Cockburn Coastal Climate Change Study Brief

Background Report

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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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Acronymns

ABS - Australian Bureau of Statistics
AGO - Australian Greenhouse Office
AMSA - Australian Marine Sciences Association
ARI - Average Recurrence Interval
BoM - Bureau of Meteorology
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
WALIS - Western Australian Land Information System
WAPC - Western Australian Planning Commission

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1. Introduction

This document is intended as an overview Report of a consultancy commissioned by the City of Cockburn, City of Fremantle, Town of Kwinana, City of Rockingham and Department of Defence (Royal Australian Navy) [1] to produce a Study Brief **(The Brief)** for a project to assess coastal vulnerability in Cockburn Sound and the Owen Anchorage **(The Project).**

The work reported on here was undertaken by CZM pty ltd and supported by Damara WA pty Ltd in consultation with the aforementioned local governments and RAN between February and June 2010.

1.1. Background

The focus of the current study brief is the coastal zone of Cockburn Sound (including the Eastern coast of Garden Island) and Owen Anchorage extending from Rous Head in the north to Cape Peron in the south (Figure 1). Like much of the Australian coast it varies widely in physical type and characteristics and is vital to the local and state economy and cultural life. The Sound's range of coastal environments provides a unique habitat for a variety of plants and animals and lends protection to coastal infrastructure by acting as a buffer against the high winds and waves of powerful storm systems. Cockburn Sound 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 settlers, Cockburn Sound has become a major centre for shipping and an important site for port facilities. In particular, 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. Industrialization was accompanied by residential and recreation development.

Population growth and industrial expansion within the area has increased dramatically in recent years. This has resulted in increased potential impacts from the pressures 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 both accelerated long-term and cyclic erosion in coming years. If these impacts are to be mitigated it is vital to establish which areas are likely to be affected and what form likely impacts will take.

1.2. Drivers and Impacts of Climate Change

1.2.1. Key Drivers

Climate and oceanic drivers are the primary forcing factors of coastal change. These drivers vary at a range of temporal and spatial scales. In addition to the key environmental variables driving climate change, a series of secondary or process variables need to be considered. These include local sea level, local currents, local winds, local waves, effects on structures, groundwater, coastal flooding, beach response, foreshore stability, sediment transport, hydraulics of estuaries, quality of coastal waters and ecology.

While change in the coastal zone may occur in response to these external variables, it may also occur as the result of exceeding an internal threshold. In this respect, an understanding of thresholds in processes that control coastal geomorphology is vital for effective management of the coastal zone.

[1] Henceforth referred to as The Client

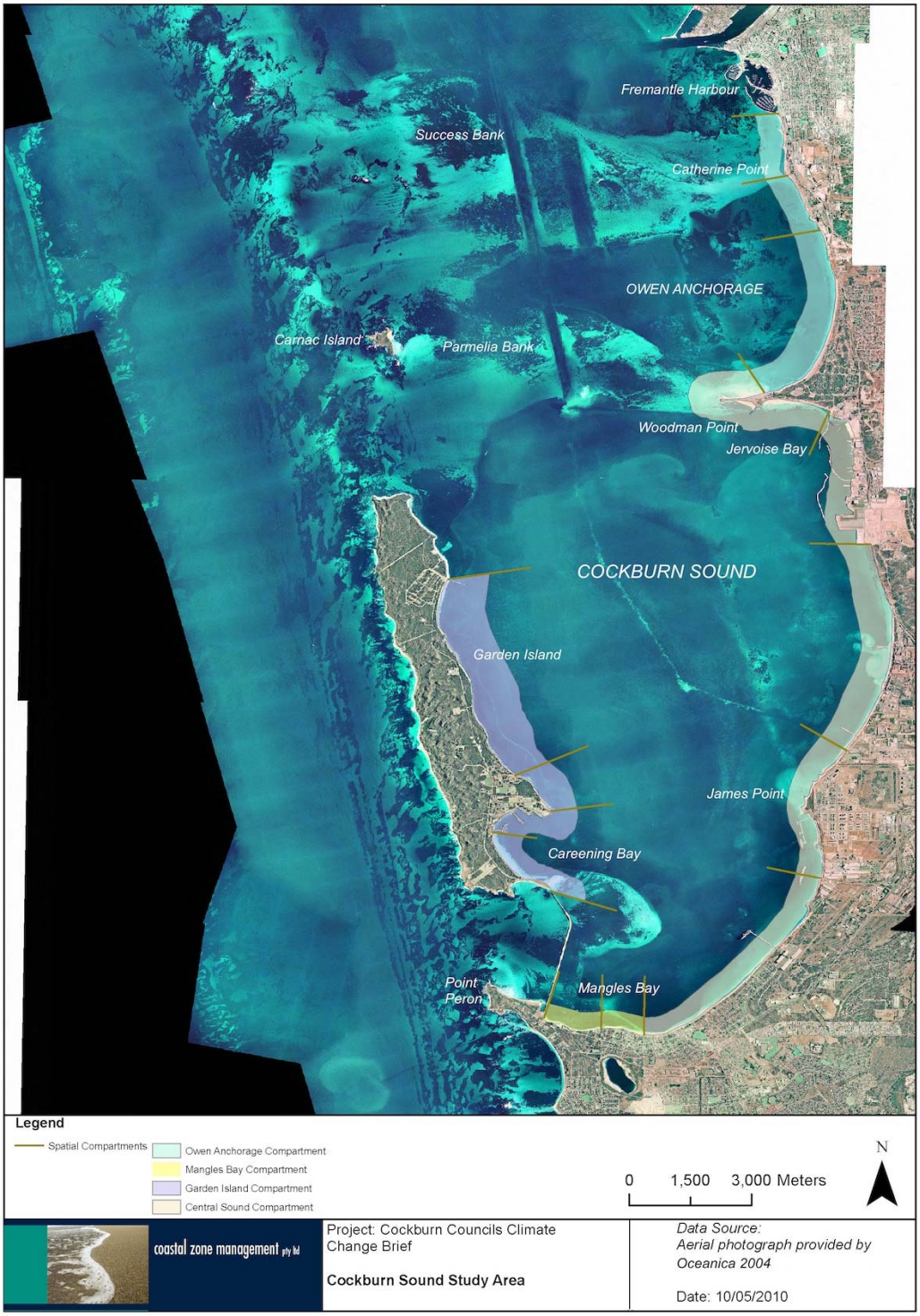

Figure 1: Annotated aerial photography of the study area

Natural coastal variability and future coastal change driven by climate change will also be substantially affected by human use of the coast. Demographic changes, industrial development, infrastructure and tourism all modify natural coastal environments, producing diverse coastlines ranging from ports and marinas, through to coastlines managed with soft engineering options such as dune management and artificial reefs.

Researchers working in the coastal zone have found differentiation between the short- and long-term effects of natural variability in coastal systems and the impacts that could be attributed to climate change somewhat problematic. Similar issues exist in isolating the components of change attributed to specific human activities. The regional and local diversity of human-induced change tends to confound these problems. In many locations, such as the intensively used Cockburn Sound, the effects of human changes to the coast exacerbate the severity of climate-induced impacts.

1.2.2. Associated Impacts

Coastal systems are particularly vulnerable to the potential effects of sea-level rise, and with more than 80% of the Australian population living along the coast.

Specific impacts of climate change likely to affect the coastal zone include:

- Higher sea levels;
- Higher sea temperatures;
- Changes in precipitation patterns and coastal runoff;
- Changed oceanic conditions; and
- Changes in storm tracks, frequencies, and intensities

These impacts in turn give rise to a range of effects on the coastal environment from both a bio-geophysical and socio-economic perspective (Table 1). Around the country many coastal settlements are already experiencing flooding with many sections of coast also appearing to be undergoing erosion (

Figure 2). Failure to adequately prepare for these changes raises the possibility of 'knee-jerk' responses by governing authorities to immediate threats, potentially magnifying rather than minimizing the negative outcomes associated with such events and increasing the likelihood of conflict between government bodies and affected communities (Green, 2008). In this context, the need to adapt to the impacts of climate change is a pressing concern.

1.2.3. Vulnerability and Adaptation

Adaptation consists of adjustment in natural or human systems in response to actual or expected climate changes or their effects that moderates harm or exploits beneficial opportunities (IPCC, 2007). The interrelationship between impacts, vulnerability and adaptation are illustrated in Figure **3**.

Figure 2: Dramatic erosion as the result of a single extreme storm event at Rockingham, Western Australia

Table 1: Impacts of Climate Change (Adapted from Abuodha and Woodroffe, 2006)

Climate Change Impacts	Effects on the Coastal Environment
• Higher sea levels • Higher sea temperatures • Changes in precipitation patterns and coastal runoff • Changed oceanic conditions • Changes in storm tracks, frequencies and intensities	Bio-geophysical effects • Displacement of coastal lowlands and wetlands • Increased coastal erosion • Increased flooding • Salinisation of surface and groundwater. Socio economic impacts associated with climate change include: • Loss of property and land • Increased flood risk/loss of life • Damage to coastal protection works and other infrastructure • Loss of renewable and subsistence resources • Loss of tourism, recreation, and coastal habitats • Impacts on agriculture and aquaculture through decline in soil and water quality. Secondary impacts of accelerated sea level rise: • Impact on livelihoods and human health • Decline in health/living standards as a result of decline in drinking water quality • Threat to housing quality Impacts on infrastructure and economic activity: • Diversion of resources to adaptation responses to sea level rise impacts • Increasing protection costs • Increasing insurance premiums • Political and institutional instability, and social unrest • Threats to particular cultures and ways of life

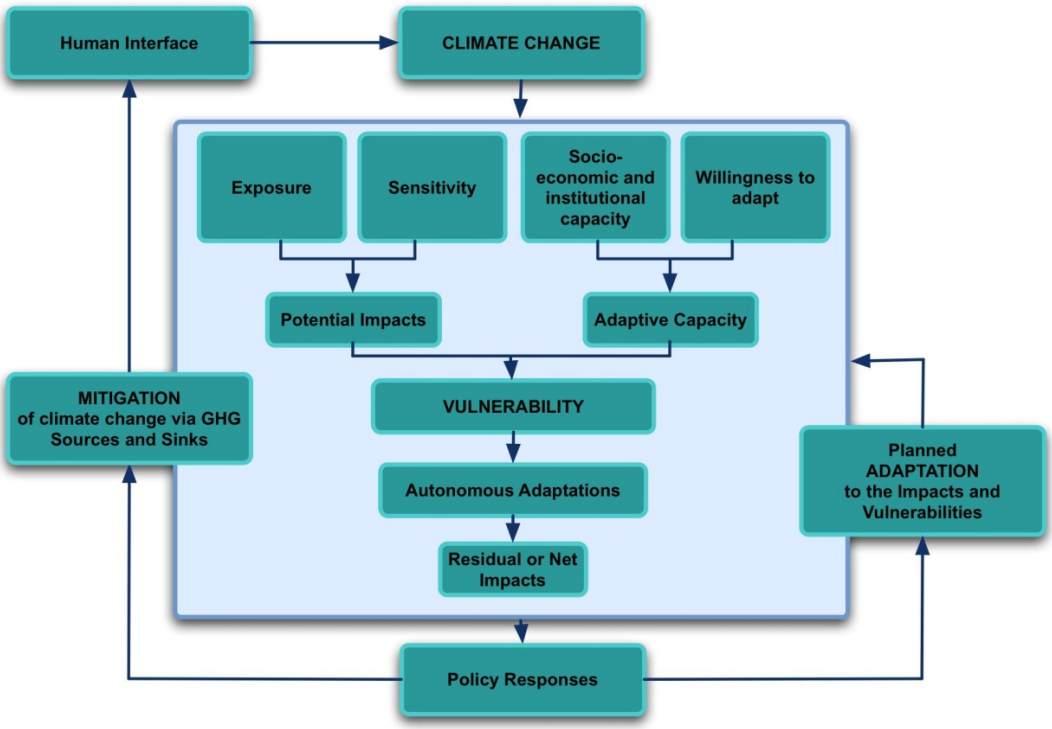

Figure 3: Conceptual diagram showing the interrelation between climate change impacts, vulnerability and adaptation.

It is clear from the above figure that effective adaptation must be built around a landscape of accurate vulnerability assessment, in turn based on meaningful determination of exposure and sensitivity and an adequate understanding of adaptive capacity. For Cockburn Sound and Owen Anchorage, it will be particularly important to consider these factors at a locally relevant scale while remaining mindful of the varying decision making frameworks and value systems advocated by discrete key stakeholder groups.

An example of stakeholder groups of relevance to the Study Brief currently under preparation is provided in Figure 5. The 'key' stakeholders for the purposes of a larger Project are the City of Rockingham, Town of Kwinana, City of Cockburn, City of Fremantle and Royal Australia Navy on Garden Island. Secondary stakeholders may potentially include local industry partners such as the Kwinana Industries Council, Cockburn Cement and the Port of Fremantle together with the State Governments Departments of Department of Environment and Conservation (DEC), Landcorp, Department of Planning (DoP) and Department of Transport (DoT)[2].

[2] A preliminary stakeholder list and accompanying text indicating why the agency/entity features as a stakeholder is provided in Appendix A to this document

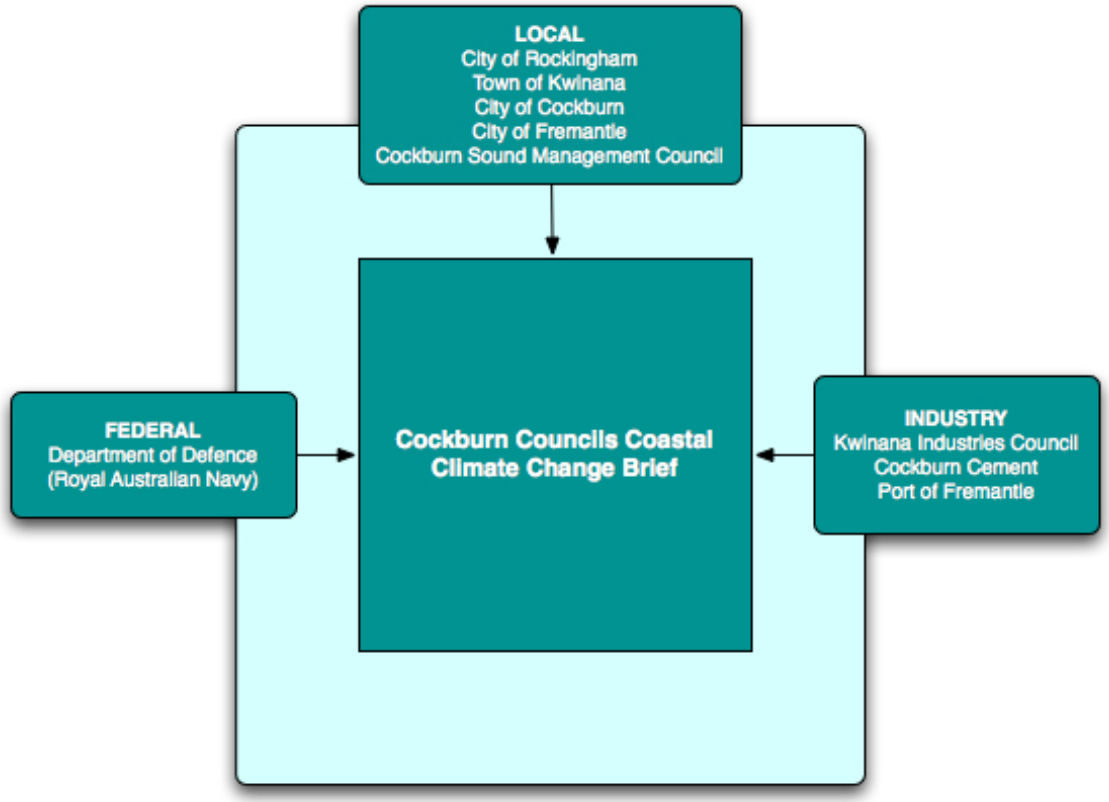

Figure 4: Potential stakeholders

1.3. Study Brief Preparation Methodology

The overriding aim of the Brief was to scope a Project that would ultimately assist in enhancing the resilience and adaptive capacity of identified stakeholders within the Cockburn Coastal Zone (Table 2).

Table 2: Cockburn Coastal Councils Climate Change Study Brief Production - Key Tasks

Project Phase	Task
1	Information Collation Phase: *Overview of existing pertinent information based on available sources* Gap Analysis of existing pertinent information both for the region as a whole and on a council-by-council basis. This included an overview of; strategic risk assessment and adaptation planning under SMRC LAPP process; discrete coastal investigations e.g. In association with setback delineation/development approvals process etc; pre-existing in-house adaptation plans. In addition, all available sources of relevant coastal data were reviewed to establish potential contribution to any subsequent coastal vulnerability and adaptation assessment. This included LIDAR (Department of Planinng; Department of Water); Sediment Cell Information and site specific geological information (Department of Planning; Western Australian Geological Survey);

Project Phase	Task
2	Consultation and Information Consolidation Phase: *Consultation with relevant council representatives for each of the 4 councils involved in preparation of the study brief*; CZM conducted a series of informal interviews with key council staff initially in person at council offices and followed up via phone/email contact. These interviews were intended to gain consensus on the findings of the initial information review and outline key priorities of individual councils towards preparation of a brief for further investigations.
3	Reporting and Draft Brief Formulation Phase: *Completion of gap analysis exercise and identification of a suitable framework to target potential funding opportunities* This work phase involved preparation of a short summary document (incorporated in Section 2 of this report) presenting findings of the review exercise including an appraisal of available coastal datasets, relevant coastal studies undertaken to date, and key priorities for participating councils in subsequent studies. This information was considered in the context of potential available funding options to guide formulation of a draft framework for the study brief (the focus of the current document).
4	Study Brief Finalisation Phase: Consolidation of draft brief and presentation to council representative meeting. Following the meeting, key comments were incorporated into the study brief in preparation for its finalisation and subsequent submission to an appropriate funding body.

The Brief 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 to be carried out by a consortium of expert practitioners within the field of local coastal studies.

2. Framework for Climate Change Vulnerability and Adaptation Assessment

Broadly speaking, approaches to vulnerability and adaptation assessment include: sensitivity analysis, impact assessment and risk assessment (Table 3). In determining the appropriate approach, a number of questions should be considered (Lu 2006).

- Who are the targeted end-users of the results of the assessment? (Answering this question will inform the level of technical detail required; methods for the treatment of uncertainties; and format for presenting results)
- What kind of output/information is expected from the assessment? (i.e. public awareness materials such as climate scenarios and their potential impacts; key vulnerabilities such as risk/vulnerability maps; a national/sectored adaptation strategy; or a combination of the above).
- What resources are available to conduct the study (human and financial)?
- How much time is there to conduct the study?

Risk management commonly follows a standardised procedure including the identification, analysis, evaluation and treatment of the considered risks (ISO Standard 31000). On the other hand the concept of vulnerability proposed by the IPCC combines the assessment of exposure (e.g. climate change projections), sensitivity (e.g. population growth) and adaptive capacity (e.g. technological options for coastal defence) (IPCC, 2007).

A vulnerability assessment is the process of identifying, quantifying, and prioritising the vulnerabilities in a system. Identifying vulnerabilities requires investigation of the biophysical and social elements of human-environment interactions. The assessments commonly cover: *exposure* to specific social/environmental stresses, associated *sensitivities*, and related *adaptive capabilities* (Polsky *et al*., 2007).

In addition, a framework used to analyse climate change drivers has been outlined by Engineers Australia in *Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering* (NCCOE 2004). The NCCOE guidelines indicate key climate change variables or drivers (such as mean sea level, K1, wave climate, K4) and secondary, or process, variables (such as local sea level, S1, coastal flooding, S7). It has been suggested that a template of this kind could be used at national assessment scales, identifying interaction between mean sea level and its effect on local sea level (K1, S1), or the effect of temperature and ecological response (K6, S13) (Abuodha and Woodroffe 2006).

The approaches adopted in many of the recent climate change risk assessments undertaken at a local level in Western Australia (e.g. Cottesloe under a EMRA Grant; Mandurah as part of the LAPP process and Scarborough Master Planning Exercise as part of the SEAS Project) have attempted to merge international best practice in vulnerability assessment with the considerable advances made within Australia in climate change risk management in recent years. Experience gained from this on-the-ground application of the risk assessment process by the Project Team has been used to inform the subsequent approach to vulnerability assessment proposed for the study area.

Table 3: Themed Approaches to vulnerability & adaptation (Source, Lu 2006)

Approach	Policy Questions	Methods, Tools and Data
Sensitivity Analysis	Does climate change really matter?	Trend analysis, synthetic scenarios
Impact Assessment	What are the potential impacts of unmanaged climate change?	Top down, scenario driven, sectoral assessment; climate and non-climate scenarios
Risk Assessment	How do we effectively manage climate change?	Critical threshold, coping range, stakeholder analysis, uncertainty, communication and management, integrated scenarios (including mitigation and adaptation scenarios)

The type of focused assessment necessary in Cockburn Sound and Owen Anchorage requires resolution of issues at a scale relevant to local government decision making as opposed to decision making at broader, regional or State scales. This is similar to the level of investigation required at a spatially relevant scale for RAN on Garden Island although the key elements against which physical change may be assessed and the process of adaptation may differ. In this respect, an approach specifically tailored to the needs of the stakeholders for whom this brief is being prepared was deemed necessary. This approach follows a 'systems' approach to vulnerability assessment as outlined in the Sections that follow.

2.1. A Systems Framework for Coastal Vulnerability Assessment

A coastal vulnerability project requires an integrated approach to vulnerability assessment and communication. This approach requires the development of specific products and outputs in conjunction with an understanding of the behaviour of natural coastal systems and policy environments (Figure 5). Successful communication of the results of, and tools and methods relevant for coastal vulnerability assessment is essential to inform an effective decision making process and facilitate adequate mitigation and adaptation measures for the Cockburn Coastal Zone.

Figure 5 below provides a schematic overview of the factors that can be considered in using a systems framework for undertaking coastal vulnerability assessment. This follows the generic approach used for the vulnerability assessment case study in the Alligators Rivers Region (Bayliss *et al*. 1997) and other wet-dry topical areas in South East Asia (van Dam 1999). Conceptually, this is a pressure-state-response framework that systematically views the effects and impacts that could arise from a range of natural (climatic), natural (catastrophic) and human stressors and drivers on the coastal zone.

The tables that follow indicate the range of natural, socio-economic and cultural variables to be considered in a systems approach to vulnerability assessment. In order for a full assessment of vulnerability to be achieved, consideration of the range and inter-relationships of these variables is necessary.

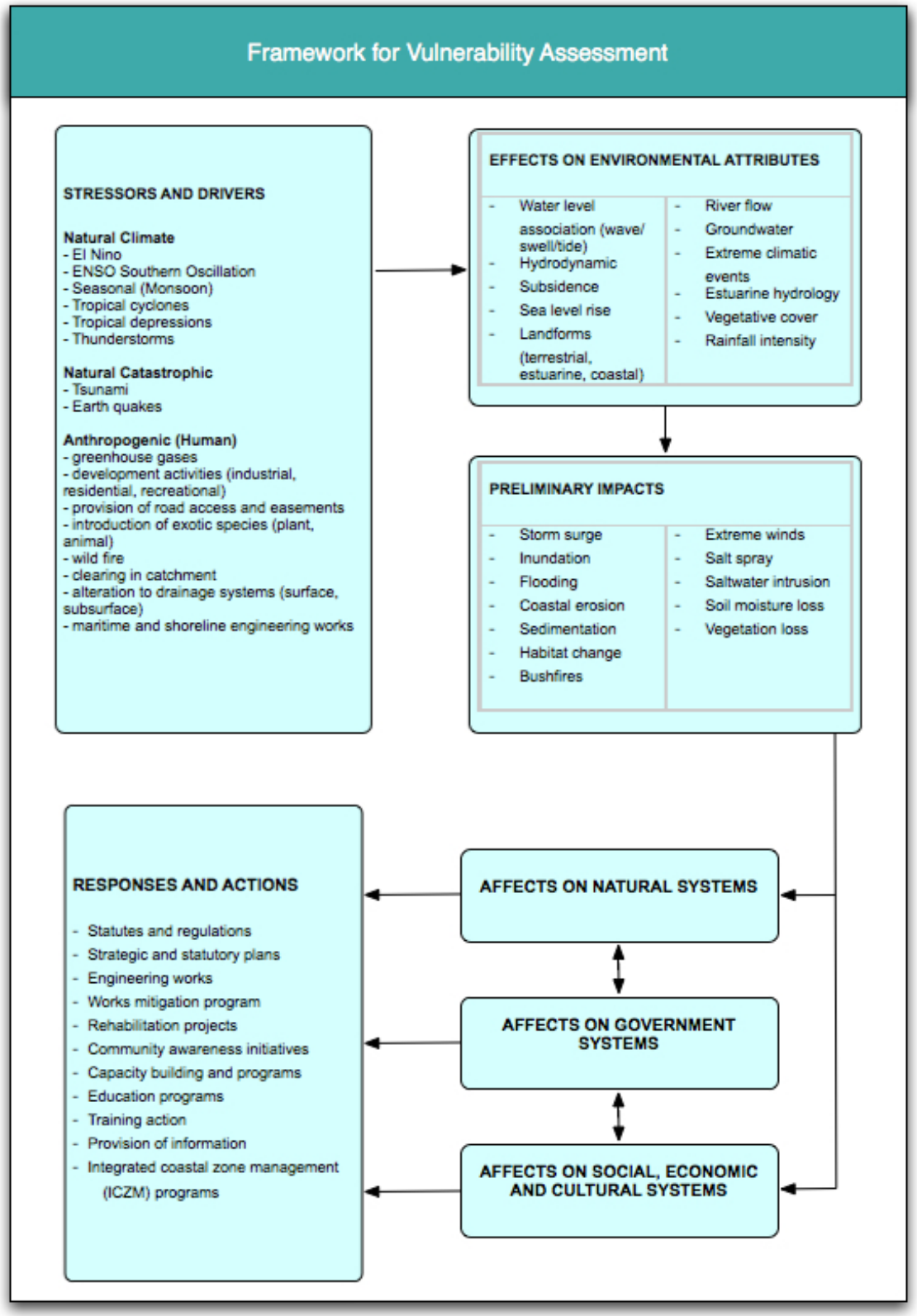

Figure 5: Example of a framework for vulnerability assessment (CZM, 2006)

Table 4: Selected factors to be considered in a Systems Approach

NATURAL SYSTEMS	
Change in Climate Conditions	Storm frequency and intensity Extreme wind events Cyclone events Seasonal changes in temperature Seasonal changes in precipitation Seasonal changes in evaporation
Change in Wave Climate	Modal annual wave height Modal wave direction Change in annual wave energy
Change in Hydrological Conditions	Ten year peak river discharge Groundwater discharges Water table fluctuation Salinisation (salt intrusion) Flood hazards Riverine and estuarine morphology (channel erosion, disposition and mobilisation of sediments)
Change in Water Level Oscillation	Tidal condition Storm surge events Near shore circulation patterns Estuarine water circulation
Changing Shoreline Conditions	Bay shape Shoreline platform Beach gradients Sediment budget Historic, stratigraphic records (Chenier development)
Changing Biological Conditions	Stability of near shore marine habitats Stability of coastal and estuarine wetland habitats Rare and endangered species Habitat adjustment (historic change in climate) Invasion by exotic species (plant, animal) Effects of wild fire
SOCIAL, ECONOMIC AND CULTURAL SYSTEMS	
Cultural and Heritage Conditions	Values of traditional owners European cultural values Moveable heritage items Natural heritage areas Sites of scientific and related interest
Social Conditions	Demographic structure Housing ownership Employment levels Land tenure Educational levels
Economic Conditions	Household incomes Disposable income Workforce structure Evaluation of local investment Environmental economic evaluation Actuarial (insurance responsibilities)
Tourist and Recreation Conditions	Provision of access (land, air and water) Tourist destinations Recreation destinations Tourist/recreation facilities Ecotourism attractions
Community Infrastructure	Public recreational areas Power/energy services Sewage and water services Transportation services Governmental facilities Port facilities Public access easements
Private Infrastructure	Industrial/business areas Residential areas Canal estates/marinas

	Private access easements
Contingency Response	Tsunami Floods Spills of oils and chemicals
GOVERNMENT SYSTEMS	
Commonwealth Considerations	International obligations Policy frameworks Legislative frameworks Cultural/heritage considerations Decision making networks Education and training Community awareness Inter-governmental liaison
State/Territory Considerations	Policy frameworks Legislative and regulatory frameworks Engineering responses Planning implications Decision making networks Education and training Community awareness Inter-governmental liaison Capacity building
Local Considerations	Strategic and statutory planning frameworks Land use and development control implications By-Laws/regulations Coastal management programs and prescriptions Mitigation measures Community awareness Risk analysis and risk sharing Inter-governmental liaison Supporting community initiatives (land care, coast care etc) Participative consultations Duty of care and due diligence Professional development and training program
Community Considerations	Community based projects (Landcare/Coast Care/Greening Australia etc NRM and other integrated catchment management projects Community awareness projects Education and training projects Participative consultations

2.2. Best Practice for Cockburn Coast

The most relevant approach for vulnerability and adaptation assessment for Cockburn Sound and the Owen Anchorage should combine the fundamentals of a systems approach with the recent progress made with respect to physical coastal process assessment both globally and particularly in Western Australia. Understanding the three-dimensional geologic framework as well as the meteorological and oceanographic (metocean) processes governing the character of the shoreface, the nearshore area in which wave energy is expended, is vital to determining coastal behaviour; particularly coastal responses to changes in metocean conditions.

It is an especially important consideration in the coastal hazard and risk assessment on largely soft coast. Cleary *et al*. (1996) and others (Pilkey *et al*. 1993; Cooper & Pilkey 2004) have argued the presence of a complex geologic framework negates application of the Bruun Rule (Bruun 1983, 1988), which has been widely applied in the calculation of setback to development on mixed sandy and rocky coast in Western Australia (WAPC 2003). It is a point originally raised by Bruun (1983) in his review of conditions for uses of the Bruun Rule of erosion (Slott 2003). Given a more complete appreciation of the geologic framework structuring the coast it would be appropriate to

consider how hazard and risk assessment might be linked to different types of landform and at different time-space scales. Identification of coastal compartments and the landforms they contain provides a means of systematically linking risk assessment to landform type.

The WA Government, through the Departments of Planning, Transport and Conservation and Environment, together with the Geological Survey of Western Australia had completed a project identifying coastal compartments based on the geology and geomorphology of the WA coast. Compartments have been identified and planning scales used by the Western Australian Planning Commission (WAPC 2003). In increasing detail, the regions and compartments respectively correspond with policy statements, regional strategies, regional and local plans and detailed local and site plans. Western Australia includes 13 broad coastal regions subject to differences in the occurrence of extreme weather events; tidal regime; geologic framework; dominant landscapes and/or seascapes; and the aspect of the shore. 36 primary, 113 secondary and 241 tertiary compartments have been identified from the 13 coastal regions. The landforms contained within the compartments have been identified to the secondary level, with more detailed description of those contained within the tertiary cells to come from integration of the compartment database with the OSRA (AMSA 2006) and Smartline (Sharples 2007) databases. More detailed descriptions of landforms are also available for the coast between Cape Naturaliste and Kalbarri; and for sediment cells identified from LIDAR imagery of the Perth Metropolitan Coast.

The next phase of work is to use the physical compartments and cells to determine the distribution of hazards and risks to natural and built resources at each of the planning scales. It is proposed that the approach adopted for Cockburn Sound should build on this work to trial the approach advocated by Eliot (*et al*. 2009) at a local level. This will show leadership and ensure alignment to current state practices.

3. Data Inventory and Gap Analysis

Accurate information on the physical features of the coast, together with biological and socio-economic datasets is an essential input to any vulnerability assessment. A full inventory of data needs and assessment of available datasets is required in the initial stages of a vulnerability assessment program on a site/region/case specific basis. A preliminary listing of likely generic needs is presented in Table 5 below and was expanded through the data inventory exercise undertaken through preparation of the Study Brief.

The approach to the data inventory and gap analysis undertaken towards production of the Cockburn Councils Coastal Climate Change Study Brief (5CSB) involved a series of meetings with key stakeholders and other parties with an identified interest in coastal management within Cockburn Sound. A stakeholder contact list and meeting log are contained in Appendix A) to this report. The outcome of the stakeholder engagement process was threefold. It enabled the Project Team to:

- Establish the current status of coastal studies and specifically coastal vulnerability and adaptation initiatives for each LGA and the RAN.
- Gain access to available reports and spatial data information in the custodianship of given stakeholders.
- Gather further contact details for GIS officers within LGAs for follow up consultation on spatial data availability and capacity.

Following initial engagement with stakeholders the Project Team conducted a detailed inventory of all available pertinent coastal information gathered from the following sources:

- Information provided by stakeholders in person (i.e. handed over at LGA and RAN offices directly to Project Team)
- A search of library and Internet data portals
- Direct contact with previous consultants who had carried out relevant works within the Sound.

Consultation with the representative for Kwinana Industries Councils did not reveal the presence of any relevant coastal investigations or climate change studies that had been undertaken by the Industries in the Kwinana Industrial Area. Additionally, Cockburn Cement and Fremantle Ports, two of the key stakeholders identified in the area, were not consulted in the information gathering process. A letter for a meeting request to Cockburn Cement remains answered and Fremantle Ports have yet to identify an appropriate point of contact for the Project Team (detailed in the stakeholder engagement log; Appendix A).

It is important to note that the availability of spatial data for the Sound and Owen Anchorage was given specific consideration due to the key role GIS analysis is intended to play in the conduct of any subsequent study stemming from the brief.

The full data inventory compiled through this study is presented in Appendix B & C and summarized in Section 3.1 below.

Table 5: Overview of Fundamental Coastal Datasets

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.	Develop 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.
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.

3.1. Overview of Pertinent Reports

In 2006 Peter Waterman compiled a comprehensive review of the engineering and environmental performance of the Garden Island Causeway through a consideration of pertinent studies for the Cockburn area dating back as far as the early 1970's. The Waterman review is useful in that it achieved the following:

- *Provided a benchmark position based on the post construction performance review in 1977*. This focused on the broad findings of the 1977 review by the Department of Construction as the benchmark point for further evaluations.
- *Established a basis for comparison when addressing environmental concerns*. This entailed providing an overview of studies and reviews undertaken from 1978 to 2003. Two additional points covered were the contextualising the studies and reviews and the core concerns relating to past examinations of the effects of the Garden Island Causeway on the pattern of exchange and intrinsic circulation.
- *Commented on the contribution that the post 1977 reviews have made towards understanding the effects that the causeway has had on the environmental conditions*. This encompassed an overview of the Southern Metropolitan Coastal Waters Study, the 1995-1996 review on behalf of the Department of Defence, the 2002 modeling study for the CSMC, and the post-graduate research findings of Nick d'Adamo.
- *Provided a summary assessment of the engineering and environmental outcomes of the structure.* This encompassed an assessment of the engineering performance and environmental outcomes of the delivery and operation of the GIC.

Elements of the review conducted by Waterman (2006) are particularly relevant to the current data inventory exercise and are summarized in the Section that follows:

3.1.1. Pre-Causeway Construction Investigations

An overview of investigations carried out prior to construction of the causeway is presented in Table 6 below. These investigations included studies on coastal process and shoreline stability; pattern and rates of exchange between the lower Sound in particular and the open ocean and hydrodynamic investigations to determine overall conditions to inform design structures of the causeway.

The findings of these investigations are summarised in a series of pertinent reports, referenced in Table 6, and referred to subsequently in review studies following construction of the causeway (Section 3.1.2).

Table 6: Overview of pre-causeway construction investigations

Source	Details
Hicks *et al*. (1973b:7)	Coastal processes and shoreline stability studies.
(DHC 1974a, b and c; Wilkenson and Associates and Environmental Management Services 1996	Hydrological studies to examine the patterns and rates of exchange of water between the open sea and Cockburn Sound through the southern opening and the intrinsic circulation of the southern sector of the Sound
Department of Construction (1977b) and by Riedel and Trajer (1978) (ERA 1971a, Waterman 1971b).	Hydrodynamic investigations documenting wave conditions within and outside the Sound to gather basic design data for the structures. Measurements of internal waves in the Cockburn Sound basin and studies of tidal conditions
Hick *et al*. (1973a:28).	Physical model studies of the structure at the Water Research Laboratory of the University of New South Wales.

3.1.2. Post Constructions Performance Review 1977

A post-construction performance review was undertaken on behalf of the Commonwealth Government in 1977 and focused specifically on the possible effects of the Garden Island Causeway on the environmental conditions of the southern sector of Cockburn Sound. The results of the review are documented in Department of Construction (1977a). This review drew on a considerable body of synthesised information presented in Department of Construction (1976 and 1977c) on water movements and Department of Construction (1977b) on the wave climate.

Material was also drawn for the reviews by the Department of Housing and Construction (1974a) on environmental monitoring, (1974b) on water movements and (1975) on beach morphology. Material reviewed by the Department of Construction (previously the Department of Housing and Construction) was heavily based on internal desktop and field based investigatory work by the Department.

Table 7: Overview of post-causeway construction investigations

Source	Details
(ERA 1970a, b and c; 1971a,c,d,e,f,g h and i; 1972a,b,c,d,g and h; 1973a,b,c, and d; 1974a,b,c and d), Foster and Nelson (1971) (DHC 1974a) Steedman and Associates (1975a,b,c and d; and 1976).	The magnitudes and directions of the currents moving within Cockburn Sound were usually not directionally proportional to the gross movement of water into and out of the Sound and were practically unchanged as a result of the causeway. The flow through the southern opening was 30-40% of that recorded prior to the construction of the causeway. On average, the total volume of water exchanged annually through the southern opening was 40-60% of the pre construction flow. It was assumed that the maximum exchange rate both before and after construction was controlled by winds and tides with some influence of season long shore coastal currents.

3.1.3. Other Studies and Reviews

Lower Sound

A wide range of investigations and studies were undertaken by departments and agencies of the Western Australian Government, consultants to government and university researchers to determine:

- The condition of the receiving waters of Cockburn Sound in the light of the point and diffuse sources of marine pollution (eg DCE 1979 and 1981, Simpson *et al*. 1993 and DEP 1996);
- The nature of the nearshore circulation along the Perth metropolitan coastline and exchange of water between the open sea and Cockburn Sound (e.g. Hearn 1991, Speedy 1994, Simpson *et al*. 1993, DEP 1996);
- The intrinsic pattern of circulation within the Sound (d'Adamo and Mills 1995, Rose 2001, d'Adamo 2002) and

  The implication of the driving mechanisms for exchange and circulation on the quality of the water within the Sound as illustrated by Meagher and LeProvost (1976), Steedman and Associates (1975a,b,c and d, and 1976), Chittleborough (1981) and CSMC (2002).

Table 8: Overview of other causeway studies and reviews 1978-2003

Study	Source	Details
Southern Metropolitan Coastal Waters Study (SMCWS)	Hearn(1991), d'Adamo (1993), Simpson *et al*. (1993), Speedy (1994), Speedy and Hearn (1995).	On average, the post-construction flushing times through the southern opening had increased by a factor of 2.6. The causeway affects the direction and magnitude of current flows within some 1500 metres of the structure. The patterns of flow have been changed by the causeway openings. The causeway is well placed with respect to minimizing the impact on circulation
1995-1996 Department of Defence Review	Wilkenson and Associates and Environmental Management Services	Review of hydrodynamic, marine biological and shoreline stability investigations for Stage 1 of the development of HMAS STIRLING from 1969-1977 Review of 1977 hydrodynamic and environmental studies (Department of Environment and Conservation 1979 and 1981);
Post-Graduate Research by Dr Nick d'Adamo	(d'Adamo 1993 and 2003).	Provides a comprehensive picture of the intrinsic circulation of the Sound Demonstrates the importance of density currents in turnover and long-shore pressure currents in the pattern of exchange with coastal waters.
Cockburn Sound Management Council (CSMC)	DAL Science and Engineering (DALSE 2002)	Modelling was used to interpret the effects of the Causeway on the environmental quality of Cockburn sound, and the potential environmental benefits of modifying its design. It was concluded that the environmental benefits of removing the Cause way did not justify the associated costs.

Study	Source	Details
Retrospective Environmental Outcomes Assessment (REOA)		There were no major unpredicted environmental effects from construction of the causeway. The Causeway appears to be performing better than predicted in terms of circulation between the open sea and Cockburn Sound.

North of the Sound and Owen Anchorage

The northern area of the Sound and Owen Anchorage have also been subject to numerous investigations in more recent times that are potentially relevant to the brief under construction. These are largely associated with existing or proposed developments and are summarised in Table 9:

Table 9: Summary of other pertinent studies for the upper Sound and Owen Anchorage

Study	Source	Details
Woodman Point West Beach Stage	MP Rogers & Assoc. (1999)	A report that explores coastal management options (nourishment, groynes, breakwaters and attenuation) for the protection of the Woodman Point West Beach
Port Catherine Development R04; R082.	Port Catherine Development Coastal Engineering Study, MP Rodgers (1999) Port Catherine Water Quality Modelling, MP Rodgers (2000)	Technical appendix for the Public Environment review for the Port Coogee redevelopment
James Point Port: Stage 1, James Point and Cockburn Sound Public Environmental Review	James point PTY, D.A Lord & Associates (2001)	The first part of the public environmental review which provides a sound overview of all pertinent environmental considerations for the James Point port development
Kwinana Beach Erosion Protection and On going Maintenance Works: Technical Report	DPI (2004)	DPI Technical report that assesses coastal management options for Kwinana beach. Concludes that the two artificial headlands now present along with a nourishment regime is the best alternative for effective management of this coast
Port Coogee Design – Metocean Conditions, R165 Port Coogee Coastal Monitoring Data Report, R179, R201, R235	MP Rogers/City of Cockburn (2005) MP Rogers/City of Cockburn (2006; 2007, 2008)	Yearly monitoring of Coastal conditions during the Port Coogee development
Ocean Water Level Variability, BP Refinery	Eliot MJ & Pattiaratchi CP2007	School of Environmental Systems Engineering, UWA & Damara WA Pty Ltd undertook study examining ocean water level variability at range of scales
Cockburn Coast District Structure plan: Coastal Processess Assessment	Oceanica, 2007	An assessment of the key coastal processes within Owen Anchorage along with a detailed inventory of coastal protection structures and dredging works

Study	Source	Details
Fremantle Ports: Report for Kwinana Quay Climate Change Risk Assessment Context Setting Brief	GHD, 2008	Context setting brief for the Kwinana Quay climate change risk assessment. Good reference to climate change variables for the Kwinana region sourced from BOM, DCC and OzClim in table 2.1.
Public Environmental review: Port Rockingham Marina	RPS, 2009; MP	summarises key oceanography and coastal processes along with identifying and assessing every environmental impact arising from construction of the marina
	Rogers, 2009	Results from hydrodynamic modelling (2G and GENESIS) of the model domain surrounding the proposed marina, outputs include predicted mode of shoreline response, and predicted changes in littoral drift.
	ASA, 2009	Model results near shore circulation, GW inflows, SW inflows, Water quality TKN, TP, Na etc and marina flushing

3.2. Gaps and Limitations

The history of human occupancy, industry and development within Cockburn Sound and Owen Anchorage, particularly the construction of the Garden Island Causeway in the early 1970's, has resulted in the existence of a wealth of coastal process information relating to the area. This is particularly advantageous when attempting to understand the behaviour of a complex environmental system through time in order to accurately predict likely behaviour into the future as a result of projected changes to coastal climate.

Although the coastal data set for Cockburn Sound and the Owen Anchorage is undoubtedly a rich resource unparalleled in many other locations in the state and even continent of Australia, several gaps and limitations do exist. An overview of information gaps associated with key coastal attributes is summarized in Table 10. Additionally, gaps in previous studies include comprehensive consideration of a number of other parameters such as:

- Sediment transfer – local sediment budgets, cross shore & long shore, erosion and accretion effects
- Current flows – seasonal and wave climate related
- Very long period and tsunami wave effects
- Health of sea grass meadows and their influence on sediment transfers
- Role of the off shore banks on sediment transfer, current flows and wave climate, and impacts of dredging and sea level rise on this
- Influences of recently introduced coastal structures, including Port Coogee Marina and the AMC development
- Likely influence of the proposed BGC Port Facility and the Fremantle Outer Harbour development
- Likely influence of the proposed Wanliss Street Rockingham Marina development

- Likely influence of the proposed Point Peron Marina development and associated modifications to the Garden island causeway

Table 10: Identification of key gaps in previous studies

Attribute	Details	Gaps
Wave Climate	Previous studies include hindcasting; wave modelling using 2GWAVE and more recently SWAN	In general modelling has not adequately accounted for the local sea breeze and the importance of fetch restricted wind waves within the study area. Need to balance modelling of swell wave components with more accurate understanding of wind wave climate
Wind Climate	Original synoptic analyses by Steedman & Craig (1979) with storm assessment by Steedman & Associates (1982). Locally relevant work by MJE, assessing geographic variation	Previous studies are not directly relevant due to fact that much of data sets used were old, short lived and from inappropriate location to apply to Study Area. Need to accurately analyse Garden Island wind record and recognize how sea breezes in the area may change with climate or apply a factor of uncertainty
Water Level	Useful studies for BP carried out by Eliot & Pattiaratchi (2007)	Need to modify existing studies to more adequately account for the seiche and local basin set up
Topography	Topography of land has been accurately surveyed & bathymetry has been established but 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
Geomophology	Recent work on Sediment Cells by DoP and coastal typology by WAGS	Need to use locally relevant compartments (as outlined in current study brief) as basis for high resolution impact assessment currently under discussion

3.3. Addressing Data Limitations and the Way Forward

These issues should be addressed further in order to conduct a comprehensive and locally relevant climate change vulnerability and adaptation assessment for the Cockburn Coast and Owen Anchorage and will require consideration in the larger Project currently being proposed for the area (the subject of the Study Brief for which this document acts as a Background Report).

Overall, while gaps exist in knowledge and understanding of potential future coastal change, there is considerable scientific and technical capacity locally with expertise available across a wide range of disciplines including emergency management, risk assessment and coastal zone management. The history of coastal studies within the wider area and specifically within Cockburn Sound provides strong foundations on which future initiatives can be built.

A potential outcome of a wider study is a comprehensive coastal information system that integrates all pertinent coastal data for the Sound across local government areas and the Royal Australian Navy's concerns on Garden Island. This type of coastal information system will be useful in its own right and highly effective for the management of coastal vulnerability if coupled with models of coastal behaviour. There is also a real need to integrate physical models with socio-economic datasets. The functionality of GIS can be used to develop powerful simulations and visualisations towards this aim. While this type of computer simulation and modelling is important in the ongoing assessment of coastal vulnerability it is also crucial that monitoring be undertaken to validate modelling outcomes and provide firm evidence of changes that have taken place.

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Appendix A: Stakeholder Engagement Log

Organization	Contact	Role	Email	Phone	Comments
City of Rockingham*	Paddy Strano Peter Ricci Darren Dropulich Bob Jeans Peter Kerp Rex Ballad Katie Callaway	Sustainability & Environment Coordinator Sustainability & Environment manager Coordinator Engineering Development Manager, Engineering Services GIS Coordinator GIS officer	Paddy.Strano@rockingham.wa.gov.au Peter.ricci@rockingham.wa.gov.au Darren.dropulich@rockingham.wa.gov.au Bob.jeans@rockingham.wa.gov.au Peter.kerp@rockingham.wa.gov.au Rex.ballad@rockingham.wa.gov.au	9528 0330 0401699843/9528 0378 95280430 95270705	Meeting with Paddy, Peter and Darren on 09/04/10 @ CoR Paddy provided data CD and report for review & follow up contact details as discussed in meeting Phone conversation with Rex about GIS data; Rex currently on leave but referred us to co-worker Follow up e-mail from Katie offering to deliver external hard drive with aerial photos to CZM (AT called back & left message 19/04/2010)
Town of Kwinana*	Ryan Munroe Tim Geldard Craig Wilson	Environmental Coordinator GIS officer Southern Metropolitan Coastcare Officer Perth Region NRM hosted by Town of Kwinana	ryan.munro@kwinana.wa.gov.au tim.geldard@kwinana.wa.gov.au craig.wilson@kwinana.wa.gov.au	9439 0218 94390260 0411078260 9439 0433	Meeting with Ryan, Craig and Tom Rose from CSMC 09/04/10 City engineer briefly attended Ryan provided data CD and report for review Ryan provided follow- up contact details for GIS officer and Chis Oughton, KIC contact AT left phone messages for Tim

	Reza Majafzadeh	Manager Engineering and Facility Services	reza.majafzadeh@kwinana.wa.gov.au	9439 0267/ 0404 458 422	Geldard – yet to be returned AT talked with Tim who subsequently sent GIS inventory to CZM (7/5/2010)
City of Fremantle*	Peter Pikor Philip Gayle Jake Tanner Paul Garbett	Director of Technical Services Manager Infrastructure Services Senior Environmental Projects Officer Parks and Landscapes Manager Planning Projects and Policy	peterp@fremantle.wa.gov.au philipg@fremantle.wa.gov.au jaket@fremantle.wa.gov.au paulg@fremantle.wa.gov.au	9432 9764 9432 9911/0403463959 9432 9973	Met with Philip and Paul 16/04/2010 - also introduced to Ross Bishop, GIS officer, who subsequently sent us inventory tables of spatial information Met with Jake Tanner briefly as we left and agreed to establish phone contact in coming week.
City of Cockburn*	Doug Vickery Gunther Schlomer Linda Metz Adrian Farrugia	Manager Infrastructure Services GIS Coordinator Environmental Officer, Natural resources GIS Analyst	dvickery@cockburn.wa.gov.au gschlomer@cockburn.wa.gov.au gisservices@cockburn.wa.gov.au lmetz@cockburn.wa.gov.au afarrugia@cockburn.wa.gov.au	9411 3574 Mob: 0447 946 429 9411 3549 9411 3536	Met on April 16th Doug provided references of reports that may be useful to obtain Doug agreed to speak with other councils reps to agree on sectoral focus of brief and communicate outcomes to CZM Doug to make initial enquiry about contact in Cockburn Cement. Dependant on direction from Doug, Matt will contact Richard Peters. Ailbhe to arrange meetings with KIC and Defence (email sent to Chris

					Oughton & meeting with Joanne Wann on Garden Island 28/04/2010) Ailbhe to communicate with Gunther re: gaining access to GIS data
Cockburn Sound Management Council#	Tom Rose		tom.rose@dec.wa.gov.au	9278 0413	Meeting with ToC 09/04/10 Subsequent call to Petra Kohn & was provided with CSMC contact list
Royal Australian Navy**	Boyd Wykes Joanne Wann		joanne.wann@defence.gov.au	9311 2252 0409990475	Emailed Joanne and subsequently caught up over phone. Meeting on GI 28/04/2010 to review GIS information and pertinent reports and discuss potential further input from Defence Meeting with Boyd and Jarrad at the Leuwinn Baracks in East Fremantle. Discussed opportunity for DoD to become part of the CCCCB agreed that this would be a good path forward.
Fremantle Port Authority**	Gino Valenti Alec Milllet Lyle Banks	General Management Business sustainability Matts contact – Hydrographics Port Engineer	Gino.valenti@fremantleports.com.au	9430 3369 0419908622	Outer Harbour Project - Doug Vickery contact – emailed on 14/04/2010 – no reply as yet
Cockburn Cement **	Richard Peters	Matts contact for access to coastal data and engineering condition assessment		0418953673	Extensive information sets and should be able to provide consultants reports

					NO CONTACT AS YET
Kwinana Industries Council**	Chris Oughton	KIC	http://www.kic.org.au Chris.oughton@kic.org.au	94191855	Contact provided by Ryan Munroe Emailed details on project and requested meeting 19/04/2010 AT met with Chris Oughton on the 12/05/2010 and discussed possible involvement of KIC. KIC were not particularly interested in the risk assessment however seemed keen on contributing to a wider study
South West Group of Local Government Authorities***	Chris Fitzhardinge Director		Chris.Fitzhardinge@melville.wa.gov.au	9364 0637	Contact from Ryan Munroe – no approach made as yet
SMRC***	Tim Youe Catherine Doran	Business Manager	tyoue@smrc.com.au cdoran@smrc.com.au	9329 2700	Contact from Ryan Munroe – no approach made as yet
BP Kwinana+					
CBH+					
Australand+					

Verve Energy+					
Water Corporation +					
DEC ***					Rockingham Marine Park
DoT ***					Fremantle Harbours
LandCorp ***					Jervoise Bay Complex and Mangles Bay Marina

* Client Council

** Key stakeholder for initial consultation as identified by client liaison

*** Potential stakeholder for subsequent consultation as identified by client liaison and initial meetings with representatives of Client Councils

Primary stakeholder involved in discussions from outset of brief preparation

Appendix B: Data Inventory Table

Report	Spatial Coverage Level	Category	Custodian	Time frame	Summary
Fairbridge RW (1950) 'The geology and geomorphology of Point Peron, Western Australia', J. Roy. Soc. WA 34:35-72	1.1	Geomorphology	Journal for the Royal Society of W.A	1950	An analysis of the Geomorphology of the Pt Peron area from a historical perspective that details the geomorphology of the area prior to the GIC
Coffey & Hollingsworth Consulting Engineers (1970) Geotechnical Investigation – Cockburn Sound Naval Base Western Australia,	1.2.2	Geotechnical	Coffey & Hollingsworth	1970	Discusses the composition of substrate and the logistics involved in driving piles, accessing materials and construction methods.
Environmental Resources of Australia Pty Ltd (1972) Beach Morphology Cockburn Sound: Autumn 1971,	0	Geomorphology	Environmental Resources of Australia	1972	Discusses the fact that Cockburn Sound beaches have a maximum volume in late summer due to deposition by predominantly low-steepness waves. Presents beach profiles for beaches along mainland Cockburn Sound.
A Review of Past Studies of the Hydrodynamics of Cockburn Sound and Surrounding Waters with an Appraisal of Physical Processes and Recommendations for Future Data Collection and Modelling	0	Metocean drivers	C.J Hearn / EPA	1991	Literature review of past hydrodynamics studies in Cockburn Sound

Hydrodynamics and Recommendations for Further Studies in Cockburn Sound and Adjacent Waters, Perth, Western Australia, Environmental Protection Authority, Perth, Western Australia.	0	Metocean drivers	EPA	1992	Draws on the previous literature review to determine the nature and extent for further hydrodynamic studies in Cockburn Sound
Department of Transport (1994) Cape Peron – Rockingham: Management of siltation at the entrance to the boat ramp basin,	0	Sedimentology	DoT	1994	Presents a discussion into recommended management measures for the siltation of the Cape Peron Boat Ramp
Southern Metropolitan Coastal Waters study (1991-1994)	0		Department of Environmental Protection	1996	
PART I					
PART II		Metocean Drivers			Presents detailed information relating to the key physical processes occurring in Cockburn sound as well as presenting methodology and results of hydrodynamic modelling
PART III					
Searle D J, Semeniuk V & Woods P J (1988) The geomorphology, stratigraphy and Holocene history of the Rockingham - Becher plain. Journal of the Royal Society of Western Australia 70: 89-109	0	Geomorphology	Searle et al.	1998	A paper that looks at the sedimentary facies, stratigraphy, age structure and sea level history of the Rockingham-Becher Plain.

Geotechnical risk assessment of garden island landforms	1.4	Shoreline morphology	Woodward Clyde	1998	
Environmental Protection Authority (1999) Seawall Construction, Land Reclamation and Dredging	1.2.3	Environmental	EPA	1999	A detailed EIA concerning the proposal by LandCorp to dredge and reclaim land for use by the shipping industry on Hendersons Road Cockburn
MP Rogers & Assoc. (1999) Woodman Point West Beach Stage 1 Report, Report R071 Rev 0,	1.2.4	Metocean drivers	MP Rogers	1999	A report that explores coastal management options (nourishment, groynes, breakwaters and attenuation) for the protection of the Woodman Point West Beach
Port Catherine Development Coastal Engineering Study, R045	1.3.1	Metocean Drivers	MP Rogers/City of Cockburn	2000	Technical appendix for the Public Environment review for the Port Coogee redevelopment
Port Catherine Water Quality Modelling, R082	1.3.1	Water Quality	MP Rogers/City of Cockburn	2000	
Longterm Shellsand Dredging, Owen Anchorage Cockburn Cement Ltd - Environmental Review and Management Programme	1.3	Environmental	Cockburn Cement	2000	
HMAS Stirling Environmental Working Paper no 14, 2000	1.4		E. Rippey/RAN	2000	

James Point Port: Stage 1, James Point and Cockburn Sound Public Environmental Review	1.2.1	Environmental	James point PTY, D.A Lord & Associates	2001	The first part of the public environmental review which provides a sound overview of all pertinent environmental considerations for the James Point port development
Chapter 6	1.2.1	Metocean drivers	James point PTY, D.A Lord & Associates	2001	Detailed hydrodynamic and sediment transport modelling of Cockburn Sound and the James Point area using the finite difference Environmental Fluid Dynamics Code (EFDC) full model set up, calibration and validation explored in detail
Cockburn Sound Management Council. The state of Cockburn Sound: A pressure state response report	0	Water Quality	CSMC/D.A Lord and Associates	2001	An older report that analyses water quality in the Sound and how it is influenced by Groundwater and Stormwater inflows
Longterm Shellsand Dredging, Owen Anchorage Cockburn Cement Ltd - EPA Bulletin 1033	1.3	Environmental	EPA WA	2001	
The influence of the Garden Island Causeway on the Environmental Values of the Southern end of Cockburn Sound	1.1 - 1.1.1	Metocean drivers	CSMC and DAL science and engineering	2002	
Benthic Habitat Mapping in Cockburn Sound	0	Environmental	CSMC and DAL science and engineering	2002	Assesses the decline in seagrass coverage using aerial photography and semi-automated mapping methods between 1967 and 1999

Town of Kwinana Industrial Strategy	1.2.0	Planning and Policy	Town of Kwinana	2003	
Cockburn Sound Profile Monitoring	0	Shoreline morphology	Dept of Defence, DALSE, DPI	2003	A data report presenting a inventory of beach profiles in Cockburn Sound
Coastal water habitat mapping project. Coastal geomorphology and classification sub project	0	Sedimentology	Geoscience Australia	2004	Gives detailed information on the location of vibracore and grab sampling points along with brief annotations of the sediments sampled in the Sound.
Kwinana Beach Erosion Protection and On going Maintenance Works: Technical Report	1.2.0	Shoreline morphology	DPI	2004	DPI Technical report that assesses coastal management options for Kwinana beach. Concludes that the two artificial headlands now present along with a nourishment regime is the best alternative for effective management of this coast
http://www.ozcoasts.org.au/geom_geol/web3d/cockburn.jsp - OzCoasts Australian Online Coastal Information - Cockburn Sound	0			2004	This is a 3D model of Cockburn Sound using bathymetry that they sourced from an unknown
State Environmental (Cockburn Sound) Policy 2005	0	Planning and Policy	State Gov't of WA	2005	

Stul T (2005) Physical Characteristics of Perth Beaches, Western Australia, Prepared for Centre for Water Research, University of Western Australia & Department for Planning and Infrastructure	0	Metocean drivers	DPI	2005	
Port Coogee Design – Metocean Conditions, R165	1.3.1	Metocean Drivers	MP Rogers/City of Cockburn	2005	Yearly monitoring of Coastal conditions during the Port Coogee development
Southern Perth Metropolitan Coast: Coastal Setback Study	0	Metocean drivers	DPI/MP Rogers	2005	
Owen Anchorage Shoreline Monitoring (1988-2006) prepared by Oceanica for Cockburn Cement	1.3.1	Shoreline morphology	Oceanica	2006	
Cape Peron Tourist Precinct Project	1.1	Environmental	EPA	2006	
Department of Defence (2006) An Overview of the Engineering and Environmental Performance of the Garden Island Causeway,		Metocean drivers	Dept of Defence	2006	
Port Coogee Coastal Monitoring 2005 Data Report, R179	1.3.1	Metocean drivers	MP Rogers/City of Cockburn	2006	Yearly monitoring of Coastal conditions during the Port Coogee development

Ocean Water Level Variability, BP Refinery, Kwinana. School of Environmental Systems Engineering, UWA & Damara WA Pty Ltd	1.2.1	Metocean drivers	Eliot MJ & Pattiaratchi CP	2007	
Port Coogee Coastal Monitoring 2006 Data Report, R201	1.3.1	Metocean drivers	MP Rogers/City of Cockburn	2007	Yearly monitoring of Coastal conditions during the Port Coogee development
Cockburn Coast District Structure plan: Coastal Processess Assessment	1.3.2	Sedimentology	Oceanica	2007	An assessment of the key coastal processes within Owen Anchorage along with a detailed inventory of coastal protection structures and dredging works.
Inter-annual variability and trends of storminess, Perth, 1994-2009	0	Metocean drivers	DPI	2008	Article that describes the storm regime in Perth using a number of different indicators such as atm pressure, wave height and wind data. Concludes that Perth experiences more low pressure systems in summer but they are of a greater intensity in Winter. The most stormiest year was 1996 with 2000 and 2007 also ranking high. Relates storminess to SOI and finds a good correlation between inversed SOI and annual storm surge hours at Fremantle. Although this paper shows annual and inter-annual variability in storms the 14 year data set is not long enough to detect a

					climate change trend.
Port Coogee Coastal Monitoring 2007 Data Report, R213	1.3.1	Metocean drivers	MP Rogers/City of Cockburn	2008	Yearly monitoring of Coastal conditions during the Port Coogee development
Kwinana Beach Foreshore Management Plan	1.2.0		Town of Kwinana	2008	Three concept plans illustrating reveg, remediation and other proposed landscaping works for the Kwinana foreshore recreation area
Fremantle Ports: Report for Kwinana Quay Climate Change Risk Assessment Context Setting Brief	1.2.1	Planning and Policy	GHD	2008	Context setting brief for the Kwinana Quay climate change risk assessment. Good reference to climate change variables for the Kwinana region sourced from BOM, DCC and OzClim in table 2.1.
SMRC LAPP by GHD	0		GHD	2008	Sections to look at include:
	0		GHD	2008	3.3.1- Recent recorded storm events: This section summarises all the storm events in the last 10 years as recorded by BoM

	0		GHD	2008	4.7- Climate Change Initiatives: Identifies a number of initiatives that each council has undertaken to reduce GG emissions and "plan"/ "adapt" to climate change.
	0		GHD	2008	5. Risk assessment outcomes. The only relevant bits of this would be the one risk that was identified for the coastal zone- risk of SLR impacting on infrastructure and environment. The adaptation option for this was to monitor dunes and foreshore and seal level monitoring. In reference to increase frequency and severity of storm they suggested that long term monitoring with reliable local coastal impact modelling. Both would be done with the collaboration of BoM and CSIRO.
Perth Metropolitan Region Coastal Protection Structures. Field Inspections & Condition Assessments. Report to Department of Transport		Infrastructure	Damara WA Pty Ltd	2009	
Port Coogee Coastal Monitoring 2008 Data Report, R235	1.3.1	Metocean drivers	MP Rogers/City of Cockburn	2009	Yearly monitoring of Coastal conditions during the Port Coogee development

Public Environmental review: Port Rockingham Marina	1.2.0	Environmental	RPS	2009	A large report put forward for public review for the proposed 500 boat Rockingham Marina off Wanliss St. summarises key oceanography and coastal processes along with identifying and assessing every environmental impact arising from construction of the marina
Appendix 4	1.2.0	Metocean drivers	MP Rogers	2009	Results from hydrodynamic modelling (2G and GENESIS) of the model domain surrounding the proposed marina, outputs include predicted mode of shoreline response, and predicted changes in littoral drift.
Appendix 5	1.2.0	Sedimentology	ASA	2009	Model results near shore circulation, GW inflows, SW inflows, Water quality TKN, TP, Na etc and marina flushing
Joint Council / Agency Coastal Vulnerability Meeting	0			2009	Some of the initiatives that were bought up have been put into "We Want…". Appendix 2 is a draft climate change adaptation table that outline the obvious impacts of severe storms and SLR and provides some basic adaptation actions and mechanisms.
Shoreline Movement Study, Point Peron Rockingham	1.1.0	Metocean drivers	DPI	2009	Technical report that details hydrodynamics and sediment transport and granulometry in the mangles bay area

Point Peron Erosion - Coastal Protection Concept Design Report	1.1.0	Shoreline morphology	City of Rockingham/mp Rogers and associates	2009	A Concept design report that details alternatives for a coastal protection structure adjacent to the Peron Camp School, gives some historical information on the nourishment and excavation regimes along with a well documented set of plans detailing vegetation lines from 1942 - 2000
Catherine Point Groyne - Extreme Metocean Conditions Analysis	1.3.2	Metocean drivers	MP Rogers/City of Cockburn	2009	
Coogee Beach SLSC - Coastal Vulnerability Assessment	1.3.0	Metocean drivers	MP Rogers/City of Cockburn	2009	
Garden Island Erosion assessment	1.4.3	Shoreline morphology	MP Rogers	2009	
Port Coogee Coastal Monitoring 2009 Data Report, R259	1.3.1	Metocean drivers	MP Rogers/City of Cockburn	2010	Yearly monitoring of Coastal conditions during the Port Coogee development
Sounding Out: A way Forward. A journey towards facilitating Multiple use of Cockburn Sound and Owen Anchorage	0		CSMC	2010	Gives an initial background to the issues facing Cockburn Sound (past, present and future) also puts forward a very comprehensive review of written and spatial information from 1900-2008
Perth Coastal Planning Strategy	0	Planning and Policy	WAPC	2010	

Appendix C: Spatial Data Inventory

DATA LAYER	City of Fremantle (Latitude/Microstation)	City of Cockburn (Map Info)	Town of Kwinana (ArcGIS)	City of Rockingham (ArcGIS)	Dept of Defence (ArcGIS)
Shoreline					
Aerial Photography	197_Reserved - 1914 maps 198_Photos 0.21m (Dec 1947) 199_Reserved - 1958 Photos 200_Reserved - 1968 Photos 201_Reserved - 1978 Photos 202_Reserved - 1988 Photos 203_Photos 0.2m (May 1999) 204_Photos 0.125m (Nov 2001) 205_Photos 0.125m (Nov 2003) 206_Photos 0.1m (May 2005) 207_Photos 0.1m (Aug 2006) 208_Reserved - 2009 Photos 209_Reserved - 2011 Photos	\2003\Aerials2003_Mosaic\Aerial2003_05112002.tab</FileName> \2003\Aerials2003Oct_Mosaic\Aerial_09102003.tab</FileName> \2004\Aerials2004Oct_Mosaic\Aerial_23102004.tab</FileName> \2005\Aerials2005Oct_Mosaic\Aerial_2005_Oct.TAB</FileName> \2006\Aerials2006Sept_Mosaic\Aerial_2006_Sept.tab</FileName> \1999\Aerials1999_Mosaic\Aerial_1999.TAB \2009\Aerials2009Jan_McMullen\93190_Cockburn_2009_10CM.tab \2009\Aerials2009Jan_McMullen\Aerial_current.TAB \2001\Aerials2001_Dola_Mosaic\city_of_cockburn_mosaic2001.TAB \2002\Aerials2002_Dola_Mosaic\Cockburn_2002.TAB \2007\Aerials2007Dec_Mosaic\93190_Cockburn_Jan08_10cm_MGA50.tab	Current Aerial Photography and Misc	METRO_CENTRAL_2009_MOSAIC. (2008, 1:10,000)	AUS 0117 DLI Aerial 1997 DLI Aerial 2000 DLI Aerial 2003 DLI Aerial Oct 2004

Coastline	9_Feature lines	\Topography\Coast\15_Coastline.tab \Topography\Coast\WACoastLine.tab	WA Coast Kwinana Ocean		Coastline
Vegetation line		\Engineering\Environmental_Services\Flora\Vegetation_Condition\2007\31_Vegetation.tab			
Coastal					
Coastal Structures	Jetties - Groynes	\Topography\Coast\14_Marine_Constructions.tab \Topography\Coast\18_Groynes_Reefs.tab			
Coastal Planning		\DevApps\DevApps_Groups\DevApps_Group_3\StateCoastalPlanningPolicyArea.TAB</FileName> \DevApps\DevApps_Groups\DevApps_Group_7\South_Beach_Railway_Buffer_Area.TAB</FileName> \DevApps\DevApps_Groups\DevApps_Group_8\South_Beach_Railway_Buff			
Beach Profiles					Beach Profiles Procoast
Drainage					
	Drainage Drainage - Storm events	\Engineering\Environmental_Services\Physical\Water\Overland_drainage\Drainage_Basins.TAB \Engineering\Environmental_Services\Physical\Water\Overland_drainage\Drainage_Catchments.TAB \Engineering\Environmental_Services\Physical\Water\Overland_drainage\Drains.TAB \Engineering\Environmental_Services\Physical\Water\Overland_drainage\Drains_Ponds.TAB \Engineering\Environmental_Services\Physical\Water\Wetlands\geomorphic_wetlands_retired.TAB \Engineering\Engineering_Services\Drainage\Stormwater_Lines.TAB \Engineering\Engineering_Services\Drainage\Stormwater_Points.TAB \Engineering\Engineering_Services\Drainage\Stormwater_Polygons.TAB	Drainage	DrgPipes Polyline DrgPits Point	Drainage_man_plan Drainage_man_plan_routes

Topography					
Contours	1m contours (1992)	\Topography\Contours\30_Contours.tab			Contours 1m
Bathymetric contours		\Topography\Contours\Bathymetric_Contours.TAB			
Utilities					
Electrical	49_Power Supply	\Utilities\Electricity\Western_Power\2007\33_Power_Communication.tab \Utilities\Electricity\Western_Power\2010\AbovegroundStructures_2010JAN.TAB</FileName> \Utilities\Electricity\Western_Power\2010\UndergroundStructures_2010JAN.TAB</FileName> \Utilities\Electricity\Western_Power\2007\WesternPower_Distribution_Pole.T			
Gas	50_Gas and Oil (Dec 2005)	\Utilities\Gas\Alinta\2007\Gas.TAB			
Water	48_Water supply	\Utilities\Water\Water_Corp\Sewer\11_Pipelines.tab \Utilities\Water\Water_Corp\Sewer\Sewer_Gravity.TAB \Utilities\Water\Water_Corp\Sewer\Sewer_Manhole.TAB \Utilities\Water\Water_Corp\Sewer\Sewer_Rising.TAB \Utilities\Water\Water_Corp\Hydrants\gis_hydrant_lge_type_annotation.TAB \Utilities\Water\Water_Corp\Hydrants\gis_hydrant_location.TAB \Utilities\Water\Water_Corp\Hydrants\gis_hydrant_sml_type_annotation.TAB			
Communications	51_Telecommunications 52_data 54_Mobile phone towers		Cables Fibre Pits		
Infrastructure					
Roads	9_Feature lines_Roads 55_Road TEXT 71_Road_polygons 74_footpaths	Engineering\Engineering_Services\Bridges\Bridges.TAB Engineering\Engineering_Services\Roads\Road_Items.TAB Engineering\Engineering_Services\Roads\Roadnames.TAB Engineering\Engineering_Services\Roads\Roads.TAB			database/facility/archive/sdb_9609_Roads

Rail		Transport\Rail\04_Railway.tab			
Amenity					
Parks and Reserves	97_Parks and Reserves	Engineering\Parks_Services\Parks_and_Reserves\Parks\Parks.TAB Engineering\Environmental_Services\Environmental\WOODMAN_PT_REG_PARK.TAB</FileName> Engineering\Environmental_Services\Environmental\WOODMAN_PT_REG_PARK_hatch.TAB</FileName>	Parks Audit		
Footpaths & Bicycle paths	144_Bike & Dual use paths 74_Footpaths	Engineering\Engineering_Services\Footpaths\Footpaths.TAB	Footpaths Loop Trail		
Conservation					
	149_Swan Rvr Management area 152_bush forever sites	Engineering\Environmental_Services\Environmental\ThreatenedFlora.TAB</FileName> Engineering\Environmental_Services\Environmental\CONSERVATION_RESERVES.TAB</FileName> Engineering\Environmental_Services\Flora\Native\Rare_Flora\DRF_FLORA.TAB Engineering\Environmental_Services\Environmental\CONSERVATION_RESERVES_Numbers.TAB</FileName> DevApps\DevApps_Groups\DevApps_Group_3\Future_Conservation_Reserves.TAB</FileName>	EnvSensitiveAreas		
Land use					
	158_Commercial Land Use (2002)	Planning\Statutory_Planning_Services\Zoning\TPS3_1_Zones.TAB</FileName>	Industrial Premises		

Appendix D: Workshop Outcome Notes

Cockburn Councils Climate Change Brief

Presentation and Workshop

21st May 2010, 10am – 12.30pm at the City of Cockburn

Attendees :

Ailbhe Travers (CZM)

Luke Dalton (CZM)

Matt Eliot (Damara WA)

Doug Vickery (City of Cockburn)

Paddy Strano (City of Rockingham)

Darren Dropulich (City of Rockingham)

Peter Ricci (City of Rockingham)

Ryan Munro (Town of Kwinana)

Tom Rose (CSMC)

Boyd Wykes (Dept of Defence)

Jarrod Scott (Dept of Defence)

Jenni Harrison(City of Cockburn)

Apologies:

Phil Gayle (City of Fremantle)

Jake Tanner (City of Fremantle)

Key Agendas and outcomes from Workshop

Stakeholder Issues

- Tom Rose indicated he has talked with BP Alcoa and other agencies in KIA, and has had insight into their climate change initiatives. They have centralised consultants/engineers working on the issue rather than using independent consultants
- Landcorp engagement should be pursued.
- Other potential stakeholder engagement: try to engage members of the KIC separately. Also, potential to informally engage with
    - DEC
    - EPA
    - Water Corporation
    - AMC (Australian Marine Complex)
    - Do we engage them now or later?
- Doug suggested soliciting mail out to all KIC parties (Tom mentioned this was a 50/50). Matt mentioned the KIC guys feel that coastal erosion is not the key thing to look at. Rather their interests lie in groundwater management due to the nature and extent of contaminated land and aquifer systems on their respective sites.
- AMC have no collective body as yet to represent themselves, however as they mature they look to become part of the KIC

Investigation and Modelling Work

- Bob Gozzard and Ian Eliot working for Western Australian Geological Survey and Department of Transport to break down the coast into more relevant sediment cells. (Distilled upgrading the information they provided for the Australia-wide Smartline database for the country)
- James point studies?
- Any issues arising from cutting off the compartment boundary at the Causeway? Not as such as Pt Peron and inside of Causeway have completely different geomorphic and wave energy and setting
- Tom Rose expressed a few questions about the formulation of compartment boundaries mainly in concern with the boundaries “being arbitrary” however it was explained that the boundaries were devised depending on relative physical processes.
- Boyd Wykes mentioned that it would be important for the RAN to be able to use wave modelling (e.g to apply it to their operational processes where possible). Important to have an idea of number of days that landing areas were likely to not be viable for example.
- LiDAR information is recently available for use however the technology is very new but can be very powerful analysis tool

- Wave climate data and modelling, when is its used by date or design life? Basically we are at a good fair stage with up to date current modelling. Some modellers may say that we should redo modelling and simulations with new LIDAR technology, however this may not have a good cost benefit ratio.
- LiDAR is great for detecting identifying sediment flows etc pathways however but cannot be used that frequently is likely to be collected infrequently, and only during summer months. Existing profile lines are appropriate to use in establishing temporal variability. Consultant for larger study should consider RAN profiles in Southern Sound and Garden Island and also gain access to profile monitoring carried out by Cockburn Cement and in association with Port Coogee further North.
- Beach profiles on Garden Island are definitely an important resource for climate change assessment and there is scope to ask for re survey of these profiles for the bigger project. Boyd Wykes mentioned that the RAN could place a bid to get these profiles re assessed in 2011/12

Data Management

- Does the CSMC have the capacity to be the key guardian of all data –i.e. gather and update information from each stakeholder in a centralised interactive database? As this would greatly increase transparency in relation to information transfer between all key players. (Tom Rose, Doug Vickery)
- Boyd Wykes questions the role of a central organisation to hold all data, as they may not have the capacity to continue this work into the future. Should we be looking at larger corporations agencies with links to Universities etc.?
- Tom Rose mentioned that the CSMC would effectively be a depository/library to safeguard all key information. Rather than being a key decision maker
- CWR also IBEC AIVEC also suggested as potential options. CWR possibly too much of a commercial entity while IBEC AIVEC more oceanography focused and perhaps would view the terrestrial component as out-of-scope
- Boyd Wykes has an inventory of data, just pertinent to Garden Island
- Decision that the question of a data management system/custodian was an important one that required further discussion – potential to have an exploratory exercise towards this aim included as a component of larger brief

Time and Budget Issues

- Need for priority as in many cases full funding may not be realised, eg ask for $1 million receive $600K what measures/projects to implement?
- Will funding from the Commonwealth have any bearing on the outcome? Eg e.g. they may have their own agenda and or own method that they may wish to use. It is very important to highlight the degree of communication between the stakeholders and demonstrate the importance of the alliance. Again the addition of Landcorp and KIC was raised
- $1850 contribution from the Dept of Defence towards the brief was approved

- Time frame for funding proposal for around August was vaguely agreed on, however this will become clearer in the coming weeks

Project Approach

- Pre V&A geotech assessments to identify define areas such as perched beaches or cliff coasts that are less sensitive.
- Doug Vickery mentioned that cultural concerns such as aboriginal heritage are of high importance in a coastal climate change V&A assessment
- What /Where/Who /When/Problem solving/Cost :Ryan Munro: In reference to WHO it was mentioned that in a multi agency case who will be ultimately responsible? (all tying back to $$$)
- If Prioritisation approach does not clarify the range and sequence of actions, there may be a need tor for a more site specific nested approach for risk assessment., Needs to be discussed
- Need for adaptation measures that are widely applicable for the Whole of Cockburn Sound as well as being implemented on a council-by-council level.
- Need for tangible risk assessments in order to allow the decision makers to implement real adaptation measures/options eg
- Scenarios used in a potential assessment eg 2030, 2070 due to the CSIRO use of these time frames. Will need to modify/calibrate these scenarios to that of Cockburn Sound.
- The “Bigger Project” needs to be consortium effort using expertise from a range of different consultancies.

Key points taken from the discussion

- It is highly desirable to engage further stakeholders such as LandCorp and individual parties within the KIC.
- The issue of collating data from all stakeholders is a very important one that will require further discussions.
- It is very important to highlight the degree of communication between the stakeholders and demonstrate the importance of the LGA/Defence alliance.
- Need for more site specific nested approach for risk assessment
- Need for tangible risk assessments in order to allow the decision makers to implement real adaptation measures/options etc
- Time frame for funding proposal for around August was agreed on, however this will become clearer in the coming weeks
- The “Bigger Project” needs to be a consortium effort using expertise from a range of different consultancies.