

Reviewer 2 Christopher Skinner (Referee) –6th September 2019

The paper describes the mathematical design of Wetropolis, a tactile, tabletop demonstrator of flooding and probabilistic nature of the rainfall which causes it. The activity is certainly novel and innovative, and I consider the use of the Galton boards to determine rainfall events inventive with there being a lot of scope for future work into how effective this is for communication of flood likelihoods.

Unfortunately, this manuscript does not do the developed activity justice as it merely describes the mathematical model used to design and parameterise the physical model, and some description of the outreach it has been used for. In its present form it lacks a clear research question.

- Pertaining to the perceived lack of research question, we point that the challenge at hand is not a research question but rather the following: “UK flood experts therefore gave us the challenge to design an outreach tool visualising what a return period is.” This article on outreach disseminates a) how we solved that challenge and b) how the tools we developed and used can lead to adaptations by the readers. We therefore disagree with the reviewer. For clarity’s sake, however, we entirely rewrote the abstract and made several adaptations and changes to the introduction to explicitly state that challenge and those dissemination goals much more clearly. We also note that the editor purposely changed the article from a HESS research paper into a HESS education and communication paper suitable for this outreach project; it should therefore be reviewed as such. Changes in the text have been indicated in red.

It is not that I don’t think that either of these elements are publishable, but both need significant development to get to that stage and most likely as two separate manuscripts.

For the mathematical model, more needs to be said about how it compared to the physical model once built – how well did the maths compare to observations from Wetropolis? How does the mathematical model compare to other numerical codes of hydraulics?

- We disagree for the following reasons (as we have already alluded to above):
 - (i) the mathematical and numerical model constitutes a lean design model, to guide the determination of the design parameters; it is not a model meant for validation of Wetropolis seen as a scientific experiment. This was already stated in the original submission (blue highlighted original text in the revision) and is even emphasized more in the revision (new red highlighted text). Design models must facilitate quick design changes and our model does.
 - (ii) There is also a misunderstanding what such a validation would entail. Wetropolis is a portable model and at every place it is set up there are slight variations in level, pump strengths, etc. At present there are two (untested) water-level measurements possible and a camera could be placed to record the moor water level. However, a proper validation would be a research project in itself, requiring full data assimilation and parameter estimation approaches because there will be significant uncertainties in the water influx, the determination of the topography, the pump strengths, riverbed roughness, etc. That is all appropriate for a substantial research project but such an endeavour has little to do with the actual establishment of the working and successful Wetropolis flood demonstrator. Note that our outreach goal is not to show that a mathematical model can be validated with an experimental model since our outreach goal is to visualise what a return period is: we clarified this goal in the revision. In conclusion, we reject the research suggestion by the reviewer for the present outreach paper while, of course, we are in the long-term interested to augment Wetropolis with a research component –even though that was never its original intention. Our intention is and was simply to solve the above-mentioned challenge posed by flood professionals.

More guidance needs to be provided by the authors into how it can be used to advance hydrological and hydraulic modelling. As it reads at the moment I cannot see what the interest in this mathematical model would be or how anyone would utilise it.

- As discussed above, the model is a lean design model and has factually been used to make the design possible, which we clearly indicate with the blue-coloured text in the revised manuscript (pertaining to text already in the original submission); the model is not meant to advance hydrological and hydraulic modelling. Any reference to advances in research have been removed from the abstract, which has been rewritten entirely, and from the main text. However, what is novel about the mathematical model is the mass-conserving coupling between the various systems and its holistic overall coupling, with the random rainfall coming from the Galton board draws. This novelty was required to establish a lean model facilitating the design.
- The requested “guidance” is now given in a rewritten abstract, more clarification is now given in the introduction and selectively further in the text. These changes have been marked in red colour.

For the outreach, there needs to be much more detail into the design choices – why was a tabletop demonstration chosen, especially when the mathematical model would lend itself to a cheaper and easier to produce numerical demonstration?

- The reason to choose a table-top design have now been given: flood professionals had posed us that challenge and one in particular, JBA Trust, has good experience with physical models for PR and educational reasons. We now mention this explicitly, also referring to JBA’s coastal wavetank, which was designed within Leeds’ CDT in Fluid Dynamics, on request of JBA Trust.
- Numerical demonstrations are flat and may be uninspiring to the general public. What was requested was an interactive physical tool.

What were the inspirations for the design?

- The inspirations for the design were clearly given in the first few pages of the introduction, which have been further clarified with statements relating it to the design that is to follow. If that is not what is meant, the design simply popped up in OB’s head and was developed in a series of iterations with designer WZ, which iteration timeline is and was available in the story told on GitHub (emails between OB and WZ literally reveal how matters developed quickly). OB and WZ are Dutch citizens and within the context of the Deltaworks, of which small-scale test versions were built in the Noord-Oost polder after the 1953 flood, conceptual modelling of river flood components like in Wetropolis is perhaps natural for Dutch engineers and designers? See also online literature of the “Waterloopkundig laboratorium” in the Noord-Oost polder.

The design of the activity needs to be positioned within a theoretical framework for public engagement, including a relevant review of the literature.

- We do not understand this request. Two of the authors are engineers and designers. We were given a public-engagement challenge by flood professionals, given the problems they face to explain what a return period is and how to visualise this to the general public, and we simply solved that challenge. Furthermore, this ‘education and communication’ paper describes in detail how we solved it. Why is that not sufficient? With theorising one does not resolve the challenge. There seems to be a collision between hands-on problem solving and theorising about solving it?
- Given the changes we have made to the manuscript, and given that Wetropolis is not going to change in any significant way when such positioning is done and given that we simply do not have the social science background to do so, we leave such a positioning to the relevant experts in a future endeavour.
- What is lacking, cf. the video made of the coastal wavetanks, is 10-15min video of the Wetropolis experience, augmenting the physical set-up, such that the visual explanation of return periods can reach a much wider audience world-wide. While making such a video is a future plan, current lack of funding (at an estimated 5000 pounds for a professional video) means it cannot be done as part of the present manuscript revision.
- **The evaluation of Wetropolis in Sections 4 and 5 is and was based on formal discussions within two workshops of the Maths Foresees network, in 2016 in Edinburgh and 2018 in Leeds, as well as (new) formal feedback from the Churchtown Flood Action Group, Leeds’ Armley Museum [pending] and the Turing Gateway found on the Wetropolis’ GitHub site.** We now made this more explicit by adding this remark in the acknowledgements and further changes within the main text.

I have no doubt that Wetropolis is a successful outreach activity, and that it is effective at achieving its aims, however, the manuscript lacks evidence for this beyond a list of events attended and some anecdotal comments. For example, on Page 21, Lines 27-29 the authors state “In particular, Wetropolis aids in raising awareness of the probabilistic character and randomness of rainfall and flooding events, also in connection with the difficulties in predicting some of these extreme events.” without demonstrating how they have come to this conclusion -for example, was this through interviews or questionnaires with those partaking in the activity?

- The audience viewing Wetropolis and the organisers of events simply told us at the time and/or in retrospect. In addition, the reflections of a discussion session on public engagement, including Wetropolis, at EPSRC “Maths Foresees” UK network meetings have been included in this paper, see, e.g., page 21 and section 5.1 of the original submission. These sections have now been clarified.

The sources cited to support a further point on Line 30 also do not provide this evidence and are news articles describing that the events happened. My recommendation for a redevelopment manuscript would be:

(a) Clearly define the messages they wish to be communicated and criteria they’ll use to assess if they have communicated these effectively.

- We have now highlighted the “messages we wish to communicate” via the rewritten abstract and additions to the introduction and throughout the text – all marked in red. The challenge posed was to create a 3D demonstrator visually explaining what a return period is with respect to flooding. We succeeded in solving that challenge and present how we solved it and how design changes can be facilitated for use by other people.

*(b) Describe, with review of literature, why the design of Wetropolis should help them achieve **this**.*

- We solve “this” as that is the challenge posed. A review of the literature is relatively futile as far as we know and as far as we have been told by various flood professionals, otherwise they would not have posed their challenge, since Wetropolis is unique in its combination of random and visualised rainfall coupled to a physical river flood model in one holistic physical model. We did refer to literature on Lego models. Even all reviewers refer to this innovative character. Why then do we need to justify that Wetropolis is innovative and solved the challenge posed while everyone already seems to agree it is innovative and solving the challenge posed?

Formal evaluation of Wetropolis at events, workshops etc. against the criteria established.

- The discussion on page 21 (of the first submission) is factually based on the comments we have received from the audience/viewers of Wetropolis and the formal discussions, led by Tiffany Hicks, on public engagement and Wetropolis within meetings of the UK EPSRC Maths Foresees network.
- We have now furthermore added, comments collected by the organisers of the flood exhibition at the Armley Museum [pending], the Churchtown Flood Action group workshop and the Study Group on flooding problems organised by the Turing Gateway.

Discussion of how results varied between different types of events, different audiences, and different methods of communication (e.g., was there an accompanying lecture).

- We did discuss how events differed already, and have added more detail about these events, and gave conclusions based on the experience at these events, which has now been clarified further; see page 21 of the original manuscript: “The strength of Wetropolis is ... While Wetropolis was designed as a public outreach project, the reception from flood practitioners and scientists working in environmental fluid dynamics has been surprisingly positive; we will discuss this reception later.”

I’m sorry I cannot provide a more positive review. I do hope the authors will revisit this and return with revised manuscripts as Wetropolis is an impressive creation and deserves to be shared widely.