7. Discussion & Overview

General objectives for coastal planning and management and management in Western Australia are outlined in the *Coastal Zone Management Policy for Western Australia* (WAPC 2001). Three of the major infrastructure objectives are:

1. Recognition of the dynamic nature of coastal environments and the consequences for coastal development and use.
2. Avoidance or mitigation of the impacts of natural hazards through intelligent siting and design of infrastructure, based on ongoing scientific research.
3. Location of new industrial and other infrastructure development away from the coastal zone and concentration in existing nodes, wherever practicable.

These objectives provide a framework for management of the coast, which has been further described through State Planning Policies (e.g. WAPC 2006, 2013) and departmental policies such as the *Coastal Protection Policy* (DPI 2006). The general approach is to use coastal setbacks as a primary means of protection, where possible, and to focus coastal use. This raises the importance of the suggested method used to estimate setbacks and requires its applicability to all coastal environments in Western Australia.

North Western Australia experiences extreme climatic and oceanographic conditions, with natural coastal hazards, particularly associated with tropical cyclones, requiring risk mitigation. However, the approach of using setbacks to provide effective hazard avoidance is often impractical as the influence of marine conditions often extends several kilometres landward. This is directly relevant for many existing coastal town sites with established infrastructure and utilities in the Northwest. Risk mitigations may include, but are not limited to, development and implementation of warning systems and evacuation plans, establishment of critical infrastructure at areas of lowest risk, definition of site specific building guidelines and provision of coastal protection works. Following risk-management principles, the criteria used for hazard mitigation will vary between applications and should be evaluated on a case-by-case basis. However, the absence of fixed criteria does not provide justification for neglecting natural hazard mitigation where development setback cannot be achieved practically. This report is intended to support a fuller risk assessment in the Pilbara region.

The key aim of the project was to provide strategic advice concerning the geomorphology of the Pilbara coast between Hope Point and Tryon Point. Particular reference is made to three Areas of Planning Interest, which encompass the town sites of Onslow, Karratha and Port Hedland. Accordingly, coastal landforms for the Study Area have been examined at two scales. Strategic information is at the scale of tertiary coastal compartments and involves description of the unconsolidated land systems and their relationship with the geologic framework. The framework is provided by the underlying coastal limestone and sandstone. The large scale land systems include the landform associations of river deltas, dune barriers and rocky coasts. The second scale is related to local area planning and examines landforms in discrete sediment cells identified for each Area of Planning Interest.

Two facets of coastal change were considered to provide a strategic description of the vulnerability of coastal land systems and landforms to current and projected changes in environmental forcing. First, the relative susceptibility or potential for erosion of a geologic structure in response to variation in metocean processes, particularly changes in sea level was estimated for different landform systems and landforms comprising the coastal compartments and sediment cells. Second, levels of relative instability were ascribed to landforms according to their current responses to metocean processes such as storms and sediment supply as well as anthropogenic factors. The estimates of susceptibility and instability were then combined to indicate the likely vulnerability of the land systems and landforms within the compartments or cells. Vulnerability in this context provides an overall estimate of land system and landform susceptibility and instability for each planning unit.

Combination of the susceptibility of coastal land systems to changes in the metocean regime with the present stability of landforms they support identifies components of the coast potentially subject to risk in response to projected environmental change. Both facets are applicable at each level in the planning hierarchy and have relevance to coastal land use. Coastal plans traditionally focus on the instability of coastal landforms, with allowances for erosion (coastal setbacks) related to the historical variability of the beach-foredune system under consideration as well as projected sea level change (WAPC 2003a, 2006, 2013). However this is complicated by several factors in the Pilbara. First, the coast is old and its inherited landform systems markedly affect present day marine processes and the landward extent to which they affect landforms. Second, the region is subject to extreme meteorological change. This is apparent at all scales but is especially notable seasonally with switching between dry season aridity and wet season flooding, as well as in the short-term by the advent of tropical cyclones with associated high winds, heavy rainfall and storm surge inundation. Third, riverine processes significantly affect coastal development through floodplain development, delta building and delivery of sediment to the coast. Fourth, feedback mechanisms linking structure and stability determine that landform susceptibility to environmental change is at least as significant as instability, with changes in either susceptibility or stability highly likely to trigger changes to the other, particularly on unconsolidated sectors of the coast.

The complexity and variability of coastal systems in the Pilbara, together with geographic differences in the metocean processes affecting them necessitates a site-specific, land syste-specific, approach to determination of coastal landform mobility in planning and management. Within a short alongshore distance, adjacent parts of the coast may be subject to different storm surge inundation, river flooding and wave regimes. Identification of land systems and landforms enables natural grouping into sections of coast which have common behavior, and therefore facilitates the use of conceptual or process models that are directly applicable to the coastal type. Models developed for ‘general’ temperate coasts commonly fail to account for the effects of geologic inheritance, the connectivity between landforms and their elements, the contribution of rivers or the impacts of extreme metocean processes. Consideration of land systems and landforms within tertiary coastal compartments and sediment cells has been adopted as a first step to coastal hazard and risk assessment due the complexity of process, landform and sediment interactions in the Pilbara region.

Riverine processes and their interaction with ocean processes are especially important in the Pilbara region. The rivers and streams are extremely variable in flow and sediment discharge at interdecadal as well as seasonal time scales and in some cases are liable to flash flooding. Additionally, through the interaction of river flow and marine process the larger rivers contribute to separation of coastal sediment cells from the geologic framework of the coast such that the relationship between form and function is not always immediately apparent.

The vulnerability assessment based on the susceptibility and instability of land systems and landforms potentially contributes to a more complete risk assessment process, such as that proposed by ISO 31000 (Standards Australia 2009), which is illustrated in Figure 7-1. This is discussed further in Section 7.5.1 below.

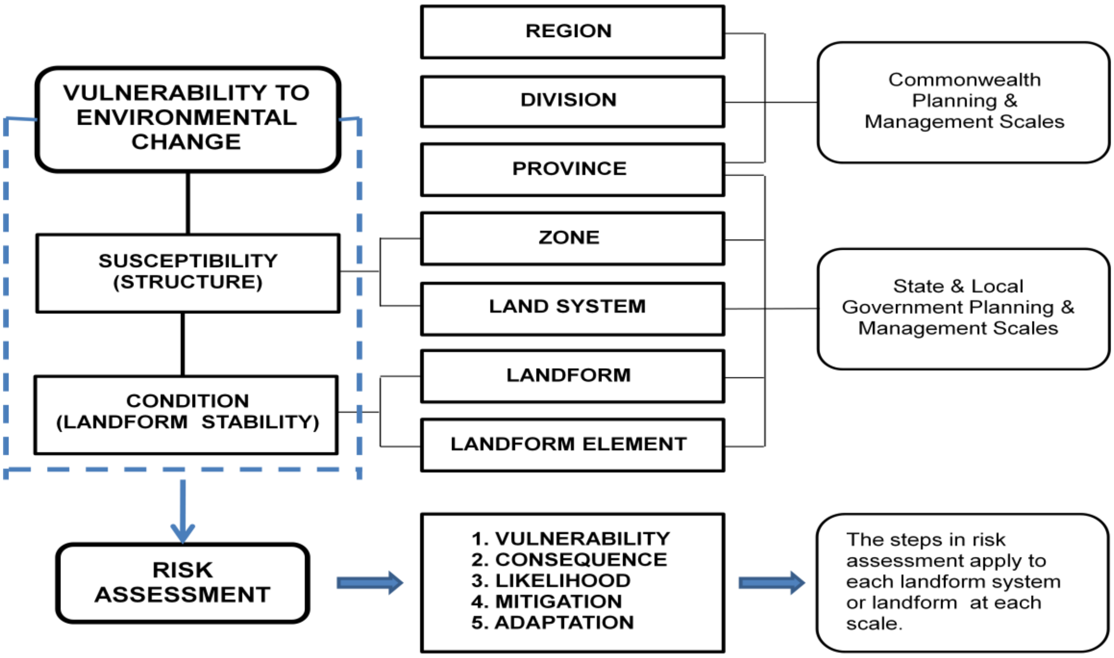

Figure 7-1: Vulnerability Assessment, Risk Assessment and Scales of Application

7.1. ASSESSMENT SCALES

At a geological timescale, the hard-rock geologic framework has provided topographic control for formation of Quaternary coastal landforms and land systems developed during the past 2 million years. Accretionary structures such as deltas, outwash plains and barrier dunes formed as unconsolidated sediment accumulated along the coast between the older rocky terrain of the region. Additionally, over millennial time scales during the late Holocene, sea level changes, river flooding and accompanying metocean processes have also re-inundated and affected the morphology of older unconsolidated landforms. This is particularly applicable to the deltas of the major river systems of the region, the Ashburton, Fortescue, Maitland, Harding, Peewah, Yule, Sherlock Turner and De Grey Rivers. It is also relevant to the low-lying outwash plains and mudflats of streams with smaller catchments and the extensive subtidal terraces fringing much of the Pilbara coast. Albeit slowly in some places, the coast is continuing to develop as sediment is moved along and across the shore. The structure of the land systems, with unconsolidated Holocene sediments overlaying and abutting older terrain, including Pleistocene limestone and sandstone topography, implies marked geographic variation in the susceptibility of the shore to erosion and suggests the need to develop different models for the prediction of shoreline movement to different parts of the coast. Hence assessment of the susceptibility of the coast to observed and projected changes in metocean conditions has been undertaken for the tertiary compartments and sediment cells that support different landform associations.

Land system susceptibility has been estimated on a comparative basis as being low, moderate or high depending on the presence, extent and elevation of outcropping rock. At the broadest scale a river delta, outwash plain or barrier land system may not be susceptible to long-term change whereas elsewhere a similar type of land system may be highly susceptible. This is apparent when a comparison is made between the outwash plains and tidal flats between Locker Point and Coolgra Point with those between Cape Lambert and Cape Cossigny. The former are sheltered by partly lithified barriers whereas the latter are cut by well developed tidal creek networks. A similar comparison may be made for the perched barriers along the Gnoorea coast between Forty Mile and Pelican Point compared to the more complex barrier system between Four Mile Creek and Beadon Creek, Onslow which may have formed over a deeper basement. The disparities provide rationale for more detailed consideration of the geotechnical qualities of the different systems.

Rise in sea level, whether a short-term recurrence of historically extreme conditions due to storminess or a sustained response to projected Global warming, potentially may trigger increased destabilisation of the foredunes and frontal dune belt along the shore as well as induce changes to the balance between fluvial discharge and tidal exchange on tidal flats of the outwash plains and deltas. It would typically facilitate landward migration of barriers where they not perched on bedrock surfaces well above high tide level. The broad scale assessment of vulnerability provides an indication of which areas are most likely to change, with consideration of the Areas of Planning Interest at a more local scale providing more specific detail concerning land forms at risk. Establishment of a rate of projected change requires estimation at a local scale due to the potential for wide differences in landform setting over short distances.

At inter-annual and longer time scales, interaction of modern metocean processes with the inherited geologic framework has several ramifications.

1. It invalidates application of the Bruun Rule (Bruun 1962) that has been widely applied in the calculation of setback to development on mixed sandy and rocky coast in Western Australia (WAPC 2003a, 2013); a point made by Bruun himself in his criticism of the application of the 'rule' (Bruun 1983, 1988).
2. Alongshore variation in coastal alignment, beach erosion and deposition, foredune formation and dune development occurs as a result of the interaction between metocean processes and the geologic framework. The reaches of unconsolidated coast most susceptible to environmental change are commonly in close proximity to shoreline salients and extensive rock outcrops.
3. Determination of coastal change as a basis for risk assessment in the region requires that: (a) localised estimation of shoreline change is necessary and should be linked to geophysical determination of the distribution and elevation of the underlying rocky

terrain supporting unconsolidated sedimentary landforms at places where development is under consideration; and (2) development of an understanding of extreme high sea levels and their impact on the coastal lowlands common is needed to provide a basis to achieve the major infrastructure objectives identified by the WAPC (2001) for management of the coast .

7.2. PILBARA COAST MORPHOLOGY OVERVIEW

The Pilbara coast is largely comprised of low-lying arid floodplain, on a broad continental shelf, dominated by meso through to macro tidal variation, with the occasional impact of severe tropical cyclones. These deliver floods and marine inundation events that impact the landscape and drive geomorphologic change on a coast which has a complex array of ancient and modern landforms. Active sedimentary landforms abut and overly a complex and old terrain cut into the hard-rock Archaean geology of the Pilbara Craton and more recently formed sedimentary rocks.

Coastal landforms, including river deltas and tidal flats, extend more than 2km inland for the majority of the Pilbara. The river channels, riverine outwash plains, river deltas, tidal flats, coastal dunes, cheniers and spits, wide subtidal terraces and extensive sand shoals of the coast are all subject to significant change under extreme meteorologic and oceanographic conditions. However, the nature of landform response varies according to the relative resistance of the coast, which is a combination of material types (geology, sediment type and presence of vegetation) and the coastal form (which may be plan form, profile, or configuration of landform elements). The factors of environmental forcing, materials and landform have considerable interaction, in which variation of one factor potentially changes the other two. In this context there is an apparent disconnection between the fixed geologic framework and unconsolidated inshore sediment bodies.

The Pilbara coast is an inherited coast, with many sedimentary coastal landforms reflecting historic environmental conditions, centuries or millennia before present. Its ancient hardrock terrain is overlain or abutted by sediments of coral reefs, flood plains and river deltas deposited through multiple phases over millions of years. In places the riverine sediments have been lithified, which along with old reefs and beachrock, now form coastal limestones.

River systems provide an important contribution to active coastal dynamics in the Pilbara region through the episodic release of massive quantities of sediment, the largest being the Ashburton, Fortescue and De Grey Rivers (Figure 1-3). Not all streams and rivers discharge directly into the ocean, with many releasing water and sediments into tidal flat basins. However, these systems are connected to the coast via tidal creeks and irregularly contribute sediment to the coast at times of flood. Whilst much of the released material is fine, and is broadly dispersed, the coarse fraction allows formation of deltaic features on the larger river systems and may contribute to sediment fans on the inner shelf region (Margvelashvili *et al.* 2006). In addition to this dynamic, smaller stream systems and tidal channel networks interact within the broad areas of tidal flats prevalent along the Pilbara coast. These areas display the majority of inter-tidal and supra-tidal coastal change, with rapid switching between accretion and erosion of the tidal flats indicating adjustment to changing metocean conditions (Eliot & Eliot 2013).

The geographic distribution of the rivers and their intermittent flow results in sediment availability along the coast being extremely variable. Where sediment supply is limited, coastal variability is largely constrained by the rock framework and old landforms forming its inherited structure. Conversely, for areas of the Pilbara coast where sediment supply is effectively unrestricted, landform changes are highly variable and readily adjust to fluctuations in coastal processes.

The broad and shallow shelf structure displays significant variability in the presence and nature of sedimentary features. These generally occur as shallow features overlying rock platforms, structurally controlled by chains of limestone ridges and islands, which are remnants of previous shorelines. Significant disturbance of sediment may occur during tropical cyclones, commonly resulting in perturbation-recovery behaviour for coastal systems. The nature of this cycle has been inferred from management of Port Hedland shipping channel; significant sedimentation was not identified immediately after tropical cyclone impact, but elevated sedimentation rates were observed for several years following, gradually declining, and with winnowing of surface sediments measured (Mulhearn & Cerneaz 1994; Harris & O'Brien 1998; GEMS 2010a).

Coastal dynamics in the Pilbara are brought about through an irregular combination of tidal flows, episodic tropical cyclone impacts, variable sediment release from river systems, generally mild ambient wave conditions and through wind drift (Pearce *et al.* 2003). These diverse environmental conditions produce change that is rarely responsive to a single forcing mechanism, with many coastal systems in the Pilbara displaying perturbation-recovery behaviour. The large range of both tides and cyclone-induced waves means that many sedimentary coastal features are capable of being heavily eroded over short time frames. However, the underlying or abutting geological framework may provide a physical limit to change. Hence sedimentary features in the Pilbara tend to fall into the following classes:

- *Supply maintained features*, including deltas and strandplains, that have sufficiently high sediment supply that they are able to maintain a permanent presence;
- *Ephemeral features*, including spits, bars and beach 'ribbons', which experience periods of declined supply of enhanced erosion sufficient to cause short-term loss, with subsequent rebuilding;
- *Controlled features*, such as perched beaches or zones of updrift detention, where there is structural control that prevents the total disappearance of a feature, even under severe conditions;
- *Uncontrolled features*, including sand sheets, where neither supply nor structural control are sustained. These features may be formed due to a singular event such as a tropical cyclone, and progressively evolve.

The distribution and relative permanence of these sedimentary features is strongly linked to the proximity to river systems and their rate of sediment release. Estimates of river system sediment delivery to the coast are not yet reliable (Ruprecht & Ivanescu 2003), with the proportions of fine or coarse sediment and the estuarine structure having a significant influence on sediment fate as plumes or deposition.

7.3. ADVICE

In the absence of existing guidelines or policy a precautionary approach was adopted for assessing susceptibility and instability on mixed sand and rocky coast or on the low-lying morphology of tidal flats, present on much of the Pilbara coast. The approach involved an analysis of coastal vulnerability based on available information, including published descriptions of the relative susceptibility of coastal land systems to change with variation in metocean processes as well as the current stability of individual landforms comprising them. The vulnerability analysis is the first part of a more extensive risk assessment which would 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 guidelines of the State Coastal Planning Policy (SPP 2.6) and Coastal Protection Policy (DPI 2006). These guidelines, in combination with coastal planning objectives (WAPC 2001) provide the principles and rationale for the advice arising from examination of vulnerability on the Pilbara coast.

7.3.1. General Principles

General principles applied in framing the recommendations are as follows:

1. The State Coastal Planning Policy SPP 2.6 identifies a range of considerations for the determination of coastal setbacks. The first two factors identified are coastal erosion and landform instability. Both are related to the interactions amongst the metocean processes, geological framework, unconsolidated sediments and landforms comprising the morphodynamic system of the coast. Briefly, following Wright & Thom (1977), a basic tenet of the vulnerability assessment applied here is that if one component of a morphodynamic system changes the rest respond. For the Pilbara coast, this response is extensively modulated by geological control.
2. The rocky terrain along and underpinning the coast provides a fixed geological framework for the development of unconsolidated, sedimentary landforms. Following research reported from elsewhere (McNinch 2004; Valvo *et al.* 2005) and field observations made in the Pilbara (Semeniuk 1996) it is a major determinant of the susceptibility of the coast to changes in the metocean regime. This is acknowledged in the delineation of coastal compartments and in assessing potential coastal change at a site level.
3. The distribution and elevation of rock outcrops, including fossil coral reefs, beachrock and coastal limestones, as well as the extensive tidal flats of the coast are significant in that the presence of mud and rock invalidates the so called ‘Bruun Rule’ of erosion (Bruun 1962) which is commonly applied in setback calculations under the State Coastal Planning Policy SPP 2.6. This point was made by Bruun (1983, 1988) in his critical assessment of the ‘rule’. The use of landform classification helps to identify those areas where the processes inherent in Bruun’s conceptual model may be invalid.
4. A secondary determinant of the susceptibility of a coastal land system is related to the volume of unconsolidated sediment comprising the landforms of the shoreface (Houser & Mathew 2011). Herein the principle followed is that the different types and

dimensions of river deltas, barrier systems and rocky topography present along the coast are related to sediment availability.

5. Conceptual models of beach type, tidal flats, barrier structure, dune typology, deltaic landforms and river mouth morphology developed elsewhere (Section 2.4) are broadly applicable to the coast of Western Australia and identification of the relative stability or instability of coastal landforms.

7.3.2. Coastal Management Advice

Advice specifically pertaining to the coastal planning and management of each tertiary compartment is listed in Appendix F. Detailed interpretation and advice has also been made for the three Areas of Planning Interest in Section 6 above.

The advice for each compartment follows the format outlined in Table 2-13 to ensure a consistent interpretation has been applied for planning and management purposes, and that it complies with established guidelines developed by the WAPC (2003a, 2013), DPI (2006) and DoT (2010a). More specific information on the integrity of natural structures (susceptibility to change) and stability (instability) of landforms is obtainable through combined interpretation of the landform descriptions for each compartment (Appendix F) and the criteria used to rate landform susceptibility and stability (Table 2-7 and Appendix F).

More general advice is as follows:

1. Preliminary schedules in the State Coastal Planning Policy (SPP No.2.6) are outlined for the calculation of coastal erosion allowance, but there is no corresponding information for the susceptibility of a landform system to metocean forcing or the overall instability of landforms comprising the system. It is recommended the two aspects of coastal vulnerability be addressed in any review of the policy guidelines.
2. Locally the elevation of rock underlying unconsolidated sedimentary landforms directly affects the susceptibility of the coast to changes in metocean forcing and influences coastal stability. It is a factor that could be determined as a planning requisite prior to implementation of any development proposal involving the establishment of rural-urban infrastructure in areas where it is close to the limits of marine inundation or on perched dunes.
3. Policy and guidelines related to the siting of infrastructure on outwash plains, tidal flats and barrier systems is currently lacking. The different types of land systems support different assemblages of landforms. Determination of setback to development could be tailored to the different types with a larger setback allowance for stationary and eroded forms that are notably susceptible to change due to metocean forcing.
4. The Pilbara coast is markedly affected by tropical cyclones and river flooding. It also may be subject to tsunami inundation. Emergency management plans, including monitoring and evacuation plans, are required for areas of high risk as indicated in Section 6.
5. Due to the high level of risk it is recommended that flood risk evaluations due to terrestrial flooding and marine inundation be reviewed on a 10-year basis for reasons of:

- Uncertainty with climate change projections (GEMS 2009), environmental knowledge-base and analysis techniques (Harper *et al*. 2010);
- Changing flood risk implications arising from ongoing, natural and engineered changes to local geomorphology, land-use, population and infrastructure; and
- Changes in available surge and flood mitigation and management techniques, such as improvement of warning systems or relative availability of mechanical plant or staff.

This does not necessarily facilitate the need to completely reproduce full numerical modelling investigations for each review.

7.4. INCORPORATION IN POLICY

The susceptibility of coastal land systems to projected environmental change over a planning horizon of 100 years, and the stability of the landforms that each system supports could be incorporated in existing State planning policies and guidelines (WAPC 2002a, 2013; DPI 2006). Examples of susceptibility, instability and vulnerability rankings as well as their implications for planning and recommended planning guidelines are listed in Table 2-13. The rankings, their implications for land use and suggested guidelines for management are listed in Appendix F for each of the compartments and within tables in Section 6 for cells examined in the Areas of Planning Interest.

The analysis of compartments and sediment cells is intended to provide a natural framework with potential for a variety of applications in coastal planning and management. In this context Geographic Information Systems (GIS) models of the compartments and cells may be populated with information at the user's discretion and at appropriate spatial scales. Under the policy and guidelines provided by the State Government, possible applications depend on the information linked with cells as overlays or tables for comparative purposes as has been done in this report. Potentially, applications range from structured audits of coastal population associated with individual land systems or landforms, infrastructure, coastal land use and tourism activities to comparative assessment of the exposure of different parts of the coast to geographically different hazards and risks.

Direction for coastal planning and management by the State and Local Government is provided in the Coastal Zone Policy for Western Australia (WAPC 2001). The policy supports strategic objectives for environmental, community, economic, infrastructure and regional development interests; particularly through the recognition of natural hazards and minimisation of risk to people and property. Application of coastal zone management is mainly directed through the *State Coastal Planning Policy* SPP 2.6 (WAPC 2013), the *Natural Hazards Policy* SPP 3.4 (WAPC 2006), the *Coastal Protection Policy* (DPI 2006) and *Sea Level Change in Western Australia* (DoT 2010a) recommendations for inclusion of sea level change projection in coastal planning. These policies contain specific reference to incorporation of coastal landforms and metocean processes in coastal planning and management. The reference provides a direct link to the hierarchy of coastal compartments and sediment cells and, through them to coastal planning at all levels.

The SPP 2.6 (WAPC 2013) promotes the establishment of coastal setbacks and foreshore reserves to achieve strategic objectives of the Coastal Zone Policy for Western Australia (WAPC 2001), with focus on the following:

- *Recognition of the dynamic nature of coastal environments and the consequences for coastal development and use.*
- *Avoidance or mitigation of the impacts of natural hazards through intelligent siting and design of infrastructure, based on ongoing scientific research.*

Through the SPP 2.6 (WAPC 2013) and the Coastal Protection Policy (DPI 2006) it is recognised that land developments may be adversely affected by a range of physical processes occurring at the coast, with three of the most common being:

- Coastal erosion or accretion;
- Coastal flooding; and
- Coastal landform instability.

A general method for calculating a horizontal setback allowance for coastal erosion is outlined in the SPP 2.6. Calculation of coastal setback to development is most appropriate at more-detailed local area planning and site scales than the sediment cell scale adopted for this report. However, the principles of recognising coastal dynamics and avoiding adverse impacts incorporated in the policy are relevant to vulnerability assessment. They are applicable in assessment of flooding and landform instability. Although site specific, they loosely entrain consideration of the susceptibility of each site to potential change and its current state of stability. Typically applications of SPP 2.6 include identification of minimum development levels, or minimum reserve widths to cater for shoreline movement and changes in sand dune formations.

Where use of wide setbacks is not practical or subsequent shoreline change has significantly reduced a setback allowance the Coastal Protection Policy (DPI 2006) allows for development of protective structures in the context of a coastal hazard and risk management plan (WAPC 2013). However, clear justification for protective works is required, and unacceptable adverse environmental, social or financial impacts to neighbouring areas must be avoided. Within this context, the effects of sand impoundment by a protective structure must be considered:

> "*The natural supply of littoral sand is a resource shared by all West Australians. Accordingly, those benefiting from future works or developments that change the natural supply of sand along the coast shall compensate for the change to that supply...*"

The points made in State coastal policy guidelines of the WAPC (2003a, 2013), DPI (2006) and DoT (2010a) provide direction for the recommendations arising from the vulnerability analysis in two respects. First, coastal development should not be proposed in areas where there is a high probability of adverse environmental and other impacts occurring that would require installation of protective works in the projected 'life' of the proposed development, especially on 'green field' sites. Second, the requirement to consider the impact of proposed development on sand impoundment necessitates determination of the coastal sediment budget at a scale commensurate with the scale of the proposed development.

Through its context in coastal policy guidelines the vulnerability assessment also provides insight into approaches that may be used in land use adaptation to projected climate change and rise in sea level. Different facets of adaptation may be considered. For example, in undeveloped areas where there is a higher than moderate level of risk the vulnerability analysis can be used to plan avoidance of sites with potential risks or incorporated in plans that include contingency measures should development be necessary. Second, in areas with established infrastructure the vulnerability analysis may be used to determine the suite of environmental problems requiring more detailed risk assessment and the incorporation of social and economic considerations.

7.5. FURTHER STUDIES

Further studies are required for hazard and risk assessment under the State Planning Policy 2.6 (WAPC 2013), to reduce information gaps, and for management purposes.

7.5.1. Risk Assessment

This report is intended to be indicative rather than prescriptive and have application for strategic planning purposes. It focuses specifically on the current and potential changes to the geomorphologic features of the coast. In a more complete assessment of coastal hazard and risk the assessment should be extended to include descriptions of landform change associated with meteorologic and oceanographic variables as well as consideration of the social and economic factors at risk. Results reported herein thus provide a first step to the application of more detailed risk and coastal vulnerability assessment procedures, such as those described by Kay *et al.* (1996), Brooks (2003), Harvey & Nicholls (2008), Harvey & Woodroffe (2008) and Finlayson *et al.* (2009). It broadly establishes the first steps to a full risk assessment. Full risk assessments are recommended for developed areas, including the townsites, and areas subject to increasing use for tourism and recreational purposes.

Frameworks and guidelines for risk assessment previously have been applied in an assessment of risk to the sustainability of a coastal, natural-resource based industry by Ogburn & White (2009) and to coastal management in New South Wales by Rollason *et al*. (2010). Both applications use the AS/NZS ISO 31000 risk assessment framework (Standards Australia 2009) to determine management outcomes in circumstances where there is considerable uncertainty and a lack of detailed data to describe coastal changes. Both describe circumstances relevant to vulnerability assessment for land systems and landforms along the Pilbara coast. A similar approach has been adopted in this report by using a combination of structure and condition to determine vulnerability of land systems and landforms to existing and projected changes in metocean forcing. The vulnerability estimates are subsequently linked to broad estimates of the likelihood of environmental changes occurring. Vulnerability rankings then may be used to establish consequence and risk tables for the coastal land systems and landforms for a more detailed risk analysis that is not undertaken in the context of this report. However, it does provide an indication of further information requirements.

Risk assessment is commonly is undertaken in an established framework, such as the principles and guidelines within AS/NZS ISO 31000 (Standards Australia 2009). Assessment provides an estimation of the likely consequences arising from occurrence of a hazardous event, ranging from insignificant to catastrophic outcomes. Estimations of the likelihood of the event occurring (Table 7-1) are based on limited experience with hazard identification, description and mitigation within the region of interest. The hazard estimates are used in consequence tables such as that presented by Australia Pacific LNG (2010) to examine the likelihood of health, safety and environmental consequences of different types of hazards (Table 7-2). They are prepared as part of Environmental Impact Statements (EIS) for major development proposals in Australia. The method subsequently enables the consequences of hazards impacting on the environment to be prioritised and considered in a full risk assessment. In this respect the framework provided by AS/NZS ISO 31000 guidelines (Standards Australia 2009) has relevance to the State Planning Policy 2.6 (WAPC 2013). Regardless of risk a full hazard and risk assessment is required for all development under existing State Government coastal planning and management policies.

Table 7-1: Probability Table Based on Metocean Forcing and Geologic Records (Source: Rollason *et al.* 2010)

Probability	**Likelihood**
Almost Certain	There is a high possibility the event will occur as there is a history of periodic occurrence
Likely	It is likely the event will occur as there is a history of casual occurrence
Possible	There is an approximate 50% chance that the event will occur
Unlikely	There is a low possibility that the event will occur. However, there is a history of infrequent and isolated occurrence
Rare	It is highly unlikely that the event will occur, except in extreme circumstances which have not been recorded historically.

Steps in the framework provided by AS/NZS ISO 31000 guidelines presuppose the availability of a wide variety of metocean, geomorphologic, social, cultural and economic information. Advisedly, collation of the physical information required for a full risk analysis would be based on a comprehensive review of available data to identify gaps and directed to enable:

- Detailed consideration of potential impacts of metocean processes (waves, winds, water levels, tropical cyclones and river discharge), including geotechnical survey (site assessment of elevation and coverage of underlying rock using drilling or other appropriate technique) where appropriate This is most likely to be where it affects elements or landforms with lower integrity of natural structures or limited natural resilience.
- Determination of the potential impacts of extreme metocean events (especially extreme tropical cyclones and tsunamis) on these elements or landforms based on geological and historical (measured and surrogate) information as well as modelling of projected future extreme events.
- Identification of sediment sources, sinks and key transport pathways as a first step to determine the rate of coastal change and the potential impact of any proposed land through modification of the coastal sediment budget and its affect on the most unstable landforms.

Table 7-2: HSE Consequence Categories for Critical and Catastrophic Levels of Risk (Source: Australia Pacific LNG 2010: p6)

	Impact to company personnel	Natural environment	Community damage/ impact/ social/ cultural heritage
Catastrophic	Multiple fatalities ≥4 or severe irreversible disability to large group of people (>10)	Long term destruction of highly significant ecosystem or very significant effects on endangered species or habitats	Multiple community fatalities, complete breakdown of social order, irreparable damage of high value items of great cultural significance. Adverse international or prolonged (>2 weeks) national media coverage
Critical	1-3 fatalities or serious irreversible disability (>30%) to multiple persons (<10)	Major off-site release or spill, significant impact on highly valued species or habitats to the point of eradication or impairment of the ecosystem. Widespread long-term impact	Community fatality. Significant breakdown of social order. Ongoing serious social issue. Major irreparable damage to highly valuable structures/items of cultural significance. Adverse national media coverage (>2 days)

The report section on coastal planning, hazards and risk provides support for more detailed risk assessments in the Pilbara region. The original intention was to also include a section on *Erosion Risk Management* with discussion of the implications of SPP2.6. Information on erosion hazard assessment, erosion hazard mitigation options and descriptions of land use sensitivity to adaptation have not been included in this report. This task was determined to be a large report in its' own right, and therefore is not a part of this project.

7.5.1. Data Requirements

Data requirements include:

- Baseline coastal monitoring information such as shoreface profiles should be collected for reaches of coast of high vulnerability that support infrastructure and for which limited historic information is available.
- It is recommend LiDAR mapping of the inshore waters be completed to provide a wider context for available bathymetric information and provide a more complete assessment of natural resources, including sediment availability and distribution. LiDAR imagery has been gathered by commercial agencies for infrastructure planning. This might be drawn into a wider coverage and is important because it would enable detailed interpretation of marine habitats and sediment movement adjacent to an area subject to increased settlement and land use pressure. Detailed inshore bathymetry for management of the inshore is available for parts of the coast, particularly in the vicinity of towns but would be extended and supplemented by the LiDAR imagery collected for large infrastructure projects.
- Coastal sediment budget information, including determinations of approximate volumetric rates of sediment transport and identification of sediment sources and sinks at Onslow and Port Hedland.

- Determinations of the elevation and coverage of underlying rock are required for sites supporting urban-rural development and infrastructure that may be located on unconsolidated sediments overlying bedrock surfaces, particularly in areas landward of storm bars. Full geotechnical survey using drilling or other appropriate technique is recommended for these sites.
- Establishment of the location, elevation and age of wrack lines indicative of the limit of storm surge or tsunami inundation during periods of unusually extreme high water level. This would clarify the frequency distribution of extreme events and the likelihood of their recurrence over a planning horizon of 100 years, contribute to identification of suitable setbacks to development, and indicate fill levels where infrastructure is necessarily located close to the shore.

7.5.2. Other Requirements for Management Purposes

Other requirements for management purposes include:

- Identification and costing of ongoing management requirements at developed sites as well as those proposed for development or increased land use.
- Determination of potential migration or retreat of unstable landforms and the potential impacts of landform change on existing and proposed development.
- Identification of costs and allocation responsibility for management of coastal protection and stabilisation works, such as engineered structures and sediment bypassing, for the adjacent coast, as well as for ongoing coastal monitoring, maintenance and management of the site.
- Strategies to respond to metocean events and other site disturbances of various frequencies and magnitudes.

7.6. RECOMMENDATIONS FOR THE AREAS OF PLANNING INTEREST

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. Some consideration may be given to setting this land aside for the purposes of coastal protection and hazard mitigation. 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).

Additionally, it is advised that development requires consideration of long-term management responsibility for coastal protection and stabilisation works, as well as for ongoing maintenance and management of the site. Required stabilisation works should be identified and costed. The Department of Transport's operational policy for coastal protection (DPI 2006) indicates that the State has not provided erosion protection for private property, and has no general obligation to do so. The authority to assist local government with finance for coastal protection works is only through ministerial direction. Advisedly, proposed developments should not devolve responsibility for protection works, or ongoing maintenance (such as bypassing), to the State or Local Government. It would be useful to investigate the applicability of *State Planning Policy 3.6 – Development Contributions for Infrastructure* (WAPC 2009b) for developer contributions to life-cycle costing for any coastal protection and stabilisation required for new developments, such as would be required for the Spoil Bank and Pretty Pool precincts in Port Hedland.

Advice and further studies have been prepared for each of the Areas of Planning Interest in Section 6. These sections should be read in conjunction with the full relevant Area of Planning Interest section and with the information on coastal planning, hazards and risk contained in Section 6.1, which excludes detailed information specific to erosion risk management.

Advice

For all areas of the Pilbara, any approach used for hazard mitigation should be cognisant of the potential transfer of risk to adjacent sites or processes when considering coastal flooding, runoff flooding or a combination of the two. Any planning or potential mitigation works for areas prone to flooding should incorporate the requirements within the *Better Water Management Plan* (WAPC 2008b) at the relevant scale. Flood hazard mitigation advice should be sought from the Department of Water with additional advice from the Department of Transport coastal engineers for works with a coastal component.

Specific advice for each area of planning interest is summarised below, with further detail contained in Sections 6.2.5 for Onslow, 6.3.5 for Karratha area and 6.4.5 for Port Hedland.

1) Onslow

- Connectivity of alongshore transport within sediment cells requires consideration for any coastal development.
- Application of emergency management principles should apply to flood hazard mitigation, considering isolation of residential properties, ensuring key facilities are located in areas of low risk and providing a suitable evacuation plan.
- Consideration is required for the maintenance, and potential failure, of the salt pond levee structures in planning, emergency management and risk assessments.

2) Karratha area

- Assessments should be undertaken at a range of scales, with active and adaptive coastal management due to the complex interplay between rock features, fluvial systems and coastal floodplains. Consideration of the full range of possible coastal and runoff flooding events should be considered, with recognition of the high degree of uncertainity in flood hazard assessments.
- Construction should be avoided within any floodways or the active coastal margin.
- Any development within the broader area should incorporate drainage management.

- Application of emergency management principles should apply to flood hazard mitigation, considering isolation of residential properties, ensuring key facilities are located in areas of low risk and providing a suitable evacuation plan. Maintenance and adaptation funding should be secured for the roads to Point Samson and Cossack townsites which are vulnerable to washout due to migration of tidal creeks.
- Natural barriers and artificial structures should be maintained or fortified to ensure they have sufficient structural capacity to minimise risk of erosion and inundation
- Sediment transport under a broad range of environmental conditions may require consideration for coastal developments, particularly where the reliability of sediment supply may affect sedimentation or post-erosion recovery rates. A range of factors should be considered for sediment supply to the rock controlled shores of the Karratha area.
- Assessment of coastal development impacts on post-event recovery processes and pathways is required for: any structures on beaches, perched beaches and spits; any plans to dispose of large amounts of dredgd material; any structure extending onto tidal flats; and any works incorporating excavation of intertidal rock and terraces.
- For Karratha townsite, consideration is required for the maintenance, and potential failure, of the Dampier salt pond levee structures in planning, emergency management and risk assessments.
- New or expanded wastewater treatment facilities will be required as the population in the area expands. Source-Receptor-Pathway investigations are required for siting of sewage outfalls for managing environmental and health risk given the broad shallow terraces and flats.

3) Port Hedland

- Construction should be avoided within any floodways or the active coastal margin. Any construction within the active coastal margin would require preparation of a Coastal Hazard Risk Management and Adaptation Plan (WAPC 2013), with consideration of risk transferral through raising land and limited placement of culverts.
- Application of emergency management principles should apply to flood hazard mitigation, considering isolation of aboriginal communities and residential properties in the main area of Port Hedland, Wedgefield and South Hedland, ensuring key facilities are located in areas of lowest practical risk and providing a suitable evacuation plan. Adaptation funding, or allowance for ongoing maintenance should be secured for roads potentially vulnerable to washout due to migration of tidal creeks or inundation.
- Adaptation to future conditions may require maintenance or fortification of both natural and artificial existing barriers to ensure they have sufficient structural capacity to minimise erosion and inundation hazards.
- It is important to note that definition of setback allowances may have little resemblance to prediction of likely coastal change.
- Sediment transport under a broad range of environmental conditions may require consideration for coastal developments, particularly where the reliability of sediment supply may affect sedimentation or post-erosion recovery rates. A range of

factors should be considered for sediment supply to the rock controlled shores of Port Hedland, particularly the perched dune systems.

- Assessment of coastal development impacts on post-event recovery processes and pathways is required for: any structures on beaches, perched beaches and spits; any plans to dispose of large amounts of dredgd material; any structure extending onto tidal flats; any works incorporating excavation of intertidal rock and terraces; cumulative impacts of previous engineered modifications; any structure on dune crests or overwash features; any emergency dune stabilisation works; and any stormwater discharge to the coast.
- Stormwater discharge to the coast should be managed to reduce sediment scour and associated dune retreat and undermining of infrastructure. Local planning documents could be updated to conside the coastal response to stormwater discharge and the requirement for any development within the broader area to incorporate drainage management. An adaptation study could be conducted for the management and possible relocation of the two large drains at Wodinga Street (Cemetery Beach) and Barker Court (Goode Street Dunes) including life-cycle costing.
- Road modification and salt pond expansion projects should consider drainage management and culvert design in relation to the existing tidal creek network and anticipated change with sea level rise.
- Active coastal management may be required in the sections of sandy coast without high-level rock control.
- Active coastal management for remediating wind drift of sediment should incorporate the cause of any dune instability.
- The Spoil Bank precinct requires a detailed investigation of coastal hazards and risk mitigation prior to preparation of structure plans including surge risk, potential sedimentation, uncertainty of future sediment supply and emergency management. The feasibility of marina operability should be assessed in the context of requirements of ongoing dredging and active sediment management, along with all associated costs.
- The Pretty Pool precinct, including land made available from the relocation of the wastewater treatment plant, requires a detailed investigation of coastal hazards and risk mitigation.
- Consideration is required for the maintenance, and potential failure, of the Rio Tinto salt pond levee structures in planning, emergency management and risk assessments.
- Expanded wastewater treatment facilities are commencing in South Hedland. A hazard and risk mitigation investigation should be prepared for the proposed eastward expansion as it encroaches into flood-prone land. If future expansions incorporate any sewage outfalls to the ocean, Source-Receptor-Pathway investigations are required for managing environmental and health risk given the broad shallow nearshore and tidal flats.

Further Studies

The following further studies were identified for at least one of the three Areas of Planning Interest with further detail contained in Sections 6.2.6 for Onslow, 6.3.6 for Karratha area and 6.4.6 for Port Hedland:

- Coastal System Stability Assessment and Barrier Stability Assessment.
- Coastal Adaptation and Flood Hazard Adapation Study.
- Inundation Review.
- Coastal Change Evaluation.
- Building Design Criteria and Auditing, including for Flood Hazards.
- Post-Event Surveys.
- Tidal Creek Baseline Assessment.
- Evaluation of Runoff-Surge Coincidence.
- Aggregation of Stakeholder and Resource Company Data.
- Use of the Spoil Bank Material in Port Hedland.

A useful further investigation could be a compilation of previous advice and any associated actions undertaken for each Area of Planning Interest. The advice would relate to planning, management and engineering with the relevant report references provided.

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Appendix A Project Brief

Development of Tertiary Coastal Compartment Concepts for the Pilbara Coast

1. BACKGROUND

The intention of this contract is to support the implementation of natural resource management through strategic regional land use planning initiatives consistent with the key findings and recommendations of the Directions Paper on the Integration of NRM and Land Use Planning (Department for Planning and Infrastructure 2008).

Guided by the State Coastal Planning Policy (SPP 2.6), this project will provide guidance to strategic planning, and direction on appropriate land uses and development for the Pilbara coastline.

The Pilbara Coast has been identified as requiring detailed investigation due to emergent development and land use pressures. The expansion of the mining, oil and gas sectors is a key driver for growth in this region. The State Government's Pilbara Cities initiative intends to expand the region's resident population and to rectify infrastructure inadequacies by the development of the twin cities of Karratha and Port Hedland, each of which will have a population of 50,000 by 2035.

It is also anticipated that the increase in demand on the region's coastal recreational sites will result in the need for additional tourism and recreational facilities, including moorings, new ramps for small boats and upgrading of existing facilities. Appropriate locations for coastal nodes for recreational and tourism development therefore need to be determined.

Previous investigations undertaken to identify coastal stability and susceptibility to change along parts of the Western Australian coast have been conducted in consultation with officers from the Departments of Planning (DoP), Transport, Environment and Conservation and the Geological Survey of Western Australia, as well as private industry groups, to assist the State Government in providing informed planning guidance for regional and sub-regional strategic planning. However, these previous studies focussed on specific local areas under increasing pressure for development and there remains a need for further investigation of the broader Pilbara Coast to guide strategic planning for future land use.

The project will not duplicate work which has been done or is currently occurring, rather it will apply a coastal compartment (geomorphic stability and susceptibility/vulnerability) methodology to provide a strategic land use context to the management of coastal and inshore marine resources to aid planning decision making, particularly at the regional level. This method has been applied along sections of the Western Australian coast from Cape Naturaliste to Lancelin, and has most recently been used to analyse the coastline between Dongara and Geraldton. The outcomes have provided the government with valuable guidance to make better planning decisions at key pressure areas along the WA coast.

At a local level, this project will provide strategic information for agencies along the Pilbara Coast to respond to key challenges such as:

- Planning for urban and industrial growth, and planning and management of tourism/recreation uses to ensure environmental impacts are acceptable and can be appropriately managed and/or mitigated (to the extent of current availability of suitable information);
- Protecting and maintaining significant environmental assets and values on the region's coast, including off-shore islands, the foreshore, coastal tidal flats, dunes, coastal ecosystems and marine waters;
- Identifying appropriate locations for recreational and/or tourism land uses;
- Maintaining and enhancing safe public access to the foreshore and coastal waters and ensuring public access is designed and maintained to conserve coastal resources; and
- Reducing community risk and exposure to the adverse impacts of natural hazards, including cyclones, flooding, and storm surge.

The Department of Planning reserves the right not to proceed to Stage Three of these services.

2. CONSULTANCY FRAMEWORK

The investigation will provide a broad understanding of the landform systems and their components in the subject areas as well as the principal hydrologic and metocean processes affecting them. This will involve assessment of aerial photography of the study area, site visits, preparation of a GIS information base for use by natural resource managers and a review of relevant and available metocean information. Certain landforms and coastal features are more at risk from variations in climate and fluctuation in sea level than others. Interpretation of the data gathered will assist decision-making regarding coastal development by allowing identification of areas for potential future development as well as vulnerable locations that are less suitable. It will also highlight areas that require more detailed, site specific, assessment.

3. GEOGRAPHIC AREAS

The contract will involve the geographic area covering coastal portions of the Shires of Ashburton, East Pilbara, and Roebourne, as well as the Town of Port Hedland. The contract stages below will need to be completed to include each of the four local government regions mentioned above.

4. CONSULTANCY COMPONENTS

The proposed Consultancy has three stages:

Stage 1

The first stage of the contract will focus on the high level assessment of coastal land systems and landforms (tertiary coastal compartments) potentially susceptible to risks related to natural variation in climate and sea level fluctuations (metocean processes), and which may be affected by projected changes in climate.

This stage of the contract will involve site visits and aerial photographic analysis of coastal geographic areas. It is the responsibility of the successful Respondent to provide details confirming that all necessary access arrangements have been secured for any site visits including, but not limited to, proof of consent from land owners and Native Title holders.

In Stage 1 of the contract, the successful Respondent will gather and assess the following information:
A. Coastal Landforms and Processes

- Description and mapping of coastal land systems for each of the Shires of Ashburton, East Pilbara, and Roebourne, as well as the Town of Port Hedland;
- Description and mapping of coastal landforms with particular reference to, mudflats and coastal lowlands, coastal dunes, beaches, rocky shores and inshore morphology;
- Review of available information describing metocean processes, including coastal processes affecting land system development; and
- Identification of land systems and coastal landforms (tertiary coastal compartments) susceptible to risks related to natural variation in climate and sea level fluctuations, and which may be affected by projected changes in climate.

B. Coastal Land Use
From existing information, the description and mapping the likely impact of current and future land use and development pressures on coastal and inshore marine resources within the subject area (including, but not limited to, tourism and recreation, urban/industrial development, mining/raw materials extraction, and regional infrastructure provision).

Stage 2
The second stage of the services will consist of incorporating data from the first stage, and preparing a technical report, supported with thematic mapping, describing the coastal land systems, landforms and processes, as appropriate.

The technical report will clearly identify opportunities for the protection and management of coastal and inshore marine resources with a view to consider issues at a more-detailed, sediment-cell level for focal areas, where considered appropriate.

Stage 3
The final stage to this contract is to present the findings of this project and provide recommendations concerning coastal planning and management to each of the Shires of Ashburton, East Pilbara, and Roebourne, as well as the Town of Port Hedland (i.e. minimum of one presentation to be undertaken in the Pilbara).

Please be aware that as outlined above, the Department of Planning reserves the right not to proceed to Stage Three of these services. Respondents are to price Stage Three separately as per the price schedule.

5. OUTPUTS
The Consultancy will provide the following outputs:

- Technical report and supporting maps (to be provided in both hardcopy and digital format) incorporating the data from the first Contract Component (above). Components to include in the report are as follows:
  - Policy framework (state legislation and/or planning policies relevant to coastal planning and management);
  - Analysis of coastal processes (identifying areas potentially at risk from sea level fluctuations and other metocean processes);
  - Identification, description and mapping of land systems and the landforms they support;
  - Identification, discussion and mapping of landform stability and susceptibility to change for each tertiary coastal compartment (including a detailed glossary); and
  - A discussion, for each coastal compartment, which identifies opportunities for the protection and management of coastal and inshore marine resources.
- A presentation made to each of the Local Governments on the findings of the investigations and the provision of recommendations concerning coastal planning and management (for example: describe any potential and inappropriate land uses in each local government area).

The Consultant shall meet with the project management team at Department of Planning on a regular basis, or at completion of each milestone, for discussion and review of the progress of the contract. Reports should be presented to the Western Australian Planning Commission (WAPC) to the Commission's Publication, Project Mapping and Display Mapping Standards.

Draft reports should be provided to the project management team at DoP, for discussion and feedback prior to finalisation.

6. REPORTS

It is anticipated that a minimum of three revisions (drafts) of the report will be provided to the project management team at Department of Planning, for discussion and feedback prior to finalisation.

Project reports shall be in Microsoft Word format, with three hard copies of each to be provided. Maps will be produced in GIS compatible format.

7. TIMING

The completion of the final reports under this Consultancy is anticipated to take no longer than 10 weeks to complete. Presentation(s) to the Pilbara Local Governments (if required) may be undertaken within approximately 10 weeks of the project management team's acceptance of the Consultant's final technical report.

Prior to commencing the Consultancy, the Consultant shall arrange an inception meeting with the project management team to:

- Confirm and clarify the scope of the Consultancy;
- Confirm Consultancy milestones, reporting timeframes and meeting timescales;
- Confirm arrangements (methodology) to commence of the Consultancy;

- Verify any other matters concerning the review;
- Obtain any relevant documents;
- Discuss specific issues related to each geographic area, for example:
  - — Potential and appropriate land uses in each geographic area;
  - — Coastal 'hotspots' in each geographic area;
  - — Clarification of study area boundaries in each geographic area; and
  - — Any other issue deemed relevant by the Consultant or DoP.
  - — Provide details to the project management team confirming that all necessary access arrangements have been secured for any site visits including, but not limited to, proof of consent from land owners and Native Title holders.

8. TRAVEL AND OTHER DISBURSEMENTS

All travel and disbursements are to be factored into the lump sum for each geographic stage of the project in the RFQ. The Successful Respondent may, if it believes it is warranted for its methodology, propose additional travel within its quotation for consideration by the Department. The acceptance of any additional travel proposed is at the discretion of the Department.

Appendix B Glossary

	Term	Explanation
A	Alongshore	Marine and beachface processes operating along the coast are *alongshore* processes. The term alongshore also indicates direction.
	Arcuate shoreline	An *arcuate shoreline* is an embayed shoreline. In plan form the arc is concave to shoreward and may be a half-heart shape, occasionally referred to as a zeta-form, or semi-circular in form. The shape provides an indication of ocean processes affecting the shore of the embayment.
	Aspect	*Aspect* is the direction to seaward the coast faces. It is estimated in the centre of the coastal feature being examined and at right angles to the trend of the coastline in plan. The direction faced by the coast determines the prevailing and dominant metocean processes to which it is susceptible. For example, unsheltered NW facing coasts in the region are fully exposed to storms from that direction.
	Avulsion	*Avulsion* is the switching, or rapid migration, of a river channel location and abandonment of the prior channel. This behaviour may be common on large active delta systems.
B	Backshore	The most landward extent of bare, unvegetated beach is the *backshore*. It is a zone infrequently inundated by storm waves active during phases of extreme, higher-than-average sea-level conditions.
	Backbarrier	The most landward barrier landforms, particularly the coastal dunes furthest inland, sandflats and washover lobes extending into coastal lagoons are referred to as *backbarrier* features.
	Barrier	*Barriers* are relatively narrow strips of sand parallel to the mainland coast. The sands occur in distinct lenses deposited at a particular geological time, with the most recent barriers being formed during the Holocene, over the past 10,000 years. Landforms associated with barriers extend from the inner continental shelf include those of the active shoreface, beach and dunes along the coast. The suite of dunes comprising the landform may be referred to as *barrier dunes*.
	Beach profile	The beach profile is the cross-sectional shape of the beach from the seaward toe of the foredune or upper reach of wave action to the seaward limit of currents generated by breaking waves. In a seaward sequence the profile may include the following morphology: berm, beachface, step, trough, ripples and bar. It is comprised of several zones defined by the dominant processes, including the subaerial beach, swash zone, and nearshore zone.
	Beach response	The response of a beach to metocean forcing, human intervention and/or alteration in sediment supply.
	Beach rock	A friable to well-cemented sedimentary rock, formed in the intertidal zone.
	Beach type	Beaches are categorised according to their environmental setting and profile configuration. In the context of this report the first distinction is between beaches located in *sheltered* or *exposed* locations where the most common wave conditions are less or higher than 50cms. *Sheltered beaches* have profiles that are flat or rounded. Both exposed and sheltered beaches may overlie a rocky substrate. These are *perched beaches*.
	Birrida	Flat, raised pan, often elliptical in shape. These are commonly lagoons and tidal creek systems that were previously connected to the ocean.
	Blowout	In plan form a *blowout* has a parabolic form with a width greater than its length. Blowouts occur in partially vegetated foredunes. A *blowout* forms when a patch of protective vegetation is lost, allowing strong winds to "blow out" sand and form a depression.
C	Calcarenite	A limestone consisting predominantly of sand-sized carbonate grains.

	Chenier	A discrete, elongated beach ridge, comprised of marine sand or shell, which is stranded on a coastal mudflat or marsh, roughly parallel to the shore. The ridges may be vegetated. . When cheniers are distributed across a wide plain on a prograding shoreline, that feature is called a 'chenier plain' (OzCoasts)
	Chenier spit	A chenier that is joined to the mainland on one end but not the other, thus forming a spit.
	Cliffed dune	The seaward margin of a foredune or frontal dune may be cut by coastal erosion that results in the formation of a low sandy cliff.
	Coastal compartment	A coastal *compartment* is a component of the geological framework of the coast. It is an area of coast bounded alongshore by large geologic structures, changes in geology or geomorphic features exerting structural control on the planform of the coast. Compartments contain a particular Land System or landform association depending on the scale at which they are being described.
	Continuous reef	*Continuous reef* occurs where an unbroken line of reef extends parallel to the shore for at least the length of the coastal feature under consideration.
	Curvilinear (rounded) beach	Beaches in sheltered environments subject to a relatively high wave regime compared with other sheltered beaches may have an upwardly convex or concave beachface profile. These are curvilinear in form and may grade to a step at the seaward limit of the swash zone.
	Cuspate foreland	On the Ningaloo coast of Western Australia *cuspate forelands* are triangular-shaped accretions of sand extending seawards in the lee of an offshore reef. *Cuspate forelands* principally develop in response to longshore movement of sediment and hence are highly susceptible to changes in metocean processes.
	Delta	A landform comprised of branched or interleaved channels and alluvial deposits occurring at the mouth of a river, due to high river discharge and sediment supply.
D	Discontinuous reef	*Discontinuous reef* occurs where the line of reef extending parallel to the shore has gaps or breaks over the length of the coastal feature under consideration. The length of gaps along the coast under consideration is significantly less than that occupied by reef.
	Dissipative beach	A *dissipative beach* is one in which wave energy is substantially expended as the wave moves from its break point to the shore. Multiple lines of breakers are present. On an exposed wave-dominated coast wave heights exceed 2.0m and the profile includes a flat beachface with multiple bars and troughs in the inshore zone. In a sheltered environment where wave heights are less than 0.25m the profile is planar, with a very broad sub-tidal terrace.
	Division	A *division* is a subdivision of a broad climatic zone. The unit provides an overview of the whole state suitable for maps at scales of about 1:5,000,000. For example, wet-dry tropics and sub-tropical areas are subdivisions of the tropical zone in north Western Australia.
	Drainage basin	The geographic area that contributes runoff to a stream. It can be outlined on a topographic map by tracing the points of highest elevation (usually ridge crests) between two adjacent stream valleys. Also referred to as a "watershed".
E	Eolianite	*Eolianite* is weakly cemented rock that is commonly comprises calcareous dune sand derived from a marine environment. The stratigraphy of the dunes in which the eolianite has formed is usually present in outcrops.
	Ephemeral creek	River or stream catchments with intermittently flowing streams that are locally important at times of high flood discharge, particularly when they interact with coastal processes.
	Episodic, transgressive dune barrier	An *episodic, transgressive dune barrier* comprises nested blowouts and/or parabolic dunes. The dunes commonly form a ridge of irregular height along the coast. The ridge and its dunes are the surface features of the barrier which also extends offshore as a marine deposit of sands with a similar mineral composition to those found in the dunes.

	Exposed beach	*Exposed beaches* are open to the full effects of metocean processes. The beaches experience average wave heights of over 1 metre and are considered to be wave dominated. They have reflective, transitional or dissipative profile features.
F	Flat beach	*Flat beaches* occur in very sheltered environments, those with a modal wave height of less than 25cms. The beach profile is likely to have a negative exponential shape with a small, narrow, upwardly concave beachface grading to a flat low tidal and wide intertidal terrace that terminates in a steep drop to deep water.
	Flood basin or flood storages	Those very low-lying parts of a floodplain that are important for the temporary storage of floodwaters during passage of a flood.
	Floodplain	The undulating portion of a river valley, adjacent to the river channel, which is covered with water when the river overflows during floods
	Floodway	Those areas where a significant volume of water flow during floods. They are often aligned with obvious naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow. This may in turn adversely affect other areas. They are often, but not necessarily, the areas of deeper flow or the areas where higher velocities occur.
	Foredune	A *foredune* is a small coastal dune or low ridge. Foredunes are commonly less than 10m in elevation, located parallel to the shoreline and along the landward margin of a beach and stabilised mainly by pioneer vegetation. Foredunes are built through pioneer vegetation trapping of windblown sand directly from the beach. They build in height until the vegetation is destroyed; blowouts are formed and migrate landwards.
	Foreshore	The *foreshore* of a beach includes the berm, swash zone and lower intertidal zone.
	Frontal dune	Blowouts and parabolic dunes closest to the shore and immediately landward of the backshore where foredunes have formed or potentially could form are the *frontal dunes* or *primary dunes*. Absence of a foredune supporting pioneer species and scarping (cliffing) of the frontal dunes is indicative of a depleted sediment supply and coastal erosion.
G	Geologic framework	The *geologic framework* of a coastal area is the surface topography or geometry of bedrock in a designated area that interacts with metocean processes and the sediment transport regime to affect the distribution of unconsolidated sediments and the development of coastal landforms.
H	Hind Dunes	*Hind dunes* are those landward of the frontal or primary dunes.
	Holocene	The *Holocene* is a geological epoch that began approximately 12,000 years ago. It is an interglacial period of atmospheric warming and sea level rise. During the last 10,000 years before present sea level rose from below 50m to a peak of 1 to 2 metres above its present level approximately 6,000 years ago. The modern coast developed in response to this rise and subsequent fall.
I	Induration	The process of becoming hard. In geomorphic terms, this is commonly associated with the calcification of marine sediments to form cohesive or sedimentary rock deposits.
	Inshore	In the context of this report the term *inshore* refers to waters and seabed less than 25m deep adjoining the shore. The area commonly includes offshore reefs and the lagoons they impound.
	Instability	*Instability* refers to the current condition of similar landforms from different places. For example, it may be apparent as the percentage of vegetation cover on different dune fields, the completeness of foredune development on sandy beaches or differences in the historical records of shoreline movement on beaches.
	Interfluves	An area between adjacent watercourses, such as stream channels or river channels.

	Intermittent reef	*Intermittent reef* occurs where outcrops are uncommonly distributed in waters along the coastal feature under consideration.
	Intertidal	Coastal area exposed and inundated under varied tidal conditions.
	Isobath	An *isobath* is a submarine contour line indicating points of equal depth on a bathymetric map.
J		
K		
L	Lagoon	A coastal *lagoon* is a water body sheltered from the full impact of oceanographic processes by an offshore reef or dune barrier.
	Land system	A *land system* is an area of characteristic landform patterns suitable for mapping at regional scales of 1:50,000 to 1:100,000. Several landforms form a landform pattern which in turn comprises a land system.
	Landform	A *landform i*s a natural feature of the Earth's surface. Landforms range in size from small features apparent at a local scale to large structures apparent at a land system or regional scales. In the context of this report the term is used to describe features apparent at a local scale of 1: 500 to 1:25,000.
	Landform association	A *landform association* is a group of contiguous landforms that are associated in some way, commonly by shared location or age structure. For example, a Holocene sandy beach perched abutting an older dune and perched on a Pleistocene limestone platform..
	Landform element	Each landform is made up of geometrically recognised components or *landform elements*. For example a blowout dune includes a slack, side walls, dune crest, slipface and toe slope.
	Landform pattern	A *landform pattern* is a group of landforms of a common geologic age that is the landform part of a land system. For example, a Holocene progradational barrier (landform system) is a low-lying plain (landform association) comprised of a sequence of foredune ridges, a beach and shoreface morphology.
	Lithified chenier	A chenier that has become cemented through a combination of induration and compaction.
	Littoral	The adjective *littoral* is used to designate the beachface and adjoining inshore areas of a sandy beach as well as the processes affecting them. The *littoral zone* extends from the spring high tide line to submarine areas affected by swash processes.
M	Mainland beach	Mainland beaches are apparent where a thin deposit of marine sands abut Pleistocene or older landforms. In some instances the sand may be sub-tidal and abut a platform or cliff.
	Metocean	*Metocean* is an abbreviation of meteorological and oceanographic. Hence *metocean processes* include all atmospheric and oceanographic processes such as storms, winds, waves, currents and tides.
	Mobile dunes	*Mobile dunes* are apparent as partially vegetated and open sand masses associated with blowouts, parabolic dunes and sand sheets.
	Morphodynamic	The coastal system is one in which morphology, sediments and processes are dynamically linked such that change in one will be associated with change in the others. This is referred to as a *morphodynamic* system.
	Morpho-stratigraphic	The term *morphostratigraphic* is used to indicate linkages between coastal morphology and stratigraphy.
	Morphology	*Morphology* describes landform associations or systems comprised of unconsolidated sediment.
	Mudflat	A relatively level vegetated area on the shore, especially in sheltered inlets, estuaries, or tidal lagoons. Intertidal mudflats are commonly exposed seaward as salt marshes or mangroves at low tide, and supratidal mudflats occur landward of salt marshes or mangroves on arid or semiarid coasts.
N	Natural Structure	*Natural structures* are geologic or geomorphological features, such as a rocky promontory or a sandy barrier.
O	Offshore	The term *offshore* is used in the report to designate either ocean seaward of

		the 30m isobath or shallower water seaward of the zone in which waves break.
	Outwash plain	The surface of a broad body of sorted and stratified sediment deposited by discharged fluvial flows.
P	Parabolic dune	In plan, a *parabolic dune* is a long U-shaped dune with long trailing arms (the vertical part of the U) pointing to windward. Parabolic dunes are common in the Gascoyne coast region, where dune migration commonly occurs over a low plain or flat marl surface.
	Pavement (rock pavement)	*Pavement* is a rock surface outcropping at an elevation close to the surrounding seabed. It may be part of a mixed sand and rock seabed, or patched reef, where it is irregular in form and elevation.
	Perched beach	Sandy beaches on which the sand overlies a rock pavement, beachrock ramp or rock platform is referred to as *perched beaches*. Under an engineering definition beaches immediately landward of a rock outcrop but separated from it by a narrow lagoon may also be classed as perched beaches.
	Pioneer vegetation	Herbaceous and grassy vegetation that first colonises the storm wrack line along the backshore as well as disturbed sites in dunes to landward is *pioneer vegetation*.
	Platform (rock platform)	A gently sloping surface produced by wave erosion, extending into the sea from the base of a wave-cut cliff.
	Pleistocene	The *Pleistocene* is the first geological epoch of the Quaternary Period and spans geologic time from approximately 2.6 million to 12,000 years before present. It is a time of repeated glaciations and sea level fluctuation on Earth.
	Pocket beach	A *pocket beach* is a small beach fixed between two headlands. Pocket beaches are commonly crescentic in plan, with the concave edge toward the sea. There is very little or no exchange of sediment between the beach and the adjacent shorelines.
	Prograded barrier	A succession of multiple foredune and/or beach ridges on the open coast and in sheltered waters form low-lying plain referred to as a *prograded barrier*. The plain may be features of a composite barrier where they merge with transgressive dune fields to landward or are overlain by blowouts along their seaward margin.
	Province	A *province* is an area defined on geological (lithology, topography and stratigraphy) or geomorphologic (major land systems) criteria suitable for a regional perspective at a scale of about 1:1,000,000. Originally described by CSIRO (1983).
Q	Quaternary	The *Quaternary* Period is the most recent of the three periods of the Cenozoic Era in the geologic time scale and has extended from approximately 2.6 million years ago to the present. The Quaternary includes two geologic epochs: the Pleistocene and the Holocene Epochs
R	Receded barrier	On coasts where sediment supply is limited *receded barriers* are thin marine sand deposits in narrow dunes that overlie estuarine, backbarrier or mainland features which outcrop at the shore.
	Reef	In the context of this report the term *reef* refers to any rock outcrop with an elevation above the surrounding sea bed. Herein, reef is described as being *continuous, discontinuous* and i*ntermittent* or as *pavement.*
	Reflective beach	A *reflective beach* is one on which incident waves are reflected seaward from a steep beachface following backwash run out. Reflective beach profiles are characterised by a berm or berms, a steep beachface, a step at the bottom of the swash zone and a deep, planar inshore zone. They are common features of coasts with a modal wave height of approximately 0.5 to 1.5 metres but also are observed on beaches comprised of coarse sediment and subject to larger waves.
	Region	A *region i*s an area with a characteristic pattern of land systems that

		differentiates it from adjacent areas. The unit is suitable for mapping at scales of approximately 1:250,000. This differs from the definition provided by CSIRO (1983) and Schoknecht *et al.* (2004).
	Rhythmic shoreline	An uninterrupted sandy shoreline is considered to be *rhythmic* when it has a sinuous plan form with shallow embayments separated by shoreline salients.
S	Salient	Part of a sandy coast protruding seaward of the average trend of the shoreline.
	Sand sheet	A *sand sheet* is either a mass of mobile sand that has become detached from a blowout or parabolic dune and is moving freely across the landscape; or it is an area of bare sand where active blowouts and/or parabolic dunes have coalesced.
	Sediment cell	A coastal *sediment cell* is a section of coast and its associated nearshore area within which the movement of sediment is apparent through identification of areas which function as sediment sources, transport pathways and sediment sinks. Classically, interruptions to movement of sediment within one cell should not affect beaches in an adjacent cell. However this is not always applicable to beaches in Western Australia where the major source of sediment is derived from offshore sources.
	Sheltered beach	*Sheltered beaches* are protected from the full effects of metocean processes by offshore reefs or by their aspect. The beaches frequently experience average wave heights of less than 1 metre and are considered to be dominated by fluctuations in sea level, particularly those associated with surge. They have flat profiles which may be segmented where longshore currents prevail, or rounded profile features under wave regimes relatively higher than those experienced on flat beaches.
	Shoreface	The *shoreface* is a zone extending seaward from the foreshore, beyond the breaker zone to the limit of wave movement of sediment. It is the zone in which the majority of sediment transport occurs.
	Shoreline	The shoreline is a discrete line along the coast. In the context of this report it is the High Water Line used in the Australian Oil Spills Response Atlas (OSRA) and described by Landgate (2006).
	Shoreline plan	The *shoreline plan* is a view of the shoreline shape from directly above so that its plan shape is readily apparent.
	Storm bar or storm ridge	Narrow sand (or gravel or shell) deposit developed to supratidal level by storm activity; occurs to landward of beach slope. It may be partially indurated. Storm ridges are similar in form to a chenier although commonly higher and may not sit on a muddy substrate.
	Storm bar retreat	Landward retreat of the storm bar or storm ridge. The process of retreat is commonly apparent by breaching of the ridge and development of washover fans on the shoreward side of the ridge
	Straight shoreline	A *straight shoreline* closely approximates a straight line over the length of coast under consideration.
	Stationary barrier	*Stationary barriers* are narrow, capped by blowout dunes overlying well developed backbarrier sandflats and washover lobes. Stationary barriers are commonly associated with coastal lagoons or adjoin alluvial flats to landwards.
	Stratigraphy	*Stratigraphy* is the study of geologic strata or layers of sediment.
	Subaqueous levee (tidal dunes)	Levee formation by deposition from sediment-laden flows debouching into open water, with interaction and feedback with tidal components.
	Substrate	The *substrate* is the surface on which a barrier sits. For example, the Holocene barriers forming the modern coast are commonly located on a coastal limestone surface of Pleistocene age.
	Subtidal terrace	A gently-inclined sedimentary accumulation feature that may be partially exposed at low tide. The subtidal terrace occurs seaward of the low tide level

		on the beachface.
	Supratidal	Coastal area above regular tidal fluctuations
	Susceptibility	*Susceptibility* is an estimate of the likelihood of a land system altering in structure over a planning horizon of 100 years. The estimate is based on a comparison of the existing structure with reported descriptions of the evolution of similar structures. Following Roy *et al.* (1994) for example, prolonged erosion of an episodic transgressive barrier complex may result in a change to a receded barrier.
	Swash	Swash describes the uprush and backwash of waves on the beachface of a sandy beach. The swash zone extends seaward from the limit of uprush down slope to include the step at the bottom of the beachface and the inshore area affected by backwash run out.
	Terrace response	Response of a subtidal terrace to metocean forcing, human intervention and/or alteration in sediment supply. A sub-tidal terrace may provide a buffer to sheltered coasts from changes in metocean forcing or extreme events, through reworking of sediments and adjustment of terrace width and depth, if there is sufficient capacity for the necessary provision or loss of sediment
	Tidal creek	Drainage channel carrying tidal water flows that incise tidal flats. Creeks may be meandering to birfurcating and their headwaters vary in function from erosional to depositional depending on interactions with sea level fluctuation and flood runoff from the hinterland.
	Tidal flat	Gently-inclined, tidally-inundated lowland connected to the shore by tidal channels. In this document the term mudflat has been applied to the area of tidal flat above mean sea level; and terrace to the mainly subaqueous landform below mean sea level for convenience. Tidal flat refers to the whole geomorphic system. Tidal flats are areas of marked interaction between rivers and tidal creeks, as well as surface run-off.
T	Time scales	The *long-term* times scale refers to coastal evolution and the *susceptibility* of land systems to change over geologic time, particularly over the geological epochs of the Quaternary Period; the Pleistocene and Holocene Epochs. The short-term time scale refers to factors affecting the *stability* of coastal landforms. These are linked to the 100 year planning horizon of the State Coastal Planning Policy (SPP 2.6) as follows: *Short-term*: 1 to 10 years *Intermediate-term*: 11 to 25 years *Long-term*: longer than 25 years
	Tombolo	A *tombolo* is a deposition landform in which an island is attached to the mainland by a narrow piece of land. Tombolos are developed by refraction, diffraction and longshore drift to form a spit or bar that connects the mainland coast to connecting a coast to an offshore island. Once attached, the island is then known as a tied island.
	Topography	In the context of this report t*opography* describes landform associations or systems comprised of rock
	Transgressive dunes	Blowouts and/or parabolic dunes migrating landward from the sediment source at the beach are *transgressive dunes* in that they bury older landforms (and infrastructure) as they migrate. Dune mobilisation takes place episodically hence the dunes may be overlain to form and episodic, transgressive barrier.
	Transitional beach	On exposed, wave-dominated coast sandy beaches may fluctuate in form between reflective and dissipative states as the wave regime alters between low and high wave extremes. Between these extremes the *transitional* state is one with profiles that have elements of both. Transitional sandy beaches are morphologically characterised by bars, troughs and rip current channels.
U	Unconsolidated sediments	*Unconsolidated sediments* are loose sediment particles such as gravel, sand, silt and clay that have not been lithified or consolidated into rock.

V	Vegetation cover	For a designated area *vegetation cover* is the proportion of the land surface covered by plants.
	Vulnerability	*Vulnerability r*efers to the likelihood of a land system or landform changing in response to changing metocean conditions. It is estimated as a combination of the long-term susceptibility and short-term instability of a coastal compartment or sediment cell.
W	Washover lobe	Under extreme storm conditions and high sea levels low barriers may be breached by waves that wash sediment from the beach onto lowland or into lagoons landwards of the barrier. The sediment is deposited in fans or *washover lobes.*
X		
Y		
Z	Zeta-form	A half heart-shaped bay, often due to headland control and a single prevailing direction of wave approach.
	Zone	*Zone* has two meanings. Firstly, in a land system context it is a broad section of the Australian Coast based on climate, and separating the tropical from temperate zones. These are referred to as regions by CSIRO (1983) and Schoknecht *et al.* (2004). Secondly, at a more detailed scale zone describes a small area where a particular suite of coastal processes and landforms are present. For example, the nearshore zone is where waves, wave driven currents and tides determine the pattern of bars and beach shape.

Appendix C Coastal Land Systems: Hope Point to Tryon Point

Legend

Tertiary compartments

Tertiary compartments

Bare Sand Point to Hooley Creek — Tertiary compartment name

Landform vulnerability

1 Low

2 Low to moderate

3 Moderate

4 Moderate to high

5 High

Land Systems

Ann	Anna Land System	Mi	Minderoo Land System
Ab	Ashburton Land System	Mnr	Mannerie Land System
Bg	Boolgeeda Land System	Ne	Newman Land System
Bo	Boolaloo Land System	Nit	Nita Land System
Bro	Brockman Land System	Ny	Nanyarra Land System
Cad	Cadgie Land System	Non	Nooingnin Land System
Cal	Calcrete Land System	Ons	Onslow Land System
Can	Cane Land System	Pa	Paraburdoo Land System
Ce	Cheela Land System	Pdg	Pindering Land System
Che	Cheerawarra Land System	Pds	Paradise Land System
Cll	Callawa Land System	Ped	Peedamulla Land System
Cp	Capricorn Land System	Phr	Phire Land System
Ct	Cheetara Land System	Py	Pyramid Land System
Dor	Dollar Land System	Rir	River Land System
Dun	Dune Land System	Rob	Robe Land System
Ed	Edward Land System	Rk	Rocklea Land System
Eig	Eighty Mile Land System	Rb	Roebuck Land System
Eli	Elimunna Land System	Rt	Ruth Land System
Et	Ethel Land System	Sc	Scoop Land System
Gir	Giralia Land System	Srk	Sherlock Land System
Gl	Globe Land System	Thr	Three Rivers Land System
Grc	Granitic Land System	Tur	Turee Land System
Hof	Horseflat Land System	Ua	Uaroo Land System
Hoy	Hooley Land System	Ury	Urandy Land System
Jam	Jamindie Land System	Wai	Warri Land System
Jur	Jurrawarrina Land System	Wnm	Wannamunna Land System
Lim	Lime Land System	Riv	River Bed Land Unit
Lit	Littoral Land System	Yam	Yamerina Land System
Lsa	Little Sandy Land System	Ya	Yankagee Land System
Mac	Macroy Land System	Ye	Yeeda Land System
Mal	Mallina Land System		

Figure C - 1: Compartment and Land System Map Legend

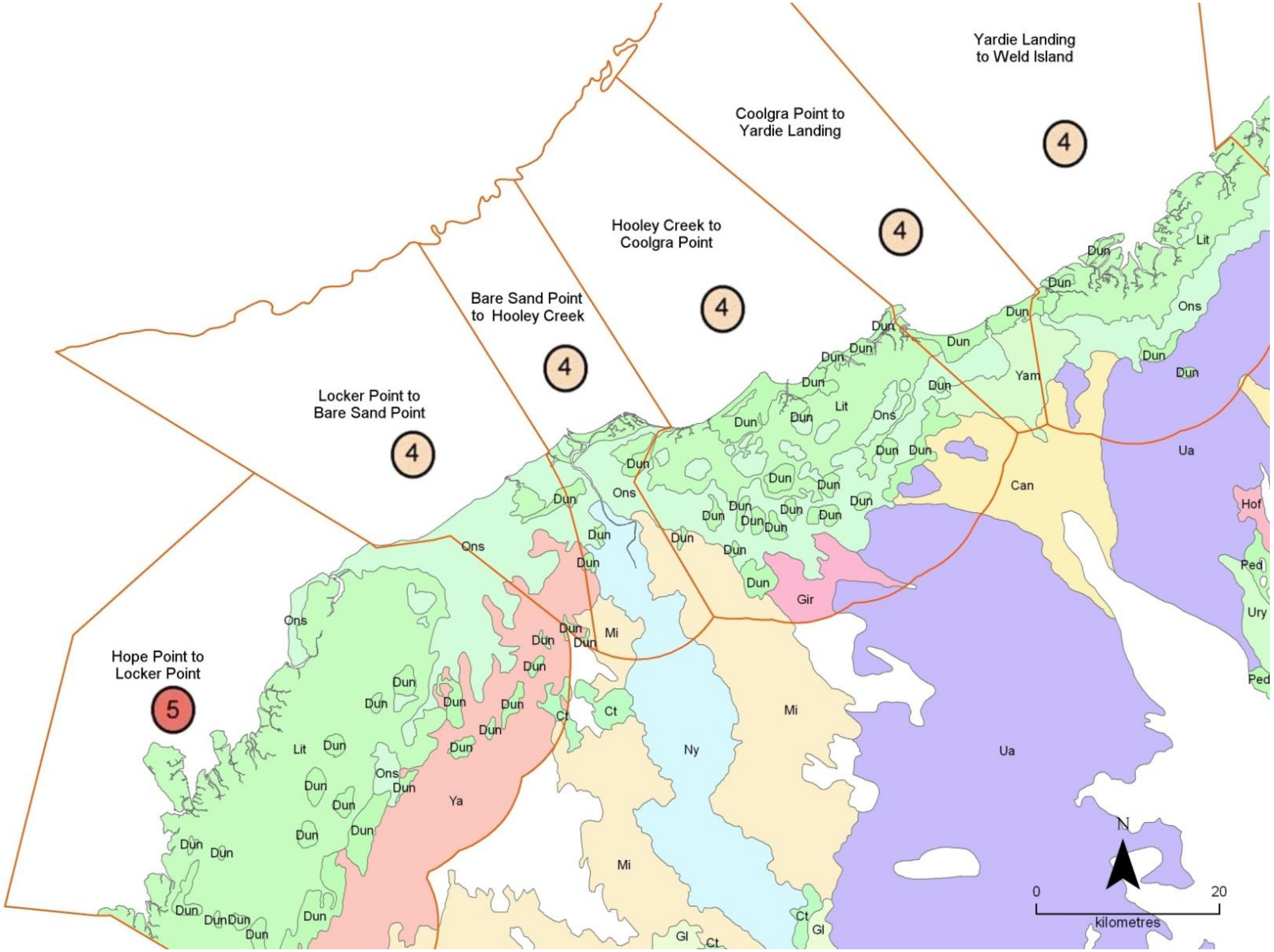

Figure C - 2: Coastal Vulnerability & Land Systems for Hope Point to Weld Island

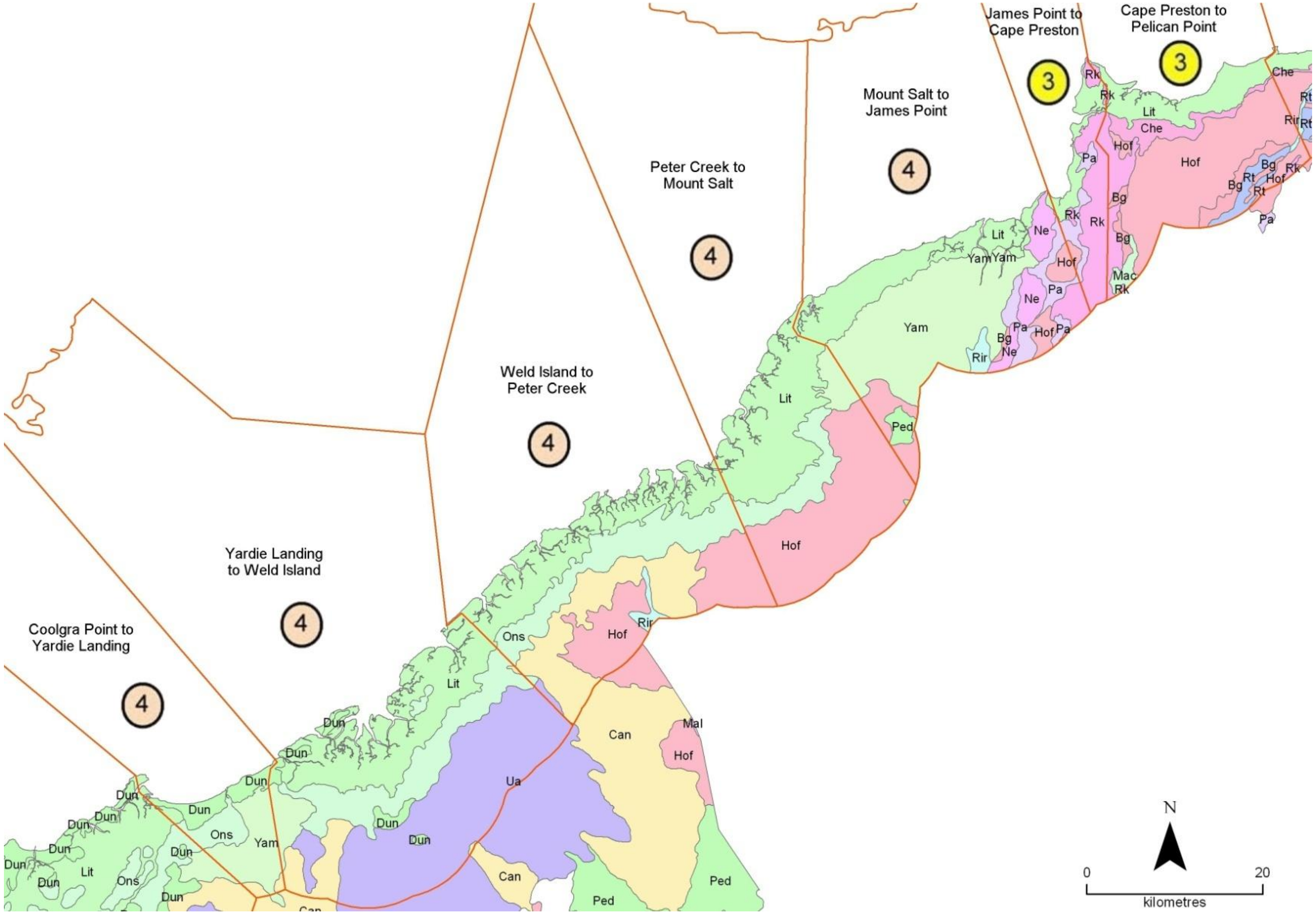

Figure C - 3: Coastal Vulnerability & Land Systems for Coolgra Point to Pelican Point

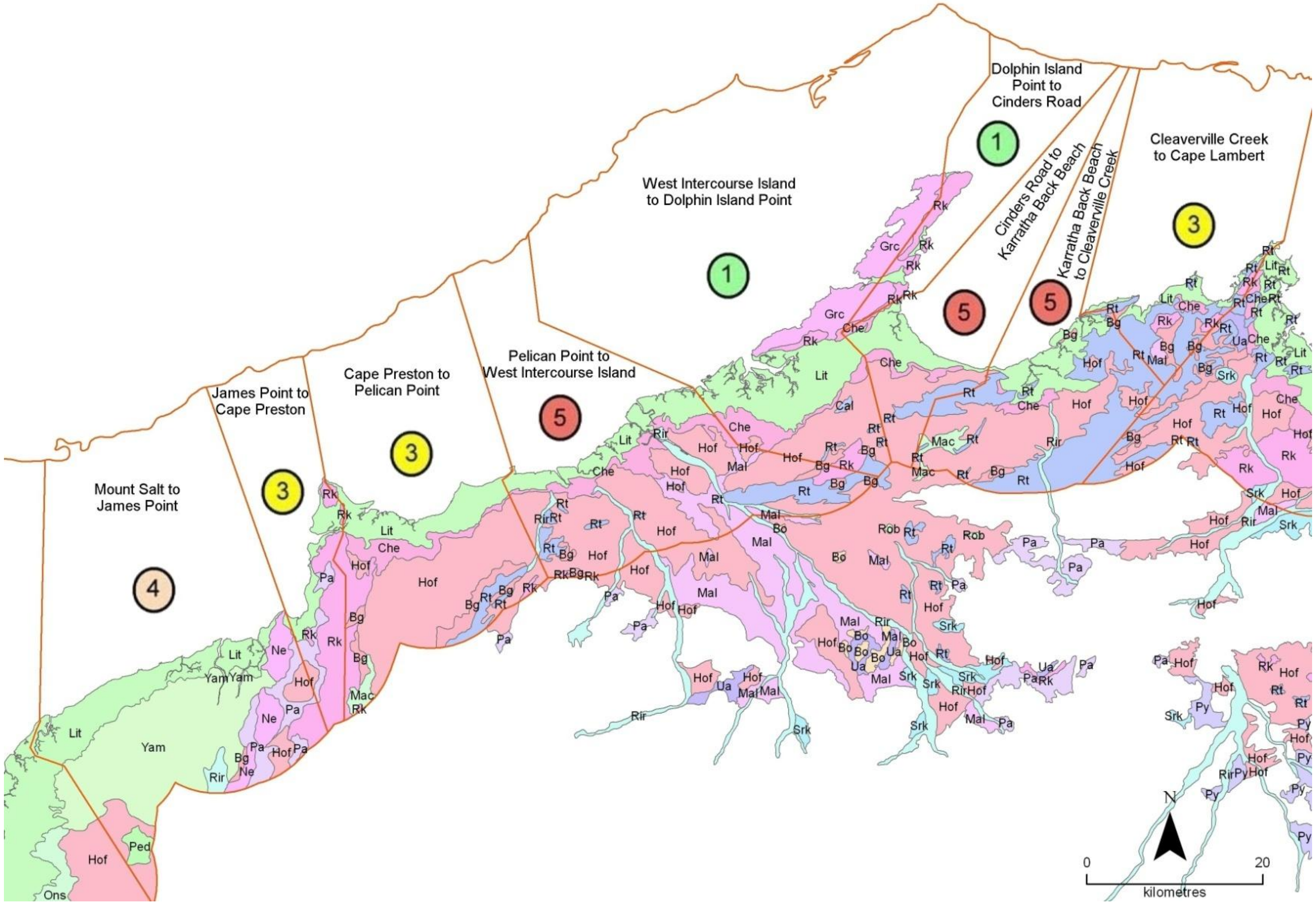

Figure C - 4: Coastal Vulnerability & Land Systems for Mount Salt to Cape Lambert

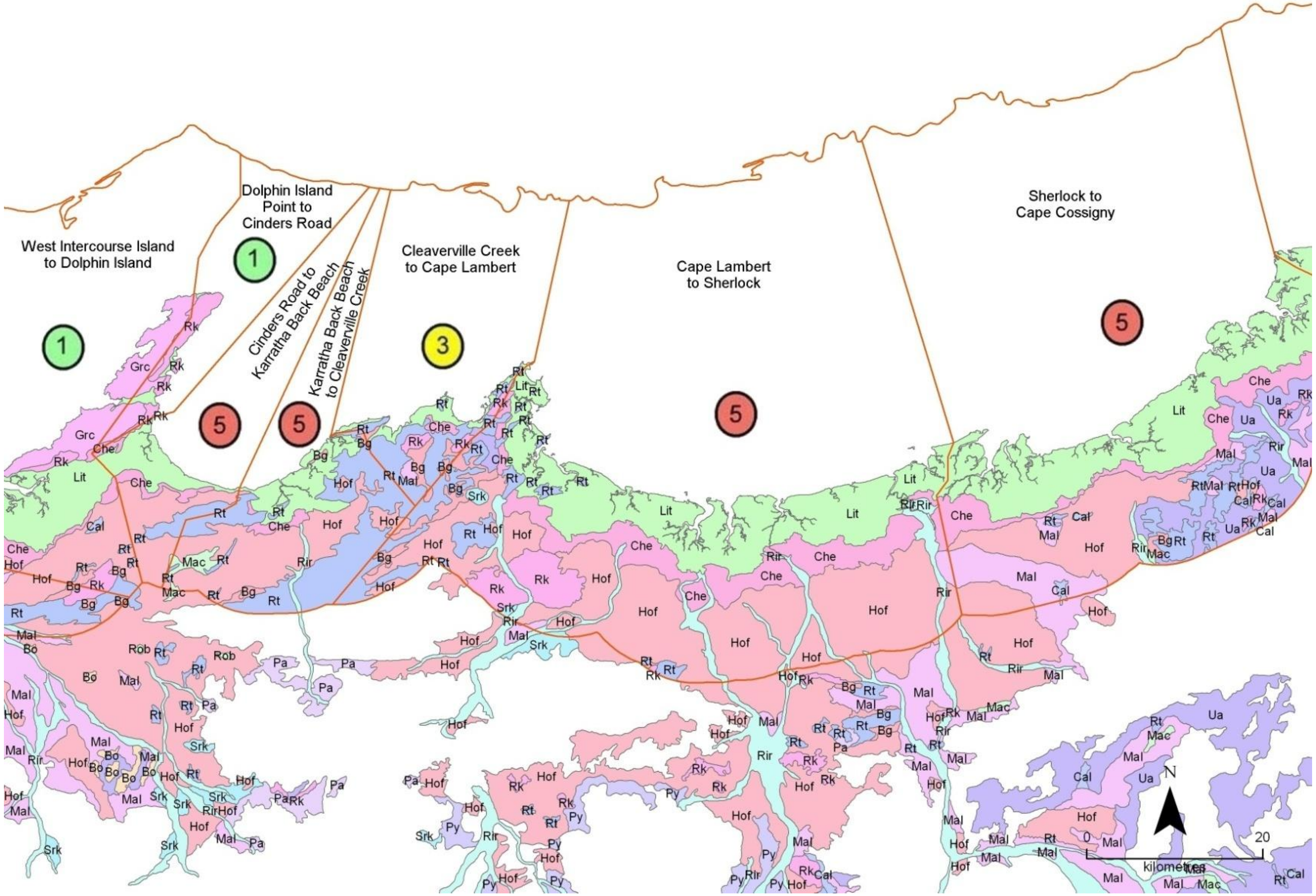

Figure C - 5: Coastal Vulnerability & Land Systems for West Intercourse Island to Cape Cossigny

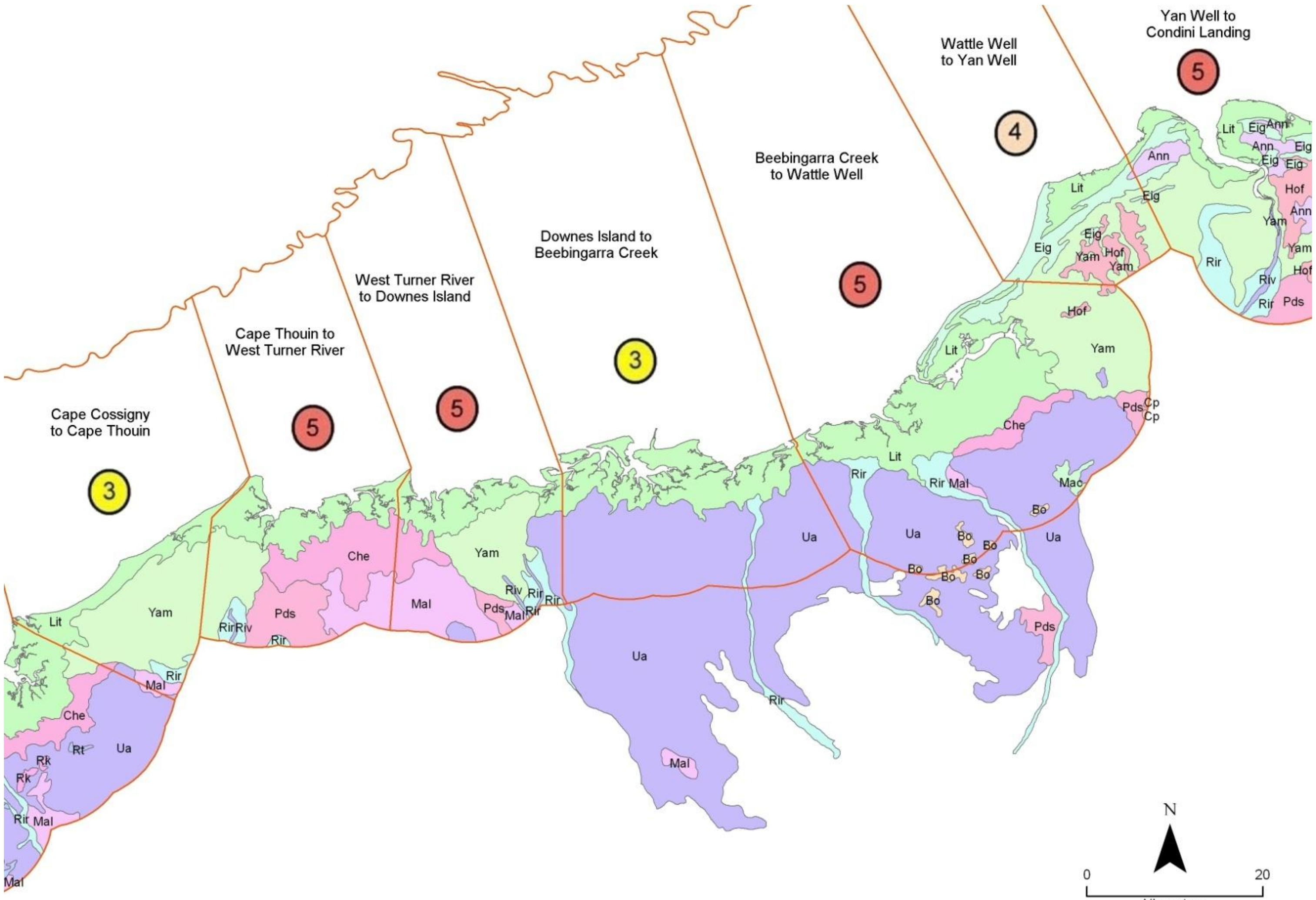

Figure C - 6: Coastal Vulnerability & Land Systems for Cape Cossigny to Yan Well

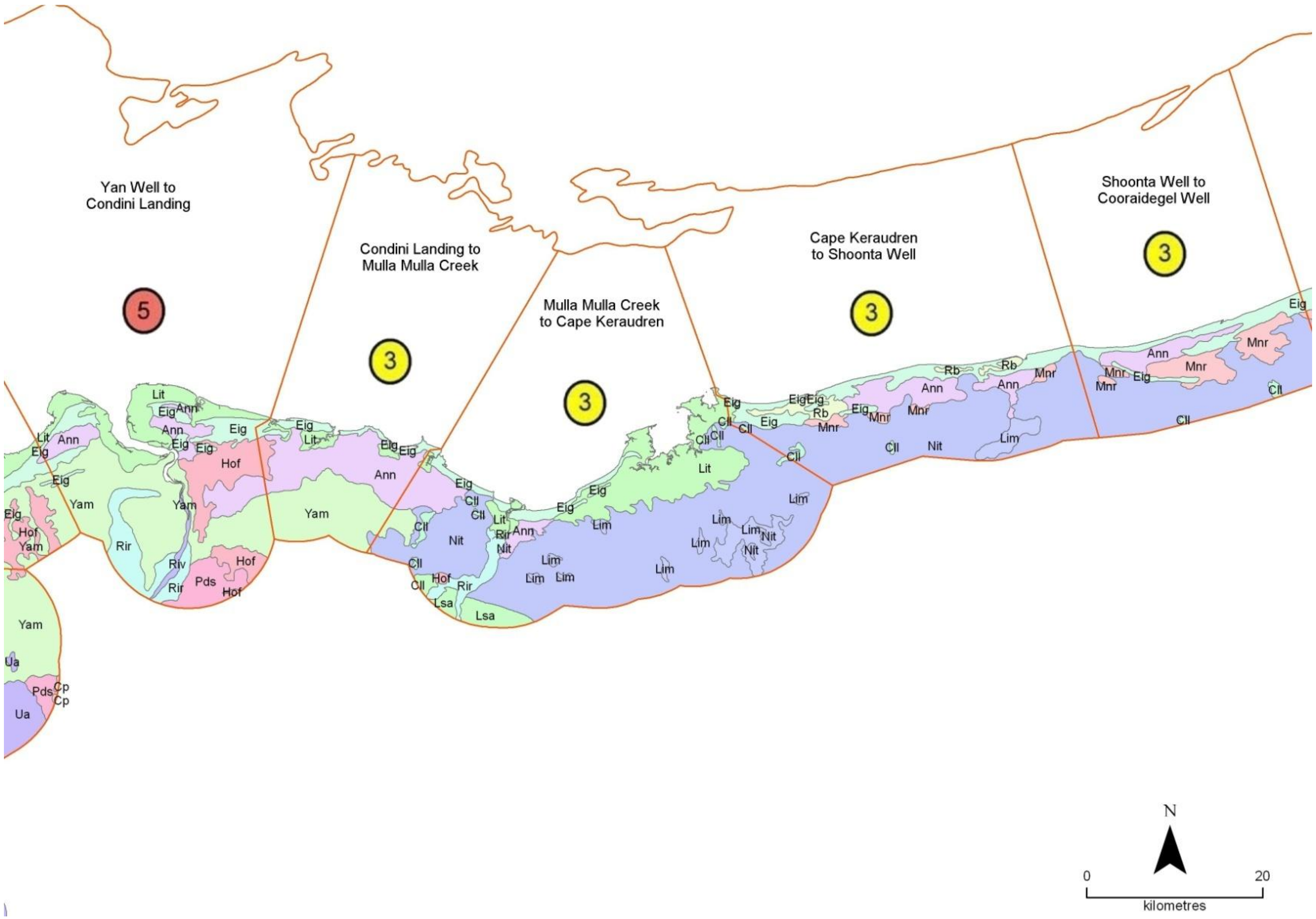

Figure C - 7: Coastal Vulnerability & Land Systems for Yan Well to Cooraidegel Well

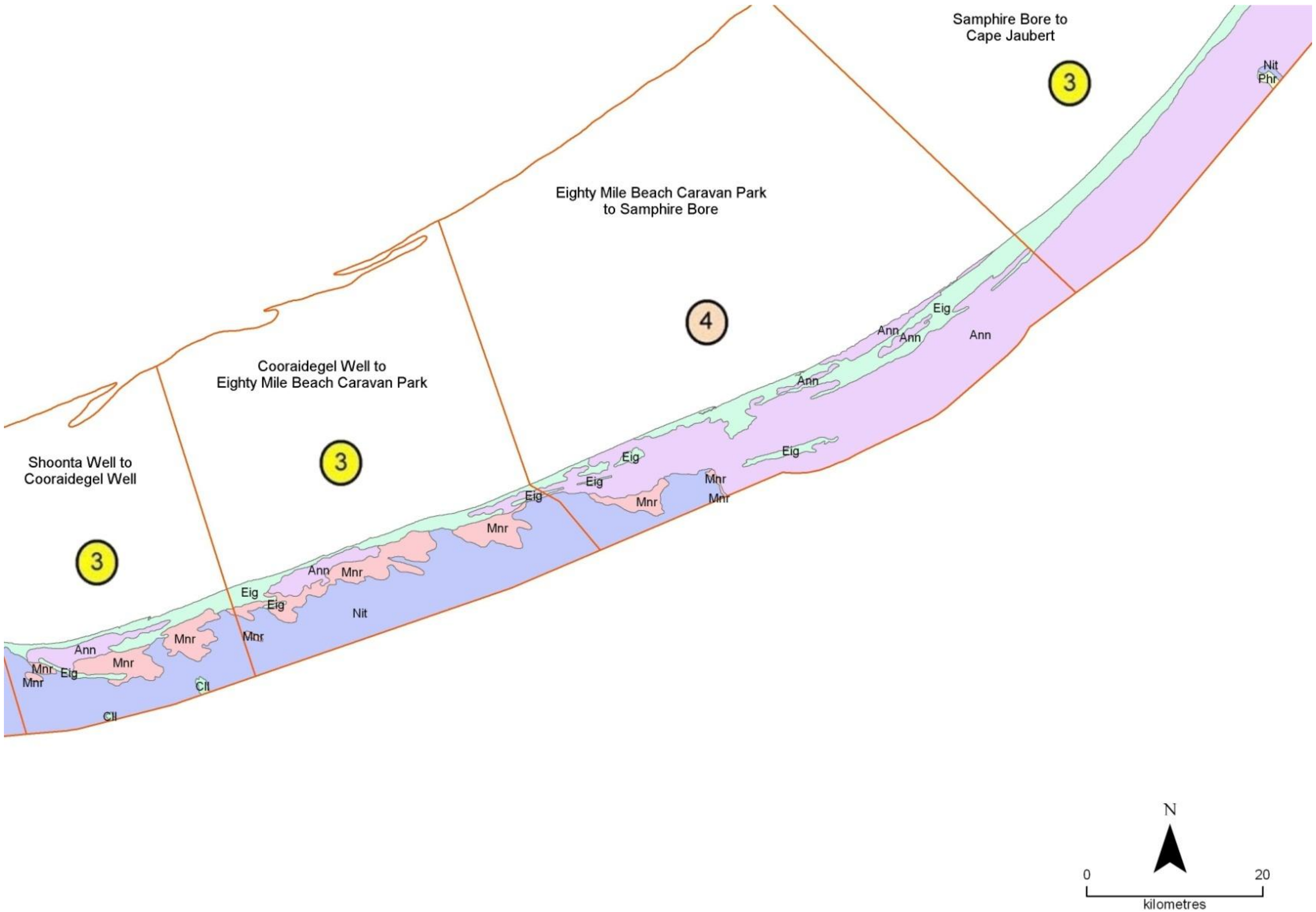

Figure C - 8: Coastal Vulnerability & Land Systems for Cooraidegel Well to Samphire Bore

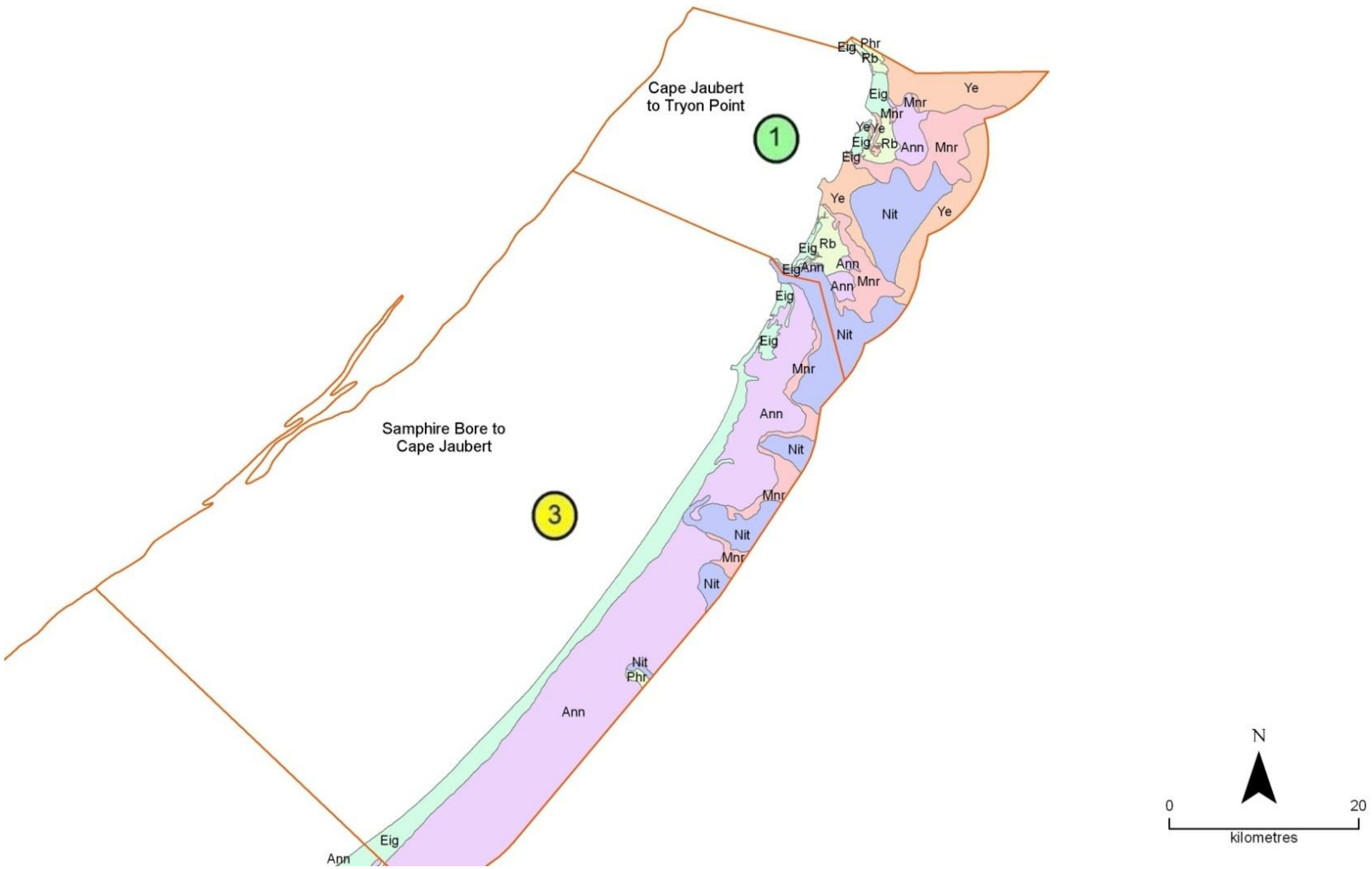

Figure C - 9: Coastal Vulnerability & Land Systems for Samphire Bore to Tryon Point

Appendix D Definitions of Land Systems of the Pilbara Region

The descriptions of land systems herein are taken directly from Payne *et al*. (1988), Payne & Tille (1992) and van Vreeswyk *et al.* (2004) with additions and modifications. These documents also contain detailed information about the constituent landforms of each land system.

Anna Land System (Ann)

Coastal plains with saline soils, supporting tussock grasslands and minor halophytic low shrublands.
Geology: Quaternary supratidal littoral deposits and old alluvium; clay, silt and sand.
Geomorphology: Broad, coastal supratidal plains on saline and calcareous littoral and alluvial deposits, minor sand sheets and sandy banks, a few narrow, sluggish internal drainage depressions but no organised drainage features.

Ashburton Land System (Ab)

Active flood plains and backplains with deep silty loam and clayey soils, shrublands and tussock grasslands.
Geology: Quaternary alluvium.
Geomorphology: Active floodplains, backplains and depressions and gilgai plains flanking the Ashburton River and its major tributaries, narrow poorly developed levee zones flanking the major channels.

Boolaloo Land System (Bo)

Granite hills, domes and tor fields and sandy plains with shrubby spinifex grasslands.
Geology: Archean granite and gneiss, minor Quaternary sand.
Geomorphology: Erosional surfaces; granite hills with boulder-strewn slopes, tor heaps and bare domes surrounded by restricted stony and sandy plains; widely spaced tributary drainage patterns of narrow drainage floors and channels.

Boolgeeda Land System (Bg)

Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands.
Geology: Quaternary colluvium.
Geomorphology: Very gently inclined stony slopes and plains below hill surfaces becoming almost level further downslope; closely spaced, dendritic and sub-parallel drainage lines.

Brockman Land System (Bro)

Alluvial plains with cracking clay soils supporting tussock grasslands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; level, non-saline alluvial plains with clay soils and gilgai microrelief and flanked by slightly more elevated hardpan wash plains, sluggish internal drainage zones on plains and occasional through-going trunk channels.

Cadgie Land Unit (Cad)

Hardpan plains with thin sand cover and sandy banks supporting mulga shrublands with soft and hard spinifex.
Geology: Tertiary cemented colluvium and alluvium.
Geomorphology: Depositional surfaces; almost level, non-saline alluvial plains with hardpan at shallow depth, surfaces with thin sand cover, washplains subject to sheet flow interspersed with low sandy banks; minor drainage tracts subject to more through flow, usually unchannelled but occasionally with shallow incision into hardpan.

Calcrete Land System (Cal)

Low calcrete platforms and plains supporting shrubby hard spinifex grasslands.
Geology: Tertiary calcrete, minor Quaternary alluvium.
Geomorphology: Depositional surfaces; valley-fill deposits, stony plains as a mosaic of calcrete tables and low rises elevated up to 10 m above the surrounding surfaces of narrow inter-table drainage areas and restricted sandy plains; drainage patterns absent to sparse tributary tracts and occasional through-going trunk channels.

Callawa Land System (Cll)

Highly dissected low hills, mesas and gravelly plains of sandstone and conglomerate supporting soft and hard spinifex grasslands.
Geology: Jurassic sandstone, conglomerate and mudstone, Tertiary ferruginous duricrust.
Geomorphology: Erosional surfaces; low hills, mesas, plateaux remnants, hill spurs and slopes dissected by short, closely spaced tributary and distributary drainage lines; also rounded gravelly plains and minor sandplain.

Cane Land System (Can)

Alluvial plains and floodplains supporting snakewood shrublands, soft and hard spinifex grasslands and tussock grasslands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; floodplains subject to fairly regular flooding and often with windblown scalds and hummocks and/or water erosion, slightly more elevated stony plains and plains with gilgai microrelief, tracts receiving more concentrated through-flow; very widely spaced to sparse patterns of non-tributary, distributing and reticulated channels and larger through-going trunk channels.

Capricorn Land System (Cp)

Hills and ridges of sandstone and dolomite supporting shrubby hard and soft spinifex grasslands.
Geology: Lower Paleozoic sandstone, greywacke, dolomite and shale.
Geomorphology: Erosional surfaces; ranges and hills with steep rocky upper slopes, more gently sloping stony footslopes, restricted stony lower plains and valleys; moderately spaced tributary drainage patterns; relief up to 180 m.

Cheela Land System (Ce)

Degraded alluvial plains with very sparse shrublands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; tributary non-saline alluvial plains extending up to 14 km downslope, severely degraded plains with incised channels and gutters, slightly higher plains with banded vegetation patterns, restricted sandy-surfaced outwash plains, restricted gilgai plains with internal drainage.

Cheerawarra Land System (Che)

Sandy coastal plains and saline clay plains supporting soft and hard spinifex grasslands and minor tussock grasslands.
Geology: Quaternary eolian sand and alluvium.
Geomorphology: Depositional surfaces; gently undulating sandy-surfaced coastal plains and level plains with saline clay soils and bare saline scalds with wind hummocks; very rare distributary drainage lines.

Cheetara Land System (Ct)

Alluvial clay plains with gilgai, mixed open tussock grasslands and tall shrublands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; broad non-saline clay plains up to 12 km in extent, with and without gilgai, maximum relief 3 m, no channelled drainage but plains subject to sheet flow and inundation for short periods.

Dollar Land System (Dor)

Stony plains supporting acacia shrublands.
Geology: Quaternary colluvium and alluvium, minor Lower Proterozoic dolomite.
Geomorphology: Depositional surfaces; level stony plains of unconsolidated colluvium, minor alluvial zones, outcrops plains and low dolomitic rises; sparse, through-going sub-parallel drainage with single and braided channels; relief usually less than 5 m but sometimes up to 10 m.

Dune Land System (Dun)

Dune fields supporting soft spinifex grasslands.
Geology: Quaternary eolian sand.
Geomorphology: Depositional surfaces; sand dunes and swales with no organised drainage, dunes trending approximately north-south and frequently becoming reticulate; narrow swales with minor areas of claypans, swamps and depressions; relief up to 15 m.

Edward Land System (Ed)

Alluvial plains with sparse degraded saltbush, bluebush and other shrub pastures.
Geology: Quaternary alluvium and colluvium derived from the Ashburton Formation shale, minor Quaternary eolian sand.
Geomorphology: Depositional surfaces; saline and non-saline tributary drainage plains up to 4 km in extent, often severely degraded with bare, scalded surfaces; through-going drainage tracts with intensely braided and anastomosing channels, minor sandy plains, dunes and sand banks, minor areas of flat internal drainage plains and depressions, occasional low shale hills; relief usually 1 to 5 m, but up to 20 m.

Eighty Mile Land System (Eig)

Beach foredunes, coastal dunes and sandy plains supporting buffel grass grasslands and soft spinifex grasslands.
Geology: Quaternary eolian calcareous sand, quartzose calcarenite, minor clay and silt.
Geomorphology: Depositional surfaces; beaches, unconsolidated (but largely stabilised) foredunes and unconsolidated to partly consolidated hind dunes mostly parallel but also reticulate; narrow sandy swales and broader sandy plains, minor interdunal corridors with more saline soils, narrow limestone ridges; no organised drainage; relief up to 15 m.

Elimunna Land System (Eli)

Stony plains on basalt supporting sparse acacia and cassia shrublands and patchy tussock grasslands.
Geology: Quaternary colluvium, eluvium and alluvium, Archean basalt and dolerite.
Geomorphology: Mainly depositional surfaces; level to gently undulating stony plains, other level plains with a mosaic of surfaces with and without gilgai microrelief, widely to very widely spaced tributary and no-tributary drainage floors with clay soils and central through channels; also sluggish internal drainage patterns on gilgai plains; occasional low hills and rises on basalt; relief up to 15 m.

Ethel Land System (Et)

Cobble plains with sparse mulga and other acacia shrublands.
Geology: Quaternary colluvium and alluvium.
Geomorphology: Depositional surfaces; extensive, slightly raised saline and non-saline cobble plains, saline and non-saline alluvial drainage floors with sub-parallel drainage patterns of moderate intensity, minor low hills and stony rises; relief mostly less than 20 m.

Giralia Land System (Gir)

Linear dunes and broad sandy plains supporting hard and soft spinifex grasslands.
Geology: Quaternary colluvium and eolian sand.
Geomorphology: Depositional surfaces; sandy plains formed by sheet flood and wind action; broad plains with thin sand cover and linear dunes; no organised drainage but through-flow areas receiving more concentrated sheet flow than adjacent plains, calcrete plains and minor calcreted drainage zones; dune relief up to 30 m.

Globe Land System (Gl)

Degraded alluvial plains supporting snakewood shrublands and minor tussock grasslands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; extensive infrequently flooded alluvial plains and gilgai plains associated with the Ashburton River, regularly flooded low-lying back plains and depressions, sandy tracts adjacent to the river; channels, banks and poorly developed levees; relief up to 5 m.

Granitic Land System (Grc)

Rugged granitic hills supporting shrubby hard and soft spinifex grasslands.
Geology: Archean and Proterozoic granite, gneiss, granodiorite and porphyry.
Geomorphology: Erosional surfaces; hill tracts and domes on granitic rocks with rough crests, associated rocky hill slopes, restricted lower plains; narrow, widely spaced tributary drainage floors and channels; relief up to 100 m.

Hooley Land System (Hoy)

Alluvial clay plains supporting a mosaic of snakewood shrublands and tussock grasslands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; level plains of clayey and stony alluvium as a mosaic of surfaces with gilgai microrelief, sometimes stony, and non-gilgaied surfaces with abundant stony mantles; mostly sluggish internal drainage but occasional drainage tracts with major through-going channels.

Horseflat Land System (Hof)

Gilgaied clay plains supporting tussock grasslands and minor grassy snakewood shrublands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; gilgaied and non-gilgaied clay plains, stony plains, narrow linear drainage depressions and dissected slopes marginal to the River Land System; mostly internally drained, some through-going trunk drainage channels.

Jamindie Land System (Jam)

Stony hardpan plains and rises supporting groved mulga shrublands, occasionally with spinifex understory.
Geology: Partly cemented Quaternary colluvium, alluvium and laterite; minor sedimentary rocks of Proterozoic age.
Geomorphology: Depositional surfaces; non-saline plains with hardpan at shallow depth and groved vegetation, stony upper plains and low rises on hardpan or rock, very widely spaced tributary drainage tracts and channels; minor stony gilgai plains, sandy banks and low ridges and hills; relief up to 30 m.

Jurrawarrina Land System (Jur)

Hardpan plains and alluvial tracts supporting mulga shrublands with tussock and spinifex grasses.
Geology: Quaternary alluvium and colluvium.
Geomorphology: Depositional surfaces; plains receiving overland sheet flow and with prominent drainage foci arranged at right angles to the direction of flow, broad drainage tracts receiving more concentrated flow, with or without defined channels and with prominent gilgaied drainage foci; minor plains with clay soils and gilgai microrelief, also occasional through-going creek channels.

Lime Land System (Lim)

Calcareous plains supporting soft and hard spinifex grasslands and melaleuca shrublands.
Geology: Quaternary sandy limestone, minor eolian sand and alluvium.
Geomorphology: Depositional surfaces; level to gently undulating calcareous plains and sandy sheets (marginal to sandplain systems) and low lying drainage tracts with weakly saline alluvium.

Little Sandy Land System (Lsa)

Sandplains with linear and reticulate dunes supporting shrubby hard and soft spinifex grasslands.
Geology: Quaternary eolian sand.
Geomorphology: Depositional surfaces; sandplains and dune fields formed by wind action; linear and reticulate dunes trending generally west-north west to east-south east, sandplains and swales as corridors between dunes, minor gravelly plains and plains with thin sand cover over calcrete and isolated low hills; no organised drainage features but some low lying tracts receiving through flow; dune relief is up to 30 m.

Littoral Land System (Lit)

Bare coastal mudflats with mangroves on seaward fringes, samphire flats, sandy islands, coastal dunes and beaches.
Geology: Quaternary mudflat deposits, clay, salt and sand, eolian sand.
Geomorphology: Depositional surfaces; saline coastal flats; estuarine and littoral surfaces with extensive bare saline tidal flats subject to infrequent tidal inundation, slightly higher samphire flats and alluvial plains, mangrove seaward fringes with dense branching patterns of shallow tidal creeks, minor coastal dunes, limestone ridges, sandy plains and beaches; relief up to 8 m.

Macroy Land System (Mac)

Stony plains and occasional tor fields based on granite supporting hard and soft spinifex grasslands.

Geology: Archean granite and granodiorite; Quaternary eluvium, colluvium and minor alluvium.

Geomorphology: Erosional surfaces; gently undulating stony plains and interfluves with quartz surface mantles, sandy surfaced plains, minor calcrete plains, closely spaced tributary drainage lines in upper parts of system becoming much wider downslope; minor granite hills, tor fields and quartz ridges; relief is up to 25 m.

Mallina Land System (Mal)

Sandy surfaced alluvial plains supporting soft spinifex grasslands.

Geology: Quaternary alluvium and eluvium.

Geomorphology: Depositional surfaces; level sandy surfaced plains on alluvium with occasional patches of small claypans, minor clay plains with gilgai microrelief, minor stony plains and occasional isolated low hills; drainage patterns restricted to rare, non tributary through channels with narrow terraces.

Mannerie Land System (Mnr)

Seepage areas on inland margins of paleo-tidal plains supporting melaleuca thickets and halophytic shrublands.

Geology: Quaternary supratidal mudflat deposits; clay, silt and sand.

Geomorphology: Depositional surfaces; level plains with seepage areas and swamps on saline alluvium, minor sandy banks; no organised drainage features.

Minderoo Land System (Mi)

Alluvial plains supporting tall shrublands and tussock grasslands and sandy plains supporting hummock grasslands.

Geology: Quaternary alluvial and eolian deposits.

Geomorphology: Depositional surfaces; old floodplains associated with the Ashburton River and plains formed by sheet flood and deflation, no organised drainage; eolian sand plain and dunes with up to 20 m relief, gilgai plains, plains receiving broad through-flow; claypans, swamps and depressions.

Nanyarra Land System (Ny)

Alluvial plains supporting tall shrublands and low woodlands with prominent tussock grasslands.

Geology: Quaternary alluvium, minor areas of Quaternary eolian sand.

Geomorphology: Depositional surfaces; alluvial plains subject to local flooding, river margins, swamps and low-lying back plains subject to regular inundation; minor low sand dunes; meandering through channels of the Ashburton River incised up to 20 m and with very steep banks.

Newman Land System (Ne)

Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands.
Geology: Lower Paleozoic jaspilite, chert, siltstone, shale, dolomite and minor acid volcanics.
Geomorphology: Erosional surfaces; plateaux and mountains - extensive high plateaux, mountains and strike ridges with vertical escarpments and steep scree slopes and more gently inclined lower slopes; moderately spaced dendritic and rectangular tributary drainage patterns of narrow valleys and gorges with narrow drainage floors and channels; relief up to 450 m.

Nita Land System (Nit)

Sandplains supporting soft shrubby spinifex grasslands with occasional trees.
Geology: Quaternary eolian sand.
Geomorphology: Depositional surfaces; level eolian sandplains and occasional linear dunes, isolated low hills and occasional stony or gravelly rises; no organised drainage features; relief up to 15 m.

Nooingnin Land System (Non)

Hardpan plains with very large groves supporting mulga shrublands.
Geology: Quaternary cemented colluvium and alluvium.
Geomorphology: Depositional surfaces; level non-saline hardpan washplains subject to sheet flow and with very large groves and low sandy banks; plains and narrow drainage zones receiving more concentrated sheet flow; very minor plains on saline alluvium and internal drainage flats; relief less than 5 m.

Onslow Land System (Ons)

Sandplains, dunes and clay plains supporting soft spinifex grasslands and minor tussock grasslands.
Geology: Quaternary quartz sand, silt, clay and gravel.
Geomorphology: Depositional surfaces; sandy plains formed by eolian and fluvial processes - gently undulating sandplains with intervening non-saline clay plains subject to sheet flow, narrow drainage zones receiving more concentrated flow, minor depressions subject to inundation; coastal fringes of low sandplain, interspersed with slightly lower saline samphire flats; also minor claypans, coastal dunes and beaches; relief up to 20 m.

Paraburdoo Land System (Pa)

Basalt-derived stony gilgai plains and stony plains supporting snakewood and mulga shrublands with spinifex and tussock grasslands.
Geology: Quaternary colluvium and alluvium derived mainly from basalt.
Geomorphology: Mostly depositional surfaces; isolated low basalt hills, stony upper interfluves and plains with small groves, stony plains with gilgai microrelief; moderately spaced patterns of sub-parallel tributary drainage extending downslope into broad zones with braided drainage and major trunk channels; relief mostly less than 8 m but isolated hills up to 25 m.

Paradise Land System (Pds)

Alluvial plains supporting soft spinifex grasslands and tussock grasslands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; plains (weakly saline in parts) with numerous small scalds and claypans on reworked old alluvium, subject to flooding; also tracts receiving more concentrated through flow with sluggish channels and minor clay plains with gilgai microrelief.

Peedamulla Land System (Ped)

Gravelly plains supporting hard spinifex grasslands and minor snakewood shrublands.
Geology: Quaternary eluvium, alluvium and minor colluvium; minor Cretaceous shale, siltstone, sandstone and conglomerate.
Geomorphology: Depositional surfaces; occasional low rises and low hills above extensive, level to gently undulating gravelly plains receiving sheet flow, minor stony clay plains with gilgai microrelief, sparse shallow tributary drainage floors with or without channels; relief up to 15 m.

Phire Land System (Phr)

Outcrop plains with lateritic gravels and low ridges supporting spinifex grasslands.
Geology: Minor sand and silt of mixed alluvial and eolian origin over laterite on mudstone of Late Cretaceous age.
Geomorphology: Erosional surface of flat to gently undulating plains up to 10 km in extent; organised surface drainage absent on flat plains with shallow depressions in undulating areas.

Pindering Land System (Pdg)

Gravelly hardpan plains supporting groved mulga shrublands with hard and soft spinifex.
Geology: Tertiary and Quaternary colluvium as partly consolidated and consolidated valley fill deposits, minor alluvium.
Geomorphology: Depositional surfaces; level to gently undulating stony plains and gravelly plains on hardpan, receiving sheet flow; numerous small linear or arcuate drainage foci (groves) arranged at right angles to direction of sheet flow, rare tributary drainage tracts with minor channels; relief up to 10 m.

Pyramid Land System (Py)

Stony gilgai plains supporting hard spinifex grasslands and minor tussock grasslands.
Geology: Quaternary alluvium and eluvium.
Geomorphology: Depositional surfaces; level, slightly elevated stony plains with a mosaic of gilgai and non-gilgai surfaces, low stony rises and occasional hills and minor calcreted plains; sparse patterns of tributary and through going trunk drainage.

River Land System (Rir)

Active floodplains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands.
Geology: Quaternary alluvium.
Geomorphology: Flood plains and river terraces subject to fairly regular overbank flooding from major channels and watercourses, sandy banks and poorly defined levees and cobble plains; banks, levees and slightly higher upper terraces receive less regular flooding than lower terraces and flood plains.

River Bed Land Unit (Riv)

Land unit of the River Land System.
Geology: Quaternary alluvium.
Geomorphology: Minor and major channels 30-1000 m wide between sandy banks 1-10 m above channel beds, bedloads of sand and gravel; no vegetation.

Robe Land System (Rob)

Low ferruginous mesas and buttes supporting soft spinifex (and occasionally hard spinifex) grasslands.
Geology: Quaternary pisolitic lateritic duricrust.
Geomorphology: Erosional surfaces; formed by partial dissection of old Tertiary surfaces, dissected plateaux and long lines of low mesas along present and past river valleys, indented near vertical breakaway faces and steep slopes with limonite outcrop and pisolitic gravelly mantles, restricted gravelly lower slopes and closely to moderately spaced narrow tributary drainage floors; relief up to 50 m.

Rocklea Land System (Rk)

Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands.
Geology: Archean basalt, Lower Proterozoic basalt, dolerite, tuff and agglomerate, minor shale and jaspilite.
Geomorphology: Erosional surfaces; hills, ridges and plateaux remnants on basalt with steep stony slopes, restricted lower slopes, stony interfluves and minor gilgai plains; moderately spaced tributary drainage patterns of small channels in shallow valleys in upper parts becoming broader floors and channels downslope; relief up to 110 m.

Roebuck Land System (Rb)

Saline coastal plains supporting salt water couch grasslands, samphire shrublands and mangroves.
Geology: Quaternary supratidal mudflat deposits; clay, silt and sand.
Geomorphology: Depositional surfaces; estuarine and littoral flats comprising grassy plains above high tides, traversed by a close network of channels; samphire flats and mangrove fringes along the seaward margins.

Ruth Land System (Rt)

Hills and ridges of volcanic and other rocks supporting hard spinifex (occasionally soft spinifex) grasslands.
Geology: Archean and Proterozoic intermediate and basic volcanic rocks; also quartz, minor chert, jaspilite, shale and siltstone.
Geomorphology: Erosional surfaces; rounded hills and ridges with restricted lower slopes and stony interfluves, moderately to widely spaced drainage patterns; relief up to 90 m.

Scoop Land System (Sc)

Stony plains with snakewood and chenopod shrublands.
Geology: Quaternary colluvium and alluvium.
Geomorphology: Depositional surfaces; non-saline stony plains and interfluves raised slightly above lower plains and gilgai plains, drainage tracts with moderately dense patterns of parallel and braided channels; channels often dissipate onto lower units or may be through-going to major trunk drainage; relief mostly less than 15 m.

Sherlock Land System (Srk)

Stony alluvial plains supporting snakewood shrublands with patchy tussock grasslands and spinifex grasslands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; level stony alluvial plains with some gilgai development; very rare, mainly non-tributary, through going drainage lines and channels.

Three Rivers Land System (Thr)

Hardpan plains and minor sandy banks supporting sparse mulga shrublands.
Geology: Partly cemented Quaternary colluvium and alluvium.
Geomorphology: Depositional surfaces; broad, non-saline plains with hardpan at shallow depth and receiving overland sheet flow; sandy banks and occasional groves, plains receiving more concentrated flow; minor tracts with channelled through flow shallowly incised into hardpan; relief up to 5 m.

Turee Land System (Tur)

Stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands.
Geology: Quaternary alluvium and colluvium.
Geomorphology: Depositional surfaces, level plains with a mosaic of stony gilgaied and non-gilgaied surfaces, groved hardpan plains and stony saline alluvial plains subject to sheet flow; sparse through drainage tracts with non-tributary and distributary channels; relief mostly less than 10 m.

Uaroo Land System (Ua)

Broad sandy plains supporting shrubby hard and soft spinifex grasslands.
Geology: Quaternary colluvium and alluvium.
Geomorphology: Depositional surfaces; level sandy plains up to 10 km or more in extent with little organised through drainage; pebbly surfaced plains and plains with calcrete at shallow depth; broad, mostly unchannelled, tracts receiving more concentrated sheet flow, minor low stony hills and rises; relief mostly less than 10 m but isolated hills up to 30 m.

Urandy Land System (Ury)

Stony plains, alluvial plains and drainage lines supporting shrubby soft spinifex grasslands.
Geology: Quaternary alluvium and colluvium.
Geomorphology: Depositional surfaces; level stony plains and plains and fans of sandy alluvium with widely spaced through going or sub-parallel distributary creek lines and channels; subject to sheet flow and overbank flooding; relief less than 10 m.

Wannamunna Land System (Wnm)

Hardpan plains and internal drainage tracts supporting mulga shrublands and woodlands (and occasionally eucalypt woodlands).
Geology: Quaternary alluvium and colluvium.
Geomorphology: Depositional surfaces; level hardpan washplains subject to overland sheet flow, drainage foci as discrete arcuate groves and broad internal drainage flats both receiving run-on from adjacent hardpan surfaces; rare channelled tracts but mostly no organised through drainage; relief up to 5 m.

Warri Land System (Wai)

Low calcrete platforms and plains supporting mulga and cassia shrublands.
Geology: Tertiary calcrete, calcareous gravel and opaline silica partly overlain by cemented Quaternary colluvium.
Geomorphology: Depositional surfaces; calcreted valley fills; level plains with a mosaic of calcrete tables elevated up to 3 m above surrounding surfaces, narrow inter-table areas and drainage floor with channels, minor plains on saline alluvium and hardpan plains subject to sheet flow; overall relief mostly below 5 m.

Yamerina Land System (Yam)

Floodplains and deltaic deposits supporting tussock grasslands, grassy woodlands and minor halophytic low shrublands.
Geology: Quaternary alluvium.
Geomorphology: Depositional surfaces; broad flood plains on non saline and saline alluvium, subject to sheet wash and overbank and channelled flow; gilgai back plains, swampy depressions and levees; sparse to widely spaced major channels in non-tributary and distributary patterns.

Yankagee Land System (Ya)

Plains with dunes and numerous claypans, soft spinifex and snakewood shrublands in the west of the area.

Geology: Quaternary alluvium, poorly sorted clay, silt, sand and gravel and eolian sand.

Geomorphology: Depositional surfaces; saline and non-saline plains formed by sheet flood and deflation; extensive clay plains with linear and reticulate sand dunes, shallow sandplain overlying clay, numerous small and large claypans with bare deflation lag surfaces; no organised drainage but clay plains are subject to sheet flow which becomes concentrated in some areas, numerous swamps and depressions subject to regular inundations but not holding permanent water; relief up to 15 m.

Yeeda Land System (Ye)

Sandplain with deep red and yellow sands supporting pindan acacia shrublands and eucalypt woodlands.

Geology: Quaternary eolian sands.

Geomorphology: Sandplain with little organised drainage, up to 16 km in extent, with shallow valleys, plains with thin sand cover and scattered pans, with limited surface drainage in zones of sheet flow up to 3 km wide and extending up to 8 km downslope from adjacent uplands.

Appendix E Tertiary Compartment Descriptions

All location names within this table are based on the three sources listed in Section 1.3.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
34. Cape Jaubert to Tryon Point	Water depth varies from 10m approximately 12km from shore to 20m approximately 25km from the shore in Lagrange Bay.	Water depth is <5m for approximately 7km from shore. The seabed has 25-50% reef or pavement but is predominantly sand covered in the inshore waters close to shore. Tidal flats narrow from over 1km in the south to approximately 0.5km in the north where the beach overlies a rock platform.	The WNW to NW facing coast includes two irregular and largely infilled embayments. In the southern embayment, between Cape Jaubert and Cape Frezier, a perched sandy beach abuts a 0.8km wide sandstone ridge. The major features of shore between Cape Frezier and Tryon Point are perched sandy beaches, a spit complex supporting mobile sands and tidal flats.	Along the shore sandstone ridges impound three mudflats to landward. The southern mudflats extend over 10km to landward, the large central mudflats to 14km, and the small northern mudflats to 1km. Each of the mudflats is drained by one or two tidal creeks lined with mangroves. There are broad expanses of mudflats with residual basins and palaeochannels.
33. Samphire Bore to Cape Jaubert	The inner-shelf is moderately wide. Water depth is <10m approximately 17km from shore; 20m approximately 31km from shore; and 50m approximately 75km from shore.	Water depth is <5m for approximately 8km from shore. There is <25% reef or pavement apparent on the inshore seabed. Tidal flats are approximately 2km wide.	Landforms in the compartment indicate a transition from the low coastal plains of Eighty Mile Beach to an irregular coast dominated by rock outcrops and pindan soils. A narrow sandy beach facing NW separates the dune ridges from a tidal flat approximately 2km wide.	An old land surface abuts and intersects mudflats up to approximately 19km wide. The mudflats are in the lee of a sequence of coastal dunes overlying a sandstone ridge.
32. Eighty Mile Beach Caravan Park to Samphire Bore	The inner-shelf is moderately wide. Water depth is <10m approximately 16km from shore and 20m approximately 33km from shore.	Water depth is <5m close to shore. No reef or pavement is apparent on the sandy inshore seabed. Tidal flats are approximately 2km wide.	A narrow sandy beach facing NW separates the dune ridges from a tidal flat approximately 2km wide.	An old land surface abuts and intersects a low plain up to 19km wide with old shoreline features and mudflats. The mudflats are in the lee of a sequence of coastal dune ridges.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
31. Cooraidegel Well to Eighty Mile Beach Caravan Park	The inner-shelf is narrow, tending to moderately wide. Water depth is <10m approximately 12km from shore and 20m approximately 25km from shore.	Water depth is <5m for approximately 6km from shore. There is <25% reef or pavement including patches of reef. Elsewhere bars, troughs and tidal channels are apparent. Tidal flats are approximately 1km wide.	A narrow sandy beach facing NNW separates a nearly continuous dune ridge from a tidal flat approximately 1km wide. Rock outcrops occur as beach rock platforms or low bluffs at the boundaries of the compartment.	The old land surface abuts a series of foredune ridges and mudflats. The latter are up to approximately 5km wide and extend along the coast. They are in the lee of a narrow coastal dune ridge with mobile sand sheets and evidence of washover likely to be associated with storm surge.
30. Shoonta Well to Cooraidegel Well	The inner-shelf is moderately wide, tending to narrow. Water depth is <10m approximately 13km from shore and 20m approximately 26km from shore.	Water depth is <5m for approximately 7km from shore. There are patches of reef in the inshore waters together with bars, troughs and tidal channels. Tidal flats are approximately 1km wide.	A narrow sandy beach separates the dune ridge from a tidal flat approximately 1km wide.	The old land surface includes desert dunes and a number of old shorelines. It abuts mudflats up to 4km wide and extending along the coast. The mudflats are in the lee of coastal dune ridges with overwash features. Three small tidal creeks drain the mudflats.
29. Cape Keraudren to Shoonta Well	The inner-shelf is narrow. Water depth is <10m approximately 10km from shore; and 20m approximately 22km from shore.	Water depth is <5m for approximately 6km from shore. There are patches of reef in the nearshore waters although bars, troughs and tidal channels are also present. A 0.5km wide tidal flat is present.	Cape Keraudren is the boundary between the outwash plains of the De Grey River and the low coastal plains of Eighty Mile Beach. A narrow sandy beach facing NNW separates chenier ridges and spits from a tidal flat over 0.5km wide.	The old land surface includes desert dunes. It abuts mudflats up to 4km wide, extending along the coast. The mudflats are in the lee of coastal dune ridges with spits and overwash features. There is some evidence of bi-directional sediment transport. Three small tidal creeks drain the mudflats.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
28. Mulla Mulla Creek to Cape Keraudren	The inner-shelf is moderately wide. Water depth is <10m approximately 28km from shore off the mouth of Pardoo Creek; and 20m approximately 31km from shore.	Water depth is <5m for approximately 23km from shore. There are lines of reef in the nearshore waters. Sand flats are approximately 1km wide.	Landforms in the compartment indicate a transition from the deltaic plain of the De Grey River to a tidal creek dominated coast. The N facing shore has two components. The first is a sandy embayment between two rocky headlands. Cheniers, spits and dune ridges have formed along this section of shore, with the spits indicating a net littoral drift to the east. Narrow sandy beaches grade onto sand flats approximately 1km wide. The second component is also headland controlled and forms two deep embayments with tidal creeks and mudflats at the head of each.	Outwash plain merges with mudflats, particularly in the eastern half of the compartment, impounded by cheniers, spits and dune ridges. The ridges have been cut by three tidal creek systems, including the estuarine reaches of Pardoo Creek, a former major distributary channel of the De Grey River. Mangroves line the tidal creeks, particularly in the eastern embayment. The major mudflat is approximately 5km wide and 21km long.
27. Condini Landing to Mulla Mulla Creek.	The inner-shelf is moderately wide. Water depth is <10m up to approximately 25km from shore; and 20m approximately 32km from shore.	Water depth is <5m for approximately 17km from shore. Much of the seabed is sandy although there are some reef outcrops, particularly close to shore. Sandy tidal flats extend 3km from shore. There is substantial sediment transport in an easterly direction along the subtidal terrace.	The NE facing coast is dissected by three tidal creeks each of which has a well-defined subtidal channel. The tidal creeks are separated by rock outcrops at the shore and subtidal rock platforms in the inshore waters. A sandy beach abutting chenier ridges and grading into sandy tidal flats extends along much of the shore. Tidal flats and mudflats in the intertidal waters support mangrove vegetation.	Three tidal creeks, with associated mudflats, separate segments of chenier spits and dune ridges. Components of the dune ridges may be lithified. A low-lying outwash plain of the De Grey River to landward has no well-defined stream channels, but has a complex network of distributary palaeochannels many of which could be reactivated.
26. Yan Well to Condini Landing	The inner-shelf is moderately wide. Water depth is <10m approximately 10km from shore off the mouth of the De Grey River; and 20m approximately 35km from shore. Bedout Island is located 40km offshore in State Waters. Large sand ridges extend up to 60km offshore from the delta shore.	Water depth is <5m for approximately 10km from shore. Large sand ridges extend up to 60km offshore from the delta shore. Tidal flats extend more than 3km from shore, particularly on the subaqueous levees adjoining the main discharge channel of the De Grey River.	The compartment includes the mouth of the De Grey River. Either side of the mouth are chenier ridges, spits and tidal flats, more than 3km wide. Fringing mangrove vegetation occurs along the coast and in the estuarine funnel.	Classic deltaic environment with abandoned, mud-filled channels and basins. There is complex interfingering of old river mouth spits and bars with mudflats and palaeochannels on the river delta, as well as with modern features.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
25. Wattle Well to Yan Well	The inner-shelf is moderately wide. Water depth is <10m approximately 23km from shore; and 20m approximately 34km from shore. There is an unusually shaped sand bar off Spit Point and North Turtle Island which is surrounded by shoals.	Water depth is <5m for approximately 7km from shore. Tidal flats extend up to 2km wide and overlie a rock platform. Different coastal processes operate on the WNW and NNW facing flanks of a large cuspate landform. Spits and bars are present on the WNW facing shore whereas tidal channels dissect the tidal flats on the NNW facing shore.	Landforms in the compartment are associated with the deltaic plain of the De Grey River. A large cuspate landform immediately landward of Spit Point is a major feature of this compartment. Sandy chenier ridges, sandy tidal flats and mudflats overlie a rock platform on the cuspate landform. The NNW facing shore supports fringing mangrove vegetation commonly on rock platforms.	The compartment includes a classic deltaic environment with abandoned, mud-filled channels and basins. There is complex interfingering of old river mouth spits and bars with mudflats and palaeochannels on the river delta. Chenier spits impound mudflats and tidal creeks on the north flank of the foreland. Tidal creeks and mudflats occur between the outwash plain and chenier spits or dune ridges. The tidal creeks support mangrove vegetation.
24. Beebingarra Creek to Wattle Well	The inner-shelf is wide. Water depth is <10m approximately 16km from shore; and 20m approximately 41km from shore. State Waters include two islands, Little Turtle Island and North Turtle Island, both surrounded by shoals.	Water depth is <5m for approximately 7km from shore. Tidal channels cross a broad sandy subtidal terrace, particularly in the northern part of the compartment.	Landforms in the compartment indicate a transition from a tidal creek dominated coast to the deltaic plain of the De Grey River. The coast faces NW. It is markedly dissected in the southern half of the embayment, where tidal creeks break continuity of the shoreline. In the northern half a sandy shoreline abuts an unbroken chenier ridge.	Tidal creeks and mudflats occur between an outwash plain and chenier spits or dune ridges. The Ridley River flows in to a lagoonal complex (13km long and 7km wide) landward of remnant ridges and mudflats enclosed for salt ponds. The pond walls redirect river flow. The landform association in the northern half of the compartment is a low plain of sandy spits and lagoons.
23. Downes Island to Beebingarra Creek	The inner-shelf is wide. Water depth is <10m approximately 14km from shore; and 20m approximately 47km from shore. Three islands are located in State Waters.	Water depth is <5m for approximately 8km from shore. The inshore waters include tidal channels, subtidal reef platforms and rock outcrops. Sandy tidal flats are 3.5km wide in the east. The Spoil Bank is a major source of sediment to the subtidal shoreface.	The shore is markedly dissected with a lithified chenier ridge and tidal flats between the ridges. Tidal flats are 3.5km wide in the east. There are approximately five tidal creeks per 10km along the irregular shore. Finucane Island has a calcarenite rock platform and low cliffs along its northern shore, with mangroves in the sheltered southwest shore. Port Hedland to Cooke Point has a sandy beach overlying beachrock and tempestites abutting Pleistocene dunes. The Spoil Bank is a major source of sediment to the coast, but also causes localised erosion.	Tidal creeks and mudflats occur between an outwash plain drained by small creeks to landward and chenier ridges, some of which are lithified. Three streams (Beebingarra, Petermarer and Tabba Tabba Creeks) and the Turner River drain onto mudflats and intermittently connect with tidal creeks.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
22. West Turner River to Downes Island	The inner-shelf is moderately wide. Water depth is <10m up to approximately 12km from shore and 20m approximately 30km from shore.	Water depth is <5m for approximately 6km from shore at its widest, which is seaward of the rocky coast in the central east of the compartment. The inshore waters include numerous tidal channels cutting the subtidal terrace, as well as rocky islets and reefs accounting for <25% reef or pavement. Much of the seabed is sandy.	Sandy cheniers and spits in the west merge with cliffed coast with rock platform in the east as more limestone outcrops become apparent along the shore. There are approximately eight tidal creeks per 10km along the irregular shore.	The compartment encompasses the deltaic plain of the Turner River with distributaries that connect with tidal creeks on mudflats. The major component of the delta is currently located landward of the limestone ridges in the eastern half of the compartment. Tidal creeks and mudflats occur between the deltaic plain and the chenier ridges. Away from rock platforms, mangroves colonise the open coast as well as sheltered waters between the cheniers and limestone outcrops along the shore. They extend along the tidal creeks up to 5km landward.
21. Cape Thouin to West Turner River	The inner-shelf is narrow. Water depth is <10m within 5km off Cape Thouin and up to approximately 7.5km elsewhere; and is 20m approximately 25km from shore.	Water depth is <5m for approximately 7km from shore. The inshore waters include numerous tidal channels dissecting tidal flats. To landwards the tidal channels are connected to tidal creeks.	Rock outcrops form a N facing embayment between Cape Thouin and the West Turner River. The shoreline is highly irregular with gaps of 1-2km between successive rock outcrops along the 20km long coast. Between the rock outcrops wide tidal creeks are connected to tidal channels flowing across tidal flats in the inshore waters. Sandy beaches are located along the seaward margins of rocky headlands, chenier ridges and spits.	The compartment comprises an outwash plain between the Yule and Turner Rivers, with the Yule River delta extending across a 3-4km wide mudflat. An irregular mudflat occurs between the outwash plain and chenier topography of the coast with its sandy beaches, moderately high and wide frontal dune ridge and mobile sand sheets. Mangroves colonise sheltered waters between the cheniers and rock outcrops and platforms along the shore as well as along the tidal creeks up to 5km landward.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
20. Cape Cossigny to Cape Thouin	The inner-shelf is narrow. Water depth is <10m approximately 13.5km from shore and 20m approximately 24km from shore. There is an extensive, elongate reef approximately 7km offshore, just outside State Waters.	Water depth is <5m for approximately 12km from shore in the western half of the compartment and adjacent to the seaward edge of the rock platform in the east. The inshore substrate includes 25-50% reef or pavement. The inshore waters have a broad rock platform.	The NNW facing coast between Cape Cossigny and Cape Thouin has a shallowly indented embayment as its western component. The shoreline to the east is nearly straight. A continuous sandy beach is perched on the broad platform.	In both parts of the compartment the long sandy beach is backed to landward by a moderately high and wide dune ridge that widens with distance northeast and includes mobile sand sheets. Mudflats occur between dune ridges and chenier spits close to shore in the northeast part of the compartment. The dunes overlie outwash plains of the Yule River and its distributaries which discharge on to mudflats in the west. There is potential interaction of the West Yule and Yule Rivers with the few tidal creeks.
19. Sherlock to Cape Cossigny	Water depth is irregular, since there are several channels across the inshore area. It is <10m approximately 15.5km and 20m approximately 40km from in the centre of the compartment. Depuch Island is a major feature in the embayment and differs geologically from the adjacent islands. West Moore Island, Sandy Island and East Moore Island and Muir Island have sandy shores. Table Rock has tidal flats to the south and hard bedrock shore to the north; whereas Ronsard Island and Reef Island have sandy beach to the south and bedrock shores to north.	Water depth is irregular, since there are several channels across the inshore area. It is <5m for approximately 10-15km from shore. Within the broader embayment, the coast between the Sherlock River and Cape Cossigny has two significant features: first, the chain of islands is a continuation of the chenier ridge from the compartment to the west; second, the shore is irregular and up to 7km landward of the island chain. Tidal flats extend up to 8km offshore.	A large zeta-form embayment extends across two tertiary compartments from Cape Lambert to Reef island off Cape Cossigny. Tidal flats extending up to 8km offshore support a line of mangroves. There are approximately five tidal creeks per 10km along the shore.	The backshore comprises mudflats located up to 8km landward of the shore. Well developed tidal creeks drain mudflats adjoining extensive outwash plains. Three river systems, Karinha Creek, Balla Balla Creek and Peawah River, have distributaries discharging on to the mudflats.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
18. Cape Lambert to Sherlock	The inner-shelf is moderately wide. Water depth is <10m approximately 20km from shore in the centre of the embayed compartment and 20m approximately 35km from shore.	Water depth is <5m from 6 to 8.5km from shore. Perched sandy tidal flats extend up to 1.5km offshore. The rock platforms supporting the tidal flats have been dissected by tidal channels.	A large zeta-form embayment extends across two tertiary compartments from Cape Lambert to Reef Island off Cape Cossigny. The irregular shoreline between Cape Lambert and Sherlock, near Caroline Island, is approximately 50km long. It has been cut by 15 tidal creeks, the largest of which are clustered in the west and central part of the coast to form a chain of perched sandy beaches on chenier ridges. The beaches adjoin sandy tidal flats abutting the chenier ridges. The tidal flats extend up to 1.5km offshore.	Low lying outwash plain and lagoonal basins dominate the hinterland between bedrock outcrops at Cape Lambert and east of the Sherlock River mouth. Remnant dune topography is close to the shore and low mounds are common on the landward side of the mudflats. Several tidal creeks cutting the chenier ridge interact with fluvial runoff and the deltas of the four major rivers: the Harding (dammed), East Harding, George and Sherlock Rivers are confined to the basins holding the mudflats.
17. Cleaverville Creek to Cape Lambert	The inner-shelf is narrow. Water depth is irregular. It is <10m approximately 6.5km from shore off Dixon Island; and 20m approximately 23km from shore and 2km north of Delambre Island. Three Islands are located in State Waters. The largest islands are Dixon Island, close to shore, and Delambre Island, which is surrounded by shoals and well offshore.	Water depth is irregular and is <5m for approximately 2.5km from shore. The inshore waters include 50-75% reef or pavement. In the lee of Dixon Island tidal flats are dissected by tidal channels.	The irregular shoreline includes two partly filled embayments, Port Robinson and a north facing embayment to the east of Bougner Entrance. In the west, rugged bedrock terrain dominates the Cleaverville coast. At Port Robinson, tidal flats up to 2km wide are lined by mangroves. Further east, sandy shore abuts and overlies rocky coast around Anketell Point and the embayment east of Bougner Entrance. In places the sandy shore is located on chenier spits and elsewhere impounds narrow mudflats. High level wrack lines are common in the Anketell area and are indicative of extreme water level events.	Tidal creeks and mudflats abut an old land surface along the Cleaverville coast from Cleaverville Creek to Port Robinson. Sandy shore abutting or perched on bedrock occurs intermittently as spits, cheniers and perched barriers around the eastern shore of Anketell and western shore of Cape Lambert. Moderately high and wide dunes are perched on extensive rock outcrops. Streams draining off the rocky topography flow into both embayments. They are connected to several small tidal creeks (>5 per 10km) in Port Robinson and the eastern embayment.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
16. Karratha Back Beach to Cleaverville Creek	The coast faces NW and is the eastern shore of Nickol Bay, a deep embayment open to the N to NE. The inner-shelf is wide. Water depth is <10m approximately 15km from shore and 20m approximately 30km from shore. There are two small islets in the inshore waters, Walcott Island and Pemberton Island.	Water depth is <5m approximately 3km from shore. The inshore waters cover mainly unconsolidated sediments. The tidal flats extend over 3km seaward of the beachrock.	An irregular shoreline is located between two rock headlands. The 10km of shore is broken by six tidal creeks, two of which have channels extending over 3km seaward across the tidal flats. The shore is lined by mangroves and overlies beachrock. Cheniers, including spits and a low, narrow foredune ridge or storm bar have formed along the northern shore.	The backshore includes an area of mudflats where marine sediments have filled an irregular depression in the bedrock topography. The mudflats follow stream channels and extend over 5km landwards at their widest. They are cut by tidal channels lined by mangroves for up to 4km landwards. The Nickol River discharges onto the mudflats but is not directly connected to the tidal creeks unless the river is in flood.
15. Cinders Road to Karratha Back Beach	The coast is set at the head of a deep NE facing embayment, Nickol Bay. The inner-shelf is wide. Water depth is <10m approximately 15km from shore.	Water depth is <5m for approximately 4km from the seaward margin of mudflats at the head of the bay. There is 25-50% rocky substrate, with a linear reef apparent in the eastern part of the compartment. Tidal flats are over 3km wide.	The NE facing shore is at the head of Nickol Bay, a deeply indented embayment approximately 32km long and 45km wide at its mouth. Along the low coast a chenier ridge approximately 100m wide is fringed with mangrove vegetation and intergrades with a tidal flat over 3km wide. The chenier has been breached by three tidal creeks along approximately 10km of coast; one creek is the drain from Dampier Salt ponds. Overwash fans occur along the landward side of the chenier ridge.	Tidal creeks and mudflats extend up to 2km to landward where they abut a retaining wall for the Dampier Salt ponds or the old land surface. The headwaters of some tidal creeks spilling from the salt pond drain have depositional fans. However, most of the tidal creeks have headwater gullies and are actively eroding the mudflat. A stream discharges on to the mudflats but is not directly connected to the tidal creeks unless it is in flood.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
14. Dolphin Island Point to Cinders Road	The inner-shelf is wide. Water depth is <10m approximately 22km from shore; and 20m approximately 37km from shore. Half of Dolphin Island, part of Legendre Island and Hauy Island are located in State Waters of this compartment.	Water depth is <5m for approximately 7km from shore. The inshore substrate includes hard rock and 50-75% reef or pavement, particularly in the southern part of the Burrup Peninsula. The small sandy beaches are perched on rock pavements with narrow tidal flats.	The Burrup Peninsula forms the western arm of a deep embayment, Nickol Bay, open to the NE. The shore of the Dolphin Island and Burrup Peninsula has a rocky coast with small sandy beaches either perched on rock platforms or located at the heads of small embayments in the hard bedrock topography. Several of the beaches, including the small embayments north of Hearson Cove, are perched on rock pavements and are fronted by narrow tidal flats and mangrove vegetation. Some of the beaches have a low ridge or storm bar along the backshore of the beach.	The coastal hinterland largely comprises the rugged bedrock terrain of the Burrup Peninsula. The southeast coast of Burrup Peninsula varies from the prevalent hard rocky coast, through small sandy beaches to small mudflats.
13. West Intercourse Island to Dolphin Island Point	The inner-shelf is moderately wide. Thirty three named islands comprising the Dampier Archipelago are located in State Waters. The islands are in waters <10m deep. Water depth is 20m approximately 28km from shore, and 50m approximately 80km from shore.	The 33 named islands of the Dampier Archipelago are in waters <10m deep. The inshore substrate includes hard rock and 50-75% reef or pavement. It also includes limesand and other unconsolidated sediments. The small sandy beaches are perched on rock platforms.	North of the mudflats and tidal creeks flanking the Dampier Salt ponds, the western shore of the Burrup Peninsula has a rocky coast with small sandy beaches either perched on rock platforms or located at the heads of small embayments. Several of the beaches, including those at Hampton Harbour, King Bay, Withnell Bay and Conzinc Bay, are fronted by narrow tidal flats and mangrove vegetation.	With localised exceptions, the coastal hinterland largely comprises the rugged bedrock terrain of the Burrup Peninsula and Dolphin Island.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
12. Pelican Point to West Intercourse Island	A shallow offshore reef is located approximately 16km offshore and extends into the compartment from the east for approximately 8km. The inner-shelf is moderately wide and includes Eaglehawk Island and a number of reefs. Water depth is <10m approximately 17km from shore and is 20m approximately 25km from shore.	Water depth is <5m for approximately 6.5km from shore. The inshore substrate includes <25% reef or pavement. Silty and sandy tidal flats are approximately 2km wide and overlie a broad rock pavement.	A sandy shore abuts an embayed chain of partly lithified chenier islands. The islands are separated by tidal creeks, several of which link with distributary streams of the Yanyare and Maitland Rivers. There are >5 creeks per 10km of shore. Sandy beaches adjoin silty and sandy tidal flats approximately 2km wide. The tidal flats overlie a broad rock pavement. In places, mangroves grow along the tidal flats and extend into tidal creeks.	The backshore is mainly active floodplain grading to low dune ridges approximately up to 0.8km wide, with nine large tidal creeks, the longest extending approximately 3.5km landward. Mudflats are located between discontinuous chenier ridges and remnants of the old land surface. A series of old shorelines present in this compartment is apparent as arcuate lines of lithified dune and reef parallel to the modern shore. Two rivers, the Yanyare and Maitland Rivers, interact with tidal creeks and have estuarine components.
11. Cape Preston to Pelican Point	The inner-shelf is narrow. Water depth is <10m approximately 12km from shore to the seaward side of the reef; 20m approximately 22km from shore; and 50m approximately 75km from shore. The shallow water isobaths are closer to shore in the eastern part of the compartment. Two islands, South East and North East Regnard Island, are located in State Waters.	Water depth is <5m for approximately 10km from shore in the central embayment, where it abuts an offshore reef. The seabed has >75% reef or pavement. Nearly all subtidal features overlie rock pavement, commonly coral reef. The central shore has tidal flats.	The complex shore has three components. In the west a N to NNE facing sandy shore abuts an older dune surface and overlies a rock platform that merges with an extensive inshore pavement. In the central part of the compartment the coastal ridge has been dissected by numerous tidal channels. The tidal flats of the central shore support mangrove vegetation and overlie a nearshore reef platform. Further east, a sandy beach is apparent along a spit segmented by tidal creeks. This merges with the NW facing flank of a cuspate foreland at Gnoorea Point and continues around the shore of a shallow embayment facing NNW between Gnoorea and Pelican Points. Nearly all intertidal shore features are perched on rock.	In a seaward direction, outwash plain merges with mudflats approximately 4km wide. In the eastern part of the compartment the backshore comprises a series of low dune ridges overlying rock. The ridge impounding the mudflats to landward comprises two spits which point towards the centre of the embayed compartment. There are 10 tidal creeks in the exposed central part of the embayment, the longest extending approximately 3km landward. Two streams, McKay and Eramuna Creeks, discharge onto the mudflats, but neither is directly connected to the ocean.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
10. James Point to Cape Preston	The inner-shelf is moderately wide. Water depth is <10m approximately 20km from shore in the centre of the compartment; 20m approximately 26km from shore; and 50m approximately 75km from shore. Five islands, including Potter Island and Carey Island, and some shoals and reefs are located in State Waters.	Water depth is highly variable but generally <5m for approximately 8km from shore. There is 25-50% reef or pavement in the inshore waters. Broad tidal flats extend northwards along the coast to landward of Carey Island. The central part of the embayment has narrow tidal flats.	Apart from a N facing embayment in its southern part the remainder of the coast faces W to WNW. Much of the coast is perched on rock pavement or platform. In the south eastern part of the embayment a narrow chenier ridge has formed landward of the mangroves. Tidal flats over 1km wide are fringed by mangrove vegetation and merge with broad tidal flats, particularly in the south eastern part of the embayment. The central part of the embayment, where rocks are close to the shore, has narrow tidal flats and a sandy shore backed to landward by a low foredune plain.	This is an area of geologic change from dominantly unconsolidated sediments of the western compartments to igneous rocks comprising the spine of Cape Preston. The mudflats of the southeast section of the compartment occupy embayments in the rocky topography. Further north the foredune plain is over 1km wide landward of the cuspate foreland at Preston Spit. There are 13 tidal creeks per 10km in the compartment with streams draining the rocky hinterland and discharging onto mudflats.
9. Mount Salt to James Point	The inner-shelf is of moderate width. Water depth is <10m approximately 18km from shore in the compartment centre; 20m approximately 30km from shore and 50m approximately 85km from shore. Three islands are located in State Waters.	Water depth is <5m for approximately 7km from shore. There is 25-50% reef or pavement in the inshore waters. The coast is the NW facing flank of the Fortescue River delta and includes its active components. A sandy shore grades to a tidal flat overlying a rock platform. Rock outcrops occur intermittently along the shore as beachrock ramps or platforms.	The coast is the NW facing flank of the Fortescue River delta and includes its active components. A perched beach overlies a rock platform. The continuity of the shore is broken by approximately three tidal creeks per 10km as well as the Fortescue and Du Boulay Rivers. The tidal creeks occur more commonly in the eastern part of the compartment, near the river mouth.	In the western part of the compartment an inactive delta front with a low rocky ridge encloses an elongate, shore-parallel mudflat that extends approximately 5km to landward. The ridge has been cut by three ephemeral streams which would be active during periods of flood and surge inundation. Tidal creek incursion and mangrove colonisation have occurred in the southwest of the compartment. Distributary fans from large tidal creeks extend into the western and eastern end of the mudflats. Fluvial creeks flowing from the hinterland discharge on to the mudflats, whereas further east the channel of the Fortescue River extends to the shore.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
8. Peter Creek to Mount Salt	Offshore from Peter Creek to James Point the 50m isobath, which is seaward of the Montebello Islands, closes with the coast, narrowing from over 60km in the lee of the Montebello Islands to 25km off James Point and 15km off Cape Preston to the east. Consequently the inner-shelf is very wide. Water depth is <10m approximately 15km from shore. Islands and shoals of the Passage Island chain are located in <5m and are approximately 10km from shore. The Montebello Islands are located in State Waters approximately 90km offshore.	Water depth is <5m for approximately 10km from shore. The coast is the WNW facing flank of the Fortescue River delta. Extensive tidal flats extend over 1.5km offshore. This is an area where a substantial amount of silty sand has been deposited.	The coast is the WNW facing flank of the Fortescue River delta. The coast is irregular in planform with rocky outcrops occurring between areas of sediment accumulation. The shore is vegetated by mangroves and has approximately five tidal creeks per 10km along the shore.	The hinterland comprises mainly mudflats and outwash plain. Mangroves grow along the numerous tidal creeks and, in places, along the shore. The longest creeks extend approximately 5km into the mudflats which are up to approximately 11km wide. Open mudflats occur landward of remnant mounds of older topography where there is potential interaction of flood runoff with marine waters during inundation of the mudflats by storm surge. Further landward are the upper deltaic plain and ephemeral distributary channels of the Fortescue River.
7. Weld Island to Peter Creek	The inner-shelf is very wide. Water depth is <10m approximately 16km from shore; and 20m approximately 80km from shore in the central part of the compartment. The 50m isobath is over 165km offshore due to the influence of Barrow Island and the Montebello Islands. The inshore depth contours are further offshore on the eastern margin of the compartment. Approximately 25 islands are located in State Waters. The largest, Barrow Island, is 60km offshore and is surrounded by extensive shallow shoals trending NNE. The Great Sandy Island chain is closer to shore and merges with the Passage Island chain to the east.	Water depth is <5m for approximately 5km from shore. The platforms and pavements support a veneer of silty to sandy sediment and provide topographic control for the entrances to tidal creeks.	Mudflats and mangroves are the dominant features of the NNW facing shore. These overlie discontinuous platforms and pavements at various levels close to sea level. In all there are approximately five tidal creeks per 10km of shore, with the longest extending over 9km to landward.	Mainly outwash plain and dune ridges, with 14 tidal creeks, the longest extending approximately 6km landward. The Robe River interacts with tidal creeks and discharges into the central part of the compartment. The Robe River delta includes open mudflats and supratidal saltflats landwards of remnant mounds of older topography. A chain of rocky ridges and platforms lies along the backshore and separates the tidal creeks. Mudflats and mangroves extend along tidal creeks and into the sheltered area landward of the ridges. There is potential interaction of flood runoff with marine waters during inundation of the mudflats by storm surge as well as more localised interaction at the river mouth at other times.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
6. Yardie Landing to Weld Island	The inner-shelf is very wide and water depth is irregular. It is <5m for up to 20km but may be <10m for the same distance. Further offshore, water depth is 20m approximately 60km from shore and over 80km to the 50m isobath. Seven islands are located in State Waters. They extend 7-16km NE from the shore and are part of a chain of barrier islands, the Great Sandy Island chain, with wide subtidal shelves and shoals. The shallow waters and subtidal shelf surrounding Barrow Island extends into this compartment.	Water depth is irregular and is <5m for up to 20km from shore. The silty to sandy sediment veneer overlying patches of rock pavement creeks support mangrove vegetation.	A highly irregular shoreline forms a shallowly indented, NW facing embayment between the floodplain of the Cane River and the active delta of the Robe River. There are approximately five tidal creeks per 10km of shore, with the longest extending over 9km landward. The creeks support mangrove vegetation. To landward the creeks are separated by older dune remnants, some of which may be partially lithified.	Extensive tidal creeks and saltflats extend approximately 9km from shore. The landward margin of the mudflats has remnant mounds of an older land surface. The tidal creeks are active and support mangroves, with one large complex in the centre of the compartment. The Cane River interacts with a tidal creek and discharges into the western part of the compartment near its boundary. Overall the hinterland is an outwash plain with numerous creeks discharging onto the mudflats.
5. Coolgra Point to Yardie Landing	The inner-shelf is wide. Water depth is <10m approximately 15km from shore; 20m approximately 50km from shore; and 50m approximately 55km from shore. Three islands are located in State Waters; Arlie Island in the offshore chain approximately 34km offshore, with the Mangrove Islands and South Island within 10km of the shore. The seabed between Coolgra Point and the Mangrove Islands includes sandy shoals and reef outcrops, with fringing reef around the islands.	The subtidal shoreface is wide. Water depth is <5m for approximately 8km from shore. There is 25-50% reef in the inshore waters and extensive sand accumulation occurs at the creek mouths.	A NNW facing shore comprises a veneer of sand overlying either rock platforms or beachrock. In all there are approximately three tidal creeks per 10km of shore, with the eastern part of the shore mainly comprising islets, spits, tidal creeks, tidal flats and mangrove communities. Yardie Creek and Yammaderry Creek have tidal components but may be brackish water creeks directly connected to the ocean.	The hinterland of the compartment includes two floodplain basins separated by the deltaic floodplain of the Cane River and is overlain by remnants of longitudinal dunes. In the western two thirds of the compartment the sandy beach is backed by a low narrow foredune ridge that has receded across remnant dune topography and mudflats. Further landward there is apparent interaction between fluvial and tidal creeks in the compartment, with one tidal creek extending approximately 3km landward. The hinterland is mainly floodplain and dune ridges.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
4. Hooley Creek to Coolgra Point	The inner-continental shelf widens to the east offshore between Hooley Creek and Coolgra Point and the barrier island chain along the NNW facing coast splits into two components. The offshore component includes Thevenard Island, which is surrounded by a shallow island fringe up to 4km wide, and the Rosily Islands as well as reefs. Within the compartment, the inner-shelf is wide. Water depth is <10m approximately 12km from shore; 20m approximately 40km from shore; and 50m approximately 45km from shore. Five islands are located in State Waters.	Close to shore and within the 10m isobath are Direction Island and the Twin Islands. The substrate comprises 25-50% reef or pavement. Water depth is <5m for approximately 4km from shore. The perched beaches merge to seaward with the unconsolidated sediments of the inshore waters.	Four shallow, zeta-form embayments constitute a sandy shoreline facing NNW. They are linked by rock outcrops at their headlands, in places to beachrock outcrops. The perched beaches merge to landward with a high dune ridge fronted by a low foredune. The curve of each zeta-formed embayment and the dune ridge it contains is broken by tidal creeks: three or four between Casugrina Point and Beadon Point; two in the embayment east of Beadon Point; and, discounting one south of Coolgra Point, one in each of the two small embayments leading to Coolgra Point. In all there are approximately three tidal creeks per 10km of shore.	In each of the embayments a moderately high and wide frontal dune ridge either abuts or overlies rocky topography. The seaward face of the frontal dune is commonly scarped. The dunes and underlying topography impound a floodplain basin extending for approximately 30km along the coast and for 12km landward. The natural components of the basin, away from the salt ponds, are inundated tidally through the tidal creeks and by flooding from the Ashburton River, and to a lesser extent the Cane River. Further landward, the basin merges with the residual mounds and palaeochannels characteristic of the floodplain.
3. Bare Sand Point to Hooley Creek	The inner-shelf is wide. Water depth is <10m approximately 15km from shore; 20m approximately 20km from shore and 50m approximately 35km from shore. Two small islands, Ashburton Island and Tortoise Island, are located in State Waters. Thevenard Island is surrounded by a subtidal shelf up to 4km wide.	The NNW facing coast includes the shallow waters immediately offshore of the Ashburton River mouth where the inshore substrate is <25% reef or pavement. Water depth is <5m for approximately 4km from shore.	The sandy shore faces NW and comprises the landward margin of the active delta of the Ashburton River that dominates the compartment. This is one of the largest and most dynamic river systems in the region. Pulsatory sediment supply by flood discharge results in the formation of transitory shoals and spits that migrate along the coast in both directions. Commonly, the intertidal shore is perched on rock pavements and platforms.	The sandy beach is backed by a low chenier ridge with sand spits where it has been breached by river outflow or cut by tidal creeks. Overwash fans are common along the ridge. East of Casugrina Point a long chenier spit ephemerally fronts a narrow lagoon and a supratidal beachrock platform underlies a high, perched frontal dune complex. The Ashburton River has undergone several phases of avulsion, as evidenced by a floodplain with numerous deltas, foredune plain insets, palaeochannels, abandoned shorelines marked by high dune ridges and lithified cheniers. It is an area of long-standing and ongoing dramatic geomorphic change.

TERTIARY COMPART.	INNER-SHELF MORPHOLOGY	SUBTIDAL SHOREFACE	INTERTIDAL SHORE	BACKSHORE LANDFORMS
2. Locker Point to Bare Sand Point	At a broad scale the coast between Locker Point and Coolgra Point faces NNW and is in the lee of a remnant barrier chain along a formerly embayed coast. The inner-shelf is of moderate width. Water depth is <10m at approximately 15 km from shore; 20m approximately 30km from shore; and 50m approximately 35km from shore. Eight islands are located in State Waters; the larger being Serrurier, Bessieres and Flat Islands.	The water depth is <5m for approximately 2-4 km from shore. A number of reefs are also apparent and the inshore substrate is on 25-50% reef or pavement and unconsolidated sediment. The curve of the embayed shoreline is broken by three small cuspate forelands, each associated with rock outcrops close to shore. A rock platform extends approximately 4.5km eastwards from Locker Point to the first foreland.	Away from the mouth of Urala Creek the sandy, shallowly arcuate shore faces NW. The coast is on an interfluve between Chinty Creek and the Ashburton River. The two eastern forelands are associated with isolated outcrops at the shore and in the inshore waters. Between the forelands the sandy beach is perched on a rock platform.	The compartment includes a prograded barrier with a high frontal dune ridge seaward of older washover features. Landward of Locker Point the dunes impound a floodplain basin into which Urala Creek, a tidal creek, flows. In the central part of the compartment they overlie an older outwash plain of the Ashburton River with numerous palaeochannels, crevasses and residual mounds. Further east the dunes include mobile sand sheets and impound a basin that drains directly into the ocean. The basin abuts an old shoreline with lithified dunes, marine sediments and evidence of extreme high water-level events.
1. Hope Point to Locker Point	The coast is the northern part of the eastern shore of Exmouth Gulf, and is open to the NW to NNE. The inner shelf is narrow but substantially sheltered. At approximately 20km from shore, the water depth deepens from 10m in the S of the compartment and deepens to 20m in the NW. There are numerous islands and reefs in the compartment, including Tent Island, Simpson Island, Hope Island, the Rivoli Islands, Brown Island, rocky islets and Fly Island as well as Exmouth, Beryl and Pearl Reefs.	The subtidal shoreface is moderately wide, with water depths <5m approximately 10km from shore. Less than 25% of reef or rock outcrop is apparent in the inshore waters. A broad subtidal terrace is cut by numerous tidal channels that are linked to tidal creeks draining the seaward margin of an extensive mudflat extending along the coast.	The highly-irregular NNW facing shore is the dissected margin of an outwash plain. There are more than five tidal creeks per 10km along the shore. In some places the tidal creeks are separated by remnants of an older land surface which form discrete points, such as Hope Point. The shore is vegetated with mangroves. With increasing distance north the coast is affected by sediment moved south from the Ashburton River. Chenier spits, a cuspate foreland with mobile sand sheets and large tidal creeks have formed in the vicinity of Tubridgi Point.	In the southern part of the compartment the backshore is comprised of broad bare mudflats up to 7km wide seaward of an extensive, low-lying outwash plain north of the Yannarie River mouth on the landward edge of the mudflats. Residual mounds of an older land surface, including weakly cemented dune sediments, are common on the saltflats. To the north and landward of Tubridgi Point, Chinty Creek drains across a floodplain into an inherited basin drained by tidal creeks, including Urala Creek.

Appendix F Tertiary Compartment Vulnerability Summary

SUSCEPTIBILITY AND INSTABILITY RANKINGS SHOULD NOT BE USED INDEPENDENTLY AS MEASURES OF VULNERABILITY. BOTH ARE BASED ON SEVERAL CRITERIA AND ARE SUB-COMPONENTS TO THE VULNERABILITY RANKING AND CONSEQUENT IMPLICATIONS.

Tertiary Comp.	From Long.	From Lat.	Susceptibility		Instability		Vulnerability		
			Rank	Implications	Rank	Implications	Rank	Risk	Rationale
Cape Jaubert to Tryon Point	121.55591	-18.940217	L	A mainly structurally sound geologic or geomorphic feature likely to require limited investigation and environmental planning advice prior to management.	L	Resilient natural system occasionally requiring minimal maintenance (eg. Alfred Cove, Milyu Reserve & Scarborough).	L	Coastal risk is unlikely to be considered a constraint for coastal management.	The site has a good combination of integrity of natural structures, natural resilience and low management requirements.
Samphire Bore to Cape Jaubert	121.169799	-19.496763	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
Eighty Mile Beach Caravan Park to Samphire Bore	120.674893	-19.751957	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Cooraidegel Well to Eighty Mile Beach Caravan Park	120.366011	-19.858423	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.

Tertiary Comp.	From Long.	From Lat.	Susceptibility		Instability		Vulnerability		
			Rank	Implications	Rank	Implications	Rank	Risk	Rationale
Shoonta Well to Cooraidegel Well	120.133406	-19.912917	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
Cape Keraudren to Shoonta Well	119.769515	-19.955911	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
Mulla Mulla Creek to Cape Keraudren	119.490036	-20.017889	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
Condini Landing to Mulla Mulla Creek	119.315702	-19.986553	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
Yan Well to Condini Landing	119.076201	-20.008356	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.

Tertiary Comp.	From Long.	From Lat.	Susceptibility		Instability		Vulnerability		
			Rank	Implications	Rank	Implications	Rank	Risk	Rationale
Wattle Well to Yan Well	118.950972	-20.136082	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Beebingarra Creek to Wattle Well	118.736696	-20.298077	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.
Downes Island to Beebingarra Creek	118.501106	-20.333843	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
West Turner River to Downes Island	118.34677	-20.327039	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.
Cape Thouin to West Turner River	118.182161	-20.336279	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.

Tertiary Comp.	From Long.	From Lat.	Susceptibility		Instability		Vulnerability		
			Rank	Implications	Rank	Implications	Rank	Risk	Rationale
Cape Cossigny to Cape Thouin	117.939833	-20.482809	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
Sherlock to Cape Cossigny	117.612435	-20.674989	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.
Cape Lambert to Sherlock	117.184594	-20.592464	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.
Cleaverville Creek to Cape Lambert	116.977282	-20.6664	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
Karratha Back Beach to Cleaverville Creek	116.883632	-20.721035	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.

Tertiary Comp.	From Long.	From Lat.	Susceptibility		Instability		Vulnerability		
			Rank	Implications	Rank	Implications	Rank	Risk	Rationale
Cinders Road to Karratha Back Beach	116.795132	-20.64922	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.
Dolphin Island Point to Cinders Road	116.884823	-20.423308	L	A mainly structurally sound geologic or geomorphic feature likely to require limited investigation and environmental planning advice prior to management.	L	Resilient natural system occasionally requiring minimal maintenance (eg. Alfred Cove, Milyu Reserve & Scarborough).	L	Coastal risk is unlikely to be considered a constraint for coastal management.	The site has a good combination of integrity of natural structures, natural resilience and low management requirements.
West Intercourse Island to Dolphin Island Point	116.581499	-20.741796	L	A mainly structurally sound geologic or geomorphic feature likely to require limited investigation and environmental planning advice prior to management.	L	Resilient natural system occasionally requiring minimal maintenance (eg. Alfred Cove, Milyu Reserve & Scarborough).	L	Coastal risk is unlikely to be considered a constraint for coastal management.	The site has a good combination of integrity of natural structures, natural resilience and low management requirements.
Pelican Point to West Intercourse Island	116.396919	-20.822805	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.
Cape Preston to Pelican Point	116.206028	-20.832458	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.

Tertiary Comp.	From Long.	From Lat.	Susceptibility		Instability		Vulnerability		
			Rank	Implications	Rank	Implications	Rank	Risk	Rationale
James Point to Cape Preston	116.165368	-20.968834	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M	Coastal risk may present a moderate constraint for coastal management.	The site has constraints due to a combination of low-to-moderate integrity of natural structures, limited natural resilience and/or ongoing management requirements.
Mount Salt to James Point	115.914899	-21.080759	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Peter Creek to Mount Salt	115.824682	-21.241944	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Weld Island to Peter Creek	115.552028	-21.411535	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Yardie Landing to Weld Island	115.376708	-21.549414	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.

Tertiary Comp.	From Long.	From Lat.	Susceptibility		Instability		Vulnerability		
			Rank	Implications	Rank	Implications	Rank	Risk	Rationale
Coolgra Point to Yardie Landing	115.234903	-21.566005	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Hooley Creek to Coolgra Point	115.017934	-21.68474	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Bare Sand Point to Hooley Creek	114.897993	-21.708684	M	Some natural structural features are unsound hence the area may require further investigation and environmental planning advice prior to management. Detailed assessment of coastal hazards and risks is advised.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Locker Point to Bare Sand Point	114.72276	-21.799008	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	M	Management responses are required to accommodate occasional major events, regular moderate events or frequent minor events. Responses may involve stabilisation work (eg. Cottesloe, Floreat & Broun Bay).	M-H	Coastal risk is likely to be a significant constraint for coastal management.	The site has significant constraints due to a combination of low integrity of natural structures, poor natural resilience and/or moderate-high ongoing management requirements.
Hope Point to Locker Point	114.454781	-22.164324	H	Natural structural features are extensively unsound. Major engineering works are likely to be required.	H	Management responses require repeated installation or repair of major stabilisation works (eg. Port Geographe, Mandurah & Geraldton).	H	Coastal risk is a major constraint for coastal management.	The site has major constraints due to low integrity of natural structures, little natural resilience and high ongoing management requirements.