5. Discussion

Inundation of six Northland communities from three tsunami scenarios at two different sea levels was modelled. The scenarios were a remote South American tsunami, representing the most probable tsunami risk facing Northland, and two regional events caused by subduction zone earthquakes in the Tonga-Kermadec Trench which generally represent worst case, local source tsunami risks for Northland. The scenarios were run with an undisturbed sea level equivalent to MHWS, in order to provide an estimate of the flooding if the arrival of the tsunami coincided with high tide. Scenarios were also run with an undisturbed sea level of MHWS + 50 cm, representing the 100 year projection for sea level rise as assessed by the IPCC Fourth Assessment Report (2007).

The remote South American tsunami is seen as the most probable event, with a return period on the order of 50 years. In general, for the communities considered here, this event poses the greatest risk. The most severe inundation for almost all communities occurred following the remote South American event. There is inundation predicted for Whangarei, Otaika, Oakleigh, Takahiwai, Marsden Cove and Whangarei Head. There is also appreciable tsunami risk along the shoreline and in low-lying areas close to rivers, estuaries and creeks along which a tsunami can propagate. Maximum current speeds exceeded 3 m s^{-1} near Whangarei Harbour mouth.

A tsunami from South America takes about 15 hours to reach New Zealand (Lane et al., 2007), sufficient time for contingency plans to be implemented, provided that early warning of the approaching wave is received.

The TKSZ scenarios produced less inundation than the South American event. The communities most at risk from the M_w 9.0 event were Marsden Cove, Takahiwai, Urquharts Bay, Waioneone Creek, Whangarei Port, Oakleigh, Otaika, Ocean Beach and Onerahi. Inundation depths were greater than 3 m in places, and maximum current speeds topped 5 m s^{-1} at Bream Head. The TKSZ M_w 8.5 event generally resulted in the least severe inundation for communities. The communities most at risk from these events were Marsden Cove, Takahiwai, Urquharts Bay, Waioneone Creek and Whangarei Port. Inundation depths were up to 3 m in places, and maximum current speeds were in the 0.5-1.5 m s^{-1} range. Tsunamis arising from TKSZ earthquakes take 70-80 minutes to reach Whangarei, providing much less time for local emergency teams to react.

It is notable that for Whangarei, the predicted impact of the remote South American tsunami event was worse than for TKSZ M_w 8.5 or TKSZ M_w 9.0, whereas for other areas modelled in this project in the past the TKSZ events caused greater inundation. The effect of tsunamis on coastal bays depends on the characteristics of the incoming wave, the physical characteristics of the bay, and the interaction between the two

(Walters and Goff, 2003). Coastal bays have a natural resonance period and length scale, so that if an incoming wave has similar characteristics, then large amplification of the incident wave can be expected i.e. the height of the wave at the coastline can be significantly greater than its height as it enters a bay. Resonance in some Northland coastal bays, therefore, will be triggered by the longer period, longer wavelength tsunamis arriving from South America, whereas in other bays the response to the shorter period, shorter wavelength waves arriving from the Tonga-Kermadec Trench will be stronger. The results here demonstrate that the amplitude of the incoming wave is not the only factor in determining the severity of the eventual impact.

In addition to inundating land areas, tsunamis elevate current speeds substantially above normal values for short periods of time and can, therefore, cause significant scouring and erosion in estuaries, beaches and dunes, and affect structures such as piers and bridges. The greatest maximum current speeds were produced by the M_w 9.0 TKSZ scenario which resulted in maximum speed exceeding 5 m s^{-1} at Bream Head.

The effect of sea level rise, when included in all the simulations, was generally to increase the extent and depth of inundation. The M_w 8.5 TKSZ scenario with 0.5 m sea level rise causes greater inundation than the South American Tsunami at the current MHWS level.

For the TKSZ events and the remote South American event maximum current speeds were similar for both sea levels.

Arrival times, in minutes after the source event, of the first wave and maximum water level for the South American and TKSZ scenarios were provided for French Island, Marsden Point, Takahiwai, Whangarei (Port), Otaika and Oakleigh. The Point (location supplied by NRC) at Hatea – Town Basin was unsuitable to use for calculating arrival times as it is only inundated in the M_w 9.0 TKSZ, and South American scenarios when sea level rise is incorporated. In addition, the level of inundation is very small making data and subsequent conclusions unclear. The point used for the presented Whangarei arrival time data is located at the port of Whangarei. The point is at the receiving edge of Whangarei Harbour, therefore, the presented times represent the minimum arrival times.

Water drainage from the Marsden Point refinery is channelled through a culvert leading from the Bercich Drain down to the shoreline in Bream Bay. The potential exists for this culvert to act as a conduit for tsunami to flood the refinery, despite the protection of the adjacent dunes. The current modelling study incorporated a virtual link between grid elements situated at either end of the culvert - thus, should sea level become elevated above the height of the culvert intake within the refinery, then water would be transported into the refinery. In the current study, water elevations due to the tsunami reached a maximum of about 3 m above MSL at the seaward end of the culvert; this was not adequate for water to emerge from the culvert into the refinery with the current model mesh configuration. However, due to the resolution of the model mesh around the culvert intake and outlet, we are unable to place high confidence in these predictions. In our view, a further study should be conducted, such as a dynamic model of the culvert analysing run-up, and with considerable refining of the model mesh around the culvert intake and outlet locations to allow better resolution of the local topography, and a more accurate calculation, therefore, of the flood risk.