Appendix B

Risk Assessment Discussion Paper

Cardno
Shaping the Future

Fraser Coast SEMP

Risk Assessment Discussion Paper

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Appendix A Erosion Prone Area Estimation Methodology

GLOSSARY AND ABBREVIATIONS

AHD	Australian Height Datum
ALS	Aerial Laser Survey
ARI	Average Recurrence Interval
DEM	Digital Elevation Model
DERM	Queensland Department of Environment and Resource Management
DTMR	Queensland Department of Transport and Main Roads
EPAWs	Erosion Prone Area Widths
FCRC	Fraser Coast Regional Council
GIS	Geographic Information System
HAT	Highest Astronomical Tide
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area
SEMP	Shoreline Erosion Management Plan

1 INTRODUCTION

1.1 Background

Cardno has been engaged by Fraser Coast Regional Council (FCRC) to prepare a Shoreline Erosion Management Plan (SEMP) for the Fraser Coast Local Government Area (LGA). For the purposes of this project, Council has developed a staged process leading up to the development of an SEMP based on the requirements of *Queensland's Coastal Policy* (DERM, 2002), but following a process similar to that adopted for Shoreline Management Plans in the UK (DEFRA, 2006). The Coastal Policy has now been updated by the State Government and published by the Department of Environment and Resource Management (DERM, 2011a) as the *Queensland Coastal Plan*.

The approach adopted for this project has therefore been adapted to the local context. It includes the following stages:

- Stage 1 – Gap Analysis Report.
- Stage 2 – Management Options and Recommendations Study.
- Stage 3 – Shoreline Erosion Management Plan.

Stage 1 has been completed and a report prepared for Council (Cardno, 2011). Some of the key findings of the *Gap Analysis Report* (Cardno, 2011) were:

- ***Need for Revision of Erosion Prone Area Widths (EPAWs)* –** It was noted that DERM were in the process of updating the *Queensland State Coastal Plan* (DERM, 2002) to incorporate the effects of projected climate change including a review of the formula for calculating EPAWs.
- ***Update of EPAWs for the study area* –** Just prior to the completion of the Stage 1 works DERM advised that they were in the process of updating the EPAWs for the entire study area. Subsequent to issue of the Gap Analysis Report the study team was advised by DERM that the updated EPAWs would not be available within the timeframe suitable for use in the Fraser Coast SEMP. DERM provided the study team with updated data and formulae to be used in the revision of the existing EPAWs. These data and formulae are discussed in this Paper and the revised EPAW estimates will form the basis for assessments to be used in the SEMP.
- ***Need to consider the economic impacts of erosion* -** Due to the significant environmental constraints associated with the Study Area, there will likely be a need to demonstrate a Net Benefit to the State in relation to any proposed coastal protection activities. This should include consideration of the socio-economic impacts (costs and benefits) associated with a proposal or with the Do Nothing option. Demonstration of Net Benefit and an overriding need for any proposal will likely be required by the approval authorities. It is recommended that Council consider the need to undertake an economic assessment of the coastal zone and the potential impact of erosion on the economy.

- ***Need to clarify the Legislative Approvals Procedures –*** The complexities of the process for obtaining approvals for any proposed works in the coastal zone had become a vexed issue for Council and State Agencies. As outlined in the *State Coastal Plan* the SEMP process aims to provide a collaborative approach to the preparation of a Plan that can be endorsed by State agencies and stakeholders and establishes a set of agreed priorities and approaches to resolving the impacts of coastal erosion on the broad range of assets within the coastal zone.

1.2 Purpose of the Discussion Paper

This Discussion Paper has been prepared as part of the Stage 2 works for the purposes of providing the Steering and Consultative Committees with a description of the procedures and underlying assumptions used in the derivation of the EPAWs, their subsequent application to the risk assessment and use in the planning context. The Discussion Paper seeks to assist the Committees in appreciating the complexity of coastal erosion processes and the methods adopted to predict the potential effects of these processes, and thereby facilitate a common understanding of the planning process leading to development of consistent erosion management policies. The FCRC may then apply these policies across the varied coastal zones within the LGA. It will also assist in dividing the larger study area into smaller management zones (or units) and in prioritising locations for any erosion mitigation/management options on the basis of levels of risk within these zones.

This report has been prepared as a technical paper and will form an Appendix to the *Erosion Management Options and Recommendations Report,* the key deliverable under Stage 2.

1.3 Scope of Works

Based on a review of the key findings of the *Gap Analysis Report* (Cardno, 2011) and subsequent discussions with DERM, the scope of works for Stage 2 has been refined in consultation with Council. The revised Stage 2 works involve:

1. **Calculation of EPAWs for the required planning horizons.** Subsequent to the finalisation of the Gap Analysis Study (Cardno, 2011), DERM have released updated EPAW mapping for the Hervey Bay portion of the study area for the 2100 planning horizon. In consultation with DERM, Cardno has calculated EPAWs for the entire study area for a range of other, interim planning horizons (2030, 2050 and 2070).
2. **Mapping of the new EPAWs.**
3. **Spatial assessment of risk to assets within Erosion Prone Areas.**
4. **Preliminary economic assessment of coastal erosion.**
5. Identify values and management issues.
6. Develop management objectives and policies for the study area.
7. Develop and assess erosion management options.
8. Prepare and present an *Erosion Management Options and Recommendations Report*.

This Discussion Paper primarily aims to provide details on the methodology for the first four activities (shown in bold text). It presents an example of the application of the methodology utilising the 2100 EPAWs. The Discussion Paper has been structured as follows:

- Risk assessment methodology is detailed in **Section 2.0**.
- Results are presented and discussed in **Section 3.0**.
- Conclusions and recommendations are provided in **Section 4.0**.
- A list of relevant qualifications and assumptions has been included in **Section 5.0**.

2 RISK ASSESSMENT METHODOLOGY

2.1 Overview

Policy Context

The EPAW is a concept that aims to provide a tool to assist in broad scale, long term planning in the coastal zone and it is necessary to consider any estimates of EPAWs in this context. Erosion prone areas were initially introduced in 1984 as a statutory planning tool under the *Beach Protection Act 1968*. They were intended to trigger a requirement for concurrence from DERM on the approval of proposed development in the coastal zone, whereby the EPAWs were used to guide decisions on land surrender for the reconfiguration of established lots. The EPAW estimation methodology (see **Appendix A**; DERM, 2011b) and the *Queensland Coastal Plan* (DERM, 2011a) have recently been updated to provide a more holistic approach to the management of coastal hazards and to incorporate a projected sea level rise component from 0.3m to 0.8m in line with recent projections.

As part of this process, new coastal hazard maps were prepared for much of the Queensland coastal zone, including the Fraser Coast Region and published on the DERM website (http://www.derm.qld.gov.au/). These maps show:

- Indicative erosion prone areas, comprising areas at risk from erosion and permanent inundation under projected sea level rise; and
- Default storm tide inundation extents for the 100-year average recurrence interval (ARI) storm event, divided into areas subject to medium hazard areas (inundation depths <1m) and areas subject to high hazard (inundation depths >1m).

Consistent with the need to consider long term planning objectives, the maps show the extents for the 2100 climate change scenario (corresponding to a 0.8m sea level rise).

Storm tide inundation areas are not considered in the development of this Fraser Coast SEMP.

Relevance to the Fraser Coast SEMP Project

The erosion prone area of the coastal zone is that area landward of the shoreline that is potentially subject to erosion by coastal processes. The shoreline is typically defined as the location of the toe of the frontal dune at some reference time. The coastal processes that cause erosion of the shoreline are dominated by complex interactions between the erosive forces of ocean waves, tidal movements, sea level rise, and the sediment types occurring at a particular location. DERM have advised that the EPAW assessment methodology was developed for sandy coasts exposed to moderate to high wave energy. In these environments the dominant processes causing erosion are long term shoreline recession (due to sediment transport processes), and wave attack (after which some beach re-building by swell waves may occur). For low energy coasts or estuarine coasts, however, the erosion process is dominated by channel migration associated with tidal wind-driven currents. For these locations a default EPAW value is typically used.

There are some important considerations relating to the use of EPAWs for the risk assessment of the Fraser Coast. The EPAW assessment methodology effectively assumes that the coastal processes are acting on a natural, sandy shoreline, which may not be the case at all locations. There may in fact be infrastructure or bedrock (underlying sandy surficial sediments) that would act to arrest the future progress of erosion from coastal processes. When assessing the erosion potential for a specific site, these features may be considered and factored into the erosion estimates. It is not feasible, however, to consider these features for large areas such as the Fraser Coast study area. It is also important to note that the processes of erosion and accretion of a shoreline are cyclical in nature, and therefore the application of recession estimates to particular planning horizons is fraught with uncertainty.

In addition, the DERM procedures adopt a precautionary approach and the methodology for estimating EPAWs (DERM, 2011b) incorporates conservative multiplier factors that are useful within the planning context but may contribute to an overestimation of the actual land area likely to be directly impacted by erosion. For example, the EPAW methodology incorporates a 'safety factor' of 140%. This component increases the width of the erosion prone area by 40% and is more applicable to undeveloped sites where there is a need to provide a set back from the area that has potential to be subject to erosion.

For these reasons, the EPAW calculations are considered conservative estimates of the risk of erosion that may potentially occur in a particular coastal location. The intent of the EPAW formula is primarily to adopt a precautionary approach to land use (or site) planning. For the purposes of this project, the EPAWs will be used to consider erosion risk and to prioritise locations requiring management within the larger Fraser Coast study area.

2.2 Digital Elevation Model (DEM)

A Digital Elevation Model (DEM) was created using the following data sets:

- Ground level information in the form of Aerial Laser Survey (ALS) data provided by FCRC;
- Bathymetric data from Chart AUS817 (published by the Australian Hydrographic Service) and other charts prepared by the Department of Transport and Main Roads (DTMR); and
- Quad bike survey data on some coastal dune and beach areas provided by FCRC.

The ALS data was used to create a DEM with a horizontal grid size of 1m with a vertical accuracy of ±15cm and a horizontal accuracy of 40cm. It is understood that the data was then re-sampled to generate a 5m x 5m grid size using the nearest neighbour or bilinear interpolation methods. The final data set was then provided to Cardno for use in this study.

In order to marry the topographic (ALS) data and the hydrosurvey (chart) data and create a continuous grid, it was necessary to interpolate between these two data sources. The ALS data are reasonably accurate to about 1m AHD (approximately 1 m above mean sea level) while the hydrographic charts provide depths to about the -0.5m AHD isobath.

The DEM was then used to derive contours of the following Highest Astronomical Tide (HAT) water levels of interest to the planning process:

- HAT_{2010} the DERM 2009 HAT estimates for the study area that vary between 2.2m AHD in Hervey Bay and 1.5m AHD in Great Sandy Straight,
- HAT_{2050} (=HAT_{2010} + 0.3m) to represent the 2050 project sea level rise, and
- HAT_{2100} (=HAT_{2010} + 0.8m) to represent the 2100 project sea level rise.

HAT_{2030} andHAT_{2070} contours will be derived in a similar fashion to represent the projected sea level rises under these scenarios.

2.3 Calculation of Erosion Prone Area Widths

The Hervey Bay (wave and tide dominated) and Great Sandy Straits (tide dominated only) areas have been considered separately due to the different coastal processes operating within these different parts of the study area (**Figure 2.1**). Within the Hervey Bay area the EPAW is calculated through application of the formulas provided by DERM as described in **Appendix A** and summarised in **Section 2.3.2** below. Along the western shoreline of the Great Sandy Straits the EPAW for 2100 is estimated as the zone bounded by the HAT_{2010} contour and a line 40m landward of the HAT_{2100} contour. This estimate is discussed further in **Section 2.3.3**.

2.3.1 Climate Change Predictions

As outlined in **Appendix A**, the EPAW assessment methodology developed by DERM (2011b) incorporates climate change predictions for:

- Sea level rise as it relates to both inundation and estimation of long term recession rates; and
- Storm activity as it relates to wave heights and estimation of short term erosion.

The *Queensland Coast Plan* (DERM, 2011a) adopts the sea level rise projections outlined in **Table 2.1**.

Table 2.1: Projected Sea Level Rises for the Year of Planning Period End (after DERM, 2011a)

Year of End of Planning Period	Projected Sea Level Rise
Year 2050	0.3 metres
Year 2060	0.4 metres
Year 2070	0.5 metres
Year 2080	0.6 metres
Year 2090	0.7 metres
Year 2100	0.8 metres

A sea level rise projection of 0.2m was adopted for the 2030 climate change scenario.

Further discussion on climate change predictions (for both sea level rise and design storms) as applied to the calculation of EPAWs is provided in **Appendix A**.

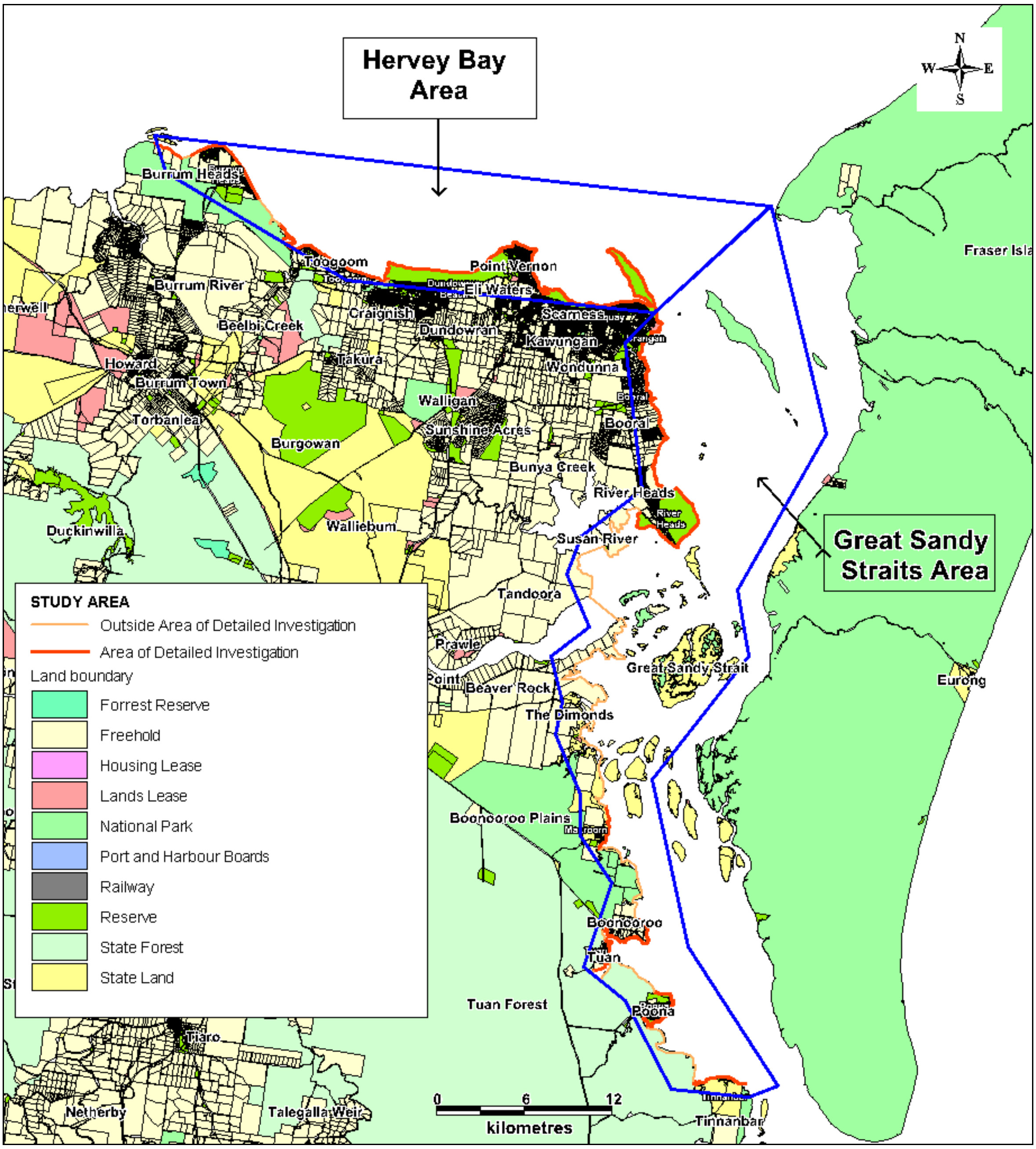

Figure 2.1: Study Area

2.3.2 Hervey Bay Coastline

As part of their update of the *Queensland Coastal Plan* (2011a), DERM have recently re-assessed the existing EPAWs for the Hervey Bay area. For the purposes of this study DERM provided the data used to revise the EPAWs as well as details as to how the EPAW estimation methodology outlined in DERM (2011b) was adapted for Hervey Bay. This relates specifically to the long term shoreline recession component, which is calculated using a Bruun Rule (see **Appendix A**).

Both wave and tidal processes contribute to erosion within the Hervey Bay area. Some protection from swell waves is afforded by the presence of Fraser Island and a series of offshore reefs, thereby limiting swell wave heights within Hervey Bay. There is, however, sufficient fetch for local sea wave generation, which is the more significant contributor to the local wave climate that influences the littoral sediment transport, erosion and accretion processes.

DERM describes the process contributing to the character and form of the beaches in the Hervey Bay area. The beaches in this area are exposed to sufficient wave energy to form a steep upper beach (typically above mean sea level) composed of coarser sandy material. The large tidal range (around 3.9-4.5m), however, contributes to the development of a wide, gently sloping lower intertidal zone (from mean sea level to lowest astronomical tide) composed of finer sedimentary material. Thus, the active beach face along the Hervey Bay coastline shows two distinct morphological units with different sedimentary characteristics, each of which responds differently to erosive forces.

Estimates of the amount of shoreline recession resulting from sea level rise are derived via application of the Bruun Rule (see **Appendix A**), that assumes the beach is comprised of uniform sediment characteristics across the shore normal profile. DERM conducted an analysis using case studies from Toogoom and Dundowran beaches which indicated that the Bruun Rule overestimates the amount of shoreline recession resulting from sea level rise for beaches with two distinct sediment types. For the Hervey Bay area DERM adopted a modified Bruun Rule approach based on the equilibrium profile of the high tide beach (i.e. the upper beach). A verification exercise undertaken by DERM indicated that this approach reliably estimated shoreline erosion (recession) due to sea level rise for the Hervey Bay beaches.

In all other respects, the 2100 EPAW estimates conformed to the methodology specified in DERM (2011b), as summarised in **Appendix A**. The updated EPAW estimates for 2100 were then translated into a GIS layer.

The EPAW estimates were derived for sandy stretches of coastline considered to have exposure to similar wave and tidal characteristics or where the coastline is primarily rock. DERM defined 27 coastal zones along the Hervey Bay coastline within which the various contributions to the EPAW estimates varied. Within each zone the estimated EPAW is assumed to be a constant set-back from the *Toe of Dune* line derived by DERM.

Erosion Prone Area Widths for 2030, 2050 and 2070

In order to ensure consistency between the 2100 EPAWs and the EPAWs for the three other climate change scenarios to be considered in the SEMP, DERM provided to Cardno for use in this study details on all data inputs to the EPAW estimation equation for Hervey Bay.

The component of the equation relating to shoreline recession (S) was re-calculated using the projected sea level rise for the corresponding climate change scenario (**Table 2.1**). In addition, due to the uncertainty associated with estimation of the annual rate of long term recession and the risk of over-estimating this component for longer planning horizons, the 2070 and 2100 planning horizons incorporated estimates of shoreline recession based on a planning period of 50 years only as recommended by DERM (pers. com, S. Sultman, DERM – D. Treloar, Cardno). In accordance with DERM's advice, for shorter periods (from 2011) the planning periods were 19 and 39 years to 2030 and 2050, and the long term recession values (N x R) were adjusted by factors of (19/50) and (39/50) for these planning horizons, respectively.

The EPAW estimates for the 2030, 2050 and 2070 planning horizons have been calculated by Cardno and reviewed by DERM. EPAW estimates for these shorter-term planning horizons fall within the 2100 EPAW estimates and will be presented in full in the *Management Options and Recommendations Report*.

2.3.3 Great Sandy Straits Coastline

As detailed in Cardno (2011), the coastal processes operating in the southern portion of the study area are predominantly tidally-driven. This is due to the presence of Fraser Island, which provides protection from ocean swell waves within the Great Sandy Straits area and, in addition, the fetch is limited so locally generated wind waves are quite small. Hence, the erosional processes in the Great Sandy Strait are tide dominated, whereby tidal inundation causes bank erosion/slumping, and recovery is negligible due to the lack of wave action for beach re-building. Tidal processes are also more complicated in the Great Sandy Straits as the tidal prism and tidal currents vary significantly throughout this area.

For the Great Sandy Straits area, the coastline response relates more directly to increases in sea level. DERM advises that a default erosion prone area of 40m from the HAT level should be adopted. Hence, it follows that the climate change component of the erosion prone area relates to the projected sea level rise, whereby there is a landward translation of the HAT line equivalent to the amount of sea level rise projected for the planning horizon under consideration.

Within the Great Sandy Straits the tidal range diminishes with increasing distance from the Hervey Bay entrance to the Straits and hence HAT values also decrease. The HAT levels derived from tide gauges maintained by the DTMR were interpolated along the Strait to derive a series of areas (polygons) of constant HAT surface level and small steps (0.1 m) along the Strait.

2.4 Risk Assessment

Risk is assessed by considering both the ***likelihood*** and ***consequences*** of an event occurring. Using erosion risk as an example, the likelihood of an erosion event occurring at a particular location depends on factors such as the ‘design’ storm adopted for short term erosion (e.g. a 100 year ARI storm) and the amount of sea level rise adopted for a particular planning horizon. The consequences associated with a particular erosion event depend on factors such as soil type, presence of rock and land use within the affected area. Therefore, for any given erosion event, the level of risk will be higher if the subject site is developed (i.e. there is a risk to life and assets) than if the site is undeveloped.

For the purposes of the current study, preliminary risk categories have been applied to the study area as follows:

Risk Factor = Number of Cadastral Parcels within in EPA divided by the length of the EPA.

This definition considers:

- The landward extent of the EPAW;
- The length of shoreline falling within that EPAW; and
- The number of cadastral parcels falling within the affected area.

Further information on infrastructure and environmental values within the EPAW zone may also be considered in the risk assessment.

The new *Queensland Coastal Hazards Guidelines* (DERM, 2011b) provide guidance on the assessment of risk from coastal hazards, however, this includes storm tide inundation areas as well as erosion prone areas. Therefore, a risk assessment protocol slightly different to that outlined in DERM (2011b) has been applied here.

2.5 Preliminary Economic Assessment

A preliminary economic assessment has been undertaken for the study area based on an analysis conducted in GIS. As a first step the total dollar value of lots within each EPA were derived from median house price data and the number of lots within the EPA.

Median residential property sales values for late-2010/early-2011 were obtained for each coastal suburb from RPData (http://www.rpdata.net.au/). Erosion prone areas were overlaid on the cadastre and suburb boundaries in the GIS. The GIS software package was then queried to derive the total number of cadastral parcels (of any land tenure category) per suburb within each EPAW. These data were then transferred to an Excel spreadsheet to calculate the approximate value of all lands within that EPAW based on the median land sales values.

The analysis counted all cadastral boundaries intersecting the EPAW, including partial lots. The existence and location of dwellings within each cadastral lot is not known, and therefore, the median land value was applied to all lots and partial lots, both improved and unimproved within the erosion prone area.

The assessment relies on median residential property sales values, and hence provides an indicative estimate only. Within the context of the large size of the study area, it is considered adequate for the purposes of comparing the potential economic damages associated with direct loss of assets within the erosion prone areas and can assist in prioritising potential locations for management intervention.

3 RESULTS AND DISCUSSION

3.1 Erosion Prone Areas – 2100

An example for Urangan is provided in **Figure 3.1**, encompassing portions of both the Hervey Bay and Great Sandy Straits erosion prone areas.

Within the Hervey Bay area the width of each EPA zone (yellow polygons in **Figure 3.1**) varies in accordance with the various coastal process parameters used to derive the EPAW (**Appendix A**).

In the tide dominated Great Sandy Straits area the default EPAW definition provides a zone for which the width varies in accordance with the local topography and the location of the HAT_{2010} and HAT_{2100} contours. The methodology for deriving the EPAWs for these locations is described in **Section 2.3.3**. Within the Great Sandy Straits area, EPAs were delineated for the developed areas (green polygons in **Figure 3.1**). These areas encompass most of the infrastructure in the region.

3.1.1 Land at Risk from Erosion

Table 3.1 summarises the assessment of numbers of cadastral lots falling within each EPAW/Suburb for the Hervey Bay and Great Sandy Straits areas. Statistics are provided on the number of cadastral parcels falling partly or wholly within the EPAs, broken down on the basis of the land tenure categories included in the cadastral layer provided in GIS format by Council.

It is noted that the GIS also recognises strata titles within the Cadastral layer provided by Council. Where a single lot includes multiple residences such as apartment buildings, each apartment has been counted within the number of freehold properties.

Figure 3.1: Example of 2100 Erosion Prone Areas for Urangan

Table 3.1: 2100 Erosion Risk Analysis of Cadastral Lots for Hervey Bay and the Great Sandy Straits Area

EPA Zone	EPA No.	Shoreline Length (metres)	Chainage (metres, from Urangan Boat Harbour)	EPAW (metres)	Number of Cadastral Parcels							Risk Category (Lots per km Coastline)	Approximate Land Value	
					Freehold	Lands Lease	National Park	Reserve	State Land	State Forest	Total		Total ($M)	$M Per km
Hervey Bay Area														
Burrum Heads	77	706	40,289	95	65						65	92	22.8	32.2
Beelbi Creek to Burrum Heads	78	3,930	39,584	160	166			10	1		177	45	62.0	15.8
Beelbi Creek to Burrum Heads	79	3,968	35,654	400	13		1	3			17	4	6.0	1.5
Beelbi Creek	80	252	31,685	Transition	67			1			68	270	20.4	80.9
Toogoom	81	1,340	31,433	175	160						160	119	48.0	35.8
O'Regan Creek to Beelbi Creek	82	527	30,093	Transition	37			2			39	74	11.7	22.2
O'Regan Creek to Beelbi Creek	83	4,452	29,566	125	141			7			148	33	44.4	10.0
O'Regan Creek to Beelbi Creek	84	301	25,114	Transition	1						1	3	0.3	1.0
O'Regan Creek	85	542	24,813	400			1	2			3	6	1.1	2.1
Eli Creek to O'Regan Creek	86	237	24,271	Transition				2			2	8	0.7	3.2
Eli Creek to O'Regan Creek	87	6,723	24,035	125	128			11			139	21	55.8	8.3
Eli Creek to O'Regan Creek	88	643	17,312	Transition	2				1		3	5	1.0	1.5
Eli Creek	89	425	16,669	400	1			1	1		3	7	1.0	2.3
Point Vernon to Eli Creek	90	658	16,244	Transition	2			3	2		7	11	2.0	3.1
Point Vernon to Eli Creek	91	1,013	15,587	105	19			1	1		21	21	6.1	6.0
Point Vernon	92	6,256	14,573	70	78	1		7			86	14	27.6	4.4
Mouth of Tooan Tooan Creek to Pialba	93	981	8,317	110	76			7			83	85	38.6	39.4
Mouth of Tooan Tooan Creek	94	365	7,337	155	12			1			13	36	6.0	16.6
Scarness Seawall to Tooan Tooan Creek	95	449	6,972	125	22			3	1		26	58	6.1	13.5
Scarness Seawall	96	517	6,523	80	52			1			53	102	13.6	26.2

EPA Zone	EPA No.	Shoreline Length (metres)	Chainage (metres, from Urangan Boat Harbour)	EPAW (metres)	Number of Cadastral Parcels							Risk Category (Lots per km Coastline)	Approximate Land Value	
					Freehold	Lands Lease	National Park	Reserve	State Land	State Forest	Total		Total ($M)	$M Per km
Torquay Seawall to Scarness Seawall	97	2,861	6,006	105	334	6		5			345	121	112.2	39.2
Torquay Seawall	98	502	3,145	80	54			1			55	110	18.8	37.5
Urangan Seawall to Torquay Seawall	99	958	2,643	80	52			2			54	56	18.1	18.9
Urangan Seawall	100	739	1,686	80	51			1	2		54	73	18.1	24.5
Boat harbour to Urangan Seawall	101	946	946	105	62	1		3			66	70	22.1	23.4
Total					**1,595**	**8**	**2**	**74**	**9**	**0**	**1,688**		**564.3**	
Great Sandy Straits Area														
Boat Harbour	102	226	226	NA	4	2		2			8	35	2.7	11.9
Boat Harbour to River Heads	103	20,800	21,026	NA	344	13		19	21		397	19	136.1	6.5
River Heads	104	1,179	22,205	NA	5			2			7	6	2.6	2.2
Maaroom	105	2,961	25,166	NA	59			2	7		68	23	18.4	6.2
Boonooroo	106	3,523	28,689	NA	255			6	4	1	266	76	63.3	18.0
Tuan	107	2,982	31,671	NA	115			1		1	117	39	50.3	16.9
Poona	108	4,588	36,259	NA	162			5		1	168	37	29.4	6.4
Tinnanbar	109	4,387	40,646	NA	14		1	3	3	1	22	5	9.9	2.3
Total					**958**	**15**	**1**	**40**	**35**	**4**	**1,053**		**312.7**	
FINAL TOTAL											***2,741***		***877.0***	

3.2 Outcomes of the Risk Assessment

As presented in **Table 3.1** there are a total of 1,595 freehold properties within the total of 1,688 cadastral lots within the Hervey Bay region EPA. The highest density of lots per km of coastline occurs around Toogoom at 270 lots per km of coastline followed by the Torquay to Scarness area with 121 lots per km of coastline. The lowest densities occur near the creek mouths and undeveloped coastal stretches in between.

Assuming that the density of lots per km provides a reasonable estimate of the freehold assets potentially at risk of coastal erosion some time into the future then the data presented in **Table 3.1** suggest that the areas at Toogoom and Torquay to Scarness present the highest risk of loss of freehold land.

Within the Great Sandy Straits area, which is generally subject to lower development intensities, there are a total of 958 freeholds properties within the 1,053 cadastral lots within the EPA (**Table 3.1**). The highest density of lots per km of coastline occurs in Boonooroo with 76 lots per km of coastline, followed by Tuan and Poona with 39 and 37 lots per km of coastline (respectively). The lowest densities occur in Tinnanbar and the undeveloped lands on the western shoreline of River Heads (inside the river).

There are also a number of reserves, national park lands, and other public open space areas that fall within the EPAs. These areas represent important recreational resources for both locals and visitors to the region.

3.2.1 Built Assets at Risk From Erosion

Built assets with the EPAs comprise a broad range of infrastructure including private and commercial buildings, roads, footpaths, stormwater and wastewater infrastructure, reserves and recreational facilities, etc. Council's GIS database was provided to Cardno to allow assessment of key infrastructure at risk through the application of GIS analyses of infrastructure within the EPAs. The method is similar for each asset type and an example output for the roads, stormwater, wastewater and buildings is summarised in **Table 3.2** and discussed below.

It is noted, however, that all of the GIS datasets provided did not cover the entire study area, as indicated in **Table 3.2**.

A total of 1,363 buildings fall within the Hervey Bay area EPA's. A number of these are apartment buildings or comprise accommodation, which accounts for the difference of 232 dwellings when comparing the number of cadastral lots (**Table 3.1**) and the number of buildings (**Table 3.2**).

Table 3.2: Built Assets Falling within Erosion Prone Areas

Built Asset	Hervey Bay Area	Great Sandy Straits Area	Total
Buildings	1,363	229*	1,592
Beach Access Points	101	7*	108
Roads			
Road Centreline	35.72 km	32.05 km	67.77 km
Road Footpath	146.78 km	1.09 km	147.87 km
Stormwater			

Built Asset	Hervey Bay Area	Great Sandy Straits Area	Total
Pipe Beach Outlets	66 total	7 total*	73 total
Drainage Pipes	8.79 km	3.00 km*	11.79 km
Drainage SQID (GPTs)	4 total	-*	4 total
Wastewater			
Sewer Pumping Stations	12 total	-	12 total
Sewer Rising Mains	4.81 km	-	4.81 km
Sewer Gravity Mains	13.94 km	3.17 km*	17.11 km
Sewer House Connections	147 total	10 total	157 total

*Only available for Urangan, Booral and River Heads (former Hervey Bay City Council LGA).

3.2.2 Potential Direct Economic Impacts of Erosion

The present day (2011) total value of cadastral lots within the erosion prone area of the 40 km stretch of Hervey Bay coastline is estimated by applying current median house prices for each suburb to the number of lots within the EPA and suburb and then summing the results.

Using this method the total estimated value of lots within the EPA in the Hervey Bay area is about $560 million. The value per unit length of coastline exceeds $35,000 per m in a number of areas including Torquay, Scarness, Pialba and Toogoom where the property densities are highest.

In the Great Sandy Straits area the total estimated value of lots within the EPA is around $310 million. The value per unit length of coastline is in excess of $15,000 per m in Tuan and Boonooroo where there is a greater density of properties.

These estimates must be viewed in the long term planning context as there are a number of assumptions have been made in the method. The estimates are intended to provide a means of identifying where the greatest risks to land tenure occur and also as a basis for assessing the cost of implementation of any potential options.

3.3 Erosion Management Policies

As identified in the *Queensland Coastal Policy* erosion management policies may include:

- Do Nothing (i.e. allow the erosion to occur);
- Managed Retreat; or
- Hold the line.

The implications of each of these options for land tenure and dwellings on threatened lands (and liability for this tenure) requires careful consideration of the infrastructure, environment and social values at threat and the likely timeframe at which mitigative or management measures need to be implemented.

The Do Nothing policy is probably only viable in areas, such as parks and reserves where little or inconsequential infrastructure exist. In built up areas where services (both underground and aerial) exist it is more likely that the Managed Retreat or Hold the Line policies become more favourable and economically viable. Managed Retreat implies that present development in the coastal zone can be removed (or relocated) and that subsequent to the move the area is allowed to erode. This policy would require careful planning and identification of triggers to determine the optimal time to make the likely significant investment in the early relocation of services and other infrastructure to secure areas. The Hold the Line policy implies the development of protection works that can arrest coastal erosion.

4 OUTCOMES

The methods described in this Discussion Paper have been developed to assist long term planning. It will allow Council to consider the potential implications of sea level rise on the Fraser Coast region at an early stage, facilitate the prioritisation of at risk areas, and assist in decision making and forward planning on the likely investment required to mitigate the effects of sea level rise.

There is a level of uncertainty associated with the predictive capability of simplified tools for estimating the complex physical processes that lead to sediment transport and erosion/accretion patterns. This necessitates the adoption of a precautionary approach. While the estimated size of the EPAs in 2100 are prone to significant uncertainty, they are considered sufficient to develop an understanding of the likely threats and mitigative options available.

The EPAs have been estimated for the Fraser Coast using DERM's assessment methodology for the wave and tide dominated Hervey Bay area, and a simpler tidal erosion formulation in the tide dominated Great Sandy Straits. EPAWs vary between 70 and 400m landward of the present day toe-of-dune line in the Hervey Bay area. The width of the EPAs in the Great Sandy Straits Area are more highly variable due to the topographic component of the EPAW calculation. In some cases the EPA extends around 500m landward of the present day HAT line.

The present (2011) value of the cadastral lots within the EPA is estimated to exceed $870 million and in the areas where the highest densities of lots per unit length of coastline occur, namely Torquay, Scarness, Pialba and Toogoom, the average value per lineal metre of coastline exceeds $35,000.

There are also a number of other built assets in the EPAs including an estimated 68km of (local and State) roads and 11km of stormwater pipes. Many of these assets are owned by Council and represent significant financial investments. The loss of these types of assets can have implications for other human activities, such as general connectivity (and emergency evacuation) in the case of roads.

It is considered that the risk assessment methodology presented herein, when combined with indicators for the environmental and social uses of each zone, will provide a sound basis for identifying management options and strategies in the Fraser Coast SEMP. It is recommended that the procedures outlined in this Discussion Paper be adopted for the subsequent stages of the study.

5 REFERENCES

Cardno (2011) *Fraser Coast Shoreline Erosion Management Plan. Gap Analysis Report.* Prepared for Fraser Coast Regional Council. January 2011, pp. 78.

DEFRA (2006) *Shoreline Management Plan Guidance*. Prepared by the UK Department for Environment, Food and Rural Affairs. March 2006, pp. 48.

DERM (2002) *State Coastal Management Plan – Queensland's Coastal Policy*. Prepared by the Queensland Department of Environment and Resource Management.

DERM (2011a) *Queensland Coastal Plan.* Prepared by the Queensland Department of Environment and Resource Management. March 2011, pp. 98.

DERM (2011b) *Queensland Coastal Hazards Guidelines.* Prepared by the Queensland Department of Environment and Resource Management. March 2011, pp. 18.

EPA (2006) *Guideline Preparation of a Shoreline Erosion Management Plan*. Prepared by Ecoaccess for the Queensland Environment Protection Agency. November 2006, pp. 8.

Appendix A

Erosion Prone Area Estimation Methodology

1.0 Introduction

The coast is a dynamic system in which shoreline variations and periodic inundation of some coastal areas are part of the natural coastal processes. Some development in the Fraser Coast Regional Council (FCRC) Local Government Area (LGA) has occurred within coastal areas that are vulnerable to storm erosion and long term recession, and in many cases this development amounts to substantial private and public investment. This condition will become worse with projected sea level rises. Protection works for the built environment in these areas is expensive and the structures themselves can cause adverse effects on coastal resources and their values; such as beach amenity.

Erosion prone areas have been developed in Queensland by the Department of Environment and Resource Management (DERM) as a coastal planning tool to assisting in planning development free buffer zones. Erosion prone area widths (EPAWs) describe the vulnerability of a coastline to encroachment from the sea or estuarine waters, that is, erosion from the sea allowing for:

- Long-term erosion trends (shoreline recession);
- Short-term storm erosion;
- Dune scarping (collapse of a near-vertical erosion scarp to a more stable slope); and
- Recession due to projected sea level rises.

In coastal areas where shore line erosion is dominated by wave activity, such as Urangan and Torquay, there can be significant spatial variability in EPAWs. On the other hand, where shoreline erosion is dominated by tidal effects, such as in the Great Sandy Strait, a constant EPAW parameter may be adopted.

Maintaining a development free buffer between land uses and the coast allows natural variations of the coastline to occur without the need for physical intervention to protect human life and property. In this context the buffer zone, or Erosion Prone Area Width (EPAW), is set out landward from the toe-of-dune line, which itself is a moving datum and must be specified at a particular date. It is often defined by the seaward vegetation line from aerial photography interpretation. Where a revetment protects a shoreline, then the EPAW width is zero – this approach assumes that the structure will provide erosion protection for the adopted planning period.

For many locations, including the Fraser Coast, EPAWs were calculated more than twenty years ago and may now underestimate the width of land vulnerable to erosion from the sea. DERM have therefore undertaken a review and revised the erosion prone area formula presented in the Queensland Coastal Plan based on recent scientific research. The component for shoreline recession due to sea level rise is of particular interest due to recent research published by the Inter-governmental Panel on Climate Change (IPCC). Based on the IPCC Fourth Assessment Report (2007), a projected sea level rise of 0.8m by 2100 (relative to 1990 sea levels) has been adopted by the Queensland Government (DERM, 2011a). The methodology for estimating the shoreline recession component has been revised by DERM based on this sea level rise projection.

Some of this work has been completed by DERM for the FCRC LGA and provided to Cardno for use in this study; including an update of the formula for calculating EPAWs, and revised EPAWs for the study area for 2100 (i.e. with 0.8m sea level rise).

This appendix summarizes the EPAW calculation methodology presented in DERM (2011b) and describes how this has been used by Cardno to develop EPAWs for a range of other sea level rise planning horizons (2030, 2050 and 2070). Much of the text on the general approach has been taken directly from DERM (2011b), with additional comment or specific information relevant to the Fraser Coast provided by Cardno as required.

2.0 EPAW Assessment Methodology

The formula currently adopted by DERM for calculating the EPAW for areas where wave action is significant is:

$$E = [(N \times R) + C + S] \times (1 + F) + D \tag{1}$$

Where: E - erosion prone area width (metres)

N - planning period (years from 2011, up to 2050 and there-after 50 years)

R - rate of long-term erosion (metres/year)

C - short-term erosion from the “design” cyclone (metres)

S - recession due to sea level rise (metres)

F - required factor of safety (adopted to be 0.4)

D - dune scarp component (metres).

In principle, the erosion prone area should determine a width of land sufficient to accommodate erosion from a design storm event at the end of the planning period. This also implies that the erosion prone area can accommodate erosion from storms greater than the design event without significantly increasing the risk of erosion breaching the erosion prone area within the planning period. The current methodology for calculating erosion prone areas is presented in the *Queensland Coastal Hazards Guidelines* (DERM, 2011b).

The following sections provide a concise description of the methods and background to the determination of the parameters described in **Equation (1)**.

The long and short-term erosion components are based on extrapolation of either past or present trends in shoreline width, but do not account for the effects of climate change. The S component accounts for the effect of climate change induced sea level rise on shoreline recession. A factor of safety of 40% is then applied to the sum of the long term erosion, short-term erosion and recession due to sea level rise. The factor of safety is intended to accommodate uncertainties and limitations in the values of these EPAW components. The dune scarp component allows for slumping of the dune as a result of the design storm event.

For the Hervey Bay region, the EPAWs are based on detailed coastal processes studies undertaken by the Beach Protection Authority (BPA, 1984). For most beaches, the EPAWs are based on desktop studies undertaken 20 to 30 years ago, and may no longer be applicable due to additional information and research now available. Hence, DERM have undertaken sufficient investigations to determine new EPAW values for the shoreline west of Urangan to Burrum Heads.

2.1 Recession Due to Sea Level Rise (S)

Climate change is predicted to cause a rise in sea level due to thermal expansion of the ocean and melting of polar ice sheets and glaciers. The EPAW formula (**Equation 1**) includes a component that accounts for shoreline recession associated with projected sea level rise (S).

In recent years there has been considerable research in relation to the effect of climate change on the rate of sea level rise. More recent research suggests a sea level rise of approximately 0.8m by 2100 (relative to the 1990 value) is likely to occur, based on current rates of greenhouse gas emissions. The erosion prone areas need to be updated to consider this higher rate of sea level rise.

Currently, the projected sea level scenarios presented in **Table A.1** are to be adopted for the determination of the EPAWs, as required by the Queensland Coastal Plan (DERM, 2011a).

Table A.1: Projected Sea Level Rises for the Year of Planning Period End (after DERM, 2011a)

Year of End of Planning Period	Projected Sea Level Rise
Year 2050	0.3 metres
Year 2060	0.4 metres
Year 2070	0.5 metres
Year 2080	0.6 metres
Year 2090	0.7 metres
Year 2100	0.8 metres

Those sea level rise projections marked with an asterix in **Table A.1** have been used to calculate the EPAWs for the wave dominated coastline of the Fraser Coast Region. The sea level rise projection adopted by Cardno for the 2030 planning horizon was 0.2m.

Shoreline recession due to sea level rise is currently estimated using the “Bruun Rule” (Bruun, 1962). This method is based on maintaining an equilibrium beach profile as sea level rises by transferring sand removed during shoreline retreat onto the adjacent inner shelf, thus maintaining both the original beach profile and near shore shallow water conditions.

The Planning Period (N)

The EPAW varies directly with the duration of the planning period (years). There are no quantitative methods for determining the ideal duration of the planning period for calculating the extent of shoreline erosion. However, DERM (2011b) has indicated that the following matters must be considered.

If the planning period is too short, persistent long-term erosion will quickly remove the buffer zone completely and direct action will be required to counter the erosion threat. This approach would negate the potential advantages of the planning concept and provides only a short-term postponement of existing problems.

If the planning period is too long it will result in a buffer zone that is unrealistically large in terms of the public's perception of the magnitude of future erosion and will have land alienation issues. Additionally, erosion and accretion trends tend to be cyclical and a long planning period can be inconsistent with the time scale of alternating erosion/accretion trends on the local beaches; should that occur. The description of these decadal (and longer) variations is difficult to quantify because they require very long periods of data.

The planning period only relates to the short- and long-term erosion components of what is considered to be an erosion-prone shoreline. It is not necessarily related to, and is separate from, the period of time over which sea level rise is considered, and is unrelated to the planning period for considering risks to development from coastal erosion when located in or adjacent to an eroding coastline.

The long-term erosion component (excluding sea level rise) of the calculation is often cyclical in nature and typically of a decadal scale. DERM have advised that for this reason it is considered that the estimated annual rate of long-term erosion should only be applied for a 50-years period to avoid over-estimation, unless there is clear evidence to the contrary. Hence for the 2070 and 2100 EPAW calculations the long term erosion component was calculated based on a planning period of 50 years. For shorter periods (from 2011) the planning periods were 19 and 39 years to 2030 and 2050, respectively (pers. com., S. Sultmann, DERM – D. Treloar, Cardno) and the long term recession values (N x R) were adjusted by factors of (19/50) and (39/50) for these planning dates, respectively.

Rate of Long-term Erosion (R)

The annual rate of long-term erosion (or accretion) occurring at an individual beach is not constant and will vary significantly depending on the period over which the average rate is assessed. Long-term erosion may be caused by reductions in extreme flood events that reduce the delivery of sand to the coastline, relocations of river and creek mouths, meandering of tidal channels and sand bar migrations onto the coast (DERM, 2011b); as well as variations in longshore transport delivery of sediments caused by varying wave conditions. Aeolian losses can occur also, as well as losses offshore caused by severe storms that transport sand offshore beyond the point from which it can be returned onshore following storm abatement. Depending upon the cause, this erosion may cease after a period of time and be followed by a period of accretion.

DERM (2011b) outlines two basic approaches to obtaining an estimate of future long-term erosion:

- Extrapolating past trends deduced from the geological record or information from surveys and aerial photographs; or
- Calculating the present local sediment budget for each beach. Any deficit (or surplus) is converted into a horizontal movement of the shoreline that can be extrapolated over the planning period.

Both approaches have limitations in the accuracy with which they can estimate the magnitude of the recent and present erosion rates and, more importantly, in the confidence with which these estimates can be projected into the future. In practice, calculations of sediment budgets are usually tested against recent recorded beach behaviour to check and calibrate the calculation procedures. In this manner, an acceptable estimate of the current annual erosion rate can be achieved.

Conversion of sediment losses into horizontal recessions requires certain assumptions about the distribution of losses across the beach and dune profile. For EPAW calculation, the form of this distribution is based on the following assumptions (after DERM, 2011b):

The average beach slope (measured from the crest of the frontal beach ridge to a base level close to the low water mark) is assumed to be locally constant for any individual beach. This is supported by normal grain size/wave energy stability considerations; and

Below the base level and close to the low water mark, the profile is assumed to continue to a cut-off with the existing profile that will vary from beach to beach, but can be identified from the form of the profile in most cases.

Based on the assumed distribution, the annual erosion quantity can be related to the annual recession rate by the following equation provided in DERM (2011b):

$Qe = (R \times h1) + 0.5(R \times h2)$ **(2)**

$= R\ (h1 + 0.5h2)$

Therefore $R = Qe/(hl + 0.5h2)$ **(3)**

where:

Qe = erosion quantity in cubic metres per metre length of beach per year ($m^3/m/yr$)

$h1$ = height of frontal beach ridge above low water mark (metres)

$h2$ = depth of closure (metres)

R = long-term erosion rate (metres/year)

Although the above calculation procedure has been developed for beach recession, it can also be applied to the calculation of the relationship between volumes and horizontal accretion for beach nourishment schemes, with any necessary modifications for grain size variations between natural and nourishment sand.

A typical beach profile response to long-term recession is shown in **Figure A.1**.

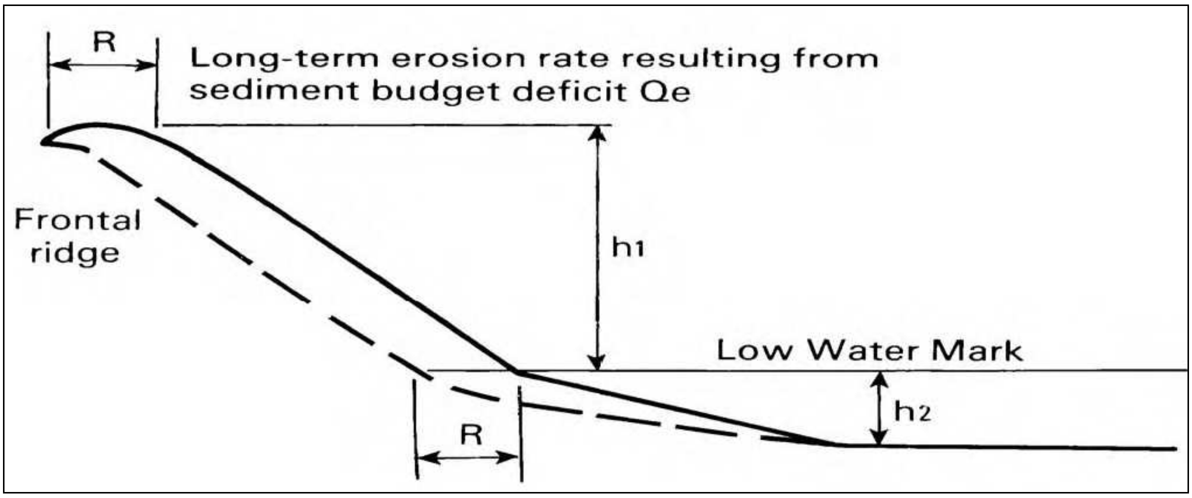

Figure A.1: Typical Beach Profile Response to Long Term Erosion (after DERM, 2011b)

Care must also be taken when determining the long-term rate of erosion that only morphological/sediment supply processes are included, and that any erosion due to historical sea level rise is excluded from this variable of the equation (DERM, 2011b). The variable 'S' provides an estimate of erosion due to future sea level rise and is discussed below.

Short-Term Erosion

As outlined in DERM (2011b), determination of the short-term erosion component (C in **Equation(1)**) involves three separate steps. They are:

- Assessing what the community considers to be an acceptable risk for assets under threat from a severe storm. This is generally assessed in terms of frequency of damage occurrence and the extent of damage, and is often expressed in monetary terms;
- Selecting the relevant parameters of the 'design' storm event; generally in terms of wave and water level criteria; and
- Estimating the horizontal recession of the beach associated with this storm event.

Acceptable Risk to the Community – 'Design' Storm Event

For this calculation, an acceptable risk is considered to be an ocean storm event of a severity that only occurs on average once in every 100 years. For a 100-years planning period, the risk that the coast will be affected by a storm of this frequency is 63%. However, the risk that assets will be affected by erosion from such an event is moderated somewhat by the safety factor in the calculation – see **Equation (1).**

Selection of Parameters for the 'Design' Storm Event

Selecting parameters for a 'design' storm is not a simple matter. Data on probabilities of various storm tide levels and average return intervals (ARIs) of various storm wave parameters (height, period and direction) and storm duration are available at some locations, including Hervey Bay. However, for any set of adopted conditions, there is always a risk that a much more severe event will occur. **Table A.2** summarizes the probabilities of occurrence for events with various ARI within the adopted 100-years planning period based on an assumed Poisson distribution of occurrences of storm events.

Table A.2: Probability of Occurrence of a Storm Tide of Particular ARI during Selected Planning Periods (after Patterson, 1986; cited in DERM, 2011b)

Probability of Occurrence (%) for the Period (Years) Shown					
ARI of Storm (Years)	**Planning Period (Years)**				
	25	**50**	**100**	**200**	**500**
50	39	63	87	98	99.9
100	22	39	63	87	99.3
200	12	22	39	63	92
500	5	9.5	18	33	63

The likely probability of occurrence of the 'design' storm within an adopted planning period can be calculated from return period data as presented in **Table A.2**. Should climate change and associated sea level rise become significant over the next ten to fifteen years, the parameters of the selected 'design' storm may change, resulting in increased storm erosion. Provision for this change can be made by increasing cyclone maximum potential intensity by 10 per cent (or wind speeds) and to undertake Monte Carlo type modelling to re-define these design parameters.

In order to select 'design' storm conditions, it is possible to break-down the 'design' storm into the 'design' wave and storm tide conditions and to define the probability of those two shoreline erosion components. The likelihood of peak storm tide and peak wave conditions influencing a particular area at the same time is statistically very unlikely and the probability of their joint occurrence cannot be readily assessed (DERM, 2001b), other than by Monte Carlo type simulations. As a cyclone approaches the coastline, the length of fetch available for wave generation is reduced, which results in an effective reduction in wave height by the time the peak storm surge is observed. However, these processes are site and event specific and can be defined reliably only by undertaking detailed numerical modelling. An alternative procedure is to undertake SBeach storm bite calculations for a large number of Monte Carlo wave and storm-tide result-sets and to undertake an extremal analysis of the storm bite results.

As discussed in DERM (2011b), the Queensland coastline exhibits a diverse range of beach profiles from high-energy wave-dominated profiles to low-energy tide-dominated beach profiles, with each profile being influenced differently by external forces. The rate at which coastal erosion occurs is dependent on how external forcing mechanisms (such as the storm tide level and significant wave height) are allowed to influence the coastline. During a storm event these two factors interact with the coastline for a length of time (duration); noting though that the changing astronomical tide, especially where there is a high range, means that the peak storm tide only occurs for an hour or so at the coastline.

For the selection of a 100-years ARI storm event (in terms of shoreline erosion), it is considered appropriate to adopt the relative impacts of waves and storm tide level for a particular coast and select:

- A storm tide level corresponding to a particular probability of occurrence; and
- An estimated wave height corresponding to a moderate storm.

For a tide dominated coast, or where storm tide levels can be high, the parameters adopted for the minimum 'design' storm erosion calculation are:

- The storm tide level corresponding to the 100-years ARI, and
- A wave height for a moderate storm using the 20-years ARI significant wave height (Hs).

However, for wave-dominated coastlines or where extreme storm tide levels can be relatively minor, such as Queensland's Gold Coast, the significant wave height and duration of the storm event are major factors which influence short-term erosion, rather than storm tide. Hence it may be necessary to consider a larger wave event (e.g. a storm event at the 100-years ARI) and a moderate storm tide level (20-years ARI). Decisions on appropriate parameters to be used must be based on local conditions and the experience of the coastal engineer undertaking the assessment.

The morphology of coastal systems is dependent on the sediment characteristics and the relative exposure to wave and tidal energy. A number of systems have been developed to classify coasts based on morphologic features.

A simple method of classifying coasts can be derived from the current erosion prone area plans prepared by DERM. The default EPAW of 40m landward of the current day highest astronomical tide (HAT) contour applies to tide dominated coastal areas. Coastlines exposed to wave energy have an erosion prone area defined by a linear distance on the plans. Coastlines exposed to wave energy can be further divided into wave dominated, tide modified and tide dominated beaches using the classification system developed by Short (1999).

In the FCRC LGA it would, in principle, be appropriate to adopt the 100-years ARI storm tide and 20-years ARI peak storm H_s in the region west and north of Urangan – a coastal area affected by wave energy, but is tide dominated. The region south of Urangan in the Great Sandy Strait is tide dominated and the default EPAW of 40m HAT contour has been adopted. The location of the HAT contour changes as sea level rises so that EPAW lines need to be determined for each of the designated planning periods.

Although the above-mentioned ARI may appear to be very infrequent, it is considered that this choice is appropriate when considered in conjunction with the method used to determine EPAWs. This method implies that the erosion-prone area has sufficient width to accommodate the 'design' storm erosion in one hundred years time, when all of the estimated long-term recession has occurred (based on 50 years of long term recession and 100 years of sea level rise related recession). Therefore it also follows that, for much of the one 100 years planning period, the erosion-prone area is sufficient to accommodate a larger storm than the one selected for design purposes. In fact, in the most critical last 10 years of such a planning period, there is only a 10 per cent probability of occurrence of the 'design' storm. Thus, the risk of a storm breaching the entire erosion-prone area at some time during the one 100 years planning period will be significantly less than 63 per cent.

Estimation of Erosion Distances

The techniques available for estimating storm recession are described by DERM (2011b) as varying from purely empirical procedures to those employing various combinations of empirical and theoretical considerations. The common link is the assumption that a characteristic beach profile is developed during storm wave conditions. The characteristic profile provides a volume balance between the sand eroded from the frontal dune and upper beach and deposited further down the shore normal profile in the nearshore zone, as shown in **Figure A.2** (after DERM, 2011b).

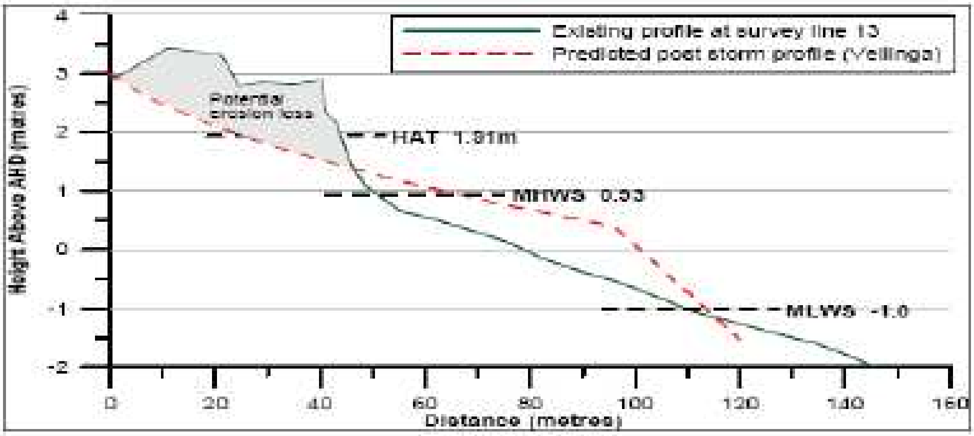

Figure A.2: Estimated Short-term Beach Profile Response to a 1 in 100-year ARI Storm Event Based on Vellinga (1983) – South Mission Beach (after DERM, 2011b)

Two methods for storm erosion estimation outlined in DERM (2011b) are:

- Vellinga (1983) developed a predictive computational model for beach and dune erosion during storm events. This method is used to evaluate the erosion distance assuming that a fully developed equilibrium profile is reached. It should be noted that the development of an equilibrium profile is a gradual process, that is, for any given storm the conditions for an equilibrium profile may not be reached. This assumption provides an additional factor of safety on the calculations.
- Shoreface models, that simulate cross-shore beach and dune erosion produced by storm waves and high water levels, are a useful tool for assessing the short-term storm beach erosion cut component (C).

Erosion Due to Sea Level Rise (metres) (S)

As discussed previously, the assessment of the planning period (N), the rate of long-term erosion (R), and storm bite/cut (cyclone erosion - C) is based on the extrapolation of either past or present trends, and therefore does not consider the effects of climate change including the accelerated rate of sea level rise (DERM, 2011b).

The projected effects of climate change must be incorporated in the assessment of EPAWs. Techniques are available for estimating shoreline response to a rise in sea level. The 'Brunn rule' (Brunn, 1962) provides a common method based on the concept that an equilibrium beach profile is maintained during sea level rise, but is translated up and landward. Sediment is removed from the upper beach and dune during shoreline retreat (recession) and deposited onto the adjacent near shore zone - thereby maintaining both the original beach profile and nearshore shallow water conditions.

The Brunn rule can be applied to uniform sandy beaches to assess the response of the shoreline to sea level rise. The physical characteristics of the coastline, such as the presence of seawalls, inlets, delta mouths, seabed rock and varying sediment size in the beach system, will affect beach response and must also be considered, however, this is not part of the Bruun rule. Results of the Brunn rule calculations are used to obtain the recession S in **Equation (1)**. Therefore, S represents the horizontal erosion component due to the predicted vertical increase in sea level (DERM, 2011b). Other potential impacts of climatic change, such as increased storm activity and changes in wind patterns, do not form part of the determination of S. It is important to note that the Bruun rule is not strictly applicable on tidally dominant beaches, where tidal energy has a greater impact on beach morphology than wave energy does, and where sediment grading can be wide and sediments poorly sorted (DERM, 2011b). A simple inundation calculation based on slope may be considered, but best practice methodology should be used.

A modified Bruun Rule approach was adopted to derive EPAWs for the Hervey Bay area, as outlined in **Section 2.3.2**.

The projected sea level rises are based on the best information currently available, and the current value adopted by DERM for calculating the erosion-prone area is 0.8 m by 2100 (relative to 1990 value), as presented in **Table A.1**.

Factor of Safety

The calculation procedures adopted for EPAW determination are consistent with current engineering practice in this field, but are subject to uncertainties and limitations. For example, the calculation of storm erosion considers beaches as two dimensional and therefore does not incorporate changes in conditions along the beach. In the process of determining values for these various terms, no conscious attempt has been made to select conservative values. Therefore, in accordance with normal engineering practice, a factor of safety should be applied to these calculations. For this purpose, a safety factor of 140 per cent has been adopted (DERM, 2011b).

Dune Scarp Component (D)

The short-term erosion calculation permits the assessment of shoreline recession as far as the limit of wave run-up for those cases where the frontal beach ridge is not overtopped. To allow for slumping of the frontal dune beyond this design run-up level, and the possible undermining and collapse of structures founded on the dune, a dune scarp component has been included in the EPAW (DERM, 2011b).

3.0 References

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