Reviewer 1 – 22nd August 2019

General comments:

The paper presents an innovative approach to demonstrating rainfall and flood probability and therefore discusses a topic relevant for the scope of HESS. The paper goes into detail regarding the numerical model used for the design, but lacks a presentation on the outcome of that modelling, i.e. what numerical tests were conducted and how that informed the selection of dimension, range of flows, rainfall intensities, moor and reservoir parameters that were used in the physical Wetropolis model.

- To highlight the goals of the paper better, we have entirely rewritten the abstract and added extra sentences in the introduction and elsewhere, emphasizing these goals. Changes have been highlighted in red in the revised text.
- That the model "*lacks a presentation on the outcome of that modelling, i.e. what numerical tests were conducted and how that informed the selection of dimension, range of flows, rainfall intensities, moor and reservoir parameters*" is factually incorrect or a misunderstanding. The outcome of that modelling is promised in lines 2-32 of page 4 (original submission), where a range of parameters is indicated, which are determined by the mathematical and numerical modelling. On pages 15 and 16, the last part of section 2, including Fig. 5 with a simulation outcome (of the original submission), exactly what the reviewer thinks is lacking is indeed presented and was determined prior to the actual physical design could be built. Also, the detailed time-line and values used in the design process can be found on the GitHub site, to which we (did) refer, in order to check that we did not made up anything, since it contains the factual email correspondence between designer WZ & mathematician OB from 2016 onwards, as well as the original 2016 Matlab code (with an error) and the final Matlab codes used. Otherwise said, we do not understand how the misunderstanding about the perceived lack of numerical testing has arisen given that we (had) considered such testing in detail:
  - lines 20-21 on page 4 (original submission) read: "The next and crucial step in the design is to identify and determine the various unknowns in order to ascertain whether a feasible design is possible at all." This is followed by a specification of the five key unknowns ending with the statement "We chose s_{res}, s_m, Q_0 a priori and determined wd and r_0 by simulation of a simplified mathematical model", which we now modified slightly. In particular, we added the following: "… of a series of simulations of a simplified mathematical and numerical model. Note that the latter model is a lean design model exclusively geared towards obtaining quick estimates of the design parameters. It is not a model geared towards validation of measured data but a model geared towards assessing design changes quickly. After all, the goal is to design and present an outreach demonstrator not a scientific experiment even though we use up-to-date mathematical and numerical methods. While none of the elements in the mathematical and numerical model are new in separation, their holistic combination with our random rainfall is indeed novel". (Quotes from the original paper have been highlighted in blue in the revised text; new text is highlighted in red.)
  - The first sentence of section 2.3 reads "Given the choice of parameter values with (or near) the values given in Table 2, the goal is to determine a suitable rainfall speed r_0 and length wd via trial-and-error through numerical simulation".
  - So "*the informed selection of dimension …*", as asked for, is and was exactly done on pages 15-16 (original submission): "Via visual optimisation, i.e., monitoring when major flooding occurred in the city for the extreme or rare events of 90% rainfall in both the reservoir and moor, a suitable value of the rainfall speed is found to lie around the value $r_0 = 2{:}0510^{-4}$/s (17). The corresponding water volumes for the various Galton-board outputs required in the moor per wd are then (1;2;4;8;9;18)Vrate = (0:18;0:36;0:72;1:44;1:62;3:24)l/wd = (0:018;0:036;0:072;0:144;0:162;0:324)l/s. (18)
  "Consequently, the pump supplying the rainfall on the moor should have a maximum discharge of about 324ml/s, which is a manageable amount from a design perspective." (Correction in red of a typo.)
- Moreover, we emphasise that the model is given in detail, including the codes, such that readers

can use it to make bespoke redesigns of Wetropolis for their catchments of interest and stated that it is also a goal of our paper. Note that we have entirely rewritten the abstract and highlighted these goals now explicitly, also via further changes in the introduction.

Specific comments:
As noted above much of the paper focuses on presentation of the mathematical model C1 developed for the design of the physical model. The authors claim in the abstract that this mathematical model "is of scientific interest from a hydrodynamic modelling perspective".

- The reviewer focuses on side remark; we have removed this sentence part "*is of scientific interest from a hydrodynamic modelling perspective*" and entirely rewritten the abstract.

There have been a considerable number of mathematical models for simulation of water flow developed over the past decades and it is not immediately clear why the authors have developed their own model rather than using an existing one. It would be of interest if the authors provided a justification or an explanation. If the authors believe that they have made a contribution to mathematical modelling, they should, as a minimum, a) provide a review of relevant literature in the introduction; b) clearly specify what is novel or added value in their modelling approach; c) provide a validation of their mathematical model against observations on the physical Wetropolis model, such as by comparing the predicted and observed outflows of the system, water levels in the city, reservoir and moor, etc. Otherwise, the sections of the paper that present model components that are not related to new contribution should be shortened.

- We have removed that offending sentence piece and kept the mathematical and numerical modelling because it is used to "... explain this mathematical model in detail since it was a crucial step in Wetropolis' design" (old abstract). It is also key that this model is minimal, focused to guide the design; it does not and is not meant to provide a validation. We emphasise again that our manuscript is submitted to HESS 'education and communication', not as a full research article.
- In addition, at the start of section 2 we added: "While the individual modelling elements in separation are known or straightforward, their holistic combination with the statistical rain modelling as well as the subtle mass-conserving coupling between the elements is nontrivial and new. In addition, dissemination of the model is also required to facilitate adaptations by the readers. One other reason to be quite pedagogical is to reach a wider readership of enlightened and interested members of the public, including educators."
- We have added references to graduate texts by Morton and Mayers (2005) and Leveque (1990).
- Since outreach, education and communication is the purpose, validation of the model as if Wetropolis is a scientific experiment is not required. Scientific validation of Wetropolis is simply not our goal even though it could, of course, be of interest in future research, as opposed to outreach. Moreover, a validation would not change the outreach design and is as such presently irrelevant.
- There are novel components in the design model, i.e. putting all known elements together in one holistic model with its novel statistics via the Galton boards for the rainfall and the subtle connections between the different elements. But these modeling novelties are focused on delivering design guidance not validation. Moreover, for validation, a full and rather non-trivial data assimilation approach is required, and that would lead to a research paper, which is not the topic at hand.

The authors should present the results of the numerical tests and explain how this informed the construction of the physical model. This presentation should provide enough information for the reader to understand what were the goals of this exercise (e.g. determining which input parameters or dimensions), what are the relations be- tween contributing flows (upstream inflow vs flows from rainfall) and conveyance (river, floodplain and canal) and in which rainfall events flooding of the city occurs.

- As discussed above in the second bullet response, this is exactly what we had done. We are surprised that the reviewer missed that we exactly did use the model results for the design? See the various blue-highlighted texts, which were already present in the original manuscript.

Regarding the latter, the authors should also confirm whether the predictions of the numerical model correspond to the observations on the physical model. In chapter 2.2.1, it is not clear how the floodplain accumulation and flow were modelled. At the first glance and without making any calculations, it seems that canals are relatively small compared to the river and floodplain.

- We offer an alternative position, as said; our modelling results are not predictions of water height but estimates with a minimal mathematical and numerical model to predict pump strengths and several parameters for the outreach design. The model solely serves to guide the actual design at low order, not as accurate predictions. In the actual design, the use of materials and pump action was changed to some degree, which is fine given that the goal was to make an outreach flood demonstrator, not a scientific experiment, which challenge was posed to us by flood professionals. We could also have used the Navier-Stokes equations but that would have been very time consuming and impractical to estimate design changes quickly. So it is on purpose that our model is quick and minimal, which was functional, since during the design we could thus quickly change the river-channel length (see the historical time line on GitHub which demonstrates this). Moreover, the editor explicitly changed our paper from a research paper to an education and communication paper, with our agreement, thus underscoring that this is not and never was meant to be a scientific research paper. Note lines 4-9 in section 5 on page 22 (original manuscript), where the above was highlighted already: "This efficient mathematical model was first presented as a coupled system of ordinary and partial differential equations which we subsequently solved numerically to define a near-optimal design. While that mathematical model is close to a prediction model for river and groundwater flows in Wetropolis, due to its relatively minimalist nature and purpose to facilitate the design, it is likely not quite sophisticated enough to make bonafide predictions. In a final modelling step, we determined the reasonable rainfall and flow rates through numerical simulation, on which rates we based the actual design and construction of Wetropolis."
- A fundamental issue is our principle that for design purposes one-to-one agreement between design model and final demonstrator is neither required nor expected, because the end-goal is the outreach experiments and its functioning itself, not validation between observations and (design) model. Design models need to be flexible and quick since in the actual construction, adaptations leading to more efficiency naturally emerge; in the model we have rainfall percentages while adjusting pump strength is a pain so in the design we replace it by percentages per wd so the pumps simply are switched on and off. There have been a multitude of such minor design changes, which do not require a rerun of the design model.
- Floodplain accumulation has not been modelled but flooding has been modelled in a simple manner since that was adequate for the design model. This is and was clearly stated on page 14 lines 4-7 and further (original paper): "… major flooding is defined to occur when the river level significantly, i.e. by 0.01m or more, exceeds the canal--1 berm along the strip of river bordering the city plain. This is monitored visually in daily snapshots".

The authors should comment on what is the role of canals in the demonstrator; does their inclusion (or omission) have other effects apart from achieving visual familiarity with the Leeds case.

- This was explained, see page 16, lines 9-10 (original manuscript): "During this time major flooding is lessened, or prevented completely, because the reservoir and canal in essence act like flood-attenuation storage sites, supplying passive flood control." And page 18, lines 11-14 (original manuscript): "Hence, active flood control can be demonstrated by manually adjusting this outflow level. Outflow into the canal can be arranged separately via an adjustable valve. Note that this is slightly different from the set-up in the mathematical and numerical design model, where the outflow of moor water was partitioned between the river and canal." See also the caption of Fig. 2 of both the original and revised manuscripts. In other words, the canal also can act as minor flood alleviation. Note that we added/altered the sentences: "The river-canal combination established is inspired by the River Aire and Leeds-Liverpool canal sharing a large part of the same river valley with the canal allowing some minor flood alleviation via (manual) flood control" and "We recall that the reservoir has valves such that the audience can store and release water interactively into the canal and river in order to control and possibly prevent flooding in the city."

Technical corrections:

On p8, line 11, symbol b usually refers to (bed) width. It seems that the authors use it for b (bed) level, in which case this word (level) should be added to avoid misunderstanding. Also for level, the symbol z could be more appropriate than b.

- The river bed b=b(s) is a variable of the winding river coordinate s; use of the vertical coordinate z (as opposed to a variable or function) is less appropriate, according to use in many numerical modelling papers, including papers of Akers and Bokhove (2008), Ambati and Bokhove (2007ab), Tassi et al. (2007), and Rhebergen et al. (2008) in the Journal of Computational Physics. It is common to use notation b=b(x,y) and, hence, here b=b(s). The symbol b from "bed" is used on purpose, as opposed to the symbol z, since z is not a letter in the name "bed" and is more often the vertical coordinate. In addition, b is a well-known choice in the applied mathematical and numerical modelling community.
- However, we added a sentence to enhance clarity "Hence, the river bottom lies at z=b(s) with vertical coordinate z and the river surface at z=b(s)+h(s,t)" in section 2.2.1.
- We removed an incorrect term in the Canal-2 equation (three times), which was a typo since the erroneous term was not present in the numerical code (which can be verified from the dated codes on the GitHub site). Similarly, the inflow of the canal into the river was missing in the write-up but was present in the codes. These corrections have been marked in red.
- We extended and modified the conclusions based on new developments and remarks by the other reviewers.