Hydrological modelling of the Benguet Province, Philippines

Environmental Change and Adaptation programme

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Hydrological modelling of the Benguet Province, Philippines

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Summary

This report describes the development and application of a hydrological model to the Benguet Province, Philippines. This is based on a downscaled version of the Philippine Hydrological Model. The model simulates the natural hydrological cycle; any surface water and groundwater abstractions or dams are not considered. The model is driven by two sets of climate data: for the historical period (1979 to 2024) by ERA5 climatology and for 1980 to 2089 by UKCP18 climate change projections.

The historical model is compared with observations at gauging stations on the rivers Agno, Bauang, Bued and Galano. There are discrepancies between the simulated and the observed flows; however, there are uncertainties in the observations and the climate data, and surface-water abstractions and dams affect the river flows. For example, the hydrological model does not consider any abstractions from groundwater and surface-water sources or dams, which both impact the flows in the Agno river basin. Comparing the simulated flows with catchment size, we find that there is a linear relationship between catchment size and simulated naturalised river flow, which supports the inference that gauge flows are both uncertain and affected by abstractions.

The future climate change projections suggest a change in the flow regimes of all simulated rivers. In general, higher flows are suggested to increase and lower flows to decrease. The magnitude of this change varies from catchment to catchment and is predominantly driven by the projected change in precipitation.

Considering a representative greenhouse gas concentration pathway (RCP) of 8.5, a scenario in which estimated global average temperatures rise to 4.3°C above the preindustrial level by 2100, the high flows (5 per cent exceedance) across the assessed locations increase on average by 18 per cent (15 to 24 per cent), whereas the low flows (95 per cent of exceedance) decrease on average by 27 per cent (-48 to 5 per cent). There are some differences between the subcatchments and ensemble members for the climate change projections. More detail is shown in **Figure 1** for four river flow gauging stations. The boxplots show the projected change in river flow for different flow percentiles and illustrate the uncertainty between the different members of the ensemble of climate projections.

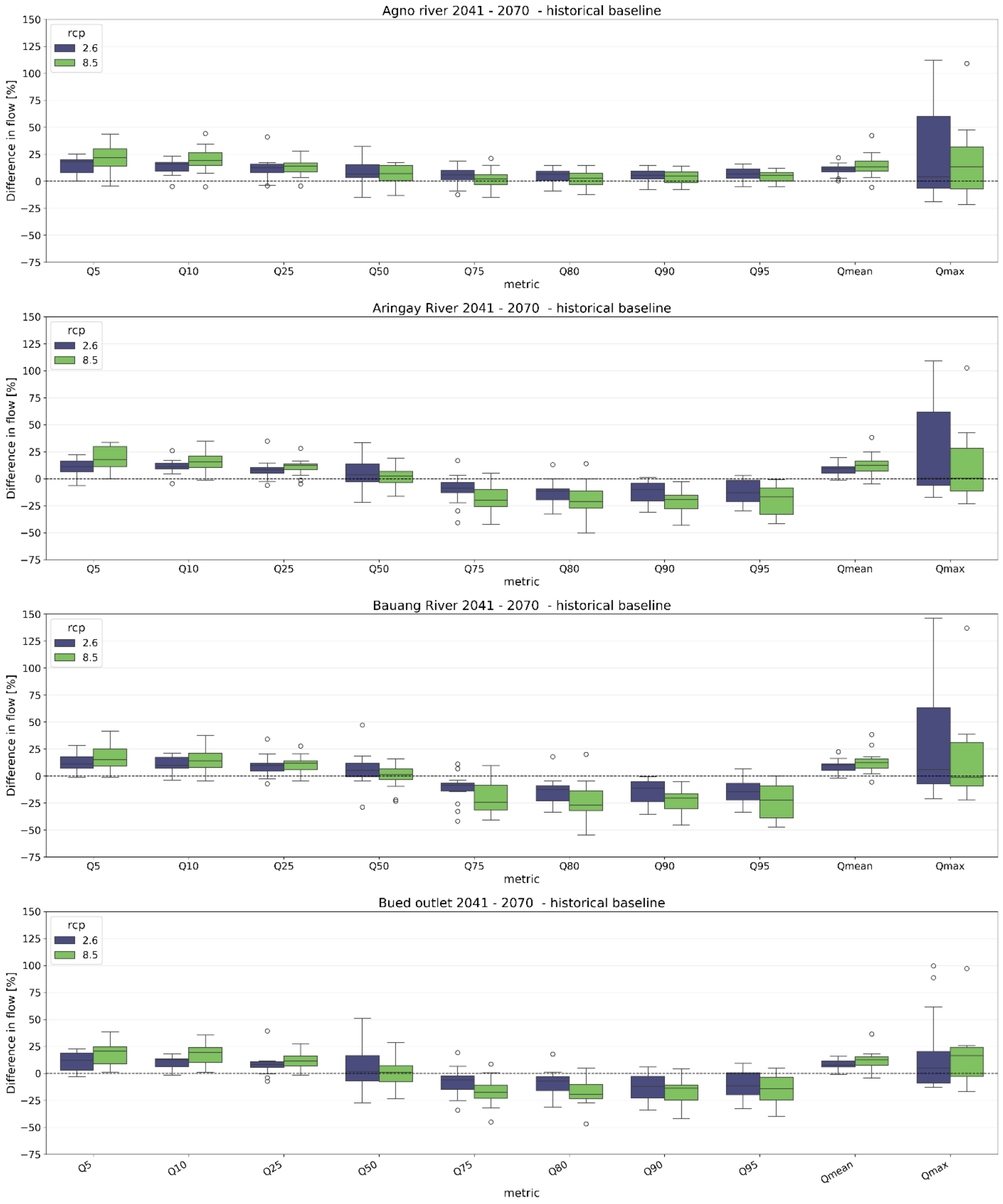

Figure 1 Differences in simulated river flow at different flow percentiles for 2041 to 2070 relative to the historical baseline (1990 to 2020) at four selected gauging stations or river outlets. Both RCP2.6 and 8.5 are considered. Q5 represents the flow that is exceeded 5 per cent of the time (high flows) and Q95 the flow that is exceeded 95 per cent of the time (low flows). Each solid-coloured box of the 'box and whisker' plot represents the interquartile range (IQR; 25 to 75 per cent) of the spread of the simulations driven by the ensemble of climate projections. The vertical 'whiskers' extend from the box to the smallest data point within 1.5 × IQR below the 25th percentile and to the largest data point within 1.5 × IQR above the 75th percentile. The circles are the simulated 'outliers'. BGS © UKRI 2026

1 Introduction

Through previous joint DOST-UKRI funding, the British Geological Survey (BGS) has developed the Philippine Hydrological Model[1]. This simulates the surface and groundwater hydrology of the country on a 2 km grid and daily time step, and produces spatio-temporal datasets of the following variables over the period 1979 to 2018 and under future climate projections:

- runoff
- river flow
- soil moisture
- evaporation
- groundwater recharge
- groundwater level

Based on this national-scale model, we have developed a bespoke, higher-resolution model for the Benguet region. The size of the model is 106 × 77 km on an approximately 178 m grid. The model simulates the natural hydrological cycle; surface-water and groundwater abstractions and the effect of dams are not considered. We simulate the historical period and generate outputs at the resolution of the model grid.

We present water balances at the Agno, Bued, Galano and Trinidad river catchments and analyse river flows at locations of the rivers considered by (Ancheta 2025, GCIEP 2025). We then summarise the simulations of the effect of projected future climate change on river flows at these locations.

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[1] https://mapapps.bgs.ac.uk/philippines-national-hydrological-model/

2 Hydrological modelling of Benguet

2.1 MODEL SETUP

The model developed for this project includes the hydrological catchments of the Agno, Bued, Galano and Trinidad rivers, and is extended to the coastline from Dorongan in the south to Catbangen in the north. The model's extent is 106 × 77 km. For the analysis, we include the locations of the potential extraction points for the four rivers as defined by (Ancheta 2025, GCIEP 2025), and the gauging stations on the rivers (**Figure 2**):

- Agno: Agno station
- Bauang: Bauang, Naguilian and Pampanga stations
- Bued: Bued station
- Galano: Aringay station

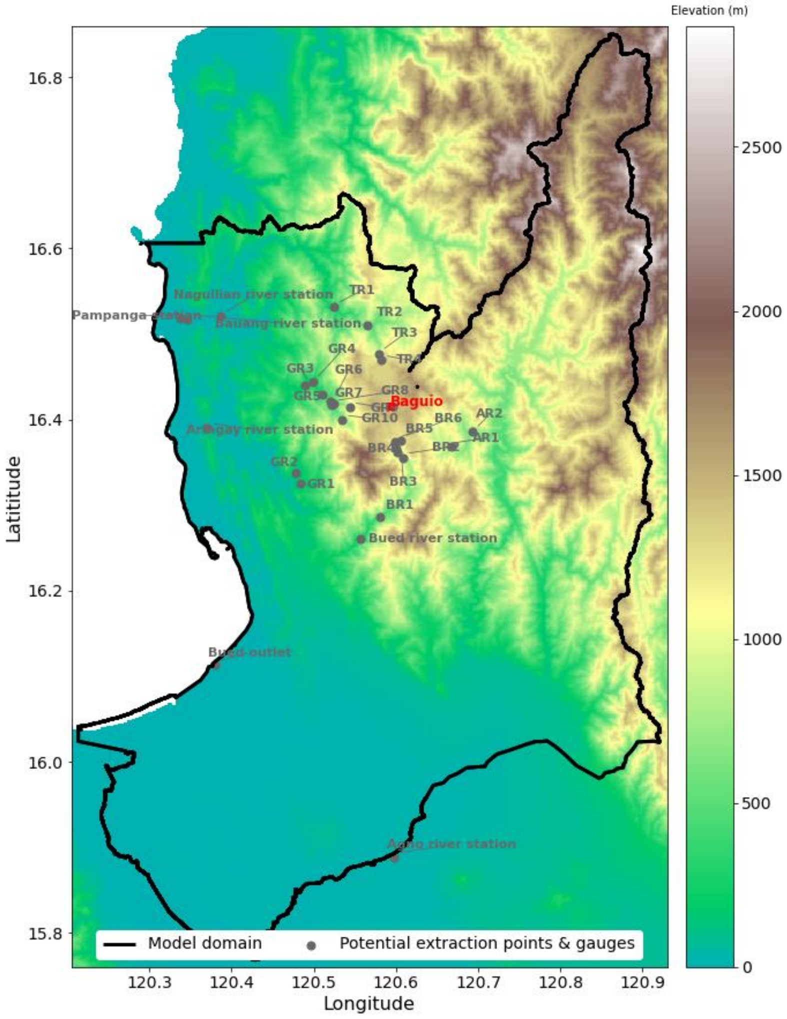


Figure 2 Model domain, potential extraction points and gauging stations. Elevation from Lehner et al. (2008) and potential extraction points from (Ancheta , GCIEP 2025). The model domain is derived as part of this project, combining catchments of the Agno, Bued, Galano and Trinidad rivers and extending it to the coastline. BGS © UKRI 2026.

2.2 MODEL FRAMEWORK

To model the surface water and groundwater system, we use the integrated VIC hydrological model coupled to a groundwater flow model (VIC-AMHAS), as developed by Scheidegger et al. (2021) (**Figure 3**). VIC is a macroscale hydrological model, which has been applied widely for water and energy balance studies (Hamman et al. 2018). The model describes full water and energy transport over a grid cell. When precipitation reaches the land surface, it is partitioned into runoff and infiltration. To accumulate flows at river gauging stations, routing of runoff and groundwater discharge to rivers is performed by post-processing the model output (Lohmann et al. 1996).

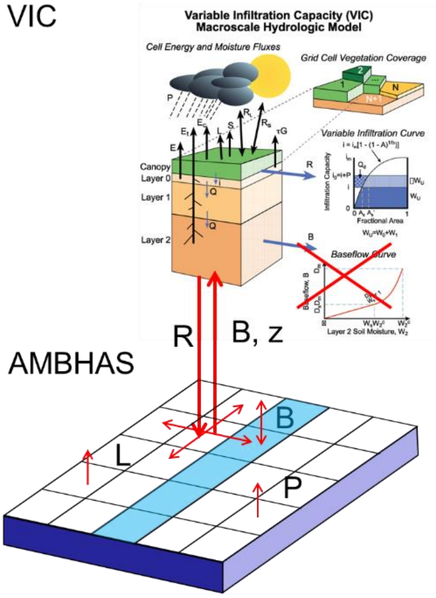


Figure 3 VIC-AMBHAS model framework. The soil column in VIC is coupled using bi-directional exchange of water between the soil and the aquifer. The aquifer allows for river baseflow, abstraction and leakage. Figure from (Scheidegger et al. 2023). BGS © UKRI.

The lateral groundwater model coupled to VIC is a distributed, one-layer, two-dimensional groundwater model driven by groundwater recharge and groundwater pumping. Groundwater recharge is derived from the interaction of the groundwater model with the VIC soil column by allowing bi-directional exchange of water between the aquifer and the soil. A full description of the lateral groundwater model and coupling to VIC is given in Scheidegger et al. (2021).

2.3 MODEL INPUTS AND MODEL OUTPUTS

The model is run on a 1/600° (approx. 178 m) grid for the Benguet region and is driven with openly available global datasets. The digital elevation model and flow accumulation are available at 3 arcsecond resolution (Lehner et al. 2008), which is approximately 93 m for Benguet. Most of the other model parameters are available at about 1 km resolution. The model is parameterised with spatially distributed parameters from a range of sources that describe the land surface, including soil properties and vegetation properties.

- Soil properties such as field capacity, plant-available water, wilting point, saturated hydraulic conductivity and residual saturation for the VIC model are taken from a global high-resolution map of soil hydraulic properties *(Zhang and Marcel 2018)*
- Quartz fraction and bulk density values are from SoilGrid1km *(Hengl et al. 2014)*
- Landcover vegetation parameters are taken from Modis *(Friedl and Sulla-Menashe 2015)*, leaf area index and albedo from Copernicus *(Smets et al. 2019)* and vegetation height from LiDAR-derived global estimates of forest canopy height (Healey et al. 2015)
- The groundwater part of the model requires values for hydraulic conductivity and specific yield, which are classified based on the groundwater availability map of the Philippines (Bureau of Mines and Geosciences and Ministry of Natural Resources 1986). A full description national-scale model on which this model is based is given in Scheidegger et al. (2022)

The VIC model is driven by meteorological forcing data using gridded, subdaily time series of meteorological variables as input. The required parameters are:

- average air temperature
- total precipitation
- atmospheric pressure
- incoming shortwave radiation
- incoming longwave radiation
- vapour pressure
- wind speed

For the historical simulation (1979 to 2024), ERA5 hourly data from 1979 to present was used (Hersbach et al. 2018). The meteorological forcing data is at 0.25° — a much coarser resolution than the soil and vegetation parameters.

The ‘Future projections of the hydrology of the Philippines’ study (Scheidegger 2025) provides projections of hydrological change for the period 1980 to 2089. These were generated using the UKCP18 climate change projections based on two greenhouse gas ‘representative concentration pathways’ (RCP): RCP2.6 and RCP 8.5 (Met Office Hadley Centre, 2018).

RCP2.6 represents a mitigation scenario that aims to limit the increase of global mean temperature to around 1.6°C above the pre-industrial level by 2100 for mid-range climate sensitivity. In contrast, RCP8.5 is a pathway in which greenhouse gas emissions continue to grow unmitigated, leading to an estimated global average temperature rise of 4.3°C above the pre-industrial level by 2100.

The estimated ranges for future climate are conditioned on a set of modelling, statistical and dataset choice assumptions with expert judgement in methodological and data choices by the producers of the UKCP18 dataset. The probabilities of the projections are interpreted as an indication of a particular future climate outcome for a given representative concentration pathway. There is more evidence for outcomes near the centre of the distribution than in the tails (Fung et al., 2018). Each of the two climate projections is composed of a 15-member ensemble, representing the uncertainty in the simulations of future climate. The UKCP18 future climate data has a spatial resolution of around 0.83° × 0.55°.

2.4 MODEL LIMITATIONS

The hydrological model used in this report represents the natural system. No abstraction from groundwater or surface waters, dams or water transfers are considered. We also do not consider any land-use change in this model. The hydrological output is strongly dependent upon the quality of the climate drivers; uncertainty in the climate forcing will directly affect the simulated river flows. The model uses globally available datasets for model parameterisation, most of which are published at a 1 km spatial resolution.

2.5 HISTORICAL SIMULATIONS

2.5.1 Results

The mean precipitation, mean evapotranspiration and mean discharge, defined as surface runoff plus baseflow, are given in **Figure 4**.

The climate drivers from ERA 5 have a strong spatial variation, which is then apparent in the simulated discharge. The discharge is also heavily dependent upon the aquifer parameterisation. The lower runoff zone towards the east of the catchment represents a basalt aquifer, which has higher simulated baseflow and lower simulated surface runoff.

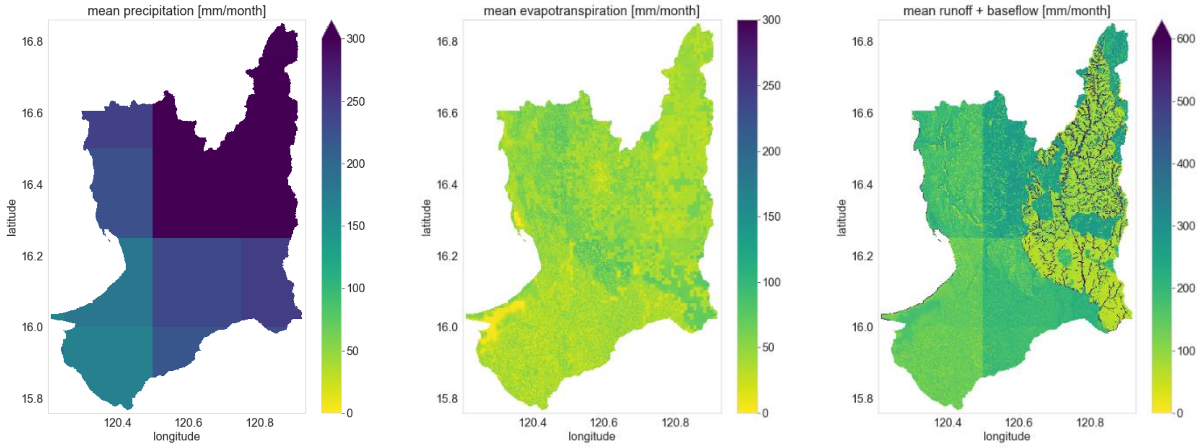


Figure 4 Mean precipitation, mean evapotranspiration and mean runoff plus baseflow in mm/month. Contains modified information from Copernicus Climate Change Service (C3S) (2023). BGS © UKRI 2026.

2.5.1.1 Mean flow vs. catchment area

There is a linear relationship between catchment area and simulated mean flow, with the Agno river station having the highest mean annual flow. It has a catchment area of 2496 km^2 and a simulated mean annual flow of 143 m^3/s. At the lower extreme is GR9, with an area of 8.3 km^2 and a mean annual flow of 0.78 m^3/s.

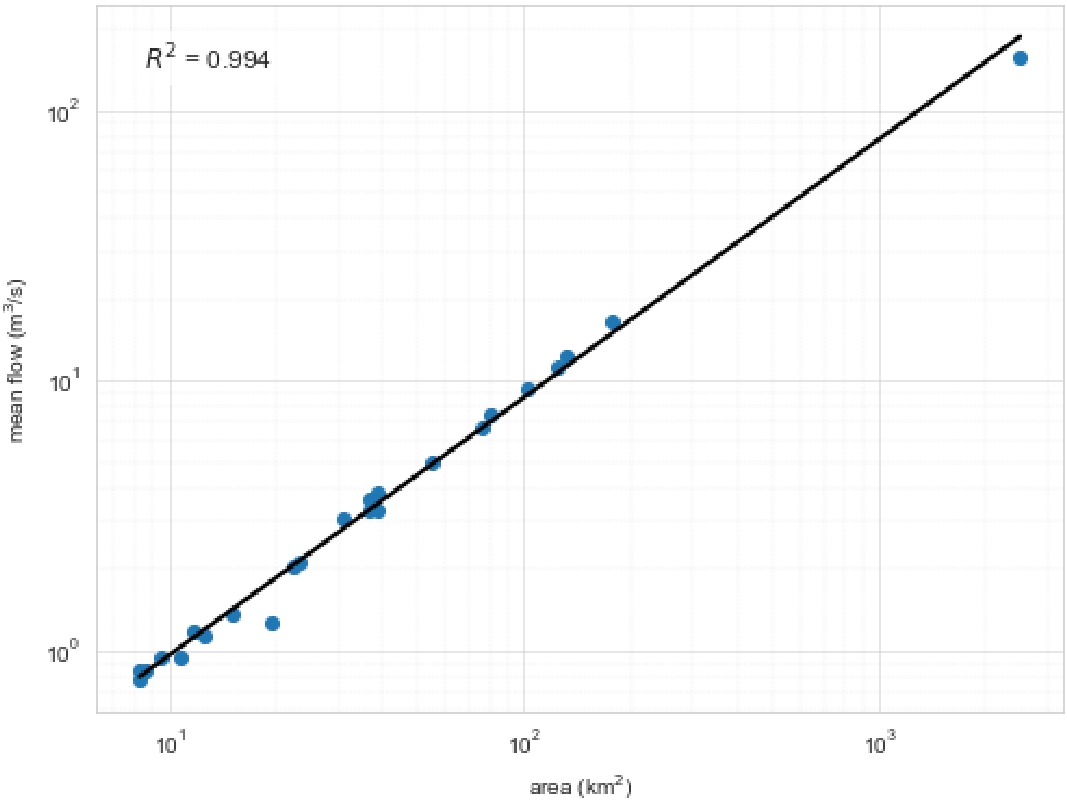


Figure 5 Mean simulated river flow against catchment area for all stations. BGS © UKRI 2026.

2.5.1.2 TIME SERIES OF RIVER FLOWS AT GAUGING STATIONS

The simulated water fluxes represent the natural system of the catchments and no ground- or surface water abstractions or dam operations are considered in the model. The simulated flows are compared to observed flows at the Bued, Agno, Naguillian, Pampanga, Bauang and Aringay stations (Figures 6 to 11).

For the Bued River station, the model captures the amplitude of the flow well. Both the low and the high flows in the model are higher than the observed flows at the Agno River station. There is a shift in amplitude of the observed river flows in the mid-1990s, which is not simulated. However, when comparing the catchment area and the mean simulated flow, the maximum value, which is the Agno river station, is on the 1:1 line. It should be noted that the Agno River is affected by dam operations, whereas our model represents the natural system and therefore a mismatch between observed and simulated river flows is to be expected.

The Naguilian, Bauang and Pampanga stations are on the Trinidad river. The flow dynamics of the Naguilian and Bauang stations are generally captured in the model; however, the peak flows are underestimated. The Pampanga station is only about 980 m downstream of the Bauang station, but the observed flow is much higher than at the two upstream stations. This could be because of tidal influence or measurement errors in the observations.

The Arringay station is on the Galano River and the simulated flow captures the observations generally well. However, in the 1990s, the observed flows are much higher than the simulated flows.

In general, the hydrological model can capture the pattern and dynamics of the observed flows, although both the model and the observations have large uncertainties. Measurement uncertainties and gaps in observations make a direct comparison challenging. For the hydrological model, the largest uncertainty remains with the climate driving data. Running the hydrological model with rainfall datasets from PAGASA might reduce this error.

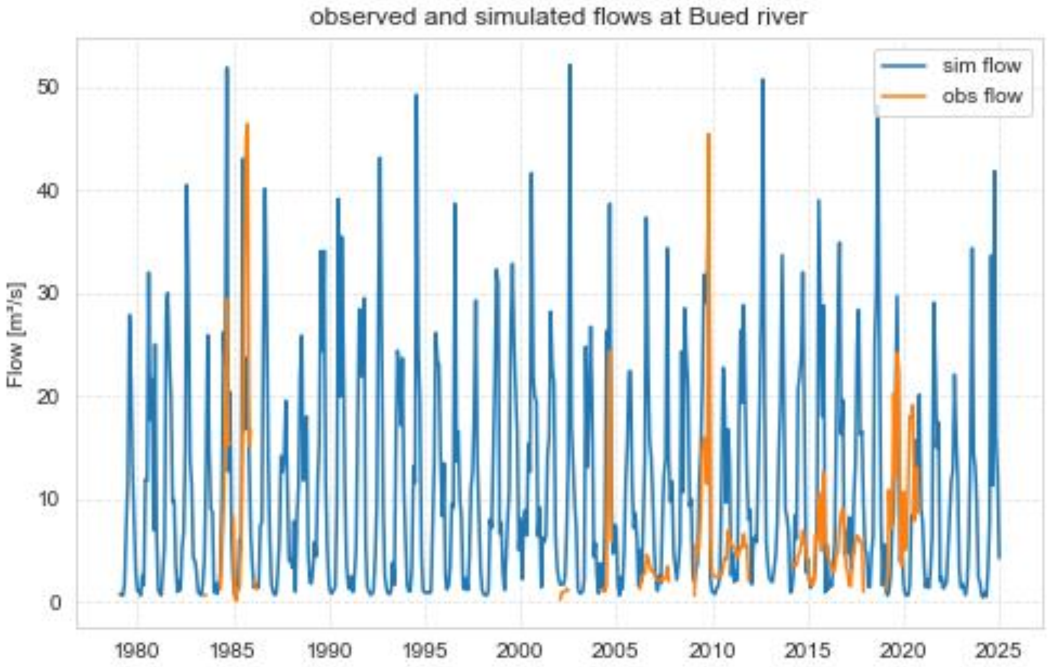


Figure 6 Comparison of simulated and observed flow at Bued gauging station, Brgy. Twin Peaks Market Proper, Tuba, Benguet. Created using data from Department of Public Works and Highways (2016). BGS © UKRI 2026.

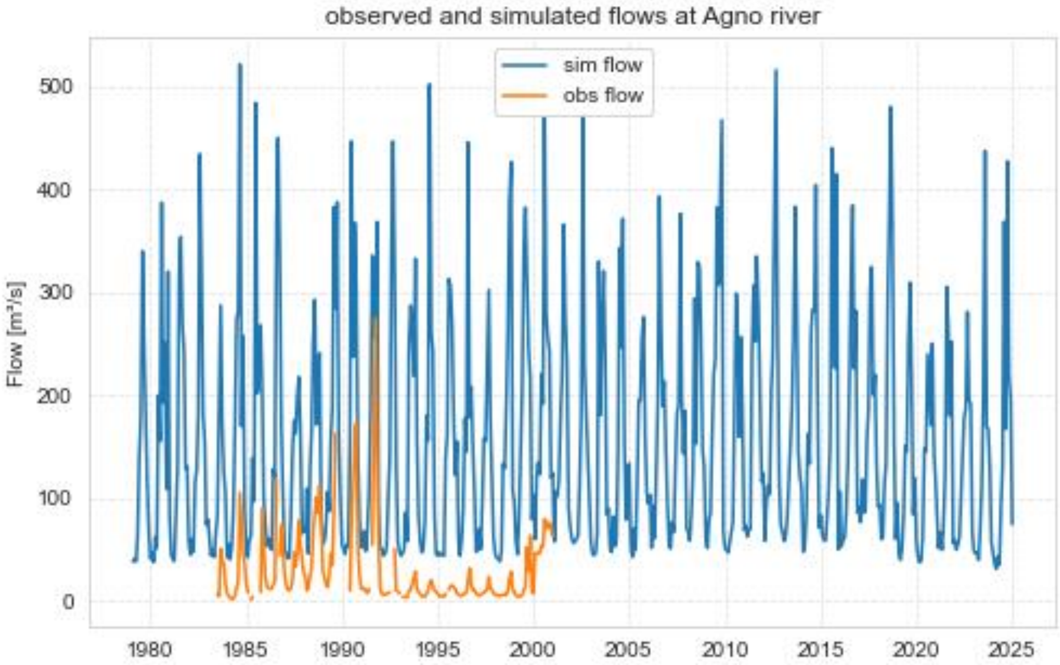


Figure 7 Comparison of simulated and observed flow at Agno gauging station at Don Teofilo-Sison Bridge, Barangay Carmen, Rosales, Pangasinan. Created using data from Department of Public Works and Highways (2016). BGS © UKRI 2026.

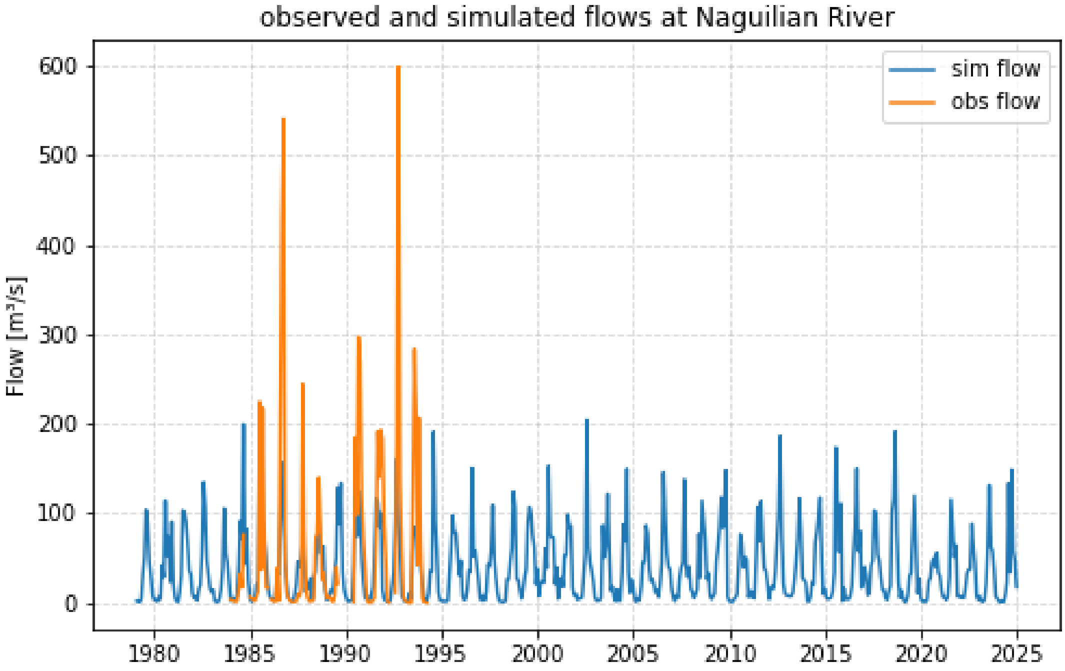


Figure 8 Comparison of simulated and observed flow at Naguilian gauging station, at Barangay Natividad, Bauang, La Union. Created using data from Department of Public Works and Highways (2016). BGS © UKRI 2026.

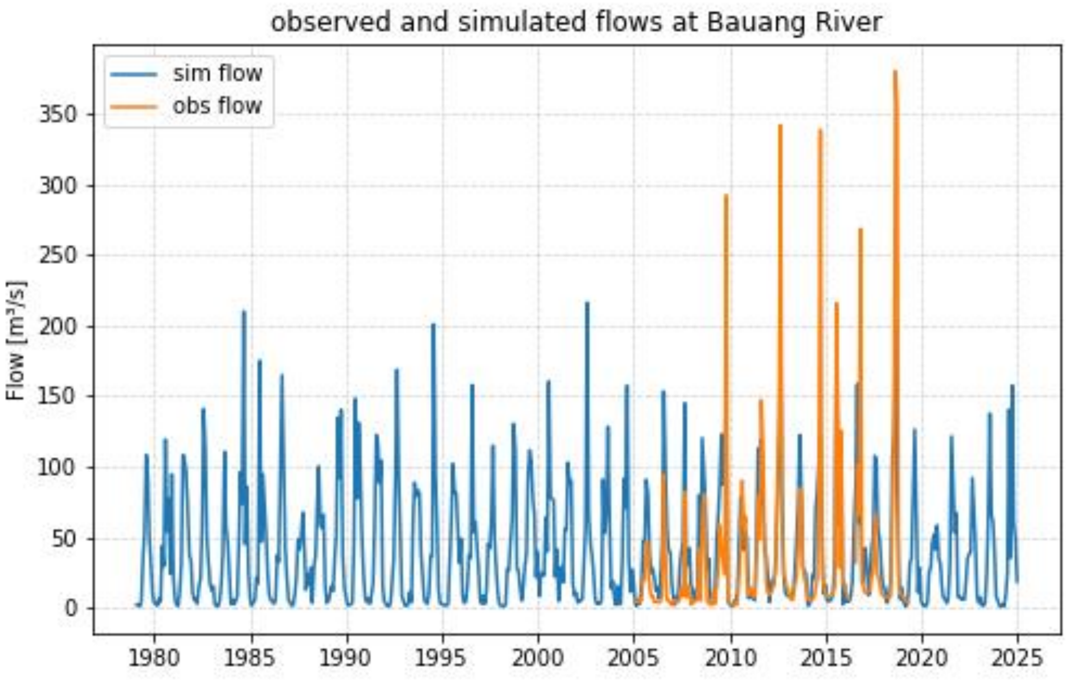


Figure 9 Comparison of simulated and observed flow at Buang gauging station, at Bugnay, Acao, Bauang, La Union Created using data from Department of Public Works and Highways (2016). BGS © UKRI 2026.

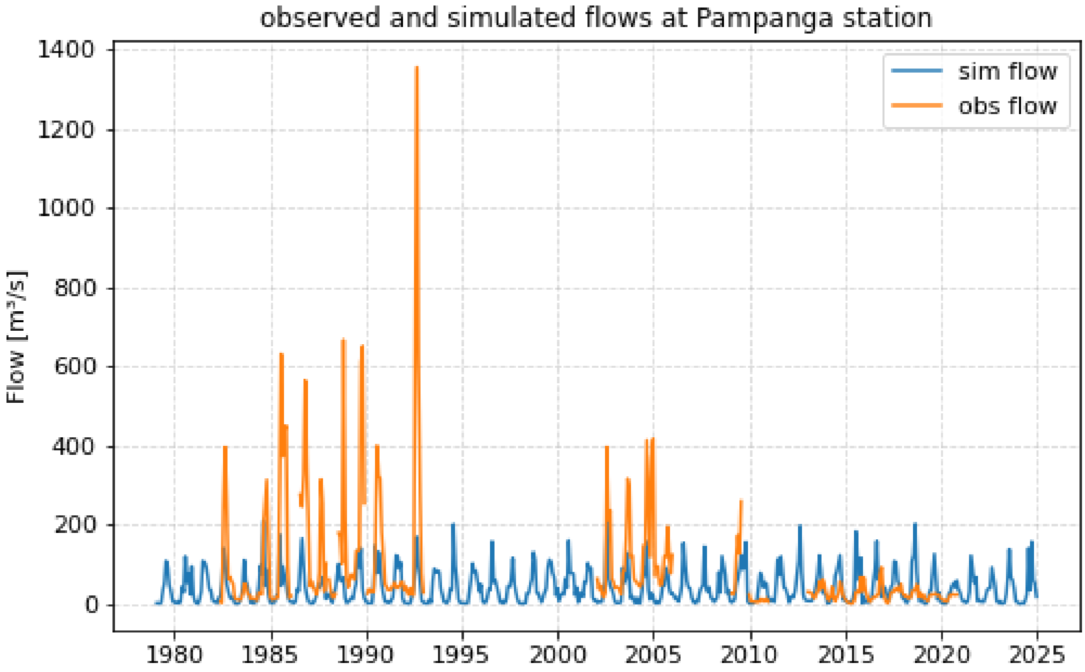


Figure 10 Comparison of simulated and observed flow at Pampanga gauging station, at San Isidro, Nueva Ecija. Created using data from Department of Public Works and Highways (2016). BGS © UKRI 2026.

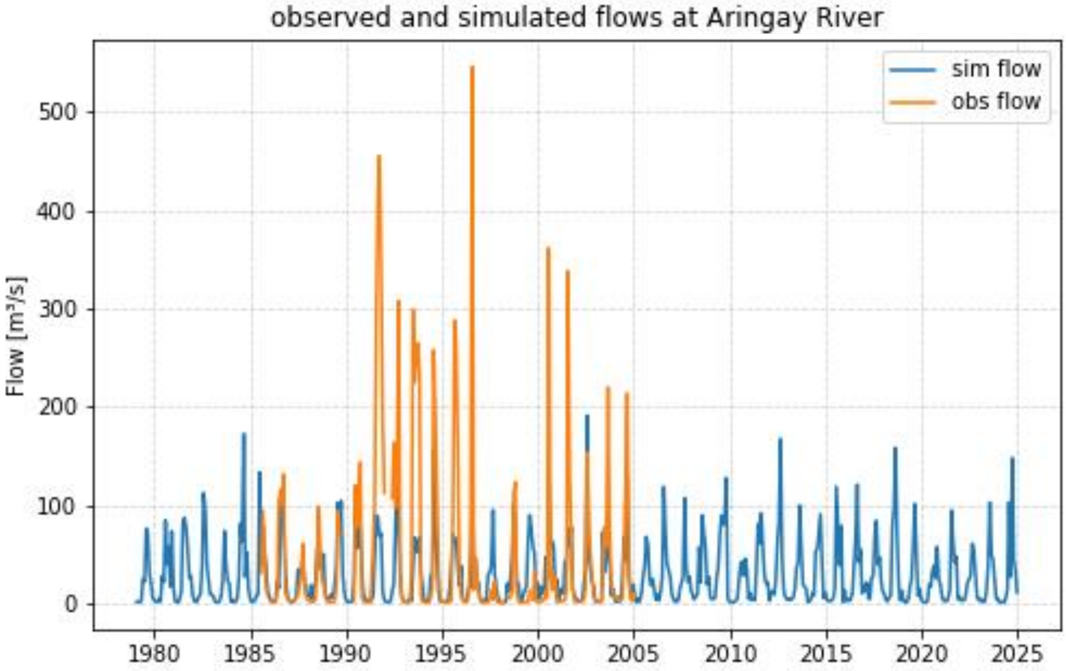


Figure 11 Comparison of simulated and observed flow at Aringay gauging station, at Barangay Station, Rita East, Aringay. Created using data from Department of Public Works and Highways (2016). BGS © UKRI 2026.

2.5.1.3 WATER BALANCES

The water balances of each catchment are represented in millimetres per month per unit area and are presented for each river basin in Figures 12 to 15.

On average, 78.4 per cent of precipitation is partitioned into surface runoff, 14.7 per cent into evapotranspiration and 1.8 per cent into baseflow. The remaining 5.2 per cent is simulated to leave the hydrological catchments as groundwater flow.

There is a strong seasonal variation, especially for precipitation and surface runoff, as shown in **Figure 15**. On average, precipitation is 702 mm/month in July and 56 mm/month in January. Similarly surface runoff is highest in July (582 mm/month) and lowest in January (35 mm/month). The extremes in baseflow lag the extremes in precipitation by one to two months. Evapotranspiration is highest in May and lowest in December.

Depending on catchment, the simulated runoff ratio (defined as the sum of runoff and baseflow divided by precipitation for each catchment) ranges from 0.70 to 0.87 (Table 1), which will depend on the topography, land cover and hydrogeological properties in the model.

The flow metrics are presented in **Table 2** for each extraction point and gauging station.

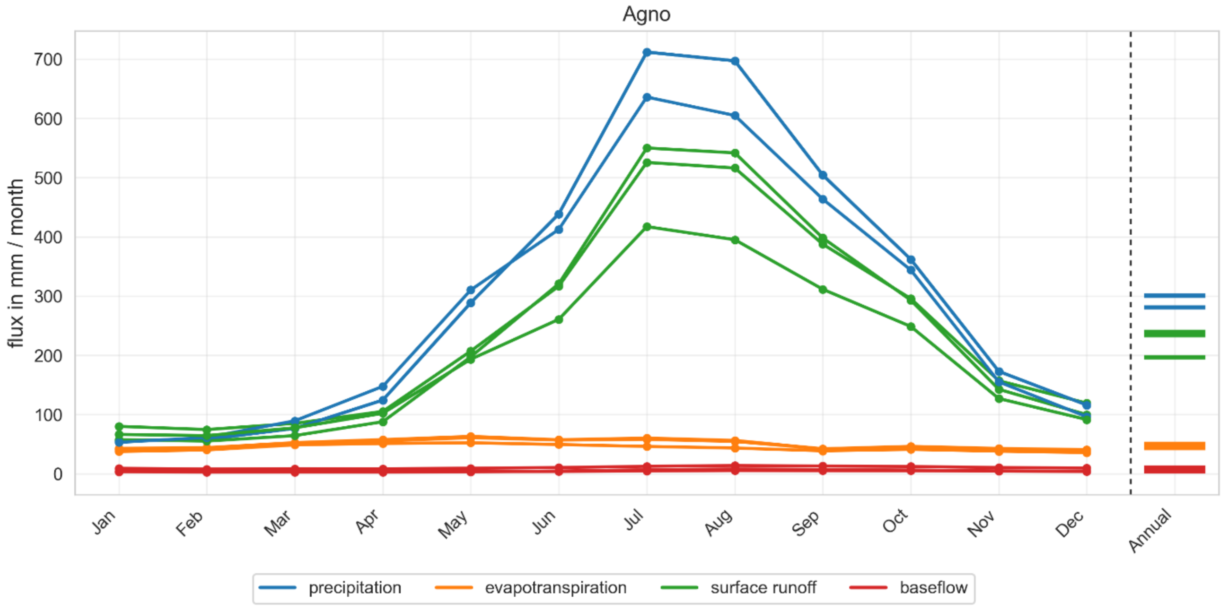


Figure 12 Monthly mean water balance for the Agno catchment. Lines of the same colour correspond to the different gauging stations and potential abstraction points within the catchment. Contains modified information from Copernicus Climate Change Service (C3S) (2023). BGS © UKRI 2026.

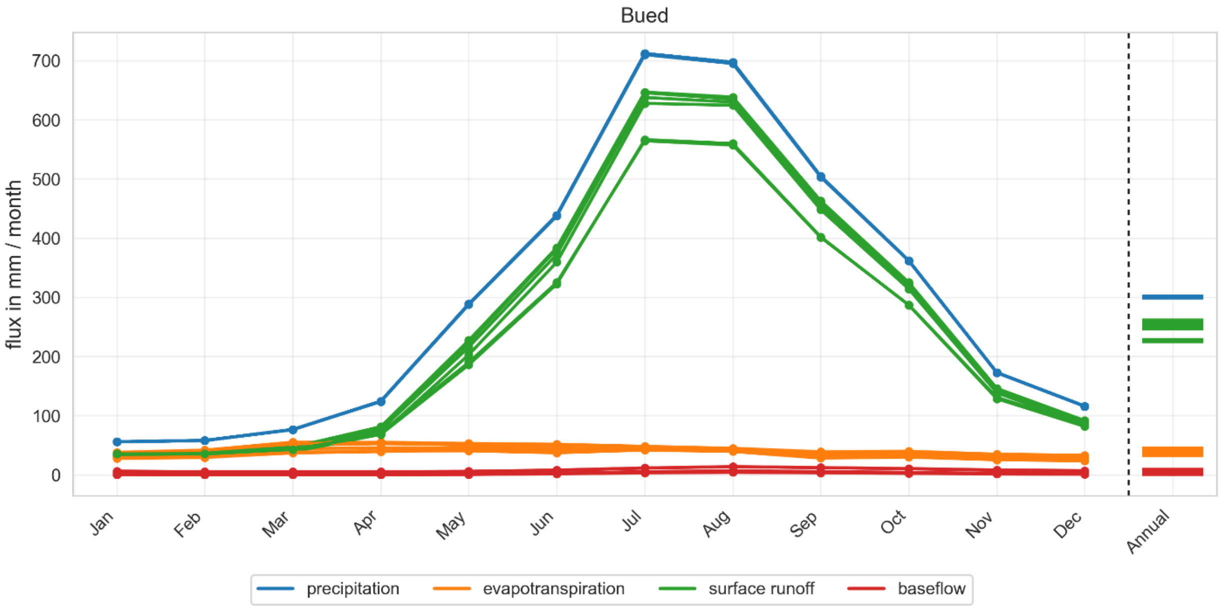


Figure 13 Monthly mean water balance for the Bued catchment. Lines of the same colour correspond to the different gauging stations and potential abstraction points within the catchment. Contains modified information from Copernicus Climate Change Service (C3S) (2023). BGS © UKRI 2026.

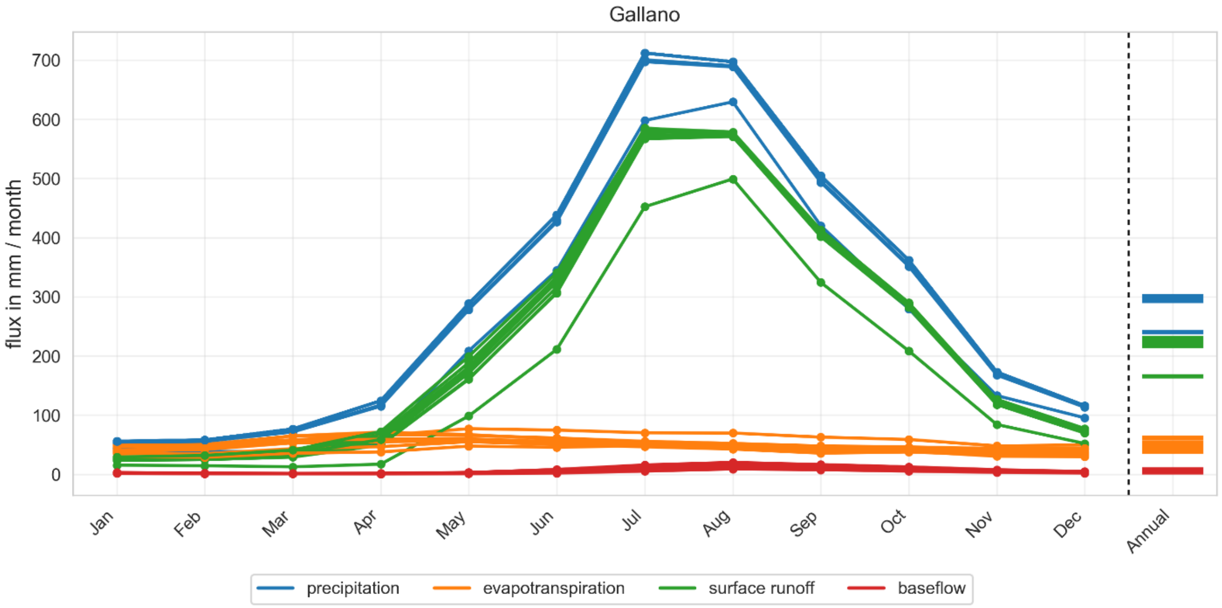


Figure 14 Monthly mean water balance for the Gallano catchment. Lines of the same colour correspond to the different gauging stations and potential abstraction points within the catchment. Contains modified information from Copernicus Climate Change Service (C3S) (2023). BGS © UKRI 2026.

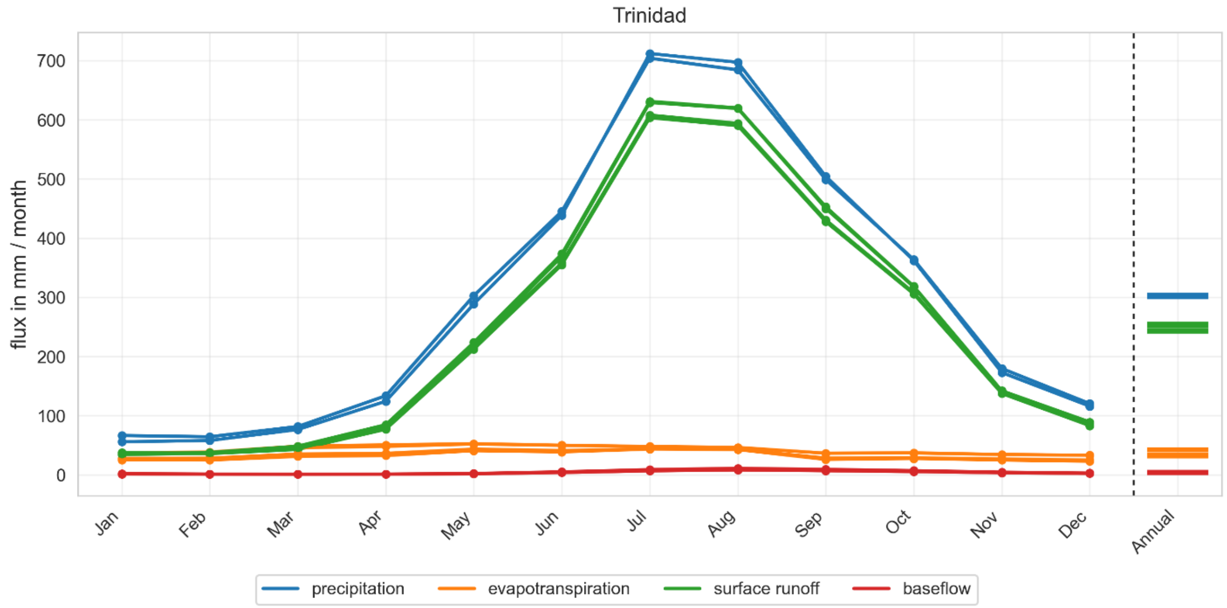


Figure 15 Monthly mean water balance for the Trinidad catchment. Lines of the same colour correspond to the different gauging stations and potential abstraction points within the catchment. Contains modified information from Copernicus Climate Change Service (C3S) (2023). BGS © UKRI 2026.

Table 1 Mean annual precipitation, runoff, baseflow and runoff ratio.

Location	Precipitation (mm/month)	Runoff (mm/month)	Baseflow (mm/month)	Runoff ratio
AR1	300.5	239.1	4.2	0.81
AR2	300.5	234.0	4.6	0.79
Agno river station	281.1	196.2	10.4	0.73
BR1	300.5	227.7	8.2	0.79
BR2	300.5	253.7	2.2	0.85
BR3	300.5	247.6	2.7	0.83
BR4	300.5	257.9	1.7	0.86
BR5	300.5	258.1	1.9	0.87
BR6	300.5	260.2	1.8	0.87
Bued outlet	232.6	179.2	2.2	0.78
Bued river station	299.7	226.4	7.8	0.78
GR1	294.5	217.1	6.0	0.76
GR10	300.5	225.1	7.9	0.78
GR2	240.2	165.8	3.3	0.70
GR3	294.0	221.1	6.3	0.77
GR4	292.8	218.2	5.2	0.76
GR5	300.5	227.2	6.9	0.78
GR6	300.5	226.4	7.2	0.78
GR7	300.5	228.1	7.2	0.78
GR8	300.5	225.6	7.3	0.78
GR9	300.5	230.4	7.9	0.79
Aringay river station	254.3	185.6	3.9	0.75
TR1	303.8	242.2	4.8	0.81
TR2	303.7	244.5	4.4	0.82

Table 2 Simulated flow duration metrics for the different river catchments and locations points (see Figure 2) for the historical simulation. For example, Q5 denotes flow that is exceeded 5 per cent of the time; Q50 is the median flow; Q95 is flow that is exceeded 95 per cent of the time.

Location	Q5	Q10	Q25	Q50	Q75	Q80	Q90	Q95	Qmean
AR1	5.18	4.39	2.83	1.50	0.73	0.67	0.56	0.51	2.02
AR2	20.11	16.69	10.73	5.13	1.99	1.76	1.35	1.20	7.29
Agno river station	382.30	317.61	220.35	122.51	61.60	58.10	48.06	44.46	155.22
BR1	26.20	22.04	13.61	6.30	1.88	1.55	1.01	0.83	9.09
BR2	10.48	8.87	5.48	2.49	0.55	0.43	0.20	0.11	3.57
BR3	3.42	2.89	1.78	0.75	0.17	0.12	0.06	0.03	1.15
BR4	2.67	2.25	1.41	0.65	0.15	0.11	0.06	0.03	0.92
BR5	2.39	2.02	1.26	0.59	0.13	0.10	0.05	0.03	0.82
BR6	2.41	2.05	1.27	0.59	0.14	0.11	0.05	0.03	0.83
Bued outlet	180.55	149.76	88.51	34.82	8.38	6.67	3.88	2.88	57.78
Bued river station	32.01	26.93	16.60	7.48	2.12	1.74	1.10	0.88	10.98
GR1	9.98	8.37	5.11	1.97	0.42	0.30	0.14	0.08	3.24
GR10	4.03	3.41	2.09	0.86	0.19	0.14	0.07	0.04	1.35
GR2	4.54	3.53	1.76	0.58	0.10	0.07	0.03	0.02	1.24
GR3	19.84	16.76	10.19	4.17	0.91	0.65	0.31	0.18	6.54
GR4	2.87	2.41	1.47	0.56	0.12	0.08	0.04	0.02	0.93
GR5	14.73	12.43	7.56	3.14	0.70	0.52	0.25	0.15	4.89
GR6	9.71	8.20	4.99	2.09	0.47	0.34	0.17	0.10	3.23
GR7	3.33	2.79	1.75	0.76	0.17	0.13	0.06	0.04	1.12
GR8	6.24	5.30	3.23	1.31	0.28	0.21	0.10	0.06	2.07
GR9	2.24	1.88	1.18	0.54	0.13	0.09	0.05	0.03	0.77
Aringay river station	95.30	77.59	41.82	15.79	3.46	2.48	1.32	0.89	28.60
TR1	47.07	40.18	24.71	11.54	2.84	2.17	1.14	0.67	16.29
TR2	34.93	29.75	18.41	8.57	2.17	1.69	0.88	0.52	12.14
TR3	10.85	9.13	5.72	2.66	0.65	0.51	0.25	0.14	3.75
TR4	8.68	7.28	4.62	2.16	0.54	0.42	0.21	0.12	3.02
Bauang river station	122.67	103.82	60.28	26.30	6.58	5.39	2.76	1.75	40.68
Naguilian river station	117.44	99.24	57.97	25.31	6.33	5.10	2.58	1.61	38.92
Pampanga station	122.99	104.07	60.41	26.37	6.60	5.41	2.77	1.76	40.78

2.6 FUTURE PROJECTIONS

We ran 30 climate change scenarios through the hydrological model: 15 ensemble members each for RCP2.6 and RCP8.5. For each ensemble member, the percentage changes in the flow percentiles (for example, Q95 — the flow exceeded 95 per cent of the time) for the period 2041 to 2070 relative to a historical baseline (1991 to 2020) were calculated. We report changes for Q5, Q10, Q25, Q50, Q75, Q80, Q90, Q90, and Qmax and Qmean.

2.6.1 Results

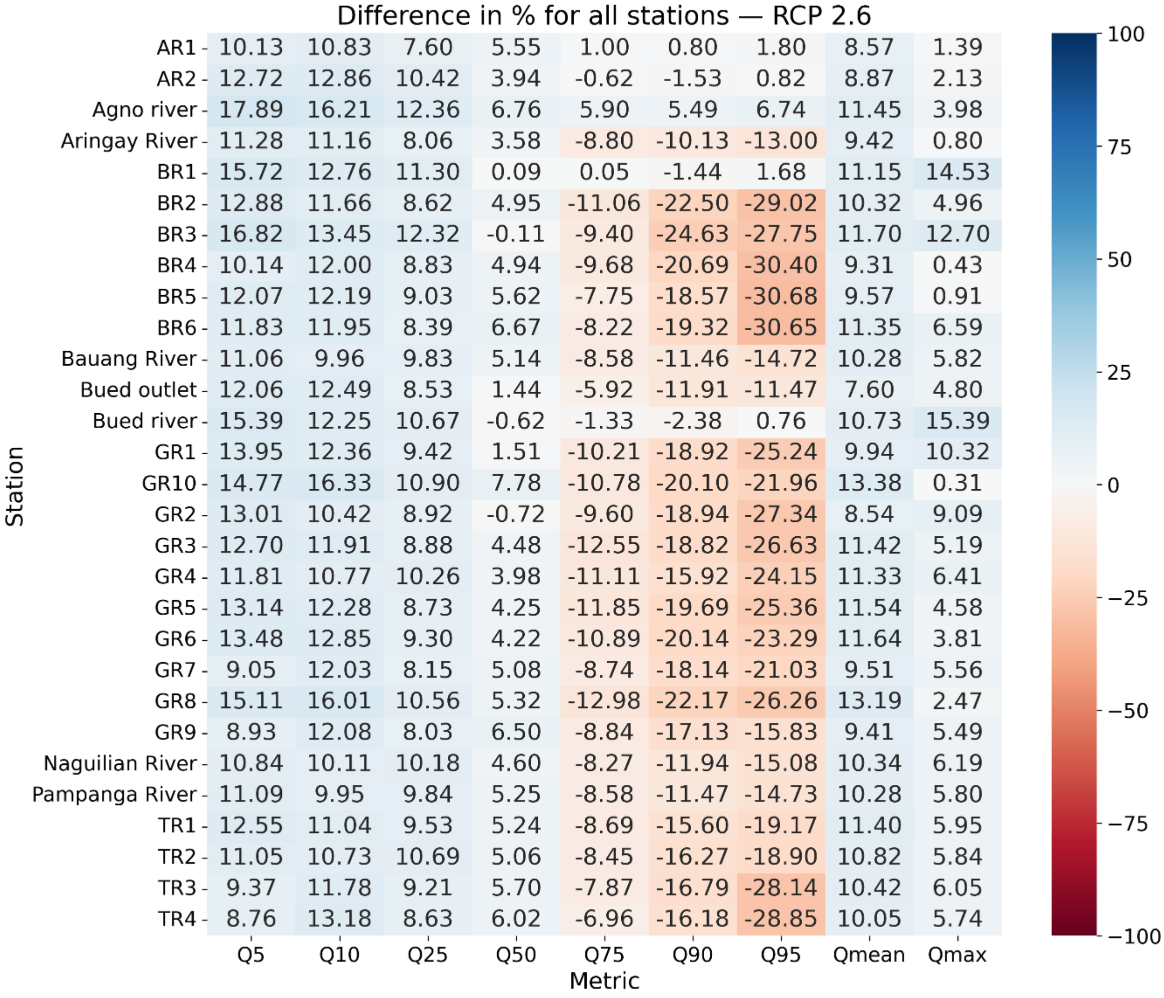
2.6.1.1 PROJECTED CHANGES IN RIVER FLOW

The changes in the median flow for all ensemble members for RCP2.6 and 8.5 at potential extraction points for different flow metrics are summarised in **Figure 16** and **Figure 17**. The mean river flow for the period 2041 to 2070 is projected to increase for all stations and both the RCP scenarios. For RCP2.6, the change in the simulated mean flow varies from 7.6 to 13.8 per cent across the locations. For RCP8.5, the change in the simulated mean flow varies from 10.43 to 16.71 per cent across the locations.

The higher flows (Q5 to Q50) are projected to increase in the future. For example, Q5 is projected to increase by between 8.8 and 17.9 per cent under RCP 2.6 and between 15.0 and 24.2 per cent under RCP 8.5.

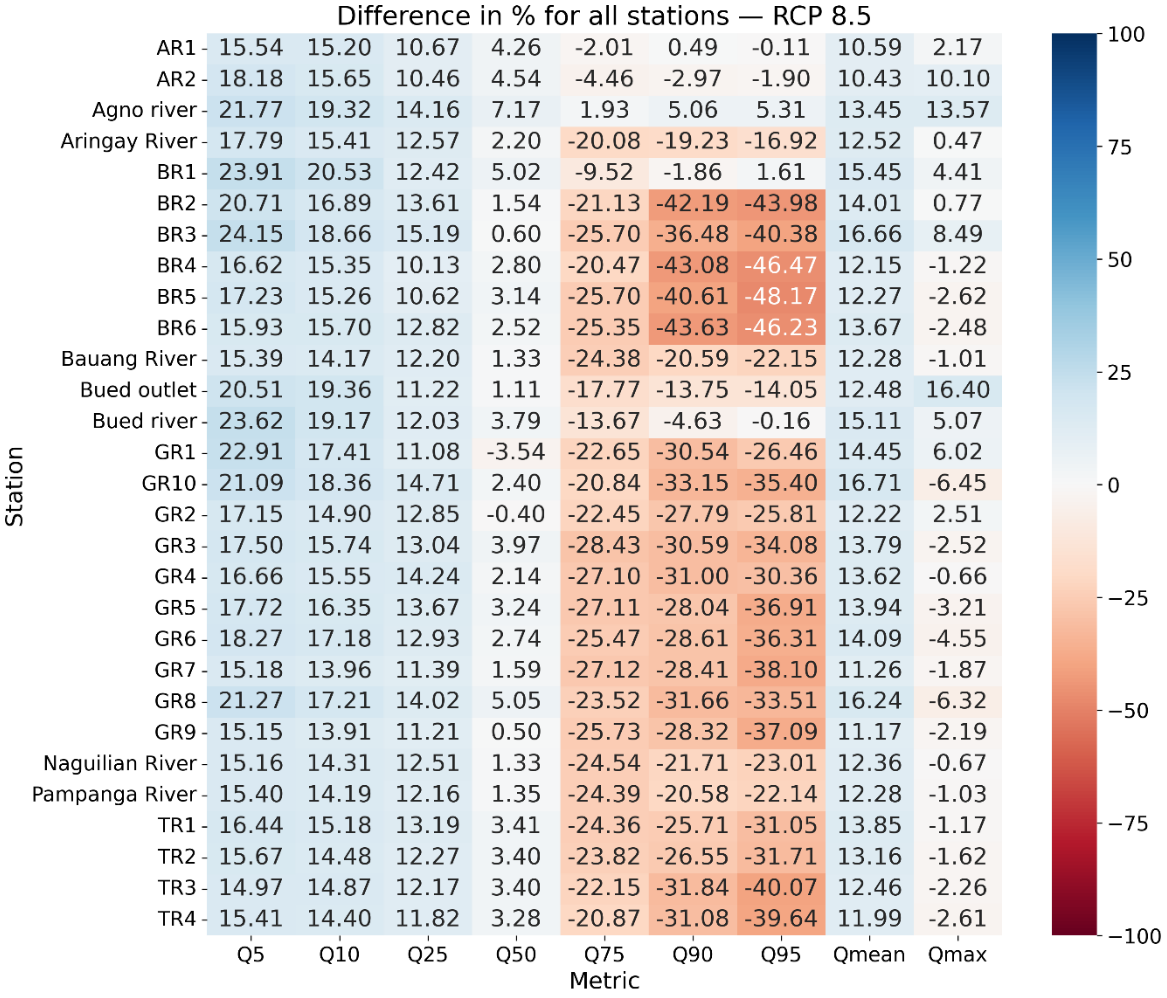
The lower flows (Q75 to Q95) are projected to decrease in the future. The low flows (Q95) generally decrease under both RCPs; however, there is some variation between the stations. This is likely due to the uncertainty in the climate data. For Q95, the mean change across all stations is a reduction in flow by 18.5 per cent considering RCP2.6 and 27.4 per cent considering RCP8.5.

As shown in Figure 18, the variation between the different ensemble members is high, especially for the lower flows where there is an inconsistent pattern: some ensemble members show an increase and other ensemble members a decrease in flow. Consequently, the future climate projections contribute considerable uncertainty to the projected river flows.



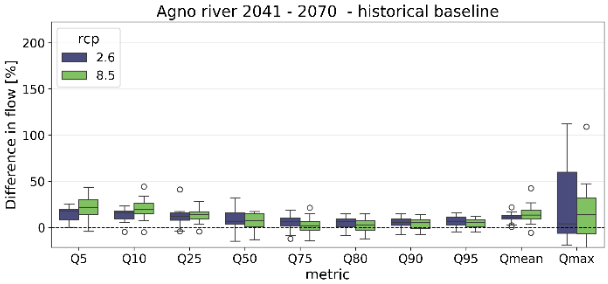
Station	Q5	Q10	Q25	Q50	Q75	Q90	Q95	Qmean	Qmax
AR1	10.13	10.83	7.60	5.55	1.00	0.80	1.80	8.57	1.39
AR2	12.72	12.86	10.42	3.94	-0.62	-1.53	0.82	8.87	2.13
Agno river	17.89	16.21	12.36	6.76	5.90	5.49	6.74	11.45	3.98
Aringay River	11.28	11.16	8.06	3.58	-8.80	-10.13	-13.00	9.42	0.80
BR1	15.72	12.76	11.30	0.09	0.05	-1.44	1.68	11.15	14.53
BR2	12.88	11.66	8.62	4.95	-11.06	-22.50	-29.02	10.32	4.96
BR3	16.82	13.45	12.32	-0.11	-9.40	-24.63	-27.75	11.70	12.70
BR4	10.14	12.00	8.83	4.94	-9.68	-20.69	-30.40	9.31	0.43
BR5	12.07	12.19	9.03	5.62	-7.75	-18.57	-30.68	9.57	0.91
BR6	11.83	11.95	8.39	6.67	-8.22	-19.32	-30.65	11.35	6.59
Bauang River	11.06	9.96	9.83	5.14	-8.58	-11.46	-14.72	10.28	5.82
Bued outlet	12.06	12.49	8.53	1.44	-5.92	-11.91	-11.47	7.60	4.80
Bued river	15.39	12.25	10.67	-0.62	-1.33	-2.38	0.76	10.73	15.39
GR1	13.95	12.36	9.42	1.51	-10.21	-18.92	-25.24	9.94	10.32
GR10	14.77	16.33	10.90	7.78	-10.78	-20.10	-21.96	13.38	0.31
GR2	13.01	10.42	8.92	-0.72	-9.60	-18.94	-27.34	8.54	9.09
GR3	12.70	11.91	8.88	4.48	-12.55	-18.82	-26.63	11.42	5.19
GR4	11.81	10.77	10.26	3.98	-11.11	-15.92	-24.15	11.33	6.41
GR5	13.14	12.28	8.73	4.25	-11.85	-19.69	-25.36	11.54	4.58
GR6	13.48	12.85	9.30	4.22	-10.89	-20.14	-23.29	11.64	3.81
GR7	9.05	12.03	8.15	5.08	-8.74	-18.14	-21.03	9.51	5.56
GR8	15.11	16.01	10.56	5.32	-12.98	-22.17	-26.26	13.19	2.47
GR9	8.93	12.08	8.03	6.50	-8.84	-17.13	-15.83	9.41	5.49
Naguilian River	10.84	10.11	10.18	4.60	-8.27	-11.94	-15.08	10.34	6.19
Pampanga River	11.09	9.95	9.84	5.25	-8.58	-11.47	-14.73	10.28	5.80
TR1	12.55	11.04	9.53	5.24	-8.69	-15.60	-19.17	11.40	5.95
TR2	11.05	10.73	10.69	5.06	-8.45	-16.27	-18.90	10.82	5.84
TR3	9.37	11.78	9.21	5.70	-7.87	-16.79	-28.14	10.42	6.05
TR4	8.76	13.18	8.63	6.02	-6.96	-16.18	-28.85	10.05	5.74

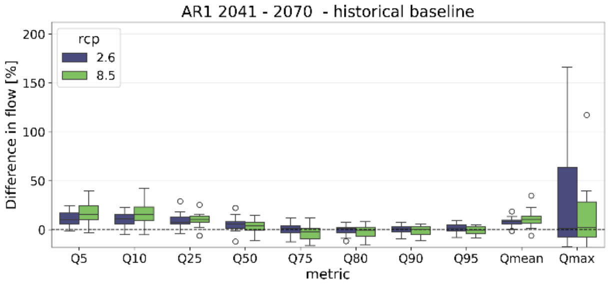
Figure 16 Summary of flow percentile changes of the 2050s (2041 to 2070) relative to the historical baseline (1991 to 2020) considering RCP2.6. BGS © UKRI 2026.

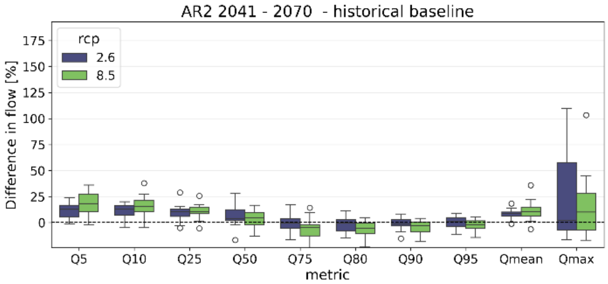

Difference in % for all stations — RCP 8.5

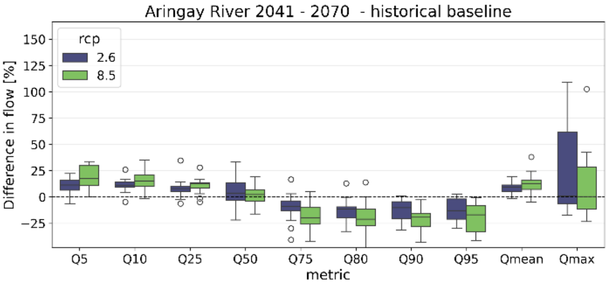
Station	Q5	Q10	Q25	Q50	Q75	Q90	Q95	Qmean	Qmax
AR1	15.54	15.20	10.67	4.26	-2.01	0.49	-0.11	10.59	2.17
AR2	18.18	15.65	10.46	4.54	-4.46	-2.97	-1.90	10.43	10.10
Agno river	21.77	19.32	14.16	7.17	1.93	5.06	5.31	13.45	13.57
Aringay River	17.79	15.41	12.57	2.20	-20.08	-19.23	-16.92	12.52	0.47
BR1	23.91	20.53	12.42	5.02	-9.52	-1.86	1.61	15.45	4.41
BR2	20.71	16.89	13.61	1.54	-21.13	-42.19	-43.98	14.01	0.77
BR3	24.15	18.66	15.19	0.60	-25.70	-36.48	-40.38	16.66	8.49
BR4	16.62	15.35	10.13	2.80	-20.47	-43.08	-46.47	12.15	-1.22
BR5	17.23	15.26	10.62	3.14	-25.70	-40.61	-48.17	12.27	-2.62
BR6	15.93	15.70	12.82	2.52	-25.35	-43.63	-46.23	13.67	-2.48
Bauang River	15.39	14.17	12.20	1.33	-24.38	-20.59	-22.15	12.28	-1.01
Bued outlet	20.51	19.36	11.22	1.11	-17.77	-13.75	-14.05	12.48	16.40
Bued river	23.62	19.17	12.03	3.79	-13.67	-4.63	-0.16	15.11	5.07
GR1	22.91	17.41	11.08	-3.54	-22.65	-30.54	-26.46	14.45	6.02
GR10	21.09	18.36	14.71	2.40	-20.84	-33.15	-35.40	16.71	-6.45
GR2	17.15	14.90	12.85	-0.40	-22.45	-27.79	-25.81	12.22	2.51
GR3	17.50	15.74	13.04	3.97	-28.43	-30.59	-34.08	13.79	-2.52
GR4	16.66	15.55	14.24	2.14	-27.10	-31.00	-30.36	13.62	-0.66
GR5	17.72	16.35	13.67	3.24	-27.11	-28.04	-36.91	13.94	-3.21
GR6	18.27	17.18	12.93	2.74	-25.47	-28.61	-36.31	14.09	-4.55
GR7	15.18	13.96	11.39	1.59	-27.12	-28.41	-38.10	11.26	-1.87
GR8	21.27	17.21	14.02	5.05	-23.52	-31.66	-33.51	16.24	-6.32
GR9	15.15	13.91	11.21	0.50	-25.73	-28.32	-37.09	11.17	-2.19
Naguilian River	15.16	14.31	12.51	1.33	-24.54	-21.71	-23.01	12.36	-0.67
Pampanga River	15.40	14.19	12.16	1.35	-24.39	-20.58	-22.14	12.28	-1.03
TR1	16.44	15.18	13.19	3.41	-24.36	-25.71	-31.05	13.85	-1.17
TR2	15.67	14.48	12.27	3.40	-23.82	-26.55	-31.71	13.16	-1.62
TR3	14.97	14.87	12.17	3.40	-22.15	-31.84	-40.07	12.46	-2.26
TR4	15.41	14.40	11.82	3.28	-20.87	-31.08	-39.64	11.99	-2.61

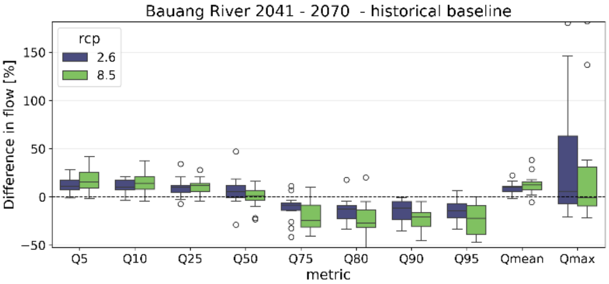
Figure 17 Summary of flow percentile changes of the 2050s (2041 to 2070) relative to the historical baseline (1991 to 2020) considering RCP8.5. BGS © UKRI 2026.

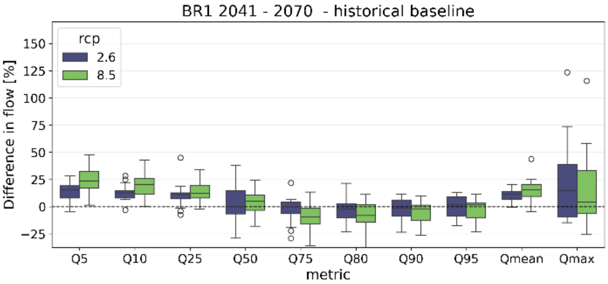

Agno river 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
200
150
100
50
0
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

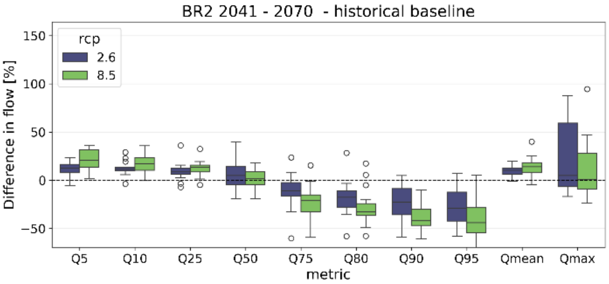

AR1 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
200
150
100
50
0
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

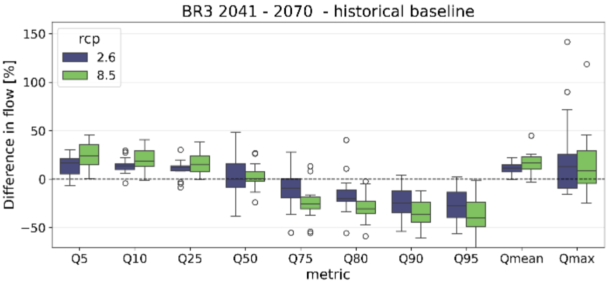

AR2 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
175
150
125
100
75
50
25
0
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

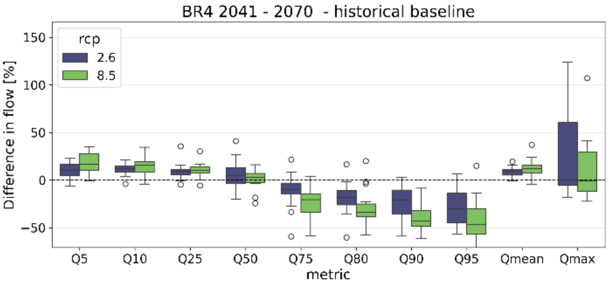

Aringay River 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
125
100
75
50
25
0
−25
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

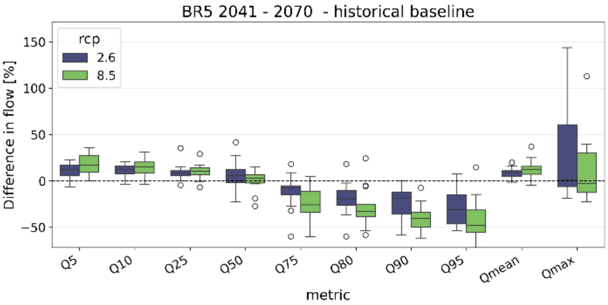

Bauang River 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

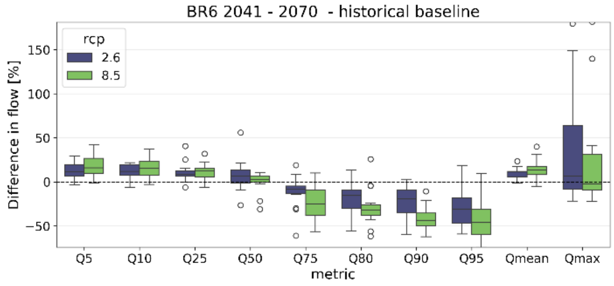

BR1 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
125
100
75
50
25
0
−25
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

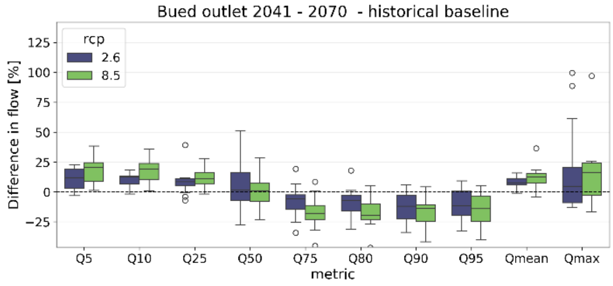

BR2 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

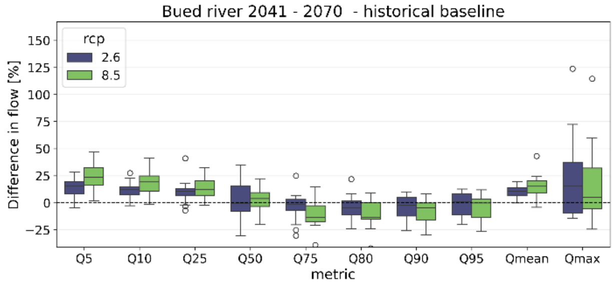

BR3 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

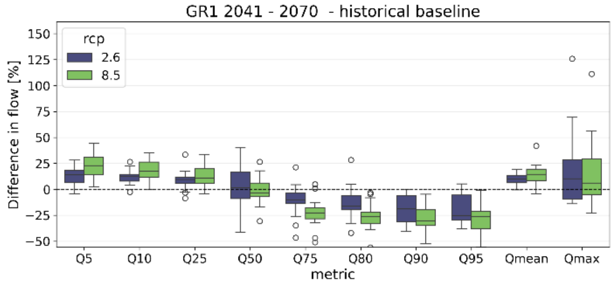

BR4 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

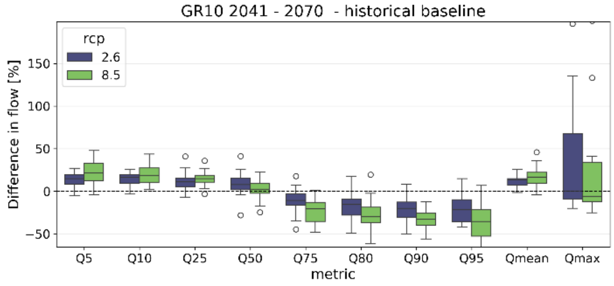

BR5 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

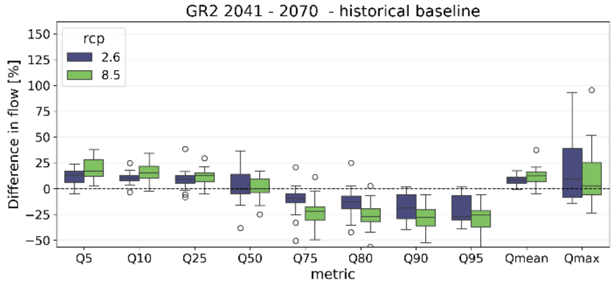

BR6 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

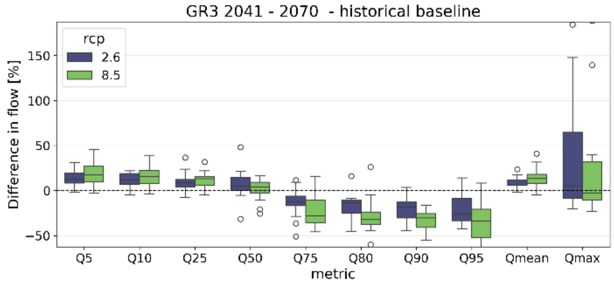

Bued outlet 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
125
100
75
50
25
0
−25
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

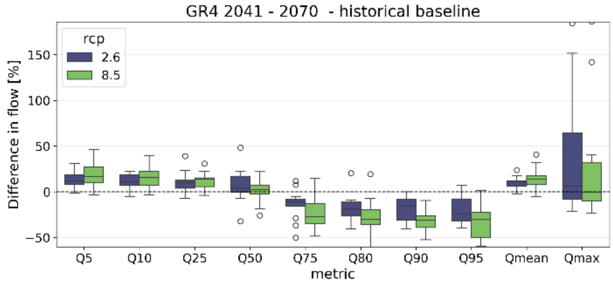

Bued river 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
125
100
75
50
25
0
−25
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

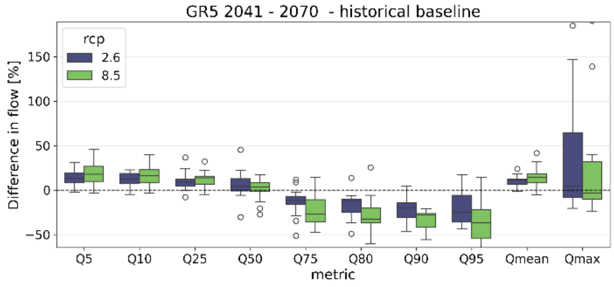

GR1 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
125
100
75
50
25
0
−25
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

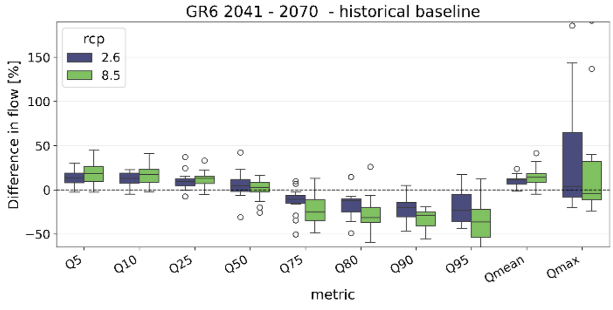

GR10 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric

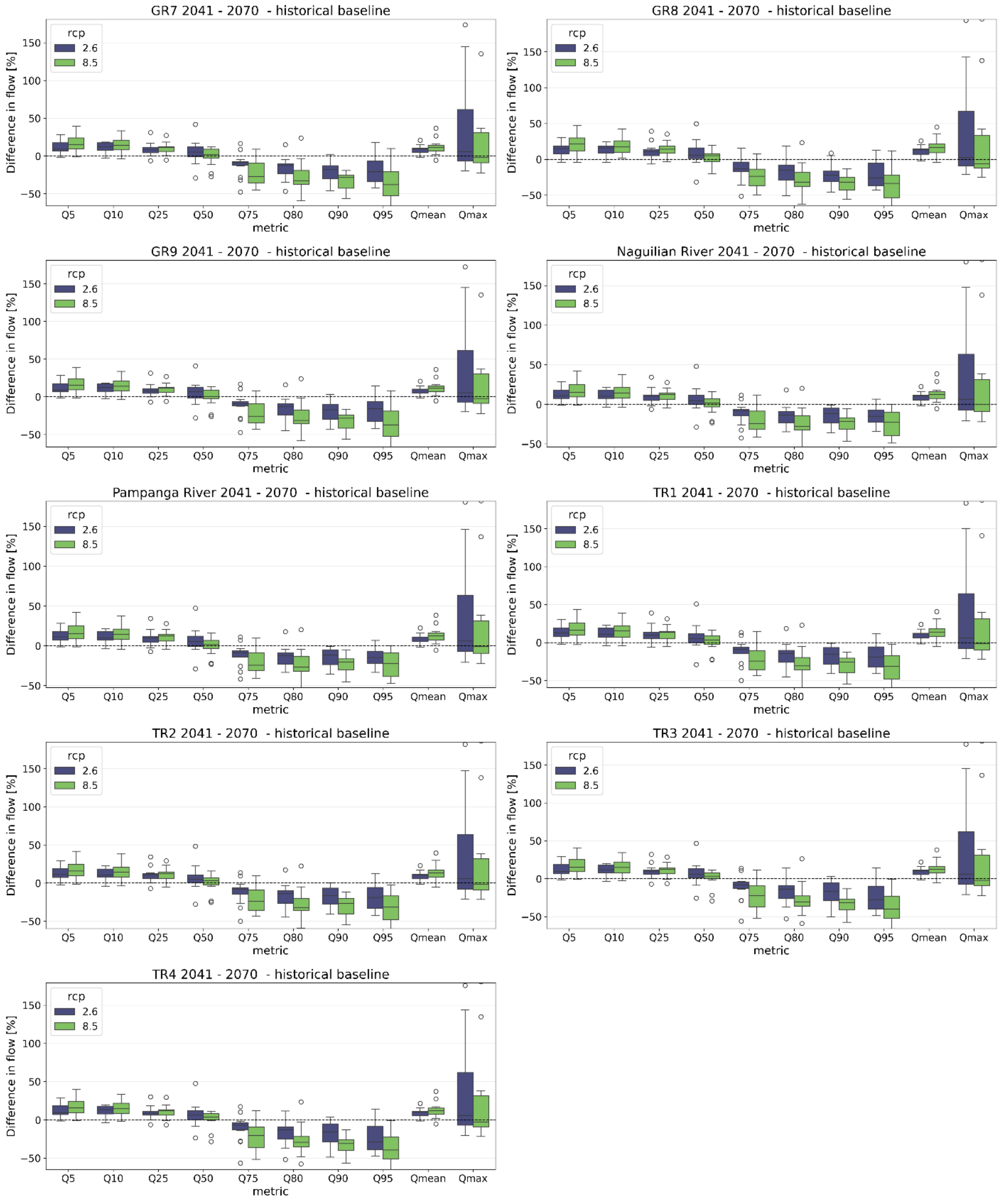

GR2 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
125
100
75
50
25
0
−25
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric


GR3 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric


GR4 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric


GR5 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric


GR6 2041 - 2070 - historical baseline
rcp
2.6
8.5
Difference in flow [%]
150
100
50
0
−50
Q5
Q10
Q25
Q50
Q75
Q80
Q90
Q95
Qmean
Qmax
metric



GR7 2041 - 2070 - historical baseline

GR8 2041 - 2070 - historical baseline

GR9 2041 - 2070 - historical baseline

Naguilian River 2041 - 2070 - historical baseline

Pampanga River 2041 - 2070 - historical baseline

TR1 2041 - 2070 - historical baseline

TR2 2041 - 2070 - historical baseline

TR3 2041 - 2070 - historical baseline

TR4 2041 - 2070 - historical baseline

Figure 18 Percentage change of river flow percentiles in the 2050s (2041 to 2060) minus the historical baseline (1991 to 2000). BGS © UKRI 2026,

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