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Uncertainty in Mapping Climate Change-Related Flooding Risk to Residential Property Values

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Abstract:

As reported in the latest Intergovernmental Panel on Climate Change (IPCC) assessment, climate change scenarios anticipate a broad spectrum of plausible societal and climatic futures with a common theme that Climate Change-Related Flooding Hazards (CCRFH) in coastal areas will become more frequent through the 21st century and beyond (Fox-Kemper et al, 2021). In quantifying which coastal land may become affected and the related risk to residential property values, spatial and non-spatial factors need to be accounted for (in bold in Fig. 1), each contributing to the net uncertainty. There are relatively few studies that examine uncertainties and their sources, in this context (e.g. Fu et al 2019).

When modelling flooding associated with sea level rise, there are many other sources of uncertainty relating to hazard model architecture choices. One of the primary sources of such uncertainty is, spatially, the resolution of the Digital Elevation Model (DEM) that represents the land that could be flooded in a GIS. Other architectural choices that act as sources of uncertainty include the choice of flooding threshold, for example, set to either Mean Sea Level (MSL) or the average of the spring high tide (i.e. Mean High Water Springs - MHWS). Hydrogeologically, the infiltration and influence of groundwater can be modelled using numerical, empirical or simplistic elevation-based "bathtub" models. Finally, when determining property risk, there is a range of potential damage functions that can be used to estimate the dollar value of property loss that depend on the architecture choices (elevation model source, resolution, inundation model and flooding threshold) and Sea Level Rise (SLR) scenario outlined above.

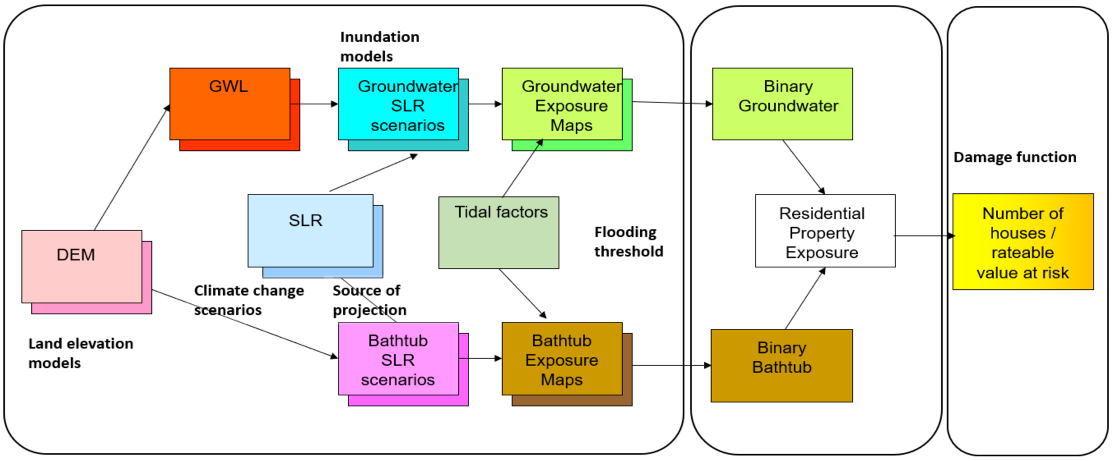

Figure 1. Process flow for calculating Climate Change-Related Flooding Hazards (CCRFH) to Residential Property Values, with sources of uncertainty highlighted in bold (GWL = Ground Water Level).

An uncertainty analysis of CCRFH on property values was carried out as part of the STRAND interdisciplinary project (funded by the Royal Society of New Zealand from 2021 to 2024 - https://blogs.otago.ac.nz/strandproject/). Figure 1 depicts the adopted modelling process flow, adapted to the South Dunedin city area – one of the more vulnerable areas in New Zealand to rising groundwater due to SLR. The sources of uncertainty implied in Figure 1 are explicitly represented in Figure 2, with the major choices and alternatives listed for scenarios and architecture choices (other sources of data uncertainty are also highlighted but earmarked for future analysis). It is important to identify and minimise sources of reducible uncertainty in such modelling endeavours so that effective policies to mitigate the risk can be formed.

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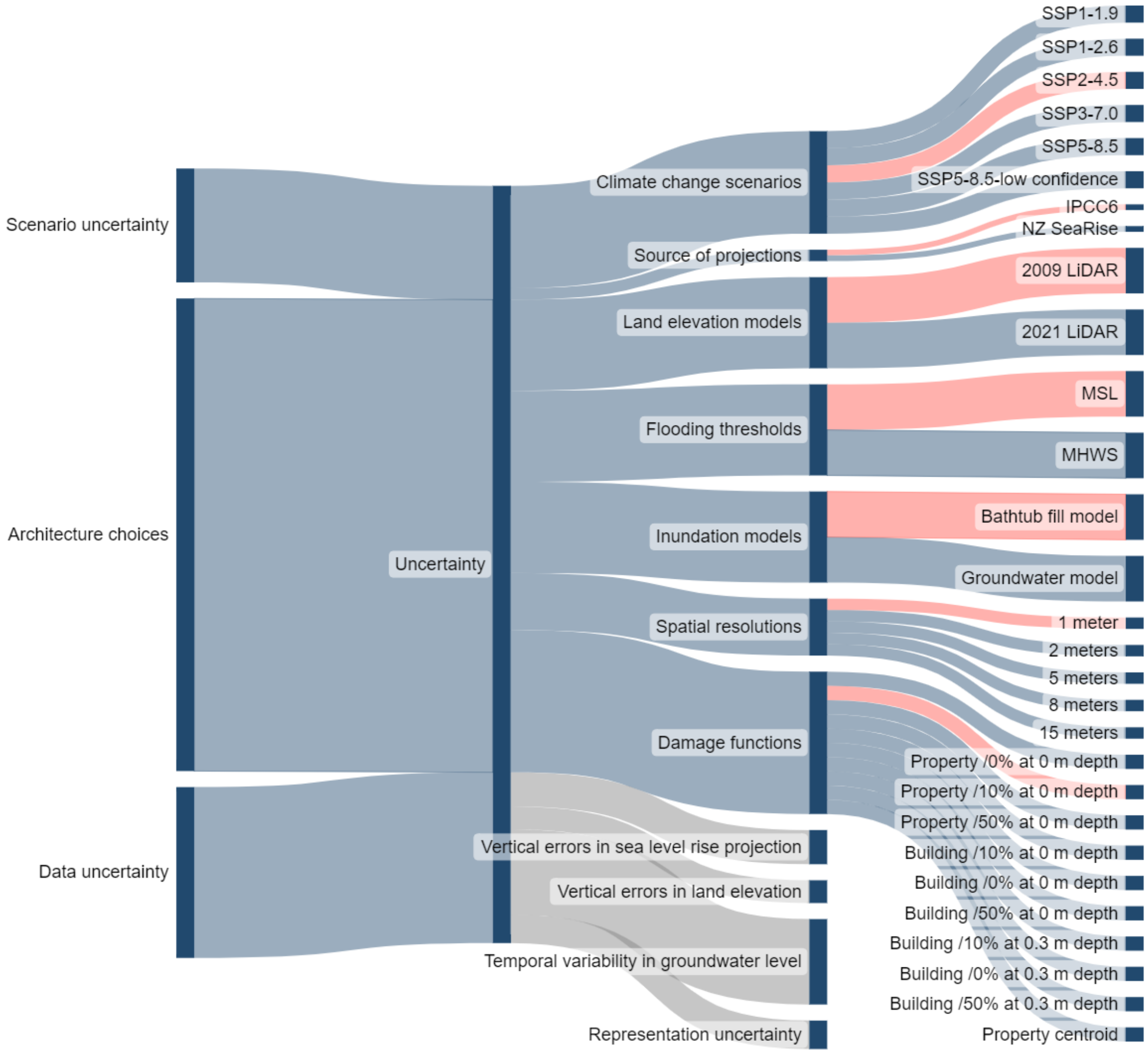

Figure 2. Sankey diagram of uncertainty groups, specific sources of uncertainty and alternatives tested for the South Dunedin case study (relative to baseline options highlighted in red).

It was found that large cumulative uncertainties were generated for the case study area, with an increase in the magnitude of uncertainty, accelerating into the second half of this century. Within the modelled uncertainty, architecture choices dominate over scenario choice. The spatial differences (extent and distribution) of flooding risks were particularly pronounced with the choice of hydrogeological model (empirical observation-based groundwater vs elevation-based bathtub model architecture). Most interesting is the non-linear relationship between the rate of SLR and flooding risk, with the relative prominence of different uncertainty choices changing over time. Therefore, the narrative of a given property, as it progresses from being seldomly flooded (<1% likelihood/year) to being occasionally flooded (~5%/year) to being very frequently flooded (20%/year) to being essentially permanently inundated (>90%/year), is complex as it may be affected by varying sources of uncertainty throughout its timeline.

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