**Chris Sharples** B.Sc. (Hons), M.Sc.
Consultant Geoscientist

Coastal Geomorphology, Geoconservation and Landform Management

ABN: 68 034 834 434

# Indicative Mapping of Tasmanian Coastal Vulnerability to Climate Change and Sea-Level Rise: Explanatory Report

## 2nd Edition



Consultant Report to:
**Department of Primary Industries & Water, Tasmania**

By:
**Chris Sharples**
May 2006

GPO Box 1941, Hobart, Tasmania, 7001, Australia
chris@sharples.com.au

ISBN-10: 0 7246 6385 1
ISBN-13: 978 0 7246 6385 9

**Recommended Citation:**

Sharples, C., 2006: *Indicative Mapping of Tasmanian Coastal Vulnerability to Climate Change and Sea-Level Rise: Explanatory Report (Second Edition)*; Consultant Report to Department of Primary Industries & Water, Tasmania, 173 pp., plus accompanying electronic (GIS) maps.

**Report available from:**

http://www.dpiw.tas.gov.au/climatechange
or
http://www.coastalvulnerability.info

(free download as a PDF document).

**Front cover photos:** Sandy coasts are mobile landforms which are highly vulnerable to erosion and increased dune mobility in response to sea-level rise. The centre image depicts a beach and dunes at Nye Bay (southwest Tasmania) whose current active erosional state is probably primarily a response to renewed global sea-level rise during the 20th Century. However, sandy shores are not the only coastal landform type potentially vulnerable to accelerated erosion with sea-level rise. The left-hand image shows a shoreline of clayey-gravelly semi-lithified Tertiary-age sediments at Cornelian Bay (Hobart) which has receded several metres over the last few decades in response to wave erosion. Coastal cliffs (right-hand image) are another landform type which typically show ongoing erosion even with stable sea levels, and may show accelerated rock-falls and slumping in response to sea-level rise. This will be particularly evident where coastal cliffs are composed of only semi-lithified bedrock, as is the case for the Tasmanian cliff depicted here.

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# FOREWORD TO 2ND EDITION

The first edition (Sharples 2004a) of this report and its accompanying mapping provided indicative ("first pass") mapping of Tasmanian shorelines vulnerable to two coastal hazards related to projected sea-level rise, namely storm surge flooding and the erosion of sandy shorelines. In addition, the distribution of a type of shoreline considered to have minimal vulnerability to coastal hazards related to sea-level rise was also mapped (moderately sloping hard-rock coasts). However Tasmanian coasts vary widely in their geological and geomorphic (landform) characteristics, and whilst the indicative flooding mapping was comprehensive for the entire Tasmanian coast, in terms of erosion hazards the identification of sandy shores vulnerable to erosion, and of robust minimal vulnerability shores, accounted for only 45% of the length of the Tasmanian coast. The other 55% remained to be classified as being either robust shores having minimal vulnerability, or non-sandy coasts having erosion, slumping, cliff instability or other vulnerabilities.

This second edition of the indicative coastal vulnerability mapping was undertaken to identify non-sandy shores potentially vulnerable to a range of other coastal geomorphic hazards that may result from sea-level rise. Following recommendations made in the first edition of this report, non-sandy shoreline types potentially vulnerable to the following hazards were identified:

- Soft muddy shores potentially vulnerable to change;
- Soft (clayey-gravelly) or colluvial (slope deposit) shores potentially vulnerable to progressive erosional retreat and / or slumping; and
- Hard-rock sea cliffs potentially vulnerable to rock falls, collapse, slumping and cliff-line retreat.

In part, the identification of these additional coastal hazard types was made possible by the addition of further mapping data to the coastal geomorphic map of Tasmania upon which much of this indicative vulnerability assessment has been based, including further field mapping and the incorporation of new geological and geomorphic information provided by Mineral Resources Tasmania.

As a result of this additional indicative vulnerability mapping, a total of 84% of the Tasmanian coastline length has now been indicatively mapped as either being potentially vulnerable to a range of coastal geomorphic hazards related to sea-level rise, or as having minimal vulnerability to these hazards. The remaining 16% of the coast that remains unclassified mostly comprises less common shoreline geomorphic types – some of which will be vulnerable and some less vulnerable – but which will probably mostly need to have their vulnerability assessed on a site-specific basis.

In undertaking this work, the following additions, changes and upgrades have been made to the First Edition of this work (Sharples 2004a) to produce this Second Edition:

- The coastal geomorphic line map (*tascoastgeo_v3*) upon which the vulnerability mapping *tascsthz* produced by Sharples (2004a) was based, has been upgraded in a number of ways. These upgrades include the addition to the map of several east coast tidal lagoons that were not previously included in the map (e.g., Henderson Lagoon), and the incorporation of new field mapping data based on additional fieldwork by C. Sharples since 2004. Further geomorphic and geological data from other sources has also been incorporated, including new geological and slump hazard mapping by Mineral Resources Tasmania (Mazengarb 2004a,b, 2005, 2006; C. Calver *pers. comm.*). These changes resulted in more confident classification of some shorelines that were difficult to interpret from air photos (on which much of the original line map was based), but have mostly not affected sandy shores since these were previously mapped from air photos at a high level of confidence in all except the case of some very narrow sandy shores. Nonetheless, the most significant mapping change of this sort has been the re-classification of some shores in the Robbins Island region of far northwest Tasmania, which were previously classified as "muddy-silty" shores on the basis of an interpretation of earlier mapping by Munro (1978), but which have now been re-classified as "sandy shores" since this better reflects their actual sedimentological texture (fine sands).

The attribute table of the coastal geomorphic line map has also been edited and re-organised in several ways, including the re-naming of a number of attributes, re-numbering of several attribute codes to make the attribute code system more logical and systematic, and deletion of several attributes now considered redundant (and not used in the vulnerability mapping). These changes have resulted in the production of a new version of the coastal geomorphic line map, *tascoastgeo_v4gda*, upon which the vulnerability mapping provided with this report (*tascsthz_v2*) is based. The changes to the line map are fully documented in the Data Dictionary for *tascoastgeo_v4gda* (Sharples 2006), and are reflected in the Data Dictionary for *tascsthz_v2* which forms Appendix 2 of this report.

- Using the upgraded *tascoastgeo_v4gda* geomorphic map, the indicative mapping of sandy coast erosion vulnerability (*sandy* attribute) and minimal vulnerability shorelines *(minhaz* attribute) that was provided in the first edition of this vulnerability mapping (*tascsthz*) has been redone using the same method as applied to the first edition (Sharples 2004a), but taking account of the new attribute names and attribute codes where relevant. The result is the *Sandyvuln* and *Minvuln* attributes of the 2nd Edition coastal vulnerability map *tascsthz_v2*. The resulting vulnerability mapping involves very little change to the indicative mapping of these coastal vulnerability categories from the first edition, with only a few differences resulting from ground truthing in certain areas since 2004 (the most significant change being the inclusion of sandy shores in the Robbins Island region, that were previously classified as "muddy silty" shores).

- Using the upgraded *tascoastgeo_v4gda* geomorphic map, indicative mapping of several new coastal vulnerability types has been undertaken, namely semi-lithified (soft) clayey-gravelly or colluvial (slope deposit) shores potentially vulnerable to progressive erosional retreat and / or slumping (*Erosvuln* attribute), hard-rock sea cliffs potentially vulnerable to rock falls, collapse, slumping and cliff-line retreat (*Cliffvuln* attribute), and soft muddy (mainly estuarine and deltaic) shores potentially vulnerable to change (*Muddyvuln* attribute).

- Significant changes to this 2nd Edition report include changes to the Data Dictionary (Appendix 2) documenting updates to the coastal line map described above, sections and text added to this report to describe the mapping of the above new vulnerability categories (in Sections 2.0 & 4.3), and incorporation of revised statistics indicating the proportions of the Tasmanian coast now covered by indicative vulnerability mapping (see Summary and Section 4.3). Due to the addition of several tidal lagoons to the coastal line map, the total length of the Tasmanian coastline cited in this report is now some 34 km longer than the length cited in the first edition of this work (Sharples 2004a). A new set of maps illustrating parts of the vulnerability mapping have been provided in Appendix 1, including a map identifying coastal segments comprising the 16% of the coast whose vulnerability remains unclassified (Figure 50). In other respects the text of this report remains essentially unchanged from the first edition, although a variety of minor editing corrections and additional information have been incorporated in various places throughout the text. These do not change the key outcomes or implications of this report in any significant way from those documented in the first edition (Sharples 2004a).

The flooding vulnerability mapping element of this work (Sections 2.2 & 4.3.2) remains unchanged from the first edition.

# SUMMARY

Considerable geological and geomorphic evidence, direct observations of subsiding coasts, theoretical considerations and experimental investigations demonstrate that rising sea levels result in significant physical changes to shorelines, as they adapt to the changing sea-level conditions. Physical changes resulting from sea-level rise, especially on soft sandy shores and in low-lying coastal areas, are likely to be sufficiently significant in some areas, over future decades, as to pose risks for buildings, roads and other infrastructure in vulnerable coastal locations, as well as causing changes to coastal landform process systems and biological communities.

This report describes and explains a digital map set that was developed during 2004 - 2006 to provide an indicative (or "first pass") identification of Tasmanian coastal areas potentially vulnerable to increased storm surge flooding, shoreline erosion, rock falls, and slumping as a result of global climate change and sea-level rise. The mapping additionally identifies some Tasmanian shores having minimal vulnerability to these hazards.

In this report, the term *risk* refers to the combination of *hazard* and *vulnerability*, where the *hazard* is a physical process or event – such as sea-level rise or storm surge events – and *vulnerability* is the degree of exposure of things, such as coastal landform features, to the impacts of the hazards[1]. In these terms, the assessment presented in this report and the accompanying mapping is essentially an assessment of Tasmanian coastal landform *vulnerability* to the *hazards* of climate change and sea-level rise. The use of this vulnerability assessment to assess the *risks* to valued socio-economic or ecological assets (for example, economically valued infrastructure, significant saltmarsh communities or prized beach environments) is a further stage of risk assessment which has not been undertaken here, but for which this indicative vulnerability assessment provides a basis.

Coastal landforms, particularly "soft" shores such as sandy coasts, are one of the most mobile and dynamically changing geomorphic (landform) environments on Earth. Even in the absence of sea-level rise and climate change, coasts can and do change their physical form significantly over relatively short periods. Flooding and shoreline erosion have affected Tasmanian coasts repeatedly over the last 6,500 years – while sea level has been mostly steady – and in many cases these ongoing changes pose risks for inappropriately-sited coastal development in Tasmania. It is important to be aware that sea-level rise and climate change are not the only causes of coastal hazards in Tasmania, however the renewed sea-level rise and climate change that has commenced over the last century or so is likely to increase or accelerate coastal flooding and erosion hazards where these have existed previously, and to initiate new phases of erosion on some shores that were previously in equilibrium.

Following about 6,500 years of relative sea-level stability, a renewed global sea-level rise of 10 – 20 cm has occurred during the last century. A sea-level rise relative to the land of about 14 centimetres since 1841 has been measured on the south-east Tasmanian coast, much of it probably having occurred during the last century. Global mean sea-level rise accelerated during the 20$^{th}$ Century, and an ongoing global sea-level rise of between 9 and 88 centimetres is now projected to occur by 2100 relative to 1990 sea level. In addition, it is possible that coastal storms of a given magnitude may occur more frequently over future decades than in the past.

The physical (geomorphic) effects of ongoing sea-level rise and climate change on Tasmanian coasts over future decades are likely to include (but are not limited to):

[1] Some workers use the term "sensitivity" in the way "vulnerability" is used here, and use "vulnerability" in a different sense (see Section 1.6), however the usage adopted in this report is more traditional in geohazards work.

- increased flooding of low-lying coastal areas during storm surges;
- erosion and landwards recession of soft sandy shorelines, particularly where these are backed by low-lying plains of soft unconsolidated sediments;
- increased mobility of coastal sand dunes, triggered by sandy shore erosion and potentially by climate stress on dune vegetation cover;
- modification of soft low-lying muddy estuarine and deltaic shores;
- acceleration of existing progressive erosion of soft clayey-gravelly shorelines (e.g., Tertiary-age sediment shores);
- increased slumping of steep landslip-prone shorelines, including shores of basalt colluvium, Tertiary-age sediment, and intensely fractured and weathered bedrock shores;
- accelerated rock fall, cliff-collapse and retreat of vertical or near-vertical bedrock sea cliffs; and
- rising coastal groundwater tables and increased penetration of salt water wedges into coastal ground waters.

On the other hand, some gently to moderately sloping hard bedrock shorelines are likely to show little physical change or significantly increased flooding in response to sea level rise over the next century.

Certain basic geomorphic (landform) characteristics – which are referred to in this report as *fundamental vulnerability factors* – predispose certain types of shores to being potentially susceptible to one or more of the physical coastal changes (above) expected to occur as a result of sea-level rise. Such changes are "risks" insofar as they are likely to threaten the integrity of infrastructure and assets that have been placed on vulnerable coasts without due consideration of sea-level rise.

However, the degree to which any particular shore having the fundamental vulnerability factors predisposing them to a certain coastal hazard will actually be changed (or "impacted") by that hazard may vary considerably depending on a wide range of local climatic, oceanographic, geological, geomorphic and topographic factors or variables which are here referred to as *regionally and locally variable vulnerability factors*. Complex feedback processes between the various processes and variables affecting particular shores mean that whilst some shores may respond to sea-level rise in relatively simple ways – e.g., by simple erosion and recession as described by the well-known "Bruun Rule" of erosion by sea-level rise – on some other shores the effect of sea-level rise can be overwhelmed by other local conditions which cause the shore to behave in different ways that the Bruun Rule would not predict.

For example, the *fundamental vulnerability factor* predisposing an open (oceanic) coast sandy shore to significant coastal erosion and recession in response to sea-level rise is the exposure of sandy shores backed by low-lying sandy sediment deposits to storm wave attack. However, there are situations in which the effects of littoral (longshore) sand drift and sediment budget may be such as to cause such sandy shorelines to respond to sea-level rise by prograding (growing seawards) rather than receding. This is likely to be the case at the southern end of Ocean Beach (western Tasmania), where sand eroded from the northern parts of the beach (see Figure 6) is drifting southwards and accumulating at the southern end, which is consequently prograding and is likely to do so more rapidly in future as sea-level rise causes accelerated erosion and southwards drift of sand from the northern parts of the beach.

Assessments of coastal hazards resulting from (or increased by) climate change and sea-level rise can occur at several different levels of detail and reliability (see detailed discussion in Section 3.0):

- *Indicative (or "First Pass") Assessments* involve simply the identification of coasts having the *fundamental vulnerability factors* predisposing them to particular coastal hazards. This approach has the advantage of rapidly providing planners and managers with a precautionary basis for making decisions on coastal development in areas where more detailed coastal vulnerability assessments are lacking, however it does not specify the *degree, pattern or rate* at which particular shores are likely to be impacted by coastal hazards.

- *Regional (or "Second Pass") Indicative Assessments* are indicative assessments in which a number of key *regionally variable vulnerability factors* are taken into account in addition to the *fundamental vulnerability factors*. This level of assessment can begin to rank different coastal areas in terms of the likely relative degree to which they may be impacted by a coastal hazard.

- *Site Specific Assessment and Modelling*, incorporating all *locally and regionally variable vulnerability factors*, is the most reliable means of predicting the likely degree, pattern and rates at which coastal hazards may impact on a particular coastal stretch or area that has been identified as potentially vulnerable by an indicative first pass assessment. However this level of assessment requires a considerable investment of time and money.

- *Shoreline Monitoring and Refinement of Models* involves regular repeated quantitative physical measurement of the form, profile and geomorphic processes of particular shorelines over periods of time long enough to reliably discern long-term trends and patterns of shoreline change. Such data can be used to test and refine site-specific coastal behaviour models (above), and so monitoring should be an integral component of any site-specific modelling. This approach to coastal vulnerability assessment is by definition very time consuming, however it is the only approach that can yield definitive data on actual trends in shoreline change.

The digital mapping accompanying this report provides an Indicative ("First Pass") Assessment of the entire Tasmanian coast (including the Bass Strait islands and other major islands, but excluding Macquarie Island) that identifies coastal areas potentially vulnerable to:

- storm surge flooding
- erosion and landwards recession of sandy shorelines
- changes in muddy estuarine and deltaic shores
- progressive erosional retreat and / or slumping of soft (typically clayey-gravelly) bedrock or colluvial shores
- rock falls, collapse, slumping and retreat of hard-rock coastal cliffs

The digital mapping additionally provides an indicative identification of:

- moderately sloping hard-rock shores with minimal potential vulnerability to hazards resulting from climate change and sea-level rise

*Indicative Storm Surge Flooding Vulnerability*
Coastal areas potentially susceptible to storm surge flooding have been identified on the basis that the *fundamental vulnerability factor* for this hazard is the presence of significant areas of low-lying low-profile land immediately landwards of the mean high water mark. For the purposes of this assessment, vulnerable low-lying coastal areas are considered to be those lying within the height range of historically recorded 0.01% exceedance (roughly 2 – year return period) storm surge event water levels, or likely to do so as a result of projected future sea-level rise. Storm surge water levels were obtained from the seven Tasmanian tide gauge stations with sufficiently long records, and have been interpolated in a linear fashion between these tide gauges around the Tasmanian coast. Low-lying coastal areas within the height range of flooding by 0.01% exceedance storm surge events were identified for the entire Tasmanian coast using the best digital topographic dataset available at a state-

wide coverage, namely the 25m Digital Elevation Model (DEM) of Tasmania. Potential flood areas were mapped for three scenarios, namely:

- 0.01% exceedance flood levels above mean sea level for 2004;
- 0.01% exceedance flood levels above the minimum projected sea level for 2100; and
- 0.01% exceedance flood levels above the maximum projected sea level for 2100.

The potential flood vulnerability areas obtained by using the 25m DEM in this way are of variable accuracy or spatial resolution around the Tasmanian coast, depending on the differing topographic data sources used to construct the 25m DEM in different parts of the state. Fortunately, in many of the more urbanised coastal areas – where coastal hazard risks to infrastructure are a bigger problem – the DEM has been constructed from relatively high-resolution 1:5,000 ortho-map contours. In all cases, however, the indicative coastal flood vulnerability zones identified by the maps accompanying this report should be considered purely as areas *potentially* prone to storm surge flooding, which are thus identified as areas that should be subjected to more detailed site-specific assessments of flood vulnerability.

The total areas of the Tasmanian coastal zone above the mean high water mark (including Bass Strait islands and other major islands apart from Macquarie Island) that have a potential storm surge flooding vulnerability under each of the 3 scenarios assessed are as follows (determined from the digital polygon maps created for each scenario from the 25m DEM):

| **Scenario** | **Indicative coastal area vulnerable to storm surge flooding in a 0.01% exceedance event (km$^2$)** | **Digital map file (shapefile)** |
|---|---|---|
| 2004 0.01% exceedance storm surge flood levels | 240 | *fldhz2004_gda* |
| Minimum 2100 0.01% exceedance storm surge flood levels | 247 | *fldhz2100min_gda* |
| Maximum 2100 0.01% exceedance storm surge flood levels | 328 | *fldhz2100max_gda* |

It is notable that in many coastal places the areas of land that may potentially be flooded under higher projected future sea levels are only a little greater than under present sea levels, due to certain characteristics of the topography of many low coasts in Tasmania (see Section 4.3.2). However it is important to note that significantly greater flood-water depths and potentially increased frequencies of storm surges will cause additional flooding impacts beyond simple increases in the (horizontal) areas of coastal land prone to flooding.

*Other Indicative Coastal Vulnerabilities, and Minimal Vulnerability Shores*

Coastal areas with a potential sandy shore erosional recession vulnerability have been indicatively identified on the basis that the *fundamental vulnerability factors* for this hazard are the presence of unconsolidated sandy shores backed by low-lying plains of unconsolidated (usually sandy) sediment. These shores have been sub-divided into open-ocean shores and coastal re-entrant shores, on the basis that erosion and recession of these two types in response to sea-level rise are partly governed by significantly differing geomorphic processes. Sandy shores immediately backed by hard bedrock rather than sandy sediment plains have also been separately identified, since whilst these may be subject to beach erosion – and potentially to complete loss of beaches – their potential for significant landwards shoreline recession in the short to medium term is limited.

Soft muddy shores have been separately identified as being vulnerable to change (including erosion) with rising sea levels and climate change, on the basis that their sedimentological characteristics mean they may behave differently to sandy shores, and also because many of them are composed of estuarine or deltaic sediment deposits whose response to climate change may be partly determined by fluvial processes in their inland river catchments.

A further category of "soft" shoreline has also been indicatively mapped as a separate vulnerability category. These are typically clayey-gravelly textured shores of semi-lithified or deeply weathered bedrock, and shores composed of unconsolidated slope deposits (including old landslide debris). Again, these are likely to behave differently to either sandy or muddy shores, and their response to sea-level rise may vary from simple progressive erosion on low profile coasts, to erosion accompanied by slumping (landslides) on steeper coastal profiles.

Finally, hard-rock sea-cliffs have been identified as a further coastal vulnerability category since these may be prone to rock-falls, slumping and collapse both under present-day conditions, and more so in response to projected future sea-level rise. The distinctive characteristics of these shorelines again means that they will probably behave differently to any of the other above categories.

An important category of indicative minimal vulnerability shores has also been identified, on the basis that the *fundamental minimal vulnerability factors* for this type of shoreline are gently to moderately sloping hard bedrock shores without significant unconsolidated slope deposits or talus deposits, and without vertical cliffs rising greater than 5 metres vertically from the high water mark. These shores are indicated to have minimal vulnerability either to flooding or to the various types of erosional impacts noted above.

The above shoreline types were identified for all Tasmanian shores using the 1:25,000 digital shoreline geomorphic types line map of Tasmania (*tascoastgeo_v4gda,* and the derived map *tascsthz_v2gda*), which contains comprehensive data on the relevant fundamental vulnerability factors for all Tasmanian shorelines. The shores indicated to be potentially vulnerable to the hazards described above, and indicative minimal vulnerability shores, are mapped in the digital line map *tascsthz_v2gda* accompanying this report using the attributes *Sandyvuln, Muddyvuln, Erosvuln, Cliffvuln*, and *Minvuln*. Shores not yet classified as either being vulnerable to any of these hazards, or as having minimal vulnerability, are identified by the *Unclass* attribute.

The lengths of the Tasmanian coastline, as mapped at 1:25,000 scale, that fall into these indicative coastal vulnerability categories are summarised in Table 1 following (determined from the digital coastal map *tascsthz_v2gda*).

It should be noted that, whilst indicative storm surge flood vulnerability areas have been determined for the entire Tasmanian coastline (previous page), in terms of other coastal hazards (listed on Table 1), only 84% of the Tasmanian coastline has been indicatively assessed as having either potential vulnerability to the hazards noted above, or as having minimal vulnerability (sloping rocky) shores. There remains a further 16% of the Tasmanian coastline, consisting of a range of other shoreline types, for which vulnerability – or lack thereof – to hazards relating to climate change and sea-level rise (other than storm surge flooding) still remains to be indicatively assessed. Many of these are minor or unusual shoreline types (e.g., cobble beaches with no significant sandy component – see Sections 2.9 & 4.3.8) whose vulnerability will need to be assessed on a site–specific basis.

| **Length (km) *** (1:25,000 scale) | **Percentage Length *** | **Shoreline Type & Indicative Vulnerability** |
|---|---|---|
| 6472[2] | 100% | Whole of Tasmania (incl. Bass Strait islands and other major islands, but excluding Macquarie Island) |
| 1259 | 19% | Minimal Vulnerability shores (sloping hard-rock shores) |
| 1129 | 17% | Open coast sandy shores backed by low-lying sandy plains (potentially susceptible to erosion and significant recession with sea-level rise) |
| 371 * | 5.5% * | Open coast sandy shores immediately backed by bedrock: (potentially susceptible to beach erosion and loss with sea-level rise, but shoreline recession likely to be minimal over next 50-100 years, except where bedrock is only semi-lithified) |
| 512 | 8% | Re-entrant sandy shores backed by low-lying sandy plains: (potentially susceptible to erosion and significant recession with sea-level rise) |
| 185 * | 3% * | Re-entrant sandy shores immediately backed by bedrock: (potentially susceptible to beach erosion and loss with sea-level rise, but shoreline recession likely to be minimal over next 50-100 years, except where bedrock is only semi-lithified) |
| 25 * | 0.5% * | Other sandy shorelines (potentially vulnerable to erosion but type unclassified) |
| 141 * | 2% * | Low profile soft clayey – gravelly shores: (Potentially vulnerable to progressive erosional recession) |
| 213 * | 3% * | Moderately to very steep soft clayey – gravelly or colluvial shores: (Potentially vulnerable to progressive erosional recession and to slumping or landslides) |
| 258 | 4% | Soft muddy shores backed by extensive low-lying unconsolidated sediment plains: (Potentially vulnerability to significant change with sea-level rise, including significant erosional recession) |
| 200 * | 3% * | Soft muddy shores mainly backed by bedrock: (Potentially vulnerable to limited shoreline change except where bedrock is colluvium-mantled or is semi-lithified bedrock) |
| 1216 * | 19% * | Exposed hard-rock cliffed shorelines: (potential vulnerability to rock falls, collapse, slumping and cliff retreat) |
| 143 * | 2% * | Sheltered hard-rock cliffed shorelines: (lower potential vulnerability to rock falls, collapse, slumping and cliff retreat) |
| 1045 | 16% | Remaining shoreline types not falling into any of the above categories (vulnerability unclassified) |

**Table 1:** Total lengths of Tasmanian shorelines classified into the vulnerability categories described in this report. * Note that the individual shoreline type lengths and percentages sum to more than 100% because several coastal vulnerability types partly overlap (as indicated by *). For example, some sandy shores backed by bedrock are also prone to slumping, cliff rock falls or progressive erosion where the backshore bedrock is cliffed, or comprises semi-lithified Tertiary sedimentary rocks. Hence these and some other overlapping shoreline types are counted in more than one of the above categories.

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[2] Note that this total length is slightly greater than the total length of 6438 km calculated by Sharples (2004a) for the original version of this indicative vulnerability mapping. This is the result of the addition of a number of coastal tidal lagoons to the shoreline geomorphic map (*tascoastgeo_v4gda*) upon which the vulnerability map *tascsthz_v2gda* is based.

***Recommendations***
The indicative coastal vulnerability mapping provided with this report constitutes the logical first step in a broader strategic approach to coastal vulnerability assessment and management. Hence, the recommendations provided below are essentially aimed at progressing such a strategy to its subsequent logical stages:

*Indicative (First Pass) Assessment:*

- The indicative coastal vulnerability assessments provided with this report should be used as precautionary assessments of coastal vulnerability to guide coastal planning until such time as more detailed site-specific assessments are available for priority areas (see Section 3.2).

- In order to guide forward planning of developments in indicatively vulnerable coastal areas, it is recommended that planners and policy-makers give consideration to the most appropriate means of defining precautionary recession vulnerability areas or "envelopes" behind shorelines indicatively assessed as being vulnerable to erosion (see discussion in Sections 2.3, 4.3.3 and 5.0). Transparent recognition of the uncertainties in predicting actual future coastal recession rates will be important in managing coastal development.

- As new geological mapping of coastal areas by Mineral Resources Tasmania is completed, this mapping should be used to upgrade the *tascoastgeo* Shoreline Geomorphic Map, which should then in turn be used to upgrade the indicative mapping of slump-prone (and other) shoreline types provided as part of this indicative coastal vulnerability mapping (see sections 2.7 & 4.3.5),

*Regional (Second Pass) Indicative Assessments:*

- The exposure, wave energy and sediment budget attributes in the *tascoastgeo_v4gda* and *tascsthz_v2gda* map datasets should be upgraded and reviewed as described in Appendix 3, and incorporated into regional ("second pass") indicative assessments of Tasmanian coastal vulnerability areas (see Section 3.3.1). These datasets could be used to build on the approach to a "Second-Pass" assessment of Tasmanian coasts using a Coastal Vulnerability Index that has been initiated by Leaver (2005).

*Site – Specific Assessments and modelling:*

- The indicative coastal vulnerability assessment provided with this report should be used – in combination with socio-economic data and trends – to identify indicative coastal vulnerability areas that are under significant pressure from development or use, and hence should be priorities for site-specific vulnerability assessments (see Section 3.3.2). Pilot studies should be undertaken at a range of such sites to determine the scale and scope of site-specific investigations needed to improve understanding of the vulnerability of each site.

*Shoreline Monitoring*

- Programs to monitor the response of a range of Tasmanian shorelines to sea-level rise should be funded, encouraged and supported (see Section 3.4). Monitored shorelines should include indicative coastal vulnerability zones that are under development pressure, relatively undisturbed "benchmark" beaches, and a broad representative range of shoreline types distributed around the Tasmanian coast.