Coping with epistemic uncertainty in the design of engineered solutions to the mitigation of extreme events

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Engineered structures as a risk mitigation strategy

- Building resistance to:
  - Seismic shaking
  - Windstorm
  - Flood
- Coastal and river flood defences
- Coastal defences against tsunamis
- Dams and slope retention structures

Design of all of these requires an understanding of the temporal and spatial hazard intensity distribution at their locations, with emphasis on the maximum hazard intensity that they are expected to resist (according to regulatory requirements and/or corporate decision makers)

- Note comment from Tim Atkinson yesterday about disconnect between what needs to be done to run an airline safely, and what needs to be done to meet regulatory requirements

Extreme events are (usually) also rare events

- Occurrences of extreme hazard intensities at particular sites are usually rare events compared to occurrences of lesser hazard intensities
  - Extreme event magnitudes
  - Very local hazard sources
- Therefore, poorly represented by historic records with generally short lengths compared to extreme hazard intensity recurrence intervals
- Trend to reliance upon complex science and technology-based models of rare event occurrence (statistical, geological, theoretical-mechanistic ……)
  - Large extrapolations from data on smaller events, or long inference chains
  - Model-dependent results subject to change with advance of knowledge
  - Models may not be able to include all relevant data
- Therefore, large epistemic uncertainties and resulting risks are generated by choices made during the hazard analyses upon which engineered solutions to mitigation are dependent
- How do large organizations and institutions such as regulators cope with this uncertainty?

Certainty as an institution

"Certainty is not a mood, or a feeling, it is an institution: this is my thesis. **Certainty is only possible because doubt is blocked institutionally**: most individual decisions about risk are taken under pressure from institutions."

(Douglas, M (2001) Dealing with Uncertainty. Ethical Perspectives, 8(3))

[my emphasis]

Example: the Onagawa Nuclear Power Plant

Sanriku coast – 1896 tsunami

The 1896 tsunami was not included in the national assessment of tsunami hazard (??)

- Just predated earliest seismometers
- "Tsunami earthquake" with minimal seismic shaking onshore, but large tsunami
- Poorly defined seismic magnitude meant that it could not be included in the seismic catalogue that formed the basis of model for tsunami hazard in the national assessment
- Opportunity to recognize potential for extreme tsunami intensity in institutional hazard assessment missed

The importance of local knowledge

- Site senior engineer Yanosuke Hirai was from Sendai and knew about the 1896 tsunami from childhood
- Tsunami memorial stones at Onagawa recorded ~14 m runup at proposed site of NPP in 1896 tsunami
- Design for layout of Onagawa NPP therefore
  - **Ignored lower criterion indicated by national assessment**
  - Used simple criterion that all safety-critical systems should be on base above the elevation of the 1896 tsunami memorial stones
- Fortunately, inundation runup at NPP site in 2011 was no greater than in 1896
- Hence, Onagawa NPP did not suffer safety-critical damage from tsunami and was shut down safely
  - Only seawater intakes and plant for final loop of cooling system, plus other non-safety-critical systems needed for operation of plant, were damaged

Questions

- Where does the responsibility for critically assessing and allowing for uncertainties in institutional models lie?

- When and how should information that is hard to incorporate in the models be admitted to the decision-making process?

“The most appropriate counter to uncertainty is adaptability”

John Boyd, *A Discourse on Winning and Losing*