Coastal Hazard Mapping for the Peron-Naturaliste Region

The following note provides a simplified summary of the approach used to generate coastal hazard maps for the region from Cape Naturaliste to Point Peron. Mapping was undertaken as part of the Peron-Naturaliste Partnership Coastal Adaptation Decision Pathways (PNP-CAPS) project *Developing Flexible Adaptation Pathways for the Peron-Naturaliste Coastal Region of Western Australia*. A more complete summary is available in Damara WA Pty Ltd report 169-01 *Coastal Hazard Mapping for Economic Analysis of Climate Change Adaptation in the Peron-Naturaliste Region*. Hazards mapped include projected coastal inundation and erosion, for time frames up to 2110.

The hazard assessment was specifically developed for economic assessments of adaptation options, which form Phases II and III of PNP-CAPS, at regional and local case-study scales respectively. This focus influences the relative treatment of hazards due to the relative tolerance of infrastructure and coastal land-use to inundation in comparison to erosion impacts. The approach used was a deliberate synthesis of existing coastal hazard studies, including extreme water level distributions derived from tide gauges (Damara WA 2008, 2011), and the regional erosion study undertaken by the University of Sydney (Cowell & Barry 2012) to support hazard assessments by Geoscience Australia (2010, 2011).

Evaluation of coastal hazards required different treatments for the phases of the PNP-CAPS project:

- Phase I (Hazard Mapping) required a spatial representation of the coastal hazards, to enable identification of the potential extent of regional impacts and facilitate selection of hazard scenarios and case-study sites.
- Phase II (Regional Economic Assessment) primarily undertook scaling of the regional impacts, looking at their maximum spatial extent for a projection time scale to 2110, compared with the equivalent present-day hazard exposure.
- Phase III (Local Case-Study Economic Assessment) required an annual time-sequence of hazard impacts, with inclusion of year-to-year variability and alternate sea level rise projection scenarios from low to high.

These needs determined that hazard assessment was required to be probabilistic and capable of use at a high resolution, suitable for Phase III.

Probabilistic thresholds for Phases I and II were initially proposed, based on typically accepted hazard levels for residential premises (100 to 500 year average recurrence interval). However, it was identified that the regional erosion study reported 'uncertainty' levels rather than probabilities, and required an alternative means of evaluation. The relative impact of inundation and erosion events was also taken into account for the selection of hazard levels, as moderate inundation is possible without structural failure, whilst any degree of erosion is likely to cause partial or complete collapse of a building that is not built on erosion-resistant foundations.

Erosion Hazard Assessment

The regional recession study (Cowell & Barry 2012) was selected as the basis for erosion assessment because it considered the impact of sea level rise based on a regional distribution of sediment volumes. However, the study was uncertainty-based, which means it made allowances for 'what we do not know' about coastal dynamics. The results, which were presented as a range of possible outcomes, therefore included possible rather than likely outcomes, with the dominant process being the transfer of sediment from the coast across the shelf to a depth of 46m. The study modelled recession distances up to 900m by 2110, which are significantly greater than setback allowances calculated using the State Coastal Planning Policy method (Oceanica & Shore Coastal 2009). This was mainly caused by shore-shelf transfer, with the regional study giving ratios of 30: 1 to 300:1 for shoreline retreat to sea level rise.

A subset of the regional study erosion estimates was selected, based on commonly applied patterns of shelf infill, with 25 to 50% range covering from exponential to linear infill (Figure 1). This range does not consider external sediment sources, or the influence of reefs and island chains upon shore-shelf sediment transfer. This is considered to generally bias the erosion estimates upwards.

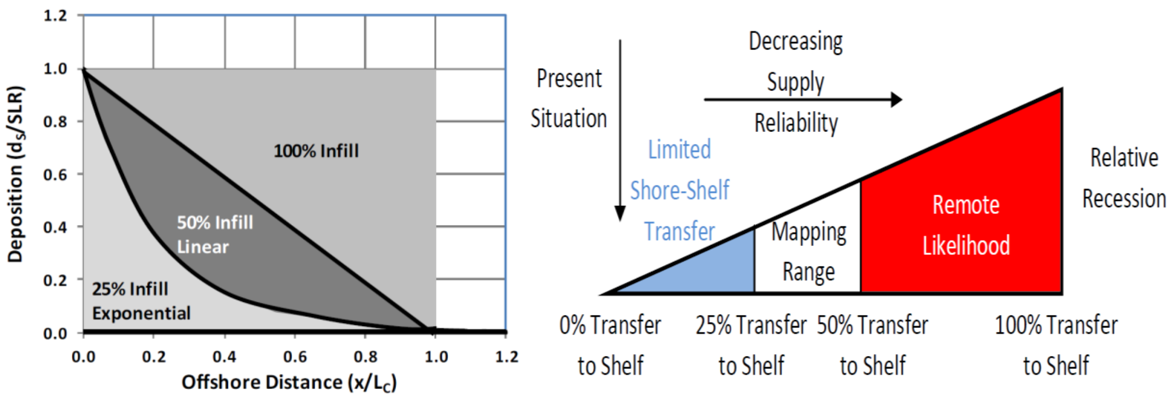

Figure 1: Shelf infill rates used for mapping
Mapping range is that used for the PNP-CAPS hazard mapping

Shelf infill rates indicate sediment volume lost from the coast due to sea level rise, but do not suggest which parts of the coast the material comes from. This was assessed through consideration of coastal geology and landforms. Erosion hazard assessment was derived from the regional erosion study (Cowell & Barry 2012) by selecting different 'uncertainty' levels along the coast (Table 1).

Table 1: Basis for Recession Line Selection
Percentages are Cowell & Barry (2012) recession exceedence probabilities.

Coast Type	Storm Recession	Low Scenario	Med. Scenario	High Scenario
Moderate-High Rock	all	99.9%	90%	80%
Rocky Substrate	all	70%	55%	40%
Sandy	all	50%	30%	10%

This pattern developed by applying Table 1 gave average erosion distances over Peron-Naturaliste coast that matched 25% to 50% infill (Figure 1) for low to high scenarios. By smoothing of erosion distances between areas of different geological structure, linearly varying erosion distances were generated next to the large headlands at Casuarina Point and Point Bouvard. This pattern strongly resembles the distribution of geologically recent coastal landforms (Figure 2).

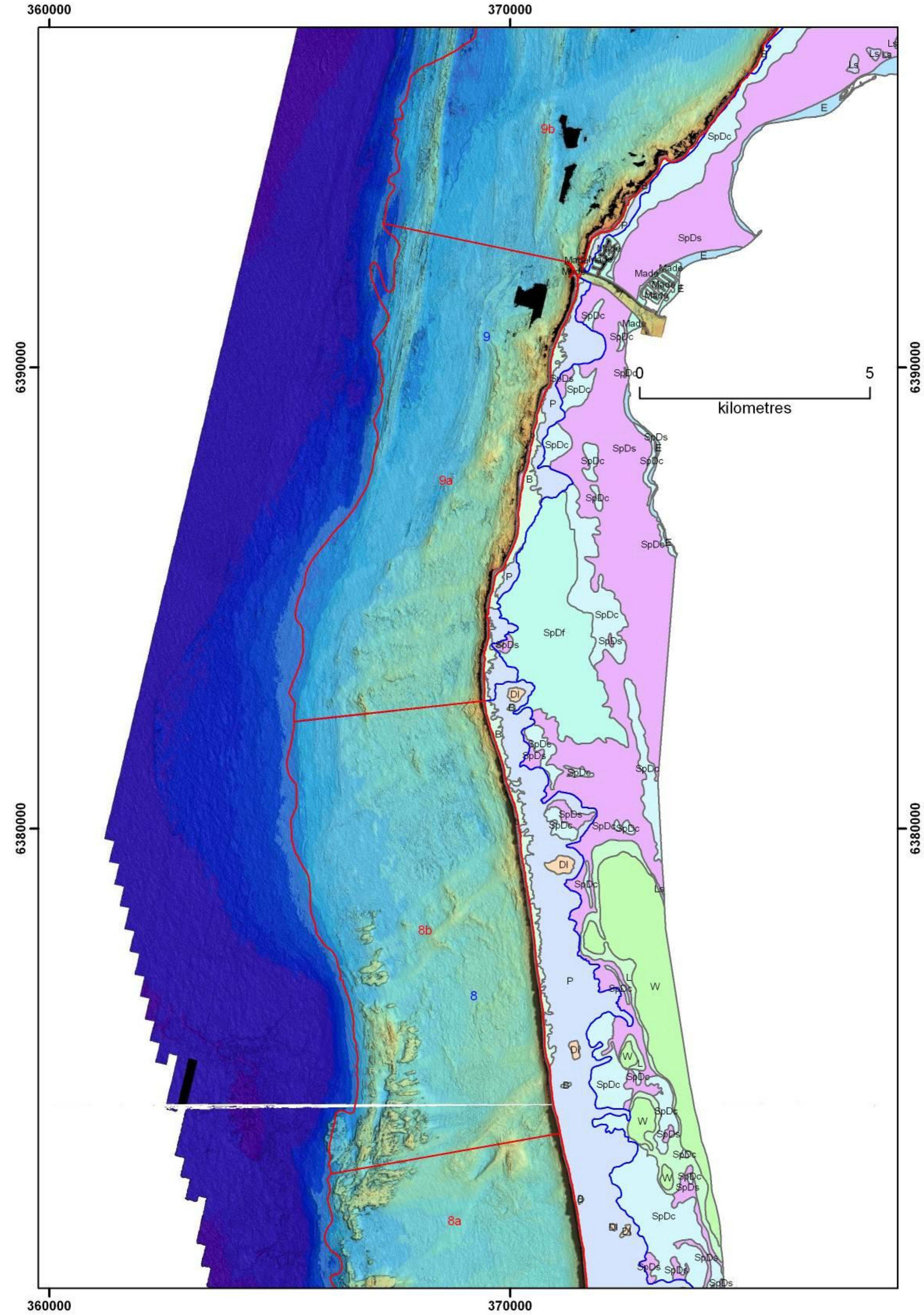

Figure 2: Example of LADS Imagery and WACoast Coastal Landform Mapping

The influence of rocky coastal features was not included in the regional erosion study, which considered aggregated behaviour within six sub-cells. This small number of 'points' and neglect of alongshore capture by headlands limited translation of the regional erosion study to a smaller scale and therefore restricts hazard mapping reliability. Regional erosion study results could only be 'downscaled' to take into account large scale features. These included reef sheltering at Becher Point and Preston Beach, and headland at Mersey Point, Roberts Point, Cape Bouvard and Casuarina Point. Key locations that are not considered to be well-represented by the erosion assessment are Quindalup-Busselton, Bunbury and Mandurah, due to the neglect of onshore sediment feeds and limited ability to represent alongshore controls. Further refinement of the erosion threat is considered to require higher resolution identification of underlying rock features, such as apparent in Figure 2 and inclusion of alongshore controls such as headlands and groynes, when evaluated at a local scale.

Results for the median erosion scenario are summarised in Table 2 for projection time scales at 2030, 2070 and 2110.

Table 2: Medium Scenario Erosion Distances

Location	Geology	Sub-cell	2030	2070	2110
Mersey Point	Rocky	1	35m	50m	170m
N Mandurah	Sandy	1	70m	150m	230m
Roberts Point	Rocky	2	50m	100m	160m
Clifton	Mixed	3	50m	150m	230m
Leschenault	Sandy	4	70m	240m	380m
Casuarina Pt	Rocky	5	30m	90m	140m
Peppermint G.	Mixed	6	40m	100m	160m
Siesta Park	Sandy	7	70m	220m	320m

A further bias in the regional erosion study is brought about by the representation of non-erodible rock strata without considering how the rock may reduce cross-shore sediment exchange. For a sediment volume model, this approach will amplify erosion distances where there are low-lying rock platforms, which are present along much of the Peron-Naturaliste coast.

Reliability of sediment supply has not been considered in the erosion hazard assessment. However, it is a factor that should be considered in the interpretation of results. As the regional erosion study does not capture large onshore feeds in southern Geographe Bay, and has limited representation of alongshore trapping, the net northwards sediment transport produces a spatial trend in the reliability of sediment supply. The high supply and limited opportunity for sediment transport interruption suggests that erosion results for Quindalup-Stratham are likely to be overstated. Increased opportunity for interruption, including coastal protection works, occur northwards, suggesting that realisation of higher erosion scenarios is more likely for Mandurah-Rockingham.

Inundation Hazard Assessment

The basis for coastal inundation mapping has been derived from observed moderate to long term tide gauge data sets at Fremantle, Mandurah, Bunbury and Busselton, along with the network of gauges within the Peel-Harvey estuarine system and post-event flood records for Leschenault, Vasse-Wonnerup and Broadwater estuaries. This information was used to distinguish 12 inundation zones (Table 3), which considered the spatial variation of high water levels and the influences of estuarine damping upon coastal flooding.

Medium and High inundation scenarios presented for PNP Phases I and II were selected on a probabilistic basis from extreme distributions derived from the tide gauge observations, superimposed upon the sea level rise projection recommended by the Western Australian Department of Planning (Figure 4). However, the reliability of derived extreme distributions was recognised as low, due to the short length of data sets and potential effects of changing water level processes. The 100-year ARI water level estimate was used for the Medium scenario, and the upper 90% confidence limit of the of the 500 year ARI water level estimate used for the High scenario (Figure 3). Present-day high inundation scenarios are comparable with the observed total flood levels (including wave action) during TC Alby, which had a similar geographic distribution. Wave runup was not included in the analysis, as due to its highly coastal nature, its effect upon inundation declines very rapidly with landward propagation.

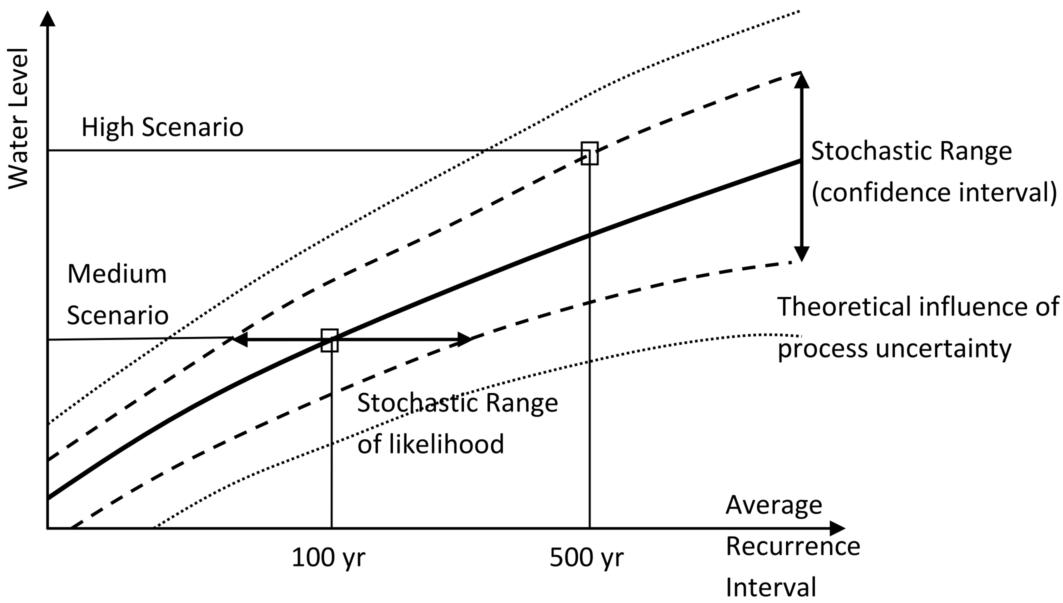

Figure 3: Schematic Showing Definition of Inundation Scenarios

Based upon correlations between the Peel and Harvey tide gauge observations to the Fremantle data, the reduction of flood levels from the ocean into the estuary basins was assessed. Comparison of flood levels inside and outside the estuaries during TC Alby was used as a basis for estimating damping in the smaller basins at Leschenault, Vasse and Broadwater.

Table 3: Present Day Inundation Scenarios

Location	Medium Inundation	High Inundation
Fremantle	1.19m AHD	1.38m AHD
Mandurah	1.19m AHD	1.38m AHD
Peel Inlet	0.89m AHD	1.08m AHD
Harvey Estuary	0.99m AHD	1.25m AHD
Binningup	1.34m AHD	1.57m AHD
Bunbury	1.49m AHD	1.76m AHD
Leschenault Estuary	1.22m AHD	1.38m AHD
Peppermint Grove	1.48m AHD	1.74m AHD
Wonnerup	1.44m AHD	1.70m AHD
Busselton	1.39m AHD	1.64m AHD
Vasse / Broadwater	1.29m AHD	1.54m AHD
Quindalup	1.39m AHD	1.48m AHD

This assessment shows a spatial pattern, with flood levels increasing towards Busselton. The small differences between Medium and High inundation scenarios highlight the subtlety of flood risk and indicate the need to use high resolution topography for the assessment.

Sea level projections were generated through addition of the extreme water level distributions (Table 3) to the sea level rise projection curve (Figure 4). This gave high inundation scenarios from 2.0 to 2.7m AHD by 2110. It is recognised that the sea level rise projection curve matches higher estimates of sea level change reported by the Intergovernmental Panel on Climate Change, with median projections being approximately half the amplitude. As a consequence, using the sea level projections of Figure 4 provides a conservative bias for inundation estimates that increases over time.

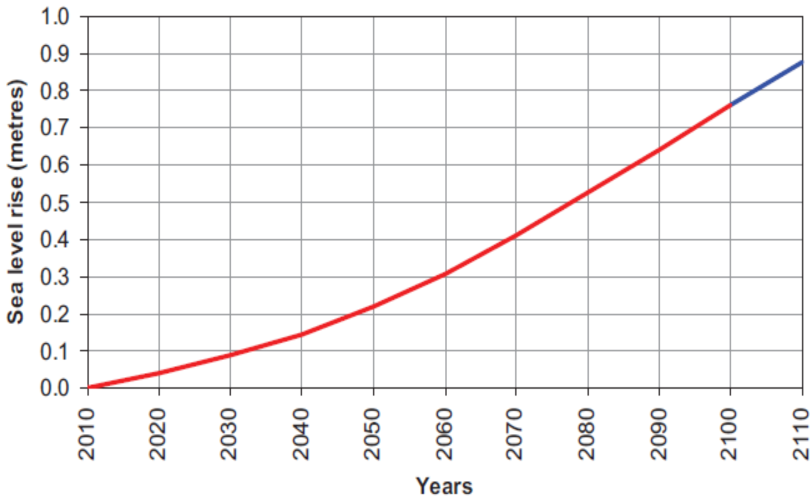

Figure 4: Sea Level Rise Projection Curve
From Department of Transport (2010)

Inundation levels were applied to the Department of Water LiDAR high-resolution topography, which enabled identification of hydraulic connections between the coast and lowlands. An example of the mapping, showing the present day 100-year ARI water level (yellow) against the corresponding Medium (green) and High (red) scenarios for 2110 is shown in Figure 5.

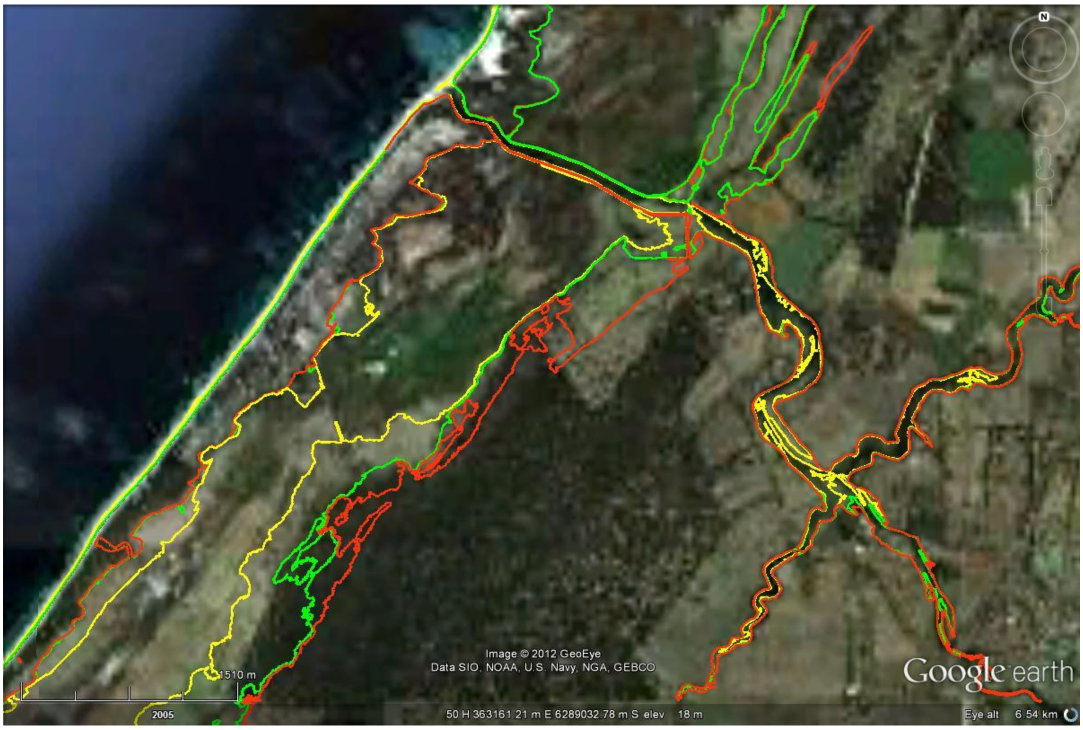

Figure 5: Sample Screen Dump of Inundation Lines
Mapped lines presented in GoogleEarth format

The potential shift of inundation zones due to sea level rise along the Peron-Naturaliste coast affects a significantly smaller area than that potentially affected by coastal erosion. For the majority of the open coast, existing coastal dunes are well above the high inundation scenario for 2110. This produces isolated areas of inundation, which reduces the need to consider variation between the zones. Significant areas of change mainly occur adjacent to estuaries, with the majority of affected area around the extensive Vasse-Wonnerup and Broadwater system.