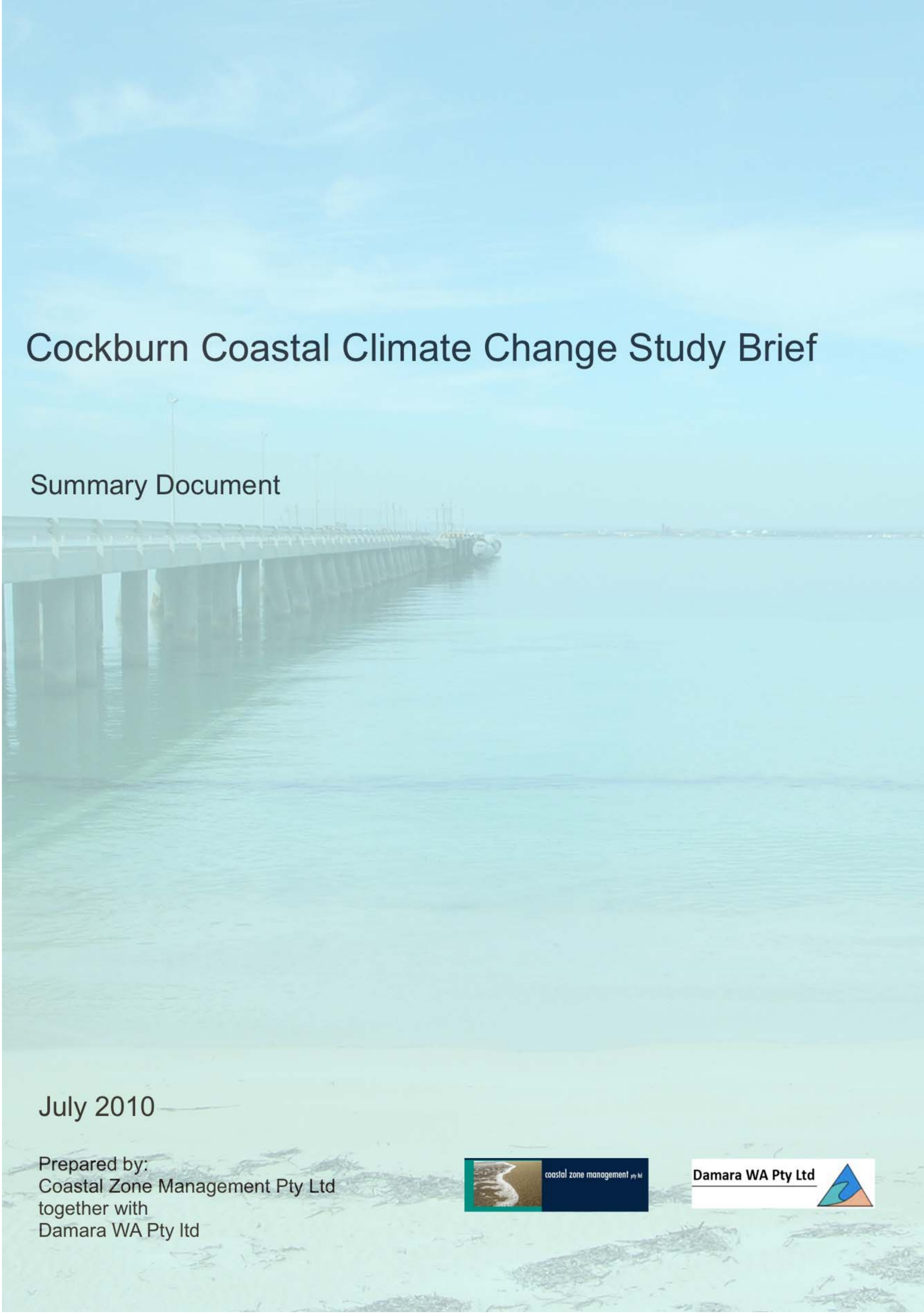

Cockburn Coastal Climate Change Study Brief

Summary Document

July 2010

Prepared by:
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together with
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The views expressed and the conclusions reached in this publication are those of the author(s) and not necessarily those of the persons consulted.

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Acronyms

ABS - Australian Bureau of Statistics
AGO - Australian Greenhouse Office
AMSA - Australian Marine Sciences Association
AWAC - Acoustic Wave and Current Profiling
ARI - Average Recurrence Interval
BoM - Bureau of Meteorology
CoC - City of Cockburn
CoF - City of Fremantle
CoR - City of Rockingham
CSIRO - Australian Commonwealth Scientific and Research Organisation
CSMC - Cockburn Sound Management Council
CZM - Coastal Zone Management Pty Ltd
DALSE - DAL Science and Engineering
DEC - Department of Energy and Conservation
DHC - Department of House and Construction
DoD - Department of Defence
DoT - Department of Transport
ERA - Environmental Resources of Australia
GIC - Garden Island Causeway
GIS - Geographic Information System
GSWA - Geological Survey of Western Australia
IPCC - Intergovernmental Panel on Climate Change
LAPP - Local Adaptation Pathways Program
LGA - Local Government Authority
LiDAR - Light Detection and Ranging
NCCOE - National Committee on Coastal and Ocean Engineering
RAN - Royal Australian Navy
SLR - Sea Level Rise
SMCWS - Southern Metropolitan Coastal Waters Study
SST - Sea Surface Temperature
ToK - Town of Kwinana
WALIS - Western Australian Land Information System
WAPC - Western Australian Planning Commission

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1. Introduction

The Cockburn Coastal Councils, together with the Royal Australian Navy (RAN), are seeking consultants with coastal management and climate change risk assessment expertise and capabilities to complete the ***Cockburn Sound Coastal Climate Change Vulnerability and Adaptation Assessment Project*** [1]**.** The Consultants will be required to fulfill the requirements of the ***Study Brief*** [2] provided in this document and indicate company and personnel capability to produce a report with findings and a proposed adaptation plan.

1.1. Context

Cockburn Sound and Owen Anchorage are located on the South West coast of Western Australia to the south of Fremantle Harbour Figure 1. The coastline in this area is characterised by relatively low energy, fetch restricted, wave climate impacted beaches but is also home to more exposed and sometimes rocky systems. The Sound's range of coastal environments provide a unique habitat for a variety of plants and animals, with existing foreshore reserves lending coastal protection against energetic winds and waves of storm systems. In addition to their complex coastal characteristics, both the Sound and Anchorage are home to a wide range of industrial, recreational, residential and commercial development usage making the area vital to the local and state economy and cultural life.

The area has had a long history as a sheltered anchorage and port. Over the 175 years since the area was used as an anchorage for the first European settlers, Cockburn Sound has become a major haven for shipping and an important site for port facilities. The past fifty years has seen the Sound become the major location for bulk cargo import and export port facilities serving the Perth Metropolitan Area and much of South Western Australia. Industrialisation was accompanied by residential

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[1] Referred to henceforth as the Cockburn Coastal Climate Change Project (4CP) or **(The Project)**

[2] The current study brief **(The Brief)** is the product of a consultancy carried out by CZM pty ltd together with Damara WA pty ltd **(The Preliminary Consultants).** This consultancy was commissioned by City of Cockburn, City of Fremantle, Town of Kwinana, City of Rockingham and Department of Defence (Royal Australian Navy) to scope the larger project to assess potential coastal impacts of climate change and identify associated adaptation options at a range of temporal and spatial scales.

A summary of tasks undertaken by the Preliminary Consultant to produce the Study Brief is presented in the report that accompanies this document **(Cockburn Coastal Climate Change Study Brief Background Report).**

and recreation development. Population growth and industrial expansion within the area has increased dramatically in recent years. This has resulted in increased pressures from impacts that threaten the coastal zone. In particular, the future threat of greenhouse-gas induced climate change and sea level rise mean that the coastal zone is likely to be subject to accelerated long-term and cyclic erosion in coming years. If these impacts are to be mitigated and/or adapted to, then it is vital to establish which areas are likely to be affected and what form likely impacts will take. The impacts of climate change will potentially eventuate in a rise in sea level and an increase in the incidence and severity of coastal inundation and erosion. This will be particularly so if accompanied by more extreme and/or more frequent storm events.

1.2. Motivation

Local Government Authorities (LGAs) in Cockburn Sound and Owen Anchorage currently regulate development within their coastal zone, considering associated risks from coastal erosion and inundation. This largely occurs as a component of Town Planning Schemes, which are required to conform to the relevant State Coastal Planning Policies. Planning decisions by Local Government and the WAPC at Regional and Local Structure Plan level, and for development applications and local management plans, relate to the usage of land (including investment in infrastructure) for a very considerable time (100 years plus). The RAN also manage their assets with an awareness of shoreline change and water level fluctuations within their environmental sustainability programs and are currently involved in planning strategies that address environmental concerns.

LGAs in the area are responsible for extensive coastal infrastructure such as coastal protection, buildings, recreational facilities, recreational areas and coastal roads. These infrastructure resources, and those of other government agencies and private interests fronting the coast, are at the front line in terms of coastal erosion and inundation risk. Their effective management both now, and in the future, requires an understanding of the exposure and sensitivity of the surrounding coastline to the potential impacts of natural variability and climate-induced change.

The key stakeholders involved in commissioning this study brief (4 LGAs and the RAN) are acutely aware of the potential impacts of climate change along their coast and have a strong desire to take strategic, proactive action in terms of assessing possible coastal risks, on behalf of themselves and other stakeholders with interests in the built and natural assets along the coast.

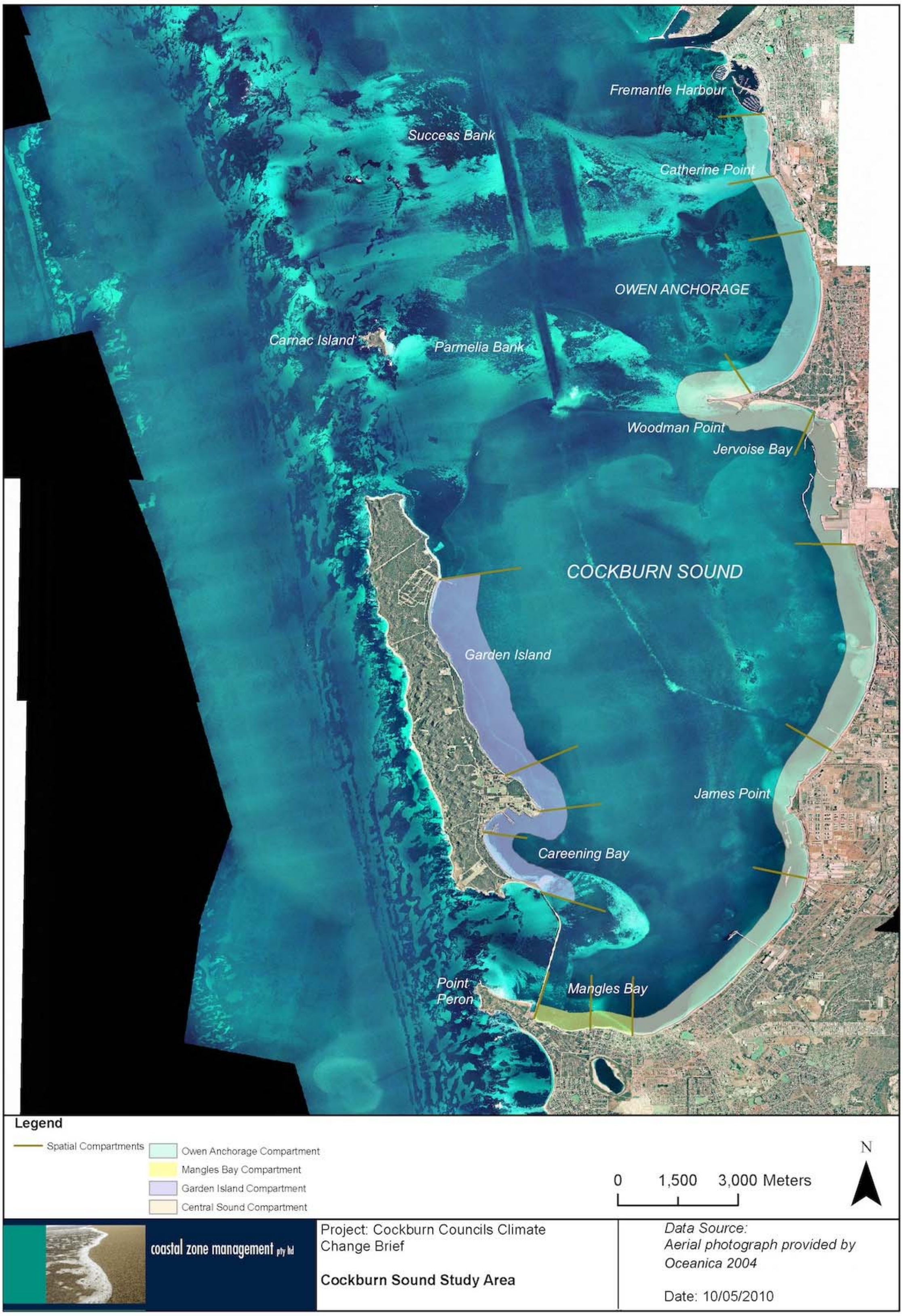

Figure 1: Annotated aerial photo of the study area (Imagery courtesy of Oceanica pty ltd)

The Cities of Rockingham, Cockburn, Fremantle and Town of Kwinana have all previously participated in the SMRC LAPP II risk assessment process that involved a strategic assessment of risk for the area and recommended a corresponding series of adaptation options and actions.

While this study provided a useful starting point in terms of climate change risks for the area, the findings were, in general, very broad in nature and lacked specific, tangible adaptation options or pathways for implementation at a council-by-council level. This is seen as a key knowledge gap for the area and has provided major impetus for commissioning the current Study Brief to inform a larger, integrated and locally relevant coastal climate change vulnerability and adaptation assessment project for Cockburn Sound.

1.3. Project Aims and Objectives

The overall aim of the Project is to assist decision makers in enhancing the resilience of the Cockburn Sound Coastal Zone and informing them of to the likely impacts of a changing climate. The objectives in achieving this aim relate to the modelling of coastal erosion and inundation impacts of climate change for the study area, as obtained from simulation based on the most up-to-date data. It is intended this information be subsequently used to assess coastal vulnerability at specified planning horizons followed by an elucidation of adaptation scenarios at a range of scales. The specific tasks associated with fulfilling the Project Aims and Objectives are discussed in further detail in Section 2 that follows within discrete project ‘Phases’. These Phases relate to the overriding Project Objectives as follows:

1. ***Objective 1: Establish Physical Sensitivity (Phase I)*** – What change can be anticipated to occur? Where? When?
2. ***Objective 2: Assess associated Vulnerability (Phase II)*** – What impacts can be expected to occur as a result of this change? Where? When?
3. ***Objective 3: Prioritise Response (Phase III) –*** What is the importance and urgency of dealing with the impacts?
4. ***Objective 4: Assign Adaptation Options and Actions (Phase IV)*** – How will the impacts be addressed at a range of temporal and spatial scales? – Whole-of-Sound and site specific. What? When? How Much?
5. ***Objective 5: Formulate an Adaptation Implementation Plan –*** How will the adaptation planning carried out in Phase IV be implemented? By Whom?

2. Scope of Consultancy

A key component of the work to be undertaken by the **Consultant**[3] is the locally relevant modelling of coastal erosion and inundation impacts of climate change for the study area as obtained from simulation based on the most up-to-date data. To inform this process, a data collation exercise and gap analysis was commissioned by the key Project stakeholders (City of Cockburn, City of Fremantle, City of Rockingham, Town of Kwinana and Royal Australian Navy). This work was carried out by the **Preliminary Consultant** to inform preparation of the current **Study Brief** and involved the collection of relevant data pertaining to physical and biological characteristics of the Cockburn Coast, particularly those related to impacts of sea level rise, wave action, storm surge, sea temperature rise and shoreline change. The availability of pertinent information sources and their relevant formats, custodians and limitations were also identified (listed in full in the Background Report and its Appendices). In addition to a review of available published consultancy reports, research papers and technical communications, a survey of spatially available information (i.e. GIS format) and associated GIS capability within each of the participating councils and for the RAN on Garden Island was also carried out.

The Consultant will be required to prepare coastal erosion modelling building on the information identified in the review carried out by the Preliminary Consultant ***(Cockburn Coastal Climate Change Study Brief Background Report)*** and will prepare scenarios for coastal climate change using the following approach and methodology.

2.1. Assessment Framework

While a wide range of approaches may be used to conduct the coastal erosion and inundation component of the Cockburn Coast Project, the most relevant of these to the climate change question and proposed for this study is a vulnerability assessment pathway. This will allow accurate elucidation of the relationship between potential impacts and associated management responses. A key aspect of the proposed Project is the focus on the increasingly detailed information that has recently become available for use in a physical processes assessment of this kind.

[3] The Consultant here refers to the successful tenderer for the Larger Project to which this brief refers; that is, NOT the preliminary consultants (CZM/Damara Pty Ltd) engaged to formulate the current study brief.

Table 1: Summary of relevant data sets

Data	Description	Gaps
Topography	Topographical information extending from shallow waters and subtidal areas to supratidal coastal lands is considered the fundamental dataset for the coastal zone	Although topography of land has been accurately surveyed & bathymetry of oceans has been established the two datasets are not seamlessly integrated. Recent LIDAR information should remove many of the previously encountered barriers in gaining accurate topographical information for a vulnerability assessment
Biophysical ocean conditions	Changes in temperature, currents and coastal nutrients. will have significant impacts on the coastal region. Need to use high-resolution techniques for future assessment	Need to link physical changes with changes in biogeochemical conditions and ecosystem impacts.
Geomorphology	Physical descriptions of the coast are important for definition of biogeomorphic regions and the provision of an adequate benchmark for change	Need to be assessed at a range of scales. Must consider morphological signature of coasts with varying influence of wave, tide and surge effects. Recent work on Sediment Cells by DoT and coastal typology by WAGS has provided an innovative step towards addressing this gap
Coastal Structures	Man made structures such as groynes, breakwaters, marinas, reclamation areas, etc. affect wave and current climate and influence and sediment transfers, current and into the future with increased sea level and changing wave climate	Recently commissioned study by DoT (then DPI) looked at coastal protection structures for which the State is responsible (Barr & Eliot, 2009); Additionally, local governments have varying degrees of mapping information on location of coastal structures and in some cases, associated condition. There is a need to collate mapping information in consistent format and also consistently establish 'condition' to aid determination of adaptive capacity in the face of changing climate
Shoreline Delineation and Mapping	Change detection is greatly aided by consistent data referenced to a common datums and collected using standard protocols.	Need for a developed protocol for mapping shorelines and their change. This should be done in collaboration with federal, state and local government to ensure consistency of baseline for assessment in a shared care area like Cockburn Sound.
Habitat Mapping	An assessment of the considerable diversity of coastal and marine habitats is a critical for effective coastal management to support planning decisions and the establishment of appropriate monitoring programs for habitat change detection.	High-resolution habitat mapping should be incorporated with geomorphological investigations) While it is necessary to have a wide appreciation of attributes of the study area as a whole, it will subsequently be necessary to undertake more detailed mapping in areas where adaptation or mitigation measures where identified as being required
Wave Climate	Knowledge of wave climate is important for establishing coastal resilience when conducting a vulnerability assessment. Data may be generated from wave-rider buoys or AWACs which may be extrapolated through the use of wave models	The fine-scale variation of wave conditions within the Sound requires a complex wave measurement program to fully describe the wave climate. The majority of existing wave climate modelling in the Sound has been undertaken by MP Rogers & associates using proprietary wave modelling software 2GWave. This is not freely transferable, and hence provides limitations to modelling

		application by different consultants. Ongoing work being undertaken by researchers such as Ivan Haigh and Charitha Pattiaratchi at the University of Western Australia may be relevant to the wider study proposed in Cockburn Sound. As such, the status of this research should be established during the Project Inception Phase of the Proposed Cockburn Vulnerability Study to determine pertinent information.
Imagery and Photography	Aerial photography, imagery and satellite photography provide an important means of benchmarking and mapping coastal change	Generally good coverage but in many cases analysis is lacking. Need consistent identification of change benchmarking features. In Cockburn Sound there is a need to co-ordinate this evaluation and incorporate previous work by consultants such as Oceanica with contemporary analysis based on LIDAR.
Socio Economic Data sets	Mapping of human use of the coastal zone is a critical component to support vulnerability assessment	Inadequate inclusion of socio-economic data in coastal datasets – unaware of any pertinent data sets for the Sound over and above. ABS information is available per local government but would need to be expanded on to more accurately assess the potential impacts of climate change Potentially relevant information in Perth Coastal Management Strategy on beach usage.

In particular, this Project may represent an opportunity to use the detailed LiDAR topographic and bathymetric information collected by the State government, and building on concurrent complementary studies (as recently undertaken in Busselton for example).

The consultant will employ an approach that refines an evidence-based framework that identifies and quantifies change to coastal landforms within a scaled hierarchy of compartments defined by geological and geomorphologic criteria[4] and introduced coastal structures. This approach has been employed previously in the risk assessment process at Cottesloe, Mandurah and Scarborough and is summarised in Figure 2.

2.1.1. Preliminary Study Compartments

The Consultant will carry out investigations at an appropriate ‘compartment’ scale. Preliminary delineation of compartments was carried out in conjunction with the data inventory and gap analysis exercise completed towards preparation of this brief (Figure 3). The compartments were delineated based on a consideration of coastal geomorphology at discrete locations within the study area, known directions and modes of change and the geographical expression of prevailing and dominant process drivers within the system. While it is recognised that compartment boundaries may require modification following more detailed elucidation of process-response relationships, the Consultant should use the delineations in Appendix A to this document as a working model.

2.1.2. Climate Change Scenarios

The most widely applied climate change science is developed through the Intergovernmental Panel on Climate Change (IPCC) series of assessment reports, most recently the Fourth Assessment Report (IPCC 2007 AR4). This provides detail on global scale climate modelling associated with a range of future scenarios based upon greenhouse gas emissions, technological change and population growth.

Application of the latest modelling results requires subsequent interpretation at regional, sub-regional and local scales. Consequently, much of the available recent literature relates to the IPCC Third Assessment Report (IPCC 2001 TAR). A framework for considering coastal impacts is suggested by the National Committee on Coastal and Ocean Engineering (NCCOE 2004). The most relevant published

[4] The methods to be applied in this assessment are outlined in detail in this proposal. The objective is to ensure the highest quality approach to assessment. However, consultants may submit alternate approaches/methodologies along with detailed explanation of the added value the recommended changes provided to the brief.

information on climate projections for the Australian region, including the Cockburn Coast is *Climate Change in Australia* (CSIRO 2007). This summarises an array of available information sources and details projected climate change impacts for the Australian region for 2030 and 2070 (Table 2). However, it will be necessary to modify these projections to be locally relevant for application in the Owen Anchorage and particularly in the lower reaches of Cockburn Sound due to the importance of locally generated wind waves and their associated process/response relationships. In addition, several of the local government stakeholders have expressed a desire to consider impacts at a 2100 timescale. While a figure of 0.9 m rise is currently being adopted as a projection for sea level rise within this timeframe at a national level, a comprehensive assessment of impacts for this timestep will require further elucidation of projections for other coastally relevant climate variables. Due to the rapidly evoloving nature of the state-of-the-art of climate science, this should be reviewed at the outset of the consultancy. That is, the status of available information at the time of Project inception will dictate a) the most appropriate figure(s) to use for SLR out to this extended time frame to Yr 2100; and b) what elements additional to changes in mean sea level should be included in scenarios for change (e.g. timing, frequency and intensity of severe storm events).

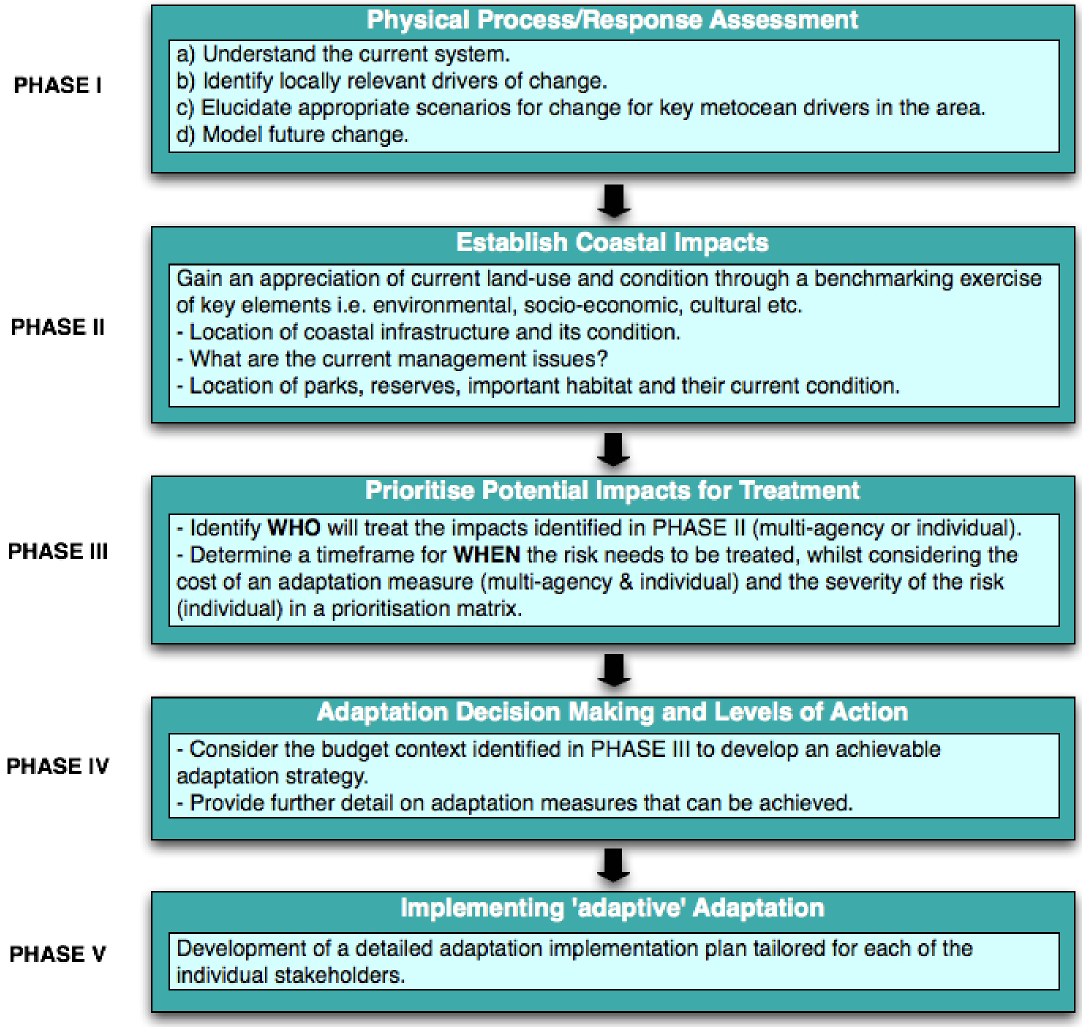

Figure 2: Project work phases

Figure 3: Example of a locally relevant study compartment

Table 2: Key environmental variables and climate change scenarios for the Perth region

Key Variable	Code	Perth Regional Coastal Scenario	Comment
Mean Sea Level	K1	Projected range of sea level rise (m) relative to 1990 baseline: The IPCC AR4 provides maximum and minimum projections for the decade 2090-2099 and for the potential dynamic response of the Greenland and Antarctic Ice Sheets but does not provide time series for projections of sea level rise throughout the 21st Century. Therefore, Hunter (in press) analysed the AR4 outputs in combination with the TAR outputs to establish time series data [5]. Values given to 2 decimal places, but exclude potential additional rise through Greenland and Antarctica ice sheet melt. Scenario Percentile 2030 2070 B1 95 0.13 0.33m A1B 95 0.14 0.41m A1F1 95 0.15 0.47m Recent research has indicated that these figures are likely to be tracking towards 0.9 to 1.1 m figures at Yr 2100.	Based on tide data analysis (Mitchell et al., 1999) Fremantle appears to be tracking to global average sea-level rise. Importantly, the decadal scale changes driven by climate variability are markedly different from global averages – by definition. This is important because these shorter-term fluctuations are likely to drive immediate changes. As reported in CSIRO (2007), through analysis of the climate models under the A1B1 scenario there appears not to a positive or negative factor than should be applied to global predictions of future SLR It is acknowledged that there may be a need to apply a Precautionary Approach in the proposed study for Cockburn Sound and Owen Anchorage – that is, not target low SLR rise values just because higher figures carry increased levels of uncertainty of occurrence. The sealevel rise figures and timesteps to be used in the proposed study should be evaluated at the outset of the Project and agreed upon by all stakeholders given the state-of-the-art of this evolving science at this time.
Ocean Currents and Temperature	K2	By 2030 the best estimate of sea surface temperature (SST) change is 0.4-1.0ºC using the A1B scenario (CSIRO, 2007 Australia). Beyond 2030 the SST changes are dependent on the emission scenarios: Median values of SST (CSIRO 2007: fig 5.49) Year 2030 2070 B1 0.3-0.6 1.0-1.5	It is not clear at present, how potential climate-change driven changes to SSTs will affect the Leeuwin Current. As such, this has implications for SSTs immediately offshore of Perth, with implications for foreshore vulnerability (direct sea-level impact) and also primary productivity with potential implications for sediment supply.

[5] See http://www.cmar.csiro.au/sealevel/sl_proj_21st.html#21C_ts

		A1B 0.6-1.0 1.5-2.0 A1F1 0.6-1.0 2.0-2.5	
Wind Climate	K3	Mean wind speeds are predicted to increase in southwest WA in summer and autumn by 2-5% under A1B scenarios and decrease in winter by 2-5%, with no changes in spring. Overall, the net effect is no less than +/- 2% change in annual means (CSIRO, 2007) Wind-speed (%) scenarios for Perth (CSIRO 2007: Table B11: 50% probability) are: 2030 2070 A1B A1FI Annual 0 -1 Summer +2 +8 Autumn +2 +6 Winter -4 -14 Spring -1 -3 These scenarios suggest an overall very small reduction in mean annual wind speed, with disproportionate seasonal changes – a reduction in winter/spring, and increase in summer/autumn.	However, Perth regional winds are highly event driven and influenced by local land sea-breeze cells (Pattiaratchi et al., 1996). Mean wind predictions will not represent these processes. Extreme winter wind projections are expected to reduce in a similar proportion to mean winter wind speeds. It is less certain whether extreme summer winds will, or are likely to, increase corresponding to mean summer winds.
Wave Climate	K4	No recent scenarios of the implications of climate change on local or swell-driven waves. Inferring wave climate from the wind climate projections (local wind wave component only) suggests a lower proportion of local wind-waves. Climate change scenarios move the swell-wave generation zone further south. At present the mean sea-wave is 2.5 m off the SW Capes and 1.5m off Shark Bay. Assuming that this North-South gradient of swell-wave energy is maintained in the future, it may be	These are initial interpretations only. The recent analysis of Hemer et al (2008) analysed historical wave climates for all Australian waters. This study is expected to form the basis of future studies that link measured historic wave climate variability with climate change models. An important consideration with respect to wave climate variables for the study area will be the ongoing work of researchers at the University of Western Australia (Haigh & Pattiaratchi). As such, the status of their work should be

		inferred that mean swell waves will decrease, and that greater decreases will occur under the higher emission scenarios.	reviewed at the outset of the proposed project to determine pertinent information for the study area.
Rainfall / Runoff	K5	Rainfall changes % change (CSIRO, 2007 Table B11: 50% probability): 2030 2070 A1B A1FI Annual -6 -19 Summer -4 -12 Autumn -4 -12 Winter -7 -22 Spring -9 -27 Runoff changes (%): 2030 2070 A1B A1FI Annual -18 -57	While changes in the frequency of occurrence of high intensity precipitation events are possible, the current understanding of climate change in SW WA precludes any conclusions being drawn in this regard (Berti et al, 2004; Pearcey, Department of Water, pers comm., Nov 2008). The work of the Department of Water with CSIRO (Berti et al, 2004), including work soon to be published on the Serpentine catchment (Pearcey, pers comm.) has developed a 'rule of thumb' of a three times multiplier of mean annual rainfall to the resulting changes in annual runoff. These multipliers have been applied here.
Air Temperature	K6	Rise in land surface air temperature degrees Celsius (CSIRO, 2007 Table B11: 50% probability): 2030 2070 A1B A1FI Annual 0.8 2.7 Summer 0.9 2.9 Autumn 0.8 2.7 Winter 0.7 2.3 Spring 0.9 2.9	Increases are possible in the frequency of occurrence of extremely high temperatures with reductions in the frequency of very low temperatures.

2.2. Phase I and II: Coastal Change Assessment

The Consultant will carry out a coastal change assessment through completion of the tasks listed within work Phases I and II (Table 4 and Table 5). This will entail an elucidation of locally relevant process/response relationships within in the Sound and Owen Anchorage; subsequent modelling of potential physical change under identified climate change scenarios; and assessment of vulnerability of key elements within the coastal zone as a result of this projected change.

Locally, within the Sound and Owen Anchorage, key factors to consider will be changes to the local wind field with subsequent implications for locally generated wind waves and associated longshore sediment transport. It will also be important to consider proposed future dredging of the Sound and anchorage and possible implications/impacts of this within the study area, for example for Fremantle Outer Harbour, Shell Sand Dredging and Shipping Channel dredging.

2.2.1. Phase I: Physical Process /Response Assessment

a) Understand the current system - interaction between metocean drivers, physical process, change receptors and response.

b) Identify locally relevant drivers of change – establish past modes and levels of change and relate to prevailing and dominant process signatures i.e. establish contemporary sensitivity.

c) Clarify appropriate scenarios for change for key metocean drivers in the area.

d) Model future change - create a morphodynamic model to predict the likely physical response to projected change at a compartment specific scale. This should include a consideration of new human influence with new developments (marinas, ports etc.) proposed along the coast

Table 3: Range of Physical Impacts

Physical Impact	Erosion / Accretion	Inundation	Change to Drainage	Change to Groundwater
Observation	Shoreline Position	Tide Gauge Data; Coastal Impacts	Runoff Flooding	Borehole Logs
Key Parameters	Winds, Waves & Water Levels	Water Levels	Rainfall; Water Levels	Groundwater; Water Levels
Data Collection	DoT tide gauges & waveriders; BoM anemometers	DoT tide gauges	BoM rain gauges; DoWflow gauges; DoT tide gauges	DoW borelogs; DoT tide gauges

Table 4: Tasks to be completed by the consultant within Phase I

Phase I: Physical Process/Response Assessment			
Understand the current Environment and Identify the drivers to which discrete compartments are sensitive What are current Metocean Drivers? What are prevailing and dominant physical processes within the Sound? How are these expressed at a compartment based scale? What are the underlying physical characteristics of each coastal compartment? How have compartments traditionally responded to physical process drivers? Is it possible to identify the key drivers/processes that each compartment is sensitive to?			
Attribute	Descriptions	Details	Required Actions
Metocean Drivers	Hydrodynamics Shelf waves Wind Waves Forcings – circulations and wave patterns	Interpretation of historic coastal dynamics and projected future change at a local scale requires a detailed understanding of the wave and water level variability under climate change.	Gross data sets already exist and be downscaled to the level necessary to understand discrete coastal behavior within areas of the Sound It will be necessary to modify CSIRO predictions for change to account for importance of locally generated wind waves in Cockburn Sound and to lesser extent Owen Anchorage
Physical Processes/Secondary Behaviour	Secondary Behaviour - Regional Characterisation of Sediment Transport Using LiDAR	Sediment transport pathways within the study area will be identified and quantified from the high resolution LIDAR collected by the Department for Planning. This data assists with the identification of offshore geology and benthic vegetation. The LIDAR data provides a critical resource for highlighting likely erosion hotspots and identifying the potential downdrift extent of any impacts caused by protection works used for adaptation.	Of key importance within the study area will be an analysis of the major sediment behaviour feeds at: John Point South West Point Entrance Point Woodman Point Catherine Point
Coastal Compartments	Sediment cells within the Sound have previously been identified through geomorphology and their behaviour verified through wave modelling	The current study proposes to build on this work to identify beach-scale compartments for coastal vulnerability and adaptation assessment activities. The rational for this exercise lies in the fact that adjacent coastal locations within the Sound are subject to fundamentally different combinations of process/response relationships and subsequent susceptibility to change.	The preliminary work carried out to produce this study brief has identified 'working' beach scale compartments for further analysis in the wider Project

Phase I: Physical Process/Response Assessment			
Morphological Scale Investigations	Typology	Local observations have indicated that sandy beach process-response models provide an inadequate representation of mixed rock and sand beaches and so will not provide useable projections of future climate change impacts. However, to date these investigations have not extended to the beaches within the Sound.	A preliminary step in the planned project would be a review of the available information from both Smartline mapping and the more detailed shoreline mapping carried out by Bob Gozzard, Ian Eliot, and Chris Nutt to identify, where, if at all, perched beaches were located within the study area. This information would subsequently be used to inform the commission of potential geotechnical investigations a precursor to a larger study. This would pre-empt a previous problem encountered when trying to undertaken coastal climate change risk assessments of this type.
	b) Variability	Establish past modes and levels of change and relate to prevailing and dominant process signatures i.e. establish contemporary sensitivity	The collective response of the interconnected set of sediment cells to potential climate changes will be evaluated by examining changes to the wave climate and corresponding sediment transport regime. The sensitivity of sediment cells to change and at a more detailed scale, the coastal compartments delineated through production of this brief, will require assessment Analysis of existing extensive aerial photography for the Sound to determine directions and rates of shoreline change within the Study area. Supplement this information with an analysis and collation of numerous profile monitoring exercises completed by RAN for lower Sound and Cockburn Cement, Jervoise Bay, Catherine Point/Port Coogee in North and for Owen Anchorage.
Projected Physical Impacts	Morphodynamic model of physical coastal change	Information on contemporary sensitivity at a local scale and projections for changes in pertinent metocean drivers can be used to model potential impacts of a changing coastal climate at a compartmentally relevant scale.	The process-response relationship of discrete coastal compartments will inform production of a morphodynamic change model in response to locally specific predictions for changes in water level, wave climate, wind direction

2.2.2. Phase II: Establish Coastal Impacts

A comprehensive, locally relevant assessment of potential impacts of coastal climate change will involve and appreciation of current land-use and associated 'condition' or status from a socio-economic, environmental, and/or cultural perspective. Subsequent to this benchmarking exercise the consultant will address the following questions:

- What is the range of potential impacts likely to affect the Sound?
- Where are they likely to occur?

Table 5: Phase II tasks

Element	Description	Details	Required Action
Landuse Mapping	Comprehensive landuse mapping required per sector per coastal compartment to reflect 'key elements' against which impact will be assessed	Currently comprehensive data on industrial and development usage but not for ecosystems and habitats.	Ensure all appropriate 'assets/values' of key stakeholder groups are accurately mapped in order to effectively determine likely impacts of physical coastal change.
Condition Assessment	Necessary to complete an assessment of the current status or condition of key elements in each compartment as a baseline against which to assess change and inform potential adaptive capacity	Some information on condition assessment exists for coastal infrastructure (specifically coastal protection structures throughout the study area) but information on LGA managed infrastructure assets and spatially referenced, integrated information on ecosystems health is lacking	Develop criteria for condition assessment for discrete key elements throughout the Sound Carry out baselining exercises to answer key questions 'What is there – in terms of socio-economic, environmental, social/cultural assets' and 'what is its current state?' This will inform HOW it will potentially respond to change in future
Impact Assessment	Impacts of physical change on key elements will be considered based on an evaluation of the information collated through landuse mapping and condition assessment exercises	Completion of this task will require an evaluation of previously elucidated physical change in the context of landuse mapping and condition assessment	Mapping of extent of coastal erosion and inundation presented in GIS format and overlaid on landuse mapping Preliminary assessment of impact on key elements based on intersection with 'change' lines in terms of terrestrial components or likely exceedance of known thresholds for impacts in terms of marine components Secondary assessment of impact based on appreciation of condition assessment i.e. is the seawall that is likely to be subject to erosion in 2030 a robust structure that has an inherent adaptive capacity?

2.3. Phase III: Prioritise Potential Impacts to Address

Having identified the range of impacts to which Cockburn Sound and Owen Anchorage will be susceptible and where they are likely to occur (i.e. spatially relevant impact assessment), the next step in the analysis will be to decide who is responsible for addressing them (Figure 4). This will fall into one of either two categories:

1) Multi-organisational.

2) Individual.

The decision-making pathways relevant for the prioritisation of risks to address will be determined by the level at which the risk needs to be assessed, so 1) or 2) above. For an individual LGA or for the RAN, or other key stakeholders, the next point of consideration will be the timeframe within which an impact will require treatment i.e. Urgent, Future or Possible (Figure 5). This occurs in conjunction with an evaluation of the indicative cost[6] of adaptive measures to inform production of a prioritisation matrix, which essentially may also be considered as an adaptation funding model. In the case of a multi-organisational response to an issue, the severity and probability of the potential threat needs to be considered in conjunction with the timeframe in which adaptive response is required and the associated indicative costing.

Table 6: Phase III, Prioritisation of Impacts for Treatment

Element	Description	Details	Required Action
Responsibility	For each risk identified, both on a whole of Sound level and a compartment by compartment basis, it will be necessary to assign responsibility for subsequent adaptive action – i.e. who will treat the impact.	Action will be applicable at either an individual stakeholder level or across multiple agencies.	An adaptation workshop should be attended by identified stakeholders to assign responsibility for treatment of impacts and discuss the decision making process for adaptation action.
Timeframes	When will the identified climate change impact require treatment.	Dictated by level of chronic and acute impact and understanding of sensitivity.	Assign a timeframe to each impact: Urgent: Does not require element of chronic change to be at risk.

[6] A fully costed assessment of adaptation action is beyond the scope of the current project. Rather indicative costs will be assigned based on consultation with key stakeholders.

			Future – requires elements of chronic change to occur. Possible – requires chronic change and still has limited risk overall.
Cost	How much will adaptive action cost.	To complete the prioritisation exercise it will be necessary to assign indicative costs to potential adaptive responses.	Assign indicative cost estimates of low, medium, high, and extreme (too high) to impacts. The thresholds and ranges for these indicative costs should be agreed in the workshop setting.

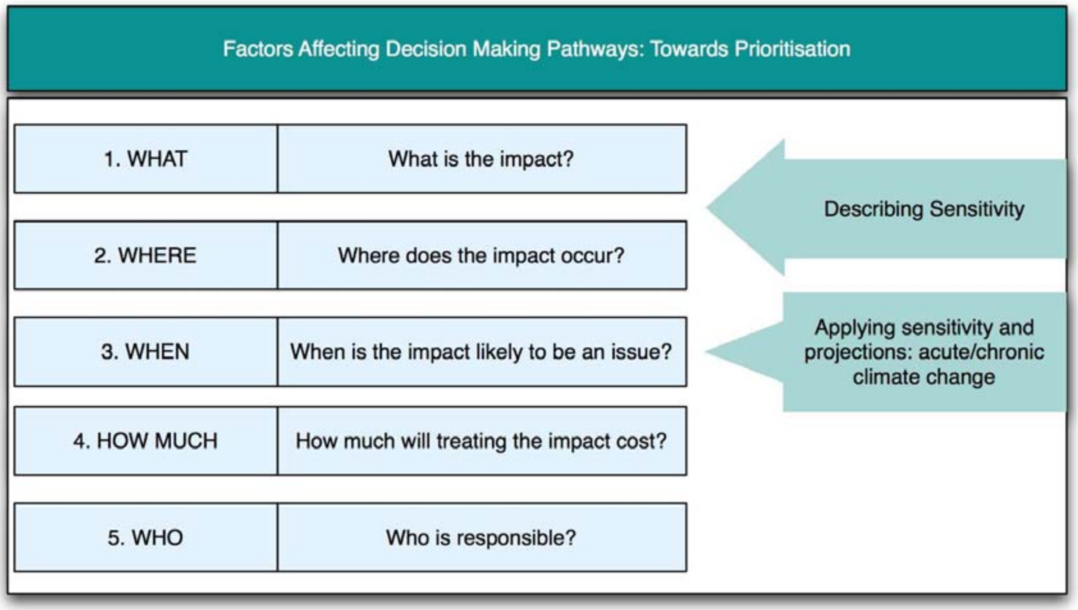

Figure 4: Adaptation Decision Making Pathways

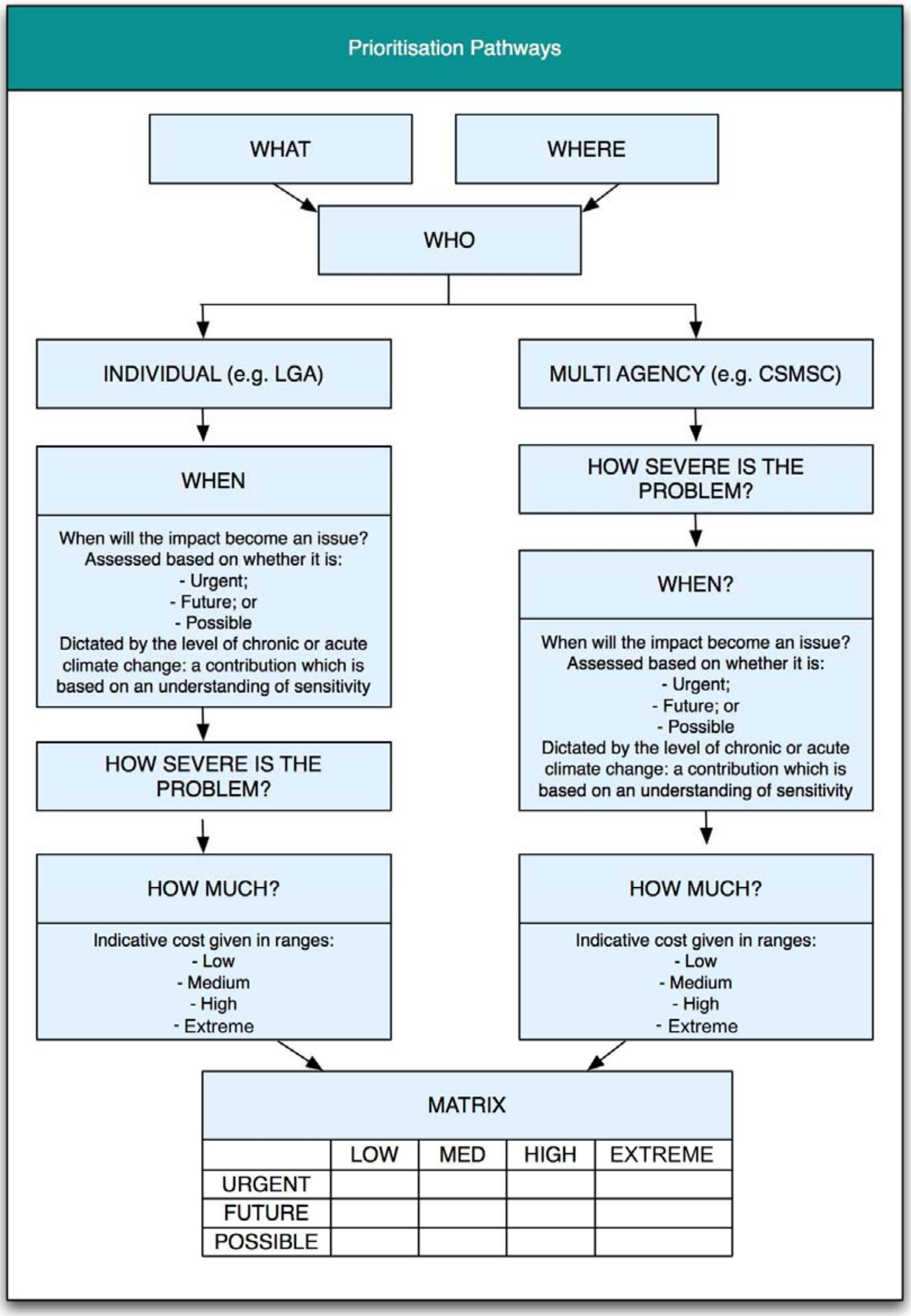

Figure 5: Prioritisation Pathways for Climate Change Adaptation Action

Table 7: When is adaptive action required?

Adaptive Response	Definition
Urgent	Does not require element of chronic change to be at risk
Future	Requires element of chronic change to occur
Possible	Requires chronic change and still has limited risk

The risk profile timeline provides a means of combining chronic change, acute event probability and the relative importance of a receptor into a simple classification of problem urgency, which provides a primary factor for prioritisation. Figure 6 illustrates a linear chronic change with no change in the frequency of acute events, but other situations, including non-linear change can be readily applied.

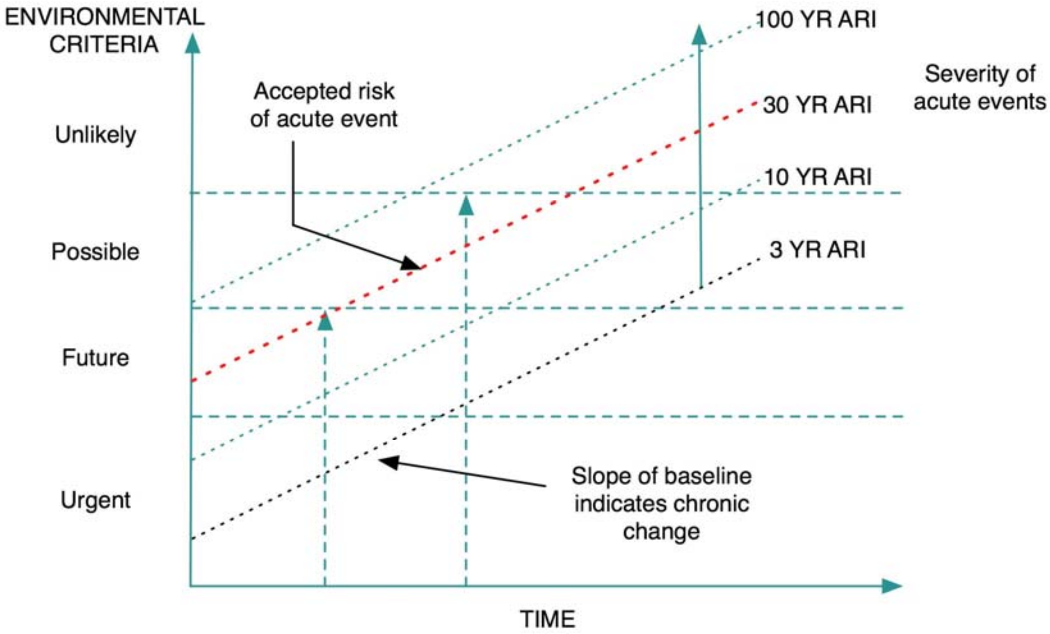

Figure 6: Risk Profile Timeline

The relative importance of a receptor is suggested by the accepted risk of an acute event, which can be nominated as either a probability or an equivalent average recurrence interval (Table 8). The selected level of risk should represent the relative value of the receptor and its expected functional life.

Table 8: Receptors and Acceptable Risk

Receptor Value	Typical Features	Acceptable Risk
Low	Foreshore reserve	10 yr ARI – 63% per decade
Medium	Roads;	30 yr ARI – 29% per decade
High	Residential housing	100 yr ARI – 10% per decade
Essential	Hospitals; Industrial estates	500 yr ARI – 2% per decade

2.4. Phase IV and V: Towards Adaptation

NOTE: It is only appropriate to provide prescriptive tasks for Phases I-III in the current brief preparation. The discrete actions that are required within Phases IV & V will depend on the outputs from the initial work phases of the subsequent Project in conjunction with the preferred decision making pathways of key stakeholders. For example, the adaptation decision making process will differ between stakeholders depending on their size/diversity (individual versus multiagency) and their value system (infrastructure focused versus ecosystem health).

2.4.1. Phase IV: Adaptation Decision Making and Levels of Action

- The budget context identified at the conclusion of phase 3 is the context for the development of an adaption strategy. It is necessary to look within the budget context; that is, impacts that require adaptive actions with high and extreme indicative costs, particularly for which action isn't urgent, are recognised as being not immediately achievable.

- For those that ARE achievable (low and medium) it is necessary to define the problem in greater detail to identify how to respond and when to respond. This may necessitate a further, more detailed level of risk assessment that may be an embedded or nested component of a potential wider study.

Table 9: Relationship between costs of adaptation and decisions on action

Cost	Adaptation Decision Making
Low	Do
Medium	Find funds to do
High	Prioritise/seek collaborative funding opportunities
Extreme	Seek external funding

2.4.2. Phase V: Implementing 'Adaptive' Adaptation

The final work phase in the proposed study will entail the formulation of a detailed adaptation implementation plan, tailored to each of the participating stakeholders, and nested in a wider adaptation plan for the whole sound.

The range of impacts that require immediate or short-term treatment (as outlined above) will be dealt with specifically to cater to the adaptive and iterative nature of the implementation process. That is, actions carried out in the immediate to short timeframes should be viewed as a pre-requisite to inform ongoing actions relating to treatment of impact in the medium and long term at a range of spatial scales. This information will feed into production of an operational risk treatment plan for discrete stakeholders clearly aligning sequencing for immediate adaptation options with relevant options for treatment. It is envisaged that the LGA Manager of Engineering Services (or a relevant counterpart in other stakeholder organisations) will manage the implementation of adaptation actions.

Thereafter, adaptation actions should be reviewed on a regular basis to ensure:

- The objectives of the task have been met; and
- New technical data is incorporated as it becomes available.

This review and implementation approach is an adaptive and 'learning-by-doing' approach to management Monitoring and review is undertaken at regular intervals and the outcomes are applied to update the adaptation planning. This type of adaptive approach recognises the uncertainties associated with predicting the consequence of actions due to underlying constraints, for example poor or lacking information.

2.5. Communication and Consultation

An important element of the proposed Project will be a rigorous and timely stakeholder engagement campaign involving all identified stakeholder groups, including interested members of the public.

During Phase I and II this should largely entail communication with the wider stakeholder group to ensure:

a) An awareness of the study aims, objectives and anticipated outcomes;

b) An efficient and comprehensive gathering of any additional information that may be in the possession of relevant stakeholder groups and required by the Consultant.

Early engagement with pertinent stakeholder groups could potentially involve a ‘kick-off’ meeting to outline the scope of the study and/or circulation of an email/informative letter to identified parties through the Project Steering Committee. It is anticipated that the Consultant will outline a proposed approach to early stakeholder engagement during Phase I and II of the Project following an initial Project Inception meeting with the Steering Committee. This meeting should occur within 3 weeks of appointment and prior to submission of a detailed Project Programme to the Steering Committee for review. This Project Programme should include a preliminary consultation plan for Phases I & II (See Section 3).

A key deliverable for the Consultant at the conclusion of Phase III will be an ongoing Communication Plan required for submission at the time of the Phase III Milestone Report. This should include a schedule for pertinent workshops/public meetings to inform identified stakeholders of the initial findings of the study and facilitate consultation towards potential pathways for adaptation. While it is recognised that the number of workshops, likely participants and envisaged output will vary dependant on identified pathways for prioritisation of climate change adaptation action, it is anticipated that the Consultant will facilitate at least one workshop during Phase III-V and will conclude the Project with a presentation of the outcomes of the study at a seminar open to the public. It will be necessary for the Consultant to communicate with the Project Steering Committee to decide on the scope and agenda for these stakeholder engagement exercises in the context of the outcomes of the foregoing work phases.

3. Project Deliverables and Timeframes

It is anticipated that the consultancy will be completed within nine months from initiation. It is expected that a draft analysis will be presented to the Project Steering Committee within the first six months of the Project with the final analysis concluded in the three months thereafter.

The Consultant should outline the proposed schedule, including commencement date, milestones, completion of deliverables and a completion date.

The Consultant will be required to maintain a close working relationship with the Client Project Manager and regularly advise on progress. Specific requirements are as follows:

- Commencement within four (4) week of appointment or as otherwise approved by Client Project Manager.
- Submission of a programme (including Phase I consultation programme) showing critical dates within three (3) week of commencement.
- Submission of milestone reports to the Project Steering Committee at the completion of each work Phase in conjunction with relevant consultation and communication plans (See Section 2.5). These reports are expected to be a summary of key findings and progress to date (up to 10 pages in length for each LGA/DoD area) as opposed to extensive reporting documents.
- Submission of draft Analysis and GIS Mapping and Adaptation Plans for consideration by the Project Working Group.
- Presentation of Draft Analysis and Adaptation Plans to the Project Working Group.
- Submission of the final Analysis and Adaptation Plans for approval by in accordance with the approved programme.

3.1. Draft Analysis

The analysis will comprise a report and series of plans that depict the current situation, projected future scenarios and identified coastal erosion and inundation impacts of change on the environment.

Digital LiDAR topographic and bathymetric data will be made available from the Departments of Water and Planning. This data will be available to the Consultant at no cost subject to the signing of a user agreement. Sediment cell information and geomorphic mapping will also be freely available from Department of Transport and Western Australian Geological Survey subject to a similar agreement.

The report should include an Executive Summary that provides sufficient details so that it can be used as a technical report for further reference and understanding by LGA staff, Council, the community and other stakeholders. The Consultant will be required to present the draft analysis to a Project Working Group prior to the preparation and delivery of the final analysis. The Consultant shall provide four copies (bound), one original (unbound) and a CD-Rom that is readable by Microsoft Office applications, as well as all plans in AutoCAD format (.dwg) unless otherwise agreed with the Project Manager.

3.2. Final Analysis

In preparing the final analysis, the Consultant shall consider all comment from the Principal Client Liason regarding the draft analysis and Adaptation Plan. Subject to the outcomes from the review of submissions, the Consultant will be required to prepare the final strategy for Council and other key Stakeholder consideration. The Consultant shall provide four copies (bound), one original (unbound), a copy of the report and plans in electronic form (Adobe portable document format) and plans in AutoCAD format (.dwg) unless otherwise agreed with the Project Manager. The Consultant will be required to present the final analysis and Adaptation Plans to the Project Working Group, the Council and/or a community information session. This would be contracted separately and does not need to be quoted at this time.

3.3. Additional Reporting Requirements

The Consultant shall prepare additional reports and technical appendices to support the draft and final Analysis and/or for later inclusion in the draft and final strategies, including GIS Mapping.

4. Consultant Requirements and Selection Criteria

The Consultant shall provide a fixed price schedule. The Consultant shall detail the fee in the format shown below. If the Consultant is not satisfied with the example *table*, the Consultant may adjust the project tasks to suit the proposed fee structure and provide an equivalent fee structure.

Contract payments will be made upon satisfactory completion of the milestones of the project, as follows:

Stage 1: 20% of the contract price on commissioning of the project

Stage 2: 40% of the contract price on submission/acceptance of the draft Analysis. This may be split into six payments with one at the completion of each work Phase (five payments in total) and the sixth payment on submission and acceptance of the complete draft analysis.

Stage 3: 40% of the contract price on completion/acceptance of the final Analysis.

Table 10 Format for Consultant fee schedule

Project Task	Relevant Personnel	Personnel Role	Hourly Rate	Hours	GST@10%	Project Fee
1. Identification of climate change scenarios						
2. Identify and define areas subject to impacts of coastal erosion and sea level rise						
3. Draft Analysis (of the potential impacts and the adaptation actions proposed in response)						
4. Final Analysis (of the potential impacts and the adaptation actions proposed in response)						
5. Drafting Requirements						
6. Disbursements - Travel expenses - Printing costs - Data collection costs						

4.1. Selection Criteria

The Project is intended as a case study for best practice in coastal climate change vulnerability and adaptation assessment and, as such, aims to build on existing work undertaken by several WA government agencies and Universities. In this respect, the brief outlined here is, by necessity, a proposal for a collaborative Project for what is expected to be carried out by a consortium of expert practitioners within the field of local coastal studies

A) Relevant Experience Weighting 30%

Describe your experience in completing similar requirements. Respondents must, as a minimum, address the following information:

(a) Provide details of similar work, including for whom the work was undertaken and the outcomes.

(b) Provide the scope of the respondent's involvement in the projects referred to.

(c) Provide details of issues that arose during the project and how the respondent managed these issues.

(d) Demonstration of sound judgment and discretion in undertaking a brief of this nature.

(e) Demonstrate competency and proven track record of achieving outcomes that meet client and other stakeholder requirements.

B) Key Personnel Skills and Experience Weighting 40%

Respondents should provide, as a minimum, information of proposed personnel to be allocated to this project, such as:

(a) Their role in the performance of the Contract.

(b) Current curriculum vitae.

(c) Membership to any professional or business association.

(d) Qualifications, with particular emphasis on experience of personnel in projects of a similar requirement.

(e) Any additional information.

C) Demonstrated Understanding Weighting 30%

Respondents should detail the process they intend to use to achieve the Requirements of the Specification. Areas that you may wish to cover include:

- A project schedule/timeline (where applicable).
- The process for the delivery of the services.
- Demonstrated understanding of the scope of work.

Appendix A

See accompanying appendix document