providers and participants.

The board should be the linking pin, facilitating the communication within the organisation, translating feedback from participants, regarding possible changes, improvements, developments and innovation, into proposals for the collective to decide upon in plenary meetings. Furthermore, the board should examine new value propositions, especially in coherence with changing value cases of related organisations, such as the water authorities. For example, introducing a “grey”-water infrastructure reliefs the drinking water network or introducing storage/infiltration basins reliefs the sewage system.

4 Roadwater quality and cleaning/treatment for possible use

4.1 The seven elements of the roadwater chain from prevention to use

We want highways to help solve local water problems in both directions (i.e. mitigate both drought and flooding). Cleaning the water is obligatory to make it available for local use. To come up with possible solutions for cleaning, it is necessary to collect experiences, assess the legal conditions and integrate water quality aspects. Cleaning/treatment of roadwater already takes place in most partner countries of the RRR-project. We identify a number of important elements of the roadwater chain. "Cleaning/treatment" is considered as the third (3^{rd}) of seven (7) basic roadwater chain elements (see current practices, Table 1):

1. Prevention
2. Collection
3. Cleaning/treatment
4. Storage
5. Distribution
6. Use
7. Ecosystem balance

Table 1: Summary of current roadwater chain practices in partner countries.

	Germany	**France**	**Netherlands**	**Flanders**
Prevention	Mobile shift	Waterproofing ditches or basins in high vulnerability zones	Updating/maintaining roadside furniture, non-tar-containing asphalt	Mobile shift towards bikes
Collection	Gullies	Ditches, pits and gutters, pipes	Shoulders, Manhole into collection sewer, ditches	Open (concrete) ditches, piping, gutters
Cleaning/ Treatment	Sieve/grid, particle separator, oil separators, reed system, sedimentation basin, infiltration	Decantation with retention basin with dead volume. Infiltration after treatment	Infiltration into shoulders or ditches, oil separator, retention facility, sewer	Infiltration, pilot treatment systems for collected water
Storage	Tanks to collect a certain amount of water for pre-cleaning, open semi-natural basins to store and clean water before infiltration to environment or release to river, buffer tanks for extreme water volumes	Temporary to avoid flooding	None	Basins (buffering), different types exist: evaporation, infiltration, concrete bottom
Distribution	None, only release to natural water cycle (infiltration or release to rivers)	None.	None, only infiltration to natural water cycle	Pilots – experimenting
Use	None	None	None	Pilots – experimenting
Ecosystem balance	Benefits to water cycle to recycle water unable to seep on sealed road areas	Basins with water all year tend to provide refuges for the fauna. Protected species of plants are also found on some basins.		Positive from a quantitative (ground & surface) water and qualitative surface water point of view, uncertainties on ground (& drinking) water quality aspects

4.2 Currently applied cleaning/treatment methods

There are already existing measures for cleaning of collected roadwater in Germany, France, Flanders and the Netherlands. Techniques are classified as natural, semi-natural, semi-technical and technical solutions and can be either centralised, partially centralised or decentralised.

In **Germany**, all runoff water from highways must be cleaned to qualities that do not negatively impact the receiving waters they are released to. Thus, infiltration into water protection zones is not allowed without appropriate water treatment. Mostly, this is done by little treatment plants next to the highways, that consist of oil separation, grids and sedimentation basins. Shoulder infiltration is almost never performed along German highways. So, the focus here is on semi-natural and semi-technical treatment strategies.

In **France**, they also make use of semi-natural and semi-technical approaches to clean roadwater, but also the use of grassed ditches as a natural technique is commonly recommended and applied for reasons of costs. Also, natural infiltration of stormwater along existing highways could occur, and is becoming increasingly common for new road infrastructure projects, particularly those located near cities.

In the **Netherlands**, shoulder infiltration as a natural technique is the most common and preferred way to clean water coming from national highways. In areas, where natural infiltration is not sufficient due to soil conditions, high groundwater levels, or the presence of sensitive environments, additional treatment facilities are used. Collected runoff water is then directed through oil separators that remove hydrocarbons.

In **Flanders** (Belgium), it is prohibited to construct infiltration facilities in protection zones for groundwater to minimize the risks of contamination of drinking water wells. Outside the drinking water protection zones, it is technically no problem to infiltrate rainwater from the road into the soil. Especially in new projects of road renovation, the shift to infiltration next to the roadside is nowadays more often made. When this is not possible, other systems are considered (buffers). Semi-technical treatment by sedimentation basins and infiltration beds are advised, but not mandatory and are rather the exception than rule. Guidelines are limited to recommendations for maximising infiltration and buffer capacity (quantity).

All in all, there are no unique EU-wide regulations or recommendations on how to deal with polluted water coming from roads. All four RRR-partner countries have their own solutions and applications with different focusses on rather natural or technical treatment approaches.

4.3 Categorisation of water qualities

There are several regulations in the NWE countries (national and EU-policies), where parameters are given, that must be analysed as quality criteria of the water types and limit values that must not be exaggerated. Depending on the roadwater reuse purpose (i.e. delivering to surface water, infiltration to groundwater, human use for irrigation (agriculture) or other domestic/industrial usage), different European legislations will apply.

When it comes to usage of roadwater within the human water cycle, different directives for water quality can become relevant and must be considered, e.g. for agricultural use, industrial processes or usage in households. In Europe, water quality standards are defined for drinking water (water for human consumption, EU2020/2184), reuse water (irrigation, EU2020/741) and bathing water (EU2006/7/EC), each with different limit values for fecal indicator bacteria (*E. coli* and *Enterococci*). These limit values are shown in Figure 2. The basis of EU water legislation is the Water Framework Directive (WFD, EU2000/60/EC), which establishes a holistic approach to water management, aiming to achieve 'good status' for all EU waters, including rivers, lakes, groundwaters, and coastal waters.

In some of the directives, also chemical limit values are given and then must be considered. The existing limit values within the EU directives are based on fundamental scientific research and national regulations and should be adapted to the reuse cases for roadwater.

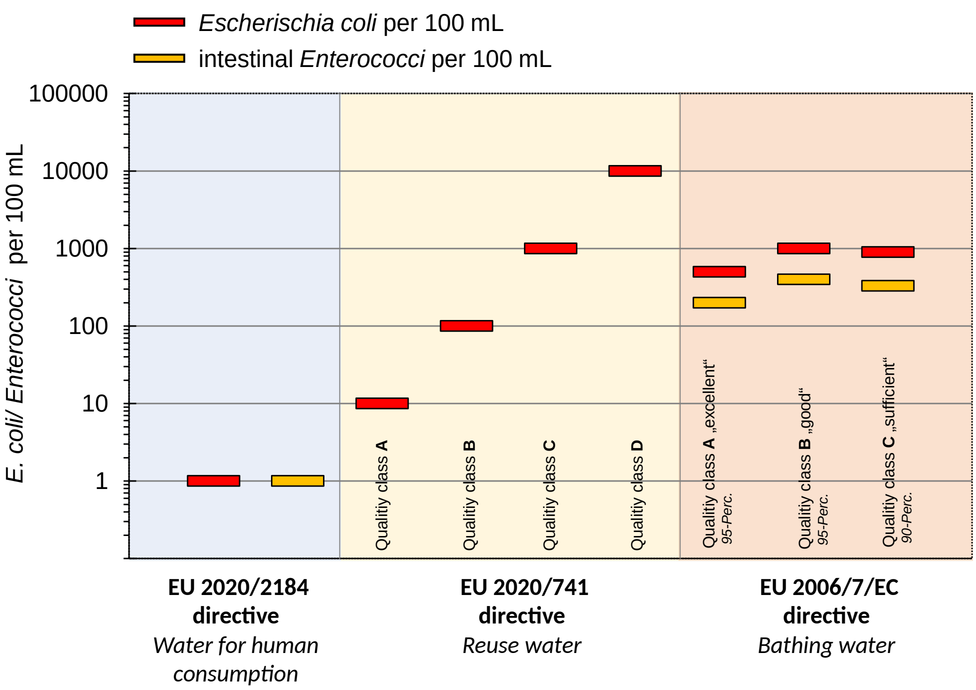


Figure 2: Limit values for fecal indicator bacteria E. coli and Enterococci within the three EU directives.

4.4 Possible uses depending on water qualities

For some applications, the reuse of roadwater could be considered. Depending on the use, different water quality standards must be fulfilled by law. For some uses also no standards are required and roadwater could just be used directly. Roadwater reuse could be easily applied (1) if an infrastructure is already partly given (e.g. if water transportation and storages are already existing but currently water of higher quality is used) and (2) if the roadwater could be directly used without a need for analyses or treatment, which is indicated by a very low water quality requirement.

In many industrial, municipal and private facilities, water of very high quality is currently used for applications, where water of lower quality would be sufficient as well. To treat water to drinking water quality standards requires a lot of material, financial and energetic resources. Thus, it is highly recommended to check, whether a local reuse of roadwater would be an option for certain purposes. Five categories for water quality were defined in relation to possible uses, see Table 2.

Table 2: Water quality categories that indicate the required quality for a certain reuse.

low quality	Water quality	Definition	EU regulation	Thresholds
5	Wastewater	untreated water such as from roads or households		
4	Surface Water	for surface waters such as rivers or lakes	2000/60/EC	
3	Bathing Water	not for consumption but for direct contact to human body	2006/7/EG	≤ 1000 *E. coli*/100 mL; ≤ 400 intestinal *Enterococci*/100 mL
2	Irrigation Water	not for consumption but for direct contact to human consumables (food)	2020/741	≤ 10 *E. coli*/100 mL; ≤ 10 mg/L BSB5; ≤ 10 mg/L TSS; ≤ 5 NTU turbidity
1	Drinking Water	for human consumption	2020/2184	0 *E. coli*/100 mL; 0 intestinal *Enterococci*/100 mL; thresholds for further hydrochemical parameters
high quality				

Use of water quality 5 (wastewater quality) can be sufficient if no microbiological or chemical limits are needed.

Possible uses for wastewater quality roadwater are:

- Industrial water utilization (e.g. industrial cooling, greenhouse warming)
- Firefighting
- Road cooling, prolonging road lifetime
- Particle extraction to make e.g. new tires
- Air washing along highways

Use of water quality 4 (surface water quality) is sufficient but needed for some reuse cases directly influencing the surrounding environment, like forestry, groundwater infiltration, road cleaning or wastewater treatment plant (WWTP) network cleaning. A user would need to make sure, that the roadwater used will not harm the environment. Therefore, at least analyses of the roadwater would be necessary and maybe some basic cleaning or dilution. For the rehydration of moors, there is already a project example existing in Germany. This roadwater reuse has the advantage of revitalisation of a sensible ecosystem and at the same time it promotes decarbonisation of the exhaust polluted air, as moors are effective CO_2 storages. The rehydration or preservation of the existence of rivers or canals can be another feasible and realistic reuse of roadwater, where exemplary projects have already been started.

For road cooling, an idea could be to install buffer tanks below roads, so no additional space would be required next to roads. This could additionally lead to evaporation and condensation in the buffer tanks in summer and thus to road cooling effects. For such purposes, still high infrastructural effort must be undertaken, which all in all leads to a lower practicability even if untreated roadwater could be used here.

However, also uses with higher water quality demands could be considered. In that case, water analyses and water treatment would be needed. Within the specific EU water regulations, microbiological and partly chemical limits are defined that must be fulfilled for a specific water use.

Possible uses for surface water quality roadwater are:

- Forestry
- Re-weat of moors
- Recharge dried out rivers
- Concrete production
- Industrial plant cleaning
- Toilet flushing (private, highway petrol stations, …)
- Cemeteries
- Wastewater treatment plant (WWTP) network cleaning

Use of water quality 3 (bathing water quality) is needed if the use of roadwater implies a possible humane uptake of the water. In the bathing water directive, three different qualities are defined for bathing water indicating if a bathing water is of sufficient (C), good (B) or excellent (A) quality. Based on long-term experiences and expertise of the RRR-partners in the water sector, it should be recommended to achieve minimum quality B (≤ 1000 *E. coli*/100 mL; ≤ 400 intestinal *Enterococci*/100 mL) for roadwater reuses where close contact between user and water is unavoidable and infection risks must be reduced.

Possible uses for roadwater at bathing water quality (minimum class B) are:

- Gardening (private gardens, green streets)
- Car wash
- Paper recycling
- Road cleaning
- Industrial tool cleaning
- Sports facilities (golf gardens, ...)

Use of water quality 2 (irrigation water quality) is needed if the roadwater is planned to be reused for agriculture/irrigation of eaten crops, vegetables, or fruits. Depending on the grown food being consumed directly or not, the EU gives different limits, since the infection risk is increased if grown food is consumed directly. In the latter case, the limits of ≤ 10 *E. coli*/100 mL; ≤ 10 mg/L BSB5; ≤ 10 mg/L TSS; ≤ 5 NTU turbidity are given in the directive for water reuse and irrigation. As a direct uptake of the roadwater through food is likely, these more strict limit values are recommended for such uses, compared to car washing or gardening (see above).

Possible uses for roadwater at the highest irrigation water quality are:

- Agriculture (eaten crops, vegetables, fruits)

Use of water quality 1 (drinking water quality) is applied for many uses where water of lower quality would be sufficient. Except for human consumption and hygiene, there are no uses of water that require this high quality. It is used for all kind of purposes now because in NWE-countries it is very cheap and easily available. However, having in mind that droughts and therefore water scarcity will become more and more relevant in the near future, and this will also affect the drinking water availability and price, it will be of high relevance to evaluate the existing infrastructure in industries, municipalities and private households on the possibilities of using roadwater as a sustainable alternative.

4.5 Evaluation categories for treatment options

There are many ways to reuse water from roads. Roadwater is usually contaminated with particles, dissolved hydrocarbons, heavy metals and other materials, that are spread from tyre wear, accidents and wastes. Moreover, as it is in contact with wastes on the roads and on the shoulders next to roads, it will normally be contaminated microbiologically.

Different treatment methods could be used to reach an optimised water quality. A ranking by different categories can be performed to visualize the applicability of a treatment method for water uses. These ranking categories and their definitions are listed in Table 3.

Table 3: Definitions of water treatment method ranking categories.

Ranking category	Definition
Installation costs	Costs for the installation of the treatment method itself
Maintenance costs	Costs for the maintenance of the treatment method (including personnel costs)
Personnel requirements	Includes personnel costs and requirements of specialists/engineers/…
Robustness	Gives indication of the durability of a treatment method
Material requirements	Gives indication on how expensive or rare materials are, that are required for construction
Applicability	Gives indication on how easy an installation and operation can be realised
Water throughput	Amount of water that can be treated in a certain time and adjustability to varying amounts
Space needed	Space that is needed to construct the treatment plant or to store (un)treated water
Local environmental impact	Environmental impact that the treatment method has for the local area

Table 4 gives the indication of the numbers used in the ranking for each category. The actual ranking of treatment methods can be found in RRR-project deliverable 1.3.1. It gives indications on how easy, cheap, robust, etcetera a treatment method can be and thus helps in choosing an appropriate strategy, when roadwater treatment is required.

Table 4: Ranking indications of water treatment method categories.

Installation costs	**very cheap**	5	4	3	2	1	**very expensive**
Maintenance costs	**very cheap**	5	4	3	2	1	**very expensive**
Personnel requirements	**very low demand**	5	4	3	2	1	**very high demand**
Robustness	**very robust**	5	4	3	2	1	**very vulnerable**
Material requirements	**conventional, easy available**	5	4	3	2	1	**very special, rare**
Applicability	**easily installable**	5	4	3	2	1	**complicated**
Water throughput	**high and/or flexible**	5	4	3	2	1	**low and/or fixed**
Space needed	**very little**	5	4	3	2	1	**very much**
Local environmental impact	**very positive**	5	4	3	2	1	**very negative**

4.6 Comparison of different treatment solutions

Natural solutions imply mainly nature-based treatment methods, such as shoulder infiltration, natural sinking basins or plant systems. These solutions require implementation and maintenance of a working system, what means the solutions are indeed nature based but still artificially constructed or a complementation to naturally existing formations. In most of the NWE-countries, these are the methods commonly applied, together with semi-natural and semi-technical methods to treat roadwater to a certain quality needed - mostly to infiltrate it back to the environment.

All the natural solutions, including natural shoulder or basin infiltration, natural sinking basins and plants, would be quite easy to install and to maintain. None of them causes strong interference with nature and mostly basins must be cleaned, or plants must be removed only once within 10-20 years. However, sometimes the capacity of such natural tanks could be too low for heavy rain events and no constructions to regulate the water amounts are existent for these solutions. Moreover, the cleaning performance is mainly reduced to particle removal or partial removal of organic substances through naturally occurring biodegradation processes. Plants could be used, if special contaminants are known to be present, that could be bioaccumulated by the plants.

Still it must be investigated, if surrounding nature will not be harmed by an accumulation of contaminants and especially regarding higher frequencies of more extreme weather events soon, perhaps alternative and more technical solutions must be considered.

Semi-natural and semi-technical solutions imply treatment methods that are artificial constructions but often complement natural solutions and do not need external energy. Often, artificial sinking basins are constructed from concrete next to roads and water cleaning is improved by grids and oil separators.

These solutions have of course slightly increased installation, maintenance and personnel costs compared to completely natural solutions, but they also offer an increased treatment efficiency without consuming high amounts of external energy. Sometimes collected water must be pumped to the artificial basins, but only temporarily. Artificial sinking basins have the opportunity, compared to natural sinking basins, that they are constructed from concrete and mostly an infiltration is avoided or directed to a certain area, when complemented by an infiltration installation. The maintenance and space needed, as well as the robustness is very comparable to the natural basin when it has been constructed. Grids and oil separators are very simple installations that do not need any external energy sources, as they are simply mechanically “filtering” the water. Since grids can clog, maintenance can be required more frequently compared to an oil separator, which should be dredged once or twice a year. Also, the maintenance of reed systems is required more often (e.g. mowing or circulate the soil).

Semi-natural and semi-technical solutions can be applied, if an optimisation of roadwater qualities is needed, but no high standards as given in the EU regulations for bathing, irrigation and drinking water are required.

There is a high variety of **technical solutions** that can be used to optimise water quality. Technical solutions usually need detailed construction and installation planning, as well as external energy for water pumping (sometimes with high pressures) or formation of disinfectants or gas bubbles. Some of these solutions also require lots of space, just like sand filter or aeration tanks.

Of course, most of the technical solutions have the advantage that they can specifically remove certain contaminants from roadwater, and that water can be treated to such a degree of purity that it can be used for almost any purpose.

Compared to the natural, semi-natural and semi-technical solutions, technical solutions require mostly higher energy, maintenance, costs, planning and space. Among the technical solutions, sand filters and aeration basins can be affordable opportunities, if the water use requires an optimised quality regarding removal of organic load. However, even if the construction and technical requirements of a sand filter can be much lower compared to highly technical methods like membrane filtration or others, sand filters can clog regularly and thus need to be refurbished or maintained frequently. The installation costs of all methods, where dosages of chemicals are somehow required (e.g. chlorine, flocculation, ozonation or hydrogen peroxide), are quite high. They can be applied to remove inorganic components, organic components or microorganisms from water. Membrane filtration techniques, as well as H_2O_2 dosage and ozonation also require lots of planning, energy, space and are prone to technical issues. However, these treatment techniques mostly only must be applied, if drinking water quality is required. Since there are so many other possible solutions to use untreated or just slightly treated roadwater, these treatment solutions must only be considered in very specific cases.

4.7 Conclusions for treatment options

Even if there are opportunities to treat roadwater, also the infrastructure must be given (1) to collect and transport the roadwater to the treatment area and/or (2) to transport the cleaned/treated water to the place where it is needed in case there is no local use opportunity, which always should be checked initially. Therefore, rivers and existing canals could be used as non-cost transportation infrastructures if a transport of uncleaned water is required and it can be guaranteed, that the roadwater will not decrease the quality of the river, which can be avoided by slow release and thus strong dilution effects. It is also possible to install transportation pipes for already cleaned water. This is normally only done for water of drinking water quality, as it is quite expensive to build these kinds of closed pipes. Such pipe systems can then only be used for the transportation of treated water and no water of lower qualities must be fed in here. Examples of "treated water distribution" are long-distance drinking water supplies (in German "Fernwasserversorgung"), which allows for instance the transportation of cleaned/treated drinking water from Lake Constance over several regions in South-West Germany via tunnel pumping. Also, pipes for directed transportation of river water (water of lower quality compared to drinking water) to open-cast mining sites have been recently constructed in Germany. Such systems could be used more easily also for the transportation of roadwater, as no specific water quality is required at the point of use. All in all, transportation systems for a variety of water qualities do already exist or can be constructed, if the benefit is high enough, which is often the case. Therefore, existing infrastructures should be checked for their suitability for roadwater transportation.

Several ideas for roadwater uses are presented according to their possible realisation or implementation, looking at criteria like costs, robustness and water quality. The existing roadwater quality and the required water quality for a specific use case will determine how big the effort must be to clean the water. Categorised according to the technical level, many opportunities to treat roadwater are given. The proposed solutions are a good starting point for detailed considerations on roadwater reuse opportunities. It can help authorities, that struggle with too high amounts of water after heavy rains, too low amounts for agricultural, cultural, municipal or industrial use in dry periods or water users looking for cheaper, more sustainable or generally available water resources for a specific application. Examples for uses or treatment methods considered or already implemented in the NWE-countries are given.

5 Legal issues

5.1 Need of defining a legislative framework for roadwater runoff discharge

Although no specific standards for roadwater exist, depending on its “end destination” different regulations apply related to either the natural cycle or the human cycle. Following Figure 3, models could be used to see if the way of discharging to the environment is not “deteriorating” its state; or whether the human use envisioned could be legally permitted.

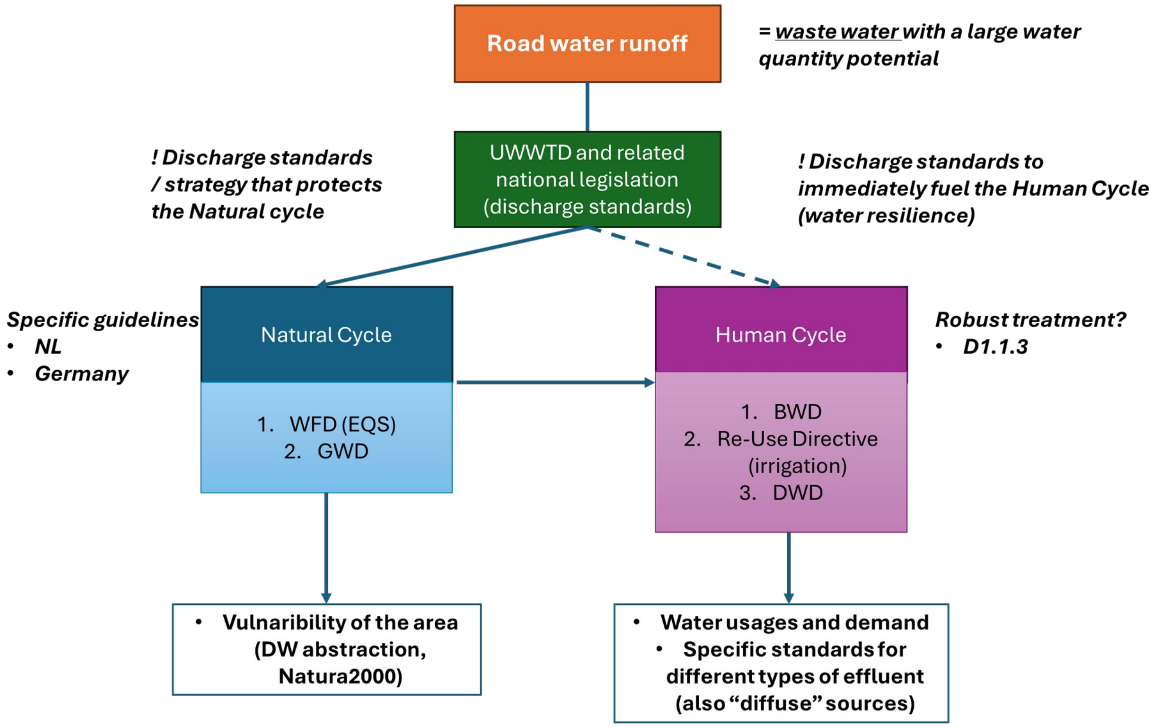


Figure 3: Schematic overview of relevant legislation for discharging roadwater in the natural and human cycle.

However, the level to which extent the water should be treated, is largely defined by the specific standards targeted. These are also depending on the vulnerability of the zone (i.e. depending on drinking water supply or nature reserve nearby etc.).

Furthermore, part of the existing regulations were not intended with these possible alternative sources of water in mind. Therefore, within this chapter, we discuss further on the implications for the natural and human cycle and finally provide some recommendations.

5.2 Natural cycle: ensure full protection of the environment

Sensu stricto the roadwater is not considered as harmful in any of the countries (no dedicated legal status), and each project is assessed *ad hoc* by environmental permit. However, from literature it is clear and all countries within the project are aware that roadwater runoff can be charged with oil, heavy metals, poly-hydrated carbons etc.

In the context of the urban waste water framework directive, some specific roadwater runoff guidelines have been developed in the Netherlands, France and Germany on how to mitigate the impact on the quality of the environment. In Flanders, there is no specific guideline for roads. However there is a “Best Available Technique” on contaminated stormwater from waste storage facilities that could be inspiring for future considerations. Currently, quality is only limitedly considered in the existing urban stormwater regulations, mostly focusing on quantity (related to flooding and drought).

In the different countries, different choices of preferential runoff discharge exist. Generally, prevention of runoff, and the prevention of pollutants in it, should always be the first step of consideration.

Next, it can be chosen to discharge to surface water or soil. In Germany and France, it is (mostly) chosen to discharge (delayed) to surface water or infiltrate to the groundwater, after pre-treatment. The pre-treatment is based on oil-separation and sedimentation and mostly applied in the more vulnerable areas (i.e. drinking water protection zones). Hence, large volumes of surface runoff, from kilometres of roads, are treated in several units along the side. In the Netherlands, a pre-treatment is reached by the structure of the asphalt (ZOAB) in the breakdown lane. Next, the remaining pollutants are discharged to the soil where they accumulate. Pollution of the groundwater is prevented by regular ZOAB cleaning and regular scraping of the top soil from the shoulders. This decentralized approach is relatively low in maintenance costs. In Flanders, since recently there is also a preferred pathway towards infiltration of the roadwater runoff in response to the need for a climate-adaptive infrastructure. However, there is no general strategy decided on quality management (no general rules on when a pre-treatment is necessary).

Both options can be justified taken that pre-treatment is regulated by a specific framework or guideline, and a combination of approaches could well be used. However, generally there seems to be a shift towards more infiltration towards the side, probably from a climate-adaptive point of view and considering the high maintenance needed for the sedimentation basins installed.

Overall, there are no specific regulations or standards related to the runoff water composition directly. Depending on the compartment to which the runoff is discharged, the impact is evaluated with respect to the standards for surface water, groundwater and/or soil (Figure 3).

Recent studies of the roadwater runoff management strategy used by the Netherlands (Jelmer et al. 2025) and a study on infiltration in France (Tedoldi et al. 2020) confirmed that the environmental impact from infiltration of roadwater to the shoulders is limited. From a climate adaptive point of view, it can be concluded that infiltration towards the soil should be the preferred strategy.

Although these studies suggest that the pollutants tend to accumulate in the upper layers, the worries remain that pollutants from roadwater runoff could leak to the deepest groundwater layers and could threaten the drinking water. In Flanders, there is no consensus yet on this topic related to quality. Table 5 contains contaminants that have been mentioned to be worrisome from a drainage point of view (info from VMM groundwater specialists, 2021).

Table 5: Standard package for analysis of drainage water and additional mobile pollutants of concern.

	Soil	Groundwater
Standard package for analyses of drainage water		
pH		+
pH-KCl	+	
Conductivity and temperature		+
Dry Matter content (%)	+	
Organic matter content (%)	+	
Clay content (%)	+	
Heavy metals (8: lead, zinc, cadmium, cupper, nickel, arsene, mercury, and chrome(III+))	+	+
BTEX (4: benzene, toluene, ethylbenzene, xylene)		+
Mineral oil	+	+
PAH (16 poly aromatic hydrocarbons: naphthalene (NAP), acenaphthylene (ACY), acenaphthene (ACE), fluorene (FLU), phenanthrene (PHEN), anthracene (ANTH), fluoranthene (FLTH), pyrene (PYR), benzo[a]anthracene (B[a]A), chrysene (CHRY), benzo[b]fluoranthene (B[b]F), benzo[k]fluoranthene (B[k]F), benzo[a]pyrene (B[a]P), benzo[g,h,i]perylene (B[ghi]P), indeno[1,2,3-c,d]pyrene (IND), and dibenz[a,h]anthracene (D[ah]A))	+	
VOCl (11 volatile chlorinated compounds: 1,2-dichloorethane, dichloormethane, tetratchloormethane, tetrachloorethene, 1,1,1-trichloorethane, 1,1,2-trichloorethane)		+
Vinylchloride		+
Additional pollutants of concern		
Siltation parameters (Na, K, Cl-, en SO4 2+…)		+
Heavy metals (cobalt)		
Fluoride		
PFAS (PFOS, PFOA…)*		+

** especially when re-use is also considered*

Furthermore, new substances of concern may arise (i.e. microplastics, cf. Vercauteren et al. 2021). It would therefore be recommended to have more research on the local specific possible impact of infiltration to the groundwater by pollutants associated with roadwater runoff (1) and to develop a software tool like the one developed by Autobahn in Germany, calculating the pollutant concentrations at the soil-groundwater interface for renovations and constructions of roads in water protection zones (2). The output of such a tool can be compared to the groundwater quality standards. Recently, in Flanders, the model tool *aquaSens* has been developed, that evaluates treatment systems for roadwater (Vinck et al. 2023). This will allow water authorities to assess the impact of the road manager activities correctly and to verify whether a pre-treatment prior to infiltration is necessary or not, depending on the impact to the groundwater and vulnerability of the surroundings (drinking water, nature). The model tool should be updated on a regular basis with respect to the most recent knowledge. Pre-treatment should be kept as natural and robust as possible, since maintenance is often challenging to integrate within the overall road management.

Generally, discharge to the sewage systems is to be avoided. However, when the restrictions by the competent authorities involved differ too much, it is difficult to find the space needed for infiltration.

Nevertheless, to decide on when and what level of treatment is needed, it would be better to have a more **clear legal status of roadwater (and other stormwater) runoff** linked to the urban waste water directive, defining it as the "waste water" it is. Or may be defining it within a separate stormwater category (i.e. towards a European Stormwater Directive currently missing). This would allow the authorities to define **a consensus decision framework** on the steps needed prior to infiltration in any situation (for different types of stormwater, different measures depending on the textures of underground, and different types of land use and vulnerabilities etc.). Ensuring the possibilities for infiltration are maximized as water becomes more valuable in times of increasing drought events, without compromising the quality of the surroundings.

Setting a clear status and framework of consecutive steps needed, will take away the insecurity of *ad hoc* based permit decisions for road managers (which may vary between countries and regions) and could lower the procedural times needed related to possible debate between the competent authorities involved.

It is very likely that the construction of roads will be more expensive towards the future, taking into account all the considerations described here above. Surely the "polluter pays principle" will open a debate of responsibilities and financing needs, needed at a higher political level. However, the transition towards a climate adaptive environment can be considered a "Duty of Care". Regulating the "Natural Cycle" adequately will be needed, ensuring both "sustainable use" and "protection" of water for the "Human Cycle" (Figure 3).

5.3 Human cycle: maximizing use possibilities for water resilience

Different legal boundaries have been explored in chapter 5 for roadwater use possibilities. Lowering the use of high drinking water quality where possible feeds into the European Water Resilience Strategy, and contributes to the main recommendations and steps that need to be taken to a water-smart society, i.e.

- Building a water-smart circular economy
- Zero pollution objectives
- Anticipate water-related climate risks
- Support disruptive research & innovation activities
- Leverage digital water opportunities

If we consider the requirements, we see limited chemical parameters within the re-use act for irrigation or bathing. However, a profound risk based assessment should be taken into account. Many components are substances of high concern (REACH) and for PFAS often a separate communication and set of standards has been issued for the different environmental compartment by the Health Departments (Table 6). Microplastics are another concern clearly linked to roadwater runoff by tyre wear (Vercauteren et al. 2021).

When thinking of roadwater use, one does not think about human consumption, but rather about **second circuit water** (to protect the public water network), including applications that do not require drinking water quality such as cleaning or toilet flushing. The microbiological component only becomes relevant for irrigation and for human consumption or bathing.

Table 6: Overview of standards among different environmental compartments for forever chemicals PFAS and derivates in the different partner countries (nav = not a value found).

Country	Surface water	Industrial water	Pumping water/ groundwater	Bathing water	Drinking water	Soil when re-used
Flanders	0,65 ng/L	Permit required when > 20 or 50 ng/L	<10 ng/L when returned (pumping water)	Sum PFOS, PFOA, PFNA & PFHxS <0,2 µg/L (child) <1 µg/L (adult)	Sum PFAS-20 < 0,1 µg/L Total PFAS < 0,5 µg/L	PFAS-20 < 15 µg/kg ds
Netherlands	0,3 ng/L (PFOA) 0,007 ng/L (PFOS)	Permit required when > 20 or 50 ng/L	*nav*	Sum of PFAS in PFOA eq. <0,280 µg/L (<0,071 µg/L in swimming pools)	Sum PFAS-20 < 0,1 µg/L	3 µg/kg ds (PFOS) 7 µg/kg ds (PFOA) 3 µg/kg ds (other PFAS)
France	PFOS surveillance since 2022 (5 PFAS)	PFOS<25 µg/L Mesures of PFAS-20 required for thousands of plants	20 PFAS to measure starting 2026 < 2 µg/L (before treatment)	*nav*	Sum PFAS-20 < 0,1 µg/L Total PFAS < 0,5 µg/L	*nav*
Germany	*nav*	*nav*	*nav*	*nav*	Sum PFAS-20 < 0,1 µg/L and Sum PFAS-4 (PFOA, PFNA, PFHxS and PFOS) < 0.02 µg/L*	*nav*

* For mineral water the PFAS standards for DW do not apply (info obtained from RRR-partners)

PFAS might be of concern, however some limited results (n = 5) from monitoring roadwater runoff from an intensively used road near Berchem (Antwerp) in StopUP are positive, showing the concentrations fall below the most strict standard set in Flanders (communication of preliminary results shared by the associated StopUP network, 2025).

5.4 Recommendations for further defining the legal boundaries

The pollution problem related to and created by the building and use of roads is a diffuse pollution source from stormwater runoff, that is currently not clearly acknowledged or tackled by any of the existing European legislation. A combined approach of (1) setting sufficiently clear European standards and policies here for different types of stormwater (incl. roadwater) with respect to the complex and dynamically connected socio-ecological water systems with shared cross-sectoral responsibility and (2) a source-oriented approach, including a modal shift (towards more sustainable transport) and applying circular economy principles (avoiding pollution and integrating re-use) will be necessary to tackle the further diffuse degradation of our environment.

Recommendations:

1. Develop a European Stormwater Directive that integrates both the quantitative **and qualitative** minimum requirements for different types of stormwater classes, integrating the requirements from the UWWTD, WFD, GWD, FD, Soil Strategy to better protect the natural environment. **Or** define it within the UWWTD as a specific type(s) of "wastewater" related to stormwater runoff.
2. For the different types of stormwater management (i.e. roadwater, roof water, railway water) **(1) a consensus decision framework and (2) technical guidelines** should be developed and provided, managed and monitored in all countries by the **water managing authorities**, being compliant to the Stormwater Directive, when it is available.
3. In the meantime, **model tools** are needed to evaluate the impact on surface water and groundwater, translating the impact to the receiving water bodies, so the existing standards can be used to meet the "no deterioration principle".
4. Linking the insights gained to the Climate Adaptation and Water Resilience Strategy, **promoting maximal safe infiltration and re-use.**
5. Screen and **update the existing legislation** of bathing water, playgrounds, drinking water, irrigation etc. **taking into account the alternative water sources** for re-use that might be considered towards the future (are all necessary pollutants screened by the current legislation which were not designed for this alternative sources of water)
6. **Continuous research and development, following-up on the harmful substances** (PS and watch list) of concern, continuously evaluating and adapting the strategy to anticipate and tackle stormwater related pollution risks (i.e. PFAS, micro-plastics).
7. Be part of a learning network on water re-use

6 Matching approach for promising combinations

6.1 Problems and challenges for water

Due to climate change, we have to cope with extreme weather conditions. Sometimes it's too dry, and other times it's too wet, sometimes even leading to flooding. It is therefore important to retain and buffer water for use in dry periods. For stormwater, buffering may also help to quickly clear the road in case of heavy rains, while delaying and then gradually releasing it to the ground or surface waters to prevent flooding and overflow of streams or rivers.

Natural sources of water are rainwater, surface water, and groundwater. We need water for both the human and the natural water cycle, while gaining and maintaining ecosystem balance, i.e. the water used, must be replenished. Surface water and groundwater are used in the human cycle for producing drinking water, for irrigation, for domestic and for industrial purposes. Water enters the natural cycle by evaporation, transpiration by plants, infiltration into the ground or discharge into surface waters.

Pollution may enter both the human and natural water cycle and, depending on the concentrations, may cause harm to people, the natural environment and aquatic life. Special considerations are needed when (1) infiltrating (polluted) water in areas where groundwater is used for drinking water or in areas with a vulnerable natural environment, (2) discharging to surface water with vulnerable aquatic life. We also have to consider that surface water volumes shrink in dry periods, inherently leading to higher concentrations of pollutants. Treatment may be necessary before releasing water into the human or natural water cycle. A more natural or technical method can be applied, depending on the type of pollution, its extent and the required quality.

We have defined five qualities of water (see Table 2) that help in determining its possible uses, based upon EU regulation and best practices, specifying chemical and biological requirements. Using water of a lower quality, if the use permits it, saves (treatment for) drinking water or other water sources of a higher quality. Water of a higher quality may, after use, be reused for purposes that permit a lower quality. Preferably, after (multiple) use(s) and treatment, the water is infiltrated or discharged near the sourcing location, thus maintaining the ecosystem balance.

Considering the immense surface of roads in North-West Europe, these can be regarded as large collectors of rainwater. This roadwater can be buffered, treated and used for all kinds of purposes, at best reducing the use of high quality drinking water for low quality purposes and reducing the extraction of groundwater. Transporting or distributing water to the location of use can be challenging and makes a strong case for using water near its origin. It may be possible to use ditches, streams, rivers or canals as means of transport and only as a last resort use a pipe infrastructure.

Roadwater can be of different qualities, containing different pollutants, depending on numerous factors, such as: surrounding area (rural, industrial), type of traffic (cars, trucks), traffic intensity, season, road construction (open/closed asphalt, concrete gutters vs. natural ditches), time between precipitation, etcetera. Furthermore, pollutants can exist in either particulate or dissolved form, affecting the ease of treatment.

Conclusion: To identify promising combinations, the local roadwater quality, the required treatment, the appropriate and legal use, the required distribution, and the support from local stakeholders must be considered and assessed in conjunction.

6.2 Promising combinations (legal, treatment, use, distribution and stakeholders)

In this paragraph, we describe and discuss use cases for each water quality category as defined in paragraph 4.4 (see especially Table 2), except for drinking water (its use we aim to reduce), to find promising and viable combinations. The possible use of water collected in a given area largely depends on its quality. For each quality category, we identify cases of direct use and assume that it might be viable to upgrade/treat the water to the next higher quality category, but not any higher. The motivation behind it is that we aim to make the best use (best match) of the water quality, as it is. By doing so, we reduce the use of (overqualified) higher quality water that is much more expensive to produce in terms of costs, infrastructure, materials and energy. We assume (not recommend) that water from a higher quality category can always be used for purposes requiring a lower quality category.

Use case Wastewater

Apart from domestic and industrial wastewater outputs to the regular sewage system, we expect cases of roadwater with wastewater quality at large, multilevel highway crossings ('cloverleaf intersections'), especially due to large road surfaces, high intensity traffic from multiple sides and cases of industrial surroundings. Part of the crossing may be sunken, requiring pumping away of groundwater. Parts of the road will be above ground, where roadwater cannot infiltrate in the shoulders. Therefore, infrastructure and buffers are required to clear the roads and prevent them from flooding. Usually, there is enough space to implement basins for that around the crossing.

There seem to be limited possibilities for direct use of untreated and polluted roadwater assumed to have wastewater quality, except for cases where there is no contact with humans or the environment, for example for cooling of roads, buildings, heat islands or data centres and maybe some industrial purposes.

However, we expect that relatively simple treatment with oil separators and sinking basins can upgrade the water to "Surface Water"-quality. The basins then combine the functionalities of flood prevention (stormwater storage) with treatment and will also contribute to the biodiversity around the crossing (e.g. birds). Attaining the “Surface Water”-quality would open up several other uses in the industrial or rural surroundings: cooling, industrial processes (e.g. concrete production), irrigation for floriculture, tree growing or (re)wetting nature, infiltration, discharging to surface water and recovering raw materials from the sludge.

Stakeholders in the area, mainly water authorities, governments, industries, nature organisations, agricultural organisations, and companies, should be involved to identify and implement the most valuable types of use.

Use case Surface Water

Wastewater and roadwater need to be treated to achieve at least "Surface Water"-quality, before discharging it into surface waters is allowed or recommended, to protect the environment and aquatic life. It may not be safe to use it in direct contact with humans. In case of no heavy pollution of the roads, the water might automatically have surface water quality after oil separation, but chemical analyses to proof this would be necessary.

Several direct uses of surface water are envisioned: cooling, industrial processes (e.g. concrete production), irrigation for floriculture, tree growing or (re)wetting nature, filling buffers for dry periods, infiltration, replenishing ditches, streams, rivers and canals. The latter options also allow transporting the water to other locations, where surface water can be used as a source for direct use or, after treatment, for higher quality uses (e.g. irrigation). Replenishing rivers and canals may also help to keep shipping routes available in dry periods, allow continued supply for industrial processes, for cooling power plants or help to lower concentrations of pollution for aquatic life.

Stakeholders are water authorities, different levels of government, industries, power plants, nature organisations, agricultural organisations and companies.

For use in the human water cycle, it must at least be treated to achieve "Bathing Water"-quality, where also microbial requirements apply.

Use case Bathing Water

The EU regulation for "Bathing Water"-quality (Quality B) specifies it as not for consumption, but allowed for use in direct contact to the human body. It must be regarded as the minimum quality for natural swimming waters that are infrequently and incidently used. It is not meant to be used for human hygiene.

The requirements for "Bathing Water" are focused on microbial contamination of the water, that can make you sick, not on chemical contamination. Except for gardening, we see limited use in the domestic environment, especially with roadwater as a source that may also contain chemical pollution. Furthermore, the limited options for domestic use will likely make it unprofitable to build a distribution infrastructure from the roads to households in rural areas.

Therefore, we see the most promising use cases next to the roads/highways, in limited contact with humans and for professional uses: road cleaning, making roads ice-free (salt in brine), solar panel cleaning, irrigation of sports fields, car washing and industrial equipment cleaning.

The stakeholders will mainly consist of road authorities, solar farms and professional organisations.

For use in a domestic environment, we see better opportunities for water upgraded to "Irrigation Water"-quality, where even stricter microbial requirements apply.

Use case Irrigation Water

The "Irrigation Water"-quality ("Quality A"-variant) is required when using water for agricultural irrigation of eaten crops. The microbial criteria are more strict than for "Bathing Water", and only few chemical criteria apply, such as turbidity and total suspended solids concentration. The water is not suitable for direct human consumption, but it is allowed to come in contact with food crops that are consumed raw. In the EU regulation 2020/741 for irrigation water, Annex II (B) additional requirements are suggested "when necessary and appropriate to ensure adequate protection of the environment and of human and animal health" and "such additional requirements may in particular concern: (a) heavy metals, (b) pesticides, (c) disinfection by-products, (d) pharmaceuticals, (e) other substances of emerging concern, including micro pollutants and micro plastics, (f) anti-microbial resistance." In the case of roadwater, additional requirements "a", "b" and "e" are most relevant.

We see limited direct use of roadwater treated to "Irrigation Water"-quality, except for agricultural irrigation very near the collecting road(s), where it can reduce the use of groundwater for irrigation. Much more potential we see when also the additional (chemical) requirements for the protection of the environment and of human and animal health are fulfilled (further referred to as: “Irrigation Water +Plus+”). Then domestic uses come within reach, lowering the use of drinking water (important note: 75% of drinking water usage in NL is for household purposes). This is particularly noteworthy, since producing drinking water is costly and energy-intensive. Furthermore, during dry periods, drinking water production and distribution are pushed to their limits.

We believe that "Irrigation Water +Plus+"-quality (suitable for domestic use) holds great promise for: irrigation, gardening, crop cultivation, food washing, toilet flushing, showering and filling of private swimming pools. Its wide applicability could make some investments in treatment and distribution more cost-effective, especially as in the (near) future prices of drinking water are likely to increase and restrictions on its use during dry periods will become more common.

We see three typical use cases that may be interconnected:

1. Roadwater from a highway (significant surface) is collected, treated and transported, along a regional/local road crossing the highway, to a nearby village. Just like with the communal wells on the central village square in the old days, the people can

obtain water for domestic use (explicitly excluding human consumption) in a central location nearby. Important note: Roadwater must be cleaned from chemicals and no fine-grained distribution is required.

2. Some villages/neighborhoods have separate sewage systems for rainwater and wastewater. This makes it relatively easy to collect, treat and buffer the rainwater and make it available again with "Irrigation Water +Plus+"-quality at central places, as mentioned before. Important note: With a separate rainwater sewage system in place, this can be a cost-effective, shared solution and the water will probably contain less chemical pollution than runoff from highways.

3. To collect, treat and buffer rainwater from the roof of a house seems most promising, because it is least polluted with chemicals and it can be used directly at the source. Internal distribution in the house is possible to toilet and garden via a pipe system separate from drinking water. No need to collect it a the "central village well". We would very much like to also use it for showering and filling swimming pools, but this is not (easily) allowed in most countries. Important note: To meet the microbial requirements, we believe that heating, UV-light exposure and local filtering may be viable (decentralised) options. Although energy consumption is a concern, the increasing prevalence of solar panels on residential rooftops creates an opportunity to leverage excess renewable energy for water treatment purposes.

The advantage of creating opportunities for domestic use is the possible involvement of a broader community of stakeholders including citizens and thus creating more awareness for problems and solutions around water.

Upgrading water of "Irrigation Water"-quality to "Drinking Water"-quality seems only useful in the absence or the dysfunction of a centralised drinking water infrastructure, e.g. for remote locations or for mobile/backup applications, such as in cases of (natural) disasters.

6.3 Value cases and organisational aspects

For a use case or water hub project to actually work, it is important to have a good overview of the resulting **values and benefits for each of the stakeholders**. These values and benefits **need not necessarily be financial**, but can for example be in the form of improved environmental quality (a.o. biodiversity), job opportunities, health, social cohesion or liveability in general.

In the case of multiple value creation, where **different stakeholders may receive different benefits or obtain multiple values from a project**, it is easier to finance the project with **contributions from different sides and in different forms**. When such values can be combined, relevant institutions are more eager to share responsibility in the process. Then blended finance (several stakeholders combine their budgets in one common project) is going to be an option, based upon broader support and resulting in a better continuity/sustainability of the project. In this way, a more advanced water hub with more functions becomes possible, beneficial for all participating parties. **Consequently, the decision making processes may become more complex, but will also become a better match towards the end-users in the region.**

The value cases developed together must **in the exploitation phase be supported by pricing models or incentives and possibilities for mutual transactions (matching water supply and demand)**. This may **need some form of organisation** that facilitates this, such as a joint cooperative. In addition, **a platform or data space may be needed to exchange information on water quantities and qualities available and requested**. These are things that must be further worked out on a per-use-case basis, depending on the infrastructure and solutions foreseen.

6.4 Mapping of opportunities

6.4.1 Introduction

As described in chapter 3 Pragmatic steps in involving the community, the best opportunities are where there is a regional challenge or opportunity for water. This can be caused by extreme weather conditions like flooding and drought, but also infrastructural renovation needs of post-war infrastructure that approaches the end of its technical lifetime. All of these will be increasing in numbers the coming years/decades and becoming more extreme. Climate adaptation solutions all promote to keep water as long and as high as possible in the system. That brings us to a third possible cause: demands for the re-use of highway water, like pumped tunnel water. Below, we describe several locations we had contact with during the project time. Of course, there will be many more in case you follow-up on extreme weather news items (Valencia 2024 floodings) or e.g. statistics/reports/maps made by EU Environmental Agency (EEA).

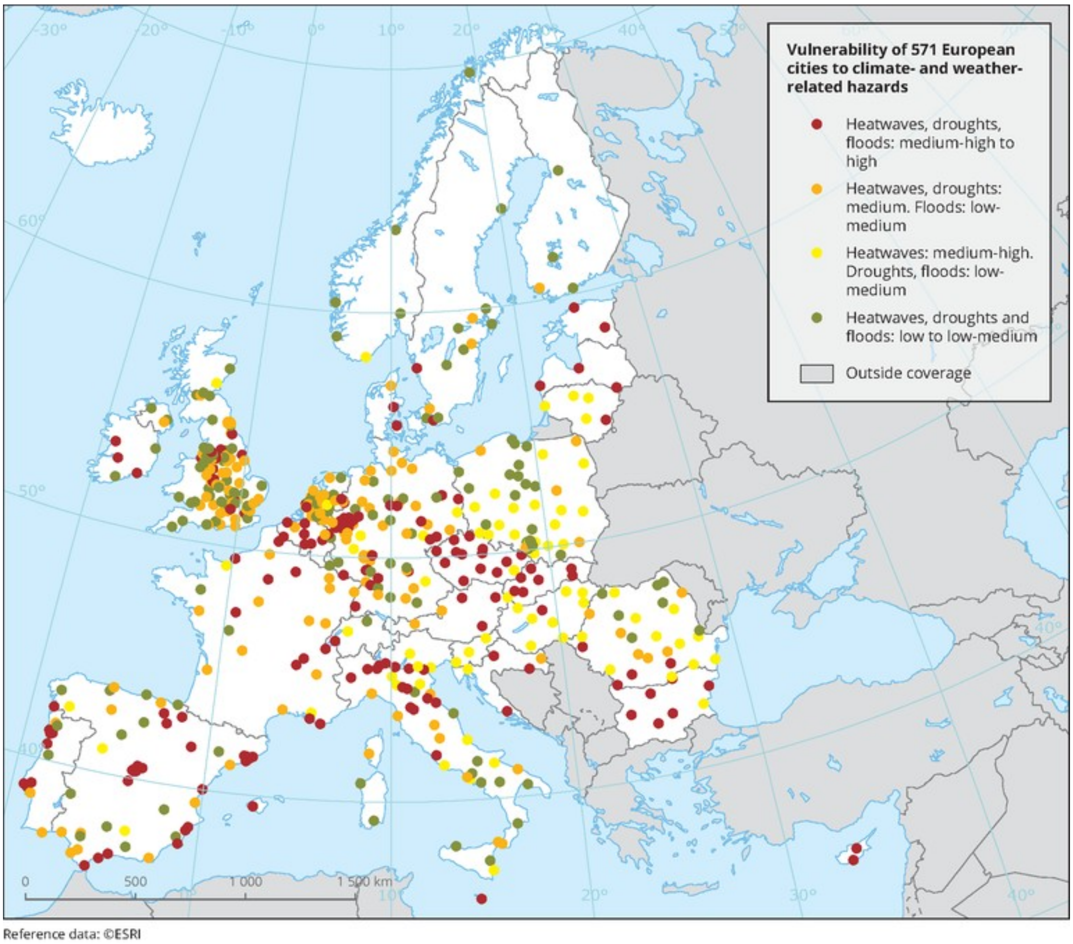


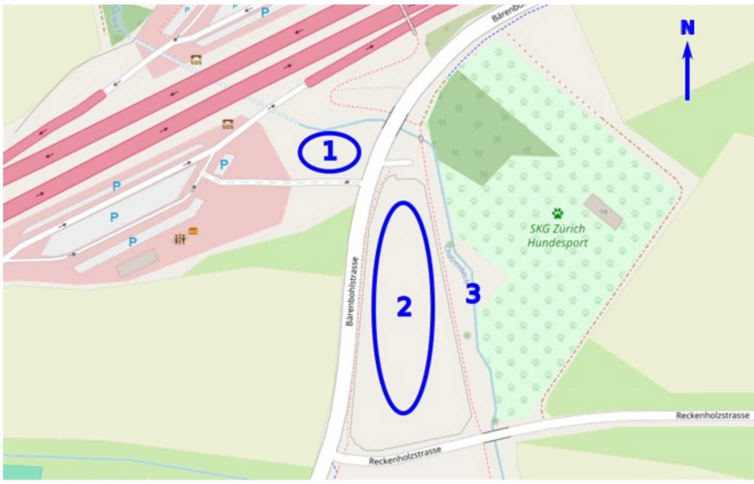
Figure 4: Vulnerability of 571 European cities to climate- and weather-related hazards (source: EEA)

6.4.2 SABA Grütwiesen

Location: Zürich Affoltern, Switzerland, next to highway A1/A4
GPS Coordinates: 47.42913, 8.51256

Site Description

SABA Grütwiesen (**S**trassen**A**bwasser**B**ehandlungs**A**nlage) is a facility that collects and cleans highway runoff. It is situated at the intermediate lowest point of the highway, near a gas station, collecting water from both directions of the highway over a total length of 4,1 km. The water is cleaned in two stages. The first basin (1) collects the water and lets particles sink to the bottom (sedimentation), while clean water from the surface layer slowly flows over the edge. The water can be (temporarily) contained in the first basin (e.g. if too polluted) or pumped into a second larger basin (2) with a (helophyte) filter. The water is again collected underneath the filter at the bottom of the basin, from where it is pumped into the stream Chatzenbach (3) that flows south-east towards Zürich Seebach.



Use Case Description

SABA Grütwiesen is the most advanced facility within the project. It uses sedimentation, biological (helophyte) and mechanical filtering, probably providing the cleanest/highest quality roadwater. It uses pumps that can be shutoff to prevent pollution from road accidents entering the second basin (maybe this can even be done automatically, based on real-time pollution sensors). Coincidentally, the neighboring institute Agroscope (east of basin) carries out applied research in agro-ecological food production, protecting natural resources. Together with the Ecotox Centre, specialized in the impact of water quality and pollution on living cells (plants/animals), with Gerophyt, specialized in vegetation and soils retaining water, the possible use of the roadwater for growing food can be investigated. Some after-processing of the water from the basin and additional infrastructure or equipment may be needed. This is where the involvement, contribution and expertise of the other partners is required.

Potential Partners

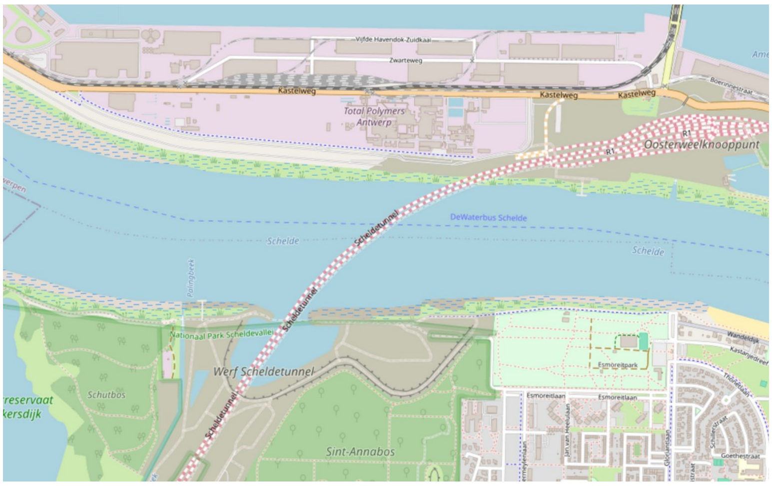
Ecotox Centre, Canton of Zürich, Agroscope, Hunziker Betatech AG, Gerophyt, Bundesamt für Strassen ASTRA

6.4.3 Antwerp Oosterweel

Location: Antwerp Oosterweel, Belgium, construction of a new highway
GPS Coordinates: [51.23814, 4.37462]

Site Description

The project 'Antwerpen Oosterweel' is under construction and connects the highway E19 with the E34 and closes the ring around the city of Antwerp. The project is executed by Lantis. After the realisation, the maintenance will be executed by the Flemish road authority Agentschap voor Wegen en Verkeer (AWV). The trace crosses the 'National Park Scheldevallei' with the nature reserve Blokkersdijk and Sint Annabos. A tunnel under the river Scheldt is part of the connection. The tunnel is used voor mobility but has also a (double) water function. The water from the tunnel is collected and cleaned and brought to nature reserve Blokkersdijk. The tunnel is also used as a reservoir that can store water in times of water overflow. The connection is about 7 km long and costs 10 billion euro. Th project will be finished around 2033.



Use Case description

The project Oosterweel is unique in the way they give the highway a water function related to the local water challenge. Road water is cleaned from PFAS and used to restore the nature reserve Blokkersdijk that suffers from water shortage. The tunnel is used for storage when Antwerp suffers from a 'downpour'or torrential rain. Lantis has experience with the use of road water for watering plants (with a truck) and for washing cars in a car wash. This makes Oosterweel a unique use case and the Lantis organisation a perfect parter.

Potential partners

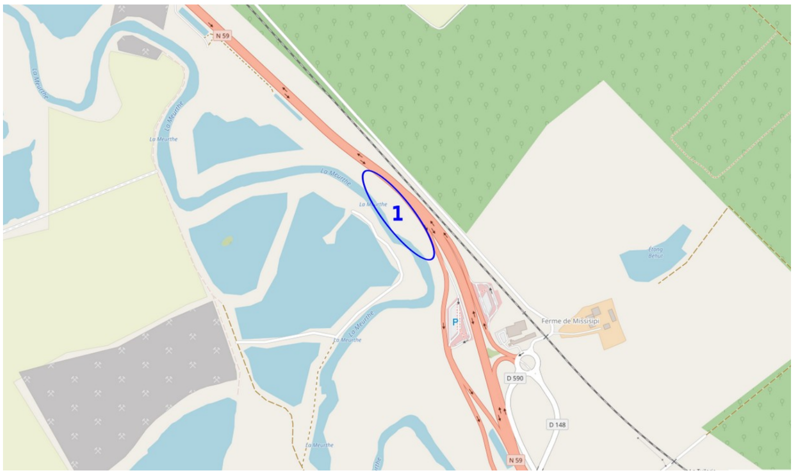
Agentschap voor Wegen en Verkeer (AWV), City of Antwerp, Flemisch Environmental Agency (VMM), Natuurpunt (Nature Organisation responsible for Blokkersdijk)

6.4.4 Nancy

Location: Nancy, France, retention basin next to national road N59
GPS Coordinates: 48.55529, 6.55486

Site Description

Since 1992 under French law, road water runoff without cleaning is not allowed. New roads and renovated roads all have basins. The road water is directed to the basins, where the water can settle and the pollution sinks to the bottom. Along the N59 in the northeast of France there are around 15 of such basins, along a straight road, about on average 5 km apart. See the map for one of them; basin indicated with (1). They're build and owned by DIR Nord-Est. The DIR uses them for cleaning of the road water before releasing it into the nearby river Meurthe. In case of accidents with hazardous substances, the outflow is blocked and the polluted water is removed. Currently, there is no regular check on the water quality and no treatment exists.



Use Case Description and Potential Partners

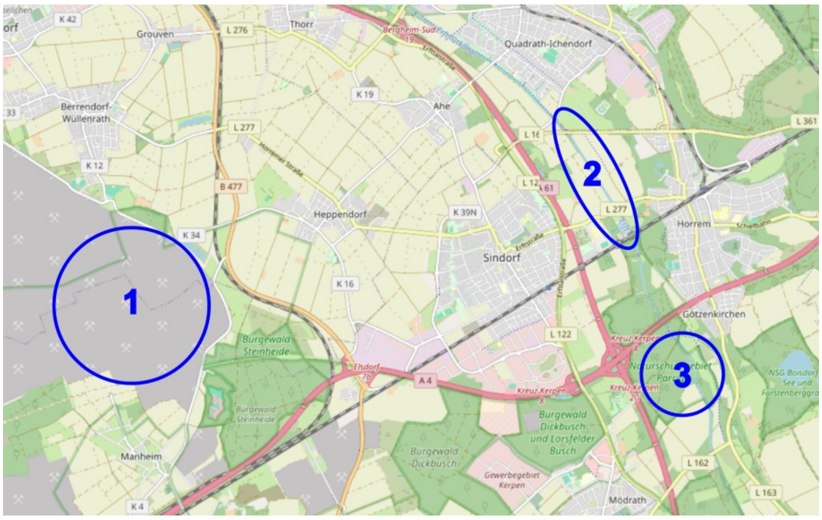
CEREMA is interested on starting a pilot to leverage the existing water cleaning and collection basins of the DIR. Potential partners are technology developers Hydro International (decanter), CEREMA (floating wetland) and Aqua B (nano bubbles). The focus of the pilot will be on further treatment of the water with several technologies done in several basins. One basin can be left untouched as a baseline. This pilot builds on prior experiences and CEREMA knowledge on roadwater collection. It supports the broader Sponge City ambitions of Nancy. On the demand side, CEREMA will map stakeholders, which are primarily nature, farmers and industry.

6.4.5 AK Kerpen

Location: AK (**A**utobahn**K**reuz) Kerpen, Germany, crossing highway A4/A61
GPS Coordinates: [50.8948, 6.6949]

Site Description

Close to Köln you find the biggest open brown cole pit of Germany named: 'Tagebau Hambach' (1). The mine is 400 meters deep and owned by the energy company RWE. The mine is closing in 2030 because of CO_2 regulations. This means that the pumping of groundwater will stop. Because of this measure, the groundwater level will rise in a big area as far as Roermond in the Netherlands. It also affects the highways around the pit. The lower laying Kreuz Kerpen (crossing of the highways A4 and A61) is expected to be affected by the increase of the groundwater level. The highway authority Autobahn GmbH has to take measure to prevent the Kreuz from flooding. The Rhein-Erft-Kreis is planning to develop the pit into the biggest freshwater lake of Germany. They are doing this via a participatory process with the people in the surrounding villages, known as 'StrukturWandel'.



Use Case Description

The Erft (2) river currently receives the (warm) groundwater from the mine. However, when this inflow stops, the river's discharge is expected to decrease significantly. Meanwhile, the water buffers for AK Kerpen are insufficient to handle future flooding. The water, that needs to be pumped out to keep Kreuz Kerpen dry, can be used to fill the Erft river by constructing pipelines from AK Kerpen to the Hambach site. A second option is that the water is pumped to the nearby moorland (3) that is drying out due to agricultural activities.

Potential Partners

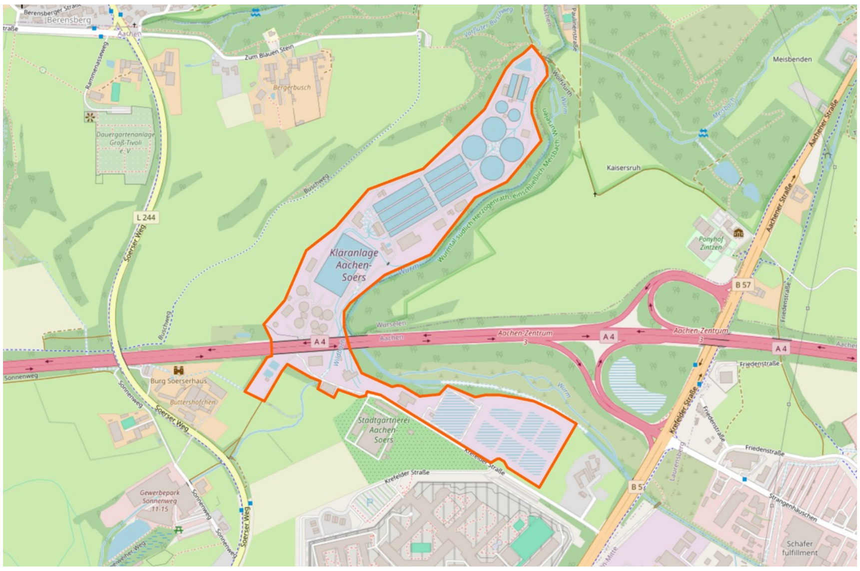
In both cases, Autobahn GmbH will have to work together with local authorities like Rhein-Erft-Kreis, nature and farmers organisations.

6.4.6 Aachen-Soers

Location: Aachen-Soers, Germany, Krefelder Str. 299 (next to highway A4)
GPS Coordinates: 50.8057, 6.0990

Site Description

Under the A4 and next to the river Wildbach, the sewage treatment plant of the city of Aachen is situated. The facilities of the treatment plant make it easy to set up a test site with treatment facilities for roadwater. Currently, road runoff from the A4 highway is discharged into the Wildbach river at Aachen-Soers without any pre-treatment.



Use Case Description

For the Aachen use case, the main interest will be to compare the different treatment solutions for highway runoff (see photo of current test site on the right). It may be interesting to identify possible uses through community engagement. For example, Tuchwerk could be a good local partner to bring citizens, institutions and other stakeholders together. Tuchwerk describes itself as follows on its website: “Under the guiding principle of 'Cultural Memory for the Future', a place has been created in TUCHWERK AACHEN that connects contemporary diversity of art and culture with science and history in an authentic industrial monument - a lively center for collaboration, exchange, and civic and social engagement in the midst of the Landschaftspark Soers.”

Potential Partners

RWTH Aachen University, Institut für Siedlungswasserwirtschaft (ISA), Rhein-Erft-Kreis, Autobahn GmbH, German Water Centre TZW, MUST

6.4.7 Opportunities outside the North-West Europe (NWE) region

While working on the RRR-project, we raised attention of several road authorities:

- **ANAS** (Italian road authority) started a ‘Aqua di Strada’ project to start using highway stormwater to combat drought periods, especially in Southern Italy (e.g. Sicily, August 2024). They invited us to collaborate on a LIFE-call about roadwater quality.
- **CEREMA** started research in Southern France to investigate the use of roadwater basins for combating bushfires.
- **Statens vegvesen**, the Norwegian road authority approached us via the CEDR environmental working group to explore a CEDR research-call on roadwater reuse. They are working on taking measures after storm Hans, August 2023.

7 Action plans (examples)

7.1 Introduction

This chapter presents the action plans for the Kloostersland (NL) and Leuven (BE) areas, focusing on improving the water balance in the area through community engagement. The plans identify possible opportunities and emphasise a collaborative approach, involving various stakeholders and ensuring that the solutions are tailored to the specific needs and context of the areas. The plans highlight the importance of long-term thinking and local value creation and describe what should be the focus in each phase of the process.

7.2 Action plan Kloostersland

The action plan for Kloostersland follows the steps described in chapter 3 Pragmatic steps in involving the community. The (1) identification and (2) exchange steps have been carried out during the RRR-project and the (3) design, (4) implementation and (5) maintain, sustain and use steps are envisioned for the "Sponge Roads"-project (Interreg NWE proposal).

The results of the identification and exchange steps are laid down in the deliverables D.1.4.1 (Illustrated Fact-sheets on two use cases) and D.1.4.2 (Two documented, exemplary sessions with stakeholders) of the RRR-project. These documents respectively describe the context of the Kloostersland area and its stakeholder setting.

We have identified a number of opportunities that we would like to further investigate and work out with the stakeholders in the area.

Opportunities around the highway and canal

- Rijkswaterstaat (RWS) has three infrastructures in the area: (1) the highway A58, (2) the rest area/innovation site Kloosters and (3) the Wilhelmina Canal.
  Water from the highway and rest area can be collected, treated and buffered for several purposes:
  1. Local use on site, e.g. toilet flushing in the Innovation Pavilion/fuel station, road cleaning/cooling and washing solar panels (solar park near the highway).
  2. Pumped into the canal for transport to users along the canal (e.g. sports fields, concrete production, car wash) or pumped, the other way around, from the canal to the uses mentioned under 1, 3 and 4.
  3. Pumped onto the heath for (1) training of Defence personnel and (2) infiltration. Defence wants to practice crossing waterways with vehicles.
  4. A new to be developed distribution system for grey water for a sustainable neighbourhood in Oirschot, being built near the highway and canal.

- Additionally (not too distant from Kloosters), Rijkswaterstaat has a highway tunnel (A2) near the village of Best, where they have to pump (ground)water to prevent the highway from flooding. The water can be used by the farmers and industry (e.g. ASML) in the surroundings and/or pumped into the Wilhelmina Canal and serve similar purposes as mentioned above. Currently, this water is simply discharged onto a ditch and lost. The canal could even be used as a (water)transport between the two locations.
- The Wilhelmina Canal streams along the village centre of Oirschot and can be used as a heat source in winter or as a cold source in summer, reducing the consumption of natural gas and its contribution to climate change. Furthermore, by adjusting the water level in the canal, it can be used for water storage.
- We would like to explore the potential for transporting much more goods by water, reducing the need for (heavy) road transport on the A58, decreasing roadwater pollution and emissions, potentially reducing the need for an extra lane. For example, the use of autonomous water drones or electric boats could be an efficient way to transport goods via the Wilhelmina Canal between Tilburg and Eindhoven.
- Between the canal and the highway near Kloosters, there is a solar park that could be combined with a water buffer underneath the panels, potentially improving their performance due to the cooling effect.
- Spraying water above or on the road surface can help capture air pollution (particulate matter and nitrogen) and cool the roads, extending the lifespan of the asphalt. Conversely, the quality of roadwater runoff can be improved by sweeping or vacuuming the lanes before a rainstorm. These measures can be tested on the innovation lane at Kloosters.
- In summer, the heat from the road surface (and from solar panels, PVT-type) can be used as a heat source for the new sustainable neighbourhood mentioned earlier.

Opportunities in the village centres

- From Kloosters, an infrastructure can be established via the provincial road to the village centre(s). At a central point in the village, residents can tap water for gardens and ponds, without installing another expensive fine-grained distribution system.
- Similarly, in parts of the villages, the rainwater sewer has been separated from the wastewater. This water can be collected, treated, and made available again locally.
- More green spaces and water in the village centre can help mitigate heat. The municipality can use the water to irrigate (new) plantings in municipal gardens and

refill ponds around the village.

- Residents can also consider collectively purchasing systems for collecting, treating and storing rain and shower water for later use in gardens and for toilet flushing.

Opportunities in the rural area

- The water balance in the rural area can be improved by redesigning the landscape and storing more water. Large open landscapes can be separated by hedges to break the wind and reduce evaporation. Farmers and nature organisations in the area can create ponds. Farmers can cultivate crops that require less water or retain water better. In this way, irrigation with groundwater or surface water can be reduced.
- On the heath in Oirschot, increasing biodiversity and planting more deciduous trees instead of conifers can help reduce evaporation. Traditional ponds can be restored.
- During the wet winter period, water from the canal can be applied to the land to infiltrate and replenish the groundwater, letting in excess water from the Meuse.
- In summer, if buffers are full, excess roadwater runoff from heavy rain can (after treatment) be released into ditches in the area, ensuring they reach their desired water levels, controlled by weirs.

Not all of these opportunities will resonate or be feasible, supported and embraced by the local community. They should therefore be viewed as inspirational and a starting point, rather than as fixed or absolute. We now have to look for local people that have their roots in the community (ambassadors) and build a network of people that are willing to take up the project. An independent creative person or team should identify the most promising cases and arouse interest and involvement from relevant local stakeholders, while in the mean time thinking about viable value cases and means of financing. Initiators should have good relations with citizens and institutions, but also have an independent role. They must bridge the gap between different interests and organisations.

Designing and co-creating

As soon as we have gathered stakeholders around a number of promising cases, we will start designing and co-creating as a group, guided by an independent team balancing the (potentially different) interests. For this, the location of the Innovation Pavilion at Kloosters is extremely suitable, due to its inspiring environment. It is also an environment (network) with a lot of knowledge about symbiotic, nature-inclusive, and sustainable building, where we can involve the right expertise, if needed.

A project must create value for all parties involved in a balanced way and contribute to the liveability of the environment. Local values are the starting point for the design. Therefore, it is essential to involve people with knowledge of the local culture and history. What is considered important in the local community? What are the direct benefits? Are the facilities accessible to everyone? Are there broader social benefits? It is essential that the design strengthens the local fabric.

We want to make as much use as possible of local materials and production chains (involve local companies already in the design phase), which may also impose limitations on the design. However, it contributes to the long-term reliability and maintainability of the systems when leveraging local resources. It further strengthens local ownership and local influence and allows the local community to take responsibility.

Implementation

For implementation, a project team will be established preferably involving persons from different stakeholders, directly or as participants of a steering group, providing both execution power and governance to the project. The project team may evolve from the design team, but it will require other skills and must be carefully composed. The team should take the (preliminary) design and transform it into a sound value case. This involves further detailing the design, carrying out feasibility studies, requesting quotations, arranging finances, looking for locations, preparing concept contracts, setup a (legal) organisation, etcetera.

When everything is prepared, a final go/no-go decision has to be made by all parties involved. After this approval, a detailed project plan can be developed, including activities, timelines, budgets, and resource allocation. Locations can be acquired, suppliers and builders can be contracted, implementation can start and the process should be monitored and steered.

Maintain, sustain and use

In this phase, our focus will be on effectively managing the infrastructure, maintaining relationships with stakeholders, and identifying opportunities for further growth and innovation. We believe that being open to feedback from the community is crucial, as it can provide valuable insights and ideas for improvement. The perspective can be broader than the specific projects that have been realised. It may be possible to leverage and combine existing projects, infrastructures and networks to create greater value.

7.3 Action plan Leuven

The action plan for Leuven (Heverlee) focuses on improving water balance in a dense urban and ecological interface zone, where stormwater from highways intersects with Natura2000-protected forests, urban infrastructure, and community initiatives. While research and stakeholder collaboration are at an earlier stage than in Kloostersland, initial interactions reveal promising opportunities and the need for integrated, context-sensitive solutions.

Following the structure described in chapter 3 Pragmatic steps in involving the community, this plan builds on the identification and initial exchange steps completed during the RRR-project and sets the course for future co-design, implementation, and maintenance activities.

Identification and exchange

Over the course of the RRR-project, initial sessions with different stakeholders were held:

- Agentschap Wegen en Verkeer (AWV) as road authority is focused on the urgent need to renovate the ageing bridge over the Naamsesteenweg (Heverlee). While water-related issues are fairly new territory for them, they acknowledge the importance of incorporating sustainable runoff strategies into their future practices.
- The City of Leuven is motivated by its ambition to become a green, climate-adaptive city and wants to avoid water damage through stronger stormwater control. It uses the permitting process to incentivise sustainable runoff management.
- The Agentschap Natuur en Bos (Forest Agency) and Province are primarily concerned with safeguarding the adjacent Heverleebos Natura2000 area from polluted runoff.
- Project Walden acts as a community platform, representing local residents with a strong interest in restoring historical watercourses to enhance biodiversity, ecosystem services, and quality of life.

This stakeholder landscape reflects a diverse set of motivations: infrastructure urgency, regulatory vision, ecological protection, and community-based restoration. Future co-creation should continue to balance these needs through shared goals and concrete, low-barrier entry points.

Preliminary scoping suggests a mix of immediate and medium-term opportunities for improved runoff handling, re-use and community value creation.

Opportunities around the highway and bridge

- Enhancing existing retention basins by introducing sedimentation traps and vegetated treatment zones to reduce pollutant loads before overflow.
- Use treated runoff for irrigation of nearby community gardens, the grounds of a local school, large student residence, and public green spaces.
- Ground infiltration systems on the north side of the highway, further away from Natura2000 zones, could allow for seasonal or event-based recharge of groundwater.
- Diverted runoff could potentially serve industrial areas further down the highway or the military domain at the Hertogstraat, especially for non-potable uses such as landscape irrigation or washing facilities.

Opportunities for broader system improvements

- Decentralised solutions such as bioswales (wadi), rain gardens, and infiltration trenches along roadsides and public areas can help absorb peak flows and promote resilience.
- Participatory monitoring involving local actors (Project Walden, KU Leuven, IMEC) can build capacity and ensure adaptive management.
- Educational partnerships with the school and student communities can turn stormwater infrastructure into living labs or educational spaces.

Designing and co-creating

While there is no central "innovation pavilion" as in Kloostersland, Leuven’s strength lies in its dense knowledge network and community engagement. Institutions like KU Leuven and IMEC can serve as innovation partners, particularly in water quality monitoring, circular resource use, and system modelling.

Project Walden provides a trusted link to local residents and an established platform for ecological restoration. They can continue to organize co-design sessions, hosted either within municipal spaces or at educational facilities.

A neutral facilitator or coordination team (embedded researchers or creative intermediaries) can guide the group, ensuring that outcomes meet diverse goals; from fast-tracking permits to long-term ecological integrity.

As in Kloostersland, design should prioritise:

- Local relevance and accessibility
- Synergies with existing sustainability goals
- Value creation for multiple user groups
- Use of local materials and expertise

Implementation

After defining promising value cases through co-creation, a project team should be assembled—drawing from relevant public agencies, research institutions and community partners.

Key implementation steps include:

- Upgrading and optimising retention basins
- Installing pilot infiltration sites and decentralised buffers
- Creating joint-use cases for treated runoff (e.g. irrigation at the school or community garden)
- Developing data-sharing agreements for monitoring and maintenance
- Preparing funding applications to programs such as Interreg, LIFE, Horizon Europe, or the Flemish Blue Deal

Because the regulatory framework currently exempts road authorities from local rainwater ordinances, the project may also serve as a test bed for policy innovation, exploring new forms of collaboration and shared responsibility between city and agencies.

Maintain, sustain and use

Long-term success depends on continued stakeholder alignment and shared stewardship.

Governance structures may take the form of:

- A joint task force or forum involving AWV, the City of Leuven, and key community partners
- Integration of infrastructure upkeep into regular city and AWV maintenance plans
- Community-led monitoring and interpretation via educational institutions or Project Walden

Ongoing feedback and monitoring (both technical and social) will be critical in scaling successful measures and refining the needed governance. In the long run, this pilot can inform a replicable framework for integrated runoff management in other Flemish cities, especially those facing similar urban-ecological tensions.

7.4 Discussion

The action plans for Kloostersland and Leuven show how local context shapes the pathway to better water management, but also reveal common principles that can guide replication in other sites.

Common ground

- Both action plans combine technical, ecological, and social solutions.
- They explore runoff reuse and buffering to ease pressure on sewers and support local needs.
- Both emphasise stakeholder co-creation and design based on local values.

Key differences

- Kloostersland is further along, with concrete use cases and a central innovation site.
- Leuven is earlier in the process, but could benefit from strong institutional partners (e.g. KU Leuven, Project Walden).
- Ecological constraints (e.g. Natura2000 forest) seem more prominent in Leuven, requiring stricter water quality controls.
- Policy leverage differs: Leuven uses permitting to push sustainability, while Kloostersland builds on infrastructure synergies.

Replication

Despite differences, the phased approach (identify–exchange–design–implement–maintain) and the focus on local co-benefits make both action plans adaptable to other regions. Core aspects such as coupling technical and spatial interventions, and exploring new governance models can be adapted to other regions or sites facing similar runoff and reuse challenges.

Insights from both action plans feed into the broader integrated pathway work described in the next chapter, but also into other knowledge dissemination activities of the RRR-project.

Tools, templates and process learnings have been made available as deliverables and via the RRR-website to be shared across regions to accelerate climate-adaptive water management across Europe.

8 Implementation pathway

8.1 Introduction

EU-reports and recent weather show tremendous water-related challenges in the NWE territory. Current research demonstrates that solutions are best found on a regional level. This RRR-project intended to show (and inspire) that roads and highways can play an important role in addressing regional water challenges. The project elaborated on community/stakeholder, technical, and legal aspects. How can the strategy for Climate Adaptive Water Hubs (CAWHs) be extended to other locations and groups of local stakeholders in the NWE-region? This chapter sketches a pathway towards implementation.

8.2 From Highway to Climate Adaptive Water Hub

Throughout North-West Europe, we saw an enormous postwar expansion of infrastructure developments. This dense and articulated/branched road network reaches the end of its technical lifetime. Therefore many **road authorities face large renovation programmes**. Since infrastructure renovation is extremely costly, road authorities also face complex prioritisation schemes to decide which road (or better said which region) to serve first. This is an excellent chance to take other current challenges into account and make it a combined, synergetic effort. By early interaction with local stakeholders and regional or sectoral agencies and authorities, collaboration options will emerge.

There's an **increasing attention for the quality and quantity of road runoff water**. Some countries like France and Switzerland issued environmental laws to reduce groundwater infiltration of polluted road water. Road authorities in these countries (respectively DIR and ASTRA) consequently started building retention basins (e.g. SABAs) with simple purification techniques along new or renovated highways.

An important observation is that **you don't need to change a highway to realise a Climate Adaptive Water Hub**. Add-ons are sufficient. Those add-ons do touch several conditions of technical, legal and social character. The NWE-network of roads is vast and intensively branched, thus having high potential in locally catching and storing water. Best practices can be developed for water hubs along highways as relatively simple add-ons with limited impact on the road construction.

We expect that highway renovation, water quality issues, the ease of "adding-on" and the potential for replication along **the vast highway network in NWE, will create a promising pathway to practical implementation**. Best chances for realisation are regions with a water-related challenge in combination with planned infrastructure renovation or maintenance.

To add water as a function to roads ideally the above described conditions come together. Of course (road or water) authorities or local communities can take up responsibility and start blending, or bringing the conditions together. Each sectoral or regional authority will have its challenges. **By setting up a multiple value case, it is possible to find overlap or synergy with other local investments and realise blended finance (a mix of finance from different angles).** Climate adaptation policies can be integrated with mobility issues to create a multiple value case. Water retention basins, like from the French and Swiss examples, are potential solutions that can be copied if proven interesting. Different solutions, co-created with the community, should be tested in a follow-up project.

8.3 Scaling

The RRR-project delivered an extensive strategy and worked out action plans for Leuven/Heverlee (BE) and Eindhoven/Kloosters (NL). These should be tested in reality in a follow-up project. Afterwards, **an upscaling approach aims to implement additional water-hubs in other regions with water challenges**, like Norway (storm Hans), Valencia, Lille, Rhine catchment area (flooding), central Spain, southern France and southern Italy (drought). In fact, we have been approached by several authorities of these regions. We also foresee **scaling of existing water-hubs or retention basins to a larger region**. Basins can be interconnected to increase their potential, possible adding existing canals or rivers to this system. We also foresee the **pioneering CAWH-communities starting to work together exchanging knowledge and experiences**, e.g. combine or prepare purchasing trajectories.

We also expect **'broadscaling' when established regional collaborative structures on water management extend their collaboration to other types of challenges/themes** (energy, air, soil). The fabric (network-of-people) that will develop within the local community enables tackling other issues as well. You might consider Cooperative Kloostersland, currently as a partner in RRR working on the subject of water, to have actually evolved from an existing local fabric that has been established during the realisation of a cooperative regional fibre-to-the-home (FttH) network. Again, **additional functions of roads may appear** and reinforce each other. One could think about themes like energy (car charging/heat collecting asphalt for neighbourhood), agriculture for bio-based (road) materials and biodiversity.

9 Collaboration and Sharing Platform

In order to share knowledge and work together on content and process documents, we set up an online sharing platform using Nextcloud open source software, hosted by Cooperative Kloostersland. In this way, all documents were accessible to everyone in the project and we could use the collaborative editing functionality to work on deliverables, together and concurrently. Inspirational articles were placed on the RRR-project website. Additionally, a Linkedin-page named Sponge Roads was launched in anticipation of a follow-up project.