RESPONSE TO REVIEWER 1 COMMENTS

Throughout this response, the reviewer's text is presented in black, our response in blue, and the proposed revisions in green. Please also note that line numbers all refer to the current submission.

This technical note introduces a numerical framework for the statistical generation of flow duration curves and then demonstrates its relevance on a hydropower planning problem. The key idea supporting the framework is the representation of Flow Duration Curves (FDC) through a set of parameters, whose value is directly related to key streamflow statistics, e.g., mean, median, or standard deviation. By sampling in the space of these statistics (through the use of multipliers), one can then stochastically generate new FDCs.

I believe the proposed approach is novel and technically sound (including the derivations provided in the SI). Importantly, the proposed approach can indeed be useful for a variety of water management applications. The presentation is clear and the manuscript well structured. Hence, my suggestion is to proceed with a minor revision.

We sincerely appreciate your thoughtful review of our manuscript. Thank you for acknowledging the novelty and technical soundness of our proposed approach, as well as the clarity of the presentation and the manuscript's overall structure.

My only major comment concerns the 'type' of streamflow data that are needed to parameterise the model; a point that, in my opinion, requires a deeper discussion. For example, I believe it may be challenging to implement the framework in a catchment characterized by land use change or other anthropogenic interventions. In other words, I suspect that the use of the framework might be limited to pristine catchments (unless the framework is complemented by a process-based model that somewhat accounts for the aforementioned drivers). Another point I would discuss is the 'safe operating space' of the framework, intended as the amount and quality of data needed for its successful implementation. With this, I am not trying to diminish this paper (which I found interesting), but simply to understand how to best use the model it presents.

Thank you for valuable feedback and insightful suggestions. Below we address separately the two points raised.

We agree with your assessment that our approach is not applicable in any catchment regardless of the amount of human intervention. We will insert the following in the revised manuscript in the discussion, after lines 211-212:

"Our method focuses on catchments free of major flow regulation (reservoir, effluent discharge). Yet, those catchments do not have to be pristine, and can for example experience significant human interference in landuse change. Indeed, the MOPEX dataset (Duan et al., 2006), which was used to assess the quality of the three parameter Kosugi model (Sadegh et al., 2016), has been found to be affected by significant human interference (Wang and Hejazi, 2011). "

Your point regarding the "safe operating space" of the framework is similarly well-made. we will clarify the amount and quality of data required for the successful implementation of our approach after equation (2):

"To fit the Kosugi model and capture flow variability within the FDC, it is necessary to daily discharge measurements over a sufficient period of time, e.g., more than 20 years.".

Finally, the authors may want to consider a full article (rather than a technical note), something that could be done by including the SI in the main manuscript and extending the description of the case study. I would leave this up to the authors.

We would like to thank the reviewer for their suggestion. We carefully considered your suggestion to change the format of this technical note. However, after careful evaluation, we have decided to maintain the current format. Indeed, the supplementary material is there mainly to provide the detailed proof that for any triplet of statistics (M,V,L) there is a unique set of Kosugi parameters; we believe that putting this lengthy proof in the main text would dilute it.

Specific comments

- Abstract: “coherent across the full range of hydrological conditions”. Could you please elaborate on or clarify the meaning of this statement?

Thank you. We will amend the text at lines 3-5:

“In this note, we introduce a new statistical generation method to produce a range of plausible streamflow futures to flexibly combine changes in average flows with changes in the frequency and magnitude of high and low flows.”

- Line 36-37: I agree with this statement, but also believe that streamflow is not the only source of uncertainty that water planners account for (water demand, for instance, is another one). This is an important caveat I would mention.

We appreciate your suggestion to consider all sources of uncertainty. We will clarify that our paper focuses only on streamflow uncertainty.

For this we will insert at lines 36-38:

“In water resource applications, this entails defining specific ranges for future uncertainties including streamflow, then sampling them to generate an ensemble of plausible future conditions.”

- Line 43: should it be “change”?

Thanks for this comment that warrants a clarification.

We will revise this sentence as:

“In fact, a study of the Rhine-Meuse basin from 1901 to 2010 shows that optimal calibration evolves with climate variability, and land use and river structure change (Ruijsch et al., 2021).”

- Line 64. I would say a few words about the Kosugi model. It is hard to follow the next paragraph (and, hence, grasp the overall contribution) without some basic information about the model.

We will add below information to the text at line 65:

“This model is frequently used in soil physics and hydrology to characterise water flow in unsaturated soils and to estimate soil water retention properties. It is based on a lognormal distribution with three parameters (Kosugi, 1994, 1996) that are determined by calibration against the empirical FDC of a watershed.”

- Equation 1: I assume that “erfc” refers to the complementary error function, right? I would mention this explicitly in the paper.

We will add the following clarification below the equation

“where [...] erfc is the complementary error function.”

- Line 132-133. I’m afraid I don’t fully understand this part: why is it necessary to verify this condition?

We appreciate your feedback and the important point you raised regarding the suitability of our model for projecting future outcomes. The ability of the proposed model to fit well with historical observations is critical to its ability to make reliable future projections, and this should be a fundamental consideration.

In a revised version, we will make the need for a good fit model clearer by adding the below text at lines 132-133:

“It is essential to prove that the FDC model provides a good representation of historical observations, otherwise a perturbation of the model would be a poor representation of a perturbation of the historical flow regime.”

- Figure 1. I would expand the caption instead of referring the readers to the main text.

We will amend our caption as follows:

Figure 1. Flowchart of the approach; (1) Kosugi model parameters are calibrated with a historical FDC, (2) a set of scenarios with modified flow statistics are determined, and a new set of Kosugi model coefficients are derived for each future scenario. (3) future scenarios are created by using these coefficients, (4) application of the method to represent possible climate change impacts on the robustness of a proposed run of river plant in Turkiye.

- Line 157. “Additional energy”?

Thank you for bringing this to our attention. We will add “additional before “energy” at line 157, to read:

Extreme low flows are insufficient to activate the turbines, and equally, flows above the design discharge do not produce additional energy.

- Line 161. Can you provide more details about the data you used? For instance, how long was this time series? What’s the minimum amount of data needed to make the application of this model successful?

In this instance, the information the reviewer is looking for seems to be already present at lines 149 – 150:

“27 years of daily discharge observation are available. The discharge fluctuates considerably between values of 2 and 38 m^3/s, with median flow of 4.79 m^3/s, first percentile flow of 2.23 m^3/s and coefficient of variation of 0.60.”

Please also note the 27-year, daily FDC for the catchment is available in the Zenodo repository. We are keen to add more information if reviewers or editors think it is warranted.

Thanks for pointing out our lack of explanation about the minimum amount of data needed to make the application of this model successful. This topic was covered in our earlier justifications.

- Line 189. What are the input variables to HYPER?

Thank you for highlighting the absence of HYPER's input in the text. We will insert this at lines 190:

“The inputs of the HYPER model are daily discharge records, ecological flow rate, and project based parameters such as gross head, penstock length, interest rate, energy selling price, project life time and site factor for civil works, maintenance and operation cost factor, fixed costs such as transmission line, expropriation costs. “

- Line 210. What are these other functional forms?

Thank you for pointing out the need to emphasise this point more explicitly in our paper. We will revise that sentence as:

“Sadegh et al. (2016) proposed other functional forms such as 2-parameter Kosugi model, 2-parameter and 3-parameters van Genuchten models for the FDC that could also be perturbed to generate future flows.”

References:

Wang, D., & Hejazi, M. (2011). Quantifying the relative contribution of the climate and direct human impacts on mean annual streamflow in the contiguous United States. *Water resources research*, *47*(10).

Kosugi, K. I. (1994). Three-parameter lognormal distribution model for soil water retention. *Water Resources Research*, *30*(4), 891-901.

Kosugi, K. I. (1996). Lognormal distribution model for unsaturated soil hydraulic properties. *Water Resources Research*, *32*(9), 2697-2703.

Thank you again for your thoughtful comments on our manuscript.