

# MULTI-HAZARD RISK ASSESSMENT FOR TONGATAPU - A COASTAL INUNDATION LENS

Edward Rowe, Arup, [ed.rowe@arup.com](mailto:ed.rowe@arup.com),  
Dougal Greer, eCoast, [d.greer@ecoast.co.nz](mailto:d.greer@ecoast.co.nz), Timothy Mote, Arup, [tim.mote@arup.com](mailto:tim.mote@arup.com).

## INTRODUCTION

A multi-hazard disaster risk assessment was undertaken for Tongatapu through the Asian Development Bank (ADB) on behalf of the Government of Tonga. This was to inform investments, urban planning and improvements to natural hazard resilience across the island (ADB, 2021). This paper presents the methodology and findings of the coastal inundation and sea level rise components and how these relate to other hazards assessed and the overarching risk assessment.

Due to its low elevation and flat topography, Tongatapu, and the Tongan capital of Nukualofa, are vulnerable to pluvial (surface) flooding associated with heavy rainfall and coastal flooding from extreme sea levels and cyclone induced storm surge. Similarly, Tongatapu is vulnerable to damaging winds associated with tropical cyclones, earthquakes particularly associated with the nearby Kermadec Tonga Trench, and tsunami inundation. The study assessed these hazards and considered the influence of climate change on intensity of rainfall and sea levels.

## PROJECT APPROACH

To establish the exposure of assets and infrastructure to hazards, a database was developed capturing location and characteristics of approximately 64,000 assets, including buildings as well as road, water and power assets across Tongatapu. Vulnerability functions were selected from existing literature or developed for the risk assessment to establish a relationship between damage and hazard intensity relative to each asset type with each hazard.

Integrating hazard intensities, exposure of assets and relative vulnerability of assets, direct financial loss was established as a representation of risk (Figure 1).



Figure 1 - risk, represented by direct financial losses, were calculated through a function of hazard intensity at the location of each asset in the exposure database and the vulnerability of the asset to damage relative to each hazard.

## COASTAL HAZARD

Storm tide was quantified to constitute coastal hazard around Tongatapu. The coastline was divided into 532-nodes where storm tide was calculated based on local conditions and morphological features as a function of wave setup, wind setup, tidal effects and the inverse

barometer effect. Intensity was quantified for Return Periods (RP) ranging from a 10-year RP through to a 1000-year RP. Coastal hazard model scenarios also considered sea level rise (SLR) scenarios of 0m, 0.5m, 1m and 2m. A further inundation scenario was also assessed for each of the SLR scenarios quantifying inundation for the highest astronomical tide (HAT).

## PLUVIAL FLOOD HAZARD

While not the focus of this paper, pluvial flood hazard was assessed independently and in conjunction with the coastal hazard. A hydrologic assessment was undertaken and informed a hydraulic model that characterised flooding hazards across Tongatapu. Coastal hazard was quantified at each of the 532 nodes to generate a water surface boundary condition around the island such that pluvial flood hazard could be assessed in conjunction with coastal inundation.

## COASTAL INUNDATION RISK

Direct financial losses were quantified in two parts:

- permanent loss - where assets were inundated by HAT (no storm surge) for each SLR scenario.
- Scenario loss - where financial loss was attributed to RPs. Annual Average Loss (AAL) was quantified.

Losses were attributed to sectors (Residential, Religion, Education, Health, etc.) as well as by asset class (buildings, power, water, roads) and were distributed at the village level to assist in the identification of vulnerable communities and the relative contribution of sectors or asset classes to financial losses. Coastal inundation risk was also assessed in conjunction with a range of pluvial flood RP scenarios.

AAL associated with coastal hazard was lower than that for pluvial flood, seismic and wind as, unlike these other hazards, exposure is limited to the coastal zone. Despite this, losses associated with SLR were more considerable, demonstrating that rises in sea levels will significantly increase coastal hazard risk. For example, with 0.5m of SLR permanent losses were assessed to be of similar magnitude to the scenario losses for a 200-year RP pluvial flooding event.

## RISK ASSESSMENT USE

The risk assessment has been used to inform response to the tsunamis associated with the eruption of Hunga Tonga-Hunga Ha'apai in January 2021, investment in the proposed Fanga'uta Lagoon Bridge and will inform the Climate and Disaster Resilient Urban Development Strategy and Investment Plan for Tongatapu.

## REFERENCES

Asian Development Bank. (2021): Multi-Hazard Disaster Risk Assessment, Tongatapu - Summary Report. [https://www.adb.org/sites/default/files/project-documents/50028/50028-001-tacr-en\\_19.pdf](https://www.adb.org/sites/default/files/project-documents/50028/50028-001-tacr-en_19.pdf).