HAWKE'S BAY REGIONAL COUNCIL

REGIONAL COASTAL HAZARD ASSESSMENT: VOLUME I ASSESSMENT

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EXECUTIVE SUMMARY

This report presents the findings of a coastal hazard assessment of the entire Hawke's Bay shoreline with a specific focus on areas with existing communities. The hazard assessment was done using existing published data and information as well as observations made during site visits by our coastal engineers. The study is reported in three volumes. The first volume (this report) contains the background, technical data, general results and management objectives and responses. Volume 2 contains the specific summaries for local settlements.

Objective

The objective of the study was to develop a consistent methodology for erosion and inundation hazard mapping of sandy shores, gravel shores and cliff shores, while taking into account the relevant physical processes, geology, morphology, historic trends, subsidence, sediment supply and climate change effects.

Hazard Zone Methodology

The hazard zone methodology has been developed taking into account that in some areas there is sufficient background information to permit a quantifiable hazard zone, while in other areas expert opinion and judgement is required to provide the basis for establishing the hazard zones. The zone widths are based on the cumulative addition expected erosion rates, episodic storm-induced erosion and climate change effects.

To provide a sufficient time scale for planning and accommodating development, a 100-year planning horizon has been considered. For long-term consistency the year 2100 was used as the actual terminal date of the analysis. Appropriate factors of safety are incorporated into each individual component of the equation.

Definition sketches of the hazard items considered for erosion and inundation are shown in Figures 5.1 and 5.2. Figure 7.1 shows the summary diagram defining the hazard lines.

Three erosion zones are delineated for soft shore areas:

CERZ: The Current Erosion Risk Zone areas subject to storm erosion, short-term fluctuations and dune instability

2060ERZ: The Erosion Risk Zone to 2060 including erosion due to climate change to 2060

2100ERZ: The Erosion Risk Zone to 2100 including erosion due to climate change to 2100

For cliff areas the hazard zone is based on the long-term retreat rate (if present) plus two times the height of the cliff.

Two inundation levels were delineated:

EIRZ: Extreme Inundation Risk Zone areas are those areas within the CERZ with ground levels below the calculated 2%AEP level including run-up and sea level rise to 2100.

MIRZ: Moderate Inundation Risk Zone areas are those areas landward of the CERZ with ground levels below the 2%AEP level, inclusive of sea level rise to 2100 but excluding run-up.

Results

The resulting hazard zone widths for soft shore erosion areas are shown in Table 7.1. The set back for cliff coast erosion is set out in Table 7.2. The resulting inundation levels for the soft shore erosion areas are shown in Table 7.3.

The results show that the entire region's shoreline is prone to storm damage and the influence of cyclical erosion and accretion trends, while there is the risk of erosion due to ongoing and accelerated sea level rise.

Moderate to high rates of long-term erosion are also evident for significant stretches of the shoreline due largely to a sediment supply deficit, ongoing adjustment to the 1931 earthquake and localised adjustments to landslides and slumps.

Coastal Hazard Management

The existing planning provisions in the various regional and district planning documents do not provide a comprehensive means of considering the potential issues associated with coastal hazards.

A suggested policy on coastal erosion, consistent with the RMA and NZCPS obligations is included in Section 8.4., including key principles, planning and regulation, coastal protection options, participation in erosion protection options and partnerships.

Potential Management Responses

Potential management responses under three main response options are identified in Section 9:

Planned retreat

Within the CERZ and cliff hazard zones we recommend the following planned retreat methods:

- No new council infrastructure be located within the CERZ unless required specifically within that zone (i.e. outfalls, changing rooms, toilet facilities, boat ramps etc).
- No new private development (i.e. no new residential lots, and no new dwellings).

Within the future hazard zones (2060ERZ, 2100ERZ) we recommend:

- No major council infrastructure be located within the zones unless required specifically within that zone.
- In existing residential zoned areas all new private development be designed to be readily and demonstrably re-locatable and habitable levels to be established above the design inundation levels. In our opinion, readily re-locatable implies lightweight construction techniques and does not allow concrete slab floor construction or the use of continuous concrete footings or edge beams.
- No further modification of land designation permitted in currently non-residential zoned land.

A range of rules is also required to take into account existing use rights for existing lawful structures and for development in the lower risk areas.

Site specific assessments by an appropriately qualified engineering geologist should be undertaken for cliff top development within the cliff hazard zones.

Adaptation (or accommodation)

Within the CERZ, 2060ERZ and 2100ERZ we recommend the following specific adaptation methods:

- Guidelines for appropriate private re-development of existing dwellings considering existing use rights, natural character, landscape and the coastal hazards.
- Notice of hazard (erosion/inundation/climate change) on land title, LIM/PIM.
- Raising awareness of hazards.
- Monitoring of erosion and inundation drivers.

Protection (or defence)

Within the CERZ we recommend the following protection methods:

- Beach nourishment
- Flood control bunds set back on the upper beach system
- Dune restoration (re-vegetation) with the assistance of community based coast care groups
- Control of access

Other protection options, including groynes, seawalls, revetments maintaining road reserves and stream training works should be considered on a case-by-case basis and only if recommended protection methods are unsuccessful.

Additional Investigations

It is possible that alternative hazard zone widths or inundation levels could be determined based on site specific investigations by appropriately qualified personnel. However, any reduction of zone width or level must be justified on the basis of additional information or investigation work.

Monitoring and Evaluation

On going monitoring and data acquisition should be carried out in accordance with HBRC's long term monitoring strategy to enable a review and refinement of the coastal hazard assessment included in this report.

Council should promote or sponsor research on quantifying wave set-up and run-up for surging breakers on mixed sand gravel beaches.

Both the ongoing climate change impacts and the performance of implemented measures should be periodically evaluated in accordance with Council's long-term coastal monitoring plan.

1.0 Introduction

Hawke's Bay Regional Council (HBRC) commissioned Tonkin & Taylor Ltd (T&T) to complete a coastal hazard assessment for the entire Hawke's Bay region using existing published data and information.

Although providing information on a region wide basis, the study had a specific focus on areas with existing communities. These areas, shown on Figure 1, include Mahanga, Maungawhio Lagoon, Whangawehi, Mahia Beach, Waikokopu / Opoutama, Nuhaka, Tahaenui, Wairoa, Waihua, Mohaka, Waikari, Aropaoanui, Waipatiki, Tangoio, Pakuratahi / Whirinaki, Esk River, Bay view to Westshore, Napier through to Clifton, Cape Kidnappers, Ocean Beach, Waimarama, Kairakau Beach, Mangakuri, Pourerere, Aramoana, Blackhead and Porangahau.

1.1 Scope of Works

The scope of work includes:

1. Coastal Hazard Zone Methodology. This includes an assessment of both the erosion and inundation hazards for the current situation and taking into account future climate change to 2100 using the latest IPCC predictions. The purpose of this assessment was to develop a consistent methodology for erosion and inundation hazard mapping of sandy shores, gravel shores and cliff shores while taking into account the relevant physical processes, geology, morphology, historic trends, subsidence, sediment supply and climate change effects using existing published information and recognising the various spatial requirements.
2. Develop hazard zone maps for the region based on the methodology developed in 1 above.
3. Identify management strategies to control and manage the potential adverse effects arising from the hazard identification.
4. We understand that HBRC staff will be involved with the project team specifically in terms of extracting and supplying the required data from

Council's data bases and to assist in developing the hazard maps in Council's GIS system.

1.2 Tasks

The following tasks will be carried out to achieve the required objectives:

1. Identify existing information, specifically with regard to availability of image, cadastral boundary and contour information from Council's GIS data.

2. Review all relevant background information, data and studies relating to coastal processes and hazards for the Hawke's Bay region.

3. Identify shoreline types and develop an erosion/inundation methodology for each shoreline type. This will be done by review of available aerial photographs, geologic maps and topographic maps.

4. Undertake site inspections for ground verification and confirmation of shoreline types. Two Tonkin & Taylor Ltd staff carried out this inspection.

5. Delineate shoreline types. There will be larger spatial resolution for non-developed areas and closer spatial extents in developed areas. For the majority of the gravel beach area we will be using the region's beach profile locations as the minimum spatial extent.

6. Issue methodology to Dr. Willem de Lange for peer review. The preferred outcome before progressing will be consensus on methodology between the peer reviewer and Tonkin & Taylor.

7. Present methodology to Council for comment.

8. Data collection including preparation of briefs for council staff regarding data requirements. This will involve council officers compiling data that will include profile data, topographic information, cadastral and aerial photographs.

9. Complete a hazard assessment for each identified area or profile and identify exclusion areas around stream and river mouths. Erosion hazard lines will be produced for the current risk and including sea level rise and climate variability allowance to 2060 and 2100. Inundation levels will also be assessed for the current hazard and including sea level rise effects to 2060 and 2100.

10. Hazard Report (First Draft - Peer review copy). This will involve issue of the report to the peer reviewer with comments sent to T&T. No meeting is anticipated for this task. The report will also identify information gaps required to be filled and update the long term monitoring plan currently being implemented by HBRC.

11. Hazard report (Second Draft – Council copy).

12. Develop hazard zones on Council's GIS. It is envisaged that a Tonkin & Taylor Ltd staff member will assist Council officers extrapolate the hazard zones between identified profiles.

13. Prepare Coastal Hazard Management Strategies Report. Identify key management issues and strategies for mitigation and management of the identified coastal hazard. It is anticipated that there will be generic options for various land uses and developments to facilitate implementation into regional and district plans. However, local strategies and rules may also be required in some cases. This report will identify the options for mitigating the effects of the coastal hazards, the pros and cons of each option and identification of the preferred options for further consideration. The report will also consider how best to dispose of engineering structures that are no longer effective and the

place and contribution of coast care schemes and Council's wetland programmes that occur along the coast.

14. Coastal Hazard Management Strategies Report (Draft for Council Review).

15. Finalise and issue both reports.

16. Presentation to Council. This will be done by the project manager

17. Public presentation. This will be done by the T&T project manager. It is assumed that the Council presentation and the public presentation will be carried out during the same visit.

2.0 Existing Information Sources

2.1 Regulatory

Information on land use and cadastral information was obtained from the Regional and District Council's GIS systems and from published planning maps. This information provided the base plan for the establishment of the hazard zones.

2.2 Topography

Digital topographic data was obtained from Land Information New Zealand (LINZ). The LINZ database contains the digital data used to create the 1:50,000 topographical maps of New Zealand. The data is expressed in NZMG coordinates. Heights are expressed in metres above mean sea level (MSL). The planimetric (x,y) accuracy of the data is defined as "90% of well defined points are within ±22 m of their actual position" (LINZ, 2002). The vertical accuracy of the data is defined as "90% of well defined points are within ±5 m of their actual height and contour lines are within ±10 m of their actual position" (LINZ, 2002).

2.3 Bathymetry

The bathymetry of Hawke Bay was derived from NZ Hydrographic charts NZ 56 and NZ 571. Scales for these maps are 1:200,000 and 1:75,000 respectively. Much of the near shore coastline south of Cape Kidnappers and portions of the shoreline adjacent to Clifton is un-surveyed due to the presence of rock reefs and shallow water.

Limited near shore bathymetric information was also available at the beach profile sites within the southern Hawke's Bay district (between Clifton and Tangoio) and at Wairoa.

2.4 Geology

The Hawke's Bay region has three major physiographic elements: inland mountain ranges; a central area of lowlands and river valleys; and coastal ranges of hills. The coastal ranges are formed predominantly by sedimentary rocks of Cretaceous and Tertiary age and these include a predominance of the rock type "papa". Apart from stretches of coast south of Napier and immediately north and south of the Porangahau River mouth, the coast is mostly very rugged. It is being rapidly eroded and this process is assisted by the bentonitic nature of some of the rocks that can result in large mudflows, such as those at Porangahau and Nuhaka and on the Mahia Peninsula. In other areas removal or modification of native vegetation, over-steepening slopes or modification of existing water tables result in accelerated earth movements. Some reefs, mainly comprising Cretaceous calcareous sandstone, are exposed at low tide one or three kilometres out to sea.

A variety of information about the geology of the Hawke's Bay region has been used in this study. Basic geological units between Wairoa and Mahia were derived from the Raukumara Area geological map (1:250,000) compiled by Institute of Geological and Nuclear Science (Mazengarb & Speden 2000). Digital geological information data was provided by HBRC sourced from the Land Resource Information Database. The database includes information about rock type, soil unit, slope, erosion and vegetation of land units. Land Resource Information (LRI) worksheets were produced in 1979 and have been updated and digitised by Landcare Research.

Generally, the Hawke's Bay region is an unstable landscape due to the soft rock structure. Pettinga (1980) carried out an extensive investigation of the geology and landslides of the Te Aute district, in the southern Hawke's Bay and confirmed the presence of tectonically induced slide failures and actively eroding coastal catchments including rock falls, earthflows, regolith and sheet slides and debris flow slides. Typically the area of hazard

susceptible to coastal erosion effects extends from the shoreline to the ridge line.

Portions of northern Hawke's Bay are protected to some degree from wave action at the base of the cliffs due to the presence of large gravel or sandy beach systems. It is possible the risk of coastal landslides may be lower along this section of coast as the buffer the beach provides may result in less wave erosion directly affecting the toe of the cliffs when compared to the more exposed cliffs in the Central Hawke's Bay District. However, there is insufficient evidence to quantify any reduction in landslide potential. Overall, the width of the cliff shoreline hazard zone ignores any potential differences in wave exposure between sites.

We note that the landslide hazard is not exclusive to the coastal margin and that hazard mapping of the landslide and geotechnical instability assessment may need to extend landward of the coastal ridgeline.

2.5 Seismic

The Hawke's Bay region lies in the most active seismic region of New Zealand (Hull 1990). Geologic evidence indicates that over the last 6,500 years the Heretaunga Plains have subsided 11 m near Hastings at a net rate of 1.7 m/1,000 years (Gibb 1980). Further north similar evidence from Poraiti indicates that the western flank of the Ahuriri Estuary has subsided at a rate of around 4.6 m/1,000 years (Hull 1986). Therefore, the geologic trend of probable tectonic downdrop in these areas is in the order of 1 to 5 m per 1,000 years (Gibb 1996). Based on the 1931 Hawke's Bay earthquake, it is likely that the actual changes are more episodic with rapid changes occurring over relatively short time frames, with longer periods of no activity. In the northern Hawke's Bay, uplift associated with the Raukumara area is variable, ranging up to about 4 mm/yr, although over the last 180,000 years, Mahia Peninsula has been characterised by co-seismic uplift in the order of 1-3 m/1,000 years (Mazengarb & Speden 2000).

2.6 Beach Material

Beach material in the Hawke Bay region includes both gravel and sands with marked differences in composition along the coast. Published information is available for the Hawke Bay gravel coast (Smith 1968; Single 1985; Paterson 2000), while there is less available information for the remaining shorelines.

Generally, the beaches south of Cape Kidnappers are composed of fine sands, although occasional gravel beach outcrops occur at several locations. These fine sands typically form perched beach systems overlying papa rock. Mixed sand gravel beaches extend from Clifton to Tangoio and along the northern Hawke Bay shoreline. The main sources of gravel have been attributed to the Tukituki, Esk and Mohaka River systems. Historic studies have concluded that abrasion is actively occurring along the shoreline reducing the size of gravel particles over time.

Embayed sand beaches are present at Waipatiki and around the Mahia Peninsula. All of the coastal plains and the tombolo formation at Mahia have formed during the last 10,000 years, indicating significant accretion during the Holocene. Sand dunes and gravel beach ridges between Wairoa and Nuhaka are present as a continuous strip about 23 km long and up to 1 km wide. The material for these features was derived from local catchments transported by river systems.

2.7 Historic Shoreline Changes

2.7.1 Inferred from Geologic Record

Pettinga (1980) noted that the coastal catchments of southern Hawke's Bay are severely eroding and that the Te Rahui to Taupata section he analysed in detail typifies active mass movement processes of the area. Pettinga (1980) concluded that the entire shoreline is affected by landsliding, and those small areas not actively involved are not only at high risk of instability but are also too small and insignificant to exclude from the overall extreme

susceptibility rating he applied. Significant erosion and land instability was also noted for the northern Hawke's Bay (ed. Mazengarb & Speden 2000). However, no specific rates of cliff shoreline retreat are presented in the literature reviewed.

In the absence of other data, an estimate of geologic long-term cliff retreat for this study is based on an examination of the width of intertidal reef platforms based on the assumption that sea level was significantly lower 10,000 years ago but has been relatively constant over the last 6,500 years. Therefore, dividing the total reef platform widths scaled from the hydrographic charts by 6,500 years can provide an indication of long-term rate of retreat assuming that the front face of the cliffs were at the edge of the reef 6,500 years ago (Group Delta Consultants, 1998). The resulting rates ranged from 0.03 m/yr up to 0.18 m/yr, with an average rate of around 0.1 m/yr. While these figures do not appear unreasonable, these rates only provide a very coarse estimate of long-term trends and may under-estimate actual rates of retreat. Additional investigations will be required to refine these estimates.

2.7.2 Photographs

Aerial mapping of shoreline change has been carried out between Clifton and Tangoio. A series of drawings have been prepared showing changes in the inferred position of the foredune and Mean High Water Mark based on aerial surveys flown in Feb 1936, Dec 1948, Nov 1962, Dec 1963, Dec 1964, Aug 1980 and Oct 1986. These aerials indicated reasonable rates of erosion between Clifton to Awatoto, reasonably stable to accreting shorelines from Awatoto to Napier, eroding shorelines at Westshore from 1962 to 1986, reasonably stable to slightly eroding shorelines from Bay View to the Esk River and slight erosion at Tangoio. Due both to the unrectified original data and the subjective visual assessment method in establishing the toe of the foredune, it is recommended that this information be treated with caution and used for qualitative assessment only.

Additional historic aerial photographs were also obtained for the cliff areas to the south and north of Hawke Bay from New Zealand Aerial Mapping. Table 2.1 schedules the specific location, year of photograph and reference numbers. A CD of the electronic data is included in Appendix A.

Table 2.1
Additional Aerial Photograph Coverage

Location	Year	Reference	Flying Scale	Pixel Size
South of Porangahau	1943	SN 230 535/54	16,000	0.3 m
	1996-1997	V24a	25,000	2.5 m
Blackhead to Aramoana	1953	SN 230 2000/31	16,000	0.3 m
	1998-1999	V23d	25,000	2.5 m
Paoanui Point	1952	SN 230 1996/35	16,000	0.3 m
	1998-1999	V23b	25,000	2.5 m
North of Waimarama	1951	SN 541 1714/83	18,000	0.3 m
	1996-1997	W22a	25,000	2.5 m
Waipatiki	1962	SN 1455 3378/47	17,000	0.3 m
	1996-1997	W20c	25,000	2.5 m
Aropaoanui	1962	SN 1455 3377/48	17,000	0.3 m
	1996-1997	W20a	25,000	2.5 m
Waihua	1962	SN 1455 3367/28	17,000	0.2 m
	1995	SN 9452 K/16	25,000	0.4 m
SN series photographs are not ortho-rectified				

These photographs indicate significant landslides and slippage have occurred in all these areas, with effects reaching up to the ridge of the coastal cliffs that extend up to 1 km inland. Also clearly evident are slumps and rock falls at the base of the cliff. We note that erosion of the steep hillside is not limited to the coastal cliffs, but also occurs inland. Therefore, toe erosion by the sea is only one of the factors contributing to land instability along the coast.

Aerial photographic analysis has been carried out for the Mahanga shoreline north of the Mahia Peninsula (Gibb, 2002) using the 1942 and the 2002 duneline and cliffline positions. Dr. Gibb derived a cliff retreat rate of 0.25 m/yr to the north of Mahanga Beach and 0.10 m/yr adjacent to the retreating Mahanga landslide. South of this area the shoreline has experienced reasonable accretion with the rates generally increasing towards the south.

Dr. Gibb inferred beach fluctuations in the order of 25 m from the aerial photographs (Gibb, 2002).

Historic photographs of Waimarama, including oblique and aerial plan views were inspected. The photographs indicated the modification brought about by the subdivision of the area in the mid-1970s with stream training and seaward encroachment to form level sections. The photographs also illustrated the large degree of variability in beach levels, with the foreshore periodically lowering down to the gravel/cobble base (Flowers 1995).

2.7.3 Beach Profile Information

Monitoring of shoreline profiles has been carried out by HBRC at selected locations along the coast. The main focus of monitoring has been the southern Hawke's Bay region, from Clifton to Tangoio and Waimarama Beach. Figures 2.1, 2.2, 2.3 and 2.4 show the locations of beach profile benchmarks within the southern (Figure 2.2) and northern Hawke's Bay (Figures 2.3, 2.4) and at Waimarama (Figure 2.1). Other profiling sites have been initiated around Mahia. However, these sites do not contain sufficient survey information to determine trends.

Tables 2.2, 2.3 and 2.4 show a summary of the data, including the date range, the number of years, the number of data points in the record and the calculated trends of shoreline movement at the 11.0 m level (just above MHWS) based on linear interpolation. A negative trend indicates erosion, while a positive trend indicates accretion. Information for the Waimarama profiles is shown in Table 2.2, Clifton and Tangoio profile summaries are shown in Table 2.3 and profile summaries of the northern extent of Hawke's Bay is shown in Table 2.4.

At Waimarama beach profiling started in 1977 along the southern end of the beach, and was extended further north in 1992 and 1994. The long-term trend at the southern end of the beach is variable, with small rates of erosion

and accretion. However, the low correlation coefficient suggests a very dynamic beach system with no discernable trend. The shorter data set of the northern end of Waimarama indicates relatively high rates of erosion that have occurred over the last 10 years. Examination of the entire cross-shore profile confirms the presence of a nearshore bar. This suggests a system with large cross-shore transport potential and hence significant fluctuation of the upper beach area.

Table 2.2: Beach Profile Analysis - Waimarama Series Long Term Trends

No.	Data Range		No. Years	No. Records	Trend (m/yr)	r^2
	From	To				
WM1	01/07/1977	19/12/2002	25	11	0.000	0.000
WM2	01/07/1977	19/12/2002	25	11	0.306	0.449
WM3	01/07/1977	19/12/2002	25	11	0.269	0.069
WM4	01/07/1977	19/12/2002	25	12	-0.029	0.023
WM5	01/07/1977	19/12/2002	25	11	0.196	0.195
WM6	01/07/1977	19/12/2002	25	11	-0.242	0.367
WM7	01/07/1977	19/12/2002	25	11	-0.005	0.000
WM8	01/12/1992	19/12/2002	10	9	-0.107	0.000
WM9	01/12/1992	19/12/2002	10	9	-0.863	0.055
WM10	01/12/1992	19/12/2002	10	9	-0.739	0.039
WM11	01/12/1992	19/12/2002	10	9	-1.940	0.324
WM12	10/12/1992	19/12/2002	10	10	0.179	0.003
WM13	01/12/1992	19/12/2002	10	9	-1.486	0.134
WM14	01/12/1992	19/12/2002	10	9	-2.387	0.242
WM15	01/12/1992	19/12/2002	10	8	-1.230	0.029
WM16	01/02/1994	19/12/2002	9	8	-5.227	0.542
WM17	01/02/1994	19/12/2002	9	8	-7.817	0.629
WM18	01/02/1994	19/12/2002	9	8	-1.235	0.080

Table 2.3: Beach Profile Analysis - Clifton to Tangoio Long Term Trends						
No.	Data Range		No. Years	No. Records	Trend (m/yr)	r^2
	From	To				
HB1	27/04/1972	09/04/2002	30	14	-0.748	0.915
HB2	23/01/1973	09/04/2002	29	42	-0.311	0.372
HB3	21/11/1974	09/04/2002	27	37	-0.418	0.620
HB4	13/11/1974	05/09/2002	28	39	-0.699	0.256
HB5	11/12/1989	09/04/2002	12	17	-0.380	0.016
HB6	11/12/1989	09/04/2002	12	17	-0.91	0.52
HB7	01/01/1939	09/04/2002	63	29	-1.740	0.840
HB8	01/01/1946	09/04/2002	56	21	0.686	0.927
HB9	19/12/1983	09/04/2002	18	25	-0.053	0.011
HB10	19/12/1983	09/04/2002	18	26	0.612	0.765
HB11	19/12/1983	09/04/2002	18	25	-0.060	0.014
HB12	12/11/1974	09/04/2002	27	34	0.892	0.657
HB13	27/08/1975	09/04/2002	27	63	-0.943	0.893
HB14	20/10/1977	09/04/2002	24	37	-0.483	0.483
HB15	01/01/1916	09/04/2002	86	29	-0.121	0.218
HB16	12/11/1974	09/05/2002	28	53	0.857	0.760
HB17	23/12/1995	09/04/2002	6	11	0.821	0.211
HB18	05/12/1991	09/04/2002	10	16	-0.998	0.593
HB19	05/12/1991	09/04/2002	10	15	-0.735	0.531
HB20	12/11/1974	09/04/2002	27	37	-0.456	0.616
HB21	12/11/1974	09/05/2002	28	53	-0.808	0.876
HB22	05/12/1991	09/04/2002	10	15	-0.216	0.016
HB23	05/12/1991	09/04/2002	10	14	-0.111	0.009

Table 2.4: Beach Profile Analysis - Wairoa Series Long Term Trends						
No.	Data Range		No. Years	No. Records	Trend (m/yr)	r^2
	From	To				
WairoaRM1	31/10/1997	20/12/2000	3	6	-0.970	0.246
WairoaRM2	31/10/1997	20/12/2000	3	6	-1.740	0.693
WairoaRM3	31/10/1997	20/12/2000	3	6	-1.326	0.390
WairoaRM4	31/10/1997	20/12/2000	3	6	-2.487	0.501
WairoaRM5	31/10/1997	20/12/2000	3	6	-2.904	0.819
WairoaRM6	31/10/1997	20/12/2000	3	7	-0.705	0.003
WairoaRM7	31/10/1997	20/12/2000	3	6	8.637	0.117
WairoaRM8	31/10/1997	20/12/2000	3	7	3.383	0.174
WairoaRM9	31/10/1997	20/12/2000	3	6	4.048	0.788
WairoaRM10	31/10/1997	20/12/2000	3	6	0.748	0.210
WairoaRM11	31/10/1997	20/12/2000	3	6	-0.970	0.246
WairoaRM12	31/10/1997	20/12/2000	3	6	-0.180	0.003
WairoaRM13	31/10/1997	20/12/2000	3	6	-2.190	0.489

Within the southern part of Hawke's Bay some data extends back to 1916, presumably based on interpretation of marine charts and historic cadastral information. The majority of profiles were established in the mid-1970s after the significant storms of 1974 or during the 1980s. Recorded shoreline movements are reasonably consistent with the inferred trends from the aerial photograph assessment. These trends are characterised by high rates of erosion at the southern end of the bay, relatively stable to accretionary trends from Awatoto to Napier, erosion along the Westshore coastline and slight erosion for the shoreline north of Westshore. Given recent trends of large-scale erosion in some areas and large-scale accretion in others, the overall sediment system appears to be dynamic but exhibits a slight trend towards erosion.

For the northern Hawke's Bay area beach profile data started in 1998. No long-term trend can be reliably inferred in this area due to the short record of shoreline movement.

2.8 Water level

Fluctuations in sea level are an important factor to consider when assessing the risk of coastal inundation and erosion. The periodic rising and falling of the level of the surface of the sea, known as the tide, is caused by the gravitational attraction of the Moon and Sun on the waters of the rotating earth. However, there are other factors that can affect water level fluctuations including large scale cyclical wind patterns, barometric pressure and storm surges.

The actual mean sea level can fluctuate by around 0.2 m when all longer-period sea-level cycles of at least 6 months are included (i.e. excluding storm effects or climate-change trends). These fluctuations are attributed to seasonal variability (heating and cooling), El Nino-Southern Oscillation (ENSO) effects and Inter Pacific Oscillation effects (IPO) (Bell et al, 2000).

Storm surge can raise water levels due to a mix of wind stress and atmospheric pressure and can occur over periods ranging from hours to days. For New Zealand the upper range of storm surge is 0.8 m to 1.0 m with around a 50:50 split between atmospheric pressure and wind stress (de Lange, 1996). Commonly a value of 0.9 m is applied to the MHWS elevation to provide an estimate of storm surge elevations with a return period in the order of 1% AEP.

Tidal water level records are available from the tidal recorder at the Port of Napier. The predicted ranges are provided in Table 2.5 as published in the New Zealand Nautical Almanac (2003/04 Edition).

The average values typically presented in the Nautical Almanac are derived from the combinations of the principal tide raising forces of the Sun (a motion represented by the S2 constituent) acting in line with that of the Moon (represented by the M2 constituent). This method effectively determines tidal levels for most locations in New Zealand. However, along the east coast it has recently been determined the S2 constituent is overtaken

by the effect of the Moon's distance from the earth as it moves between its closest approach (Perigee) and furthermost approach (Apogee) – a motion represented by the N2 constituent. Tidal levels based on all the constituents are provided as mean values in the table below. A comparison of the two methods to determine typical tidal levels suggest that the revised all-constituent MHWS equivalent to 10% of the high water levels, is more than 0.23 m above the historically predicted MHWS.

At each surveyed beach profile the origin of the erosion hazard zone on soft shores is taken to be the 11.0 m contour level (to HBRC Datum), which is situated just above the MHWS position calculated by the mean prediction method.

Table 2.5
Predicted Tide Levels, Port of Napier

Tidal level	w.r.t. LINZ (m)		w.r.t. Chart Datum (m)	
	Average Value	Mean Value	Average Value	Mean Value
HAT	1.05	1.05	2.00	2.00
MHWS	0.73	0.96	1.68	1.91
MHWN	0.64	0.61	1.59	1.56
MSL	0	0	0.95	0.95
MLWN	-0.65	-0.56	0.30	0.39
MLWS	-0.74	-0.93	0.21	0.02
Chart Datum	-0.95	-0.95	0	0

Notes

- Source: NZ Nautical Almanac (2003)
- Average value is the historically presented information in terms of S2 and M2
- Mean values derived from all tidal constituents

2.9 Waves

Limited wave information exists for the HBRC region. The following data are available:

- Anecdotal observation of historic storms
- Visual shoreline observations at Marine Parade, Napier from 1975 to 1979 (held by NIWA).

- Ongoing visual wave observations at Marine Parade, Westshore and Wairoa from 1998 to present (undertaken by Hawke's Bay Regional Council).
- Deepwater wave buoy measurements from 10 May to 6 September 2000 and 19 May to 26 August 1999 (obtained and held by NIWA).
- Wave measurements by the Port of Napier at 16 m Chart Datum (CD) from August 2000 to the present.
- WAM hindcast data at 3 hourly intervals between 1979 and 1998.

The WAM hindcast is the only available dataset sufficient to provide a long-term wave climate. The WAM data suggests a deepwater significant wave height of 7.0 m represents a 5% exceedance significant wave height. The dataset is uncalibrated for Hawke Bay as the recorded data is generally inadequate for calibration or do not overlap the hindcast period. However, a comparison of the WAM data with recorded data near the port showed good correlation in terms of height and direction (Gorman et al. 2003).

Tonkin & Taylor (2003) carried out a transformation of the WAM hindcast to nearshore wave conditions (10 m water depth) using the SWAN model (Simulating WAves in the Nearshore) for a variety of output points within Hawke Bay (Figure 2.1). Empirical relations were used to transform waves to the southern open coast. A summary of the model results for the Hawke Bay area is shown in Table 2.6 and Figure 2.1.

Table 2.6
Wave Climate Statistics for Hawke Bay, 1979 to 1988

Output Point[1]	Mean H_s (m)	Sd.dev. H_s (m)	Max. H_s (m)	Mean T_p (m)	Sd.dev. T_p (m)	Mean Wave Direction (deg)	Sd.dev. Wave Direction (deg)
1	0.6	0.4	3.3	10.7	2.5	87	6
2	0.5	0.3	3.4	10.2	2.4	84	6
3	0.5	0.3	3.5	9.9	2.6	95	7
4	0.6	0.4	3.8	10.2	2.7	101	7
5	0.6	0.4	4.1	10.5	2.8	106	7
6	0.5	0.3	3.4	10.7	2.8	99	5
7	0.6	0.4	3.9	10.7	2.8	109	6
8	0.6	0.4	4.2	10.7	2.9	113	7
9	0.7	0.4	4.4	10.8	2.8	116	7
10	0.7	0.4	4.3	10.9	2.8	120	7
11	0.7	0.4	4.3	10.5	2.6	131	9
12	0.9	0.5	4.7	10.7	2.6	149	9
13	1.0	0.6	4.8	11.0	2.5	163	8
14	1.2	0.7	4.9	11.4	2.2	183	7
15	1.0	0.6	5.3	11.6	2.4	192	3

[1]Position of selected Output Points shown in Figure 2.1

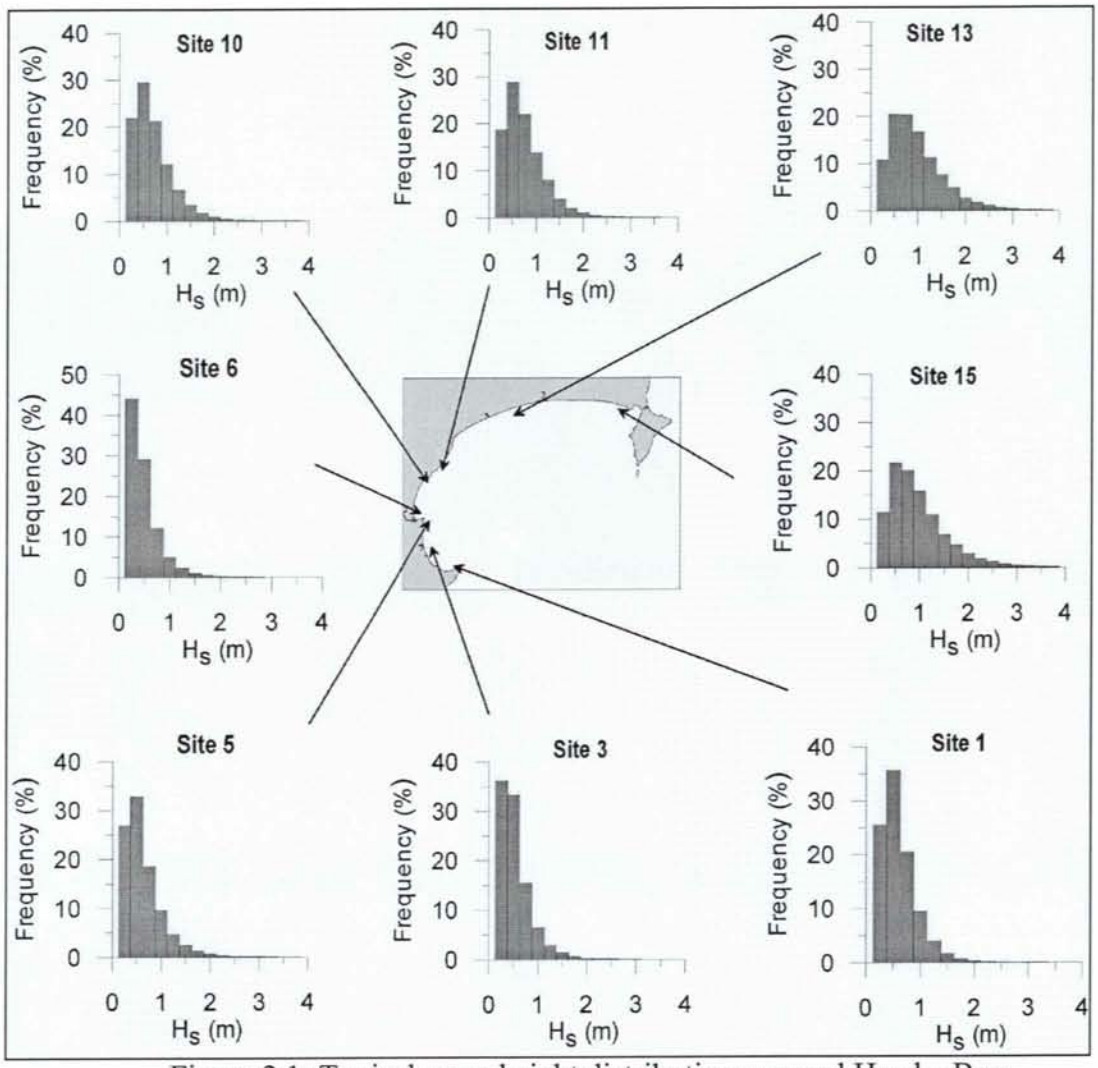

Figure 2.1: Typical wave height distributions around Hawke Bay

The following conclusions were drawn from the modelling study:

- The offshore spectra indicate a dominant swell component with a mean offshore wave direction from the South, mean H_s of 1.76 m and mean T_p of 10.4 s.
- The nearshore wave climate at the open coast locations, south of Cape Kidnappers, indicate a dominant southerly wave component with a mean H_s and T_p of approximately 1.0 m and 10.5 s respectively.

- The nearshore wave climate within Hawke Bay varies with respect to the location along the coastline. Typically, the mean wave energy along the shoreline increases to the east towards the Mahia Peninsula (mean H_s of 0.46 m at Westshore to 0.97 m at the Mahia Peninsula).
- The nearshore modelling results for different periods of El Nino and La Nina cycles has indicated no distinguishable trends.
- Maximum significant wave heights at the nearshore locations varied from around 5.5 m at the northern end of Hawke Bay and along the southern shores to 3.3 m in the lee of Cape Kidnappers.

Historically significant storm events have been noted in 1890 (March and November), 1891(February), 1894 (April), 1907 (April), 1925 (July) and 1974 (June and August). Observed storm wave heights were typically in the order of 4.5 m to 9.0 m. It is assumed that the 9 m height represents the maximum wave height rather than the significant wave height of storm events. This range of wave heights is consistent with the transformed SWAN wave heights from the WAM hindcast.

The Port wave gauge recorded a maximum wave height of 4.7 m with an associated period of around 15 s during the recent April 2002 storm. This appears to be on the lower end of the scale of significant storm wave heights. However, it did combine with a reasonably high tide level (1.7 m CD) to create significant damage along the Haumoana foreshore.

2.10 Currents

Hume et al. (1989) found that tide and currents in the vicinity of the port do not exceed 0.05 m/s 95% of the time. Larger currents are generated by the wave shoaling and breaking process, with wave heights of more than 0.5 m able to generate currents sufficient to transport fine sands. Therefore, transport of sediments is primarily associated with wave events and is likely to be episodic, rather than steady, over time.

2.11 Tsunami

Tsunami can be generated by large earthquakes that rupture the seafloor, submarine landslides, undersea volcanic eruptions or from large coastal cliff slides into the sea. There are two types of tsunami, local and remote.

Local tsunamis are generated on New Zealand's continental shelf and can be characterised as having short periods between wave crests and could reach heights of greater than 10 m over relatively short stretches of coast. The 1931 Napier earthquake generated two separate tsunami; a very localised 15.3 m high tsunami due to a landslide in the Waikari River estuary and a co-seismic tsunami with a maximum height in the range of 3.0 to 5.5 m (de Lange, in print). On 25 March 1947 a locally generated tsunami on the Hikurangi Margin of 6 to 7 m occurred along Mahanga and Pukenui Beaches. This tsunami caused flooding up to 250 m inland but did not cause significant erosion of the dune system (Gibb 2002).

Remote tsunamis are generated beyond New Zealand's continental shelf with South America being the predominant source area. These tsunamis have longer periods and more limited maximum wave height. However, they can affect wider stretches of coast and can persist for several days. Along the Napier shoreline a 1m tsunami has a return period of around 56 years, while a 2.5 m tsunami has a return period of around 97 years (de Lange and Fraser 1999).

3.0 Coastal Hazard Potential

Large areas of the Hawke's Bay shoreline do not have extensive data sets that can be used to evaluate coastal hazards. However, the result of the background data review and site inspections identified that there are significant coastal hazards along the entire Hawke's Bay coastline, both in terms of erosion and inundation risk.

The geological setting suggests that landslides, mud flows, earthquakes and tremors are an ongoing likelihood, with the resulting effects of both uplift and downdrop. Where large scale local slumping occurs within the seabed and river areas, there is a risk of local tsunami induced inundation.

Erosion of the soft shores occurs both as a result of erosion of the headland controls and reductions in sediment supply suitable for replacing natural losses from the coastal system. The reduction in supply is due to a range of factors, including the ongoing impact of the 1931 earthquake and the episodic nature of significant material discharge from cliff areas. Some of the earthquake impacts can be expected to reduce in time. However, where changes in river outlet position or discharge occur, effects could still be ongoing.

Therefore, ongoing retreat can be expected in many areas. However, the rate of ongoing erosion varies significantly along the coast. Potential climate change effects may also further exacerbate coastal erosion and inundation by changing local wave climates and increasing sea levels.

The high risk areas are typically those where existing urban settlements are in close proximity the shore. Of these, the southern Hawke Bay settlements between Clive and Clifton appear to have the most significant erosion and inundation risk due to high rates of ongoing shoreline erosion, apparently as

a result of a drop in ground levels at the time of the 1931 earthquake, reduced gravel sediment supply from the Tukituki River and possibly from reduced sand and gravel supply from Cape Kidnappers. The remaining settlement areas appear susceptible to large scale and possibly cyclical shoreline movement as well as low rates of long-term erosion.

4.0 Coastal Hazard Delineation

4.1 Shoreline Behaviour Units (SBU)

The shoreline has been divided into the following categories:

- Gravel beaches,
- Sand beaches,
- Cliff shores, and
- River mouth spit/barrier beach.

Figures 4.1 to 4.4 show the delineation of Shoreline Behaviour Units. Where cliffs are within 80 m of the high water mark (or the LINZ 1: 50,000 topographic map coastline where aerial photographs were unavailable), the shorelines have been defined as cliff shores. This mainly applies to shoreline areas south of Cape Kidnappers, the Tangoio cliff area and around the Mahia Peninsula.

4.2 Land Use

Land use areas have been divided into three main categories:

- Residential/industrial,
- Reserves (including recreation, esplanade, nature), and
- Rural.

The Residential/Industrial land use area was defined using either digital or hard copy zoning maps supplied by Central Hawke's Bay District Council, Hastings District Council, Napier City Council and Wairoa District Council. As each council has different nomenclature and range of zones, a list of the specific zones from each TLA included in the Residential/Industrial classification is provided in Table 4.1.

Table 4.1 Zones Included in Residential/Industrial Land Use Area According to Territorial Local Authority		
Territorial Local Authority	**Residential/Industrial Area Classifications**	**Source of Boundaries**
Central Hawke's Bay District	Township (TSP)	CHBDC GIS
Hastings District Council	Coastal Residential Plains Industrial 4 Industrial 6 Suburban Commercial	HDC GIS checked against Proposed District Plan Maps (2000)
Napier City Council	Rural Settlement Fringe Commercial Inner City Commercial Marine Parade Character Main Residential Main Industrial	City of Napier Proposed District Plan Maps (Amended to Incorporate Decisions 18 January 2003)
Wairoa District Council	Residential Settlement Town Centre	Wairoa Proposed District Plan (2001) Maps

The "Reserves" land use category was defined using cadastral information supplied by Hawke's Bay Regional Council to identify land parcels classified as some form of reserve, including but not limited to, Esplanade Reserve, Foreshore Reserve, Government Purpose Reserve, Local Purpose Reserve, Marine Reserve and Reserve for Nature.

All other coastal land not identified as Residential/Industrial or Reserve was classified "Rural". This classification is generally the same for all TLAs, however in Hastings District the Rural classification also includes land zoned "Plains".

5.0 Hazard Methodology

The hazard zone methodology has been developed taking into account the fact that in some areas there is sufficient background information to permit a quantifiable hazard zone, while in other areas expert opinion and judgement is required to provide the basis for establishing the hazard zones.

5.1 Soft Shore Erosion Zone

For both gravel and sand shores the following generic approach was used to determine the width of the coastal erosion hazard zone:

$$Hz = ST+SE+DS + SL+LT \quad (1)$$

Where:

Hz is the width of the hazard zone,

ST = Horizontal short-term fluctuations (m), equal to two times the standard deviation of annual shoreline movement at each profile measured 1.0 m above MSL (taken to be equivalent to MHWS of 11 m above HBRC datum),

SE = the shoreline response to Storm Erosion (m), equal to the standard deviation of annual shoreline movement at each profile measured at 1.0 m above MSL,

DS = distance from 1.0 m above MSL (i.e. 11 m above HBRC Datum) to the active dune/beach, effectively providing the width of the existing sub-aerial beach which is assumed to remain constant in width even with ongoing shoreline retreat,

SL = the magnitude of shoreline retreat due to possible accelerated sea level rise based on a modified Bruun Rule approach excluding allowance for local relative sea level rise change due to tectonic activity, and

LT = the long term rate of horizontal shoreline movement (m/year) taking into account abrasion, cross-shore and longshore losses based on the greater of the long term trend of beach profile data or inferred by expert judgement from aerial photographs (where available).

To provide sufficient time scale for planning and accommodating development a 100-year planning horizon has been considered. For long-term consistency the year 2100 was used as the actual terminal date of the analysis.

Appropriate factors of safety are incorporated into each individual component of the equation. The methodology to determine each component of the equation is described in Section 6.

Formula 1 was applied at all HBRC coastal profile sites shown on Figure 2.1 and 2.2. The extent of shoreline representative of each profile site was assessed during the site visit and the initial review stage. It was assumed that the profiles were representative of reasonable lengths of shoreline on either side of the profile.

In areas where there were either no coastal profiles or insufficient data from profiles, an erosion hazard width was obtained by assuming that the short-term fluctuations (i.e. ST and SE) along the unrestricted shoreline of Waimarama Beach were representative of all sand beach movements in the region. No DS value was applied and the zone was established at the vegetation line boundary from the most recent aerial photograph.

The area at risk from coastal erosion along soft shores was divided into three zones as illustrated in Figure 5.1 and described below:

- Current Erosion Risk Zone (CERZ): This zone includes those areas that are subject to storm erosion, short-term fluctuations, and dune instability (eg, (SE+ST)*1.25+LT(10)+DS). This area includes all the land presently at risk from shoreline change erosion, with a factor of safety of 1.25 applied to the short term fluctuation. An allowance of ten years of erosion trend (LT(10)) was also applied to take into account the long term trend associated with adjacent cliff retreat rates.

- 2060 Erosion Risk Zone (2060ERZ): This zone includes the CERZ and additional areas that are predicted to be subject to shoreline movements due to the long term rate of erosion and SLR to the year 2060. This provides councils with assistance in terms of Building Act reviews.

- 2100 Erosion Risk Zone (2100ERZ): This zone includes the CERZ and those areas predicted to be affected by shoreline movements due to both the long-term rate of erosion and SLR from 2060 to 2100.

5.2 Cliff Shore Erosion Zone

Results of the literature review, historic aerial photograph analysis and site observations suggest that while there are some areas of reasonably competent cliffs, generally the cliff shores are unstable and prone to landslides, slips and mudflows.

The estimated width of cliff erosion zones was based on inferred distances from the NZMS topographic information and checked using the following formula:

$$Hz = 2H + (LT \times T)$$

Where:

Hz = the width of the hazard zone,

H = the height of the cliff above its toe,

LT = the long term rate of horizontal shoreline movement (m/year) as determined by expert opinion, based on site inspection and a comparative review of historic and recent aerial photographs. This was taken uniformly to be 0.1 m/yr, or 10 m over the planning period, and

T = Planning time period (100 years).

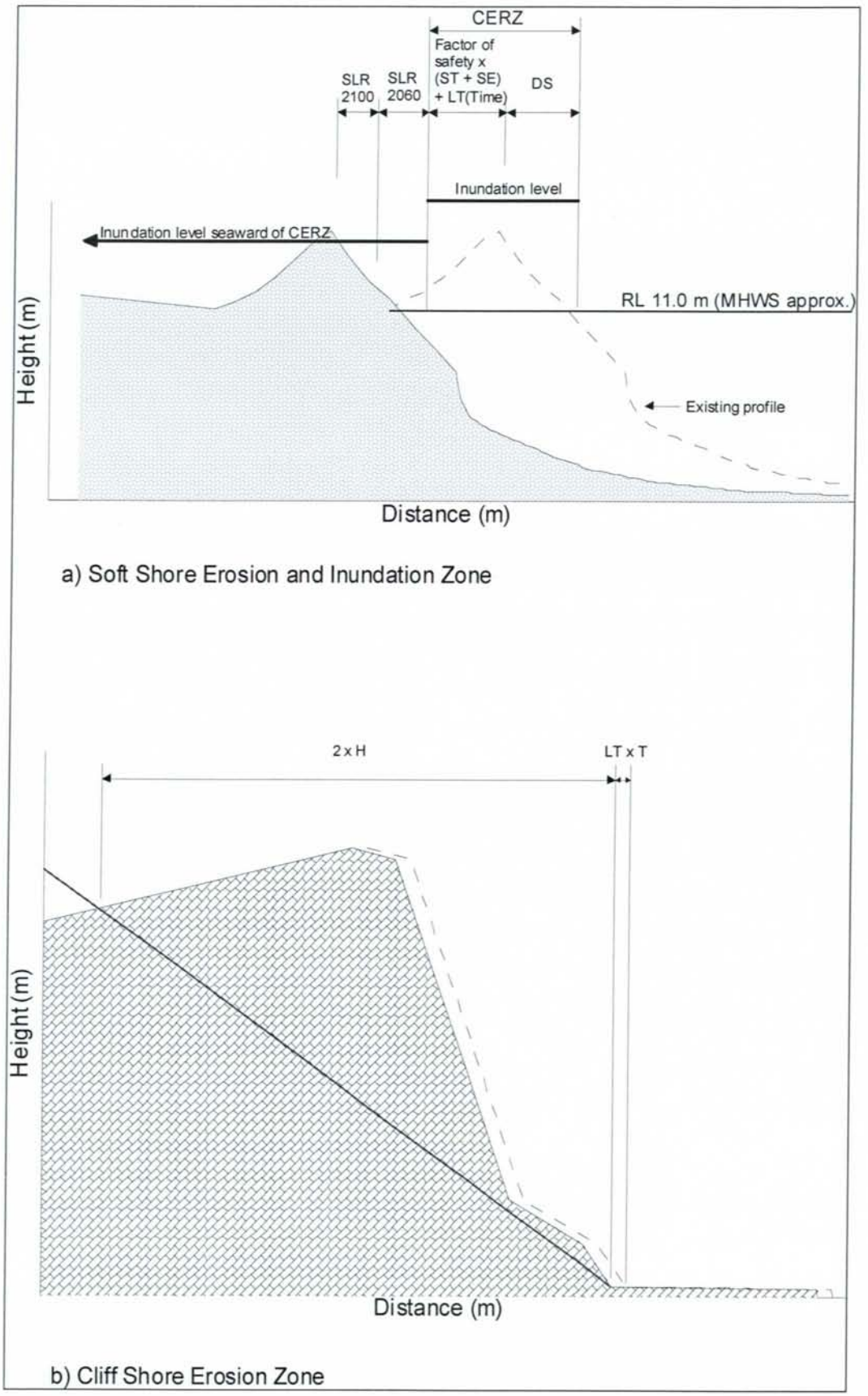

Figure 5.1: Coastal Erosion Hazard Definition Sketch

This method was proposed by the California Coastal Zone Conservation Commission for slopes of low stability and is considered suitable for competent cliffs in rural zoned areas and reserve areas. Only one zone was established along cliff shores. The width of this zone was set by the greater of the two methods. However, it should be acknowledged that all slopes up to the ridgeline could be classed as potentially susceptible to effects of coastal hazards based on the wave action removing toe support to the cliff shores. Cliff slopes landward of the ridgelines are also at risk from landslides. However, potential risks for the land catchments are not considered in this report.

5.3 River Mouths, Spits and Bars

River mouths, spits and bars are typically more sensitive areas due to additional hydraulic forcing of the river or estuary system acting on them. It is proposed that the entire spit or bar length be identified as an area susceptible both to erosion and inundation by visual inspection of aerial photographs. Where the soft shore erosion method has been used to calculate the hazard zones for residential areas adjacent to the river mouth, the landward boundary of the hazard zone will be the same as the adjacent ERZ2100 hazard zone.

5.4 Origin of Erosion Hazard Zone

At each surveyed beach profile the origin of the erosion hazard zone on soft shores is taken to be the 11.0 m contour level (to HBRC Datum), which is situated just above the MHWS position calculated by the mean prediction method including all tidal constituents.

The location of the origin of the hazard zone along the shoreline has been identified at intervals of no greater than 1 km and at around 50 m to 100 m centres along shorelines of developed areas.

The location of the origin between the beach profiles was interpreted from aerial photographs as the line between the wet and dry beach area. However, the vegetation line has been used for soft shore areas outside Hawke Bay as this provides a more readily identifiable feature from aerial photographs than the wet line.

For the cliff shores the origin of the hazard zone was based either on visual assessment of the location of the cliff toe from aerial photographs or from the location of the cadastral boundary where no photographs were available.

5.5 Inundation

To determine minimum ground levels or building platform heights, a range of standards and factors require consideration. Building Act considerations require that an event with an Annual Exceedance Probability (AEP) of 2% should not enter a dwelling. New subdivision design practice usually considers 1% AEP events (100 year return period). Locally, Central Hawke's Bay District Council require a consideration of 100 years return period for secondary flow paths and a minimum freeboard of 500 mm while Napier City Council and Hastings District Council accept stormwater design for secondary flow paths based on a 50 year return period event with no specified freeboard.

Taking the various stormwater design requirements into account, the mapping of areas at risk from coastal inundation were divided in the following two zones:

- Extreme Inundation Risk Zone (EIRZ): Those areas where the land elevation within the CERZ is below the calculated 2% AEP combined tide and storm surge event including run-up with SLR to 2100.
- Moderate Inundation Risk Zone (MIRZ): Those areas where the land elevation landward of CERZ is below the calculated 2%AEP combined tide and storm surge event excluding wave run-up with SLR to 2100.

Figure 5.2 shows the Inundation Hazard Definition sketch.

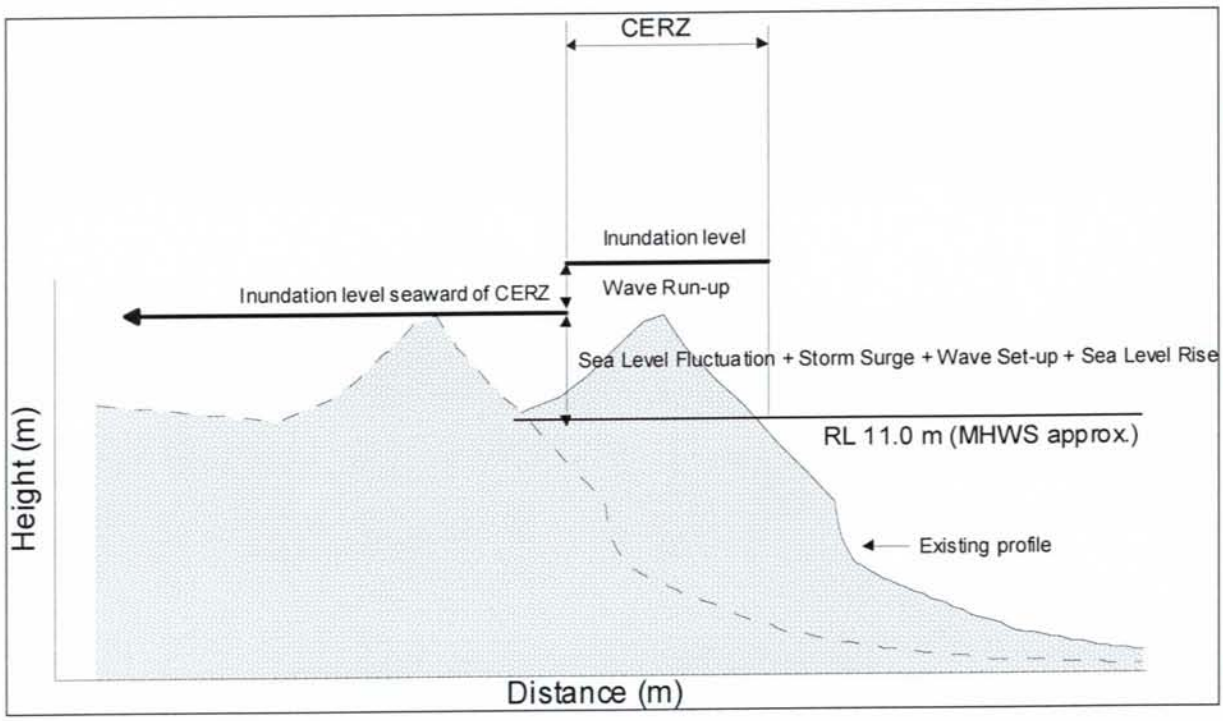

Figure 5.2: Inundation Hazard Definition Sketch

The inundation levels were determined using the formulas

$$EIRZ = MHWS + SLF + SS + SU + SLR2100 + RU$$

and

$$MIRZ = MHWS + SLF + SS + SU + SLR2100$$

Where:

MHWS: Mean High Water Springs is set at a constant value of 11 m.

SLF: Sea Level Fluctuation is set at a constant value of 0.2 m to account for fluctuations in sea level over periods greater than

6 months, e.g. El Nino, Inter-decadal Pacific Oscillation (MfE, 2003).

SS: Storm Surge is set at a constant value of 0.9 m, based on the assessment by Bell et al. (2000) that a storm surge of 0.9 m is likely to have a return period of 80 to 100 years.

SU: Maximum wave Set-Up calculated using methods outlined in Part II, Chapter 4 of the Coastal Engineering Manual (USACE, 2003) as follows: (symbols defined in Figure 5.3) The maximum set-up is calculated as shown in equation II-4-25a,

$$\bar{\eta}_{max} = \bar{\eta}_s + \frac{d\bar{\eta}}{dx}\Delta x \qquad \text{(II-4-25a)}$$

Where the distance between the still water setup and point of maximum set up, Δx, is calculated as

$$\Delta x = \frac{\bar{\eta}_s}{\tan\beta - \frac{d\bar{\eta}}{dx}} \qquad \text{(II-4-25b)}$$

And the gradient of setup from the point of maximum water level set-down on a planar beach is

$$\frac{d\bar{\eta}}{dx} = \frac{1}{1 + \frac{8}{3\gamma_b^2}}\tan\beta \qquad \text{(II-4-23)}$$

The set up at the still water shoreline

$$\bar{\eta}_s = \overline{\eta_b} + \left[\frac{1}{1 + \frac{8}{3\gamma_b^2}}\right] h_b \qquad \text{(II-4-24)}$$

Where the set down at the break point (η_b) is calculated as

$$\bar{\eta} = -\frac{1}{8}\frac{H^2\frac{2\pi}{L}}{\sinh\left(\frac{4\pi}{L}d\right)} \qquad \text{(II-4-21)}$$

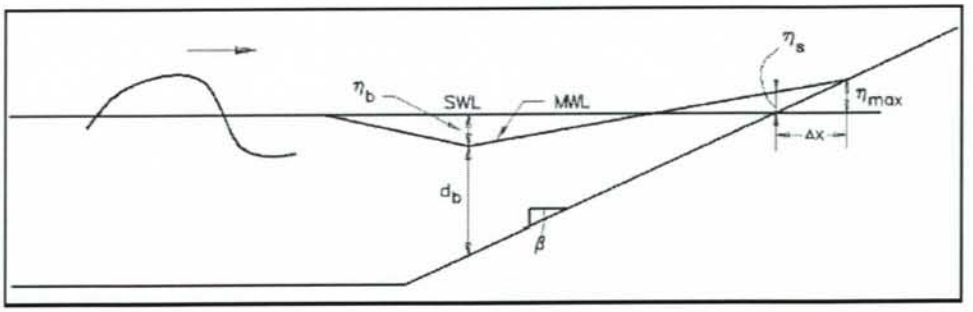

Figure 5.3 Definition sketch for wave setup (Figure 11-4-7, USACE 2003)

SLR2100: Sea Level Rise to 2100 calculated using the Bruun Rule (Refer Section 5.1 of this report).

RU: Wave Run-Up is 70% of significant wave height (H_s) (MfE, 2003).

We note that wave set-up and run-up will vary with the beach state, so that a dissipative beach with spilling waves will experience different results than a reflective beach with plunging waves for the same deep water wave height. Much of the Hawke Bay comprises mixed sand gravel beaches that involve surging breakers.

The formulae used are derived from research on planar sandy beaches. We could not source any other method of evaluating run-up more accurately or appropriately than the methods presented in this report. However, we recommend that Councils consider supporting ongoing research into quantifying the wave set-up and run-up for surging breakers on mixed sand gravel beaches.

6.0 Technical Assessment

6.1 Long Term Erosion Rates

Long-term trends were assumed possible for beach profile data sets with records of at least 18 years. Shorter records are likely to include significant scatter due to the natural dynamic movement of the beach systems. Long records may also skew average shoreline trends due to closer proximity in time to the 1931 earthquake. The length of data is relatively short for the prediction of long-term trends. Expert judgment is required to interpolate and derive a consistent long-term trend due to the variable start times of the record. An acknowledgement of remaining uncertainty results in a precautionary approach to this assessment, which can be refined with a longer data set.

Recorded accretion rates were not taken into account to offset potential erosion rates. Therefore, in areas of accretion or inferred dynamic stability the long-term erosion trend was set to zero. This process effectively assumes that there will be no further long-term accretion.

The benefit of ongoing beach replenishment and nearshore sand dumping within the Westshore area was taken into account by setting the long-term trend to zero from the Lagoon to midway between profile HB 15 and HB16. This assumption requires Council to maintain the beach profiles at the present position and not to permit any long-term shoreline retreat.

At Waimarama the long-term record set is located along an area backed by an extensive seawall. Therefore, shoreline movements are confined due to the presence of a structure and cannot be reliably used to define long-term trends. The number of sites available for interpretation from beach profile information is limited to the southern Hawke's Bay area. For the remainder of the shoreline inferred rates have been derived from a range of

information sources including rate of cliff retreat, previous reports and aerial photograph assessment (refer Section 2.7).

Table 6.1 shows the long-term rates used at all soft shore coastal locations. Included in this table are the calculated long-term trend (where available) and the inferred trend based on expert judgement. For the southern most beaches, from Porangahau to Ocean Beach, the long-term trend has been based on the inferred rate of cliff retreat. This assumption is based on the observation that the beaches are headland controlled, and as the headlands retreat due to cliff erosion the beaches will retreat at the same rate.

The long term rate for the Hawke's Bay profiles were interpreted from the results presented in Table 2.2. In general, long term rates of shoreline movement for the northern Hawke's Bay and along the majority of the south facing shores of Mahia were set to zero (no long term retreat). However, in particular local areas, such as the northern end of Mahanga and the eastern end of Mahia Beach and Whangawehi, long-term retreat rates based on adjacent cliff erosion rates were used.

Table 6.1
Shoreline Retreat Rates on Soft Shores

Location	Profile	Dist from 11 m to Origin (m)	LT (m/yr)	SE (m)	ST (m)	DS (m)
Porangahau	None	ND	0.12	14	28	N.D.
Blackhead	None	ND	0.09	14	28	N.D.
Aramoana	None	ND	0.11	14	28	N.D.
Pourerere	None	ND	0.18	14	28	N.D.
Mangakuri	None	ND	0.14	14	28	N.D.
Kairakau	None	ND	0.14	14	28	N.D.
Waimarama	WM 1	16.46	0.13	14	28	7.76
Waimarama	WM 2	25.43	0.13	14	28	7.63
Waimarama	WM 3	17.88	0.13	14	28	9.68
Waimarama	WM 4	19.15	0.13	14	28	8.95
Waimarama	WM 5	17.04	0.13	14	28	5.24
Waimarama	WM 6	41.62	0.13	14	28	5.32

Table 6.1 Shoreline Retreat Rates on Soft Shores						
Location	Profile	Dist from 11 m to Origin (m)	LT (m/yr)	SE (m)	ST (m)	DS (m)
Waimarama	WM 7	53.17	0.13	19.59	39.18	10.37
Waimarama	WM 8	42.06	0.13	15.92	31.85	11.16
Waimarama	WM 9	35.49	0.13	10.29	20.58	9.39
Waimarama	WM 10	36.79	0.13	10.62	21.24	11.39
Waimarama	WM 11	41.26	0.13	7.72	15.45	13.46
Waimarama	WM 12	35.17	0.13	10.86	21.71	21.96
Waimarama	WM 13	66.34	0.13	10.18	20.36	31.84
Waimarama	WM 14	106.02	0.13	10.58	21.17	65.12
Waimarama	WM 15	39.02	0.13	20.61	41.22	23.12
Waimarama	WM 16	58.30	0.13	17.29	34.58	39.9
Waimarama	WM 17	48.54	0.13	19.5	39	37.24
Waimarama	WM 18	60.03	0.13	13.06	26.13	36.73
Ocean Beach	None	ND	0.13	14	28	ND
Clifton	HB 1	55.34	0.75	2.15	4.3	12.14
Te Awanga	HB 2	103.88	0.31	5.16	10.32	20.28
Haumoana	HB 3	54.70	0.42	3.73	7.45	22.3
Haumoana	HB 4	82.37	0.7	6.46	12.92	26.07
Clive	HB 5	129.29	0.7	12.01	24.02	35.29
Clive	HB 6	158.58	0.7	3.82	7.63	34.58
Awatoto	HB 7	143.21	0.7	6.04	12.08	77.51
Awatoto	HB 8	67.63	0	3.65	7.3	26.53
Napier	HB 9	120.37	0	3.52	7.04	38.37
Napier	HB 10	141.69	0	2.62	5.23	38.29
Napier	HB 11	111.60	0	3.33	6.65	36
Napier	HB 12	79.14	0	5.66	11.32	30.54
Westshore	HB 13	83.62	0	5.66	11.32	35.02
Westshore	HB 14	37.27	0	4.87	9.75	17.17
Westshore	HB 15	80.22	0	5.03	10.06	41.62
Bayview	HB 16	87.97	0.05	3.58	7.17	60.07
Bayview	HB 17	134.70	0.1	5.49	10.98	46.9
Esk River	HB 18	54.67	0.1	2.57	5.15	41.47
Esk River	HB 19	72.86	0.46	3.01	6.01	50.46

Table 6.1 Shoreline Retreat Rates on Soft Shores						
Location	**Profile**	**Dist from 11 m to Origin (m)**	**LT (m/yr)**	**SE (m)**	**ST (m)**	**DS (m)**
Esk River	HB 20	85.94	0.46	5.06	10.12	54.94
Tangoio	HB 21	156.88	0.34	3.25	6.5	69.88
Tangoio	HB 22	90.20	0.22	6.44	12.88	66.9
Tangoio	HB 23	87.77	0.11	4.86	9.72	44.17
Waipatiki	None	ND	0	13.85	27.7	N.D.
Aropaoanui	None	ND	0	13.85	27.7	N.D.
Waikari	None	ND	0	6.44	12.88	N.D.
Mohaka	None	ND	0	6.44	12.88	N.D.
Waihua	None	ND	0	6.44	12.88	N.D.
Wairoa	None	ND	0	6.44	12.88	N.D.
Tahaenui	None	ND	0	6.44	12.88	N.D.
Nuhaka	None	ND	0	6.44	12.88	N.D.
Waikokopu/Opoutama	WO1	93.02	0	14	28	63.82
Waikokopu/Opoutama	WO2	100.75	0	14	28	55.55
Waikokopu/Opoutama	WO3	141.61	0	14	28	43.31
Waikokopu/Opoutama	WO4	134.53	0	14	28	49.83
Waikokopu/Opoutama	WO5	93.76	0	14	28	87.46
Waikokopu/Opoutama	WO6	33.80	0	14	28	27.6
Mahia Beach	None	ND	0.1	14	28	N.D.
Whangawehi	None	ND	0.1	14	28	N.D.
Maungawhio Lagoon	None	ND	0.1	14	28	N.D.
Mahanga	MH1	83.15	0.1	14	28	27.55
Mahanga	MH2	49.34	0	14	28	30.54
Mahanga	MH3	78.49	0	14	28	55.89

Notes

T&T Hazard zones measured from 11 m contour

SE = 1 standard deviation, representing typical storm movement

ST = 2 standard deviations, representative of cyclical changes

LT = Inferred long tem trend

DS = Horizontal distance from 11 m contour to crest of active beach/vegetation line. Vegetation line used in lieu of DS where no profile data exists.

6.2 Short Term Fluctuations

The short-term fluctuation factor takes account of the variability of the long-term trend of shoreline movements. This is particularly important for coasts close to being in a state of dynamic equilibrium. For these coasts, while the long-term trend is one of stability with little net change, there are fluctuations in shoreline position with the shoreline retreating at times, and advancing at other times. These patterns of movement are for a longer period than an individual storm event and are in response to natural variations in climatic conditions and sediment supply. For example, there may be variations in the direction and magnitude of shoreline movements associated with El Nino and La Nina conditions. However, the resulting fluctuations may mask a long-term trend of relative stability.

Temporal variations in the supply rate of river sediment can also result in fluctuations of shoreline position with shoreline stability or growth common following high intensity rainfall in adjacent catchments, while shoreline retreat occurs during periods of little river sediment supply. This is particularly the case on barrier spits and around river mouths where rapid fluctuations in shoreline position may mask long-term trends.

The magnitude of the erosional component of these fluctuations is important for coastal hazard mapping, as we need to make sufficient allowances for these periods of retreat in the current extreme risk hazard zone.

6.2.1 Data Used in the Analysis

The HBRC beach profiles have been surveyed over a period of between 6 and 29 years. These records of annual or near annual beach change generally include four periods of persistent La Nina weather pattern (05/81-03/82, 5/88-10/89, 07/95-2/97, 5/98-3/01), four periods of persistent El Nino patterns (04/82-06/83, 8/86-6/88, 8/89-12/95,3/97-4/98) and include major storm events. It is therefore considered the profiles provide an adequate database for determining the magnitude of short-term changes in shoreline

position. However, all the records were taken during a positive period of the IPO. This has the potential to create a bias in shoreline changes and therefore an acknowledgement of the IPO is included in the assessment.

To standardise the data, the analyses were limited to these annual or near annual surveys. At sites with more than one survey per year, only one survey was used in the analysis and additional surveys at other times of the year were disregarded. In this way all time periods were standardised across all sites, eliminating the possibility of inconsistent and biased results due to comparing changes over different time periods.

6.2.2 Method Used to Measure Shoreline Movement

There are several methods that could be used to measure short-term fluctuations in beach positions. The relative merits and shortfalls of each were considered before the adopted measure was accepted.

Maximum Recorded Retreat

This measure is often used as the short-term component in the calculation of hazard zones and is used in situations where there is no better source of data.

The method also suffers from inconsistencies between sites where different survey intervals have been used making direct comparisons between the sites difficult, and the results are also limited by the length of record available.

Maximum Recorded Retreat in Regular Time Intervals

This method overcomes the inconsistencies of the maximum-recorded retreat method and allows for direct comparisons between sites. However, the length of record available places limitations of the usefulness of the result. For short lengths of record, and particularly those biased by El Nino

conditions, the record is unlikely to include the full range of possible shoreline fluctuations.

Maximum Movement in an Erosion Phase

This method involves identifying phases of erosion that are continuous over several survey intervals. This method has the potential to accurately measure the full range of fluctuations possible at each site, and allows for natural variations in the timing and magnitude of erosion responses at individual sites. However, it is still restricted to the actual movements recorded and is limited for data sets with short record lengths. Differences in survey interval used at different sites also result in inconsistencies.

Short Term Retreat determined by Linear Regression

This method is also limited for hazard mapping purposes, as a mean rate obtained will be exceeded in the order of 50% of the time. Therefore, the resulting short-term retreat will not account for the maximums observed in the record. Clearly, this does not accurately represent the level of risk from short-term fluctuations, and our knowledge of the potential impact of a negative IPO on shoreline retreat.

Arithmetic Mean Movement

While this method removes the need to test for a relationship between net movement of the dune toe and time, it still has the same limitations for use in a hazard zone calculation as the linear regression method.

Standard Deviation of the Mean Movement

To use this method we first have to satisfy the assumption that the magnitude of shoreline movements are normally distributed. At each site the distribution of annual shoreline movement were subjected to tests for normality involving comparison of the observed frequency with the expected normal distribution frequency as outlined in Bhattacharyya & Johnson (1977).

Although the sample sizes are small, the results indicate that the distribution of shoreline movement can generally be considered to be normal, although at a number of sites the observed distribution is slightly skewed.

Having largely satisfied the normality of the data, we can then use the standard derivations (sd) from the mean as our measure of short-term fluctuation. From normal probability theory, we know that an observation value at 1sd, 2sd, 3sd from the mean will have corresponding probabilities of occurrence of 16%, 2.5%, and 0.5% respectively. Since our data is annual movements, these probabilities can be considered to be equivalent to Annual Exceedance Probabilities (AEP). Therefore, a shoreline retreat greater than 2sd is the same as a 40-year return period event, and greater than 3sd is the same as a 200-year return period event. However, the analysis of the results showed that 3sd events did occur during the relatively short data set at profiles HB1, HB7, HB13 and HB14 suggesting large movements may occur at more frequent return periods.

Given that for coastal erosion hazard zoning purposes we wish to define the absolute level of risk such that we are confident that any area not included in the zone will not be affected by the hazard, the 2sd annual movement of the dune toe is adopted as the short-term fluctuation component in the hazard zone. The results of the short-term analysis of the HB and Waimarama series of beach profiles are shown in Tables 6.2 and 6.3. The resulting use of these short-term trends is shown in Table 6.1.

Table 6.2: Short Term Trends in Shoreline Movement, Waimarama									
No.	Data Range		No. Years	No. Records	Mean (m)	1sd (m)	2sd (m)	3sd (m)	Maximum (m)
	From	To							
WM1	22/12/1997	19/12/2002	5	6	-0.034	0.511	1.022	1.534	-0.710
WM2	22/12/1997	19/12/2002	5	6	0.016	4.108	8.216	12.324	5.180
WM3	22/12/1997	19/12/2002	5	6	0.476	3.131	6.261	9.392	5.430
WM4	22/12/1997	19/12/2002	5	6	0.296	1.717	3.434	5.150	-2.570
WM5	22/12/1997	19/12/2002	5	7	-0.507	5.930	11.860	17.790	-7.440
WM6	22/12/1997	19/12/2002	5	6	-0.814	4.841	9.681	14.522	6.380
WM7	22/12/1997	19/12/2002	5	6	-3.588	19.590	39.180	58.770	27.020
WM8	22/12/1997	19/12/2002	5	6	-2.286	15.923	31.845	47.768	-25.990
WM9	22/12/1997	19/12/2002	5	7	-1.788	10.291	20.583	30.874	-19.550
WM10	22/12/1997	19/12/2002	5	7	-1.563	10.621	21.241	31.862	-19.710
WM11	22/12/1997	19/12/2002	5	7	-2.575	7.723	15.446	23.169	-14.140
WM12	22/12/1997	19/12/2002	5	7	-3.337	10.855	21.710	32.565	-19.270
WM13	22/12/1997	19/12/2002	5	7	-0.662	10.180	20.360	30.541	-16.780
WM14	22/12/1997	19/12/2002	5	7	0.042	10.583	21.166	31.750	14.870
WM15	22/12/1997	19/12/2002	5	6	0.292	20.610	41.221	61.831	29.740
WM16	22/12/1997	19/12/2002	5	6	-5.408	17.288	34.575	51.863	22.760
WM17	22/12/1997	19/12/2002	5	6	-9.102	19.498	38.996	58.494	-34.350
WM18	22/12/1997	19/12/2002	5	6	-0.660	13.065	26.129	39.194	18.320
Positive indicates accretion, negative shoreline movement indicates erosion									

Table 6.3: Short Term Trends: Southern Hawke's Bay									
No.	Data Range		No. Years	No. Records	Mean (m)	1sd (m)	2sd (m)	3sd (m)	Maximum (m)
	From	To							
HB1	20/12/1995	09/04/2002	6	8	-1.810	2.151	4.301	6.452	-4.600
HB2	12/10/1973	09/04/2002	29	28	-0.491	5.162	10.325	15.487	15.740
HB3	20/04/1978	09/04/2002	24	25	-0.429	3.726	7.451	11.177	-8.760
HB4	21/02/1978	05/09/2002	25	24	0.002	6.459	12.918	19.377	-14.170
HB5	11/12/1989	09/04/2002	12	14	-0.345	12.011	24.022	36.033	31.910
HB6	11/12/1989	09/04/2002	12	14	0.228	3.817	7.635	11.452	9.330
HB7	02/12/1992	09/04/2002	9	11	1.463	6.040	12.080	18.121	11.750
HB8	02/12/1992	09/04/2002	9	11	0.558	3.649	7.298	10.947	8.480
HB9	19/12/1983	09/04/2002	18	18	0.374	3.519	7.038	10.557	6.420
HB10	19/12/1983	09/04/2002	18	20	0.599	2.617	5.234	7.851	4.960
HB11	19/12/1983	09/04/2002	18	19	0.353	3.327	6.654	9.981	6.420
HB12	20/04/1978	09/04/2002	24	24	0.723	5.661	11.322	16.982	17.250
HB13	16/10/1975	09/04/2002	26	28	-0.767	4.304	8.608	12.912	11.840
HB14	02/12/1986	09/04/2002	15	17	-0.779	4.874	9.749	14.623	13.160
HB15	22/12/1995	09/04/2002	6	8	0.114	5.031	10.062	15.093	-8.410
HB16	12/11/1974	09/05/2002	28	31	0.496	3.585	7.169	10.754	13.130
HB17	23/12/1995	09/04/2002	6	8	0.464	5.491	10.983	16.474	-7.700
HB18	05/12/1991	09/04/2002	10	12	-1.435	2.573	5.146	7.719	4.500
HB19	05/12/1991	09/04/2002	10	12	-0.693	3.006	6.013	9.019	-4.940

Table 6.3: Short Term Trends: Southern Hawke's Bay									
No.	Data Range		No. Years	No. Records	Mean (m)	1sd (m)	2sd (m)	3sd (m)	Maximum (m)
	From	To							
HB20	18/05/1979	09/04/2002	23	24	-0.481	5.058	10.116	15.173	-12.860
HB21	12/11/1974	09/05/2002	10	12	0.576	3.248	6.497	9.745	4.710
HB22	05/12/1991	09/04/2002	10	12	-0.085	6.439	12.879	19.318	10.420
HB23	05/12/1991	09/04/2002	10	12	0.161	4.858	9.717	14.575	-6.780
Positive indicates accretion, negative shoreline movement indicates erosion									

The results presented in Tables 6.2 to 6.3 indicate that at all sites the 3sd value generally returns a larger amount of retreat than the observed maximum annual retreat, while the 2sd is generally less than the maximum annual retreat. Therefore, it is considered that the use of this statistic to measure short-term retreat due to variations in climatic conditions has overcome the potential limitations imposed by using actual measured retreat from a short or biased dataset. A factor of 1.25 was applied to these distances to estimate a short-term fluctuation likely to be greater than a fluctuation with a return period of between 50 and 100 years.

6.3 Storm Cut

There is insufficient frequency in the survey profile data to determine the shoreline fluctuation due to storms. To take the effect of storm cuts into account 1sd was used to represent the shoreline retreat during a storm. This method suggests the shoreline retreats some 2 to 7 m for the majority of the southern Hawke Bay gravel beach profiles and the profiles at Wairoa. At Waimarama and Mahia, where sand beaches predominate, the potential movement range increases to more than 20 m. A factor of 1.25 was applied to these distances to estimate a storm cut likely to be greater than a cut with a return period of between 50 and 100 years. Proposed storm cut allowances, excluding factors of safety are shown in Table 6.1.

6.4 Foreshore Slope

Where detailed survey results were available, the distance from RL 11.0 m to the dune crest or beach berm was measured from the most recent beach

profile data. This provided the width of the foreshore from high tide line to beach crest.

For areas without survey data the dune slope was not used and the measurements were applied from the visually identified vegetation line or dune toe line. The proposed beach slope allowance is shown in Table 6.1.

6.5 Sea Level Rise

Empirical models to estimate the potential shoreline retreat for a given sea level are still the only consistent approach currently available. The most commonly used and internationally recognised empirical model is the Bruun Rule and its various modifications.

Per Bruun developed the Bruun Rule in 1962. The rule simply suggests that with a rise in sea level there is a corresponding upward and landward movement of the shoreline. The formula provides the extent of landward retreat based on the assumption of a closed material balance system between firstly the beach and nearshore and secondly the offshore profile, and that the profile, whatever its form, maintains its shape during a period of sea level rise.

Therefore, if sea level rises "a" meters, and the width of the bottom influenced by sea level rise is "l" meters extending to a depth "h" meters, the shoreline recession "S" is determined by:

$$S = (l * a)/h$$

It is important to understand that this model is a very simple mechanism for attempting to define and quantify a very complex process. The limitations of the Bruun Rule have been clearly identified by Bruun (1988), many reviewers and specialists (Komar et al.1991), as well as the recent review of the NIWA report (Brookes & Benson 1999). Key limitations include:

- The shoreline retreat is based on simple profile geometry for sand beaches,
- The model is two-dimensional and care should be taken in expanding it three-dimensionally, and
- The theory is one of erosion not accretion.

Although the Bruun Rule has been the subject of intense debate since the early 1970's, the general consensus is that the rule still has an overall general validity (Komar et al. 1991, Diez 2000).

Paterson (2000) identified that erosion has occurred along the shorelines where there was a relative increase in sea level due to the 1931 earthquake, suggesting that the concept of erosion due to increasing sea level rise was justified.

Paterson's assessment of the Bruun rule utilising the slope of the gravel beach face to establish the effective beach slope suggested that the rule appeared to under predict the actual erosion, indicating that other erosion forces such as a net deficit in sediment supply may also be contributing to the erosion and/or the nearshore environment also contributed to the potential losses due to accelerated sea level rise.

Paterson suggested that the closure depth is likely to be further off shore than the toe of the gravel beach, although no suggestion was provided as to a preferred methodology to establish the location of the closure depth.

As the long-term trend assessment should take into account historic effects of sediment supply and the earthquake, it was considered that the Bruun Rule could be applied to provide an estimate of the component of shoreline change that could possibly occur due to accelerated sea level rise given the lack of a more suitable relationship. Closure depth was determined by

measuring the distance to the end of the littoral zone (d_l) as determined by the inner Hallermeier limit, where:

$$d_l = 1.75\ H_{s(0.137)}$$

This limit was determined utilising the results of the recently completed wave hindcast study (Tonkin & Taylor, 2003). Validation checks were made comparing the inferred depth of the littoral zone with observed offshore profile changes. In general the empirical estimation of the littoral zone compared favourably with the observed changes in offshore profiles.

The "most likely" mid-range estimates of sea level rise as presented by the IPCC was used to provide projections of future sea level rise for the Hawke's Bay above mean 1990 levels (IPCC, 2001). No allowance was made for historic sea level rise in this instance due to the long-term geologic trend of downdrops for the majority of the Hawke Bay area. The geologic uplift rate identified at Mahia was also discounted in the analysis due to the order of magnitude difference in time scales of the applicability of hazard zones (100 years) and geologic time scales (1,000s years) combined with the lack of certainty with regard to steady geologic changes over the next 100 years.

The resulting impact of potential sea level rise is also shown in Table 6.4. This table uses a sea level rise of 0.2 m by 2060 and 0.5 m by 2100 in accordance with best estimates from the IPCC. The typical shoreline retreat due to accelerated sea level rise for gravel coasts is around 4 m by 2060 and 10 m by 2100. These rates compare favourably with suggested rates of 5 m (2050) and 10 m (2100) for gravel coasts presented in the draft guidance notes for coastal hazards produced by MfE (2003). For sand coasts the potential impact of sea level rise effects is significantly greater due to the flatter slope of the beach system. Based on the methodology used, shoreline movement could be affected by up to 26 m for sandy coasts.

Table 6.4
Sea Level Rise Prediction Based on the Bruun Rule

Location	Profile	Seaward crest elevation d_c	Distance from origin to crest L_c	Wave height from SWAN results $H_{s\ (mean)}$	Closure depth d_i	Distance from origin to closure depth L_{cd}	Length from crest to closure, $L_{cd} - L_c$	Beach and foreshore slope $(d_s-di)/(L_{cd} - L_c)$	SLR 1999 to 2060	SLR 2060 to 2100	Shoreline change 1990 to 2060	Shoreline change 2060 to 2100	Shoreline change 1990 to 2100
		(m)	(m)	(m)	(m)	(m)	(m)		(m)	(m)	(m)	(m)	(m)
Porangahau	N/A	13.6	22.4	5.4	-0.1	577	555	0.02	0.20	0.30	8	12	20
Blackhead	N/A	13.6	22.4	5.3	0.1	577	555	0.02	0.20	0.30	8	12	21
Aramoana	N/A	13.6	22.4	5.3	0.1	577	555	0.02	0.20	0.30	8	12	21
Pourerere	N/A	13.6	22.4	5.3	0.1	577	555	0.02	0.20	0.30	8	12	21
Mangakuri	N/A	13.6	22.4	5.4	-0.1	577	555	0.02	0.20	0.30	8	12	20
Kairakau	N/A	13.6	22.4	5.4	-0.1	577	555	0.02	0.20	0.30	8	12	20
Waimarama	WM 1	14.6	8.7	5.3	0.1	500	491	0.03	0.20	0.30	7	10	17
Waimarama	WM 2	14.7	17.8	5.3	0.1	499	482	0.03	0.20	0.30	7	10	17
Waimarama	WM 3	13.7	8.2	5.3	0.1	500	492	0.03	0.20	0.30	7	11	18
Waimarama	WM 4	13.9	10.2	5.3	0.1	550	540	0.03	0.20	0.30	8	12	20
Waimarama	WM 5	13.8	11.8	5.3	0.1	550	538	0.03	0.20	0.30	8	12	20
Waimarama	WM 6	13.1	36.3	5.3	0.1	550	514	0.03	0.20	0.30	8	12	20
Waimarama	WM 7	13.6	42.8	5.3	0.1	583	541	0.02	0.20	0.30	8	12	20
Waimarama	WM 8	13.6	30.9	5.3	0.1	550	519	0.03	0.20	0.30	8	12	19
Waimarama	WM 9	13.4	26.1	5.3	0.1	550	524	0.03	0.20	0.30	8	12	20
Waimarama	WM 10	13.0	25.4	5.3	0.1	550	525	0.02	0.20	0.30	8	12	20
Waimarama	WM 11	13.4	27.8	5.3	0.1	550	522	0.03	0.20	0.30	8	12	20
Waimarama	WM 12	13.7	13.2	5.3	0.1	550	537	0.03	0.20	0.30	8	12	20
Waimarama	WM 13	13.6	34.5	5.3	0.1	600	566	0.02	0.20	0.30	8	13	21
Waimarama	WM 14	13.2	40.9	5.3	0.1	600	559	0.02	0.20	0.30	9	13	21
Waimarama	WM 15	13.4	15.9	5.3	0.1	605	589	0.02	0.20	0.30	9	13	22
Waimarama	WM 16	13.5	18.4	5.3	0.1	700	682	0.02	0.20	0.30	10	15	25
Waimarama	WM 17	13.6	11.3	5.3	0.1	700	689	0.02	0.20	0.30	10	15	26

Table 6.4 Sea Level Rise Prediction Based on the Bruun Rule													
Location	Profile	Seaward crest elevation d_c	Distance from origin to crest L_c	Wave height from SWAN results $H_{s\ (mean)}$	Closure depth d_i	Distance from origin to closure depth L_{cd}	Length from crest to closure, $L_{cd} - L_c$	Beach and foreshore slope $(d_s\text{-}di)/(L_{cd} - L_c)$	SLR 1999 to 2060	SLR 2060 to 2100	Shoreline change 1990 to 2060	Shoreline change 2060 to 2100	Shoreline change 1990 to 2100
		(m)	(m)	(m)	(m)	(m)	(m)		(m)	(m)	(m)	(m)	(m)
Waimarama	WM 18	13.2	23.3	5.3	0.1	700	677	0.02	0.20	0.30	10	15	26
Ocean Beach	N/A	13.6	22.4	5.3	0.1	577	555	0.02	0.20	0.30	8	12	21
Clifton	HB 1	13.5	43.2	2.8	4.5	330	287	0.03	0.20	0.30	6	10	16
Te Awanga	HB 2	13.8	83.6	2.8	4.5	330	246	0.04	0.20	0.30	5	8	13
Haumoana	HB 3	13.8	32.4	2.8	4.5	323	291	0.03	0.20	0.30	6	9	16
Haumoana	HB 4	13.7	56.3	2.8	4.5	414	358	0.03	0.20	0.30	8	12	19
Clive	HB 5	14.1	94.0	2.8	4.5	432	338	0.03	0.20	0.30	7	11	18
Clive	HB 6	13.9	124.0	2.8	4.5	314	190	0.05	0.20	0.30	4	6	10
Awatoto	HB 7	13.7	65.7	3.0	4.1	307	241	0.04	0.20	0.30	5	8	13
Awatoto	HB 8	14.5	41.1	3.0	4.1	234	193	0.05	0.20	0.30	4	6	9
Napier	HB 9	14.7	82.0	3.0	4.1	317	235	0.04	0.20	0.30	4	7	11
Napier	HB 10	15.0	103.4	3.1	3.9	368	265	0.04	0.20	0.30	5	7	12
Napier	HB 11	14.5	75.6	3.1	3.9	345	270	0.04	0.20	0.30	5	8	13
Napier	HB 12	14.6	48.6	3.1	3.9	294	245	0.04	0.20	0.30	5	7	11
Westshore	HB 13	14.1	64.7	2.6	4.7	290	225	0.04	0.20	0.30	5	7	12
Westshore	HB 14	15.5	20.1	2.9	4.3	282	262	0.04	0.20	0.30	5	7	12
Westshore	HB 15	15.3	38.6	2.9	4.3	313	274	0.04	0.20	0.30	5	7	12
Bayview	HB 16	15.5	27.9	2.9	4.3	257	230	0.05	0.20	0.30	4	6	10
Bayview	HB 17	16.5	87.8	3.0	4.1	292	204	0.06	0.20	0.30	3	5	8
Esk River	HB 18	15.3	13.2	3.0	4.1	172	159	0.07	0.20	0.30	3	4	7
Esk River	HB 19	16.6	22.4	3.1	3.9	183	161	0.08	0.20	0.30	3	4	6
Esk River	HB 20	16.6	31.0	3.1	3.9	175	144	0.09	0.20	0.30	2	3	6
Tangoio	HB 21	17.0	87.0	3.1	3.9	318	231	0.06	0.20	0.30	4	5	9
Tangoio	HB 22	17.6	23.3	3.1	3.9	321	297	0.05	0.20	0.30	4	6	11
Tangoio	HB 23	17.1	43.6	3.1	3.9	377	333	0.04	0.20	0.30	5	8	13
Waikokopu/Opoutama	WO1	14.6	29.2	4.6	1.2	577	548	0.02	0.20	0.30	8	12	20

Table 6.4
Sea Level Rise Prediction Based on the Bruun Rule

Location	Profile	Seaward crest elevation d_c	Distance from origin to crest L_c	Wave height from SWAN results $H_{s\ (mean)}$	Closure depth d_l	Distance from origin to closure depth L_{cd}	Length from crest to closure, $L_{cd} - L_c$	Beach and foreshore slope $(d_s\text{-}di)/(L_{cd} - L_c)$	SLR 1999 to 2060	SLR 2060 to 2100	Shoreline change 1990 to 2060	Shoreline change 2060 to 2100	Shoreline change 1990 to 2100
		(m)	(m)	(m)	(m)	(m)	(m)		(m)	(m)	(m)	(m)	(m)
Waikokopu/Opoutama	WO2	16.4	45.2	4.6	1.2	577	532	0.03	0.20	0.30	7	11	18
Waikokopu/Opoutama	WO3	15.4	98.3	4.6	1.2	577	479	0.03	0.20	0.30	7	10	17
Waikokopu/Opoutama	WO4	16.1	84.7	4.6	1.2	577	492	0.03	0.20	0.30	7	10	17
Waikokopu/Opoutama	WO5	15.6	6.3	4.6	1.2	577	571	0.03	0.20	0.30	8	12	20
Waikokopu/Opoutama	WO6	13.2	6.2	4.6	1.2	577	571	0.02	0.20	0.30	10	14	24
Mahia Beach	N/A	15.2	45.0	4.6	1.2	577	532	0.03	0.20	0.30	8	11	19
Whangawehi	N/A	14.0	32.3	4.6	1.2	577	545	0.02	0.20	0.30	9	13	21
Maungawhio Lagoon	N/A	14.0	32.3	4.6	1.2	577	545	0.02	0.20	0.30	9	13	21
Mahanga	MH1	12.9	55.6	4.6	1.2	577	521	0.02	0.20	0.30	9	13	22
Mahanga	MH2	14.2	18.8	4.6	1.2	577	558	0.02	0.20	0.30	9	13	21
Mahanga	MH3	15.0	22.6	4.6	1.2	577	554	0.02	0.20	0.30	8	12	20

7.0 Coastal Hazard Assessment Results

7.1 Soft Shore Erosion

The resulting hazard zone widths for soft shore erosion areas are shown in Table 7.1. The CERZ and ERZ2060 are very similar in width for gravel shores where there is no significant long-term trend of erosion.

7.2 Cliff Coast Erosion

The setback for cliff coast erosion is set out in Table 7.2. The setbacks are described between key locations, and the table includes information on the typical height of the cliffs within each cell, the evaluation based on 2 x H + LT, and the inferred setback based on observed topography within the cell. Existing published information is also indicated in the table. The proposed set back distance is the larger distance inferred from the observed topography.

7.3 Inundation

The resulting inundation levels for the soft shore erosion areas are shown in Table 7.3. Results are presented in terms of the existing inundation levels (excluding possible sea level rise) and including sea level rise to 2100. Beach crest levels are provided where existing beach crest information is known.

Inundation levels including SLR(2100) and run-up are to be applied in the CERZ and ERZ2060 zones. Inundation levels taking into account SLR(2100) but excluding run up can be used landward of the ERZ2060.

7.4 Application

An example of hazard zone mapping is shown in Figure 7.1. Figure 5.1 shows the components of the various zones.

Complete hazard zones are provided on the attached CD for inclusion in Council's GIS system. Figures showing the hazard zones for each local community area identified in Section 1.0 are provided in Volume II. In some areas, Pourerere for example, the soft shore hazard zones extend up the hillside. In this case, the hazard zone effectively includes the beach and land up to the toe of the hill.

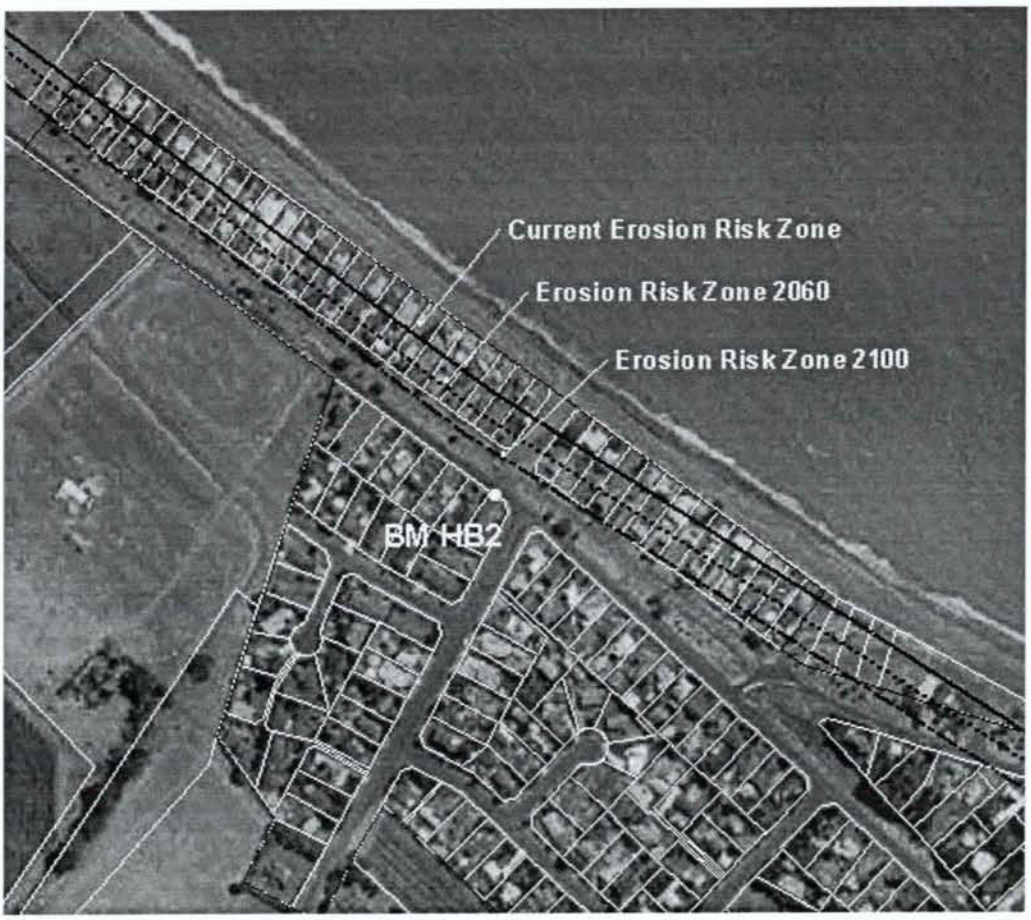

Figure 7.1. Example of hazard zone mapping

Table 7.1: Coastal Erosion Hazard Widths for Soft Shores											
Location	CERZ					2060 ERZ			2100 ERZ		
	Profile	LT(10) (m/yr)	SE+ST+LT(10) (m)	DS (m)	Total (m)	LT (m)	SLR (m)	Total (m)	LT (m)	SLR (m)	Total (m)
Porangahau	None	1.2	42.8	N.D.	43	6.8	8.1	58	4.8	12.1	73
Blackhead	None	0.9	42.5	N.D.	42	5.1	8.2	56	3.6	12.3	71
Aramoana	None	1.1	42.7	N.D.	43	6.3	8.2	57	4.4	12.3	73
Pourerere	None	1.8	43.3	N.D.	43	10.3	8.2	62	7.2	12.3	80
Mangakuri	None	1.4	42.9	N.D.	43	8	8.1	59	5.6	12.1	75
Kairakau	None	1.4	42.9	N.D.	43	8	8.1	59	5.6	12.1	75
Waimarama	WM 1	1.3	42.9	7.8	51	7.4	6.8	65	5.2	10.2	79
Waimarama	WM 2	1.3	42.9	7.6	50	7.4	6.6	65	5.2	9.9	78
Waimarama	WM 3	1.3	42.9	9.7	53	7.4	7.2	67	5.2	10.9	82
Waimarama	WM 4	1.3	42.9	9	52	7.4	7.8	67	5.2	11.7	83
Waimarama	WM 5	1.3	42.9	5.2	48	7.4	7.9	63	5.2	11.9	79
Waimarama	WM 6	1.3	42.9	5.3	48	7.4	7.9	64	5.2	11.9	79
Waimarama	WM 7	1.3	60.1	10.4	70	7.4	8	86	5.2	12	102
Waimarama	WM 8	1.3	49.1	11.2	60	7.4	7.7	75	5.2	11.5	91
Waimarama	WM 9	1.3	32.2	9.4	42	7.4	7.9	57	5.2	11.9	73
Waimarama	WM 10	1.3	33.2	11.4	45	7.4	8.2	60	5.2	12.2	76
Waimarama	WM 11	1.3	24.5	13.5	38	7.4	7.8	53	5.2	11.8	69
Waimarama	WM 12	1.3	33.9	22	56	7.4	7.9	71	5.2	11.9	87
Waimarama	WM 13	1.3	31.8	31.8	64	7.4	8.4	80	5.2	12.6	96
Waimarama	WM 14	1.3	33.1	65.1	98	7.4	8.6	114	5.2	12.9	131
Waimarama	WM 15	1.3	63.1	23.1	86	7.4	8.9	103	5.2	13.3	120
Waimarama	WM 16	1.3	53.2	39.9	93	7.4	10.2	111	5.2	15.3	130
Waimarama	WM 17	1.3	59.8	37.2	97	7.4	10.2	115	5.2	15.3	134
Waimarama	WM 18	1.3	40.5	36.7	77	7.4	10.3	95	5.2	15.5	114

Table 7.1: Coastal Erosion Hazard Widths for Soft Shores											
Location	CERZ					2060 ERZ			2100 ERZ		
	Profile	LT(10) (m/yr)	SE+ST+LT(10) (m)	DS (m)	Total (m)	LT (m)	SLR (m)	Total (m)	LT (m)	SLR (m)	Total (m)
Ocean Beach	None	1.3	42.9	N.D.	43	7.4	8.2	58	5.2	12.3	75
Clifton	HB 1	7.5	13.9	12.1	30	42.6	6.4	75	29.9	9.6	107
Te Awanga	HB 2	3.1	18.6	20.3	44	17.7	5.3	62	12.4	8	79
Haumoana	HB 3	4.2	15.4	22.3	41	23.8	6.3	68	16.7	9.4	90
Haumoana	HB 4	7	26.4	26.1	59	39.8	7.8	100	28	11.7	133
Clive	HB 5	7	43.0	35.3	89	39.9	7	125	28	10.6	157
Clive	HB 6	7	18.5	34.6	58	39.9	4	97	28	6.1	124
Awatoto	HB 7	7	25.1	77.5	109	39.9	5	148	28	7.6	176
Awatoto	HB 8	0	11.0	26.5	40	0	3.7	41	0	5.6	47
Napier	HB 9	0	10.6	38.4	52	0	4.4	53	0	6.7	60
Napier	HB 10	0	7.9	38.3	48	0	4.8	51	0	7.1	58
Napier	HB 11	0	10.0	36	48	0	5.1	51	0	7.6	59
Napier	HB 12	0	17.0	30.5	52	0	4.5	52	0	6.8	59
Westshore	HB 13	0	17.0	35	56	0	4.8	57	0	7.2	64
Westshore	HB 14	0	14.6	17.2	35	0	4.7	36	0	7	43
Westshore	HB 15	0	15.1	41.6	60	0	5	62	0	7.5	69
Bayview	HB 16	0.5	11.3	60.1	74	2.9	4.1	78	2	6.2	86
Bayview	HB 17	1	17.5	46.9	69	5.7	3.3	73	4	4.9	81
Esk River	HB 18	1	8.7	41.5	52	5.7	2.8	59	4	4.3	66
Esk River	HB 19	4.6	13.6	50.5	67	26.2	2.5	93	18.4	3.8	110
Esk River	HB 20	4.6	19.7	54.9	80	26	2.2	103	18.2	3.4	120
Tangoio	HB 21	3.4	13.1	69.9	86	19.2	3.5	106	13.4	5.3	121
Tangoio	HB 22	2.2	21.5	66.9	94	12.3	4.3	105	8.6	6.5	118
Tangoio	HB 23	1.1	15.7	44.2	64	6.4	5	71	4.5	7.6	82
Waipatiki	None	0	41.6	N.D.	42	0	3	45	0	4.6	49

Table 7.1: Coastal Erosion Hazard Widths for Soft Shores											
Location	CERZ					2060 ERZ			2100 ERZ		
	Profile	LT(10) (m/yr)	SE+ST+LT(10) (m)	DS (m)	Total (m)	LT (m)	SLR (m)	Total (m)	LT (m)	SLR (m)	Total (m)
Aropaoanui	None	0	41.6	N.D.	**42**	0	3	**45**	0	4.6	**49**
Waikari	None	0	19.3	N.D.	**39**	0	2.8	**41**	0	4.1	**45**
Mohaka	None	0	19.32	N.D.	**39**	0	2.6	**41**	0	4	**45**
Waihua	None	0	19.32	N.D.	**39**	0	2.6	**41**	0	4	**45**
Wairoa	None	0	19.32	N.D.	**39**	0	2.6	**41**	0	4	**45**
Tahaenui	None	0	19.32	N.D.	**39**	0	2.6	**41**	0	3.9	**45**
Nuhaka	None	0	19.32	N.D.	**39**	0	2.6	**41**	0	3.9	**45**
Waikokopu/Opoutama	WO1	0	41.56	63.8	**105**	0	8.2	**114**	0	12.3	**126**
Waikokopu/Opoutama	WO2	0	41.56	55.6	**97**	0	7	**104**	0	10.5	**115**
Waikokopu/Opoutama	WO3	0	41.56	43.3	**85**	0	6.8	**92**	0	10.2	**102**
Waikokopu/Opoutama	WO4	0	41.56	49.8	**91**	0	6.6	**98**	0	10	**108**
Waikokopu/Opoutama	WO5	0	41.56	87.5	**129**	0	7.9	**137**	0	11.9	**149**
Waikokopu/Opoutama	WO6	0	41.56	27.6	**69**	0	9.5	**79**	0	14.3	**93**
Mahia Beach	None	1	42.56	N.D.	**43**	5.7	7.6	**56**	4	11.4	**70**
Whangawehi	None	1	42.56	N.D.	**43**	5.7	8.5	**57**	4	12.8	**73**
Maungawhio Lagoon	None	1	42.56	N.D.	**43**	5.7	8.5	**57**	4	12.8	**73**
Mahanga	MH1	1	42.56	27.6	**70**	5.7	9	**85**	4	13.4	**101**
Mahanga	MH2	0	41.56	30.5	**72**	0	8.6	**81**	0	12.9	**94**
Mahanga	MH3	0	41.56	55.9	**97**	0	8.1	**106**	0	12.1	**118**

Table 7.2: Coastal Erosion Hazard Widths for Cliff Shores					
Location	Max cliff height (m)	Coastal Hazard Zone from Cliff Toe			Source
		Calculated (m)	Inferred from topo map data (m)	Published sources (m)	
Southern boundary to Blackhead Pt.			900		
Blackhead Pt to Blackhead	200	410	450		
Blackhead to Aramoana	200	410	450		
Aramoana to Pourerere	160	330	350		
Pourerere to Paoanui Pt	110	230	250		
Paoanui Pt to 4 km south of Mangakuri Beach	210	430	900		
4 km south of Mangakuri Beach to Mangakuri Beach	130	270	500		
Mangakuri Beach to Kairakau	140	290	500		
Kairakau to Waiomana	150	310	300		
Waiomana to 2 km north of Waiomana	150	310	350	250	Pettinga (1980)
2 km north of Waiomana to Karamea Island	300	610	900	900	Pettinga (1980)
Karamea Island to Waimarama	110	230	400	400	Pettinga (1980)
Waimarama to Ocean Beach	100	210	250	250	Pettinga (1980)
Ocean Beach to Cape Kidnappers	130	270	300		
Cape Kidnappers to Clifton	140	290	300		
Clifton to Tangoio	N/A	N/A	N/A		
Tangoio to Waipatiki	130	270	300		
Waipatiki to Moeangiangi	160	330	350		
Moeangiangi to 6 km north	390	790	800		
6 km north of Moeangiangi to Waikari River	100	210	250		
Waikari River to Mohaka River	130	270	300		
Mohaka River to Waihua	130	270	300		
Waihua to Whakamahi	100	210	250		

Table 7.2: Coastal Erosion Hazard Widths for Cliff Shores					
		Coastal Hazard Zone from Cliff Toe			
Whakamahi to Opoutama	100	210	250		
Opoutama to Mahia Beach	N/A	N/A	N/A		
Mahia Beach to Ahuriri Pt	150	310	350		
Ahuriri Pt to Kahutara Pt	180	370	400		
Kahutara Pt to Oraka Beach	100	210	250		

Table 7.3: Inundation levels (m above Mean Sea Level)													
Location	Profile Ref.	elevation, hc	MHWS	SL fluctuation	Storm surge	SLR 2100	Hs (max)	Setup max	Run-up	Current Excluding run-up	Including run-up	With SLR(2100) Excluding run-up	Including run-up
Porangahau	N/A	ND	11.0	0.2	0.9	0.5	5.4	1.4	3.8	13.5	15.8	14.0	16.3
Blackhead	N/A	ND	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Aramoana	N/A	ND	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Pourerere	N/A	ND	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Mangakuri	N/A	ND	11.0	0.2	0.9	0.5	5.4	1.4	3.8	13.5	15.8	14.0	16.3
Kairakau	N/A	ND	11.0	0.2	0.9	0.5	5.4	1.4	3.8	13.5	15.8	14.0	16.3
Waimarama	WM 1	14.6	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 2	14.7	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 3	13.7	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 4	13.9	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 5	13.8	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 6	13.1	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 7	13.6	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 8	13.6	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 9	13.4	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 10	13.0	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 11	13.4	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 12	13.7	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 13	13.6	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 14	13.2	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 15	13.4	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 16	13.5	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 17	13.6	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Waimarama	WM 18	13.2	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Ocean Beach	N/A	ND	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.7	14.0	16.2
Clifton	HB1	13.5	11.0	0.2	0.9	0.5	3.3	1.0	2.3	13.0	14.4	13.5	14.9

Table 7.3: Inundation levels (m above Mean Sea Level)													
Location	Profile Ref.	elevation, hc	MHWS	SL fluctuation	Storm surge	SLR 2100	Hs (max)	Setup max	Run-up	Current Excluding run-up	Including run-up	With SLR(2100) Excluding run-up	Including run-up
Te Awanga	HB2	13.8	11.0	0.2	0.9	0.5	3.4	1.0	2.4	13.0	14.4	13.5	14.9
Haumoana	HB3	13.8	11.0	0.2	0.9	0.5	3.4	1.0	2.4	13.0	14.4	13.5	14.9
Haumoana	HB4	13.7	11.0	0.2	0.9	0.5	3.4	1.0	2.4	13.0	14.4	13.5	14.9
Clive	HB5	14.1	11.0	0.2	0.9	0.5	3.5	1.0	2.4	13.1	14.5	13.6	15.0
Clive	HB6	13.9	11.0	0.2	0.9	0.5	3.5	1.0	2.4	13.1	14.5	13.6	15.0
Awatoto	HB7	13.7	11.0	0.2	0.9	0.5	3.8	1.1	2.7	13.2	14.7	13.7	15.2
Awatoto	HB8	14.5	11.0	0.2	0.9	0.5	3.8	1.1	2.7	13.2	14.7	13.7	15.2
Napier	HB9	14.9	11.0	0.2	0.9	0.5	3.8	1.1	2.7	13.2	14.7	13.7	15.2
Napier	HB10	15.6	11.0	0.2	0.9	0.5	4.1	1.2	2.9	13.2	14.9	13.7	15.4
Napier	HB11	15.9	11.0	0.2	0.9	0.5	4.1	1.2	2.9	13.2	14.9	13.7	15.4
Napier	HB12	15.7	11.0	0.2	0.9	0.5	4.1	1.2	2.9	13.2	14.9	13.7	15.4
Westshore	HB13	14.1	11.0	0.2	0.9	0.5	3.4	1.0	2.3	13.0	14.4	13.5	14.9
Westshore	HB14	15.5	11.0	0.2	0.9	0.5	3.9	1.1	2.8	13.2	14.8	13.7	15.3
Westshore	HB15	16.3	11.0	0.2	0.9	0.5	3.9	1.1	2.8	13.2	14.8	13.7	15.3
Bayview	HB16	17.6	11.0	0.2	0.9	0.5	3.9	1.1	2.8	13.2	14.8	13.7	15.3
Bayview	HB17	17.9	11.0	0.2	0.9	0.5	4.2	1.2	2.9	13.3	15.0	13.8	15.5
Esk River	HB18	17.4	11.0	0.2	0.9	0.5	4.2	1.2	2.9	13.3	15.0	13.8	15.5
Esk River	HB19	19.1	11.0	0.2	0.9	0.5	4.4	1.3	3.1	13.3	15.2	13.8	15.7
Esk River	HB20	20.1	11.0	0.2	0.9	0.5	4.4	1.3	3.1	13.3	15.2	13.8	15.7
Tangoio	HB21	18.6	11.0	0.2	0.9	0.5	4.3	1.2	3.0	13.3	15.0	13.8	15.5
Tangoio	HB22	17.9	11.0	0.2	0.9	0.5	4.3	1.2	3.0	13.3	15.0	13.8	15.5
Tangoio	HB23	17.1	11.0	0.2	0.9	0.5	4.3	1.2	3.0	13.3	15.0	13.8	15.5
Waipatiki	N/A	ND	11.0	0.2	0.9	0.5	4.3	1.2	3.0	13.3	15.0	13.8	15.5
Aropaoanui	N/A	ND	11.0	0.2	0.9	0.5	4.3	1.2	3.0	13.3	15.0	13.8	15.5
Waikari	N/A	ND	11.0	0.2	0.9	0.5	4.7	1.4	3.3	13.4	15.3	13.9	15.8
Mohaka	N/A	ND	11.0	0.2	0.9	0.5	4.8	1.4	3.3	13.4	15.4	13.9	15.9
Waihua	N/A	ND	11.0	0.2	0.9	0.5	4.8	1.4	3.3	13.4	15.4	13.9	15.9
Wairoa	N/A	ND	11.0	0.2	0.9	0.5	4.8	1.4	3.3	13.4	15.4	13.9	15.9

Table 7.3: Inundation levels (m above Mean Sea Level)													
Location	Profile Ref.	elevation, hc	MHWS	SL fluctuation	Storm surge	SLR 2100	Hs (max)	Setup max	Run-up	Current Excluding run-up	Including run-up	With SLR(2100) Excluding run-up	Including run-up
Tahaenui	N/A	ND	11.0	0.2	0.9	0.5	4.9	1.4	3.4	13.5	15.5	14.0	16.0
Nuhaka	N/A	ND	11.0	0.2	0.9	0.5	5.3	1.5	3.7	13.6	15.8	14.1	16.3
Waikokopu/Opoutama	WO1	14.6	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Waikokopu/Opoutama	WO2	16.4	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Waikokopu/Opoutama	WO3	15.7	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Waikokopu/Opoutama	WO4	16.6	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Waikokopu/Opoutama	WO5	15.6	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Waikokopu/Opoutama	WO6	12.8	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Mahia Beach	N/A	ND	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Whangawehi	N/A	ND	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Maungawhio Lagoon	N/A	ND	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Mahanga	MH1	12.8	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Mahanga	MH2	14.2	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3
Mahanga	MH3	15.0	11.0	0.2	0.9	0.5	5.3	1.4	3.7	13.5	15.8	14.0	16.3

8.0 Coastal Hazard Management

This document sets out the key issues required to be addressed with a comprehensive coastal hazard management strategy, identifies the current planning approach and includes a suggested policy on management of coastal hazards.

8.1 Identification of Issues

To determine appropriate management of coastal hazard strategies for the region's shoreline, a good understanding of the long-term development plans and needs of the community is required as well as knowledge of coastal processes, impacts of climate change and risk. The best strategies occur when there is a clear and unified long-term vision or goal for an area incorporating the various drivers.

The results of the coastal hazard assessment study have identified that the entire region's shoreline is prone to storm damage and the influence of cyclical erosion and accretion trends, while there is the risk of erosion due to ongoing and accelerated sea level rise. Moderate to high rates of long-term erosion are also evident for significant stretches of the shoreline due largely to a sediment supply deficit, ongoing adjustment to the 1931 earthquake and localised adjustments to landslides and slumps.

The influence of the 1931 earthquake can be expected to reduce over time, with the most significant changes having occurred over the first few years to decades after the event. However, it is possible that the earthquake may have had permanent or long-term effects on positions of river mouths and sediment yields.

Taking the above into consideration, there is an expectation for ongoing shoreline erosion. In addition, the weak geology of the area results in significant risks along the cliffed shorelines, in terms of wave erosion undercutting the toe as well as slumping, mudslides and landslides. The

Hawke's Bay region is also prone to inundation both due to storm surge and tsunamis.

Inland catchment development, including vegetation modification, and storm water run-off as well as development on the natural beach crest/dune system have exacerbated the erosion of the shoreline.

The natural beauty of the area is recognised through the increasing scale and value of development occurring within the coastal area. It is highly likely this trend of increased development will continue with the net result over time being a significant increase in the value of assets along the shoreline.

Along with the increased value of development will be an enhanced user demand as the population within the region continues to grow. Apart from the sub-divisional pressures there will be additional pressure to provide more recreational space and amenities, such as picnic areas, toilet and changing facilities and car parks.

These needs will tend to conflict with the natural functions of the shoreline system, the requirement to maintain and protect property and to maintain a high quality coastal environment to suit the value of the properties.

Therefore, management methods must take into account the various conflicts and develop a long-term approach to:

- Reduce the risk of the event by decreasing its probability of occurrence.
- Reduce the risk of the event by limiting its potential effects.
- To increase societies ability to cope with the effect of the event.

Climate change effects are not necessarily going to occur rapidly, requiring immediate implementation of a particular strategy. However, climate change is likely to be relentless and therefore a long-term vision is required to accommodate the potential effects.

The following quote from the Intergovernmental Panel of Climate Change (2001) summarises the challenge of selecting an appropriate management method:

"The challenge is not to find the best policy for today for the next hundred years, but to select a prudent strategy and to adjust it over time in the light of new information".

8.2 Planning Approach

8.2.1 Resource Management Act

The key purposes of the Resource Management Act (RMA, 1991) as set out in Section 5, is to promote the sustainable management of natural and physical resources. Sustainable management is defined as "*managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing while;*

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystem; and

(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment."

Section 6, also requires, as a Matter of National Importance, "*the preservation of the natural character of the coastal environment, wetlands, and lands and their margins, and the protection of them from inappropriate subdivision, use and development*"

Under these sections the RMA requires both regional and district councils to address coastal hazards as part of the requirement to sustainably manage the environment.

Section 30 of the RMA includes a requirement for regional council to have a function to (amongst others):

a) The establishment, implementation, and review of objectives, policies and methods to achieve integrated management of the natural and physical resources of the region;

c) The control of the use of land for the purpose of-
iv) The avoidance or mitigation of natural hazards

Section 31 of the Act sets out the functions of territorial authorities under the act, and includes:

(b) the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of:
*(i) the avoidance or mitigation of **natural hazards**; and*
*(ii) the prevention or mitigation of any adverse effects of the storage, use, disposal, or transportation of **hazardous substances**; and*
*(iii) the maintenance of indigenous **biological diversity***

8.2.2 New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement has six specific policies relating to the management of the impact of coastal hazards and potential climate change effects:

3.4.1: Local authority policy statements and plans should identify areas in the coastal environment where natural hazards exist.

3.4.2: Policy statements and plans should recognise the possibility of a rise in sea level, and should identify areas which would as a consequence be subject to erosion and inundation. Natural systems which are a natural defence to erosion and /or inundation should be identified and their integrity protected.

3.4.3: The ability of natural features such as beaches, sand dunes, mangroves, wetlands and barrier islands to protect subdivision, use, or development should be recognised and maintained, and, where appropriate, steps should be required to enhance that ability.

3.4.4: In relation to future subdivision, use and development, policy statements and plans should recognize that some natural features may migrate inland as the result of dynamic coastal processes (including sea level rise).

3.4.5: New subdivision, use and development should be so located and designed that the need for hazard protection works is avoided.

3.4.6: Where existing subdivision, use or development is threatened by a coastal hazard, coastal protection works should be permitted only where they are the best practicable option for the future. The abandonment or relocation of existing structures should be considered among the options. Where coastal protection works are the best practicable option, they should be located and designed so as to avoid adverse environmental effects to the extent practicable.

8.2.3 Regional and District Plans

Currently, the Regional Coastal plan identifies areas of the shoreline sensitive to hazards in Policy 4.1.5 and Schedule IV. However, the identification process is not comprehensive, with no information included for significant extents of the coastline. Where information is provided, it is

presented in terms of an annual retreat rate based on historic observation and does not include allowances for climate change or consider inundation.

Policy 4.1.6 identifies that *"HBRC will encourage territorial local authorities to recognise and avoid, or where avoidance is not practical, mitigate the coastal hazards identified in Policy 4.1.5 in their District Plans and take them into account when considering land use consents for activities, particularly subdivision, in areas adjacent to these hazards."*

District Councils within the region are addressing hazards in a number of ways. Napier City is progressing on a detailed coastal hazard assessment for the shoreline north of the port, including a coastal erosion hazard zone and rules for development within the coastal hazard zone.

Central Hawke's Bay District Council have identified the coastal margin as extending from the shoreline to the ridgeline. Therefore, the coastal margin varies from around 500 m to around 1.5 km. Within this zone there are restrictions concerning the planting of exotic trees and limitations on building floor area per lot.

Hastings District Council has included the entire coastal margin as a coastal hazard resource management unit and identified rules and policy in Section 12.3 of the District Plan.

The proposed Wairoa District Plan (2001) has a 500 m wide coastal zone from MHWS. The only hazard provisions included in the plan are associated with flooding with a requirement to provide floor levels 0.3 m above the 50-year flood level.

The Building Act also provides for mechanisms to control activities for the purpose of avoiding or mitigating natural hazards. Under Section 36 of the Building Act (1991) a territorial authority must refuse to grant a building permit if:

"The land on which the building work is to take place is subject to, or is likely to be subject to, erosion, avulsion, alluvium, falling debris, subsidence, inundation, or slippage; or

The building work itself is likely to accelerate, worsen or result in erosion, avulsion, alluvium, falling debris, subsidence, inundation, or slippage of that land or any other property."

unless it is satisfied that adequate provision is made to protect the property. If the land is subject to a natural hazard, but the building work is not likely to accelerate the hazard, the authority may grant the consent on condition that an appropriate entry is made on the certificate of title on the land.

8.3 Vision

A vision or overall goal is required to provide the broad goals and objectives of the coastal management strategy. Typically this is determined through stakeholder participation, and may require an overarching vision from HBRC with site specific goals for each community settlement. However, at this stage the goal is to be consistent with the guiding principles of the RMA and NZCPS.

8.4 Policy on Coastal Erosion Planning and Response

This section sets out a possible vision and policy on coastal erosion that could be adopted by regional and territorial authorities, consistent with RMA and NZCPS obligations.

8.4.1 Key Principles

1. The Regional Council should be proactive in protecting and enhancing coastal landforms and processes, such as increasing sediment transported through coastal watersheds to the coastline.

2. While coastal developments and protective devices may be safe from hazards for many years they should be considered for removal once they are no longer safe or necessary.

3. Regional and territorial and local community cost-sharing partnerships should be pursued and promoted to leverage various resources and encourage multi-objective regional approaches to coastal projects.

4. Restoration of beaches should be pursued where it is deemed that further loss of beach or beachfront land used for habitat, recreation, tourism, public safety, coastal access or coastal protection is unacceptable.

5. Development on coastal lands subject to erosion can threaten public safety, public and private property, habitats and recreational opportunities and should be avoided whenever possible. The preferred order for addressing development on coastal lands within the Hawke Bay region should be:

   i. Hazard avoidance is the preferred method for addressing coastal erosion;

   ii. In cases where existing development is threatened, a first priority should be to evaluate the feasibility of relocating such development. A second priority should be to evaluate the use of beach nourishment to reduce the threat or risk of erosion to existing development; and

   iii. The use of hard structures should be considered only after these and other less environmentally damaging alternatives are evaluated and deemed unfeasible.

8.4.2 Planning and Regulation

1. In planning for the use of land adjacent to the coastline, local authorities should ensure the following:

    i. Effective land use plans and regulations are in place taking into account the hazard zones presented in this report to reduce the vulnerability of existing and future developments to beach and coastal erosion, seasonal beach fluctuations, coastal flooding and other natural hazards;
    ii. Measures are taken to control surface runoff, groundwater infiltration, and other process that contribute to cliff instability; and
    iii. Procedures are established for the orderly demolition and relocation of damaged, hazardous or threatened development and for the disposition of parcels of land that cannot safely be developed.

2. Developments and activities within the coastal watershed can have significant impacts on the coast by blocking the flow of sediment to the coastline. Developments planned, constructed or authorised by the regulatory authorities should meet the following conditions:

    i. Whenever feasible, the development will not reduce the quality or quantity of the natural supply of sediment to the coastline
    ii. Where feasible and appropriate, the developments or activities should include measures to ensure an unimpeded sediment supply; and
    iii. The development should comply with any existing regional plan governing the sediment budget within the coastal watershed in which the development is planned.

3. All dredged or excavated material removed from within the coastal zone or offshore waters that complies with toxicity guidelines and is suitable in quantity, size, distribution and composition is a valuable resource and should be considered for discharge as follows:

    i. Deposited directly onto a beach or nearshore berm in an appropriate manner for effective beach restoration and nourishment and in a manner to protect significant natural resources and the public use of such resources;
    ii. When beach nourishment is unnecessary, infeasible or inappropriate at the time of dredging or excavation, the material suitable for beach restoration should be stored for eventual use, provided that suitable locations are available and steps are taken to protect both significant natural resources and the public use of such resources at those locations;
    iii. Should neither of the above uses be appropriate, the material should be used to optimize its value as a mineral resource, utility as construction material or material for other forms of habitat construction.

4. Any development by regional or territorial authorities in areas subject to erosion should be expendable or moveable unless specific determinations have been made that the risk of loss of the development is clearly offset by its necessity and value. Structural protection and re-protection of developments are permitted only when the cost of protection is commensurate with the value of the development of be protected and the protection will not have a significant adverse effect on the environment.

8.4.3 Coastal Protection Options

The first priority if development is threatened, should be to evaluate the feasibility and desirability of re-locating the development. If re-location is not feasible or appropriate, the next step is to evaluate options that minimise or eliminate the hazard. Hawke's Bay Regional Council should use the following principles when evaluating erosion protection applications:

1. Restoration and nourishment of beaches should be the preferred erosion response measure should there be no significant adverse effect on natural, physical, spiritual or cultural resources.

2. Construction of seawalls, revetments, breakwaters, groynes or other artificial structure for coastal erosion control should be discouraged unless each of the following conditions are met:

i. No other non-structural alternative is effective or feasible to reduce erosion risk over the useful life of the development;

ii. The protection option is to serve a coastal dependent use or to protect an existing principal development or facility in danger from erosion;

iii. The protection option is consistent with the principles of the RMA, NZCPS and pRCP.

iv. There is a demonstrated need for the erosion protection option and the option is designed and can be constructed and maintained to withstand the specified design criteria, including expected trends and consideration of possible climate change effects.

v. There will be no net reduction in public access to and use and enjoyment of the coastal environment

vi. Measures are included to ensure that the protection option can and will be maintained through its design life and removed at the expense of the project sponsor if the protective device fails or has an unmitigated effect on other sections of the coastline, or is no longer necessary.

3. Coastal protection options should not cause the loss or destruction of public beaches, dunes and coastal access ways.

8.4.4 Local Authority Participation in Erosion Protection Options

1. Local Authority participation in coastal erosion protection options is recommended only when the following conditions are met:

   i. The proposal is consistent with the principles of the RMA and NZCPS;
   ii. Public benefits, including the long-term environmental, social and economic impacts of the project are found to be greater than the project cost. The area to be protected should contain substantial and valuable public-owned lands or development of greater value that the cost of the proposed project, and the protection scheme should provide, maintain or improve public use and enjoyment of the coastline;
   iii. The proposal does not encourage or support inappropriate development in areas of significant coastal erosion;
   iv. The project should use non-structural solutions as the preferred alternative or as a part of the recommended alternative, unless it is not appropriate or feasible;
   v. Public access is maintained or enhanced

2. Local Authorities should be partners to share costs and liabilities

3. In emergency situations where erosion is threatening permitted development, regulatory authorities should respond immediately. Assistance should first be directed to emergency situations involving public assets or where human health is in danger. All emergency actions should be considered temporary until evaluated for compliance under applicable policies and rules.

4. The policy should be supported by long-term, on-going research and planning studies, either directly or in partnership.

9.0 Potential Management Responses

This section outlines the usual management responses for protection of the coastal hazards. The recently published report on planning for climate change effects on coastal margins (MfE, 2001) identified three main types of response options to climate change impacts in coastal margins:

- Planned retreat
- Adaptation (or accommodation)
- Protection (or defence).

It identifies the broad scale options for mitigating the effects of the coastal hazards, the pros and cons of each option and identification of the preferred options for further consideration. As many of the issues are common, generic options for various land uses and developments are included to facilitate implementation into regional and district plans. However, local strategies and rules may also be required in some cases.

Volume II contains individual summaries of the hazards relevant for each settlement. For each area we evaluate potential risk and present strategies for mitigation and management.

While these responses can be considered as "stand alone" options, we recommend considering planned retreat or adaptation responses as the ideal approach over the long term, accepting however that in the short term, protection may be required. Should protection options be implemented, they should not prevent other long-term management options being put in place.

In addition there are options that are required to be considered in the RMA. These include:

- Do nothing
- Status quo

This study is limited to considering methods to address the issues affecting the erosion and inundation levels and potential impacts on property and infrastructure. It does not consider the implications of climate change effects on environmental aspects such as saltwater intrusion.

9.1 Do Nothing

Do nothing, as the name implies, means not providing any means to address hazards. It also suggests that no change to the existing catchment or development mix should occur. As it is unlikely that the catchment will remain unmodified as development pressures are ongoing the "Do Nothing Option" is not considered a realistic response for the sustainable management of coastal hazard risks.

9.2 Status Quo

The status quo response is to maintain the existing system that includes ongoing piecemeal development of the coastal margin with each development assessed based on the results of a site-specific assessment. This places an extensive cost burden on each individual developer, as well as providing potential for inconsistent assessments. The status quo option does not provide the best option either for sustainable coastal management or for the treatment of coastal hazards.

Development pressures can be expected to continue along the HBRC shoreline. Allowed to continue into the future the Status Quo option is only likely to slow the rate of extensive development within the coastal area with high value residential development and possibly commercial activities, such as restaurants, hotels, etc. There will also be increased recreational demands with conflicts associated with parking and space between visitors and residents of the area.

Ultimately, the status quo will not provide an optimal outcome for the HBRC shoreline.

9.3 Planned Retreat

Planned Retreat means progressively giving up threatened or vulnerable land by moving away from the coastal frontline, or by preventing future developments along the coast that may be affected.

A summary of potential methods for planned retreat is outlined below:

- Increase or establish set back zones
- Relocation of threatened buildings
- Presumed relocatability, rolling easements
- Phased-out or no development in susceptible areas
- Creating upland buffers, providing sufficient land area landward of existing development where properties could be relocated.

In effect the proposed coastal hazard zones provide a series of set back zones. Within the CERZ and cliff hazard zones we recommend the following planned retreat methods:

- No new council infrastructure to be located within the CERZ unless required specifically within that zone (i.e. outfalls, changing rooms, toilet facilities, boat ramps etc).
- No new private development (i.e. no new residential lots, and no new dwellings).

Within the future hazard zones (2060ERZ, 2100ERZ) we recommend:

- No major council infrastructure to be located within the zones unless required specifically within that zone.
- In existing residential zoned areas all new private development to be designed to be readily and demonstrably re-locatable and habitable levels to be established above the design inundation levels. In our opinion, readily re-locatable implies lightweight construction

techniques and does not allow concrete slab floor construction or the use of continuous concrete footings or edge beams.

- No further modification of land designation permitted in currently non-residential zoned land.

A range of rules is also required to take into account existing use rights for people with existing lawful structures. Within the CERZ we recommend rules that allow for maintenance, replacement and minor alterations of existing houses, as long as there is no substantial change to the existing building envelope and the changes comply with other statutory requirements. Provision for additions of decks should be less than 30 m^2 in area.

For the remaining risk zone areas within soft shore environments, we recommend the general application of re-locatability for extensions or modifications to existing dwellings. However, where existing dwellings are constructed with concrete slab footings, modifications/extensions could be carried out using similar construction methods to the original as long as they do not extend the building any further seaward.

Site specific assessments by an appropriately qualified engineering geologist should be undertaken for cliff top development within the cliff hazard zones.

9.4 Adaptation (Accommodation)

Adaptation refers to the adjustment in natural or human systems in response to actual or expected hazards and climate change effects, which moderates harm or exploits beneficial opportunities. As such, reducing coastal vulnerability to natural hazards and climate change is a form of adaptation (Klein et. al., 2001). Adaptation means more than increasing the design level of particular protection options. Adaptation includes the policy process that involves making decisions and applying technologies in a number of successive stages and can include continued but altered use of

land as well as adaptive responses such as elevation of buildings and infrastructure.

A summary of potential methods for adaptation is outlined below:

- Emergency planning – Civil defence. Early warning systems, evacuation systems.
- Hazard insurance.
- Modification of land use, i.e. changing zoning in the extreme risk area from residential to reserve.
- Strict regulation of hazard zones.
- Modification of building codes (platform levels, foundations, etc).

Emergency planning involves ensuring procedures are in place to communicate storm warnings to Civil Defence personnel and to carry out emergency procedures, such as evacuations. This is currently carried out through Lifelines and Civil Defence. Copies of this report should be made available to both agencies for review.

Hazard insurance is a tool that is currently used both in the USA and the UK. In the USA there is the National Flood Insurance Programme (NFIP). Communities participating in the NFIP agree to enforce floodplain management regulations in identified flood hazard areas. In return, citizens in these communities are eligible to purchase flood insurance that is not normally available through private insurance companies. This option is not yet viable in New Zealand as private insurance is still available to the majority of beachfront owners. However, ongoing erosion and climate change effects could change the insurance availability in the future. A national (central government) or regional impetus would be required to enable the hazard insurance option.

Within the CERZ, 2060ERZ and 2100ERZ we recommend the following specific adaptation methods:

- Guidelines for appropriate private re-development of existing dwellings considering existing use rights, natural character, landscape and the coastal hazards.
- Notice of hazard (erosion/inundation/climate change) on land title, LIM/PIM.
- Raising awareness of hazards.
- Monitoring of erosion and inundation drivers.

9.5 Protection

Protection is the most traditionally used method to protect investments from ongoing shoreline erosion and/or inundation and involves the construction of defensive measures and seeks to maintain shorelines in their present position. This can be through hard options such as seawalls, revetments, groynes, offshore breakwaters, reefs, dikes, levees, floodwalls, floodgates and tidal barriers, or by soft options such as beach renourishment, dune restoration and creation, wetland restoration and creation, and afforestation (i.e. replanting coastal cliffs).

Beach replenishment has proven to be effective to protect the Westshore coastline and could be considered in other areas. HBRC could facilitate the use of beach replenishment on a community wide basis by making beach replenishment for coastal protection either a permitted or discretionary activity and by facilitating the use of river gravels/sand for replenishment purposes where it is evident that sediment supply is not reaching the coastal environment.

In our opinion, there are only limited options for hard engineering protection works that could be considered to protect against long-term shoreline retreat along the Hawke's Bay shoreline. Groynes may be suitable to reduce longshore transport and to contain pocket beaches that are affected by headland erosion. However, due to the high wave energy, these structures tend to be large and costly. Armoured flood protection bunds and

seawalls can provide protection both in terms of erosion and inundation, such as at those currently in place at Waimarama. However, the consistency of increasing hard structures in the coastal environment needs to be carefully considered to be consistent with any erosion policy.

Within the CERZ we recommend the following protection methods:

- Beach nourishment
- Flood control bunds set back on the upper beach system
- Dune restoration (re-vegetation) with assistance of community based coast care groups
- Control of access

Other protection options, including groynes, seawalls, revetments maintaining road reserves and stream training works should be considered on a case-by-case basis and only if recommended protection methods are unsuccessful.

9.6 Works by Private Individuals

Protection works such as near-vertical seawalls, offshore breakwaters, submerged offshore reefs, beach nourishment, beach face dewatering, etc are generally not considered practicable for implementation by private citizens due either to expense or uncertain benefits. Works possible by individual property owners to protect against erosion are limited to rock and concrete revetments and groynes. Both revetments and groynes have advantages and disadvantages with no system that is clearly superior.

However, there are significant adverse effects that may result from allowing individual property owners to undertake their own protection works. These include:

High Cost. The high cost of a reliable design may encourage property owners to consider lower cost alternatives, which have a higher probability

of failure during significant storm events. When failure occurs, the next step is to place more material on the foreshore, to create a larger mass. These processes result in increased occupancy of the foreshore and reduced access.

Reclamation. In our experience, individual property owners may seek to regain land lost from historic erosion, by extending the wall to their original property boundaries. This can increase the potential lee-side erosion and edge effects.

Lee-side erosion. Seawalls and revetments can act as groynes, interrupting longshore sediment transport. This can increase the erosion on up-drift property owners that can either result in increased land loss if the up-drift property is unprotected, or destabilise any protection system.

Edge effects. Seawalls or revetments can also increase erosion to adjacent shorelines by preventing material from entering the system, either creating or exacerbating a long shore transport gradient. This increases erosion adjacent to the seawall or revetment.

Increased overtopping. Due to their more reflective nature, revetments and seawalls can increase overtopping. Therefore, more inundation and property damage by sea inundation can occur during less severe storm events. The increased inundation may lead to higher crest elevations being required.

Lack of security of constructed elements. Important design and construction aspects may not be carried out adequately, which can affect the overall stability of the system.

Visual inconsistency. Private citizens may undertake a number of different designs options along a stretch of shoreline which will increase the visual inconsistency along the shoreline due to the range of alternative systems or options utilised.

9.7 Additional Investigations to Refine Hazard Assessments

The coastal hazard assessments presented in this report are based on the best information available and using consistent methodologies to provide a uniform method of assessment along the entire Hawke's Bay coastline.

The scale of investigation is reasonably broad (typically kilometre scales) and does not extend to house lot size levels of accuracy. In addition, where no existing information was available the assessments tended on the conservative side in keeping with the precautionary approach.

Therefore the hazard zone width may be able to be refined at particular locations by more site specific investigations, using say additional survey data, field investigations and modelling to further refine and quantify the particular hazard.

9.8 Monitoring and Evaluation

It is recommended that both the ongoing climate change impacts and the performance of implemented measures are periodically evaluated in accordance with Council's long term coastal monitoring plan.

Additional surveys should be undertaken at all beach settlements, with at least three profiles undertaken annually for a minimum of 10 years to provide an improved understanding of shoreline variability.

Monitoring of cliff erosion should also be carried out, especially of the Cape Kidnappers system that is attributed as a significant source of gravels and therefore an important part of the sediment budget analysis. The Lidar survey results are probably the most accurate means to quantify change over a large area. Comparisons on 5 yearly or 10 yearly basis should provide useful information on volume change. In the interim the cliff face should be mapped by an engineering geologist, or suitably qualified specialist to quantify proportions of cliff material and assess likely quantities of material suitable to be retained on the beach system.

Council should consider sponsoring specific research to assist quantifying wave set-up and run-up for surging breakers on mixed sand-gravel beaches as part of the ongoing research into coastal processes and hazards within the Hawke Bay region.

10.0 Peer Review Comments

A peer review of this report has been carried out by Dr. Willem de Lange of the University of Waikato and Dr. Paul Komar of Oregon State University. This included an initial review of the proposed methodology by Dr. de Lange, followed by a review of two drafts of this report by both Dr. de Lange and Dr. Komar. Copies of the review comments are included in Appendix B.

10.1 Methodology

Overall the review considered the methodology employed acceptable and appropriate. However, Dr. de Lange noted that the limitation for the definition of the coastal hazard zones is likely to be the quantity and quality of the data available and recommended regular review and ongoing monitoring.

10.2 Review of First Draft

Dr de Lange's review of the first draft report identified points in the summary of coastal processes that were confusing or apparently inconsistent. His comments have generally been incorporated into the text, improving the clarity of the report.

Dr. de Lange also notes the relatively short time series used for estimating long-term retreat rates but acknowledges there is no alternative to applying the available data for the method used.

The reviewer identified a lack of information on the key aspects of the effects of wave erosion increasing landslide risk and the on-going impact of the 1931 earthquake on coastal erosion. We agree that there is insufficient information available to quantify these effects and recommend further research and monitoring.

A review of gravel barrier behaviour is not within the scope of this study, but should be considered as an aspect to include in a future review.

Overall, we support the Peer Reviewers conclusions, and recommend the hazard assessment be reviewed at least every 10 years, tied in with District and Regional Plan preparation.

10.3 Review of 2nd Draft

The second review by Dr. de Lange and Dr. Komar concluded that all issues had been addressed and the additional information included on run-up was standard and up-to-date given the lack of specific knowledge on run-up characteristics on gravel coasts. Recommendations were made for additional research on quantifying the wave set-up and run-up for surging breakwaters on mixed sand gravel beaches. In Dr Komars' opinion, there would be benefit in further analyses of the profile responses. Specifically he recommends:

- Correlations be made for representative profile sets between the measured volume changes and variations in the shoreline positions assessed at the 11-meter profile position to determine whether either could have been used to represent the beach responses to the causative processes;
- Comparisons be made for beach volumes and changes in shoreline positions between adjacent to distant profiles, to determine the alongshore uniformity of the beach responses to the erosion processes;
- Correlations be made between the annual changes in beach volumes and shoreline positions with the heights and calculated swash runup levels of storm waves that had occurred since the previous profile surveys, using the NIWA hindcasts and wave measurements by the Port of Napier gauge.

We support these recommendations.

11.0 Applicability

This report has been prepared for the benefit of Hawke's Bay Regional Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD
Environmental and Engineering Consultants

Report prepared by:

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R.A. Reinen-Hamill

H. M. Reynolds

Authorised for Tonkin & Taylor by:

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J O Grimston

RRH
30 January, 2004
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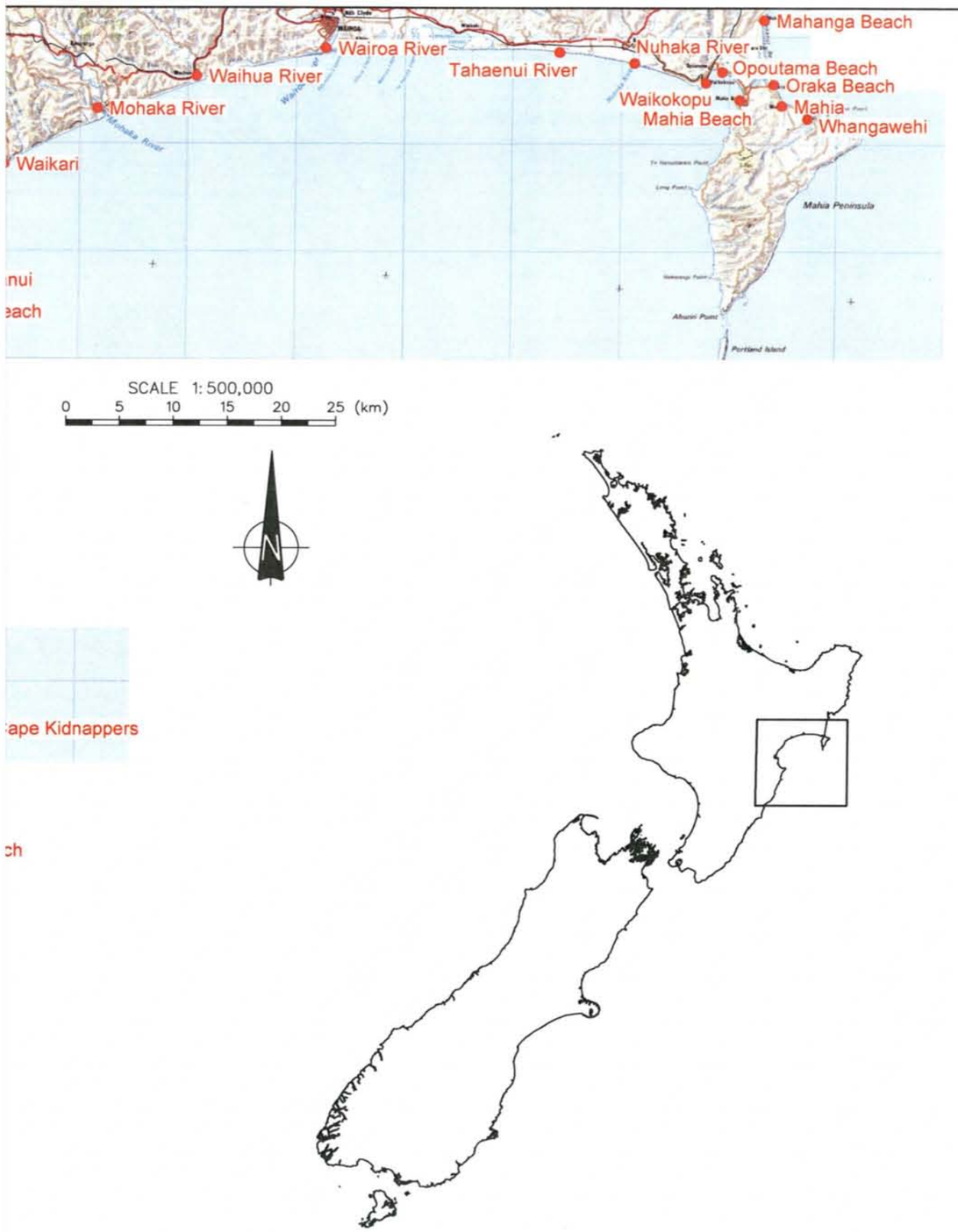

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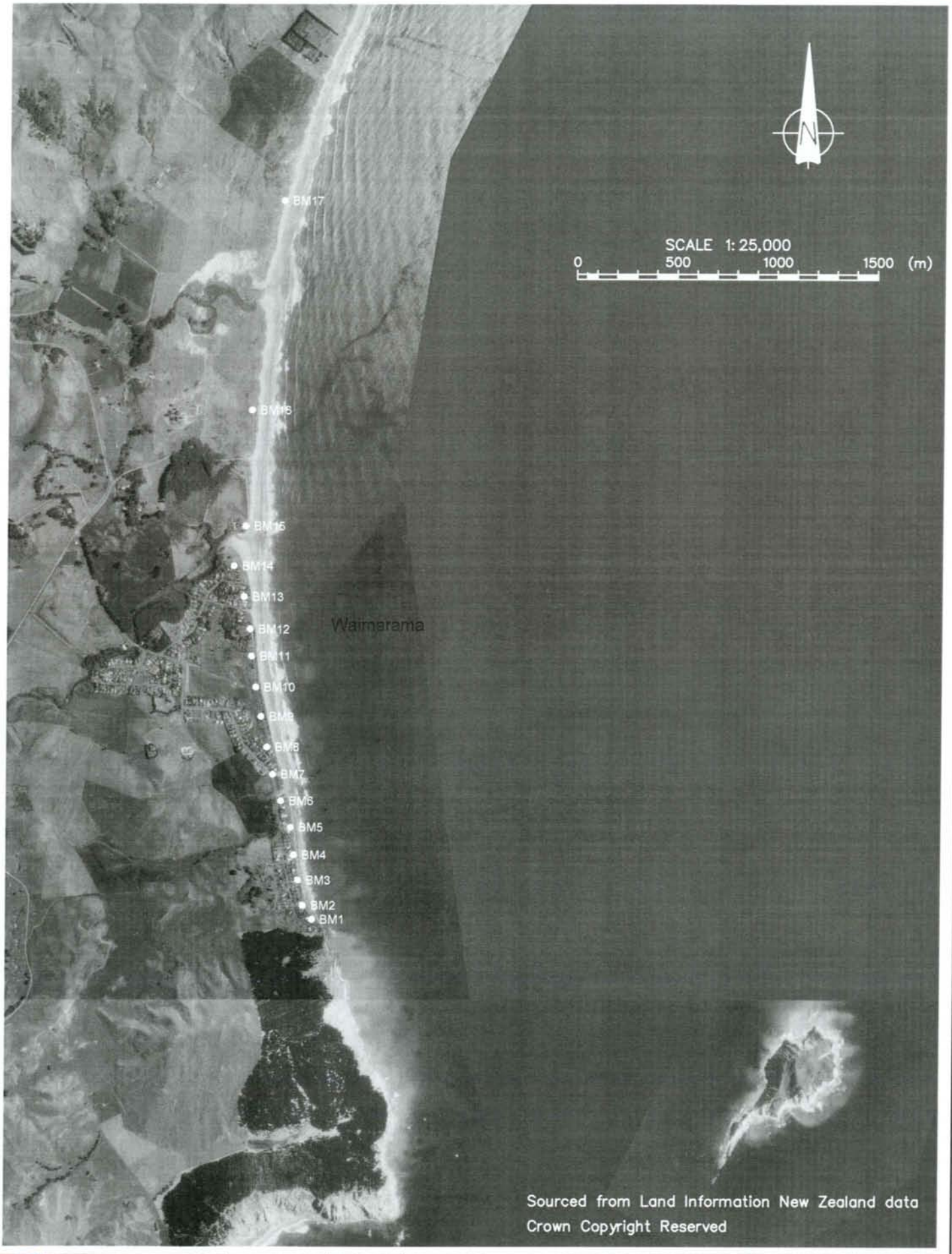
HAWKES BAY REGIONAL COUNC
REGIONAL COASTAL HAZARD ASSESSM
Location Plan

FIG. No. Figure 1



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HAWKES BAY REGIONAL COUNCIL
REGIONAL COASTAL HAZARD ASSESSMENT
Waimarama Beach
Profile Locations

FIG. No. Figure 2.1

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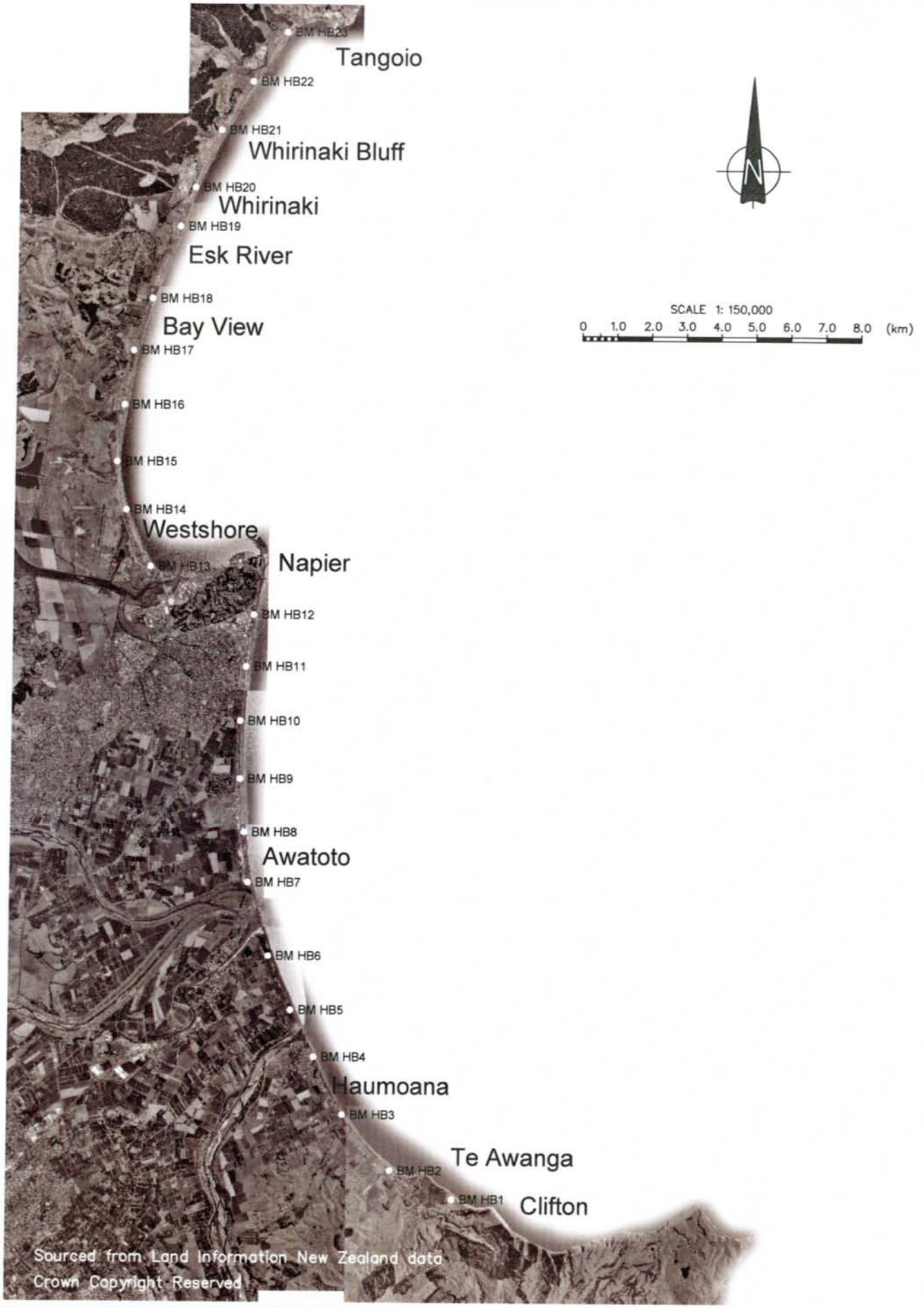

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REGIONAL COASTAL HAZARD ASSESSMENT
Southern Hawke Bay
Beach Profile Locations

FIG. No. Figure 2.2

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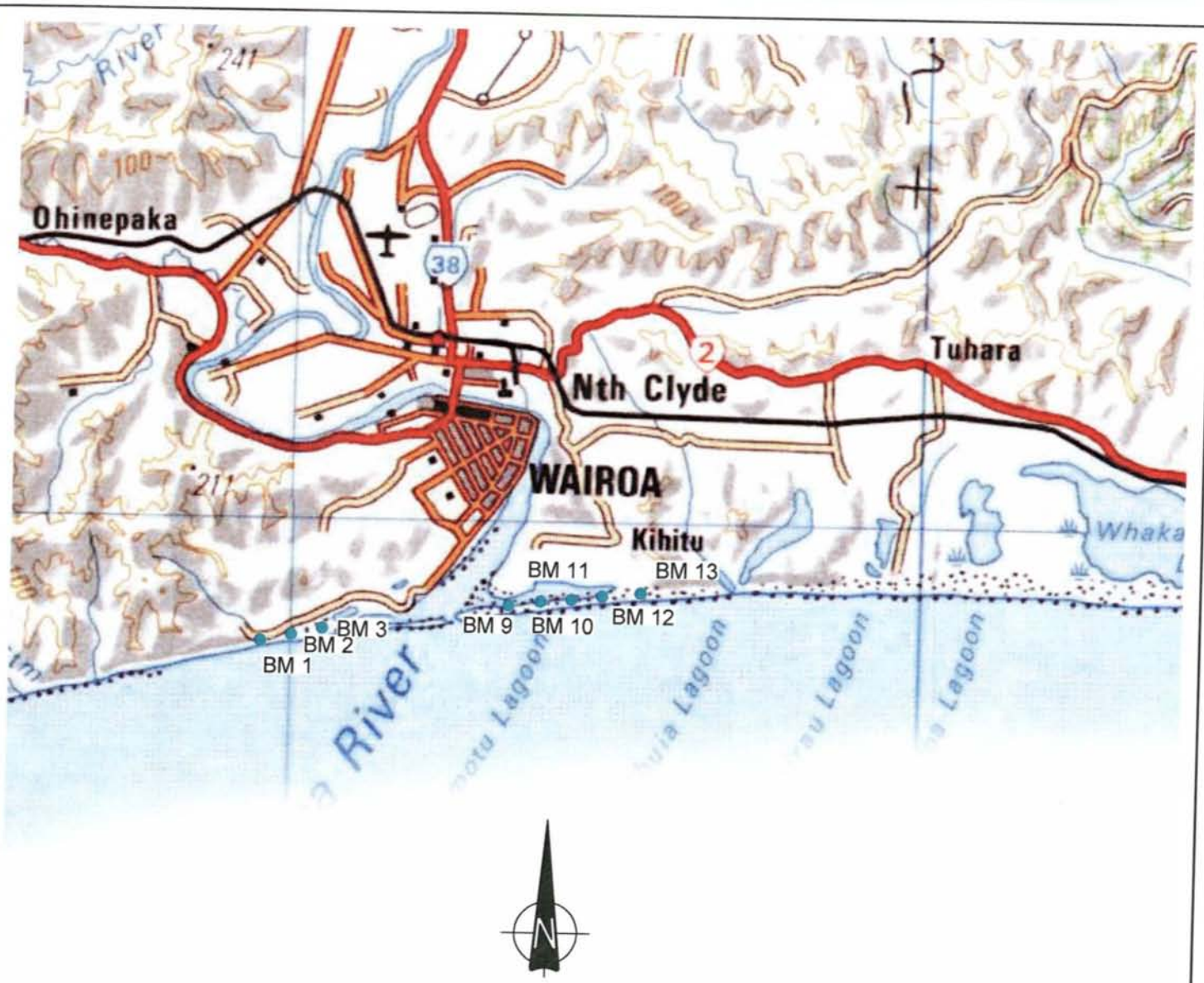

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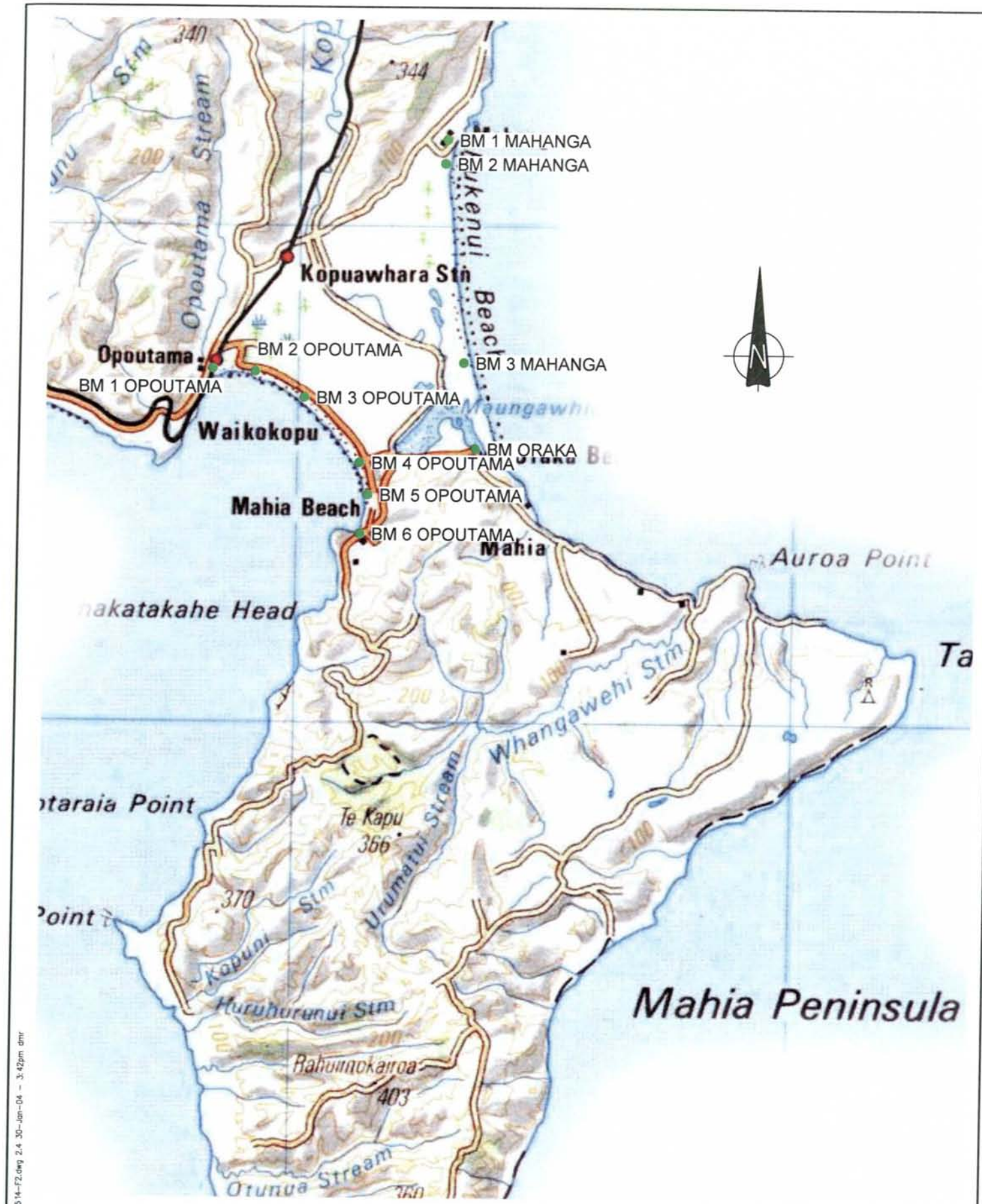
HAWKES BAY REGIONAL COUNCIL
REGIONAL COASTAL HAZARD ASSESSMENT
Northern Hawke Bay
Beach Profile Locations

FIG. No. Figure 2.3 REV. 0



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HAWKES BAY REGIONAL COUNCIL
REGIONAL COASTAL HAZARD ASSESSMENT
Northern Hawke Bay
Beach Profile Locations

FIG. No. Figure 2.4

REV. 0

Pourerere

Aramoaana

Blackhead

Porangahau

Legend:

Shoreline Behaviour Units

- Cliff
- River Mouth
- Gravel Beach
- Sand Beach

Coastal Property Boundaries

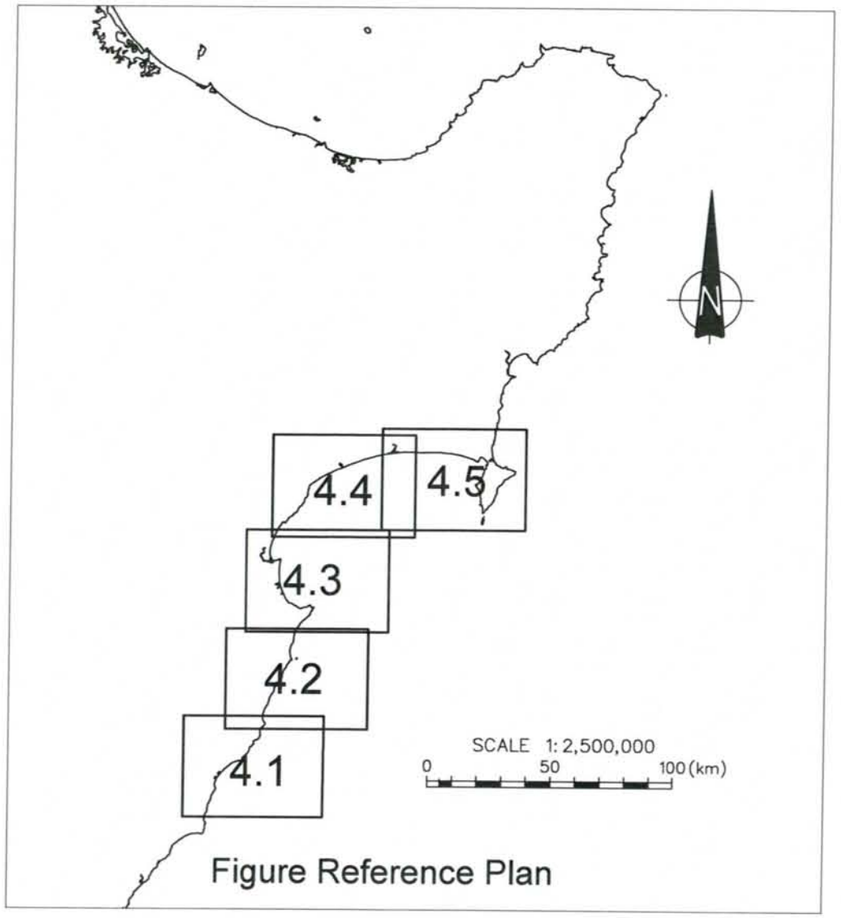

Figure Reference Plan

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HAWKES BAY REGIONAL COUNCIL

REGIONAL COASTAL HAZARD ASSESSMENT

Shoreline Behaviour Units

Porongahau to Pourerere

FIG. No. Figure 4.1

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Ocean Beach

Waimarama

Kairakau Beach

Mangakuri Beach

Pourerere

Legend:

Shoreline Behaviour Units

- Cliff
- River Mouth
- Gravel Beach
- Sand Beach

Coastal Property Boundaries

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SCALE 1: 150,000

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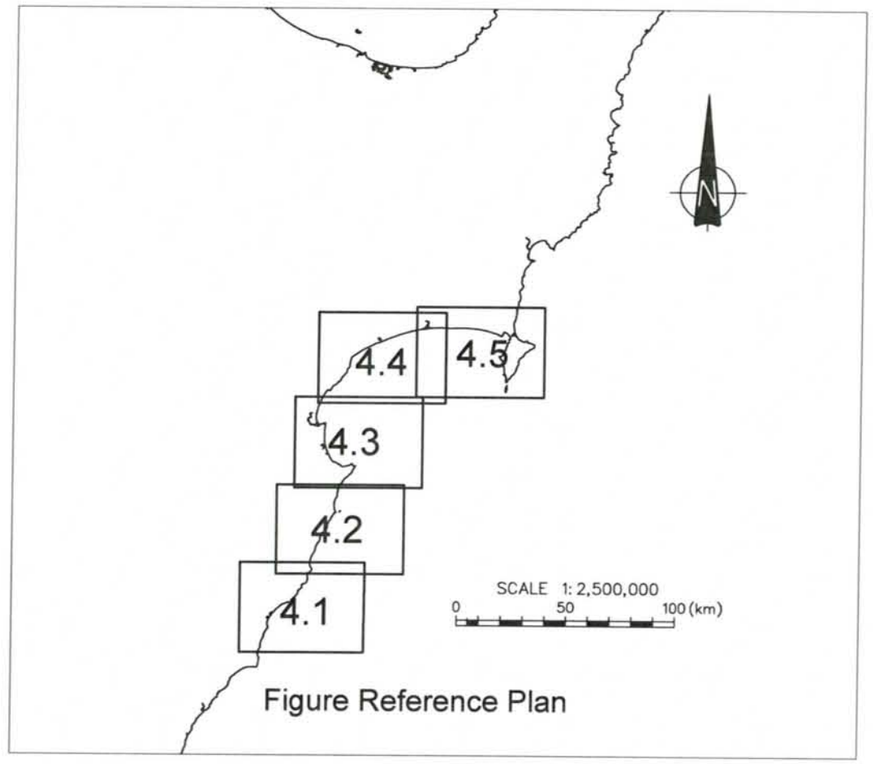

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HAWKES BAY REGIONAL COUNCIL

REGIONAL COASTAL HAZARD ASSESSMENT

Shoreline Behaviour Units

Pourerere to Waimarama

FIG. No. Figure 4.2 REV. 0

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Whirinaki

Esk River

Bay View

Westshore

Napier

Awatoto

Haumoana

Te Awanga

Clifton

Cape Kidnappers

SCALE 1: 150,000

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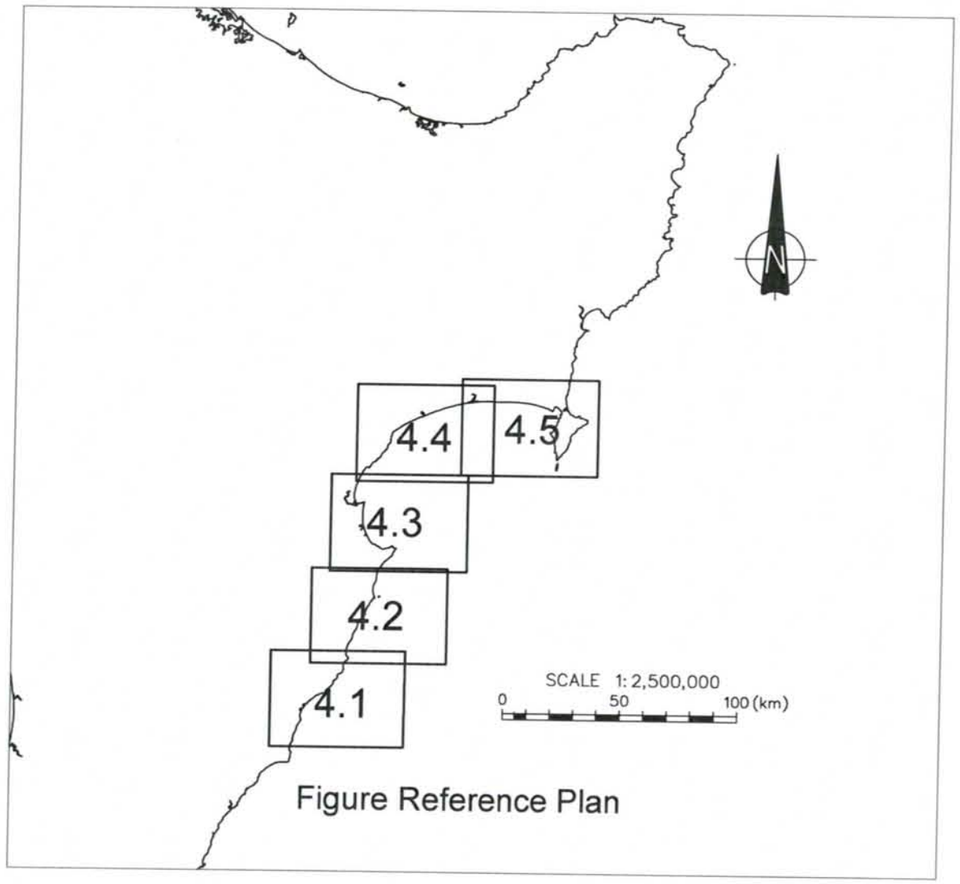
Legend:

Shoreline Behaviour Units

- Cliff
- River Mouth
- Gravel Beach
- Sand Beach

Coastal Property Boundaries



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HAWKES BAY REGIONAL COUNCIL

REGIONAL COASTAL HAZARD ASSESSMENT

Shoreline Behaviour Units

Clifton to Whirinaki

FIG. No. Figure 4.3 REV. 0

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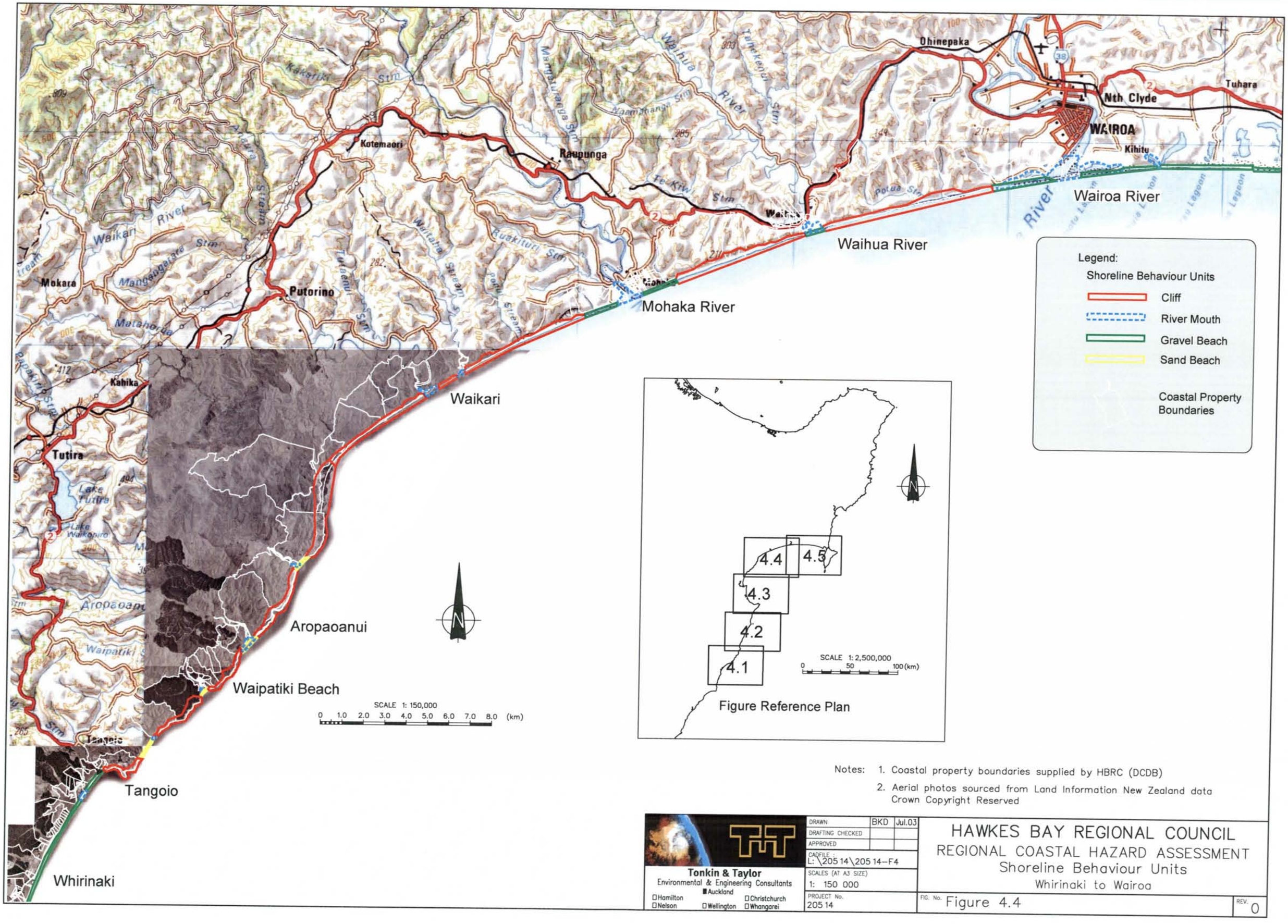

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HAWKES BAY REGIONAL COUNCIL
REGIONAL COASTAL HAZARD ASSESSMENT
Shoreline Behaviour Units
Whirinaki to Wairoa

FIG. No. Figure 4.4 REV. 0

Wairoa River

Tahaenui River

Nuhaka River

Waikokopu

Mahia Beach

Mahanga Beach

Opoutama Beach

Oraka Beach

Mahia

Whangawehi

Table Cape

Mahia Peninsula

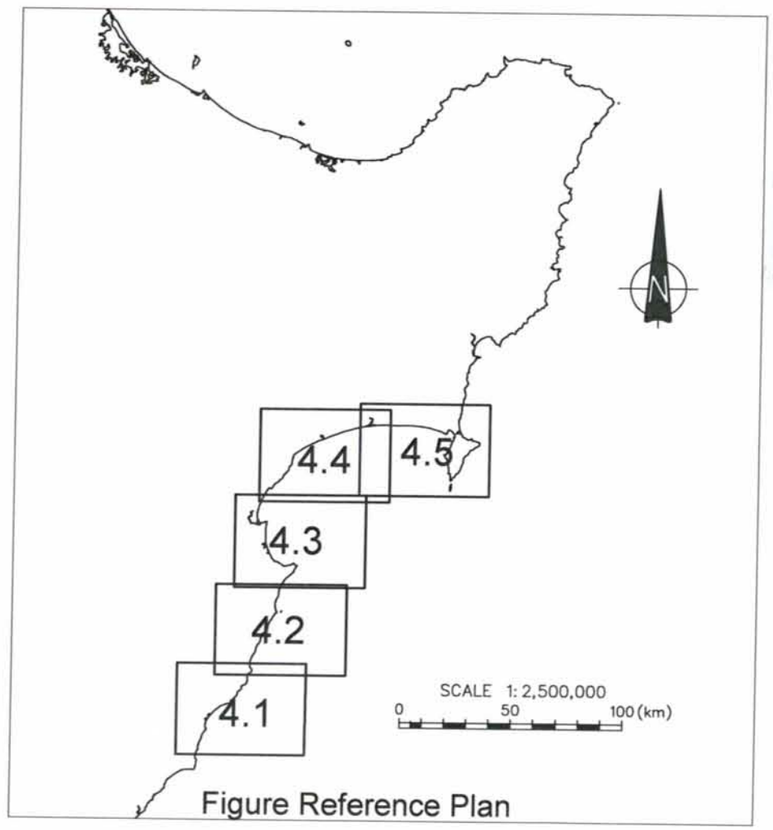

Figure Reference Plan

Legend:

Shoreline Behaviour Units

- Cliff
- River Mouth
- Gravel Beach
- Sand Beach

Coastal Property Boundaries

SCALE 1: 150,000

0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 (km)

Notes:
1. Coastal property boundaries supplied by HBRC (DCDB)
2. Topomap sourced from Land Information New Zealand data Crown Copyright Reserved

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Tonkin & Taylor
Environmental & Engineering Consultants
Auckland
Hamilton Christchurch
Nelson Wellington Whangarei

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HAWKES BAY REGIONAL COUNCIL
REGIONAL COASTAL HAZARD ASSESSMENT
Shoreline Behaviour Units
Wairoa to Mahia

FIG. No. Figure 4.5 REV. 0

APPENDIX A

CD OF HISTORIC AERIAL PHOTOGRAPHS AT SELECTED CLIFF SHORE SITES

APPENDIX B

PEER REVIEW COMMENTS

AUG 2003
RH

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Te Whare Wānanga o Waikato

Hawke's Bay Regional Council: Regional Coastal Hazard Assessment

Report prepared by Tonkin & Taylor Ltd

I have reviewed volumes 1 and 2 or this report, and detailed comments are on the draft copies. This is a summary of the main points.

Volume 1 outlines the methodology used to make the coastal hazard assessments, summarises available data on regional drivers of coastal processes, and reviews the RMA (1991) and suggested management strategies for dealing with coastal hazards. I have previously reviewed the methodology and this review is included as Appendix B in volume 1. The review of the RMA (1991) and related legislative tools, as well as the coastal management strategies, follows the guidelines for coastal hazard management being published by the Ministry for the Environment. These guidelines have been subjected to wide peer-review, and I have nothing to add to material presented in this report (apart from the minor corrections to the draft).

My comments largely relate to summary of coastal processes. In no particular order of importance, a few aspects that I would like clarified are:

- It is evident from the data presented that landslides are a common feature of the Hawke's Bay coastal zone. Further, the cited studies indicate that there is no difference in magnitude or frequency for landslides exposed to wave action. Therefore, the risk is the same for landslides at the coast, and further inland. This suggests that the hazard zone accounting for landslide may need to extend landward to the ridgeline as one local authority has already implemented.
- The impact of the 1931 earthquake on coastal erosion needs to be clarified. There are suggestions that management of the coast include restoring or augmenting the sediment supply, based on the assumption that the sediment supply has been reduced in some way. Further, it is suggested that the coast may not yet be in equilibrium with the changes resulting from ground deformation during the 1931 earthquake. How long are the coastal responses to this event expected to continue? Will it continue to be a factor in AD 2100?

- Cliff erosion rates need to be evaluated. Can a monitoring scheme be implemented for a few sites to run in conjunction with beach profiling? The main reason for assessment of rates is that it appears that cliffs are a significant contributor of gravel-sized sediment to beaches in Hawke Bay based on our textural analyses. Reasonable assessments of cliff contributions would be needed to develop any sediment budgets for Hawke's Bay. Incidentally, I suspect that the slightly higher erosion rates estimated by Dr Gibb are due to the use of non-rectified images.
- I find the use of positive and negative values in the tables confusing. In some areas, the data refer to shore changes or trends, where positive indicates accretion and negative indicates erosion. This convention appears to have been transferred to data relating to erosion rates, and hazard zone widths. Here a negative rate or width to me implies the opposite situation to the trend data. For example, a negative erosion rate implies accretion, and a negative hazard zone width implies moving the hazard line offshore. Could the positive and negative signs only be applied to trend or change data?
- The section of water level needs revision. In particular I do not understand the discussion concerning average and mean water levels. The LINZ tidal predictions are based on 60 tidal constituents (which I have but won't list here), not the limited number used by computer models such as WXTIDE and NIWA's online tidal prediction website. If MHWS is >0.23 m higher than predicted by the LINZ data, there is a problem. The LINZ constituents were derived by a harmonic analysis of 11 years of hourly data by the RNZ Hydrographic Office. I'm not sure when the data were collected, but I think it was around the 1970s. It is possible that there has been a change in relative sea level in that time, or more likely a shift in the recording site. However, this should have changed all of the tidal parameters more or less equally. Table 2.5 shows this is not the case, implying a significant change in tidal behaviour, or an error in the analysis method. I believe the later is more likely. As far as I can tell, the results of this analysis are not really used elsewhere, as the hazard assessments are based on a RL = 11 m as being approximately MHWS. It would seem more appropriate in this section to justify the use of this level, and to avoid the distractions of the LINZ datum and the chart datum (if they are included, they should also be expressed relative to the RL datum used).
- Do the authors have any confidence in the WAM hindcast wave data, given that it is uncalibrated? If so they should say why. I don't have any problems with it, but the implied accuracy of the data in Table 2.6 is not justified.
- The 1960 Chilean tsunami caused inundation of land around the Hawke Bay coast, particularly within estuaries (flooding houses at Scapa Flow) and is reported to have

scoured 17,000 m^3 of sediment from the harbour at Napier. The coastal hazard zones proposed do not account for this, as they don't extend into estuaries.

- The different inundation levels in Figure 5.1a need to be explained.
- The discussion of short-term and long-term erosion rates is confusing. In my view, large short-term fluctuations can mask long-term trends, particularly if the available data is relatively short term. I don't understand how long term trends can mask short term ones? If the long-term trend is so large as to swamp the short-term signal, then the short-term behaviour is probably not significant.
- I'm a little concerned that there is insufficient data to produce estimates of the long-term standard deviation of shoreline changes. The largest data set has 31 records over 28 years, while most have less than 15 records. There is no alternative to applying the available data for the method used. However, it is important to recognise that there is a large uncertainty and a precautionary approach combined with periodic review is advisable.
- I would like to see further assessment of a suitable model for predicting gravel barrier response to sea level rise. The closure depth for gravel is probably ~2.5 m, and historic data indicates the barrier erodes by migrating inland, with any gravel transported offshore being lost from the system. This doesn't fit with the conceptual model on which the Bruun Rule is based. A review of gravel barrier behaviour is not within the scope of this study, but should be considered as an aspect to include in a future review.
- I'd like to see a summary diagram defining the hazard lines and their contributing factors in section 7.
- The references (section 12) need revision as quite a few of the sources cited in the text are omitted, and some of those cited in the references do not appear in the text.

Volume 2 consists of site-specific summaries of the coastal hazard assessments for coastal settlements around Hawke Bay. I have not reanalysed any of the assessments, and I have assumed that the appropriate data have been processed using the methodologies outlined in volume 1. As a general comment, the assessments are made at a broad spatial scale and often are limited by a paucity of suitable data. Therefore, I suggest that the recommendations of this report be subject to periodic review.

Dr Willem de Lange

Senior Lecturer in Earth Sciences

Monday, August 25, 2003

28 OCT 2003

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Wednesday, October 22, 2003

Dr Richard Reinen-Hamill
Tonkin and Taylor Ltd
PO Box 5271
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Dear Richard

I'm happy that the issues I raised with you concerning the first draft report have been addressed in the second draft, and I have no further comments to make on them.

Concerning the wave set-up and run-up determinations, the methodology used is standard. However, there are some aspects that may need to be considered eventually:

1. The wave set-up determination is based on the dissipation of wave radiation stress by establishing a pressure head. The approach predicts a constant slope that is projected from the break point to the beach face, so if the width of the surf-zone is known then the wave set-up can be calculated. This approach appears complicated compared to the method used for wave run-up. If the wave run-up approach is followed, then the wave set-up is about 25% of the wave run-up (or 17% of the deep-water significant wave height.
2. The main difficulty I have is that the wave set-up and run-up vary with the beach state: so that a dissipative beach with spilling waves will experience different results than a reflective beach with plunging waves for the same deep-water wave height. All the methods used in the draft don't allow for changing wave steepness (or period). There are methods that do consider beach state. Unfortunately, much of Hawke Bay comprises mixed sand gravel beaches that involve surging breakers (particularly during extreme conditions causing property loss as at Te Awanga recently). I don't know of any method applicable to surging breakers. From observations, the wave run-up exceeds the breaking wave height, so 70% of the deep-water significant wave height may under-estimate the run-up.

I suggest that unless Professor Komar is aware of a more suitable method for the Hawkes Bay conditions, that you stick with the present methods and that research be undertaken into quantifying the wave set-up and run-up for surging breakers on mixed sand-gravel beaches.

Yours faithfully

Dr Willem de Lange

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USA

22 December 2003

Mr. Mike Adye
GROUP MANAGER ASSET MANAGEMENT
Hawke's Bay Regional Council
102 Vautier Street
Private Bag 6006
Napier, NEW ZEALAND

RE: Comments on the revised Tonkin & Taylor report, REGIONAL COASTAL HAZARD ASSESSMENT

Dear Mike:

I received a revised 2nd draft of the Tonkin & Taylor Report Volume I: ASSESSMENT, the report I had reviewed earlier in its 1st draft. I also received a copy of their Report Volume III: BEACH PROFILE DATA ANALYSIS, which was prepared in response to my review and specifically my request to have graphs presented of surveyed shoreline positions, those used in the methodology to assess long-term erosion rates. Finally, I received a letter from Mr. R.A. Reinen-Hamill, the coastal engineer with Tonkin & Taylor who has primary responsibility for the preparation of these reports; his letter is a response to the comments and questions offered in my earlier review. Attached to his letter was an email message from Willem de Lange, who also responded to my comments.

Overall I feel that this 2nd draft represents a considerable improvement over the 1st. The expanded discussion of the Short Term Fluctuations (Section 6.2) was particularly helpful explaining their statistical approach and the use of standard deviations in monitored shoreline positions as measures of the effects of climate change, varying sediment supplies, and occurrences of major storms. The revised report with its expanded explanation makes it clearer that the standard deviations are being used only to infer the shoreline-change effects of the natural processes, and notes that research into those processes is needed to establish this connection.

In my opinion there would be benefit in further analyses of the profile responses. Specifically I recommend:

- Correlations be made for representative profile sets between the measured volume changes and variations in the shoreline positions assessed at the 11-meter profile position to determine whether either could have been used to represent the beach responses to the causative processes;
- Comparisons be made for beach volumes and changes in shoreline positions between adjacent to distant profiles, to determine the alongshore uniformity of the beach responses to the erosion processes;
- Correlations be made between the annual changes in beach volumes and shoreline positions with the heights and calculated swash runup levels of storm waves that had

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occurred since the previous profile surveys, using the NIWA hindcasts and wave measurements by the Port of Napier gauge.

Such analyses could lead to a better understanding of the responses of the Hawke Bay beaches as well as establishing whether or not the standard deviations of the surveyed shoreline positions actually relate to beach erosion processes.

The Tonkin & Taylor report limits its inundation consideration to calculations of water elevations, without hinting at the potential destructiveness of such an event to homes in the path of the inundation. I recall seeing extensive overwash deposits of gravel landward from the Hawke Bay beaches, I think in the area of The Gap, carried landward as far as the highway. Those deposits likely date back to before the 1931 earthquake, to a period when the beach ridge was lower by a meter or two, having been raised at the time of the earthquake. Still, those deposits provide evidence for the effects of inundation during a 100-year storm or perhaps an even more extreme event.

I accept the Tonkin & Taylor methodology as an interim approach until we have a better understanding of the processes responsible for the erosion of the Hawke Bay shore and of the morphologic responses of the mixed sand-and-gravel beaches found there. In the mean time, the statistical methodology used by Tonkin & Taylor can serve as the basis for the establishment of reasonably conservative hazard zones for Hawke Bay.

Sincerely yours,

Paul D. Komar

Paul D. Komar

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