Results of the Meuse extreme drought Hackathon

A report on the observations shared by the participants

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Disclaimer: The views shared in this report can differ from the views of the organizing organizations.

All cartoons displayed in this report were made by Jan Selen of Jam Visual Thinking during the hackathon.

Executive Summary

On 11 September 2024, a Meuse extreme drought hackathon was hosted at the University of Liège, aimed to:

1. Better understand the different interests and impacts of droughts among the Meuse River Basin countries. This enables the integration of hydrological system knowledge and promotes informed decision-making both during and after droughts in a transboundary context.
2. Create awareness about the importance of international cooperation in the field of water allocation by enabling a water dialogue.

To reach these aims, 24 hydrological experts from Germany, France, the Netherlands, Flanders, and Wallonia were invited to participate in the hackathon. We collaboratively answered the following research question: *What is the impact of an extreme drought on the Meuse River Basin and consequently different sectors and regions? What can be done to reduce this impact and/or create synergies?*

Multiple impacts of the extreme drought were identified by the participants and clustered per sector. For example:

- For industry and energy, power plants will likely be shut down, resulting in less heating of the Meuse, as well as reduced hydropeaking.
- Not all Meuse countries are equally dependent on the Meuse for drinking water: The Netherlands and Wallonia can more easily switch to other sources, whilst Flanders depends highly on the Meuse for drinking water. Salt intrusion might require the drinking water intake points to move further inland.
- Nature at the Grensmaas is vulnerable and will likely be impacted to a large extent. For nature in general, a minimum flow is necessary.
- Irrigation is one of the first uses restricted in their water use during droughts, resulting in economic damages and likely more import of agricultural products.
- Shipping becomes less reliable during droughts and has the highest priority for water allocation in Wallonia.
- There is still a lack of coordination in water prioritization, possibly resulting in unequal and inefficient distributions.

To reduce the identified impacts, short-term and long-term measures and synergies were discussed, including combinations of both structural and non-structural solutions, as well as combinations of nature-based and grey solutions. Multiple measures were brought forward by the participants on four topics, for example:

1. Water demand reduction: Increased awareness and more recycling and reuse.
2. Sectoral and spatial adaptation: Implement diversification of sources for drinking water and implement closed-loop cooling for energy and industry.
3. Conflict prevention: Enable knowledge exchange platforms and cooperation between drinking water companies.
4. Water retention and nature-based solutions: Bring back the sponge function of the landscape and increase the number of reservoirs.

A discussion on next steps with the participants resulted in the following recommendations:

- Quantify the goals we want to achieve within the hydrological system, (e.g. to achieve a certain sponge function) and quantify the impact of identified measures;
- Improve knowledge on governance structures and discuss the implementation requirements for different measures (e.g. necessary Meuse agreements).

Artist impression of the day.

Contents

1 Introduction

1.1 The Meuse extreme drought hackathon

On 11 September 2024, a Meuse extreme drought hackathon was hosted at the University of Liège, in Belgium, back-to-back to the Meuse symposium. Different organizations were part of the preparations, consisting of RIWA-Maas, Rijkswaterstaat, Deltares, University of Liège, University of Aachen, and Programmabureau Stroomgebied Maas.

1.2 Why a Meuse extreme drought Hackathon?

The multiple different sectors and areas within the Meuse Basin are increasingly negatively affected by droughts, primarily due to the increasingly occurring low river discharges. In 2018 and 2022, the river discharge dropped to less than 20 m^3/s at Eijsden (The Netherlands). The transboundary context of the basin forms an additional challenge to coordinate drought adaptation decision-making. Therefore, the MICCA[1] network was established, a knowledge exchange and consultation platform on climate adaptation for the entire Meuse River basin. Through this MICCA network, more knowledge and information exchanges occur, enabling international collaboration on water allocation, especially important in times of droughts.
The increasing negative effects of climate change felt within the Meuse Basin, combined with the need to continue knowledge exchange on drought, led to the idea to host a Meuse extreme drought hackathon. Accordingly, the aims of this hackathon were to:

1. Better understand the different interests and impacts of droughts among the Meuse River Basin countries. This enables the integration of hydrological system knowledge to cater to diverse stakeholders and promote informed decision-making. Organizing this hackathon, herein, supports water managers and policy makers to make improved decisions before, during and after droughts in a transboundary context. This can contribute to improving transboundary Meuse River Basin management.
2. Create awareness about the importance of international cooperation in the field of water allocation. We do so by enabling a water dialogue between experts from the different Meuse countries and sectors, through sketching the problems and impacts in the basin. This gives more clarity about the impact of droughts on different sectors and countries, and herein contributes to an increased consciousness about the importance of international collaboration in the area of water allocation.

We chose the hackathon format to reach these aims, as it is time-efficient, has an exploratory character and helps to look at problems and solutions in a different way. During this pressure-cooker event, an interdisciplinary group of people answers one research question in one day. Using maps, simple mathematical models and expert knowledge, questions are discussed and answered in groups. It has an open character, where everyone has an equal say and listens to each other. An important difference with other events is that participants are working jointly to answer a question in a very limited time window. It is important to state that, even though solely 24 hydrological experts participated in this hackathon, the outcomes are meant for a wider audience, consisting of both water managers and water users.

1.3 Research question and program

The question to answer in this hackathon was the following: *What is the impact of an extreme drought on the Meuse River Basin and consequently different sectors and regions? What can be done to reduce this impact and/or create synergies?*

[1] *Mosan Initiative for Climate Change Action*

The participants were invited to think about the whole river system (e.g. groundwater, soil moisture, the agricultural sector, etc.) and not solely discharge. Different activities were determined to both answer the research question and gather information to reach the hackathon aims. Hence, the program of the day was the following:

Table 1-1 Program of the Meuse extreme drought hackathon.

Time	Content	More specific information
09:00 – 09:25	Walk-in and welcome	
09:25 – 09:55	Introduction to the day and extreme drought event in the Meuse River Basin	Tami de Lange, Programmabureau Stroomgebied Maas, sets the scene by sketching a fictive but realistic extreme drought event in September 2028.
09:55 – 10:15	Walk-the-line exercise	Introductory exercise for the participants.
10:15 – 11:15	Serious game by RIWA-Maas	Maarten van der Ploeg has, through RIWA-Maas, developed a serious game in which the participants represent different countries, which need to allocate scarce Meuse water to different sectors. They do so in collaboration, and as long as everyone can meet their demand, everyone wins. Otherwise, everyone loses. It illustrates that collaboration is key in the Meuse River Basin during periods of droughts, as solely through collaboration all countries can reach (most of) their water goals.
11:15 – 11:35	*Break*	
11:35 – 12:00	Demo on the extreme drought effects and introduction of group work	Marjolein Mens, Deltares, gives a short presentation on how the extreme drought used in this hackathon is quantified. This drought I based on new KNMI'23 climate scenarios and data, which is, through the hydrological model Wflow_sbm, translated into river discharge data. From this new river discharge data, a very dry year is selected based on having the largest summer discharge deficit as well as the lowest precipitation in the preceding winter period. The determined discharges occurring during this extreme drought have been put on a large map of the Meuse Basin, which is used in the first group work assignment (see Annex A).
12:00 – 13:00	Group work to discuss impact of extreme drought on the Meuse, different tributaries and sectors (e.g. hydropower, nature, agriculture, drinking water, industry)	In this group assignment, the map of the Meuse Basin, displaying the discharges during an extreme drought event is used. In five groups, the impacts of an extreme drought on different sectors in the different Meuse tributaries are discussed. When possible, it is visualized and quantified where the impact is largest and why.
13:00 – 14:00	*Lunch*	The cartoon artist, who is present during the whole day, shares his preliminary drawings with us.
14:00 – 14:30	Plenary: Groups present their most important findings	
14:30 – 15:30	Group work to discuss possible synergies, short-term and long-term measures to make the whole basin more resilient against droughts	In this group assignment, focusing on measures, a scorecard (see Annex B) is used. The participants are grouped into four main categories, each focusing on different measures: Water demand reduction Sector adaptation and spatial adaptation Conflict prevention Water retention and nature-based solutions Within each group, short-term and long-term measures and synergies are discussed falling within that category to make the Meuse Basin more resilient. Through the scorecard, the measures are made as specific as possible.
15:30 – 15:45	*Break*	
15:45 – 16:05	Plenary: Groups present their top three synergies/measures	
16:05 – 16:25	Discuss: How can we bring these results further?	Aim is to collect important topics and/or research questions that result from this hackathon.
16:25 – 17:00	Closure	The cartoon artist shares his final drawings with us and elaborates on them.

Figure 1. Impression of the serious game by the cartoonist.

1.4 The participants

Ultimately, 24 people participated in this hackathon, from the different Meuse countries - Germany, France, the Netherlands, and Belgium (from both Wallonia and Flanders). These participants were mainly research-oriented, as the focus of this hackathon was to predominantly gather scientific information.
There were, however, also people present doing research-work, but oriented towards governance. The participants work in various types of organizations, ranging from drinking water companies, water boards, nature conservation, energy-oriented organizations etc. Table 1-2 gives the division of participants present per country. An additional 8 people were present from the organization team or were present to moderate, working at RIWA-Maas, Rijkswaterstaat, Deltares, VITO, University of Aachen, and Programmabureau Stroomgebied Maas.

Table 1-2 Overview of participants during hackathon (excluding organization team members and moderators) per Meuse country.

Country	Number of participants
Germany	2
France	2
The Netherlands	10
Belgium - Wallonia	5
Belgium - Flanders	5

2 Results

2.1 Expectations of the participants

We asked the participants at the beginning of the day about their expectations of the hackathon. They indicated that they were hopeful to:

- Get the conversation going on drought management to stimulate and foster collaboration and communication between the different Meuse countries. This is important to:
    - Learn about droughts in general.
    - Learn about droughts measures taken within each Meuse-country and which (out-of-the-box) measures you can still take.
    - Understand the organizational structure and water allocation structure (prioritization scheme) within each Meuse country during periods of drought.

The sections below report the observations made by the participants during the hackathon, in their own words.

2.2 Results from round 1 – impacts on water system

In the first group assignment, participants were invited to think about the whole Meuse River system during a period of drought, using a map displaying the extreme discharges. Annex C displays the maps containing the results from each group. Several observations came forward, which are also coherently displayed in Figure 2-1:

Industrial and electricity sector

- The impact of a drought on power plants might not be the most important impact, as people will still get their electricity in another manner when power plants need to be shut down. The electricity supply and data centres are, therefore, less vulnerable in a drought compared to other sectors.
- Shutting down nuclear power plants during periods of droughts might result in less heating of the Meuse River, as less cooling water needs to be taken in.

- The impact of hydropeaking[2] is large during low flow conditions and can become either more or less serve during an extreme drought: It will become more severe when the power plants are not yet switched off, but when the power plants need to be switched off during extreme droughts, hydropeaking will actually decrease.

Water quality, drinking water sector

- Salt intrusion will progress further inland in both the Netherlands and Flanders, combined with higher salt concentrations. Additionally, the influent flows into wastewater treatment plans decrease during drought conditions, resulting in decreased water quality downstream of these water treatment plants. These phenomena both deteriorate the water quality, where the impact is particularly large at the drinking water extraction points. Consequently, extraction points might have to be moved more upstream, further away from the connection to the sea.
- Flanders depends highly on the Meuse for its drinking water and will, therefore, likely suffer most. Also, the Albert Canal and the Scheldt are the only water source for Antwerpen, making the Albert Canal very important for Flanders.
- Several of the Meuse countries can move to groundwater extractions for their water supply, when there is insufficient water in the Meuse River, such as Wallonia and the Netherlands.
- During extreme drought events, dams will experience difficulties in providing sufficient water for the different uses (e.g. drinking water), as they have not been filled up as much, e.g. for the Rur Dam.

> ***The impact of droughts on the drinking water production***
> ***Mirjam van Roode – stakeholder manager WML (water utility Limburg)***
>
> “The River Meuse is an important water source for drinking water, both in Flanders and in the Netherlands. WML, the water utility in the Dutch Province of Limburg, abstracts groundwater and Meuse water to produce 70-80 million m^3 of drinking water annually. During prolonged periods of drought, the water availability becomes an issue. This could be caused by falling groundwater tables, but more often has to do with the Meuse water quality not meeting the intake standards. Due to limited dilution during low flows, harmful contaminants (from industrial discharges, pesticides, cosmetics, medicine, PFAS, etc.) can be found in relatively high concentrations. WML, therefore, continuously screens samples of Meuse water, and utilizes a biomonitor (mussels and water fleas). In case of alarming monitoring results (concentrations exceeding one or more standards), or an alert triggered by the biomonitor (e.g., mussels closing their shells or altered movement patterns of water fleas), the intake of Meuse water for the drinking water production stops automatically. Unfortunately, WML already has to deal with intake stops on a regular basis. With climate change and the occurrence of more prolonged periods of drought, water abstraction from the river Meuse might be seriously restricted in the future.”

Nature

- The impact on nature, especially fish, is large, as a minimal flow is needed for the fish ladders. During extreme droughts, these ladders might need to be closed.
- Vulnerable nature in the Grensmaas, which forms the border between Belgium and the Netherlands, can experience significant and sometimes even irreversible damage when droughts occur.

[2] *Hydropeaking is the phenomenon where a power station turns on and off multiple times a day to meet peak demand. This influences and modifies low flow patterns, water temperature, sediment dynamics and dissolved gas levels.*

The impact of droughts on the Atlantic Salmon
Cornel van Schayck – Board member of 'Sport fishing Limburg / 'Sportvisserij Limburg

"The Meuse River is an important habitat for the Atlantic salmon. The birth and development of young salmon starts in the fast-flowing and groundwater-fed tributaries of the Meuse in the Ardennes. After migrating up the river, the adult salmon spawn. It is, herein, important that the river water temperature does not exceed 25ºC, and that the fish ladders have sufficient water to sustain bait flow for the migrating salmon. Too low and too warm water increases the risk of exhaustion and predation, as oxygen depletion occurs and concentrations of toxins in the water increase. During prolonged and consecutive periods of drought, fewer and fewer animals arrive at the upstream destination in the Ardennes. At the Lixhe weir in Belgium, returning salmon have been counted and deployed for the Walloon recovery program Saumon 2000. After an initial increase until 2015, numbers declined at an alarming rate, caused by the hot, dry summers 2018-2023. The re-supply of cool groundwater from the capillaries of the catchment to the Meuse and its tributaries is crucial for the preservation and survival of this species."

Agriculture

- Irrigation is one of the first functions to be prohibited during droughts, although irrigation is increasingly needed during these periods. This results in decreased crop productivity over large areas, leading to loss of income in the region.
- Consequently, more agricultural products might have to be imported in the future, which will have large economic effects.

Shipping/navigation

- Shipping becomes less reliable during periods of drought, as flows become too low, shipping routes need to be shut down and waiting times at the locks increase.
- Navigation has the highest water priority in Wallonia. This is likely because groundwater, and not the Meuse water, is used for drinking water production. Especially the Albert Canal is an important shipping route in Wallonia.

Water allocation and prioritization

- There is a lack in consistency of policy approaches on drought management, which can result in inequal water distributions between the Meuse countries.
- During water scarcity, France, Flanders and Germany prioritize water allocation for drinking water, whilst the Netherlands prioritizes water allocation for dike safety and irreversible damage, and Wallonia for shipping. The Meuse countries, hence, differ in their prioritization approaches during periods of drought. This is not necessarily undesirable, however, there is still ample opportunity to coordinate better on a basin-wide level in times of water scarcity. The Meuse countries, thus, do not need to have the same prioritization, but coordination and information exchange is beneficial to prevent ending up with unequal and inefficient distributions and ensure a win-win situation for all.
- The extreme drought impact will not be equally big in each Meuse country, as several countries have other sources (e.g. groundwater sources) or contingencies (buffers and/or reservoirs) to fall back on. Other opportunities lie in collaborating on the enlargement of the water supply sources or jointly looking for alternatives.

- During previous droughts, the drinking water supply could still be ensured, but this will likely not be the case in the future. The water prioritization schemes will, therefore, likely change in the future.

> **Water allocation priorities within the Meuse countries**
> **Esmée Mes – Advisor/researcher freshwater availability at 'Deltares'**
>
> "During a period of drought, scarce water is often allocated to the different sectors based on prioritization schemes. These schemes differ between the Meuse countries and can even be contradictory. In the Netherlands, the 'Landelijke Verdringingsreeks' is used, which is a pre-defined priority list consisting of four categories: 1) dike safety and irreversible damage to nature; 2) drinking water and water for cooling; 3) high value water uses and 4) other uses, e.g. shipping, grasslands and recreation. This is different from Germany and France, where no large-scale prioritization schemes are set up. Drinking water supply is, however, always prioritized in both countries. In Wallonia, priority is given to the transport function of the waterway, where the 'Decree on the Management of Non-Navigable Watercourses' allows the suspension of specific activities. Flanders, on the other hand, uses the 'Reactief afwegingskader prioritair watergebruik tijdens waterschaarste', for water allocation and to implement restrictions during different phases within a drought period. It consists of four building blocks: 1) indicators; 2) water balance; 3) reactive measures; and 4) guiding principes, which together enable prioritization by the drought organizations."

Tourism and recreation

- Tourism and recreation were not mentioned to a large extent; however, the sector does have a high priority in France due to the large economic damages stemming from it.

General

- In the most upstream part of the Meuse, low flows are not a big issue for the different sectors, but floods are.
- The water discharges decrease during droughts, resulting in less continuous throughflow of the water and more compartmentalization of certain regions within the Meuse Basin.
- Risk awareness of drought might be insufficient, also resulting from a lack of knowledge on the drivers.
- Better and fit for purpose forecasts are important to better support decision-making for the short and long term (seasonal).
- It is important to see the interconnection of floods and droughts, as less water is able to infiltrate in dryer periods, resulting in faster runoff.
- We should also be aware that the Meuse water is used for different purposes, both within a country as between the different Meuse countries. This is important as the Meuse River is one big connected system, and the different water uses all influence this system. A concrete example of different water uses by different countries for the same location is the Albert Canal. In Flanders, this Canal is used for drinking water, industrial cooling and shipping, but it is primarily used for shipping in Wallonia.
- The Meuse treaty currently goes into effect at a discharge lower than 100 m^3/s at Monsin. During the extreme drought, the discharge is predicted to be around 23 m^3/s, hence, all sectors are impacted immensely.
- It is important to not solely look at reduced water quantity, but also water quality (referring both to high concentrations and high water temperatures). It is, namely, not the moment of no flow that water cannot be supplied anymore, but already earlier when the water quality is deteriorating. This impacts different sectors, such as the drinking water sector and energy sector.
- During low flow situations, sensors struggle to remain accurate, which impacts decision-making.
- Water consumption increases during extreme droughts.

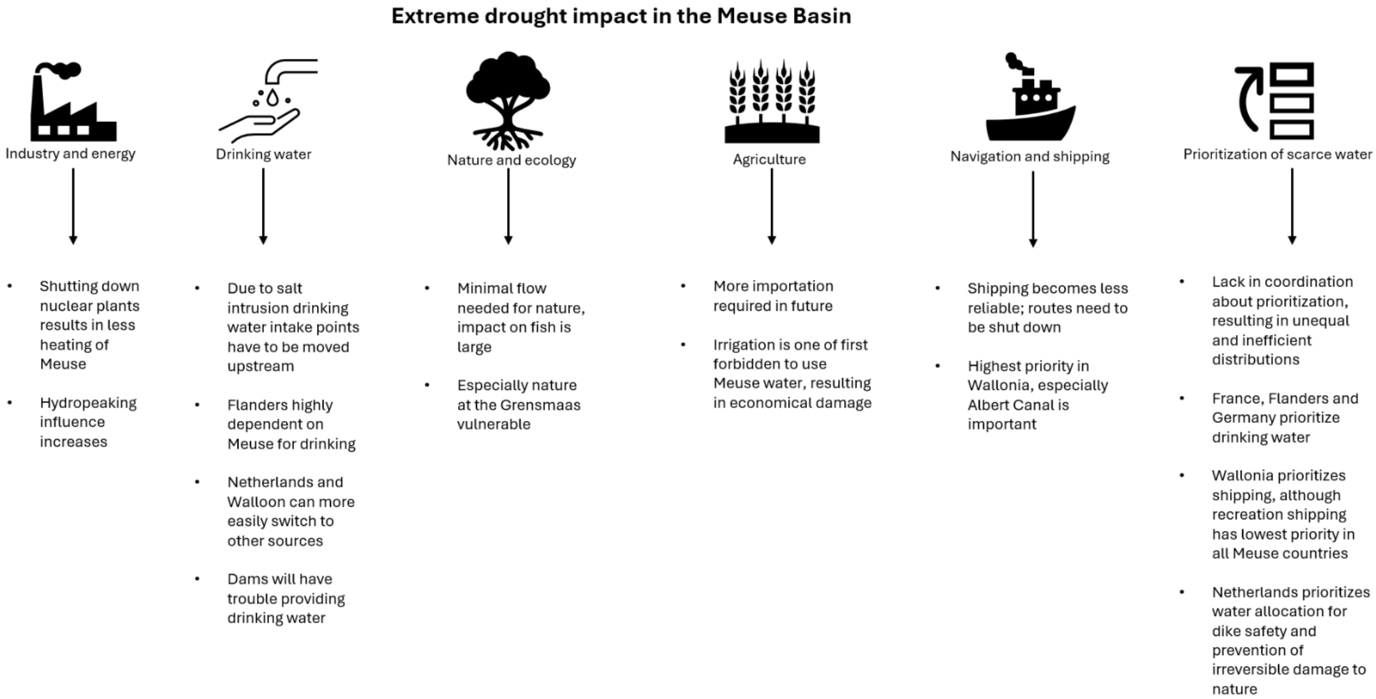


Figure 2-1 Overview of the most important observations from round 1, displayed per sector.

2.3 Results from round 2 – measures and synergies

Different measures were discussed and presented, which are subdivided into four categories:

1. Water demand reduction
2. Sectoral adaptation and spatial adaptation
3. Conflict prevention
4. Water retention and nature-based solutions

In general, several aspects were deemed necessary by the participants to reduce the impacts in the Meuse Basin:

- A combination of technical and societal/collaborative solutions.
- Financial assessments and the involvement of different parties for funding, knowledge and capacity.
- A combination of nature-based solutions to improve sponge working and grey structural solutions, such as the building or enlargement of reservoirs.
- Educating the public on water savings as this can reduce the water demand in a relatively easy and cost-effective manner.

Water demand reduction (Annex D)

1. More awareness and legislation to restrict unnecessary activities, such as car washing and the filling of pools. This can be done through water pricing (when using more water, the price is higher) on which the government should take the lead. It is a relatively effective measure, but there will likely be resistance to it by society. It is also expensive to apply and difficult to implement and regulate. Additionally, it can result in an even larger financial gap between rich and poor.
2. Make an inventory of industries that use water, and include for what purposes they use it, how critical the water supply is to them and when they use it. Based on this, make a priority of industries that need the scarce water the most. This does require much manpower for the administrative, technical and legal aspects, and it is time-consuming, making it a costly measure.
3. Decouple the human water system from the natural water system, meaning everything needs to be recycled and re-used. This requires research, as it needs to be determined what should be done with the concentrate of the system (brine). This also requires many consequent investments and a long time to implement. It does have a large potential as it ensures self-sufficiency and less dependence on the Meuse water.
4. Smart agricultural drainage, which can also help rainfall management. It does, however, likely result in resistance from the farmers, as they are the ones that need to implement this measure. In the Netherlands, the water boards can assist and stimulate the implementation process of the farmers. This measure, hence, requires incentive, but also technical readiness and education.
5. Researching the demand of water used by canals to foresee in their functions and ensure their minimal flow. This can result in a huge reduction of maintenance costs but is costly due to the required research. It is advised that the national water authorities should perform this research.

Sectoral adaptation + spatial adaptation

1. For the drinking water sector, implement diversification of sources, such as desalinization or groundwater use. This results in less dependence on solely surface water. Several of the downsides are, however, the salty brine, large ecological impact and the depletion of groundwater resources. Besides this, it is very difficult to implement, as rules of use are required on where to desalinize and where to use groundwater.

It is a costly measure as well. The policy in the Netherlands shows an opposite trend, moving away from the use of groundwater to the use of surface water and other water sources.
2. For the industrial and energy sector, implement closed-loop cooling. This positively impacts nature, as no heating of the surface water occurs. The remaining heat could be used for other purposes, such as the heating of houses. It is a relatively easier measure to implement as the companies can implement the measure themselves.
3. Implement more flexible water levels in the Meuse and canals. This specifically entails that the water levels are increased in times of surplus, so that you have a buffer during times of deficit. You do need to heighten the dikes for this to accommodate flood risks and increase bridge heights to accommodate shipping. This results in a high implementation time and huge implementation costs.

Conflict prevention

Two key terms were mentioned related to conflict prevention: 1) increase awareness; and 2) political priorities. To implement measures without conflict you generally need trust and respect and to understand different groups of people. The following main measures were mentioned:

1. Build multi-interest networks and platforms with easy information sharing facilities, as it needs to be accessible.
2. Increase the number of people in the International Meuse Commission (IMC) to revise the treaties and arrangements of the commission and to be able to organize more. The IMC should take the lead in the implementation of measures.
3. Implement a Meuse hotline, which ensures you know who to contact and how.
4. Ensure better cooperation between drinking water companies, both nationally and cross-border. This can make the drinking water system more resilient and reliable. Also, better cooperation between drinking water and wastewater treatment companies is desired. The costs and efforts for this measure are high, as it requires new pipelines and treaties.

Water retention and nature-based solutions

Measures within this category are not feasible everywhere as nature is very local. Hence, these measures need to be locally implemented:

1. Landscaping, bringing back the sponge function to increase infiltration, for example through hedges and reducing pavement. This measure has small costs, but requires big effort, as it is not one investment, but needs to be done in collaboration with multiple stakeholders. It increases the baseflow, reduces discharge peaks, potentially also reducing flood damage, and increases biodiversity. It does, however, results in more evapotranspiration.
    a. Plant hedges in order to slow down the Meuse flow. This results in better infiltration and consequently reloads the aquifers. The costs for implementation are relatively low, it is easy to implement, and anyone can implement it. It additionally reduces flood risk.
    b. Restore forests and peaty zones. This measure is even more effective than planting hedges but is more costly. It is also less easy to implement, as local authorities are responsible for implementation. This measure also reduces flood risk.
2. Increase the number of reservoirs or re-use open mines to be flooded in case of need. This measure is very effective, but the costs are higher. It is also less easy to implement and needs to be implemented by regional authorities. For this measure, studies also need to be done on how to avoid negative impacts on the water users downstream when you are filling the reservoir.

In round 1 ‘Improving weather forecasts’ was also stated as a promising measure. A summarizing table of all measures mentioned above is presented in Annex E. The short table below shows a summary of the most important measures mentioned.

Table 2-1 Overview table of the most important measures mentioned during the Meuse hackathon.

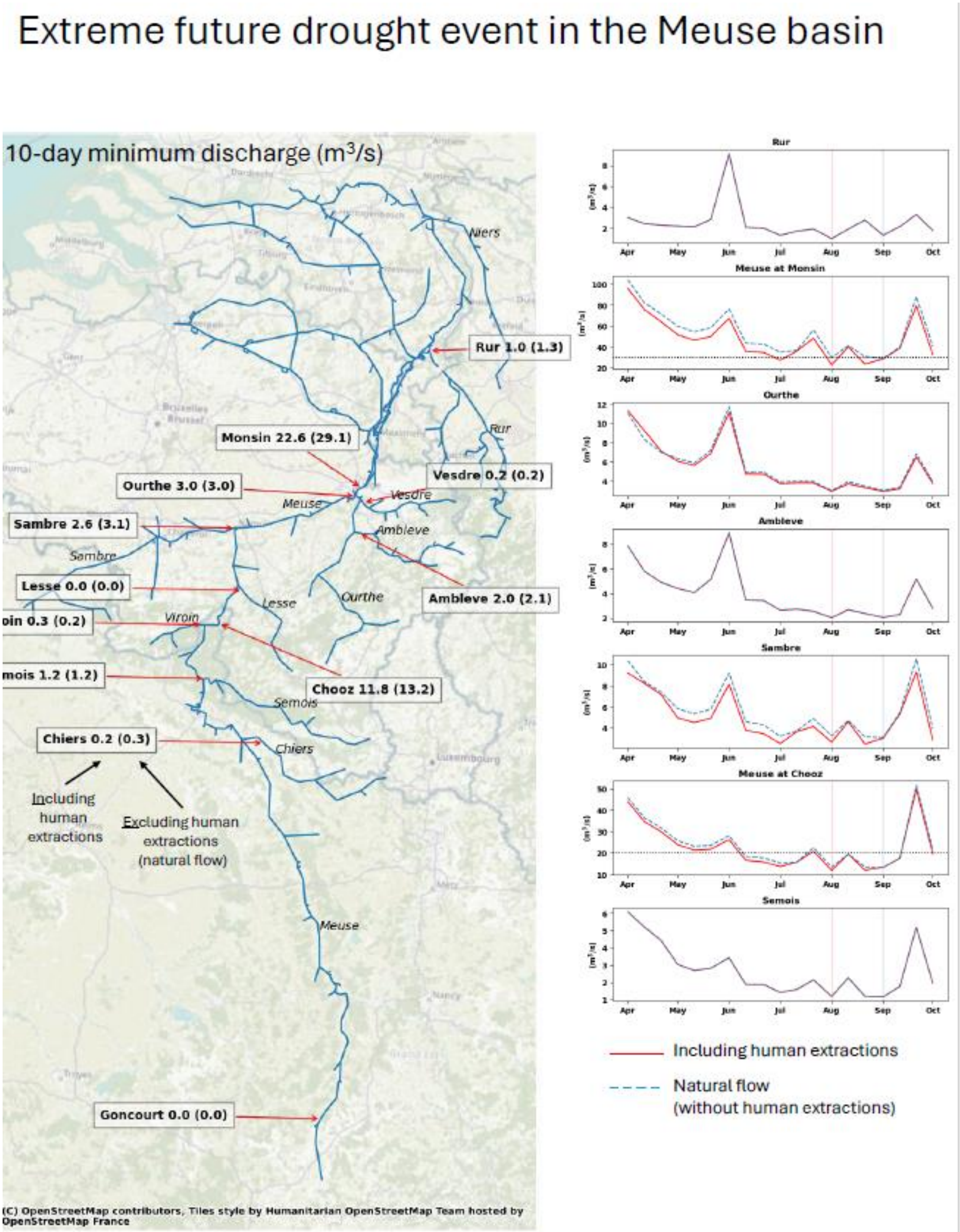
Type of measure	Measure
Water demand reduction	More awareness and legislation to restrict unnecessary activities (e.g. through water pricing)
	Recycle and re-use / Decouple human and natural water system
Sectoral adaptation + spatial adaptation	Drinking water sector: implement diversification of sources
	Industrial / energy sector: implement more closed-loop cooling
Conflict prevention	Enable platforms for knowledge exchange (e.g. for drought forecasting updates)
	Better cooperation between drinking water companies
Water retention and nature-based solutions	Landscaping to bring back sponge function and slow down Meuse flow
	Increase the number of reservoirs or re-use open mines to be flooded

3 Next steps and ideas

The following ideas for next steps were shared by the participants:

- There are several (bilateral) agreements, such as the agreement Belgium and The Netherlands have on water sharing. There is, however, still a lack of coordination and information exchange on the division of scarce water, and no general agreement for all Meuse countries.
- The next steps should also focus on quantification of the actual goals we want to achieve, for example how much water do you need to achieve a certain sponge function goal and how much does it affect discharge level in a dry period? What is the effect on drinking water security? Costs should also be quantified. We need collaboration to get the local data.
- The next steps could also focus on studying whether the identified measures are the right and most efficient ones.
- A governance hackathon could be organized to discuss how to implement all these measures and ideas. Each Meuse country, namely, has a different governmental structure, water allocation priority, and different or no drought organizations in place to handle low flow situations. It would, hence, be beneficial to discuss the implementation process.
- Involve students and perhaps repeat this hackathon format with students.
- Invite experts from other parts of the world to inspire us on how to implement drought measures. Until now, knowledge was mainly transferred from developed countries to developing countries, but for drought issues, we can learn a lot from developing countries. We can explore opportunities and determine how to adapt certain measures to our context.
- We have network of living labs available, which we can use to show the possibilities of different measures.
- We should inform policy makers about the outcomes of this hackathon.
- We should learn about who does what inside our own organization, country and region. We often don’t even know, as there are many groups, projects and models.
- We should raise awareness on the fact that the world will change. We need to buffer better and connect droughts and floods herein. We should look at these in an integral manner.

A Map of discharges during extreme drought in the Meuse Basin

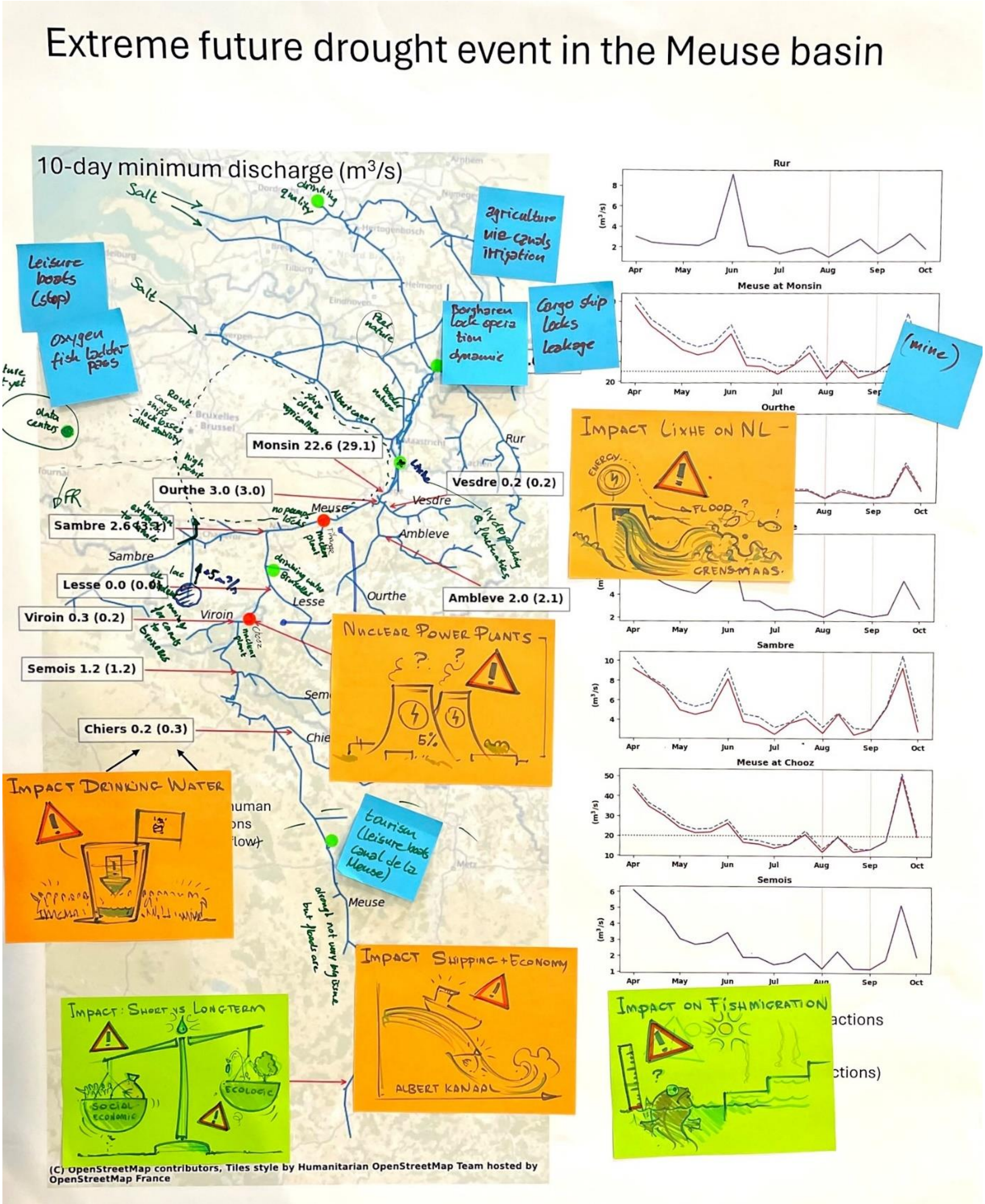


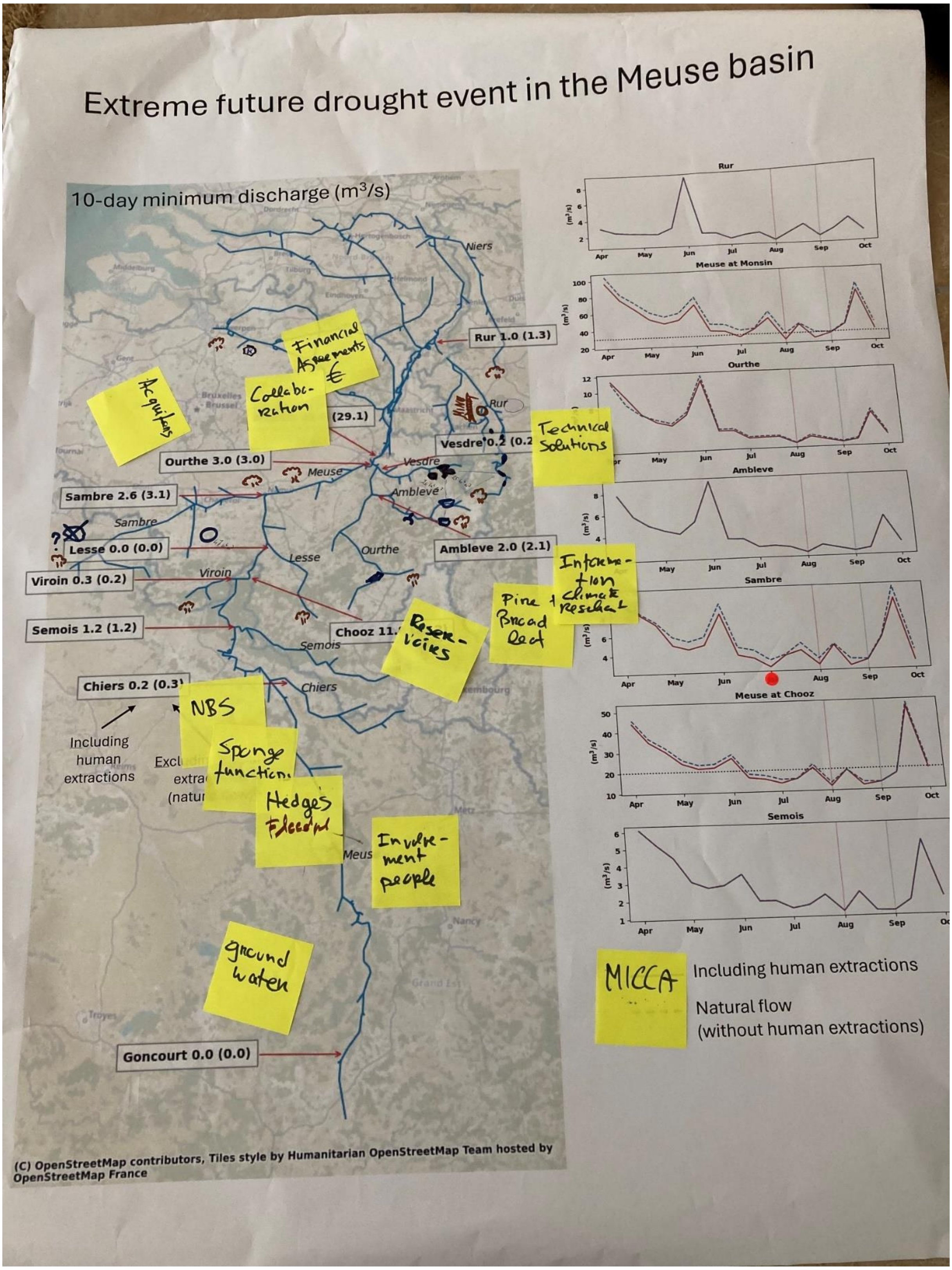
B Scorecard

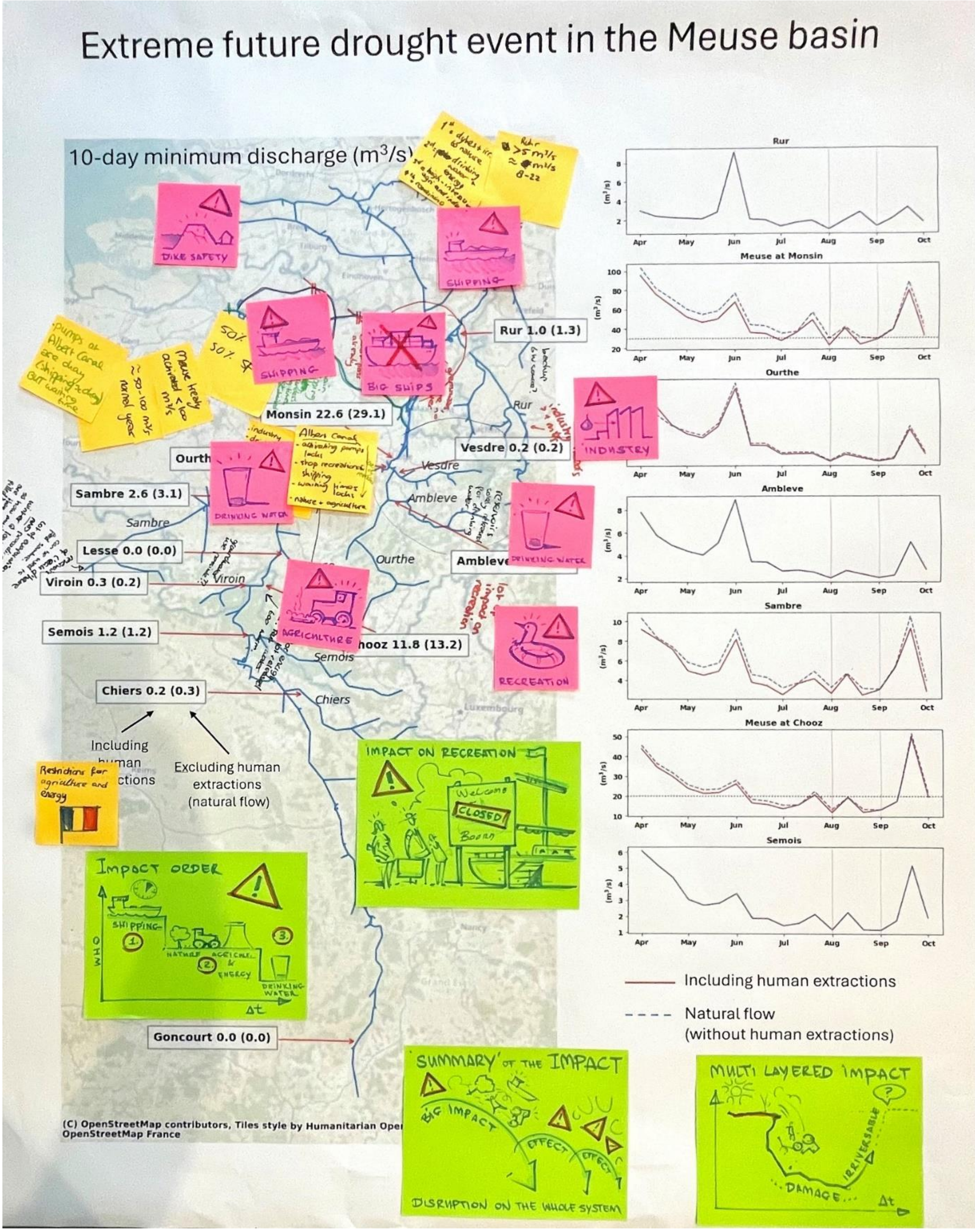
Measure/ Intervention	Effectiveness (+/++/+++)	Other impacts (neg/pos)	Beneficiaries	Costs (€/€€ /€€€/€€€€)	Ease of implementation	Who should implement
Improve water efficiency of industries along the Meuse	+	No other impacts	All water users Meuse	€€€	Fully dependent on collaboration of industry. Regional government plays a role	Industry, regulators

Costs (Implementation + O&M)
- € = 1-50.000
- €€ = 50.000 – 500.000
- €€€ = 500.000 – 5 million
- €€€€ = >5 million

C Poster results round 1




Extreme future drought event in the Meuse basin
10-day minimum discharge (m³/s)
Rur 1.0 (1.3)
Vesdre 0.2 (0.2
Ourthe 3.0 (3.0)
Sambre 2.6 (3.1)
Ambleve 2.0 (2.1)
Lesse 0.0 (0.0)
Viroin 0.3 (0.2)
Semois 1.2 (1.2)
Chiers 0.2 (0.3
Goncourt 0.0 (0.0)
Including human extractions
Natural flow (without human extractions)
Financial Agreements €
Collabo-ration
Acquifers
Technical Solutions
Informa-tion climate resilient
Pine + Broad leaf
Reser-voirs
NBS
Sponge functions
Hedges
Invol-ment people
ground water
MICCA
Rur
Meuse at Monsin
Ourthe
Ambleve
Sambre
Meuse at Chooz
Semois
(C) OpenStreetMap contributors, Tiles style by Humanitarian OpenStreetMap Team hosted by OpenStreetMap France



Extreme future drought event in the Meuse basin
10-day minimum discharge (m3/s)
Rur 1.0 (1.3)
Monsin 22.6 (29.1)
Vesdre 0.2 (0.2)
Sambre 2.6 (3.1)
Lesse 0.0 (0.0)
Viroin 0.3 (0.2)
Semois 1.2 (1.2)
Chiers 0.2 (0.3)
Goncourt 0.0 (0.0)
Including human extractions
Excluding human extractions (natural flow)
DIKE SAFETY
SHIPPING
BIG SHIPS
INDUSTRY
DRINKING WATER
AGRICULTURE
RECREATION
IMPACT ON RECREATION
IMPACT ORDER
SUMMARY OF THE IMPACT
DISRUPTION ON THE WHOLE SYSTEM
MULTI LAYERED IMPACT
Restrictions for agriculture and energy
Rur
Meuse at Monsin
Ourthe
Ambleve
Sambre
Meuse at Chooz
Semois
Including human extractions
Natural flow (without human extractions)
(C) OpenStreetMap contributors, Tiles style by Humanitarian OpenStreetMap France

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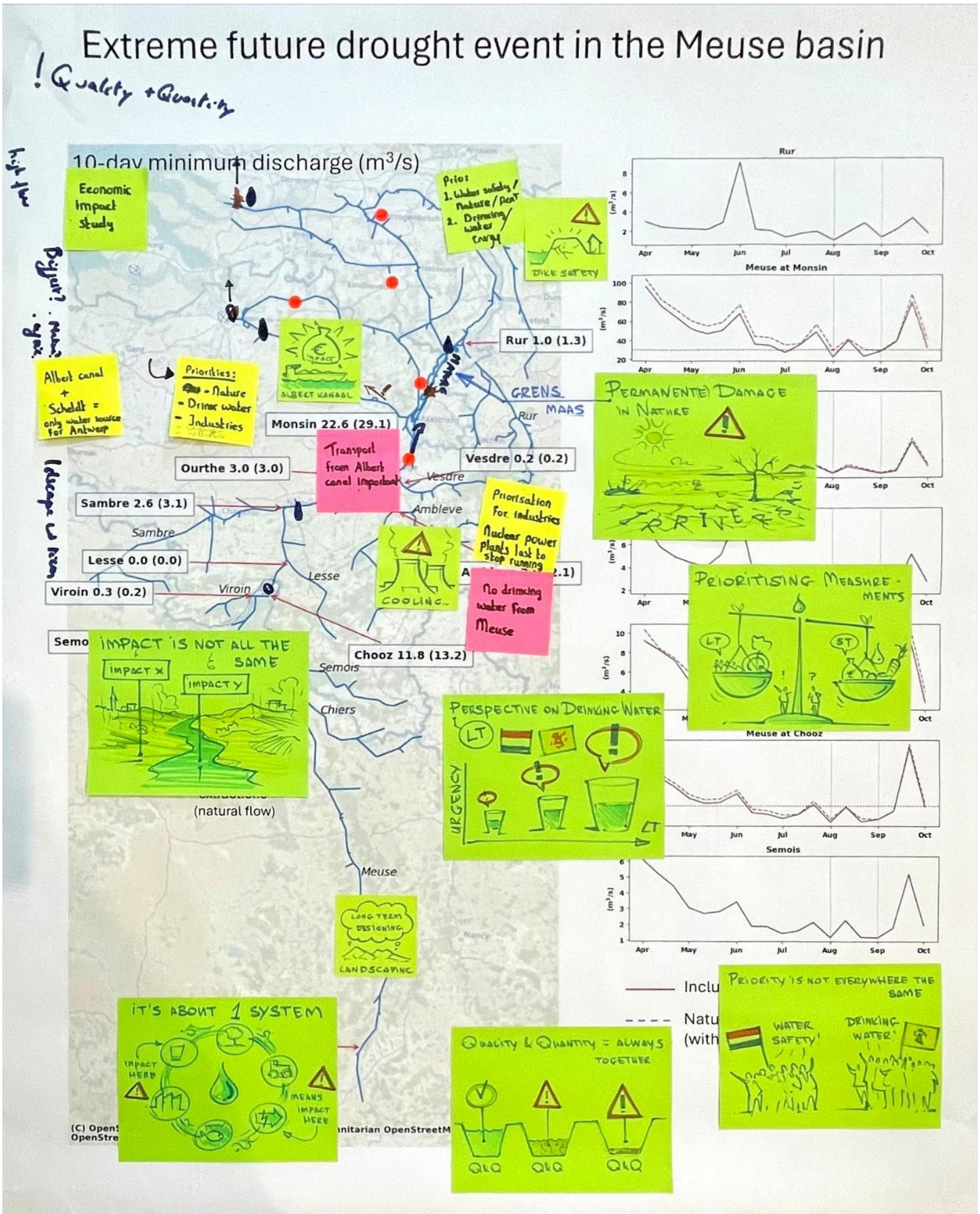
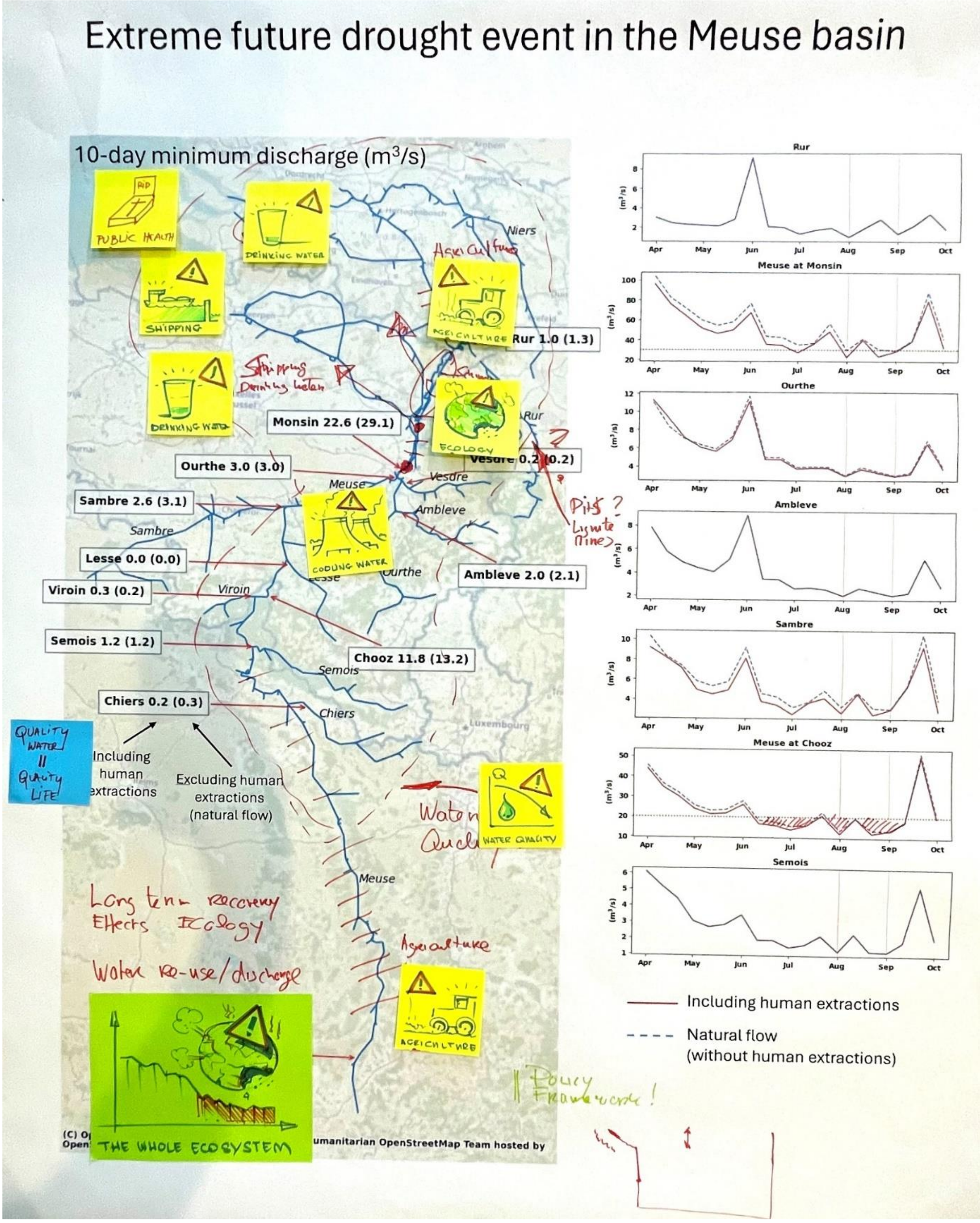
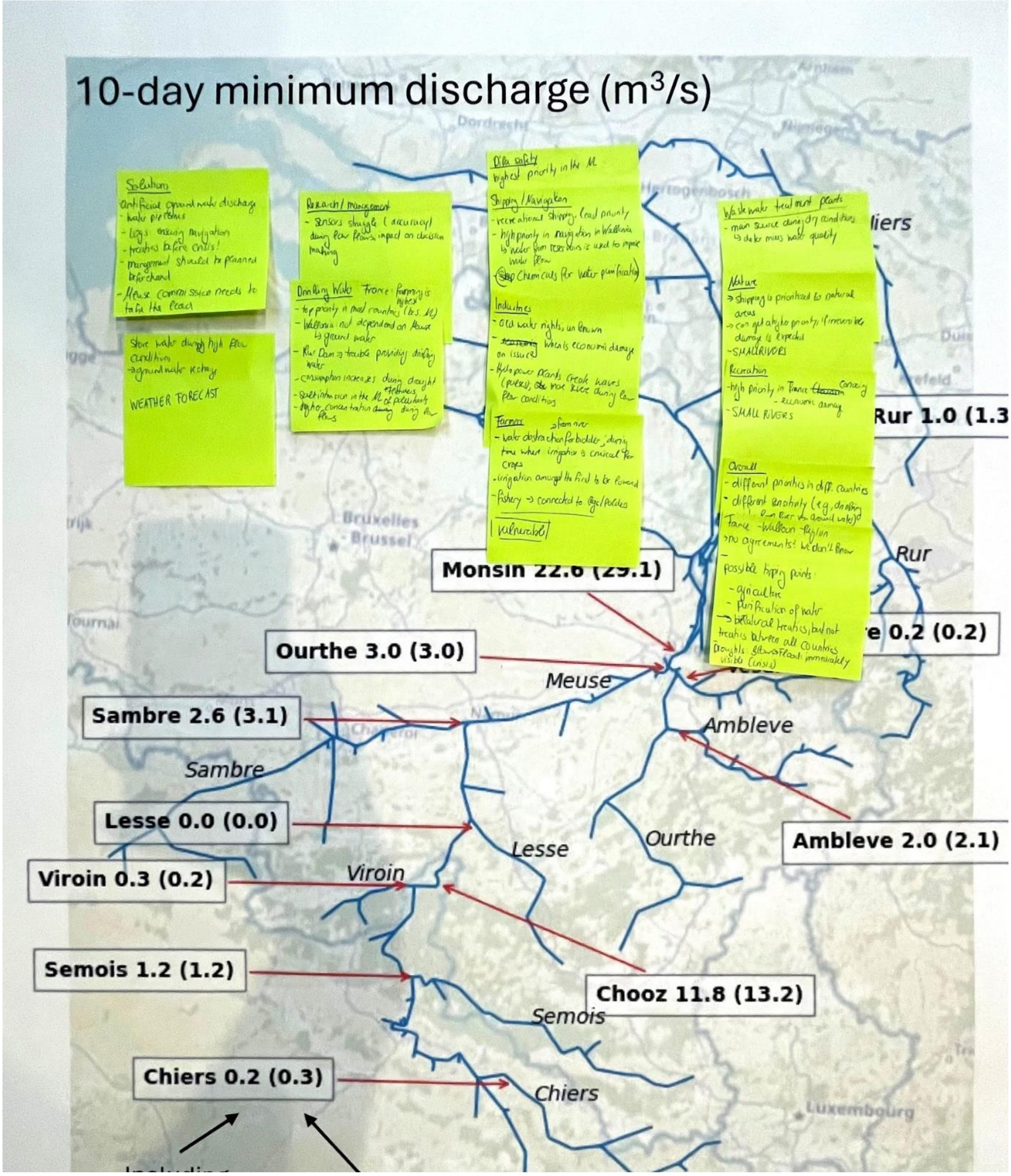
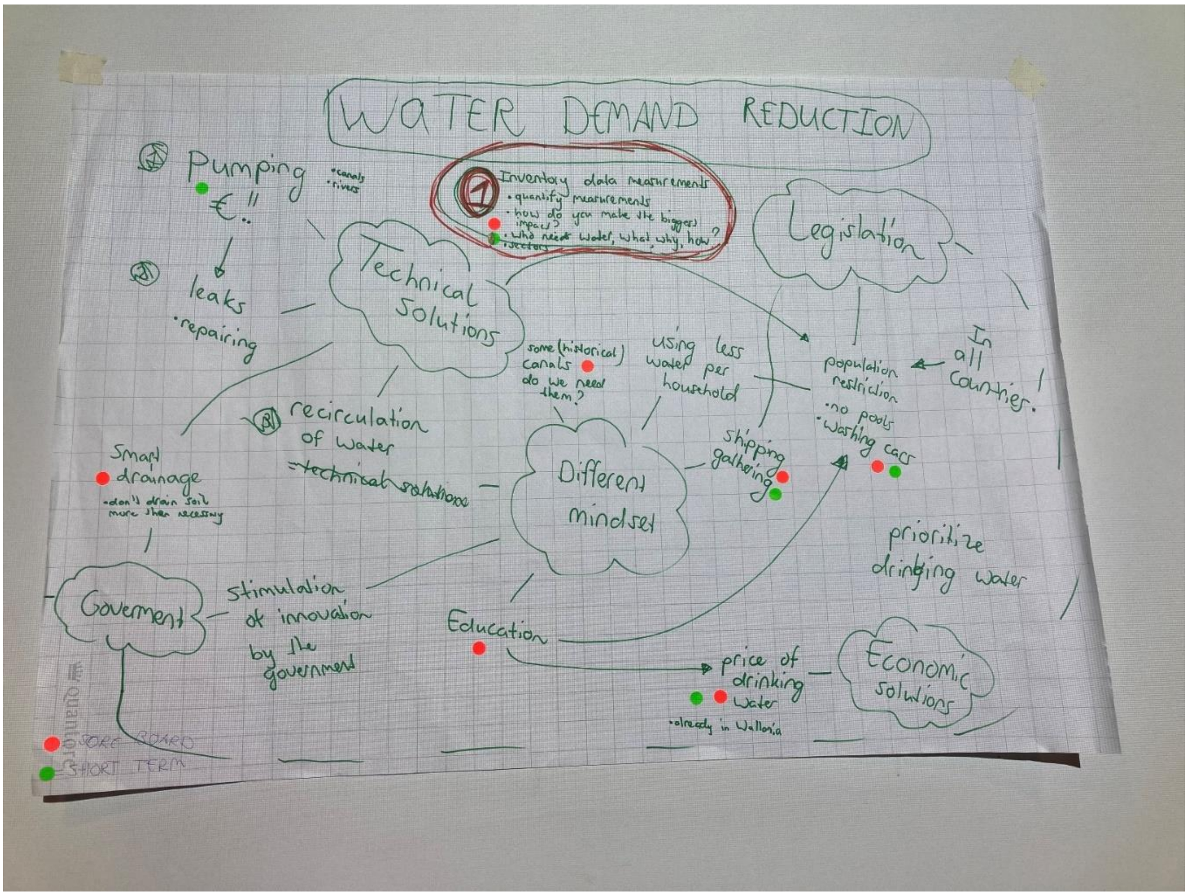

Extreme future drought event in the Meuse basin
10-day minimum discharge (m3/s)
Economic impact study
Albert canal + Scheldt = only water source for Antwerp
Priorities: Nature, Drinking water, Industries
Rur 1.0 (1.3)
Monsin 22.6 (29.1)
Ourthe 3.0 (3.0)
Vesdre 0.2 (0.2)
Sambre 2.6 (3.1)
Lesse 0.0 (0.0)
Viroin 0.3 (0.2)
Chooz 11.8 (13.2)
Transport from Albert canal important
No drinking water from Meuse
DIKE SAFETY
ALBERT KANAAL
GRENS MAAS
PERMANENTE DAMAGE IN NATURE
PRIORITISING MEASURE-MENTS
IMPACT IS NOT ALL THE SAME
IMPACT X
IMPACT Y
PERSPECTIVE ON DRINKING WATER
URGENCY
LONG TERM DESIGNING
LANDSCAPING
IT'S ABOUT 1 SYSTEM
IMPACT HERE
MEANS IMPACT HERE
QUALITY & QUANTITY = ALWAYS TOGETHER
PRIORITY IS NOT EVERYWHERE THE SAME
WATER SAFETY!
DRINKING WATER!
Rur
Meuse at Monsin
Meuse at Chooz
Semois
(natural flow)



Extreme future drought event in the Meuse basin
10-day minimum discharge (m³/s)
Rur 1.0 (1.3)
Monsin 22.6 (29.1)
Vesdre 0.2 (0.2)
Ourthe 3.0 (3.0)
Sambre 2.6 (3.1)
Lesse 0.0 (0.0)
Ambleve 2.0 (2.1)
Viroin 0.3 (0.2)
Semois 1.2 (1.2)
Chooz 11.8 (13.2)
Chiers 0.2 (0.3)
Including human extractions
Excluding human extractions (natural flow)
PUBLIC HEALTH
DRINKING WATER
SHIPPING
AGRICULTURE
ECOLOGY
COOLING WATER
WATER QUALITY
THE WHOLE ECOSYSTEM
QUALITY WATER = QUALITY LIFE
Long term recovery Effects Ecology
Water re-use/discharge
Rur
Meuse at Monsin
Ourthe
Ambleve
Sambre
Meuse at Chooz
Semois
Including human extractions
Natural flow (without human extractions)


10-day minimum discharge (m3/s)
Solutions
artificial groundwater discharge
WEATHER FORECAST
Research / management
- sensors struggle (accuracy) during low flows, impact on decision making
Drinking Water
- top priority in most countries
Shipping / Navigation
- recreational shipping, lowest priority
Industries
- old water rights, unknown
Farmers
- irrigation amongst the first to be lowered
vulnerable
Wastewater treatment plants
Nature
- SMALL RIVERS
Recreation
- high priority in France
- SMALL RIVERS
Overall
- different priorities in diff. countries
possible tipping points
- agriculture
- purification of water
Monsin 22.6 (29.1)
Ourthe 3.0 (3.0)
Sambre 2.6 (3.1)
Lesse 0.0 (0.0)
Viroin 0.3 (0.2)
Semois 1.2 (1.2)
Chiers 0.2 (0.3)
Chooz 11.8 (13.2)
Ambleve 2.0 (2.1)
Rur 1.0 (1.3
e 0.2 (0.2)
Meuse
Sambre
Lesse
Viroin
Ourthe
Ambleve
Semois
Chiers
Rur
Bruxelles
Brussel
Luxembourg

D Poster "Water Demand Reduction"



E Summary of the results related to measures

Type of measure	Measure	Effectiveness	Costs	Other notes
Water demand reduction	More awareness and legislation to restrict unnecessary activities (e.g. through water pricing)	Effective	Costly	- Government should take lead in implementation - Resistance by society - Difficult to implement and regulate - Larger financial gap between rich and poor
	Prioritize industries that need to use scares water the most based on inventory of industries done beforehand	Uncertain	Costly, because of manpower for administrative, technical and legal aspects	- Time-consuming
	Recycle and re-use / Decouple human and natural water system	Effective, because ensures self-sufficiency	Costly, as it requires consequent investments	- Requires research on what to do with brine - Long time to implement
	Smart agricultural drainage	Less effective compared to other measures	Not too expensive, many smaller spread-out investments	- Farmers or water boards should implement - Requires education and technical readiness
	Researching the consumption of water in the canals	Uncertain	Costly, but this cancels itself out, as it ultimately reduces maintenance costs	- National water authorities should perform this research
Sectoral adaptation + spatial adaptation	Drinking water sector: implement diversification of sources	Highly effective	Very costly	- Less dependence on solely surface water - Several disadvantages are the salty brine, ecological impact and depletion of groundwater resources - Difficult to implement
	Industrial / energy sector: implement more closed-loop cooling	Effective when all smaller effects are combined	Costs are divided over many companies, therefore, relatively small	- Easy to implement by companies themselves
	Implement more flexible water levels in Meuse	On long-term very effective	Very costly, because you need to heighten dikes and bridges over long period of time	- Very high implementation time
Conflict prevention	Build multi-interest networks and platforms and set up Meuse hotline, on who to contact for what	Little direct effect, promotes information sharing	Not costly	- Requirement is that it needs to be accessible
	More people in IMC to revise treaties and implement more	Highly effective if treaties and measures are implemented	Costly if IMC needs to take lead in implementing measures and setting up treaties	

	Better cooperation between drinking water companies	Very effective on long-term	Costly, because large efforts, new pipelines and treaties required	- Makes drinking water system more resilient and reliable
Water retention and nature-based solutions	Landscaping to bring back sponge function and slow down Meuse flow	If done on a large scale by many parties, it is highly effective	Small costs locally, as planting happens on a local scale. Costs are therefore divided over multiple parties	- Can be done through planting hedges and restore forests and peaty zones - Small costs, but big effort by many parties - Reduces flood risk and increases biodiversity - Increases evapotranspiration
	Increase the number of reservoirs or re-use open mines to be flooded	Very effective	High costs	- Implemented by regional authorities, but less easy to do - Studies need to be done on how to avoid negative impacts

Deltares is an independent institute for applied research in the field of water and subsurface. Throughout the world, we work on smart solutions for people, environment and society.

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