Rheinblick2027: interim project report

Tobias Wechsler[1,4], Michael Schirmer[2], Frederiek Sperna Weiland[3], Joost Buitink[3], Julie Collignan[4], Sebastian Wrede[5], Jules Beersma[6], Julianna Regenauer[7], Enno Nilson[7], Roel Burgers[8], Judith ter Maat[3], Petra Schmocker-Fackel[9], Helmut Habersack[10]

[1] *Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland*

[2] *University of Zurich, Switzerland*

[3] *Deltares, the Netherlands*

[4] *Institut national de recherche pour l'agriculture, l'alimentation et l'environnement INRAE, France*

[5] *Hessisches Landesamt für Naturschutz HLNUG, Umwelt und Geologie, Germany*

[6] *Royal Netherlands Meteorological Institute KNMI, the Netherlands*

[7] *Bundesanstalt für Gewässerkunde BfG, Germany*

[8] *Ministry of Infrastructure and Water Management Rijkswaterstaat, the Netherlands*

[9] *Bundesamt für Umwelt BAFU, Switzerland*

[10] *BOKU University, Austria*

Project aim

Generating streamflow scenarios for the Rhine River and its major tributaries to assess climate change impacts on special items such as flash floods, groundwater, sea level rise, and more.

Model framework

The scenarios are based on the

- KNMI'23 scenarios
- EURO-CORDEX scenarios

and the three hydrologic models:

- wflow_sbm
- LARSIM-ME
- PREVAH

Contact

The International Commission for the Hydrology of the Rhine Basin (CHR) initiated the project. Interested in contributing, using data, or writing a thesis within this project?

Get in touch with:

Michael Schirmer UZH Michael.Schirmer@wsl.ch

Tobias Wechsler WSL Tobias.Wechsler@wsl.ch

04 December 2025

Contents

1 Introduction

In April 2024, the International Commission for the Hydrology of the Rhine Basin (CHR) launched the *Rheinblick2027* project, a successor to *Rheinblick2010* (formerly *Rheinblick2050*). The *Rheinblick2027* project investigates the impacts of climate change on the discharge of the Rhine River and its major tributaries. The project's main goals are to:

1. compare model differences,
2. develop hydrological scenarios up to the year 2150, and
3. assess the effects of climate change on selected hydrological special items.

Beyond achieving these main goals, *Rheinblick2027* aims to strengthen stakeholder engagement and foster collaboration among different modelling groups. To this end, the project regularly organises outreach activities and interactive platforms that bring together stakeholders from the Rhine catchment and scientists from various institutions to exchange ideas and learn from each other. It is of particular interest to maintain close collaboration with the two other Rhine commissions: (i) the International Commission for the Protection of the Rhine (ICPR) and (ii) the Central Commission for Navigation on the Rhine (CCNR).

Rheinblick2027 officially started in September 2024 and will run until the end of 2027. So far, the project has already made good progress, with further steps outlined in the work plan shown in Figure 1.

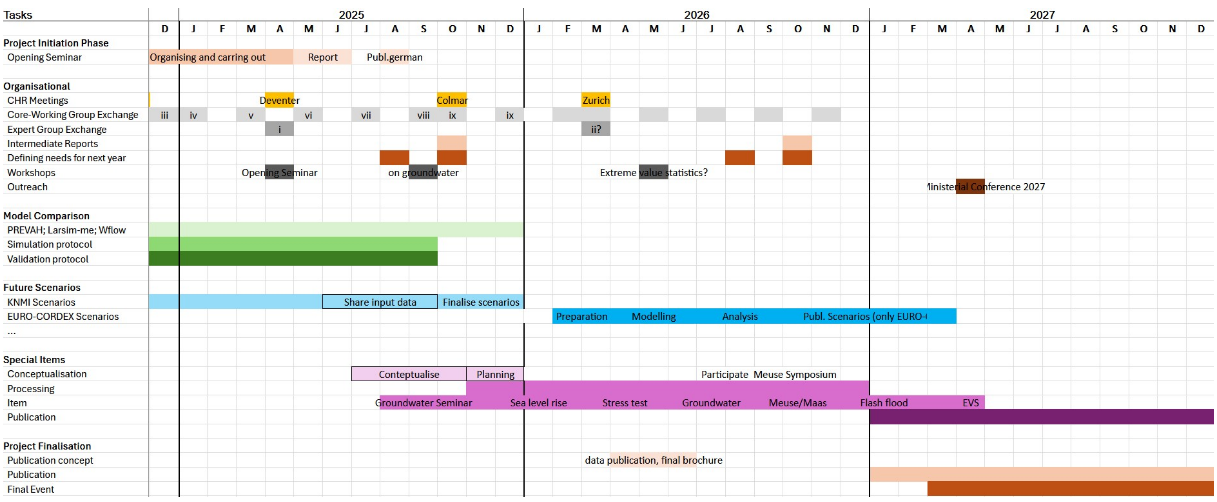

Figure 1: Work plan for the *Rheinblick2027* project, scheduled to run from September 2024 to December 2027.

This interim report provides an update on ongoing activities, outlines the project's organisational structure, and outlines the next steps.

2 Update on ongoing work

2.1 Model comparison

Rheinblick2027 started with a model comparison and test simulations of historical and future climate simulations using the three hydrological models introduced by the key modelling teams in the project's Core-Working Group: Deltares with wflow_sbm, BfG with LARSIM-ME, and WSL with PREVAH.

Activities in 2025:

- Hindcast runs based on the HYRAS dataset version 5.0
- Hydrological simulations based on the KNMI'23 scenarios

To ensure consistency in simulations, a simulation protocol was established by the Core-Working Group. The protocol addresses, among others, input datasets, simulation period, initial states, output variables, and reporting stations. As a reference for comparison, Table 1 provides an overview of the modules and methods used across the models for the main components of the hydrological system.

Table 1: Overview of main hydrological model characteristics.

Component	**LARSIM-ME**	**PREVAH**	**wflow_sbm**
Extent	Rhine basin up to Lobith	Rhine up to Basel	Rhine basin up to Lobith
Resolution	~5 x 5 km (some steps sub-scale)	200/400 m	~1 x 1 km
Snow module	Altitude zoning, day-degree approach, snow compaction, snow-mass-transport	Temperature-based degree-day method, calibrated, kriging interpolation	Temperature-based degree-day method, uniform within cell
Glacier module	No simulation	Degree-day method, glacier retreat every 5 years	Similar to snow; constant spatial extent, variable volume
Reservoir module	Basin capacity line, regulation specs	Approximate routing for dams and lakes	Reservoir dimensions, target level-discharge tables
Potential/actual evaporation	Penman-Monteith	Penman-Monteith	Makkink
Precipitation correction	Calibration + wind drift correction	Calibration, kriging regionalization	n.a. in version 1.0
Groundwater	Base flow component, recharge estimate	Conceptual module for low flows	Shallow groundwater only, leakage term
Key reference	LARSIM-Entwicklergemeinschaft, 2024	Viviroli et al., 2009	Van Verseveld et al., 2024

2.1.1 Comparison of model outputs for the hindcast period

For Lobith, the annual discharge cycle simulated by wflow_sbm and LARSIM-ME follows a similar pattern. Yet, wflow_sbm simulations are relatively high in winter and low in the second half of summer (Figure 2c). For Basel, the discharges simulated by LARSIM-ME and PREVAH are similar. wflow_sbm underestimates the observed discharges throughout the year (Figure 2b). For Bruegg-Aegerten, there is a seasonal pattern in PREVAH and LARSIM-ME that is less pronounced in the much lower-discharge simulations of wflow_sbm; this can be addressed by updating the lake-level tables in the model (Figure 2a). In addition, for wflow_sbm, a few locations were identified where simulations can be improved by updating the lake-level regulation tables.

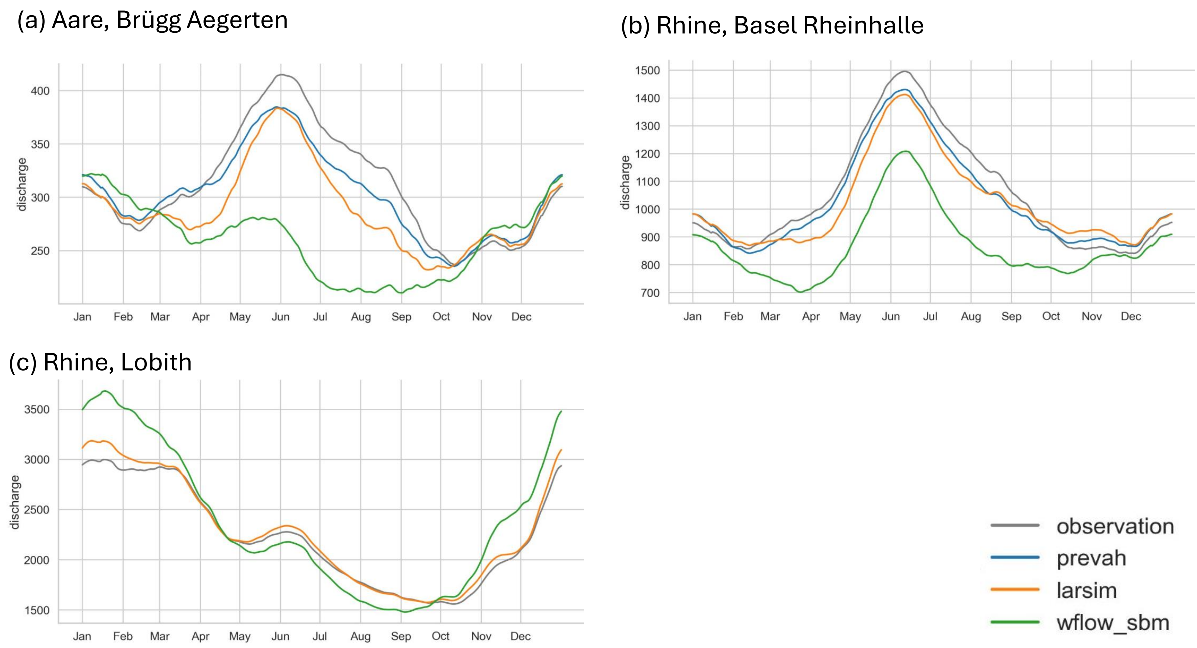

Figure 2: Long-term average simulated discharges for the hindcast period (1991-2020) based on the HYRAS dataset for the (a) Aare at Bruegg-Aegerten, (b) Rhine, Basel and (c) Rhine, Lobith.

2.1.2 Comparison of model inputs for the hindcast period

After running the simulations and comparing the model inputs, we compared the model inputs. Figure 3a illustrates the precipitation grids for a given day, prepared as input to the wflow_sbm model (left) and the LARSIM-ME model (right). For precipitation, Deltares applied nearest-neighbour interpolation to downscale from 12x12 km climate model output to the 1x1 km wflow_sbm grid. In contrast, BfG applied bilinear interpolation to obtain the 5x5 km LARSIM-ME model grid. For air temperature, both groups used altitude-dependent inverse-distance interpolation with a constant lapse rate. However, the similarities between the grids are high Figure 3B. PREVAH applied similar, but independently derived methods as LARSIM-ME to bridge the gap to a 200/400 m resolution. In the final EURO-CORDEX simulations, the situation will differ because bias-corrected climate model data will already be available on the 5 km LARSIM-ME grid. Downscaling to 1 km (wflow_sbm) and 200 m (PREVAH) will use consistent methods that preserve the main characteristics of the coarse dataset. These methods will be documented as part of the simulation protocol.

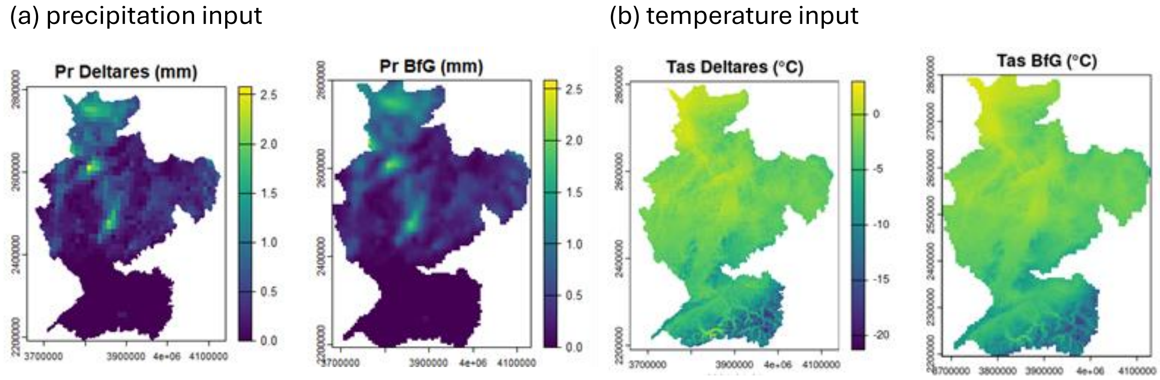

Figure 3: Exemplary model inputs for (a) precipitation and (b) temperature, used by the two groups Deltares (wflow_sbm) and BfG (LARSIM-ME).

A critical difference between the models is that PREVAH and LARSIM-ME include a precipitation correction, whereas wflow_sbm doesn't. This correction is especially important for the mountains, where the measurements are too low due to (wind) undercatch and the low density of stations at higher elevations. As a first step towards improving simulation, the wflow_sbm team has introduced a precipitation correction for Switzerland based on elevation (Figure 4; Hernegger et al., 2018; Pulka et al., 2024). Herewith, the discharge at Basel will increase.

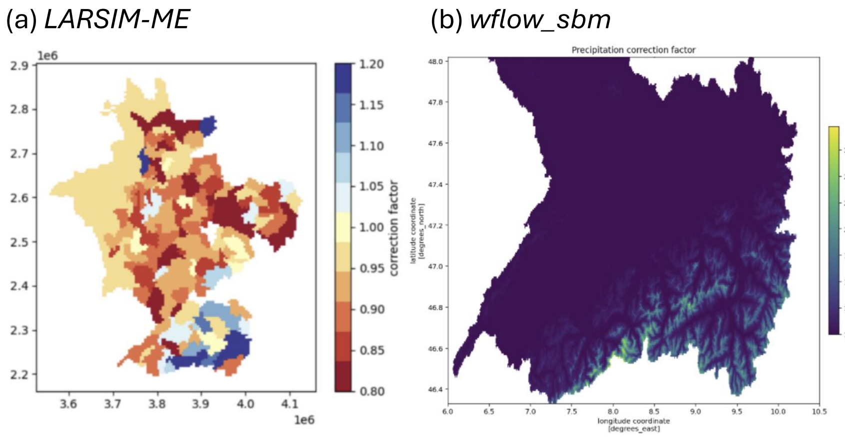

Figure 4: Precipitation correction factors for (a) LARSIM-ME, which does not not include wind corrections and for (b) wflow_sbm.

In addition to differences in simulated discharge, we also observe differences in other model output variables (Figure 5). In the remainder of the year, these will be further investigated, and the analysis will be extended to other locations and model outputs. Based on this, potential hydrological model improvements will be identified and implemented in early 2026.

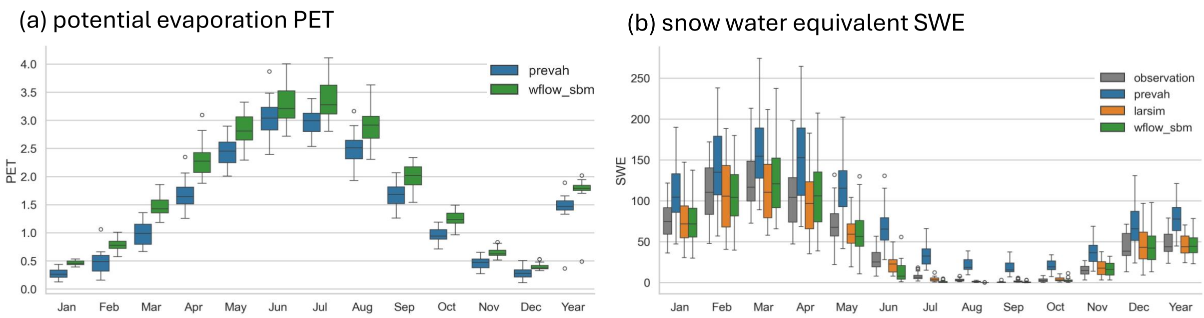

Figure 5: (a) Average potential evaporation PET and (b) snow water equivalent SWE upstream of Basel as available from the models with the observed SWE amount in grey.

Next steps:

- Complete a detailed analysis of the model differences.
- Based on results of the model comparison, optimise at least the `wflow_sbm` model and introduce a precipitation correction.
- Document the model differences and potential improvements by the end of 2025.

2.2 Generating hydrological scenarios

2.2.1 KNMI'23 scenarios

The KNMI'23 scenarios are among the few high-resolution datasets currently available for CMIP6 (van der Wiel et al., 2024; van Dorland et al., 2024). Within *Rheinblick2027*, the scenario set is used as a rehearsal to prepare for the EURO-CORDEX scenarios (Nydegger, 2025). The KNMI used the GCM EC-Earth3 in combination with the RACMO RCM to produce high-resolution climate projections at 12 km horizontal resolution (van der Wiel et al., 2024). To capture the CMIP6 model spread, the CMIP6 responses were reconstructed by resampling internal variability within this single GCM–RCM initial-condition ensemble. Model biases and resampling artefacts were corrected using univariate Quantile Delta Mapping (QDM; Cannon et al., 2015; van der Wiel et al., 2024). KNMI refers to the selected Shared Socioeconomic Pathways (SSPs) as SSP1-2.6, SSP2-4.5, and SSP5-8.5, and labels them as low, moderate, and high emission scenarios, respectively. The KNMI'23 climate scenarios provide time slices for the reference period (1991–2020) and projections for three main future periods: 2050, 2100, and 2150. Each period represents 30 years, centred on the corresponding year. For each time slice, scenario, and wetness condition, an 8-member ensemble is provided (Figure 6).

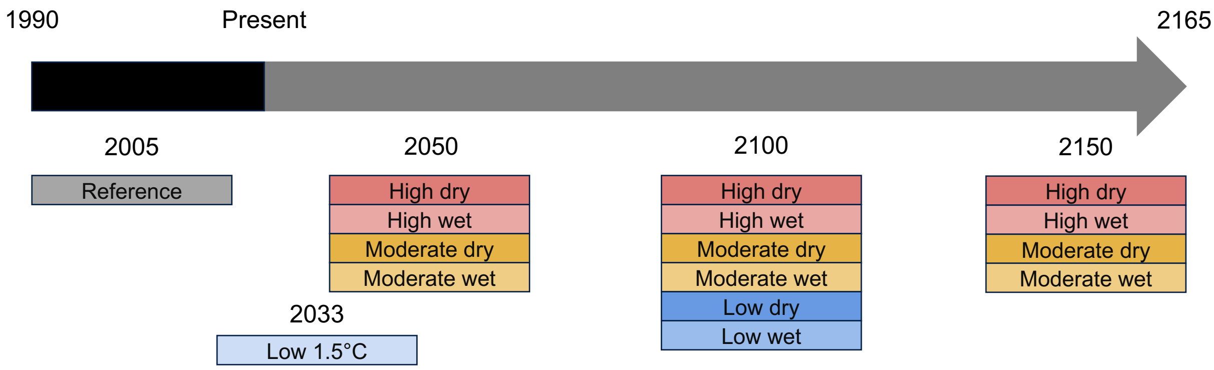

Figure 6: Available combinations of emission scenarios (low, moderate, high), precipitation variants (dry, wet, 1.5 °C), and future time periods in the KNMI'23 climate scenarios (Figure from Nydegger, 2025).

2.2.2 Hydrological projections

All three modelling groups ran the KNMI'23 scenarios with their hydrological models. Each modelling group independently addressed the challenge of non-transient data from KNMI'23, applying solutions that reflected their model requirements. The first results are presented here (Figure 7) and compared with the outcomes of the HCLIM scenario summary prepared for the Rhine (ICPR, 2024), calculated for the high emission scenario RCP8.5, which is most comparable to the SSP5-8.5 scenario of KNMI'23 (red). Despite differences that prevent a direct comparison (e.g., different time windows and emission scenarios), it can still be stated that the projected change in 7-day minimum flow (NM7Q) lies within the existing envelope of projections (pink band in the left panel; Figure 7a). The use of consistent KNMI'23 climate model input was the main reason that future projections were more constrained than previous projects, all of which relied on different climate model chains. For KNMI'23, the differences and order between scenarios are similar for all three hydrological models. The decrease projected by wflow_sbm is the smallest, which may be a result of the model bias at Basel that will be further investigated.

Figure 7b shows the projected change for annual maximum discharge (MHQ) at Lobith. The future projected changes from LARSIM-ME and wflow_sbm are comparable and are again enclosed by the pink envelope of projections obtained from HCLIM. Both models project an increase in maximum annual discharge for (nearly) all scenarios.

WSL collaborated with an MSc student at WSL/ETH Zurich who conducted additional analyses based on the KNMI'23 simulations using the PREVAH model (Nydegger, 2025). Figure 8 provides an example from the MSc thesis, showing the change in the number of days below the 95th percentile threshold (a low-flow indicator) for both the different emission scenarios and the future periods.

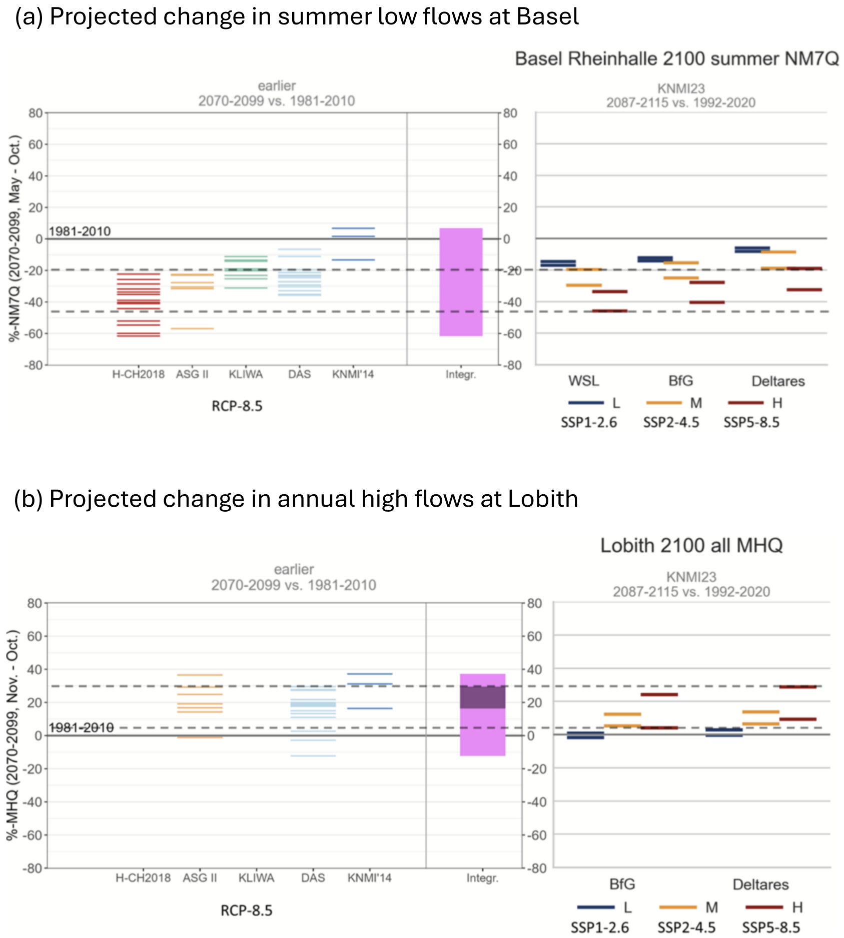

Figure 7: Projected change in (a) summer low flows (NM7Q) at the Rhine in Basel (Rheinhalle) by the end of the century, and (b) annual maximum flow (MHQ) at the Rhine at Lobith by the end of the century. The projected change is relative to the simulated reference periods 1991–2020 using the KNMI'23 scenarios (right panels in a & b) and 1981-2010 for previous projections compared by HCLIM (left panels in a & b).

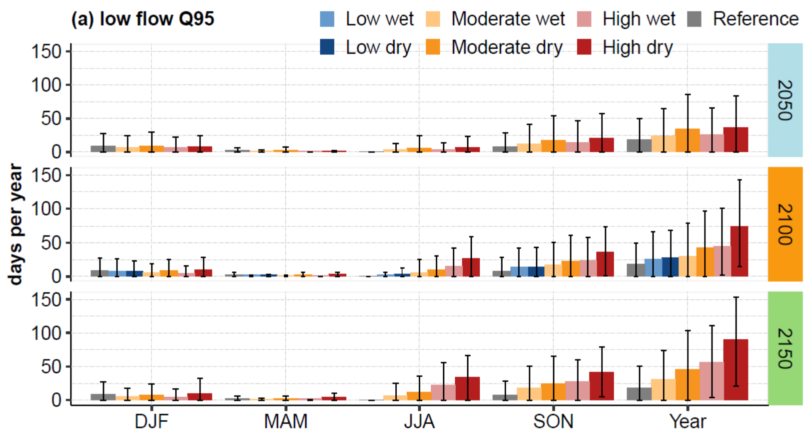

Figure 8: Number of days per season and per year with discharge below the 95th percentile threshold, based on KNMI'23 forced simulation in the reference period (1991–2020), at Basel Rheinhalle. Colored bars show the mean values for the different emission scenarios, while error bars indicate the 10% and 90% percentile ranges. Figure from Nydegger (2025).

Note:
During the Core-Working Group retreat in Colmar, Enno Nilson (BfG) presented the status of the availability of the EURO-CORDEX datasets for CMIP6. DWD is preparing a dataset for Germany that covers both Germany and the Rhine basin. The dataset will be available in spring 2026, and the *Rheinblick2027* team will receive early access to the files. There will be simulations available for a representative set of scenario–model combinations covering SSP1-2.6 (10 models), SSP2-4.5 (3 models), SSP3-7.0 (15 models), and SSP5-8.5 (3 models). The data will be transient from a reference period in the past to the end of the century, bias-corrected using a multivariate approach, and available on a 5 km grid.

Next steps:

- Finalise the analysis of the first round of simulations using KNMI'23 scenarios.
- Refine the modelling protocol and adapt it for the second round using transient EURO-CORDEX scenarios.
- Launch the second round of simulations in early 2026.

2.3 Special items

A dedicated sub-working group has drafted a concept for assessing climate change impacts on six special items (i) groundwater, (ii) extreme value statistics, (iii) stress test scenarios, (iv) flash floods, (v) Sea level rise, and (vi) Meuse/Maas River. The concept proposes tailored approaches for each special item, varying in depth and format—from literature reviews to targeted analyses. It follows an adaptive framework that allows for adjustments as the project evolves. For example, in the case of the groundwater special item, where our expertise is limited, we organised a two-hour online seminar on climate change impacts on groundwater recharge, in collaboration with groundwater experts. This allows us to gain insights into feasible approaches, while also strengthening stakeholder engagement—a key objective of *Rheinblick2027*.

The overarching goal of assessing climate change impacts on these special items is to minimise complexity while harvesting low-hanging fruit. The special items are intended to inform and support decision-making for shaping a potential future Rheinblick project. A detailed concept outlining how we assess the impact of climate change on the selected special items is provided in the special item concept (available on Teams) and summarised in Table 2.

Table 2: Overview of how to assess climate change impact on the selected special items, prioritised according to *Rheinblick2027*; structured by our expertise, the conceptualised approach, and the associated tasks.

Special item	**Expertise**	**Approach**	**Tasks**
i. Groundwater	Limited	Deep dive; stakeholder engagement; collaborations	Organise an online seminar on groundwater recharge Compare hindcast model outputs for the reference with an existing groundwater model
ii. Extreme Value Statistics	High	Literature review; deep dive	Provide an overview of methodologies currently used in extreme value statistics to advise CHR/ICPR Develop a workflow for estimating extreme value statistics Estimate extreme value statistics based on Rheinblick2027 discharge scenarios
iii. Stress Test Scenarios	High	Deep dive; collaborations; science/stakeholder engagement	Identify and define stress test scenarios with the Expert Group Conduct stress tests using hindcast model outputs, focusing on the reference period
iv. Flash Floods	Limited	Literature review	Provide a literature review
v. Sea Level Rise	Limited	Literature review; collaborations	Collect observed sea level data for France, the Netherlands, and Germany Gather defined reference values under future climate scenarios Engage in knowledge exchange with relevant institutions
vi. Meuse/Maas	Limited	Collaborations	Participate in the Maas Scientific Symposium in September 2026 Generate meteorological input scenarios for the Maas catchment

Subsequent research activities will be planned and carried out throughout 2026, with finalisation expected by mid-2027. Some of the more specialised tasks will rely on output data from the second simulation round using EURO-CORDEX scenarios. They will therefore be processed at a later stage in the project. Each special item will be documented in an individual item report that follows a format similar to the Opening Seminar Report. Depending on the relevance of its findings, it may be featured in the final outreach brochure.

Next steps:

- Finalise the concept and define work steps, and collaborations by the end of 2025.
- Begin assessments in early 2026, with final results expected by mid-2027.

3 Organisational

Rheinblick2027 is organised into the following three working levels:

1. **Core Working Group / Steering Group (Level 1)**
   - Meets every six weeks to coordinate ongoing work.
   - Holds an annual in-person retreat to focus on internal workflows and key project aspects.
2. **Expert Group (Level 2)**
   - Currently consists of 14 members (open to expansion, e.g., groundwater experts).
   - Next meeting on 27.03.2026 in Zurich, focusing on developing stress test scenarios.
3. **Sub-Working Groups (Level 3)**
   - Temporary groups composed of internal members and external experts, formed to address specific tasks.
   - Currently focusing on (i) simulations, (ii) special items, and (iii) organising the online seminar on climate change impacts on groundwater recharge.

CHR Meetings

- We contribute to CHR meetings by sharing project progress updates and integrating CHR feedback into our workflows.
- These meetings provide a relevant opportunity to learn about connections to other CHR projects and to the ICPR and CCNR commissions.

4 Collaborations & capacities

A key limiting factor in *Rheinblick2027* is the availability of human resources. Careful planning of internal capacities and the establishment of strategic collaborations are therefore essential. These collaborations aim to enhance the project's capacity, ensure continuity, and bring in relevant expertise. To date, members from *BOKU University, BAFU, BfG, Rijkswaterstaat, Deltares, HLNUG, KNMI, WSL, UZH, Université de Lorraine, and INRAE* contribute to the project.

5 Communication strategy

Rheinblick2027 follows a targeted communication strategy:

- Publications, stakeholder engagements, and other news are shared on the CHR website.
- The hydrological scenarios based on EURO-CORDEX will be published as a data publication that describes the model framework and includes a literature review on hydrological climate projections.
- The hydrological scenarios are intended to be integrated into the new CHR information platform: `khr-infosystem.terrestris.de`.
- Short reports will be produced for each of the special items, some of which may also be published in outreach journals (e.g., *HyWa*).
- As a final product, a concise brochure will be developed for stakeholders, public authorities, and policymakers—similar to previous projects such as ASG and Hydro-CH2018.

6 Project outputs

Rheinblick2027 is regularly presented in talks and at conferences. To also achieve the project goal of strengthening stakeholder engagement and fostering collaboration among modelling groups, the project organises dedicated platforms. Ultimately, to make outcomes publicly available, we aim to publish our results. Below, we present lists of achieved outcomes.

Talks:

- Wechsler, T., et al. (2024): Rheinblick2027, Poster. 22nd Swiss Geoscience Meeting, Basel, 09.11.2024.
- Herzog, P. & Nilson, E. (2024): Folgen des Klimawandels für den Rhein. Steering comitee "Aktionsplan Niedrigwasser Rhein". Bonn, 11.12.2024.
- Nilson, E. (2025): Der Rhein im Klimawandel. 3. Stakeholder Workshop of the project "Zukunft Rhein", Düsseldorf, 09.01.2025.
- Nilson, E. (2025): Abflussszenarien für die Fließgewässer Deutschlands. Workshop of BMFTR project R2K-Klim+, Koblenz 03.06.2025.
- Wechsler, T., et al. (2025): Rheinblick2027, Poster. ICPR Workshop Klimawandel. Arnhem, 19.03.2025.
- Nilson, E. (2025): Hydrologische Klimaforschung und -beratung in der Bundesanstalt für Gewässerkunde. Meeting of topic group on climate change and adaptation of the BMV research network, online 15.09.2025.
- Nilson, E. (2025): Klimawandelbedingte Abflussszenarien für das Rheineinzugsgebiet. 8th German-Durtch flood conference, Rees 03.12.2025.
- Wechsler, T. (2025): Effets du changement climatique sur l'hydrologie et leurs implications pour la gestion de l'eau. Séminaire INRAE Aix. Aix-en-Provence, 20.11.2025.

- Wechsler, T. (2025): Climate Change impact on Alpine hydrology and their implications for water resources management. Seminar INRAE Antony. Paris, 27.11.2025.
- Schirmer, M., et al. (2025); Rheinblick2027 – hydrological climate projection for the Rhine catchment, Poster. 23nd Swiss Geoscience Meeting, Bern, 06.12.2025.

Stakeholder engagements:

- *Rheinblick2027* Opening Seminar with 50 participants, organised by the Core-Working Group. Deventer, 14.04.2025.
- *Rheinblick2027* online seminar with 60 participants on climate change impact on groundwater recharge, organised by Christian Moeck (CH-GNet & Eawag, Switzerland), Mario Hergesell (HLNUG & KLIWA Groundwater Working Group, Germany), Albrecht Weerts (Deltares, Netherlands), and Tobias Wechsler (WSL & INRAE). Online, 22.10.2025.

Publications:

- Wechsler, T., Schirmer, M., Sperna Weiland, F., Nied, M., Wrede, S., Beersma, J., Regenauer, J., Nilson, E., Burgers, R., ter Maat, J., Schmocker-Fackel, P., Habersack, H. (2025). Rheinblick2027 opening seminar report: a transdisciplinary exchange to align the project design with stakeholder needs. International Commission for the Hydrology of the Rhine Basin CHR, 7 P.
- Wechsler, T., Schirmer, M., Sperna Weiland, F., Nied, M., Wrede, S., Beersma, J., Regenauer, J., Nilson, E., Burgers, R., ter Maat, J., Schmocker-Fackel, P., Habersack, H. (2025). Rheinblick2027 Eröffnungsseminar: Ein transdisziplinärer Dialog zur Ausrichtung des Projektdesigns auf die Interessen der Stakeholder. HW, 69(5), 265-267.
- Nydegger, N. (2025). Impact of Climate Change on the River Rhine discharge in Switzerland using the KNMI'23 Climate Scenarios. Master's thesis. Institute of Environmental Engineering, ETH Zurich & Swiss Federal Institute for Forest, Snow and Landscape Research WSL.
- Wechsler, T., Björnsen, A., Wartmann, F., Rohr, C., Schädler, B. (2025). Das Wasserschloss Europas im Wandel. Eine Zeitungsartikelanalyse zur Verwendung der Metapher im Kontext der Klimaerwärmung. Aqua & Gas, 105(12), 64-69.

7 Outlook

The first round of simulations using the KNMI'23 scenarios provided an excellent opportunity to strengthen collaboration and establish common workflows toward a well-defined simulation protocol. This initial phase, which included a model comparison, represents a crucial step in preparing for the second round of simulations using EURO-CORDEX CMIP6 scenarios, scheduled to become available in March 2026. In parallel, we are beginning to assess the impacts of climate change on six selected special items—each varying in depth and format. Through these special items, we are exploring new fields beyond the traditional CHR agenda and creating opportunities for future projects. The *Rheinblick2027* project continues to serve as a platform for fostering exchange among modelling groups and enhancing stakeholder engagement. These interactions are crucial to ensure that the final results align with stakeholder interests and provide climate services for water resource management. The CHR meeting in Colmar (October 2025) set the course for producing, based on the outcomes of *Rheinblick2027* and the *socio-economic scenarios* project, a consolidated 10-page summary jointly approved by CHR, ICPR, and CCNR, along with a concise two-page version.