



LAYMAN REPORT
2022–2026



From evidence to action

How STARS4Water worked with seven European river
basins towards water resilience

Seven river basins. Four years. One shared approach, seven local answers.



Funded by the European Union

www.stars4water.eu

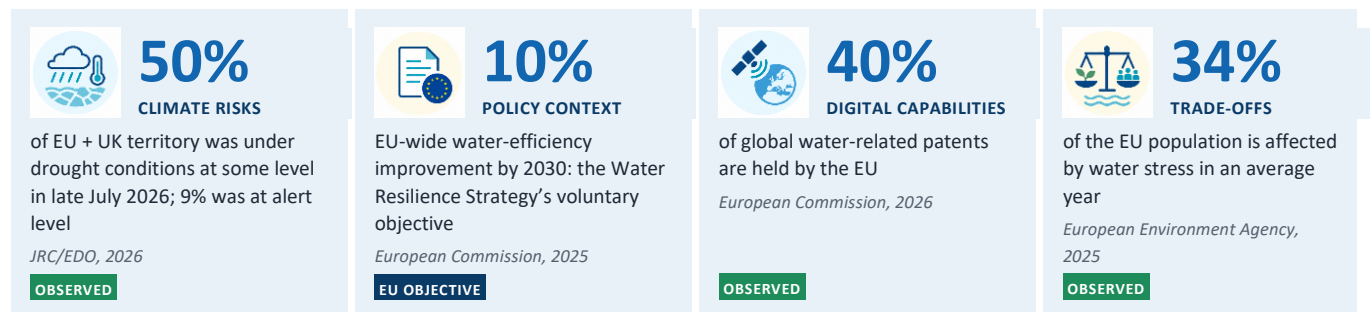
WHY CHANGE

The past is no longer a reliable guide

Europe's river basins can no longer be managed by looking only at the past. Water is changing faster than the six-year management cycles established under the EU Water Framework Directive, and no one can know exactly which future will arrive. Planning for uncertainty and building flexibility into water management is a must to make our basins more resilient to change.

Four changes at once

Four conditions are simultaneously changing. They are moving faster than the traditional cycle of diagnosing a problem, commissioning a study and waiting for the next planning round.



Four conditions are changing at once.

Climate risks are becoming more persistent and compound. In late July 2026, half of the territory of the EU and the UK was under drought conditions at some level. By mid-August, drought alerts stretched across France, Benelux, southern Germany, northern Italy and much of the Danube basin.

The policy context has shifted. The 2025 European Water Resilience Strategy aims to restore and protect the water cycle, build a water-smart economy and secure clean and affordable water and sanitation for all. Those goals become real only where water is allocated and trade-offs are negotiated: in the river basin.

Digital capabilities are racing ahead. Satellites, data-driven models and artificial intelligence are expanding what water managers can know. But technology can advance faster than institutions can adopt, maintain and trust it.

Trade-offs are getting sharper. In an average year, water stress affects 34% of the EU population. Basin organisations must balance the needs of rivers and wetlands with drinking water, farming, energy, industry and shipping, often with less predictable water.

Averages can hide the risk

Climate change alters more than the annual average river flow. For example, it shifts the seasons, the length and intensity of low-flow periods, groundwater recharge, snowmelt and demand. A basin can become wetter over the year and still less reliable in summer. In Norway's Drammen basin, annual water availability may increase, yet summer low-flow periods are projected to last longer.



Too much and too little water in one basin. Left: floods in May 2018 in the town of Nesbyen in the Drammen catchment, Norway (photo: Knut Møen). Right: drought affecting Lake Strandavatn in the Drammen river basin in 2022 (photo: Irene Brox Nilsen). **OBSERVED**



The seven River Basin Hubs cover a wide range of climates, water uses and governance settings, from international rivers to a single agricultural plain.

STARS4WATER AT A GLANCE

2022–2026

Horizon Europe research project,
October 2022 – September 2026

21

partners from 10 countries,
coordinated by Deltares

7

River Basin Hubs: Danube, Drammen,
Duero, East Anglia, Messara, Rhine,
Seine

€4,580,979

EU contribution

A practical question

STARS4Water, short for Supporting Stakeholders for Adaptive, Resilient and Sustainable Water Management, set out to answer a practical question: how can river basin managers understand these changes, anticipate what may come next and make better-informed decisions for a more water-resilient future?

The project did not begin with a technology. It began with the management questions that matter in seven River Basin Hubs, from the snow-fed Drammen in Norway to the irrigated Messara plain on Crete. The hubs worked as living laboratories, where researchers and basin organisations tested new data, models, indicators and communication tools together.

The pages that follow trace the **STARS4Water journey**, from co-creating the questions to learning from what happens next. They present a connected evidence chain that makes data accessible, turns observations into understanding through models, explores plausible futures, translates results into meaningful indicators and thresholds, and communicates them through tools that support real-world management decisions.

WHY IT MATTERS

Averages can hide the extremes that matter. In the Rhine and Danube, a single extreme low-flow year can cause prolonged disruption to shipping, water supply, ecosystems and the economy, even where the projected change in long-term average flow is moderate.

THE STARS4WATER JOURNEY



The STARS4Water journey. Co-creation runs beneath every step, and what is learned feeds the next round of questions.

READING THE EVIDENCE LABELS IN THIS REPORT

OBSERVED

Measured or reported

MODELLED

A model estimate of past or present conditions, not a measurement

PROJECTED

A scenario or what-if result, not a prediction

MANAGEMENT OPTION

A choice people can make

STEP 1 CO-CREATE

It started with people, not tools

STARS4Water began with the decisions people needed to make, not with the technology. In every basin, the people who manage and use the water helped shape what the science should answer.



Scoping workshop for the Drammen dashboard, April 2025, bringing together model builders from NVE and Deltares, decision makers and basin stakeholders.



Co-creation workshop in the Drammen River Basin in Norway.



Co-development meeting in the Seine River Basin in France.



Workshop with the stakeholders of the Rhine River Basin in Arnhem, the Netherlands.



Site visit to Anglian Water boreholes, January 2025.

A champion in every basin

STARS4Water was implemented in seven River Basin Hubs. Each River Basin Hub had a “stakeholder champion”: an organisation with a strong network in the basin. Champions included the Duero River Basin Authority, EPTB Seine Grands Lacs, the Region of Crete, Anglian Water, Norway’s Water and Energy Directorate NVE, the three International Rhine Commissions (CHR, ICPR, CCNR) and the International Commission for the Protection of the Danube River (ICPDR). They teamed up with research partners and strengthened a wider community around each hub: public authorities, water utilities, irrigation associations, hydropower companies, navigation bodies and environmental organisations.

Needs before tools

The first round of workshops, held in all seven hubs between February and April 2023, asked a simple question: what do you need to know? In Drammen, participants wrote their needs as short user stories: who they are, what information they lack and which decision it would support. The answers across the basins ranged from low flows and shipping on the Rhine and Danube to reservoir operation on the Seine and groundwater over-abstraction on Crete. The research team then set priorities by matching these needs with what the project could realistically deliver.

STAKEHOLDER VOICE

“The question is when we need to build new water reservoirs?”

Stakeholder at the first Drammen workshop, 2023, on long-term planning for water supply

IN PLAIN LANGUAGE • Co-creation

Stakeholders, water users, experts and scientists define the problem and the information needed together, then design solutions together. STARS4Water built this on two principles: shared perception, a common understanding of the risks, and shared science, jointly developed data, models and methods.

Co-creation all the way through

Co-creation did not end with a list of needs. Over four years, stakeholders helped collect data, choose indicators, write scenario narratives, check model results, identify the limits that matter in their basin, and design dashboards and Story Maps.

Their feedback changed the work. In Messara, stakeholders checked the model's abstraction rates and water demand and asked for an upgrade to the latest version of the allocation software. On the Seine, the reservoir operator helped frame "what-if" questions, such as how the river would behave without reservoir regulation or under different operating rules. In East Anglia, the STARS4Water scientists building a groundwater-quality mapping tool, met Anglian Water weekly online, and held two workshops and a field visit. In the Rhine basin we co-created the first transboundary socio-economic scenarios projecting plausible futures - a joint and collaborative effort of the three River Basin Commissions (CHR, ICPR, CCNR).



Participants at the first stakeholder workshop in Messara, 14 March 2023.

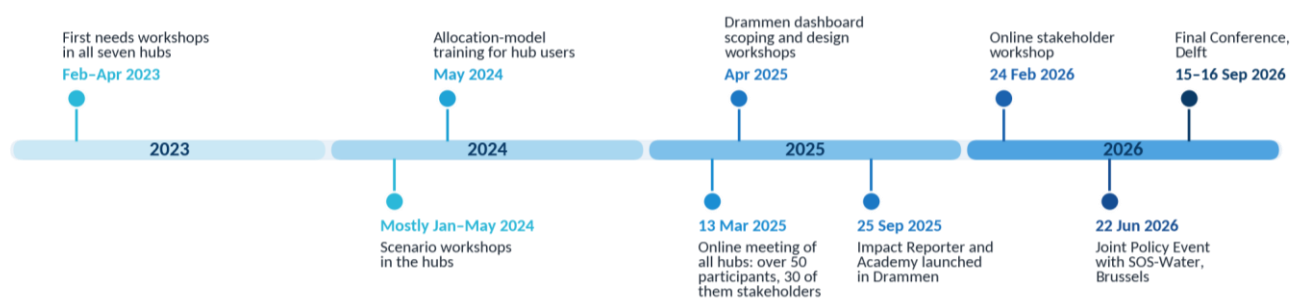
Why local knowledge matters

Basin managers know things no global dataset contains how reservoirs are really operated, which low-water levels stop the ships, when a drinking-water source comes under stress. Building this knowledge into the models made them more realistic and helped link long-term planning with day-to-day operation. Working together also built trust. People who help shape a tool are more likely to trust it and keep using it.



Participants at the first stakeholder workshop in Drammen, 28 March 2023.

FOUR YEARS OF CO-CREATION



Four years of co-creation, from the first needs workshops in 2023 to the Final Conference in 2026.

FROM THE BASIN · Duero, Spain

A questionnaire went out through the Duero River Basin Authority's mailing list to about 800 people, from public administrations and farmer associations to water suppliers and conservation groups. 103 replies were received. At a follow-up workshop, 23 participants representing nearly all major stakeholder groups ranked the forces most likely to shape the basin's water future: climate, water quality, EU farm policy, population change and EU environmental policy. These rankings became the basis for three socio-economic scenarios, developed with the stakeholders. A later workshop explored how a Safe Operating Space could help set acceptable limits under the Water Framework Directive.

SHARED PERCEPTION + SHARED SCIENCE



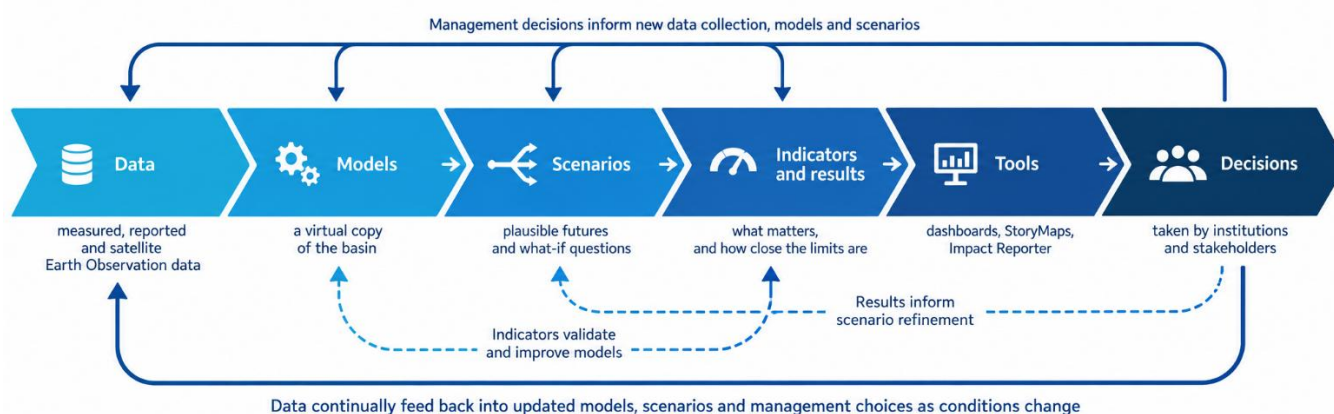
Co-creation combines shared perception, a common understanding of the risks, with shared science, jointly developed data, models and methods.

STEP 2 FIND & OBSERVE

What do we know, and what is missing?

River basin managers rarely need “more data” in the abstract. They need the right evidence, easy to find, combined sensibly with local knowledge, and transparent about its limits.

THE EVIDENCE CHAIN



The evidence chain: each step turns raw data into something closer to a decision.

Scattered evidence

Europe produces a vast amount of water and climate data every year, but it is scattered across organisations, platforms and scales. Basin authorities rarely have time to keep track of every new source. In workshops across the seven hubs in 2023 and 2024, the “data problems” stakeholders reported fell into three groups: data they could not find, data they could not access or use, and data that did not fit their decisions. Every basin also lacked figures on how much water economic sectors use and how much water ecosystems need.

A catalogue for water data

The [STARS4Water Metadata Portal](#) makes this evidence easier to find. It works like a library catalogue. Each record describes a dataset (what it covers, where, when and who made it) and links to the data where it is kept. The portal’s guiding idea is “Metadata, not data”. Records follow the FAIR principles: findable, accessible, interoperable and reusable. The portal now lists more than 490 datasets at global, European and regional scales, including the project’s own open datasets. Deltares will maintain it after the project ends.

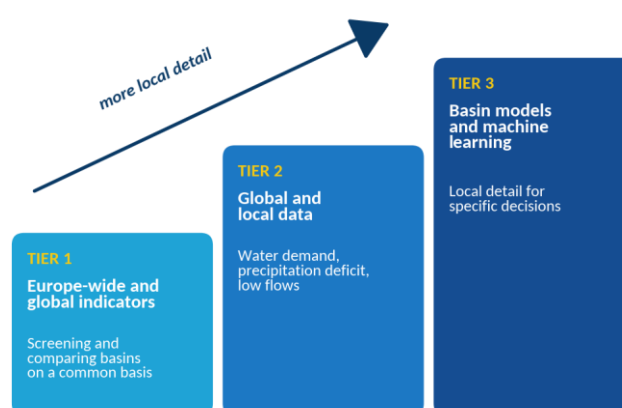
From global to local, in three tiers

Global datasets cover every basin in the same way, but they are coarse. STARS4Water therefore built its indicators in three tiers. Tier 1 translates European and global climate and socio-economic projections into practical indicators for each basin. Tier 2 combines global and local data into indicators more directly linked to practical management, such as water demand, precipitation deficit and low flows. Tier 3 draws on the basin models and machine-learning tools.

WHY IT MATTERS

Finding and trusting data is a basic but persistent barrier. Lowering it reduces duplicated effort and shows more clearly where important gaps remain.

THREE TIERS OF INDICATORS



Three tiers of indicators, from Europe-wide screening to basin models.

TOOL IN ACTION · Metadata Portal

What is it?

An online catalogue of water-related datasets.

What problem does it solve?

Relevant data for integrated river basin management are scattered and hard to find.

Who can use it?

Water managers, river basin authorities, researchers and policymakers.

What does it enable?

Searching by keyword, topic, period or an area drawn on a map, to see what exists and where to get it.

Honest and transparent limits

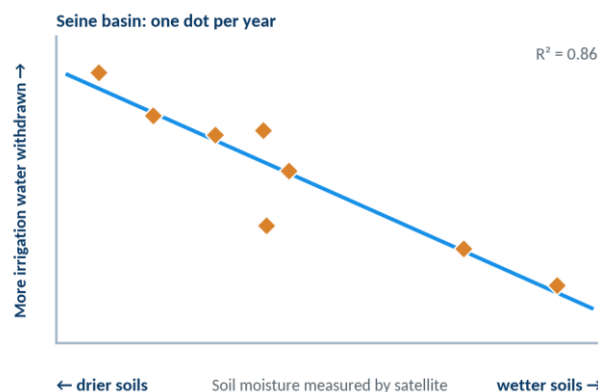
Global indicators are good for screening and comparing basins, and as a starting point for discussion. They do not replace local knowledge. When the first indicators were discussed with representatives of all seven hubs in March 2025, participants warned that global data are not always accurate at local scale and should be used with caution. In Drammen, stakeholders considered one global temperature projection unrealistic for their basin.

Where local monitoring is thin, other sources can help. On Crete, global weather data reconstructed from past observations filled gaps in local rainfall and temperature records. In the Seine basin, soil moisture measured by satellite tracked reported irrigation volumes closely, a possible way to estimate water demand where records are missing.

IN PLAIN LANGUAGE · Metadata

Metadata is data about data: a short description of what a dataset contains, where and when it applies, who made it and how to get it. Like a library card, it tells you whether the book is worth fetching.

SEEN FROM SPACE



Seen from space: in the Seine basin, years with drier soils, as measured by satellite since 2015, were years with larger declared irrigation withdrawals (a strong correlation in a first test, $R^2 = 0.86$). **OBSERVED**

SEARCH ABOUT

Filter CLEAR FILTERS

Domain: StarsWater

Topic: Search topic...

Start date: PICK A DATE

Search title or description

Available datasets: 496

Geoscientific Information: 111 datasets

Farming: 105 datasets

Climatology, Meteorology, Atmosphere: 82 datasets

Environment: 58 datasets

Inland Waters: 35 datasets

Society: 52 datasets

Soil and terrain suitability for rain-fed maize, with high and low inputs - GAEZ v4 (Global - about 1 km)

Soil and terrain suitability for maize dataset, at about 1 km resolution, investigates soil suitability and both soil and terrain suitability for maize, under rain-fed condition, with high and low inputs. The Soil and terrain suitability for crops datasets are part of the GAEZ v4 Theme 1 Land and Water Resources. Soil Suitability sub-theme. In the GAEZ v4 the Soil Suitability assessment sub-theme, soil qualities are evaluated for each...

https://lo.apps.fao.org/geoserver/wms/GAEZ_V4/LR_SOI2/v2?service=WMS&version=1.3.0&request=GetCapabilities

View details

January 1st, 2041 - December 31st, 2099

AEZ classification by climate, soil, terrain, land cover (57 classes) - GAEZ v4 (Global - about 1 km)

AEZ classification by climate, soil, terrain and land cover (57 classes) at about 1 km resolution at the equator, using different climate data source and based on different Representative Concentration Pathways (RCPs) according to the time period as follows: - climate data source CRUTS32 based on historical data for the time period 1981-2010; - climate data source ENSEMBLE based on the Representative Concentration...

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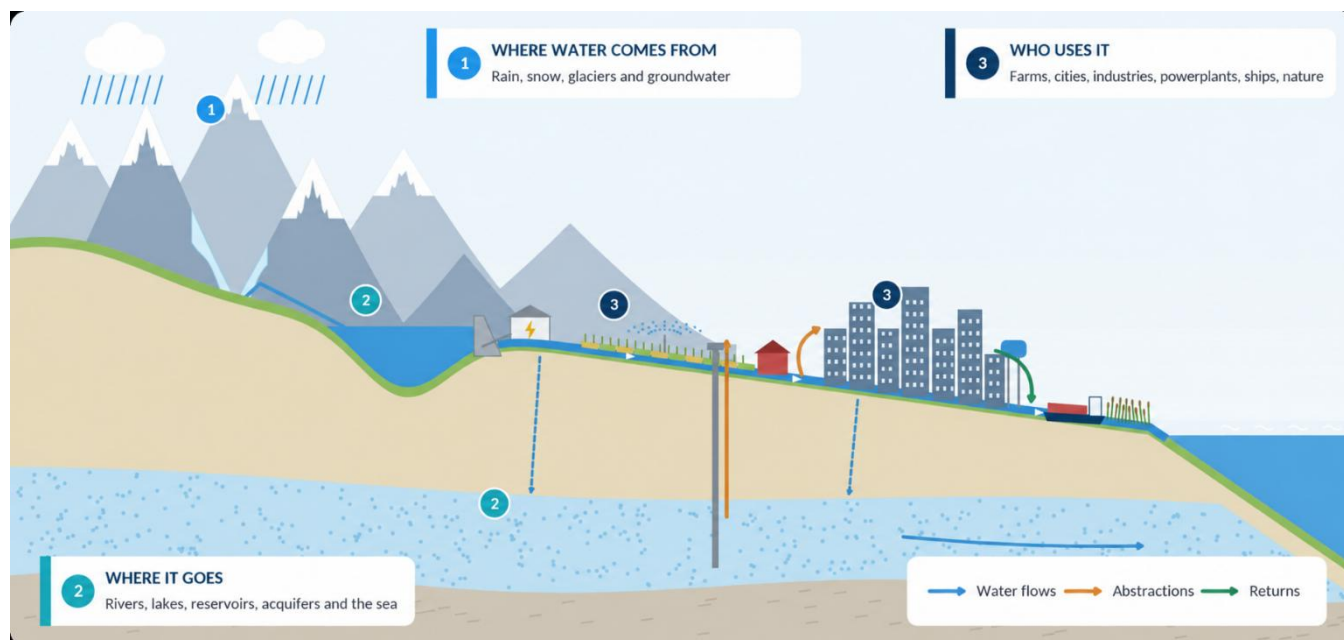
Mapbox © OpenStreetMap Improve this map

The STARS4Water Metadata Portal lets users search more than 490 datasets by keyword, topic, period or map

STEP 3 UNDERSTAND

A virtual river basin

A model is a virtual version of a river basin. It shows where water comes from, where it goes, who uses it, and how a decision in one place ripples through the rest of the system.



A virtual river basin: a model represents where water comes from, where it goes and who uses it, so choices can be tested before they are made in the real river.

Joining the dots

Measurements show what is happening at one gauge or one well. Process-based models join the dots. They represent rain and snow, rivers and reservoirs, aquifers, farms, cities, power plants and ecosystems, and how water moves between them. That lets managers test questions they cannot try out on the real river: what happens if a reservoir is run differently, if irrigation grows, or if summers become drier?

Filling the gaps that mattered

STARS4Water first compared the models each basin already used with what its stakeholders needed. It then filled the most important gaps.

On the Danube, the project built a model to study low flows along the river. It was co-developed with the stakeholders, covering the Danube main stem and how water withdrawn from it affects hydropower, shipping, farming, industry and drinking water. Developed with the International Commission for the Protection of the Danube River (ICPDR), it is the first water management model for the Danube to bring together such a wide range of water demands.

IN PLAIN LANGUAGE • Model

A model is a simplified, computer-based copy of the basin. It is not a crystal ball. It explains how the water system works and shows what might happen under different conditions.

In Drammen, a basin-wide model now represents all 54 regulated reservoirs and links river flows to hydropower production. On Crete, the Messara water-allocation model was rebuilt in finer detail, connecting water availability and sectoral water demands, keeping drinking water a first priority. On the Seine, the operating rules of the four large upstream reservoirs are now part of the basin model.

Nature's share

Rivers and wetlands need water too, yet their needs are often treated as whatever is left over. STARS4Water's ecological-flow tool compares future river flows with today's, across 70 flow indicators, and shows the risk to ecosystems in simple traffic-light colours. It was used in more detail in East Anglia, Drammen, the Rhine and the Seine.

TOOL IN ACTION • RIBASIM water resources model

What is it? An open-source tool for modelling managed water systems at the river basin scale.

What problem does it solve? Assess whether water supply can meet competing demands.

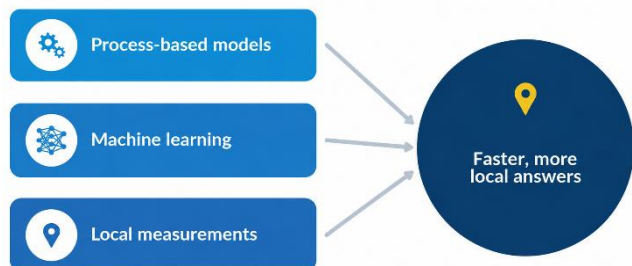
Who can use it? Basin authorities, water managers, researchers and planners.

What does it enable? decision makers to build consensus amongst water users and make smart decisions about how to manage water resources optimally considering uncertainties now and in the future.

More information is available [here](#)

Faster, but not alone

Machine learning adds speed and fills gaps. STARS4Water tools map irrigated areas in the Rhine basin from satellite data, estimate snow in Drammen, forecast how full reservoirs will be one to three months ahead, map where groundwater is likely to exceed nitrate limits, and track changes in groundwater storage. The project's lesson is clear: these tools work best alongside process-based models and local measurements, not instead of them, and their assumptions and limits must be transparent.



Hybrid modelling combines process-based models, machine learning and local measurements to give faster and more local answers.

Trust through testing together

A model helps only if people trust it. Stakeholders checked results against what they know of their basin: abstraction rates and unmet demand in Messara, low-flow outputs on the Danube, and how well the Seine model matched past river flows. Every correction made the virtual basin closer to the real one.

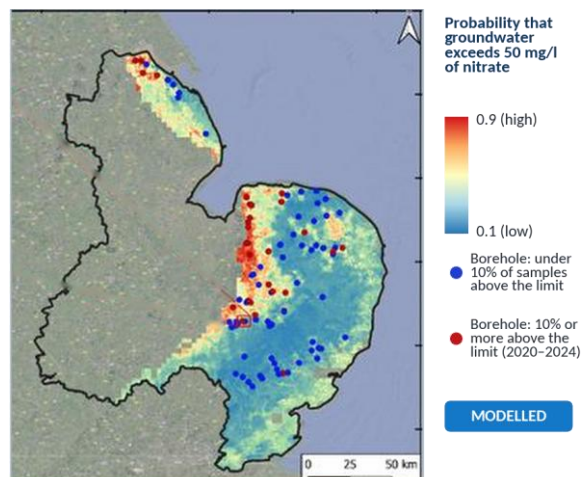
FROM THE BASIN · Seine, France

Four large dams upstream on the Seine can store about 810 million m³ of water. They are run to support flood control, sustain low-flows and guarantee water is always there for the environment. EPTB Seine Grands Lacs, which operates them, was concerned that in future the reservoirs might not fill before the dry summer. Together with the French research institute INRAE, they took into account the current reservoir rules in a river basin model and tested stakeholder-defined “what-if” questions: no regulation at all, alternative operating strategies and contrasting future climates. In October 2025, the results were discussed with more than fifteen representatives of water utilities, navigation, hydropower and flood forecasting.



Lake Pannecière-Chaumard on the Yonne, a tributary of the Seine, is one of the four lakes managed by Seine Grands Lacs to maintain summer flows and reduce the risk of flooding (image: seinegrandslacs.fr).

WHERE NITRATE IS LIKELY TO EXCEED THE LIMIT



Predicted probability that groundwater in the chalk aquifers of East Anglia exceeds 50 mg/l of nitrate. Dots mark Anglian Water boreholes; red dots are boreholes where at least 10% of measurements exceeded the limit (2020–2024). **MODELLED**

TOOL IN ACTION · Groundwater nitrate mapping (MLMapper)

What is it? A machine-learning tool that maps where groundwater is likely to exceed nitrate limits.

What problem does it solve? Monitoring wells cannot be everywhere.

Who can use it? Basin authorities, water managers, regulators, researchers and planners.

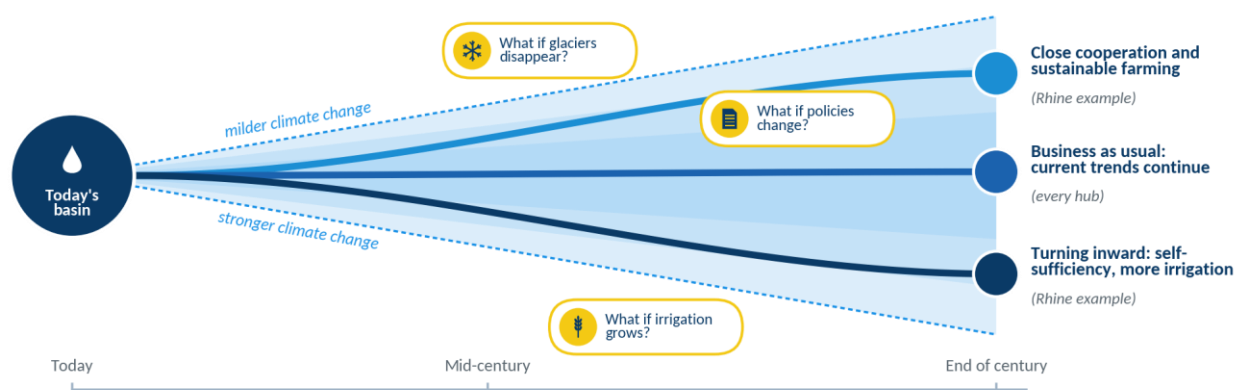
What does it enable? Exploring pollution patterns and choosing where to site new monitoring or abstraction boreholes. First built for the Duero, it was developed for East Anglia's chalk aquifers together with Anglian Water.

More information is available [here](#)

STEP 4 EXPLORE FUTURES

What futures might a river basin face?

There is no single knowable future for a river basin. Instead of betting on one forecast, STARS4Water developed and tested each basin against several plausible futures, to see which risks keep appearing and which choices still hold up.



Scenarios are not predictions. They describe plausible futures, so that plans can be tested against more than one.

No single future

Historical records are no longer a sufficient guide, and no one can say exactly how climate, population, land use or policy will change. So STARS4Water did not try to predict the future. It combined climate projections with assumptions about socio-economic development, water demand, land use and management choices to build plausible scenarios. The basin models then showed how each basin might respond. The models do not predict one exact future. They show a range of plausible conditions and help managers identify risks that appear consistently across different futures and plan for resilience.

Futures written with the basins

The scenarios were co-developed with the people who know each basin. For every hub, stakeholders and researchers first described a “business as usual” future, a middle-of-the-road path in which current trends continue. Then they asked “what if?”. The hubs formulated 24 what-if questions, between two and eight each. Climate change featured in 12 of them and in every hub; others explored water policy, land use, water allocation and socio-economic change. On the Rhine, two contrasting futures were drawn up alongside the middle road: one in which the Rhine countries cooperate closely and shift to sustainable farming, and one in which they turn inward, towards self-sufficiency and more irrigation.

What if...?

Seven of the 24 what-if questions formulated by the River Basin Hubs with their stakeholders, as published in the project’s scenarios report.

DANUBE

What would be the consequences of a 20% reduction of discharge caused by a disappearance of glaciers for various water users (e.g. navigation, hydropower, irrigation, habitats)?

DRAMMEN

What would be the consequence of three consecutive drought years (two such years occurred in 2021-2022) for various water users and energy sector?

DUERO

What would be the consequence of continued EU environmental policies advocating the reduction of fertilizer inputs for groundwater nitrate concentrations?

EAST ANGLIA

What would be the consequence of more frequent droughts and/or drastic changes of seasons due to climate change for meeting the water demand (groundwater vs surface water availability, in particular)?

MESSARA

What would the impacts be on water resources, further exploitation of groundwater and irrigation demand if five or seven consecutive drought years occur?

RHINE

What if the Rhine countries in the Rhine river basin under climate change distance from each other, form a nationally oriented society, form national economies [...], shift to more irrigation intense agriculture, reduce export and import on the Rhine?

SEINE

What if the upstream reservoirs cannot fulfil their management objectives in the future climate (more severe low flows) and socio-economic changes leading to a higher water demand downstream of reservoirs?

Stress-testing the system

On the Rhine, the project generated 125 artificial but plausible climate series, consistent with the latest international climate projections. It ran each one through a hydrological model, counted the days when flows would fall below the level that matters for shipping, and screened changes in the flow pattern that matter for river life. Averaged over many years, the risk around 2050 looked low, rising to low to moderate by 2080. Yet single years showed more than 80 days below the shipping threshold. The results are preliminary, and the thresholds reflect expert judgement and stakeholder consultation rather than formal standards. The lesson is clear all the same: long-term averages can mask the extreme years that do the most harm.

DANUBE NAVIGATION



Upper Danube, one critical section for shipping: days per year with critical navigation conditions in a dry year like 2011. Model reference: 50 days. Worst-case what-if for 2050, combining climate change, glacier retreat and extra water abstraction: 90 days. The dashed line marks the 22-day crisis threshold. The indicator is a simplification based on modelled river flows and does not account for riverbed changes or dredging; the worst case uses the most pessimistic of the climate studies reviewed.

WHY IT MATTERS

Testing choices against many plausible futures shows which risks appear in most of them, and which measures still work when conditions change.

FROM THE BASIN • Drammen, Norway

The Drammen basin is expected to become wetter overall. Compared with 1991–2020, annual runoff is projected to rise by 3% by mid-century and by 6% by the end of the century under a medium-emission scenario. Yet the water stored as snow is projected to fall by 22–40% under the medium-emission scenario and by 55–69% under a high-emission scenario, depending on the period. Snowmelt comes earlier, and summer low-flow periods are projected to last longer, with consequences for hydropower, water supply and river life. Stakeholders asked the project to explore two extremes: unprecedented floods and three consecutive drought years. **PROJECTED**

IN PLAIN LANGUAGE • Scenario

The project's scenarios approach is practical: their "goal is not to predict; they do not answer questions such as 'how likely is this?', but rather they assist in thought provoking discussions in terms of 'what will we do if this happens?'" A what-if question changes one or more drivers, such as glacier melt, irrigation demand or licensing rules, and asks what follows.

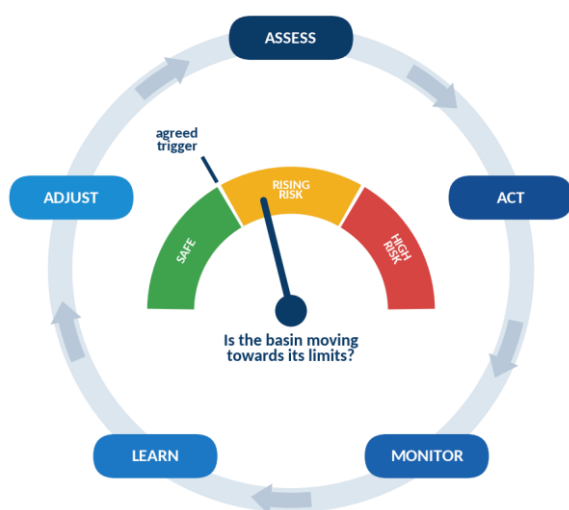


Snow and ice store water for months in Norway's mountains, and their melt feeds hydropower and water supply. The Hardangerjøkulen glacier in Norway (photo: Bjørn Lytskjold).

STEP 5 ASSESS LIMITS

Knowing the limits

Resilience means knowing your limits. The Safe Operating Space asks how far a river basin can be pushed before the things people and nature depend on start to fail, and what should happen as those limits come closer.



The Safe Operating Space as part of adaptive management: know the limits, watch the indicators, act before crossing into the red.

What “safe” means is local

There is no universal threshold. STARS4Water worked with stakeholders to choose indicators and limits for the functions that matter in each basin: days with critically low water for shipping on the Danube and the Rhine; how intensively aquifers are pumped in the Duero; how reliably farms get irrigation water on Crete; the minimum flows that hydropower reservoirs must release in Drammen; the risk to river life from changing flows in East Anglia; reservoir filling and low-flow levels on the Seine. Some limits come from existing rules, such as the legal fairway depth on the Danube, Drammen’s hydropower licences, official low-flow thresholds in Paris and Water Framework Directive status in the Duero. Others, such as the Rhine shipping thresholds, rest on expert judgement and stakeholder consultation. Either way, they serve here as aids to discussion and adaptation planning.

IN PLAIN LANGUAGE • Safe Operating Space

Picture a gauge for each function that matters, such as drinking water, shipping or river life: green while the basin can cope, amber as pressure builds, red when harm becomes likely. Agreeing beforehand what happens when the needle reaches amber turns the gauge into a management tool.

A question, not just an indicator

The Safe Operating Space is not one more number on a chart. It starts from a question: within what conditions can the water system continue to provide the ecological, social and economic functions that matter, and what happens as those conditions are approached or exceeded? Answering it means knowing the condition of the system, the pressures on it, the risks it may face in future, and the environmental and social limits that should not be crossed.

WHAT “SAFE” MEANS IN EACH BASIN



DANUBE

Days with critically low water for shipping



RHINE

Days with critically low water for shipping



DUERO

How intensively aquifers are pumped



MESSARA

How reliably farmers get irrigation water



DRAMMEN

Minimum flows that hydropower reservoirs must release



EAST ANGLIA

Risk to river life from changing flows



SEINE

Guaranteeing reservoir filling and sustaining low-flow levels

What “safe” means depends on the basin context: each hub chose indicators and limits for the functions that matter most for them. But “safe” needs to be considered holistically across the basin, recognising that protecting one function or water use can affect another. Making these trade-offs visible is essential for informed discussion and for helping stakeholders agree on balanced pathways towards resilience. This is the kind of dialogue that needs to be promoted and facilitated among stakeholders.

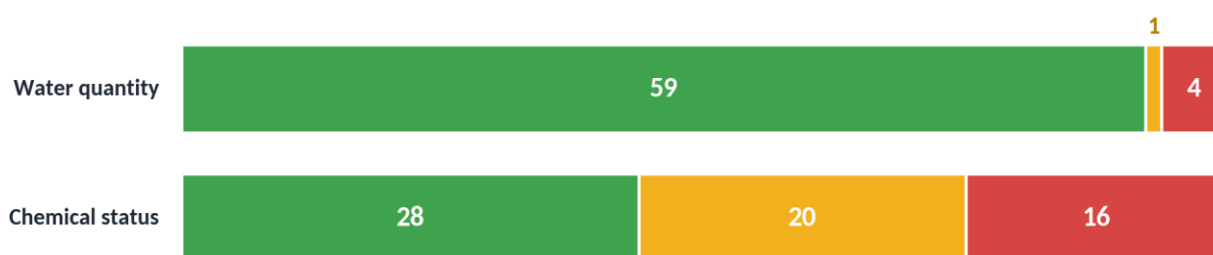
Green, amber, red

Several assessments sort conditions into colour-coded classes of rising risk. In the Duero, each of the 64 groundwater bodies was placed in one of three zones: a safe operating space, a zone of increasing risk or a zone of high risk. For good quantitative status, 59 are in the safe zone, one is at increasing risk and four are at high risk, where pumping is heavy and water levels are falling. Quality is the bigger worry: only 28 are safe for good chemical status, while 20 are at increasing risk and 16 at high risk, mainly from nitrate, ammonium and arsenic. Used this way, the approach works as an early warning, flagging water bodies at risk that formal Water Framework Directive assessments have not yet identified.

On the Crete Messara plain the lens is water supply reliability. Over the 1989–2022 reference period, the Messara model shows 58% of the basin's agricultural areas facing a water deficit almost every year, with irrigation supply reliability of only 0–9% in the worst-affected areas.

DUERO GROUNDWATER

Status of the 64 groundwater bodies in the Duero basin



OBSERVED

Safe operating space

Increasing risk

High risk

Status of the 64 groundwater bodies in the Duero basin, for water quantity and for chemical status. Green: safe operating space. Amber: increasing risk. Red: high risk. Current status, assessed from monitoring data and estimated recharge.

FROM THE BASIN • Duero, Spain

In the Duero, the project used two signals to place each groundwater body in a zone: the long-term trend in measured water levels, and the exploitation index, which compares how much water is pumped with how much is available from recharge. Where levels are falling, stricter limits apply. Water quality is judged separately from each body's chemical status. The approach was also discussed with stakeholders at a workshop on how the Safe Operating Space can support the Water Framework Directive.

A limit that moves

A Safe Operating Space is not fixed: climate change, new demands and management choices can shift it. On the Seine, model runs for 2070–2098 under a high-emission pathway show the four large reservoirs might fail to fill as they do today when considering four contrasted climate scenarios. Yet management choices still matter. Extending the release season into November kept the Paris crisis threshold from being crossed in more than 5% of years, even under the driest climate scenario tested. In runs without the reservoirs, the crisis threshold was crossed every month in all the climate scenarios.

This is why the Safe Operating Space belongs in an adaptive cycle: assess, act, monitor, learn and adjust. A threshold becomes useful when everyone knows in advance which measures can be triggered as an indicator enters the danger zone, who acts, and what evidence would justify changing course.

WHY IT MATTERS

Measures that make water use more efficient may not, on their own, protect ecosystems, and local actions can shift pressures elsewhere. Only a whole-system view shows whether a basin is moving towards its limits.

STEP 6 DECIDE

From evidence to decision

Evidence only matters if people can use it. STARS4Water invested in making results understandable, not only in producing them. Models generate evidence. Decision-support tools help people make sense of it. Institutions and stakeholders decide how to act.

1 Models generate evidence

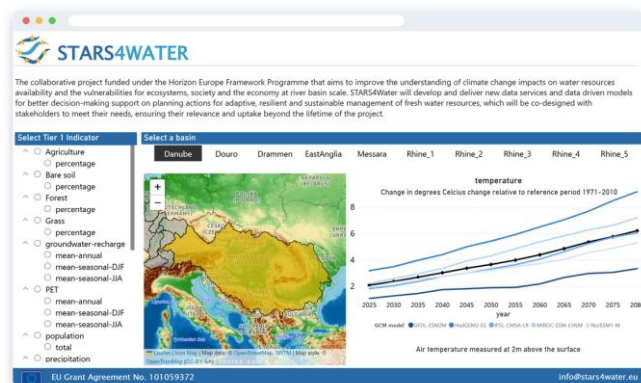
2 Decision-support tools help people make sense of it

3 Institutions and stakeholders decide

Evidence people can use

Data, model results and future scenarios are not enough on their own. They need to be clear, accessible and connected to the questions decision-makers actually face. STARS4Water therefore built a family of tools, each with a different purpose.

EXPLORE THE EVIDENCE

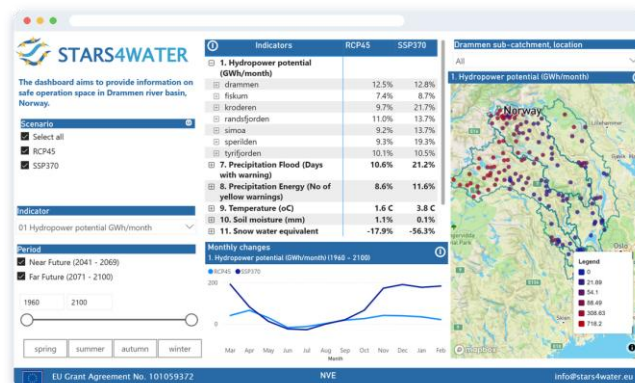


Explore the evidence: the generic dashboard compares climate and water indicators across all seven hubs.

Explore the evidence: the generic dashboard

A public online dashboard presents climate, water and land-use indicators for all seven hubs on a common basis, drawn from consistent European and global datasets. Users can compare basins and see the direction of expected change. It offers a useful first look, especially where no detailed local model exists, and the underlying data are openly available. Just as importantly, it provides a practical starting point for discussion: what additional information is needed, which questions should be explored in more detail, and how should results be presented to support decisions? In this way, the dashboard helps get the co-creation process up and running quickly and provides a common evidence base from which more tailored analyses and tools can develop.

FROM EVIDENCE TO LOCAL INSIGHT



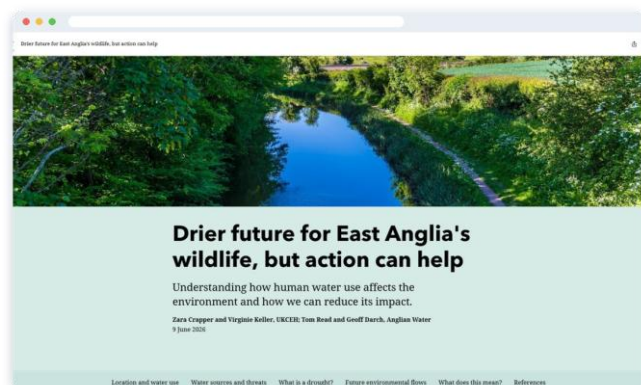
From evidence to local insight: the Drammen dashboard, co-designed with basin stakeholders and maintained by NVE.

From evidence to local insight: the Drammen dashboard

In Drammen, NVE and Deltares built a dashboard around the basin's own models and questions. It began in April 2025 with a scoping workshop, where hydropower producers, water suppliers, municipalities and regional water managers set out what they needed. They asked to see trade-offs, such as hydropower production against environmental-flow requirements; to compare today's conditions with future climate and management scenarios; and to spot periods when water supply and river ecosystems are under stress at the same time.

The design moved from an interactive card to slides to a working dashboard, each round shaped by feedback. After a two-day stakeholder workshop, NVE decided to maintain the dashboard and use it for planning, operations and informing a wider audience. It has been demonstrated in an operational setting, and its final version was scheduled for release in September 2026. Further development for full operational use lies with NVE.

UNDERSTAND THE FUTURE

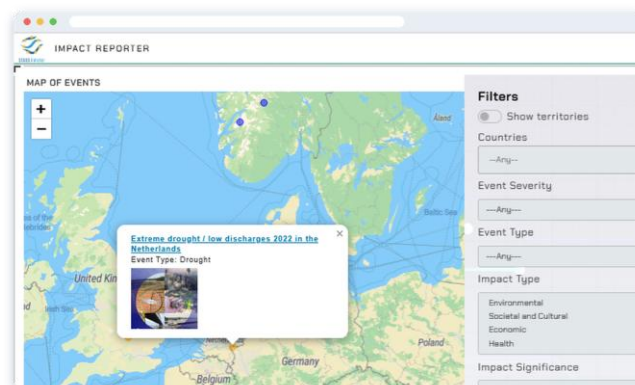


Understand the future: Story Maps turn model results for each River Basin Hub into visual stories.

Understand the future: StoryMaps

Eight illustrated web stories turn scenarios and model results into plain-language narratives with maps and images: one for each River Basin Hub, plus a transferability case on the Meuse. They were created with basin stakeholders and link to further data and reports.

LEARN FROM EXPERIENCE



Learn from experience: the Impact Reporter records the impacts of past floods, droughts, storms and heatwaves, and the measures taken.

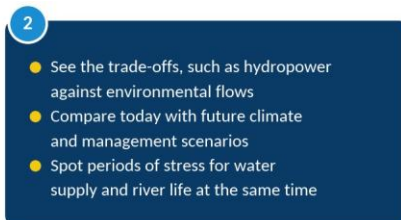
Learn from experience: the Impact Reporter

Decisions are taken under uncertainty, and every drought or flood creates new evidence. The Impact Reporter is an open-access online platform that records the impacts of past floods, droughts, storms and heatwaves, and the measures taken in response. Anyone can browse it; registered users add new events. Learning what worked, and what did not, feeds the next round of questions.

FROM STICKY NOTES TO DASHBOARD



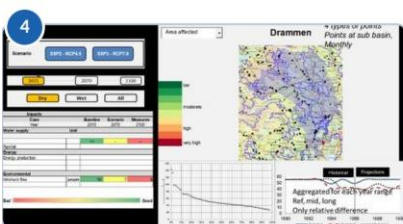
Scoping workshop, April 2025



What users asked for



Mock-up 1: interactive card



Mock-up 2: slides



Mock-up 3: Power BI



Tailor-made dashboard

From sticky notes to dashboard: needs voiced at the April 2025 workshop shaped mock-ups that evolved into the working dashboard.

STAKEHOLDER VOICE

“Bringing together all climate-related indicators for the basin in one place makes the information easier to access and interpret.”

Stakeholder feedback on the Drammen dashboard

TOOL IN ACTION · Drammen dashboard

What is it? An online dashboard built on NVE's basin models.

What problem does it solve? Raw model outputs are hard to interpret.

Who can use it? Water managers, hydropower producers, water suppliers and municipalities.

What does it enable? Exploring climate scenarios, seasons and trade-offs, such as hydropower against environmental flows, in one place.

WHY IT MATTERS

The strongest request from Drammen users was for more explanation, so that everyone understands the figures are “model-based scenario results rather than direct observations or forecasts”. Trustworthy tools say clearly what they cannot do.

ALL SEVEN BASINS

Seven basins, different questions, shared lessons

From the snow-fed mountains of Norway to the irrigated plains of Crete, the seven River Basin Hubs face very different pressures. The approach travelled; the answers stayed local.

The hubs differ in climate, water use, institutions and the questions they needed answered. An international commission needed a basin-wide picture of low flows. A reservoir operator needed to test its rules against a changing climate. A hydropower basin needed to see the trade-offs between energy and ecosystems. STARS4Water adapted the same journey to each.

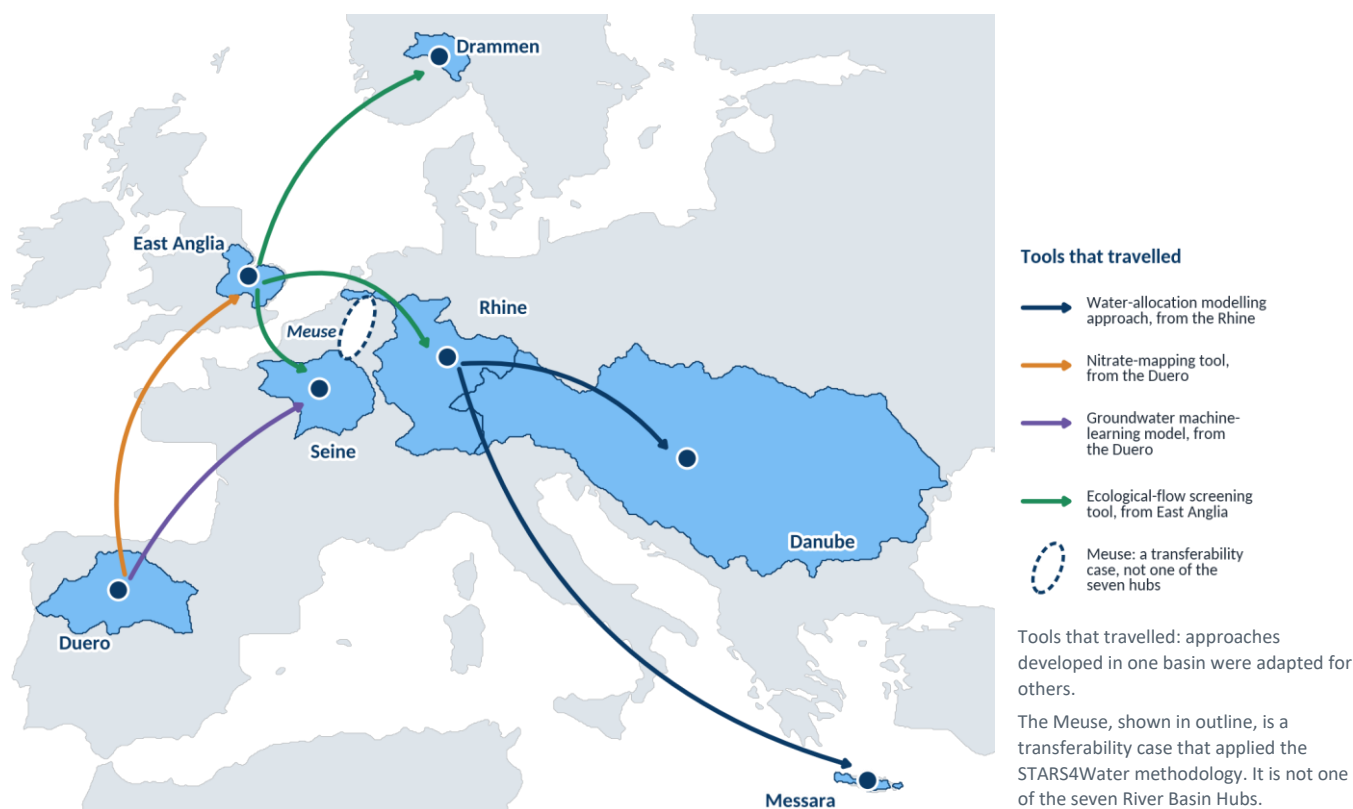
Shared lessons

Despite their differences, the basins point the same way. Water scarcity is no longer only a Mediterranean problem: it is becoming a serious concern across Western and Central Europe too. Six of the seven hubs face reduced summer flows and more frequent droughts; three see earlier snowmelt or glacier loss; five expect more rainfall-driven floods.

Groundwater is a vital buffer against drought, but over-abstraction and falling recharge threaten it. Healthy rivers are a condition for resilience, so environmental flows should count as an essential water demand, not as what is left over. And in regulated basins, how reservoirs and abstractions are managed can matter as much as the climate itself.

Tools that travelled

Several approaches moved between basins. The Rhine's water-allocation modelling approach was taken up in the Danube and Messara. A nitrate-mapping tool first built for the Duero was developed for East Anglia's chalk aquifers. A groundwater machine-learning model moved from the Duero to the Seine. The ecological-flow screening tool was applied from East Anglia to Drammen, the Rhine and the Seine.



SEVEN BASINS AT A GLANCE

**Danube** international

THE PRESSURE Drier summers and retreating glaciers threaten shipping, hydropower, power-plant cooling and river life.

WHAT WAS BUILT A new low-flow water-allocation model for the Danube main stem, developed with its International Commission.

WHAT “SAFE” MEANS Days per year with critical low water for shipping; more than 22 is a crisis.

HEADLINE FINDING Worst-case what-if for 2050: 90 critical days in a dry year at one Upper Danube section. **PROJECTED**

**Drammen** Norway

THE PRESSURE A snow-fed, heavily regulated hydropower basin with shifting runoff and seasons.

WHAT WAS BUILT A basin-wide model with all 54 regulated reservoirs, linked to hydropower, and a tailored dashboard.

WHAT “SAFE” MEANS Minimum flows that reservoirs must release; ecological risk from altered flows.

HEADLINE FINDING More runoff over the year, but 22–69% less water stored as snow, depending on scenario and period. **PROJECTED**

**Duero** Spain

THE PRESSURE Irrigation drives heavy groundwater use; nitrate pollutes aquifers.

WHAT WAS BUILT An extended groundwater model with nitrate, nitrate-risk maps, and machine-learning forecasts for reservoirs and groundwater.

WHAT “SAFE” MEANS How hard each aquifer is pumped, and its chemical status.

HEADLINE FINDING Today, 4 of 64 groundwater bodies are at high risk for quantity and 16 for chemical status. **OBSERVED**

**East Anglia** United Kingdom

THE PRESSURE One of England’s most water-stressed regions, with low rainfall and high demand from farming, energy and public supply.

WHAT WAS BUILT Ecological-flow risk screening, nitrate mapping with Anglian Water, reservoir forecasts one to three months ahead.

WHAT “SAFE” MEANS Ecological risk from altered river flows at 13 gauging stations.

HEADLINE FINDING By 2060–2079, under high-emission projections, most sites are at medium ecological risk; climate matters more than demand. **PROJECTED**

**Messara** Crete, Greece

THE PRESSURE Groundwater over-abstraction and high irrigation demand in Crete’s largest agricultural plain.

WHAT WAS BUILT A rebuilt water-allocation model linked to groundwater, with ecological-flow limits.

WHAT “SAFE” MEANS Reliability of irrigation supply and the water balance of each sub-basin.

HEADLINE FINDING Over 1989–2022, 58% of farmland faced a water deficit almost every year. **MODELLED**

**Rhine** international

THE PRESSURE Summer water scarcity and rising demand, with trade-offs between shipping, households, industry, farming and hydropower.

WHAT WAS BUILT Updated water modelling, socio-economic futures shaped with the Rhine commissions, and a 125-climate stress test.

WHAT “SAFE” MEANS Days below the shipping threshold; ecological flows; unmet water demand.

HEADLINE FINDING Low average risk around 2050, yet single years with more than 80 days below the shipping threshold (preliminary). **PROJECTED**

**Seine** France

THE PRESSURE More severe low flows; four upstream reservoirs holding about 810 million m³ might not reach full capacity before summer.

WHAT WAS BUILT A basin model that includes the reservoirs’ operating rules, plus an ecological-flow assessment.

WHAT “SAFE” MEANS Guaranteeing reservoir filling and sustaining low-flow levels up to Paris.

HEADLINE FINDING For 2070–2098 under a high-emission pathway, extending releases into November may keep exceedances of the Paris crisis threshold under 5% of years, even in the driest scenario. **PROJECTED** **MANAGEMENT OPTION**

BEYOND THE HUBS · The Meuse

The approach is already travelling. A study of the Meuse, carried out alongside STARS4Water and using its methodology, combined socio-economic scenarios, future river flows and stakeholder engagement to test ways of easing low flows, from nature-based solutions to better reservoir operation. It found that nature-based solutions can help, but their effect depends on where and how they are implemented. The Meuse is not one of the seven River Basin Hubs: it is a transferability case, with its own Story Map and its own Wflow-Ribasim modelling framework (similar to Rhine and Danube).

Seven basins, different questions: the pressure, what was built, what “safe” means and one headline finding for each River Basin Hub. Tags show whether a finding is observed, modelled or projected. Photographs from the seven basin Story Maps.

STEP 7 LEARN & ADAPT

From tools to practice

Good tools matter, but so do competent institutions, accessible information and trusted collaboration. A tool only makes a difference when someone owns it, maintains it and knows when to use it.

Tools need people and institutions

A recurring lesson from four years of work is that science and software alone are not enough. Tools need users who understand them, organisations that can host and maintain them, and communities that trust the evidence they provide. Each kind of product brings its own demands. Data services travel easily and are good for screening. Integrated models are powerful but need data, expertise and long-term owners. Machine-learning tools are promising complements. Dashboards and Story Maps open the evidence to more people, but they need hosting, updates and user support.

Who keeps it running beyond the project end

Owners are named for their key tools. NVE will maintain the Drammen dashboard, Deltares the Metadata Portal, and INRAE the Seine model. Deltares will also maintain the Ribasim model software and support the Ribasim modelling community (Rhine, Danube, Messara, Drammen). The Region of Crete will continue to use and update the Messara model and has expressed interest in extending the approach across the entire island. On the Rhine, results are already feeding the update of the International Commission's climate adaptation strategy. On the Seine, a three-year follow-up study is planned from 2027.

Skills to use them

The STARS4Water Academy turns project experience into training material: 27 webinars by September 2026, at three levels, from what a tool does, through worked examples, to step-by-step guidance. A hands-on course in May 2024 trained users from the hubs in water-allocation modelling, and a joint workshop with the DRHYM project on machine learning drew 35 participants on site and 15 online. Practitioner guidance distils ten principles for climate-resilient basin management and advice on choosing data services and models that fit a basin's questions, data and capacity.

PULL QUOTE

"A tool is not 'operational' because it exists online. It is operational when a responsible organisation knows when to use it, trusts the evidence and uncertainty, has staff and resources to maintain it, and can connect its outputs to an established decision or planning process."

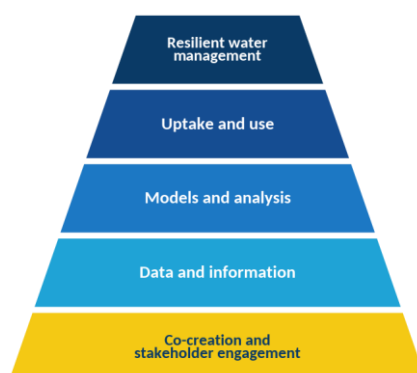
Joint STARS4Water/SOS-Water policy brief

WHAT MAKES A TOOL OPERATIONAL

- ✓ A responsible owner
- ✓ Long-term maintenance
- ✓ Interoperable data
- ✓ Trained staff
- ✓ Capacity to convene across sectors
- ✓ A clear route from evidence to decision

What makes a tool operational: six conditions, from a named owner to a clear route from evidence to decision.

FROM CO-CREATION TO LASTING IMPACT



From co-creation to lasting impact: each layer builds on the one below, and uptake is a continuing cycle of development, use, learning and adaptation.

TOOL IN ACTION · STARS4Water Academy

What is it? A library of training webinars on the project's data, models and tools.

What problem does it solve? New tools are only useful if people know how to apply them.

Who can use it? Practitioners, decision-makers and other interested users.

What does it enable? Learning at the right depth, from a first overview to step-by-step practice.

WHO KEEPS IT RUNNING



NVE
Drammen dashboard



Deltares
Metadata Portal
Ribasim model software



INRAE
Seine model



Region of Crete
Messara model

Who keeps it running after the project.

STEP 7 LEARN & ADAPT · RECOMMENDATIONS

What Europe can take forward

Europe does not lack scientific knowledge, data or tools for water resilience. The challenge is to turn them into lasting, everyday decisions in its river basins.

At the Joint Policy Event in Brussels in June 2026, organised with the sister project SOS-Water, researchers, policymakers and practitioners highlighted a key bottleneck is increasingly the uptake and practical use of existing knowledge, rather than the availability of knowledge itself. Scientific gaps remain, for example in linking global and local data. Yet impact now depends on the pathway from a successful research result to a maintained service, an institutional workflow and an implemented measure. Regions face very different challenges, so recommendations cannot be identical everywhere. But four years in seven basins point to seven messages.

VOICE FROM BRUSSELS

“Many excellent research results never reach the politicians and water managers who need them most.”

Joint Policy Event, Brussels, June 2026, as quoted in the STARS4Water policy synthesis report

1

Plan for the future, not the past.

Build forward-looking assessments, scenarios, thresholds and triggers into River Basin Management Plans rather than into parallel plans, so that decisions can be revisited between six-year cycles.

GOV SEC R&I

2

Make co-creation standard practice.

Involve basin organisations and water users from framing the question to interpreting the results and keep partnerships going beyond single projects.

GOV INV R&I

3

Build usable evidence chains, not isolated tools.

Make data findable and reusable, combine global and local data, and communicate uncertainty clearly.

DIGI R&I

4

Define limits that matter locally.

Use the Safe Operating Space approach to set basin-specific thresholds for water abstraction and ecological flows, linked to actions agreed in advance.

GOV SEC R&I

5

Turn research results into lasting services.

Name an owner, a maintenance plan and funding before a project ends.

INV R&I GOV

6

Invest in people and institutions.

Fund the skills, data management and staff needed to interpret uncertainty, and treat digitalisation as organisational change, not only a technology upgrade.

DIGI R&I

7

Let river basin organisations convene beyond water.

Give them the mandate and resources to bring agriculture, energy, industry, spatial planning and nature together around shared evidence.

GOV INV SEC

ENABLING AREAS OF THE EU WATER RESILIENCE STRATEGY

GOV governance

INV investment

DIGI digitalisation

R&I research and innovation

SEC security and preparedness

Seven messages for policymakers and practitioners, each linked to the enabling areas of the EU Water Resilience Strategy.

RECOMMENDATIONS

WHY IT MATTERS

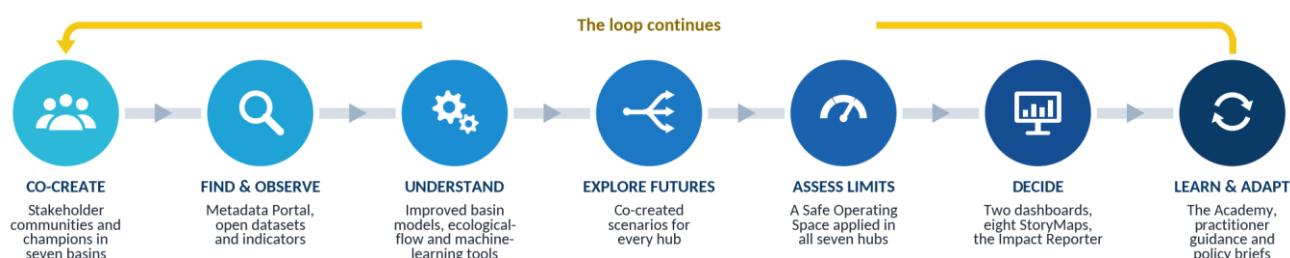
The legal foundations already exist in the Water Framework Directive and the Floods Directive. The gap is implementation: the European Commission's 2025 assessment of the latest river basin management plans found only 39.5% of assessed EU surface water bodies in good ecological status or potential.

STEP 7 LEARN & ADAPT · WHAT STARS4WATER LEAVES BEHIND

A beginning, not a conclusion

STARS4Water leaves more than datasets and models. It leaves a tested way of working, and building blocks that other basins can adapt.

Water resilience is not achieved through a single model, indicator, measure or plan. It is a continuing process: co-creating the questions, observing and understanding the system, anticipating plausible futures, knowing the limits, deciding and learning. STARS4Water showed how that process can be organised in seven very different basins, and how it can continue after the project ends.



What STARS4Water leaves behind, step by step along the journey.

What remains

- **Partnerships:** stakeholder communities and champions in seven basins, and science–practice collaborations, several of which are continuing.
- **Open evidence:** the Metadata Portal, open datasets and indicators for every hub.
- **Better models:** improved basin models, an ecological-flow tool and machine-learning tools
- **Futures and limits:** co-created scenarios and a Safe Operating Space applied in all seven hubs.
- **Tools for decisions:** the generic and the Drammen dashboards, eight Story Maps and the Impact Reporter.
- **Skills and guidance:** the STARS4Water Academy, practitioner guidance and policy briefs.

The loop continues

In every basin, work is already under way to refine indicators and thresholds and to bring the results closer to everyday management. The climate will keep changing, and so will the questions. The way of working stays the same: start with the people who decide, build the evidence together, test many futures, know the limits, and keep learning.

The building blocks are available. The next basin can start from here, adapting them to its own questions, data and capacity.

SCAN TO EXPLORE THE STARS4WATER SERVICES AND RESOURCES



STARS4Water website
stars4water.eu



Metadata Portal
stars4water.openearth.eu



Story Maps for the seven hubs
stars4water.eu/our-7-hubs



Impact Reporter
ir.stars4water.eu



STARS4Water Academy
stars4water.eu/the-stars4water-academy



Generic dashboard
bit.ly/stars4water-tier1



Drammen dashboard
bit.ly/nve-stars4water



Public deliverables
stars4water.eu/output/public-deliverables

ABOUT THIS PUBLICATION

ABOUT STARS4WATER

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PHOTO AND IMAGE CREDITS

Cover: Bjørn Lytskjold (Lake Vangsmjøsi, situated close to the very top of the Drammen River Basin, September 2021. Pages 2–3: Knut Møen (Nesbyen flood, May 2018); Irene Brox Nilsen (Lake Strandavatn drought, 2022). Pages 4–5 and 14–15: STARS4Water partners. Pages 16–17: StoryMap cover images. Screenshots: STARS4Water dashboards, StoryMaps and Impact Reporter. Page 7: chart redrawn from the STARS4Water report on next-generation water resources data services. Page 9: nitrate risk map adapted from the STARS4Water report on data-driven modelling tools; Lake Pannecière-Chaumard, seinegrandslacs.fr. Page 11: Bjørn Lytskjold (Hardangerjøkulen glacier). Graphs 1 and 2 redrawn from the STARS4Water report on projections of water resources availability and risks. Maps of the River Basin Hubs redrawn from project maps.

THE 21 STARS4WATER PARTNERS FROM 10 COUNTRIES

- 01 Stichting Deltares (coordinator) · Netherlands
- 02 SEVEN Engineering Consultants · Greece
- 03 Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE) · France
- 04 VanderSat B.V., now part of Planet Labs · Netherlands
- 05 Universität für Bodenkultur Wien (BOKU) · Austria
- 06 Instituto Geológico y Minero de España (IGME-CSIC) · Spain
- 07 Universidad Complutense de Madrid (UCM) · Spain
- 08 Romanian Research-Development Institute for Marine Geology and Geoecology (GeoEcoMar) · Romania
- 09 Rijkswaterstaat, Ministry of Infrastructure and Water Management · Netherlands
- 10 UK Centre for Ecology & Hydrology (UKCEH) · United Kingdom
- 11 Forschungszentrum Jülich GmbH · Germany
- 12 Johannes Kepler Universität Linz · Austria
- 13 Norwegian Water Resources and Energy Directorate (NVE) · Norway
- 14 Warsaw University of Life Sciences (SGGW) · Poland
- 15 Region of Crete · Greece
- 16 Anglian Water Services Ltd · United Kingdom
- 17 Bundesanstalt für Gewässerkunde (BfG) · Germany
- 18 Hellenic Ministry of Environment and Energy, Directorate for the Protection and Management of the Aquatic Environment · Greece
- 19 EPTB Seine Grands Lacs · France
- 20 Lower Danube River Administration, Galați · Romania
- 21 Confederación Hidrográfica del Duero · Spain



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