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Interactive comment on "Topography- and nightlight-based national flood risk assessment in Canada" *by* Amin Elshorbagy et al.

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The authors would like to thank the anonymous reviewer for providing a very thoughtful assessment and very useful suggestions. We are providing here below our detailed response to each remark. 1. The authors have used what they consider to be a static entity like topography through two quantities "elevation above nearest drainage" and "distance from nearest drainage" to create a flood hazard level for each grid cell. The floods in the Bow and Elbow Rivers in Calgary, Alberta in 2007 for example, (one of the locations the authors use to verify one of the maps) significantly affected drainage to the point that it changed the rivers' locations, meander and moved a significant amount of sediment. While this would not likely affect a product that is based on a resolution of over 300 metres (at best) because these rivers may not change bank locations by more than 100 metres in one flood, it does beg the question of how often

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should this product be updated, maintained, etc. Products like this should be given technical support but there is no suggestion of technical support. This is fine because I don't think the development of a product is something that is suitable for publication in HESS and perhaps the authors are more interested in providing an approach leading to a potential product. Well in that case, a much more rigorous evaluation of that approach is required and that is lacking here. What is currently presented is really nothing more than a simple GIS exercise, which I might suggest is not suitable for HESS and thus, the work needs greater discussion, validation and verification if the ultimate objective is indeed to suggest an approach.

R1. We would like to emphasize that the approach we are proposing here proposes for the first time the integration of detailed topographic information, in the form of distance and elevation from streams, with hydrologic and human settlements information to assess flood risk. What is obtained here is much more than a flood inundation map, as we integrate information on hazard and exposure, therefore moving a step forward towards large scale estimation of flood risk. Actually, what is intended here is both an approach that can be followed in any place across the globe and a product (for Canada). Therefore we believe that the article is presenting significant innovation. For example, many developing countries can benefit from this as global remotely sensed data are becoming increasingly available. We validated the approach using the example of Calgary in a qualitative visual way, but in the revised manuscript we will also provide the evaluation quantitatively in the form of error metrics. We agree that big floods may change the river course, however, even most local hydraulic modeling for flood inundation purposes do not consider such geomorphological changes. Our approach can be easily updated when significant topographical changes happen in the landscape and this information is updated into the DEM being used. We believe little technical support is needed as we can provide relevant codes and GIS layers that can be re-run when significant changes happen in topography or landuse.

2. Page 7 lines 12-19 – The authors need to state in greater detail what they are doing

with the comparison around the City of Calgary. Is this a validation or verification? It seems like none of these, than what is this comparison for? If you want to make a comparison, it should be quantitative, instead it is entirely qualitative.

R2. It would be useful if the reviewer clarified what is meant by validation and verification, as these terms are sometimes used in hydrology with different meanings with respect to what is defined, for instance, in the ISO 9000 rule (for more details please see https://en.wikipedia.org/wiki/Verification_and_validation; see also Biondi et al., 2012). Our application to the city of Calgary is intended to be a validation, according to the following definition of the term: "Validation is the assurance that a product, service, or system meets the needs of the customer and other identified stakeholders. It often involves acceptance and suitability with external customers". To meet the above requirements, in hydrology validation is often performed by referring to independent set of data, as we did in our case. We agree with the reviewer that it is possible to provide a more quantitative assessment of the results. As mentioned earlier, in the revised version of the paper we will indeed make our validation quantitative, and will call it evaluation of the topography-based flood hazard mapping.

3. Page 8 – The Canada DEM resolution is reported as 326 metres. This is the spatial resolution – what is the elevation resolution and accuracy – 1 metre? 50 cm? What are the implications of this error on flood risk or hazard? The authors combine two topographic indices to create a skewed topographic index and call this flood hazard. I don't necessarily agree that this is flood hazard – what it definitely is, is a new topographic index related to position from a "drainage point". If the authors want to suggest a surrogate for flood hazard that is easy to create, then they would have to verify that surrogate but that has not been conducted here. At this point, the authors should be true to what they have presented and not label that products as flood hazard but simply the product of two topographically related indices.

R3. We respectfully disagree. There is no universal measure of flood hazard. Typically probability of occurrence is used. Here we are assuming that our proposed classifica-

tion of the landscape, in the surrounding of the rivers, based on topography reflects its probability of being flooded, and thus, reflects hazard. We will make the assumption clearer. We are currently reproducing the entire work using a 20m resolution DEM that has a vertical accuracy ranging from zero to 10m for more than 90% of the entire country (Natural resources Canada, 2013; Beaulieu and Clavet, 2009). Information on metadata and errors will be provided at relevant locations. Therefore, the reliability of the DEM is not a question and, in general, does not affect the validity of the approach and the assumption that flood hazard can be inferred from landscape topography. Others have related flood hazard maps to topography, e.g. Lugeri et al. (2010), which is cited in our manuscript. As this approach can be followed using any elevation dataset, readers could reproduce these maps with improved accuracy in the presence of more accurate and finer DEMs/DTMs. Statements mentioning the vertical accuracy and its implications on the flood hazard map will also be included in the revised manuscript.

4. Page 9 – the authors state “horizontal distance” from nearest drainage network. What is this exactly? Are the authors referring to a buffer like distance? If so, why not just create a buffer? A “horizontal distance” makes no sense in a GIS context, the authors must be careful with their terminology and provide greater detail. For example, in the definition of EAND, the authors intention I suspect is the nearest drainage cell, or point on the drainage network defined by the ArcGIS. But if a point is equally distant from two drainage points, how is the choice made? Details like this should be noted as well as metadata information, errors in the data, etc.

R4. We are referring to a buffer like distance while describing DFND. However, in GIS, the term “buffer” is usually applied to concentric distances to a feature (line, point or polygon) in vector format. For the present study, the stream network was retained in raster format to maintain consistency in all subsequent calculations. Horizontal distance refers to the Euclidean distance between the drainage cells and adjoining cells that are estimated using the “Euclidean distance” tool in ArcGIS, followed by reclassification using the limits mentioned in Table 1. Hence, the word “buffer” was avoided

and “horizontal distance” used instead. The term horizontal was used as this measure considers only the distance and not the elevation difference between the drainage cells and the adjoining cells. The reviewer is right that in EAND, the elevations to the nearest drainage cell is estimated as described in section 3.1. Additional metadata information on the DEM and errors, as well additional details to clarify the procedure, will be included in the revised manuscript.

5. Page 9 – line 2 – the authors state that they developed a drainage network as the river network from the ARCGIS tools. Even with a filled DEM, etc, as the authors report, it is well known that a river network derived from a topographic map can often deviate from the actual river network because of errors in the DEM. Given the scale of the DEM used and the size of many of the rivers in Canada, it is possible for drainage points on the DEM derived drainage network not to coincide with actual river locations. Surely this is a problem so why wouldn’t the authors use the actual river network for Canada or at least correct their product for actual rivers?

R5. Some of the Reviewer’s concerns will be addressed when we present everything using the 20 m DEM. Even the river network made available through Environment and Climate Change Canada (ECCC) is generated using DEMs, and seems to be based on even coarser DEM than 20 m. We used Google Earth to compare the river network we generated against actual rivers, and the comparison, which validates our approach, will be presented in our Response letter.

6. One of the reasons why the authors went with such a resolution was because they felt that it made the problem tractable but with “reasonable” detail. But because of the large expanse of this country with little population, there are large areas of the maps with no interest because there are no urban areas. Page 12 refers to Table 2, which shows that the percentage of Canada covered with land use 4 and 5 is less than 6%. The nightlights confirm the enormous area with little population and therefore, with little interest in products like this. It makes me wonder why the authors would create a product that covers all of Canada. Why not create a higher resolution produce that

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just focuses on urban areas and simply cut out all the rest? The authors state how problematic political borders are to watershed management. Well then why not create products in only the most hazardous areas? Why not eliminate all the region that is of no interest and not display them? Instead we get maps of the entire extent which has a lot of information that does not have to be displayed or provided. Because the authors rely on visual representation of their work, these visual representations are all that can be critiqued.

R6. We respectfully disagree with the Reviewer as this suggestion contradicts the purpose of our work. Several municipalities attempt to model or use consultants to hydraulically model the few kilometers river reaches that pass through urban areas, but the bigger picture of an entire province or Basin is missing. Development of new areas is moving fast in Canada and encroaching into flood hazard areas is happening (as we presented the case of Fort McMurray) because such areas were not modeled as they were not populated! The flood hazard map indicates that larger areas of Canada are in significantly high flood hazard areas, but the vulnerability is, of course, centered around urban areas. There is a difference, and we need to highlight hazard areas to help planning and future developments, and also indicate the flood hazards in agricultural areas, important heritage areas, vulnerable ecosystems,..etc. It is not just about urban centres.

7. In Table 3, the percentage of areas covered by high and very high luminosity is tiny in comparison to the rest of the country. The nightlight DN value between 0 and 63 with resolution of one is now descritized into five classes each separated with the same value – one. The authors lump DN values from 11 to 63 for medium to very high luminosity in three out of five classes. Why not instead descretize those regions of interest (medium to very high) into five classes because ultimately you create a skewed product (when you multiply this five level classification with another five level classification scheme) that ignores the detailed information (nightlight, population, land use) and distribution that resides within the two most important classes. In doing this,

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the authors relegate two whole classes out of five for the bulk of the country that is of no interest. It would make more sense for the authors to focus in on the regions of interest and have five maybe 10 levels of classification within areas of interest. Why did the authors choose five levels of classification and not two, or four or 10?

R7. We believe this is related to the earlier point of focusing on smaller urbanized part of Canada or doing the entire country. Our choice and preference is the latter, but other researchers are free to take our approach and focus on any area they prefer.

8. The risk product combines a 326 metre resolution DEM with a 30 arc second DEM. At the Canadian-US border this resolution is probably around 600 metres. So what merging algorithm did the authors use when combining two grids of differing resolutions? What is the ultimate resolution of their product?

R8. Only one DEM (326m resolution) was used in the preparation of risk map for the entire country. The 30 arc second resolution corresponds to the Nightlight dataset that was used to prepare the exposure map. The nightlight images were resampled to match the resolution of the DEM within the entire study area and the final risk map was produced by combining the hazard and exposure map. The final product was a risk map of 326 m resolution itself. For further clarity, a description on the resolution of the derived maps will be provided in the revised manuscript. 9. Page 13 lines 14 - 15, the authors state that “airports and industrial and commercial areas are highly luminous but the census data show low or no population”. Floods create numerous environmental hazards that are equally as lethal as is the potential for floods to drown people. If that is what the flood exposure map is about – human harm, then I would argue, it is incorrect to negate the potential human health risk associated with flood waters having moved through an industrial site simply because no one is living there at night. Flood waters in urban areas are more polluted than sewage and carry harmful hazardous waste that can be extremely harmful if people are exposed. The authors ignore this and simply acknowledge residential areas. This is the general problem I have with this approach.

R9. We agree, we just wanted to show that census data showing zero population do not mean no human presence. There is still capital investment. Human lives are disturbed at a different level when homes are impacted, more than having a place of work impacted, but certainly human harm could still happen in industrial areas. We think that a statement about this in the revised manuscript will address the issue.

10. There are too many figures and few that are actually useful. Figure 1 really is not very useful. If you really want to use up valuable journal paper space then why not superimpose (a) and (b)? I would just remove (a).

R10. Sure, this can be done.

11. I would appreciate better attention to semantics. For example, on line 13 page 6. How is sufficient defined here by Apel or the authors?

R11. Sure, it is subjective term that relates to “acceptable” level of accuracy and representation. Different users and uses dictate different levels of acceptability.

12. Page 14 refers to Figure 2. Again (a) and (b) are both not necessary – just have (b). Figure 3’s caption should be revised to read “resulting from EAND X DFND” because this is not a flood hazard map but a map of that index. The topographic index defined by the authors contributes to one kind of flooding but there are others that are equally as hazardous that are not well represented. British Columbia suffers from severe flash flooding that moves enormous amounts of debris yet there seem to be few hazards associated with this type of flooding that is mostly in mountanous regimes showing up in the map because of the way the authors have chosen their index. Can the authors comment on the universality of their choice in Canada? The authors clearly state early in their paper that extreme flooding in Canada is the result of many factors like ice jams, etc. This is very true and thus, the index defined by the authors cannot in fact be toted as a flood hazard by virtue of the fact that what leads to sudden high streamflow – the really danger - is not simply a flat area close to a stream bank. But if that’s what the authors want to create, that’s okay but then it requires a good discussion of

why the approach is novel for defining a flood plain and what the benefits are (like computational ease), then they need to report the computational cost of creating these maps and report a quantitative comparison with things like the 1/100 year flood plain map in Calgary. Figure 5 refereed to on page 15 shows areas of overlap between the product and the flood plain map. This is again qualitative. A more quantitative comparison is required with even something simply like number of grid cells overlapped versus not overlapped to start with.

R12. Figure 2 (a) and (b) help the readers see the difference that reclassification into 5 classes cause to the map. As discussed earlier, we disagree on the issue of Hazard definition. The issue of debris from the mountain can be just another index added to Hazard based on proximity to erodible mountains in the headwaters. The issue of ice jamming is true as a cause of flooding, but inundated areas first impacted are the lowlands and lands close to the stream, we cannot see how ice jams negates the universality of our proposed hazard index.

13. This brings me to my next point. Large municipal urban centres already have information on high flood risk regions. What information does this product bring them that they don't already have at a better resolution? Risk of fire is largely a problem when it starts encroaching on an urban area and not generally at the same time as a flood risk so how can this low resolution product be helpful to Calgary?

R13. We believe that we addressed this point earlier, and also in the manuscript. What an approach like this brings is different. This approach helps prioritize areas for detailed modeling, help development planning, and other studies such as investigation various population groups and their vulnerability to certain hazards, which is useful for resource allocation.

14. The discussion is lacking in many regards in this paper particularly where figures are produced. Page 16 for example refers to figure 6 but honestly, there is nothing really discussed or noted of significance here. Figure 7 is too coarse a resolution to be

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useful. Figure 8 is an “enlarged” version of an area for better visual interpretation but if they don’t provide the exact area in space (not just with hatchmarks but perhaps with an areal photo showing the flood plain in the area) it is not a useful figure. This figure also has little discussion.

R14. We believe that enough discussion is provided for Figure 6 and others. However, we will attempt to expand on figure discussion a bit in the revised manuscript.

15. The authors don’t provide a rigorous enough evaluation of their product at this stage. In Figure 10, the authors refer to reduced levels of social risk for commercial regions. Again I disagree with this but perhaps this is due to a lack of rigerous definitions on the part of the authors as to what is “social” – human residential impairment? The authors should revise all their captions to state what is truly shown. Also, there were numerous areal photos of flooded regions within Calgary during the 2013 floods. Why not use this valuable information to compare to their product? That would be a much better evaluation and would demonstrate the deficiencies and limitations of the product in an actual flood that was not 1 in 100 but with an extent that was outside the 1/100 year flood plain.

R15. The issue of population in residential and commercial/industrial areas was discussed earlier. We compared with 100-year flood modeling in Calgary because a georeferenced map was made available to us, and the hydraulic modeling is supposed to be the “accurate and scientific” way of mapping flood inundation. Therefore, enough information is available to perform a validation of our results. However, we also managed to obtain a high resolution aerial phot of the 2013 flood in the Qu’Appelle River Basin, which is one of the most challenging areas in Canada for hydrologic and hydraulic modeling – the Canadian Prairies. We compared our product with this photo and the results are very good, and we will show this in our response letter and perhaps in the revised manuscript. We thank the reviewer for bringing this up because it gave us the opportunity to conduct another compelling validation of our approach and product.

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16. Page 17: line 17, the authors refer to the “average” effect. Why would they be integrated in the first place? Why is “average” in quotes? My point is that this work is really a GIS exercise and the GIS community understands the issues and limitations with combining data of different resolutions, etc., yet I’m concerned with the lack of attention to terminology or basic GIS concepts used in the discussion. A more formal language is preferred along with greater detail on what was actually created and how.

R16. Simply what we meant is that integrating two aspects in one can mask the individual effects. Sometimes integration is a must, and we did it, for example, with EAND and DFND, but in case of effect on population we wanted it to be explicit, that’s all! As suggested, additional details on the GIS-related analysis will be provided at relevant locations in the results and discussion sections in the revised manuscript. We agree that the application of the work is basically a GIS exercise, which however makes use of an innovative idea.

17. I really do think products like these are good ideas but it’s not just what is novel that must be shown but how it is useful and why it is needed. Unfortunately, I do not feel that the reader is given a full understanding of how this approach or product is useful. There is some attempt but more depth is needed. For example, on page 18, line 15, the authors state: “In other regions, and depending on the topography, the 100 year flood might cover two or three of the flood hazard classes.” I don’t mean to sound curt but so what? How is this useful to a planner that is required by most by-laws to deal with the 100 year flood or design with the 5, 10 or 30 year flood in Canada? Typographical errors: Line 13, Page 6 – insert “data” after “remotely sensed” Page 8 – insert “an” or “the” before “eight” Page 11 – line 9 replace “from” with “for” Page 32: Spelling eerror in the caption of Figure 8 (should be severe not sever)

R17. We believe that our approach is indeed presenting an original contribution, and we also believe that it is extremely useful. It allows the identification of critical areas, where subsequent detailed analyses should focus on. For example, local authorities may want relate flows at different flood frequencies (e.g., 100 year) to water stage (can

be done using rating curves available locally). The stage of different floods will indicate clearly which of our hazard classes will be inundated. This way local authorities can convert our map to flood frequencies. We will better explain in the revised manuscript the practical advantages that an extensive and quick mapping of risk may provide for local management and decision making.

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