Dear Reviewer,

Many thanks for your thorough review and the constructive comments on our work. We are happy that you found the results to be interesting and relevant, and that you suggest the manuscript to be considered for publication.

Your comments were very helpful for further improving our paper, and we are happy to address each comment in the revised manuscript. Below, we reply to each specific remark and discuss how they will be incorporated in the revised manuscript.

Comment:
[However], since the monetary valuation of the building stock and the implications of the analysis for risk financing play a key role in the paper, the issue and the methodologies of the assessment of building/property values deserve more attention. Property values can be assessed by their (re)construction costs (in prices of a specified reference year), their market value (which are driven by local demands, not only costs) or their depreciated value (i.e. the construction and maintenance costs minus the loss in value due to utilization). A discussion about these different concepts and their implication for the results and conclusions is completely missing and should be added in the revised version. This is especially important, since different insurance systems use different concepts in their compensation payments. In the US, for example, compensation of flood damage is based on depreciated values (to my knowledge), in Switzerland and Germany it is based on replacement/repair costs. The question is whether the results of the analysis and their implications for risk financing would differ if different valuation concepts were used. The relevant literature should be added in the introduction and the implications should be discussed in the discussion and conclusions sections.

Reply:
We agree with the reviewer that acknowledging the different types of valuation of assets (i.e. replacement values, depreciated values, market values) is crucial when quantifying potential damages from flooding. In this paper, however, we do not attempt to quantify potential damages nor the expected insurance pay-outs. Instead, we mainly look at *trends* in exposure in flood prone versus non flood prone areas, in which case absolute exposure values are less important.

As we discuss in the paper, the value of a specific property is largely based on the selling price of similar properties in the direct vicinity. This thus represents the market value of the property. According to earlier studies (e.g. Botzen et al (2009b) and Bin et al. (2008)), this property market value is strongly related to the expected flood damage and is therefore a good proxy to be used in insurance-related studies. The underlying reasons for this could be that people who can afford an expensive house tend to have more expensive interiors, better quality materials and more valuable content (e.g. electronics). Since this would lead to higher damages in case of a flood, insurance premiums tend to take into account the value of both the structure and contents (see Bin et al. (2008) for an extensive analysis for the United States)
Another benefit of using selling prices is the fact that these partly result from location preferences of people, and therefore may reflect risk perception (Bosker et al., 2013). This is important for the current study, and this would not be clear when using replacement or repair values. We agree that we should include some lines on this topic and explain what the values discussed represent exactly. We now added the following lines in the revised Section 3.2.2:

> "The WOZ values are market values, and are similar to the full replacement value of the properties, excluding contents. The availability of these detailed property market values has two main advantages for this study. First, the market values are strongly related to potential damage and thus potential insurance claims (Bin et al., 2008; Botzen et al., 2009b). This could be caused by the fact that people who can afford an expensive house, tend to have more expensive interiors and possessions (e.g. expensive floors and electronics) as well. Second, the values partly result from location preferences of buyers, and may therefore reflect their perception of flood risk (Bosker et al., 2013)."

Comment (aggregation of three individual comments):
Furthermore, the relevant literature on disaggregation of property values as well as other studies that analyzed asset development in- and outside of the floodplains should be better considered and discussed. […] Further remark to the introduction: There is at least one study that shows that settlement development in flood-prone areas is NOT stronger than outside the floodplains (Cammerer & Thieken, 2013). You might find more. […]Section 3.2.2: see my comments above on the monetary valuation of buildings. Obviously, market values are used in this data base. I am wondering whether this approach is reasonable for discussions on risk financing, since compensation payments are either based on construction/repair costs or on depreciated values. Demand on the market and its effect on selling prices of buildings is something different.

Reply:
We are aware of three studies that looked at development of assets in flood prone and non-flood prone areas. De Moel et al (2011) have done this for The Netherlands; Jongman et al (2012) on a global scale; and the reviewer now pointed us at Cammerer & Thieken (2013), who have analyzed this for Austria. We agree with the reviewer that both De Moel et al (2011) and Cammerer & Thieken (2013) should be better discussed alongside the results presented here. Also, for supporting the differences in findings between different areas, we thought it would be important to mention literature with respect to the 'levee effect', which may be part of the explanation. We added the following paragraph in Section 4.1.1:

> "[On a national level, we found that the growth of property stock in flood prone areas has been larger than growth in not flood prone areas.] This is in line with earlier findings of De Moel et al (2011), who used historical geographical maps to show that urban expansion rates in flood plains are greater than urban expansion rates in non-flood prone areas. This trend, however, is not visible in all regions. In Austria for example, asset growth in flood prone areas has been slower than in areas not prone to flooding (Cammerer & Thieken, 2013). A possible explanation could be that the higher flood protection standards, and thus lower flood probabilities, in the Netherlands have resulted in a stronger sense of safety and thus relatively more development in flood prone areas (the so-called 'levee effect', see Di Baldassarre et al. (2009); Lane et al. (2011); Husby et al. (2014))."

We also added some lines to the discussion of results (Section 4) and the conclusions (Section 5) that relate to the issue of valuation and the limitations of our results - see the responses to later reviewer

comments for this. As for the discussion on the use of market values, we refer to the answer to the previous remark (see above).

Comment:
The title should make clear that the data are solely from the Netherlands. I suggest: “Financing increasing flood risk: evidence from the Netherlands”.

Reply:
Suggestion adopted: we reconsidered the title of the paper, and suggest to change it to *“Increasing flood exposure in the Netherlands: implications for risk financing”*

Comment:
p. 139, lines 11-14: The referenced paper by Kreibich et al. (2005) does not provide risk estimates at the local scale, nor are hazard and exposure models combined in that paper. You could refer to the studies of Apel et al. (2009) and Wünsch et al. (2009) that were published by the same research team. The full references are provided at the end of this text.

Reply:
We agree that Kreibich et al (2005) is not the most appropriate reference at this point. We replaced this citation as suggested by Apel et al (2009).

Comment:
p. 140, line 18: Please outline the Dutch safety standards in more detail. To my knowledge there are clear regulations (1250-year flood at Lobith for inland rivers (at least for the Rhine) and 10000-year events along the coast).

Reply:
Yes there are clear regulations. There are also maps outlining these safety standards, see for example Wesselink et al (2013). The protection standards along the rivers range from 1/250 to 1/1,250, and along the coastal sections from 1/4,000 to 1/10,000. We now improved the description of the safety standards to make it clearer.

> Originally:
> “Over time, flood protection measures have been implemented in several steps, offering safety levels for flood occurrences with probabilities ranging between 1/250 to 1/10000yr. These safety levels are based on population density and potential hazard intensity.”

Revised:
"Over time, upgrades of flood protection measures have been implemented in several steps. The current safety levels, measured in terms of the exceedance probability of floods the defenses are designed to withstand, range from 1/250 to 1/1,1250yr along the main rivers, and 1/4,000 to 1/10,000yr along the coasts (Wesselink et al., 2013). Flood protection standards are generally higher in areas with high population density and potential losses (Kind et al., 2013)."

Comment:
p.141, line 11-13: In Germany and Austria, governmental compensation payments are also financed by tax revenues. Reconsider your statement.

Reply:
We now changed this:

Originally:
"The Netherlands is the only country in Europe with an ex-post legal arrangement, in which the government pays compensation from general tax revenues (De Vries, 1998)."

Revised:
"In the Netherlands, ex-post compensation payments to cover flood losses follow a legal arrangement, and are financed by the government from general tax revenues (De Vries, 1998)."

Comment:
p. 142, Section 2.3: There is relevant literature on the comparison of different flood insurance systems, which should be considered in this Section, e.g. von Ungern-Sternberg (2004) or Schwarze et al. (2011).

Reply:
Yes, there is an extensive literature base on flood insurance systems in use throughout Europe. We do not aim to describe these, or compare them to the Dutch situation, but we agree it would be good to include a statement about this. We now included the following in Section 2.3:

"A variety of different flood insurance schemes are in use throughout Europe. These include private insurance systems, public-private partnerships and full public compensation schemes. For a discussion on these different practices, see Botzen et al (2013); Schwarze et al. (2011); and Paudel et al. (2012)."

Comment:
p. 143, Section 2.4, line 12-15: To overcome these limitations, unit values could be adapted/scaled in accordance with the regional GDP or another economic parameter.

Reply:
Indeed, we agree that GDP-scaling could be used as a proxy to control for the economic value of buildings. However, it does not correct for changes in density. Jongman et al. (2012) show that urban areas that are assigned to the same general land-use classification (e.g. 'high density residential area') can still have vastly different densities of buildings. This affects risk assessment using aggregated land-use data.

Following this suggestion of the reviewer, we now removed '..and economic value…' in the revised manuscript.

Comment:
p. 144, line 9-11: The definition of the zone "outer dike" is not totally clear. I was wondering whether properties in this zone were also affected in 1953, 1993 or 1995.

Reply:
Indeed, this intuition is correct. We see that this may not have been fully clear. In the revised manuscript, we now added a clear definition of 'outer dike areas' in line 123 – 126:

> "In addition to this, an estimated 115,000 people are currently living in so called 'outer dike' areas, which are the areas between the water and the embankments and which are thus more prone to flooding (De Graaf and Veerdonk, 2012)."

To improve the clarity regarding the overlap between hazard zones, we now added the following in Section 3.1:

> "[There is a degree of overlap between hazard zones 1, 2 and 3 (Table I)], which results from the fact that some areas that are classified as 'outer dike' were also flooded in 1953 or 1993/1995."

Comment:
p. 144, line 17: The proper status (i.e. a date/year of compilation) should be provided for the flood depth map.

Reply:
The Risk map was published in 2008. We now added this specifically in the relevant line, and also added the webpage to the citation in the References Section.

Comment:
p.144, line 22-26: These sentences were not clear to me. How valid is the assumption on constant hazard zones? Were there no changes in protection levels of embankments etc.?

Reply:
In this paper we assume that the flood hazard maps as presented have remained unchanged over the period of analysis. This assumption is valid because the hazard maps present the potential inundation if the embankments would fail. Over time, the protection levels have been upgraded, meaning that the probability that this potential inundation actually takes place is decreased. However, we can expect that the potential inundation area itself has not changed much. Some things might have slightly changed, such as the elevation in areas where the soil is declining due to water drainage, but the effect of this on inundation extents will be local and relatively minor.

Comment:
p. 145, line 6: “these” instaed of “this”

Reply:
Accepted and changed.

Comment:
p. 145, line 9: I suggest using “building use” instead of “building function”.

Reply:
This has been changed on each occurrence of ‘building function’.

Comment:
p. 145, line 9: How is the “surface area” defined or calculated?

Reply:
It is the total floor space of the property. We now added that explicitly in this line.

Comment:
p. 146, line 15-17: It is not clear how different building types (single homes, multi-family houses etc.) are distinguished during the data processing.

Reply:
This distinction was not made. The property values (WOZ values) are not available for individual properties, but for blocks of 100m x 100m. As such, the average value of each 100m x 100m grid cell was assigned to each property. For most areas this assumption will be fair. Some grid cells may contain different types of homes that are likely to have different values, but we did not have this information, and therefore we did not make a distinction.

Comment:
p.147, line 13: Does "the average value per square meter" refer to the floor space (usable area) or the base area (= surface area?)?

Reply:
It refers to floor space. We now added this explicitly to Sections 3.3.2 and 4.2.

Comment:
p.147, line 26 to p.148, line 2: This test protocol should be mentioned earlier.

Reply:
The respective line reads "Third, we estimated trends in exposed economic value using the estimated property value for 2011, assuming that relative property values are geographically distributed similarly between 1960 and 2011". We agree this could have been mentioned earlier, and now added this to the revised Section 3.3.1.

Comment:
p.148, line 20-25: Are there any explanations for this trend?

Reply:
Yes, as mentioned in the responses to earlier questions, we have added a new paragraph to this section. In this section we now discuss how these findings relate to conclusions from previous studies, and provide a potential explanation (the levee effect). The new section reads as follows:

> "On a national level, we found that the growth of property stock in flood prone areas has been larger than growth in not flood prone areas. This is in line with earlier findings of De Moel et al (2011), who used historical geographical maps to show that urban expansion rates in flood

plains supersedes urban development in non-flood prone areas. This trend, however, is not visible in all geographies. In Austria for example, asset growth in flood prone areas has been slower than in areas not prone to flooding (Cammerer & Thieken, 2013). A possible explanation could be that the higher flood protection standards, and thus lower flood probabilities, in the Netherlands have resulted in a stronger sense of safety and thus relatively more development in flood prone areas (the so-called 'levee effect', see Di Baldassarre et al. (2009); Lane et al. (2011))."

Comment:
p.149, line 11-16: You could simply calculate the number of buildings per km^2 to get an idea of the building density.

Reply:
Yes, calculating the number of buildings per km2 would give an indication of the building density. However, the point here was to compare building-level data with existing aggregated land-use data, which is why the comparison with De Moel et al (2011) was presented.

Comment:
p.150, line 11-12: Here, the question arises whether the analysis should be better performed per province, not on the national level. Maybe rural areas are overrepresented in the non-flood prone areas. At least, you should discuss this issue or consider the introduction of a kind of normalization with regard to the proportion of rural/urban areas.

Reply:
Thanks for the suggestion. The scope of the present paper is to analyze trends in absolute and relative flood exposure, and to discuss what the implications are for current and potential future risk financing schemes. The data shows that the share of properties and property value located in flood prone areas is increasing over time, as more buildings are added in those areas than in non-flood prone areas. In the last part of Section 4.1.2, we give some possible explanation why this trend may have occurred. However, in the Dutch (and international) flood insurance and compensation schemes, premiums and pay-outs are the same for buildings in rural and urban areas. Further exploring the reasons behind the trends we present here is not within the current scope of the paper, but would indeed be interesting for future studies to pick up.

Comment:
p. 153, line 15-29: In these paragraphs the concepts of market valuation and replacement values/costs are definitely mixed up. Please clarify.

Reply:
In this section, we discuss how the increasing share of total property value that is located in flood prone areas, may influence the feasibility and sustainability of risk financing schemes in The Netherlands. The underlying assumption here, is that high property values are linked to high potential risk, and thus to high insurance premiums. This is shown to be realistic in earlier studies (e.g. Bin et al., 2008; Botzen et al., 2009b). However, we agree that we should put more emphasis on this, and explain the limitations of this approach as well. We have now added some lines that discuss this in Section 3.2.2 (Real estate values); Section 3.3.3 (Assumptions and limitations); and to the first paragraph of Section 4.3 (Implications for flood risk financing). For this, see our replies to the earlier comments on this paper.

Comment:
General remark on Sections 4 and 5: Discuss also the limitations of your results as well as their transferability to other countries/systems. In addition, the government is also responsible for flood protection, not only for compensation payments. The relation between the level of protection and risk financing should deserve more attention

Reply:
We agree that the relation between the level of protection and risk financing is important. We mentioned this in the original manuscript at the end of Section 4.3, but we have now extended this and added an explicit comparison to the situation in the United Kingdom:

> "In the United Kingdom, similar concerns have led to a 'gentlemen's agreement' between government and the insurance sector, in which the government agreed to keep investing in flood protection to secure affordable insurance for everyone at risk (Surminski and Eldridge, 2014). In the Netherlands too, the government will have an important role in maintaining an affordable flood risk financing system in The Netherlands, either in a public or private insurance system."

To further elaborate on the limitations of the results, we extended Section 3.3.3 ('Assumptions and limitations') on the basis of previous remarks of the reviewer, and we added a new paragraph to Section 5 in which we describe some limitations and calling for more research on these issues:

> "We have also identified a number of limitations to the methodology developed in this study (see Section 3.3.3). The trend analysis is conducted on a national scale, whereby a stable hazard level is assumed and market values of properties are used as a proxy for financial losses. Future research should focus on improving the understanding of the drivers of these risk trends on a national and sub-national level, and on the accurate assessment of the effects of these trends on the affordability of insurance premiums."

References

Bin, O., Kruse, J. B. and Landry, C. E.. Flood Hazards, Insurance Rates, and Amenities: Evidence From the Coastal Housing Market. Journal of Risk and Insurance, 75: 63–82. doi: 10.1111/j.1539-6975.2007.00248.x, 2008

Botzen, W. J. W., J. C. J. H. Aerts, and J. C. J. M. Van Den Bergh. Dependence of flood risk perceptions on socioeconomic and objective risk factors. Water Resources Research 45, no. 10, 2009b.