6. Project Overview and Conclusions

In the course of this project, the potential impacts of tsunamis from three different sources on the Whangarei Harbour Region were considered. Detailed predictions of maximum onshore inundation and current speed for each event, at two different sea level heights, have been made for six locations in Whangarei Harbour. The modelling was performed using the general hydrodynamic model RiCOM.

The results presented here cover the likely range of tsunami that might be expected in Whangarei Harbour. Overall, the South American event caused the most inundation in Whangarei Harbour. The M_w 8.5 TKSZ event resulted in slightly less inundation than the M_w 9.0 TKSZ. Including 0.5 m of sea level increase resulted in more inundation from the TKSZ scenarios than the South American event at present-day MHWS. Tsunamis originating from South American subduction earthquakes have a return period of about 50-100 years. In contrast, the return period of large events from the TKSZ is estimated at about 500-2000 years (Lane et al., 2007; Goff, 2008). The resulting impacts of these higher frequency South American events are potentially much greater for Whangarei Harbour compared with other Northland areas and other scenarios from previous modelling. Past simulation results (Lane et al., 2007; Gillibrand et al, 2008) show that the lower frequency TKSZ events more severely impact the majority of Northland communities used in these simulations. However, the more likely South American event more severely inundates Whangarei Harbour.

Predicted wave heights at the coast from the South American tsunami exceed 3 m in many areas. Wave heights for the Tonga-Kermadec events reach up to a maximum of 3 m in fewer areas. These values could be exceeded in some localised areas.

Arrival times of the first wave for the Whangarei Harbour coast are about 85 minutes for tsunamis from the Tonga-Kermadec Trench, and about 15 hours for the South American event. The first wave may not necessarily be the largest; usually a series of large waves arrive over the course of the next few hours. The maximum water level can occur at any time during this period.

Predicted onshore inundation is highly variable between the six modelled locations, depending primarily on local submarine topography. Waves typically propagate up streams and creeks that discharge into the sea and could, therefore, penetrate considerable distances inland along these waterways. Settlements on tombolos and along the shores of estuaries are also typically at risk of flooding. Coastal roads may be inundated by these events, cutting off escape routes and impairing subsequent access.

6.1. Uncertainty of the Modelling Results

The physics of wave propagation are well understood, and the numerical treatment of the problem by RiCOM has been carefully developed over more than 20 years to ensure efficient and accurate simulation. However, the modelling performed here is dependent on, and, therefore, limited by numerous factors. In particular, the generation processes and initialisation of the tsunami for each earthquake source is based on theoretical analysis that is difficult to confirm by observation. Also, the simulation of inundation is strongly dependent on the quality of the LiDAR topographic data and the bathymetric data for adjacent inshore waters. Bathymetric data are often relatively sparse and of indeterminate quality, thus influencing the accuracy of modelled inundation water depths and speeds. This is true for the bathymetric data used for the modelled inundation presented here, adding to the uncertainty of the actual characteristics of inundation likely from an event equivalent to those modelled.

The greatest uncertainty in modelling tsunami impacts arises from the representation of the wave generation process. Regional source tsunamis generally arise from earthquakes along subsea faults, which are transformed into tsunamis using Okada's (1985) elastic dislocation model. Details of the rupture (e.g., fault rupture length, angle, movement, etc.) are entered into the model to derive a displacement of the seabed. This displacement acts as the initial condition for RiCOM simulations. Inevitably, however, there is considerable uncertainty over both the accuracy of the predicted seabed movement and the validity of the assumption that the seabed displacement translates directly to the sea surface. Nevertheless, Okada's (1985) model is widely used by tsunami modellers and remains an established tool.

Remote tsunamis generated in the Pacific to the west of South America are simulated as a series of solitary waves entering the eastern boundary of the model. The amplitude and period of the waves have been fitted against sea level data collected from Lyttelton Harbour following the 1960 Chilean earthquake and, as such, have been qualitatively validated. The model's predictions could be improved by modelling the propagation of the tsunami from source to inundation on a single, continuous, trans-Pacific computational grid, and research is currently focussed on achieving that goal.

Other uncertainties in the modelling study include sparse bathymetry data, particularly in the near-shore region, disjointed or mismatched topography and bathymetry data from different sources and spatial resolutions, and the representation of a continuous coastline by meshed cells, which can deform the true shape of bays and estuaries. The effects of building and land features on wave drag are largely unknown, but could substantially modify the onshore propagation of tsunamis. Improving the drag representation remains a goal of current research. Eradication of the other errors is constrained by limitations of data quality and the practicalities of grid resolution; models always represent an approximation of reality.

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 protection by adjacent dunes. The current modelling study incorporated a virtual link between grid elements situated at either end of the Bercich culvert. With the current model mesh configuration, water elevations due to tsunami will not cause water to emerge from the culvert into the refinery, unless they are greater than the height of the culvert intake (4.75 m above MSL). Further modelling with considerable refinement of the model mesh around the culvert intake and outlet locations to better resolve the local topography is advised. This refinement will result in an adjustment and improvement in the internal elevation calculations of the modelling software and allow a more accurate calculation of the inundation risk via this route.

This study focuses on the six areas of interest to Northland Regional Council, other areas of land have been excluded from this study to minimise the size of the model mesh. The coastline has been used as a boundary for the model mesh and creates an impenetrable barrier to fluid flow: except where land has been incorporated. Edge effects resulting from the modelling constraints may cause disparities at the edges of the areas of interest and where islands are missing or coarsely resolved in the model mesh. The results at these places are likely to have a larger error component.

Model uncertainty can be quantified by running multiple simulations with small variations in key parameters, an approach known as ensemble prediction or sensitivity analysis. Such an approach would provide an envelope of predicted solutions, rather than single "worst-case" or "scenario-type" predictions. However, running many simulations increases the computational and research costs, and, in any event, model forecasts can never be certain, because our knowledge of all the geophysical processes involved in tsunami generation, propagation and inundation remains incomplete.

Quantitative calibration of the tsunami inundation model against real measurements is difficult due to the uncertain nature of historical tsunami impact data from New Zealand and the consequent difficulty in identifying tsunami events from the past. Nevertheless, the RiCOM model has been continuously validated against standard analytical test cases (e.g., Walters and Casulli 1998; Walters 2005), and model predictions of run-up height have compared well to palaeotsunami data for the Bay of Plenty (Walters et al. 2006c) and along the Otago coastline (unpublished data).

Despite the inherent uncertainties in numerical modelling of tsunami impacts on New Zealand, we believe that the current modelling exercise provides the best possible estimate of inundation in Northland from remote and regionally sourced tsunamis available to date.