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Coastal Management/Set-back Lines for the West Coast District

Coastal Processes and Risk Modelling

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1 INTRODUCTION

With climate change and the dynamic nature of coastal zones in mind, the prediction of sea level changes and calculation of the related risk to coastal communities have become a necessity in the face of the potentially extensive impact of sea level rise-related storms and storm surges on the coastal zone. The Western Cape Government Department of Environmental Affairs & Development Planning (WCG) proposes to delineate coastal set-back lines[1] for the West Coast District (WCD) as one strategy through which responsible coastal management can be ensured.

Delineation of coastal set-back lines must be undertaken in accordance with the National Environmental Management: Integrated Coastal Management Act (Act No. 24 of 2008)(ICM Act), the National Environmental Management Act (Act No. 107 of 1998)(NEMA), Environmental Impact Assessment (EIA) Regulations, 2010, as well as the Western Cape Provincial Spatial Development Framework (PSDF). Coastal set-backs are proposed as a means to facilitate improved planning and management of sensitive and often vulnerable coastal areas.

The project consists of two main components – modelling of coastal processes on the one hand, and determination of management guidelines on the other. The technical modelling includes the determination of a refined high water mark (HWM), and various lines describing natural coastal processes in respect to short, medium and long term risks. Management guidelines are then derived by means of a stakeholder engagement process which is based on the technical information.

It is envisaged that at the end of the project, the following would be available:

- an accurate delineation of the high water mark as defined by the ICM Act
- lines demarcating physical processes or sea-based risk in the short, medium and long term (1:20, 1:150 and 1:100)
- one or more management lines, or coastal set-back lines, that can be used to manage development along the coast
- a line demarcating the Coastal Protection Zone (CPZ) (as required by the ICM Act)

2 COASTAL SET-BACK LINES IN TERMS OF THE ICM ACT

Coastal set-back lines, as detailed in the ICM Act, are prescribed boundaries that indicate the limit of development along ecologically sensitive or vulnerable areas, or an area that poses a hazard or risk to humans. According to the recent proposed amendments to the ICM Act, as detailed in the ICM Amendment Bill (Bill no 8 of 2013), the lines will be referred

[1] Proposed amendments to the ICM Act are likely to see 'coastal set-back lines' renamed to 'coastal management lines' in future. Refer to Section 2 for more detail.

to as ‘coastal management lines’ in future to avoid confusion with EIA development setback lines.

The coastal management line prohibits or restricts the construction, extension or repair of structures that are either wholly or partly seaward of the line, and may even be situated outside the coastal zone. The ultimate intention of the coastal management line, as defined in the ICM Act, is to protect or preserve:

- coastal public property such as beach amenities and other infrastructure such as parking
- coastal private property such as private residences and business properties
- public safety in the face of extreme climate and other natural events
- the coastal protection zone
- the aesthetics or “sense-of-place” of the coastal zone

The establishment of coastal management lines is a provincial responsibility but a relevant Member of the Executive Council (MEC) can only establish such a line(s) after consultation with Municipalities and interested and affected parties (I&APs). The MEC must communicate this by publishing regulations or a notice (as per the ICM Amendment Bill (Bill no 8 of 2013)) in the Gazette. Once determined this line must be delineated on the map or maps that form part of the municipal zoning scheme. This is done so that the public may determine the position of the set-back line in relation to existing cadastral boundaries (Celliers, *et al.* 2009).

The coastal set-back or management line is proposed to give specific direction in respect to locating the future development footprint and coastal planning schemes will zone the coastline in respect to proposed activities and land use. Effective coastal governance structures should ensure that future decision making is in line with the National, Provincial and Municipal Coastal Management Programmes (CMP) and any related norms and standards to assist decision makers in respect to best practice.

Coastal management/set-back lines may be established for various reasons and there may be more than one management line in any given area. For example, one management line may be an anticipated erosion set-back line, while another may relate to aesthetics and control the height of buildings to protect a specific scenic landscape. Management lines will assist in controlling development along an ecologically sensitive or vulnerable area, or any area that poses a hazard or risk to humans.

3 STAKEHOLDER ENGAGEMENT

A holistic and comprehensive stakeholder engagement process was proposed to ensure that interested or affected members of the public have the opportunity to contribute meaningfully to the delineation of the proposed coastal management/set-back lines and the associated development management proposals.

The consultation process was undertaken in two stages.

Initial public engagement was sought on the basis of the completed coastal hazard modelling. This offered the public an opportunity to engage on the scientifically defendable 'risk' projection, and offer comments and suggestions on how the information could be used to manage development around the risk zone.

A second engagement round followed once the draft coastal management/set-back lines had been determined. This granted the public a chance to confirm that the proposed management lines are practical, appropriate, and responsive to the public comments raised during the first round of engagement.

More detail is provided in the parent report detailing the full process of determining a coastal management/set-back line.

4 PHYSICAL PROCESSES MODELLING

The determination of risk zones or areas where coastal processes are active along the West Coast is based on the application of a consistent delineation methodology applied along the study area. The process, as it unfolded, is described below.

4.1 Data Sources

The data used for the various modelling processes in this study were sourced as:

4.1.1 Aerial photography

Historical aerial photographs covering the study area or a portion thereof were obtained from the National Geo-spatial Information (NGI), a component of the national Department of Rural Development and Land Reform (DRDLR) (previously the Chief Directorate: Surveys and Mapping). All photography of the coastline was geo-referenced where necessary with particular emphasis placed on sections of sandy shoreline, where trends in long-term beach retreat or accretion were identified.

4.1.2 LIDAR

Existing ground topography information was not considered accurate enough to determine the beach and rocky shore slopes, and therefore a LIDAR survey was undertaken. This laser based technology provides for an accuracy of 20-50cm in modelling. The LIDAR information is used to determine the wave run-up element of the analysis as well as to create the accurate digital elevation model upon which the simulation results are modelled upon.

4.1.3 Wind and Wave data for the region

Wind and wave data was sourced for the study area.

Wave data was obtained from actual and virtual wave buoys in the area, and analysed to determine wave heights, wave period, extreme (storm) values and wave direction. The results were then used in a SWAN model to determine inshore (15m depth) wave characteristics.

4.2 Determining the physical processes line (risk zone)

4.2.1 Step 1: Determine the 1:10. 1:20, 1:50 and 1:100 year storm off-shore wave height

The 1:10 (current HWM), 1:20 (short term), 1:50 (medium term) and 1:100 (long term) year storm wave heights and periods (see Figure 1) were determined using available wave statistics.

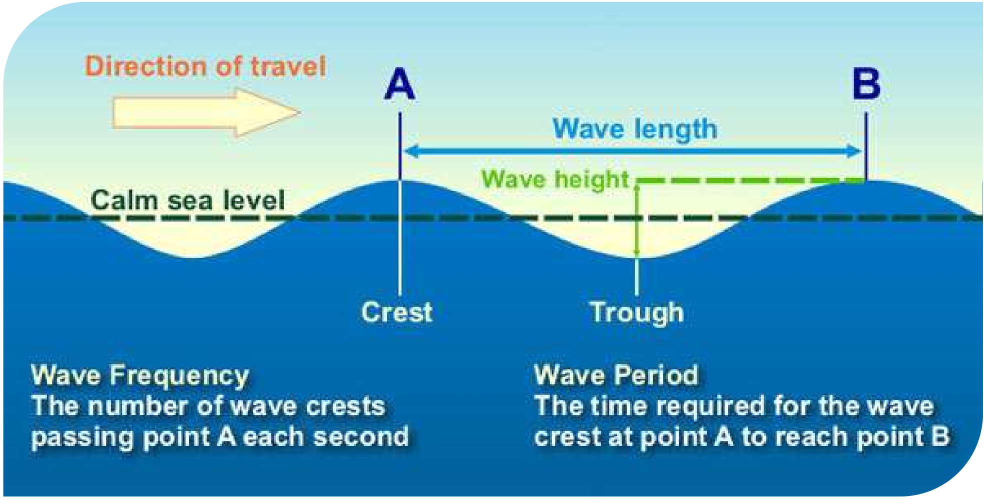

Figure 1: Wave characteristics and terminology (credit: US National Oceanic and Atmospheric Administration (NOAA) Ocean Service)

Analysis of the records show that the direction of major storm events originate predominately from the South East sector (213,75 to 236,25 deg.). Since 1997, 36 storm events were recorded (based on wave heights exceeding 6m), of which nearly half occurred in the past 5 years. The most extreme waves occurred during a storm in August 2012.

Figure 2: Predominant direction of storms - 213,75 to 236,25 degrees

Including a 17% increase to allow for the effects of climate change (100 year horizon), the extreme 1:100 year offshore wave height was determined to be 10.6m (Table 1).

Table 1: Current and future offshore wave heights and periods

WAVE RETURN PERIOD (Years)	PRESENT WAVE HEIGHTS (m)	PRESENT WAVE PERIODS (sec)	FUTURE WAVE HEIGHTS (+17%) (m)	FUTURE WAVE PERIOD (+17%) (sec)
1:1	7,0	14,4	8,2	16,8
1:5	8,4	15,7	9,8	18
1:10	8,9	16,2	10,4	18,9
1:20	9,4	16,8	11,0	16,6
1:30	9,7	17,1	11,4	11,3
1:50	10,1	17,4	11,8	20,4
1:100	10,6	17,9	12,4	20,9

4.2.2 Step 2: Determine the HWM based on wave run-up models

Wave run-up heights are determined using the models of Mather *et al.* (Mather, Stretch, & Garland, 2010) for sandy shorelines and the Eurotop manual for rocky shorelines (Pullen, 2008). The different run-up heights for future wave height scenarios of 1:10 (current HWM), 1:20 (short term), 1:50 (medium term) and 1:100 (long term) year inshore wave heights were used to determine different coastal risk areas. The run-up of the 1:10 year storm wave height also doubles as demarcation of the current high water mark, in accordance with the prescriptions of the ICM Act.

Wave run-up modelling requires offshore waves to be transformed inshore in order to represent the actual wave conditions at the nearshore. In order to do this, a SWAN model is used to transform these waves from a water depth of -149m to -15m at various locations along the coast. Nearshore wave heights are then used as input into subsequent wave run-up models. The west coast is a fairly open and straight coastline, and it was determined that 46 locations along the -15m contour were sufficient to represent the nearshore climate along the coast. Sites were chosen either for their immediate urban development, at changes in the orientation of the coast, across reef structures as well as in the middle of sandy embayments.

Figure 3 below shows a section of the modelling with the different return period wave storm event wave heights indicated. The 1:10 year wave run-up is considered to represent the current HWM.

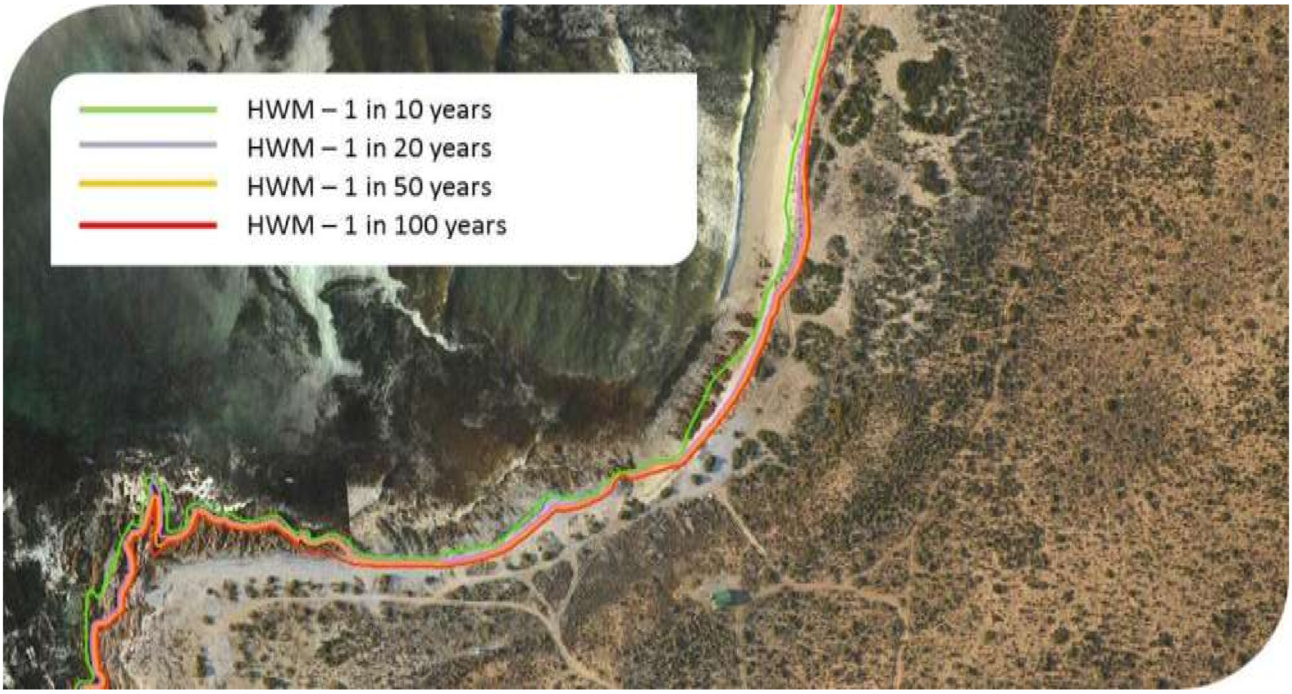

Figure 3: Modelled wave run-up for different return periods

4.2.3 Step 3: Determine the predicted future shoreline regression due to sea level rise

Where beach retreat takes place, the physical processes modelling needs to accommodate the accumulated future retreat for the various time horizons. For the purposes of this study, short, medium and long term time horizons are designated as 20, 50 and 100 years respectively, and the associated retreat (in metres) is added to the modelling.

Climate change related sea level rise is predicted to result in the shoreline moving inland due to inundation as well as increased sediment losses from increased wave energy at the shoreline. To model this anticipated change, the most commonly applied model used is the Bruun Rule (Bruun, 1962).

The amount of shoreline regression will depend on the amount of sea level rise expected. As sea level rise will vary into the future, approximate sea level rise amount for each wave return heights was predicted. This is an attempt to match scenarios of similar risk of occurrence to each other. Therefore the maximum expected sea level rise of 1 000 mm was equated to the 1:100 year horizon and a straight linear distribution was applied to the lesser return periods as shown in Table 7. It must be noted that wave height and sea level rise are completely independent of each other, i.e. a 100 year wave event can occur with no sea level rise.

Table 2: Combinations of wave height returns and sea level used in the three scenarios

Scenario	Sea level rise (mm)	Wave height return (years)
Short term	200	1:20
Medium term risk	500	1:50
Long term risk	1000	1:100

For each wave run-up scenario, the corresponding sea level rise was used to calculate the amount of long term retreat of sandy sections of the shoreline in accordance with the Bruun's Rule. On rocky shorelines, the line demarcating the maximum extent of physical processes is easier to define as no calculation of beach retreat is required. In this case the additional 20cm, 50cm or 1m of sea level rise (depending on the risk projection) is simply added to the wave run-up positions.

Figure 4: Shoreline retreat according to the Bruun rule

4.2.4 Step 4: Determine the short-term storm erosion risk along the coastline

During storm events the shoreline moves back temporarily, as sand is lost, but soon recovers to its pre storm position. This short-term loss is an important factor in the determination of risk lines. Usually this is done using measurements taken from shoreline surveys but, as there was no such data available for the study area, an average short term shoreline retreat of 20m was applied along sandy sections.

Figure 5: 1:20 year run-up with 20m buffer

4.2.5 Determine long-term beach retreat due to natural sand movement

Historical aerial photography is used to determine if any long term beach regression is taking place. Beach regression can be the result of natural variability in coastal circulation patterns, changes to wind-blown sand movement or due to disruptions of natural patterns. Of concern are instances where sand deposition decreases or erosion increases along sandy sections of the coastline. A nett reduction in the amount of sand being delivered to beaches means that over time, the beach will recede landward along with the high water mark.

The approach taken to determine long term erosion trends is based on detail analysis of the historical shoreline positions from available aerial photography for sandy shorelines. The historical imagery were georeferenced, and common points of reference used to align the images, whereafter the relative movement of the shoreline was measured.

The factors influencing this type of survey are:

- the quality of photography
- availability of common control points for accurate georeferencing
- pixel size variation between different scales of photography
- accurately identifying the wet line (or other reference line) on grey scale imagery
- tidal influences

For the West Coast District, historical imagery were sourced dating back to 1938 or 1942, depending on location. After georeferencing 1994, 1986 and 1974 images against 2013 orthophotos, it was found that:

- the resolution and quality of high resolution scans of historic photos is not good enough for proper analysis
- some beaches are featureless making identification of common features difficult
- some images are more generalised (bigger pixel size) than others making identification of control points difficult
- it is often not clear where the wet line is, and the vegetation line seems to meander slightly over the years
- tidal information was not available at the time

The average error (uncertainty) varied between 0.3 and 4.5m. Also, due to scale differences between years, some images had pixels representing larger areas than others. For instance 1994 had a pixel size of 3m and 1986 a pixel size of 1.5m.

By way of example, the average distance between the 0m contour and the wet line of 25 cross sections along the Paternoster beach were measured for the 1971, 1986, 1994 and 2013 aerial photography. An 8.9m difference was evident between the 2013 and 1994 orthos, but no significant change is observed during the preceding years. Unfortunately, the quality of the historic aerial photography for the preceding years is not good enough to be certain of the measurement though, which means that the 8.9m difference cannot be confirmed as a long term trend. Despite a fairly good correlation coefficient (+0.8) for the values that can be measured, the uncertainty about the correctness of the finding remains, due to the above mentioned uncertainty issues affecting the accuracy of measurements off older photosets.

Furthermore, since no clear trend is evident, the long term changes are assumed to be in the range of a few meters. At the same time, the measurement and georeference errors create uncertainties at the same scale of metres. It is therefore assumed that, for the purposes of this project, no long term erosion trend is evident.

4.2.6 Determination of a final physical processes line

In order to generate single lines denoting a zone where dynamic coastal processes will impact on development in future, only the highest of the 'stacked' wave run-up lines are considered along with littoral active zones. Littoral active zones were identified based the presence of windblown sand furrows indicating currently active sand belts on the most recent aerial photographs (2012/2013). As a final step, joins are created between the modelling for rocky and sandy sections of the shoreline. The resultant unbroken lines are used and referred to as Physical Processes or Risk Lines – respectively for the current, short, medium and long terms. An example of the lines is shown in Figure 6.

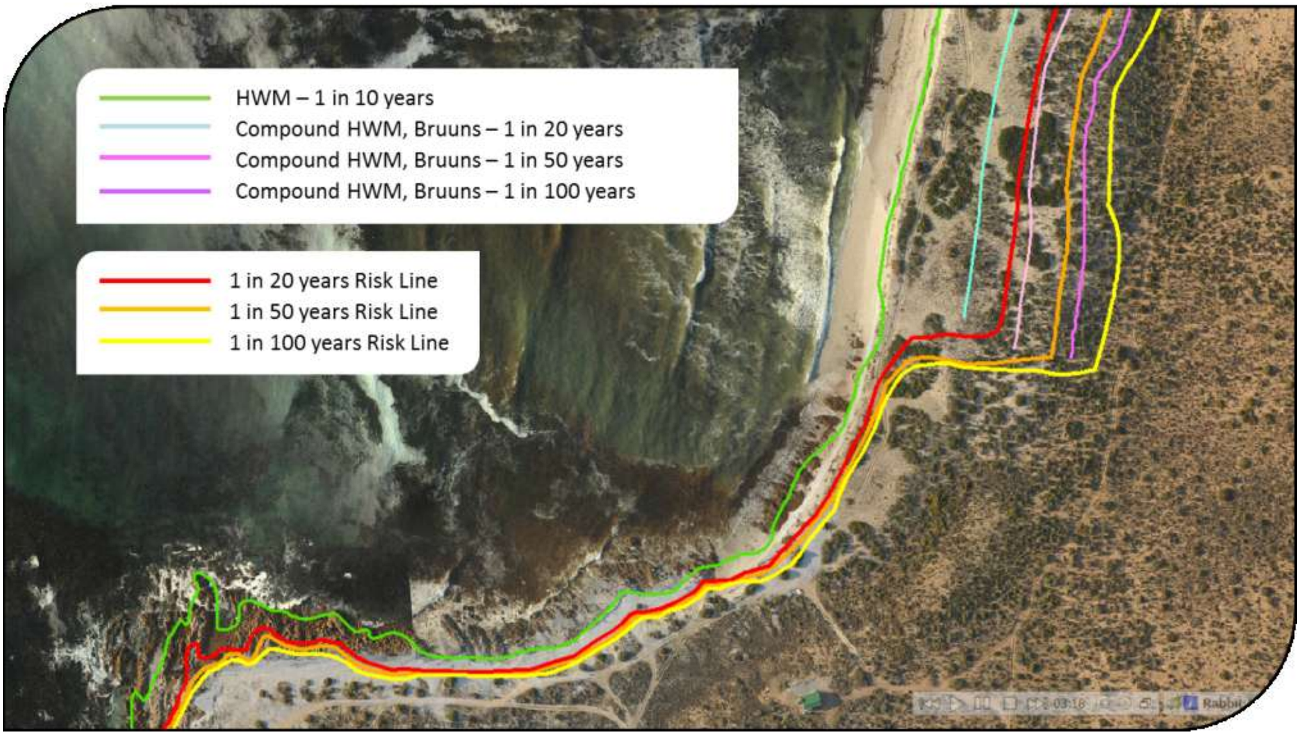

Figure 6: All scenarios modelled for sea level rise, short term erosion and wave run-up

4.3 Estuaries

4.3.1 General approach

Estuaries are particularly dynamic ecological systems that display characteristics of both terrestrial and marine systems. This makes estuaries extremely complex and sensitive, and consequently also challenging to manage. Nevertheless, degradation of estuaries often results from increasing coastal development and the impact of human activities. In order to preserve the remaining ecological functioning, biodiversity, and sustainable use of these sensitive coastal resources, effective co-operative and integrated management is essential.

Since inundation in estuaries represents the primary risk, floodline determination that can anticipate flood events with different return periods will be valuable in understanding how flood dynamics will impact on existing and future development. Unfortunately, to generate the necessary information within the scope of a regional coastal set-backs demarcation project will be prohibitively expensive. Consequently an approach is adopted that will use a simple contour height line to inform coastal management/set-back lines for estuaries, but with the option to defer to existing fine-scale management plans where such have been prepared. Additionally, some indication of recurring inundation can be gleaned from an assessment of the vegetation surrounding estuaries.

As a test case, actual floodlines were generated for the Berg River estuary as part of the project. The floodlines showed that for the most part, there was alignment of the 5m contour and 1:100 year floodline for this area. A similar picture emerges in the Verlorenvlei, where the 5m contour closely follows a marked change in vegetation differentiating regularly inundated area from non-inundated land. By implication, the approximation of risk according to the 5m and 10m contours, in the absence of more detailed information, is considered an acceptable approach.

Estuary Management Plans have been prepared for the Olifants, Berg and Verlorenvlei estuaries, and the Langebaan Lagoon is partly covered by the West Coast National Park's Management Plan. Within these estuaries, the local fine-scale planning being undertaken by Municipalities, through the guidance and assistance of bodies such as estuary management forums or CapeNature, should dictate the coastal management/set-back lines. It is therefore recommended that the 5m or 10m amsl contour be used as a reference line to determine or inform development coastal management/set-back lines, until such time as an adopted Estuary Management Plan and zonation plan delineates an appropriate coastal development set-back for individual estuaries.

4.3.2 Langebaan Lagoon

The Langebaan Lagoon – Saldanha Bay area is treated as an exceptional case, since the combination of semi-open bay and lagoon dictates a unique approach. To model long term coastal risks, a hybrid approach is taken with an adjusted wave impact model for the bay area and a simple inundation model for the lagoon area where little or no wave impact is expected.

The process of determining coastal risk in the bay is similar to the open sea analysis used along the open coast. However, since wave energy is restricted through the mouth, wave heights within the bay are lower and focused in an arc opposite the mouth. It is also clear that the Marcus Island causeway, iron ore jetty and Salamander Point headland divides the bay up into three wave height zones as shown by the red lines in Figure 7 below.

Inshore wave heights were normalized between wave heights at the entrance and the wave heights at the shoreline. Off shore wave heights were then used to calculate inshore wave heights as shown in the individual tables in Figure 7. From these inshore wave heights, wave run-up was calculated and the Bruun rule applied thereafter to account for sea level rise regression using the same approach but actual location data around the lagoon.

In the southern section, south of Langebaan, the bay turns into a simple lagoon system with a restricted catchment area and limited connection with the bay area. As this area does not receive direct wave attack, a 'bath tub' inundation model was applied to get the future water level position. The risk projections for the lagoon area consequently rely simply on contour heights to indicate future coastal risk (Figure 8).

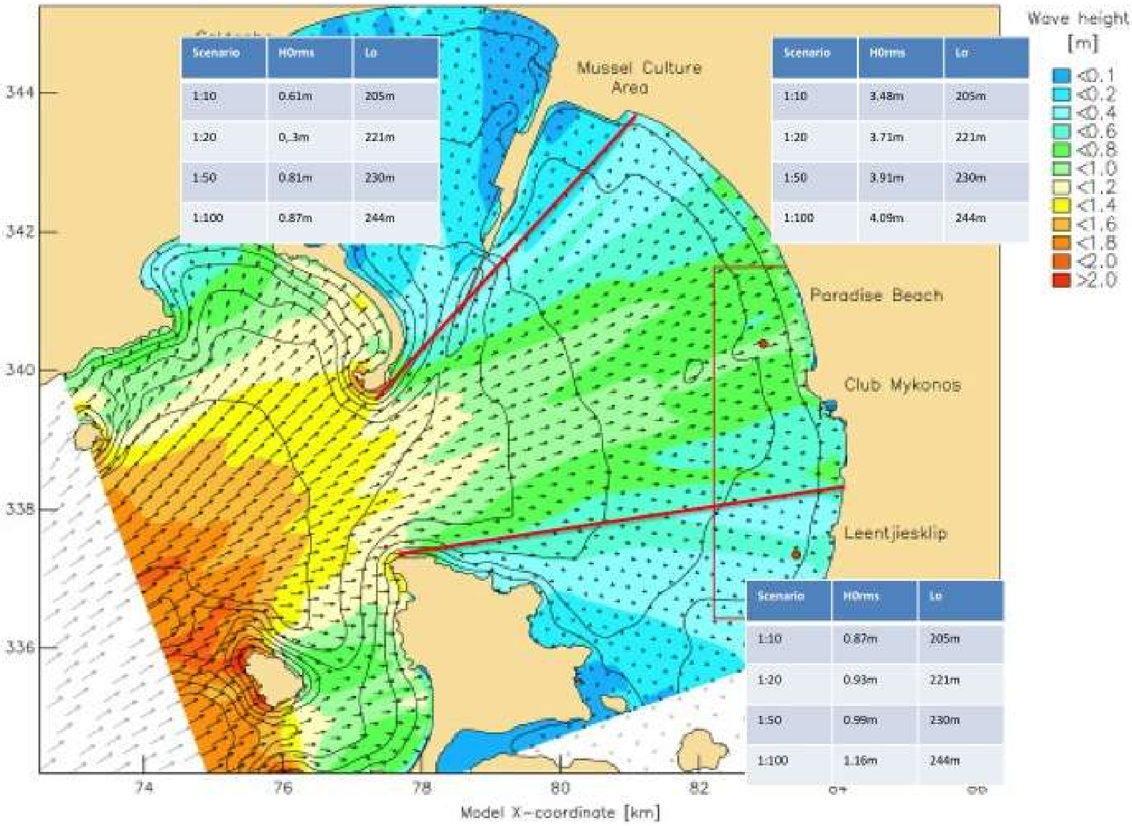

Figure 7: Wave height distributions for Saldanha Bay

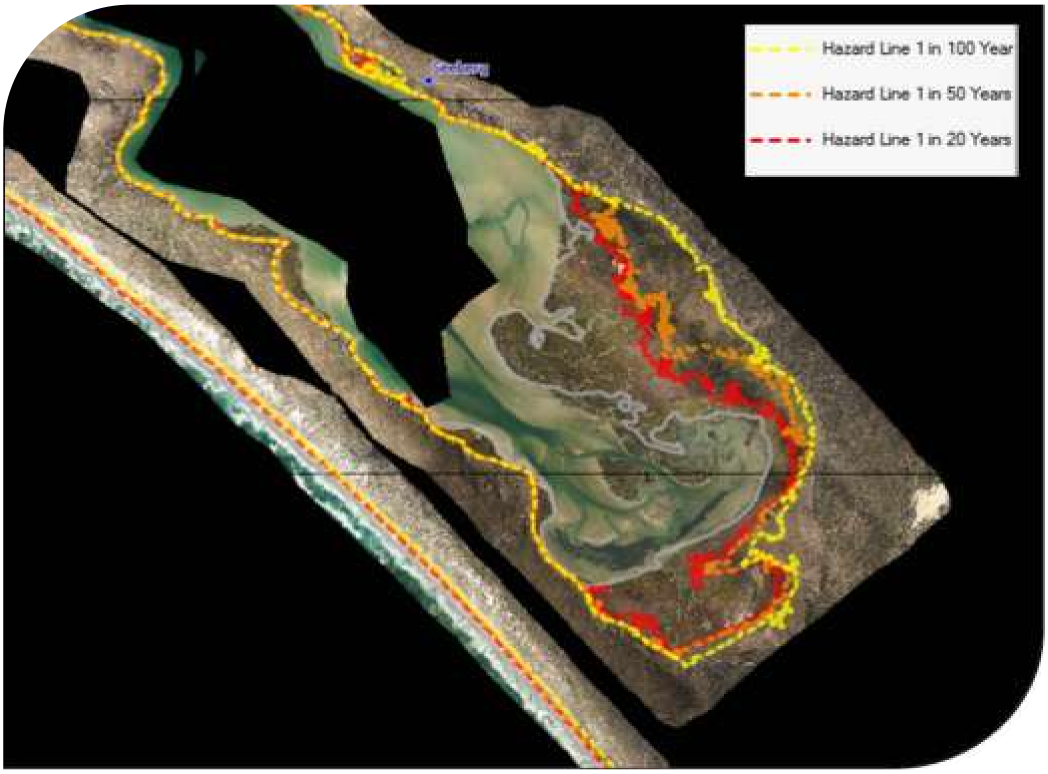

Figure 8: Risk projections for Langebaan Lagoon

5 DISCUSSION ITEMS

A number of key discussions need to follow from the contents of this report. These centre on general understanding of the risk modelling undertaken, and the ways in which the information can be used for integrated coastal management.

Discussion can therefore include:

- clarification of aspects used as part of the physical processes line delineation methodology
- confirmation of the proposed short term erosion run-up
- confirmation of historical sediment movement
- detail in respect to environmentally sensitive areas and windblown sand corridors
- suggestions on how the physical processes lines can be used to inform development
- suggestions on how authorities should use the physical processes lines, or derived lines for regulatory control of coastal development
- criteria that can be applied to developments in terms of how they relate to the identified risk zones

The contents of this report form the groundwork on which the delineation of risk zones, coastal management/set-back lines and the Coastal Protection Zone can be based. Detail of these delineations and the determination of an associated management scheme are contained in the main report that this report is appended to.

6 REFERENCES

Bruun, P. (1962). *Sea level rise as a cause of shore erosion*. Journal of Waterways and Harbors Division, 117-130.

Celliers, L., Breetzke, T., Moore, L. & Malan, D. (2009): *A User-Friendly Guide to South Africa's Integrated Coastal Management Act*, The Department of Environmental Affairs and SSI Engineers and Environmental Consultants, Cape Town, South Africa.

Mather, A. A., Stretch, D. D., & Garland, G. (2010). *A simple empirical model for extreme wave run-up on natural beaches*. International conference on Coastal Engineering, Shanghai. China.

Pullen, T. A. (2008). *Eurotop – overtopping and methods for assessing discharge*.