DEVELOPMENT PRESSURES AND CATCHMENT PLANNING IN A COASTAL COMMUNITY

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ABSTRACT (200 WORDS MAXIMUM)

This paper details both the historical and current development pressures that are placed on the northern Waihi Beach catchments. It also identifies some of the management methods that have been adopted to control development in areas prone to natural hazards.

The paper provides a brief overview of flood hazard mapping that has been carried out. Most importantly, the paper identifies how a quantitative flooding assessment was used to assist decision makers with asset planning, catchment planning and investment budgets for the future, using a risk based approach.

The paper provides an appraisal of the flood damage assessment at Waihi Beach using depth damage curves to quantify damage costs. The report finds that many of the recommendations of a 2004 report to the NZ Climate Change Office regarding understanding of flood damage are still valid in 2012.

KEYWORDS

Flood hazard; flood damage assessment; hydraulic modelling; catchment planning; flood mitigation; natural hazard

PRESENTER PROFILE

Jon Rix is a Water Resources Engineer at Tonkin & Taylor. He has been working in New Zealand for the last 6.5 years and spent 3 years prior to that working in the UK, primarily on EC Bathing Waters related work. His main areas of expertise are in flood hazard assessments, water quality assessments, hydraulic modelling and hydrology.

Jon has utilised his skills for flood hazard assessments around New Zealand in both urban and rural environments. He has developed innovative solutions for flood mitigation measures and stormwater upgrades in complex urban environments such as Mission Bay and Pukekohe South. He has been a key member of a number of ICMP studies and was also heavily involved in the assessment of the impacts of the Waterview Connection Project on Oakley Creek for NZTA.

1 INTRODUCTION

Waihi Beach is located in the North West corner of the Bay of Plenty, at the southern end of the Coromandel Peninsula. The residential population is approximately 1773 people (2006 census), having increased dramatically from the 200 people resident in Waihi Beach in 1976 (ORH, 1976).

Based on population estimates in the wider Waihi Beach Ward during summer months (WBOPDC, 2007), the peak summer population at Waihi Beach township increases to approximately 11,000 people.

In addition to the high demand for non-permanent residential housing, there are projections of population growth in the area. Therefore it is likely that the strong historical development pressure in the area will continue in the future.

There are a number of natural hazards that constrain development in the local Waihi Beach community. Therefore before further development is permitted, a review of the natural hazard constraints, and potential sites for mitigation, is being carried out. The main area of interest for this project is at North Waihi Beach, which includes the area from Two Mile Creek northwards.

2 BACKGROUND

2.1 TOPOGRAPHY AND GEOLOGY

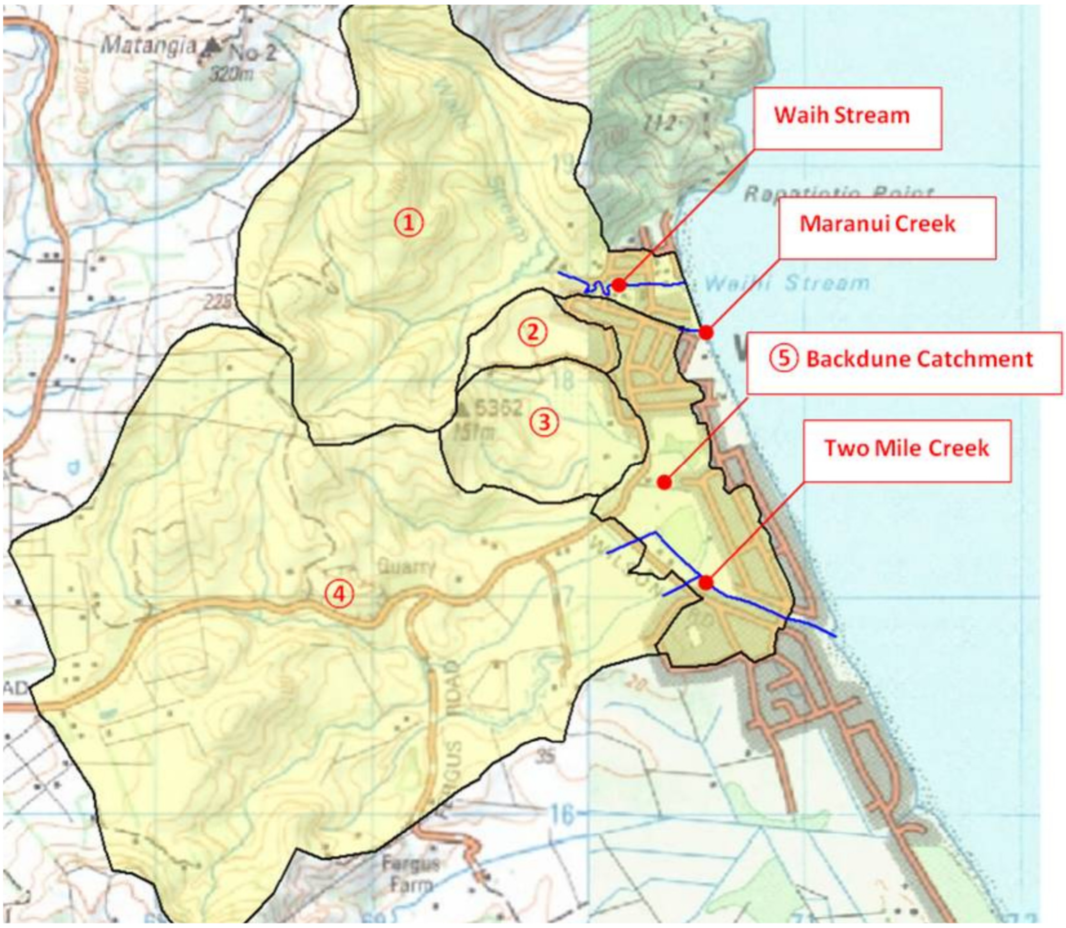
The North Waihi Beach foredune topography is characterised by irregular but rhythmic large-scale features described by Stephens (1996) as "arcuate dune line embayments". The embayments are 800m to 2,500m in length with centres ranging from 400 to 3,000m apart, generally averaging 30 to 50m in depth (Stephens 1996).

Behind the foredune system lies a flat backdune area of alluvial or colluvial sediments including silty clay and peat. There is also evidence of ancient Pleistocene dune complexes thought to have formed about 125,000 years ago during the last interglacial high sea-level (T&T, 2004). Further upstream lies a steep and geologically variable catchment comprising of lava flows and domes, volcaniclastic sediments, local pumice breccias, siltstone, mudstone and sandstone.

The Northern Waihi Beach catchment comprises of four sub-catchments, which drain to the backdune system at Waihi Beach. A fifth sub-catchment represents the backdune system that comprises of numerous sub-catchments which interconnect in different ways depending upon the size of the rainfall event. The five sub-catchments are shown in Figure 1.

At the northern and southern ends of Northern Waihi Beach, stormwater runoff drains naturally to Waihi Stream and Two Mile Creek respectively. For the middle sub-catchments draining to Maranui Creek, stormwater runoff first passes through the public piped stormwater system. Due to the presence of the foredune and backdune systems, there is very limited potential, or in some areas no potential, for the two middle sub-catchments (2, 3 & 5) to pass overland to the Maranui Stream.

Figure 1: Waihi Beach catchment delineation



2.2 HISTORY AND DEVELOPMENT OF WAIHI BEACH

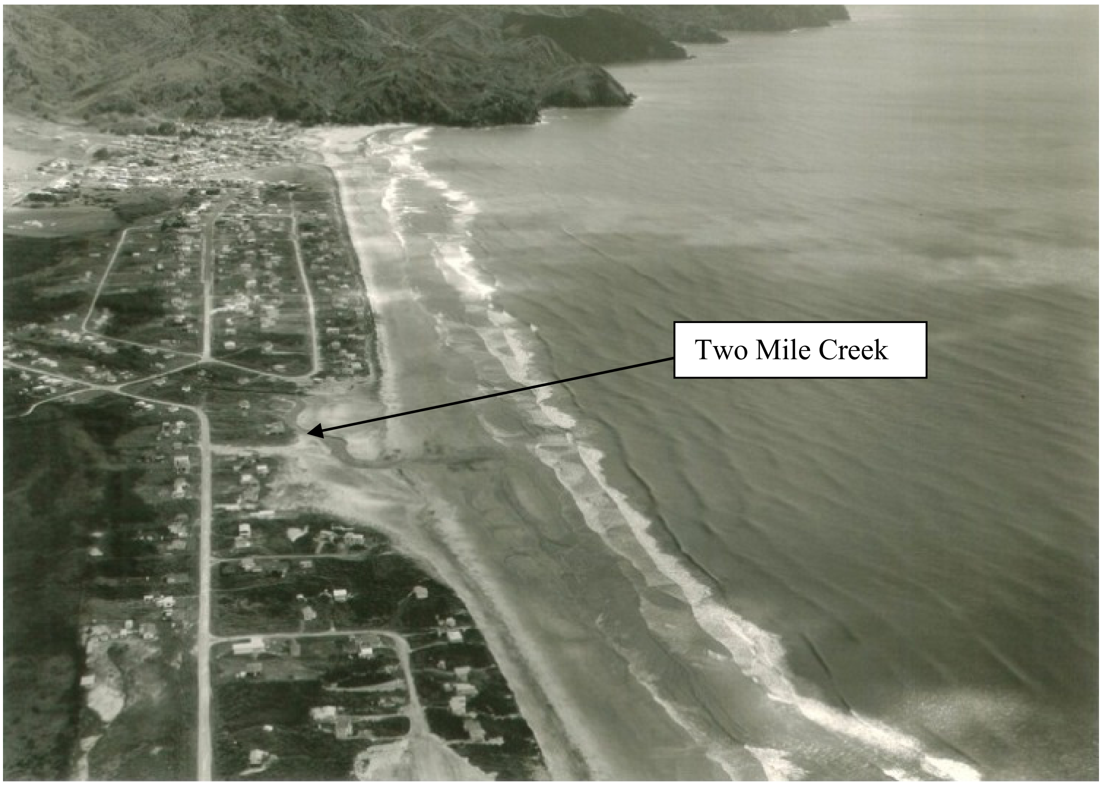
Development at Waihi Beach dates back to 1870 when gold prospectors moved into the area following early mining reports indicating small quantities of gold in the Waihi Stream. During the next four to five decades, increasing numbers of people, often associated with the mining industry in and around the area moved to Waihi Beach. The large influx of people to the area created some problems associated with shanty town developments. Therefore in 1919 the Borough Council compulsorily purchased 76 acres (30.75 ha) of private land, partly to ensure some development control but also to enforce some sanitary management. The Borough Council also created a camping area since Waihi Beach was becoming popular as a holiday destination.

As the population increased, infrastructure and facilities were developed to service the growing settlement's population.

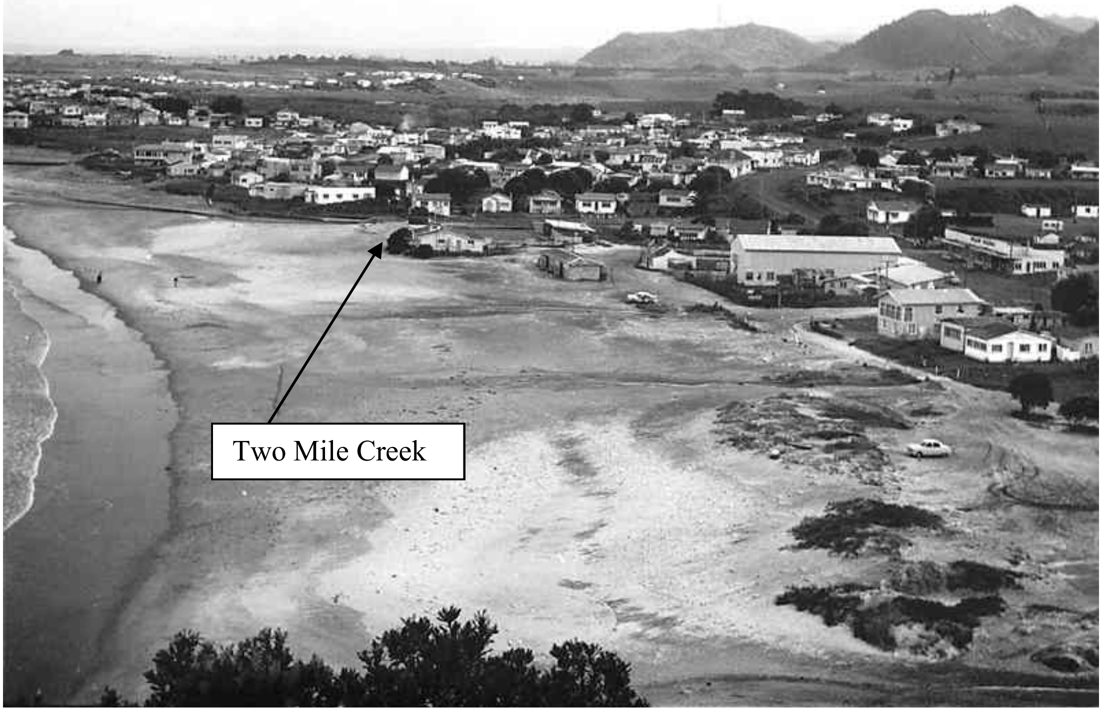
In 1939 an area of land was purchased from one of the major landowners in the area to the south side of the Main Road, known as the "Peninsula". It was called the "Peninsula" because of the very wet swampland that nearly surrounded the land. Upon purchase of the land, a drainage channel was excavated to drain the swampland, so creating the start of the Two Mile Creek (ORH, 1968).

The historical images shown in Photograph 1 and 2 show the Waihi Beach township approximately 50 years ago.

Photograph 1: Waihi Beach – 1959 (http://www.waihibeachinfo.co.nz/about-us/history/)



Photograph 2: Waihi Beach – 1962 (http://ohinemuri.org.nz)



As more growth occurred, new infrastructure developed and existing infrastructure was extended in the 1950s. By 1960, development had spread over most of the Waihi Beach Ward (WBOPDC, 2007).

Prior to 1997, development at Waihi Beach area had occurred with few constraints and as a result it became increasingly apparent that properties and infrastructure may be at risk from natural hazards.

The first assessment of coastal erosion took place in 1997. It identified that 84 properties were located within an extreme Risk Erosion Zone along the coastline that were subject to adverse effects from erosion (Gibb and T&T. 1997).

The aerial image shown in Photograph 3 provides an indication of current development extents in Waihi Beach. The aerial photograph was carried out prior to coastal protection works along the dune faces and mouth of Two Mile Creek.

Photograph 3: Waihi Beach – 2008 (copyright Terraview)

2.3 DEVELOPMENT CONTROL

As a result of the 1997 coastal erosion study, WBOPDC notified a change to its District Plan making building activity within the Coastal Protection Area (CPA) a discretionary activity. The development controls were advanced further in 2002 when WBOPDC identified a Primary Risk Area of the CPA where subdivision was made a prohibited activity and second dwellings a non-complying activity. In the secondary risk area subdivision is now a non-complying activity in the District Plan.

Photograph 4 shows a reflected wave at the mouth of Two Mile Creek prior to coastal protection works.

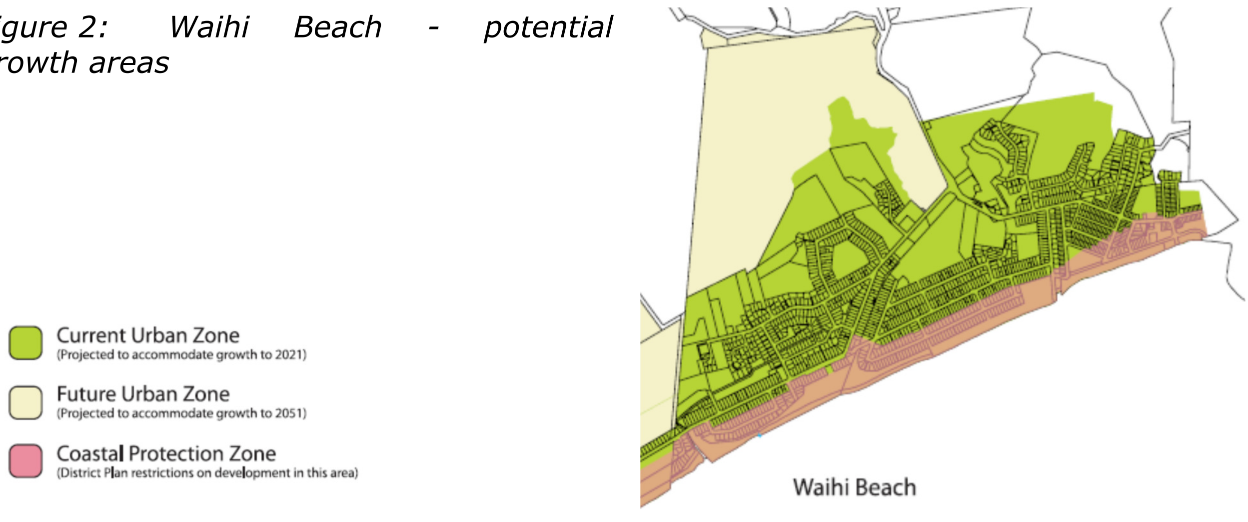
Photograph 4: Two Mile Creek mouth prior to coastal protection works

The building and development controls significantly improved the risk management controls available to Council. In addition, following a 14 year duration of erosion assessments and options assessments, new coastal protection works were approved by an Environment Court decision in 2008. The coastal protection works, which have now been completed, protect 80 private properties and 2.2km of reserve, and fulfill a range of other objectives.

Whilst considerable investment had been placed on protecting the Waihi Beach assets along its coastline, there still remains high development pressure for the backdune system area and wider catchment. Projections of the Waihi Beach Ward's population indicate an increase in numbers from 2,946 in 2006 to 5,180 people by 2021 and 8,770 by 2051 (WBOPDC, 2007). Since development is now restricted along the foreshore, development demand has become focused further inland.

To help guide the development of housing, infrastructure, services and facilities, the Waihi Beach community developed a 20 year plan in a guidance document in 2007. The community plan also feeds into the 50 year plan to manage growth in the Tauranga and Western Bay of Plenty. The 20 year plan identified the potential growth areas (WBOPDC, 2007) shown in Figure 2.

Figure 2: Waihi Beach - potential growth areas



Prior to permitting additional development, WBOPDC carried out a review of development constraints to Waihi Beach based on its experience gained during the Coastal Erosion risk assessment work. The review highlighted that additional work was required to understand the flood hazard at Waihi Beach, particularly given a perception of highly frequent flood events. Furthermore WBOPDC did not want to allow new development in areas that may later be required to alleviate or mitigate flooding in the area.

3 FLOOD HAZARD STUDY

3.1 REASON FOR NEW STUDY

In 2011, T&T carried out a detailed review of an earlier Waihi Beach flood study (T&T, 2001) and identified that the flood assessment and flood maps needed to be updated in accordance with current best practice, and to use additional information that had become available since 2001. WBOPDC commissioned a new modelling study of the area using photogrammetric survey data of the area to build a 2D model, dynamically coupled to a 1D open channel model and stormwater reticulation model. The model also needed to represent catchment upgrades and coastal protection works that had been carried out since 2001. The purpose of the flood hazard study was to provide up to date flood hazard maps to identify development constraints and options for flood mitigation.

3.2 HISTORICAL FLOOD EVENTS AT WAIHI BEACH

There are no flow gauges or rain gauges in the Waihi Beach catchments to analyse for flood events or to carry out a flood frequency analysis. Therefore discussions with locals and an analysis of newspaper cuttings was carried out to identify whether the perception of high flood frequency was true. The process identified that six storm events since 2006 had occurred that caused disruptive flooding (and some damage), indicating that the perception of high flood frequency was true for this recent period.

An analysis of rain gauges from two nearby catchments was carried out to determine the likely magnitude of the rainfall events. The rainfall duration and rainfall depth was compared with HIRDS (version 3) rainfall statistics to determine a rainfall return period.

The storm events and results of the rainfall analysis are shown in Table 1.

Table 1: Recent flooding events at Waihi Beach and nearby rain gauge depths

Event Date	Queens Head			Golden Cross		
	Duration	Total Rainfall Depth (mm)	ARI based on HIRDS (v3)	Duration	Total Rainfall Depth (mm)	ARI based on HIRDS (v3)
28-Apr-06	6hr	136.5	20yearARI	6hr	161	20yearARI
30-Jul-08	15hr	265.5	100yearARI	15hr	118.5	10yearARI
6-Mar-09	18hr	47.6	<2yearARI	18hr	115.5	<2yearARI
24-May-10	18hr	41.5	<2yearARI	18hr	53.5	<2yearARI
29-Jan-11	10hr	104.5	5yearARI	10hr	125	3yearARI
26-Apr-11	16hr	58.5	<2yearARI	16hr	116	<2yearARI

The results indicated that the high frequency of flooding at Waihi Beach was not due to an unlikely period of particularly severe rainfall and that therefore the flooding was attributable to rainfall events that could be expected with relatively frequent occurrence.

3.3 HYDROLOGY

As part of the flood hazard mapping process for Waihi Beach, T&T carried out a hydrological study of nearby gauged catchments (flow and rainfall) to derive hydrological parameters that could be applied to the Waihi Beach sub-catchments. The process involved calibrating hydrological models from gauged rainfall and gauged flows from the nearby Torrens Farm and Woodlands Road catchment.

Calibration of curve number for different land use types (bush & pasture) and time of concentration was carried out for three storm events using the SCS (US Soil Conservation Service) approach. The results of the hydrological calibration for the two nearby catchments are shown in Table 2.

Table 2: Hydrological calibration results

	Calibration Events					
	Torrens Farm catchment			Woodlands Road Catchment		
	18/9/2005	28/4/2006	29/7/2008	17/7/2005	24/1/2006	28/4/2006
Curve No. (Bush)	58.8	58.2	56	66	52	68.5
Curve No. (Pasture)	71.5	71	69	75	65	77.5
Lag time (minutes)	140	140	160	50	70	50

The results of the model calibration indicated similar curve numbers for bush and pasture in the Torrens Farm catchment for all calibration events. However the curve numbers were more varied for the Woodlands Road catchment, where lower curve numbers were calibrated for the January 2006 event (this may have been partly due to dry antecedent conditions experienced at the time).

A review of the catchment geology in the three catchments suggests that there is a greater portion of volcanic deposits in the Woodlands Road catchment, and a higher portion of alluvial sands and gravels in the Torrens Farm and Two Mile Creek. We recognise that there can be high localised infiltration rates in areas of volcanic geology, however overall we believe that there will be less runoff from the alluvial sands and gravels. This is reflected in the generally higher calibrated curve numbers (2 of 3 storm events) for the Woodlands Road catchment.

Given the closer proximity of the Torrens Farm catchment to the Two Mile Creek catchment, and the similar geology, we placed greater emphasis on the Torrens Farm calibration numbers than the Woodlands Road catchment.

Based on the calibration results and the discussion above, we estimated that the following curve numbers should be used for the Two Mile Creek catchment:

- CN (Bush) = 60
- CN (Pasture) = 71
- CN (Impervious) = 98

A hydrological model was then created to represent the sub-catchment in the northern Waihi Beach catchments. Sub-catchment characteristics were determined for the existing development (ED) and for maximum probable development (MPD) in accordance with development proposed in the District Plan.

Initial hydraulic model runs indicated that runoff volume may have a greater impact on flood extents and flood depth than peak flows. Therefore we developed a design rainfall distribution based on the Chicago method (Keifer and Chu, 1957), which is based on intensity-duration-frequency curves that were obtained from HIRDS (v3). This method ensures that both short intensity peak rainfalls and longer duration storms can be represented through a single hyetograph. Initially a 24 hour storm duration was used for hydraulic modelling. Subsequently a sensitivity assessment of both shorter and longer duration storms was carried out.

The rainfall depths for each of the return period events can be seen in Table 3.

Table 3: Rainfall depth (HIRDS, v3)

Return period	2 hour rainfall depth (mm)	6 hour rainfall depth (mm)	12 hour rainfall depth (mm)	24 hour rainfall depth (mm)	48 hour rainfall depth (mm)	72 hour rainfall depth (mm)
2 year ARI	45.7	79.3	103.3	159.2	196.9	223
5 year ARI	60.3	103.6	112.4	204.9	253.4	287
10 year ARI	72.5	123.5	145.7	242.1	299.5	339.2
20 year ARI	86.4	146.3	173	284.3	351.6	398.2
50 year ARI	108.6	182.2	203.9	349.8	432.7	490
100 year ARI	128.9	214.6	252.4	408.7	505.5	572.5

For scenarios relating to climate change, a 16.8% increase in total rainfall was applied based on 2.1^{o}C warming.

3.4 HYDRAULIC MODELLING

A detailed model build report was prepared for WBOPDC (T&T, 2012 draft), however in summary:

- A hydraulic model of the area was created using DHI's Mike Flood model, which dynamically links the 2D model (Mike 21) with the 1D open channel model (Mike 11) and 1D stormwater reticulation model (Mike Urban).
- The 1D stormwater reticulation model was created using WBOPDC data from available GIS records. Where GIS records were unavailable, an asset survey was carried out so that all important features were represented. The 1D open channel model was developed following a cross section survey of the open watercourses.
- The 2D model was created using photogrammetric survey data of the catchment. LIDAR data was not available for the area.
- Varying roughness values were used across the model to represent different land uses.

A limited hydraulic model validation was carried out based on the January 2011 flood event. The validation was limited due to availability of information. The model validation used hydrological flows generated from rainfall recorded at the Queens Head and Golden Cross rain gauges. Very similar rainfall was recorded by both gauges, and an average of the two gauges was therefore used. Despite the shortcomings in available data, anecdotal information from the local fire service indicated that model extents and depths were similar to their recollection of the event. The fire service had been involved in a number of evacuations during the storm event and the locations of the evacuations agreed with the elevated flood depths in the hydraulic model. Their response was that the flood extents appear correct and that areas to the south of Beachaven Holiday Park were in excess of 1m deep, as shown in the model. There was an expectation that shallow areas of flooding were more widespread than shown on a flood map; however this was explained by the flood map only showing flood depths greater than 0.1m

3.4.1 MODEL RESULTS

Model results were obtained for the scenarios shown in Table 4.

Table 4: Hydraulically modeled scenarios

	Existing Development					**Maximum Probable Development**				
	2 hr	**6hr**	**12hr**	**24hr**	**48hr**	**2 hr**	**6hr**	**12hr**	**24hr**	**48hr**
				✓					✓	
5 year ARI	✓			✓					✓	
10 year ARI		✓	✓	✓	✓				✓	
20 year ARI	✓			✓					✓	
50 year ARI	✓	✓	✓	✓	✓				✓	
100 year ARI				✓					✓	
50 year ARI + climate change (16.8% increase)									✓	
100 year ARI + climate change (16.8% increase)									✓	

Flooding in the catchments draining to Waihi Stream and Two Mile Creek were mainly affected by limited channel capacity partially due to low hydraulic gradients. For the two middle sub-catchments and the backdune system catchment (refer Figure 1), the model results identified the following characteristics:

- Very limited flood conveyance through the piped drainage system
- Limited potential for overland flowpaths to drain to the coast
- Overland flowpaths drained to low lying areas in the backdune system, where significant ponding occurred
- Significant flooding of residential areas
- Low velocities of overland flow paths around the residential areas
- High flood depths in low lying areas.

Generally, the critical factor in determining flood extent was the runoff volume. Therefore for differing durations of the same return period event, the shorter duration events resulted in less flooding. However there was very little increase in flood depth or flood extent between a 24 hour duration storm and a 48 hour duration storm for the 10 year ARI and 50 year ARI events modelled.

Overall flooding in the middle three sub-catchments is caused by limited capacity of the stormwater drainage system including limited outlet channel capacity and "ponding" characteristics of the topography caused by the dune complex. Essentially the low lying areas pond with water and water can not drain from the area (other than infiltration and the piped network) until the "crest" of the pond is overtopped. In such areas (e.g. Beachaven Holiday Park) there was therefore very little difference in flood extent between storm evens of differing return periods.

4 FLOOD DAMAGE

In order to determine appropriate flood mitigation options, a quantitative assessment of the flooding damagescenarios needs to be carried out so that the costs and benefits of future options can quantifiably be assessed.

4.1 FLOOD DAMAGE CATEGORIES

Flood damages can be divided into four main types, which are combinations of the following categories:

- Direct - damage caused by physical contact with the water,
- Indirect - damage caused by flood induced disruption or stress
- Tangible damages – the monetary value of the damage
- Intangible – the non monetary value of the damage

The matrix shown in Figure 3 provides examples of each of the categories.

Figure 3: Matrix of damage category examples

	Direct	**Indirect**
Tangible	Damage to infrastructure, buildings and contents, vehicles, boats etc	Flood fighting, cleaning up, emergency response
Intangible	Death by drowning, loss of items of cultural significance and personal memorabilia	Inconvenience, stress induced ill health and mortality, disruption to schooling, trade, transport, industrial or agricultural production, tourism

As noted by Handmer (1984) the amount of time and energy expended on the various costs and benefits in most flood mitigation studies is directly proportional to ease of measurement. Therefore in general, risk management decisions are almost always based on estimates of tangible losses (NZIER, 2004).

Due to limited data sets in New Zealand, financial considerations and required timeframes, the flood damage assessment at Waihi Beach focused on direct tangible damages. However we recognize that indirect damages and intangible damages can be significant. There is evidence that in some circumstances intangible damages can comprise the majority of flood damages (Green et al. 1983).

Research in the UK (Penning-Rowsell et al, 2002) showed that flood incidents in 2000 were accompanied by significant emergency costs relating to police, fire and ambulance survey costs, Local Authority Costs and Environment Agency costs. These costs were quantified at 10.7% of property damages. However following 2007 floods, guidance on emergency costs were reduced to 5.6% of property damage (FHRC, 2010).

Estimation of indirect damages vary considerably with estimates of up to 75% of direct losses, but typically 15-40% (Handmer, 1985). The Victorian Department of Natural Resources and Environment (NRE) guidance document for floodplain management recommends assuming that indirect damages are 30% of direct damages (NRE, 2000).

4.2 FLOOD DAMAGE FACTORS

Factors affecting flood damage are both physical and human. Physical factors include water velocity, flood depth, debris, flood duration, warning time and presence of pollutants. Human factors are generally related to preparedness, but also include state of emergency services, ease of evacuation, socio-economic status (age, infirm, single parent families) and building structure characteristics.

Flood preparedness and available warning time appear to be critical factors in deriving actual damages from potential damages. In an inexperienced community with a relatively short warning time (<24hrs) actual losses would be approximately equal to potential losses (Handmer, 1985). At the other extreme in an experienced community with along warning time potential damages can be reduced substantially. For example Smith et al (1980) found that actual damage in Lismore consisted of 52.4% and 23.5% of potential damage for the residential and commercial sectors respectively. Lismore is a very experienced and well prepared flood-prone town with about 6-12 hours warning of a major flood (Handmer, 1984).

For a community who have not experienced flooding in the last five years with approximately 12 hours warning time, a factor of 0.8 is used to reduce the potential damages to actual damages (NRE, 2000).

4.3 ESTIMATING FLOOD LOSSES

There are a range of ways to estimate flood losses (monetary value of flood damage), including survey, insurance claim data and depth-damage curves. Surveying households and businesses which have directly experienced damage is arguably the most effective means of gathering accurate flood impact information (NZIER, 2004). However results are actual damages (as opposed to potential damages) and the losses experienced are at one point in time, given the community’s preparedness and length of warning. There are no guidelines for the maximum duration after a flood event that accurate recollection can be relied upon. However there is a suggestion that surveying within two years of an event will produce the most reliable flood impact information (NZIER, 2004). In the case of Waihi Beach, the time and cost to survey all households would have been prohibitive, particularly given the high percentage of holiday homes, which would make surveying the homeowner (who may be away) more time consuming and costly.

Where insurance claims information is available for hazard events, it can provide an easily accessible form of damage estimate relative to survey information. However accessibility to the information and issues relating to over or under-insurance can cause problems with this approach. ICNZ estimate that as many of as one quarter of New Zealand's households are underinsured, with that figure rising to 40% in smaller communities (NBR, 2004).

For the Waihi Beach flood assessment, it was determined that depth damage curves were likely to provide the most appropriate method of damage assessment. Depth-damage curves provide a means of estimating the loss of actual and potential future flood events. Synthetic damage curves have the advantage of being able to be constructed independently of any flood data, and relate to potential rather than actual damage. Damage curves relate solely to water depth and are generally only applicable in areas where flooding is characterised by slow-rising, low-silt and low flow in nature (NZIER, 2004), as observed in the model results at Waihi Beach.

Major advantages of a synthetic depth damage approach are that:

- Damages can be calculated for any flood in any community
- There is a consistent appraisal of flood damages
- Sensitivity analyses are easy and quick to perform
- The benefits of flood alleviation schemes can be quantified

Depth damage curves are typically used to assess damages to buildings and their contents. Therefore the sum of other tangible damages should be added to the damage estimated.

4.3.1 FLOOD DAMAGE AT WAIHI BEACH

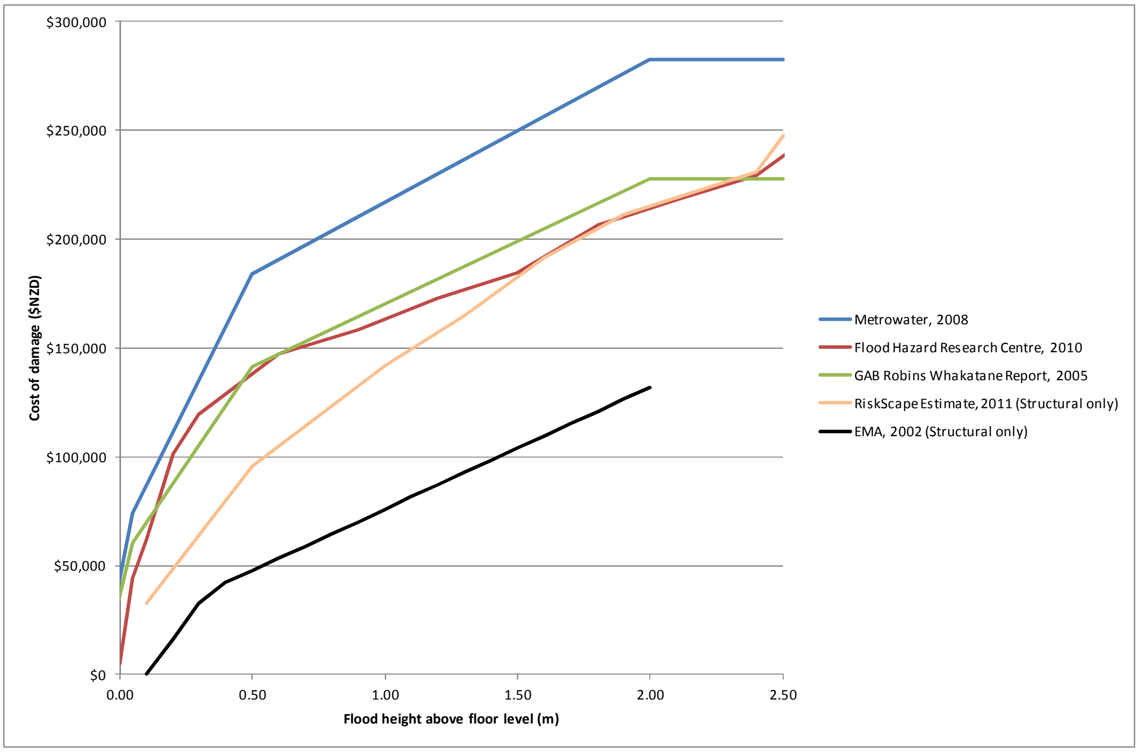
Depth damage curves should ideally be developed from an inventory of property contents and for different structure types specific to a locality. However the data sets publically available in New Zealand do not permit this level of assessment. NZIER (2004) identified that literature on New Zealand hazard tends to be scattered amongst private researchers, government departments and academic institutions.

Flood damage curves using a number of different methods are shown in Figure 4. It should be noted that three damage curves are related to New Zealand conditions but two of these were derived from the same study (Metrowater, 2008 and GAB Robbins, 2005). The Metrowater depth damage curves were developed from the GAB Robbins (2005) depth damage curves to suit Auckland buildings. The GAB Robins (2005) depth damage curve originates from an assessment of flood damages in Whakatane during the 2005 floods. The Riskscape (NIWA and GNS, 2011) depth-damage curve was based on a single storey timber/weatherboard house from surveyed damages that occurred at Manawatu, Bay of Plenty and Lower Hutt (no published report available, curve obtained from http://www.riskscape.org.nz/structure/vulnerability).

The Flood Hazard Research Centre (FHRC) (2010) and Emergency Management Australia (EMA)(2002) depth damage curves were established for UK and Australian conditions respectively. For the UK study flood damage curves were developed for five different house types, seven building ages and four different social classes of the dwellings' occupants (FHRC, 2010). The average of the flood damage curves is shown in the FHRC (2010) curve on Figure 3.

For the purposes of the depth-damage curve comparison shown in Figure 4, foreign currency damages have been converted to NZ dollars, and damages relating to building area and building value have been adjusted to 135m^2 and $330,000 respectively. A 135m^2 house was the basis of the GAB Robbins (2005) and Metrowater (2008) flood damage curves, and is also an appropriate average value to use for Waihi Beach properties. The building value was estimated from averaged monthly median sales prices between 2007 and 2011 minus the median sales price of vacant residential sections. Therefore based on a house sale price of approximately $450,000 (www.zoodle.co.nz), and a vacant residential section price of $114,00 (Motu, 2006) we have estimated a buildings value to be approximately $330,000. For the flood damage assessment provided later in the report the building value for all flooded properties was determined from WBOPDC valuations.

Figure 4: Comparison of depth damage curves



In order to calculate flood depth at each flooded property a floor level survey was first carried out of all properties shown to flood in the worst case modelling scenario. Buildings were identified by overlaying flood maps over aerial photographs. The aerial photographs identified that 285 buildings needed to be surveyed. Following the survey the number of properties increased to 333 residential buildings. This was mainly due to a number of large properties being divided into smaller flats, that appeared as one building from an aerial photograph. Caravans, garages and a small number of non-residential buildings (e.g. surf life saving club) were excluded from the survey.

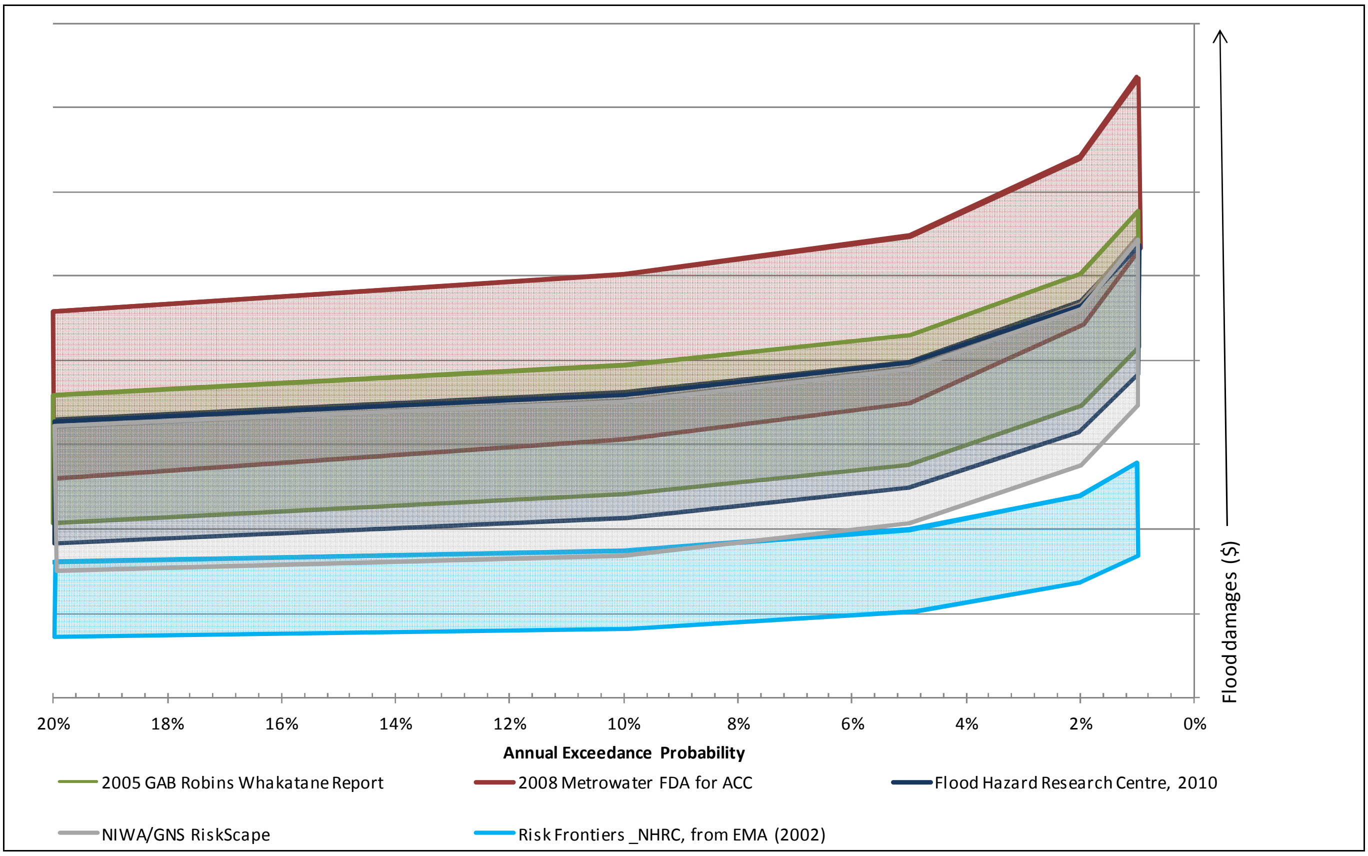
As part of the survey, the surveyors also recorded gully trap levels at each property to help identify potential for stormwater ingress into the wastewater system. The gully trap levels also provided additional useful information to compare ground levels from the photogrammetric survey near to houses. The results of the comparison of ground levels from the photogrammetric survey and the gully trap levels (gully traps typically 50mm above ground level) showed a high discrepancy between surveyed levels and photogrammetric levels used to build the 2D model. The discrepancy varied, with surveyed levels typically 100 mm to 300mm lower than photogrammetric levels, however larger level differences were identified in some areas.

Due to the differences in ground levels from the two sources of information, the flood levels from the model results (based on flood depth) above actual floor levels would also vary. Therefore since it was not practicable to carry out a detailed topographic survey of the entire town area, it was determined that a flood damage assessment using a maximum and minimum flood depth for each property was the most appropriate method for assessing flood damage. This would provide an upper and lower bound of flood damage estimation.

In order to apply the depth damage curves related to house price (Riskscape, 2011; EMA, 2002), it was determined that the average house price method identified earlier was not suitable. Therefore we assessed the flood damage from house valuations obtained from the Council rates assessments.

A flood damage curve was determined for 24 hour duration storms for the existing development scenario using the different depth damage curves presented earlier. The results are shown in Figure 5.

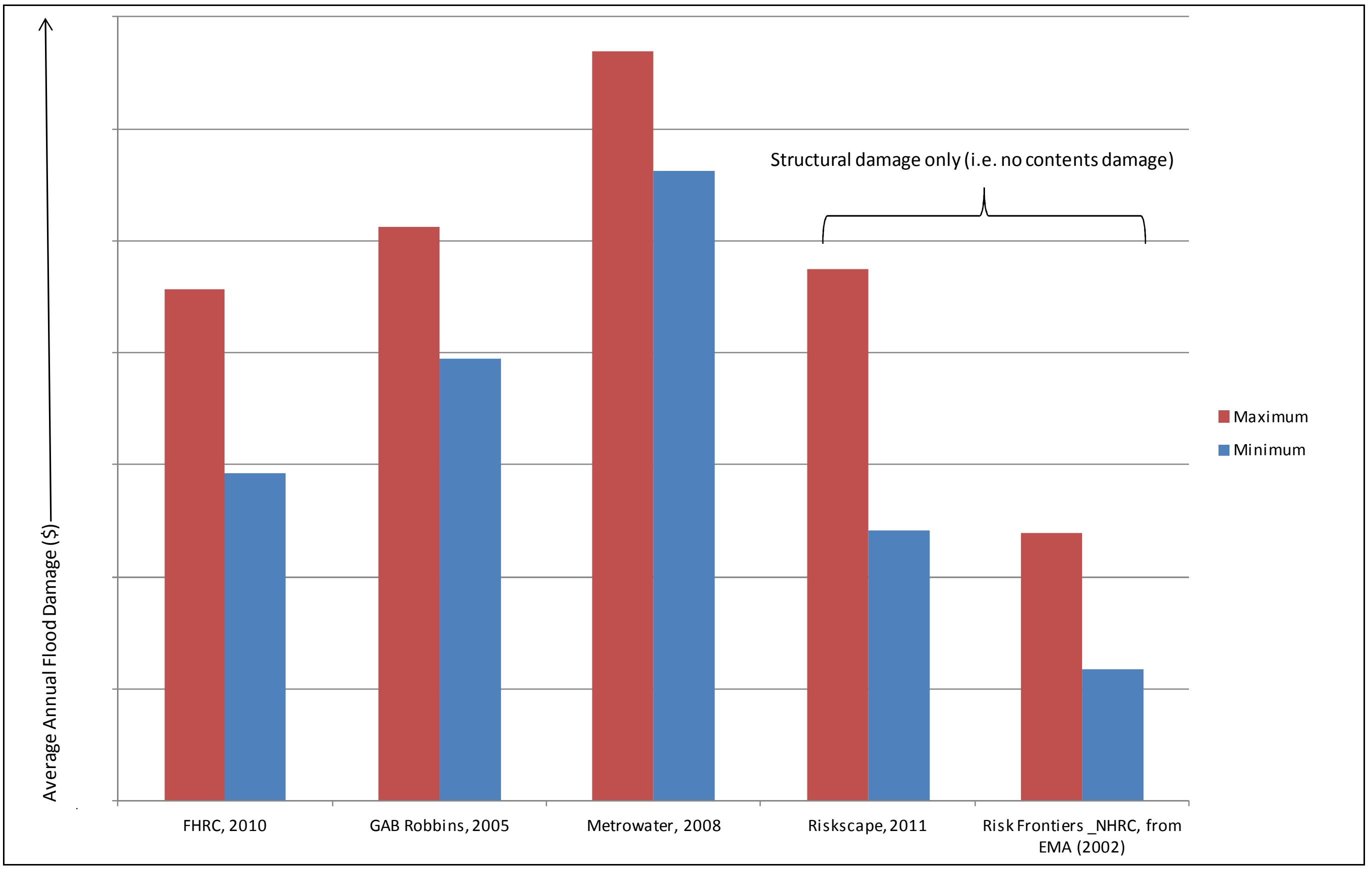
Figure 5: Flood damage curve



The flood damage curves for Waihi Beach show the large range in flood damage estimates using the different depth damage curves. It also shows that at Waihi Beach the damage does not change significantly between a storm event of 20% AEP to a storm event of 5% AEP.

Based on the results of the flood damage assessment shown above, an assessment of Average Annual Damage (AAD) can be made. Given the variability in depth damage curves, the AAD was calculated for the range of methods. The results of the AAD are shown in Figure 6.

Figure 6: Average Annual Damage



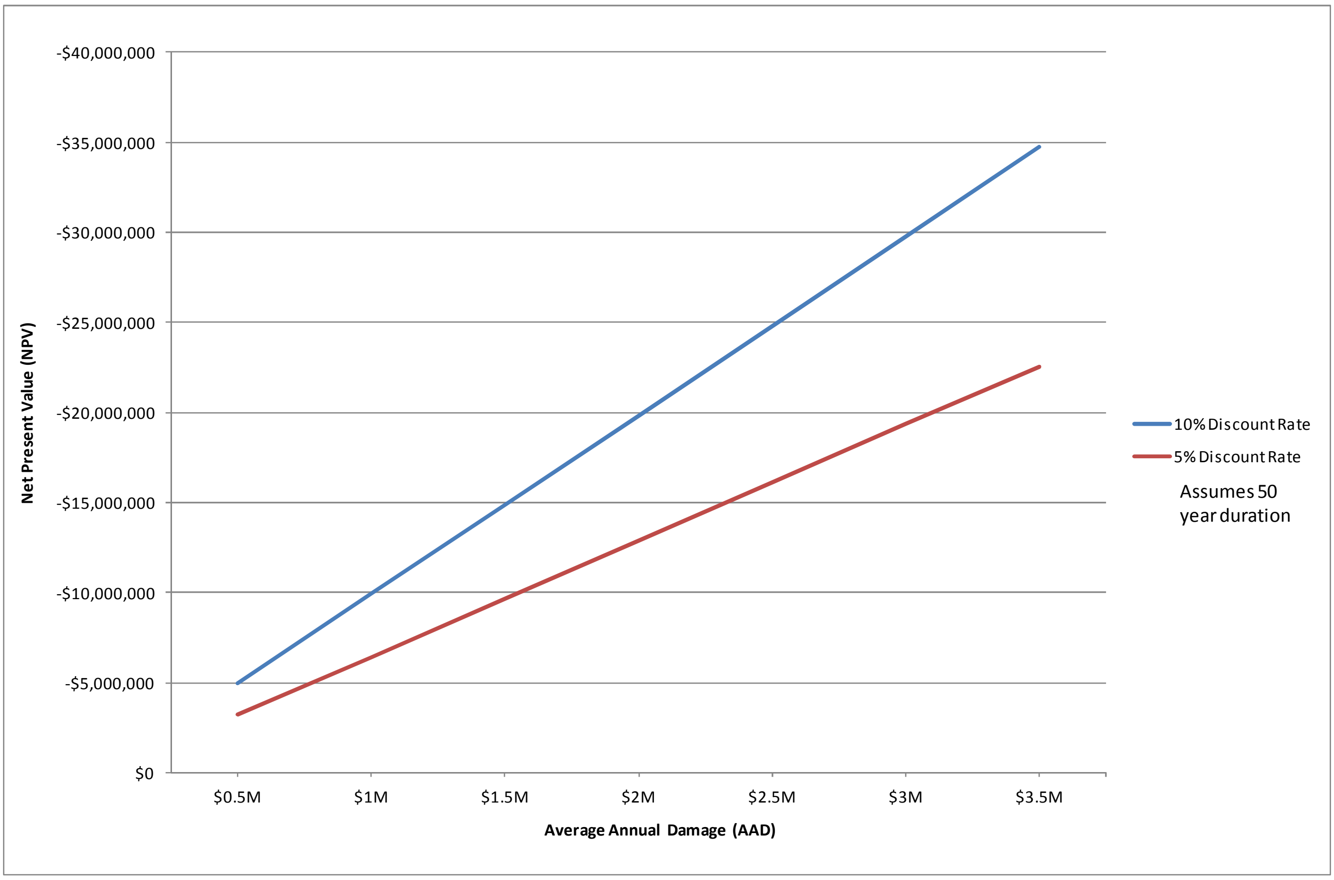
The AAD shown in Figure 6 above relate to property damage and contents damage unless otherwise stated. As previously mentioned, the FHRC (2010) and NRE (2000) approaches would add an additional 5.6% and 30% respectively (note that the 5.6% is not included in Figure 6). The 5.6% and 30% increases would account for emergency costs and other indirect damages respectively (note that the 5.6% from the FHRC approach would be part of the 30% NRE approach).

Based on the AAD results, a Net Present Value (NPV) for not providing any flood mitigation can be calculated. The NPV can then be used as a basis for economic decision making, where an optimal investment is determined if the cost of the flood mitigation project minus the NPV of flood losses is greater than zero. The greater the number above zero, the more beneficial the investment becomes. In any NPV calculation the discount rate (e.g.5-10%) and return period for the investment (e.g. 50 years) is critical. An example of the NPV for a range of AAD's is shown in Figure 7.

Based on the example shown in Figure 7, the NPV for doing no flood mitigation works in an area that experiences average annual damages of $3M is -$30 million (based on a 10% discount rate over 50 year period).

Using the example shown above, the results indicate that a net benefit would be obtained by potentially investing up to $30 million in a project with a 50 year design horizon. However it would be more economically desirable to achieve a higher benefit/cost ratio than 1.

Figure 7: NPV calculation for a range of AAD's



4.4 DISCUSSION

An upper and lower bound of average annual flood damage at Waihi Beach was provided due to uncertainty in ground levels, and depth damage curves. However the upper and lower bounds does not allow for uncertainty relating to:

1. Appropriateness of depth damage curves to Waihi Beach buildings
2. Hydrological assumptions (e.g. rainfall depth, rainfall distribution, catchment parameters)
3. Preparedness of the community to flooding

The appropriateness of the depth damage curve would be crucial to the flood damage assessment. Despite the advantages previously mentioned with regards to an assessment of damages from depth damage curves there may be a number of reasons why it may be appropriate to modify the depth damage curves to Waihi Beach conditions:

- To account for "flood proofing" of contents and structure due to the relatively high frequency of flooding at Waihi Beach. For example, in repairs following floods, electrical sockets in properties may have been elevated, or carpeted floors may have been replaced with water resistant materials.
- To account for structure and contents typical of a holiday home due to the high percentage of non-permanent residential houses.

- House type, building age and social class of the dwellings' occupants (as per FHRC, 2010).

Furthermore, due to the high frequency of flooding that occurs at Waihi Beach it is likely that the community preparedness will be high, therefore in accordance with the NRE (2000) approach it may be appropriate to reduce the potential damages to actual damages based on a factor of 0.8.

The AAD provides an assessment of the sum of financial losses from individual households. However it is important to distinguish between economic and financial losses. The economic losses are those losses experienced by a defined region, since one person's loss can be another person's gain. For example if a carpet is damaged as a result of flooding, the financial loss is the market price of a new carpet; however the economic loss is the depreciated value of the carpet, since the new carpet will need to be purchased from another business (their gain). In the case of WBOPDC, the economic loss of a residential building (not contents) due to flooding may be close to zero so long as the building is rebuilt using products and services from within the WBOPDC region. However if the region was defined as Waihi Beach township, the economic loss may be much greater since products and services from outside the township may be used to rebuild.

In the NZIER (2004) report to the NZ Climate Change Office it was stated that *"The highest priority to advance New Zealand's understanding of the potential changes in flood costs under climate change should be to develop a firmer understanding of current flood costs. This could be achieved through the development of New Zealand –specific depth-damage curves in parallel with surveys to validate those curves and estimate industry losses for specific events."* Recommendations from the report included the need for a floods and impacts database, and construction of New Zealand depth-damage curves. It also recommended more in depth analysis relating to insurance loss, and the effect of socio-economic conditions on flood damage, as well as establishment of a centralised library of New Zealand literature relating to hazards and flood mitigation projects with their costs and benefits quantified.

As part of the research carried out for the Waihi Beach project, and for this paper, it would appear that the same concerns identified in the NZIER (2004) report are still valid in 2012.

5 CONCLUSIONS

A flood hazard assessment has been carried out at Waihi Beach to identify flood prone areas, and to quantify average annual damages caused by flooding. The identification of flood prone areas will assist WBOPDC to determine suitable areas for future development. The flood hazard maps will also assist WBOPDC to restrict development in areas subject to flooding.

The assessment of average annual damages caused by flooding will assist WBOPDC in making future economic decisions for flood mitigation options. However, the project analysis has revealed that there is a high degree of uncertainty in the average annual damage cost (AAD) estimation. The uncertainty is due to a number of reasons relating to the hydrological model, hydraulic model and method of damage assessment. However, based on the availability and accessibility of information including both hydrometric data and damage assessment data, we do not believe that there was a more appropriate method to assess flood damage.

Despite concerns regarding uncertainty in the AAD, the method used for assessing flood damage will provide WBOPDC with a quantifiable way of assessing flood mitigation options.

The results suggest that future flood mitigation options should be assessed using all the depth damage curves identified in this report. By carrying out a AAD and NPV calculation for all depth damage curves, a Benefit/Cost ratio for each method can be applied. If a flood mitigation option can be shown to have a net benefit using all depth damage curves then there will be increased confidence that an optimal solution has been determined. By calculating the net benefit for a range of options, WBOPDC will be able to determine which option provides the most value for their investment.

ACKNOWLEDGEMENTS

Western Bay of Plenty District Council

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