TECHNICAL REPORT

The Coast of the Shires of Shark Bay to Exmouth, Gascoyne, Western Australia:
Geology, Geomorphology and Vulnerability

December 2012

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Planning**

Department of **Transport**

The Department of Planning engaged Damara WA Pty Ltd to prepare this report as a background technical guidance document only. Damara conducted this project in conjunction with the Geological Survey of Western Australia.

Damara WA Pty Ltd
Email: office@damarawa.com
Tel: (08) 9445 1986

Geological Survey of Western Australia
Department of Mines and Petroleum
Tel: (08) 9222 3333

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Cover Photographs
Top-left:
Perched beach at Vlamingh Head (Photograph: Bob Gozzard. May 2011).

Top-right:
Climbing dune on the Ningaloo coast (Photograph: Bob Gozzard. May 2011).

Bottom-left:
Coral Bay (Photograph: Bob Gozzard. May 2011).

Bottom-right:
Gascoyne River delta at Carnarvon (Photograph: Ian Eliot. May 2011).

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website: www.planning.wa.gov.au
email: corporate@planning.wa.gov.au

tel: 08 655 19000
fax: 08 655 19001
National Relay Service: 13 36 77
infoline: 1800 626 477

EXECUTIVE SUMMARY

The key aim of this project was to determine the vulnerability of landforms along the Gascoyne coast to changing environmental conditions, including projected changes in climate. The determination involved site visits, assessment of aerial photography, a review of available meteorologic and oceanographic information and land system mapping of coastal land systems between Murchison River and Locker Point. Landforms were considered in detail for Areas of Planning Interest including populated and proposed development sites. Interpretation of the information gathered was intended to identify vulnerable locations within the Study Area and assist decision-making regarding the location of any proposed coastal development and for coastal management purposes.

The Gascoyne coast is mainly an inherited coast with many coastal landforms reflecting historic environmental conditions, often hundreds or thousands of years before present. There is limited availability of sediment along the coast, with the exception of silty sands supplied by the Gascoyne River distributed between the river mouth and Point Quobba. A result of the limited sediment availability is that coastal variability is largely constrained by the rocky framework and old landforms forming its inherited structure. Conversely, on those sections of the coast where sediment supply is effectively unrestricted, landform changes are highly variable and readily adjust to fluctuations in environmental conditions. This includes variation of sediment supply, with the Gascoyne River delta responding in a cyclic fashion after runoff flooding.

The Gascoyne coast marks a transitional zone for environmental conditions. At its southern end, the coast is influenced by mid-latitude synoptic systems and microtidal diurnal conditions. Northwards, there is increasing influence of tropical synoptic systems, with increased influence of semi-diurnal tides and larger tidal range. There are further regional variations in metocean processes due to the influence of the inner shelf and gulf structures at different spatial scales. These determine whether coastal variability is constrained by the geologic framework or if there is a stronger relationship between landform structures and environmental conditions.

Features along the Gascoyne coast suggest the variability of coastal processes across the region. Sediment is most abundant between Carnarvon and Point Quobba, fed by a large but irregular supply from the Gascoyne River. Elsewhere, sediment is less readily available. The Zuytdorp Cliffs indicate a general deficit of sediment in the nearshore north of the Murchison River. Sediment supply from the Wooramel and Yannarie river systems is moderate to low and highly irregular with active coastal processes mainly consisting of sediment reworking of the mudflats. These low-lying environments are highly susceptible to extreme metocean events; particularly river flooding resulting from high rainfall during cyclonic events and marine inundation due to storm surge and fluctuation in sea levels. Bioproduction on subtidal terraces in Shark Bay and on coral reefs in Ningaloo locally contributes some sediment to inshore waters and the shore. Again these sources are markedly affected by metocean processes and sediment may be lost to deeper water offshore.

Approach

In any coastal environment some coastal features are more vulnerable to climate and sea level variation than others. Along the Gascoyne coast, where sediment availability is limited, coastal landforms largely inherited from the geological past and landform changes are constrained by the rocky framework. The vulnerability of different parts of the coast is likely to be highly variable. Intuitively, areas where rock outcrops or supports unconsolidated sediments above high water level are likely to be less vulnerable than low-lying sandy or muddy shores. However, vulnerability also depends on other factors, such as hardness of the rock, the current stability of the landforms it supports and extreme weather and oceanographic processes affecting the shore. Hence landform vulnerability was estimated as a combination of the susceptibility of the geological structure supporting the landforms to environmental change and the current condition of the landforms as indicated by existing evidence of erosion. Together, a geological structure and the landforms it supports define a land system. The assessment involved consideration of the integrity of the geological or geomorphologic structures of land systems, their susceptibility to change, and the condition or stability of the landforms they support. The analysis was intended to be indicative rather than prescriptive, with applications for strategic planning purposes a first step to more detailed risk assessment procedures.

Bedrock geological control, land systems and metocean processes were used to identify discrete coastal compartments and sediment cells. Changes to land systems and landforms in one part of a compartment or cell were highly likely to affect adjoining landforms within the compartment or cell but with potentially limited affect on adjoining compartments or cells. Vulnerability ratings were then estimated for the coastal compartments and sediment cells. The Gascoyne coast comprises seven primary, twenty four secondary compartments and forty eight tertiary compartments. In its northern reaches the Study Area partly extends into an eighth primary compartment, the Eastern Gulf which includes the Yannarie salt flats. The vulnerability of the seven complete primary compartments, including the Zuytdorp, Freycinet, L'Haridon, Gascoyne, MacLeod, Ningaloo and Western Gulf compartments has previously been considered for strategic planning. They were not considered at this scale further in this report.

Secondary compartments were considered at a land system scale appropriate to strategic planning. Land systems for the twenty four secondary compartments were identified, mapped and their geology, geomorphology and landforms described. Tertiary compartments were not considered in this study, given its dual focus on broad strategic planning and local area planning.

Sediment cells of the Gascoyne coast were considered in detail at a landform scale appropriate to local area planning for fifteen Areas of Planning Interest. The Areas of Planning Interest included fifteen primary sediment cells and five secondary sediment cells, providing an incomplete coverage of the Study Area. The landforms for each sediment cell were identified, mapped and described at a finer spatial scale than that used to describe the secondary compartments.

The analysis was intended to be indicative rather than prescriptive and has application for strategic planning purposes as a first step to more detailed risk assessment procedures.

Land System Susceptibility

Susceptibility rankings were determined from values assigned to marine topography on the inner continental shelf and near the shore; the shape of the shoreline; coastal orientation; and the prevailing landform types present in the secondary compartment or sediment cell under consideration.

Seventeen of the 24 (71%) secondary compartments had a low susceptibility. Five secondary compartments (21%) were moderately susceptible and two (8%) were highly susceptible. Secondary compartments had low susceptibility where the coast was protected by a nearly continuous offshore reef or a wide shelf; there was a wide sub-tidal terrace or bank; rock outcrops with some cliffs and bluffs outcrop along the shore; the coast was sheltered from metocean forcing; beaches were perched on an intertidal rock surface; and/or the dune barrier was likely to be perched on a rock surface above the highest astronomic tide.

The areas with low susceptibility were the:

- Zuytdorp cliffs with narrow a continental shelf, including two compartments between Nunginjay Spring Coast North and Cape Inscription;
- Six compartments within Shark Bay between Cape Bellefin and Nilemah Coast East with wide sub-tidal terraces underpinned by the geologic framework;
- Wooramel Bank with a wide sub-tidal terrace, inherited deltaic features and tidal flats, including two compartments from Nilemah Coast East to Grey Point;
- Five compartments along Ningaloo coast from Cape Cuvier to North West Cape with the exception of the highly susceptible Point Cloates to Winderabandi Point. The five have shallow coral reefs, inshore lagoons, bluffs, perched dunes and arcuate coasts; and
- Western Exmouth Gulf, including two compartments extending from Northwest Cape to Giralia that are partially sheltered from swell and have sub-tidal terraces, receded barriers, rocky coasts and some inherited deltaic features in the south.

Secondary compartments considered moderately susceptible to change were exposed to metocean forcing; had unconsolidated landforms; part of active river deltas; and lack bedrock support or offshore reefs were not common in the Study Area. The moderately susceptible secondary compartments were:

- Murchison River to Nunginjay Spring Coast North with a westerly aspect, deep intermittent reef and a source of sediment from the Murchison River;
- Cape Inscription to Cape Bellefin on eastern Dirk Hartog Island with unconsolidated inshore sediments, a northerly aspect and no barrier;
- South Bejaling Hill to Point Quobba with shallow intermittent reef, high exposure, beach rock and dunes above high tide level;
- Point Quobba to Cape Cuvier with extensive platforms and cliffs on an exposed coast with deep inshore bathymetry; and
- Giralia to Locker Point with inherited deltaic features and wide tidal flats.

The two tracts of coast highly susceptible to change in the natural structure were Grey Point to South Bejaling Hill, part of the active Gascoyne River delta; and Point Cloates to Winderabandi Point with a westerly aspect, cuspate forelands and a sandy shoreface.

Landform Stability

Instability rankings were based on the proportion of rocky versus sandy seabed; number of tidal creeks per 10km of shoreline; beachface shape; whether the frontal dune complex had been eroded; an overall estimate of vegetation cover on sand barriers and the characteristics of tidal flats.

Relatively stable secondary compartments displaying low instability occurred where the coast had a limited amount of sediment stored inshore with sheltering by inshore reefs and/or rocky pavement; sandy beachface was either not present, perched on rock or had a sheltered profile; the frontal dune complex was relatively intact or perched on rock above highest astronomic tide; the barrier dunes were well vegetated; and/or they had vegetated tidal flats with few tidal creeks or a continuously lithified chenier ridge. Most secondary compartments, 17 of the 24 (71%) had a low instability, which is to say they were stable compared to other compartments in the region. Five secondary compartments (21%) were moderately unstable and two (8%) were highly unstable.

Areas with low landform instability were the:

- Zuytdorp cliffs without a barrier or beach, including two compartments extending between Nunginjay Spring coast N and Cape Inscription;
- Shark Bay compartments, including six between Cape Bellefin and Nilemah Coast East. The compartments had sheltered sandy beaches perched on inshore rock platforms and discontinuous or partly scarped foredunes.
- Southern Wooramel Bank, from Nilemah Coast East to Wooramel Coast ,with inshore rock pavement, sheltered beachfaces and moderately stable tidal flats;
- Ningaloo coast from Point Quobba to North West Cape with the exception of the moderately-unstable Point Cloates to Winderabandi Point, included six secondary compartments. It had sheltered beachfaces perched on inshore rock and was in the lee of reef, had less than 25% active dunes and some frontal dune scarping; and
- Western Exmouth Gulf, including two secondary compartments between Northwest Cape and Giralia, with sheltered beachfaces perched on inshore rock and moderately stable foredunes.

Secondary compartments with moderately unstable landforms were not common in the Study Area. Combinations of some of the following factors indicated present levels of landform instability: the inshore seabed containing more bare sand; beaches commonly subject to higher wave conditions or river activity; there were fewer foredunes and the frontal dune may have been cliffed; vegetation cover was low and mobile dunes were present on the barrier; and tidal flats had less vegetation and more tidal creeks.

The moderately unstable secondary compartments were:

- Cape Inscription to Cape Bellefin on eastern Dirk Hartog Island with bare sand surfaces in the inshore;
- Wooramel Coast to Grey Point with bare sand in the inshore and tidal flats with many tidal creeks and limited vegetation landward of the area affected by surge;
- Grey Point to South Bejaling Hill with contemporary sediment supplied by the Gascoyne River and reworking of these and older sediments across the inshore, beachface, foredunes and frontal dunes;
- Point Cloates to Winderabandi Point, which had bare sand surfaces inshore of reef, more exposed beaches and active foredunes, frontal dunes and mobile dunes; and
- Giralia to Locker Point, where there were bare tidal flats with many tidal creeks and limited vegetation.

Two tracts of coast with highly unstable landforms were the two compartments immediately north of active river systems, the Murchison and the Gascoyne Rivers. The compartments were: Murchison River to Nunginjay Spring Coast North with an exposed perched beach on shallow pavement, scarped frontal dune and a source of sediment from the Murchison River to the south; and South Bejaling Hill to Point Quobba with less than 25% reef with a source of sediment from the Gascoyne River to the south, exposed beaches, low frontal dune vegetation cover and some mobile dunes.

Vulnerability

Difference between the rankings for susceptibility and instability assigned to the same compartment were notable and highlight the significance of long-term versus short-term change. These were factors that were drawn together in determination of vulnerability which is expressed as a combination of landform association susceptibility to change due to metocean forcing and landform instability. A compartment or cell ranked at one level s highly likely to contain components of susceptibility and/or instability ranked at another. In particular, a compartment or cell ranked at a moderate level may have elements that are highly susceptible to change in the metocean regime and/or has landforms that are currently unstable. The qualification is particularly important at increasingly broader spatial scales in the land system hierarchy where a wider range of land systems and landforms is included at each compartmental scale.

The majority of the secondary compartments, 16 of the 24 (67%) had a low vulnerability. Two secondary compartments (8%) had low-to-moderate vulnerability, two (8%) had moderate vulnerability, four (17%) had a moderate-to-high vulnerability and none had a high vulnerability.

Secondary compartments with low vulnerability were those with less susceptible natural structural features and low landform instability. The areas with low vulnerability, where coastal risk is unlikely to be a constraint to coastal management at a secondary compartment scale, were the:

- Zuytdorp cliffs, including the two compartments from Nunginjay Spring Coast North to Cape Inscription;

- Shark Bay, including the six compartments from Cape Bellefin to Nilemah Coast East;
- Southern Wooramel Bank , extending from Nilemah Coast East to Wooramel Coast;
- Ningaloo coast, including the five compartments from Cape Cuvier to North West Cape but with the exception of Point Cloates to Winderabandi Point which had a moderate-to-high vulnerability; and
- Western Exmouth Gulf, with two compartments between Northwest Cape and Giralia.

The secondary compartments with low-to-moderate vulnerability were those with less susceptible natural structural features or low landform instability. They were areas where coastal risk is likely to present a low constraint to coastal management at a secondary compartment scale. The two compartments were Wooramel coast to Grey Point with moderate instability associated with active inshore sediments and tidal flats; and the exposed Point Quobba to Cape Cuvier with moderate susceptibility associated with deep inshore bathymetry and extensive platforms and cliffs.

Secondary compartments of the Gascoyne coast with moderate vulnerability were those with moderately susceptible natural structural features and moderate landform instability. These are areas where coastal risk may present a moderate constraint to coastal management at a secondary compartment scale. The two compartments were Cape Inscription to Cape Bellefin with unconsolidated sediments active in the inshore, a northerly aspect and no barrier; and Giralia to Locker Point with wide tidal flats with inherited deltaic features, many tidal creeks and limited vegetation landward of the area affected by surge.

The secondary compartments with moderate-to-high vulnerability were those with highly susceptible natural structural features or high landform instability. These were areas where coastal risk is likely to be a significant constraint to coastal management at a secondary compartment scale. The two compartments highly susceptible to change were associated with mobile structures on the active Gascoyne River delta between Grey Point and South Bejaling Hill and the cuspate forelands from Point Cloates to Winderabandi Point. The two compartments with highly unstable landforms were immediately north of active river systems, they extend from the Murchison River to Nunginjay Spring Coast North immediately north of the Murchison River and from South Bejaling Hill near the Gascoyne River to Point Quobba.

Twenty sediment cells were considered. Four cells ranked as low vulnerability, seven as low-to-moderate, six as moderate, none as moderate-to-high and three as high vulnerability. Many of the cells had a higher vulnerability ranking when considered at a finer spatial scale than the secondary compartments because the areas of higher coastal risk represented a higher proportion of the coast of interest. Higher coastal risk could be attributed to a higher proportion of susceptible natural structural features, such as cuspate forelands, and/or more unstable landforms, such as active dunes and scarped foredunes.
A more detailed assessment of the vulnerability of each area was completed at a sediment cell scale.

Fifteen Areas of Planning Interest were identified for the Shires of Shark Bay to Exmouth. The more detailed vulnerability assessment for each Area of Planning Interest included the the susceptibility, instability and vulnerability rankings; identification of the landforms most at risk and other coastal constraints related to metocean forcing; advice for coastal management; and identification of relevant further studies. The fifteen Areas of Planning Interest included:

- Nanga
- Denham
- Little Lagoon
- Monkey Mia
- Carnarvon
- Miaboolya Beach
- Blowholes
- Quobba Station
- Red Bluff
- Three Mile Camp
- Gnaraloo Station
- Gnaraloo Bay
- Coral Bay
- Vlamingh Head
- Exmouth.

Overview

The Gascoyne coast contains a broad range of coastal types, for which existing planning policies provide an equally broad range of vulnerability assessment techniques, and often suggest case-by-case evaluation. The application of simple conceptual models, such as *Schedule One* of the State Coastal Planning Policy, produces a highly varied risk profile, in which the results more strongly reflect the applicability of the model than anticipated coastal dynamics. Due to the complexity and variability of the Gascoyne coast, there are numerous locations in which secondary processes, neglected in a simple model, are dominant. Coast types where existing planning policies are difficult to implement directly are prevalent across the Gascoyne, including mixed sand and rock coast, large river deltas or low-lying tidal flat morphology. Consequently, an approach was developed, assessing coastal vulnerability based on land system and landform information. The approach used published descriptions of the relative susceptibility of coastal land systems to respond to metocean processes variability; as well as the present stability of individual landforms comprising them.

Susceptibility of coastal land systems is defined by structural characteristics, including materials, and encompasses the capacity for coastal change to reach critical thresholds or tipping points. Susceptible systems are usually affected by gradual environmental changes. Instability relates to the degree to which landforms are responsive to short-term environmental variability, and captures the cyclic or progressive nature of disturbance and recovery. The technique of combining inherent structural susceptibility and observed instability aims to account for both gradual and rapid responses to environmental change. Along the Gascoyne coast, extensive geologic and geomorphic inheritance commonly causes

dissociation between susceptibility and instability. This has implications for the use of *Schedule One* of the State Coastal Planning Policy, which is strongly tied to modern observations and therefore provides an indication of instability only.

The vulnerability analysis provides a foundation for more extensive risk assessments which could identify the processes of change in more detail; examine social and economic implications; determine the consequences of projected and existing patterns of coastal change; and plan and implement adaptation strategies. To some extent, some of the adaptation strategies are embedded in the *Coastal Zone Management Policy for Western Australia,* which provides the principles and rationale for advice arising from examination of vulnerability on the Gascoyne coast.

Compartments or cells with a high vulnerability ranking were areas where the potential effect of metocean processes was considered a major constraint to development due to weakness of the natural structures or poor natural resilience. These areas potentially require high ongoing management requirements and typically are suitable for limited development. Sufficient justification to address major constraints usually occurs only if there is a very strong economic and social imperative, such as large-scale infrastructure requiring coastal access for marine-based industries, major harbours or port facilities. Detailed investigations are recommended as the basis for establishment of such infrastructure, including geotechnical studies (site assessment of elevation and coverage of underlying rock using drilling or other appropriate technique), sediment budget analysis (approximate volumetric rates of sediment transport including sources and sinks) and numerical modelling (such as wave, current and sediment transport modelling to provide further context for the volumetric rates of sediment transport).

Lower levels of estimated vulnerability for each compartment or cell identify more specific constraints to potential land use and whether the constraint is linked to long-term susceptibility to landform change or short-term instability. In general, susceptibility requires engineering intervention to alleviate potential problems whereas instability is commonly addressed by less obtrusive management including the use of coastal setback to development.

Assessment within each of the Areas of Planning Interest has illustrated that there are significant challenges to the synthesis of existing studies and plans across the Gascoyne Region. In many cases, studies describing observed change or projecting potential change are preliminary or basic in nature, with few recognising the inherited nature of many coastal landforms. The relative absence of planning criteria for developed areas has, in some cases, resulted in an inconsistent application of coastal planning and coastal risk mitigation. This is well illustrated by a lack of consideration of coastal hazards within the Red Bluff Masterplan and failure to translate engineering requirements for hazard mitigation into planning for Coral Bay.

WEB SUMMARY

The aim of this project was to determine the vulnerability of landforms along the Gascoyne coast to changing weather and oceanographic conditions, including projected changes in climate. The Gascoyne coast is mainly an inherited coast. There is limited availability of sediment along the coast, with the exception of silty sands supplied by the Gascoyne River to the coast between the river mouth and Point Quobba at times of flood discharge. The determination involved assessment of aerial photography of coastal land systems between The Murchison River and Locker Point, land system mapping, site visits and a review of available meteorologic and oceanographic information. Interpretation of the information gathered was intended to identify vulnerable locations within the Study Area and assist decision-making regarding the location of any proposed coastal development and for coastal management purposes.

Certain landforms and coastal features are more vulnerable to climate and sea level variation than others. The Zuytdorp Cliffs are a feature of the coast but indicate a general deficit of sediment in nearshore north of the Murchison River. Further north limited sediment supplies include highly irregular fluvial supply and sediment reworking of the Wooramel and Yannarie mudflats. These low-lying environments are highly susceptible to extreme metocean events; particularly river flooding resulting from high rainfall during cyclonic events and marine inundation due to storm surge and fluctuation in sea level. Bioproduction on subtidal terraces in Shark Bay and on coral reefs in Ningaloo locally contributes some sediment to inshore waters and the shore. Again these sources are markedly affected by metocean processes .and sediment may be lost to deeper water offshore.

Landform vulnerability was estimated as a combination of the susceptibility of the geological structure supporting the landforms to environmental change and the current condition of the landforms as indicated by existing evidence of erosion. Together, a geological structure and the landforms it supports define a land system. The assessment linked the integrity of the geological or geomorphologic structures of land systems and the condition or stability of the landforms supported in a matrix to estimate five grades of vulnerability (Figure A). The analysis was intended to be indicative rather than prescriptive, with applications for strategic planning purposes as a first step to more detailed risk assessment procedures.

Results included the identification of secondary coastal compartments together with an estimate of the vulnerability of each cell as shown in Table A, with boundaries shown in Figure B. Vulnerability rankings were determined on a five-point scale for each secondary compartment indicating 16 (67%) of the 24 secondary compartments had a low level of vulnerability; two (8%) were of low-to-moderate vulnerability; two (8%) were moderately vulnerable; four (16%) were of moderate-to-high vulnerability and none had a high vulnerability (Figure C). A more detailed assessment of vulnerability has been completed at a sediment cell scale for fifteen Areas of Planning Interest in the Shires of Shark Bay to Exmouth. More detail is available from the full technical report *The Gascoyne Coast, Western Australia: Shires of Shark Bay to Exmouth. Geology, Geomorphology & Vulnerability*.

			INSTABILITY (CONDITION) (Existing morphologic change to land surface)		
			Low (Stable)	Moderate	High (Unstable)
			Example		
SUSCEPTIBILITY (STRUCTURE) (Potential change to geological structure	Low	Barrier perched on extensive tracts of coastal limestone	(1) Vegetated swales in parabolic dunes landwards of a vegetated frontal dune ridge overlying coastal limestone above HWL	(2) Vegetated dunes landwards of a vegetated frontal dune ridge and perched on coastal limestone at HWL	(3) High foredune ridge and/or vegetated foredune plain overlying coastal limestone below HWL
	Moderate	Weakly lithified barrier with intermittent limestone outcrops	(2) Mainly vegetated swales in parabolic dunes landwards of a mainly vegetated frontal dune ridge	(3) Vegetated dunes landwards of a mainly vegetated frontal dune ridge (50 to 75% cover) and overlying coastal limestone	(4) Cliffed or discontinuous foredune fronting moderate numbers of mobile blowouts and sand sheets (<50% of the alongshore reach)
	High	Barrier comprised wholly of sand. No bedrock apparent along shore or in dunes	(3) Swales in parabolic dunes landwards of a partly vegetated frontal dune ridge	(4) Mainly vegetated dunes landwards of a partly vegetated frontal dune ridge with 25 to 50% cover	(5) No foredune. Eroded frontal dune with numerous mobile blowouts and sand sheets (>50% of the alongshore reach)

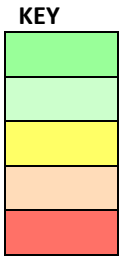

Figure A: Indicative Vulnerability Matrix for a Mixed Sandy and Rocky Coast

Note: Susceptibility of a geologic structure to environmental change and the current instability of coastal landforms were estimated for each coastal cell on a three point scale as being low, moderate or high. In the matrix these were combined to provide a five point estimation of the vulnerability.

Table A: Susceptibility, Instability and Vulnerability Rankings for Each Secondary Compartment

Secondary Compartment	Susceptibility Rank	Instability Rank	Vulnerability Rank
Giralia to Locker Point	M	M	M
Learmonth to Giralia	L	L	L
North West Cape to Learmonth	L	L	L
Winderabandi Point to North West Cape	L	L	L
Point Cloates to Winderabandi Point	H	M	M-H
Point Maud to Point Cloates	L	L	L
Alison Point to Point Maud	L	L	L
Gnaraloo Bay to Alison Point	L	L	L
Cape Cuvier to Gnaraloo Bay	L	L	L
Point Quobba to Cape Cuvier	M	L	L-M
South Bejaling Hill to Point Quobba	M	H	M-H
Grey Point to South Bejaling Hill	H	M	M-H
Wooramel coast to Grey Point	L	M	L-M
Nilemah coast E to Wooramel coast	L	L	L
Petit Point to Nilemah coast E	L	L	L
Monkey Mia to Petit Point	L	L	L
Cape Peron North to Monkey Mia	L	L	L
Goulet Bluff to Cape Peron North	L	L	L
Giraud Point to Goulet Bluff	L	L	L
Cape Bellefin to Giraud Point	L	L	L
Cape Inscription to Cape Bellefin	M	M	M
Steep Point to Cape Inscription	L	L	L
Nunginjay Spring coast N to Steep Point	L	L	L
Murchison River to Nunginjay Spring coast N	M	H	M-H

Key	Vulnerability of environmental change	Implications for coastal management (see Table 2-11 in the full report for further description)
	Low	Coastal risk is unlikely to be a constraint to coastal management
	Low -to-moderate	Coastal risk may present a low constraint to coastal management
	Moderate	Coastal risk may present a moderate constraint to coastal management
	Moderate-to-high	Coastal risk is likely to be a significant constraint to coastal management
	High	Coastal risk is a highly significant constraint to coastal management

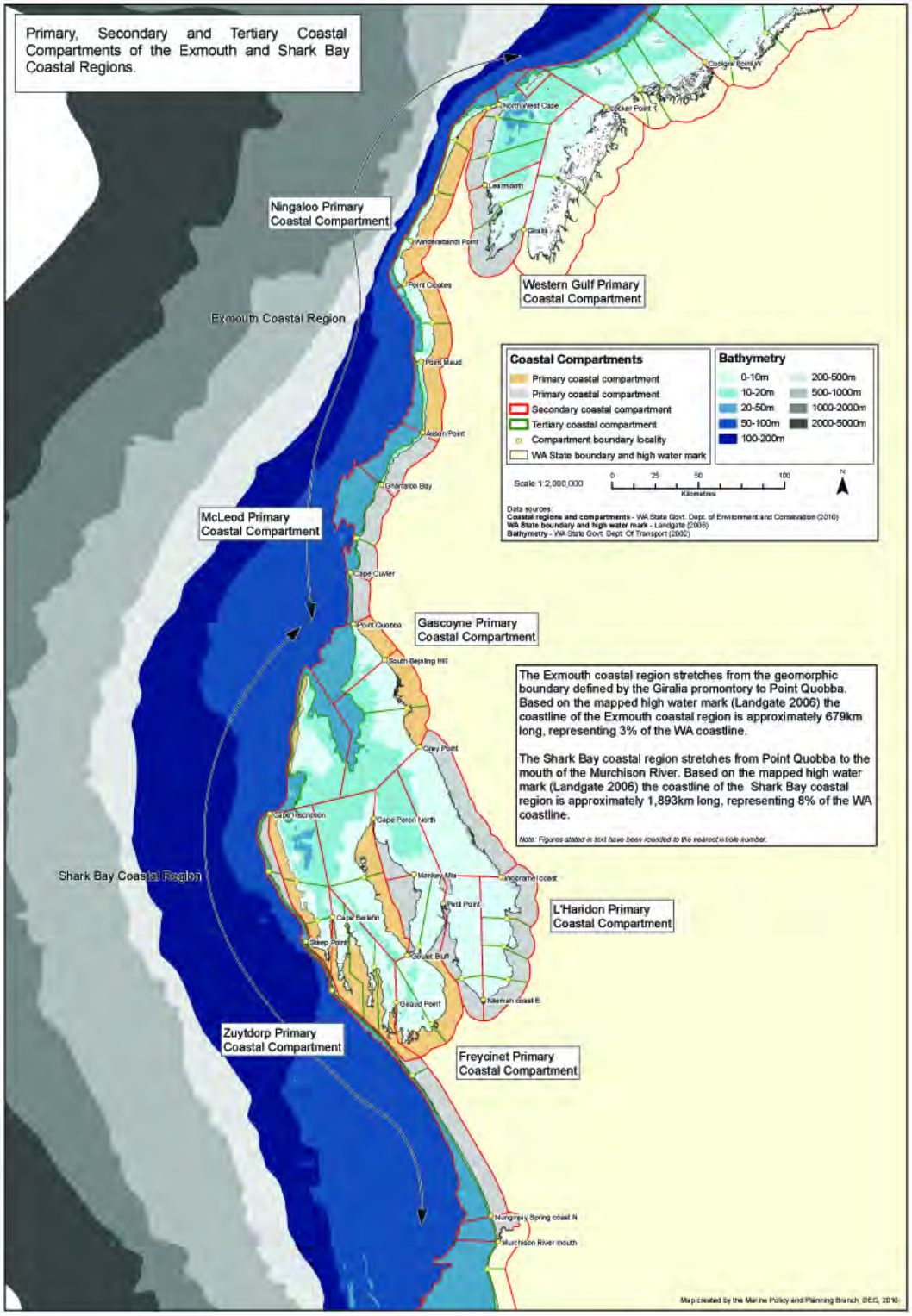

Figure B: Study Area and Secondary Compartment Boundaries for the Gascoyne Coast

Note: Compartments were defined as large sections of coast with a common land system. Three levels were identified from primary to tertiary compartments, with the offshore boundaries at the 130m, 50m and 20m depth contours. Each compartment contained a number of sediment cells to which the vulnerability rankings were ascribed. The vulnerability rankings referred to the cell as a whole but not to individual landforms. Different landforms within each cell were likely to have higher or lower levels of vulnerability than the cell as a whole.

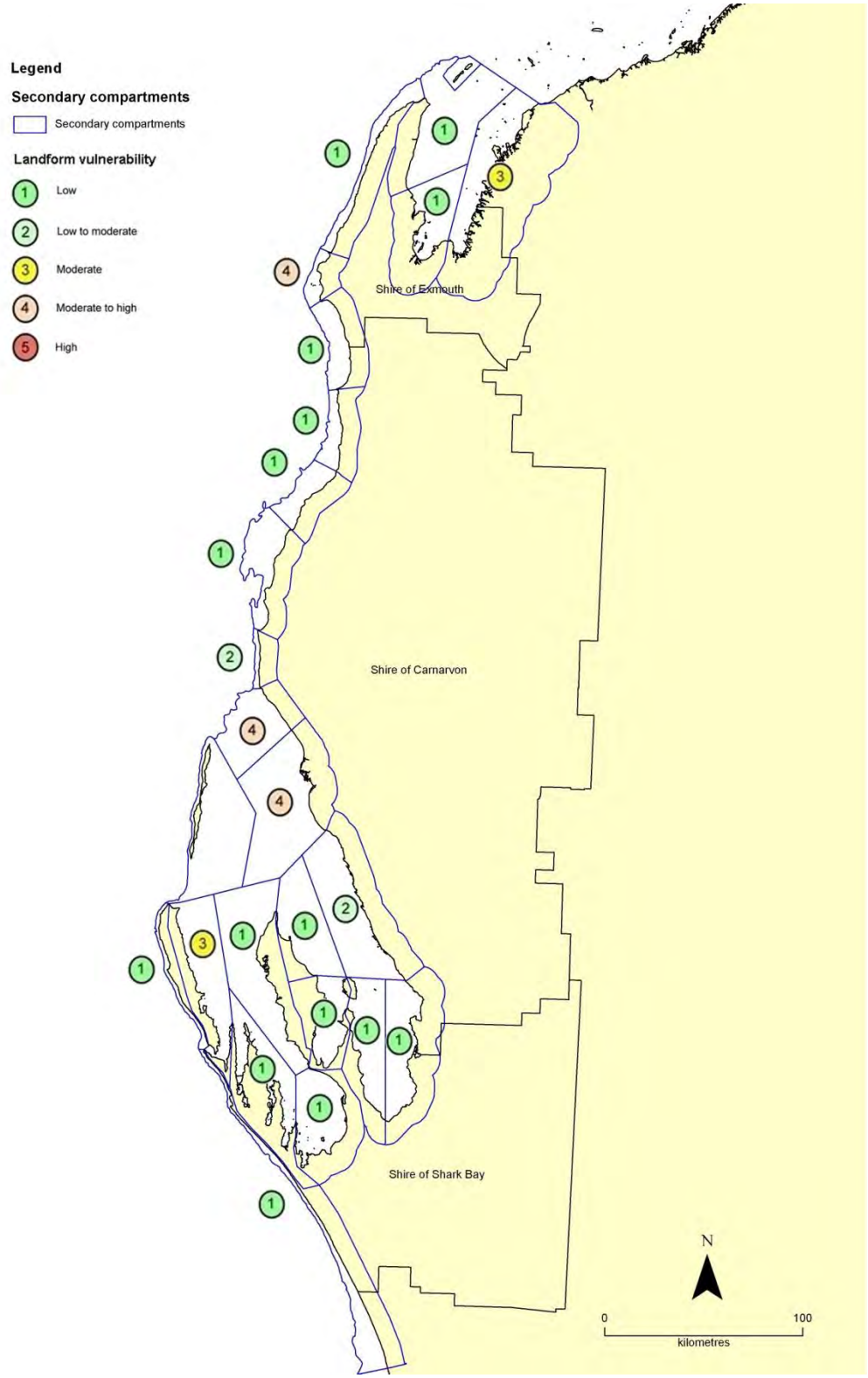

Figure C: Vulnerability Rankings of Secondary Compartments of the Gascoyne Coast

Note: Compartment labels are contained within the report