SHIRE OF IRWIN
DONGARA-PORT DENISON
A BRILLIANT BLEND

Irwin Coastal Hazard Risk Management and Adaptation Plan (CHRMAP)

Literature review

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NACC
Managing Natural Resources

Curtin University

Western Australian Planning Commission

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Acronyms

ARI	Annual Recurrence Interval
BoM	Bureau of Meteorology
CHRMAP	Coastal Hazard Risk Management and Adaptation Plan
DEM	Digital Elevation Models
DoT	Department of Transport
ECMWF	European Centre for Medium-Range Weather Forecasts
GSWA	Geological Survey Western Australia
LiDAR	Light Detection and Ranging
NACC	Northern Agricultural Catchments Council
NSW	New South Wales
SPP 2.6	Western Australian State Coastal Planning Policy 2.6
SoI	Shire of Irwin
WA	Western Australia
WAPC	Western Australian Planning Commission

1. Introduction

1.1. Project Background

The Shire of Irwin coastline has significant environmental, economic and social assets with the Port Denison harbour area holding a large socio-economic significance. Residential growth over the next 10 to 20 years has been defined within the Shire's Local Planning Strategy (2008); and is likely to occur on the land to the north of the Harbour. This may result in the strengthening of the local economy through the creation of further tourism and recreational opportunities.

The most significant coastal asset for the Shire is the Port Denison Harbour, which was largely constructed between 1977 an 1979 (Paul 1981). Over the years, the foreshore beaches within the harbour, Granny's Beach and Surf Beach have been subject to coastal erosion. A sea wall has been constructed at Granny's Beach to protect the adjacent tourist park. The dunes near the Irwin River mouth have shown evidence of erosion as a result of fluctuations in the sand-barred river mouth, further the alluvial flats adjoining the River have been identified as being vulnerable to inundation. The fishermen's/tourist nodes south of Port Denison have also experienced erosion, as has Seven Mile Beach, north of Dongara. A major problem with previous management plans is that they have been temporary and/or ad hoc, focusing on short term measures, the Shire feels that these may be inadequate and costly in the long term.

The Irwin Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) is an outstanding planning task from the Shire of Irwin's Local Planning Strategy. The CHRMAP will enable the Shire to provide a consistent management approach, whilst being more informed and prepared for coastal issues and hazards in relation to the natural environment and the Shire's assets.

1.2. Purpose of the Project

The CHRMAP is intended to update and provide for a consistent management and adaptation plan across the Shire's coast. Its purpose is to update and provide strategic guidance on coordinated, integrated and sustainable management and adaption for land use and development in the coastal zone likely to be affected by coastal hazards. The CHRMAP will further provide a consistent approach to coastal management, by ensuring an appropriate risk assessment and management planning framework is used to incorporate coastal hazard considerations in the decision-making processes of the Shire of Irwin. Specifically the CHRMAP will:

- Provide information on the effects of coastal hazards;
- Present a decision-making framework to assess the associated risks;
- Highlight coastal hazard vulnerability zones;

- Highlight coastal hazard risk zones; and
- Suggest possible adaptation options.

1.3. Objectives

The objectives of the CHRMAP are to:

- Increase knowledge of coastal features, processes and hazards in the Shire.
- Include stakeholders and community in the planning and decision-making process.
- Identify and value assets (both natural and man-made) impacted by coastal hazards and their functions.
- Determine sensitivity and exposure of impacts from coastal hazards on assets and assign a level of vulnerability.
- Determine likelihood and consequence of impacts from coastal hazards on assets and assign a level of risk.
- Identify relevant management/adaptation actions and how these can be incorporated into short and long term planning.

2. Literature Review

As the first step of the project, a literature review process has been conducted aiming to collect and review all available information, whilst identifying data gaps and project requirements.

The literature review was conducted under several sub topics including state government policy and CHRMAP guidelines, CHRMAP studies conducted nationally and internationally, information on the study area, literature on data availability and literature on modelling methods.

2.1. State Government Policy and CHRMAP Guidelines Context

There are several documents relevant to the study and include State Planning Policy 2.6 (SPP 2.6) (State Coastal Planning), SPP2.6 Guidelines and the Status of Coastal Planning in Western Australia (2012) report. These policies and guidelines provide guidance for decision-making within the coastal zone including managing development and land use change; establishment of foreshore reserves; and to protect, conserve and enhance coastal values.

The study aims to strictly follow the guidelines and specifications recommended by relevant authorities and agencies. Special care has been taken to highlight the recommendations from SPP2.6 (WAPC, 2013) in relation to; the planning time frame; storm event for modelling; allowance for sea level rise; allowance for storm surge inundation; and allowance

for erosion. Further recommendations on an appropriate allowance for mean sea level change to be used in coastal planning in Western Australia are given by Bicknell (2010).

As the vulnerability of land use and development within the Western Australian coastal zone to physical process hazards is expected to increase in the future the Department of Planning, on behalf of the Western Australian Planning Commission, prepared the Coastal Hazard Risk Management and Adaptation Planning Guidelines for Western Australia (WAPC, 2014) to support the implementation of SPP2.6. The publication is designed to assist statutory decision-makers (e.g. local governments, State government agencies, the Western Australian Planning Commission and the State Administrative Tribunal) to:

a) Consider coastal hazards and to evaluate their likelihood and the consequence for specific assets;
b) Identify realistic and effective management and adaptation responses to those risks; and
c) Prioritise the management and adaptation responses.

From a national perspective guidelines have been prepared by other states and include Guidelines for Preparing Coastal Zone Management Plans, NSW (NSW Government, 2010), Victorian Coastal Hazard Guide (The Victorian Government Department of Sustainability and Environment, 2012) and Guideline for Preparing a Coastal Hazard Adaptation Strategy, Queensland (Queensland Government, 2013).

2.2. CHRMAP Studies Available in the Literature

Numerous CHRMAP studies have been undertaken focusing on the potential impacts of coastal inundation and erosion hazards on the Western Australian coastline. These studies such as the Gingin-Dandaragan Coastal Hazard Risk Assessment (NACC, 2015) follow the objectives of SPP 2.6 and the guidelines provided within the Coastal Hazard Risk Management and Adaptation Planning Guidelines for Western Australia. This study considers both present extremes of climate and also projected changes in future climates until the year 2100 for the Gingin-Dandaragan coastline.

A CHRMAP for Yanchep Surf Life Saving Club (YSLSC) was done for the redevelopment of the YSLSC facilities (Cardno, 2014). This report is to be used for the decision-making process for the entire 50 years (2070) design life of the Club's facilities.

Cockburn Sound Coastal Vulnerability Values and Risk Assessment Study (2014) identified the cost of risk to the coastal assets and presented an approach to managing these coastal risks. The study further provided a strategy for coastal management, incorporating present and future coastal hazards to develop an adaptation plan (BMT, 2014).

The Coastal Adaptation Decision Pathways Project initiated to develop flexible pathways for the Peron-Naturaliste Coastal Region of WA. The project consisted of three phases; a synthesis of coastal hazards affecting the region; a regional-based assessment of impacts, comparing present day conditions with those projected at snapshots in time up to 2110; and a detailed locally-based assessment at four case study areas of impacts and potential responses, which will change over time(Peron Naturaliste Partnership, 2012). This project was largely innovative and has generated a great deal of new learning's, knowledge and sharing of information and resources for the partnership (Peron Naturaliste Partnership, 2012).

2.3. Information on the Study Area

A desktop review shows that there is a large amount of background information for the study area including studies on the natural attributes of the coastal environmental; climate change and oceanography, cultural attributes and issue based management strategies (Peter H & A, Landvision, 2000).

The potential impacts of climate change in Mid-West region such as sea level rise presents a significant issue for the region's ports and coastal towns, home to the majority of the region's population and vital infrastructure (AECOM, 2010).

The beach erosion process in Dongara- Denison beach, adjacent to the Caravan Park (the Dongara Denison Holiday Park) was investigated taking several aspects into account; shore line movement; relationship between ocean water levels with beach erosion and other factors; and option for managing the beach erosion (M J Paul, 2001). Findings and recommendations are in Section 4.2 in this report.

Further investigation on coastal erosion at Dongara Denison Beach Holiday Park was conducted and a seawall was constructed to protect the Dongara Denison Beach Holiday Park. (M.P. Rogers, 2012).

The Shire of Irwin undertakes coastal erosion monitoring at along the coastline by taking photographs at appropriate locations. This monitoring has been opportunistic and covers the years from 2009 to 2013. The monitoring has identified erosion issues at Freshwater Point, Port Denison foreshore, Granny's beach, Surf Beach, Seaspray Beach and Seven Mile Beach (Shire of Irwin, 2013).

The Irwin River Estuary Coastal Management Plan was prepared in 2005 to document management measures and to recommend passive and active facilities for the Irwin River Estuary and the coastal foreshore area to Granny's Beach. The Plan acknowledges the

regional significance of the site with regards to its cultural heritage and environmental values. By providing and implementing the Plan for the Irwin River, the Shire aimed to maximise the potential for public access and facilities to the area, without compromising its current cultural, environmental, heritage and recreational value. This plan has recently been superceded by the Irwin River Estuary Management Plan 2014. The priority of 2014 plan is to facilitate improved access, signage and low-key recreational facilities which blend into the natural environment to enable residents and visitors to enjoy this highly valued asset.

In 2000, Shire of Irwin Coastal Development Strategy was completed. The purpose of this Strategy was to provide a framework for rehabilitation of coastal lands following the removal of squatter shacks, whilst providing for the establishment of ecologically sensitive small development nodes and coastal access points. The Strategy was somewhat successful, however several issues still remain such as the squatter shacks at Knobbies Head, Freshwater Point, and Cliff head.

2.4. Literature on Data Availability

Several reports have investigated coastal data availability to date in Western Australia such as Climate Change Risk to Busselton(Evelyn ,2013), Coastal Inundation Modelling for Busselton (Martin ,2014), Data and Information Gap Analysis: Coastal Hazard & Risk Assessment, Gingin-Dandaragan Coast, Hill Primary Coastal Compartment (NACC ,2013). and Gingin-Dandaragan Coastal Hazard Risk Assessment (NACC ,2015).

Predicted sea levels along the Western Australian coast are analysed by Bicknell within Sea Level Change in Western Australia: Application to Coastal Planning (2010). It was noted within this report that there is undisputable evidence that the global mean sea level will continue to rise over the 21st century as a direct result of anthropogenic climate change, and the regional projects indicate that the rate of sea level rise along the Western Australia coastline will be similar to the global mean (Bicknell, 2010).

Maximum water levels for different average recurrence intervals (ARI) have also been assessed for the coastline subject to this CHRMAP (Haigh et al. 2012). Further this study presents some statistical water level data in Geraldton, which is useful for the present study.

These reports highlight the main data sources such as water levels, wave data and bathymetry are available from the Department of Transport (DoT), and Meteorological data for the Irwin coastline can be accessed from Bureau of Meteorology (BoM). A. The effectiveness of the data and information that is currently available for assessing and mapping coastal hazards, at a scale that is useful for local planning and decision-making, is highlighted in Data and Information Gap Analysis: Coastal Hazard & Risk Assessment, Gingin-Dandaragan Coast, Hill Primary Coastal Compartment (NACC, 2013).

Further, studies such as Coastal Sediment Cells for the Mid-West Coast in (Damara, 2014), The Coast of the Shires of Coorow to Northampton, Mid-West, Western Australia (2012) and Dongara to Cape Burney Coastal Geomorphology (2011) have produced a number of available data sets such as light detection and ranging (LiDAR), digital elevation models (DEM) and aerial photographs.

2.5. Literature on Modelling Methods

There are different models for inundation, with two main models mentioned in the literature. Those are the simplified bathtub model and the dynamic model (Storlazzi, et al 2013). Most of the literature shows "bath tub" approach is a reliable method when the analysis is limited only to inundation modelling., Considering Tidal Modification when Mapping Inundation Hazards in NSW Estuaries (Foulsham, et al, 2013), and Mapping & Responding to Coastal Inundation (McInnes, 2012).

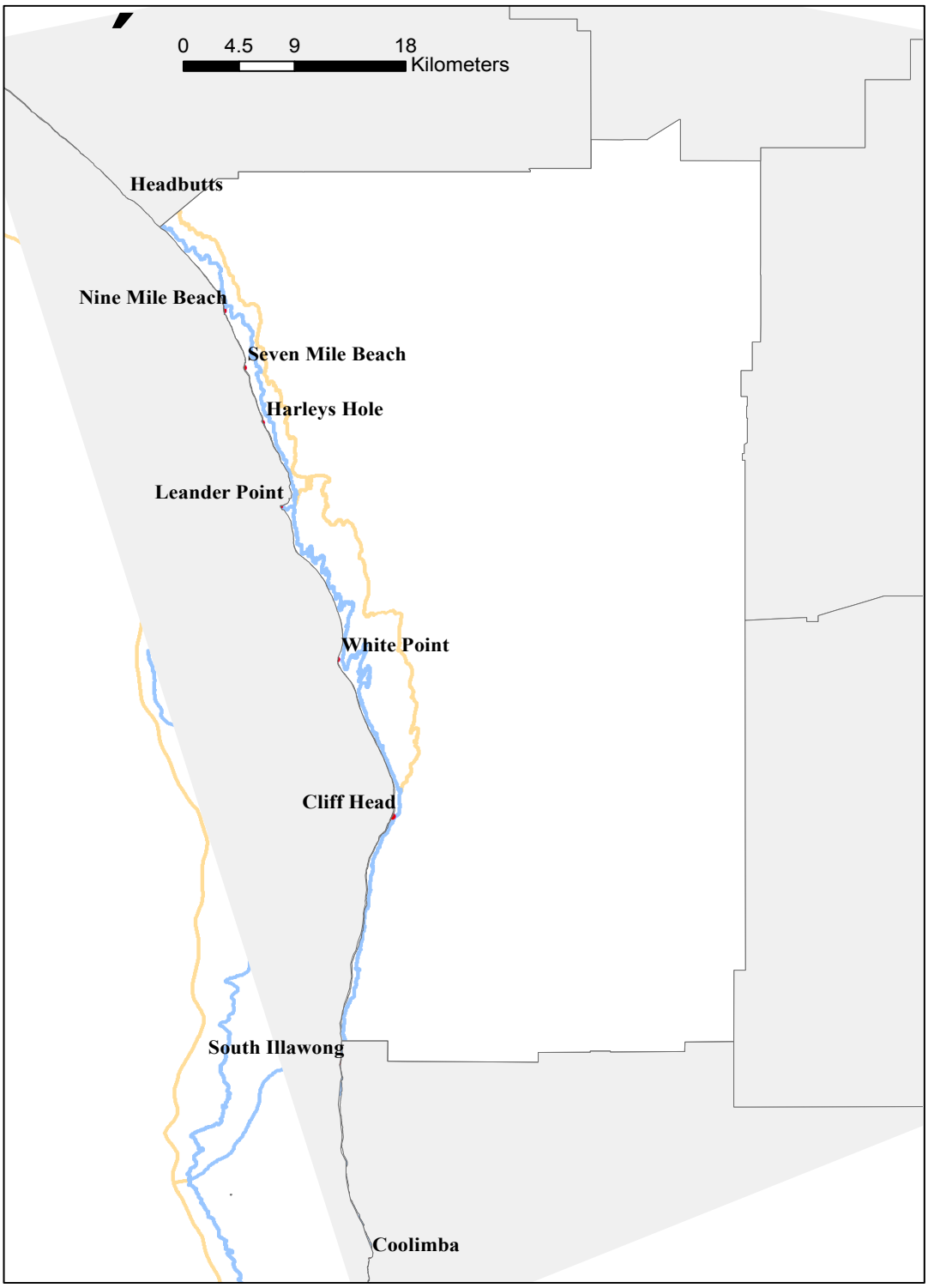
When the study is for both inundation and erosion modelling, researchers used bath tub approach for inundation and another model (usually XBEACH and/or SBEACH) for erosion (Cockburn Sound Coastal Alliance, 2013, Martin, et al., 2014).

Advantage of MIKE21, as identified through several pieces of literature (Evelyn, 2013, Kulkarni, 2013, Pattiaratchi and Wijeratne, 2011) is that it is capable of modelling both inundation and erosion processes.

None of the reports mentioned/discussed the calibration/verification of the model. This may be due to lack of data. Therefore calibration could be done only if historical observations data is available and sourced.

3. Study Area

The Shire of Irwin coastal belt is the main focused study area. The study area is composed of a 75 km long continuous stretch of land from Illawong to the south, through to Bookara which is northern boundary of the Shire. The twin towns of Dongara and Port Denison are located on either side of the Irwin River mouth. The Shire of Irwin is in the Mid-West region of Western Australia and covers an area of over 2, 370 km^2. Fig 1 shows the study area and main important landmark locations.



Source: Coastal Sediment Cells for the Mid-West Coast

3.1. Significance of the Study Area

- Environmental

The Shire's coastline has various areas of environmental significance. These include the internationally recognised wildcatch rock lobster fisheries, two nationally recognised Nature Reserves (including Beekeepers Nature Reserve which is approximately 25% of the Shire's area and has National Heritage Listing due to its exceptionally diverse flora, the and Dongara Nature Reserve), numerous state recognised environmental assets (Irwin River, Irwin River Estuary Foreshore Reserve and Thungara Trials) as well as locally important areas (Granny's Beach, Surf Beach, Seven Mile Beach and South Beach).

Further, a large proportion of the Shire's coastline is undeveloped and contains intact native vegetation. This area has extraordinarily diverse flora (much of which is endemic to the region) and provides critical habitat for native fauna species. Lack of development which may represent an opportunity for natural coastal landscapes and ecological values to be preserved and managed in advance of potential development pressures.

- Cultural heritage

The Shire's coastline holds mythological and historical significance to the local indigenous people (Yamaji). The Heritage Council of Western Australia place register lists the mouth of the Irwin River as a heritage site (Place No. 12480). The Shire of Irwin Municipal Inventory Place Records also lists the Irwin River mouth as a heritage site due to its connection to the establishment of the first port and harbourmaster's house dating from the early 1850's. The area also has two quarries and a shipwreck site just beyond the estuary.

- Social

The coastal zone in the Shire holds a 'sense of place' for residents and tourists alike. The Port Denison Harbour is largely considered as the place that holds the largest social significance within the Shire, with many different people associating this asset with recreational activities (swimming, snorkelling, fishing and kayaking), community events (Larry Lobster Festival, Blessing of the Fleet and Australia Day activities) and sporting events (Kitestock: the premier kitesurfing event in WA). Several beaches (Granny's Beach, Surf Beach Seven Mile Beach and South Beach) also hold important social significance, being associated with popular recreational activities.

- Key economic drivers

Agriculture, fishing, mining, residential and tourism are prominent and valuable sectors in the Shire's diverse economy. The Port Denison harbour is the key coastal infrastructure of

economic significance. The Shire believes that in general, these economic and employment sectors are sustainable and have the potential to generate income in the future. However, shortfalls in recreation, tourism accommodation and aged care/ housing facilities have been identified.

3.2. Pressures and Stress in the Study Area

The Shire of Irwin's coastal zone is experiencing various pressures due to natural and anthropogenic activities. These include substantial population growth, increased construction, a rise in tourism numbers, increased pollution, modification of sediment transport processes, sea-level rise, storm surges, tides and wave action. As there is development along the Shire's coastal zone, coastal erosion and inundation also present a significant pressure. These pressures can separately and/or accumulatively impact of coastal assets and diminish the assets' functionally.

Each of the current pressures operate at different spatial (local to regional), temporal and economic scales. For example the Shire's population is gradually increasing over time and extending further along the coastline. The scale of increased construction reflects this pattern throughout the region. There is an influx in tourism numbers during peak holiday times (school holidays, Easter and Christmas), bringing with it a surge in the local economy. The popular Granny's Beach is subject to coastal erosion (from wave movements and ocean swell), at varying levels throughout the year. In particular during periods where northerly winds predominate the pressure from erosion is greater.

Without effective management these current pressures will continue into the future. Furthermore, climate change will exacerbate these pressures through rising seas levels, increased number of extreme events, increased temperature and decline in rainfall. In the face of this predicted global climate change the Shire of Irwin will be presented with a set of challenges pertaining to the management and maintenance of its valuable coastal resources and infrastructure. The diversity and conservational significance of the Shire's natural environments and the expanse of 'coastal living' throughout the area, mean the effects of climate change are likely to have a significant impact on the natural/social balance within the Shire in years to come.

4. Identification of Coastal Hazards

After review of the available literature the following coastal issues have been identified throughout the study area. The following sections present the coastal issues recorded in the

literature and other historical records. Information is listed for each location and supported by the relevant literature.

The locations highlighted here are; Freshwater Point, Port Denison Foreshore, Granny's Beach, Granny's/Surf Beach, Seaspray Beach and Seven Mile Beach.

4.1. Freshwater Point

Erosion occurred in 2011 and fisherman's shacks were damaged by erosion. Tamarisk (athel pine) trees are being up rooted due to erosion.

Remediation actions: Seaweed accumulation in the erosion zone has probably prevented more erosion. In 2011, limestone Marl fill was being placed in the eroded areas. (Reference: *Monitoring of Coastal Erosion in 2013*)

4.2. Port Denison Foreshore

The Shire of Irwin has been experiencing erosion of the beach adjacent to the Dongara Denison Holiday Parkwhich is located immediately north of the Port Denison Boat Harbour in 2001. The results obtained from beach profile monitoring confirm that the beach erosion was limited to a 400m long section of the beach extending from about 50m to 450m north of the Port Denison Harbour. The worst erosion occurs at a point about 250m north of the Harbour where about 12m of erosion has occurred over a period of 24 years, i.e. at an average erosion rate of 0.5m per year. There may have been more sand losses in deeper water. However, in view of the relatively small differences in water depth observed between the 1973 and 2001 using near-shore hydrographic surveys, the additional sand loss was believed to be less than 6,000m^3. Allowing for this possible additional sand loss, the net sand loss south of chainage 600m (within 600m, from port to north side) was conservatively estimated to be less than 22,100m^3. i.e. an average erosion rate of about 920m^3 per annum over the 24 year period since April 1977. This is relatively small rate of littoral sand movement. (Reference: *Shire of Irwin- Department of Transport, Port Denison, Beach Erosion Investigations Report, 2001 July*)

The sediment cell from Leander Point to Dongara North is located south of the study area. It influences coastal processes and stability further north through discharge from the Irwin River and erosion of the beach immediately north of Port Denison Harbour. (Reference*: Dongara to Cape Burney, Western Australia: Coastal Geomorphology, October 2011*)

In December 2009, the height of the erosion was approximately 180cm. Erosion has been continually damaging Port Denison area with the Shire having to replenish each year, concrete blocks weighing 350kg each were used to build a wall to protect the area however, these remedial actions were unsuccessful, due to the ongoing impacts of coastal processes.

Erosion problems occurred again in September 2012. Concrete blocks that were used to prevent further erosion have been washed out in September 2012. Sand placed on the flex mat had been eroded, however the mat has remained unscathed due to high tide events in 2012. (Reference: *Monitoring of Coastal Erosion in 2013*)

Remediation actions:

The Shire had placed about 600m^3 of sand (sourced from the sand dune) on to the beach in October –November 2000. (Reference: *Shire of Irwin- Department of Transport, Port Denison, Beach Erosion Investigations Report, 2001 July*)

The Shire arranged to replenish each year, concrete blocks weighing 350Kg each were used to build a wall to protect the area. Flex Mat was placed in the Port Denison foreshore. After laying of all the mat, good quality sand was distributed over the top and grass were encouraged to grow over the top (Reference: *Monitoring of Coastal Erosion in 2013*)

4.3. Granny's Beach

Stormy conditions that caused the erosion problems in August 2009 and the beach erosion occur during winter in 2010. Erosion caused by large ocean swell and seaweed build up. The seaweed buried in the corner of the retaining wall has forced the water to swirl around cutting out the sand from under the footings of the wall and exposed footing in October 2013. Further, the retaining wall has sunk and there was some extensive cracking in the brickwork in this general area. (Reference: *Monitoring of Coastal Erosion in 2013*)

Remediation actions:

In 2008/2009 sand replenishment was undertaken at Grannies Beach. Approximately 13000m^3 of sand added to the beach. Irwin River Mouth was looked at to move sand from this area and replaced it back onto Granny's beach for nourishment in 2009.

Retaining wall repair was undertaken in October 2009. Old limestone blocks were used to build up the foundations before the wall was re-built. Sections of the wall that were still standing, were supported with brackets. They were then pegged and additional concrete was added to strengthen the wall in October 2009. Again, sand replenishment was undertaken in December 2010.

The limestone retaining wall was re-built in November 2011 and the Eroded area was covered with sand in October 2013. Footing has been covered and seaweed has been pushed over the top, compacted and in turn covered with fresh sand to stabilize it and excess seaweed has been moved back into the water to disperse it further north in October 2013. (Reference: *Monitoring of Coastal Erosion in 2013)*

4.4. Granny's/Surf Beach

The first recorded major erosion problem was in October 2009. The limestone rocks were placed along the beach in approximately 1997. The footpath was damaged after winter storm events and extensive erosion occurred at Surf Beach in May 2011.
(Reference: *Monitoring of Coastal Erosion in 2013*)

Based on observed trends in the historical shoreline movement, two major contributors to the erosion are likely to be:

- The construction of Port Denison in 1978, which increased reflected wave energy to the north.
- The large number of extreme water level events that have occurred since the mid 1990's, increasing cross-shore transport of sediment to deeper water.

(Reference: *Shire of Irwin Dongara Beaches - Concept Development, M P Rogers & Associates, April 2012)*

Remediation actions:

The seawall protecting infrastructure with geo-fabric was been completed in 2011 with the exception to the tie in to Surf Beach. (Reference: *Monitoring of Coastal Erosion in 2013***)**

In 2010, the Shire commissioned the staged construction of a rubble mound seawall in front of the caravan park. The first stage involved the construction of approximately 30 m of seawall at the southern end of the caravan park and was completed in 2010. The second stage was completed in 2011 and extended the wall by approximately 170 m. Further seawall stages of approximately 150 m length are required to complete the coastal protection structure and protect the remainder of the caravan park and the car park at Surfers Beach. (Reference: *Shire of Irwin Dongara Beaches - Concept Development, M P Rogers & Associates, April 2012***)**

River sand replenishment was undertaken to reduce the erosion problems on Surf Beach. After the erosion problems in 2010/2011, quarry rock was added to prevent further erosion. Under guidance from the Department of Transport and Landcare, the Shire removed up to half of the existing car park and the footpath and commenced battering down the dune to give better and safer access to the beach. Armour rocks were placed to prevent future erosion and dunes were cut down to allow better gradients and safer access to the beach. Armour rocks were also placed to the sides of the newly constructed surf beach and concrete blocks were used as a border to define the beach from the car park and also to prevent vehicle access to the beach. (Reference: *Monitoring of Coastal Erosion in 2013***)**

4.5. Seaspray Beach

Erosion issues at the Seaspray Beach have unearthed infrastructure placed during the days of the crayfish factory. Pipes and cabling were washed out of the sand dune and rusted off

star pickets, which were used to secure the pipes in place. A suction pipe was exposed by erosion and rusted and unsafe in May 2013. (Reference: *Monitoring of Coastal Erosion in 2013*)

4.6. Seven Mile Beach

Beach access was eroded away and had a 1.5m drop to the beach in October 2013. The dune heading south has under gone extensive erosion through the winter months.

Remediation actions:

Sand replenishment works have helped to protect the adjoining car parking area and fill up the drop caused by winter storms in 2013. Rocks were placed on site in October 2012 to stabilize the access onto the beach. Rocks were topped up with limestone marl during the next two years to allow that access to the beach. Sign boards were added in September 2013 to preserve the dune system in the area. The car park was cut down and imported materials were removed away from the beach in October 2013. Re-shaping the beach was done to prevent safety problems with erosion and cutting out the roundabout system to construct a new parking area in October 2013. The old roundabout has been gravelled and water bound. (Reference: *Monitoring of Coastal Erosion in 2013*)

4.7. Recorded Anthropogenic Hazards in the Coastal Area

In addition to the issues due to natural reasons, the available literature also recorded some anthropogenic impacts on the coastal zone.

Fluctuations in shoreline adversely impact upon use of the coast in some locations. An example is the steepening of the beach and fore-dune area at Carson's Beach. This makes it necessary for off-road vehicles to travel onto the fore-dunes during periods of high tide causing substantial damage to the vegetation of the fore-dunes.

- Where fore-dunes have been dissected by off-road vehicles, (including trail bikes and heavy machinery) there is a need for immediate rehabilitation to prevent further loss of vegetation through deflation. Access to beaches by tracks which are in the same alignment as the prevailing wind direction have been exacerbated by wind erosion.
- Dune erosion and migration is a natural process that is often exacerbated by the reduction of vegetation cover and density as a result of;
    - Off-road vehicle use
    - The trampling of dunes by uncontrolled pedestrian activity
    - Stock and feral animal grazing
    - Inappropriate placement of infrastructure, such as carpark, boat launching areas, buildings (including squatters shacks) which interrupt natural processes; and.
    - Destruction of vegetation by fire

(Reference: *Irwin Coastal Plan- Environmental Assessment and Management recommendations, Shire of Irwin, 2000)*

4.8. Irwin River and the Dongara-Port Denison Bridge

The Irwin River Estuary Coastal Management Plan (2005) states that "the estuary and lower river are affected by tides when the seasonal sand bar is breached". Observations by local people in March 2015 indicate that the tidal impact extended upstream beyond the Dongara-Port Denison Bridge, following a breach in the sandbar.

The original bridge was built in 1889 by Mr Grosse and Matthew Price Snr, and was demolished and a new bridge was built using concrete piers in 1964. Sir David Brand, Premier of Western Australia, officially opened the new bridge on 14/11/1964. The bridge approaches were washed away 1971 when a 1 in 100 year flood was said to be 1m higher than the level of the bridge. The structure suffered from concrete cancer and was closed for some time in 1975. The deck was upgraded in 1996. Following the 1999 flood, the bridge was repaired and strengthened, and the road on the south side of the bridge was lowered. The land on either side of the road here was re-shaped to allow the river to flow round the Bridge on the south side during significant flood events, instead of backing up.

Two 100 year ARI Flood Maps were produced by the State Government's Department of Water in 2012. They demonstrate that part of the town centre and some other adjoining areas will be affected such floods (Shire of Irwin's District Water Management Strategy 2014) and are used to inform the Shire's approach to flood risk. As the river will be vulnerable to the 0.9m sea level rise over the next 100 years and there will likely be an increase in the frequency and intensity of storms, the Shire is concerned about the combined impacts of coastal inundation and flooding on the town centre and adjoining residential areas.

5. Review of Available Data

5.1. Proposed Inundation and Erosion Modelling Methodology

Most of the literature shows "bath tub" approach is a reliable method when the analysis is limited only to inundation modelling. When the study is for both inundation and erosion modelling, researchers used the bath tub approach for inundation and another model (usually XBEACH and/or SBEACH) for erosion. Further, the literature highlights that the advantage of dynamic wave models, such as MIKE21, is that they are capable of modelling both inundation and erosion process.

Based on this information, the proposed modelling method of the project is to:

- Conduct bathtub based modelling (contour plotting) of the water level for each sea level rise scenario and find the extent of inundation in the study area;
- This outcome will also show the areas which have high probability of inundation/high risk areas to give careful consideration in detailed modelling;

- Then the inundation process will be modelled the using MIKE21 (dynamic wave modelling). The model grids will be arranged to portray fine resolution (condensed grids) for the areas shown as high risk (in bathtub model) and other important locations (such as town of Dongara, Port Denison and other highly interested locations identified by the Shire/NACC);
- Conduct the erosion model using integrated approach of MIKE21 and SBEACH models, as MIKE21 is capable of modelling long-shore sediment transport, but SBEACH has more capacity in modelling cross-shore sediment transport phenomena; and
- Calibration and verification of the simulations could be done ONLY if relevant historical observation data is available. Otherwise model will be verified against historical information/records/experience.

5.2. Data Requirements /Availability

Series of data and information is gathered from literature, online sources, personal communications, and other project partners (Department of Transport, Shire of Irwin and NACC). The following table summarizes the required data and their availability.

Table 1: Data requirements and availability

Data	Source	Status
Bathymetry	DoT	Location data
	GeoScience	From UWA – 250m resolution land side Bathymetry
	Google Earth /GSWA	Should be digitized (coast line)
Vegetation line / shoreline movement	DoT / GSWA / Landgate	DoT -1944 data….new data GSWA – Aerial photographs
Topography	NACC	LiDAR data, DEM
SLR	SPP 2.6	SLR Scenarios
Beach profiles	SoI/GSWA	GSWA coast report , ebookshop
Wave and water level	DoT	Geraldton and Jurien Bay
Meteorological data (Cyclone data, current data)	BoM / UWA	To be collected
Wind field data	ECMWF	http://www.ecmwf.int/
Beach geology/ Geomorphology	NACC / SoI	GIS data, GSWA
Sediment data	NACC / SoI	Field tests in April

6. Conclusion

The literature review has provided an overview of the background information that is available, the significance of the project and the pressures and stressors of the study area. The review has also helped to increase the understanding of the basics of the project specifically in regards to other CHRMAP studies conducted nationally and internationally and how they relate to the current study, information on the study area, data availability and modelling methods.

Based on this information, the modelling approach of the project will be to conduct bathtub based inundation modelling initially, and then expand the model to a dynamic model using MIKE 21. The erosion model will be conducted as an integrated approach of MIKE 21 and SBEACH models. This integrated approach will be more successful as MIKE21 is capable of modelling long-shore sediment transport, but SBEACH has more capacity in modelling cross-shore sediment transport phenomena.

Also it is clear that calibration and verification of the simulations has not been done in any of the projects found in the literature. Therefore calibration and verification of the modelling could be done only if relevant historical observation data is available. Otherwise model will be verified against historical information/records/experience.

7. References

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