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Has the Hundred-Year Flood had its day?

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Figure 1: Flooding on the mid-north coast of NSW. The definition of flood events by return periods in years can often lead to an under-appreciation of the risk posed to stakeholders. Source: The Guardian (2021).

The ongoing flood event impacting, in particular, the mid-north coast of NSW, has led some to call this a "hundred year" or "generational" flood event. However, describing extreme floods in this way – as the probability of an event happening in a given timeframe – is common but potentially misleading. It often leaves us asking the question – why are we getting so many 100-year events?

The 100-year hazard event is often used as a planning and structural design benchmark for a range of natural perils, most notably for inland and coastal flooding and erosion. It is a term that provides a sense of security to those behind levees or a seawall, as it implies an unlikely occurrence of this type of event, or bigger, in our lifetime. It also suggests that if we *were* unfortunate enough to experience this type of event, then we won't be due another for at least the next 100 years. Both of these concepts are fundamentally wrong and lead to a malaise in risk awareness and preparedness.

Here we argue that there needs to be more done to better communicate these risks to stakeholders, and perhaps start talking about these probabilities through a different lens. Indeed, basing land use planning policies on the probability of an event alone ignores the possible consequences of the risk and instead should be risk based considering both probability and consequence, expressed using Annual Exceedance Probabilities (AEP) of specified hazard levels.

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The chance of a 100-year flood is not 100 % in 100 years

The term ‘1-in-100-years’ implies a degree of certainty that we can expect an event of this magnitude, or larger, to occur every 100 years. By this reasoning, the occurrence probability of the 100 RP (return period) event over a 100-year period should be close to 100 %. This, however, is not the case.

The real probability of experiencing the 100-year flood in any given 100-year period is roughly 63% (when modelled using a Poisson or binomial distribution). And indeed, there may be some 100-year periods in which we experience no floods of this magnitude, and others where multiple floods occur that exceed the nominal 100-year magnitude.

This is because the climate system is stochastic – i.e. semi-random. Extreme weather events can be modelled as a set of random, independent Poisson-distributed variables that describe the level of variance around a mean expectation of occurrence. In Figure 2, the expected occurrence of the 100-year flood has been simulated for one hundred separate 100-year time periods using Poisson random sampling. This could be viewed as 100 possibilities of how many 100-year floods (or larger) we may expect to get, all things being equal, over the next 100 years.

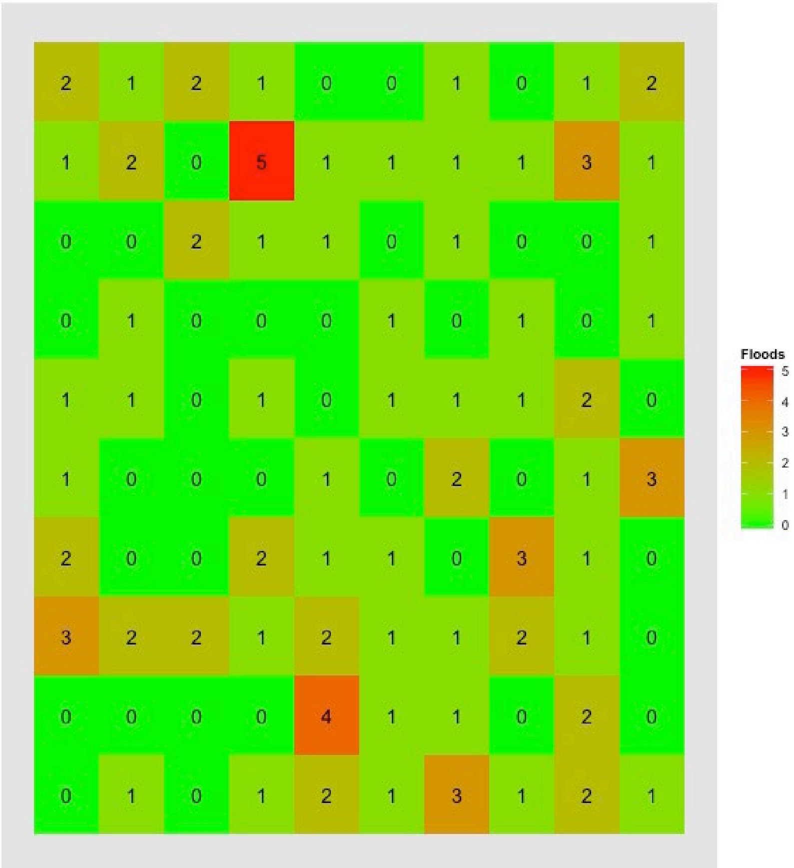

Figure 2. Simulation of the number of 100-year floods occurring in 100 (10 x 10), 100-year sequences. Source: tonyladson (2015).

As can be seen, most modelled runs of the next 100 years show there to be no or one exceedance of the 100-year flood – as to be expected, since we know that the average expectation of experiencing the 100-year flood in any 100 year period is around 63% (i.e. moderate). But we also see that it is perfectly possible to experience more than one, 100-year event in 100 years. In the modelled ensemble, we can see that some 100-year periods experience the 100-year event four, or even, five times.

Importantly, there is no auto-regressive aspect to this; in other words, the occurrence of a 100-year flood event in one 100-year period does not lessen or preclude the probability of a 100-year flood or greater occurring in the subsequent 100-year period. The same goes for a 10-year flood in a 10-year period, or a 5 year flood over 5 years. To generalise, if you've experienced a large natural hazard event yesterday, it doesn't necessarily lessen the chance of you experiencing the same or higher magnitude event tomorrow. You're not safe for another 100 years if you've just been flooded by the 100-year event today.

A shifting baseline

The above example shows that on a wholly statistical basis, there is a range of possibilities of how many times we may expect to experience the 100-year event in 100 years.

However, this assumes a static baseline, or 'stationarity'. Unfortunately, our relatively short observational record of natural hazard events, combined with interannual to multidecadal climate variability, means the climate baseline is highly non-stationary. For example, more cyclones and floods are generally expected during La Niña phases of El Niño Southern Oscillation and cold phases of the Pacific Decadal Oscillation (PDO), while bushfire risk is enhanced during positive phases of the Indian Ocean Dipole (IOD) and negative phases of the Southern Annular Model (SAM).

Climate variability basically means we can expect extreme weather events to be more clustered in time than with stochastic variability alone. So, depending on the background climate state, there may be a higher probability of experiencing two or more 10-year magnitude flood events in a 10-year period than might be expected from stochastic behaviour alone.

This is important for natural hazard risk management. The impact on a catchment of two flood events in quick succession, or the response of a beach to two closely-spaced storm events, is much larger than if the events are considered independently (as we show in Briefing Note 423 "How Many Storms Make a Big Storm?") as the antecedent conditions change.

Drawing a line in the sand (or mud)

The sense of security around the term "1-in-100-year event" is compounded by the inferred certainty of a 100-year flood map, or coastal erosion zone. The (rather large) uncertainties inherent in flood and coastal modelling are not adequately communicated by drawing static hazard extents.

In flood modelling, some of the largest uncertainties relate to the underlying digital terrain data. While resolutions are improving, the vertical error can still be on the order of metres. This means that even if every other element of the flood model is accurate, on a low-lying flood plain, the mapped extents of that flood may be erroneous by up to hundreds of metres.

By drawing a line in the sand (or mud) for a flood of a given probability level, we are implying a high degree of certainty that does not exist. In most cases, floods and coastal erosion zones are mapped for a range of probability levels (i.e. in the case of flood, up to the Probable Maximum Flood, PMF). However, if risk is only disclosed for a single probability level - for example when someone seeks information from a council before purchasing a property – there is the suggestion that flood risk outside of the disclosed flood/erosion zone is zero.

All models are wrong, but some are useful, as the saying goes. There is now a much-welcome move in both flood and coastal risk management towards a more probabilistic, rather than deterministic, representation of the hazard. In this way, for example, every area within a flood plain is assigned a probability of exceeding a certain flood depth within a given range of uncertainty, which more effectively gets the message across that residual risk exists outside of the planning benchmark.

The COVID effect

One advantage of the pandemic is that everyone has become a statistician, or at least exposed to statistics more than during normal times. This is a good thing for risk managers, and perhaps an opportune time to ramp up the discourse around the true meaning of natural hazard risk.

We have long argued for a move away from talking about natural hazard risk in terms of return periods and instead towards Annual Exceedance Probabilities (AEP). Communicating with stakeholders that they have a 2 % chance of being flooded in any given year, rather than that their property is within the 50-year flood zone, adds immediacy to the discourse that is often lost when talking in terms of annualised return periods. The move towards probabilistic risk mapping as opposed to 'drawing a line in the sand' is also a step in the right direction towards a better communication of natural hazard risk.