

Network Criteria

20th April 2022 V1: Created for the ROBIN Workshop 1.

09th August 2022 V2: Update following workshop discussions.

The bulk of the text in this document is unchanged from v1. The additional blue boxes that feature throughout the document, present a high-level summary of the discussions held at the Workshop on 20th April 2022.

The aim of Reference Hydrological Networks (RHNs) is to observe the effect of variations in climate on hydrology (Stahl et al., 2010). To do this RHNs need to be defined based on catchments with stable conditions which have as little human influence as possible, and which are gauged by stations producing reliable streamflow data. This is to prevent spurious trends resulting from human impacts (e.g., abstractions/withdrawals, reservoir operations) or poor-quality data (e.g., step changes due to instrument changes) (Whitfield et al., 2012).

The ROBIN project aims to develop a global RHN network. While RHNs are well established in many countries (e.g., see Whitfield et al. 2012, Burn et al. 2012), in many, others' efforts to establish RHNs are at early stages, or have not commenced. Members of the ROBIN Network have already led some efforts to establish networks of RHN catchments, or at least RHN-like catchments, across international boundaries (e.g., Stahl et al. 2010; Hodgkins et al. 2017). In such ventures, it has often proved difficult to develop a suitable set of criteria for inclusion of sites – not least because there are very different definitions of what constitutes a 'natural' catchment and 'good quality data' between (and even within) countries. In some parts of the world RHNs can be based on truly 'pristine' unaltered catchments, whereas in a majority of localities, some degree of human disturbance must be tolerated. Moreover, there is always a trade-off between having exacting RHN criteria, which by definition, results in a limited number of sites and ensuring good coverage and representativeness of the network.

Within ROBIN we aim to balance the need for near-natural catchments against network density, and therefore propose an inclusive two-level approach to gauging stations within the ROBIN Network.

Data from Level 1 gauging stations would be directed towards analysis of extreme flows (both high and low) where the highest quality and most complete data from 'pristine' catchments (or as close to this as possible) will be required. Data from Level 2 gauging stations would be used for analysis of less sensitive hydrological variables such as monthly, seasonal or annual mean flows and water balances.

The two levels are intended to give a more flexible approach to balance the requirements of robust data analysis with good coverage of global geographies and hydrological regimes. In the case of Level 1 criteria, they are heavily influenced by those used in the Low Flows Study (Hodgkins et al., in prep). An open question (for discussion in ROBIN) is whether to also define Level 1 catchments as being suitable for high flows, which would mean the ROBIN network has higher overall utility in future but would mean more effort in the short term. It is anticipated that this will be addressed in the analysis phase of ROBIN, when the impact of the criteria on the analysis can be assessed.

ROBIN Network Criteria Summary

The ROBIN Network Criteria is summarised below, and the four elements that make up the criteria are explored further below this:

- [Catchment development and artificial influences](#)
- [Data quality](#)
- [Record length](#)
- [Missing data](#)

The criteria are in many ways qualitative in their nature which allows for a degree of flexibility in station inclusion, and we accept that compromise may be required to ensure there is a geographically representative network for the globe. The local knowledge of the ROBIN Partners is key to ensuring the network is representative and the inclusion of stations is appropriate.

ROBIN Network Criteria Summary

Level 1 Network	Level 2 Network
Largely free from human disturbances such as urbanisation ($\leq 10\%$ of the catchment), river engineering and water abstractions. Modest net impact of all influences on low flows and high flows and any impacts stable over time. No known major changes in land use likely to impact streamflow regime.	Fairly free from human disturbances such as urbanisation ($\leq 20\%$ of the catchment), river engineering and water abstractions. Modest net impact of all influences on monthly and annual flows and any impacts stable over time.
Very high quality daily mean river flow data capable of reliably representing high and low flows. Appropriate metadata.	High to fair quality daily mean river flow data capable of reliably representing monthly average flow conditions with appropriate metadata.
Record length of at least 40 years	Record length of at least 20 years – countries are welcome to flag catchments that are close to making the 20 year record.
No data gaps longer than three years.	

Catchment Development and Artificial Influences

To detect climate-driven trends we need to analyse river basins that are undisturbed by human impacts. Ideally catchments should be pristine but can be considered ‘near natural’ if reasonably free from human disturbances such as urbanisation, river engineering and water abstractions and therefore represent a natural flow regime such that the effects of climate-driven changes in river flow can be discerned from the noise of more direct human influences.

In many RHN initiatives, including the UK Benchmark Network, a pragmatic approach has been taken where some degree of influence is tolerated, provided that the river approximates a natural regime – influences should still be modest, have a limited net impact on flows (water abstractions and returns, e.g. sewage treatment discharges, can be tolerated provided the *net* effect is modest) and ideally any influences should be stable over time (Harrigan et al., 2018). Recognising the challenges of finding stations that are suitably natural across the flow range, the UK has adopted ‘sub-networks’ of the RHN suitable for analysing high and average flows but not low flows (and vice versa) for example.

Hence, for ROBIN, the impact of catchment development and artificial influences on the catchment should be minimal or at least stable although this should be based on judgement and local expertise. We acknowledge definitions of near-natural are likely to differ country-to-country and to some extent that there is a limitation of the number of catchments that could be called legitimately pristine due to them being situated in or near populated areas. We propose different criteria for the two levels, with Level 1 being the closest to approximating 'pristine' conditions and analogous to previous international efforts (Hodgkins et al. 2017; Hodgkins in prep). Level 1 is designed to enable the analysis of extremes including low and high flows, whereas Level 2 the analysis of variables such as monthly and annual averages.

Summary of workshop discussion

- It was noted that some gauging stations may be more suited to high flows or low flows for example as seen in Norway, Ireland and the UK. It was agreed that stations could be included in the ROBIN Network if they were only suitable for one end of the flow regime (i.e. high or low flows), as long as they were appropriately flagged in the relevant metadata – there is a freetext comments box in the metadata sheet for this kind of comment. See the [ROBIN Data Submission document](#) for more information on this.
- In some cases summer low flows are also affected by vegetation growth and this can be highlighted within the data flags if available or within the freetext comments box in the metadata.
- It could be interesting to have some criteria to answer the question 'When is the data good enough for low flows/flood analysis?' However, this is difficult in practice and may often be determined on a site by site basis; an example is that for the UK Benchmark Network Q95 should be within 10% of the natural value. Without specific local knowledge of the gauge this is hard to determine – it may be useful to share how different countries make these assessments.
- It was noted that the assessment of catchment development and artificial influences is likely to be subjective from country to country. However, given the challenges in applying a standardised and simple set of rules and thresholds globally as there are lots of different circumstances. Within ROBIN we feel that the best approach is to rely on the judgement of local data collectors and users.

Catchment Development and Artificial Influences Criteria	
Level 1 Network	Level 2 Network
Largely free from human disturbances such as urbanisation ($\leq 10\%$ of the catchment), river engineering and water abstractions.	Fairly free from human disturbances such as urbanisation ($\leq 20\%$ of the catchment), river engineering and water abstractions.
Modest net impact of all influences on low flows and high flows and any impacts stable over time.	Modest net impact of all influences on monthly and annual flows and any impacts stable over time.
No known major changes in land use likely to impact streamflow regime.	

Data Quality

Ideally, only stations that are considered to record high quality, fit-for-purpose streamflow data and adequate metadata should be considered for inclusion in the ROBIN Network. Stations should also have homogeneous time series, i.e., there should not be major step-changes resulting from changes to gauging structures or instrumentation. Definitions of data quality will be different in different countries (or regions within) depending on their circumstances and it is important to recognise that historical elements of records may reduce quality but still provide utility by allowing much longer record lengths. Assessment of data quality

should be based on judgement and local expertise. A flexible approach to this will be required within ROBIN. The two levels listed below have different criteria for data quality depending on the type of analysis each level is intended to support.

Summary of workshop discussion

It was agreed that the stability of data quality is perhaps more important than it being better than it was in the past. A way of tracking this could be metadata and quality flags. Where there is a modest net disturbance it would be good to document this in the metadata.

The general approach to data quality will be for the criteria to be inclusive and a secondary level screening applied by the core analysis team can determine whether the stations are suitable for inclusion for ROBIN analysis. This will make the ROBIN Network legacy, in general, more inclusive for future analyses (after all we don't know researchers might want when they analyse the data in 10 years' time!), and we don't want to exclude data that may be useful.

We discussed sharing knowledge and experiences within the ROBIN Network, including the production of guidance to help future countries identify suitable near-natural catchments. It was agreed that if there are certain sites that are identified in the station selection process that would be good to turn into a case study for a guidance document, the details can be passed to the UKCEH ROBIN team to collate.

Data Quality Criteria	
Level 1 Network	Level 2 Network
Very high quality daily mean river flow data capable of reliably representing high and low flows and appropriate metadata.	High to fair quality daily mean river flow data capable of reliably representing monthly average flow conditions with appropriate metadata.

Record Length

Flow record lengths should be as long as possible so that decadal variability can be distinguished from longer term trends. Record length is critical in the detection of trends in hydrological variables, and it has been shown in many studies that the results of trend analysis are dependent on the chosen period, which can have a significant impact on trend magnitude and direction (Dixon et al., 2006; Hannaford et al., 2013).

In trend analyses, study periods are usually selected to represent a trade-off between record length and network density. Within ROBIN we support the use of the longest river flow datasets that are available but recognise the need for a sufficient number of stations to be included in the network.

We propose any ROBIN station should have a minimum record length of 20 years (Level 2 Network), however for use in the Level 1 Network the record length must be of more than 40 years.

Summary of workshop discussion

The workshop participants were generally happy with the proposed record lengths and no suggestions were made to change this.

It was noted that even though some stations may not be up to 20/40 years of data, it won't take very long to get there, and if the station is good it should be included in ROBIN. The plan is the ROBIN Network continues growing into the future, so those sites that might not make the 20 year threshold now, will do in a few years time.

Record Length Criteria	
Level 1 Network	Level 2 Network
Record length of at least 40 years.	Record length of at least 20 years – countries are welcome to flag catchments that are close to making the 20 year record.

Missing Data

Missing values can lead to biased results in statistical and hydrological analyses and therefore within ROBIN, to conduct a robust analysis of river flow data, missing data should be kept to a minimum. Therefore, we propose that a minimum of 10% missing data would be acceptable for the ROBIN network and this criterion is applicable to both levels. A percentage is chosen to reflect a wide range of record lengths meaning a set number of years may not be appropriate.

Summary of workshop discussion

It was felt that specifying a percentage of missing data might not be the most helpful way assessing station suitability and may end up throwing away a lot of data that might actually be useful. It would be beneficial for future users not to make any restrictive decisions on throwing away data that can't easily be checked themselves.

There might also be scenarios where for example, the data at the start of the record may be patchy, but the resulting 30+ years may have great data.

Therefore we have changed the criteria to say that there shouldn't be more a gap in the data of more than three years.

Any further filtering of missing data may then be done at the analysis stage, e.g. removing stations with more than x% missing data across the record, with the threshold of acceptable missing data dependent on the analysis methods being used.

Missing Data Criteria
Level 1 and 2 Network
No data gaps longer than three years.

Other comments

Summary of workshop discussion

Station Inclusion

Stations do not need to necessarily be operational, but in order to provide up-to-date relevant trends assessments and for the legacy of ROBIN, it would be preferred if they were still operational. We discussed combined records (e.g. where station have moved) and whether they could be included. It was decided that as long as there is no step change in the record (a change point analysis could be carried out) and the combined station still meets the ROBIN Network Criteria then combined records can be included.

Metadata

In-country metadata, if available, will be used as default. However where metadata isn't available we would look towards deriving from global datasets such as CARAVAN, [GSIM](#) etc. It is very important to flag where this metadata has come from.

Minimum requirements should include the catchment boundary and catchment area.

Data Sharing

If you are unable to share raw flow data with ROBIN, later on in the process we will share scripts / codes to derive the indicators that we will be using in the analysis. We are hopeful you will then be able to share the derived indicators with us. See the Data Submission document for more information.

Number of stations to submit

There is no magic number per country and all stations are valued additions to ROBIN! There will be big differences in the number and density of stations that meet the criteria but also time to engage with gauging authorities. The two level criteria will hopefully mean we have a more inclusive network and addresses differences in density and number of stations.

Data types

The primary focus of ROBIN is gauged daily mean flows. In principle, sub-daily data is important, especially for the flooding side of the analysis, however this would be very ambitious to fit into the initial phase of the ROBIN project. Likewise, instantaneous 15-minute data, while very useful and something to explore in the future, it doesn't feature in this initial phase of ROBIN.

References

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