

REVIEW OF THE 1995 WAINUI BEACH COASTAL HAZARD ZONE

by
Jeremy G Gibb, PhD, BSc (Hons), TIPENZ
Director
Coastal Management Consultancy Limited, Tauranga, New Zealand

PART I - BACKGROUND

1. INTRODUCTION

On 23 March 2001, Coastal Management Consultancy Limited (CMCL) were commissioned by Gisborne District Council (GDC) to review the Coastal Hazard Zone (**CHZ**) for Wainui Beach (1995 Wainui Beach CHZ), assessed by Dr JG Gibb (Director, CMCL) in 1995 for GDC. The recommendations of the 1995 study (Gibb 1995, p.46) were received, considered, adopted and implemented by GDC. After a process of extensive public consultation, the 1995 Wainui Beach **CHZ** was incorporated into GDC's Proposed Regional Coastal Environment Plan and the Proposed Combined Regional Land and District Plan.

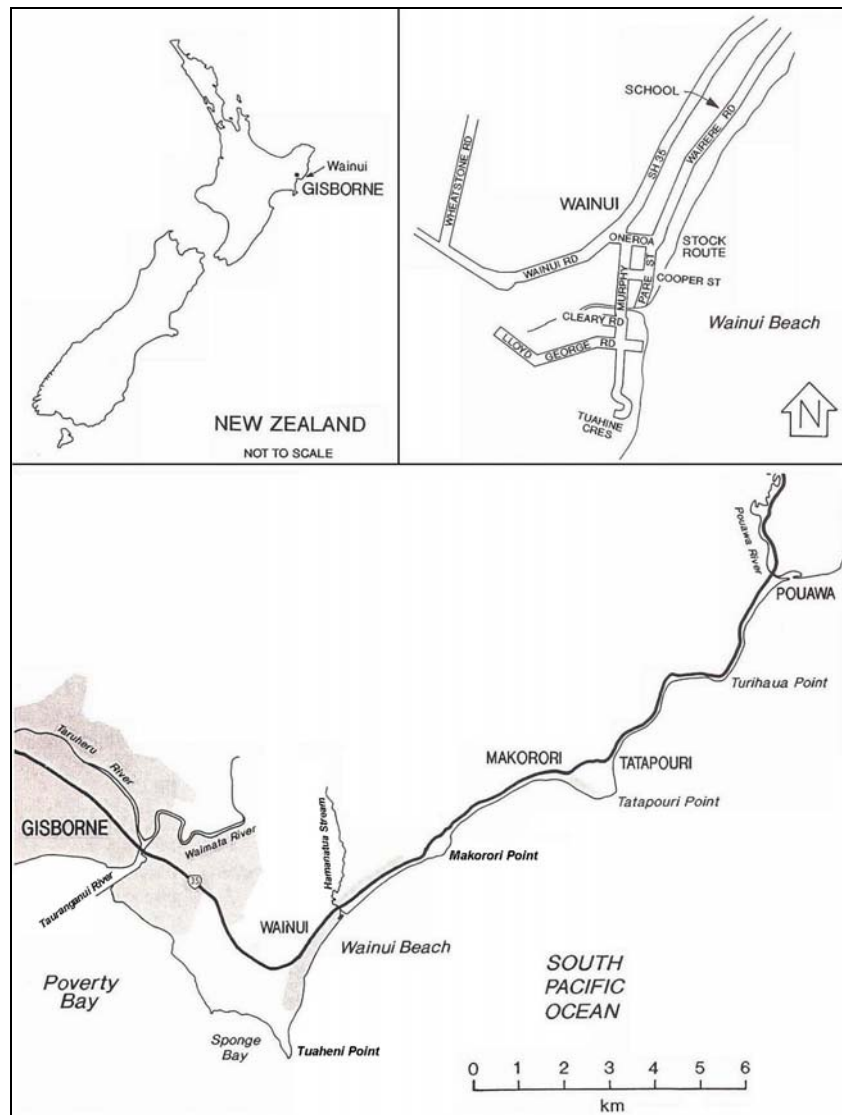
Recommendation (viii) of the 1995 study (Gibb 1995 p.47) stated that GDC should: "Reassess the Coastal Hazard Zones every 10 years using the same factors used in this assessment, OR after the occurrence of significant natural phenomena (e.g. large storms, tsunami, earthquakes, etc.), OR after significant new information becomes available (e.g. Climate Change and sea-level rise, monitoring programme), OR after significant failure of the property protection works at southern Wainui Beach and northern Waikanae Beach."

In the 6 years that have elapsed since the 1995 Wainui Beach **CHZ** was assessed a number of important changes have occurred to justify GDC undertaking this review. First, CMCL have developed a parametric Geographic Information System (GIS) computer model that precisely calculates the extent and location of Coastal Erosion Risk Zones from a number of parameters. Second, very accurate survey data are now available to quantify actual and potential erosion hazard along Wainui Beach. Third, in 2001 the Intergovernmental Panel on Climate Change published a revision of their 1990 and 1995 forecasts for Climate Change and associated global sea-level rise from an enhanced Greenhouse Effect. Taken together, these factors are likely to revise the extent and location of the Risk Zones assessed for the 1995 Wainui Beach **CHZ**.

In this report, the methods adopted for the review are described including the GIS computer model and parameters used in the model. The parameters are derived both from field investigations and research into both the geology, coastal dynamics and geologic hazards along Wainui Beach and are quantified from either new data where such data exists, or from existing data used to assess the 1995 Wainui Beach **CHZ**, where no new data exists. The report is accompanied by GIS maps of the revised **CHZ** for Wainui Beach which has been incorporated into GDC's GIS. The report concludes with recommendations for consideration by Council. The revised **CHZ** is here defined as the 2001 Wainui Beach **CHZ**.

1.1. WAINUI BEACH

Wainui Beach lies about 4km due east of Gisborne City on the East Coast of the North Island. The 4.2km-long open exposed beach faces Southeast and is slung between Tuaheni Point to the South and Makorori Point to the North over a total distance of about 6.2km. Hamanatua Stream separates the intensely developed 2.1km-long beachfront residential development to the South from the 2.1km-long public reserve (Lysnar Domain) to the North (Figure 1) where development is located on the landward side of State Highway 35.



• **Figure 1:** Location of Wainui Beach. (Adopted from Gibb 1998, fig.1).

The residential area of Wainui Beach became established about 1912 with a few beachfront cottages along the seaward side of State Highway 35. Between the two World Wars, subdivisions were made at the southern end of the beach from Tuahine Crescent to a point opposite where the primary school is now located on Wairere Road (Figure 1). After World War II, subdivision spread Northwards to Hamanatua Stream. During this period, the character of the settlement changed from a holiday resort to a substantial residential area with many of the original small baches being replaced by superior modern homes. Today, Southern Wainui Beach has 235 sections of which 106 adjoin the beach over a distance of 2.1km (Gibb and Jones 1977).

2. METHODS

Unlike the assessment for the 1995 Wainui Beach **CHZ**, most of the 2001 Wainui Beach **CHZ** was defined in this study with a standardised GIS computer model housed and used by Dr JG Gibb since 1996 at Tauranga District Council. For both the undeveloped, landslip prone Tuahine and Makorori Headlands the same techniques adopted in 1995 were used in this study as the computer model is limited only to erosion of sand dunes.

2.1. GIS COMPUTER MODEL

The GIS computer model was conceived, developed and standardised by Dr Gibb for erosion hazard for the open-exposed sand shores of Tauranga District (Gibb 1996a) and has since been applied to Gisborne District (Gibb 1998b), and various coastal areas in Whangarei District (Gibb 1999). The initial development and testing of the model was carried out by Dr Gibb with GIS analysts with Tauranga District Council (TDC). Final development, standardising and application of the model was carried out by GIS Consultants with the Geographic Technologies Unit, Auckland UniServices Ltd., with Dr Gibb. More recently, the model has been modified by Tonkin & Taylor Ltd, Auckland. The essential features of the GIS model include:

- i. **Risk Zonation.** The model generates **Extreme, High** and **Moderate Risk Erosion Zones** and **Safety Buffer Zone** which, in total, contribute to a **Coastal Erosion Hazard Zone (CEHZ)**.
- ii. **Consistency.** A standardised model means that the same parameters are used to assess **Coastal Hazard Risk Zones (CHRZ)** for all parts of a Local Authority's coast, providing internally consistent outputs.
- iii. **Sensitivity.** The model is sensitive and responsive to natural variability in the various parameters along the coast such as land and seabed topography, duneline fluctuations and long-term shoreline trends. In this sense, it is very responsive to alongshore variations in the physical natural character.
- iv. **Flexibility.** The model allows for individual parameters to be revised upon acquisition of new information. Such information could arise from coastal monitoring programmes, new scientific research, changes in forecasts of climatic effects from an enhanced Greenhouse Effect, or from the effects of coastal management schemes and the application of hard and soft engineering solutions.

- v. **User Friendly.** Council staff processing applications for either coastal subdivisions or building permits are able to retrieve **CHRZs** at the scale of one or many properties on computer terminals on a fully rectified orthophoto or contour map base incorporating the Digital Cadastral Database (DCDB) showing property, reserve and other boundaries. Existing and intending property owners should be able to obtain hard copies at appropriate scales at the front counter of the Local authority.
- vi. **Policy Framework.** The **Coastal Hazard Risk Zones** graduated from **Extreme** to **Moderate** provide a framework for Councils to develop and apply appropriate policies to control human activities within the **Risk Zones**. By displaying the **Risk Zones** generally on planning maps in District Plans and specifically on Council's GIS the landowners and public are forewarned about the presence of the identified natural coastal hazards.

2.2. GIS MODEL PARAMETERS

The following parameters were used in the GIS computer model for Wainui Beach to generate the 2001 Wainui Beach **CHZ**. They were derived from existing reliable information and from intermittent fieldwork between April 1999 and September 2001. Knowledge of the geology and coastal processes is essential for quantifying the various physical parameters used for **CHZ** assessment.

- i. **Digital Terrain Model.** A Digital Terrain Model (DTM) was generated by Air Logistics (NZ) Ltd in 2000 from fully controlled Aerial Surveys flown by Aerial Surveys (Nelson) of Wainui Beach on 22 April 1999 (Aerial Survey SN12596B). Based on the DTM, contours of the coast were generated by Air Logistics, for Wainui Beach with respect to Mean Sea Level (MSL) Gisborne Provisional Datum 1926. The contours have a positional and vertical height accuracy of better than one decimetre and provide information on the shape, height and volume of the foredune complex for hazard assessment. The contours produced by the DTM are at 0.5m intervals for Wainui Beach.
- ii. **Duneline and Crestline.** The seaward toe of the foredune complex (duneline) and seaward crest (crestline) were identified and positioned on the DTM by Dr Gibb. Using 3-Dimensional computer images of the coast at Air Logistics both the duneline and crestline were identified to an accuracy of $\pm 0.5\text{m}$ from the 1999 Aerial Surveys. These lines were then digitally captured by air Logistics for inclusion in the GIS model. The duneline is the representative shoreline used for **CEHZ** assessments along sandy coasts.
- iii. **Profiles.** Parallel profiles at 4m intervals were constructed with the GIS model perpendicular to a baseline approximating and seaward of the curvature of the shore. The profiles have a seaward and landward limit. The seaward limit was the April 1999 duneline, which was the start point for all model calculations along each profile. The landward limit was set at 250m inland from the duneline to fully accommodate the **CEHZ** which was calculated along each of the 4m-spaced profiles.
- iv. **Long-Term Shoreline Trend.** Controlled vertical aerial surveys over the last 57 years (1942-1999) provide the most reliable database to determine long-term historic shoreline trends. The long-term trend of either erosion or accretion was determined on the GIS model at TDC by comparing the 1942 duneline position with

that of the most recent reliable survey of the duneline. Rates of erosion or accretion in metres per year were calculated by the model by dividing the precise horizontal distance between surveys by the relevant survey period along the 4m-parallel profiles.

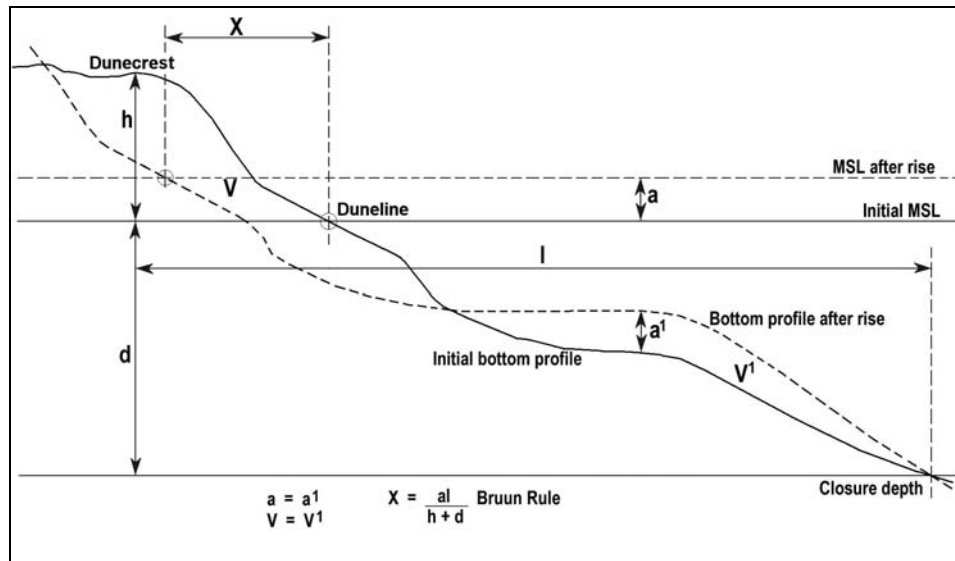
The 1942 duneline position was compared along most of Wainui Beach with the 1999 duneline position to quantify the long-term trend. The exception was the stretch of beach between Wainui Stream and Hamanatua Stream where the 1942 duneline was compared with the 1982 duneline position. For this area, the 1982 duneline provided a more accurate measure of the long-term trend of erosion of the ancient main foredune upon which development has taken place. Since 1982, a temporary incipient foredune has grown at the base of the main foredune. To use the 1999 duneline position in this area would create an erroneous trend of significant long-term advance based almost entirely on a short-term duneline fluctuation.

The earliest, most reliable survey of the duneline adopted in this study was Aerial Survey SN225 flown on 22 October 1942. The period 1942-1999 provides a survey period of 57 years, which is adequate to determine the long-term shoreline trend along Wainui Beach. The 1942, 1982 and 1999 dunelines were identified by Dr Gibb using 3-Dimensional computer images of the coast at Air Logistics. The 1942 and 1982 dunelines were positioned on the DTM to an accuracy of $\pm 1-2.0\text{m}$ so that they could be accurately compared with the 1999 duneline position which was positioned to an accuracy of $\pm 0.5\text{m}$.

Air Logistics Ltd., have also prepared coloured Aerial Plans (AP-1086) from the 1999 Aerial Survey at 1:2000 Scale. Five sheets cover Wainui Beach between Tuaheni and Makorori Points which show cliffines (base of seacliff) along both Tuaheni and Makorori Points and dunelines along Wainui Beach from aerial surveys made in 1942, 1965, 1982 and 1999. In Appendix I, rates are calculated for 31 sites at approximately every 200m between the 2 Points.

- v. **Short-Term Duneline Fluctuations.** The maximum extent of short-term duneline fluctuations was determined from the combination of geologic and anecdotal evidence, field measurements from repetitive survey profiles at 14 sites and historic duneline positions recorded by Aerial Surveys flown on 22 October 1942, 23 September 1965, 14 November 1982 and 22 April 1999. From this evidence the average maximum volume of sand in cubic metres involved in such fluctuations was measured precisely by Dr Gibb on the GIS at TDC for selected areas along Wainui Beach. Where sand volumes varied along the coast, volumes were linearly interpolated by the GIS model along each of the 4m-spaced profiles generated by the model between known volumes.
- vi. **Dune Scarp Stability Angle.** The average eventual stable angle of the dune scarp cut into the dunes at Wainui Beach was measured directly from profile data of the foredune complex held by GDC (Gibb 1995a, 1996a) and entered into the GIS model. Along Southern Wainui Beach, the complex geology results in localised steepening of the seaward face of the foredune over and above the natural angle of repose (AOR) of dry, loose, medium to fine sand of 33° .
- vii. **Erosion from Sea-Level Rise (SLR).** The well-established and widely accepted "Bruun Rule" (Bruun 1962; 1983) was incorporated into the GIS model to assess

the potential effects of SLR. The parameters required to use the “Bruun Rule” are shown in Figure 2. The “Bruun Rule” states that: “for a shoreline profile in equilibrium, as sea-level rises, beach erosion takes place in order to provide sediments to the nearshore so that the nearshore seabed can be elevated in direct proportion to the rise in sea-level” (Bruun 1962). The horizontal distance between the crestline and closure depth (l) with respect to MSL Datum was calculated along the coast by the model from the closure depth and crestline height of the foredune already included in the model (Figure 2).



• **Figure 2:** Diagram showing the response of the beach and nearshore zone to rising sea-level, where:
 V = volume; a = Sea-Level Rise; X = amount of duneline retreat; h = height of dune crest; d = depth of closure; l = distance to closure depth from dune crest (from Gibb & Aburn 1986, fig.11).

- viii. **Closure Depth.** The depth of closure is commonly defined as the “*minimum water depth at which no measurable or significant change in bottom depth occurs*” (Gorman *et al.* 1998). Closure depth is related to energy factors at various coastal sites and “*moves depending on waves and other hydrodynamic forces*”. Therefore, the active portion of the shoreface equilibrium profile adjacent to the beach can be expected to vary in width throughout the year depending on wave conditions (Gorman *et al.* 1998).

In effect, *closure depth* is a “*time-dependent quantity that may be predicted based on wave climatology or may be interpreted statistically using repeat profile surveys*” (Gorman *et al.* 1998). For Wainui Beach there are insufficient repeat profile surveys and data on wave climatology is grossly inadequate. In view of this, closure depth was identified in this study from the combination of both precision hydrographic surveys of the nearshore seabed and sampling and analysis of seabed sediments in April-May 2000. The tentative findings were compared with previous work on closure depth identification in similar coastal environments at Wainui Beach specifically (Gibb 1995) and in New Zealand generally (Dell *et al.* 1985; Gibb &

Aburn 1986; Hume & Hicks 1993; Healy 1993; Gibb 1987, 1995a, 1996a, 1996b, 1998b; Gibb & Reinen-Hamill 1997; Dr DM Hicks, NIWA, pers. comm. 1999).

The hydrographic surveys were conducted by Discovery Marine Ltd (DML) using a 5m Stabicraft fitted out with an array of sophisticated survey equipment. Profile lines were surveyed off Wainui Beach on 14-19 April 2000. All soundings were reduced to Mean Sea-Level (MSL) East Coast Catchment Board Datum which averages about 0.05m below the commonly used Gisborne Provisional Datum 1926 (DML 2000). The maximum combined error for soundings was 0.087m at -5m depth and 0.094m at -10m depth. Sediment samples were collected during the hydrographic surveys and sampling stations are described in Table 1. The closure depth was digitally captured by Air Logistics Ltd for inclusion in the GIS model from precision bathymetry supplied by DML.

• **Table 1:** Sediment Sampling Stations off Wainui Beach collected by DML on 18 April 2000 by weighted dredge from a 5m Stabicraft boat. Depths are accurate to 0.09m and station positions to 2.0m. MSL Datum used was East Coast Catchment Board Datum. Position coordinates are in terms of Poverty Bay Local Circuit. Sediment type based on both field and laboratory analyses.

STATIONS	POSITION		DEPTH (MSL)	FIELD DESCRIPTION
	Northing	Easting		
Profile 8A				
1	692425	318252	-21.3	Very Fine Muddy Sand
2	692661	318002	-18.9	Fine to Very Fine Muddy Sand
3	692793	317856	-16.8	Very Fine Muddy Sand
4	692918	317699	-14.9	Very Fine to Fine Shelly Sand
5	693072	317455	-12.2	Very Fine to Fine Shelly Sand
6	693198	317366	-11.2	Medium to Fine Shelly Sand
7	693305	317208	-9.0	Fine to Medium Shelly Sand
8	693373	317104	-6.2	Medium to Coarse Shelly Sand
9	693422	317063	-4.8	Coarse to Medium Shelly Sand
Profile 4				
1	692284	316478	-4.0	Coarse Shelly Sand
2	692218	316668	-7.3	Rock
3	692202	316798	-8.5	Rock
4	692176	316947	-10.6	Medium to Coarse Shelly Sand
5	692136	317152	-13.8	Rock
6	692057	317301	-15.4	Rock
Profile 12				
1	694383	317998	-3.4	Medium to Coarse Shelly Sand
2	694277	318099	-7.8	Fine to Medium Shelly Sand
3	694151	318204	-10.7	Very Fine to Fine Muddy Sand
4	694015	318289	-12.1	Fine Sandy Mud
5	693857	318399	-13.7	Fine Muddy Shelly Sand
Profile 7				
1	692900	316685	-4.6	Coarse Shelly Sand
2	692849	316877	-7.1	Medium Shelly Sand
3	692672	317105	-10.5	Fine to Medium Sand
4	692565	317282	-13.7	Rock/Sponge/Fine Muddy Shelly Sand
Profile 10A				
1	693415	317925	-13.9	Very Fine to Fine Sand
2	693600	317745	-12.0	Very Fine to Fine Sand
3	693763	317567	-8.3	Fine to Medium Shelly Sand
4	693858	317468	-5.0	Medium to Coarse Shelly Sand

The values for SLR (a) adopted for the model were based on the current average “most likely” projections by the IPCC (2001) for the years 2050 and 2100 less historic SLR for Northern New Zealand. The Bruun Rule (Figure 2) can only be applied to sand coasts and not to cliffed coasts. It is 2-dimensional and does not allow for sedimentation processes that occur independently of long-term SLR. This deficiency is overcome in the GIS computer model by incorporating the historic long-term shoreline trend that has occurred from a number of influences including historic SLR. The long-term trend is a good indicator as to whether the beach-nearshore profile is advancing in the long-term from a positive sediment budget or retreating from a negative budget.

- ix. **Factor of Safety.** A factor of Safety was incorporated into the GIS model to make provision for uncertainties in the model parameters. Potentially, the Safety Factor can range from 1 (no uncertainty) to 2 (large uncertainty). Values commonly adopted by Dr Gibb and others in the past have ranged from the following:

- 1.2 Very Low uncertainty
- 1.3 Low uncertainty
- 1.4 Moderate uncertainty
- 1.5 High uncertainty
- 1.6 Very High uncertainty

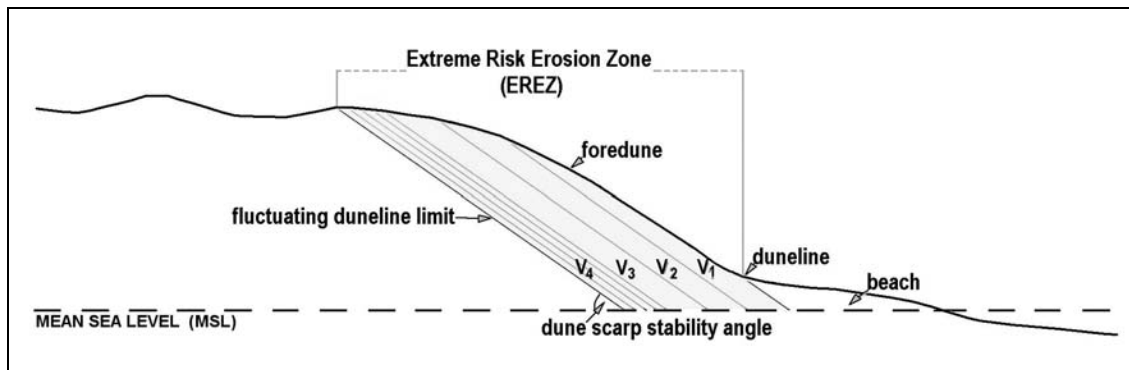
Initially, the model applied the Safety Factor over all the parameters. Recent modifications to the model have restricted the application of the Safety Factor to the short-term duneline fluctuation volume.

2.3. RUNNING THE GIS MODEL

The model is run on the Arc/Info GIS and aims to plot firstly; the maximum potential volume of foredune involved in short-term duneline fluctuations; secondly, long-term duneline retreat (if any) from historical processes; and thirdly, duneline retreat (if any) from a projected sea-level rise over planning horizons to 2050 and 2100. These three scenarios are described as **Extreme Risk Erosion Zone**, **High Risk Erosion Zone** (2050) and **Moderate Risk Erosion Zone** (2100), respectively. In addition, there is an added **Safety Buffer Zone** which allows for uncertainties in the various parameters used in the model.

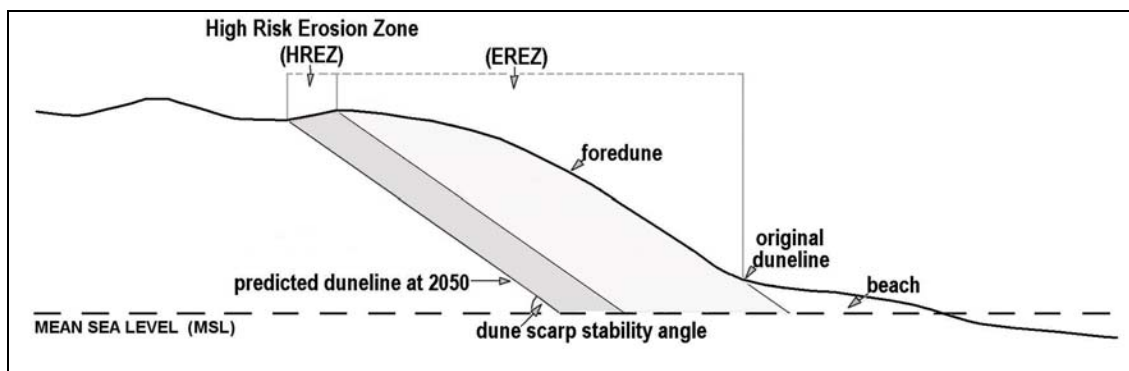
The initial start volume (Figure 3) is calculated by assessing the height of the duneline above MSL by querying the DTM and projecting a line back seaward at the dune scarp stability angle. The GIS then moves at 1m increments inland along the profile line at parallel lines to the dune scarp stability angle and calculates the area indicated by V1, etc., in Figure 3.

To accurately define the landward location of where the volume is finally reached, the model changes from 1m intervals to 0.25m intervals for the area calculations as the target volume for the **Extreme Risk Erosion Zone** is approached. The final position of the **Extreme Risk Erosion Zone** (on each profile line) is retained by the GIS and the next profile line is then processed in the same way. The model ends up with a point on each of the 4m-spaced profile lines which, is joined with all the others to create a line along the coast representing the **Extreme Risk Erosion Zone** with respect to the reference shoreline position.



• **Figure 3:** Conceptual diagram illustrating the volume calculation method used in the computer model to calculate the *Extreme Risk Erosion Zone*.

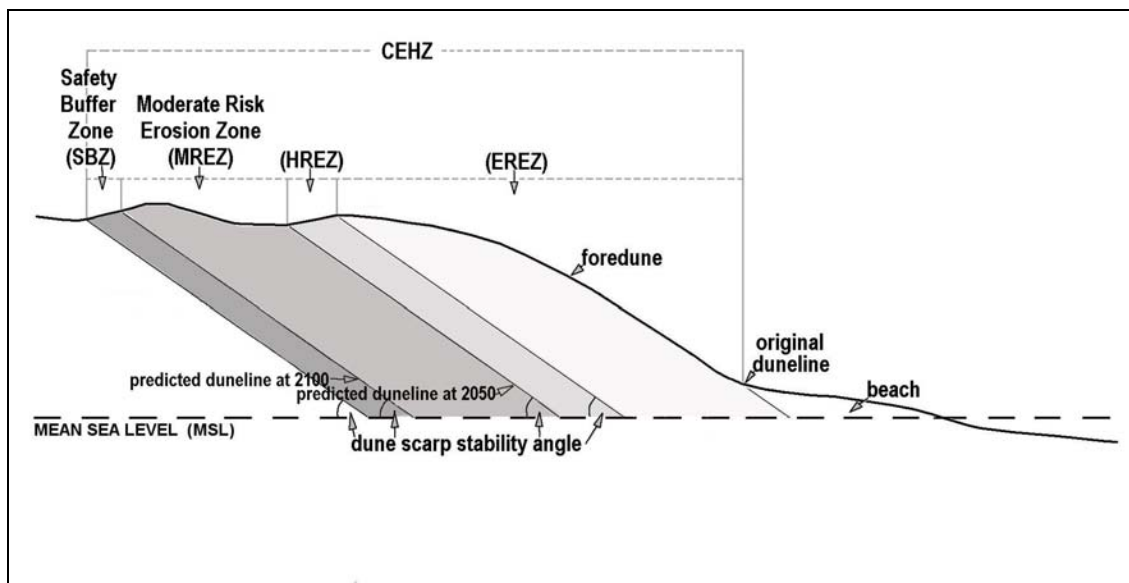
The **High** and **Moderate Risk Erosion Zones** are calculated in a similar way but a new starting point (inland of the current duneline) is calculated (Figure 4) using the Bruun Rule (Figure 2). The new starting point is the estimated location of the duneline after the combination of a period of net SLR over an above historic SLR, plus any projected historical long-term erosion or accretion trends. That is, it takes the current duneline and moves it inland by a distance calculated with the Bruun Rule coupled with the long-term erosion trend. The model is run twice using the Bruun Rule for planning horizons up to 2050 and 2100 to determine **High** and **Moderate Risk Erosion Zones**, respectively (Figure 5).



• **Figure 4:** Conceptual diagram illustrating the volume calculation method used in the computer model to calculate the **High** and **Moderate Risk Erosion Zones**, taking into account potential erosion from sea-level rise (Bruun Rule) coupled with long-term erosion trends.

If potential erosion from sea-level rise is negated by the natural long-term rates of accretion, then the Bruun Rule value is set to zero and in the model, the duneline will stay where it is. Thus, it is possible in an area of accreting coast to have an **Extreme Risk Erosion Zone** and one (or none) of the zones of **High** or **Moderate Risk**.

Once the three **Risk Zones** have been determined, a fourth zone, the **Safety Buffer Zone**, is calculated (Figure 5). This zone is expressed on a scale from 1.0 (no uncertainty) to 2.0 (large uncertainty) of the total **Extreme Risk Erosion Zone** width in the GIS model (Figure 5). For previous CHZ assessments the writer has adopted uncertainty values ranging from 1.2 (20%) (Gibb 1998c), to 1.6 (60%) (Gibb 1999a) to determine **Safety Buffer Zone** widths.



• **Figure 5:** Conceptual diagram illustrating the **Risk** and **Safety Buffer Zones** which comprise the **Coastal Erosion Hazard Zone** on a coast with a past history of either erosion or dynamic equilibrium. A coast with a past history of significant accretion will have just the **EREZ** and **SBZ**.