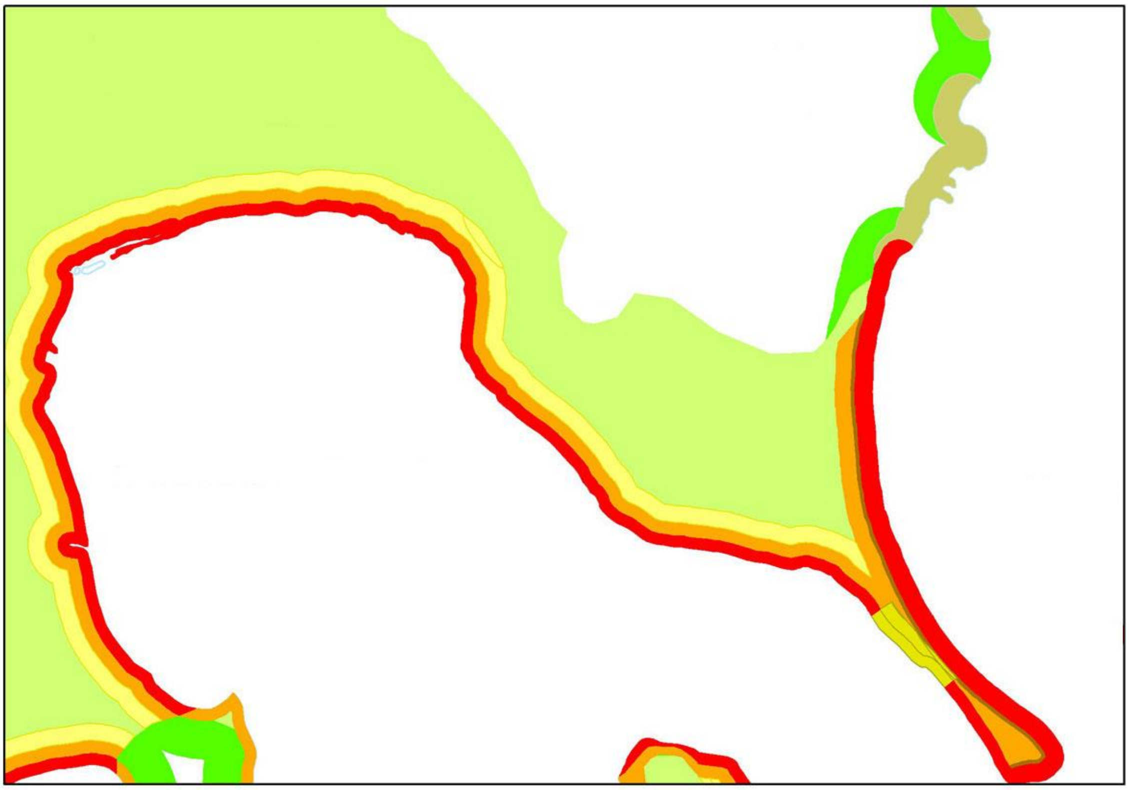
Coastal erosion susceptibility zone mapping for hazard band definition in Tasmania



Report to:
Tasmanian Department of Premier and Cabinet

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Front cover: Example of coastal erosion hazard banding for northern Pipeclay Lagoon area (SE Tas.), defined according to the process described in this report (see sections 5.0 & 6.0 for details).

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1.0 Summary

The purpose of this work is to provide digitally-mapped (GIS) geological and geomorphic data for the whole Tasmanian coast, and to use this to rank all parts of the coast into four coastal erosion hazard bands (acceptable, low, medium and high) according to their susceptibility to coastal erosion and shoreline recession, both under present conditions and under projected future sea-level rise conditions. This mapping and hazard band definition has been undertaken for the purpose of providing a clearly-defined basis for coastal erosion hazard management and planning policies at State and Local Government levels.

Coastal landform behaviour including storm erosion and longer-term shoreline recession is driven by a complex range of processes and factors that may vary considerably from one coastal location to another. These may include the inherent resilience of the physical shoreline substrate type, local wave climate exposure, storm frequencies and magnitudes, local sediment sources and sinks, tidal and river discharge currents and the effects of artificial changes to the coast. The interactions between many of these factors in driving coastal changes is complex to model, and this is especially so because the mix of specific factors driving coastal change (or stability) may vary significantly over short distances along any given coastline.

Consequently it is not possible to predict the behaviour of many shores with high accuracy, which means that any coastal hazard zoning at a state-wide level must necessarily be of an indicative or generalised nature only. However there are a number of factors which are of primary importance in determining the *potential* susceptibility of shores to erosion, of which arguably the most fundamental is the inherent erodibility of the materials of which different shores are composed (e.g., soft sand versus hard bedrock). The approach taken in this project has therefore been to identify and use a small number of the most fundamental determinants of potential shoreline erodibility in order to rank shorelines into very broadly-defined categories of greater or lesser potential susceptibility to erosion. These provide a first-order delineation of coastal hazard zones for the purposes of defining hazard management and planning policies appropriate to each zone. It is inherent in the broadly-defined nature of each hazard zone and the complex nature of coastal processes, that there may be scope to justify modifying the planning constraints defined for each zone on a case-by-case basis depending on the specific mix of conditions found at specific locations within each zone.

This project uses and has contributed to upgrading the most comprehensive currently available state-wide coastal landform and substrate (geology) mapping datasets for Tasmania. Using these data, the fabric or composition of Tasmanian coastal landforms has been divided into three broad classes which reflect fundamental differences in susceptibility to coastal erosion, namely:

- Soft sediment (typically muddy or sandy types, most readily eroded but also very mobile and capable of accretion (growth) as well as erosion); and
- ‘Soft-rock’ (generally cohesive clayey materials which are more resistant to erosion than soft sediment, but not as resistant as well-lithified rock; these may erode slowly but significantly over time, and do not rebuild as soft sediment shores may); and

- Hard-rock shorelines (mostly resistant to noticeable erosion on human time-scales although steeper hard rock shores may be notably unstable).

Each of these basic categories has been further sub-divided according to key characteristics that also play important roles in determining susceptibility to coastal erosion at a regional scale, including broad landform distinctions between (more stable) sloping rocky shores and (less stable) hard or soft-rock cliffs, and exposure to or sheltering from open coast swell wave climates.

Several methods have been used as appropriate to define potential erosion susceptibility zones (or ‘setbacks’) behind shores of each broadly-defined category. For open coast sandy beaches a well-established and widely-used erosion and recession hazard modelling technique was used, based on approaches previously used in NSW and Queensland. However similarly well-established and widely-used modelling approaches for swell-sheltered soft sediment shores or soft-rock shores were not identified, and for these we used empirical data (from historic air photos and shoreline profiling surveys) to define erosion and recession setbacks based on actual measured erosion cuts and shoreline recession rates for Tasmanian shores, with a precautionary factor applied to allow for the limited scope of the available empirical data. For hard-rock cliffs an appropriate setback modelling technique was identified, but cannot yet be employed until high resolution topographic mapping is available for more of the Tasmanian coast. In lieu of this we have defined a precautionary setback that is adequate to cover the scales of cliff instability considered likely for Tasmanian coasts. Moderately sloping hard rock shores are considered to have acceptable (negligible) erosion hazard based on the lack of significant historically-observed instability in this shoreline type. Resilient artificial shores are also considered to have negligible erosion hazard, whilst artificial shorelines judged to not be resilient are treated as if no artificial works were present.

Using these approaches, coastal erosion and recession susceptibility zones were defined as shoreline buffers or ‘setbacks’ of differing widths for each shoreline category. For each category, setbacks of four different types were generally defined, namely:

1. Storm bite erosion hazard (the amount of erosion and consequent scarp instability that could potentially occur at any time in response to “1 in 100 year” storms).
2. Shoreline recession to 2050 (the amount of shoreline recession that could potentially occur in response to projected sea-level rise to 2050, in addition to the storm bite erosion hazard).
3. Shoreline recession to 2100 (the amount of shoreline recession that could potentially occur in response to projected sea-level rise to 2100, in addition to the storm bite erosion hazard).
4. Shorelines beyond the limit of potential erosion or recession by 2100.

Some exceptions to this scheme were applied, including the definition of a single precautionary hazard zone for hard-rock cliffs (in the absence of sufficient data or methods to apply more nuanced zones) and the definition of a short term (to 2030) recession (rather than storm bite) zone for soft –rocks, due to the tendency of this shoreline to recede slowly but steadily rather than in large storm bites.

A pairwise assessment was finally used to rank and combine the various erosion susceptibility zones defined for each shoreline category into four final overall erosion hazard bands ranked from High through Medium, Low and Acceptable hazards.

2.0 Introduction

The purpose of this work is to provide digitally-mapped (GIS) geological and geomorphic data for the whole Tasmanian coast, and use this to rank all parts of the coast into four hazard bands (acceptable, low, medium and high) according to their susceptibility to coastal erosion and shoreline recession, both under present conditions and under predicted future sea-level rise conditions.

It is not possible to predict the timing, magnitude or frequency of erosion events or shoreline recession at any given coastal location in detail or with a high degree of confidence. This is a consequence of the inherent complexity of coastal processes, the degree of local variation in these around the coast, and uncertainties about the timing and magnitude of storm events which may cause erosion. Considerable research is underway in many places which seeks to better understand coastal erosion and to improve our ability to identify more and less erosion-prone locations, however whilst it is expected that this understanding will improve with time, it can never be perfect.

Nonetheless, despite these inherent uncertainties it is possible to identify a number of first-order characteristics of coasts which predispose identifiable parts of them to being more or less susceptible to erosion than other parts. The purpose of the mapping described here is to make the best possible use of relevant mapped information that is available for the whole Tasmanian coast, in order to credibly identify areas of higher and lower coastal erosion potential at a ‘first pass’ level, which can provide an appropriate basis for state-wide natural hazard management policies.

To date, most efforts to identify coastal erosion zones in Australia for coastal erosion policy and planning purposes have focussed primarily on open coast sandy beaches (e.g., in NSW and Queensland). This project has endeavoured to develop a basis for defining coastal erosion susceptibility zones for all Tasmanian shorelines, including not only swell-exposed open coast beaches, but also sheltered (e.g., estuarine) sandy shores, soft-rock (cohesive clay) shores, and hard rocky shores including cliffs. This allows all shores to be ranked into potential hazard bands ranging from Acceptable (negligible) hazard sloping hard rock shores, through a range of Low and Medium hazard shores to High hazard exposed soft sediment shores.

Earlier versions of several of the key map datasets produced by this project were developed by Chris Sharples and others during previous projects including an earlier Tasmanian first – pass coastal vulnerability assessment (Sharples 2006), several coastal landform mapping projects for the three Tasmanian Natural Resource Management (NRM) zones (e.g., Sharples & Mowling 2006), a first pass national coastal vulnerability assessment (DCC 2009, Sharples *et al.* 2009), and a Coastal Hazards Assessment for Kingborough LGA (Sharples & Donaldson 2013). These datasets have been variously checked and edited or extended to the full Tasmanian coast. However the use of these datasets to create ranked erosion susceptibility zone maps has not previously been undertaken for Tasmania and this is a new contribution from this project.

2.1 Project Overview

For the purposes of this erosion susceptibility mapping, coastal landforms have been considered in three fundamental groups based principally on their composition or substrate type, which is arguably the most fundamental determinant of their susceptibility to coastal erosion. These three groups – which between them encompass the full range of Tasmanian coastal landform types - are:

1. *Unconsolidated soft sediments* (sand, mud, gravels, etc); these are mostly geologically recent (Holocene to some Pleistocene) sediments comprised of loose clasts which generally show little or no induration or lithification and thus are inherently very susceptible to erosion.

2. ‘*Soft rock’ substrates*; these include semi-lithified sediments and deeply weathered formerly ‘hard’ bedrock. The most widespread coastal soft rock type on Tasmanian shores are Tertiary-age cohesive clayey sediments, however additional types include some older dominantly soft mudstone sequences, well podsolised Pleistocene sands in areas such as far NW Tasmania, and other types. These substrates are coherent enough to form cliffs and bluffs in some coastal locations, but are nonetheless sufficiently friable as to be potentially susceptible to significant wave erosion over human time spans.

3. *‘Hard rock’ shores*; these include platforms and sloping ramps or vertical cliffs of hard well-lithified bedrock, comprising many bedrock types on Tasmanian shores. Hard rock shores generally exhibit little noticeable erosion over human timescales, although some degree of rock fall and slumping may sporadically occur on steep or vertical cliffs.

Mapping that defines the extent of each of these three coastal landform substrate groups around the entire Tasmanian coastal has been produced or checked and edited using the best scale and most recent geological and geomorphic information available for the whole Tasmanian coast, as described in section 3.0 below. Criteria considered to best differentiate the potential susceptibility of shores of each substrate group at a ‘first pass’ level into higher and lower hazard bands for erosion and recession were then identified as described in section 4.0. These criteria are primarily based on attributes of the coastal geomorphic mapping itself, or can be applied to attributes of the mapping. Section 5.0 describes how appropriate available criteria were selected and used to map coastal erosion susceptibility zones for each mapped coastal substrate.

Fieldwork was undertaken at a selection of coastal sites (in north-eastern Tasmania and the Tamar area) to check and validate the coastal substrate mapping and to identify issues related to using the mapping to zone coastal areas according to erosion and recession hazards.

2.2 Glossary of Terms & Acronyms

Accretion	Deposition and accumulation of sediment, either horizontally or vertically.
AHD	The Australia Height Datum. This was nominally intended to be mean sea-level, however AHD for Tasmania was defined in 1983 as the mean sea-level measured at Burnie and Hobart in 1972. Thus, owing to ongoing sea-level rise and inter-annual sea-level variability, AHD is close to but not identical to mean sea-levels subsequent to 1972.
ARI	Average Recurrence Interval. A measure of the average frequency at which a storm of a given magnitude recurs (ideally based on statistical analysis of recorded historical storm data). Thus a 100 year ARI storm is one of a

	magnitude that statistically occurs every 100 years on average. Note however that this is a statistical average and not a measure of actual recurrence intervals. Thus it is entirely possible that two 100 year ARI storms could occur in the same year.
Bruun Factor	a multiplier used to define the amount of horizontal shoreline recession that results from a given sea-level rise. For example, a Bruun Factor of 100 means a shoreline recedes horizontally by 100 times the vertical rise in mean sea-level. The use of Bruun Factors is a highly simplified application of the Bruun Rule of erosion by sea-level rise.
DEM	Digital Elevation Model; A grid or pixel – based (raster) form of digital topographic mapping used in Geographical Information Systems (GIS).
DPAC	Department of Premier and Cabinet, Tasmania.
DPIPWE	Department of Primary Industries, Parks, Water and Environment, State Government agency, Tasmania.
Erosion	Removal of material by an erosive agent, such as waves and currents. In this report, ‘coastal erosion’ generally refers to erosion that may occur in a single erosion event or cluster of events (a ‘storm bite’); in contrast the term ‘coastal recession’ is used to refer to a progressive ongoing retreat of a shoreline due to multiple erosion events over a period of years or decades.
GIS	Geographic Information System (computerised digital mapping systems)
HWM	High Water Mark (high tide line)
LGA	Local Government Area (municipality)
LiDAR	Light Detection and Ranging; a contemporary method of high resolution topographic mapping using laser reflections off ground and other surfaces.
LIST	Land Information System Tasmania, a map information system managed by DPIPWE.
NRM	Natural resource management
Progradation	Seawards growth of a shoreline, resulting from prolonged accretion of sediment.
Recession	Landwards retreat of a shoreline resulting from repeated erosion events over a prolonged period of time.
Storm bite	The amount of erosion that occurs during a single (usually storm) event.
TASMARC	The TASmanian shoreline Monitoring and ARChiving project. A beach monitoring program which commenced in 2005 with the aim of compiling measured data on Tasmanian beach behaviour to better inform understanding

	of the shoreline erosion and recession behaviour of Tasmanian beaches. The project is managed by the Antarctic Climate and Ecosystems Co-Operative Research Centre at the University of Tasmania, and compiles beach surveys undertaken at regular intervals by volunteers into a database which can be accessed at www.tasmarc.info .
Wave Climate	The mix of swell and/or locally-generated wind waves received at a particular coastal location, including average wave heights and directions, and the degree of variability in these that is characteristic of the given coastal location.

2.3 Prioritisation

Given the limited time frame that was available for this work, it was not possible to complete the mapping of the base geomorphic datasets to a high level of detail (say a nominal 1:25,000 scale) for the entire length of Tasmania's coastline. Therefore the mapping work was prioritised with more attention paid to some parts of the coast than others, according to the following hierarchy of priorities:

Priority 1: *Mapping was completed for the entire Tasmanian coast to at least 1:250,000 and preferably 1:100,000 scale.* That is, there are no gaps in the data, however for some lower-priority areas it was necessary to limit completed mapping to 1:250,000 scales (which is the best scale of geological mapping currently available for the whole of Tasmania).

Priority 2: *More attention was paid to checking, editing and refining the mapping for urban and settled areas of the coast, or those likely to be subject to development pressures, than to dominantly rural or unsettled coasts.*

2.4 Acknowledgements

Paul Donaldson (formerly University of Tasmania) participated in the commencement and early mapping work associated with this project.

Colin Mazengarb and Michael Stevenson (Mineral Resources Tasmania): provided geological mapping data, active coastal landslide mapping and gravity survey data (used to refine the boundaries of coastal soft rock bodies beneath Quaternary sediments cover).

3.0 Coastal erosion susceptibility map datasets

This section describes the primary mapped datasets produced to define the distribution and extent of the three coastal substrate groups as identified in section 2.1 above, which constitute the primary mapped data used in the production of coastal erosion susceptibility zone maps produced as described in section 5.0.

3.1 Unconsolidated soft sediment shores

Two polygon map datasets have been prepared for this coastal substrate group, one mapping the full known extent (alongshore and landwards) of coastal soft sediment bodies, and another mapping the natural recession limits of these sediments (i.e., the maximum extent to which they could conceivably erode and recede landwards under a specified sea-level rise scenario, which may be less than their full extent where they mantle bedrock surfaces that themselves rise above sea-level).

3.1.1 *Coastal soft sediment polygon mapping*

This is a map depicting the full landwards and alongshore extent of coastal soft-sediment bodies and landforms, an earlier incomplete version of which was compiled by Chris Sharples in the course of several NRM-funded projects (e.g., Sharples & Mowling 2006). The data custodian is the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE), and Chris Sharples and Paul Donaldson recently upgraded and edited the map for the Kingborough LGA (Sharples & Donaldson 2013).

Although soft-sediment bodies are depicted on existing Tasmanian Geological Survey mapping, the need for production of this stand-alone layer arises because most Geological Survey mapping depicts both bedrock and soft sediment bodies as a single layer, which results in compromises since the full extent of some known (and erodible) coastal soft sediment bodies may be omitted in order to depict underlying bedrock. The 'stand-alone' soft sediment map which was produced during previous work was prepared by firstly copying the soft sediment polygons from existing Geological Survey mapping, then augmenting this with additional fieldwork and interpretation to identify and map areas of soft sediment not depicted on the Geological Survey maps. However the stand-alone soft sediment map produced previously still had known deficiencies in some areas. Work undertaken during this project to remedy some of these deficiencies included:

- Filling remaining gaps in the mapping with soft sediment polygons derived from existing geological survey mapping, mostly at 1:250,000 scale. This primarily involved filling previous data gaps in south-west Tasmania, Maria and Freycinet National Parks, and around some major river estuaries.

- Some topologically-disjointed polygons in north-east Tasmania were replaced with soft sediment polygons from 1:25,000 and 1:250,000 Geological Survey mapping.

- Soft sediment polygons in the main settled coastal areas of Tasmania were checked and edited using detailed 1:25,000 Geological Survey mapping, topographic mapping and limited field inspections.

Figure 1 includes an example of the soft-sediment polygon mapping prepared for Kingborough LGA. Appendix A1.3 provides a data model and attribute tables for this dataset (*tascoastsed_v7_MGA.shp*).

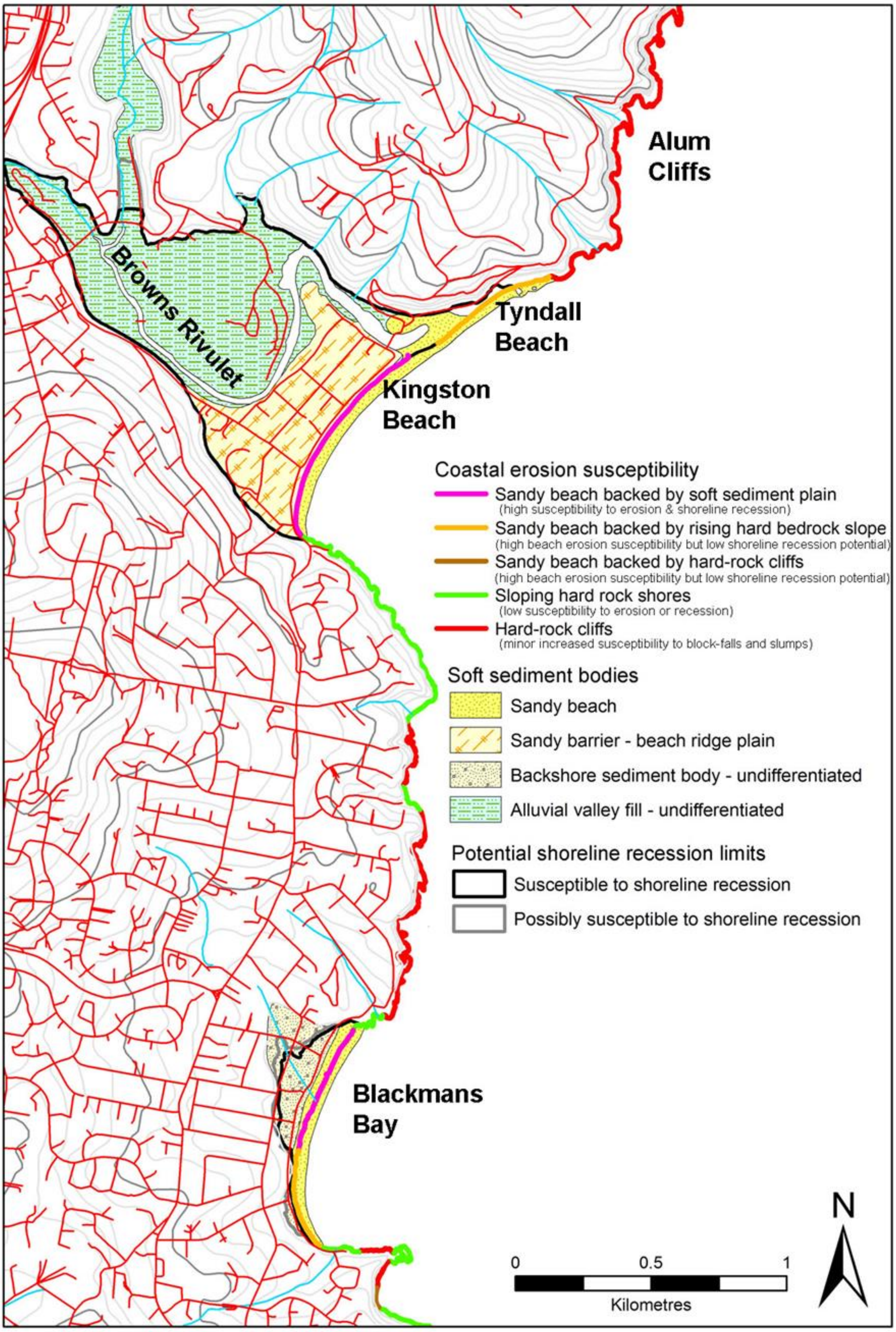

Figure 1: Example map depicting portions of the soft-sediment polygon map, natural recession limits mapping and one attribute layer from the Smartline coastal line map, as prepared for Kingborough LGA during 2012. The current project involved extending or upgrading these same datasets for the entire Tasmanian coast.

3.1.2 *Natural recession limits for coastal soft sediment bodies mapping*

This map uses the soft sediment map in combination with topographic data, other geological mapping and any relevant available drilling or geophysical data to define the maximum landwards extent to which the soft sediment bodies could conceivably be eroded under a specified sea-level rise, as a worst case scenario. Natural recession limits have been defined based on a 0.8m sea-level rise by 2100 (relative to 2010) that has been adopted as a sea-level rise planning allowance for Tasmania (TCCO 2012). The map estimates how far to landwards the soft sediments extend in depth to below the level of 0.8 metres above the 2010 Mean High Water Mark, before the upper surface of the hard bedrock underlying the sediments rises above that level. This is the point at which landwards erosion of the soft sediment would finally expose the underlying hard bedrock if it were to recede to the maximum possible extent under the specified sea-level scenario. If this occurred, the natural recession limit defines where a new resilient rocky shoreline (at a new High Water Mark line) would be exposed that would effectively halt further shoreline recession (unless and until sea-level subsequent rose still further). Figure 2 illustrates the rationale used to define these recession limits.

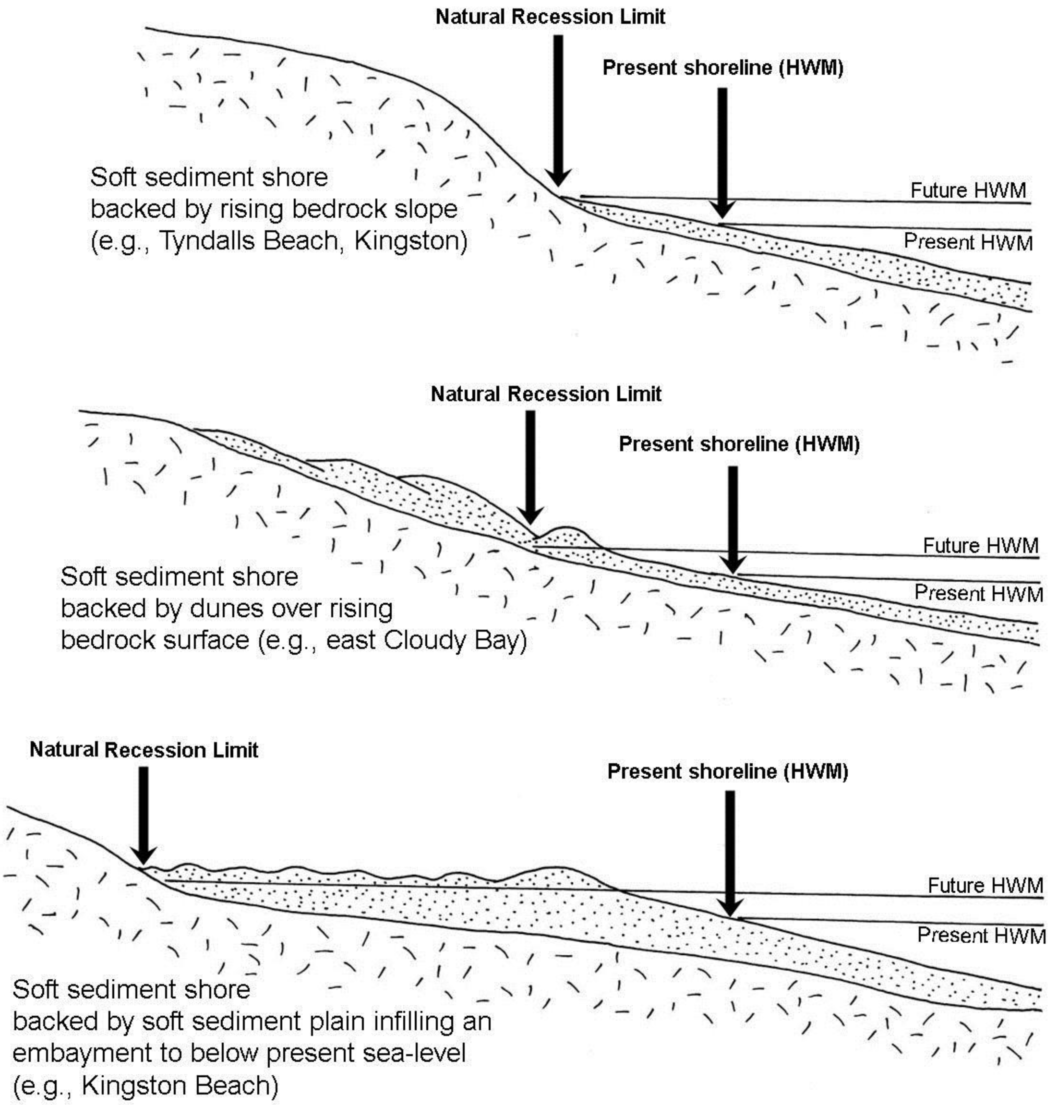

Figure 2: Figure depicting the rationale behind the definition of natural recession limits polygons for coastal soft sediment bodies.

Note that the natural recession limits are not a prediction of how far a shoreline will actually recede under the defined sea-level rise scenario. Many local process factors and conditions will govern the rate and magnitude of the recession that actually occurs at any given site and in many locations the degree of recession that actually occurs may be considerably less than the maximum that could conceivably have occurred. The natural recession limits simply define the theoretical landwards limit to which shoreline recession could proceed for a given amount of sea-level rise, if the worst possible combination of local conditions allowed this to happen.

Ideally these limits would be defined using drilling and geophysical data to precisely map the (buried) bedrock surface topography and determine exactly where it rises to the level of 0.8m above the present mean High Water Mark; however in reality such data is rarely available for Tasmanian coastal areas. Consequently in most cases the likely location of the (buried) natural recession limit has been mapped on the basis of interpretation of mapped geology and topography (using LiDAR DEMs where available and topography derived from 1:25,000 LIST mapping elsewhere). In general, a distinct break of slope at the back of low-lying coastal sediment plains is interpreted as indicative of a rise in the underlying bedrock surface, except where the rise is clearly due to dunes or other features known to not indicate a rising bedrock surface beneath. Where the resulting uncertainty about the precise horizontal position of the 0.8m level above the 2010 Mean High Water level on the (buried) bedrock surface is greater than approximately ±20 metres, we have allowed for this by mapping polygons representing the areas of uncertainty within which we judge the recession limit to lie.

Figure 1 includes examples of natural recession limits mapping for Kingborough LGA. Appendix A1.4 provides a data model and attribute tables for this dataset (*TasRecessionPotential_v1_MGA.shp*).

3.2 ‘Soft rock’ shores

One polygon map dataset was prepared mapping the full known extent (alongshore and onshore) of soft rock coastal substrate bodies.

3.2.1 *Coastal soft rock polygon mapping*

This map depicts the full extent alongshore and landwards extent of the other key highly-erodible shoreline substrate on Tasmanian coasts, namely semi-lithified ‘soft-rock’ substrates which in Tasmania are mostly (but not exclusively) Tertiary-age sedimentary rocks. As with the soft sediment bodies, soft rock bodies are also depicted on existing Tasmanian Geological Survey maps, however their full extent is not always depicted since in some areas of these single-layer maps overlying soft sediment veneers are depicted instead. Our soft rock mapping has mainly been created by copying the equivalent polygons from existing Geological Survey mapping. However we have used geological knowledge and interpretation of the relevant geological structures and basins to infer the full extent of soft rock bodies where these were not depicted on the Geological Survey maps because of overlying soft sediments. In some areas we additionally used gravity (geophysical) mapping supplied by Mineral Resources Tasmania (Colin Mazengarb and Michael Stevenson) to further interpret the boundaries of Tertiary-age sedimentary soft rock bodies obscured by soft sediment veneers, using a ‘first vertical derivative of gravity’ dataset which is considered most useful in differentiating these bodies.

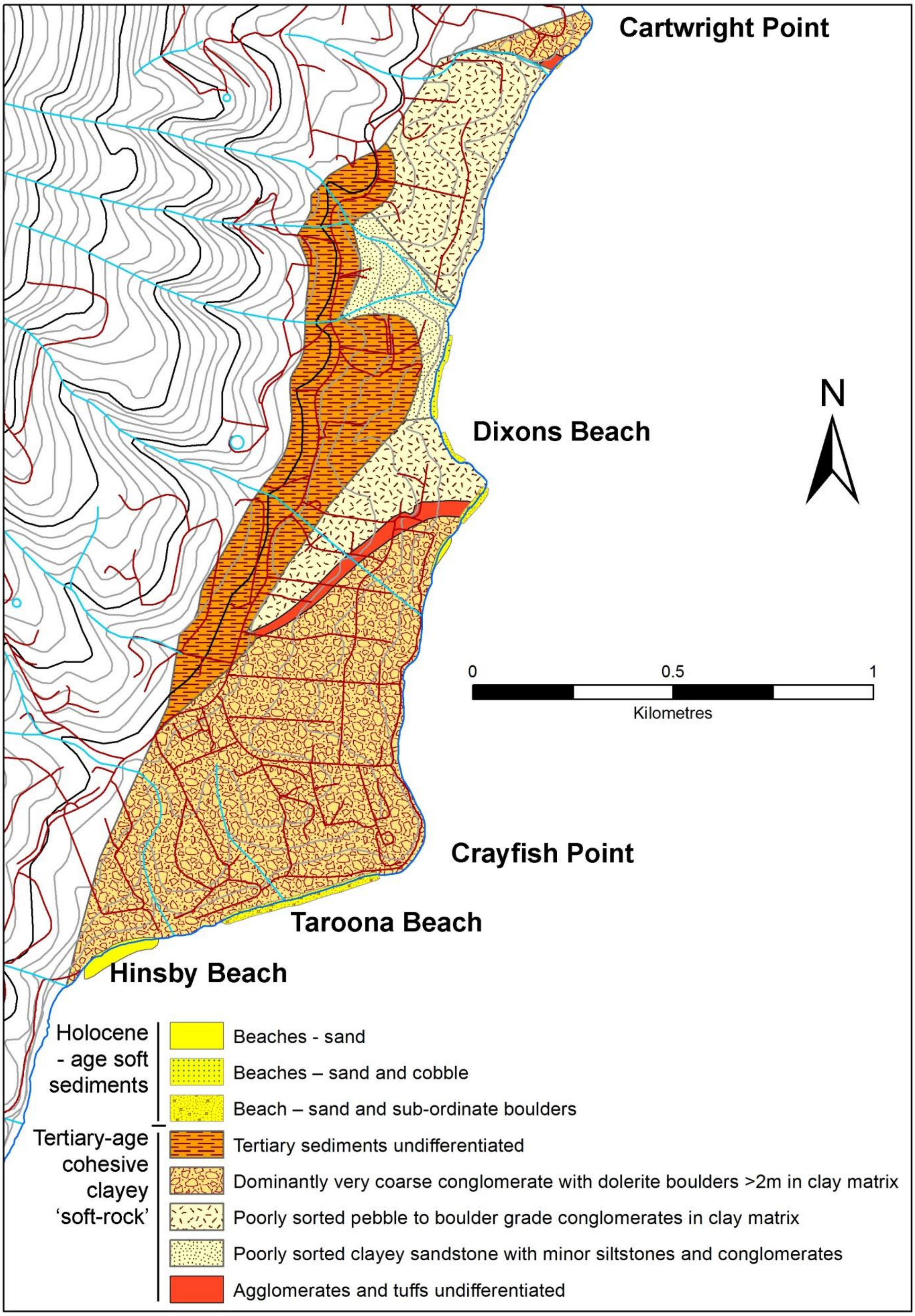

Figure 3: Example map showing a portion of the soft-rock polygon map prepared for Kingborough LGA (together with depiction of beaches from the soft-sediment polygon map).

Chris Sharples and Paul Donaldson previously commenced preparation of this map layer for the Kingborough LGA (Sharples & Donaldson 2013) and this mapping has now been extended to the entire Tasmanian coast by Hannah Walford and Chris Sharples. Figure 3 provides an example of soft rock polygon mapping prepared for Kingborough LGA. Appendix A1.5 provides a data model and attribute tables for this dataset (*TasCoastSoftRock_v1_1_MGA.shp*).

Soft rock types mapped on the Tasmanian coast include:

- The dominant soft rock type on the Tasmanian coast is Tertiary-age sediments (including cohesive clayey sediments, boulder clays and soft Tertiary marine limestone sedimentary bodies).
- Soft deeply weathered Tertiary age basalts are present and have been mapped in a few places (e.g., parts of the NW coast)
- Minor soft-rock types include soft mudstone-dominated coal measures units in the older Permian Cygnet Coal Measures (e.g., Randall's Bay) and Late Triassic Coal Measures, and other mudstone – dominated intervals in the Triassic-age sandstone sequence (e.g., at Coningham Beach).

Soft rock polygon mapping rules adopted:

In preparing the stand-alone coastal soft-rock mapping, a number of mapping conventions have been used in order maximise the utility of the mapping for coastal erosion hazard assessment and minimise the inclusion of unnecessary data. These are:

- Soft rock bodies which occur at sea-level on the coast are mapped as polygons to their full inland extent (as far as is known or can be inferred). Inland soft rock bodies disconnected from the current shoreline are not included since these are unlikely to be affected by coastal erosion within human time frames.

- Coastal soft rock bodies are mapped in cases where they are not shown on published geological mapping but can be reasonably inferred (from a variety of evidence as noted above) to be present beneath a thin veneer of unconsolidated Quaternary sediments depicted on available geological mapping.

- Near-coastal soft rock polygons which do not extend to the current shoreline within a few metres vertically above or below present sea-level are not mapped. This includes Tertiary sediments perched on hard bedrock close to but well above the present shoreline in areas such as Low Rocky Point and the Pieman River (west coast) and parts of north-east Tasmania.

- Soft rock bodies are not mapped where they are known or inferred to underlie coastal Quaternary (soft sediment) bodies but are also known or considered likely to be covered by those Quaternary sediments to some depth below present sea-level, and hence are unlikely to be exposed to coastal erosion now or in the foreseeable future. Examples include Ocean Beach, southern Waterhouse Bay and Seven Mile Beach near Hobart.

Since many soft-rock bodies have significant topographic relief, extend well inland from the coast, and would erode at a slower (albeit probably steadier) rate than soft sediments, it is difficult to define meaningful worst case natural recession limits for these since in most cases erosion would be highly unlikely to reach the full landwards extent of these bodies by 2100. The criteria used to zone soft rock bodies into erosion susceptibility zones therefore differ from those used for soft sediment bodies, and are further described in section 5.3.

3.3 Hard Rock shores

One map dataset was prepared mapping the alongshore (only) extent of hard rock shores as a line-format map:

3.3.1 *Coastal hard rock line map (the 'Smartline' map)*

This existing coastal landform map identifies shoreline landform and substrate types via a GIS line map. Whilst it includes soft sediment and soft rock shores (without defining their landwards extent), the particular value of the map to this project is its identification of hard-rock shoreline types which can be expected to be generally resistant to erosion to 2100. In effect these hard-rock shores fill the shoreline gaps between the soft sediment and soft rock polygon maps described above. Since landwards recession of these hard-rock shores is expected to be negligible by 2100, their depiction as a simple line map is appropriate for the purposes of this project; however the map does differentiate between sloping and cliffed hard-rock shores which is important as it allows cliffs to be identified as a higher risk category (potentially subject to some rock falls and slumping) than the sloping hard rock shores that have negligible erosion or slumping hazard.

This map is an existing dataset that was created for DPIPWE by Sharples (2006), and was subsequently extended nationally with an improved classification system by Sharples *et al.* (2009), who renamed it the "Smartline" coastal geomorphic map of Australia. The custodian of the current map is Geoscience Australia; however we anticipate there will be negotiations between DPIPWE and Geoscience Australia as to the long term management of the Tasmanian tile of the national map. Although the map is complete for the whole of Tasmania, we have undertaken some minor edits and updates based on recent error-checking and ground truthing. Figure 1 provides an example of one attribute layer from the Smartline map depicting hard bedrock (and other) shorelines in part of Kingborough LGA.

This map forms a key element in the hard rock coastal erosion hazard banding, which is based on this map and several additional criteria as described in section 4.4. Appendix A1.2 provides a data model for this dataset (*auscstgeo_tas_v1.shp*).

4.0 Susceptibility zoning criteria for coastal erosion and recession

This section 4.0 describes a range of data and modelling techniques that were identified in the course of this project as being potentially useful in defining coastal erosion susceptibility zones or setbacks. Section 5.0 describes the implementation of those data and techniques that have actually been used. Some of the techniques described in this section 4.0 were not used because they require further refinement or additional data which was not available to this project, but are likely to be worth revisiting in the course of future refinement of coastal erosion susceptibility zoning methods.

Note that the data listed does not include that describing sea-level rise *per se*, since although this is a key factor driving coastal erosion the hazard banding is based on taking as 'given' certain sea-level rise scenarios as defined for policy purposes (TCCO, 2012).

4.1 Introduction

The map layers described in section 3.0 delineate the maximum alongshore and landwards extent of coastal substrates with potential to be susceptible (or resistant) to hazardous coastal erosion and shoreline recession by 2100, based on interpretation of the most reliable coastal geological, topographic and landform mapping available as at 2013. However it is unlikely that all parts of these potentially erodible areas will actually be eroded by 2100.

Consequently, the areas of these potentially erodible substrates have been divided into higher and lower susceptibility zones according to their likely susceptibility to coastal erosion and shoreline recession. The susceptibility *zones* defined for each of the differing coastal substrate types have then been grouped into four overall hazard *bands*, in accordance with principles described in the draft DPAC document "Guide to considering risk from natural hazards in land use planning" (DPAC 2012). These hazard bands have been formulated to represent four broadly-defined levels of the likelihood of hazards occurring, the consequences if they do, and the appropriate levels of planning control which should be applied in each case to most appropriately manage risks. These are briefly paraphrased in Table 1 following. The process of grouping susceptibility zones into overall hazard bands was undertaken using a pairwise assessment as described in section 6.0.

Susceptibility zone definition

Well-established modelling techniques exist for estimating coastal erosion and recession hazards on open coast sandy beaches, and Mariani *et al.* (2012) have used these to provide generic erosion and recession hazard zoning guidance for open coast beaches around Australia. The approach that has been adopted here for open coast beaches therefore combines elements of empirical data (natural recession limit mapping based on geological and topographic data) delineating the maximum possible extent of 'worst-case' shoreline recession for Tasmanian open sandy coasts, together with shoreline behaviour modelling that provides 'best-estimate' measures of the potential magnitude of erosion and recession that may actually occur under specified sea-level rise and storm surge scenarios. The modelling used to delineate sandy open coast beach erosion susceptibility zones for Tasmania (adapted from Mariani *et al.* (2012) as described in sections 4.2 and 5.2 below) is consistent with the

Table 1: General characteristics of hazard bands for natural hazards including coastal erosion (paraphrased from DPAC 2012).

Hazard Band	**Boundaries of Hazard Bands** (Likelihood of coastal erosion)	**Control level** (Consequences)
Acceptable	Natural hazard does not occur, or may occur at such low frequency or magnitude as to be a negligible risk.	No damage is likely to occur, or will be manageable in the normal course of events if it does; No special planning or development controls required.
Low	Hazard may affect an area, but frequency or magnitude is low enough that minimal damage or loss is likely to be experienced.	Relatively minor and infrequent damage may occur, but can be kept to acceptable levels by simple means; Simple site assessments of hazard levels should occur, resulting in implementation of any basic measures needed to limit impact of the hazard to tolerable levels.
Medium	Hazard may affect an area, and level of impact if it does is likely to be significant.	Structures are likely to sustain significant impacts (damage) due to the hazard over their service life unless mitigating measures are applied; Developments likely to be exposed to the hazard should be discouraged; careful assessment of the hazards and appropriate planning responses should be required for developments that do occur.
High	Hazard is likely to affect an area, with an impact likely to be considered intolerable.	Without extraordinary measures being applied, structures are likely to sustain repeated significant damage over their design life; Development should generally be prohibited unless exceptional circumstances apply.

methods that have been used to define coastal erosion susceptibility zones for this shoreline type in NSW and Queensland (see Mariani *et al*. 2012).

It is important to be aware of the limitations of coastal erosion and recession modelling methods, which must be understood as being ‘potential’ or ‘indicative’ rather than absolute in nature. Whilst a variety of numerical (i.e., computer) models that ‘simulate’ coastal erosion and recession processes have been developed to varying levels of sophistication, none are widely agreed to be highly reliable predictors of coastal erosion and recession, and instead are best regarded as simply providing indicative estimates of potential erosion magnitudes (see Mariani *et al.* 2012 for a useful review of coastal erosion modelling methods). The theoretical understanding of coastal erosion and the processes that drive it is an active field of scientific research; hence whilst some aspects and causes of coastal erosion are well understood, the capacity to reliably predict variability in the rates and magnitudes of erosion in different parts of a coastal stretch is not and may never be completely achievable due to the complexity of the many other causes and processes involved.

However in contrast to open coast sandy beaches, there are no well-established and widely-adopted methods available for modelling erosion and recession of swell-sheltered sandy shores, nor for soft-rock and hard-rock shores. Moreover, with the exception of rocky sea cliffs in NSW (Patterson Britton 2005), no other Australian state jurisdictions have previously attempted to define erosion susceptibility zones for coastal substrate types other than open coast sandy beaches. Consequently, it has been necessary for this project to develop rationales and methods for defining susceptibility zones on these other coastal substrate types. In doing so we have used a combination of the (limited) empirical data available on erosion and recession of these shore types in Tasmania (Appendices 2 & 4) together with relevant research on the behaviour of these other shore types (e.g., Trenhaile 2011). The methods we have adopted for zoning these other shore types are described below and in section 5.0.

4.2 Unconsolidated soft sediment coastal erosion susceptibility zoning criteria

Data and methods that were identified as potentially useful for the purpose of defining and mapping broad coastal erosion susceptibility zones for soft sediment shores (especially but not entirely limited to sandy shores) on the Tasmanian coast are briefly described below.

The use of these data and methods to define susceptibility zones is described in section 5.2 below.

Coastal soft sediments polygon mapping

Coastal soft sediment polygon mapping (described in section 3.1.1 above; see Figure 4) provides the fundamental data for defining soft sediment erosion and susceptibility zones, in that it comprehensively maps out the full alongshore and landwards extent of coastal soft sediment bodies susceptible to erosion. This mapping has been used in preparing natural recession limits mapping for Tasmanian coastal soft sediment bodies as described below.

Natural recession limits mapping

Natural recession limits are the mapped limits of conceivable worst-case erosion and shoreline recession, in this case under a scenario of 0.8m sea-level rise by 2100. Since some

Figure 4: The full extent of coastal soft sediment bodies on the Tasmanian coast (pink polygons, as mapped by the soft sediments polygon mapping described in section 3.1.1 and Appendix A1.3). This map depicts the full extent of mapped Quaternary-age soft sediment bodies in Tasmania whose extent reaches the coastline, but does not include many inland soft-sediment bodies that do not reach the coast. Note that many soft sediment bodies such as sandy beaches do not appear at this scale, but are included in this dataset. Some of the sediments depicted on this map are thin veneers over hard bedrock above sea-level, however the additional 'natural recession limits' polygon mapping (described in section 3.1.2 and Appendix A1.4) identifies those portions of these soft sediment deposits that extend in depth to below sea-level and are thus potentially susceptible to coastal recession.

parts of the coastal soft sediment bodies mapped (above) sit over bedrock surfaces at levels too high to conceivably be eroded under the adopted scenario, this mapping is in effect a subset of the soft sediment polygon mapping defining those areas of soft sediment that could actually be potentially susceptible to erosion and recession by 2100. A mapped dataset of natural recession limits for all soft sediment shores in Tasmania has been prepared for this project, as described in section 3.1.2, and has been used to define the maximum limits to which erosion susceptibility zones defined by other methods (below) can extend.

Modelled generic erosion setbacks

Modelled coastal erosion setbacks comprising allowances for storm bite erosion, consequent dune instability zones, and longer term shoreline recession due to sea-level rise have been calculated at a very broad and generic level for Australian (including Tasmanian) open coast beaches by Mariani *et al.* (2012). This modelling was commissioned by the Antarctic Climate and Ecosystems Co-operative Research Centre (Hobart) and undertaken by Water Research Laboratory (University of New South Wales) for the purpose of providing guidance in estimating the scale of erosion that might be expected on open coast Australian beaches subject to differing regional wave climates, in response to both very large storms and ongoing sea-level rise.

Appendix 3 reproduces the modelled setbacks for Tasmania that were calculated by Mariani *et al.* (2012). The modelling divided Tasmania into three coastal 'hydraulic zones' (i.e., wave climate zones), and within each zone characteristic or 'typical' wave climate, beach profiles and beach types were used to calculate 'generic' coastal erosion magnitudes (volumes and distances eroded). The widely used SBEACH and XBEACH modelling software was used to calculate generic short-term storm bite magnitudes (S1) for a 'design storm' comprising two back-to-back 100 year ARI storms; an allowance for a zone of reduced foundation capacity (or dune instability) backing the consequent erosion scarp was calculated as an additional setback (S5) using the method of Nielsen *et al.* (1992); and long term shoreline recession resulting from two sea-level rise scenarios of 0.4 m and 0.9 m rise by 2050 and 2100 relative to 1990 was estimated using a simplified application of the Bruun Rule. See Mariani *et al.* (2012) for further details of the conceptual basis and methodology used. It is important to note that the methods used (wave climate zoning, SBEACH / XBEACH and Bruun Rule) are applicable to open coast swell-exposed sandy beach environments, but not to swell-sheltered re-entrant or estuarine sandy or other soft sediment shores.

Whilst the methods and assumptions used by Mariani *et al.* (2012) are necessarily simplified for the purpose of calculating generic setbacks at the level of coastal zones (as opposed to individual beaches), this is at the same time the most sophisticated approach yet taken to defining potential erosion and recession setbacks for Tasmanian beaches generally, using widely accepted modelling techniques.

Consequently this project has adopted the erosion and recession susceptibility zones provided by Mariani *et al.* (2012), incorporating a recalculation (by the method of Mariani *et al.* 2012) of recession susceptibility setbacks to the 0.2m and 0.8m sea-level rise by 2050 and 2100 relative to 2010 allowances that are the adopted basis for Tasmanian coastal hazard policy (TCCO 2012).

Recorded storm bite magnitudes and recession rates

Further simple empirical criteria that can contribute to defining soft sediment erosion susceptibility zones is data on the measured magnitude of storm bites (from individual or clustered storms) and longer-term net shoreline recession rates that have actually occurred on Tasmanian beaches and other soft sediment shores. These data can be measured from time series of historical air photos and shoreline profile surveys.

Only limited measured storm bite and recession rate data has yet been compiled for Tasmanian sandy beaches, and none for other soft sediment shores such as muddy estuarine shores. Data that is available to date has been compiled in Appendix 2. These data comprise storm bites and longer-term recession rates measured from ortho-rectified air photo time series and TASMARC beach profile measurements. Most of these data have only been collected during the last decade (including analyses of historic air photo time series going back to the 1940s), however it is anticipated more storm bite and longer term recession data will become available for more soft sediment shores as such work progresses.

For this project we have used the modelling of Mariani *et al.* (2012) to define erosion and susceptibility zones for Tasmanian open coast swell-exposed beaches, as described above and in section 5.2. For these shores the limited available empirical data on Tasmanian open coast beach erosion and recession (Appendix 2) has been used simply as a 'reality' check to confirm that the modelled erosion and recession susceptibility zones are of a credible order of magnitude (see section 5.2).

However as noted above this modelling is not applicable for swell-sheltered (e.g., estuarine) soft sediment shores. We have not identified other available methods of modelling generic erosion and recession setbacks for swell-sheltered shores that are sufficiently well-developed and widely-adopted as to be appropriate for use in this project. Consequently we have used the available empirical data on sheltered Tasmanian soft sediment shore historic erosion bites and recession rates as a basis for defining erosion and recession susceptibility zones for these shores since it is the only suitable data available for this purpose (see section 5.2). It is difficult to locate comparable data for sheltered soft sediment shores elsewhere beyond Tasmania, and moreover the applicability of such data to Tasmanian sheltered shores would in any case be doubtful owing to differences in regional wind-wave climates and other relevant process conditions elsewhere. It is expected that erosion and recession susceptibility zones defined in this way will be refined in future as more empirical data for a wider range of sheltered soft sediment shores in Tasmania becomes available.

Wave climate

Waves are in most places the primary coastal process or energy that drives erosion and sediment mass transfers, consequently it is evident that in principle the combination of inherent shoreline susceptibility to erosion (substrate and geomorphic type) and the wave climate to which different shores are exposed should define a substantial proportion of the variation in the degree of erosion and recession hazard along many coasts (Sharples *et al.* in prep.).

However research aimed at integrating geomorphic and wave climate data so as to yield more reliable regional to local-scale assessments of alongshore coastal variation in erosion susceptibility are still at early stages of research and development (Hemer 2009, Sharples *et al.* in prep.). Moreover, the detailed wave climate data that would be needed for this purpose, is for Tasmania, only available from one long-term observational record off the west coast (the Cape Sorell wave-rider buoy), and in a modelled format for parts of south-eastern Tasmania (Carley *et al.* 2008, Sharples *et al.* in prep.). Although it is anticipated that swell wave climate modelling on a (medium resolution) 4 km grid will be available for the entire Australian coast during 2013 (M. Hemer *pers. comm.* Nov. 2012), at the time of writing the best available wave climate models for the whole Tasmanian coast are very coarse resolution models such as those provided by Hemer *et al.* (2007).

At present the swell wave climate of most of the Tasmanian coast can be characterised very broadly in terms of two coarse-scale elements, namely wave energy zoning and (swell) wave exposure zoning as described below.

- *(Swell) Wave Energy Zones*: The actual offshore swell wave energy received by a given coastal stretch. Tasmania's coast has been divided into several broadly defined coastal swell wave energy zones using beach sand characteristics (Davies 1978), and coarse resolution significant wave height (*Hs*) wave modelling (Hemer *et al.* 2007 as reproduced in Mariani *et al*. 2012).

- *Relative wave exposure*: This is the degree of exposure to whatever swell wave energies the coastal region receives, and is dependent on coastal planform in relation to regional swell directions. Thus for example a highly exposed shore on a moderate wave energy coast might receive less total wave energy than a moderately exposed shore on a high energy coast. Relative swell wave exposure has been estimated using simple cartographic methods for the whole Tasmanian coast and is provided as an attribute within the Smartline coastal geomorphic map (*auscstgeo_tas_v1.shp*) described in Section 3.3.1 and Appendix A1.2. The categories of swell exposure mapped are:

    - swell-sheltered (variable local wind-wave exposure), e.g., Five Mile Beach;
    - low swell exposure, e.g., Dover Beach and other sites within southern D'Entrecasteaux Channel;
    - medium swell exposure, e.g., Taroona and other sites within the lower Derwent estuary;
    - high swell exposure, e.g., Ocean Beach, Clifton Beach.

In general, for sandy soft sediment shores it is anticipated that higher swell wave energies and higher degrees of exposure to any given swell wave energies should correlate with larger storm bites (other factors being equal); however under current sea-level conditions there is not necessarily a systematic relationship between degree of swell exposure or swell energy and net longer term shoreline recession rates (if any), since any degree of swell wave exposure tends to also drive recovery and rebuilding of sandy shores, thereby tending more towards masking rather than driving long term recession of sandy shores. However as a result of continuing sea-level rise, a threshold is expected to be reached at which recession of sandy shores will begin to dominate over their capacity for swell-driven recovery. Once this threshold is passed it is likely that more exposed and higher wave energy shores will recede faster, mainly due to a tendency towards larger storm bites which will drive the recession once beach recovery is insufficient to keep up.

In contrast, in swell-sheltered waterways (fully sheltered from swell and thus having zero swell exposure and zero swell wave energy) storm bite capacity is defined by the local wind-wave fetch lengths rather than by swell exposure. Thus storm bite may be highly variable in 'swell-sheltered' coastal environments, depending on local fetch and dominant wind directions. The measurement or modelling of wind-wave fetch exposure depends on detailed local wind climate records, topography and bathymetric data, and so is beyond the scope of this project. However, a swell sheltered coastal environment is also one which tends to favour long term recession in sandy shores because there is no swell to drive shoreline recovery after storm bites. Long term recession of swell-sheltered sandy shores without any sign of recovery between erosion events has been demonstrated using air photo time series at Five Mile Beach (Pittwater) and south Pipe Clay Lagoon near Hobart, by Sharples *et al.* (in prep.).

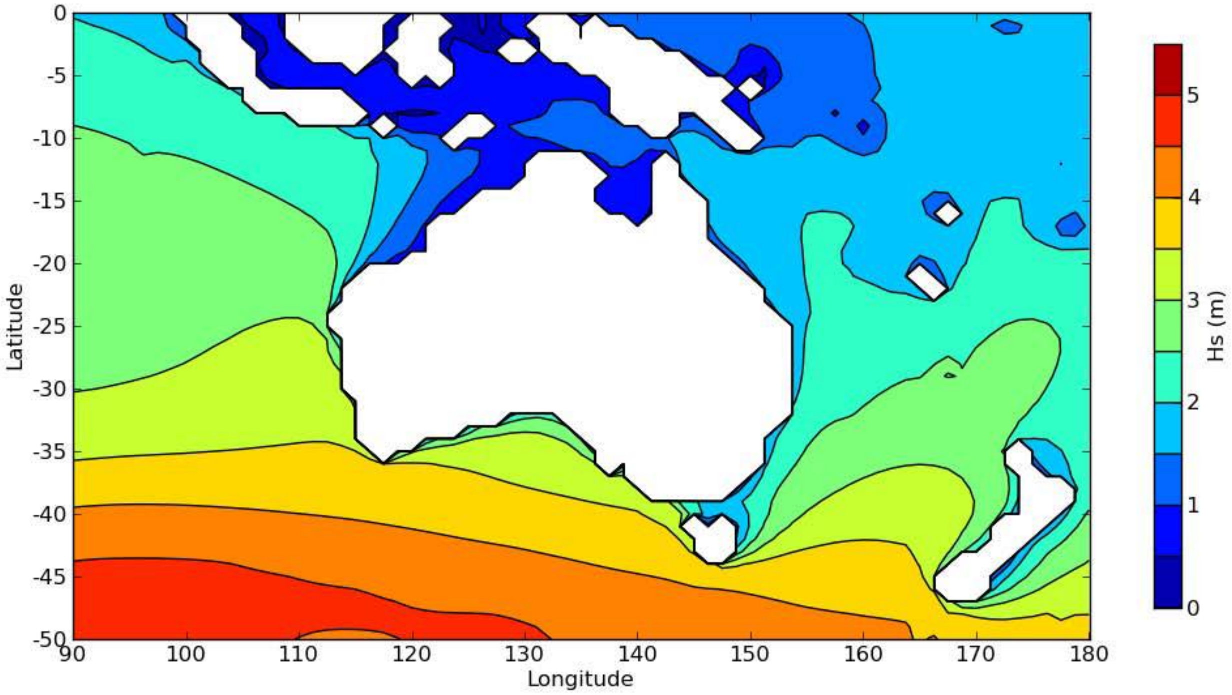

Figure 5: Coarse-resolution modelling of long-term mean significant wave height (Hs) for Australian coasts, from Hemer *et al.* (2007). Significant wave height is the average of the highest one third of waves in a wave train or wave record, and is related to wave energy. Despite the coarse resolution of this model several distinctive wave climates are clearly definable around the Tasmanian coast, ranging from a high energy west-southwest coast regime to lower energy east coast and Bass Strait coast wave climates.

The coarse-scale wave climate modelling of Hemer *et al*. (2007) has been used by Mariani *et al.* (2012) in defining regional ‘hydraulic zones’ for their generic modelling of open coast erosion and recession setbacks (described above), and hence is incorporated into the definition of erosion susceptibility zones for this project in that manner.

Because of the important differences between erosion and recession processes on swell-exposed as opposed to swell-sheltered coasts, the swell wave exposure mapping incorporated into the Smartline coastal geomorphic map has also been used in this project for the purpose of defining the distinction between swell-exposed and swell-sheltered shores. For the former the modelled erosion susceptibility zones of Mariani *et al.* (2012) have been used for sandy beaches. For the latter – where the modelling of Mariani *et al.* is not applicable - soft sediment erosion susceptibility zones have been defined using available empirical data as described above and in section 5.2.

4.3 Soft rock coastal erosion susceptibility zoning criteria

Although there have been studies of coastal soft rock erosion and recession processes (e.g., Trenhaile 2011) there are no widely accepted or used methods for generating generic (widely-applicable) soft rock coastal erosion susceptibility zones comparable to those for open coast sandy beaches (as described in the previous section). However, we have identified a limited range of data and modelling methods which can be used to define coastal soft-rock erosion and recession susceptibility zones for Tasmania. Data that was identified as potentially useful for this purpose is briefly described below, and the use of these data is further described in section 5.3.

Mapping of the extent of coastal soft rock bodies

The polygon map layer (*TasCoastSoftRock_v1_1_MGA.shp*) defines the full alongshore and landwards extent of erodible coastal 'soft rock' substrates on the Tasmanian coast (Figure 6). This provides the ultimate constraint on the potential extent of soft rock shoreline erosion and recession, and has been used for that purpose in defining the limits of soft-rock coastal recession susceptibility zones as described in section 5.3. The soft rock mapping was prepared as described in section 3.2.1 above.

It is noteworthy that in many cases the mapped landwards extent of soft rock bodies (extending to below present sea-level) is much greater than could be conceivably eroded by coastal processes up to 2100. However it was not judged meaningful to define natural recession limits for soft rock, as was done for soft sediments, since the soft-rock is itself bedrock (which defines the natural recession limits for soft sediments).

Broad sub-categories of soft rock fabric (differing inherent susceptibility to erosion)

One basic distinction has been made amongst soft rock types encountered on Tasmanian coasts, for the purpose of distinguishing a broad range of generally erodible types from a distinctive type which is mainly resistant to coastal erosion, namely that between:

- Very coarse boulder clays (with hard rock boulders >1m diameter in a cohesive clay matrix) – wave erosion results in minor settling and formation of "self-armouring" shores;

and:

- Cohesive clayey soft rocks (with very fine to cobbly/small boulder sizes hard rock particles) – wave erosion may result in considerable shoreline erosion, slumping and recession.

Whereas most 'soft-rock' types are dominated by cohesive clays and may erode and recede significantly, some very coarse boulder clays of Tertiary age – which are considered a soft rock type because of their soft clay matrix – may behave rather differently. These form part of the shoreline at Taroona (Hobart). Although subject to a degree of slumping hazard on steeper slopes inland of the shore, at the shoreline waves rapidly winnow the clay matrix out of this substrate type, allowing the large boulders to settle and form a very resilient wave-resistant hard-rock shoreline type reminiscent of a boulder wall or revetment, which is a type of artificial structure often constructed to protect shores from erosion.

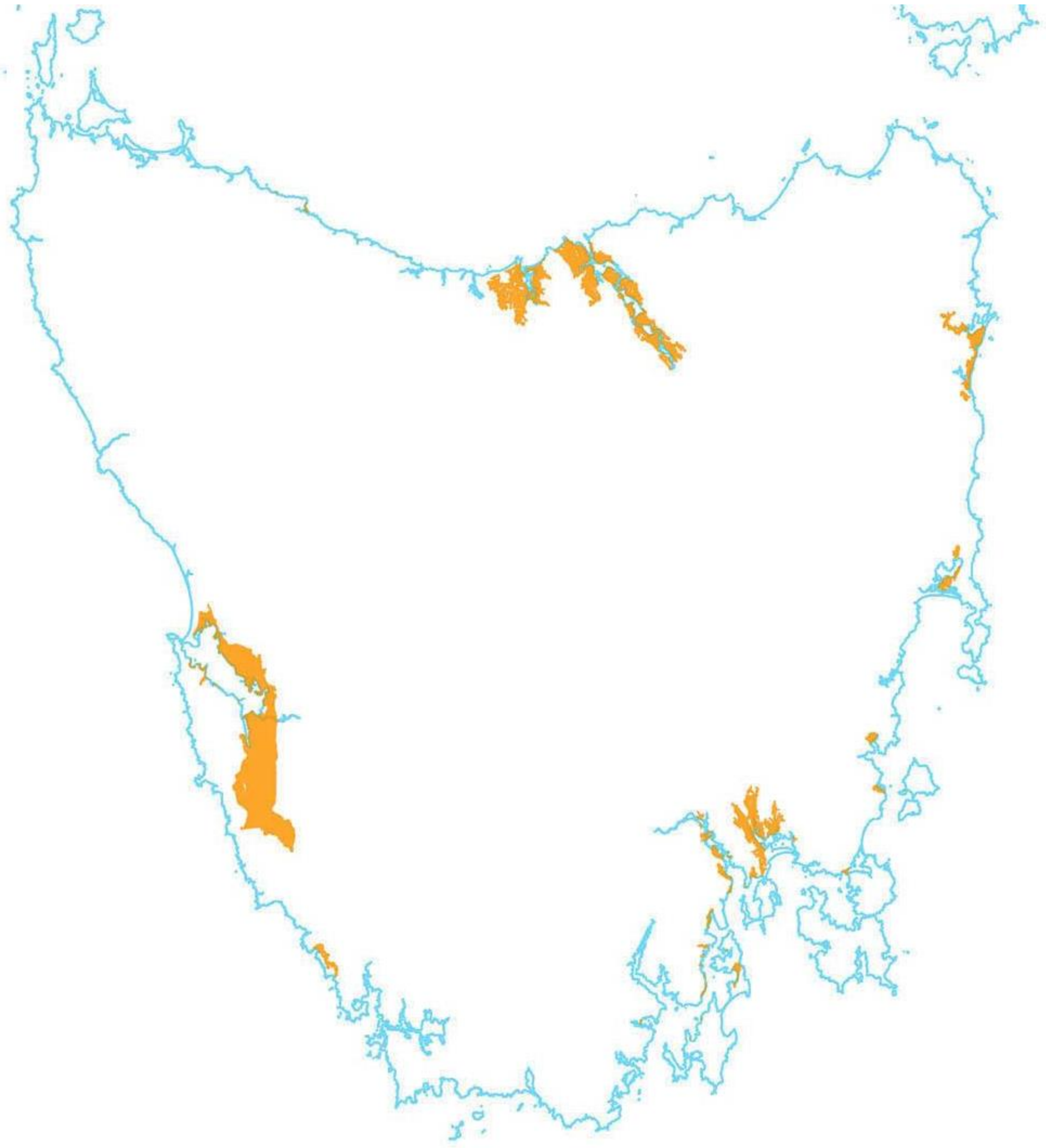

Figure 6: The full extent of coastal 'soft rock' bodies on the Tasmanian coast (orange polygons, as mapped by the soft rock polygon mapping described in section 3.2 and Appendix A1.5). This map depicts the full extent of mapped (mainly Tertiary-age) soft rock bodies in Tasmania whose extent reaches the coastline, but does not include many inland soft-rock bodies that do not reach the coast. Note that some small coastal soft rock bodies do not appear at this scale, but are included in this dataset.

For the purposes of coastal erosion susceptibility zoning, the coarse boulder clays are treated as having significantly less erosion susceptibility than those soft-rock classes dominated by cohesive clays.

Historical data on measured soft rock recession rates

Historical rates of soft rock shoreline recession are the best available indicators of potential future rates, albeit it is expected that ongoing sea-level rise will cause some acceleration of historical rates of soft rock shoreline recession (discussed further below).

However individual storm bites as recorded and used for unconsolidated sediment shores are not as useful for soft rock shores. Soft rock erodes less in a given storm than soft sediments may, however it does not recover from erosion and so tends to exhibit notable recession rates over longer periods, representing the cumulative effect of repeated small storm bites. Thus a progressive average recession rate is a more useful figure for quantifying soft rock shoreline recession[1].

Historical soft-rock shoreline recession data for Tasmania is currently limited to two Tasmanian coastal locations, at Barilla Bay and Rokeby Beach in south-eastern Tasmania (see data in Appendix 4, from Sharples *et al.* in prep.). Although this data is limited, it should be noted that each site encompasses several tens of data points spread along the shore, with a wide variety of wind-wave fetch exposures (and swell exposure at Rokeby Beach), which has resulted in a wide spread of recession rates at each site that are therefore likely to be reasonably representative of the range of recession rates on Tasmanian soft rock shores. Note that data on soft rock shoreline retreat rates is available for a variety of overseas coasts, however this data was not used owing to uncertainties about its applicability to differing soft rock types and regional wave climates on the Tasmanian coast; local Tasmanian data was considered likely to be more pertinent, despite its limited availability.

The available historical shoreline recession data for Tasmania (Appendix 4) has been used as the primary basis for defining soft-rock shoreline erosion and recession susceptibility zone widths or ‘setbacks’ for Tasmania, as described in section 5.3. It is anticipated that these setbacks will be further refined as more empirical (historical) data on soft-rock shoreline behaviour over time is obtained for Tasmanian shores.

Soft rock recession rate acceleration allowance for sea-level rise

Trenhaile (2011) provides evidence that soft rock shores tend to progressively erode and recede landwards at slow to moderate but fairly continuous rates under stable sea-levels[2]. Many Tasmanian soft rock shores exhibit reasonably fresh vertical erosion scarps at the HWM line, albeit these may vary in height from less than 0.5m to as much as 20m high (e.g., at Taroona, Macquarie Harbour and elsewhere). It is probable that some degree of slow recession of these shorelines has been in progress for millennia, under mostly stable sea-level conditions. Interpretation of historic air photo images of soft rock (cohesive clayey sediment) shores at Rokeby Beach and Barilla Bay have demonstrated relatively constant retreat of these shores since around 1950, at rates varying from as low as 0.013 metres per year up to 0.35 metres per year over the last 50 to 60 years (see Appendix 4). The variability in recession rates observed to date may partly relate to variable sediment characteristics, but has been strongly correlated with differing wind-wave exposure on different parts of these shorelines.

However, soft rock shoreline retreat rates are expected to increase with a rising sea-level, primarily because of reduced wave attenuation as water deepens over the near shore profile, allowing stronger wave attack (Trenhaile 2011). There is as yet insufficient data to determine whether there has yet been any acceleration of soft rock shoreline retreat rates on Tasmanian coasts in response to the sea-level rise that has occurred over the last century. However, modelling of soft rock recession processes by Trenhaile (2011) suggests that with continuation of the sea-level rise acceleration now being observed, cliff recession rates in

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[1] In contrast unconsolidated sands may erode further in one storm bite, but then may recover so that net rate of recession may be low or zero; hence a storm bite is a more relevant measure of actual hazard in soft sandy sediments.

[2] This is in contrast to hard-rock shores which are considered to respond to sea-level changes by initially establishing a new equilibrium profile relative to any new sea-level, but will then show only very slow change thereafter if sea-level remains constant.

cohesive clay soft rock shores may be 1.5 to 2 times greater over the next century than they were in the last 100 years.

In order to allow for expected acceleration of shoreline retreat rates with sea-level rise, a conservative allowance of 2 x historical recession rates has been applied to model soft-rock recession susceptibility zones for Tasmania (section 5.3).

Presence of recent instability (slumping and landslides)

Observed active instability of soft rock coastlines is a clear criterion of high erosion susceptibility. Colin Mazengarb and Michael Stevenson (of Mineral Resources Tasmania) supplied current digital mapping of active coastal slumps and landslides on several Tasmanian soft-rock shorelines (including Parnella and Taroona) to this project.

Since this mapping is only available for a small proportion of the soft-rock coasts in Tasmania, it has not been used directly to define coastal erosion susceptibility zones at specific sites, as to do so would result in arbitrary differences in the rationale behind soft-rock erosion susceptibility zones at different locations.

However, the mapped instability was compared with the soft rock susceptibility zones derived from other criteria (described above and in section 5.3), and this confirmed that these zones were mostly of an appropriate and credible scale. The majority of mapped slumps fall within the modelled susceptibility zones, although a few actual slumps at Taroona extended further landwards, indicating that the modelled zones were if anything arguably too restricted in a few locations. However these more extensive slump zones relate as much to terrestrial slumping processes as to wave-induced erosion, and are captured by a separate landslide hazard zoning scheme, hence it was not considered appropriate to extend the coastal erosion susceptibility zones to fully encompass them.

Cliff and steep coastal slope regression (landslide susceptibility) modelling

A cliff slumping and regression susceptibility modelling method has been developed by Colin Mazengarb of Mineral Resources Tasmania, and is considered a promising approach for defining hard rock coastal cliff erosion and recession susceptibility zones in Tasmania (see section 4.4 below). A similar modelling approach would theoretically be applicable to soft rock coastal cliffs.

However, this approach has not been applied to soft-rock coastal cliffs in this project because the high resolution topographic data coverage needed for the modelling (e.g., Lidar-based DEMs) is currently incomplete for the Tasmanian coast. The regression modelling method was tested using only the medium –resolution topographic data that is currently the best dataset available for the whole coast, and was found to be unable to identify many known coastal cliffs. Hence application of this method must await a more comprehensive coverage of high resolution topographic data.

Given this limitation, the available empirical data on soft-rock shoreline recession rates for Tasmania (described above) was considered the best available basis for estimating potential soft rock cliff recession rates for Tasmania, and so has been used for those as well as for lower profile shores, as described in section 5.3.

Landslip A and B zones

A small number of coastal soft rock areas including Parnella and Taroona have been mapped as landslide hazard zones by Mineral Resources Tasmania, and are defined in legislation as either "Landslip A" or "Landslip B" hazard zones for planning policy purposes. In principle these could be incorporated into coastal soft rock erosion and recession susceptibility zones for this project.

However this has not been done. This is firstly because the defined Landslip A and B zones only cover a small proportion of the coastal soft rock areas that might be prone to recession around the Tasmanian coast (albeit the most populated such areas), and thus are not a basis for consistent zoning of such susceptibilities at state-wide level. Secondly, the defined Landslip A and B zones are in any case captured by the erosion susceptibility zones defined using other criteria (above) for this project.

Coastal slope

A notable limitation of the empirical soft-rock shoreline recession data (Appendix 4) used to define soft rock recession susceptibility zones for this project is that it is derived only from low profile (low gradient backshore) shorelines, albeit these invariably exhibit an active vertical erosion scarp that may be several metres high in places. However no measured historical shoreline recession rate data is currently available for steeply rising Tasmanian soft rock shores.

This is potentially a limitation on the applicability of the available measured data, since steeper soft rock coastal slopes imply a greater bulk of material to be removed by wave erosion and thus potentially slower net recession rates than low-profile slopes. On the other hand however, steeper slopes are also more prone to slumps which may propagate landwards from the actual receding shoreline scarp, so that it is arguable that the net rate at which instability propagates landwards on an eroding soft rock shoreline might be of a comparable order of magnitude for both low and steep profile shores.

Although this proposition remains to be tested through acquisition of further long-term historical shoreline recession rate data for both low and steep profile Tasmanian shores, it has been used in this project as a working hypothesis which justifies the use of the same erosion and recession susceptibility setbacks for all soft-rock shores (i.e., low profile as well as steep profile). It is intended that future acquisition of additional soft rock shoreline recession data will allow refinement of recession susceptibility setbacks and in particular testing of the suitability of these for steeper as well as gentler coastal slopes.

Wave climate

A brief outline of wave climate distinctions between different parts of the Tasmanian coast is provided in section 4.2. Given that soft rock shores do not rebuild (in contrast to sandy soft sediment shores which may do so), swell wave energy and exposure are likely to have a more direct relationship to both storm bite magnitudes and recession rates for these shores than is the case for sandy shores (where higher swell exposure may result in larger erosion bites but also in more effective shoreline recovery after erosion). Thus for soft rock shores, higher exposure and higher wave energies will tend to yield larger storm bites which – due to lack of shoreline recovery – will also drive faster long term shoreline recession.

However, it is notable that most Tasmanian soft rock shores occur in swell-sheltered re-entrants, with only a few such as Taroona and Rokeby Beach occurring in locations receiving low to low-medium swell wave exposure. In contrast, areas of high to high-medium wave exposure such as Ocean Beach (W. Tas.) and Clifton Beach (SE. Tas.) where Tertiary-age soft rocks are known to occur at shallow depths – and have probably been exposed at the surface in the past – are uniformly mantled by thick sandy beaches as a result of the soft rocks having long since been eroded to below sea-level by high wave energies.

Thus, it is evident that Tasmanian soft rock shores are only found today on relatively low wave energy coasts[3] since on the higher energy coasts they have already been eroded down to below sea-level and then covered by sand. That is, Tasmanian soft rock shores occur only in swell-sheltered re-entrants (where the wave climate comprises only intermittent local wind waves of variable fetch and frequency) or on the less energetic of the swell exposed shores.

Consequently no wave climate distinction has been applied to soft rock recession susceptibility zones (as was done for soft sediment coasts: see section 4.2). Any differences in behaviour that might exist between swell-exposed and swell-sheltered soft rock coasts are likely to be of less significance than the differences within the available recession rate data (Appendix 4) between shores exposed to longer and shorter wind-wave fetches within swell-sheltered re-entrants. Thus given the (limited) range of data and recession modelling methods available at present, it would not be meaningful to attempt to distinguish between soft-rock recession rates between Tasmanian swell-exposed and swell-sheltered shores.

4.4 Hard rock coastal erosion susceptibility zoning criteria

Data and methods that were identified as potentially useful for the purpose of defining and mapping broad coastal erosion susceptibility zones for hard rock shores on the Tasmanian coast are briefly described below. The use of these data to define susceptibility zones is described in section 5.4 below.

In all cases, the presence and alongshore extent of hard rock shorelines was determined using the Smartline coastal geomorphic map of Tasmania (Sharples *et al*. 2009; see section 3.3.1). The attributes of this map differentiate hard rock shoreline types into gently to moderately sloping, and steep to cliffed hard rock shores; and identify where rocky shores of either type include a fringing sandy shore such as a narrow sandy beach backed by bedrock (Figure 7). Differing erosion susceptibility criteria have been applied to each of these groups, as described below and applied in section 5.4.

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[3] Note this is not always the case elsewhere, for example on the Norfolk coast of England or the Port Campbell coast of Victoria where extensive soft rock deposits are exposed to relatively high open coast wave energies. A major reason for the difference is that the soft rocks of the Port Campbell and Norfolk coasts are much more extensive than the Tertiary-age cohesive clays of Tasmania, so have yet to be fully eroded away despite their high exposure to wave energies.

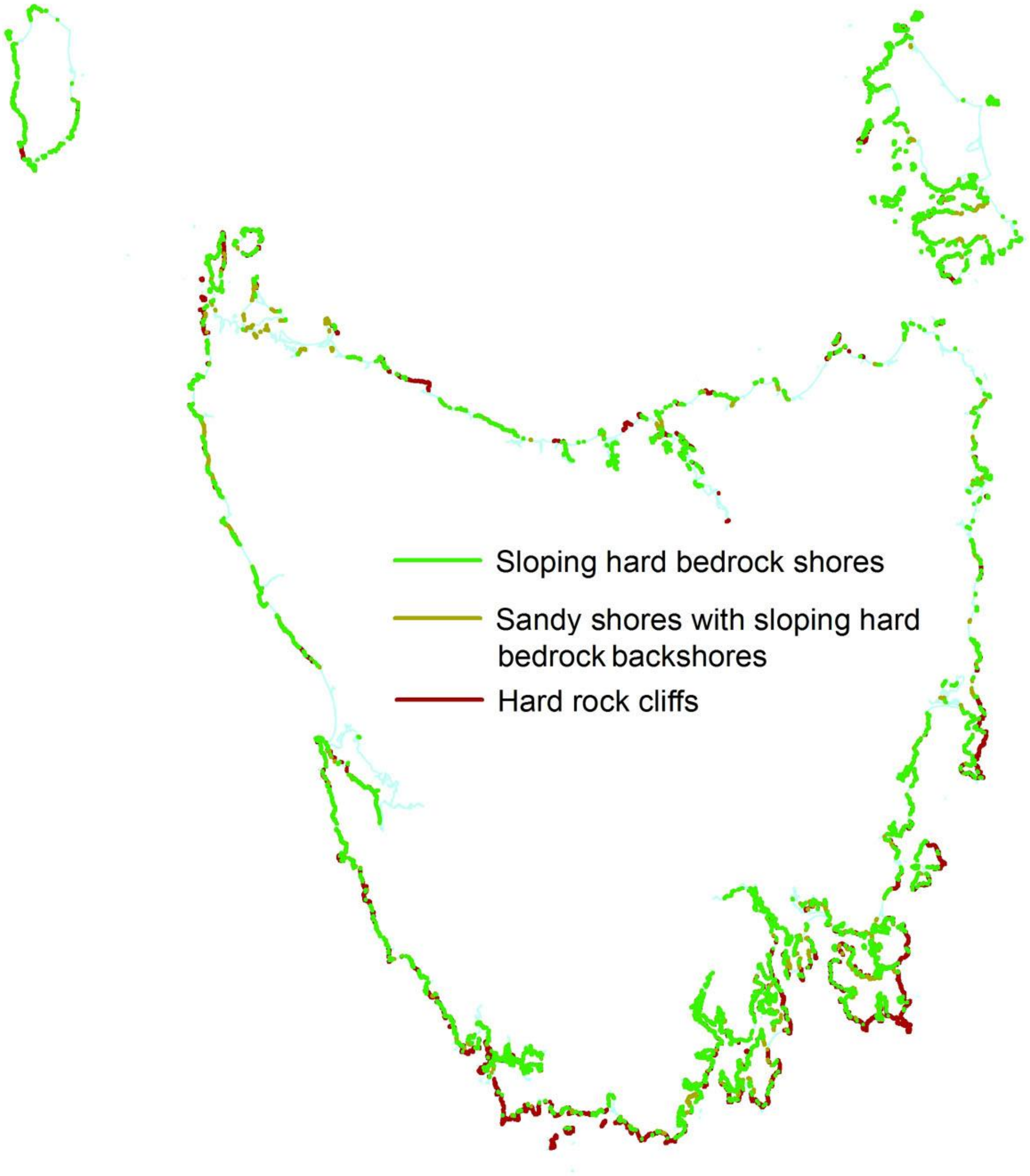

Figure 7: The extent of the three categories of hard-rock shorelines defined for this coastal hazard assessment. Since the potential landwards recession associated with hard rock shores is mostly negligible or limited to 2100, these shores are identified using a simple line map rather than a polygon map. The 'Smartline' coastal geomorphic map as described in section 3.3.1 and Appendix A1.2 was used to identify and map these shoreline types. Note that at this coarse scale short rocky shores appear to merge and obscure short intervening soft sediment shores, however the latter information is preserved and accurately represented at management – relevant scales in the dataset itself.

4.4.1 Gently to moderately sloping hard rock shores and backshores

Hard rock foreshores and backshores (with or without soil mantles) that slope up at gentle to moderate angles to landwards are regarded as having acceptable (i.e., negligible) erosion susceptibility. Although some may exhibit small erosion scarps (typically lower than 5 metres) backing a shore platform, these have generally developed on millennial time scales since the end of the last post-glacial marine transgression circa 6,500 years ago, and are eroding at very slow rates which in most cases can be expected to be virtually un-noticeable over human time frames.

Since this shoreline category is classified as having negligible erosion or recession susceptibility over human time frames, no criteria are required to differentiate between higher and lower susceptibility zones for this category. All shores and backshores falling into this category are simply classified as having “Acceptable” (negligible) erosion or recession hazard (see also section 5.4).

4.4.2 Sandy shores backed by sloping hard bedrock above sea level

Sandy shores immediately backed by low profile to moderately rising hard bedrock slopes above present sea-level are classed separately to ‘pure’ hard bedrock shores since these may in some cases exhibit a degree of storm erosion of the sandy beach and/or the foredunes overlying the hard bedrock backshore, albeit significant shoreline recession is unlikely. However hard bedrock shores fronted by muddy or cobble sediments are not included in this category since these materials rarely significantly overlie the bedrock backshores (these are categorised as simple sloping or cliffed bedrock shores as described above or following). In addition, hard rock steeply sloping or cliffed shores fronted by sandy shores are included in the hard rock cliffed category (below) since their cliffed morphology will dominantly govern their susceptibility to coastal erosion hazards.

Sandy shores backed by rising hard bedrock have been treated as having negligible susceptibility to long-term shoreline recession since – like the previous category – their backing by rising bedrock surfaces will effectively prevent significant shoreline recession over human time frames. However because these shores are fronted by sandy beaches – and their backshores are commonly mantled by dune or other windblown sands over bedrock above sea-level – they are regarded as being susceptible to short-term storm bite erosion events affecting the beach and any dune sands over the backshore bedrock.

The storm bite susceptibility zones for these shorelines are calculated using the same criteria that are applied to pure sandy shores in the same wave climate setting (open coast or swell-sheltered), since the scale of storm bite erosion that results for their sandy component can be expected to be comparable. These criteria have been identified in section 4.2, and their application is described in sections 5.2 and 5.4.

4.4.3 Cliffed to steeply sloping hard rock shores

Steeply sloping to cliffed hard rock foreshores and backshores are normally much less susceptible to coastal erosion and recede at much slower rates than soft rock or soft sediment shores. Nonetheless their steepness is itself an indication that these are actively eroding landforms, and these shores may be prone to block falls and slumping on scales and event frequencies sufficient to be noticeable and problematical over human time frames. Many steep coastal slopes are mantled by bedrock talus blocks (unconsolidated slope deposits) derived from past instability and prone to ongoing slumping, while bedrock block falls from vertical faces will occur periodically in response to basal wave erosion gradually undermining the cliff base. It is therefore necessary to treat steep to cliffed hard rock shores as potentially susceptible to erosion and recession.

Available data and modelling methods that potentially could be used to define coastal erosion and recession susceptibility zones for steep and cliffed hard rock shores are described below. Whilst some of these methods show considerable promise, current data limitations have made it impractical to implement these, and a simple precautionary buffer approach has instead been used as described in section 5.4. It is however recommended that some of the approaches outlined below (especially cliff regression modelling) be used to refine the precautionary buffer approach when adequate data becomes available for this purpose.

Historical data on measured hard rock cliff recession rates

Fresh recent rock fall and slumping scars are common features of these shores in Tasmania, and coastal cliff rock-fall events in Tasmania have occasionally been reported in newspaper items (e.g., at Alum Cliffs south of Hobart; see Figure 18). These observations confirm the potential coastal erosion hazards associated with hard rock cliffs. However in contrast to soft sediment and soft rock shores, no measurements of historic hard rock cliff retreat rates have as yet been obtained for any Tasmanian shores.

In some cases where shore platforms are developed at the base of hard rock cliffs, the shore platform width (typically ranging from around 5 to 20 metres) may be inferred to represent the horizontal cliff retreat that has occurred over the circa 6,500 years since post-glacial sea-levels stabilised at close to their present levels. However it would be problematical to attempt using such data to determine hard rock cliff recession hazard bands for several reasons, namely:

- From first principles it can be assumed that cliff retreat rates will vary considerably depending on rock type, degree of fracturing and relative degree of wave exposure, hence considerable analysis of shore platform data would be needed to either specify variable susceptibility zone widths for differing sites, or else to derive justifiable 'worst case' susceptibility zones widths applicable to any sites; and:
- Shore platforms are poorly developed or not developed in some rock types on Tasmanian coasts, particularly dolerite and granite shores, hence this data source would not be applicable to these cases; and:
- An average recession rate derived by assuming shore platform width represents 6,500 years of recession would not necessarily be representative of shoreline retreat rates over recent (or future) centuries, since it is likely that hard rock shoreline erosion was more rapid immediately following stabilisation of sea-level at circa 6,500 years ago, and has subsequently slowed over recent millennia as an equilibrium shore profile has been reached (Trenhaile 2011).

For the above reasons, no attempt has been made to use historic hard rock cliff retreat rates as a basis for defining hard rock cliff erosion hazard bands. Ideally, if adequate measured hard rock cliff retreat data for Tasmanian coasts becomes available in future, this should then be reconsidered for use in refining coastal erosion susceptibility zones.

Presence of recent instability (slumping and landslides)

Observed active instability of steep and cliffed hard rock coastlines provides clear evidence of erosion susceptibility.

Mineral Resources Tasmania has undertaken mapping of active coastal slumps and landslides in several regions of the Tasmanian coast, and this data was made available for coastal erosion susceptibility zone definition[4]. However this mapping mainly applies to steep and cliffed soft-rock shores (see section 4.3), and the few cases in which it applies to hard rock cliffs do not provide a sufficient basis for using it to define hard rock cliff erosion susceptibility zones on a state-wide basis.

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[4] Slump mapping supplied by Colin Mazengarb and Michael Stevenson as digital mapping files.

Cliff and steep coastal slope regression (landslide susceptibility) modelling

Hard – rock cliff regression (slumping) hazard zones have previously been estimated for NSW coastal hard rock cliffs by manually mapping a potential slump hazard zone extending the same distance horizontally landwards of the cliff top (‘escarpment line’) as the height of the cliff above its base, which generally approximates the High Water Mark (Patterson Britton 2005). This method created a hazard buffer landwards of sea cliffs by assuming a maximum slumping and instability angle of 45° rising landwards from the base of the cliff.

For the current hazard zoning project, we have investigated a refinement of this approach developed by Colin Mazengarb of Mineral Resources Tasmania, which uses a similar principle to model cliff regression hazard zones in a GIS environment using a Digital Elevation Model (DEM). This method is described below:

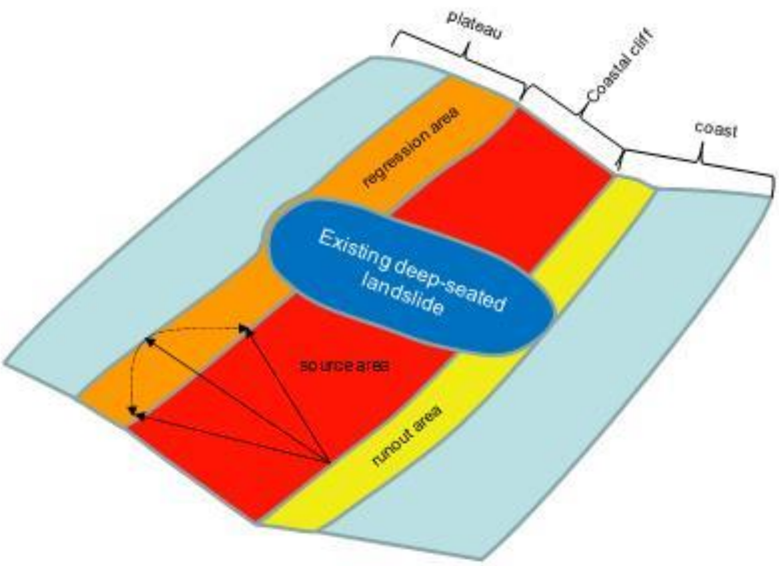
Although individual cliff failures such as rock falls and slumps may be of widely varying sizes and shapes, it is possible to conservatively predict the maximum area (and volume) behind any given cliff that is potentially at risk of instability at any given stage in the long-term retreat of a cliff-line. As indicated in Figure 8, this maximum zone of potential instability (or ‘Landslide Susceptibility Zone’) is defined by a plane rising to landwards from the base of the cliff, which represents the maximum angle on which a cliff failure may propagate upwards and landwards from the foot of a cliff. The ‘beta angle’ at which the failure line or ‘regression line’ defining the maximum failure plane subtends upwards and landwards varies for differing rock types and for rocks with differing fractures, weathering, hydrology or a variety of other factors that may vary from site to site, although in all cases the zone of potential instability behind the cliff top becomes wider as the cliff height increases.

The regression modelling approach was trialled for this project by Colin Mazengarb of Mineral Resources Tasmania. Cliffs were identified using a 10 metre DEM constructed from LIST topographic data including 5 and 10 metre contours and spot height data.

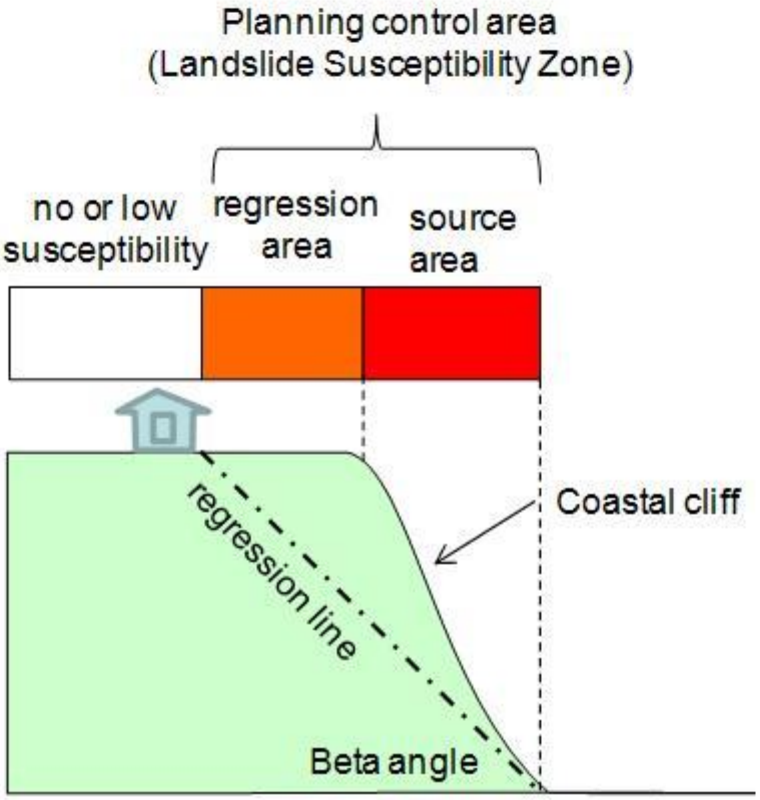
The following model parameters were used:

Regression line beta angle: Because of the variability in conditions and thus regression line beta angles from cliff to cliff, for the purposes of a state-wide modelling exercise it is necessary to choose a conservative generic beta angle which is considered adequate to cover all likely cases. A 45° beta angle was used, in accordance with previous coastal hard rock cliff failure modelling for the NSW coast (Patterson Britton 2005, p.23).

Minimum cliff slope angle: The modelling process identifies cliffs based on slope angles defined by the DEM. A DEM slope angle of 45° was used to define the minimum slope angle for which Landslide Susceptibility Zones were modelled (i.e., ‘coastal cliffs’ were identified as coastal slopes between 45° and 90°). The minimum 45° slope corresponds to a relatively steep slope which in many coastal situations is likely to be mantled with talus and other landslide-prone slope deposits.



Conceptual oblique diagram of coastal cliff demostrating landslide regression susceptibility modelling principles. Fanning method for a given source area is shown at left.



Conceptual cross-section of coastal cliff demostrating landslide regression susceptibility modelling principles

Figure 8: A conceptual cross-section of a coastal cliff demonstrating landslide regression susceptibility modelling principles. Figure courtesy of Colin Mazengarb, Mineral Resources Tasmania.

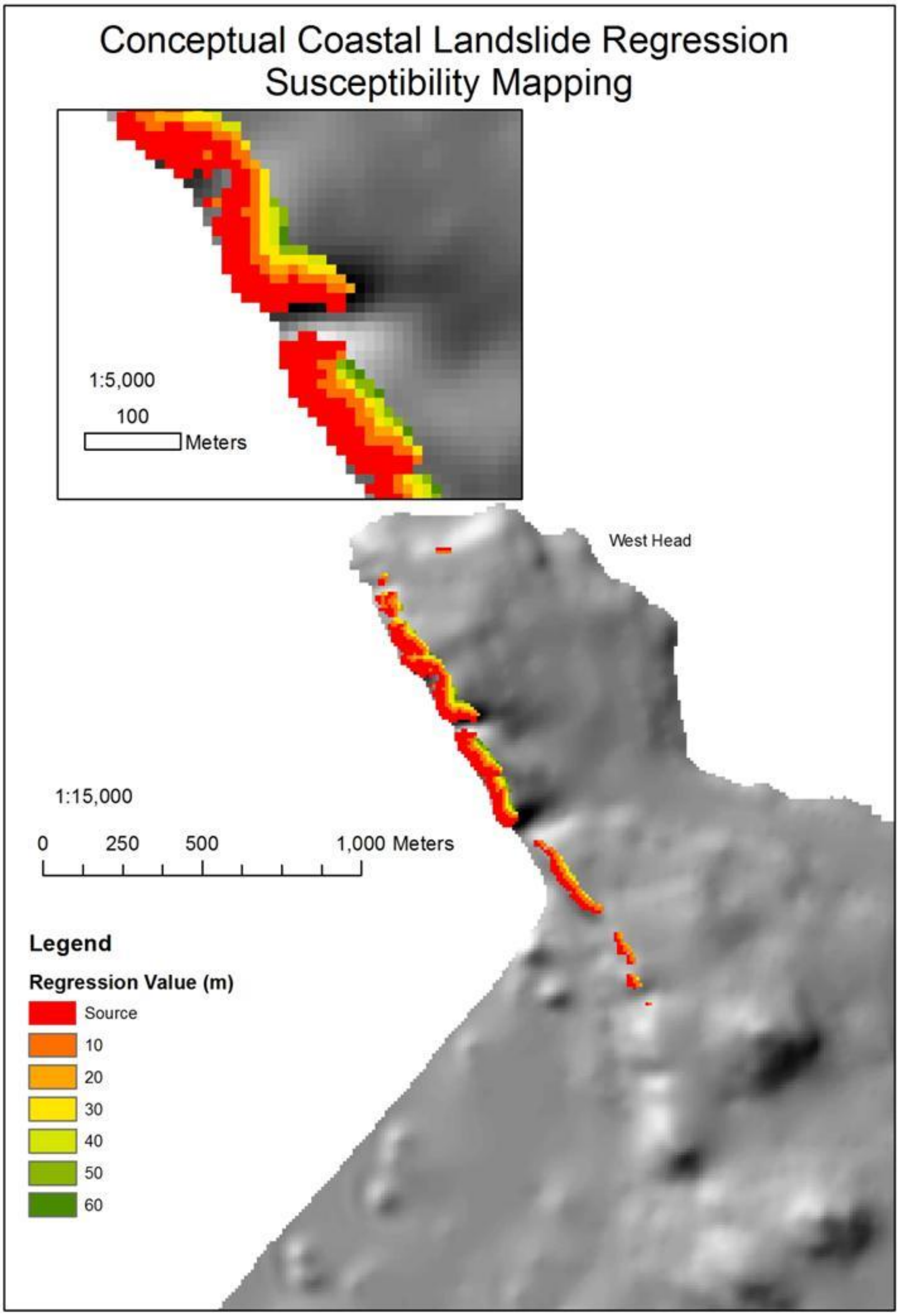


Figure 9: An example of coastal cliff regression modelling which was prepared using a 10 metre DEM derived from 5m and 10m LIST contours. Figure courtesy of Colin Mazengarb, Mineral Resources Tasmania.

Maximum regression cutoff distance to landwards of cliff tops: In extreme cases such as the 300 metre high dolerite sea-cliff near Cape Pillar (Tasman Peninsula), it is unlikely that foreseeable cliff failures would actually extend inland to the full distance suggested by regression line modelling. In part, this is because higher sea-cliffs will generally be composed of more resilient materials, since otherwise they would not be mechanically capable of maintaining very high cliff faces. Consequently a regression zone cutoff horizontally behind the cliff top would need to be adopted for full-scale implementation of this method; however this was not considered in the initial test modelling undertaken for this project.

Trial modelling results:
The trial run of this method faithfully identified many larger cliffs on the Tasmanian coast, and produced appropriate regression or landslide susceptibility zones for these. However the trial run failed to identify a large number of smaller coastal cliffs because of the scale limitation inherent in using topographic data that is based on 10 metre contours in most areas. Because of this limitation, many significant coastal cliffs in the 20 to 40 metre height range were not identified, including for example parts of the Alum Cliffs near Hobart where instability has been recorded (see Figure 18), and the soft rock cliffs at Taroona. Most of these smaller cliffs are however identified on the Smartline coastal geomorphic map (Section 2.3.1).

It is apparent that higher resolution topographic data is necessary for the modelling method to identify smaller – but still important – coastal cliffs. The ideal is the use of Lidar-based DEMs, however since these are at present available for only limited portions of the Tasmanian coast it is evident that it will not be possible to consistently model coastal cliff regression zones for the whole Tasmania coast until such data is available on a state-wide basis.

Consequently this modelling approach has not been used to generate hard rock coastal cliff regression (landslide susceptibility) zones for this project; however it is recommended that the method be employed to refine the susceptibility zones that have been produced (see section 5.4) when suitable high-resolution topographic data does become available for the whole coast.

Sea-level rise erosion acceleration allowance
Trenhaile (2011) provided evidence that whenever a significant change in sea-level occurs, hard rock shores (especially cliffs) develop a new wave-attenuating profile relatively quickly (i.e., over a few centuries), but thereafter show only much slower rates of change as long as sea-level is again constant. Given that a renewed onset of sea-level rise has occurred over the last century, following about 6,500 of relative sea-level stability, it may be expected that hard rock cliffs will begin to exhibit acceleration in their rates of erosional recession as they adjust to the rising sea-level. However given the lack of data on historical hard rock cliff retreat rates on Tasmanian coasts, it is problematical to attempt to calculate such accelerated retreat rates. Given that Trenhaile suggests that accelerations amounting to a retreat rate several metres per century faster than historical rates are likely, for the purposes of cliff recession susceptibility zone it has been assumed that the conservative precautionary buffer approach that has been used (see below and section 5.4) is sufficient to allow for any increased rate of cliff regression due to sea-level rise.

Cliff heights and types

Greater cliff heights imply a wider Landslide Susceptibility Zone above and behind a cliff face (see Figure 8); however this is implicit in the cliff regression modelling described above, and therefore has not been considered separately. Differing cliff types - including differing rock types, degrees of fracturing and amount of talus or other unconsolidated deposits on cliffs or steep slopes – may also affect the landwards extent of a Landslide Susceptibility Zone associated with coastal cliffs. These factors can only be properly accounted for through site-specific investigations. For the purposes of the precautionary buffer approach taken for this project (see below and section 5.4) the buffers used are assumed to be sufficiently conservative as to allow for the effects of the full variation in hard rock coastal cliff types, which therefore have not been considered separately.

Wave climate

As is the case with soft sediment and soft rock shores, it can be expected that hard rock cliffs more exposed to higher wave energies would retreat more rapidly than less exposed shores (all other factors being equal). However in the absence of measured historical retreat rates for Tasmanian coastal cliffs with a range of differing wave exposures, it is problematical to attempt to quantify how much hard rock coastal cliff retreat rates for Tasmania might vary for this reason. Given that hard rock cliff retreat rates are likely to be significantly slower than soft rock shores in any case, the effects of variable wave climate exposure on hard rock coastal cliff hazard zones are likely to be sufficiently small that it is assumed the precautionary buffers used for this project (see below and section 5.4) are sufficiently conservative as to allow for the effects of this source of variability, which therefore is not considered separately.

Precautionary buffers

In the absence of any readily applicable approach to defining erosion and recession zones for hard rock coastal cliffs on the basis of available data or modelling methods (see above), a simpler interim precautionary buffer approach has been adopted, which it is proposed should be reviewed and replaced by regression modelling (see above) when adequate topographic data is available. The interim method adopted uses the Smartline map (section 3.3.1) to identify all Tasmanian hard rock coastal cliffs (defined as vertical rock faces higher than 5 metres: Sharples *et al.* 2009), and buffers all of these with an erosion and recession susceptibility polygon to 50 metres landwards of the cartographic High Water Mark. The application and justification of this approach is described further in section 5.4 below.

4.5 Hazard banding criteria for artificially protected shores

Properly designed and constructed artificial shoreline structures can be effective in preventing shoreline erosion and recession; however if poorly designed or inadequately constructed they may have little value in preventing erosion.

The presence and resilience of artificial protection structures on Tasmania's coast has been incorporated into the Tasmanian coastal erosion susceptibility zoning mapping where-ever adequate data on the presence of artificial shoreline protection structures is available. The use of the data is based on differentiating between resilient and inadequate artificial shoreline protection as described in section 5.5.

Where shoreline protection is judged resilient, the coastal zone behind the protection is considered to have Acceptable (negligible) susceptibility to coastal erosion or recession; however where the shoreline protection is inadequate, the coastal erosion and recession susceptibility is classified according to whatever the natural shoreline type at the site is (i.e., as if the artificial protection were not present).

The source of artificial shoreline protection mapping used for this project is the Smartline coastal geomorphic map (v1) as described in section 3.3.1 and Appendix A1.2. The Smartline classifies shorelines into a range of artificial shoreline types where-ever such information was available and accessible at the time the mapping (v1) was compiled (2007 – 2009). However no fieldwork or other investigation was undertaken at the time to ensure this element of the Smartline data was complete, and it has subsequently become apparent that other artificial shorelines exist that are not mapped as such in the Smartline (these shores are mapped according to their natural characteristics only, as determined from geological maps, air photo interpretations or other 'remote' data).

Moreover the Smartline data does not include any measures of the state of repair of artificial structures, nor any measure of their likely capacity to prevent or halt shoreline erosion and recession. However the general type of structure is recorded and in many cases this gives a good indication of likely resilience. Moreover, some of the major structures are known to and have previously been inspected by Chris Sharples, and have been here identified as either resilient or inadequate on this basis.

Although the Smartline data on artificial shores is known to be incomplete it was considered better to use incomplete data where it does positively indicate an (artificially) resilient shoreline, even though this means that some other shores that are similarly protected will be (conservatively) classed as unprotected and erodible. Where this situation arises, a site inspection will quickly resolve such information inadequacies.

It is expected and recommended that future work will be undertaken to fill gaps in the available data on artificially protected shores in Tasmania, and that erosion susceptibility zoning mapping will be refined and updated accordingly.

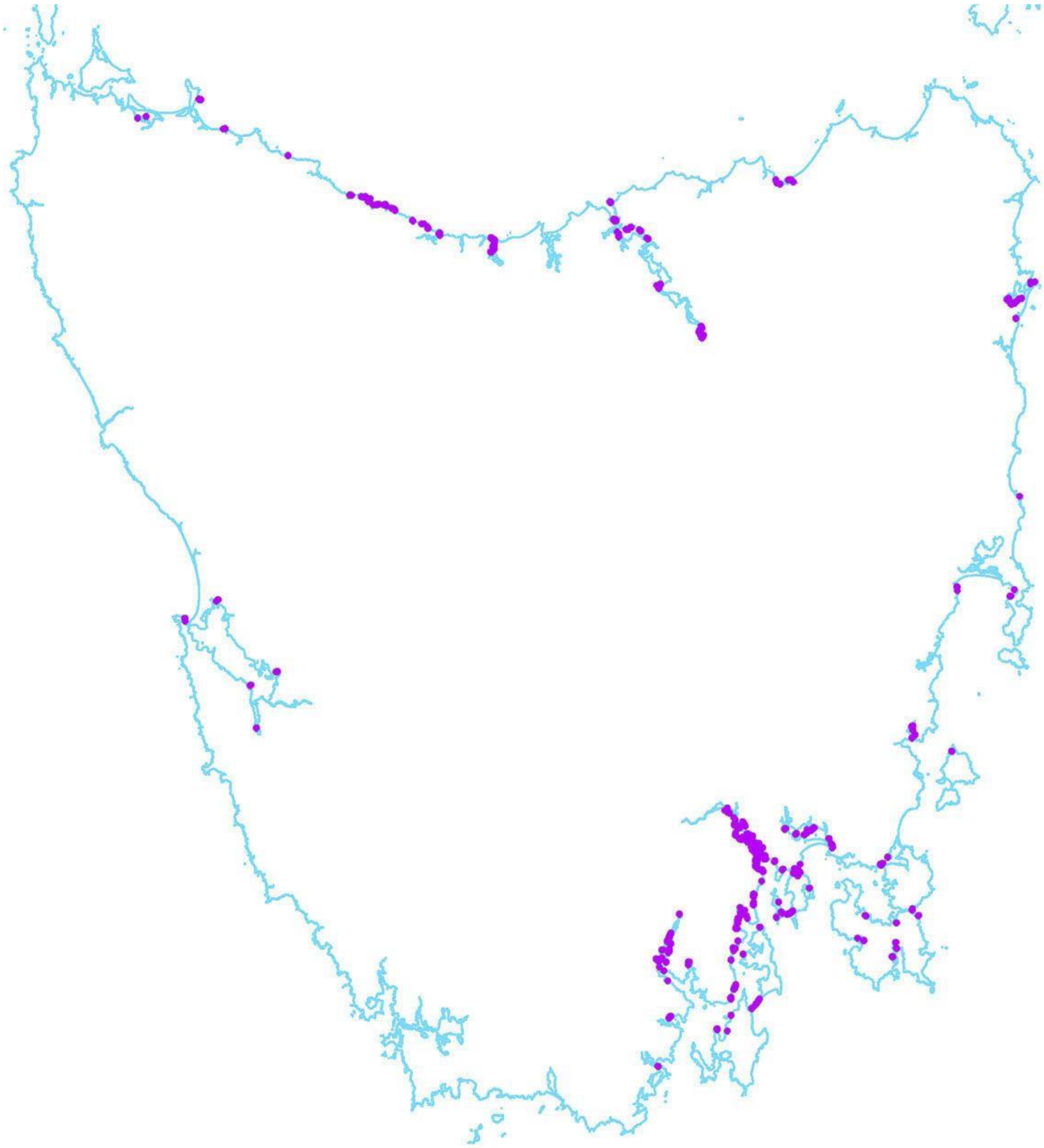


Figure 10: The extent of artificial shorelines incorporated into this coastal hazard assessment. These comprise those artificial shores mapped in the 'Smartline' coastal geomorphic map as described in section 3.3.1 and Appendix A1.2. It is recognised that this is not a comprehensive map of all artificial shores on the Tasmanian coast, and it is recommended that this mapped coverage be progressively improved as opportunities permit.

5.0 Coastal erosion susceptibility zone definition and mapping

5.1 Introduction

Section 4.0 has described a range of methods or criteria that could potentially be used to define coastal erosion susceptibility zones for a variety of differing shoreline types in Tasmania. The following sub-sections of this section identify the methods or data that have actually been used for this purpose, and provide an outline of how they are used.

Some of the methods described in section 4.0 were not used because they were judged less appropriate or impractical; however some of the methods not used have been identified as good methodologies and were only not used due to lack of appropriate data (e.g., hard rock cliff regression modelling). These unused but promising methods are identified in section 4.0, and it is intended that with improvements in data availability they will in future be used to further refine the erosion susceptibility zones defined in this initial coastal erosion hazard banding project.

5.2 Soft sediment coastal erosion susceptibility zoning

5.2.1 Use of available criteria

The available data and criteria that have been identified as having utility for defining coastal erosion susceptibility zones for soft unconsolidated sediment coasts have been described in section 4.2. Drawing upon some of these, soft sediment erosion susceptibility zones have been defined using coastal soft sediment polygon and natural recession limits mapping, modelled generic erosion setbacks, recorded (historical) storm erosion bites and shoreline recession rates, and a very simple distinction between coasts exposed to or sheltered from swell wave climates. The relevance of each of these to defining susceptibility zones is described below.

Coastal soft sediments polygon mapping and Natural Recession Limits mapping

These data place ultimate boundaries on the areas of erodible coastal soft sediment that could *in principle* be susceptible to marine (wave) erosion & shoreline recession, based on the actual mapped extent of soft sediments that could be reached by waves if sea-level were 0.8m higher than at present *and* if consequent erosion and recession of soft sediment shorelines continued until rising hard bedrock slopes prevented further recession. See further explanation in sections 3.1.1 and 3.1.2. Any erosion susceptibility zones that are defined on other criteria (below) and which would on those criteria alone extend beyond mapped natural recession limits are truncated at the natural recession limits.

Since the actual location of natural recession limits depends on where bedrock underlying the cover of soft sediments rises to a level exceeding 0.8m above present sea-level, it can in some circumstances be difficult to define precise natural recession limits for coastal soft sediment bodies using available information. For example where there is no abrupt steepening of the underlying bedrock surface but only a gradual rise underneath an obscuring soft sediment cover, then short of using drilling or geophysical survey methods it is very difficult to pick precisely where the hidden bedrock surface rises above the critical level. In such cases two recession limits polygons have been mapped, namely a narrower polygon showing the distance to landwards of HWM to which the soft sediments are considered *likely* to extend deeper than present sea-level (and thus to be susceptible to erosion and recession), and a further polygon to landwards showing additional areas where the soft sediments may *possibly* extend below present sea-level but with significant uncertainty.

Modelled generic erosion and recession setbacks (open coast beaches only)

Whereas Natural Recession Limits place an outside limit on soft-sediment areas that could *in principle* be eroded by the sea, modelled setbacks are used to provide estimates of areas within those limits that *might reasonably be expected* to erode with a defined time period. The only currently-available criteria which appear suitable and sufficiently comprehensive for generating credible generic erosion susceptibility zones for Tasmanian sandy open-coast swell-exposed shores are the modelled generic setbacks calculated by Mariani *et al.* (2012); see Appendix 3. These setbacks were generated using widely-accepted contemporary methods of modelling erosion and recession hazards on open coast sandy beaches as described in section 4.2.

Table 2: Adopted generic setbacks used to define erosion susceptibility zones for Tasmanian swell-exposed sandy shores. These are the generic modelled setbacks calculated for Tasmanian coasts by Mariani *et al.* (2012), with the following modifications: (a) because beach profile data is not available for most Tasmanian beaches, the most conservative combinations of generic modelled storm bite (S1) and dune instability zone width (S5) – namely those calculated for a shore profile characterised by 4.0m ground level (GL) AHD at the back of the beach (e.g., the dune crest height) - are used for each coastal zone; and (b) long term recession due to sea-level rise is recalculated for the adopted Tasmanian sea-level rise allowances of 0.2m sea-level rise by 2050 relative to 2010, and 0.8m rise by 2100 relative to 2010 (TCCO 2012), in each case using the same Bruun Factor of 50 that Mariani *et al.* (2012) used to generate sea-level rise recession factors for slightly different scenarios for Tasmania. Modelled generic setbacks are reproduced in Appendix 3 for comparison.

Coastal Region	**S1 (m)** Storm Bite: 2 x 100 ARI storms	**S3 (m)** Recession due to sea-level rise (Bruun Factor = 50)		**S5 (m)** Width of zone of reduced dune stability
	4.0 m GL AHD	0.2 m SLR by 2050 relative to 2010	0.8 m SLR by 2100 relative to 2010	4.0 m GL AHD
North Tas coast (Region 14): Cape Woolnorth to Cape Portland	25	10	40	10
East Tas coast (Region 15): Cape Portland to Cape Pillar	38	10	40	10
Storm Bay, SE Tas coast (Region 15a): Cape Pillar to Southeast Cape	25	10	40	10
West – South Tas coast (Region 16): Southeast Cape to Cape Woolnorth	63	10	40	10

The generic open coast setbacks were calculated for three different Tasmanian coastal regions characterised by different wave climates, one of which was sub-divided to yield four Tasmanian coastal regions in total. For each region, short term storm bite setbacks were calculated for three differing representative beach profile classes, and long-term recession setbacks were generated for two sea-level rise scenarios which differ slightly from those that have now been adopted as standard sea-level rise planning allowances for policy purposes in Tasmania (TCCO 2012). Because measured beach profile data is lacking for most Tasmanian beaches, the most conservative calculated storm bite setbacks calculated by Mariani *et al.* for each coastal region have been applied to Tasmanian beaches in each region. The sea-level rise recession allowances have been recalculated to comply with the Tasmanian sea-level rise allowances (TCCO 2012), but using the same Bruun Factor recommended by Mariani *et al.* for each coastal region. The results – comprising the generic setbacks used to define erosion susceptibility zones for Tasmanian open coast sandy beaches – are set out in Table 2 above.

Recorded (historical) storm bite magnitudes and recession rates:

Historical data on actual storm bites and shoreline recession rates for Tasmanian soft sediment shores (from air photos and beach profile surveys) was used as a "reality check" for modelled open coast swell-exposed sandy beach erosion susceptibility zones or 'setbacks', and as the main source of data to define these setbacks for swell-sheltered soft sediment shores (where the modelling methods of Mariani *et al*. (2012) do not apply).

The recorded storm bite and recession-rate data for Tasmanian soft sediment shores that has been compiled to date (Appendix 2) is limited to a relatively small number of records at a very limited distribution of sites around the Tasmanian coast. Moreover with only one exception the magnitudes of the storms which have produced the recorded storm bites are unknown (because the date of most storm bite events is constrained only by the period between the air photos which are the main evidence for most recorded Tasmanian storm bites). It is likely that few if any of the recorded storm bites were produced by 100 year ARI storms, which is significant because 100 year ARI hazard events are commonly regarded as an appropriate benchmark for defining precautionary allowances for structures potentially at risk.

Swell-sheltered soft sediment shores – definition of erosion and recession susceptibility setbacks

Despite these limitations the available historical data has been used to define erosion susceptibility zone setbacks for swell-sheltered soft sediment shores in Tasmania, because the modelled setbacks of Mariani *et al.* (2012) do not apply to such shores and use of the available empirical data was the only credible method identified for the purpose. Since these setbacks (Table 4) are based on limited data, it is intended that ongoing collection of more such data will allow refinement and improved confidence in the calculated setbacks over time.

In contrast to open coast sandy beaches, comparatively little attention has been paid to modelling swell-sheltered coastline erosion since these shores have commonly been (wrongly) assumed to be subject to little erosion or recession compared to more energetic open coast shores, despite the fact it is evidently occurring and is doing so at significant rates on some Tasmanian shores (e.g., Mount *et al.* 2010, Sharples *et al*. in prep.). Whilst there has in recent decades been more attention paid to developing models of swell-sheltered shore erosion (e.g., Hennecke and Cowell 2000), we have not identified modelling methods sufficiently well established, robust and simple enough to confidently define generic erosion susceptibility zones covering a broad range of Tasmanian sheltered shore situations.

Hence we have simply and conservatively defined erosion susceptibility zones for these shores (Table 4) using such empirical data as is available on actual measured sheltered soft shore erosion bite and recession rates for Tasmania (Appendix 2). For defining storm bite susceptibility zones we have used the maximum recorded storm bites and have added an allowance for reduced soft sediment shore stability, which is the same as that used for swell-exposed sandy shores by Mariani *et al.* (2012), based on Neilsen *et al.* (1992), since the stability of a soft sediment erosion scarp will be independent of the wave climate that generated the erosion scarp.

To define longer-term recession susceptibility zones we have used the maximum recorded recession rates that have been observed for such shores in Tasmania, and have applied a conservative doubling of these to allow for both the limited spread of the available data coverage to date, and the likelihood that accelerating rates of sea-level rise will result in higher rates of shoreline recession in future than have been observed in the past.

In contrast to swell-exposed shores, the same erosion and recession hazard zone widths are used for all Tasmanian sheltered soft sediment shores since variability in the wave climate to which these are exposed depends mainly on local wind-wave fetches (not differing oceanic environments as for swell). These vary widely on localised site-specific scales and cannot be characterised into broader regional differences as swell wave climates can. Similarly, the susceptibility zones conservatively apply to all swell-sheltered soft sediment shore types – whether dominantly sandy or muddy – since insufficient empirical data exists as yet to determine whether these differing soft shore types exhibit characteristically different storm bite and recession magnitudes.

Swell-exposed sandy shores – verification of modelled erosion susceptibility setbacks
In contrast to swell-sheltered shores, available erosion and recession modelling techniques were considered sufficiently robust to use in defining erosion susceptibility zones for these shores as discussed above (Mariani *et al.* 2012). In this case, the available Tasmanian storm bite data (Appendix 2) has been used simply as comparative data to ensure that the erosion susceptibility setbacks used are of a credible scale given that they are intended to represent 2 x 100 year ARI storm bites whereas the empirical storm data is probably related to storms of (mostly) significantly lesser magnitude.

The empirical storm bite data recorded in Appendix 2 shows that the 40 year ARI storm event on 9th – 10th July 2011 resulted in storm bites on south-eastern Tasmanian beaches that were mostly in the range of 4 – 10 metres, with a maximum recorded storm bite of 15 metres at one location. Other recorded storm bites (from storms of unknown magnitude) ranged from 3 to 15 metres for SE Tasmanian beaches, and up to 8 metres for Ocean Beach in western Tasmania. These storm bites – which in most cases are likely to have been produced by storms of substantially less than 100 year ARI magnitude – are all roughly half or less than the generic storm bite allowances (S1) calculated by Mariani *et al.* (2012) for 2 x 100 year ARI storms (see Table 2 above). Thus the empirically recorded storm bite magnitudes suggest that the generic S1 storm bite allowances (Table 2) are of roughly the right order of magnitude to conservatively provide adequate protection against very large storms.

Wave Climate – Wave Energy Zones and Swell Wave Exposure:
The wave energy and wave climate zoning for Tasmania (as described in section 4.2) is a factor in the calculation of modelled generic erosion setbacks by Mariani *et al.* (2012), and being already implicit in those setbacks should not be used as an additional separate criterion

for coastal erosion. Thus differing degrees of swell-wave exposure (high, medium or low) are not taken into account for these purposes (but would be relevant for more detailed site-specific assessments of coastal erosion risk).

However the very basic wave exposure distinction between swell-exposed and swell-sheltered shorelines is used to differentiate between those swell-exposed coasts where the generic erosion setbacks modelled by Mariani *et al.* (2012) are applicable (Table 3), and those swell-sheltered coasts where we have used empirical historic erosion and recession data to define generic erosion setbacks (Table 4).

5.2.2 Definition of soft sediment coastal erosion susceptibility zones

Swell-exposed open coast sandy shores

Using the available criteria as described above, coastal erosion susceptibility zones (setbacks) for Tasmanian swell-exposed sandy beaches are defined as outlined in Table 3 below (and as illustrated in Figure 12).

Table 3: Definition of coastal erosion susceptibility zones for Tasmanian swell-exposed sandy shores, using modelled generic coastal erosion setbacks calculated by Mariani *et al.* (2012), and natural recession limits mapping prepared by Chris Sharples, Paul Donaldson and Hannah Walford (this project). The susceptibility zones are shore-parallel buffer zones whose widths are specified in this table, and are measured landwards from the present day (nominally 2010) cartographically-defined High Water Mark (HWM) line. A near- term erosion susceptibility zone is defined using storm bite (S1) erosion allowances and consequent dune instability zones (S5), since large storm erosion events could occur at any time. Medium and longer term recession susceptibility zones are defined as those additional areas to landwards of the storm bite susceptibility zone that may be subject to shoreline recession due to sea-level rise (S3) by 2050 and 2100 respectively, relative to 2010.

Coastal Region **Erosion susceptibility**	**Susceptibility zone widths (landwards from High Water Mark) in metres**			
	North Tas coast (Region 14): Cape Woolnorth to Cape Portland	East Tas coast (Region 15): Cape Portland to Cape Pillar	Storm Bay, SE Tas coast (Region 15a): Cape Pillar to Southeast Cape	West – South Tas coast (Region 16): Southeast Cape to Cape Woolnorth
Storm bite and consequent reduced foundation stability zone (**S1** + **S5**)	35 m landwards from HWM, or to natural recession limit	48 m landwards from HWM, or to natural recession limit	35 m landwards from HWM, or to natural recession limit	73 m landwards from HWM, or to natural recession limit
Potential shoreline recession to 2050 (**S3** to 2050)	10 m landwards of storm bite hazard zone or to natural recession limit	10 m landwards of storm bite hazard zone or to natural recession limit	10 m landwards of storm bite hazard zone or to natural recession limit	10 m landwards of storm bite hazard zone or to natural recession limit
Potential shoreline recession to 2100 (**S3** to 2100)	40 m landwards of storm bite hazard zone, or to natural recession limit	40 m landwards of storm bite hazard zone, or to natural recession limit	40 m landwards of storm bite hazard zone, or to natural recession limit	40 m landwards of storm bite hazard zone, or to natural recession limit
Unlikely to be susceptible	Landwards of recession to 2100 hazard zone or landwards of natural recession limit	Landwards of recession to 2100 hazard zone or landwards of natural recession limit	Landwards of recession to 2100 hazard zone or landwards of natural recession limit	Landwards of recession to 2100 hazard zone or landwards of natural recession limit

Figure 11: Clifton Beach in south-eastern Tasmania (Storm Bay region): a swell-exposed sandy beach backed by erodible sand dunes and sand deposits extending below present sea-level and hence potentially susceptible to shoreline erosion. Photo by C. Sharples

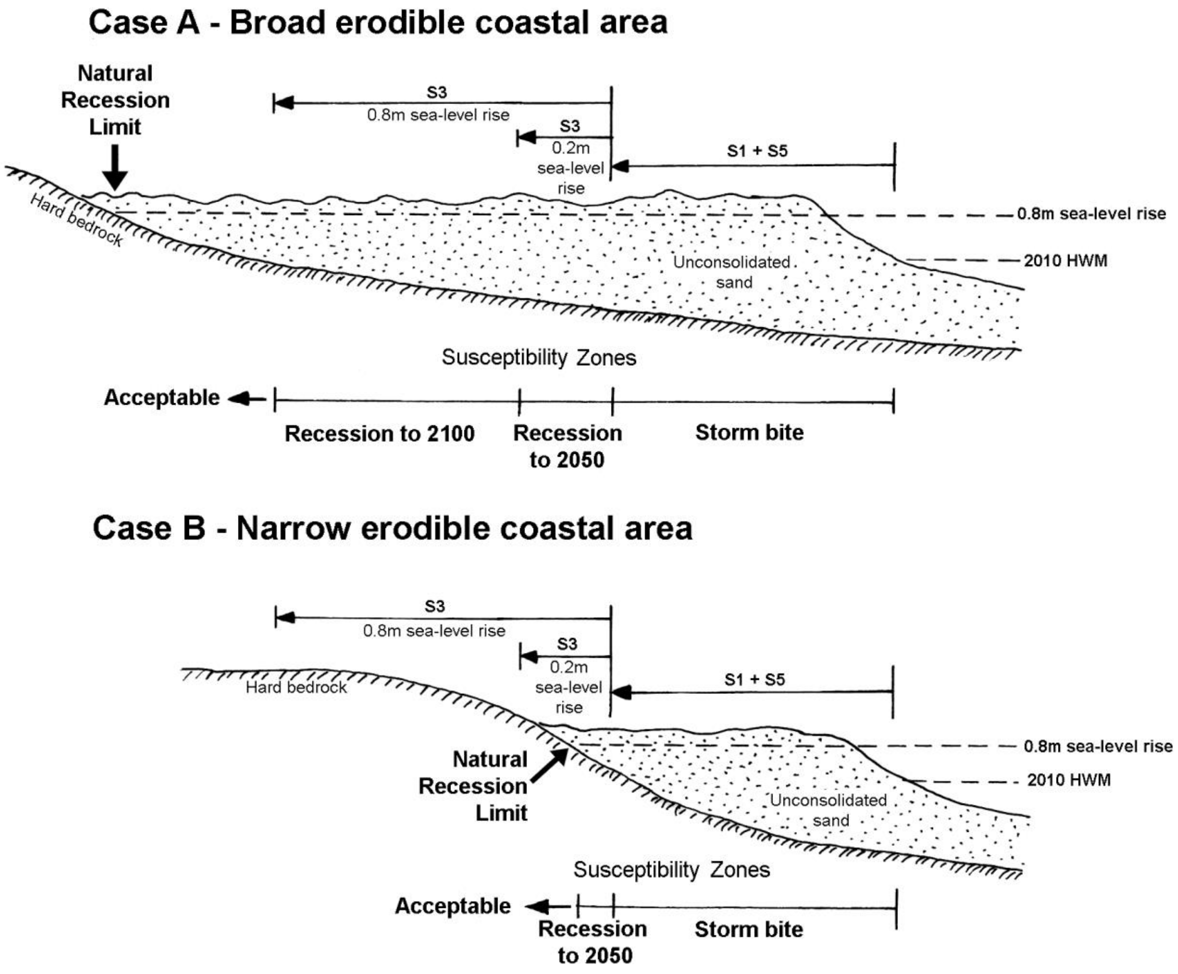


Figure 12: Diagram illustrating how coastal erosion susceptibility zones for Tasmanian swell-exposed (open coast) sandy beaches are defined. Distances for S1, S3 and S5 are provided in Table 3 above, and for (S1 + S5) these vary between different coastal zones as listed on Table 3. Coastal erosion hazards are 'Acceptable" (i.e., unlikely) to landwards of the Natural Recession Limit or the full extent of (S1 + S3 (0.8m SLR) + S5), whichever comes first (diagram illustrates an example of each case). 'HWM' is the mean High Water Mark.

Swell-sheltered sandy and other soft sediment shores

Using the available criteria as described above, coastal erosion susceptibility zones for Tasmanian swell-exposed sandy beaches are defined as outlined in Table 4 below.

Table 4: Definition of coastal erosion susceptibility zones for swell-sheltered (estuarine, tidal lagoon or channel) sandy or other soft sediment shores in Tasmania.

Erosion susceptibility	**Susceptibility zone width** (metres)	**Rationale**
Storm bite and consequent reduced foundation stability zone	22 m landwards from HWM, or to natural recession limit	Potential short term erosion hazard = 12 m (max. recorded sheltered sandy shore storm bite for Tasmania, at Five Mile Beach – see Table 13) + 10 m reduced stability zone (Mariani *et al*. 2012).
Potential shoreline recession to 2050	27 m landwards of storm bite hazard zone or to natural recession limit (i.e., to 49 m landwards of HWM or to natural recession limit)	Potential additional hazard to 2050 relative to 2010 = 0.34 m/yr. (maximum recorded long term sheltered soft sediment shore annual recession rate for Tasmania - Table 14) x 2 (allowance for acceleration of recession with ongoing sea-level rise) x 40 years (2010-2050).
Potential shoreline recession to 2100	61 m landwards of storm bite hazard zone or to natural recession limit (i.e., to 83 m landwards of HWM or to natural recession limit)	Potential additional recession hazard to 2100 relative to 2010 = 0.34 m/yr. (maximum recorded long term sheltered soft sediment shore annual recession rate for Tasmania - Table 14) x 2 (allowance for acceleration of recession with ongoing sea-level rise) x 90 years (2010-2100).
Unlikely to be susceptible	Landwards of recession to 2100 hazard zone or landwards of natural recession limit	Areas deemed to have negligible hazard of coastal erosion or recession before 2100.

Figure 13: An eroding swell-sheltered sandy shoreline in far northwestern Tasmania. This shoreline scarp in the Welcome River estuary is eroding into old Pleistocene wind-blown sand deposits. This location experiences Tasmania's largest tidal range of approximately 3 metres, but is fully sheltered from swell waves behind Robbins Island and Point Woolnorth. Photo by C. Sharples.

5.3 Soft rock coastal erosion susceptibility zoning

5.3.1 Use of available criteria

The available data and criteria that have been identified as having utility for defining coastal erosion susceptibility zones for soft rock coasts have been described in section 4.3. Drawing upon some of these, soft rock erosion susceptibility zones have been defined using mapping of the lateral extent of soft rock bodies, recorded (historical) soft rock shoreline recession rates, modelling of soft-rock shoreline behaviour under a rising sea, and a very simple distinction between two primary classes of differing soft rock types. The relevance of each of these to defining susceptibility zones is described below.

Mapping of maximum lateral extent of coastal soft rock bodies

The specialised soft-rock geological polygon map (*TasCoastSoftRock_v1_1_MGA.shp*; see Appendix A1.5) is the most fundamental layer used to define coastal soft rock recession hazards, since it defines the maximum or inferred maximum extent of erodible coastal soft rock bodies both alongshore and in the landwards direction (as described in section 3.2.1). This map layer therefore identifies the ultimate possible extent to which erosion and recession of soft rock bodies could conceivably extend under worst case scenarios, and thus is used to truncate any defined soft rock hazard zones that would otherwise extend further alongshore or inland[5].

Broad sub-categories of soft rock fabric

Whereas the majority of soft rock coastal bedrock types found in Tasmania comprise a wide range of generally sandy to gravelly or bouldery cohesive clay rocks that are mostly quite readily erodible, another distinctly different soft rock class is also found in a few Tasmanian shores (see section 4.3). These are very coarse boulder clays comprising very large hard rock boulders in a (soft, cohesive but readily erodible) clayey matrix. Although only recorded at a few coastal sites to date (parts of Taroona), these boulder clays respond very differently to most soft rocks, in that after initial wave action winnows out the soft clay matrix, the very coarse residual boulders are too large to be moved by local wave action and settle to form coarse hard rock revetment-like deposits that are comparable to sloping hard rock shores in their high resilience to further coastal erosion. This is an unusual case of a “self-armouring” soft rock shoreline. These soft rock types are differentiated using the soft rock polygon map described above.

For the purposes of coastal erosion susceptibility zoning, the susceptibility of the more common generic erodible sandy to gravelly or bouldery cohesive clayey soft rock types are zoned using other criteria identified below; however the coarse boulder clays are more simply zoned using a narrow buffer immediately landwards of the present High Water Mark (HWM) to indicate a low but not negligible hazard since some slumping and settling of the boulder clays immediately above HWM may occur as their clay matrix is winnowed out. A conservative width of 20 metres landwards of the present HWM line has been used for this buffer (see Table 5), to account for wave run-up capable of winnowing the clay matrix (and so causing settling) under a projected sea-level rise of 0.8m to 2100.

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[5] Note that ‘Natural Recession Limits’ mapping (see section 3.1.2) is only used to define potential erosion limits for soft *sediment* bodies where a rising underlying bedrock surface would prevent further shoreline recession. Since soft-rock bodies are also bedrock and generally extend to unknown depths below sea-level in the backshore, the full extent of the soft rock bodies is the relevant limiting factor in this case.

Historical data on measured soft rock recession rates

It is problematical to attempt to predict soft rock shoreline recession rates for Tasmania using data from other parts of the world, since such rates depend strongly on a range of local conditions including soft-rock type, local wave climates and tidal ranges, and other factors. Thus, although only limited data is yet available on shoreline recession rates for Tasmanian soft rock shores (Appendix 4) we nevertheless judged this to be the most pertinent data for defining erosion and susceptibility zones for Tasmanian soft rock shores and have used it as the primary criterion in defining erosion and recession susceptibility zones for the most common generic sandy to gravelly and bouldery cohesive clay soft rock types on the Tasmanian coast. It is intended that ongoing collection of more such data will allow refinement and improved confidence in the calculated setbacks over time.

Interpretation of historic air photo images of soft rock (cohesive clayey Tertiary-age sediment) shores at Rokeby Beach and Barilla Bay have demonstrated relatively constant retreat of these shores since around 1950, at rates varying from as low as 0.013 metres per year up to as high as 0.35 metres per year over the last 50 to 60 years (see Appendix 4). The variability in recession rates observed to date probably partly relates to variable sediment, scarp height and slope characteristics, but has also been significantly correlated with differing wind-wave exposure along different parts of these shorelines.

We have used the faster of these recorded recession rates (0.35m/year) as the basis for calculating erosion susceptibility zones for the dominantly cohesive clayey soft rock shores (see Table 50). This is a conservative or precautionary approach which allows for the limited data available at present and the fact that the shorelines whose recession have been measured to date are low-profile shores with scarp heights between 0.5m (Barilla Bay) and 4 – 5m high (Rokeby Beach). Without any historical data to date about recession rates of higher cliffed soft rock shores in Tasmania (e.g., Taroona, Parnella and Macquarie Harbour) there is some uncertainty as to the likely recession rates of shores such as these where large scale slumping will be a more important process, hence we have used the most conservative measured recession rates available. Ideally, it may be possible to define differing recession rates for differing soft rock shore types in future when more empirical data is available.

No differentiation has been made between recession rates for open coast and ‘sheltered’ soft rock shores since Tasmanian soft-rock shores are mainly found in swell-sheltered estuarine or re-entrant situations. The few examples of Tertiary-age soft rocks on swell-exposed shores are located on relatively sheltered parts of such shores (e.g., at Wynyard and Taroona), hence it serves little purpose to suggest a distinction between sheltered and ‘swell-exposed’ soft-rock shores since all are relatively sheltered. Higher energy swell-exposed shores where Tertiary soft-rock bedrock can be inferred to have once been exposed to wave erosion have long since been eroded to below sea-level and the shoreline mantled by sandy sediments, for example at Ocean Beach (western Tasmania) and Seven Mile Beach (SE Tasmania).

Soft rock recession rate acceleration allowance for sea-level rise

Modelling of soft rock recession processes by Trenhaile (2011) indicates that with a rise in sea-level, scarp and cliff recession rates in cohesive clay soft rock shores may be 1.5 to 2 times greater than under an equilibrium sea-level (see section 4.3). This is expected primarily because of reduced wave attenuation as water deepens over the near shore profile, allowing stronger wave attack (Trenhaile 2011). Although there is as yet insufficient data to determine whether there has yet been any acceleration of soft rock shoreline retreat rates on Tasmanian coasts in response to the sea-level rise that has occurred over the last century, the ongoing and projected acceleration in sea-level rise expected over the next century means that some acceleration of soft rock recession rates is likely over that period. We have accordingly applied a 2 times factor in calculating erosion and recession susceptibility zone widths for soft rock shores in accordance with Trenhaile's modelling (see Table 5).

Figure 14: An eroding soft rock (cohesive clay) shoreline at Rokeby Beach (Storm Bay region). This is a soft rock shoreline for which historic recession rate data is available from aerial photography. Photo by C. Sharples.

Figure 15: A "self-armoured" shoreline near Crayfish Point, Taroona. This rare shore type is produced when the soft clay matrix is weathered out of very coarse Tertiary-age boulder clays leaving boulders too big to be moved by local wave action, which settle in place to become a very resilient revetment-like shoreline. Photo by C. Sharples.

5.3.2 Definition of soft rock coastal erosion susceptibility zones

Table 5 below summarises the coastal erosion susceptibility zones defined for Tasmanian soft rock shores on the basis of the considerations outlined above.

Table 5: Definition of coastal erosion susceptibility zones for soft rock shores on the Tasmanian coast. Note that nearly all Tasmanian soft rock shores occur in swell-sheltered environments, albeit with widely differing local fetch wave exposure; hence no distinction between erosion susceptibility zones for soft rock are made on the basis of swell-exposure or sheltering.

Erosion susceptibility	**Dominantly cohesive clayey soft rock shore types** [susceptibility zone widths & rationales]	**Very coarse boulder clays ('self-armouring' shores)** [susceptibility zone widths & rationales]
Potential near-term recession (to 2030)	To 14 metres landwards of HWM or to full landwards extent of soft rock, whichever is less. [Maximum recorded historic recession rate of 0.35 metres per year for Tasmanian soft rock shores x 2 allowance (Trenhaile 2011) for acceleration with sea-level rise to 2030 compared to 2010]	n/a [Not considered to have significant near-term erosion susceptibility.]
Potential recession to 2050	To 28 metres landwards of HWM or to full landwards extent of soft rock, whichever is less. [Maximum recorded historic recession rate of 0.35 metres per year for Tasmanian soft rock shores x 2 allowance (Trenhaile 2011) for acceleration with sea-level rise to 2050 compared to 2010.]	n/a [Not considered to have significant erosion susceptibility to 2050.]
Potential recession to 2100	To 63 metres landwards of HWM or to full landwards extent of soft rock, whichever is less. [Maximum recorded historic recession rate of 0.35 metres per year for Tasmanian soft rock shores x 2 allowance (Trenhaile 2011) for acceleration with sea-level rise to 2100 compared to 2010]	To 20 metres landwards of HWM or to full landwards extent of very coarse boulder clays, whichever is less. [conservative low hazard zone for 'self-armouring' boulder clays (allowance for some settling and minor slumping during 'self-armouring' process in response to longer – term sea-level rise to 2100).]
Unlikely to be susceptible	Soft rock areas over 63 metres landwards of HWM, or areas beyond mapped landwards extent of soft rock. [Areas beyond maximum mapped soft rock extent OR soft rock areas landwards of areas potentially susceptible to recession to 2100 band.]	Beyond 20 metres landwards of HWM or beyond full landwards extent of very coarse boulder clays, whichever is less. [Based on assumption that self-armouring-process under credible sea-level rise scenarios will limit zone of settling related to wave-winnowing of clay matrix to less that arbitrarily-defined 20m landwards of HWM to 2100.]

Note that in contrast to soft sediment shores (Table 3 and Table 4); no 'storm bite' susceptibility zone has been defined for soft rock shores in Table 5, but rather a short-term recession zone (to 2030). This is because individual storm bites are generally small in soft rock compared to soft sediments, however the lack of shoreline recovery means that recession through repeated incremental storm bites is the dominant mode of shoreline retreat.

5.4 Hard rock coastal erosion susceptibility zoning

Hard rock shorelines have been identified and their alongshore extent determined using the Smartline map (*auscstgeo_tas_v1.shp* described in section 3.3.1; see also Appendix A1.2). Although hard rock shores are generally the most resistant to erosion, they have been divided into three sub-types which nonetheless represent some significantly differing susceptibilities to coastal erosion amongst these more resilient shores. The three sub-types have been identified from the Smartline map attributes and their differing susceptibilities are described and zoned as outlined below.

5.4.1 Use of available criteria

Hard rock erosion susceptibility zones for each of the three hard rock shoreline sub-types have been defined as follows (and as summarised in Table 6):

Gently to moderately sloping 'pure' hard bedrock shores

Gently to moderately-sloping hard rock shores backed by bedrock slopes, and without associated soft sediment deposits such as fronting sandy beaches, are considered to be the most robust and erosion-resistant Tasmanian shoreline type. Apart from minor superficial erosion of the seaward edges of backshore soils mantling the bedrock, these shores are expected to show little physical change (erosion) in response to sea-level rise on century time scales (albeit some development of shore platforms at higher levels may occur on millennial time scales). These shores are classed as having 'acceptable' (i.e., negligible) susceptibility to wave erosion and shoreline recession. No differentiation has been made between open coasts and 'sheltered' sloping hard rock shores since these are expected to be resilient in either coastal environment.

Since this shoreline type is considered to have acceptable (negligible) erosion susceptibility, no criteria are needed to define erosion susceptibility zones in this case. Nonetheless for cartographic purposes these shorelines have been mapped using 100 metre wide 'Acceptable' buffer polygons extending landwards from the cartographic High Water Mark.

Figure 16: A resilient hard rock moderately sloping shoreline. This shore (near Kingston Beach, southern Tasmania) comprises hard Permian-age marine siltstones. With future higher sea-levels, this shore may develop a new shore platform above present sea-level after several millennia of weathering; however visible physical changes due to sea-level rise will probably be negligible over human time scales. Photo by C. Sharples.

Sandy shores backed by gently to moderately sloping hard bedrock above sea-level

Sandy shores immediately backed by gently to moderately rising hard bedrock backshores above present sea-level are classed as resistant to shoreline recession but potentially susceptible to significant short-term storm-wave erosion. Because sand from beaches is readily transported landwards by wind, these shores are commonly (albeit not always) backed by windblown sands (including foredunes) overlying the backshore bedrock slopes. Although the rising bedrock backshores are expected to resist significant long-term progressive shoreline recession resulting from sea-level rise for at least the next century, these shores may nevertheless exhibit substantial short-term storm-wave erosion bites affecting the fronting beaches and any foredunes or other sands overlying the immediate backshore bedrock (see Figure 17). Infrastructure built too close to the shore on backshore sand mantles, or on the beaches themselves, may be at risk of damage from such erosion.

These shores have been identified from Smartline mapping, and for erosion susceptibility zoning purposes are classed as having negligible long-term recession susceptibility up to 2050 and 2100, but as being potentially susceptible to short-term erosional storm bites. Although in this case the beach and backshore sand sits on bedrock above sea-level, the erosion of those overlying sands during an individual storm is assumed to be governed by the same factors that would determine the erosion of any other sandy shore in the same coastal environment. Hence the (short term) storm bite erosion susceptibility zones defined for these shores (Table 6) are equivalent to those of ‘pure’ sandy shorelines exposed to the same wave climates (i.e., either open coast erosion susceptibility zones as per Table 3, or swell-sheltered coast zones as per Table 4). Storm bite erosion susceptibility zones for these shoreline types have been prepared as buffer polygons extending landwards from the HWM line.

Note that hard bedrock shores fronted by muddy or cobble sediments are not included in this category since notable quantities of these materials rarely overlie the bedrock backshores; in addition, hard rock steeply sloping or cliffed shores fronted by sandy or soft sediment intertidal fringes are included in the hard rock cliffed category (below) since their cliffed nature will dominantly govern their susceptibility to coastal erosion hazards.

Figure 17: Example of a sandy beach backed by gently rising hard bedrock (granite), at Tomahawk in NE Tasmania. Geological mapping indicates that the granite bedrock seen here outcropping on the beach rises gently in the backshore area, hence significant erosional shoreline recession from sea-level rise over the next century is not expected here since the granite bedrock is very resilient. However, although the bedrock behind the beach rises above present sea-level, it is also overlain by a mantle of windblown sand forming low dunes. Large storms could potentially erode this overlying sand mantle for tens of metres landwards, which would threaten any infrastructure built too close to this shore, even though long-term recession of the shoreline (HWM) is unlikely to be significant before 2100 because of the resistant underlying granite. Photo by Chris Sharples.

Steep to cliffed hard bedrock shores

Steep to cliffed hard rock shores generally owe their cliffed nature to faster rates of shoreline erosion and recession than occur on more moderately sloping hard rock shores (above). This typically occurs as a result of greater exposure to wave energies and/or higher prior landscape relief, although other processes may be responsible in some cases. For coastal erosion hazard zoning purposes, steeply sloping to cliffed hard rock shorelines are categorised separately to other hard rock coastal types (above) because of their greater susceptibility to rock falls, slumping and progressive cliff-line recession (or ‘regression’) than other hard rock shoreline types.

The preferred approach to cliff erosion susceptibility zoning is to base this on regression modelling as described in section 4.4 above. This modelling approach was experimented with during this project, and it was determined that useful results could be obtained where high resolution LIDAR – based Digital Elevation Modelling (DEM) is available, however results obtained using a medium-resolution 10 metre DEM (based on 5 and 10 metre LIST contours) failed to identify and model some quite significant coastal cliffs which are mapped in the Smartline coastal map (section 3.3.1). Since high resolution LIDAR DEMs are only available for parts of but not the entire Tasmanian coastline, it is evident that it will not be possible to consistently model coastal cliff regression zones for Tasmania until such data is available for the whole coast.

Consequently, a simpler interim precautionary approach has been adopted, which it is proposed should be reviewed and refined using regression modelling when adequate topographic data is available. The interim method adopted uses the Smartline map (section 3.3.1) to identify all Tasmanian hard rock coastal cliffs (defined as vertical rock faces higher than 5 metres: Sharples *et al.* 2009), and buffers all of these with an erosion and recession susceptibility polygon to 50 metres landwards of the cartographic High Water Mark (see Table 6). This buffer is intended to allow for both short-term slumping hazards and longer-term cliff regression to 2100. The same 50m buffer is applied to cliffs of any height since – in the absence of comprehensive digital modelling using a high resolution DEM – it would be difficult to manually determine the height of each cliff from available (1:25,000 scale 10m

Figure 18: A Hard rock coastal cliff at Alum Cliffs between Taroona and Kingston in south-eastern Tasmania, showing a recent rock-fall. Photo by C. Sharples.

contour) map data, and apply a proportional buffer size accordingly. In addition no differentiation has been made between open coast and 'sheltered' steep to cliffed hard rock shores since in the absence of any measured erosion and recession rates for Tasmanian coastal cliffs there is insufficient data to assume differing cliff regression rates between these coastal environments.

In the absence of more detailed cliff regression modelling, a uniform 50m hazard buffer was settled on as the best available precautionary hazard zone for hard rock sea-cliffs. This captures the scale of most (albeit not all) sea-cliff or coastal slope instability observed in Tasmania (see section 4.4). Moreover since the majority of Tasmanian coastal cliffs are less than 50 metres high, in these cases a simple 50m buffer provides a buffer equivalent to or wider than the 45° cliff regression angle previously assumed for coastal cliff hazard zones in NSW (Patterson Britton 2005; see section 4.4), yet is not an unreasonably large precautionary zone behind smaller cliffs. The same buffer width is also considered to provide adequate precautionary hazard zones for cliffs higher than 50 metres, since it is generally the case that higher cliffs have only developed where more resilient or coherent bedrock has allowed higher cliff faces to persist. Thus it is unlikely these higher cliffs would actually slump on a 45° angle from their base, but rather smaller individual block falls are probably the dominant mode of cliff regression in these cases.

5.4.2 Definition of hard rock coastal erosion susceptibility zones

Table 6 below summarises the coastal erosion susceptibility zones defined for Tasmanian hard rock shores on the basis of the considerations outlined above.

Table 6: Definition of coastal erosion susceptibility zones for hard rock shores on the Tasmanian coast.

	Susceptibility zone widths (m) [and rationales]		
Hard rock shore category **Erosion susceptibility**	**Gently to moderately sloping 'pure' hard rock shores**	**Sandy shores immediately backed by sloping hard bedrock backshores above sea-level**	**Steep to cliffed hard bedrock shores**
Storm bite and consequent reduced foundation stability zone	n/a	If swell-exposed: storm bite & reduced stability (S1 + S5) allowance as for sandy shores in same coastal region (Table 3); If swell-sheltered: 22m landwards of HWM as for swell-sheltered sandy shores (Table 4).	50m to landwards of HWM
Potential shoreline recession to 2050	n/a	n/a	50m to landwards of HWM
Potential shoreline recession to 2100	n/a	n/a	50m to landwards of HWM
Unlikely to be susceptible	All areas from HWM landwards [erosion hazards with or without sea-level rise probably negligible over human time frames]. Note: 'Acceptable' buffer polygons to 100m landwards of HWM created for cartographic purposes.	All areas landwards of storm bite and consequent reduced foundation stability zone [erosion bites comparable to other sandy shores may occur in dune sands over bedrock behind HWM, but recession unlikely due to rising hard bedrock under dunes]	All areas landwards of a line 50m landwards of HWM

5.5 Erosion susceptibility zoning for artificially protected shores

5.5.1 Use of available criteria

Section 4.5 above described the data on artificial shorelines that has been used to inform the zoning of the Tasmanian coast into erosion susceptibility zones, namely the Smartline coastal mapping data (Sharples *et al.* 2009; see Appendix A1.2).

The artificial shoreline data has informed the definition of coastal erosion hazard bands via the following procedure:

1. All Tasmanian coastline segments with artificial components recorded in the Smartline coastal geomorphic map were selected via an attribute query on *Intertidal* or *Backshore proximal* artificial structures (see Sharples *et al.* 2009).

2. These artificial shores were classified into two categories on the basis of expected structure resilience as follows:

    i. **Resilient** (likely to resist coastal erosion for more than 10 years; and/or to be maintained and repaired as necessary to continue resisting erosion); or
    ii. **Non-resilient** (unlikely to resist coastal erosion for 10 years; and/or no clear commitment to be maintained and repaired; or unknown).

    Structures were classified as resilient (likely to resist coastal erosion for more than 10 years) on the basis of:

    i. Known structural performance to date, where suitable information is available (including Smartline attributes indicative of high resilience); or
    ii. All those in existing urban or industrial areas (regardless of current condition): it is assumed these will be repaired and maintained as necessary.

    It is assumed that structures sufficiently well-constructed as to be expected to resist erosion for more than 10 years are of sufficient importance that they can be expected to be repaired as necessary for their long-term maintenance, and hence to be resilient for as long into the future as protection may be actively required.

3. Where an artificial structure classified as resilient has been mapped along the seawards margin of an erodible shoreline, the erosion susceptibility bands that would be delineated in the absence of artificial protection (as described in sections 5.2 - 5.4 above) are modified as follows (see also Figure 21):

    i. Erosion susceptibility or hazard is classified as ‘Low’ for the short-term storm bite zone that would otherwise have applied in the absence of artificial protection, on the grounds that if the protection were to fail, it would immediately be susceptible to erosion as per the susceptibility of the underlying material;

    and:

    ii. Erosion susceptibility or hazard is classified as ‘Acceptable’ to the full landwards extent of the longer-term shoreline recession zones that would otherwise be defined, on the grounds that the presence of artificial protection stops recession occurring;

and:

Figure 19: A resilient artificial shoreline at Cornelian Bay, Hobart. This coastal open space is a highly valued asset in Hobart and thus the artificial shoreline seen here can be expected to be maintained. This is demonstrated by the fact that this robust coastal protection structure was constructed to stop relatively rapid erosion of this shoreline, and in part replaced an earlier coastal protection structure that was failing (see Figure 20). Photo by C. Sharples (2013).

Figure 20: A non-resilient artificial shore. This short stretch of inadequate ‘armoured’ shoreline at Cornelian Bay in 2002 had failed to perform properly and was backed by an erosion scarp progressing landwards behind it! However because of a commitment to protect the shore, this under-performing artificial shoreline was later replaced with the much more resilient artificial shore shown in Figure 19 above. Photo by C. Sharples (2002).

iii. The boundary between erosion hazard bands defined behind a natural and an artificially-protected shore is a straight line extending landwards perpendicularly to the coast from the end(s) of the artificial protection.

4. Where a structure is classified as unlikely to resist coastal erosion for ten years, hazard bands are defined purely on the natural characteristics of the shore (as described in sections 5.2 - 5.4 above), as though no artificial structures were present.

5.5.2 Definition of artificial shoreline erosion hazard zones

Table 7 below summarises the coastal erosion susceptibility zones defined for artificially protected Tasmanian shores on the basis of the considerations outlined above.

Table 7: Definition of coastal erosion susceptibility zones for artificially protected shores on the Tasmanian coast.

	Susceptibility zone widths (m) [and rationales]	
Erosion susceptibility \ **Artificial shoreline type**	**Resilient artificial shore** (life >10 years) [erosion hazard zoned ‘acceptable’ or ‘low’ to the distances the shore would otherwise have been zoned susceptible to erosion]	**Non-resilient artificial shoreline** (life <10 years) or unknown quality artificial shores [treated as per natural substrate category, i.e., as if artificial shoreline absent]
Storm bite and consequent reduced foundation stability zone	Low hazard (Considered as probably resilient to short term storm hazards given the assumption that current protection is of adequate structural quality, but susceptible if the protection should fail)	To landwards distance defined for backing substrate without protection (as defined in Sections 4.2 – 4.4)
Potential shoreline recession to 2050	Acceptable (Not susceptible to recession because the artificial protection reduces the susceptibility to long term recession provided the protection remains intact)	To landwards distance defined for backing substrate without protection (as defined in Sections 4.2 – 4.4)
Potential shoreline recession to 2100	Acceptable (Not susceptible to recession because the artificial protection reduces the susceptibility to long term recession provided the protection remains intact)	To landwards distance defined for backing substrate without protection (as defined in Sections 4.2 – 4.4)
Acceptable	Landwards from maximum area that would have been zoned susceptible to erosion in the absence of artificial protection.	Landwards from maximum distance defined as susceptible to erosion in the absence of artificial protection.

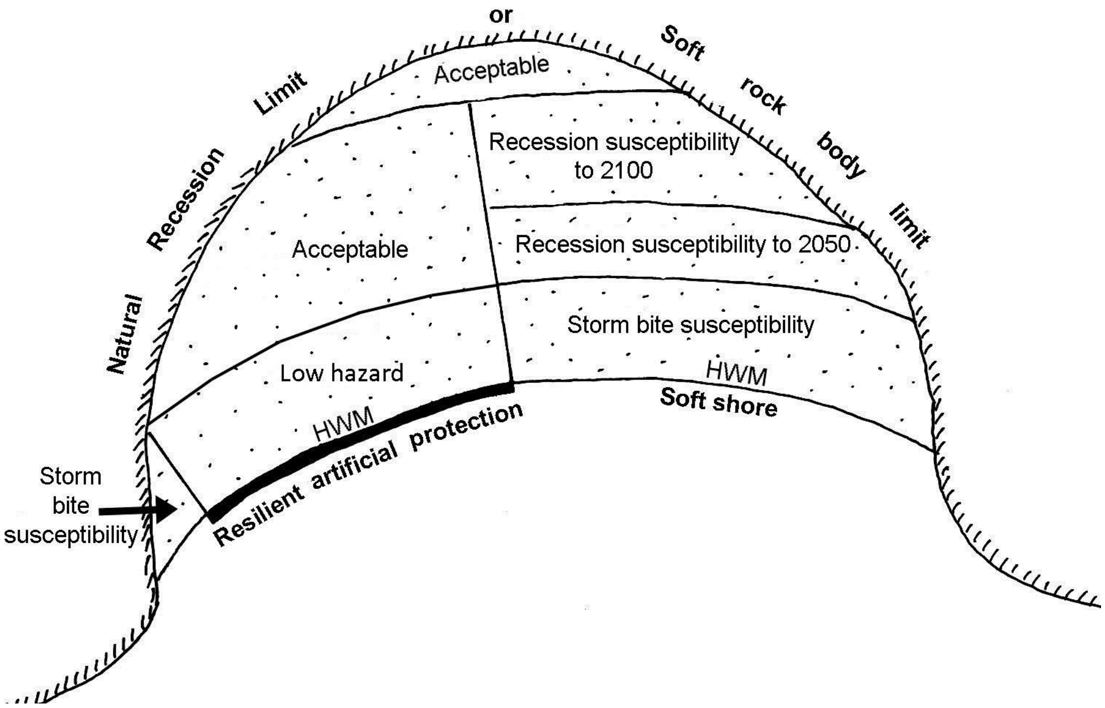

Figure 21: Diagrammatic illustration of the definition of erosion susceptibility zones for a section of erodible coast protected by an resilient artificial structure (see also text). 'HWM' = cartographic High Water Mark.

6.0 Final coastal erosion susceptibility zone components for hazard band definition

Previous sections of this report have described the definition of erosion hazard zones as adopted for the three broadly defined coastal substrate types (soft sediments, soft rock and hard rock), as well as artificial shorelines. However, to develop an integrated coastal erosion susceptibility map each of the zoning schemes need to be merged into a single hazard susceptibility scheme which incorporates an assessment of the relative hazards posed by the various hazard zones within each substrate type. This has been done by means of a pairwise assessment.

A pairwise assessment is a tool to support decision-making by assisting non-technical experts to understand the relative susceptibility of each coastal erosion hazard component (Hansen and Ombler 2009). The pairwise assessment delivers two outcomes:

- It translates the expert knowledge on coastal hazards to policy makers. The expert knowledge includes an understanding of the components that make up coastal erosion on the Tasmanian coastline, confidence in the spatial and attribute accuracy, and the expert opinion on the 'likelihood' that the erosion may occur in this area and its scale/magnitude.

- It provides an order of importance for the merging of the components into a single planning layer, ensuring that a less important component does not overwrite a more important feature.

The coastal erosion hazard zone components are the distinctive zones of differing susceptibility (or potential susceptibility) to coastal erosion that can be defined using the criteria applied in section 5.0 above. On this basis, the following hazard zone 'components' were defined for Tasmanian coasts (Table 8):

Table 8: Coastal erosion susceptibility zone components for Tasmanian coasts.

Susceptible soft sediment shoreline zones – open (swell-exposed) shores *(Differing-width zones for the 4 hydraulic zones cartographically combined in each component).* See Table 3 for details
Storm bite (S1 + S5) High hazard zone (open coast soft sed. shore) – to likely natural recession limit
Storm bite (S1 + S5) High hazard zone (open coast soft sed. shore) – to possible natural recession limit
Recession (S3) to 2050 Med hazard zone (open coast soft sed. shore) – to likely natural recession limit
Recession (S3) to 2050 Med hazard zone (open coast soft sed. shore) – to possible natural recession limit
Recession (S3) to 2100 Low hazard zone (open coast soft sed. shore) – to likely natural recession limit
Recession (S3) to 2100 Low hazard zone (open coast soft sed. shore) – to possible natural recession limit
Susceptible soft sediment shoreline zones – swell-sheltered shores See Table 4 for details
Storm bite (S1 + S5) High hazard zone (sheltered soft sed. shore) – to likely natural recession limit
Storm bite (S1 + S5) High hazard zone (sheltered soft sed. shore) – to possible natural recession

limit
Recession (S3) to 2050 Med hazard zone (sheltered soft sed. shore) – to likely natural recession limit
Recession (S3) to 2050 Med hazard zone (sheltered soft sed. shore) – to possible natural recession limit
Recession (S3) to 2100 Low hazard zone (sheltered soft sed. shore) – to likely natural recession limit
Recession (S3) to 2100 Low hazard zone (sheltered soft sed. shore) – to possible natural recession limit
Acceptable soft sediment shoreline zones – all (swell-exposed and sheltered) 'acceptable' zones As defined by Table 3 & Table 4
Acceptable zone (all soft sed. shores) – to likely natural recession limit
Acceptable zone (all soft sed. shores) – to possible natural recession limit
Acceptable zone (all soft sed. shores) – landwards of likely and possible natural recession limits
Soft Rock Shorelines See Table 5 for details
Near-term potential recession hazard zone (normal soft rocks) – High hazard zone 14m to 2030
Medium-term potential recession hazard zone (normal soft rocks) –Med hazard zone 28m to 2050
Longer-term potential recession hazard zone (normal soft rocks) – Low hazard zone 63m to 2100
Longer-term potential settling & slumping hazard (very coarse boulder clay soft rocks) – 20m
Acceptable zone (normal soft rocks)
Acceptable zone (very coarse boulder clay soft rocks)
Hard Rock Shorelines See Table 6 for details
Acceptable zone (all gently to moderately sloping 'pure' hard rock shores)
Storm bite (S1 + S5) hazard zone for exposed sandy shores backed by moderately rising hard bedrock) *(Differing-width zones for the 4 hydraulic zones cartographically combined).*
Storm bite (S1 + S5) hazard zone for sheltered sandy shores backed by moderately rising hard bedrock)
(Acceptable zones landwards of Storm Bite (S1-S5) hazard zones for sandy shores backed by bedrock were assumed but not mapped as separate polygons)
Regression & slump hazard zone (steep to cliffed hard rock shores) *(standard precautionary 50m buffer used in all cases)*
(Acceptable zones landwards of hazard zone for steep to cliffed hard rock shores were assumed but not mapped as separate polygons)
Artificial Shorelines See Table 7 for details
Acceptable zone landwards of resilient artificial shores *(defined as acceptable hazard to the landwards extent that any (non-acceptable) hazard zones would be defined for the shoreline type present in the absence of resilient artificial protection)*
(non-resilient artificial shores ignored; zoned according to the natural shoreline type in the absence of artificial protection)

Pairwise assessment of the coastal erosion hazard zone components listed in Table 8 above was undertaken jointly by Chris Sharples and Luke Roberts. The results are provided in Table 9 below. Each component is listed on both the horizontal and vertical axes of the table. Considering each column versus each row in turn, the question was asked: "Which (of each column vs. row pair) is more susceptible to coastal erosion?" Depending on the answer agreed, the intersecting column vs. row cell was scored as follows, a value of 1,000 was given to the component that was 'more susceptible' and one was given to the component that was 'less susceptible'. A value of 100 was given to both components if they were considered equally susceptible. The pairwise assessment is shown in Table 9. The scores for each column were summed to give total scores for each component giving a hierarchy of susceptibility shown in Figure 22 and Table 10 below.

Table 9: Pairwise assessment of coastal erosion susceptibility zone components, with total scores for each (row) category shown at bottom.

N = Column category not as susceptible as row category(1)
Y= Column category more susceptible than row category (1000)
"=" Column category as susceptible as row category (100)

Basis for pairwise assessment decisions: Basic question is "Which (of a pair) is more susceptible to coastal erosion?" (assessment of column vs. row)	Storm bite (S1 + S5) High hazard zone (open coast soft sed. shore) – to likely natural recession limit	Storm bite (S1 + S5) High hazard zone (open coast soft sed. shore) – to possible natural recession limit	Recession (S3) to 2050 Med hazard zone (open coast soft sed. shore) – to likely natural recession limit	Recession (S3) to 2050 Med hazard zone (open coast soft sed. shore) – to possible natural recession limit	Recession (S3) to 2100 Low hazard zone (open coast soft sed. shore) – to likely natural recession limit	Recession (S3) to 2100 Low hazard zone (open coast soft sed. shore) – to possible natural recession limit	Storm bite (S1 + S5) High hazard zone (sheltered soft sed. shore) – to likely natural recession limit	Storm bite (S1 + S5) High hazard zone (sheltered soft sed. shore) – to possible natural recession limit	Recession (S3) to 2050 Med hazard zone (sheltered soft sed. shore) – to likely natural recession limit	Recession (S3) to 2050 Med hazard zone (sheltered soft sed. shore) – to possible natural recession limit	Recession (S3) to 2100 Low hazard zone (sheltered soft sed. shore) – to likely natural recession limit	Recession (S3) to 2100 Low hazard zone (sheltered soft sed. shore) – to possible natural recession limit	Acceptable hazard zone (all soft sed. shores) – to likely natural recession limit	Acceptable hazard zone (all soft sed. shores) – to possible natural recession limit	Acceptable hazard zone (all soft sed. shores) – landwards of likely and possible natural recession limits	Near-term potential recession hazard zone (normal soft rocks) – High haz zone 14m to 2030	Medium-term potential recession hazard zone (normal soft rocks) –Med haz zone 28m to 2050	Longer-term potential recession hazard zone (normal soft rocks) – Low haz zone 63m to 2100	Longer-term potential settling & slumping hazard (very coarse boulder clay soft rocks) – 20m	Acceptable hazard zone (normal soft rocks)	Acceptable hazard zone (very coarse boulder clay soft rocks)	Acceptable hazard zone (all gently to moderately sloping 'pure' hard rock shores)	Storm bite (S1 + S5) hazard zone for exposed shores (soft sed. shores backed by moderately rising hard bedrock)	Storm bite (S1 + S5) hazard zone for sheltered shores (soft sed. shores backed by moderately rising hard bedrock)	Regression & slump hazard zone (steep to cliffed hard rocks)	Resilient artificial shores	Non-Resilient artificial shores
Storm bite (S1 + S5) High hazard zone (open coast soft sed. shore) – to likely natural recession limit		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100	1	1	1	cant assess
Storm bite (S1 + S5) High hazard zone (open coast soft sed. shore) – to possible natural recession limit	1000		1	1	1	1	1000	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1000	100	1	1	cant assess
Recession (S3) to 2050 Med hazard zone (open coast soft sed. shore) – to likely natural recession limit	1000	1000		1	1	1	1000	1000	100	1	1	1	1	1	1	100	1	1	1	1	1	1	1000	1000	1	1	cant assess
Recession (S3) to 2050 Med hazard zone (open coast soft sed. shore) – to possible natural recession limit	1000	1000	1000		1	1	1000	1000	100	1	1	1	1	1	1	1000	100	1	1	1	1	1	1000	1000	1	1	cant assess
Recession (S3) to 2100 Low hazard zone (open coast soft sed. shore) – to likely natural recession limit	1000	1000	1000	1000		1	1000	1000	1000	100	1	1	1	1	1	1000	1000	1	1	1	1	1	1000	1000	1	1	cant assess
Recession (S3) to 2100 Low hazard zone (open coast soft sed. shore) – to possible natural recession limit	1000	1000	1000	1000	1000		1000	1000	1000	1000	100	1	1	1	1	1000	1000	100	1	1	1	1	1000	1000	100	1	cant assess
Storm bite (S1 + S5) High hazard zone (sheltered soft sed. shore) – to likely natural recession limit	1000	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1000	100	1	1	cant assess
Storm bite (S1 + S5) High hazard zone (sheltered soft sed. shore) – to possible natural recession limit	1000	1000	1	1	1	1	1000		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1000	1	1	1	cant assess
Recession (S3) to 2050 Med hazard zone (sheltered soft sed. shore) – to likely natural recession limit	1000	1000	100	100	1	1	1000	1000		1	1	1	1	1	1	1000	100	1	1	1	1	1	1000	1000	1	1	cant assess
Recession (S3) to 2050 Med hazard zone (sheltered soft sed. shore) – to possible natural recession limit	1000	1000	1000	1000	100	1	1000	1000	1000		100	1	1	1	1	1000	100	1	1	1	1	1	1000	1000	1	1	cant assess
Recession (S3) to 2100 Low hazard zone (sheltered soft sed. shore) – to likely natural recession limit	1000	1000	1000	1000	1000	100	1000	1000	1000	100		1	1	1	1	1000	1000	100	1	1	1	1	1000	1000	1	1	cant assess
Recession (S3) to 2100 Low hazard zone (sheltered soft sed. shore) – to possible natural recession limit	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000		1	1	1	1000	1000	1000	100	1	1	1	1000	1000	100	1	cant assess
Acceptable hazard zone (all soft sed. shores) – to likely natural recession limit	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000		1	1	1000	1000	1000	100	1	1	1	1000	1000	1000	100	cant assess
Acceptable hazard zone (all soft sed. shores) – to possible natural recession limit	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000		1	1000	1000	1000	1000	1	1	1	1000	1000	1000	1000	cant assess
Acceptable hazard zone (all soft sed. shores) – landwards of likely and possible natural recession limits	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000		1000	1000	1000	1000	1	1	1	1000	1000	1000	1000	cant assess
Near-term potential recession hazard zone (normal soft rocks) – High haz zone 14m to 2030	1000	1000	100	1	1	1	1000	1000	1	1	1	1	1	1	1		1	1	1	1	1	1	1000	1000	1	1	cant assess
Medium-term potential recession hazard zone (normal soft rocks) –Med haz zone 28m to 2050	1000	1000	1000	100	1	1	1000	1000	100	100	1	1	1	1	1	1000		1	1	1	1	1	1000	1000	1	1	cant assess
Longer-term potential recession hazard zone (normal soft rocks) – Low haz zone 63m to 2100	1000	1000	1000	1000	1000	100	1000	1000	1000	1000	100	1	1	1	1	1000	1000		100	1	1	1	1000	1000	100	100	cant assess
Longer-term potential settling & slumping hazard (very coarse boulder clay soft rocks) – 20m	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	100	100	1	1	1000	1000	100		1	1	1	1000	1000	100	100	cant assess
Acceptable hazard zone (normal soft rocks)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000		1	1	1000	1000	1000	1000	cant assess
Acceptable hazard zone (very coarse boulder clay soft rocks)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000		1	1000	1000	1000	1000	cant assess
Acceptable hazard zone (all gently to moderately sloping 'pure' hard rock shores)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000		1000	1000	1000	1000	cant assess
Storm bite (S1 + S5) hazard zone for exposed shores (soft sed. shores backed by moderately rising hard bedrock)	100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	cant assess
Storm bite (S1 + S5) hazard zone for sheltered shores (soft sed. shores backed by moderately rising hard bedrock)	1000	100	1	1	1	1	100	1000	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1000		1	1	cant assess
Regression & slump hazard zone (steep to cliffed hard rocks)	1000	1000	1000	1000	1000	100	1000	1000	1000	1000	1000	100	1	1	1	1000	1000	100	100	1	1	1	1000	1000		1	cant assess
Resilient artificial shores	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	100	1	1	1000	1000	100	100	1	1	1	1000	1000	1000		cant assess
Non-Resilient artificial shores	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	cant assess	
(ROW CATEGORIES ABOVE)																											
Total	24100	21102	17205	15207	13110	9312	22101	21003	15306	12309	10311	7215	5217	4020	3021	18105	14307	7512	5514	2022	1023	24	24000	20202	7413	5316	

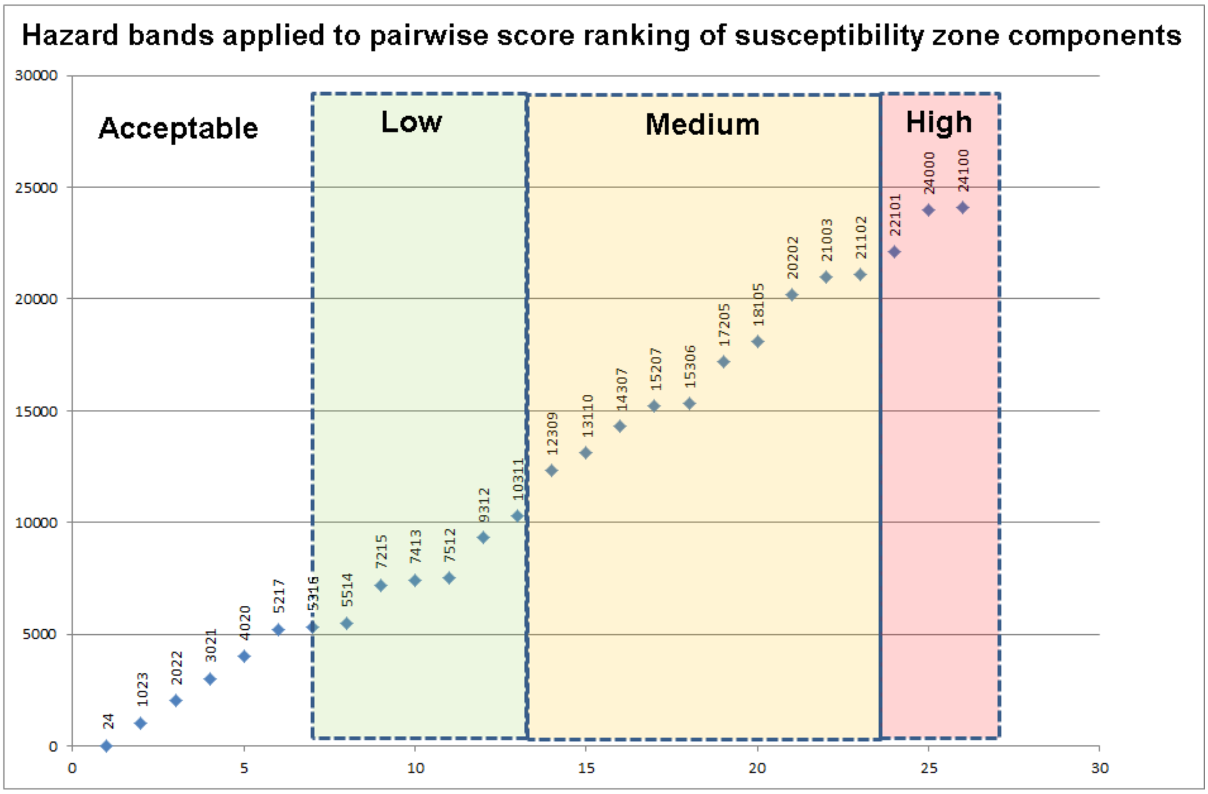

Figure 22: Coastal erosion component pairwise assessment scores charted in order of lesser to greater scores left – right. High, medium and low hazard bands, and acceptable hazard bands, are definable from natural breaks between clusters of components. Note resilient artificial shores (score 5316) fall into the low hazard band for storm bite erosion and the acceptable band for all other recession (see Section 5.5.1 for explanation). The components are labelled by their pairwise scores (see Table 9) on this chart.

Table 10: Coastal erosion hazard components ordered from most acceptable (lowest susceptibility, lowest pairwise scores) to most susceptible to erosion (highest pairwise scores). Note resilient artificial shores (score 5316) fall into the low hazard band for storm bite erosion and the acceptable band for all other recession (see Section 5.5.1 for explanation). Cells are coloured according to the equivalent hazard bands indicated in Figure 22 above.

Coastal erosion hazard zone component	**Pairwise assessment score**
Acceptable hazard zone (all gently to moderately sloping 'pure' hard rock shores)	24
Acceptable hazard zone (very coarse boulder clay soft rocks)	1023
Acceptable hazard zone (normal soft rocks)	2022
Acceptable hazard zone (all soft sed. shores) – landwards of likely and possible natural recession limits	3021
Acceptable hazard zone (all soft sed. shores) – to possible natural recession limit	4020
Acceptable hazard zone (all soft sed. shores) – to likely natural recession limit	5217
Resilient artificial shores (Acceptable recession zones landwards of resilient artificial shores)	5316
Resilient artificial shores (Low hazard storm bite zone landwards of resilient artificial shores)	5316
Longer-term potential settling & slumping hazard (very coarse boulder clay soft rocks) – 20m	5514
Recession (S3) to 2100 Low hazard zone (sheltered soft sed. shore) – to possible natural recession limit	7215
Regression & slump hazard zone (steep to cliffed hard rocks)	7413

Longer-term potential recession hazard zone (normal soft rocks) – Low hazard zone 63m to 2100	7512
Recession (S3) to 2100 Low hazard zone (open coast soft sed. shore) – to possible natural recession limit	9312
Recession (S3) to 2100 Low hazard zone (sheltered soft sed. shore) – to likely natural recession limit	10311
Recession (S3) to 2050 Med hazard zone (sheltered soft sed. shore) – to possible natural recession limit	12309
Recession (S3) to 2100 Low hazard zone (open coast soft sed. shore) – to likely natural recession limit	13110
Medium-term potential recession hazard zone (normal soft rocks) –Med hazard zone 28m to 2050	14307
Recession (S3) to 2050 Med hazard zone (open coast soft sed. shore) – to possible natural recession limit	15207
Recession (S3) to 2050 Med hazard zone (sheltered soft sed. shore) – to likely natural recession limit	15306
Recession (S3) to 2050 Med hazard zone (open coast soft sed. shore) – to likely natural recession limit	17205
Near-term potential recession hazard zone (normal soft rocks) – High hazard zone 14m to 2030	18105
Storm bite (S1 + S5) hazard zone for sheltered shores (sandy shores backed by moderately rising hard bedrock)	20202
Storm bite (S1 + S5) High hazard zone (sheltered soft sed. shore) – to possible natural recession limit	21003
Storm bite (S1 + S5) High hazard zone (open coast soft sed. shore) – to possible natural recession limit	21102
Storm bite (S1 + S5) High hazard zone (sheltered soft sed. shore) – to likely natural recession limit	22101
Storm bite (S1 + S5) hazard zone for exposed shores (sandy shores backed by moderately rising hard bedrock)	24000
Storm bite (S1 + S5) High hazard zone (open coast soft sed. shore) – to likely natural recession limit	24100
Non-Resilient artificial shores (ignored)	

Following the completion of the pairwise assessment the components were merged together based on their order, to produce a coastal erosion hazard band map. An extract of the mapping is shown in Figure 23.

The final hazard banding mapping produced by merging (or strictly, unioning) these susceptibility zone components is provided as a shapefile:

tascoasterosionhazardbands_v1_2013_MGA.shp

Metadata and a data dictionary for this mapping are provided in Appendix A1.1

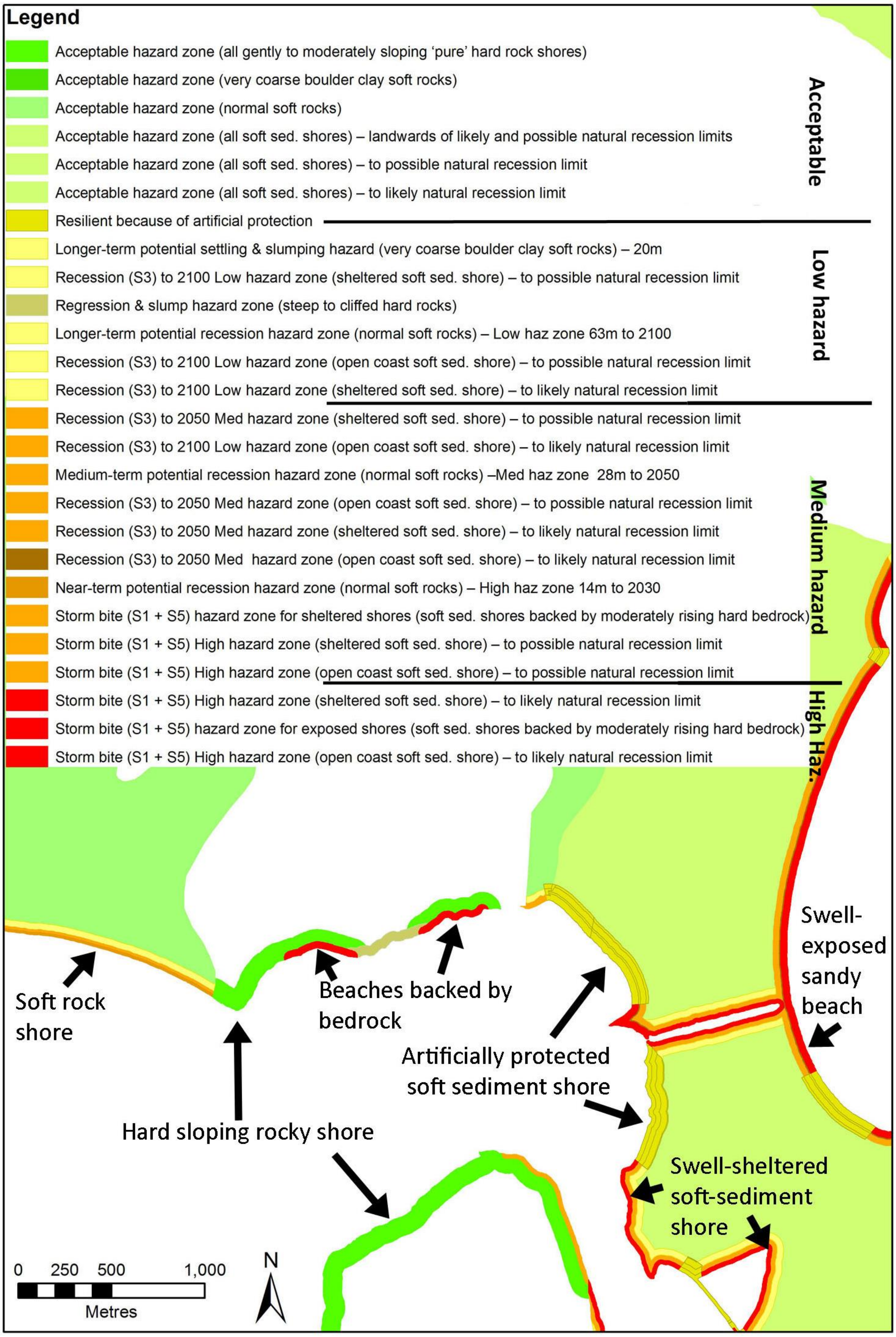

Figure 23: Example of the final coastal erosion hazard band mapping (Ralphs Bay – Lauderdale area), produced by unioning erosion susceptibility zones in an order of priority determined by pairwise assessment of all susceptibility zone components against all others. Individual susceptibility zone components (listed in legend) are colour-coded into the four hazard bands (here: Acceptable = green; Low hazard = yellow; Medium hazard = brown/orange; High hazard = red). Note that full landwards extent of soft sediment and soft-rock bodies is mapped and banded "Acceptable" to landwards of hazard zones; uncoloured land is hard bedrock which is all Acceptable hazard but only colour-coded in a nominal coastal strip.

7.0 Coastal erosion investigation areas

7.1 Introduction

Because of inherent limitations in the underlying datasets, the final hazard band mapping that was produced as described in Section 6.0 above is known to contain some errors. Portions of the hazard band mapping identified as containing errors or uncertainties have been assigned to 'Coastal erosion investigation areas' to be further investigated and the problems resolved as opportunity allows so that appropriate hazard bands may be assigned. This section describes the identification of the coastal erosion investigation areas.

The coastal erosion investigation areas represent some of the areas of uncertainty within the underlying geomorphology and coastal attribution. While the coastal erosion investigation areas represent identifiable errors within the underlying data that include incomplete data or have a logical inconsistency within the data set, it does not however include areas with inaccurate underlying data that could only be identified with extensive field work or local knowledge.

As a basis for the creation of the coastal erosion investigation area the following assumptions were adopted for the purpose of testing the coastal erosion hazard areas for errors and inconsistencies:

- All parts of the coast have been classified into a hazard component and coastal erosion hazard band (hazard band) including high, medium, low, coastal erosion investigation area, or acceptable. The hazard bands have been supplied by the Department of Premier and Cabinet as an output of the Coastal Hazards Planning Report (in draft).
- Not all hazard components will intersect with the coast line (some are present only landwards of the coast line).
- The coastline for the purposes of this hazard banding is the cartographic LIST High Water Mark line, which is based on cartographic interpretation of air photos and may not be correct in all locations.
- Temporal and some spatial / attribute errors cannot be validated through this process and should be reviewed in a local context.
- Coastal erosion hazard banding is based on the project data set *tascoasterosionhazardbands_v1_2013_MGA.shp*.
- Higher hazard bands should not occur landwards of lower hazard bands (such situations may be validly based on accurate base data, for example where soft Tertiary clays overlie a hard rock shoreline just landwards of the shore; however in such cases the Tertiary clays are effectively protected from marine erosion and thus are not actually at higher risk of erosion than the hard shore).

A process of testing for inconsistency with these assumptions was undertaken as described following, which resulted in inconsistent areas being reclassified as 'coastal erosion investigation areas' for further assessment. Finally, a manual inspection of the resulting hazard band mapping was undertaken by Chris Sharples to further test for logical consistency and geomorphic accuracy; as a result a number of further errors or logical inconsistencies were identified and either corrected where possible or else assigned as further 'Coastal erosion investigation areas' for later work to resolve them.

The final hazard banding with ‘coastal erosion investigation areas’ identified has been prepared as a shapefile Coastal_Erosion_Hazard_Map_V1.shp

7.2 Defining the coastal erosion investigation areas

The coastal erosion investigation areas are defined by the uncertainty within the underlying data sets. Table 11 outlines the uncertainty by reviewing the errors being checked for and the method used to identify the areas for inclusion in the coastal erosion investigation area. Appendix 5 outlines further details of methods and supporting processes used to identify and resolve errors.

For the errors able to be tested (for logical consistency and incomplete data) either visual assessment has been used to test for errors, or queries based on location and attribute type have been used. Each of the assessment processes have been outlined within Table 11 following.

Table 11: Data errors and method of testing

Error	**Comment**	**Method of testing**
Incomplete data		
Voids in the data set	These are blank areas in the base data that have no classification as a component or as a hazard band, due to incomplete base data.	The test region[6] was intersected with the base hazard banding; any area without attribution was considered a void. Further checks included: • Spatial query to identify all voids within 0.5m of the Smartline. Unclassified areas connected to the coast were included in the identified coastal erosion investigation areas. Appendix 5 outlines the process and provides an example area.
Incomplete natural recession limits	The natural recession limit represents the maximum area of recession that is possible before bedrock is met on soft sediment coastlines. The recession limits (developed as part of this project) define the hard back edge of what can physically erode within human timescales. The incomplete recession limit represents areas soft coast that do not have a defined recession	Incomplete recession limits are identified when the attributes indicate that a component is a soft sediment but not in the possible zone or landwards of a natural recession limit. These areas have been clipped to the test region to be included in the coastal erosion investigation area.

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[6] A test region was developed to assist in the identification of errors within the high – medium- low hazard boundaries. The test region was also used as an input into the final data set for the coastal erosion investigation area. The test region divides the coastline into four coastal regions that describe the relative wave climate or energy (as described previously in this report). Each region has a maximum potential buffer for hazardous erosion and recession. The test region has been clipped to the land mass to remove any areas on the seaward side of the coastline.

	limit.	
Logical inconsistencies within the data set		
Attribute inaccuracy.	Attribute inaccuracy occurs due to a misclassification in one of the undying data sets. The error becomes apparent when combined with the relative susceptibility to erosion and classified into the hazard banding.	This error was identified through a combination of spatial and textual queries to identify: • Components that should not touch the coast. • Softrock on a hard rock foreshore. Appendix 5 outlines the process used.
Hazard band areas not connected to the coast.	If a hazard band area (high, medium or low) is not in contact with the coast either directly or through another hazard area, then it is not vulnerable to coastal erosion.	Using the coastal erosion thresholds supplied by DPAC to the project, hazard banding areas of high, medium, or low that are surrounded by an acceptable classification, were identified and reclassified as “acceptable”. Appendix 5 outlines the process used.
Higher hazard band areas surrounded by lower band areas.	Typically a thin sliver of a higher hazard band rank sandwiched between lower ones, or a higher hazard band inland of a lower hazard band.	As part of the visual inspection these areas were identified and reclassified as appropriate (noting that “Acceptable” hazard bands seawards of the HWM line (shore) were an artefact within the data and were removed at the end of the review). Observations from the visual inspection can be found in appendix 5: Observations from the visual inspection.
Geomorphic errors	Geomorphic errors were identified based on professional experience to check that the hazard bands corresponding to beaches and rocky headlands are in the correct relationships	As part of the visual inspection the hazard banding was checked to see if it conformed to the author’s knowledge of the coastal geology of Tasmania (noting that the underlying data was not reviewed.) Observations from the visual inspection can be found in appendix 5 : Observations from the visual inspection
Areas that do not appear to be the correct interpretation.	Areas which appear to have visually inconsistent outcomes.	This was a visual inspection by lead author to identify areas, which do not appear to be visually correct. Each of the areas was reviewed by the lead author in order to either leave the existing classification (if the interpretation turned out to be correct), or change the hazard banding into “acceptable” or “coastal erosion investigation area”.

Inaccurate underlying data		
Spatial inaccuracy	Spatial inaccuracy will occur due to scale of capture for the underlying data. The data used range from 1:5000 to 1:250000 in accuracy; this inaccuracy will be carried into the final data sets. Spatial inaccuracy will result in topological errors and positional errors. • Topological errors occur when adjacent line segments do not meet due to the scale of capture. • Positional errors depend on the scale of capture.	The undying data sets are considered correct to scale of capture for the topological and positional accuracy. As such they will be considered fit for purpose. However: • an intersect between the test area and the base data sets will identify topological errors. This will be used to assist scoping further work on the coastal hazard banding; and: • A quality assurance process with local government councils may be required to test the positional accuracy of key attributes such as coastal defences.
Temporal inaccuracy	Temporal inaccuracy will result from the age of the underlying data sets, in the case of the geological data this may date back to the 1960s, while the Smartline data dates back to 2007. In combination with this the age of the source data for each of the underlying data sets will vary, this may result in data being interpreted recently but using old inputs.	The undying data sets have some temporal errors that result from changes in the coast line through human modification or natural processes. It is very difficult to keep datasets updated with such information, and at best Government can agree that available mapping represents the best known position. As such they will be considered fit for purpose. A quality assurance process with councils may be required to test the positional accuracy of key attributes such as coastal defences.
Attribute inaccuracy	Attribute inaccuracy may occur because the underlying classification is incorrect, with the incorrect attribute being in the right spatial location.	The undying data sets will have attribute errors that result in the incorrect classification of the coast This is also very difficult to identify without ground truthing, and at best Government can agree that the available data represents the best known classification. As such they will be considered fit for purpose. A quality assurance process with councils may be required to test the positional accuracy of key attributes such as coastal defences.

7.3 Results for the coastal erosion investigation areas

The coastal erosion investigation areas represent the areas in which uncertainty exists within the underlying data resulting in uncertainties in the hazard banding process. The spatial, temporal or attribute errors will require data inspection, ground truthing and ongoing maintenance to correct them as the use of the hazard banding becomes more widely spread.

The coastal erosion investigation areas make up almost 10% of the total coastal erosion hazard banding area when considered part of the acceptable, low, medium, high, and the coastal erosion investigation area zoning. Of note within the coastal erosion investigation areas is that over half of the uncertainty is found on the west and south coasts, with the minority around the urban extents (generally due to more detailed base data mapping in those areas).

Table 12: Proportion of hazard banding by type.

Hazard Band	Area Ha	Proportion %
Acceptable	24 093	44.7%
Coastal erosion investigation area	5 324	9.8%
Low	10 309	19.1%
Medium	6696	12.5%
High	7 358	13.5%
Grand Total	**53 780**	**100%**

The ongoing maintenance of the data sets is discussed in section 8 of this report.

8.0 Data maintenance and recommendations

8.1 Introduction

The reliability of the base datasets on which the coastal erosion hazard zones described in this report were defined is not perfect. Given the length of the Tasmanian coastline (over 6,000 kilometres at 1:25,000 scale including Bass Strait Islands, which is as long as the Victorian and NSW coasts combined), and the fact that both the geological and the topographic mapping data currently available for this coast varies considerably in scale and reliability in different areas, an equally high reliability in the base map data sets (and thus the hazard band zones) cannot currently be expected in all areas.

The use of the hazard banding defined using these data can allow for these uncertainties by being used in an explicitly precautionary manner, and by being open to revision where site-specific investigations demonstrate a need for the zoning to be modified in particular areas. However, given that some sources of uncertainty in the existing mapping and zoning can readily be identified, it is also possible to identify a number of ways in which the reliability of the available base data and hazard band zones can be improved in a systematic ongoing way, additional to incorporating *ad hoc* improvements as these become available.

The following sub-sections identify key ways in which the primary datasets on which the current hazard band zoning is based can be improved. It is recommended that an ongoing program of data upgrades be planned to progressively upgrade the data as opportunities and funding become available. Whether such upgrades should best be undertaken as a series of scheduled data maintenance cycles or on the basis of an ongoing program of progressive data refinement will dependent on the potential sources and availability of funding to undertake the work.

8.2 Topography base data

High resolution (Lidar-based) topographic data is available for portions of the Tasmanian coast, particularly in the south-east and north coast / Tamar estuary areas. However for the remainder of the Tasmanian coast the best available data is medium resolution 5 or 10 metre contour mapping based on the LIST 1:25,000 topographic map dataset. This limitation has meant that coastal cliff regression modelling – the preferred method of defining coastal cliff erosion & instability zones – could not be undertaken for this project (see section 4.4.3). Limitations on topographic base data has also placed limitations on the accuracy that could be achieved for the Natural Recession Limits mapping for coastal soft sediment bodies (see section 3.1.2).

The coverage and reliability of these two key datasets – coastal cliff instability susceptibility mapping (regression modelling) and soft sediment natural recession limit mapping – could both be considerably improved if high resolution topographic data were available for the whole Tasmanian coast. Additionally – and although this is beyond the scope of this report – high resolution topographic data is also of primary importance for coastal inundation susceptibility mapping, with the result that to date high resolution inundation hazard zones can only be defined for those limited parts of the Tasmanian coast where Lidar-based topography is available (Lacey *et al.* 2012). Consequently it is recommended that:

- high resolution topographic data (ideally Lidar-based DEMs) be captured for the entire Tasmanian coastal region; and:

- when such a comprehensive dataset is available, it should be used to model coastal cliff instability hazard zones for the Tasmanian coast (which should then replace the simpler precautionary coastal cliff instability susceptibility zones defined for this project as described in section 5.4.2); the same data should also be used to refine the soft sediment natural recession limit mapping prepared for this project (see section 8.4 below).

8.3 Coastal soft sediment polygon mapping

The coastal soft sediment polygon mapping used as a key data source for this project (section 3.1.1) is primarily based on Geological Survey of Tasmania mapping at a range of scales between 1:25,000 and 1:250,000. However it is known that the Geological Survey mapping of soft sediments is not comprehensive, partly because of competing priorities with the need to also depict bedrock on a single-layer map, hence additions to the previous Geological Survey mapping have been made in some areas by Chris Sharples and others as described in section 3.1.1.

Although portions of the resulting mapping are considered to be of relatively high resolution quality – especially in parts of south-eastern Tasmania and the north coast - nonetheless large portions of the coastal soft sediment polygon map comprises mapping prepared at relatively coarse scales, which is many areas are no better than 1:250,000 scale (e.g., in parts of north-east Tasmania). This is true of both the original Geological Survey mapping and of additional mapping added by Chris Sharples and others. Some possible errors in the current coastal soft sediment polygon map (listed separately) have been identified in this project but would require fieldwork to reliably correct. Since coastal soft sediment bodies are in many respects the most inherently susceptible to coastal erosion, further review of this dataset in areas where uncertainties appear to exist would contribute to better definition of coastal erosion susceptibility zones and hazard bands. Consequently it is recommended that:

- the coastal soft sediment mapping be systematically reviewed (especially in areas of coarser scale mapping) to identify potential uncertainties and possible errors, and these be checked using fieldwork and other data sources as appropriate to yield more reliable mapping of the extent of soft sediment bodies on the coast. This work could be prioritised according to areas of high potential human usage which remain only coarsely mapped to date.

8.4 Natural recession limits mapping

Natural recession limit mapping (section 3.1.2) is a fundamental dataset that this project has used to define maximum conceivable coastal erosion and recession susceptibility zones for soft-sediment coasts in Tasmania. These limits have been defined on the basis of existing mapping of coastal soft sediment bodies (polygon mapping as described in section 3.1.1), interpretation of the position of underlying bedrock topography using geological interpretation of topographic data, and (in rare cases) use of drilling or geophysical data defining the topography of underlying bedrock surfaces.

However in the absence of comprehensive drilling or geophysical data there are significant uncertainties associated with the mapped position of natural recession limits, and this project has endeavoured to account for these uncertainties by defining ‘likely’, ‘probable’ and ‘possible’ natural recession limits depending on the apparently reliability of the interpretation that could be undertaken with the available data. The reliability of the natural recession limits mapping could be considerably improved if higher resolution topographic data becomes available for areas where the existing limits were defined based only on interpretation of medium resolution 1:25,000 scale LIST topographic data, and if more drilling and geophysical data defining actual bedrock depths could be incorporated into the definition of natural recession limits.

In addition, the natural recession limits mapping prepared for this project was undertaken on a ‘first pass’ basis for the entire Tasmanian coast using the relevant datasets currently available, and has not yet been subject to a thorough ‘second pass’ rechecking process (which would be a relatively time consuming process). Some possible errors in the existing limits mapping have been identified on an *ad hoc* basis and warrant further checking and possible modification on the basis of more detailed interpretation of the presently available data. Consequently it is recommended that:

- whilst it can be assumed that any obvious errors in the current natural recession limits mapping will be identified in the course of any future site-specific coastal hazard assessments that may be undertaken, and allowed for in defining coastal hazard management requirements for such specific sites, it would be preferable for a comprehensive systematic review of the ‘first pass’ natural recession limits mapping be undertaken as soon as possible. A number of possible issues (recorded separately) could be reviewed and corrected if necessary, and the reliability of the mapping as a whole enhanced in this way; and:

- when high resolution topographic data (ideally Lidar-based DEMs) becomes available for the whole Tasmanian coast, the natural recession limits mapping should be systematically reviewed and updated where interpretation of the topography indicates more reliable natural recession limit locations than were previously defined using medium resolution topographic data (see also section 8.2 above); and:

- that drilling and relevant geophysical data records be sought (from Mineral Resources Tasmania) for coastal soft sediment areas, and be used to systematically improve natural recession limit mapping reliability.

8.5 Coastal soft rock polygon mapping

The most important element of the coastal soft rock mapping for Tasmania (section 3.2) is clay-rich Tertiary-age sedimentary rock sequences. These occur on only limited portions of the Tasmanian coast (Figure 6), and have mostly been mapped at good geological mapping scales of 1:25,000 or better. These parts of the dataset are therefore considered largely reliable and probably require little upgrading.

However a secondary category of coastal soft rocks in Tasmania comprises deeply weathered portions of mostly hard coastal bedrock sequences, including clay-rich mudstone dominated horizons in Permo-Triassic age sedimentary rocks, and some deeply weathered coastal basalt outcrops. These are rarely depicted as ‘soft’ rock on existing geological mapping, and are usually of limited extent. However they are also important as discrete locations where significant susceptibility to coastal erosion and recession exists. It is therefore recommended that:

- A systematic program be undertaken to identify smaller bodies of coastal ‘soft-rocks’ and incorporate these into the coastal soft rock polygon mapping. Such a program would involve using existing geological mapping to identify areas where mapped hard rock bodies could potentially include soft deeply-weathered portions, followed by field work to identify the extent of any soft rock bodies that may actually be present.

8.6 Coastal geomorphic Smartline mapping

This mapping is described in section 3.3.1 and Appendix A1.2, and has primarily been used in this project to identify hard rock shorelines (resolving these into 3 distinct categories as described in section 4.4), and to identify artificial shorelines.

In principle the custodianship of this dataset rests with Geoscience Australia, who is responsible for data maintenance and upgrades to the dataset, however Geoscience Australia has yet to implement any data maintenance process for the Smartline, and in practice Chris Sharples has been independently compiling upgrades for the Tasmanian tile of the Smartline in the hope these can eventually be used to update the master copy held by Geoscience Australia. It is envisaged that data maintenance for this map would ideally be undertaken in co-operation between Geoscience Australia and DPIPWE (the custodian of the original Tasmanian coastal geomorphic line map (Sharples 2006) from which the national Smartline originated). It is recommended that:

- a process be initiated whereby DPIPWE manages upgrades to the Tasmanian tile of the Smartline, with these being periodically provided to Geoscience Australia to update the national master copies.

The original Smartline dataset (Sharples *et al.* 2009, DCC 2009) was compiled from a range of pre-existing datasets using geoprocessing techniques, primarily including reclassification of data from an earlier Tasmanian coastal map produced by Sharples (2006). Since the Tasmanian Smartline was produced as part of a comprehensive national coastal geomorphic Smartline map, only basic data checking procedures could be undertaken within the framework of that project, and there has never been a thorough systematic check of the mapping against the original base data from which it was constructed. Subsequent use of the mapping in Tasmania (and mainland Australia) has demonstrated that a high degree of accuracy was achieved by the geoprocessing techniques that were employed, such that the mapping can be considered largely reliable.

However, as may be expected, some errors and omissions have been identified in the data, both for Tasmania and elsewhere. A separate list of known data issues and specific updates required has been compiled, and some of these have been undertaken by Chris Sharples on the Smartline version used in this project (Appendix A1.2). However there remain a number of known upgrade requirements that have yet to be undertaken, and it is evident that a systematic review of the mapping would likely identify further desirable edits. It is therefore recommended that:

- using the list of identified upgrade requirements that has been compiled separately by Chris Sharples as a starting point, the Tasmanian tile of the national coastal geomorphic Smartline map that was used for this project should be systematically checked against key base datasets and field observations, and edited and upgraded as necessary.

Note the previous recommendation above regarding management of upgrades to the Smartline dataset

Artificial shores

The presence of resilient artificial coastal protection works has been used as an important basis for categorising some otherwise erodible shores into the “low” coastal erosion hazard band (section 5.5). The mapping of artificial shores used in this project is derived from such shores that have previously been mapped in the Smartline dataset. This data is known to be incomplete, and there is no other comprehensive Tasmania-wide map of artificial coastal protection works. However some local councils maintain databases of artificial coastal works, and similar data may also be held within some state government bodies. These data could be incorporated into the Smartline dataset to provide a basis for a comprehensive state-wide map of coastal artificial shoreline structures. Such a map would be of use not only for upgrading the coastal erosion hazard banding maps, but also for a variety of other coastal infrastructure maintenance and management works. It is therefore recommended that:

- in co-operation with local councils and relevant state government bodies, existing mapping and databases of artificial coastal structures be sought and used to upgrade the mapping of coastal structures currently included within the Smartline dataset.

8.7 Coastal erosion hazard bands and ‘coastal erosion investigation areas’

The coastal hazard band mapping which is the output of this project has been defined using GIS geoprocessing techniques and pairwise assessment (described in section 5.0 and 6.0) based on the base input datasets described above and in section 3.0. Any changes to the base datasets will necessitate corresponding changes to the hazard band mapping. Whilst such changes could be made manually on an *ad hoc* basis whenever relevant changes are made in the base datasets, it would be more efficient to produce new hazard band mapping on a comprehensive basis following a significant program of base dataset updates. Thus it is recommended that:

- a program of systematic priority updates to the base datasets (above) be undertaken, and following this the entire hazard band dataset be produced again from scratch using the techniques described in section 6.0. It may be most efficient to define data maintenance cycle periods which allow such updating to be undertaken at defined intervals alongside an ongoing program of progressive updates to the base datasets.

Many of the updates that are needed in the underlying base datasets will be identified as a result of investigation of the ‘coastal erosion investigation areas’ defined as described in section 7.0 above, which represent areas where apparent errors and inconsistencies in the hazard band indicate likely problems with the underlying base data sets. Consequently it is recommended that:

- highest priority be given to investigating the ‘coastal erosion investigation areas’ defined as described in section 7.0; where the cause of the identified issues is determined to be inaccuracies in the underlying data, these should be corrected on the basis of field work or other relevant methods as a priority.

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Appendix 1 – Mapping Data Dictionaries and Metadata

Sub-section A1.1 below provides ANZLIC-format metadata and a short data dictionary for the final coastal erosion hazard band mapping which is the primary outcome of the project described by this report. The following sub-sections (A1.2 – A1.5) provide Data Dictionaries for the GIS datasets which have been used (and edited) during the course of the project as base data from which the final hazard banding is ultimately derived.

A1.1 Final coastal erosion hazard banding (version 1) for Tasmania

The data model for the final (version 1) coastal erosion hazard band map of Tasmania is provided below, followed by ANZLIC – format metadata for the same dataset.

Shapefile: *tascoasterosionhazardbands_v1_2013_MGA.shp*
Type: Vector polygon map, as ESRI shapefiles
Projection: Map Grid of Australia (MGA), Zone 55, using the GDA94 datum
Description: Polygon map depicting coastal erosion hazard band buffers and polygons derived from base coastal geomorphic datasets for Tasmania (as described in Section 2.0 and Appendices A1.2 – A1.5 of this report), which have been classified into erosion susceptibility zones using criteria described in Section (4.0) of this report, then unioned in a prioritised order as described in Section (5.0) to yield a final hazard band map (*tascoasterosionhazardbands_v1_2013_MGA.shp*).
Custodian: DPIPWE

Attribute Fields:

Field	Type	Width	Attributes	Comments
The dataset contains two text attributes only:				
Component	string (text)	254	The final hazard zone component (erosion susceptibility classification) that each final polygon in the hazard band map represents, as listed in Section (5.0) Table 8 of this report.	Where several hazard zone components overlap (as can be the case under some circumstances) the final component is the one deemed most important to consider from a coastal erosion hazard policy perspective.
NaturalZon	string (text)	254	The Component that would have formed the shore and be listed as the "*Component*" attribute if the shoreline were not artificially protected; i.e., the natural shoreline type and erosion susceptibility as it would be in the absence of artificial protection.	Used only for polygons whose '*Component*' is "Resilient because of artificial protection".

ANZLIC format Metadata:

General Properties

File Identifier	**Not assigned**
Parent File Identifier	**Not assigned**
Hierarchy Level	**dataset**
Hierarchy Level Name	**dataset**
Standard Name	**ANZLIC Metadata Profile: An Australian/New Zealand Profile of AS/NZS ISO 19115:2005, Geographic information - Metadata**
Standard Version	**1.1**
Date Stamp	**2013-06-21**
Resource Title	**Tasmanian Coastal Erosion Hazard Bands Map, version 1**
Alternate Resource Titles	***tascoasterosionhazardbands_v1_2013_MGA.shp*** **(digital dataset (shapefile) name)**
Other Resource Details	**The recommended citation for this dataset is as follows: Sharples, C., Walford, H. and Roberts, L. (2013) Tasmanian Coastal Erosion Hazard Bands Map, version 1. Hobart: Tasmanian Department of Primary Industries, Parks, Water and Environment & Tasmanian Department of Premier & Cabinet**
Format Name	***.docx**
Format Version	**Unknown**

Key Dates and Languages

Date of creation	**2013-06-21**
Date of publication	**2013-06-21**
Metadata Language	**eng**
Metadata Character Set	
Dataset Languages	**eng**
Dataset Character Set	
Abstract	**The Tasmanian Coastal Erosion Hazard Bands Map, version 1 is a digital dataset that depicts coastal erosion hazard bands (classed as ‘High’, ‘Medium’, ‘Low’ and ‘Acceptable’) as shoreline buffers and polygons for the whole of Tasmania and its larger adjacent islands.** **The map was compiled using information from several existing geological and geomorphological spatial datasets, which were themselves edited further during the production of this map.** **The Tasmanian map is provided in ESRI shapefile format, using the GDA94 Map Grid of Australia (Zone 55) Projected Coordinate System.** **For further information about the Tasmanian Coastal Erosion Hazard Bands Map, version 1, please refer to the project report (referenced below).**
Purpose	**The Tasmanian Coastal Erosion Hazard Bands Map, version 1 was compiled to provide a spatial framework for coastal erosion hazard management policies by the Tasmanian state government.**

Metadata Contact Information

Name of Individual	**Chris Sharples**
Organisation Name	**University of Tasmania**

Position Name	**Honorary Research Associate**
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Role	**custodian**
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Address	
	Australia

Credit

The Tasmanian Coastal Erosion Hazard Bands Map, version 1 was derived from digital data provided by the following agencies and individuals:

Geoscience Australia

TAS Department of Primary Industries, Parks, Water and Environment (Formerly Department of Primary Industries and Water)

Lineage Statement

The "Tasmanian Coastal Erosion Hazard Bands Map, version 1" was derived from 4 existing digital datasets. A list of these source datasets with additional metadata is available in Section 2.0 and in the appendices of the project report (referenced below). The four datasets comprise:

1) A line map of Tasmanian coastal landform types ("The Smartline" map v1), used to identify differing classes of hard rock shorelines.

2) A polygon map depicting the full known extent of Tasmanian coastal soft sediment landforms and deposits.

3) A polygon map depicting the extent of Tasmanian coastal soft sediment deposits that could in principle be eroded by the sea (at sea-levels up to 2.0m higher than at present) before rising bedrock slopes prevent any further erosion.

4) A polygon map depicting the full extent of all known 'soft-rock' bedrock bodies that outcrop at the Tasmanian coast.

A set of criteria were developed to identify coastal erosion hazard zones for differing soft sediment, soft rock and hard rock coasts in Tasmania, corresponding to: zones susceptible to short term erosion at any time; zones of potential shoreline recession under sea-level rise to 2050 and 2100; and regions considered to have acceptable (low) susceptibility to 2100.

Erosion susceptibility zones corresponding to each combination of shoreline type and hazard criteria were generated as polygons

derived from each existing dataset (including buffer polygons derived from the line map). Polygons representing each distinctive shoreline type and hazard criterion were designated as erosion hazard zone ‘components’.

A pairwise assessment was undertaken to rank all components in order of increasing hazards.

The digital components were unioned in the order of their ranking to yield a final map in which any lower-ranking polygons are only preserved where they do not overlap higher ranking (‘more hazardous’) polygons.

The final map is the “Tasmanian Coastal Erosion Hazard Bands Map, version 1"

The steps outlined above are described in more detail in the project report (Sharples, C., Walford, H. and Roberts, L. (2013) Coastal Erosion Susceptibility Mapping and Hazard Zone Definition for Tasmania. Hobart: Tasmanian Government, Department of Premier and Cabinet).

Jurisdictions

Tasmania
Australia

Search Words

GEOSCIENCES-Geology
GEOSCIENCES-Geomorphology
MARINE-Hazards
MARINE-Coasts
MARINE-Geology-and-Geophysics

Themes and Categories

Topic Category	geoscientificInformation

Status and Maintenance

Status	completed
Maintenance and Update Frequency	unknown
Date of Next Update	

Reference system

Reference System	GDA94
Reference System	GDA94 / Map Grid of Australia (Zone 55)

Data Scales/Resolutions

Scale	1:5000
Scale	1:250000

Spatial Representation Type

Spatial Representation Type	vector

Extent - Geographic Bounding Box

North Bounding Latitude	-39.191996
South Bounding Latitude	-43.860374
West Bounding Longitude	143.818576
East Bounding Longitude	148.503134

Additional Extents - Geographic

Identifier	**aus**
Identifier	**TAS**
Distribution Information	
Distributor 1	
Distributor 1 Contact	
Name of Individual	
Organisation Name	**Tasmanian Department of Primary Industries, Parks, Water and Environment**
Position Name	
Role	**custodian**
Voice	
Facsimile	
Email Address	
Address	
	Australia

A1.2 Smartline coastal geomorphology and erosion susceptibility mapping

The current Smartline map of Tasmania (which is part of a national coastal geomorphic map: see www.ozcoasts.gov.au for further information) has been used to identify hard rock shores and classify these into sub-types. During the course of this project, updates and corrections based on new field work have been made to the copy of the Smartline that was used to prepare the coastal erosion hazard band map (see Appendix A1.1), however these updates have not been supplied to the Smartline custodian (Geoscience Australia) as yet.

The data model for the Smartline as supplied is summarised below. Attribute (lookup) tables for the Smartline attributes are provided in a comprehensive Smartline Data Dictionary and Manual (Sharples *et al.* 2009) which can be downloaded from www.ozcoasts.gov.au .

Shapefile: *auscstgeo_tas_v1.shp*
Type: Vector polyline map, as ESRI shapefiles
Projection: Map Grid of Australia (MGA), Zone 55, using the GDA94 datum
Description: Line map (generally representing MHWM), divided into geomorphically distinct segments. Attribute fields (as listed below) allow each segment to be tagged with unique geomorphic descriptions and data pertaining to the shoreline segment. Attribute field names have been restricted to 10 characters to comply with limitations in some formats. Each geomorphic descriptor (attribute field) is presented in two versions – a numerical code (*_n*) and a brief descriptive verbal label (*_v*) – in order to facilitate a variety of uses and analyses of the mapped data. The attributes for each field (geomorphic descriptor) are listed in detail by Sharples *et al.* (2009).
Custodian: Geoscience Australia

Attribute Fields:

Field	Type	Width	Attributes	Comments
Base Map Descriptors: Refers to base line map, which has been segmented and attributed to create this coastal geomorphic map.				
Baseline	string (text)	4	**Reference ID for source of base line map** (See Sharples *et al.* (2009) for listing of source details)	Reference ID code referring to a meta-database giving full details of base shoreline map used for Smartline
Basescale	string (text)	10	**Scale of base map** (which has been segmented and attributed with data from a variety of sources with differing source scales as indicated by *_s* attributes - see below) Format: 10K, 25K, 100K, etc, (where '10K' = '1:10,000 scale', etc) or indicate a range of scales where applicable, e.g., '250K-100K'	As quoted by source agency/custodian, else estimated. May vary along a coast.
Basefeat	string (text)	50	**Coastal feature upon which base line map is based** (e.g., MHWM)	May differ in different parts of coast.
Reference Data:				
Auscstfid	Long Integer (numeric)	-	**Unique Australian coastal segment identifier number (v.1.0).** Consecutive series of	Nationally-unique Feature ID numbers assigned to every feature (line

			numbers for each state, commencing with a different numerical prefix for each state as follows: (1 - not used) 2 – NSW 3 – Vic 4 – Qld 5 – SA 6 – WA 7 – Tas 8 – NT (i.e., same numerical prefix as state postcodes)	segment); current for version 1.0 only (subsequent editing will require new FID sequence for each new map version).
Updated	Date	-	**Date of data currency or last update**, appearing as "YYYYMMDD" or "DD/MM/YYYY" depending on the GIS software used (e.g., in YYYYMMDD format, "20090626" means 26th June 2009)	Refers to last update of any of the *geomorphic* descriptors (only) for *this* line map segment (including date of importing data from older sources); does not necessarily refer to the age of the source data used, which is specified in *source* attributes (below).
ABSAMP_ID	string (text)	10	**Beach number** used by Dr Andrew Short & Surf Life Saving Australia, in ABSAMP database format. Number applied only to Smartline segments representing beaches.	Allows linking with ABSAMP database (& cross-referencing with Short beaches books).
Coastal Geomorphic Themes:				
Backprox_n *Backprox_v*	string (text)	6 50	**Backshore proximal landform** (numerical string code). (verbal label) The first notable landform feature immediately backing the intertidal zone. See Sharples *et al.* (2009) for attribute tables.	The width of the proximal backshore zone is not defined – it depends on the scale of the proximal backshore landform type.
Backdist_n *Backdist_v*	string (text)	6 50	**Backshore distal landform** (numerical string code). (verbal label) Dominant distinctive backshore landform type inland of the first notable landform class backing the intertidal zone (i.e., inland of *Backprox* above). See Sharples *et al.* (2009) for attribute tables.	Distal backshore coastal landforms are classified to a distance up to 500m inland of the MHWM for the purposes of this mapping. *Backdist* may be the same as *Backprox*, if *Backprox* landform type extends to over 500m inland of MHWM.
			Backshore profile class	

Backprof_n *Backprof_v*	string (text)	3 30	(numerical string code). (verbal label) Generalised seawards slope gradient of backshore terrain, classified into only a few broad classes. See Sharples *et al.* (2009) for attribute tables.	Averaged backshore terrain gradient from the intertidal zone to the first major inland high point or to 500 metres inland, whichever is the lesser distance (high foredunes are ignored, if present), except high cliffed coasts.
Intertd1_n *Intertd1_v*	string (text)	6 50	**Intertidal zone landform element 1** (numerical string code) (verbal label) Primary, upper or co-equal intertidal landform element. See Sharples *et al.* (2009) for attribute tables.	
Intertd2_n *Intertd2_v*	string (text)	6 50	**Intertidal zone landform element 2** (numerical string code) (verbal label) Secondary, lower, co-equal or additional intertidal landform element. See Sharples *et al.* (2009) for attribute tables.	Identifies additional intertidal landform features, may be an unclassified record if primary intertidal element 1 adequately describes intertidal zone.
Intslope_n *Intslope_v*	string (text)	3 20	**Intertidal zone slope** (numerical string code) (verbal label) Slope of the intertidal zone. See Sharples *et al.* (2009) for attribute tables.	Defined as the slope of a line from MHWM to MLWM, categorised into only a few broad slope classes.
Subtid1_n *Subtid1_v*	string (text)	6 50	**Subtidal landform element 1** (numerical string code) (verbal label) Primary or co-equal landform element in near-shore subtidal zone. See Sharples *et al.* (2009) for attribute tables.	Dominant substrate(s) & landform type(s) found immediately seawards of & below intertidal zone; area considered may nominally extend to 500 metres horizontally offshore, but the subtidal attributes are essentially intended to record the dominant substrates immediately below the intertidal zone.
Subtid2_n *Subtid2_v*	string (text)	6 50	**Subtidal landform element 2** (numerical string code) (verbal label) Secondary, co-equal or additional landform element in	Identifies additional subtidal landform features, may be an unclassified record if primary subtidal element 1 adequately describes

			near-shore subtidal zone. See Sharples *et al.* (2009) for attribute tables.	subtidal zone.
Exposure_n *Exposure_v*	string (text)	3 20	**Shoreline segment exposure** (numerical string code) (verbal label) Exposure of the individual coastal segment to whatever swell wave energy is received by the coastal region. See Sharples *et al.* (2009) for attribute tables.	Classified into only 4 broad categories, one of which indicates the segment is not significantly exposed to swell waves. Not to be confused with *amount* of wave energy received by the coastal region.
Geology1_n *Geology1_v*	string (text)	6 50	**Primary Geological Substrate** (numerical string code) (verbal label) Only or lowermost litho-structural geological substrate (bedrock) type on or into which the present shoreline has developed. See Sharples *et al.* (2009) for attribute tables.	Primary geological substrate present prior to development of present coastline. Includes inferred bedrock underlying soft sediment coasts where bedrock is not exposed.
Geology2_n *Geology2_v*	string (text)	6 50	**Secondary Geological Substrate** (numerical string code) (verbal label) Secondary or superficial litho-structural geological substrate (bedrock) type on or into which the present shoreline has developed. See Sharples *et al.* (2009) for attribute tables.	Secondary geological substrate present prior to development of present coast. Generally refers to hard substrates in the backshore zone which overlie a ‘Primary’ bedrock type exposed in or underlying the intertidal zone.

Feature- Level Metadata: Geomorphic Data Sources and Scales
Because of the multitude of data sources used in compiling this map, it is necessary to provide the following metadata fields (data source & scale) for each geomorphic attribute field of each feature (line segment). For a given attribute field, different records (coastline segments) may have differing data sources, and conversely the data in different geomorphic attributes (fields) for the same coastline segment (record) may be derived from different sources.

A differently-named field for each geomorphic attribute: *Backprox_r* *Backdist_r* *Backprof_r* *Intertd1_r*	string (text)	4	**Source (reference) from which the data in each record in each field was obtained**. Source ID or Reference_ID code number which refers to (and can be linked to) to a separate meta-database providing the full bibliographic details of each data source.	Refers to pre-existing map datasets or other references used to compile the mapped attribute field, or may include new fieldwork or remote sensed data acquisition by specified

Intertd2_r *Intslope_r* *Subtid1_r* *Subtid2_r* *Exposure_r* *Geology1_r* *Geology2_r*			(See Sharples *et al.* (2009) for listing of source details)	people where pre-existing data was not the primary source. May be a null record if corresponding *_n* & *_v* fields are "Unclassified".
A differently-named field for each geomorphic attribute: *Backprox_s* *Backdist_s* *Backprof_s* *Intertd1_s* *Intertd2_s* *Intslope_s* *Subtid1_s* *Subtid2_s* *Exposure_s* *Geology1_s* *Geology2_s*	string (text)	10	**Scale of geomorphic data capture in the source data for each record in each field** Format: 10K, 25K, 100K, etc, (where '10K' = 1:10,000 scale, etc) or indicate a range of scales where applicable, e.g., '250K-100K'	Different to base map scale. Refers to the scale of source data either as cited by the source, or estimated. May be a null record if corresponding *_n* & *_v* fields are "Unclassified".
Shoreline substrate and erosion susceptibility themes:				
Muddy_n *Muddy_v* *Muddy_l*	string (text)	3 100 30	**Muddy Shores** Dominantly fine-grained soft-sediment intertidal zones. Includes some mangrove, tidal flat, estuarine and deltaic shores.	Potentially highly mobile, subject to erosion and/or accretion with varying conditions. See Sharples *et al.* (2009) for attribute tables.
Sandy_n *Sandy_v* *Sandy_l*	string (text)	3 100 30	**Sandy Shores** Dominantly sand – grade soft-sediment intertidal zones. Includes sandy beaches, tidal flats and other sandy shores.	Potentially highly mobile, cyclic erosion & accretion with coastal processes is normal & may mask underlying progressive changes due to long-term process or environment changes. See Sharples *et al.* (2009) for attribute tables.
Dunes_n *Dunes_v* *Dunes_l*	string (text)	3 100 30	**Sand Dune & Beach Ridge Coasts** Backshore dunes or beach ridges present; intertidal zone may be sandy, rocky or other types. Distinct from "Sandy" theme above, since dunes & dune fields may occur inland of rocky shores.	Potentially prone to dune mobility or stabilisation depending on wind and precipitation, vegetation and disturbance. See Sharples *et al.* (2009) for attribute tables.
Coarsed_n *Coarsed_v*	string (text)	3 100	**Coarse Sediment Shores** Primarily dominantly boulder to pebble-grade shingle beaches,	Colluvial types generally prone to slumping, likely accelerated with sea-level

Coarsed_l		30	or dominantly coarse colluvial (talus) unconsolidated sediment shores.	rise; behaviour of coarse-grade beaches probably variable but many are likely prone to some cyclic cut-and-fill and progressive recession. See Sharples *et al.* (2009) for attribute tables.
Undifsed_n *Undifsed_v* *Undifsed_l*	string (text)	3 100 30	**Undifferentiated Sediment Shores** Shores dominated by soft sediment in the Intertidal zone, where sediment type is unknown.	Assumed potentially prone to erosion and recession. See Sharples *et al.* (2009) for attribute tables.
Softrock_n *Softrock_v* *Softrock_l*	string (text)	3 100 30	**“Soft Rock” Shores** Dominantly “soft rock” landforms in the backshore zone. May include landforms of semi-lithified or inherently soft bedrock, weathered bedrock or regolith including laterite profiles. May include gently to moderately sloping to cliffed profiles and sub-ordinate colluvium.	“Soft Rock” landforms are a distinctive category - much more erodible and slump-prone than hard rock shores, but less mobile than soft sediment shores. However erosion is mainly progressive and irreversible & long-term ‘net’ recession rates may be comparable to soft sediment shores. See Sharples *et al.* (2009) for attribute tables.
Hardrock_n *Hardrock_v* *Hardrock_l*	string (text)	3 100 30	**Hard Rock Shores** Gently to moderately sloping or steep to cliffed hard rocky intertidal and backshore landforms (steep to cliffed shores may include sub-ordinate colluvium).	Gently to moderately sloping shores are generally resilient, stable shores over foreseeable human time-frames. Steep to cliffed shores potentially prone to rock falls, slumps, collapse and shoreline retreat. See Sharples *et al.* (2009) for attribute tables.
Undfrock_n *Undfrock _v* *Undfrock _l*	string (text)	3 100 30	**Undifferentiated Rock Shores** Gently sloping to cliffed bedrock shores where bedrock ‘hardness’ unspecified in intertidal to backshore proximal zone.	On a Precautionary basis, susceptibility to instability may be assumed comparable to soft rock shore types. See Sharples *et al.* (2009) for attribute tables.
Coral_n *Coral_v* *Coral_l*	string (text)	3 100 30	**Coral Coasts** Shore dominated by biogenic reef structures of ‘living’ reefs, and derived coastal materials.	Complex responses to climate change & sea-level rise but may include death and physical break-up of reef structures. See Sharples *et al.* (2009) for attribute tables.
			No Stability classification	

Unclass_n *Unclass_v* *Unclass_l*	string (text)	3 100 30	Coasts not classified into stability categories.	See Sharples *et al.* (2009) for attribute tables.
Other:				
Comments	string (text)	254	**General notes** and comments pertaining to the coastal segment.	Generally used to note special geomorphic issues or mapping issues pertaining to the segment.

A1.3 Coastal sediment polygon mapping

The Tasmanian coastal Quaternary sediment polygon map (*tascoastsed_v7_MGA.shp*) delineates the full extent of Tasmanian coastal soft sediment bodies. The dataset custodian is DPIPWE. Earlier versions of this dataset (held by DPIPWE) have been updated with some new field data (ground-truthing) and edits by Chris Sharples, Paul Donaldson and Hannah Walford.

A data model and attribute tables (lookup tables) are provided below. Note that a new and simplified data model and attributes were developed for the dataset during this project, replacing an earlier more cumbersome classification used in earlier versions of this dataset.

Shapefile: *tascoastsed_v7_MGA.shp*
Type: Polygon
Projection: Map Grid of Australia (MGA), Zone 55, using the GDA94 datum
Description: Map of unlithified coastal sediment deposits and landforms in the coastal region, including dune fields, sand sheets, intertidal/subtidal sediment flats, beaches, etc.
Custodian: DPIPWE

Field	**Type**	**Width**	**Attributes**	**Comments**
Updated	Date	-	Date of last data update, in "DD/MM/YYYY" format	Refers to date of updates to GIS data, not to the date for which the data was current (which is given by the *Year* field).
Year	Short Integer	4	Year for which the data on which the mapped polygon is based was current If the year is unspecified or unknown, this field is attributed "unsp" If the year is unknown but the decade is known, this is indicated by a final "X", e.g., the 1990's would be indicated as "199X".	For field data: year of fieldwork; for remote sensing data: year of data capture; for published data (e.g., maps): year of publication. Day & month not specified. Intended for use mapping polygons with highly changeable landform characteristics, especially dunes which may vary rapidly between stable (vegetated) and unstable (mobile, unvegetated state). However of more general use in indicating currency of data on which

				polygons are based.
Age_n	text	3	Geological age of sedimentary landform Unit, expressed as a numerical code. See attribute table below.	Numerical code
Age_v	text	50	Geological age of sedimentary landform Unit, expressed as a verbal description. See attribute table below.	Verbal description
System_n	text	3	Classification of the primary depositional system of each mapped *unit*, defined as numerical codes. See attribute table below.	Numerical code
System_v	text	50	Classification of the primary depositional system of each mapped *unit*, as verbal description. See attribute table below.	Verbal description
Unit_n	text	3	Classification of coastal Quaternary sedimentary landform (morpho-stratigraphic) units, as numerical codes. See attribute table below.	Numerical code
Unit_v	text	100	Classification of coastal Quaternary sedimentary landform (morpho-stratigraphic) units, as verbal description. See attribute table below.	Verbal description
Lithology_v	text	100	Classification of sediment type, where known, listed in order of decreasing dominance. See attribute table below.	Verbal description
Source	text	3	Source of mapped information: includes field or air photo interpretation by specified people, previous geological mapping, referenced publications, etc. See attribute table below.	See Bibliography for cited references.
Notes	Text	200	Notes and comments pertaining to the coastal segment or to the data sources used.	

Attribute tables

The following attributes are used in the Tasmanian Coastal Sediment Polygon map (*tascoastsed_v7_MGA.shp*).

Geological Age of Sediment Bodies and Soft Sediment Landforms

Used in shapefile/theme: *tascoastsed_v7_MGA.shp*
Field names: *Age_n; Age_v*
Field type: text string
Field width: 3; 50
Explanation: Geological age of sedimentary landforms, expressed as chrono-stratigraphic time units, as defined by the International Commission for Stratigraphy. All units are mapped as Quaternary (i.e. Quaternary undifferentiated) unless a more specific age (Pleistocene or Holocene) is known.

Attribute summary:

Code (*Age_n*)	Verbal Geological Age (*Age_v*)
000	Unclassified
100	Quaternary
200	Pleistocene
300	Holocene
	NOTE that sub-divisions of "Pleistocene" and "Holocene" can be added to this attribute table as needed, by using the third digit to create sub-divisions within the existing categories.

Quaternary Depositional System

Used in shapefile/theme: *tascoastsed_v7_MGA.shp*
Field name: *System_n, System_v*
Field type: text string
Field width: 3; 50
Explanation: The primary depositional system of each Quaternary sedimentary landform Unit. Each category is defined by the broad depositional setting and dominant depositional processes.

Attribute summary:

Code (*System_n*)	Verbal description: Primary depositional system (*System_v*)
000	Undifferentiated
100	Alluvial and/or palludal
200	Estuarine
300	Non-estuarine re-entrant
400	Coastal Barrier
500	Dominantly bedrock coast
600	Terrestrial aeolian
700	Colluvial
800	Anthropogenic

Quaternary Sedimentary Landform Units

Used in shapefile/theme: *tascoastsed_v7_MGA.shp*
Field name: *Unit_n; Unit_v*
Field type: text string
Field width: 3; 100
Explanation: Sedimentary landform Units mapped on the basis of depositional processes, lithology and geomorphology. Two identical Units from varying depositional

settings are differentiated at the System level (e.g. an *estuarine channel* is mapped as Estuarine > Channel, and a *fluvial channel* is mapped as an Alluvial > Channel; and an *undifferentiated coastal dune* is mapped as Coastal Barrier > Dunes – undifferentiated, and an *undifferentiated inland-cold climate dune* is mapped as Terrestrial aeolian > Dunes – undifferentiated).

Attribute summary:

Code (*Unit_n*)	Verbal description: Quaternary coastal sediment and landform types (*Unit_v*)
000	Undifferentiated
100	Alluvial valley fill - undifferentiated
110	Alluvial fan
120	Lake
130	Terrace
140	Floodplain
150	Swamp
155	Alluvial and swamp deposits undifferentiated
160	Levee
170	Channel
180	Palaeochannel
190	In-channel bar
200	Delta
210	Estuarine basin
220	Coastal lagoon
230	Inlet
300	Subtidal flats
310	Intertidal - subtidal flats
320	Intertidal flats
330	Intertidal - supratidal flats
340	Supratidal flats
350	Subtidal sloping sediment body
400	Barrier complex - undifferentiated
405	Backshore sediments - undifferentiated
410	Beach ridge plain and strandplain deposits
420	Beach ridge (single - foreshore)
430	Barrier lake
440	Backbarrier flat
450	Marsh
500	Beach - undifferentiated
510	Coarse (pebble to boulder) beach
520	Sandy beach
530	Shelly beach
540	Artificial beach
550	Marine sediment body - undifferentiated
600	Perched gravel beach
610	Perched sandy beach
620	Residual sediment shoreline - undifferentiated
630	Residual boulder shoreline
640	Residual gravel shoreline

700	Foredune(s) +/- incipient dune
710	Parallel dunes
720	Transgressive dunefield (may be active or vegetated/stabilised)
730	Mobile dune(s)
740	Deflation basin
750	Aeolian sand sheet
760	Dunes - undifferentiated
770	Aeolian sands - undifferentiated; nominally includes combination of sand sheets plus dunes
780	Bedrock mantling dune(s)/dunefield
800	Colluvial deposits - undifferentiated
810	Colluvial fan
820	Colluvium
900	Artificial deposits - undifferentiated
910	Artificially stored water
920	Disturbed land

Quaternary Lithology

Used in shapefile/theme: *tascoastsed_v7_MGA.shp*
Field names: *Lithology_v*
Field type: text string
Field width: 100
Explanation: Sediment type(s) associated with each sedimentary landform *Unit*. Where multiple lithologies are present, they are listed in order of decreasing dominance (e.g. Sand, Gravel, Mud). *Lithology* is based on field data, thus two identically mapped *Units* may have varying *Lithology* attributes.

Attribute summary:

Verbal description: Quaternary sediment types (*Lithology_v*)
Boulder
Pebble
Cobble
Gravel
Sand
Sand to mud
Indurated sand
Silt
Clay
Shell
Organic mud
Peat
Undifferentiated
N/A

Mapping Data Sources

Used in shapefile/theme: *tascoastsed_v7_MGA.shp*
Field names: *Source*
Field type: text string
Field width: 3
Explanation: Source of information used to map polygons in sediment type map (*tascoastsed_v7_MGA.shp*).

Attribute summary:

Source no. (*Source*)	Source description
00	Unknown
01	Fieldwork plus air photo and geological map interpretation, by C. Sharples
02	Fieldwork only, by C. Sharples
03	Air photo and geological map interpretation only, by C. Sharples
04	Davies (1959)
05	100K maps in Sharples (1998), digitised in 1999 for WNW Councils
06	250K Digital Geological Map of Tasmania (undiff sheets)
07	Fieldwork plus air photo &/or geological map interpretation by Frances Mowling
08	Fieldwork only by Frances Mowling
09	Air photo &/or geological map interpretation only by Frances Mowling
10	LIST 25K maps coastal flats and tidal zone polygons
11	Cullen (1998)
12	Fieldwork only, by Cliff Massey
13	Fieldwork plus air photo and geological map interpretation, by Dax Noble
14	Taroona 25K Geology Map
15	Fieldwork plus air photo, LiDAR DEM and geological map interpretation by Paul Donaldson
16	Fieldwork plus air photo, LiDAR DEM and geological map interpretation by Chris Sharples and Paul Donaldson
17	Kingborough 1:50K Geological Map sheet
18	Dover 1:50K Geological map sheet
19	25K Digital Geological Map of Tasmania (undiff. sheets)
20	50K or 63K Geological Map of Tasmania (older sheets) undiff.

A1.4 Coastal recession potential polygon mapping

The Coastal Recession Potential polygon map (*TasRecessionPotential_v1_MGA.shp*) depicts the maximum theoretical landwards extent to which coastal soft sediment bodies could in principle erode and recede in response to sea-level rise projected to 2100 (the 'Natural Recession Limit'). This theoretical limit is defined as the landwards line at which the upper surface of harder (more erosion-resistant) bedrock underlying the soft sediment body rises above 0.8 metres above present sea-level; this is the point at which further landwards penetration of erosive wave action would be limited until such time as considerable further sea-level rise occurs (see further discussion in section 3.1.2).

This map was created during a concurrent coastal hazard assessment project undertaken for Kingborough Local Government Council (Sharples & Donaldson 2013), and was subsequently extended statewide during this hazard banding project. The Recession Potential polygon map is intended to be used in conjunction with the Coastal Sediment Polygon Map (*tascoastsed_v7_MGA.shp*), which provides geological and geomorphic data regarding the erodible sediment bodies to which the recession potential polygons refer.

The attributes specify the basis (evidence) on which the potential recession line has been mapped, and indicate the degree of certainty or confidence that the mapped recession potential limit position is correct.

A data model and attribute tables (lookup tables) are provided below.

Shapefile: *TasRecessionPotential_v1_MGA.shp*
Type: Polygon
Projection: Map Grid of Australia (MGA), Zone 55, using the GDA94 datum
Description: Polygon map depicting the maximum theoretical landwards extent to which coastal soft sediment bodies could in principle erode and recede in response to sea-level rise (or other coastal processes in the longer term) in the foreseeable future. By convention, these polygons are mapped extending landwards from the LIST High Water Mark line as digitised on current LIST 25K mapping.
Custodian: DPIPWE

Field	**Type**	**Width**	**Attributes**	**Comments**
Updated	text	10	Date of last data update, as a string in format "DD/MM/YYYY" (e.g., 07/04/2001 for 7th April 2001)	Refers to date of updates to GIS data, not to the date for which the data is/was current.
Recpot_n	text	3	Evidence or rationale for location of polygon boundaries (recession potential limits). See attribute table below	Numerical code
Recpot_v	text	100	Evidence or rationale for location of polygon boundaries (recession potential limits). See attribute table below	Verbal description
Recpconf_n	text	3	Level of confidence that polygon delineates recession-prone areas comprising erodible sediments	Numerical code

			extending to below present sea-level. See attribute table below	
Recpconf_v	text	100	Level of confidence that polygon delineates recession-prone areas comprising erodible sediments extending to below present sea-level See attribute table below	Verbal description
Source	text	200	Source of mapped information: includes field or topographic mapping interpretation by specified people, previous geological mapping, drill hole data, etc.	Currently a verbal description in the attribute field only
Notes	text	200	Notes and comments pertaining to recession potential or to the data sources used.	

Attribute tables

The following descriptors are used in the Coastal Recession Potential polygon map (*TasRecessionPotential_v1_MGA.shp*).

Evidence or Rationale for Recession Susceptibility Potential Limits

Used in shapefile/theme: *TasRecessionPotential_v1_MGA.shp*

Field names: *Recpot_n, Recpot_v*

Field type: text string

Field width: 3; 100

Explanation: Type of evidence on which the polygon landwards boundary defining potential soft sediment shoreline recession limits (i.e., line at which underlying hard bedrock surface rises above present sea level) has been mapped

Attribute summary:

Code (*Recpot_n*)	Verbal description: Rationale for delineating recession susceptibility potential limits (*Recpot_v*)
000	Unclassified
100	Break of slope (may be mantled by soft sediment, but interpreted as indicative of underlying bedrock rising above sea-level at inland boundary of soft sediment infill to below present sea-level)
110	Break of slope – poorly defined
120	Break of slope – well defined
200	Bedrock slope bounding soft sediment (low-lying soft sediment infill to below present sea level bounded by well-defined rising bedrock (± soil) slope)
210	Bedrock slope bounding soft sediment - poorly defined boundary
220	Bedrock slope bounding soft sediment - well defined boundary
300	Mixed rationale (may include combination of break of slope and bedrock slope boundary; provide details in notes)

Confidence in Recession Susceptibility Potential Limits
Used in shapefile/theme: *TasRecessionPotential_v1_MGA.shp*
Field names: *Recpconf_n, Recpconf_v*
Field type: text string
Field width: 3; 100
Explanation: Degree of confidence that the mapped polygon landwards boundary defines potential soft sediment shoreline recession limits (i.e., line at which underlying hard bedrock surface rises above present sea level).

Attribute summary:

Code (*Recpconf_n*)	Verbal description: Level of confidence that polygon delineates recession-prone areas comprising erodible sediments extending to below present sea-level (*Recpconf_v*)
000	Unclassified
100	Not susceptible to shoreline recession (soft sediment veneer over hard bedrock above sea level; soft sediment depth does not extend to below present sea-level)
200	Possibly susceptible to shoreline recession (soft sediment depth uncertain – may extend to below present sea level to polygon landwards limit; some rising topography present but guesstimated to not necessarily indicate underlying bedrock rising above sea level.)
300	Likely susceptible to shoreline recession (soft sediment depth unconfirmed but likely to extend to below present sea level to polygon landwards limit; no direct drilling or geophysical evidence; sediment infill which may have some minor rising topography but form is generally consistent deep soft sediment infill to below present sea-level)
400	High confidence susceptibility to shoreline recession (high confidence that soft sediment depth extends to below present sea level to polygon landwards limit; ideally based on drilling or geophysical data if available; otherwise based on very flat low-profile sediment infill areas extending from sea to first significant landwards break of slope)

A1.5 Coastal soft rock polygon mapping

The Tasmanian coastal soft bedrock polygon map (*TasCoastSoftRock_v1_1_MGA.shp*) is a geological map depicting *only* “soft –rock” bedrock. This map was used for this project because existing Tasmanian geology maps sometimes depict Quaternary sediment bodies over parts of older, ‘soft’ bedrock units whose presence is not indicated by map attributes but must be inferred by the user. This map fills the need for a soft bedrock-only map which depicts the full extent of soft rock bedrock (as far as it is known), even when partly mantled by Quaternary sediments.

This map was created during a concurrent coastal hazard assessment project undertaken for Kingborough Local Government Council (Sharples & Donaldson 2013), and was subsequently extended statewide during this hazard banding project.

A data model and attribute tables (lookup tables) are provided below.

Shapefile:	*TasCoastSoftRock_v1_1_MGA.shp*
Type:	Polygon
Projection:	Map Grid of Australia (MGA), Zone 55, using the GDA94 datum
Description:	Map of soft bedrock units underlying coastal and adjoining regions of Tasmania. These largely include unlithified, semi-lithified or lithified Tertiary-age sediments, but may also include soft older (pre-Tertiary) bedrock geology, such as highly weathered, fractured, and semi-lithified units.
Custodian:	DPIPWE

Field	**Type**	**Width**	**Attributes**	**Comments**
Updated	date	-	Date of last data update, as a string in format "DD/MM/YYYY"	Refers to date of updates to GIS data, not to the date for which the data was current.
Age_n	text	3	Geological age of soft rock polygons, expressed as a numerical code. See attribute table below.	Numerical code.
Age_v	text	50	Geological age of soft rock polygons, expressed as Period names. See attribute table below.	Verbal description.
Softrock_n	text	3	Classification of erodible soft rock polygons, as numerical codes. See attribute table below.	Numerical code.
Softrock _v	text	100	Classification of erodible soft rock polygons, as verbal descriptions. See attribute table below.	Verbal description.
Reference	text	200	Source of geological data for the mapped polygon. May be a bibliographic citation or details of specific data sources used to map polygon, where relevant (including fieldwork by a specified person).	Currently a verbal description in the attribute field only
Notes	text	200	Notes and comments pertaining to the coastal segment or to the data sources used.	

Attribute tables

The following descriptors are used in the coastal Soft Rock Polygon Map *TasCoastSoftRock_v1_1_MGA.shp*

Geological age of soft rock bodies

Used in shapefile/theme: *TasCoastSoftRock_v1_1_MGA.shp*
Field names: *Age_n; Age_v*
Field type: text string
Field width: 3; 50
Explanation: Geological age of soft rock bodies, expressed as chronostratigraphic time units, as defined by the International Commission for Stratigraphy.

Attribute summary:

Code (*Age_n*)	Verbal Geological Age (*Age_v*)
000	Unclassified
100	Holocene
120	Pleistocene
140	Quaternary
150	Tertiary
200	Cretaceous
220	Jurassic
240	Triassic
260	Permian
300	Carboniferous
320	Devonian
340	Silurian
360	Ordovician
380	Cambrian
400	Proterozoic
500	Archean
600	Hadean (may be slightly irrelevant…)
	NOTE that additional sub-divisions can be added to this attribute table as needed.

Soft rock bodies (highly erodible bedrock)
Used in shapefile/theme: *TasCoastSoftRock_v1_1_MGA.shp*
Field names: *Softrock_n, Softrock_v*
Field type: text string
Field width: 3; 100
Explanation: Classification of erodible soft rock polygons (classified and digitised as separate polygons to Quaternary-age sediment bodies; may overlap the latter); these are commonly semi-lithified and/or highly weathered/fractured soft-rock bedrock bodies which contrast with unlithified Quaternary sediment bodies and may be overlain by the latter.

Where 1:25,000 Geological Survey of Tasmania mapping data is available, this is generally the source of the sediment type classes used, however in some cases multiple units as depicted on the geological survey mapping have been lumped into a single unit for simplicity in applying the data to coastal sensitivity assessment purposes.

Attribute summary:

Code (*Softrock_n*)	Verbal description: Soft rock substrate type (*Softrock_v*)
000	Unclassified
100	Sediments undifferentiated
105	Semi-lithified clays, sandstones and gravels or conglomerates
150	Mixed clay, sand, gravel and duricrusts (laterites and/or silicastone)
200	Dominantly silt and clay
210	Mudstones (lithified but soft, easy-fretting)
220	Soft mudstone-dominated parts of lithified mudstone/sandstone sequences
300	Dominantly soft sandstone
400	Poorly sorted clayey sandstone with minor siltstones and conglomerates
500	Conglomerates undifferentiated
511	Poorly sorted pebble to boulder grade conglomerates in clay matrix (with dolerite and sedimentary rock clasts)
512	Dominantly very coarse conglomerate with dolerite boulders >2m in clay matrix
600	Agglomerates and tuffs undifferentiated (volcanic sediments)
610	Weathered volcaniclastics and basalt

Appendix 2 – Tasmanian Soft-Sediment Storm Bite and Recession - Empirical Data

A ‘storm bite’ is the landwards (horizontal) distance that a shoreline (typically measured as the vegetation line or scarp backing a beach) recedes by eroding during a storm or clustered series of storms. This appendix (see Table 13 below) tabulates available empirical (observed) data on erosional storm bites in sandy (soft sediment) beach shores in Tasmania. No storm bite data is available for muddy or coarse soft sediment shores in Tasmania. To date, very little quantitative data on measured storm bites has been available for Tasmania since it is only in the last few years that efforts have been made to systematically monitor Tasmanian beaches and collect historic beach behaviour data from air photos. This is in contrast to some other places such as NSW, where detailed beach monitoring records have been kept since the 1970s. However applying NSW beach storm bite data to Tasmanian shores would be of questionable utility owing to the somewhat different geomorphic and oceanographic conditions to which the two regions are subject.

The data tabulated below is the most pertinent storm bite data that was available at the time of writing to inform definition of coastal erosion hazard zones for Tasmania. This data has been drawn from objective measurable sources comprising historic air photos (especially Sharples *et al.* in prep.) and shore profile survey measurements undertaken for the TASMARC project (www.tasmarc.info). Anecdotal reports of storm bite distances have not been used as experience shows these may be considerably exaggerated by the vagaries of memory[7]. Except where otherwise noted, it is generally the case that the available historic record (e.g., air photos a few years apart) does not allow determination of whether the observed storm bite resulted from a single storm or a series of storms; there is currently only one case in which measured storm bite data for a single significant coastal storm erosion event on a known date has been obtained for Tasmanian beaches (9th – 10th July 2011: see Table 13). In all other cases the storm bites recorded are strictly speaking the amount of shoreline recession evident between two surveys or two air photo epochs (which may be some years apart). However although this recession may have occurred over several years rather than during a single storm, from the perspective of coastal erosion risk assessment it is nevertheless useful data since it is indicative of the amount of erosion that may occur over a short enough period to be a major hazard for assets. Moreover, with the exception of the 40 year ARI July 2011 storm (Miller 2011) which produced several of the measured storm bites listed on Table 13 , the magnitude of the storm or storms responsible for the measured storm bites are also generally not known (this typically quantified as an average recurrence interval (ARI) based on statistical water level data, for example a 100 year ARI storm represents a very large storm of a magnitude statistically estimated to occur every 100 years *on average*). This is a result of the general lack of availability or analysis of detailed coastal storm event records in Tasmania.

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[7] *Note re topographic interpretation of storm bites:* Old shoreline erosion scarps behind younger accreted incipient foredunes are evident in Lidar DEM’s of some beaches (e.g., central and western Seven Mile Beach). These give a useful indication of the potential amplitude of the cut-and-fill (erosion - recovery) distances on some beaches; however the limitation on this data is that the date of the event that formed the erosion scarp is not obtainable from the topographic data, and the distance of the erosion scarp behind the present foredune front is not necessarily indicative of a storm bite. For example the shore may have receded to the scarp position over a very long period, in many storm bites, before the incipient dunes accreted again over a long period in front of the scarp. Storm bite distances (on time scales of a few years at most) are most reliably interpreted from air photos or measured beach profiles, since a time frame within which a certain amount of shoreline recession occurred can be constrained using the air photo or profile dates.

Table 13: Empirical (observed) data on measured horizontal storm bite distances for Tasmanian sandy beaches. Note that in no cases are the Average Recurrence Intervals (ARI) of the storm events responsible for these storm bites known, nor in most cases is it known whether the storm bite occurred in a single storm event or a cluster of closely spaced storm events.

Location	**Storm bite** (distance metres, mean values rounded up to nearest metre)	**Information Source**	**Notes**
Roches Beach, Lauderdale (swell-exposed)	3	Sharples *et al.* in prep. (historic air photo analysis)	1975-1977 erosion event(s), mean for central part of beach
Roches Beach, Lauderdale (swell-exposed)	5	Sharples *et al.* in prep. (historic air photo analysis)	1984-1986 erosion event(s), mean for central part of beach
Roches Beach, Lauderdale (swell-exposed)	7.75m (1975-1977 event(s)) 8.0m (1984-1986 event(s))	Sharples *et al.* in prep. (historic air photo analysis)	Largest measured historic storm bites for Roches Beach: on transect TAS007330 (south of canal); also indicated to be largest pre-2011 storm bites by previous results of Sharples (2011)
Roches Beach, Lauderdale (swell-exposed)	5 (mean for central part of beach) 15 (maximum: behind Bambra Reef)	Dell & Sharples (2012): air photo analysis	9th – 10th July 2011 storm (estimated 40 year ARI: Miller 2011)
Cremorne Beach (swell-exposed)	15	Dell & Sharples (2012): historic air photo analysis	Central part of beach: assumed pre-1959 storm bite estimated from beach recovery between 1958 - 2012
Seven Mile Beach (western end, swell-exposed)	4 to 10	Dell & Sharples (2012): historic air photo analysis	9th – 10th July 2011 storm (estimated 40 year ARI: Miller 2011)
Bellerive Beach (swell-exposed)	3	Dell & Sharples (2012): historic air photo analysis	Mean shoreline retreat 2005 – 2012
Howrah Beach (swell-exposed)	5	Dell & Sharples (2012): historic air photo analysis	Mean shoreline retreat 2005 – 2012
Clifton Beach (swell-exposed)	7.25	Sharples *et al.* in prep. (historic air photo analysis)	Mean of largest recorded storm bites (post-1975) on transects TAS007180, 7188, 7191.
Clifton Beach (swell-exposed)	7.45 (Middle transect)	TASMARC beach profile data (at www.tasmarc.info)	Measured storm bite (storm 9th – 10th July 2011; estimated 40 year ARI: Miller 2011)
Carlton Beach (swell-exposed)	5.25m(east transect) 4.76 m (middle transect)	TASMARC beach profile data (at www.tasmarc.info)	Measured storm bite (storm 9th – 10th July 2011; estimated 40 year ARI: Miller 2011)
Hope Beach (South Arm, swell-exposed)	10.5m (east transect)	TASMARC beach profile data (at www.tasmarc.info)	Measured storm bite (storm 9th – 10th July 2011;estimated 40 year ARI: Miller 2011)
Five Mile Beach (swell-sheltered)	7m av. (max. 12.25m)	Sharples *et al.* in prep. (historic air photo analysis)	Mean shoreline retreat during (probably) single event between 1989 – 2008, possibly summer 1991/92.
Ocean Beach (west Tas, swell-exposed)	7.90m (av. over southern third of beach)	Walford (2011)	Mean retreat over a 3 year period 1979 - 82; largest mean storm bite in air photo record for Ocean Beach.

Whereas Table 13 above provides data on measured storm bites for both open (swell-exposed) and swell-sheltered (Five Mile Beach) shores, data on longer term recession rates for open coast swell-exposed shores has not been provided here since it is commonly of problematical use and requires informed interpretation. Whereas a storm bite over a relatively short period can be clearly related to a short term erosion event or cluster of events, if only a few shoreline position measurements are available then an apparent recession may be a statistical artefact in cases where open coast shores are actually eroding and then recovering on a cyclic or episodic basis.

In contrast, swell-sheltered soft sediment shores (other than some saltmarsh-colonised shores: Mount *et al.* 2010) generally have little capacity for recovery after erosion and hence any erosion of such shores generally tends to be part of a long-term ongoing shoreline recession trend. Measured data on such trends may be useful for estimating the ranges of potential future recession rates that may occur on such swell-sheltered shores in the future under conditions of rising sea-levels. Unfortunately, due to a historic focus on open coast erosion issues, little measured data is available on long term shoreline recession rates for swell-sheltered soft sediment shores in Tasmania. However Mount *et al.* (2010) and Sharples *et al.* (in prep.) have recently acquired a small amount of such data from studies of historic air photo time series. The pertinent data is provided in Table 14 below.

Table 14: Measured long-term recession rates for swell-sheltered soft sediment shores in Tasmania (based on time series studies of ortho-rectified historic air photos).

Location (shore type)	**Recession rates** metres/year (max., min.)	**Information source**	**Notes**
Pipe Clay Lagoon (sandy shore backed by saltmarsh)	Max: 0.179 m/yr. Min: 0.024 m/yr.	Sharples *et al.* (in prep.)	Nine air photo dates 1948 - 2010; ongoing progressive recession over 62 year period
Boullanger Bay region, far NE Tas. (sandy + saltmarsh shores)	Max.: 0.30 m/yr. Av.: 0.20 m/yr. Min.: 0.12 m/yr.	Mount *et al.* (2010)	Six air photo dates 1952-2006; dominantly ongoing recession over 54 year period
Boullanger Bay region, far NE Tas. (sandy shores, no saltmarsh)	Max.: 0.18 m/yr. Av.: 0.13 m/yr. Min.: 0.00 m/yr.	Mount *et al.* (2010)	Five air photo dates 1968 – 2006; dominantly ongoing recession over 38 year period.
Gordon, D'Entrecasteaux Channel (sandy marine sediment terrace, at extreme limit of weak swell penetration)	Max. 0.34 m/yr. Min. 0.12 m/yr.	Sharples (2012)	Based on comparison of surveyed HWM line in 1947 and 2012: net recession over 65 year period; ongoing progressive recession observed by local residents over 11 years to 2012.

Appendix 3 – Tasmanian Soft-Sediment Storm Bite and Recession - Modelled Data

A variety of numerical coastal erosion and recession modelling techniques and software packages have been developed by coastal engineers over the last few decades (see Mariani *et al.* (2012) for a useful review). These techniques model – or simulate – the processes involved in shoreline erosion and recession on sandy beaches so as to provide estimates of the amount of shoreline erosion that may be expected to result from a storm of a specified magnitude, and / or the amount of shoreline recession that may occur over time in response to a specified amount of sea-level rise. Whereas most such numerical models have been tested and calibrated against actual observed storms, relative sea-level rise and erosion events at specific beaches, their application to other beaches is always subject to a degree of uncertainty since the complexity of coastal environments and processes is such that no two beaches ever behave in exactly the same way. Thus whilst numerical modelling of beach erosion and recession can be regarded as a useful indication of potential erosion magnitudes at given beaches, it cannot be expected to provide precise predictions of storm bites or long term shoreline recession rates.

In recent years two significant projects have generated modelled storm bite erosion and long term recession magnitudes for Tasmanian beaches. Selected data from these studies is provided in this appendix, and informs the method used to define soft sediment (sandy) shore erosion hazard banding in section 5.2 of this report.

Table 15: Modelled horizontal storm bite distances for selected swell-exposed sandy beaches in Clarence LGA (south-east Tasmania). These data were modelled by Carley *et al.* (2008, Table 12.1 & 20.1) using SBEACH storm erosion modelling software, and in all cases represent the modelled horizontal storm bite resulting from two back-to-back 100 year ARI storm events. This represents the 'design erosion event' selected as a worst case scenario for assessing sandy beach coastal erosion hazards for the Clarence LGA coastal hazards assessment project.

Beach	**Modelled Design Storm Bite** metres, rounded to nearest 5 m (2 x 100 year ARI storms)	**Notes**
Opossum Bay, South Arm	20	Actual storm bites may be limited by natural recession limit
Roches Beach, Lauderdale	40	
Howrah Beach	10	
Seven Mile Beach (western 1 km only)	10	
Mays Beach	10	
Clifton Beach (western 500m)	25	
Glenvar Beach, South Arm	20	Actual storm bites may be limited by natural recession limit
Halfmoon Bay, South Arm	10	
Bellerive Beach	15	

Table 15 above tabulates modelled horizontal storm bite distances for selected sandy beaches in Clarence LGA (south-east Tasmania). These data were modelled by Carley *et al.* (2008) using SBEACH storm erosion modelling software, and in all cases represent the modelled storm bite resulting from two back-to-back 100 year ARI storm events. This represents the ‘design erosion event’ storm magnitude selected as a worst case scenario for assessing sandy beach coastal erosion hazards for the Clarence LGA coastal hazards assessment project. Wave modelling data, sand grainsize and beach profile data specific to each beach were input to the SBEACH model, hence the modelling was highly site specific and responsive to differences between individual beaches.

Whereas the erosion modelling conducted for the Clarence beaches (above) was site specific - using data and providing erosion setbacks specific to each beach - Mariani *et al.* (2012) have subsequently calculated generic erosion magnitudes (erosion volumes and distances) for ‘typical’ beaches around Australia. This project was commissioned by the Antarctic Climate and Ecosystems Co-operative Research Centre at the University of Tasmania for the purpose of providing a basis for estimating and comparing likely erosion magnitudes resulting from storms and sea-level rise of given magnitude in different regions of the Australian coast characterised by differing marine conditions including wave climate. The project divided Tasmania into three such ‘hydraulic regions’, and within each region characteristic or ‘typical’ wave climate, beach profiles and beach types were used to calculate ‘generic’ coastal erosion magnitudes (volumes and distances eroded). The widely used SBEACH and XBEACH modelling software was used to calculate generic short-term storm bite magnitudes (S1) for a ‘design storm’ comprising two back-to-back 100 year ARI storms; an allowance for a zone of reduced foundation capacity (or dune instability) backing the consequent erosion scarp was calculated as an additional setback (S5) using the method of Nielsen *et al.* (1992); and long term shoreline recession resulting from two sea-level rise scenarios of 0.4 m and 0.9 m rise by 2050 and 2100 relative to 1990 was estimated using a simplified application of the Bruun Rule. Relevant results for Tasmania are reproduced as Table 16 below. See Mariani *et al.* (2012) for further details of the conceptual basis and methodology used.

Whilst the methods and assumptions used by Mariani *et al.* (2012) are necessarily simplified for the purpose of calculating generic setbacks at the level of coastal regions (as opposed to individual beaches), this is at the same time the most sophisticated approach yet taken to defining potential erosion and recession setbacks for Tasmanian beaches generally, using widely accepted modelling techniques. Whilst it is intended that further acquisition of more empirical data on erosion responses of Tasmanian beaches will in the future allow generic erosion setbacks for Tasmania to be refined and improved, at the present time the generic setbacks calculated by Mariani *et al.* (2012) are arguably the best available basis on which to define coastal hazard zones for Tasmanian beaches generally.

Table 16 below reproduces an extract of the generic erosion setbacks data calculated by Mariani *et al.* (2012) for Tasmanian beaches. This data informs the method used to define soft sediment (sandy) shore erosion hazard banding in section 5.2 of this report.

Table 16: Generic coastal erosion setbacks calculated for Tasmanian open coast sandy beaches by Mariani *et al*. (2012). These setbacks comprise an allowance for short term storm bite from two back-to-back 100 ARI storms (S1, metres distance), a consequent zone of reduced dune stability behind the storm erosion scarp (S5, metres width), and an allowance for long term shoreline recession due to sea-level rise (S3, metres distance). Mariani *et al.* (2012) found no significant difference in calculated generic setbacks for differing beach morphodynamic types in each Tasmanian hydraulic region, and also recommended the use of the same generic Bruun Factor of 50 for all Tasmanian coastal regions and beach types (i.e., a generic long term recession due to sea-level rise of 50 x vertical sea-level rise was considered an appropriate conservative factor for all Tasmanian beaches). Within each coastal hydraulic region, differing storm bite distances and zones of reduced dune stability were calculated for differing beach profile angles which are represented in the table by differing average ground levels (GL in metres above AHD) at the back of the beach (i.e., at the foredune crest). Storm bite distances (S1) are less on steeper beaches because of the greater volume of sand to be removed for each horizontal metre of storm bite, whereas conversely dune instability zones (S5) are wider for steeper beaches (higher dunes) since there is greater potential for slumping of higher dune scarps.

Region	**S1 (m) storm bite** (2 x 100 ARI storms)			**S3 (m) Recession due to sea-level rise**		**S5 (m) Width of zone of reduced dune stability**		
	4.0 m (GL AHD)	6.0 m (GL AHD)	10 m GL AHD)	0.4 m SLR	0.9 m SLR	4.0 m (GL AHD)	6.0 m (GL AHD)	10 m GL AHD)
North Tas coast (Region 14)	25	17	10	20	45	10	13	19
East Tas coast (Region 15)	38	25	15	20	45	10	13	19
Storm Bay, SE Tas (Region 15A)	25	17	10	20	45	10	13	19
West – South Tas coast (Region 16)	63	42	25	20	45	10	13	19

Appendix 4 – Tasmanian Soft-Rock Recession Rates – Empirical Data

‘Soft rock’ shores are relatively erodible shores but, unlike sandy beaches, are incapable of naturally recovering or rebuilding after erosion events. Although individual erosion events occur stochastically, all erosion is cumulative on these shores. Hence over a sufficiently long period (decades) these shores display an average recession rate which provides a useful measure of erosion hazard or risk.

No data is available on individual storm bites in ‘soft rock’ shorelines on the Tasmanian coast; however data obtained from historic ortho-rectified air photo time series by Sharples *et al.* (in prep.) does allow determination of maximum and minimum recession rates for two Tasmanian ‘soft rock’ shores (both Tertiary-age semi-lithified sandy and gravelly cohesive clay shores). See Table 17 below. No other data on storm bites or recession rates is known to have been collected for Tasmanian soft rock coasts.

Table 17: Maximum and minimum shoreline recession rates for two progressively eroding cohesive clay shores at Rokeby Beach and Barilla Bay, Tasmania, calculated from air photo time series over the dates indicated. These are the only Tasmanian ‘soft rock’ shores for which recession rate data is known to be available.

Location	**Recession rate** (metres per year)	**Wave Exposure Class**	**Information Source**	**Notes**
Barilla Bay (maximum recession rate)	0.35	Fully sheltered from swell (exposed to local wind waves only)	Sharples *et al.* in prep. (historic air photo analysis)	Low profile active scarp in cohesive clay, air photo series 1946 - 2010
Barilla Bay (minimum recession rate)	0.02	Fully sheltered from swell (exposed to local wind waves only)	Sharples *et al.* in prep. (historic air photo analysis)	Low profile active scarp in cohesive clay, air photo series 1946 - 2010
Rokeby Beach (maximum recession rate)	0.104	Low (exposed to local wind-waves and to refracted & attenuated swell)	Sharples *et al.* in prep. (historic air photo analysis)	Low profile active scarp in cohesive clay, air photo series 1957 - 2010
Rokeby Beach (minimum recession rate)	0.013	Low (exposed to local wind-waves and to refracted & attenuated swell)	Sharples *et al.* in prep. (historic air photo analysis)	Low profile active scarp in cohesive clay, air photo series 1957 - 2010

Appendix 5 – Queries and examples of errors used to define the coastal erosion investigation areas

This appendix provides details of investigations used to identify ‘coastal erosion investigation areas;’ as described in section 7.0 of this report.

Process to identify voids in the coastal area

1. Intersect the test area layer with the base erosion hazard banding layer
2. Delete all polygons with a base hazard banding attribution
3. Attribute the remaining areas as coastal erosion investigation areas
4. Merge back into the coastal erosion hazard banding layer
5. Attribute the hazard band as “Coastal Erosion Investigation Area”
6. Figure 25 below shows an example of a void in the data (green) which has no undying base data.

Figure 24: Example void area in the data (shown as green). Area shown is at St. Helens, north-eastern Tasmania.

Process to identify hazard band areas not connected to the coast

1. Select all high, medium, and low hazard band polygons
2. Dissolve all features in to a single multipart feature
3. Explode the multipart feature into individual features
4. Select all polygons not connected to the coastline by more than 0.5m
5. Using the selection, create a selection within the original hazard banding layer to identify all polygons not connected to the coast.
6. Reclassify as “acceptable” hazard bands

Attributes which should not touch the coast

Some hazard zones should not touch the coast (e.g., Table 18). However instances have arisen where this has occurred; the following procedure was run to identify such cases for subsequent manual examination and correction:

Table 18: Hazard band components or zones which should not touch the coast (considered as the cartographic HWM line).

Component	reason
'Acceptable hazard zone (normal soft rocks)'	This area should always be landwards of the soft rock recession areas This will occur due to a misclassification in the soft rocks layer.
'Longer-term potential recession hazard zone (normal soft rocks) – Low haz zone 63m to 2100'	This area should always be landwards of the medium hazard zone to 2050. This will occur due to a misclassification in the soft rocks layer.
'Medium-term potential recession hazard zone (normal soft rocks) –Med haz zone 28m to 2050'	This area should always be landwards of the high hazard zone to 2025 This will occur due to a misclassification in the soft rocks layer.
'Acceptable hazard zone (all soft sed. shores) – landwards of likely and possible natural recession limits'	This layer should never intersect the coastline, if it does it is due to a missing or poorly classified likely or possible natural recession limit.

1. Using the erosion layer clipped to the test region.
2. Spatial query will identify all polygons within 0.5m of the Smartline.
3. Attribute query to check if it should logically touch the coast.
4. Select the following attributes, and query as follows:
   "Component" = 'Acceptable hazard zone (normal soft rocks)' OR "Component" = 'Longer-term potential recession hazard zone (normal soft rocks) – Low haz zone 63m to 2100' OR "Component" = 'Medium-term potential recession hazard zone (normal soft rocks) –Med haz zone 28m to 2050' OR "Component" = 'Acceptable hazard zone (all soft sed. shores) – landwards of likely and possible natural recession limits'
5. reclassify as coastal erosion investigation area

Soft rock on a hard rock foreshore

To identify areas which have a soft rock perched on top of a hard rock shoreline, these areas are highly unlikely to erode under the predicted sea level rise for the next 100 years.

1. Using the coastal erosion hazard areas clipped to the test region.
2. Using the Smartline identify all of the hard rock coasts.
3. Buffer the areas rock coasts by the test region
4. Select all of the soft rock coasts that fall within the hard rock buffer area.
   "Component" = 'Acceptable hazard zone (normal soft rocks)' OR "Component" = 'Longer-term potential recession hazard zone (normal soft rocks) – Low haz zone 63m to 2100' OR "Component" = 'Medium-term potential recession hazard zone (normal soft rocks) –Med haz zone 28m to 2050' OR "Component" = 'Near-term potential recession hazard zone (normal soft rocks) – High haz zone 14m to 2030'

5. Change hazard band classification to acceptable, and mark for manual review.

Observations from the final visual inspection by Chris Sharples

Following data tests and identification of coastal erosion investigation areas using geoprocessing techniques as described above and in section 7.0, Chris Sharples undertook a manual (visual) inspection of the resulting hazard banding for the south-east, eastern, north-eastern, northern and northwestern coasts from Huonville anti-clockwise to Smithton. During this process some hazard banding errors were able to be corrected, and others were classified as additional coastal erosion investigation areas to be corrected when possible. During this process, a number of general observations were made, as follows:

- On the other hand many “Acceptable” soft sediment polygons were shown reaching HWM in the initial hazard banding based on the underlying datasets; this “appears” incorrect so most of these have been identified as ‘coastal erosion investigation areas’. In many cases the problem is that these are indeed soft sediment polygons but they overlie bedrock above sea-level (with bedrock outcropping only at the shoreline and not mapped as such). Thus these should indeed be ‘Acceptable’ hazard bands but the methods used have not recognised this. However it should be possible to identify and reclassify these manually fairly quickly.

- However there may also be cases where these soft sediments do extend below sea-level (so should not be “Acceptable”) but incorrectly did not have a recession polygon drawn for them, thus were classified as “beyond recession polygon boundaries” and thus “Acceptable” when they actually should have had High, Med and/or Low hazard bands. This means further checking & editing of the recession polygon data set will be needed.

- Some very hazardous soft rock slopes at Georges Bay (Parnella) have been given Low and Acceptable hazard band ratings because of a mapped artificial structure at their base; however this structure is not resilient (its falling apart) and should not have been classified as such; these shores should be rezoned urgently as appropriate for (unprotected) soft rock shores.

- A significant number of ‘coastal erosion investigation areas’ have been identified in north-east Tasmania and I think a large proportion of the problems here relate to the use of very coarse-scale Quaternary sediment polygons in this area (e.g., many are copied from1:250,000 scale geological maps; these polygons show a poor fit to the (1:25,000) HWM line map of the coast, and are in need of significant editing. Some were corrected during this project (they were identified as a priority) but there wasn’t time to fix them all.

- Tertiary soft rock sitting over hard bedrock at the shore created zoning problems in some places (e.g., Tamar & Port Sorell). These were resolved on the basis that hard rock at the shore means a resilient shore despite any soft rock sitting over it further inland – i.e., the whole shore is “Acceptable” in such cases. This problem mostly gets resolved on logical grounds – i.e., hazard bands landwards of acceptable bands are illogical.

- At Devonport harbour, the mapping does not appear to have identified a significant number of artificial shores which consequently were given too high a hazard band. These have been identified as coastal erosion investigation areas – the full extent of the artificial shores should be properly mapped.