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Section 1

INTRODUCTION

Sinclair Knight Merz (on behalf of Pacific Reef Fisheries) is currently preparing an Environmental Impact Statement for a proposed aquaculture development near Guthalungra - some 43kms northwest of Bowen. One of the issues being addressed by the EIS relates to the risk of cyclone-induced erosion to a pump station and pipelines located on the nearby foreshores of Abbot Bay.

Coastal Engineering Solutions Pty Ltd has been commissioned by Pacific Reef Fisheries to investigate the extent of cyclone-induced erosion at the location of the shore-crossing. This report presents a summary of the findings of that investigation.

The report is structured such that there is a discussion in Section 2 of the methodology applied to the assessment of shoreline response, followed in Section 3 by a description of the specific characteristics and parameters that will affect erosion processes at the Guthalungra foreshore. Section 4 then presents the results of the calculations that predict the response of the local foreshore to a range of cyclone events.

Section 2

METHODOLOGY

2.1 General

The elevated ocean levels, large waves and strong winds generated by a cyclone can cause severe erosion to sandy foreshores.

There are several computational models available which can be applied to predict the response of a sandy beach to cyclone conditions. However it is important to consider the merits and shortcomings of each when determining the most appropriate model for the physical environment and prevailing oceanographic conditions along the Abbot Bay shoreline.

Whenever ocean water levels and/or wave conditions change rapidly (such as during a cyclone) it is necessary to utilise "*dynamic*" models to investigate shoreline response. These types of mathematical models consider the time dependent nature of beach erosion and acknowledge that stable "equilibrium" conditions are most unlikely to be attained on a sandy beach during a severe storm.

The numerical model SBEACH has been applied to determine the response of the Guthalungra foreshore to cyclone events. This is a dynamic computational model and therefore considers the transient nature of the beach profile adjustments. The model is used extensively throughout the world by the coastal engineering profession when investigating beach response to storm waves.

This Storm-induced BEAch CHange (SBEACH) model is a numerical simulation model of cross-shore beach, berm, and dune erosion produced by storm waves and elevated ocean water levels. It was developed by the Coastal Engineering Research Center of the US Army Corps of Engineers, specifically for examining the performance of beach systems subject to onshore/offshore sand movements under strong wave action.

SBEACH incorporates a detailed description of breaking wave transformation and sediment transport across the beach profile, especially near the breakpoint. The model approximates the equation for conservation of sand in finite difference form - with vertical changes in water depth determined by horizontal gradients in sediment transport rate. It is therefore suited to simulating offshore sand bar formation and evolution.

Coastal Engineering Solutions Pty Ltd used SBEACH for the design of the major beach nourishment of The Strand at Townsville. During that design process, the model was calibrated and verified against surveyed beach profiles following the erosion caused by TC Justin in March 1997 and TC Sid in January 1998. Consequently it can be applied to the prediction of cyclonic beach erosion on the foreshores of Abbot Bay with a degree of confidence.

2.2 Cyclone Events for Modelling

Events having Average Recurrence Intervals (ARI) of 20 years, 50 years and 100 years have been selected to investigate the risk of cyclone-induced erosion to the foreshores of Guthalungra.

The selection of appropriate parameters which constitute these various cyclonic events is unfortunately not a straightforward nor simple task. It involves the joint occurrence of large waves and elevated ocean water levels. An assessment of these issues has been undertaken utilising the results of previously published reports and studies. This has been supplemented with information relating to the specific physical characteristics of the beach and nearshore region in the vicinity of the proposed shore-crossing and pump station at Guthalungra.

The selection of specific ocean water levels, wave climate and foreshore characteristics at the project site is discussed in the following Section 3. However some general comments as to the source and application of this information is warranted.

Ocean Water Level

The storm surge can generally be estimated for a cyclone of any given intensity and size, however the storm tide level depends upon when the peak surge occurs in relation to the astronomical tide. A large surge with severe waves occurring at low tide might result in less erosion than a mild surge and moderate wave conditions occurring at high tide.

Information regarding the probability of occurrence of various peak storm tide levels on the foreshore of Abbot Bay is available as a consequence of an earlier study (Beach Protection Authority, 1984). This information has been used when selecting appropriate 20 year, 50 year and 100 year ARI cyclone characteristics for investigation.

When considering the time-dependent nature of storm tides at Guthalungra, the form of the ocean level hydrograph has been estimated from that measured at Townsville during T.C. Althea.

Cyclonic Waves

The SBEACH numerical model used to assess the foreshore response to cyclones requires information about the wave characteristics in deep waters offshore.

When selecting appropriate offshore significant wave heights (H_s) reference has been made to the results of the comprehensive numerical modelling exercise recently completed by the Marine Modelling Unit of James Cook University. The results have been published on the internet as an "*Atlas of Tropical Cyclone Waves in the Great Barrier Reef*". The Cooperative Research Centre for the Great Barrier Reef World Heritage Area funded the development of this wave atlas, and the Marine Modelling Unit of the Department of Civil and Environmental Engineering of James Cook University is the developer of the atlas.

The effects of wave shoaling, wave breaking and wave setup as these offshore waves propagate to the shoreline at Guthalungra have been assessed by Coastal Engineering Solutions. Primarily the effects are calculated by the SBEACH numerical model assuming straight parallel contours. Given the bathymetry of the nearshore waters at Guthalungra, this is a conservative approach since it does not incorporate the attenuating effects of seabed friction or the effects of the isolated shoals and sand banks which exist as part of the nearby Elliot River delta.

Foreshore Characteristics

The foreshore topography and nearshore bathymetry are defined by the surveys conducted specifically for this EIS. These surveys define the form of the dune system at the rear of the beach, the slope of the beach face itself and the form of the intertidal regions of the local shoreline. Further offshore, the bathymetry is defined on the published Chart AUS 826.

The physical characteristics of the sand in the vicinity of the shore-crossing have been investigated as part of a comprehensive fieldwork and laboratory testing exercise completed for the EIS (Dalla Pozza & Hopley, 2003). The D_{50} sand grain size is used by the SBEACH model when computing sand transport rates and this information can be obtained from the results of the laboratory testing of sand samples taken during the fieldwork.

2.3 Factor of Safety

Whilst the calculation procedures applied to the determination of foreshore response are consistent with sound coastal engineering principles, they are subject to various uncertainties and limitations. Consequently (and in accordance with normal engineering practice) a factor of safety is normally applied to the calculations.

A value of 40% is currently applied by the Queensland Government's Beach Protection Authority as an appropriate factor of safety when calculating the effects of long-term changes, cyclone-induced erosion, and climate change on the foreshores of Queensland.

Therefore when determining beach recession for the Guthalunra foreshore, an additional 40% is added to the results reported by the SBEACH model as a safety factor.

Section 3

CHARACTERISTICS OF THE GUTHALUNGRA SITE

3.1 Introduction

The preceding Section 2 of this report briefly summarised the methodology by which the response of the foreshore to various cyclone events have been estimated. In order to predict the response, it is necessary to have an appreciation of the prevailing oceanographic conditions and the specific physical characteristics of the Guthalungra site.

For instance, the SBEACH predictive model of beach response requires information about the form of the beach; the seabed approach slopes; the nature of the sand; the anticipated storm surge levels; and the incident cyclone wave characteristics.

Prior to reporting on the results of the modelling (in Section 4 of this report), a discussion of these specific aspects at Guthalungra is warranted.

3.2 Nearshore and Beach Profiles

The seabed approach onto the Guthalungra foreshore will determine how and where the incoming cyclone waves will break. Consequently the form of the seabed immediately offshore of the site will have a significant influence on the amount of wave energy reaching the beach.

The beach topography and nearshore seabed levels are defined on Sinclair Knight Merz' Drawing Numbers 3417-C-SK19, 3417-C-SK20 and 3417-C-SK23.

These levels and cross sectional profiles have been used (and supplemented with bathymetry from Chart AUS 826 as appropriate) to schematise the form of the seabed approach slopes up onto the Guthalungra Beach and inland across the local sand dune system.

The available bathymetric and topographic data indicate that the seabed in Abbot Bay immediately offshore of the project site slopes very gradually up to approximately the RL-6m AHD contour, where it then becomes somewhat steeper. Nevertheless, the intertidal area and the beach itself are still relatively flat, being approximately 1 in 27.

A feature of the upper beach area is the front sand dune. The front slope of this dune is also relatively flat as it rises to a height of approximately RL+3.3m (to AHD).

3.3 Sediment Characteristics

An extensive sand sampling program has been undertaken by staff of James Cook University throughout the nearshore regions of Abbot Bay (Dalla Pozza & Hopley, 2003). Surface samples were taken from dune, beach, intertidal and offshore areas along the coastline between Cape Upstart and Mount Curlewis. These were then subjected to laboratory tests to investigate various physical characteristics.

An inspection of the laboratory test results suggest that the dune and beach in the vicinity of the pipeline shore-crossing consist of sand having a D_{50} value of approximately 0.19mm to 0.24mm. Consequently, when calculating beach response it would be appropriate to adopt the smaller (and therefore more mobile) D_{50} value of 0.19mm to represent sand in the active beach system.

3.4 Storm Tide Characteristics

Predictions as to the frequencies of various storm tide levels along the shores of Abbot Bay near the Elliot River entrance are presented in the publication "*Storm Tide Levels – Bowen Region*" (Beach Protection Authority, 1984). Figure 3.1 has been reproduced from that document and indicates that the peak storm tide level associated with events less severe than approximately the 120 year ARI combination of tide and storm surge is less than the Highest Astronomical Tide (ie. a level quoted in the document as RL+2.2m AHD).

Consequently for this assessment of foreshore response to cyclone influences, the same peak storm tide level of RL+2.2m AHD has been adopted for the 20 year, 50 year and 100 year ARI events. The severity of the wave conditions will however vary - as discussed in the following Section 3.5.

In subsequent years the level of Highest Astronomical Tide in Abbot Bay has been redefined as RL+2.0m AHD - however for the purposes of this assessment, the higher and more severe level of RL+2.2m AHD has been adopted.

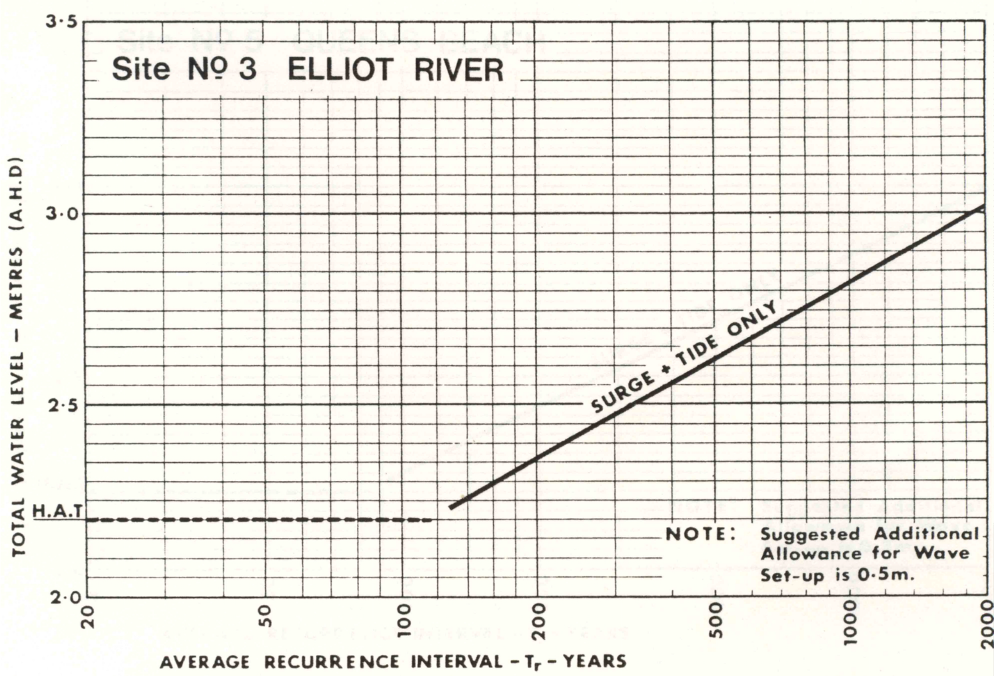


Figure 3.1 : Predicted Storm Tide Levels near entrance to Elliot River
(Reproduced from Beach Protection Authority, 1984)

An allowance for wave set-up effects should be added to this storm tide level. Where a specific investigation of wave set-up is not carried out, then the Beach Protection Authority recommends a value of 0.5 metres for locations along the shores of Abbot Bay. As discussed previously, the proposed SBEACH numerical modelling will in fact include calculations of site specific wave set-up.

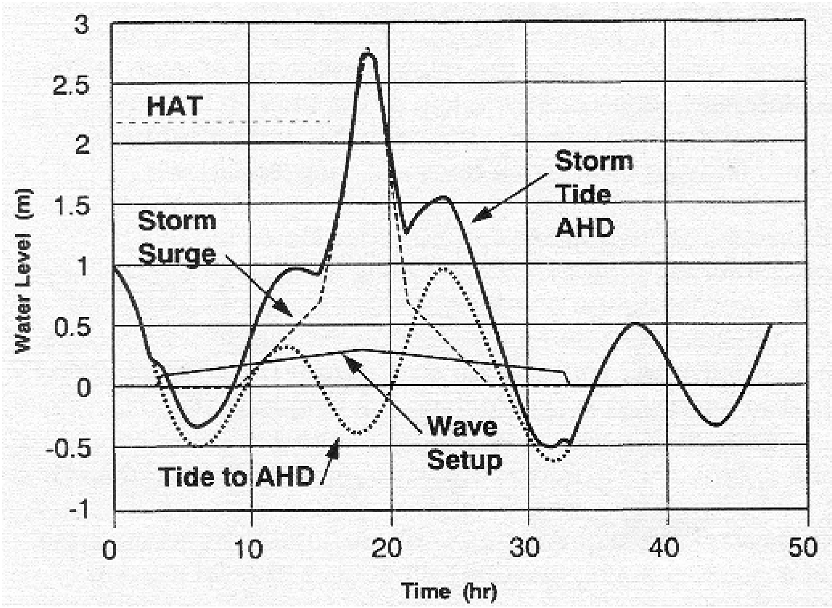
3.4.1 Storm Tide Duration

The duration of the storm tide is a critical consideration when determining the effect on sandy foreshores. The elevated ocean water levels which occur during a storm tide event enable larger waves to reach the shoreline and also enable them to attack the upper regions of the beach profile. The surge component of the storm tide typically builds to a peak over only some two to four hours then drops away over a similar timeframe as the cyclone influences pass.

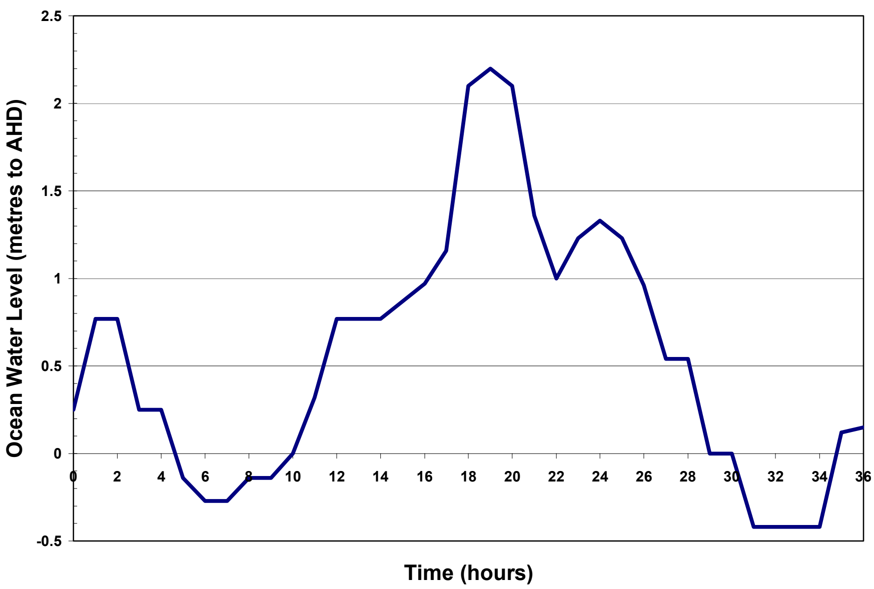
In the absence of any site specific storm tide studies of measurements, the surge and resulting storm tide produced by TC Althea at Townsville in December 1971 can be taken as representing a typical scenario of ocean water level variations during a cyclone event. Whilst being a severe cyclone which generated a significant storm surge of around 2.9 metres, the peak of TC Althea occurred near the time of low tide. Consequently the maximum water level only reached a level some 0.5 metres above the Highest Astronomical Tide. The consequences to Townsville would have been far more severe had the surge occurred some 5-6 hours later during the high tide.

A schematisation of the TC Althea storm tide has been prepared by Harper (1996) and reproduced in the publication "*Storm tide threat in Queensland : History, prediction and relative risks*" (Department of Environment and Heritage, 1999). The top part of Figure 3.2 has been reproduced from that document.

When undertaking the calculations for the cyclone-induced erosion at Guthalungra, the form of this storm tide hydrograph has been adopted. However the vertical scale of the Guthalungra hydrograph needs to be modified such that the peak level of RL+2.2m AHD is used rather than the TC Althea peak of RL+2.6m AHD. The basic form of the Guthalungra storm tide hydrograph is presented in the lower section of Figure 3.2 – however some sensitivity testing would be prudent when calculating the recession of the upper beach under these cyclone influences.



(a) Schematisation of the Storm Tide of Cyclone Althea, Townsville 1971
(Reproduced from Dept. of Environment and Heritage, 1999)



(b) Schematisation of the Storm Tide at Guthalungra

Figure 3.2 : Storm Tide Hydrographs

3.5 Cyclone Wave Characteristics

As discussed previously, the Marine Modelling Unit of the Department of Civil and Environmental Engineering of James Cook University has completed a comprehensive numerical modelling exercise to define the extreme wave climate throughout various regions of the Great Barrier Reef World Heritage Area. The results have been published on the internet.

Interpretation of this information suggests that it is appropriate to adopt the *significant wave heights* (H_s) listed in Table 3.1 for a location in approximately 25 metres depth of water offshore of the pipeline shore-crossing at Guthalungra.

The Queensland Beach Protection Authority has maintained a Waverider recording station offshore of Cape Cleveland since 1975. Perusal of the peak wave period (T_p) values recorded by the Waverider Buoy during major meteorological events indicates wave periods ranging from 4.2 seconds to 8.0 seconds (Department of Environment, 1997). For the purposes of investigating response of the beach at Guthalungra to various cyclonic wave events, the estimated wave periods listed in Table 3.1 have been adopted.

Average Recurrence Interval	H_s	T_p
20 years	5.6 metres	7.5 secs
50 years	6.8 metres	8.5 secs
100 years	7.3 metres	9.5 secs

Table 3.1 : Cyclone Wave Characteristics for Modelling

The duration of cyclonic wave attack at any specific coastal site is variable and would be determined somewhat by the position of each cyclone as it tracks through the region. For the purposes of this investigation, it is assumed that the above wave conditions for each of the Average Recurrence Intervals will prevail over at least 36 hours - that is, for the entire duration of the storm tide hydrograph.

Section 4

CALCULATION OF FORESHORE RESPONSE

4.1 Introduction

The preceding sections of this report outlined the methodology, techniques and parameters adopted for estimating the response of the beach at Guthalungra to cyclone conditions. This section presents the results of the SBEACH modelling process that calculates the response of the local foreshore.

The model has been run for the beach characteristics nominated in the preceding Sections 3.2 and 3.3, and for the cyclone parameters presented in Sections 3.4 and 3.5. The resulting beach response to the 20 year, 50 year and 100 year ARI events are shown plotted on Figures 4.1, 4.2 and 4.3 respectively.

4.2 Model Testing

Some sensitivity testing was undertaken in relation to the form of the storm tide hydrograph. This related to the relative phasing of the storm surge and astronomical tide components. However when doing this re-phasing, the peak storm tide level of RL+2.2m AHD was maintained – it was only the form of the storm tide hydrograph that was varied. For example, the beach response to the scenario where the peak surge coincides with a high tide was investigated. This particular phasing of surge and tide results in a very rapid build up of the storm tide to RL+2.2m and a similarly rapid falling away of the elevated water level.

For the scenario where the surge component coincides with a low tide (similar to that which occurred during Cyclone Althea and adopted in the SBEACH modelling for Guthalungra) the ocean water levels tend to remain elevated for longer durations, giving the incoming cyclone waves longer access to the upper beach area. This causes a slightly greater recession of the beach.

Consequently the proposed storm tide hydrograph is considered to be the most appropriate, since it results in greater short-term erosion.

The storm tide hydrograph developed for Guthalungra does not include an allowance for wave set-up. This phenomenon causes a localised increase in ocean water level shoreward of the wave breakpoint. The Beach Protection Authority recommends that an additional 0.5 metres be included for locations on the shores of Abbot Bay in the vicinity of the Elliot River entrance (Beach Protection Authority, 1984). However, the SBEACH model does account for wave set-up and uses calculation techniques developed for random wave fields. Maximum water levels (as a consequence of storm tide and wave set-up) are reported by SBEACH.

All of the cyclone wave conditions modelled for the Guthalungra site resulted in maximum wave set-up components that exceeded 1 metre. This is greater than the generic value of 0.5 metres recommended (Beach Protection Authority, 1984) for Abbot Bay. Consequently the SBEACH model is suggesting water levels and incident wave heights on the upper beach which are greater than what might otherwise be applied for less rigorous analysis techniques.

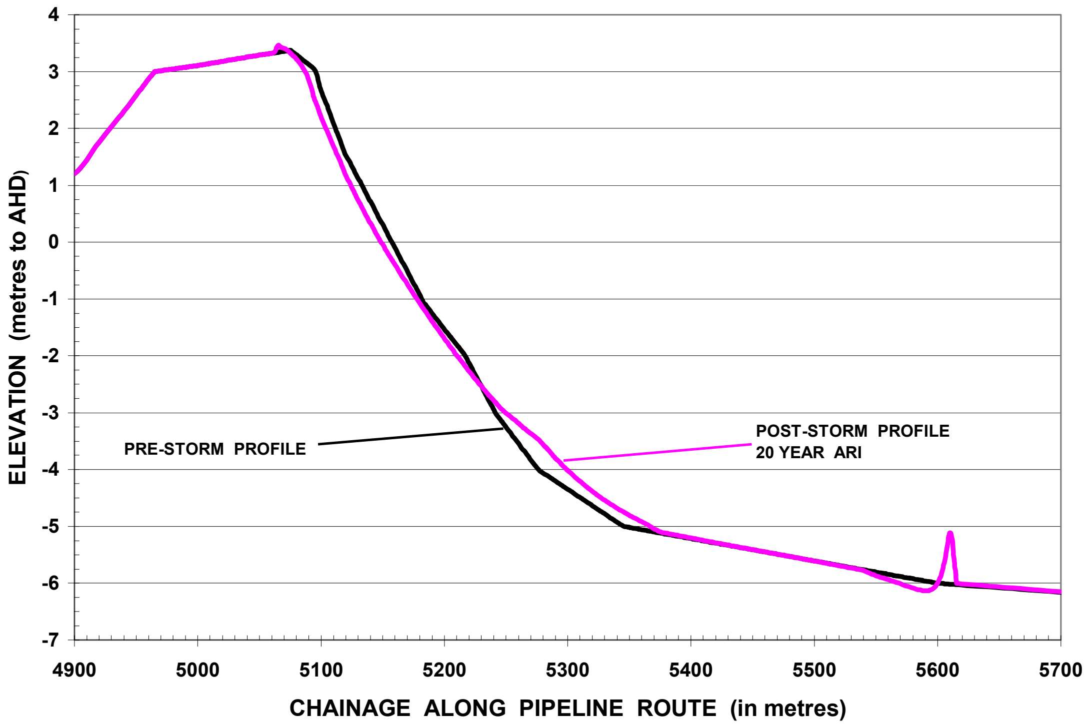
4.3 Results of Model Testing

The purpose of the modelling investigation was to determine the risk of cyclone-induced erosion to the intake / discharge pipeline system on the foreshores of Abbot Bay. The risk relates to the following scenarios:

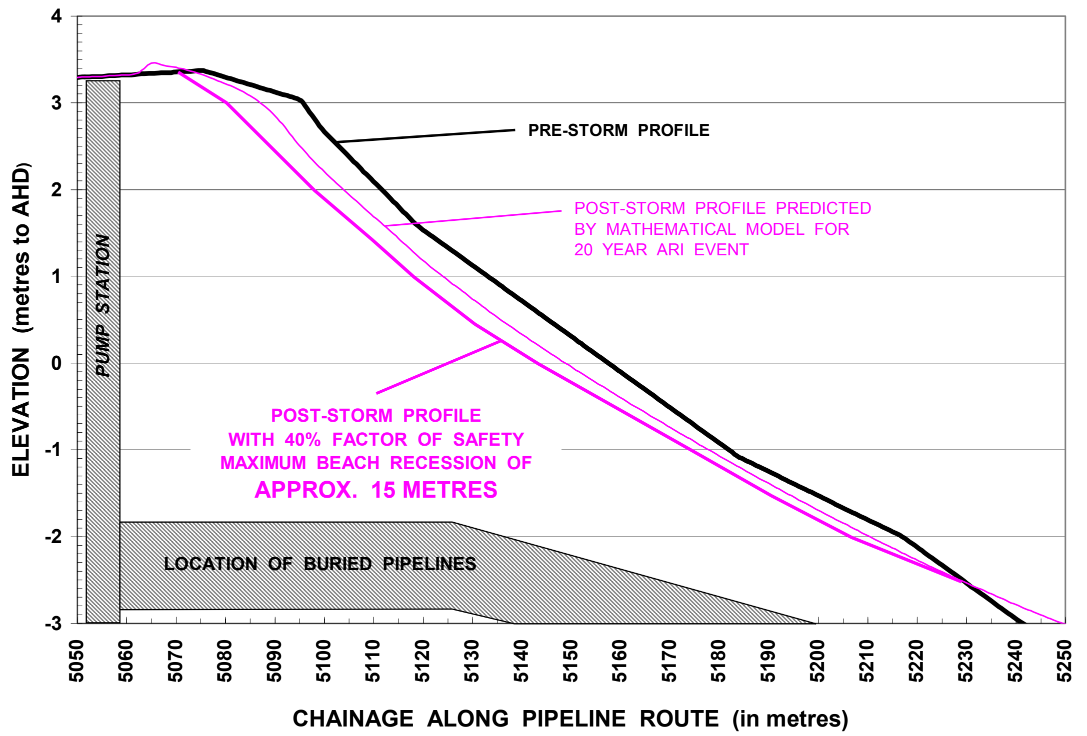
- recession of the upper beach and dune area such that the onshore pump station is exposed to wave action;
- re-profiling of the beach / dune by wave action such that the buried pipes are uncovered during the cyclone and exposed to wave loading and further localised scour.

The storm profiles of the Guthalungra Beach formed in response to the 20 year, 50 year and 100 year ARI events are shown on Figures 4.1, 4.2 and 4.3 respectively.

The pump station is located at chainage 5058.00m on the pipeline route. Its position is noted on the figures. The buried intake and discharge pipes are also shown located on the figures.

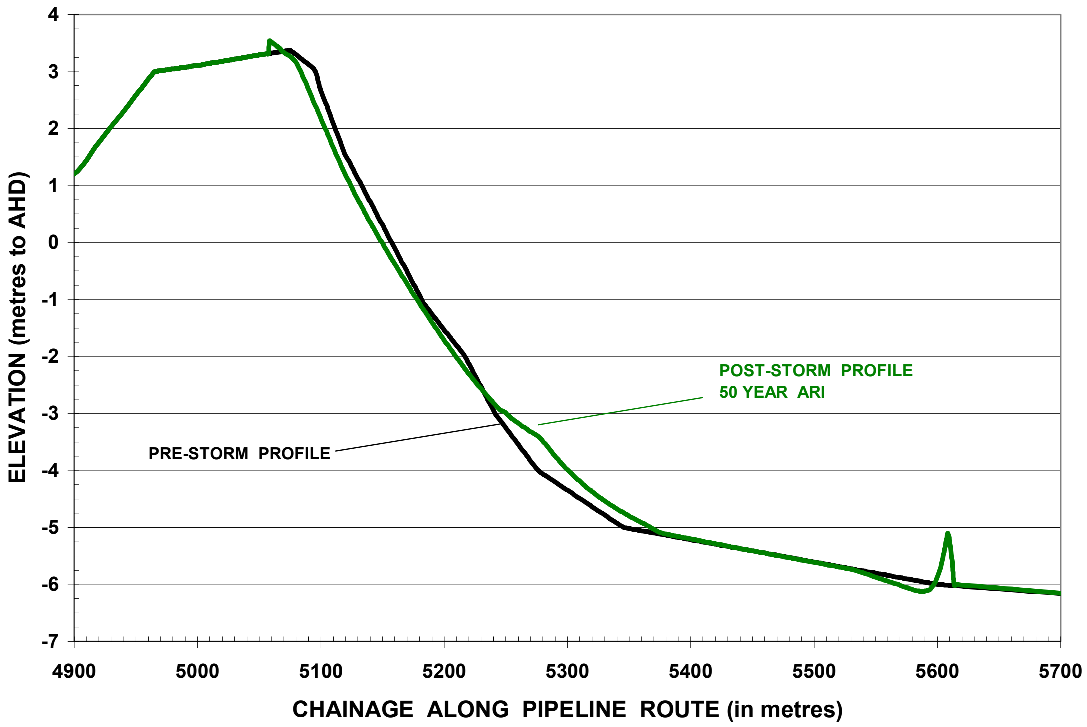


(a) Entire Active Profile

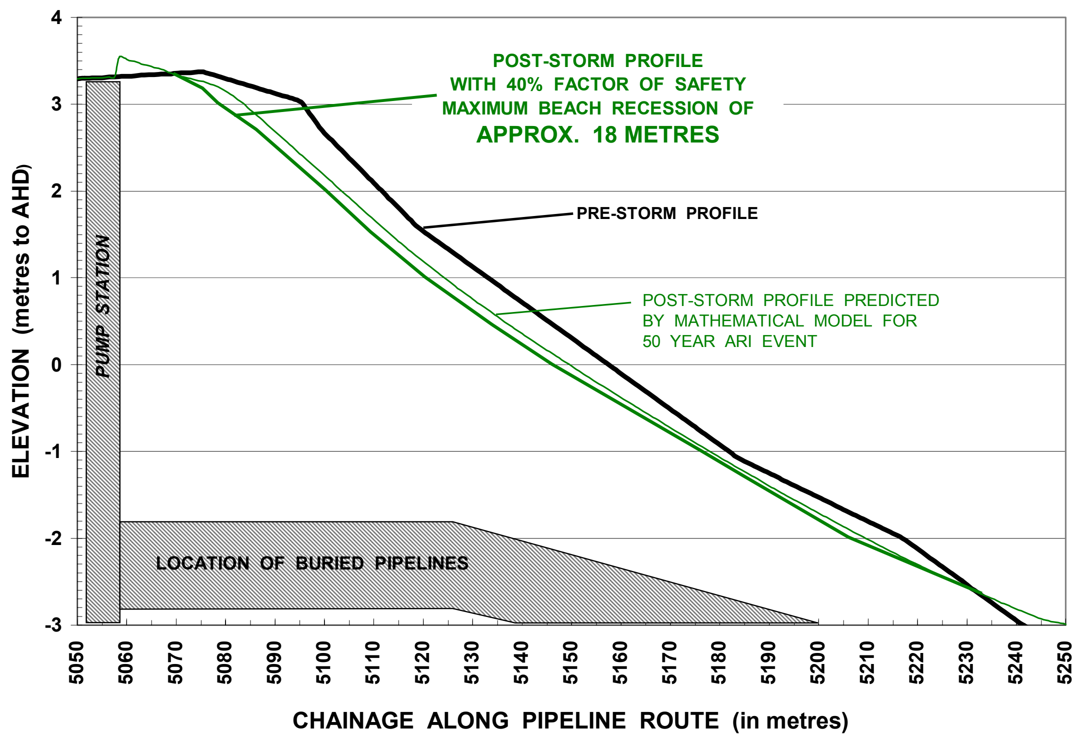


(b) Upper Beach & Dune

Figure 4.1 : Predicted Foreshore Response to 20 year ARI Storm Conditions

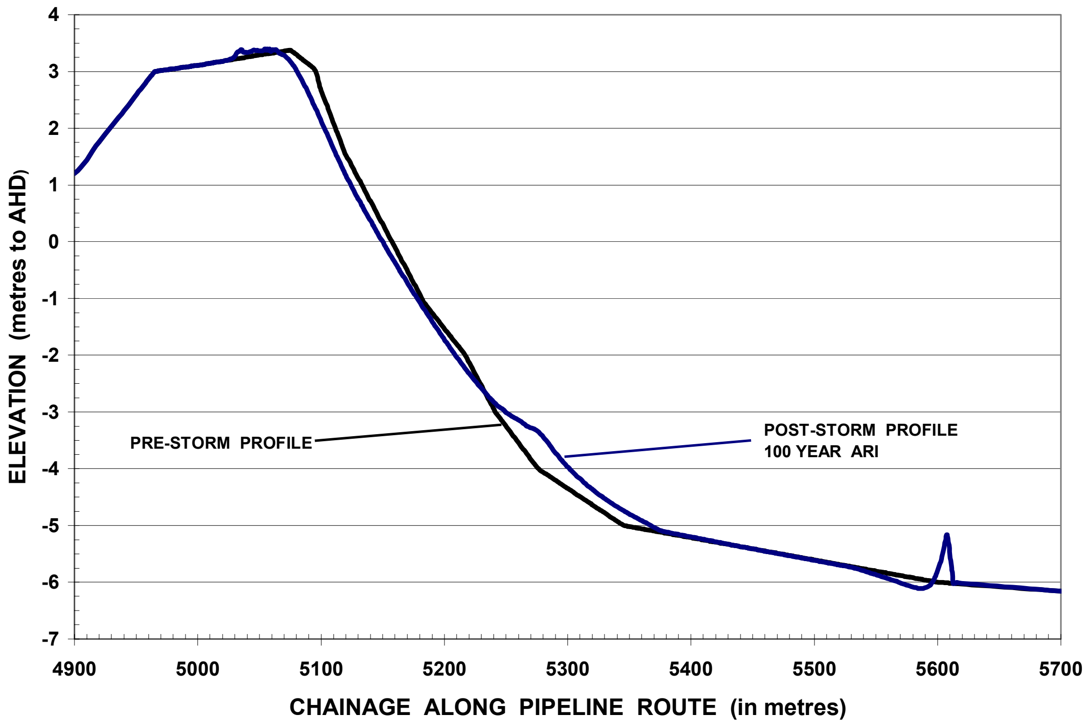


(a) Entire Active Profile

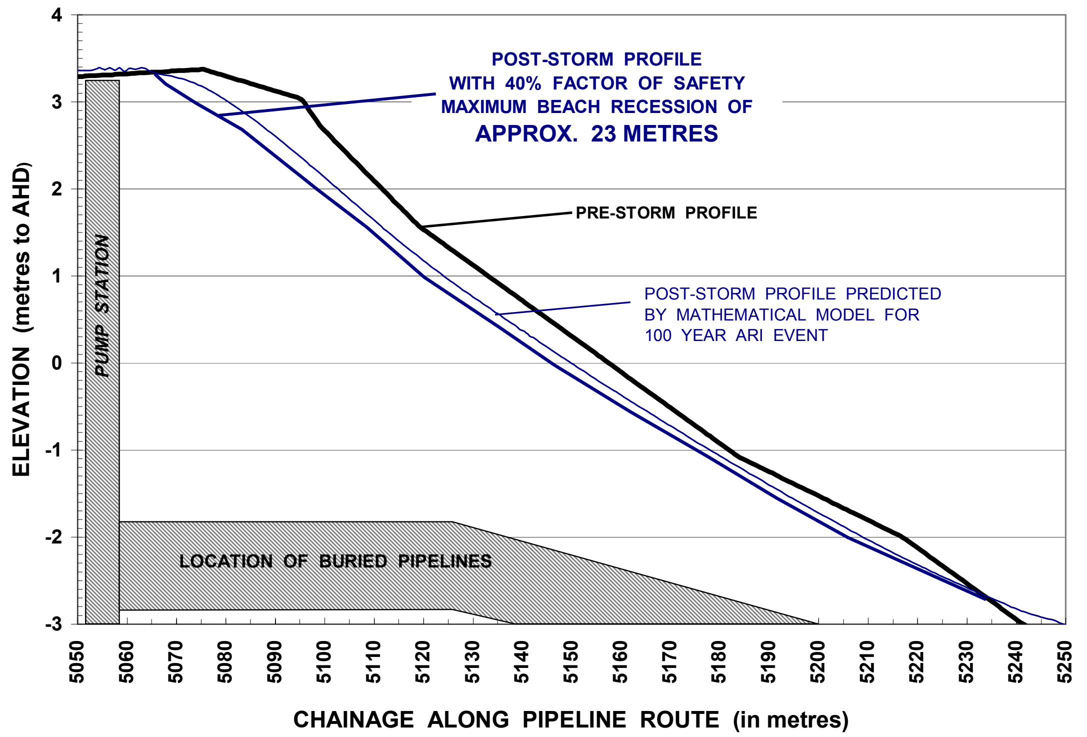


(b) Upper Beach & Dune

Figure 4.2 : Predicted Foreshore Response to 50 year ARI Storm Conditions



(a) Entire Active Profile



(b) Upper Beach & Dune

Figure 4.3 : Predicted Foreshore Response to 100 year ARI Storm Conditions

Figure 4.1 shows the cross section of the Guthalungra foreshore predicted to occur in response to the 20 year ARI event. Typically the predicted recession of the beach between Mean Sea Level and the crest of the front dune is some 15 metres (including the 40% allowance as a Factor of Safety - as discussed in Section 2.3). The level of the beach drops by approximately 0.5m to 0.6m in this region also. This does not represent an erosion threat to either the pump station or the buried pipelines.

Figure 4.2 shows the estimated profile of the foreshore in response to the 50 year ARI cyclone event. The beach recedes horizontally some 18 metres in the upper area. The level of the beach drops by approximately 0.6m to 0.7m in this upper region also. This does not represent an erosion threat to either the pump station or the buried pipelines. The modelling suggests that the combination of storm tide level, wave setup and wave runup on the beach face results in some minor overtopping of the front dune. This local overtopping could result on some landward transport of sand off the crest of the front dune. Nevertheless, this overtopping does not represent a threat to any of the proposed infrastructure.

Figure 4.3 presents the profile of the local foreshore in response to the 100 year ARI cyclone event. The beach recedes some 23 metres in the upper area. The level of the beach drops by approximately 0.7m to 0.8m in this upper region also. This does not represent an erosion threat to either the pump station or the buried pipelines. The modelling again suggests that the combination of storm tide level, wave setup and wave runup on the beach face results in some minor overtopping of the front dune. Nevertheless, this does not represent an erosion threat.

Figures 4.1 to 4.3 illustrate the common response of a sandy beach to storm/cyclone events, namely the removal of sand from the beach face and front dune area and its deposition offshore as a sandbar in the surf zone. The specific location of the offshore sandbar at Guthalungra is somewhat dependent upon the severity of the storm/cyclone event, however this is typically around the RL-6m AHD contour. The SBEACH modelling of 20 year, 50 year and 100 year ARI events suggests that the sandbar could be around 1m high following such storms.

The offshore diffuser on the outlet pipe is located in the general vicinity of the RL-6m AHD contour. Consequently there could be some deposition of sand and the creation of a sand bar around the diffuser during a severe erosion event. This may need to be considered when undertaking the detailed engineering design and documentation of the diffuser system.

Section 5

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