ASSET MANAGEMENT GROUP
Technical report

ISSN 1174 3085

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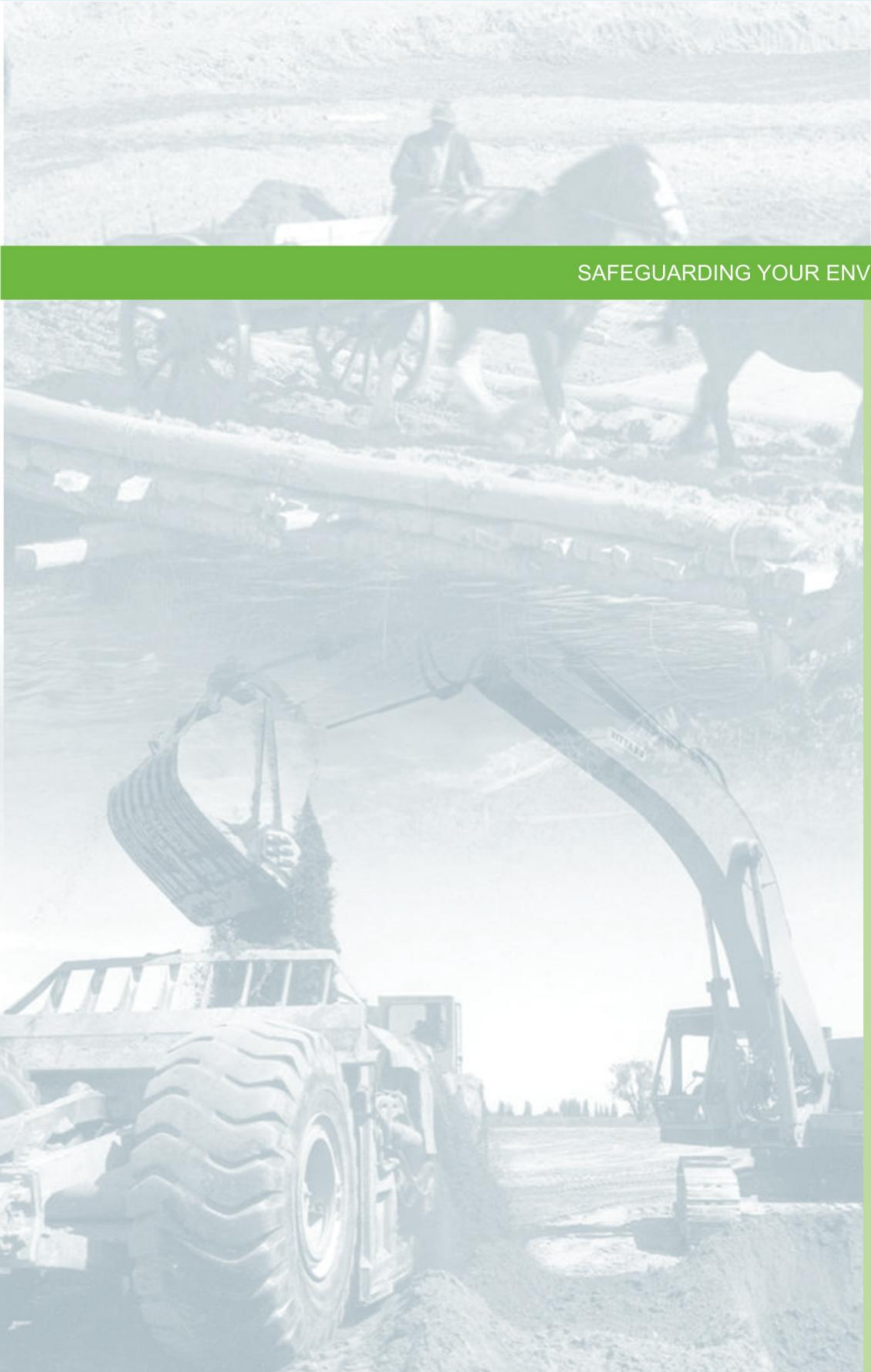

Taranaki Tsunami Inundation Analysis

**Prepared for
Taranaki Civil Defence
Emergency Management Group**

Final Version

**June 2012
AM 12/07
HBRC Plan Number 4362**

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Asset Management Group
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Engineering Section

Taranaki Tsunami Inundation Analysis

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1 Executive Summary

This report provides the results from a series of computer models which simulate Tsunami Inundation for the coast around Taranaki, from Tongaporutu to Patea. While most areas along this coast have steep headlands and are not susceptible to inundation, several communities are built in river estuaries or have coastal exposure, which carries some risk of inundation. These areas have been studied in this report.

The tsunami waves used in the model are based on the GNS report *Review of Tsunami Hazard and Risk in New Zealand* (Berryman, 2005), which indicates the wave heights for the Taranaki coastline to be approximately 2 m for a 500 year return period event, and 3 m for a 2500 year return period event. The 84th percentile envelope (1 standard deviation) for the 2500 year return period event includes a wave height up to 4.1 m. Using these wave heights as a guide, the present analysis includes simulations using 2 different wave heights, being 2 m and 4 m in height.

The results indicate there is very little infrastructure at risk from Tsunami inundation in the Taranaki Region. Most places have a steeply rising coastal area which prevents any significant inland inundation. In places where there are river estuaries, there are some houses, roads and infrastructure which are at risk. In particular, the communities of Tongaporutu, Urenui, Onaero, Waitara, New Plymouth, Oakura, Opunake, and Patea all have low lying areas which are at risk from inundation as a result of tsunami waves. Details of the inundation areas and infrastructure at risk are included in this report.

Output from the analysis is also provided as layers available to be used in a geographic information system. These layers may be used to assist in developing maps showing evacuation areas, in accordance with the Ministry of Civil Defence and Emergency Management guidelines.

2 Method of Analysis

A typical tsunami wave analysis usually includes a method of generating the offshore waves using a model which simulates underground movement of the earth (an earthquake or underwater landslide), which then causes the rapid rise or fall of the water surface, which then generates the series of waves commonly called Tsunami. The present analysis does not use any deformation of the sea bed, rather it uses predetermined wave heights (2 m and 4 m) applied to a 2-dimensional computer model of the local sea bed and coastal area. The computer models used were created with the 2-dimensional hydrodynamic modelling software Mike21-HD (Danish Hydraulic Institute).

Results from the computer models were then used to create three evacuation zones, according to the Ministry of Civil Defence and Emergency Management Guidelines (MCDEM 2008). The zones recommended by MCDEM are:

Red Zone: Shore exclusion zone that can be designated off limits in the event of any expected tsunami.

Orange Zone: Includes the area to be evacuated in most if not all distant and regional-source official warnings, from sources more than 1 hour of travel time.

Yellow Zone: Should cover all maximum credible tsunami, including the highest impact events.

These zones were applied at the study area locations described below.

3 Study Area

The area covered in this analysis is the coast administered by the Taranaki Civil Defence Emergency Management Group. The entire coast is susceptible to some degree of inundation from tsunami. For this analysis, areas where there was some population at risk, as well as having suitable data available for inundation studies were targeted. Five sections were identified as meeting these criteria, as shown in Figure 1. Areas between the study areas are also at risk from inundation, however, the absence of suitable data made inundations studies impractical. For these areas where no inundation study has taken place, a common sense approach should be utilised and the best action to take during an event is for people to move immediately to the nearest high ground, or as far inland as possible, as recommended by MCDEM. While this may not be easily translated to evacuation maps for planning purposes, it is applicable in cases where a local source tsunami occurs, and there is insufficient time for any official warning to be provided.

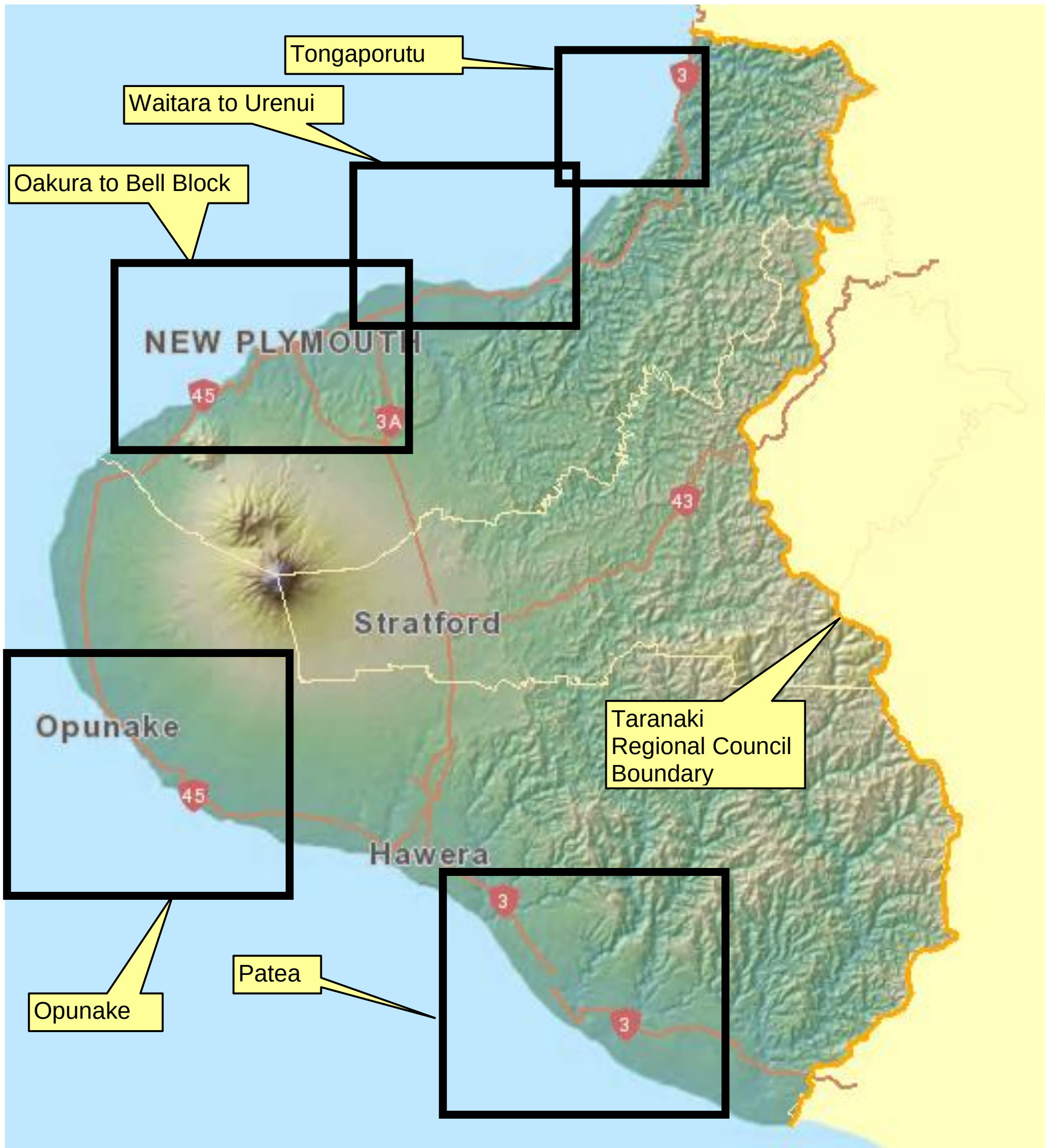

Figure 1: Study areas

A computer model was made for each of the study areas, with the tsunami waves being applied at the boundaries. Details of the models and results are presented below.

4 Model Details

Basic inputs to the 2D models consist of a digital elevation model (DEM) created using the onshore ground elevations as well as the offshore bathymetry. The water level which simulates the tsunami waves was applied at the seaward boundary of the model. Other parameters such as bed friction and eddy viscosity are involved in the model, however, the model results were found to be not sensitive to these parameters. A global bed roughness of n = 0.04 was applied to all models, along with an eddy viscosity of 10. These values were chosen based on similar models, and the sensitivity testing in this study.

In areas where inland inundation occurs up a river inlet, it was assumed that there was no significant flow in the river at the time of the tsunami inundation. In the unlikely event that a combined tsunami and major flood occurred simultaneously, the water levels in the river would be higher, although the return period associated with these combined events would be much greater than 2500 years. Since this study focusses on the impacts of tsunami, no river flooding was included in the modelling.

For all the models created for this project, one common input was the offshore bathymetry provided by Land Information New Zealand (Linz) (depth-contour polyline, 1:90k – 1:350k, and 1:350k to 1:1,500k), as shown in Figure 2.

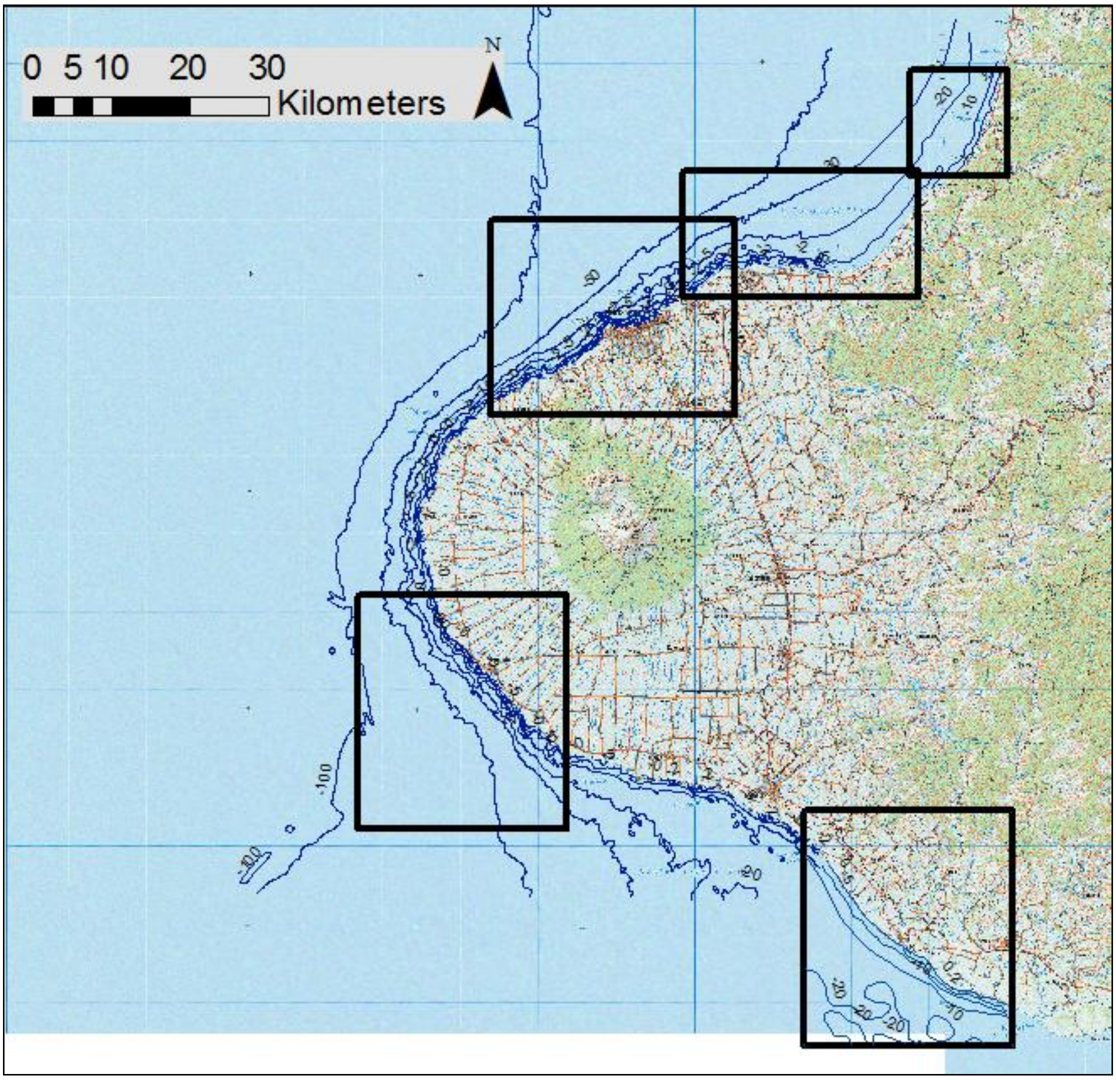

Figure 2: Offshore bathymetry used in models (source – Linz, 2012)

4.1 Wave Heights and Period

Berryman (2005) provides possible wave heights based on various earthquake scenarios for the entire coast of New Zealand. The wave height versus return period for New Plymouth (and the Taranaki Coast) is shown in Figure 3.

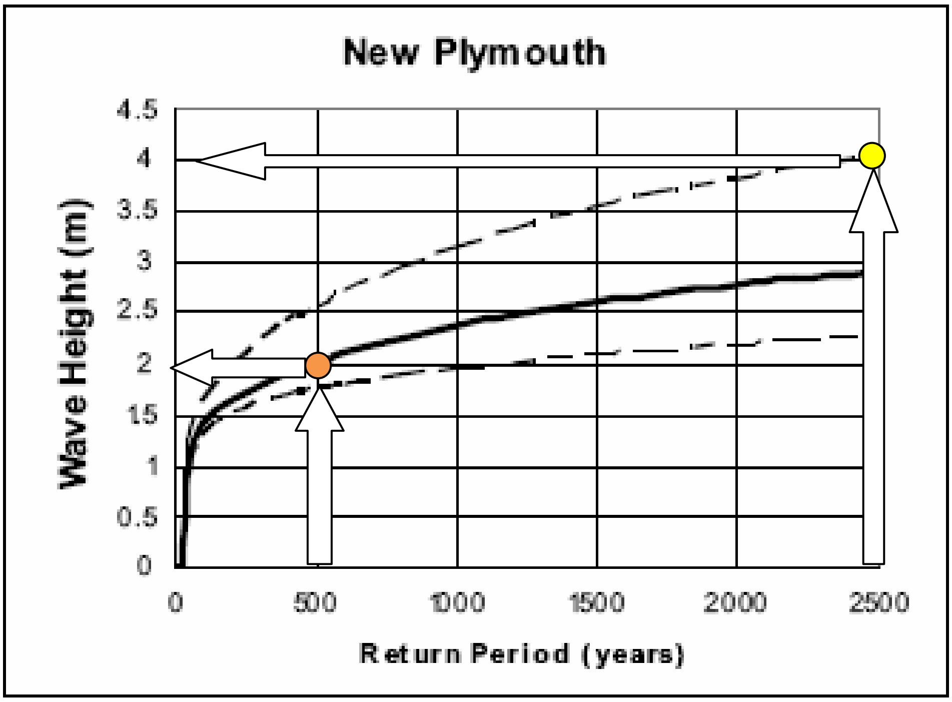

Figure 3: Tsunami Wave Height vs. Return Period for New Plymouth (Berryman, 2005)

Berryman emphasises the uncertainty in the results presented in the 2005 report since they are based on empirical relationships between earthquake size and tsunami height. The present analysis has taken the results of the Berryman study, and applied two wave heights of 2 m and 4 m (along with an appropriate wave period) to the boundary of the 2D model. These wave heights represent the 500 year average wave height (2 m), and an extreme case of the 2500 year return period (4 m).

For this study, the 2 m wave height corresponds to the orange evacuation zone and the 4 m wave height to the yellow evacuation zone, where the zones are defined in Section 2. In this study the extreme case of 4 m was applied (as opposed to the average wave height of 3 m for 2500 year return period) as a measure to take into account the uncertainty that exist in the development of the wave heights.

Tsunami waves normally consist of a series of waves which arrive in succession. For this study, a series of 5 waves were applied to each model, with the third wave being the largest. This largest wave was also set to occur at a normal high tide of 2 m. One set of waves was created for the 2 m model, and another set for the 4 m model. Terminology of tsunami wave heights is based on the Ministry of Civil Defence and Emergency Management (MCDEM, 2010) guidelines, as shown in Figure 4, where the wave height refers to the vertical distance between the highest wave crest and the lowest trough.

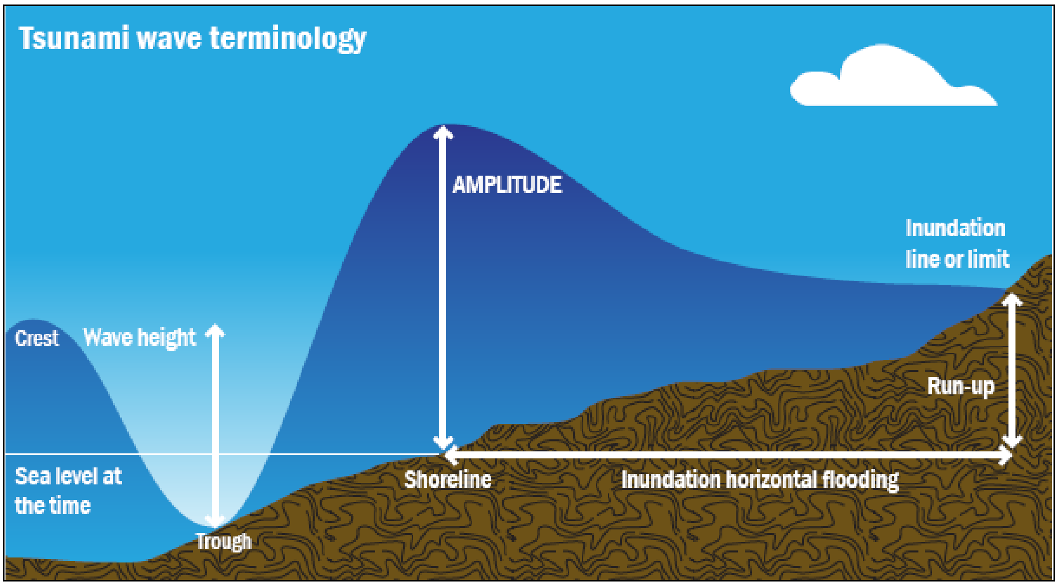

Figure 4: Tsunami Wave Terminology (MCDEM, 2010)

The wave patterns used in the models are shown in Figure 5.

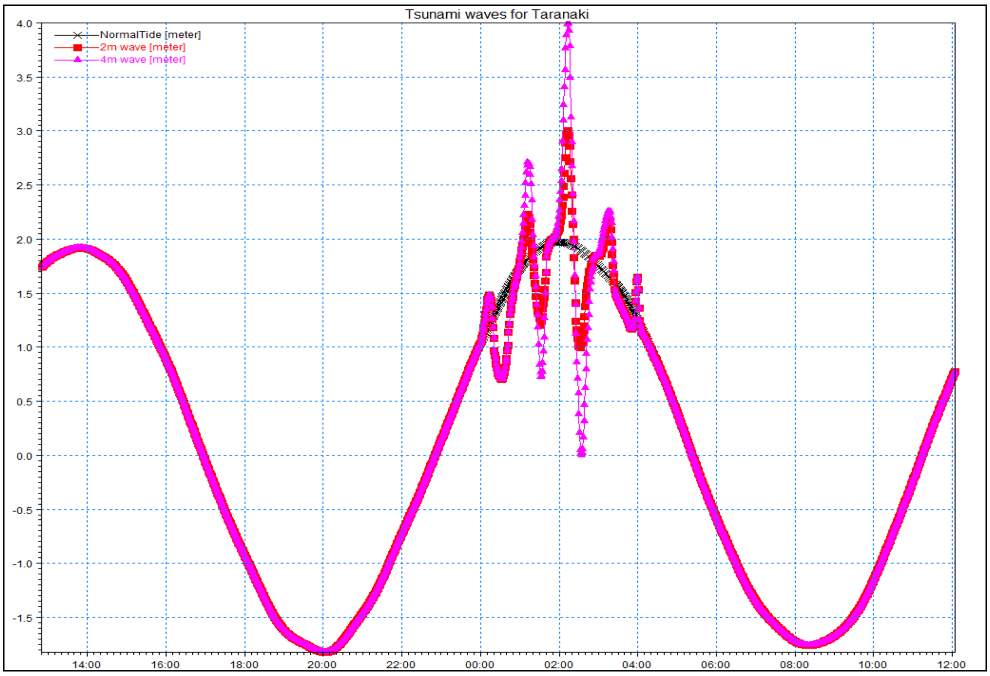

Figure 5: Tsunami Wave Patterns used in 2D model

Note that the 2 m wave rises 1 m above and falls 1 m below the normal high tide of 2 m, and the 4 m wave rises 2 m above and falls 2 m below the normal high tide of 2 m. The timing between the peak and the trough was set to 20 minutes. This was based on anecdotal evidence from recently occurring tsunami from Indonesia, Chile, Samoa and Japan. These waves were applied to the offshore boundary.

4.2 Tongaporutu Model Details and Results

The Tongaporutu study area is shown in Figure 6.

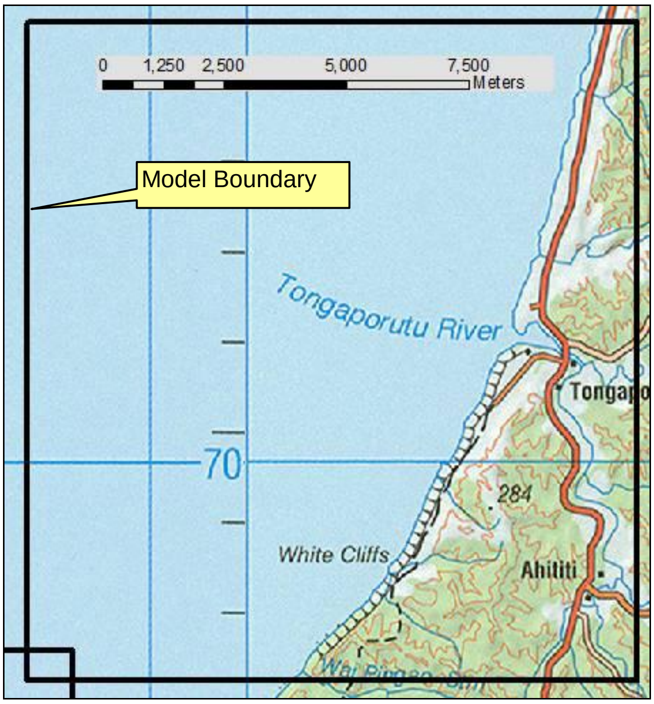

Figure 6: Tongaporutu study area

Details of the bathymetry and ground elevation data are shown in Figure 7.

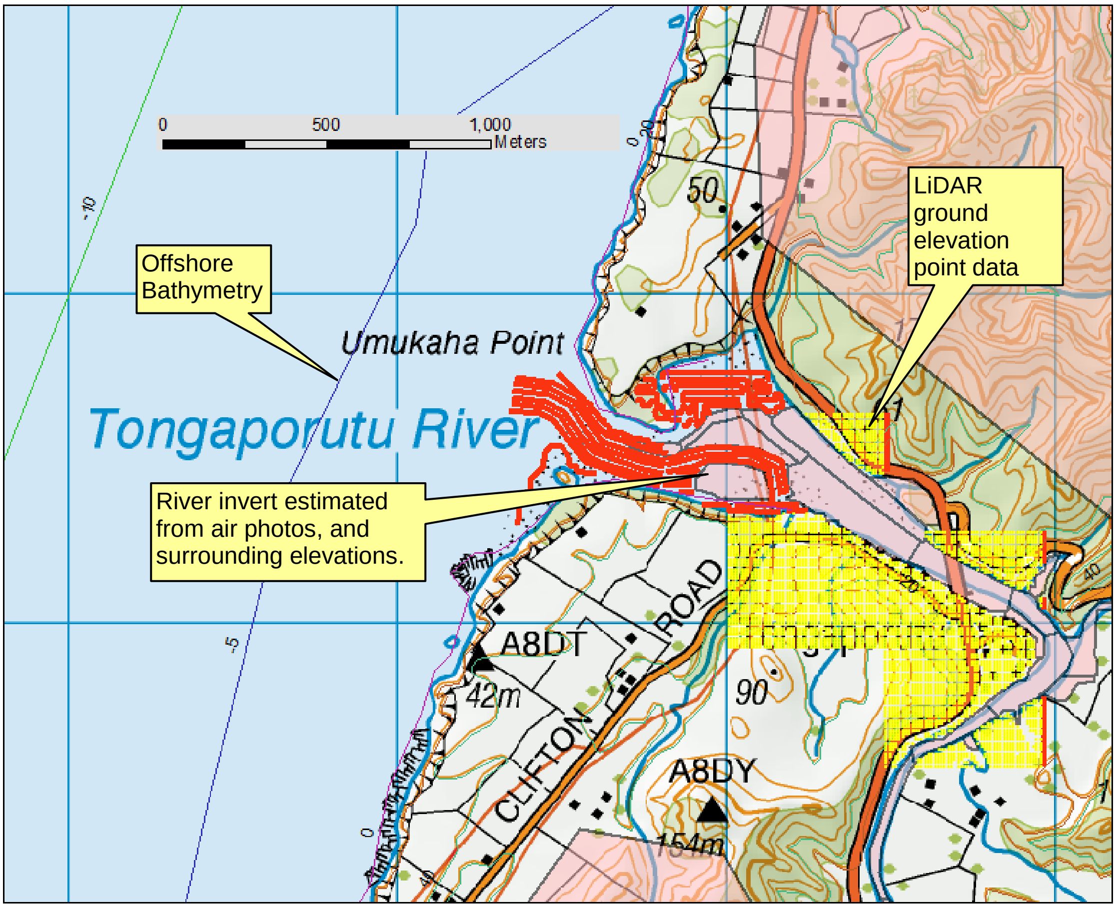

Figure 7: Details of Tongaporutu study area showing data sources

The LiDAR data was collected in 2010, and was provided by Taranaki Regional Council in a 10 m grid. Invert levels in the river were not available, however, estimates were made based on observations from air photos which show tidal areas with no vegetation, and deeper areas in mid river areas. The invert estimates were joined to the existing LiDAR data to check the validity. The significance of using estimates for the river inverts as opposed to obtaining accurate surveyed inverts was determined to be minor, since the waves that were being applied to the model were many times larger than the possible difference in model invert level from the true invert level.

The results from translating the computer model results to the evacuation zones are shown in Figure 8.

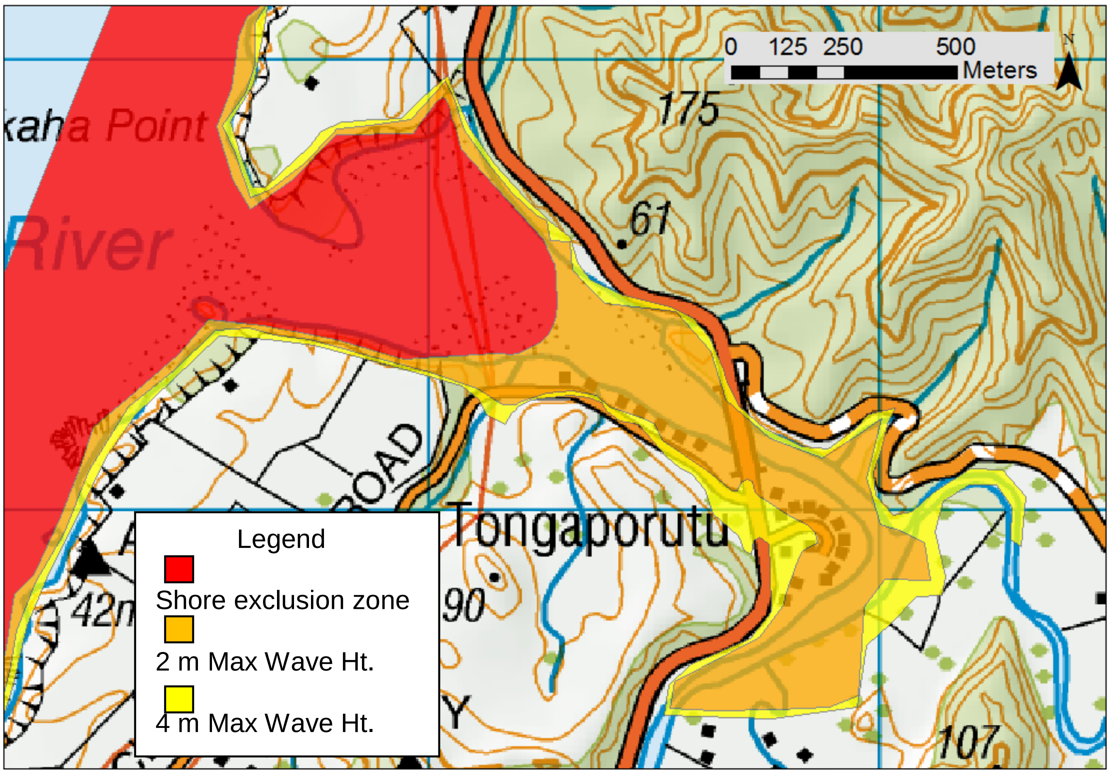

Figure 8: Tongaporutu Tsunami Evacuation Zones

The houses along the Tongaporutu River appear to be located relatively close to river's edge, and are only marginally above the high tide level. The results indicate the 2 m and 4 m waves inundate these areas.

4.3 Waitara to Urenui Model Details and Results

The study area is shown in Figure 9, and the data sources for Urenui and Onaero in Figure 10.

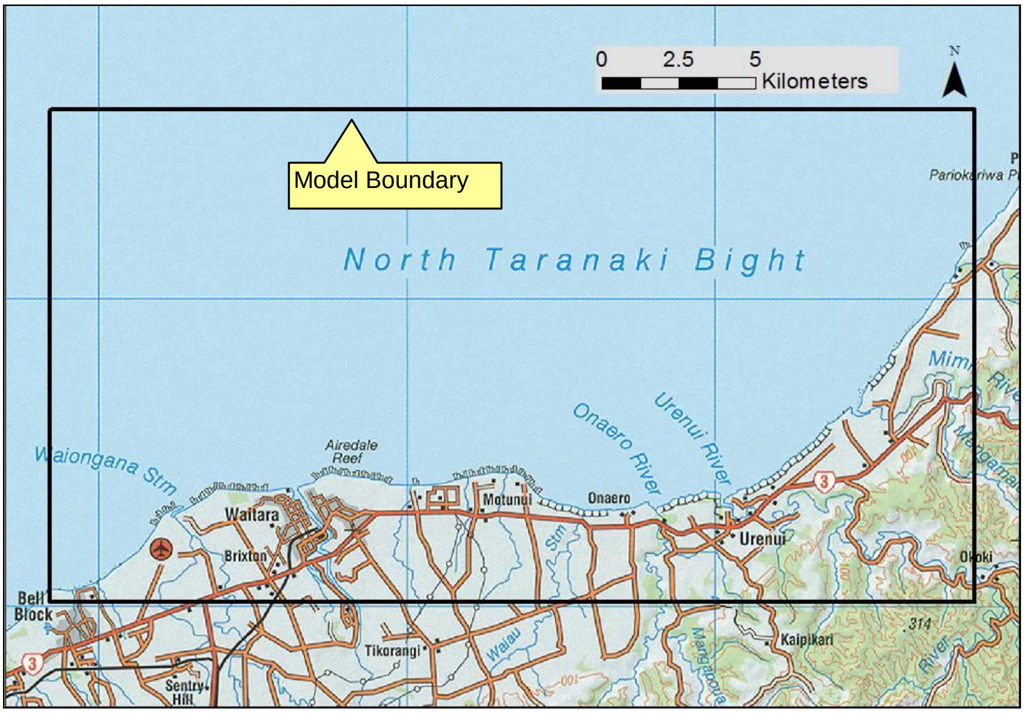

Figure 9: Waitara to Urenui study area

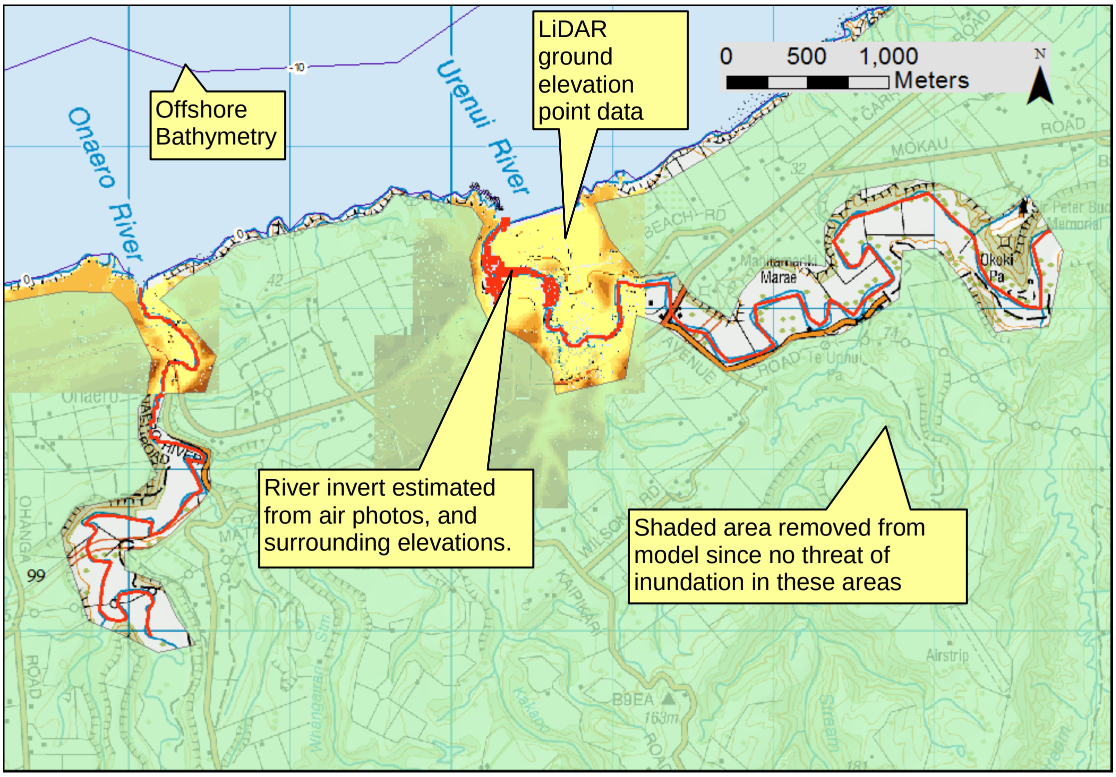

Figure 10: Details of Urenui and Onaero study area showing data sources

The evacuation zones for Urenui and Onaero are shown in Figure 11 and Figure 12.

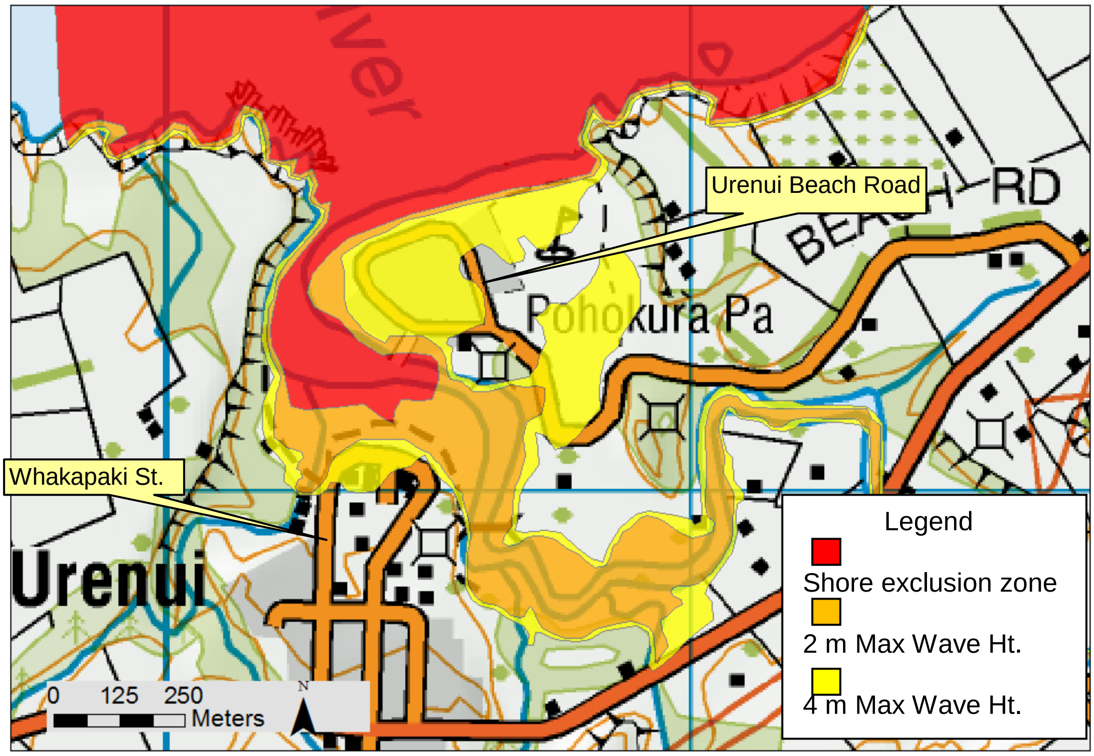

Figure 11: Urenui Tsunami Evacuation Zones

Results indicate the area of Urenui Beach Road and the end of Whakapaki Street are susceptible to inundation during the 4 m wave scenario. The 2 m scenario is generally contained within the river area.

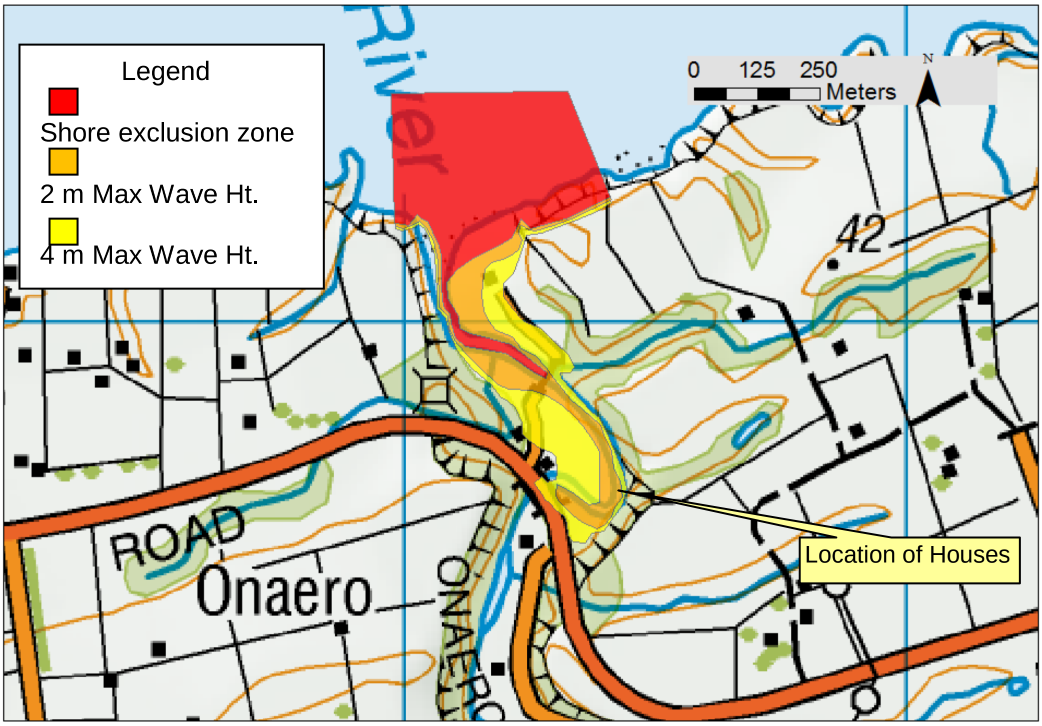

Figure 12: Onaero Tsunami Evacuation Zones

Results indicate the 2 m scenario is contained within the river area, however, the 4 m wave causes inundation in the area with the houses.

Data sources for Waitara are shown in Figure 13.

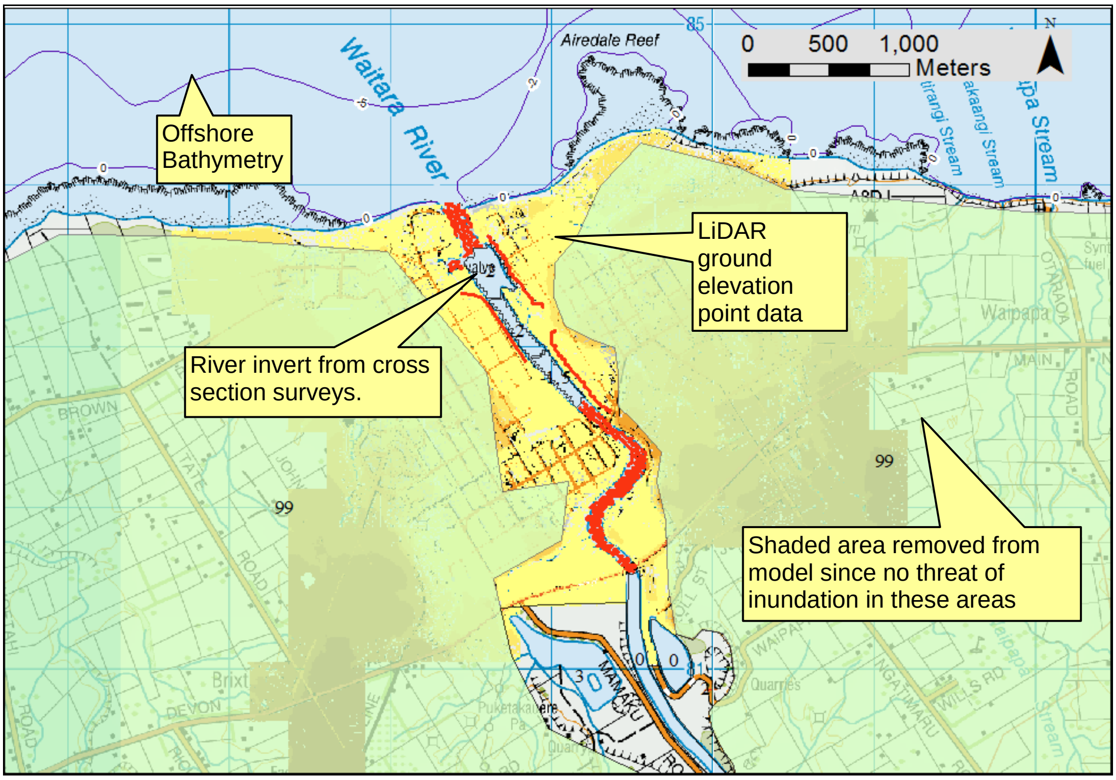

Figure 13: Details of Waitara study area showing data sources

River cross section survey data was available for the Waitara River, and was used to create the DEM in the river area.

The evacuation zones for Waitara are shown in Figure 14.

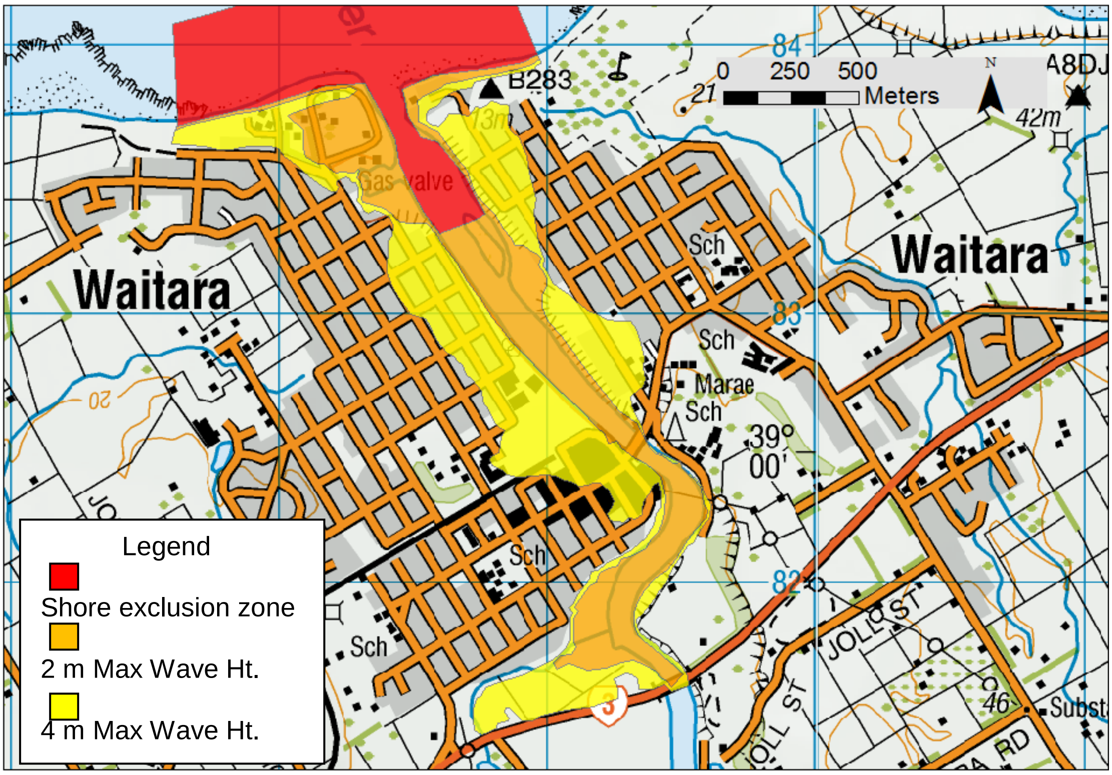

Figure 14: Waitara Tsunami Evacuation Zones

Results indicate the 2 m scenario is contained in the river corridor, apart from the low lying area at the left of the river mouth. The 4 m scenario overtops the river stopbanks and floods several streets on both sides of the river. This is significant in terms of potential damage, however, the return period for this type of event is approximately 2,500 years, which indicates the relative infrequency of occurrence.

4.4 Oakura to Bell Block Model Details and Results

The study area is shown in Figure 15, and the data sources for Bell Block in Figure 16.

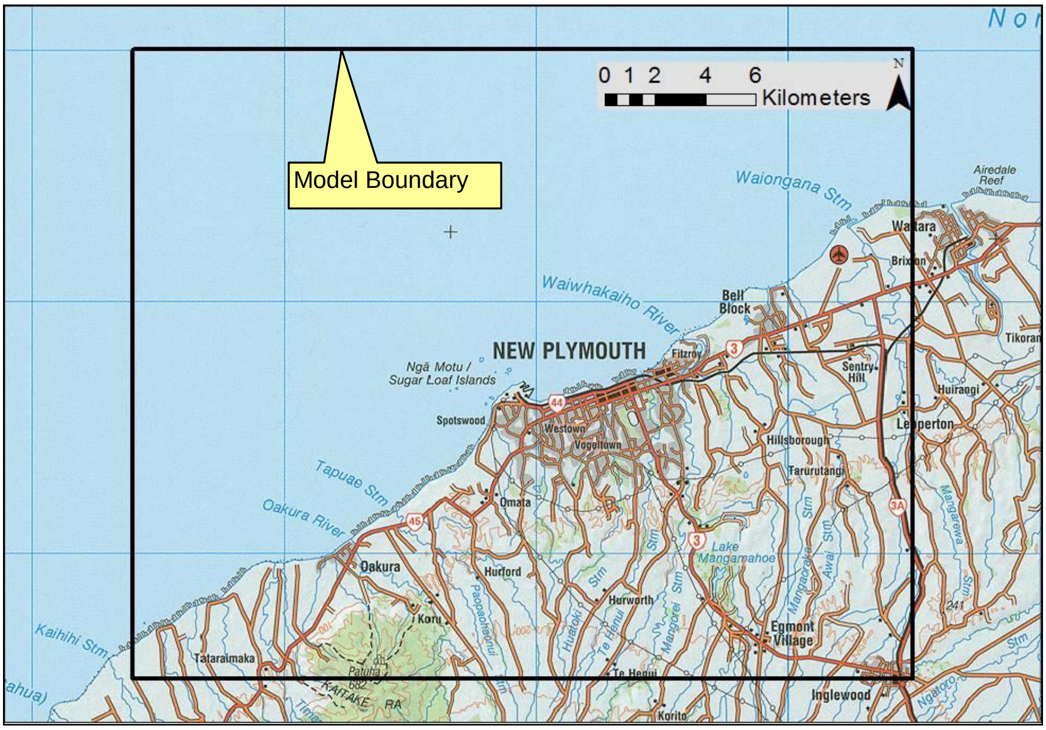

Figure 15: Oakura to Bell Block study area

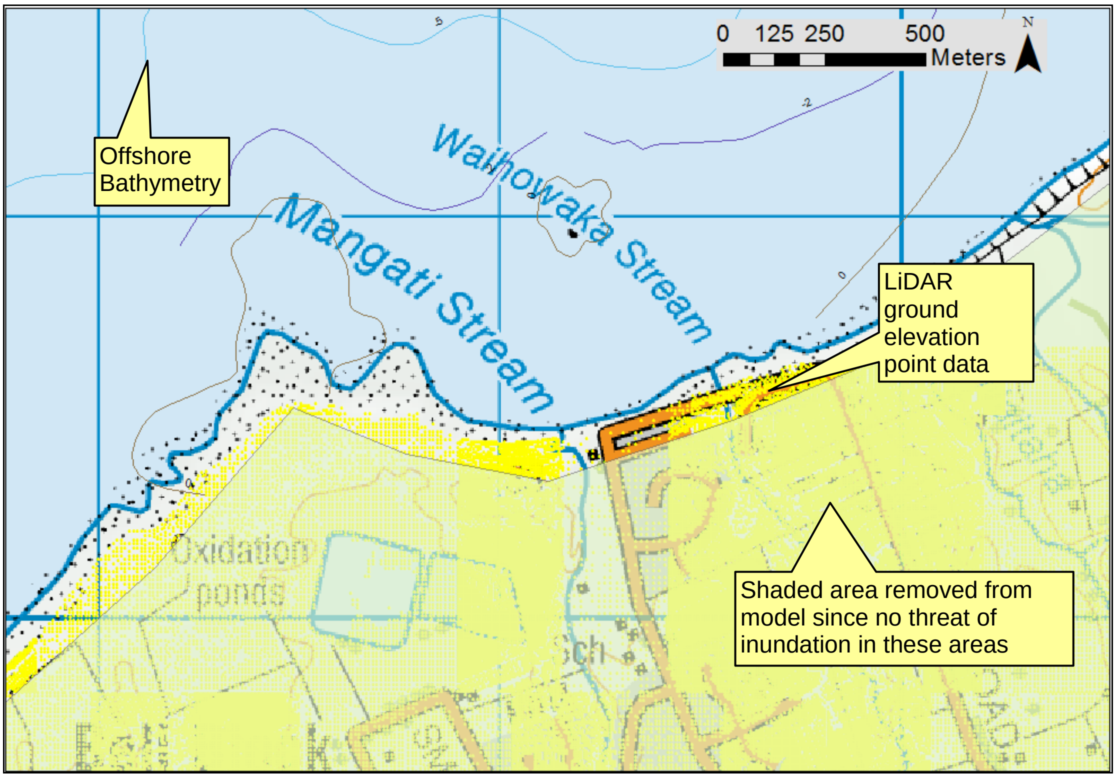

Figure 16: Details of Bell Block area showing data sources

The evacuation zones for Bell Block are shown in Figure 17.

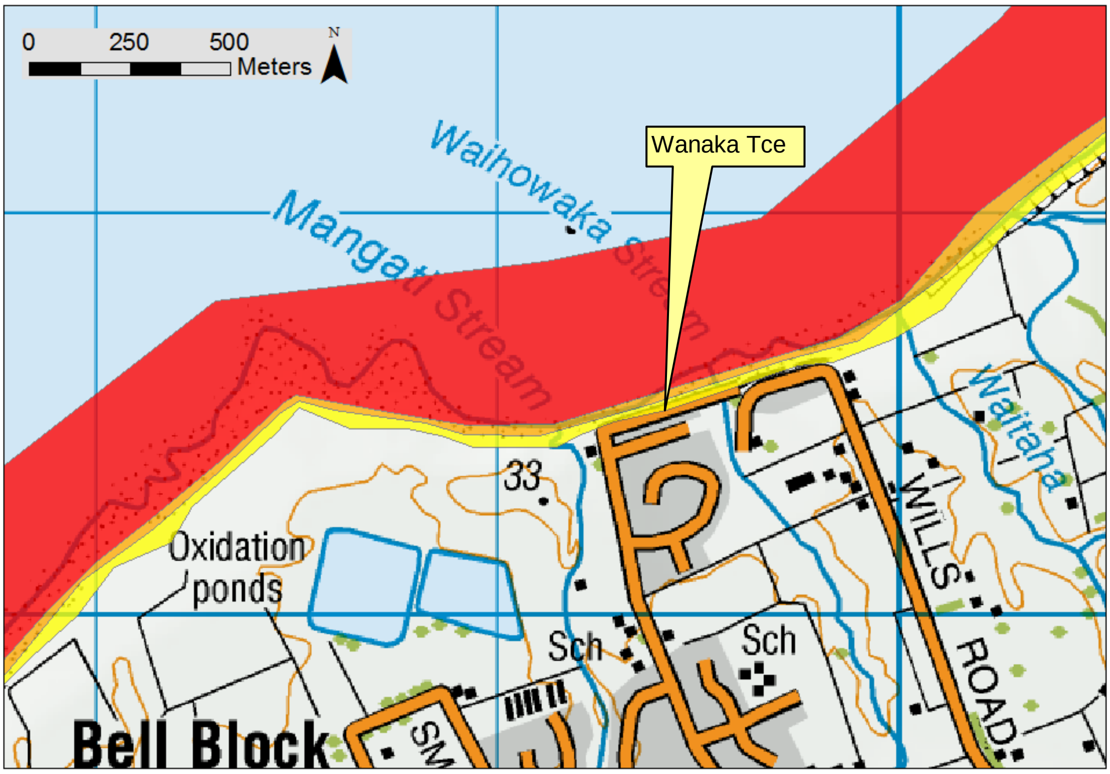

Figure 17: Bell Block Tsunami Evacuation Zones

At Bell Block, the results indicate only the coastal frontage on Wanaka Terrace appears to be at risk.

The data sources for the Fitzroy area of New Plymouth are shown in Figure 18.

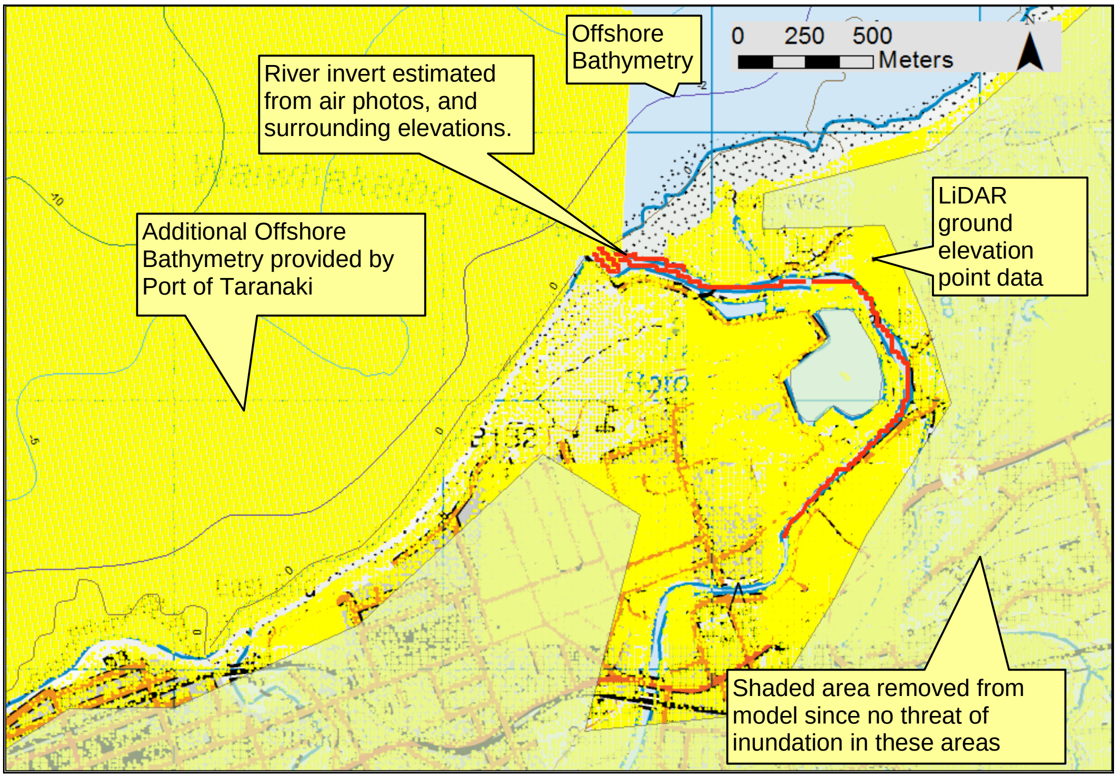

Figure 18: Details of Fitzroy area showing data sources

The evacuation zones for Fitzroy are shown in Figure 19.

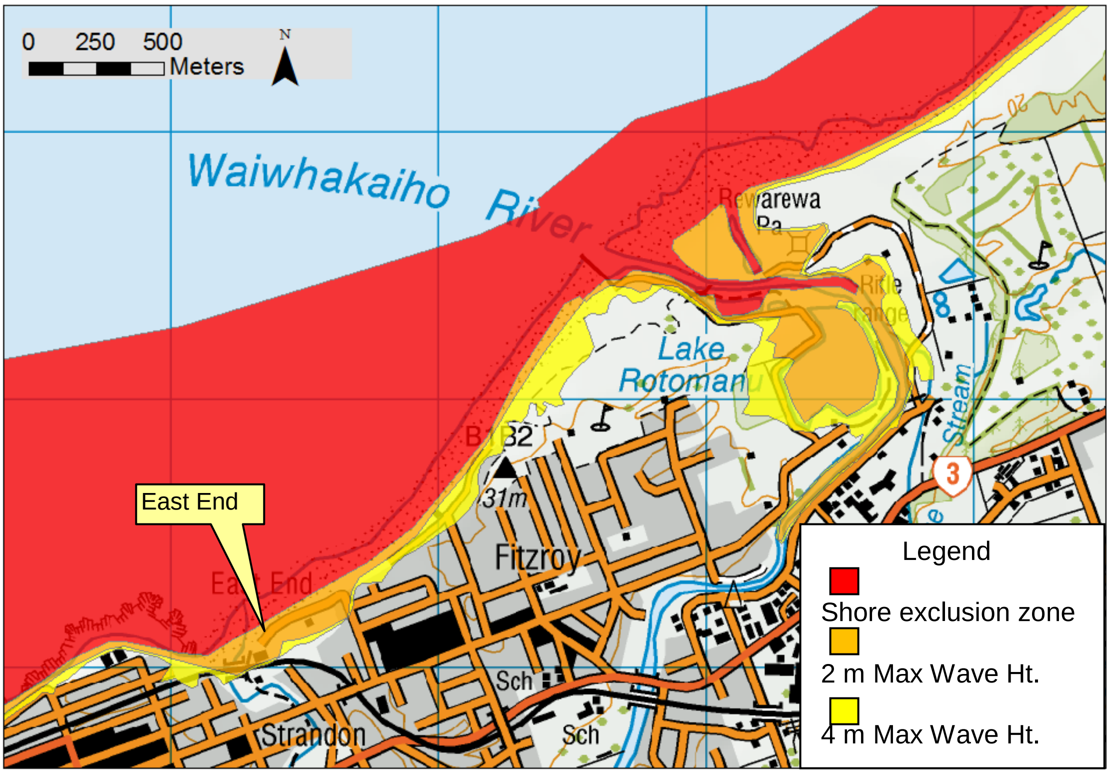

Figure 19: Fitzroy area Tsunami Evacuation Zones

The model results indicate inundation areas around Lake Rotomanu, as well where the small stream comes out at East End

The data sources for New Plymouth are shown in Figure 20.

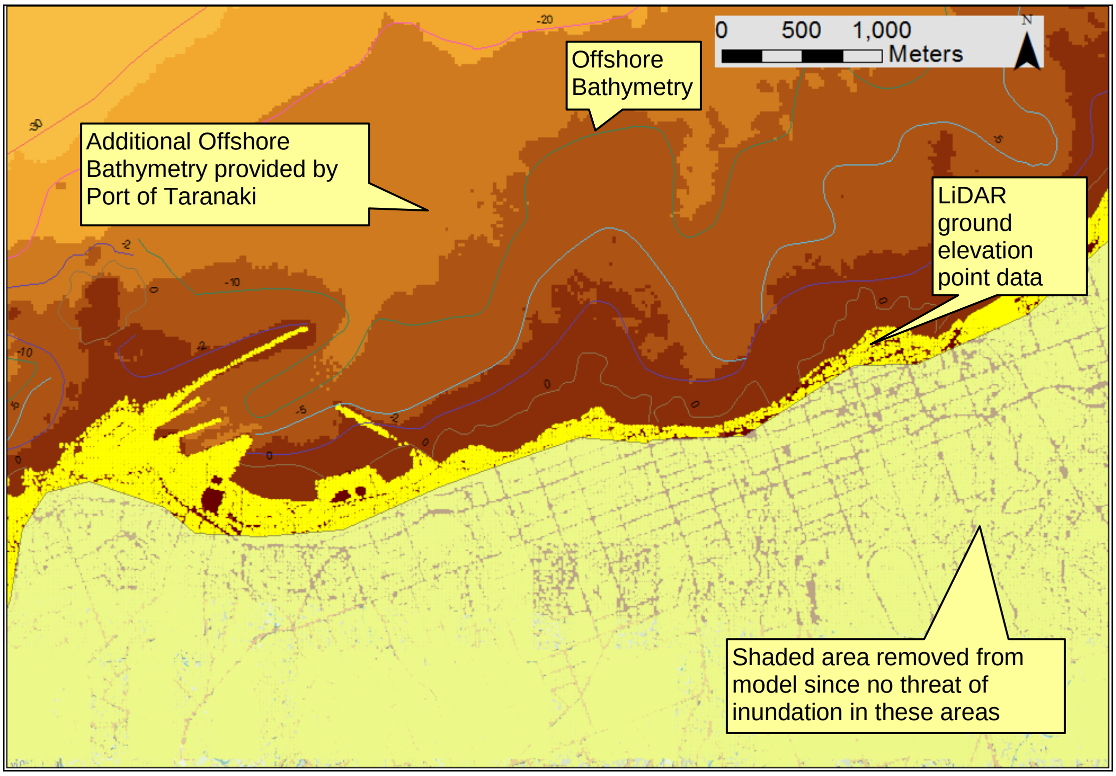

Figure 20: Details of New Plymouth area showing data sources

The evacuation zones for New Plymouth are shown in Figure 21.

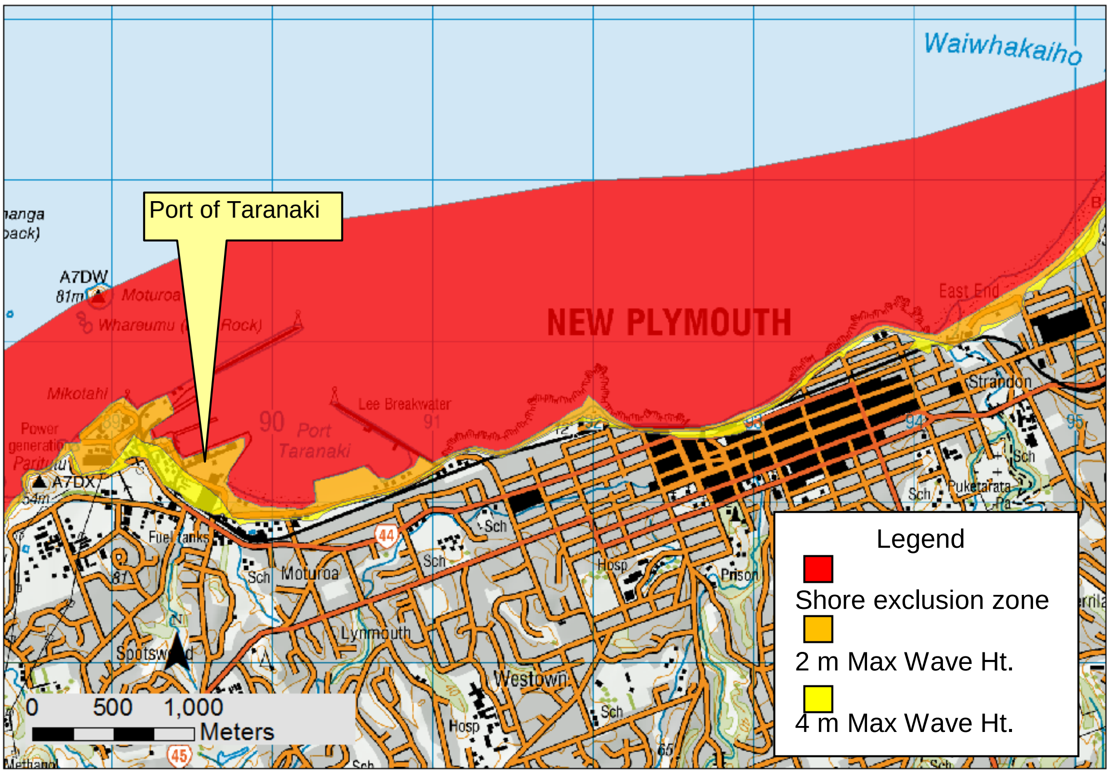

Figure 21: New Plymouth area Tsunami Evacuation Zones

The coast at New Plymouth is relatively steep, which prevents any inland inundation. Model results show a narrow strip on the coast, as well as low flat areas around the Port of Taranaki which are susceptible to inundation from the 2 m and 4 m wave scenarios.

The data sources for Oakura are shown in Figure 22.

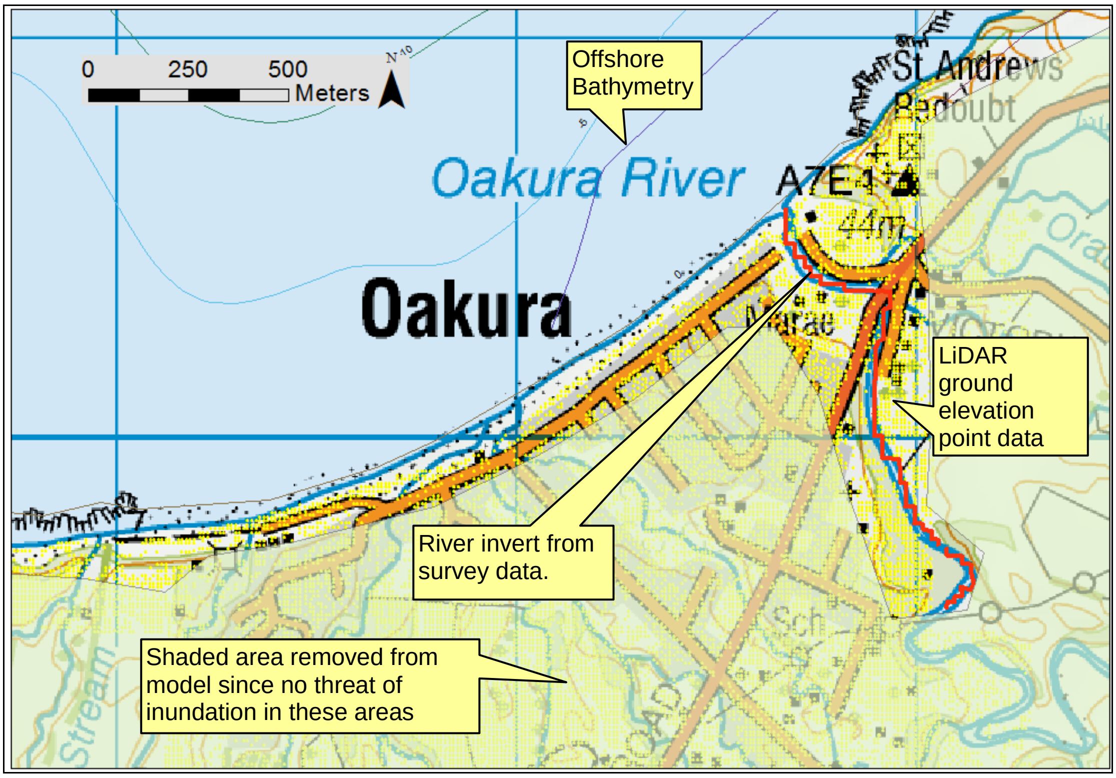

Figure 22: Details of Oakura area showing data sources

The evacuation zones for Oakura are shown in Figure 23.

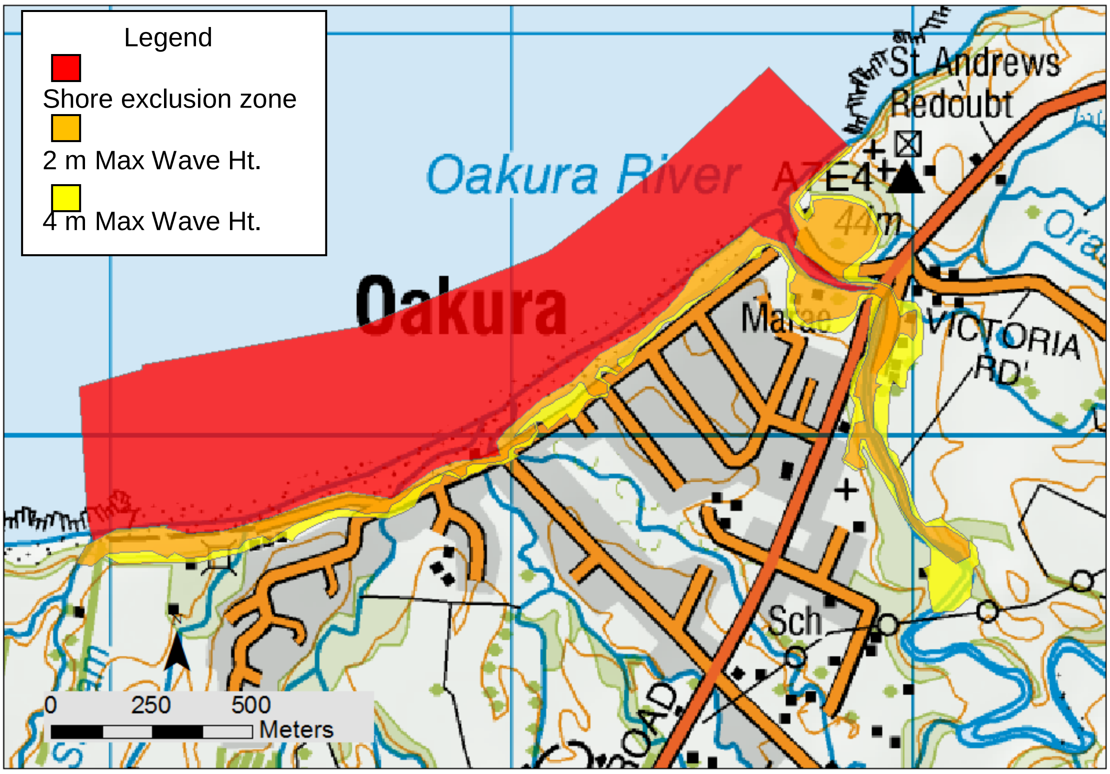

Figure 23: Oakura area Tsunami Evacuation Zones

The coastal frontage at Oakura is susceptible to inundation, as well as areas up the Oakura River.

4.5 Opunake Model Details and Results

The study area is shown in Figure 24.

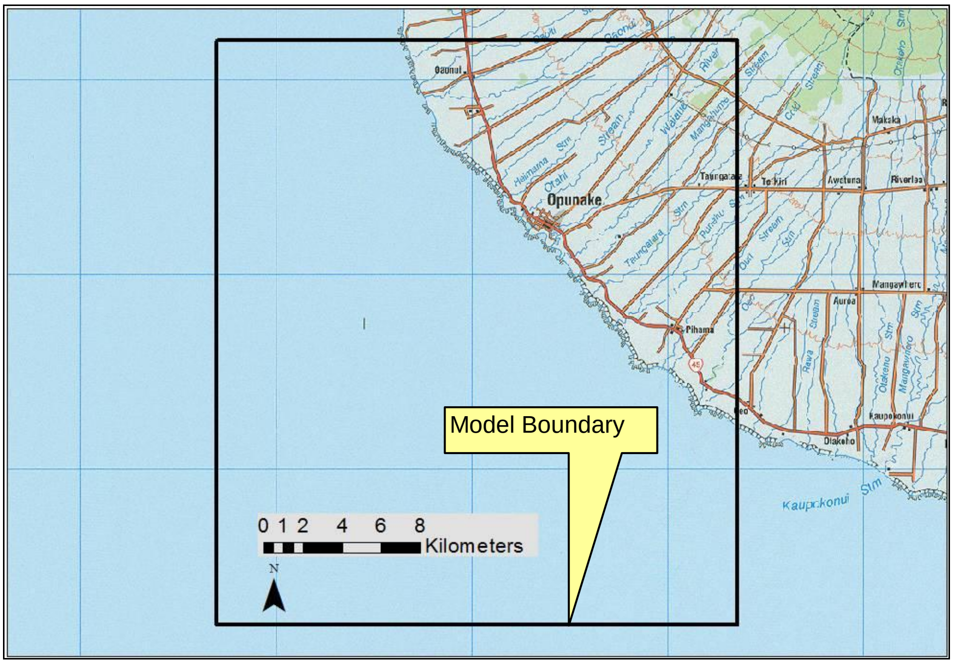

Figure 24: Opunake study area

The data sources for Opunake are shown in Figure 25.

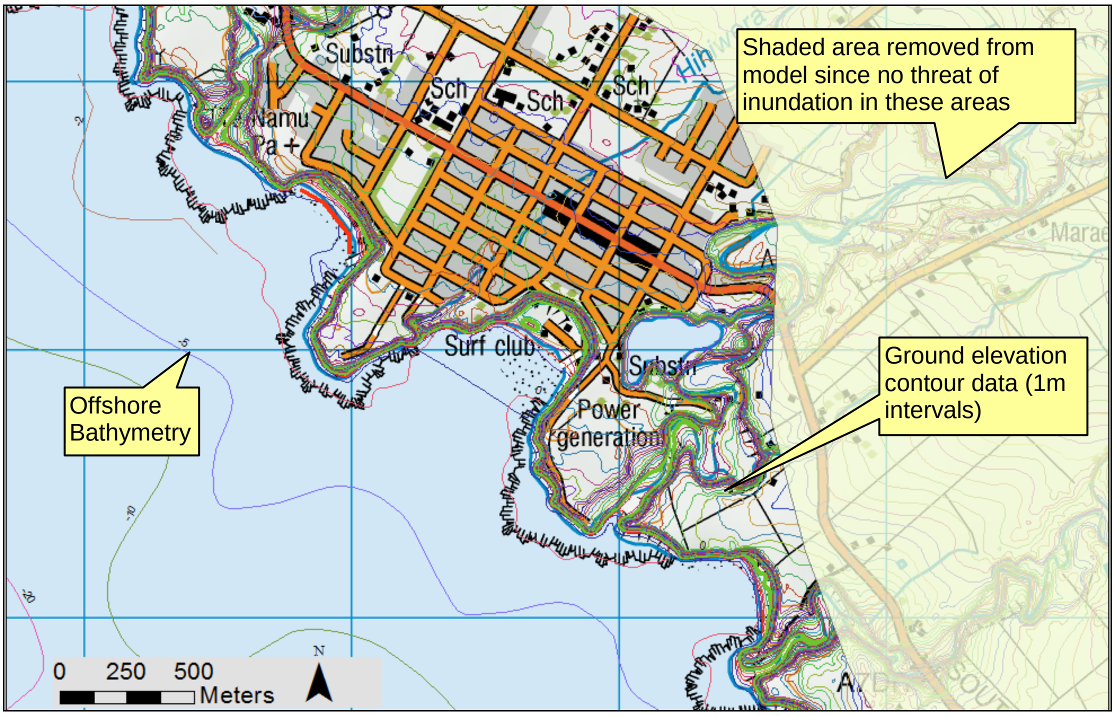

Figure 25: Details of Opunake area showing data sources

Ground elevation data for the south coast areas was obtained from 1 m contours.

The evacuation zones for Opunake are shown in Figure 26.

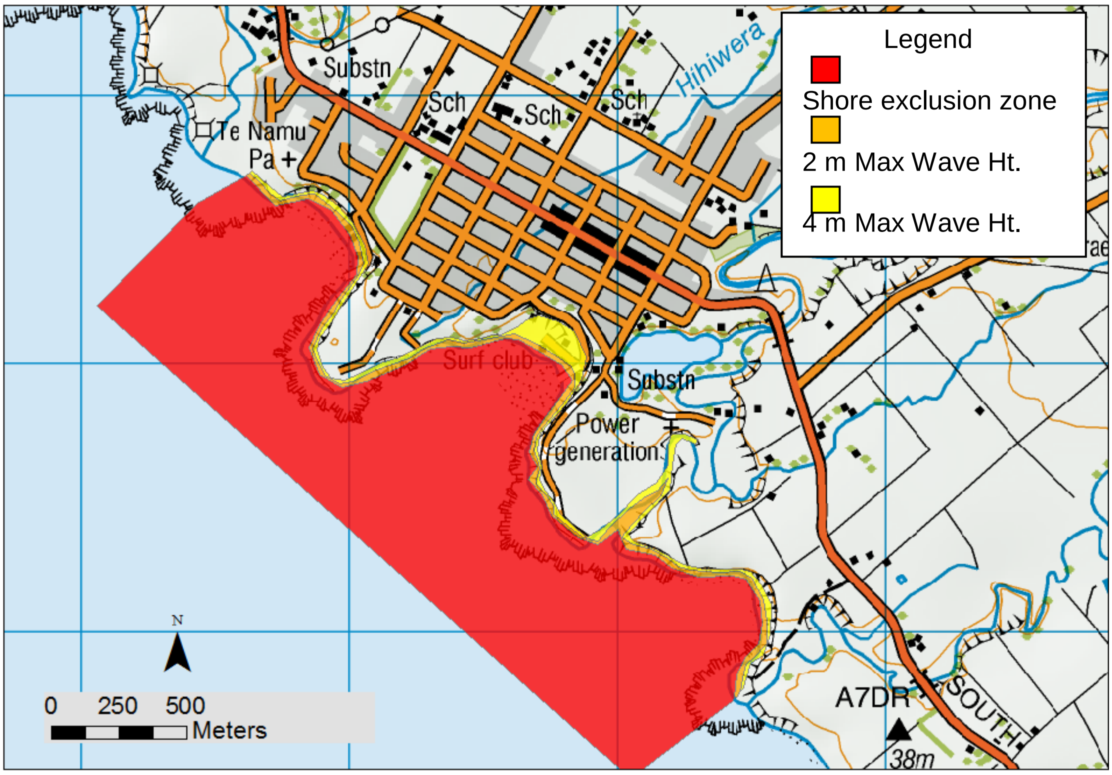

Figure 26: Opunake area Tsunami Evacuation Zones

Model results indicate only minor inundation at the beach frontage at Opunake.

4.6 Patea Model Details and Results

The study area is shown in Figure 27.

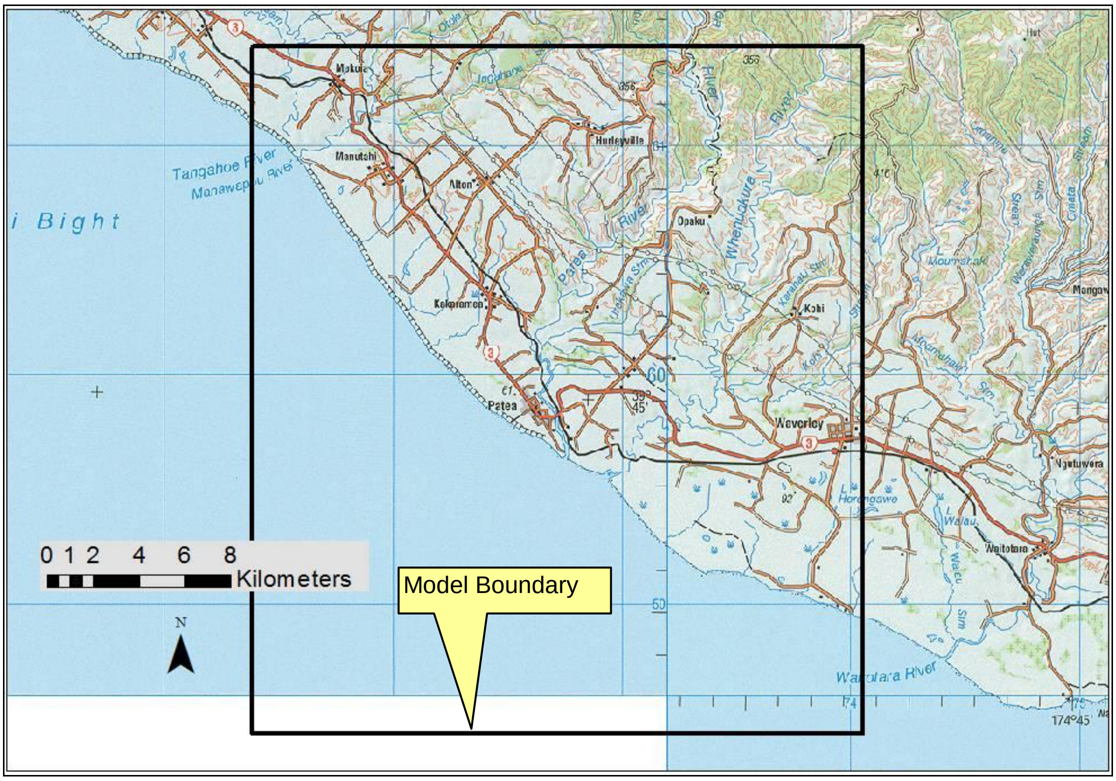

Figure 27: Patea study area

Data sources for Patea are shown in Figure 28.

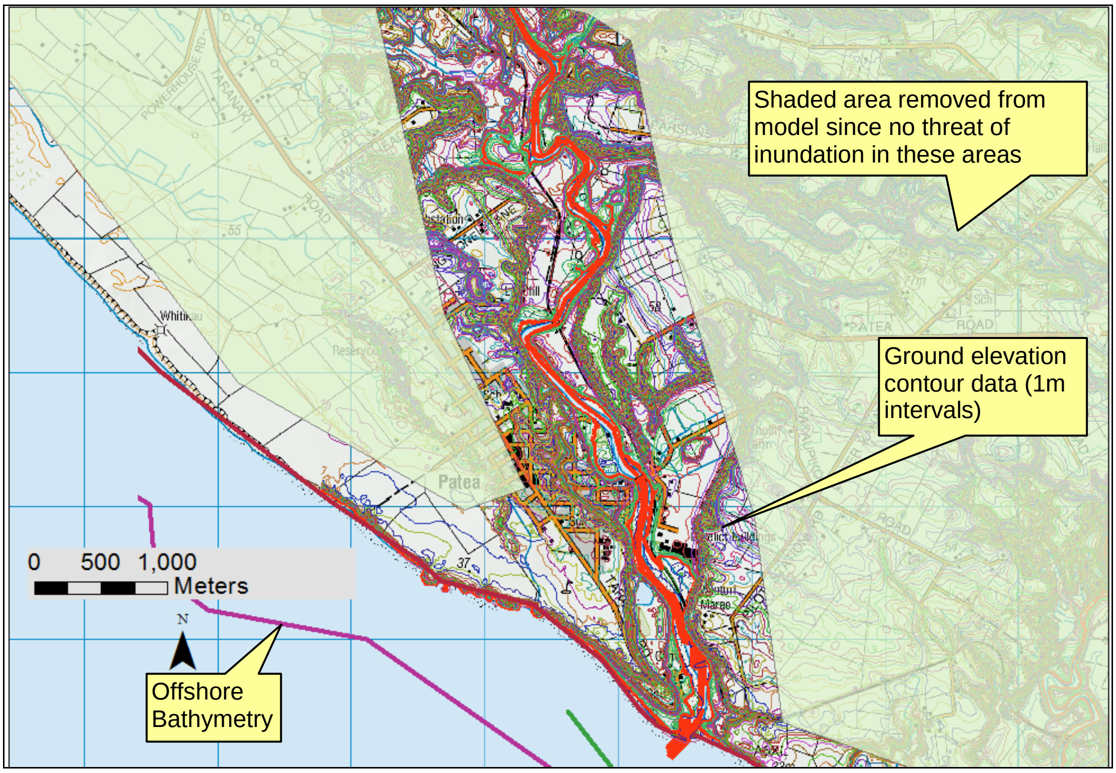

Figure 28: Details of Patea area showing data sources

The evacuation zones for Patea are shown in Figure 29 and Figure 30.

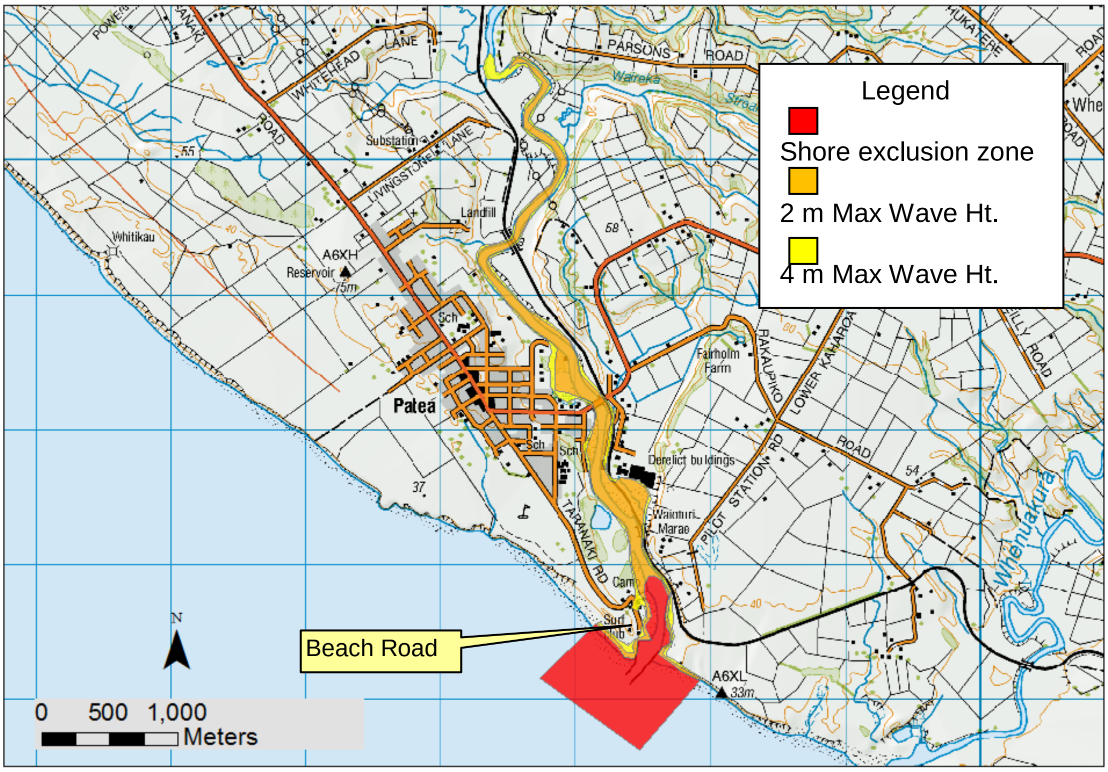

Figure 29: Patea area Tsunami Evacuation Zones

Model results indicate inundation up the Patea River, as well as low lying areas near the coast at the end of Beach Road. A smaller scale view is shown in Figure 30.

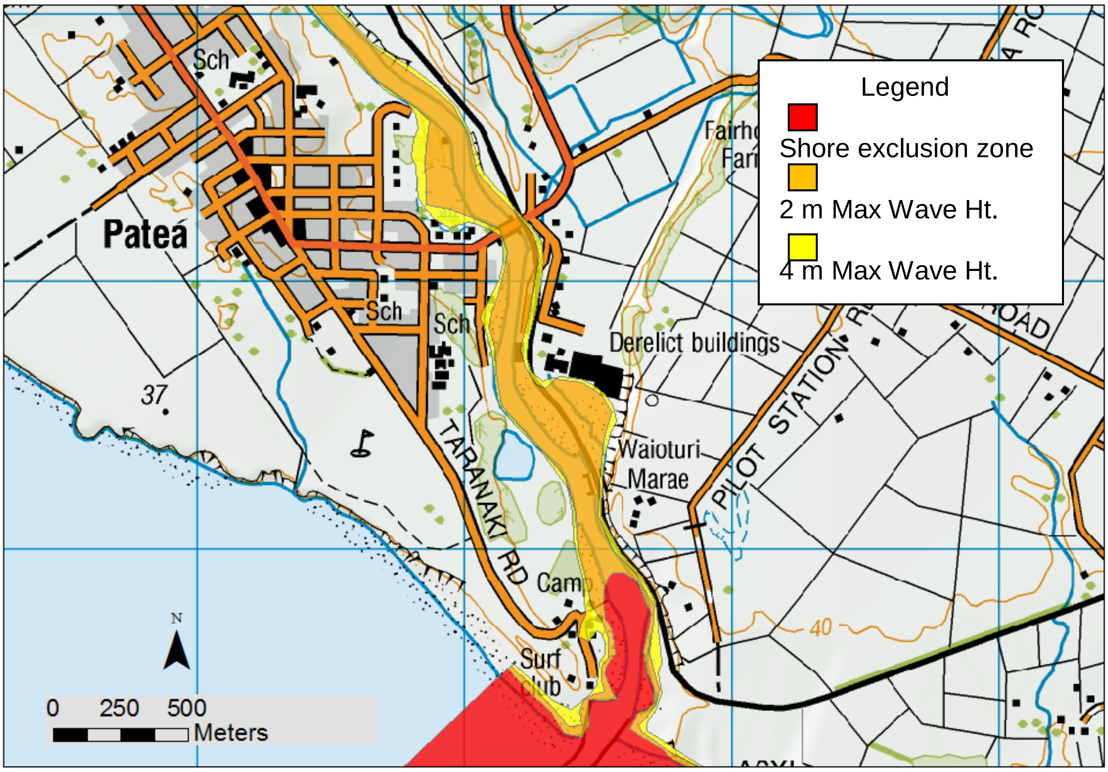

Figure 30: Patea area Tsunami Evacuation Zones

5 Limitations and Accuracy

The results presented in this report are based on computer models which provide an output based on the input parameters chosen. While care and research has gone into selecting the input parameters, there are many unknown variables which could alter the parameters and produce slightly different results in terms of inundation depths, extents and timing of the waves. The scenarios examined and the range of parameters chosen have given a broad spectrum of results, including extremely severe scenarios which may have return periods of many thousands of years. It should be stressed that the overall accuracy of such modelling results is limited; however the model results do represent plausible scenarios which provide an indication of the severity of the possibility of tsunami waves hitting this particular coastline.

6 Conclusion

A series of waves simulating tsunami events with 2 m high and 4 m high waves were applied to computer models of areas around the Taranaki Coast. Inundation extents were generated from the models, which were plotted according to the guidelines from Ministry of Civil Defence and Emergency Management.

In general, there are many areas along the Taranaki Coast that would only suffer very localised threat and minor damage from even the largest plausible tsunami. Several areas that have river inlets, with infrastructure in low areas near the river edge would likely suffer more damage due to inundation. These areas have been identified, and shown in this report.

7 References

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