3D NUMERICAL MODELLING OF FIVE SUBMARINE LANDSLIDE SCENARIOS IN PERTH CANYON, AUSTRALIA TO ASSESS TSUNAMIGENIC HAZARD

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INTRODUCTION

Submarine canyons have been identified on nearly all margins around the world (Urlaub et al., 2013). Their configuration and morphology has been attributed to several factors including geology, tectonism, sea-level variations, and sediment supply to the region (Laursen & Normark, 2002) with processes occurring over varying temporal and spatial scales driving complex morphologies (Drexler, et al., 2006). A common process in submarine canyons is the mass wasting of sediment in the form of submarine landslides (SMLS) (Brothers, et al., 2013). A SMLS is a displacement of sediment or debris driven by gravity where the downslope forces are greater than the forces that are acting to resist the mass-failures (Mountjoy & Micallef, 2018).

SMLSs pose a threat to coastal, oceanic, and seabed infrastructure and have been shown to be capable of triggering tsunami that can have more localised impacts than earthquake generated tsunami (Moore & Moore, 1984; Harbitz, et al., 2006; Masson, et al., 2006). Buller et al. (2021) identified five SMLS sites near the mouth of the Perth Canyon offshore Western Australia. These slides ranged in length from 1340 m to 7253 m, with average thickness ranging from 219 m to 363 m and volumes from 0.94 km^3 to 10.34 km^3.

The morphology of the western Australian margin is somewhat comparable to that of Australia's eastern margin; both margins are aseismic, passive margins, that are sediment starved and have little to none of the preconditioning factors associated with the extensive SMLSs observed (Boyd et al., 2004; Harris et al., 2005; Heap & Harris, 2008). However, compared to Australia's eastern margin, the south-west margin has relatively few geomorphic features (Heap & Harris, 2008). This makes the presence of SMLS along the margin curious and the Perth Canyon an interesting study region.

The potential tsunami hazard posed by these SMLS was assessed by Buller et al. (2021) using empirical calculations which showed that these SMLSs posed a tsunami threat to the adjacent coastline with calculated wave amplitudes ranging from 2.13 – 15.90 m. However, the tsunami risk assessed in their study was a conservative initial assessment and did not consider how local bathymetry influenced tsunami propagation.

3D NUMERICAL MODELLING

3D numerical modelling allows for further investigation of the tsunamigenic risks associated with these identified SMLS sites. This study achieved this using the two-layer extension of the open-source numerical code, Basilisk (Popinet, 2015). Basilisk has been extensively validated for tsunami modelling and benchmarked against real world tsunami events and is considered reliable for modelling tsunami generated from SMLS sources (Mollison, 2021). The model domain consisted of approximately 32,580km^2, including ~220 km of the west Australian coastline from Guilderton to Mandurah.

Four elevation data sets were used in all model domains: a 100 m resolution underlying dataset, a 40 m resolution bathymetry dataset of the Perth Canyon Marine Park, a 20 m resolution nearshore region dataset, and a 5 m resolution onshore digital elevation model. Model simulations were run for 150 minutes real world time, which was found to be sufficient to allow the modelled tsunami to impact the entire coastline within the model domain. The maximum output cell size for the modelling conducted in this study was 44 m. Modelling was conducted for the five potential SMLS scenarios identified in Buller et al. (2021).

RESULTS

This study demonstrated that all five scenarios produced a tsunami, with wave amplitudes up to ~ 4.25 m for the PCN4 slide scenario (Figure 1). Throughout the five models, wave velocities at the coastline ranged from 6.67 – 12.64 m/s with results showing that the PCN4 scenario produced the most severe impacts at the coastline. The most vulnerable areas across all models, were those south of Perth, primarily around Mandurah.

Inundation was calculated both including and excluding Rottnest and Garden Island. Inundation depths ≥ 0.1 m were considered inundated for the purpose of this study. Inundation was most prominent in areas to the south of Perth, including Rockingham, Mandurah and Avocet Island, where in PCN4, the barrier island is inundated entirely across the narrowest point. PCN4 resulted in the most extensive inundation, with more than 81.30 km^2 of inundation modelled, including areas on Rottnest Island and Garden Island with 75.32 km^2 of inundation on the mainland. The modelled that produced the least inundation, PCS, still resulted in inundation affecting over 20km^2.

The modelling conducted shows that the regions adjacent to the slides and to the north are experiencing a negative leading wave with less severe impacts. On the contrary, the areas to the south of the SMLSs are more likely to be impacted by a positive leading wave due to the slide orientations and the process of the sediment failure pushing downslope into the canyon in a southwest direction. The canyon therefore facilitates the propagation of the positive leading wave by allowing the positive leading wave to travel faster due to the depth of the canyon.

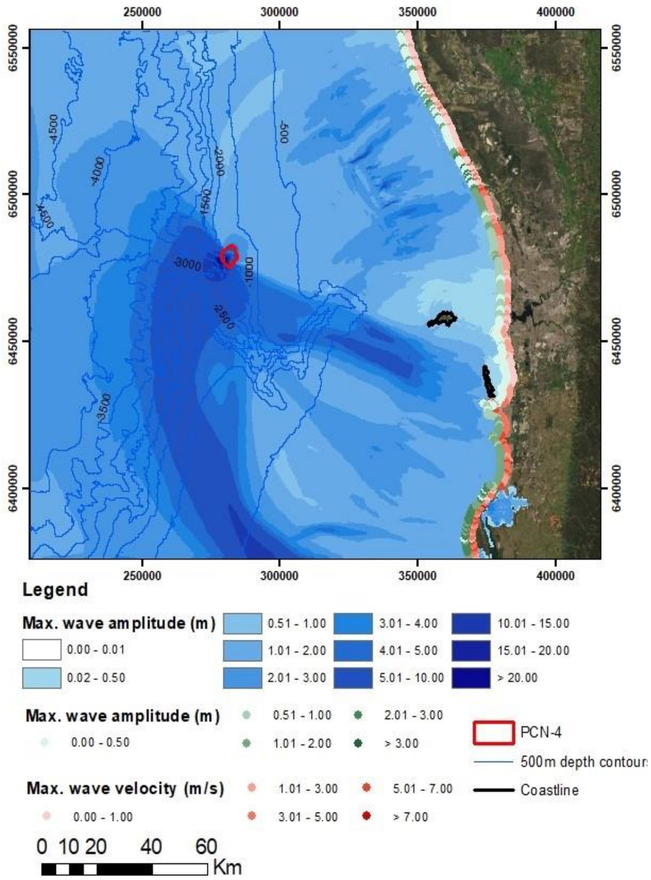

Figure 1 – PCN4 maximum wave amplitude and inundation 2.5 hours after initial failure.

Wave arrival times are approximately 60 minutes or less from time of sediment mass failure at all coastal sites. The arrival time at Shoalwater, a southern suburb of Perth, was as low as 45 minutes from initial failure which was modelled to experience a positive leading wave, hence offering no visible warning to the public of the hazard – a key concern when managing hazards such as these.

This study found that the SMLSs identified within the Perth canyon have tsunamigenic potential and identified arrival times at nearby coastlines, inundation extents, wave amplitudes, and water velocities at the coastline to provide a more accurate assessment of the hazard posed by these SMLSs. This study may be considered a foundational study of the two largest SMLSs within the canyon and the associated tsunami hazard but also highlights the need for site specific modelling in instances like these. Further modelling should be conducted to the south of Perth as the local bathymetry of the continental shelf and canyon heavily influences the wave propagation patterns.

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