3.0 GEOCONSERVATION AND GEOHERITAGE VALUES OF THE TWWHA AND ADJACENT AREAS

3.1 Introduction

This section provides an assessment of the geoconservation (geoheritage) values of the TWWHA, with particular emphasis on the identification of geoconservation values of World Heritage significance. This assessment is based on:

- a review (Section 2.3.2) of the geoconservation values cited in the 1989 TWWHA nomination (DASETT 1989);
- a review of relevant new scientific data that has become available since 1989 (Section 2.4); and:
- the use of contemporary procedures for rigorous justification of geoconservation significance (see Section 2.2) in terms of the updated World Heritage Criteria (UNESCO 1999; see this report Section 2.3.3).

In general, this review indicates that the major geoconservation World Heritage values of the TWWHA identified in 1989 are robust and remain valid. However, only a handful of individual sites or features in the TWWHA are considered to have World Heritage value in their own right, as physical features considered in isolation (e.g., Exit Cave). In general it is the diversity, extent and inter-relationships between numerous features, sites, areas or processes that gives World Heritage significance to certain geoheritage “themes” in the TWWHA (e.g., the "Ongoing Natural Geomorphic and Soil Process Systems" and “Late Cainozoic "Ice Ages" and Climate Change Record” themes). This “wholistic” principle underpinned the 1989 TWWHA nomination (DASETT 1989, p. 27; see this report Section 2.3.2), and is strongly supported by the present review (see discussion and justification of this principle in Section 2.2).

A corollary of this principle is that many of the particular features and sites contributing to a theme of World Heritage significance may not individually be of World Heritage significance, but rather may individually be considered to have lower levels of significance (i.e., significance at local to national levels). Geoconservation inventory work since 1989 (see Section 2.4) has indeed resulted in the identification of a large number of features contributing to World Heritage themes in the TWWHA, most of which have individually been assigned lower significance levels; these features and their significance levels have been recorded in the Tasmanian Geoconservation Database (TGD 2001). This section (3.0) focuses primarily on the geoconservation themes and sites of World Heritage significance in the TWWHA; however, Appendix (1.0) provides a comprehensive listing of all features and sites – of all significance levels - within the TWWHA that have been listed on the TGD, together with the significance levels assigned to each. Whereas many of these features contribute to the World Heritage themes discussed in this section, there are also numerous sites listed which both are of less than World Heritage significance individually, and which also do not contribute to World Heritage themes. Such features are still of conservation significance, and warrant appropriate protective management, however they are not the primary focus of this review.

A comprehensive statement of the geoconservation values recognised in the TWWHA at the present time – at all levels from World Heritage to Local significance levels - can be considered to be comprised by the World Heritage themes and features identified in this Section (3.0), the individual features contributing to those themes including those listed in Appendix (1.0), together with all those other features of lesser significance levels listed in Appendix (1.0).

Some of the geodiversity phenomena previously cited in the 1989 TWWHA nomination as contributing to World Heritage values do not withstand scrutiny as having World Heritage
significance (eg, Precambrian multiple fold phases, Collingwood River eclogites). In general this is because these sites cannot be ascribed World Heritage value as individual features, and also do not significantly contribute to a broader identifiable World Heritage theme. Most of these features are considered to have geoheritage significance at State or even National levels, but not at World levels, and so are best considered as non-World Heritage geoconservation values which nonetheless contribute to the geoheritage value of the TWWHA and remain worthy of conservation management (as noted above).

A significant result of this review is that, whilst numerous features contributing to the significance of World Heritage themes have been newly identified or better understood, and significant new aspects of previously identified themes have been discovered (e.g., significance of palaeokarst in cave development processes, influence of blanket bogs on fluvial landforms, etc), no entirely new World Heritage geoconservation themes, beyond those previously identified in the 1989 nomination, have been identified. It is likely that this is at least partly because most scientific research conducted in the TWWHA since the 1989 nomination has been funded and directed towards facilitating better management of those World Heritage value themes for which the TWWHA was inscribed in the World Heritage List.

### 3.2 TWWHA World Heritage Geoconservation Values

This section presents the World Heritage geoconservation values of the TWWHA, as recognised as an outcome of this review, in two different formats. Section (3.2.1) below summarises the values in tabular form, and provides a direct comparison between the values recognised in the 1989 TWWHA nomination, and those values recognised in the current (2002-2003) review. Section (3.2.2) following organises the recognised values according to themes, and provides the justification for the recognised values based on the current World Heritage criteria (Section 2.3.3) and on current geoconservation significance assessment procedures (Section 2.2).

#### 3.2.1 Table of TWWHA World Heritage Geoconservation Values (by World Heritage Criteria)


<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Criterion (i)</strong> Be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of land forms, or significant geomorphic or physiographic features.</td>
<td></td>
</tr>
<tr>
<td>The wilderness character of the TWWHA means that it is one of only 3 large temperate regions in the southern hemisphere where natural processes (including on-going geomorphic and soil processes, which are included within the category of &quot;on-going geological processes&quot; under Criterion i) continue to operate in an unmodified fashion, thus it provides a global &quot;benchmark&quot; for temperate natural processes (DASET 1989, p. 27).</td>
<td><strong>Ongoing Natural Processes theme:</strong></td>
</tr>
<tr>
<td>The following ongoing geomorphic and soil</td>
<td>This review strongly supports the outstanding universal value of the large area of the TWWHA in which effectively natural geomorphic and soil processes continue as an overarching <strong>Ongoing Natural Processes</strong> theme of World Heritage significance.</td>
</tr>
<tr>
<td></td>
<td>This over-arching World Heritage theme has been classified into several sub-themes, as detailed below, several of which not only</td>
</tr>
</tbody>
</table>
processes were cited in the 1989 TWWHA nomination as globally significant because they are ongoing in an essentially undisturbed environment, and hence have world value as "benchmark" processes against which to compare the effects of human activity elsewhere:

Fluvial processes are ongoing in an essentially undisturbed environment (very briefly mentioned only).

| contribute to the overall value of this theme, but also have World Heritage significance in their own right. |
| Ongoing Fluvial Geomorphic Process Systems sub-theme: |
| Systematic research into TWWHA fluvial systems has been in progress only since the late 1980's. Effectively undisturbed natural fluvial process systems of the TWWHA comprise the largest area of undisturbed temperate fluvial glacial-influenced systems free of contemporary glacial (glacio-fluvial) influences in the southern Hemisphere and probably the world. As such, the Ongoing Fluvial Geomorphic Process Systems sub-theme has outstanding universal value in its own right, and also as a major element of the Ongoing Natural Processes World Heritage theme. |
| Several individual fluvial geomorphic systems of the TWWHA have outstanding universal value in their own right: |
| • The New-Salisbury River Basin has outstanding universal value in its own right as the largest entire source-to-sea fluvial system in the TWWHA (and Tasmania as a whole) that is free of effective Aboriginal or European process disturbances, and includes a wide diversity of undisturbed fluvial (and karst) sub-systems. |
| • The Birches Inlet – Sorell River – Pocacker River Tectonically-Influenced Peat Land Fluvial System (and related marine terraces at Birches Inlet) has outstanding universal value in its own right as an ongoing fluvial process system exemplifying tectonic and peat soil influences on fluvial processes. |

The largest fluvial system in the TWWHA, the Gordon River basin, is unfortunately partly disturbed, and its World Heritage value under this theme is under threat. However, major tributary catchments of the Gordon System remain largely or wholly undisturbed.
Lakes were noted in the 1989 TWWHA nomination only as important habitats – see Criterion iv.

Blanket bog organic soil processes ongoing in an essentially undisturbed environment; these are the most extensive ongoing blanket bogs in the southern hemisphere. Associated peat mounds enhance significance of the blanket bogs.

Periglacial processes continue on higher summits (very briefly mentioned only).

Marine & aeolian (coastal and coastal-aeolian) processes are ongoing in an essentially undisturbed environment (very briefly mentioned only)

---

Ongoing Lacustrine Process Systems sub-theme:

Lakes of the TWWHA are also important as undisturbed lacustrine geomorphic systems (with undisturbed catchments) under Criterion (i). They display a wide diversity of origins, processes and types (glacial lakes, flood-plain lakes, karst (sinkhole) lakes, dune lakes, meromictic lakes, oligotrophic and dystropic types, etc).

- The Lower Gordon levee-flood basin – meromictic lakes are of outstanding universal value. However, the values of these lakes are under threat as a result of human disturbance of the Gordon River fluvial process system.

Blanket Bog Peat Land Soil Systems sub-theme:

This sub-theme has outstanding universal value in its own right, and also contributes significantly to the overarching Ongoing Natural Processes World Heritage theme, to the Ongoing Fluvial and probably the Ongoing Karst Geomorphic Process sub-themes. The TWWHA blanket bogs are of a different type (non-sphagnum based) to most comparable northern hemisphere blanket bogs, and a large proportion of their extensive area remains effectively natural and undisturbed (by European, and (arguably) by Aboriginal activities), in contrast to the comparably extensive but significantly more degraded Irish and Scottish Blanket bogs.

Ongoing Periglacial Geomorphic Process Systems sub-theme:

Minor ongoing undisturbed geomorphic processes, not of outstanding universal value in their own right, but important as an element contributing to the broader undisturbed Ongoing Geomorphic Process Systems World Heritage theme.

Ongoing Coastal Geomorphic Process Systems sub-theme:

The TWWHA coastline has outstanding universal value in its own right as the longest undisturbed stretch of high energy embayed temperate ("Roaring Forties") rocky and sandy coastline globally, and also contributes significantly to the Ongoing Natural Processes theme.
Karst processes are ongoing in an essentially undisturbed environment. Outstanding universal value because of the exceptional expression, scale and diversity of karst processes (karst diversity very wide due to variety of carbonate rock substrates, topographical situations, climatic variability across Tasmania, and influence of past glacio-karstic interactions which have influenced the ongoing karst processes today).

World Heritage theme. Sandy barrier beach parts of the coast are highly sensitive to environmental change and to human disturbance, thus their undisturbed character is particularly significant in a global context. The undisturbed sandy coasts will prove especially valuable in a global context as benchmark sites that will allow monitoring of the geomorphic effects of sea level rise free of other complicating human disturbances.

Ongoing Karst Geomorphic Process Systems sub-theme:

World Heritage justification provided in the 1989 nomination remains valid, for essentially the reasons put forward originally. This sub-theme has World Heritage significance in its own right, as well as contributing significantly to the Ongoing Natural Processes World Heritage theme.

Additional work since 1989 has shown that the characteristics of contemporary TWWHA karst systems owe more than was formerly recognised to former multiple phases of palaeokarst development (going back up to 400 million years) including phases of hydrothermal karstification, and to more extensive glacio-karstic influence than was previously recognised. Humic acids derived from peat soils are also likely to play a significant and unique role in TWWHA karst processes. These factors enhance the World Heritage significance of the karst by resulting in even greater diversity of karst processes than formerly recognised.

Ongoing karst process systems in the TWWHA include some of the longest, deepest and largest cave systems in the southern Hemisphere; hence the scale of process development is outstanding on a global scale.

- The Weld River Catchment Karst System is of outstanding universal value in its own right under the Ongoing Natural Processes theme and Ongoing Karst Geomorphic Processes sub-theme for its extensive area and exceptional scale of karst development in a large catchment basin undisturbed by European or effective Aboriginal disturbances.
Geoheritage Values – Tasmanian Wilderness World Heritage Area

TWWHA karst systems recognised as having outstanding universal value not only as an ongoing process system, but also for the scale and diversity of other attributes, including:

- glacio-karstic interactions;
- sub-fossil deposits in caves, including Pleistocene megafauna;
- caves containing Pleistocene Aboriginal occupation sites that are of cultural World Heritage significance;
- the karst record is significant in understanding other aspects of landscape development and significance.

Late Proterozoic Weld River Group dolomites unusually thick and contain unusual karst features.

Diverse Karst Landform and Process Systems theme:

The TWWHA karst systems are recognised as having World Heritage value in themselves (not only as sub-themes contributing to the Ongoing Natural Processes and Late Cainozoic Ice Ages World Heritage themes) due to the diversity and scale of their attributes. Important attributes include those previously specified (see at left), and all those attributes noted under Ongoing Natural Processes (above) and Late Cainozoic Ice Ages (below) World Heritage themes.

The extensive scale of karst development in the Weld River Group dolomites of the Weld Valley includes an outstanding scale of glacio-karst development in a present-day alpine karst (at Mt Anne NE Ridge, including one of the deepest caves in the southern hemisphere - Annakananda), and unusual quartz crystal–lined caves at Mt Weld (related to hydrothermal cave development).

- The Weld River Catchment Karst System and its subsidiary Mt Anne NE Ridge Karst System are of outstanding universal value in their own right under the Diverse Karst Landform and Process Systems theme, as well as under the Ongoing Natural Processes theme and Ongoing Karst Geomorphic Processes sub-theme (see above).

Exit Cave (in Ordovician limestone) is one of the longest caves in Australia, and exhibits a diversity of palaeo-karst, glacio-karst and possibly hydro-thermal karst features in good condition at exceptional scales.

- Exit Cave is of outstanding universal value in its own right under criteria (i) & (iii) for its exceptional scale of development and diversity of characteristics relating to Ongoing Natural Processes, Late Cainozoic Ice Ages and Diverse Karst Landform and Process Systems themes.

70
Glacial features in TWWHA are of major international significance as the best available record of temperate glacial processes during the "Late Cainozoic Ice Ages" in the southern hemisphere, due to Tasmania's maritime climate, tectonic stability and diversity of glacial environments.

<table>
<thead>
<tr>
<th>Glacial and Glacio-fluvial Landforms sub-theme:</th>
<th>Late Cainozoic Ice Ages and Climate Change Record Theme:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific research since 1989 has shown Tasmania's glacial record to be more extensive (in time and space) and more diverse than was known to be the case at the time of the 1989 nomination. This enhances the outstanding universal value of the TWWHA Glacial and Glacio-fluvial Landforms sub-theme and Late Cainozoic Ice Ages theme.</td>
<td></td>
</tr>
</tbody>
</table>

Glacial features within this sub-theme that are of outstanding universal value in their own right include:

- **Lake Pedder (the natural lake):** globally unique landform of glacio-fluvial origin.
- **Central Plateau glacial terrain:** largest ice-abraded plateau in Australia, and dominating individual landform with the Tasmanian Cainozoic glacial landform complex.
- **Cynthia Bay Thule Baffin Moraines:** unusual occurrence of polar/continental type moraines in a temperate maritime glacial environment.

Glacio-karstic interactions (especially at Mt Anne NE Ridge and Mt Bobs) are an important aspect of the glacial features of the TWWHA which are outstanding at a world level because of the extensive scale and diversity of glacio-karst interactions compared to other southern temperate glacial regions.

<table>
<thead>
<tr>
<th>Glacio-karstic Phenomena sub-theme:</th>
<th>Mt Anne NE Ridge Karst System is of outstanding natural value in its own right for the exceptional scale of development of glacio-karst characteristics relating to the Glacio-karstic Phenomena sub-theme of the Late Cainozoic Ice Ages theme.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific research since 1989 has demonstrated glacio-karst interactions to have been more extensive and diverse than was known in 1989. Glacio-karst interactions have been shown to be a major influence on the development of TWWHA karst systems (also of World Heritage significance as a theme in their own right).</td>
<td></td>
</tr>
</tbody>
</table>

| Mt Anne NE Ridge Karst System is of outstanding natural value in its own right for the exceptional scale of development of glacio-karst characteristics relating to the Glacio-karstic Phenomena sub-theme of the Late Cainozoic Ice Ages theme. |
"Extra-glacial" landforms and deposits in the TWWHA produced by changing Late Cainozoic climates are important in complementing and adding to the glacial record of the Late Cainozoic Ice Ages.

These include:

<table>
<thead>
<tr>
<th>Fluvial landforms including glacio-fluvial terraces;</th>
<th>Late Cainozoic Ice Ages and Climate Change Record theme:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The &quot;extra-glacial&quot; landforms were only briefly mentioned in the 1989 TWWHA nomination, however subsequent research (especially on coastal landforms) has significantly improved knowledge of these features and the record they provide of the <em>Late Cainozoic Ice Ages and Climate Change Record</em> World Heritage Theme:</td>
</tr>
<tr>
<td>Periglacial features including slope mantles;</td>
<td>Glacial and Glacio-fluvial Landforms sub-theme:</td>
</tr>
<tr>
<td></td>
<td>Although erosional highland glacial features provide spectacular glacial scenery, glacial deposits (including glacio-fluvial deposits) in valleys below the glacial highlands provide the most useful scientific information allowing unravelling of the history of glacial and interglacial environmental changes. Glacio-fluvial terraces and related fluvial landforms such under fit streams and meander wavelengths unrelated to contemporary conditions have, and will continue to yield information on the Late Cainozoic Ice Ages that cannot be obtained from the more spectacular erosional glacial landforms.</td>
</tr>
<tr>
<td>Coastal terraces and other features reflecting changing sea levels that correspond to changing Late Cainozoic climates (only briefly mentioned in 1989 nomination);</td>
<td>Periglacial Landforms sub-theme:</td>
</tr>
<tr>
<td></td>
<td>Periglacial landforms are widespread but still poorly studied within the TWWHA. These features, which occur on a diversity of different substrates in a wide variety of environments, have high potential to yield new insights into the <em>Late Cainozoic Ice Ages</em> theme in Tasmania.</td>
</tr>
</tbody>
</table>

Many areas of aesthetically outstanding mountain scenery (also significant under Criterion iii) within the TWWHA owe their spectacular forms to periglacial, not glacial, erosion (eg, Precipitous Bluff).

| Late Cainozoic Coastal Landforms and Sediments sub-theme: |
| Scientific studies since 1989 have identified numerous Pleistocene shorelines and uplifted marine terraces in the TWWHA. Outstanding sequences of marine terraces at Birches Inlet are related to tectonically-influenced fluvial systems that are of outstanding universal value |
in their own right under the *Ongoing Geomorphic Process Systems* World Heritage theme (see above). Much scientific work remains to unravel the Late Cainozoic changes recorded by these marine features, but the diversity and extent of features preserved along the TWWHA coastal zone ensures that their information content will contribute significantly to the outstanding universal value of the *Late Cainozoic Ice Ages* World Heritage theme, albeit the lack of detailed studies to date precludes attributing outstanding universal value to the *Late Cainozoic Coastal Landforms and Sediments* sub-theme in its own right at the present time.

Port Davey – Bathurst Harbour exemplifies the characteristics of a flooded (glacial phase) fluvial landscape (as a "ria" coast), which illuminates another important element of the *Late Cainozoic Coastal Landforms and Sediments* sub-theme, and also provides a unique biological habitat of World Heritage significance (Criterion iv).

Long Pleistocene lake sedimentary and palynological (flora) record in Darwin Crater is of world significance for the length and continuity of its record of Pleistocene environments.

*Cainozoic Sedimentary and Palaeo-botanical Record* sub-theme:

Late Cainozoic (Tertiary and Quaternary) sedimentary and palaeobotanical (including palynological) deposits within the TWWHA, including the Darwin Crater record and Lower Gordon meromictic lake sediments, have yielded evidence that contributes strongly to understanding of environmental (including climatic) change during the Late Cainozoic Ice Ages, and thus provide further important records of the *Late Cainozoic Ice Ages* World Heritage theme in the TWWHA. However, many of the key Tasmanian Cainozoic palynological and palaeobotanical deposits known to date lie outside the TWWHA, hence whilst this sub-theme contributes to the *Late Cainozoic Ice Ages* World Heritage theme, the sub-theme is not yet demonstrated to be of outstanding universal value – within the TWWHA boundaries – in its own right.
Super-imposed river gorges and wide moorland-floored valleys with glacial outwash (eg, Vale of Rasselas) were cited as examples of geomorphic features of outstanding universal value.

The features identified in the 1989 nomination are elements of the best expressed and most extensive temperate-zone fluvial strike ridge and valley landscape in Australia, which covers a large proportion of the TWWHA and dominates the Gordon River basin. Although not necessarily the best example of a strike ridge landscape globally, these features contribute significantly to the World Heritage significance of the Ongoing Fluvial Geomorphic Processes sub-theme of the Ongoing Natural Processes World Heritage theme, in that the TWWHA has the best and most extensive example globally of a temperate strike ridge–dominated fluvial landscape whose ongoing fluvial geomorphic processes remain predominantly undisturbed.

Also significant under Criterion (iii).

<table>
<thead>
<tr>
<th>Feature Description</th>
<th>Significance Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambrian tectonic melanges of the Adamsfield Trough are superb examples of their type, comparable with Western USA examples.</td>
<td>Requires further review – World Heritage significance not established by evidence provided in 1989 nomination (see Section 4.5.1).</td>
</tr>
<tr>
<td>Denison Range Cambro-Ordovician fan-delta flysch sequences are one of the best examples of their type globally.</td>
<td>Requires further review – World Heritage significance not established by evidence provided in 1989 nomination (see Section 4.5.1).</td>
</tr>
<tr>
<td>Ordovician limestone sequence is the longest and most complete Ordovician stratigraphic sequence in the southern hemisphere.</td>
<td>Requires further review – World Heritage significance not established by evidence provided in 1989 nomination (see Section 4.5.1). The most important and complete type sequences (Mole Creek &amp; Florentine Valley) both lie outside the TWWHA.</td>
</tr>
<tr>
<td>Dolerite/Parmeener Supergroup sedimentary sequence provides well exposed accessible evidence of Gondwana flora/fauna, an important record of the Permo-Carboniferous glaciation, and evidence of the break-up of Gondwana.</td>
<td>Requires further review – World Heritage significance not established by evidence provided in 1989 nomination (see Section 4.5.1).</td>
</tr>
<tr>
<td>Precambrian rocks with multiple fold phases exceptional at world scale.</td>
<td>World Heritage significance not supported.</td>
</tr>
<tr>
<td>Eclogites and gneissic rocks &quot;rare and unusual&quot;.</td>
<td>World Heritage significance not supported: significant only in Tasmanian or Australian context.</td>
</tr>
<tr>
<td>Late Proterozoic Weld River Group dolomites unusually thick and contain unusual karst features.</td>
<td>Requires further review – World Heritage significance of bedrock sequence (as opposed to karst developed within it) not established by evidence provided in 1989 nomination (see Section 4.5.1).</td>
</tr>
</tbody>
</table>
Geoconservation Values of the TWWHA and Adjacent Areas

<table>
<thead>
<tr>
<th>Darwin Crater, impact glass strewn field and sedimentary record within crater stated to be of World significance.</th>
<th>World Heritage significance of crater and impact glass not supported; however contained Quaternary sedimentary/palynological record is significant under Late Cainozoic Ice Ages theme (see above).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Edgar Fault good example of a fault scarp at State and National level.</td>
<td>World Heritage significance not supported: possibly best example in Australia, but not of outstanding universal value in comparison with other examples globally.</td>
</tr>
<tr>
<td>Rocks formed in every geological time period are present in the TWWHA, which therefore provides an unusually complete and diverse geological record for an area of its size.</td>
<td>World Heritage significance not supported: significance doubtful, based on ultimately arbitrary divisions of geological time.</td>
</tr>
</tbody>
</table>

**Criterion (ii)** *Be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.*

No values specifically identified under this criterion, however values listed under Criterion (iv) below are closely related. World Heritage geodiversity values listed under "Ongoing Natural Processes" theme (above) and "Outstanding Biological Habitats" theme (below) contribute in fundamental ways to biological values identifiable under this criterion.

**Criterion (iii)** *Contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance*

Geomorphic and geological features are primary factors contributing to the World Heritage quality of the landscapes (aesthetic values) of the TWWHA. Specific features contributing to this significance include:

- glacially-sculpted peaks and lakes
- distinctive dolerite and quartzite mountains
- karst landforms (eg, upper Weld Valley)
- high energy coastal landforms
- broad lowland plains

Significance of geomorphic and geological features as primary factors contributing to the World Heritage quality of the landscape (aesthetic) values of the TWWHA is justified. Additional features contributing to this significance include:

- sandy barrier beach coastal landforms
- outstanding fold structure landforms including prominent quartzite strike ridges, broad flat-floored strike valleys and exceptional strike ridge gorges including the Gordon Splits.
- blanket bog moor lands
- alpine landforms including both glacial and periglacial features
Geoheritage Values – Tasmanian Wilderness World Heritage Area

| Karst systems of the TWWHA are "excellent", "superb" and "magnificent" (DASETT 1989, p. 46). | Outstanding universal value of karst systems justified for scale and diversity of development as well as aesthetic values (see also *Ongoing Natural Geomorphic Processes, Late Cainozoic Ice Ages and Diverse Karst Landform and Process Systems* World Heritage themes under Criterion i).

Karst systems under these themes or sub-themes that are individually of outstanding universal value as superlative natural phenomena include (see also above):

- Exit Cave
- Mt Anne (NE Ridge) Glacio-karst |

| Glacial features of the TWWHA are "superlative", "superb" and of "great significance" (DASETT 1989, p. 46). | Part of *Late Cainozoic Ice Ages* World Heritage theme (see criterion i).

Glacial features of the TWWHA, including numerous glacially-sculpted peaks and lakes, constitute a major component of the outstanding natural beauty of the TWWHA, and are outstanding geomorphic phenomena.

Glacial features within this theme that are individually of outstanding universal value as superlative natural phenomena and/or as areas of outstanding natural beauty include (see also above):

- Lake Pedder (the natural lake)
- Central Plateau Glacial Terrain |

| Some other geomorphic features of the TWWHA were stated to be "superb", "magnificent" and "superlative" (DASETT 1989, p. 47), however no justification was provided. These include: | World Heritage significance under this criterion not supported.

Little research into large scale erosion surfaces in the TWWHA has occurred since 1989, and these features remain poorly understood. However, some prominent surfaces in the TWWHA are now considered to be well-developed fluvial terraces (eg, Sorell - Spero Rivers region) and uplifted marine terraces, rather than extensive base-level erosion surfaces of the sort implied here. Both these feature classes are considered significant under the |

- Well-expressed erosion surfaces |
### Geoconservation Values of the TWWHA and Adjacent Areas

#### Ongoing Natural Processes

<table>
<thead>
<tr>
<th>Feature</th>
<th>World Heritage themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>New River Lagoon and barrier beach</td>
<td>Ongoing Natural Processes (Ongoing Fluvial Geomorphic Processes sub-theme) and Late Cainozoic Ice Ages (Late Cainozoic Coastal Landforms and Sediments sub-theme) World Heritage themes</td>
</tr>
<tr>
<td>Coastal sea caves and geos</td>
<td></td>
</tr>
<tr>
<td>Various elevated marine terraces</td>
<td></td>
</tr>
<tr>
<td>Ria coast at Port Davey and Bathurst Harbour</td>
<td></td>
</tr>
<tr>
<td>Super-imposed river gorges</td>
<td></td>
</tr>
<tr>
<td>Wide moorland-floored valleys with glacial outwash (eg, vale of Rasselas)</td>
<td></td>
</tr>
</tbody>
</table>

Apart from these fluvial and marine terraces, however, the TWWHA is notably lacking in extensive well-preserved base-level erosion surfaces, which are better expressed in parts of western and northeastern Tasmania that lie outside the TWWHA.

#### Outstanding universal value of ongoing coastal geomorphic processes justified

<table>
<thead>
<tr>
<th>Feature</th>
<th>World Heritage themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>New River Lagoon and barrier beach</td>
<td>Ongoing Natural Processes (Ongoing Fluvial Geomorphic Processes sub-theme) and Late Cainozoic Ice Ages (Late Cainozoic Coastal Landforms and Sediments sub-theme) World Heritage themes</td>
</tr>
<tr>
<td>Coastal sea caves and geos</td>
<td></td>
</tr>
<tr>
<td>Various elevated marine terraces</td>
<td></td>
</tr>
<tr>
<td>Ria coast at Port Davey and Bathurst Harbour</td>
<td></td>
</tr>
<tr>
<td>Super-imposed river gorges</td>
<td></td>
</tr>
<tr>
<td>Wide moorland-floored valleys with glacial outwash (eg, vale of Rasselas)</td>
<td></td>
</tr>
</tbody>
</table>

Outstanding universal value of ongoing coastal geomorphic processes justified (see Ongoing Processes theme: Ongoing Coastal Geomorphic Processes sub-theme) under Criterion (i). Many of these coastal features also contribute to the outstanding aesthetic significance of the TWWHA under Criterion (iii)

#### Outstanding universal value of uplifted and drowned Pleistocene coastal landforms justified

<table>
<thead>
<tr>
<th>Feature</th>
<th>World Heritage themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>New River Lagoon and barrier beach</td>
<td>Ongoing Natural Processes (Ongoing Fluvial Geomorphic Processes sub-theme) and Late Cainozoic Ice Ages (Late Cainozoic Coastal Landforms and Sediments sub-theme) World Heritage themes</td>
</tr>
<tr>
<td>Coastal sea caves and geos</td>
<td></td>
</tr>
<tr>
<td>Various elevated marine terraces</td>
<td></td>
</tr>
<tr>
<td>Ria coast at Port Davey and Bathurst Harbour</td>
<td></td>
</tr>
<tr>
<td>Super-imposed river gorges</td>
<td></td>
</tr>
<tr>
<td>Wide moorland-floored valleys with glacial outwash (eg, vale of Rasselas)</td>
<td></td>
</tr>
</tbody>
</table>

Outstanding universal value of uplifted and drowned Pleistocene coastal landforms justified (see Late Cainozoic Ice Ages theme: Late Cainozoic Coastal Landforms and Sediments sub-theme) under Criterion (i). Many of these features also contribute to the outstanding aesthetic significance of the TWWHA under Criterion (iii)

#### Blanket bogs

<table>
<thead>
<tr>
<th>Feature</th>
<th>World Heritage themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blanket bog organic soils of the TWWHA are the most extensive blanket bogs in the southern hemisphere.</td>
<td></td>
</tr>
<tr>
<td>Blanket bogs of the TWWHA are of outstanding universal value under Criterion (i) – see above – and are an outstanding phenomenon in terms of their undisturbed extent and their control of</td>
<td></td>
</tr>
</tbody>
</table>
other geomorphic and biological processes within the TWWHA. Their extent and textures also impart a characteristic aesthetic quality to TWWHA landscapes which give them a large part of their significant aesthetic value under Criterion (iii).

Not in 1989 nomination.

Collingwood River White Schist

*Requires further review*; assigned world significance on the TGD after 1989, but does not contribute to a recognised World Heritage theme and justification as a superlative individual feature of World Heritage value is not yet demonstrated.

Not in 1989 nomination.

Reward Creek Mineralisation

*Requires further review*; assigned world significance on the TGD after 1989, but does not contribute to a recognised World Heritage theme and justification as a superlative individual feature of World Heritage value is not yet demonstrated.

Not in 1989 nomination.

Adamsfield Workings Mineralogy

*Requires further review*; assigned world significance on the TGD after 1989, but does not contribute to a recognised World Heritage theme and justification as a superlative individual feature of World Heritage value is not yet demonstrated.

**Criterion (iv)**  *Contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation*

An number of specific geomorphic and soil features were identified in the 1989 TWWHA nomination as habitat for biological species of outstanding universal value, namely:

(below)

"*Outstanding Biological Habitats*" theme:

Most geomorphic and soil features of the TWWHA that have been identified as significant for providing habitat for significant biological species and communities have also been identified as being significant purely for their geodiversity values (above). Nonetheless, the importance of geomorphic and soil features in providing habitat for important species is sufficiently significant as to warrant identifying these values as a World Heritage theme in their own right.

A number of important geomorphic features have been shown to have been important glacial
Geoconservation Values of the TWWHA and Adjacent Areas

- Alpine (mountain-top) habitats in general, and more specifically including:

- High altitude dolomite karst habitats at Mt Anne;

- Considerable research into cave fauna since 1989 has resulted in the identification of a number of TWWHA caves - at all altitudes, not merely alpine caves - as critical habitat for species of outstanding universal value; in many cases, the species evolved in individual cave systems, have highly restricted distributions, and are critically dependent on maintenance of natural cave environments.

- Caves provided refugia for invertebrate fauna during Late Cainozoic glacial phases, and some present-day TWWHA cave fauna evolved into cave-adapted species as a result of becoming restricted to these refugia during glacial phases.

- Riparian (riverside) habitats in general, and more specifically including:

- Riparian limestone cliffs (Franklin & Lower Gordon Rivers);

- Alkaline pans (soil features) of the south-west moor lands;

- Coastal habitats;

- Bathurst Harbour, whose unique environmental characteristics are strongly dependent on its development as a flooded Pleistocene river valley and plain, provides habitat for a unique biota of outstanding universal value.

- Some lakes served as invertebrate refugia during Late Cainozoic glacial periods.

- Lakes (alpine lakes; dystrophic, oligotrophic and transitional types; meromictic lakes and coastal lagoons).

- The Lower Gordon levee-flood basin – meromictic lakes are of outstanding universal value in their own right as ongoing lacustrine process systems under Criterion (i), and as biological habitats under Criterion (iv). The values of these lakes are under threat as a result of human disturbance of the Gordon River fluvial process system.

<table>
<thead>
<tr>
<th>Alpine (mountain-top) habitats in general, and more specifically including:</th>
<th>Considerable research into cave fauna since 1989 has resulted in the identification of a number of TWWHA caves - at all altitudes, not merely alpine caves - as critical habitat for species of outstanding universal value; in many cases, the species evolved in individual cave systems, have highly restricted distributions, and are critically dependent on maintenance of natural cave environments.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High altitude dolomite karst habitats at Mt Anne;</td>
<td>Caves provided refugia for invertebrate fauna during Late Cainozoic glacial phases, and some present-day TWWHA cave fauna evolved into cave-adapted species as a result of becoming restricted to these refugia during glacial phases.</td>
</tr>
<tr>
<td>Riparian (riverside) habitats in general, and more specifically including:</td>
<td>Bathurst Harbour, whose unique environmental characteristics are strongly dependent on its development as a flooded Pleistocene river valley and plain, provides habitat for a unique biota of outstanding universal value.</td>
</tr>
<tr>
<td>Riparian limestone cliffs (Franklin &amp; Lower Gordon Rivers);</td>
<td>Some lakes served as invertebrate refugia during Late Cainozoic glacial periods.</td>
</tr>
<tr>
<td>Alkaline pans (soil features) of the south-west moor lands;</td>
<td>The Lower Gordon levee-flood basin – meromictic lakes are of outstanding universal value in their own right as ongoing lacustrine process systems under Criterion (i), and as biological habitats under Criterion (iv). The values of these lakes are under threat as a result of human disturbance of the Gordon River fluvial process system.</td>
</tr>
<tr>
<td>Coastal habitats;</td>
<td>---</td>
</tr>
<tr>
<td>and:</td>
<td>---</td>
</tr>
<tr>
<td>Lakes (alpine lakes; dystrophic, oligotrophic and transitional types; meromictic lakes and coastal lagoons).</td>
<td>---</td>
</tr>
</tbody>
</table>
3.2.2 TWWHA World Heritage Geoconservation Values (by Theme)

This section provides the key discussion and review of the World Heritage geoconservation values ("geoheritage") of the TWWHA.

As noted in Section (3.1), the present review supports the "wholistic" principle which underpinned the 1989 TWWHA nomination (DASETT 1989, p. 27), namely that the most important elements of geodiversity contributing to the World Heritage values of the TWWHA are for the most part not individual sites and features that are of World Heritage significance in themselves as isolated features (although some of these can be identified), but rather themes or inter-related assemblages of features or systems. These themes have outstanding universal value in their totality because of the extent, diversity and inter-relationships of their constituent sites, processes or phenomena (see discussion and justification of this principle in section 2.2)\(^{19}\).

The following discussions identify and justify those geodiversity themes of the TWWHA which this review has determined to have World Heritage geoconservation value under the current (i.e., 1999) World Heritage Criteria (UNESCO 1999). This review has also shown that a number of specific features (or specific geomorphic systems) in the TWWHA can be considered as having World Heritage significance in their own right. In general, these are outstanding exemplars of a broader World Heritage theme. Such specific features or systems are also identified in the following discussion.

It is also noteworthy that the most well justified geoheritage sites and themes of World Heritage value that have been identified to date relate mostly to geomorphic and soil themes rather than to bedrock geology themes. This may reflect a real lack of bedrock World Heritage themes, or it may simply be because there has been less effort from professional bedrock geology specialists to systematically identify and justify bedrock themes of outstanding universal value than there has been from geomorphologists and soil scientists\(^{20}\).

The 1989 TWWHA nomination (DASETT 1989) gave strong weight to the justification of karst and glacial geomorphic values, and it is considered that the World Heritage significance of these themes is well established (see Section 2.3.2). Consequently the following discussions only address these themes briefly, and devote more attention to reviewing other themes, especially blanket bog peat lands, fluvial and coastal geomorphic process themes, which were only briefly addressed in the 1989 nomination, but whose World Heritage value has been emphasised by subsequent work.

Assessment and justification of World Heritage Geoconservation Values

As noted in section (3.1) above, this review assesses and justifies the geoconservation values of the TWWHA on the basis of using current geoconservation significance assessment procedures

\(^{19}\) Thus, for example, there are few if any individual patches of blanket bog peat soil that could be attributed World Heritage value in isolation, as individual features, however taken as a whole the entire assemblage of blanket bog peats in the TWWHA has outstanding universal value because it represents the most extensive known blanket bog system of its type in the southern hemisphere, and possibly the world (the extent of some northern hemisphere blanket bogs outside Europe is poorly known, hence firm comparative figures are unavailable for these), whose ongoing natural processes remain in largely undisturbed condition (e.g., the comparable Scottish and Irish blanket bogs are of greater extent, but have been much more extensively degraded by a variety of human activities).

\(^{20}\) Thus for example, it is noteworthy that the massive sulphide mineral deposits in the Cambrian Mt Read Volcanics of western Tasmania are sometimes cited as being a "World Class" economic mineral province (Large 1992, p. 118); however, by deliberate design of the TWWHA boundaries these deposits and the known extent of their host rocks lie entirely outside the TWWHA. Bedrock geology specialists have shown little interest in assessing their potential World Heritage values.
(mostly formalised subsequent to 1989; see Section 2.2) to assess significance in terms of the current World Heritage criteria (Section 2.3.3).

In essence, this means that in order to be justified as having World Heritage geoconservation significance (i.e., "Outstanding Universal Value") a geodiversity feature, site or theme must:

- have characteristics corresponding to those specified in the current World Heritage criteria (UNESCO 1999, paragraph 44(a)); see this report Section 2.3.3);

- on the basis of the best currently available scientific and comparative data, be a feature, or assemblage of features contributing to a theme, which individually or as a whole express the key characteristics of their type or class as well or better than the best comparable examples globally (see Section 2.2);

- have as high or better integrity - as described in the current World Heritage criteria (UNESCO 1999, paragraph 44(b)) - as the best expressed comparable examples globally (see this report Sections 2.2 & 2.3.3).

A theme comprising the whole assemblage of a number of inter-related sites and features may meet these conditions as a whole, even though some or all of the component inter-related sites may not do so when assessed individually in isolation from other inter-related sites (see this report Section 2.2).
**Geodiversity Themes of World Heritage Significance**

The major geodiversity themes of World Heritage significance that can be identified and justified under the current World Heritage criteria in the TWWHA, using current scientific data and significance assessment methods, are described below.

**Theme:**

**Ongoing Natural Geomorphic and Soil Process Systems**

These are natural systems substantially undisturbed by present day human activities, and in many cases without effective ongoing process disturbance due to earlier Aboriginal activities. They are “benchmark” or “baseline” geomorphic and soil process systems.

**Description**

The wilderness quality of much of the TWWHA is one of the over-arching themes for which the region was nominated for World Heritage listing (DASETT 1989, p. 27). Although the idea of "wilderness" is commonly considered to be a purely anthropocentric (and "culturally conditioned") perspective on natural lands, the concept is nonetheless widely used in a sense which implies a lack of (objective) human disturbance of natural processes. Several methods have been used to obtain quantitative assessments of wilderness quality in Tasmania (Hawes & Heatley 1985, Lesslie et al. 1988, Kirkpatrick and Haney 1980). These methods have applied differing emphases on the relative importance of perceived ("culturally conditioned") wildness as compared to objective biophysical naturalness, where the latter term refers to the degree to which the environment is free of identifiable biophysical disturbances caused by the influence of modern technological society. Biophysical naturalness can be considered an indicator of areas in which ongoing geomorphic and soil processes are more or less free of human process disturbance, and this quality was one of the major indicators used in the wilderness quality assessment method of Lesslie et al. (1988). The Wilderness Quality assessment of Tasmania using the method of Lesslie et al. was subsequently updated during 1996, in the course of scientific studies leading to the Tasmanian Regional Forest Agreement (TPLUC 1996, p. 187 – 191).

The 1996 Wilderness Quality map of Tasmania (TPLUC 1996), based substantially on indicators of biophysical naturalness, shows that large portions of the TWWHA have high wilderness quality (see Figure 2). This implies that temperate – zone geomorphic and soil process systems continue to operate and change at natural rates and magnitudes over large parts of the TWWHA without significant physical or process disturbance due to present day human activities.

However, the biophysical naturalness indicators used in the 1996 (and earlier) wilderness quality assessments are based on limited data and generalised over large areas. There are a number of caveats on the use of these biophysical naturalness indicators as a measure of lack of human disturbance of natural processes. These include:

- Global climate change due to human disturbances (especially increased greenhouse gas emissions) is indisputably in progress (IPCC 2001), and changes to effective precipitation, stream flow regimes, temperatures, frequency of extreme weather events, wave climates and other climatic factors are likely to modify most geomorphic processes to some degree. However, this anthropogenic disturbance is of global extent, and will affect all areas – wilderness or otherwise – on Earth.

- Local present-day anthropogenic process disturbances can be identified in some areas of the TWWHA, for example changes to fluvial processes in the Lower Gordon River due to hydro-electric development upstream, and to tourist boats wave-wash (Bradbury et al. 1995). Nonetheless, it is also the case that no significant local present day anthropogenic process disturbances are identifiable over large regions of the TWWHA.
Figure 2: The 1996 Wilderness Quality map of Tasmania (TPLUC 1996), based largely on indicators of biophysical naturalness. In the method of Wilderness Quality assessment used to produce this map (see text), WQ (Wilderness Quotient) values of 12 or above indicate "high wilderness quality". This wilderness assessment highlights the degree to which the TWWHA encompasses a very large region in which natural geomorphic and soil processes are continuing to function with little substantial modification due to modern human activities.

NOTE: "TWWHA" boundary depicted includes proposed TWWHA extensions described in Section (3.3).
It is likely that past (Holocene and Pleistocene) activities by Aborigines have influenced geomorphic processes in some parts of the TWWHA. Aborigines are known to have fired buttongrass moor lands (Marsden-Smedley 1998), and although such firing is thought to have mainly been of low intensity this may in some cases have resulted in peat soil destruction on some moor land slopes, resulting in pulses of accelerated erosion, alluvial fan development and modification to the sediment budget of streams, and pulses of increased sand supply to some coastal areas. However, the degree to which Aboriginal activities such as burning actually influenced geomorphic processes, and indeed influenced the extent of blanket bog soils and associated vegetation types, remains highly uncertain and controversial (see Blanket Bog Peat Land Soil Systems sub-theme following). Indeed, in some respects it is difficult to speculate on what the present and Pleistocene environment of parts of the TWWHA would have been like had Aborigines not been present. Nonetheless, there is also reason to consider that large parts of the TWWHA have are not subject to identifiable ongoing process disturbances due to past Aboriginal activities. For example, the entire New River – Salisbury River catchment basin, and the upper Weld, Murchison and Picton River basins are mantled by undisturbed old growth forests showing no apparent fluvial process disturbance. Even if parts of these basins were not forested, and/or were deliberately burnt by Aborigines during the Pleistocene or early Holocene, they have probably now been fully forested for several millennia at least, and are now in a natural equilibrium state with no evident significant process disturbances inherited from any earlier phase of Aboriginal disturbance.

Thus, although it is not possible to say that the TWWHA is entirely unaffected by human disturbance, taking into account the above caveats it nonetheless remains true to say that large regions of the TWWHA remain free of identifiable present – day anthropogenic process disturbances other than climate change (which is globally ubiquitous), to a degree which is globally unusual, and indeed it is arguable that substantial parts of the TWWHA are likely to also be free of significant past process disturbances due to Aboriginal activities.

The fact that large areas of the TWWHA exhibit ongoing soil and geomorphic processes undisturbed by contemporary human disturbances (other than ubiquitous climate change) mean that the TWWHA has great potential scientific significance as a "benchmark" or "baseline" environment. In such an environment, undisturbed processes can be monitored and compared with equivalent processes in disturbed areas, so as to qualitatively and quantitatively measure the effects that human disturbances have on particular natural processes. Without undisturbed benchmark areas, quantifying the effects of human disturbance on natural processes is much more problematical and, given the importance of understanding human impacts on nature, the existence of benchmark natural process regions will potentially be of great practical importance in the future.

The significance of the TWWHA as a benchmark natural process region is already being realised through the establishment of the Warra Long Term Ecological Research Site, which straddles portions of the TWWHA and adjacent State forests in the Weld Valley, and is being used to measure the effects of forestry practices by comparing natural processes in areas subject to forestry with those in comparable undisturbed parts of the TWWHA (Packham 1995, Brown et al. 2001). Again, the undisturbed sandy coastlines of the TWWHA provide an ideal environment for identifying and quantifying the physical effects of global sea level rise on sandy coasts, since they are the only extensive sandy coastlines in south-eastern Australia, at least, where the effects of other human interferences with coastal processes do not obscure and complicate the effects of sea level rise.
**Condition & Integrity**

The majority of the natural (ongoing) geomorphic and soil process systems of the TWWHA meet the necessary conditions of integrity for World Heritage values (UNESCO 1999, para. 44(b)) under the 1999 World Heritage Criterion (i) because:

- All the inter-related elements of many entire fluvial and karst systems and catchments are contained within the TWWHA (see following sub-theme discussions). In the case of coastal geomorphic processes, the TWWHA coast is highly compartmentalised with little long-distance littoral sediment drift (Cullen 1998a), which means that all sediment movements and sediment budgets affecting the TWWHA coastlines are fully contained within the TWWHA coastal areas and the adjoining hinterland fluvial catchments (which are also in most cases fully within the TWWHA).  

There are, however, some areas of concern where the current TWWHA boundaries do not contain all the relevant elements of certain individual geomorphic process systems. For example, the outstanding karst process systems and catchments of the Mole Creek region are only partly within the TWWHA, with some important cave catchments including that of Croesus Cave being outside the TWWHA and in many cases unprotected. Similarly, the fact that a large part of the middle Gordon River catchment is outside (albeit surrounded by) the TWWHA, and is heavily disturbed, is part of the reason for fluvial process disturbances and threats in the Lower Gordon region that lies within the TWWHA (see Ongoing Fluvial Geomorphic Process Systems sub-theme discussion following).

Despite these inadequacies, however, there is little doubt that, in terms of areal extent and inclusion of all relevant elements, the majority of undisturbed ongoing geomorphic and soil process systems of the TWWHA meet the necessary integrity condition (UNESCO 1999, para 44(b)(i)) for the 1999 World Heritage Criterion (i).

- As required by the other relevant integrity conditions (UNESCO 1999, para 44(b)((v) & (vi))), the TWWHA has a Management Plan which specifically addresses geomorphic and soil processes (PWS 1999), and it has long term legislative protection under the various acts by which the National Parks, Conservation Areas and Forest Reserves of which the TWWHA is composed were declared. Natural geomorphic and soil processes in the TWWHA are also specifically protected under the State Regional Forest Agreement (Land Classification) Act 1998 which provides that a purpose of all these reserve categories is to protect "geological diversity", which is defined in the Act to include geomorphic and soil processes.

**Justification**

The *Ongoing Natural Geomorphic and Soil Process Systems* theme has World Heritage value ("outstanding universal value") in terms of Criterion (i) of the current Operational Guidelines of the World Heritage Convention (UNESCO 1999), as being the most extensive area, or comparable to the most extensive areas, of undisturbed ongoing temperate-zone maritime-climate natural "geological" process systems globally.

---

21 Note however that some movement of weed plant seeds into and out of the TWWHA is known to be occurring due to ocean currents, and some of these (eg, marram grass) have potential to disturb coastal geomorphic processes (Cullen 1998b); however, this threat can be managed (see Section 4.3), and the currents concerned have little effect on coastal sediment movement.

22 The term "geological" as used in the World Heritage Criterion (i) (UNESCO 1999) is understood to include geomorphic and soil features and processes.
The World Heritage value ("outstanding universal value") of the undisturbed natural process systems of the TWWHA (under the current World Heritage Criterion (i)) can be justified on the following grounds:

**Distinctiveness**
Subject to the caveats outlined above, the TWWHA includes large regions in which a wide diversity of ongoing natural soil, fluvial, karst, coastal and minor periglacial processes continue to operate without significant modification due to present day human disturbance and, in some substantial areas, without evidence of having inherited effective process disturbances from past human activities. With a few exceptions, these geomorphic and soil processes display a high degree of integrity in terms of the World Heritage Guidelines (UNESCO 1999, para 44(b)).

**Comparative Assessment**
There are only two other areas in the southern hemisphere (New Zealand & Patagonia), where a comparably diverse suite of temperate-zone, maritime-climate ongoing geomorphic and soil processes continue to function in a natural fashion without substantial present-day disturbance by human activities. No comparably extensive temperate maritime-climate undisturbed regions have been identified in the northern hemisphere, where the most important temperate undisturbed ("wilderness") areas occur in continental settings with significantly different climatic influences on geomorphic and soil processes. Thus in terms of diversity, areal extent and integrity, the ongoing natural soil and geomorphic process systems of the TWWHA are as well expressed as, and have as high integrity as, the best comparable areas globally. Indeed, the TWWHA is significantly different to Patagonia and New Zealand in terms of its tectonic stability and lack of present day glacial influence on geomorphic processes, and in this light it is highly probable that the TWWHA exhibits the best expressed undisturbed natural soil and geomorphic process systems of their type globally.

The following sub-sections provide further details justifying the World Heritage significance of the particular major soil and geomorphic process systems (sub-themes) encompassed by this theme, that are of particular importance in the TWWHA.
Sub-Theme:

**Ongoing Fluvial Geomorphic Process Systems**

Fluvial geomorphic systems are those landform systems formed by running water, and include landform elements ranging from catchment slopes and basins, to stream channels, depositional terraces and plains, and many other features. Fluvial geomorphic processes are today by far the dominant ongoing geomorphic processes in the TWWHA, and indeed in Tasmania as a whole. In terms of the proportions of the TWWHA landscape directly influenced by the range of present day geomorphic processes, the areas directly influenced by present day periglacial, karst and coastal geomorphic processes are very limited in contrast to the ubiquity of ongoing fluvial geomorphic processes – which must therefore be considered of prime importance in any consideration of land management or geoconservation issues.

**Description**

The fluvial geomorphic process systems of the TWWHA can be broadly characterised as temperate–zone maritime-climate high discharge fluvial systems, whose geomorphology exhibits the legacy of past glacial and glacio-fluvial processes, but which are not influenced by ongoing present-day glacial and intense periglacial processes (in contrast to the other most nearly comparable large regions of mostly-undisturbed southern hemisphere temperate maritime fluvial systems, those of Fiordland (New Zealand) and Patagonia (South America), which both experience substantial ongoing glacial and periglacial processes).

The fluvial geomorphic system controls that have influenced the development of fluvial landforms in the TWWHA are in some respects representative of much of the variability of certain system controls across Tasmania (e.g., bedrock geology), yet in respect of certain other system controls are uniquely characteristic of western Tasmania and quite different to the system controls on eastern Tasmanian rivers (e.g., climatic, topographic and soil system controls). Consequently, large parts of the TWWHA are dominated by fluvial landforms and processes which are characteristic of and unique to western Tasmania, rather than representative of Tasmania as a whole. Jerie *et al.* (2003) have provided a georegionalisation (spatial classification) of Tasmanian fluvial geomorphic landform and process types which demonstrates that many of the fluvial georegions found in the TWWHA are poorly represented elsewhere in Tasmania (and vice versa). See Figure (3).

**Climatic System Controls**

In terms of climatic system controls on fluvial landform development much of the TWWHA encompasses a region which is climatically distinct from other parts of Tasmania. Western Tasmania and the TWWHA in particular are the wettest parts of Tasmania, with average annual rainfalls up to 3400 mm (Pemberton 1989) and average effective precipitation (rainfall minus evaporation) up to 2500 mm (Jerie *et al.* 2003). These high rainfalls are the result of a temperate-zone west-coast location with the orographic effects of numerous north-south oriented mountain ridges encouraging precipitation (Pemberton 1989, p.13; see this report Figure 4).

Stream and river discharges in western Tasmania are consequently relatively high, and although seasonal variation in effective precipitation is also high, base flows are sufficiently constant that streams exhibit mostly perennial flows. This is in marked contrast to eastern Tasmania, where lower average annual effective precipitation and a large seasonal variation means that even moderate-sized rivers sometimes dry up.

---

23 The largest river system in the TWWHA, the Gordon River (including tributaries) has a mean annual flow of 9 km³ (SDAC 1996, p. 7.48). The natural catchment basin of the Gordon River covered 4,949 km², although the hydro-electric diversion of the upper Huon River into the Gordon artificially increased the catchment area by an additional 264 km² (areas calculated from catchment polygons depicted in Figure 5).
Figure 3: Tasmania-wide distribution of those fluvial environmental domain mosaics found in the TWWHA, from unpublished mapping based on Jerie et al. (2003). Each fluvial environmental domain mosaic represents a region - effectively a "fluvial georegion" - of characteristically associated environmental domains delineated on the basis of bedrock geology and structure, climate, geomorphic process history, and topography. This map graphically illustrates the fact that the TWWHA encompasses most of the extent of a set of fluvial geomorphic process regions which are strongly characteristic of the TWWHA, but are found to only a limited extent elsewhere in Tasmania. NOTE: “TWWHA” area shown includes proposed extension areas listed in Section (3.3).
Geoconservation Values of the TWWHA and Adjacent Areas

**Bedrock Geology**
In respect of bedrock geology system controls, the TWWHA is dominated by folded Precambrian quartzites, schists and phyllites, in which the fold structures have exerted a strong influence on drainage pattern development. However, large portions of the TWWHA also include Jurassic dolerite sheets and Permo-Triassic flat-lying sedimentary rocks, on which normal faulting exerts strong drainage control, as well as a variety of other bedrock system controls including large areas of Tertiary sediments and carbonate rocks (limestone and dolomite). TWWHA fluvial processes are therefore relatively diverse in terms of bedrock and structural influences.

**Strike Ridge & Valley Landscapes / Trellised Drainages**
Nonetheless, the TWWHA encompasses within its boundaries the greater part of Tasmania's surface exposure of an association of strongly folded Precambrian and Palaeozoic quartzites, schists, phyllites, limestones and other rocks. The geomorphic process history of the region has acted to produce a prominent strike ridge and valley topography that is nowhere else as extensive or well-expressed in Tasmania. This constitutes the dominating large scale physiographic feature of the TWWHA, especially when viewed at the broadest scales (see Figure 4). This strike ridge region, which includes most of the Gordon River catchment basin - the largest fluvial catchment in the TWWHA (see Figure 5) - exhibits a very well-developed "trellised" drainage pattern in which major rivers flow for the most part along strike valleys, but in places turn and cut directly through hard quartzite strike ridges, forming very deep and narrow strike ridge gorges such as the aesthetically outstanding Gordon Splits on the Gordon River. The rows of prominent parallel strike ridges (see Figures 4 & 16) and deep cross-strike gorges of the Gordon basin constitute one of the most outstanding and immediately obvious fluvial geomorphic characteristics of a large portion of the TWWHA. The trellised drainage pattern, which is inexplicable on the basis of present-day geomorphic processes or the currently exposed geology, has been explained as a "superimposed" drainage pattern (Davies 1965). The major trunk channels which today flow directly through resistant strike ridges are considered to have originally developed on formerly-overlying flat-bedded Parmeener Supergroup rocks and dolerite sheets, and/or on uplifted erosion surfaces formerly "planed off" across the folded bedrock (see below). As those cover rocks were removed by erosion and/or the erosion surfaces were dissected, exposing and etching out the folded rocks beneath, the main trunk channels had sufficient power to maintain their original courses and were able to down-cut through the resistant quartzite strike ridges to form gorges, while smaller tributary streams could not do so and were forced to follow strike valleys.

**Relict Erosion Surfaces**
In contrast to the strike ridge and valley landscapes of the TWWHA, relict erosion surfaces - often "planed off" flat across steeply dipping bedrock - are a prominent landscape feature in some large areas of western Tasmania, where they have exerted strong influences on drainage system development (Jerie et al. 2003). Prominent surfaces such as the "Henty Surface" are thought to represent extensive erosion to base level followed by tectonic uplift during the Tertiary Period (Davies 1959, Banks et al. 1977), however their age and origins have been a surprisingly neglected area of study in Tasmanian geomorphology despite their obvious control of drainage patterns over large areas of the western Tasmanian landscape. Parallel or dendritic drainage networks are commonly developed on erosion surfaces where they are planed off across folded or structurally-dismembered bedrock types, a geology on which a more trellised or fault-controlled drainage pattern might otherwise be expected. Steep eroding escarpments with high gradient dendritic streams typically mark the receding edges of residual uplifted erosion surface fragments, while well-developed structurally-controlled drainages patterns have developed in deeply dissected areas beyond the edges of residual erosion surfaces.

Although erosion surfaces are still clearly identifiable in some parts of the TWWHA landscape (eg, the "Western Dissected Surfaces" and "Western Coastal ... Remanent Surfaces" fluvial mosaics – see Figure 3), and some broad flat-floored strike valleys such as the Olga-Hardwood Valley may represent erosion surfaces, for the most part residual uplifted erosion surfaces in western Tasmania are best preserved outside the TWWHA, especially in a broad coastal belt from Macquarie Harbour.
Figure 4: Digitally-generated relief map of the Gordon River catchment region of the TWWHA, showing prominent strike ridges and valleys which give much of the TWWHA its strongly "trellised" fluvial landform character. Map generated using the 25 metre digital elevation model (DEM) of Tasmania.

northwards to the Arthur River region where well-preserved erosion surfaces at several levels are prominent over extensive areas.

Within the TWWHA, however, former erosion surfaces appear to have been deeply and extensively dissected leaving only a few large surfaces such as the Central Plateau surface, and other small residual fragments such as Eliza and Gallagher Plateaux. Indeed, it is this deep dissection of former erosion surfaces in the TWWHA which has allowed structural and lithological controls to re-assert themselves, producing the prominent strike ridge and valley landscape with its well developed trellised landscape as described above. If anything, the strike ridge and valley
landscape of the TWWHA is notable and distinctive in the western Tasmania context for its relative lack of extensive well-preserved erosion surfaces, in marked contrast to large parts of western Tasmania north and west of the TWWHA.

Pleistocene Glacial and Periglacial Process Influences
Another distinctive element of the fluvial landform systems of the TWWHA is the degree to which their geomorphic process systems have been influenced by Pleistocene glacial and periglacial processes. Repeated phases of energetic Pleistocene glacial and associated periglacial erosion have strongly modified the topography of the region and diverted drainages, while supplying large quantities of very coarse sediment to valley floors and terraces. Rapid erosion and seasonally intense melt water discharges carved out "oversize" valleys too big for the present streams occupying them to have produced. Large accumulations of glacial, glacio-fluvial and other sediments filled valleys, sometimes impounding lakes such as Lake St. Clair and the original Lake Pedder, and producing braided stream patterns which in many places persist as active anabranches today (e.g., in the middle reaches of South Cape Rivulet: C. Sharples unpublished observations). Many of these valley-filling sediments were subsequently incised to form river terraces. As a result of Pleistocene glaciation and periglacial processes, many valleys today contain extensive sediment deposits too coarse to be transported by modern river discharges except in rare flood events. Although some other major Tasmanian river systems and catchments outside the TWWHA have also been influenced strongly by past glaciation (e.g., the Derwent, Mersey, Forth, Pieman, Huon and Henty Rivers), those non-TWWHA fluvial environments mainly exhibit the "down-valley" effects of glacial and glacio-fluvial sediment deposition. In contrast, the TWWHA encompasses the full diversity of glacial landform environments ranging from glacially-eroded high altitude peaks on a range of bedrock types including both quartzite and dolerite mountains, to down-valley morainal deposits and outwash terraces. This implies that the TWWHA encompasses a broader and more complete range of glacial and periglacial process influences on fluvial landforms than do most other glacially-influenced fluvial regions in Tasmania.

Given the extent to which past glaciation has influenced ongoing fluvial processes in the TWWHA, it is important to note the lack of present-day ongoing glacial and intense periglacial processes in the region. Glacial and periglacial processes including mass-wasting, rapid erosion, glacio-fluvial outwash sediment transport and wide seasonal and diurnal meltwater discharge variations continue today in the otherwise most comparable undisturbed southern hemisphere fluvial environments of New Zealand and Patagonia, producing bedload transport rates, flow regimes and channel forms quite distinct from present - day Tasmanian ones. In contrast, Tasmania has during the Quaternary Period been a more marginal glacial environment in which environmental conditions have repeatedly switched from glacial to non-glacial. This alternation has produced a range of fluvial landforms and deposits more complex than and distinct from those of the more continuously-glaciated environments of New Zealand and Patagonia.

Peat (Blanket Bog) Soil Influences on Fluvial Geomorphic Processes
A further distinctive and pervasive element of the TWWHA fluvial process systems is the widespread influence of blanket bog peat soils on fluvial systems in the TWWHA. The blanket bog peat soils of western Tasmania constitute an important World Heritage value of the region in their own right (see Ongoing Blanket Bog Peat Land Soil Systems sub-theme discussion below), and cover a very large proportion of the TWWHA (see Figure 11).

Blanket bog peat soils are thought to exert strong controls on fluvial landform development in at least two respects, namely in their control of physical channel forms, and in their control on catchment and stream hydrology (Jerie et al. 2003, Bridle et al. 2003):

- The TWWHA blanket bog peats form a cohesive erosion-resistant surface layer which allows peat land stream channels to maintain relatively narrow and deep channels, even where the underlying substrate is a relatively soft material like the Tertiary sediments of the Birches Inlet –Spero River region (see description of Birches Inlet – Pocacker – Sorell - Spero Rivers fluvial
system below). Tunnelling is also a common stream morphology in such environments. Peatland stream channels can be highly sinuous, and channel migration rates are likely to be slow due to the cohesiveness of the peat surface (Jerie et al. 2003).

- Peat exerts strong controls on fluvial catchment hydrology, albeit these controls are still poorly understood and are the subject of ongoing research (Jerie et al. 2003, Bridle et al. 2003). Peat is thought to absorb and hold large quantities of rain water, resulting in stream flood peaks which are more delayed, lower and longer-lasting (i.e., less "flashy") than in otherwise comparable catchments lacking in peat soils. Peat soil catchments also appear to produce characteristic stream base flow conditions related to poorly-understood hydrological characteristics of the Tasmanian blanket bog peats: the water table in Tasmanian blanket bog soils may rise and fall by up to 30 - 40 centimetres on a diurnal basis (e.g., see Pemberton 1994, 2001), for as-yet poorly understood reasons which may relate to a mechanism of (temperature-dependant?) water uptake and release within the peat itself. However that may be, this hydrological behaviour may give rise to unusual diurnal stream base flow variations characteristic of blanket bog environments.

The large portion of the TWWHA that is covered by blanket bog peat soils (see Figure 11), the unique mechanical and hydrological influence of blanket bogs on fluvial geomorphic processes, and the fact that the extent of undisturbed blanket bog in the TWWHA is in itself of World Heritage significance (see later section below), gives the fluvial geomorphic systems of the TWWHA additional characteristics that are both distinctive within Tasmania, and significant in a global context. Whilst it has in the past been argued that the extent of blanket bogs and their characteristically associated button grass vegetation in western Tasmania is to a significant extent an artefact of anthropogenic burning (Jackson 1968, Bowman & Jackson 1981), one contemporary perspective now holds that – with some exceptions – the blanket bogs of western Tasmania are an essentially natural phenomenon, with their distribution largely determined by natural environmental factors rather than former Aboriginal firing patterns (Pemberton 1989; & in: Hannan et al. 1993, p. 25) (see also Ongoing Blanket Bog Peat Land Soil Systems sub-theme). Thus whilst Aborigines probably regularly fired the button grass (Marsden-Smedley 1998), this (mainly low-intensity) firing may not have significantly extended the range that button grass and blanket bogs would have occupied in the absence of anthropogenic firing. Whilst it must be noted that this latter issue remains controversial and badly in need of further research, the widespread influence of blanket bog peat soils on fluvial geomorphic processes in western Tasmania is probably an important and pervasive characteristic of natural ongoing fluvial geomorphic processes in the TWWHA.

Summary
The fluvial geomorphic process systems of the TWWHA are not broadly representative of Tasmanian fluvial geomorphic systems as a whole; rather the TWWHA encompasses most of the spatial extent of a particular assemblage of fluvial geomorphic environments and catchments which are distinctive within Tasmania. The temperate maritime-climate fluvial geomorphic systems of the TWWHA are characterised by perennial streams and rivers in a high precipitation, high discharge environment, in which former uplifted erosion surfaces have been largely dissected allowing the development of an outstanding trellised drainage network dominated by a prominent strike ridge and valley topography on folded bedrock over much of the region, although some portions of the TWWHA also exhibit the lithostructural influence of extant flat-lying block-faulted bedrock sequences. The TWWHA fluvial landforms exhibit the pervasive influences of former (Pleistocene) glacial and periglacial processes, but are not influenced by ongoing glaciation or intense periglaciation, and instead large areas are significantly influenced by the hydrology and physical characteristics of blanket bog peat soils whose areal extent and relative lack of disturbance are globally unusual.
Condition & Integrity

For the purposes of World Heritage significance assessment in terms of Criterion (i), the condition and integrity of ongoing natural fluvial geomorphic process systems in the TWWHA can be considered in terms of the degree to which the TWWHA encompasses inter-related elements of fluvial geodiversity (i.e., inter-related fluvial georegions), and the degree to which it protects catchments, which are in natural condition without significant process disturbances due to modern human interference (see UNESCO 1999, para 44(b)).

Fluvial Geodiversity Integrity

Figure (3) demonstrates that the fluvial geodiversity of the TWWHA (classified as the fluvial mosaics – effectively "georegions" - of Jerie et al. 2003) is distinctive in Tasmania, and that the TWWHA contains a very large proportion of the full extent of those distinctive elements of fluvial geodiversity. Thus, the TWWHA has a high degree of integrity in regard to its containment of the key inter-related elements of the distinctive fluvial geodiversity of western Tasmania.

Catchment Basin Integrity

In terms of the degree to which the TWWHA encompasses catchment basins, the highest integrity is possible when entire source-to-sea catchments are contained within the TWWHA, so that the full range of natural fluvial landforms and processes from headwater streams to estuaries are protected. Where this is not the case, the next best alternative is the containment of extensive upstream catchment basins within the TWWHA. Even if the lower reaches run beyond the TWWHA and are disturbed, the upstream parts within the TWWHA will be able to maintain natural fluvial process integrity within the TWWHA. However, the opposite situation – disturbed headwaters outside the TWWHA but downstream channels and catchments within the TWWHA – is less satisfactory, since upstream disturbances outside the TWWHA will propagate downstream and affect fluvial processes within the TWWHA.

The Gordon Basin (including Franklin River and all other tributaries) is the largest river system and fluvial catchment basin in the TWWHA, and is almost completely contained within the TWWHA apart from two small areas on the West Coast and D'Aguilar Ranges, and the Lake Gordon (former middle Gordon River) area which is excluded for hydro-electric and forestry purposes, but is surrounded by the TWWHA (see Figure 5). The natural Gordon River catchment basin has an area of 4,949 km², although an additional 264 km² of the upper Huon River catchment is now diverted into the Gordon by hydro-electric development (see below). The next largest entire source-to-sea catchment basin that is entirely contained within the TWWHA is the Davey / Crossing River system (803 km²). Other complete source-to-sea catchments entirely contained within the TWWHA include the New / Salisbury River system (309 km²), Giblin River, Old River, Spring River and South Cape Rivulet systems.

A number of other major river systems have large headwater catchments entirely within the TWWHA, although lower reaches flow out of the TWWHA. The largest of these is the Huon River headwater catchment, which however has been significantly disturbed both within the TWWHA (see below) and downstream of it. However several major tributaries of the Huon have extensive undisturbed headwater catchments contained entirely within the TWWHA, most notably the Upper Picton River catchment above Farmhouse Creek (327 km²), the Upper - Middle Weld

Note that fluvial georegions and catchments are not the same thing – any given catchment basin may contain widely differing fluvial landform types (i.e., different elements of fluvial geodiversity), whilst any given elements of fluvial geodiversity may straddle multiple catchments. However, catchment integrity is fundamental to maintaining natural fluvial processes, hence the ideal is to maintain key inter-related elements of fluvial geodiversity within an integrated assemblage of intact catchment basins.

Catchment areas have been calculated from GIS mapping during this project, using ESRI Arcview software.
River catchment \((322 \text{ km}^2)\) and the Cracroft River catchment. In the northern part of the TWWHA, the undisturbed upper Murchison River catchment above the Lake Murchison hydro-electric impoundment is most notable \((517 \text{ km}^2)\). All these rivers and/or their catchments are highly disturbed down stream of TWWHA boundaries. Smaller portions of the headwater catchments of the Forth, Mersey, Nive and other rivers are sourced in parts of the TWWHA on the Central Plateau that have varying degrees of disturbance within the TWWHA due to firing and grazing (Cullen 1995). See Figure (5). However, whilst many rivers originating within the TWWHA become artificially disturbed downstream of the TWWHA boundaries, this is not everywhere the case. For example, the Spero River maintains a mostly undisturbed condition downstream of the TWWHA boundary until it reaches the sea.

In contrast, only very few and minor rivers flow into the TWWHA from more upstream areas outside the TWWHA, notable examples being some streams flowing off the slopes of the West Coast Range and the D'Aguilar Range into the TWWHA. On the other hand, despite being sourced in and entirely surrounded by the TWWHA, the Gordon River is subject to disturbance (hydro-electric development) in its middle reaches, which are excluded from the TWWHA, and these disturbances have affected fluvial processes in downstream reaches of the Lower Gordon and Huon Rivers where they flow through the TWWHA (see Figure 5 and further discussion below).

However by far the overwhelming situation is that those rivers and streams which are not entirely contained in the TWWHA in nearly all cases flow from undisturbed sources within the TWWHA to downstream areas beyond the TWWHA, such that any artificial disturbances propagate downstream away from the TWWHA, not into it. This gives the TWWHA a high degree of catchment basin integrity, even where it does not contain entire source-to-sea catchments. There are also some rivers, such as the Spero River, which maintain their undisturbed catchment integrity downstream of the point where they flow out of the TWWHA.

**Anthropogenic Disturbances**

Although deliberate vegetation cover change in catchments is a disturbance that has major impacts on fluvial geomorphic processes, this disturbance is one which is largely absent in the TWWHA and which the Management Plan for the TWWHA (PWS 1999) sets out to avoid. Large parts of the TWWHA remain essentially undisturbed by human activities since European settlement of Tasmania, hence justifying the designation of much of the TWWHA as wilderness (see above). However, certain anthropogenic disturbances of fluvial landforms and processes are present in some parts of the TWWHA. These are summarised below:

- **Aboriginal Blanket Bog firing disturbances**
  Although - as noted above - Aboriginal firing may not be responsible for most of the broad extent of blanket bog peat lands in the TWWHA - as was once thought to be the case – nonetheless Aboriginal firing of these peat lands may have had some effects on fluvial processes. Since blanket bog peats probably exert significant control on fluvial processes (see above), degradation of peat by excessive burning will affect fluvial processes by suddenly removing those controls in excessively burnt areas, in particular by modifying hydrology to produce "flashier" streams, by allowing modification of channel shapes and plan forms, and by exposing unconsolidated substrates to accelerated erosion (eg, Tertiary alluvium and Pleistocene slope deposits). Large areas of blanket bog terrain in the TWWHA are thought to have been frequently burnt by Aborigines (Marsden-Smedley 1998), and although most such fires were probably of low intensity some may have damaged peat sufficiently to disturb fluvial processes. Indeed, frequent low intensity fires may simply have reduced the accumulation rate of peat (Bridle et al. 2003, p.7), thus affecting fluvial processes by limiting the thickness of peat and hence it's hydrological influence on fluvial processes. Jerie et al. (2003, Vol. 2, p. A8-6) cite 1830's observations by the early explorer Robinson, suggesting that gully erosion resulting from burning of blanket bog peats could have been present in the Wanderer River valley at that time.
Figure 5: Selected fluvial catchments of the Tasmanian Wilderness World Heritage Area. Although the largest catchment in the TWWHA, that of the Gordon River, is almost entirely contained within the TWWHA from source to sea, it exhibits a number of significant anthropogenic disturbances (as indicated on the map). The largest entire source-to-sea fluvial catchment exhibiting no notable anthropogenic process disturbances in the TWWHA (and in Tasmania as a whole) is that of the New / Salisbury River, which is also contained entirely within the TWWHA. See text discussion. NOTE: “TWWHA” area shown includes proposed extension areas listed in Section (3.3).
Although the degree of peat and fluvial process disturbance by Aboriginal firing remains uncertain and controversial, it seems likely that some occurred.

- **Post-European settlement Blanket Bog firing disturbances**

  In contrast, evidence of post-European settlement disturbance of blanket bog fluvial processes by anthropogenic burning is clear. Early European explorers of south-west Tasmania, such as T.B. Moore, deliberately burnt large areas of button grass (blanket bog terrain), and further extensive fires occurred in Southwest Tasmania during the 1930's, 1970's and 1980's (Marsden-Smedley 1998, Jerie et al. 2003, Vol. 2, p. A8-6). Button grass fires lit by Europeans in southwest Tasmania have probably been less frequent but larger and more intense than previously. Pemberton (1988) documented the effects of firing of blanket bogs in an area of southwest Tasmania, and showed that in some areas the peat soils have been entirely removed by erosion following intense fires, with likely consequent effects on fluvial processes. Areas of the TWWHA which have suffered significant loss of blanket bog peats following fire include the Sorell – Spero Wanderer River area, Lost World Plateau and the De Witt Range (Pemberton 1988, SDAC 1996, p. 2.13), whilst outside the TWWHA there has been considerable blanket bog degradation in the Zeehan – Pieman River area. It is virtually inevitable that these peat losses will have had some effect on fluvial processes in the TWWHA. Despite these examples of peat degradation, however, very large proportions of the TWWHA blanket bogs remain intact (see Ongoing Blanket Bog Peat Land Soil Systems sub-theme) and thus probably support natural peat-influenced fluvial processes.

- **Grazing and firing disturbances – Central Plateau**

  Approximately 10,890 hectares of the Central Plateau portion of the TWWHA is affected by erosion of alpine soils including peats, resulting from grazing by stock and (introduced) rabbits, and by anthropogenic firing (Cullen 1995). Although the effects of this erosion on fluvial processes have not been quantitatively measured, it is likely to have resulted in hydrological disturbances and increased sediment transport from eroded areas.

- **Hydro-electric development – middle Gordon River**

  The most severe anthropogenic disturbances to fluvial processes in the TWWHA are those associated with the Middle Gordon hydro-electric development, which was constructed in the late 1960's and early 1970's on the middle reaches of the Gordon River. The (artificial) Lake Gordon and Gordon Power Station area are excluded from (but surrounded by) the TWWHA (see Figure 5), however other areas disturbed by the hydro-electric development, such as the Huon – Serpentine impoundment, lie within the TWWHA boundaries. Disturbance to fluvial landforms and processes resulting from the hydro-electric development include:

  - Flooding of a long stretch of the middle Gordon River, and adjoining tributaries and catchment, to form Lake Gordon (see Figure 5). This included the inundation of a number of spectacular strike ridge gorges, and the excavation and filling of the major (deep and narrow) strike ridge gorge in which the Gordon Dam (damming Lake Gordon) was built (Dean 2002, p. 91).

  - Flooding of the Serpentine River (Gordon tributary), upper Huon River, and adjoining plains, to form the Huon-Serpentine Impoundment (see Figure 5). This flooding inundated the outstanding meandering channel of the Serpentine River, and the original Lake Pedder (Kiernan 2001a), and diverted the flow of the Serpentine and upper Huon Rivers into Lake Gordon via the artificial McPartlan's Pass canal.

  - Diversion of runoff from an area of 264 km$^2$ of the upper Huon River catchment into the Gordon River via the Huon – Serpentine Impoundment, resulting in a
reduction in the Huon River catchment area of roughly 10%, and consequent reduced discharge in the Huon River within the TWWHA, downstream of the artificial impoundment (Livingston 2001). See Figure (5). Physical changes to the channels of both the Gordon and Huon Rivers will have occurred in response to this.

• Modification of flow regimes in the Lower Gordon River (within the TWWHA) due to operation of the Gordon Power Station at Lake Gordon, in particular by reducing winter and spring discharges and increasing summer discharge (Bradbury et al. 1995, p.269). Current proposals to supply peak period electricity to mainland Australia via a Bass Strait cable have the potential to further modify flow regimes on a daily basis, if (as is proposed) the Gordon Power Station is used to provide peak period power to mainland Australia (Koehnken et al. 2001).

However, whilst the main trunk channel of the Gordon River and its Serpentine River tributary are artificially disturbed from the middle Gordon area downstream, it is significant that most large tributaries of the Gordon River remain essentially undisturbed, including the Franklin, Jane, Maxwell, Denison and Olga Rivers (see Figure 5).

• Tourist boat wake erosion – lower Gordon River
The operation of large tourist boats on the lower Gordon River has resulted in bank erosion due to boat wakes, in places causing up to 10 metres of bank recession and toppling trees into the river (Bradbury et al. 1995). Management actions have been undertaken to minimise future erosion (reduced boat speeds and reduced-wake hull designs), however the existing damage is not repairable.

• Roading
Roading in catchments within the TWWHA has caused localised physical disturbance of fluvial landforms, locally concentrated runoff from road surfaces, and caused minor erosion. The most important roading within TWWHA catchments (see Figure 5) includes the Lyell Highway, Gordon River Road, Scott's Peak Road and Mt McCall Road within the Gordon and upper Huon catchments, and the Mueller Road, an unsealed, gated power-line maintenance road crossing the upper-most Weld River catchment. Other unsealed roading exists on the eastern and south-eastern side of the artificial Lake Gordon (but is excluded from the TWWHA), and in the Sawback Range – Adamsfield area. Unsealed vehicular tracks south of Birches Inlet continue to locally affect fluvial systems in that area.

• Forestry
Forestry activities including clearfall logging occurs on the eastern and south-eastern side of the artificial Lake Gordon, in an area of State forest excluded from but surrounded by the TWWHA, and within the Gordon River catchment basin.

• Climate Change
Anthropogenic climate change (IPCC 2001) is in the future likely to have measurable effects on fluvial processes in the TWWHA, in particular through changes in effective precipitation and consequently total stream water discharges and seasonal variation thereof. Global warming may also cause reduction of blanket bog soils (Bridle et al. 2003, p. 40), changing the form and hydrology of streams in current blanket bog areas. However, modification of fluvial processes due to climate change, in differing ways, is likely to be a globally ubiquitous anthropogenic effect, and hence should not be considered relevant to assessing the integrity of fluvial process systems for the purposes of World Heritage significance assessments.
Extent of Disturbed vs Undisturbed Fluvial Systems

The most significant artificial disturbances to ongoing fluvial geomorphic systems are those associated with hydro-electric development in the Gordon and Huon River Basins. These mainly affect the trunk channels of the Gordon and Huon Rivers, and the Serpentine River, however they are substantial and the World Heritage values of those trunk rivers under the ongoing fluvial process theme must be considered under threat. However most large tributaries upstream of the Gordon River trunk channel, including the large Franklin River system, are unaffected by hydro-electric development, so that the effects of hydro-electric development on TWWHA fluvial processes is contained within a limited area of the TWWHA, albeit the Gordon River is the largest river in the TWWHA.

Fluvial process disturbances due to boat wake erosion, roading and forestry affect only very limited and localised areas in the TWWHA. Aside from hydro-electric development, the other potentially most significant fluvial process disturbances in the TWWHA are disturbances related to erosion following fire and grazing, both of alpine soils on the Central Plateau and of blanket bog peat soils in other parts of the TWWHA. Soil erosion due to these disturbances over the last century or so is significant in several locations such as the Central Plateau, some areas south of Birches Inlet and Lost World Plateau, whereas erosion due to Aboriginal firing, whilst it has probably occurred, was of uncertain extent and impact. Most of the blanket bog peats of the TWWHA appear currently intact and functioning naturally, albeit there remain unresolved questions regarding what the extent and thickness of blanket bog peats in the TWWHA would have been if Aboriginal firing had not occurred during the Pleistocene and early Holocene (Bridle et al. 2003) (see Ongoing Blanket Bog Peat Land Soil Systems sub-theme). Thus, the greater part of blanket bog – dominated and mixed blanket bog / forested TWWHA catchments, such as those of the Davey / Crossing, Giblin, Old, Spring, Cracroft, Maxwell, Franklin, Denison and Olga Rivers, are effectively undisturbed peat land fluvial systems, which are significant natural fluvial geomorphic process systems in their own right.

The TWWHA fluvial catchments whose undisturbed nature is most clear are the fully forested (old growth) catchments, most importantly the Upper Murchison, Upper Weld, Upper Picton and the entire New / Salisbury River catchments. These catchments exhibit no effective fluvial processes resulting from historic disturbance or inherited from possible earlier Aboriginal disturbances. Even if parts of these basins were not forested, and/or were deliberately burnt by Aborigines during the Pleistocene or early Holocene, they have probably now been fully forested for several millennia at least, and are now in a natural equilibrium state with no evident significant process disturbances inherited from any earlier phase of Aboriginal disturbance. These catchments together encompass 1475 km², which is a significant portion of the TWWHA (see Figure 5).

Conclusion – Condition & Integrity

Despite a number of fluvial landform and process disturbances, most notably hydro-electric development and anthropogenically-induced erosion of some alpine and blanket bog soils, the condition of fluvial landforms and processes is essentially undisturbed over by far the greater portion of the TWWHA.

The integrity conditions for natural World Heritage properties (UNESCO 1999, para 44(b)) are met by the Ongoing Fluvial Geomorphic Process Systems theme in the TWWHA because:

- Integrity criterion 44(b) (i) (Inclusion of key inter-related elements):
  The elements ("georegions") of fluvial geodiversity characteristic of the TWWHA are mostly – and in many cases entirely – contained within the TWWHA boundaries, hence the fluvial geodiversity of the TWWHA has a high degree of integrity in this respect. With only minor

---

26 Note that these three integrity criteria from UNESCO (1999, para 44(b)) are the only ones pertinent to the Ongoing Fluvial Geomorphic Processes sub-theme in respect of its outstanding universal value under World Heritage criterion 44(a) (i) (see Section 2.3.3).
exceptions, the TWWHA encompasses either entire source-to-sea fluvial catchments (including the largest catchment in the TWWHA, that of the Gordon River), or else contains the complete upstream catchments of those river systems whose downstream parts flow beyond the TWWHA. The high degree of inclusion of key inter-related elements of fluvial geodiversity and of complete or upstream catchments gives the TWWHA adequate integrity under this criterion to comprehensively represent an inter-related assemblage of fluvial landforms, and to allow maintenance of ongoing natural fluvial geomorphic processes.

- **Integrity criterion 44(b) (v) (Management Plan):** Management of the Ongoing Fluvial Geomorphic Process Systems within the TWWHA are subject to (and specifically protected by) a statutory management plan (PWS 1999).

- **Integrity criterion 44(b) (vi) (Adequate long term protection):** The ongoing fluvial geomorphic process systems within the TWWHA are protected by legislation, since the TWWHA comprises lands of declared National Park, Conservation Area and Forest Reserve land tenure, and these are subject to the provisions of the Regional Forest Agreement (Land Classification) Act 1998, which specifies that one legislative purpose of these reserve categories is the conservation of geological diversity (which is defined in the Act to include geomorphic processes). The fact that nearly all fluvial systems in the TWWHA are either entirely contained within the TWWHA, or flow from within the TWWHA to outside areas, ensures that fluvial disturbances outside the TWWHA will not impact on fluvial processes within the TWWHA. The one major exception to this is the Middle Gordon Hydro-Electric scheme, which is enabled by its own legislation and has both directly disturbed fluvial landforms within the TWWHA, and also has caused modified river flow regimes and channel modifications in the Lower Gordon and Huon Rivers within the TWWHA.

**Justification**

The TWWHA is not representative of Tasmanian fluvial geomorphic systems generally, but is rather a distinctive fluvial geomorphic region within the state. In a global context, it constitutes an extensive mostly undisturbed exemplar of a particular fluvial geomorphic environment which is unlikely to be replicated elsewhere, and which includes within its boundaries most of the full extent of the catchments and georegions characteristic of that geomorphic environment. The ongoing fluvial geomorphic process systems of the TWWHA have outstanding universal value under Criterion 44(a)(i) (UNESCO 1999) as an example of "significant on-going geological processes in the development of landforms", in two ways:

1. The TWWHA fluvial systems are outstanding in being largely undisturbed over a region of comparable extent to the largest undisturbed temperate fluvial environments globally; and

2. The TWWHA fluvial systems are outstanding in encompassing nearly all of the full extent of a particular type of temperate fluvial environment which is unlikely to be replicated elsewhere (globally) in a similarly extensive undisturbed area.

Additionally, the trellised strike ridge and valley fluvial landscape of the TWWHA with its outstanding strike ridge gorges contributes to the outstanding universal value of the TWWHA under Criterion 44(a)(iii) (UNESCO 1999) as an example of "areas of exceptional natural beauty and aesthetic importance".

These justifications are elaborated below:

**Distinctiveness**

The TWWHA fluvial geomorphic systems are a largely undisturbed temperate-zone maritime-climate high-discharge fluvial system, strongly influenced by past glacial processes but not by present day glaciation or intense periglaciation. Large portions of the TWWHA have fluvial systems developed on blanket bog peat lands, which exert characteristic controls on fluvial
processes, and are themselves of World Heritage significance (see Blanket Bog sub-theme). Large-scale fluvial landforms in the TWWHA are dominated over a large portion of the TWWHA by very well expressed "trellised" river patterns with prominent strike ridges and valleys, and spectacular strike ridge gorges.

**Comparative Assessment**

In terms of areal extent and lack of disturbance, the most nearly comparable temperate-zone maritime-climate fluvial systems influenced by glacial processes are those of Patagonia (South America) and Fiordland (New Zealand); however these fluvial systems differ significantly in being subject to ongoing glacial, intense periglacial and glacio-fluvial processes, which produce distinctive channel forms, distinctive diurnal and seasonal flow regimes not found in Tasmania, and cause much higher rates of erosion and ongoing bedload transport than are found in Tasmanian rivers. Thus the TWWHA ongoing fluvial systems have no real comparable examples elsewhere that are undisturbed over similar sized regions, and so have outstanding universal value as the most extensive undisturbed example of their type of fluvial geomorphic system in the world.

Whereas the trellised strike ridge and valley fluvial landscape of the TWWHA is not necessarily the best example of such a landscape in the world (or even Australia), it is arguably the best example in an undisturbed temperate fluvial process environment of comparable scale, and thus is an element of the fluvial geomorphology of the TWWHA which contributes significantly to its outstanding universal value under Criterion 44(a)(i). In addition, the strike ridge and valley topography of the TWWHA is one of its most distinctive large scale aesthetic features, and one which often dominates published photos of the region (see Figure 16). Along with spectacular strike ridge gorges such as the famous Gordon Splits, this fluvial topography is a key aesthetic element of the TWWHA and contributes significantly to its outstanding universal value under Criterion 44(a)(iii).

**Comments**

Whilst the contribution of ongoing undisturbed fluvial processes to the World Heritage values of the TWWHA received only very brief mention in the 1989 nomination (DASET 1989, p. 42; see this report Section 2.3.2 "Other Geomorphological Processes"), subsequent work highlights that the ongoing fluvial geomorphic process systems of the TWWHA are one of the most extensive regions of comparable undisturbed fluvial processes globally. They are consequently of outstanding significance both for their intrinsic value, and as a benchmark or "baseline" site for studying undisturbed temperate fluvial processes and comparing these with the effects of human activities on comparable fluvial systems elsewhere.

**Individual sites or systems of World Heritage significance in their own right**

Within this sub-theme, the following individual areas or systems exemplify the characteristics of the ongoing fluvial geomorphic process theme to such a high degree that they arguably have World Heritage value in their own right (not merely as features contributing to the overall theme):

**New-Salisbury River Catchment Basin Ongoing Fluvial Process System**

Although the largest catchment in the TWWHA, that of the Gordon River, is almost entirely contained within the TWWHA from source to sea, it exhibits a number of significant anthropogenic disturbances (see above). Other large source-to-sea catchments entirely contained within the TWWHA, such as the Davey-Crossing River basin, Giblin River basin, and others are mosaics of forested areas and blanket bog peat lands; in some cases the peat lands and associated fluvial processes are known to have been disturbed by historic fires, whereas in other cases there are unresolved questions as to the extent to which Aboriginal burning disturbance of peat lands has modified peats and fluvial processes (see above). The TWWHA catchments which are most confidently considered to be entirely free of significant effective ongoing anthropogenic fluvial process disturbance, either by Aborigines or Europeans, are those which are completely mantled by undisturbed old growth forests. Of these, the largest entire source – to - sea fluvial catchment
Figure 6: Map of the New and Salisbury River catchment basin. The basin contains a diversity of key fluvial geomorphic landform association (environmental domain mosaics or "georegions"), which are representative of domains occurring widely within the TWWHA (compare Figure 3). In particular, the catchment basin includes pristine karst systems on both Precambrian dolomites (New River) and Ordovician limestones (Salisbury River and New River Lagoon). The Salisbury River karst is well developed (Eberhard et al. 1991) and is consequently of high conservation significance given its pristine fluvial setting.
exhibiting no notable effective anthropogenic disturbances in the TWWHA is that of the New / Salisbury River. Whilst larger undisturbed forested fluvial catchments exist in the TWWHA (the upper Murchison, Weld and Picton catchments; see Figure 5), these are all significantly disturbed in their lower reaches, which extend beyond the TWWHA.

The New–Salisbury River source – to – sea catchment basin covers an area of 309 km$^2$, all of which is contained within the TWWHA. With the exception of water bodies, some natural alpine grasslands on ridge tops, and a small area of button grass and scrub at New River Lagoon$^{27}$, the basin is entirely mantled by old growth forest which has never been logged, roaded, mined, settled, farmed or otherwise significantly disturbed by European settlers, and which shows no evidence of significant inheritance of effective Aboriginal disturbance of fluvial processes$^{28}$. As such, the New – Salisbury River catchment is the largest entire source-to-sea river catchment basin in the TWWHA which can confidently be said to be free of significant effective anthropogenic fluvial process disturbance on current knowledge. Given the degree of process disturbance outside the TWWHA (see Figure 2), this also makes it the largest pristine source-to-sea fluvial catchment basin in Tasmania.

Apart from containing all the basic geomorphic components of a complete source-to-sea fluvial system, in fluvial geodiversity terms the fluvial landform assemblage types (fluvial environmental domain mosaics) of the New-Salisbury Basin include a diverse cross-section of many of the most extensive fluvial mosaics characteristic of the TWWHA as a whole (compare Figures 3 and 6). The geomorphic diversity of the New-Salisbury River basin includes:

- extensive areas of both folded strike-ridge dominated Precambrian rock types and flat-lying Parmeener Supergroup rocks and dolerites;
- well-developed pristine karst areas on both Precambrian dolomites and Ordovician limestones;
- outstanding exemplars of glaciated alpine mountain tops of both the quartzite (Federation Peak) and dolerite (Precipitous Bluff) types most characteristic of the TWWHA;
- steeply dissected fluvial terrains and deep strike ridge gorges on Precambrian rocks, and low-gradient streams on extensive Parmeener Supergroup plateaux;
- coastal plains and an extensive coastal estuarine lagoon.

The fluvial environmental domain mosaics found within the New-Salisbury Rivers basin (Figure 6) are representative parts of fluvial landform assemblages that cover fully 47.06% (6611 km$^2$) of the 14,049 km$^2$ TWWHA as a whole$^{29}$; in essence the New-Salisbury River catchment contains

---

$^{27}$ This small area on the shores of New River Lagoon displays sharp boundaries and is evidently the result of fire; however it was evidently fired some considerable time ago, and there is no evidence available as to the cause of the fire, which could have been natural. The area is also at the downstream end of the New River basin, hence any effects its burning has had on fluvial processes are limited to the lowermost parts of the system.

$^{28}$ The Tasmanian Aboriginal Sites Index (TASI) records rock shelters with possible former Aboriginal occupation below Precipitous Bluff, at New River Lagoon (the New River estuarine lagoon), however no Aboriginal sites are recorded on the TASI database anywhere else in the New River Basin (albeit there has been little systematic searching for such sites in that region). The New River lagoon area awaits serious investigation for evidence of human occupation; however the lack of burnt areas anywhere in New-Salisbury Basin above New River Lagoon suggests little likelihood of significant human disturbance in the middle or late Holocene. As noted previously, even if parts of the New / Salisbury River basins were not forested, and/or were deliberately burnt by Aborigines during the Pleistocene or early Holocene, they have probably now been fully forested for several millennia at least, and are now in a natural equilibrium state with no evident significant process disturbances inherited from any earlier phase of Aboriginal disturbance.

$^{29}$ Calculated by C. Sharples using GIS mapping of the TWWHA and fluvial environmental domain mosaics.
representative undisturbed exemplars of the fluvial geomorphic assemblages occupying nearly half of the area of the TWWHA (albeit this does not equate to half of the fluvial diversity – or fluvial environmental domain mosaic types – found in the TWWHA). Much of the remaining half of the area of the TWWHA is occupied by fluvial landform mosaics where blanket bog peat soils (absent in the New-Salisbury basin) or a high altitude glaciated plateau (the Central Plateau) exert influences on fluvial landform development.

Only one fluvial feature within the New / Salisbury River catchment has been previously listed on the Tasmanian Geoconservation Database (TGD), namely the New River Delta and Overbank Deposits (HUO10, outstanding significance at local level; see Appendix 1). However it is evident that the New-Salisbury River catchment basin as a whole has outstanding universal value in its own right under Criterion (i) of the World Heritage Criteria (UNESCO 1999), as the most extensive effectively undisturbed, complete source-to-sea, temperate maritime-climate fluvial catchment basin displaying ongoing fluvial geomorphic processes in the TWWHA - and thus in Tasmania and Australia. As such it is probably comparable to the best examples globally. The fact that this undisturbed catchment contains within itself fluvial landform assemblages representative of a wide range of important such assemblages in the TWWHA as a whole, considerably enhances the significance of the area from the perspective of the intrinsic value of the diversity of undisturbed landform types it contains, and because of the scientific potential of the area to provide undisturbed baseline reference sites for fluvial landform processes over much of the rest of the TWWHA. The Integrity conditions for natural properties on the World Heritage List (UNESCO 1999, para. 44(b)) are easily met, since the entire undisturbed catchment lies within the TWWHA, which as a whole meets the integrity conditions for the World Heritage List (see above).

**Birches Inlet – Sorell – Pocacker / Spero River Tectonically-Influenced Peat Land Fluvial Geomorphic System.**

This is an ongoing peat-land fluvial process system displaying outstanding assemblages of river terraces (Jerie et al. 2003, Appendix 8), which are evidently related to nearby marine terraces at Birches Inlet / Macquarie Harbour (McClenaghan & Findlay 1989, 1993). The fluvial system exemplifies tectonic and peat soil control of fluvial system development, and has been described in detail by Jerie et al. (2003, Appendix 8), following a reconnaissance by Bradbury (1996).
Three factors that are not known to elsewhere occur together have combined to produce exceptionally well-developed and preserved fluvial terraces in the Birches Inlet – Spero River – Wanderer River (Macquarie Graben) region of the TWWHA (Ian Houshold pers. comm.):

1. Significant Quaternary tectonic uplift has and continues to strongly influence rivers in the region, causing rapid incision and terrace development due to repeatedly lowered base levels. The tectonic uplift is possibly partly local (geologically recent faulting is evident in the Macquarie Graben, including a prominent fault scarp on the D’Aguilar Range adjacent the Pocacker River), but is probably largely related to ongoing uplift of southern Australia due to processes involved in the northwards drift of the Australian continental plate (Bowden & Colhoun 1984, Murray-Wallace & Goede 1991, 1995). The degree of Quaternary neotectonic uplift is greatest in Tasmania as compared to other parts of Australia to the north (Murray-Wallace & Belperio 1991), which has provided the potential for greater incision - and thus a larger geomorphic response to each tectonic movement - in Tasmania as compared to other parts of Australia. This has resulted in a more sensitive & detailed record of tectonic uplift movements than elsewhere in Australia.

2. The presence in the Macquarie Graben of very thick deposits (up to 500 metres) of easily-erodible Tertiary quartz gravels has allowed rapid incision and terrace formation to occur in response to each tectonic movement, providing a sensitive and relatively complete record of the history of tectonic uplift. In contrast, other areas of southern Australia (including elsewhere in Tasmania) have more lithified (less erodible) bedrock substrates, or only much thinner Tertiary gravel deposits, which therefore show a much less complete and less sensitive geomorphic response to tectonic movements.

3. The presence of cohesive, erosion-resistant blanket bog peat soils on the Tertiary gravel terraces has protected terrace surfaces from erosion – once uplifted and incised – resulting in much better preservation of terrace morphology than would normally be expected on soft Tertiary gravels. Again, this has resulted in unusually good preservation of the detailed record of tectonic uplift that is represented by the fluvial terraces. Within Australia, the blanket bog soils are unique to Tasmania, and their extent and condition gives them World Heritage value in their own right (see Blanket Bog sub-theme section).

Figure 8: An outstanding flight of fluvial terraces in the Spero River valley, TWWHA (photo: Ian Houshold). Well preserved flights of as many fluvial terraces as this are globally rare, and this is probably the best example in temperate Australia.
Figure 9: Map of the Birches Inlet – Sorell – Pocacker / Spero Rivers region, indicating the area of thick un lithified Tertiary alluvial sediments filling the Macquarie Graben, which have played a significant role in the development of this fluvial landform system. The TWWHA boundary is indicated.
In addition to the outstanding record of tectonic uplift preserved by terraces in this fluvial landform system, the system is unusual because river system development is not controlled by hard bedrock within the Macquarie Graben, and is instead influenced by cohesive peat soils, producing very steep meandering systems (Jerie et al. 2003). The development of whole system, including river captures, is strongly influenced by geologically-recent uplift, but not by bedrock structures (within the area of the sediment-filled Macquarie Graben).

This unique set of circumstances which have allowed development of an extensive, well-developed and well-preserved fluvial terrace landform suite that sensitively preserves evidence of the history of Quaternary (and earlier?) tectonic uplift in southern Australia, together with the close spatial relationship of these terraces with genetically-related marine terraces at Macquarie Harbour, gives this fluvial landform system outstanding importance in the Australian context. As the best fluvial landscape record of the Quaternary tectonic movement of the Australian tectonic plate, this fluvial landform system is thus the best example of its type globally, and is consequently of outstanding universal value.

Although the Birches Inlet – Sorell – Pocacker / Spero River tectonically-influenced peat land fluvial system is in part a record of past tectonic movements, it is probable that the tectonic uplift responsible is continuing today, with the ongoing drift northwards drift of the Australian tectonic plate. Hence the development of fluvial terraces and tectonically-influenced evolution of the fluvial landform system is probably an ongoing fluvial process system, not merely a suite of relict landforms.

Portions of the Birches Inlet – Sorell – Pocacker - Spero River fluvial system have been listed on the Tasmanian Geoconservation Database (TGD), but were only assigned significance at a State level (see Appendix 1). Related features including the Birches Inlet Marine Terraces and the D'Aguilar Range fault scarp are also listed on the TGD (Appendix 1). However, Bradbury (1996) has previously recommended that the entire fluvial system be listed as the "Macquarie Graben Fluvial Systems" and assigned significance at World level. This recommendation is supported by the present review:

In virtue of its sensitive geomorphic responses to tectonic uplift, the Birches Inlet – Sorell – Pocacker - Spero River tectonically-influenced peat land fluvial geomorphic system has outstanding universal value in its own right under Criterion (i) of the World Heritage Criteria (UNESCO 1999), as an outstanding ongoing tectonically-influenced fluvial process system whose key landform characteristics are unusually well-expressed due to their development on thick un lithified Tertiary alluvial deposits and which are unusually well-preserved due to the influence of blanket bog soils in preserving soft incised-alluvium landforms.

Some anthropogenic disturbance of the fluvial geomorphic system has occurred, due to historic (and pre-historic?) firing of peat and consequent erosion in some areas (Pemberton 1988, 1989; Jerie et al. 2003, Vol. 2, Appendix 8), and to the past construction of a vehicular track through the area for mineral exploration. However large portions of the system remain intact, displaying their key landform features and intact blanket bog soils, and undergoing natural geomorphic processes (Jerie et al. 2003, Vol. 2, Appendix 8). Additionally, the fluvial systems and catchments concerned are not entirely contained within the TWWHA boundaries, with some areas of fluvial landform development on Tertiary sediments extending beyond the TWWHA boundaries, and portions of the catchments and trunk channels of key rivers (including the Wanderer and Spero Rivers) extending beyond the TWWHA boundaries in both up– and down-stream directions (see Figure 9). Nonetheless, several key rivers including the Sorell and Pocacker Rivers and their catchments are mostly contained within the TWWHA, as are large portions of the Spero River and its associated terraces (see Figure 8).

The Integrity conditions for natural properties on the World Heritage List (UNESCO 1999, para. 44(b)) are met, albeit imperfectly, since key inter-related landform elements, including several
nearly-entire river catchments, are contained within the TWWHA (integrity condition 44(b)(i)), with large portions of these free of significant physical anthropogenic disturbance of the key landforms and blanket bog soils. Integrity conditions 44(b)(v & vi) are also met, as elsewhere in the TWWHA, since the area has a management plan (PWS 1999) and has long term legislative protection.

**Sub-Theme:**

**Ongoing Blanket Bog Peat Land Soil Systems**

**Description**

Blanket bogs are a distinctive landscape unit characteristically containing organic soils ("organosols" or peats) that are not confined to depressions (see Figure 10). Blanket bogs form in response to very humid climates, and not only occur on undulating plains and across valley floors, but also climb onto surrounding slopes where they may thin slightly and become more fibric (M. Pemberton *pers. comm.*). In western Tasmania, blanket bogs are widespread on slopes up to 40°, at altitudes from sea level to 700 metres, and typically support sedge-land and heath-land vegetation, particularly buttongrass (Pemberton in: Hannan et al. 1993; Pemberton 1989, 2001). The organosols of the blanket bogs on slopes in the TWWHA are typically around 300mm thick, in contrast to “topogeneous peats” in poorly-draining depressions at low altitudes, which may be several metres deep.

Organosols (“peats”) of blanket bogs cover roughly 750,000 hectares of western Tasmania, in areas having a cool wet maritime climate and heavy reliable rainfall of up to or exceeding 3,500 mm p.a. in some areas (Pemberton in: Hannan et al. 1993, Pemberton 1989, 2001). See Figure (11). There is evidence that under these climatic conditions, organic soil development is favoured in areas having poor drainage and inert siliceous substrates (eg, quartzite bedrock) upon which mineral soil development is minimal (Pemberton in: Hannan et al. 1993, p. 25).

Peat mounds are notable component features associated with the Blanket Bog theme (Macphail et al. 1999). The best developed examples of these somewhat enigmatic features known from within the TWWHA are at Louisa Plains and parts of the Moore's Valley - Birches Inlet area, but they occur in other locations too (e.g., Mt Anne area and the Vale of Rasselas?), and excellent examples also exist immediately outside but adjacent the TWWHA at Melaleuca (SW Conservation Area). These occurrences were considered by Macphail et al. (1999) to be probably unique in the southern hemisphere.

Of roughly 750,000 hectares of blanket bog in Western Tasmania, approximately 380,000 hectares lie within the TWWHA (mostly under National Park land tenure), whereas 370,000 hectares fall outside the TWWHA (mainly in areas of Conservation Area and Regional Reserve tenure, but also on a large area of unallocated crown lands in the Pieman River region). See Figure (11).

---

30 Calculated from a GIS map prepared for the Tasmanian Geoconservation Database in 1996, using buttongrass moorland distribution as a surrogate for blanket bogs. Earlier estimates indicated that Tasmania had in excess of one million hectares of button grass / blanket bog (Duncan 1985, Jarman et al. 1988), however this figure was based on early coarse-scale vegetation mapping and is probably an over-estimate. Nonetheless the present map also requires improvement: problems remain with the use of vegetation mapping as a surrogate for blanket bogs, and some large areas where blanket bogs exist but have been degraded by fire are either not shown, or only arbitrary portions of them are shown.
Figure 10: Typical example of blanket bog terrain in the TWWHA, showing sedge-dominated peat soils on undulating to moderately steep ground in the Crossing River area. The results of fire can be seen in the lower left hand area, where complete destruction of an area of peat soil following fire has exposed the underlying quartzite bedrock.

The western Tasmanian environment is a marginal one for the development of blanket bog peats, being slightly warmer than is optimal for peat accumulation (Bridle et al. 2003, p. 4). At typical thicknesses of 300mm, the Tasmanian blanket bog peats are shallow by world standards. This may be because the marginal Tasmanian environment causes rates of peat accumulation and decay to reach equilibrium at around 300mm (Balmer 1991), however it may also be that frequent low intensity burning by Aborigines in the past (see further below), whilst not necessarily destroying peat, has limited the rate of peat accumulation (see Bridle et al. 2003).

Although Tasmanian blanket bog peats may sometimes be even thinner than 300mm, in which case some technical definitions would exclude them as true blanket bog peats, their extent, variable thickness and effective role in natural processes such as fluvial geomorphic processes (see Ongoing Fluvial Geomorphic Process Systems sub-theme above) makes it reasonable to regard them as a characteristically thin variety of blanket bog peat, which is in part unique for that very reason.

The TWWHA blanket bogs are also of a significantly different type to many other extensive examples elsewhere in the world, particularly many northern hemisphere blanket bogs, in that they are not primarily sphagnum moss bogs, but rather are dominated by sedges and shrubs (Lindsay 1995, p. 61, Bridle et al. 2003, p. 4).

It has been argued that Tasmanian blanket bogs are not a fully natural landscape unit in Tasmania, but are at least in part an anthropogenic soil / vegetation association, in that regular Aboriginal firing during the Pleistocene and early – mid Holocene (Marsden-Smedley 1998) may have created and maintained button grass moor lands with their characteristic blanket bog peat soils in western Tasmania (Jackson 1968, Bowman & Jackson 1981). However, Pemberton (1989; & in: Hannan et al. 1993, p. 25) considers that fire is not essential for maintenance of button grass moorland / blanket bogs, at least in poorly drained situations on inert siliceous substrates. On the contrary, too much firing is known to have destroyed some areas of blanket bog peat soil in western Tasmania (Pemberton 1988, 1989, Pemberton & Cullen 1995), and it can reasonably be expected that in the
Figure 11: Distribution of Blanket Bogs in Western Tasmania with respect to the Tasmanian Wilderness World Heritage Area (TWWHA). Note that some areas of degraded blanket bogs (e.g., south of Birches Inlet) are not included. Blanket bog distribution shown on this map has been derived by using vegetation mapping as a surrogate, and requires refinement (see text).

NOTE: "TWWHA" boundary shown includes proposed TWWHA extension areas listed in Section (3.3).

Long term regular firing would tend to constrict rather than expand the areas occupied by button grass / blanket bog associations. Pemberton considers that extensive blanket bog moor lands probably existed prior to human arrival and the onset of regular anthropogenic burning in Tasmania, and that the button grass normally found on blanket bogs may be an edaphic climax community on those soils, which does not necessarily require anthropogenic firing for its maintenance. Pemberton points to strong evidence that the distribution of button grass/blanket bog and rainforest in many places clearly reflects bedrock geology and soil drainage, rather than fire.
history. This implies that, in addition to being undisturbed by present day human activities, some substantial areas of blanket bog/button grass moorland in western Tasmania may not have undergone significant effective process disturbance due to Aboriginal burning in the past, which was generally of low intensity (Marsden-Smedley 1998). In areas where a blanket bog / button grass association forms a natural edaphic climax, the occasional Aboriginal fire probably maintained – but was not essential to maintain – that ecology. On the other hand, however, it is also possible that frequent low-intensity Aboriginal burning may have limited peat accumulation rates in blanket bogs, causing Tasmanian blanket bog peat soils to be thinner than might otherwise have been the case (see above and Bridle et al. 2003, p. 7).

Insufficient scientific study of Tasmanian blanket bogs has yet been done to provide conclusive demonstration of whether or not extensive blanket bog/button grass ecologies existed in western Tasmania prior to the Aboriginal influx circa 40,000 years BP, and what their nature (including thicknesses) were. However, given the likelihood that this is the case, the areas most likely to support button grass/blanket bog ecologies as a natural edaphic climax community are the more poorly-drained valley-bottom areas on siliceous substrates (eg, quartzite or quartzite/schist associations), such as Louisa Plains, Olga-Hardwood Valley, the Melaleuca Valley and - prior to its artificial inundation in 1972 – the Serpentine Valley floor (Mike Pemberton, pers. comm.). It is likely that the main ecological change caused by Aboriginal firing was to displace rainforest from, and gradually extend button grass and blanket bogs onto, the better drained hill slopes surrounding the poorly drained valley floors which the button grass / blanket bogs naturally occupied prior to the arrival of human burning regimes (Cosgrove et al. 1990, Fletcher 2000). Given the removal of regular firing, it can be expected that rainforest could gradually recolonise well – drained slopes with non-siliceous substrates, but not certain poorly drained valley floors on siliceous substrates where the button grass is the edaphic climax community on blanket bogs.

**Condition & Integrity**

As noted above, there remain unresolved questions over the degree to which the extent and thickness of the TWWHA blanket bog soils have or have not been influenced by past Aboriginal activities, particularly low intensity burning. In fact, it can be said that we are uncertain as to what the thickness and extent of blanket bog peats in the TWWHA would have been had Aborigines been absent from the region during the Pleistocene and early Holocene. Irrespective of these uncertainties, however, it appears likely that the blanket bog peat soils of the TWWHA are essentially a natural phenomenon, and that they occupy an essentially natural range. Whatever influence Aboriginal burning may have had in the past, blanket bogs in many parts of the TWWHA are no longer subject to those influences, and are presumably reaching, or have reached, a natural process equilibrium.

Nevertheless, intense burning under inappropriate conditions is capable of entirely destroying blanket bog peats, and is known to have done so in several parts of the TWWHA due to Europeans burning off parts of the TWWHA either deliberately or accidentally (Pemberton 1988, 1989, Pemberton & Cullen 1995). Pemberton (1988) and SDAC (1996, p. 2.13) conservatively estimate that 1000 km² (100,000 ha) of blanket bog has been degraded (in some cases totally destroyed) in south-west Tasmania alone by the effects of anthropogenic burning followed by wind and water erosion,. In addition a large area has been degraded around the Pieman River in north-west Tasmania (outside the TWWHA). At a rough estimate, it is likely that around 200,000 ha total (about 30%) of the whole Western Tasmania blanket bog assemblage has been degraded, leaving roughly 550,000 ha (about 70%) more or less intact. In the south-west region, the largest degraded areas of blanket bog occur outside the TWWHA, south of Birches Inlet, but some areas within the TWWHA have also been degraded around Birches Inlet, De Witt Range and Lost World Plateau (north of Port Davey). However, large areas of blanket bog remain intact within and adjacent the TWWHA, for example at Louisa Plains, Melaleuca, Arthur Plains, Olga-Hardwood Valley and in the Spires – Vale of Rasselas region.
Whilst inappropriate burning regimes are the most critical threat to blanket bog soils in the TWWHA, and ongoing research is directed towards understanding the response of blanket bogs to fire (Bridle et al. 2003), another potential threat to the TWWHA blanket bogs comes from ongoing climate change. Bridle (et al. 2003) have noted that the TWWHA blanket bogs exist already in a marginal environment which is almost too warm. Any further increase in average temperatures will lead to decay of organic soil horizons in the TWWHA unless there is also a significant compensating increase in rainfall (Bridle et al. 2003, p.40), hence one threat of global warming is that it may lead to a decrease in the area and thickness of blanket bog peat soils in the TWWHA.

In summary, around 70% of the total (very large) area of Western Tasmania blanket bogs remain effectively intact and in an effectively natural condition, with the worst areas of degradation being outside the TWWHA boundaries. Climate change is a threat to the TWWHA blanket bogs, but one which has yet to take effect if indeed it will.

The integrity conditions for natural World Heritage properties (UNESCO 1999, para 44(b)) are met by the Ongoing Blanket Bog Peat Land Soil Systems sub-theme in the TWWHA because:

- **Integrity criterion 44(b) (i) (Inclusion of key inter-related elements):** The large areal extent of the TWWHA encompasses roughly half of the total area of blanket bogs in Tasmania (see above), ensuring that the area captures representative samples of all or most of the various climatic, micro-climatic and topographic situations in which the blanket bogs develop. The TWWHA also includes large portions of areas of blanket bog whose nature and ecology are most likely to be effectively un-modified by Aboriginal firing (eg, Louisa Plains, Olga-Hardwood). A group of peat mounds (significant contributing features within the blanket bog theme) are also present within the TWWHA at Louisa Plains, although it is noteworthy that another major group of mounds, at Melaleuca, lies adjacent but just outside the World Heritage area boundary.

- **Integrity criterion 44(b) (v) (Management Plan):** Management of the blanket bog peat soils within the TWWHA are subject to (and specifically protected by) a statutory management plan (PWS 1999).

- **Integrity criterion 44(b) (vi) (Adequate long term protection):** The blanket bog peat soils within the TWWHA are almost entirely protected by legislation, since nearly all portions of the TWWHA that contain areas of blanket bog peat soils are of National Park land tenure, and subject to the provisions of the Regional Forest Agreement (Land Classification) Act 1998, which specifies that one legislative purpose of National Parks is the conservation of geological diversity (which is defined in the legislation to include soils and soil processes). The boundaries of the National Park are such that most areas of blanket bog within the park are unlikely to be impacted by the effects of activities outside or adjacent the park boundaries.

---

31 Note that these three integrity criteria from UNESCO (1999, para 44(b)) are the only ones pertinent to the Blanket Bogs sub-theme in this context, because it is here attributed outstanding universal value under World Heritage criterion 44(a) (i) only (see Section 2.3.3).
Justification
The blanket bog peat lands of the TWWHA have outstanding universal value under Criterion 44(a)(i) (UNESCO 1999) as an example of "significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features", because the TWWHA comprises large parts of the most extensive ongoing effectively undisturbed blanket bog peat soil process systems in the southern hemisphere, and probably the largest undisturbed area of their type of blanket bog (non-sphagnum, marginal environment) anywhere globally.

Large proportions of the system display effectively natural ongoing processes, in contrast to comparably extensive northern hemisphere examples in Ireland and Scotland which display much greater proportions of disturbed and degraded areas. The Tasmanian blanket bog peat soils are also distinctive compared to other types globally (including possibly more extensive Russian blanket bogs), in that they comprise a very large extent of characteristically thin peat soils existing at the margin of the environmental range for blanket bog development, and in contrast to most northern hemisphere blanket bogs are not sphagnum blanket bogs, but rather are dominated by sedges and shrubs.

This justification is further elaborated below:

Distinctiveness
Given that the Tasmanian blanket bogs exist at the margin of their environmental range, and that they are a globally-unusual non-sphagnum blanket bog type, their existence in such an environment, and their nature, is globally unusual. The large areal extent of such a marginal and unusual blanket bog system, in a substantially natural and undisturbed state, is globally significant.

The marginal nature of the TWWHA environment for blanket bogs also means that the effect of global warming on the blanket bogs may allow them to serve as a sensitive "baseline" indicator of the effects of global warming.

Comparative Assessment
The blanket bog peat soils of western Tasmania are significant at a world level on several grounds:

- “Topogeneous” peat soil development in depressions is common globally; however the widespread development of peat extending beyond the confines of depressions – i.e., blanket bog peats as in Tasmania - is globally uncommon (Lindsay et al. 1988, Lindsay 1995, Macphail et al. 1999);

- The Tasmanian blanket bogs are the most extensive blanket bogs in the southern hemisphere, and comparable to the most extensive globally. Whilst there are restricted blanket bog areas in New Zealand and Tierra del Fuego, only in a few places such as Ireland, Scotland and Russia

---

32 Large parts of the Tasmanian blanket bogs also occur outside the TWWHA boundary; see Figure (11).

33 Globally, blanket bogs are known from maritime parts of Newfoundland, the Aleutian Islands and adjacent mainland, Iceland, Ireland, Wales, Scotland, Norway, Northern Japan, Kamchatka Peninsula, from the central African Ruwenzori Mountains, and, in the southern hemisphere, from Tasmania, southernmost New Zealand, southernmost South America (including the Falkland Islands) and various southern oceanic islands only (Lindsay et al. 1988, Lindsay 1995). The Irish and Scottish Blanket Bogs are widely regarded as the most extensive, and are considered the “type region” for blanket bogs (Lindsay et al. 1988, p. 32; Lindsay 1995 p. 61). The extent of many of the other blanket bog areas is poorly known, although it is likely that the Russian blanket bogs may be the most extensive globally.
are there known or likely to be blanket bogs of comparable extent to those in Tasmania\textsuperscript{34} (Gore 1983, Lindsay \textit{et al.} 1988, Pemberton 1989, Jarman \textit{et al.} 1988, Hannan \textit{et al.} 1993, Lindsay 1995, Macphail \textit{et al.} 1999). The simple geographical extent of blanket bog development in Western Tasmania thus constitutes a value of world significance\textsuperscript{35}.

- The southern hemisphere blanket bogs are of a different type to the “\textit{sphagnum bog}” types of the northern hemisphere blanket bogs (Lindsay 1995, p. 61). Thus the Tasmanian examples are the most extensive blanket bogs of their type globally.

- Severe anthropogenic degradation of blanket bog soils (mostly due to anthropogenic firing followed by wind and water erosion) has affected roughly 30% of the Western Tasmania blanket bog soils, however the worst affected areas lie mainly outside the TWWHA (see above)\textsuperscript{36}. Elsewhere large areas (about 70%) of the Western Tasmania blanket bogs within and adjacent the TWWHA maintain ongoing soil processes essentially undisturbed by present day human activities.

Overseas, comparable-size areas of blanket bog soil development are known only in Ireland and Scotland (see footnote), but there they have been significantly disturbed and reduced by centuries of intensive human activities including, since 1945, commercial “mining” of peat for fuel (Lindsay \textit{et al.} 1988, p. 29), forestry planting, overgrazing, burning, moorland drainage and acid precipitation (Lindsay 1995, p.108-111). Lindsay (1995, p. 111) estimates that only 10% of the original area of blanket bogs in Britain remain in a more or less natural state. Thus it is probable that western Tasmania includes the largest area, globally, where blanket bog peat soil processes are proceeding in essentially natural ways. On this basis, the Western Tasmania blanket bogs have outstanding universal value as a “benchmark” soil process system.

\textsuperscript{34} Lindsay \textit{et al.} (1988, p. 29) cite an original total area of 700,000 ha of blanket bog in Ireland, but state this has now been much reduced by commercial exploitation for fuel peat. Lindsay (1995, p.103 – 111) cited the total original extent of blanket bog in Scotland, Wales and England as 1,429,106 ha (mainly in Scotland: 1,056,198 ha), but considered that due to forestry, overgrazing, burning, artificial drainage and acid precipitation (which destroys sphagnum no more than 10% of this total survives in a relatively undisturbed state. Lindsay \textit{et al.} (1988) note that other European and Icelandic blanket bogs are more restricted and fragmented by rugged terrain.

In southern hemisphere areas, extensive blanket bogs only occur in the extreme southwest of New Zealand and on some associated islands (Dobson 1979), and their distribution in New Zealand is stated by Thompson (1987, p. 12) to be limited compared to the Irish blanket bogs. Pisano (1983) has documented the blanket bogs of Tierra del Fuego (South America), but the extent of these bogs is unclear. Whilst the Irish and Scottish blanket bogs are widely regarded as the “type” regions for blanket bogs, and have been cited as the most expansive blanket bogs globally (Lindsay \textit{et al.} 1988, p. 32; Lindsay 1995 p. 61), the Tasmanian blanket bogs are in fact comparably expansive (750,000 ha+) and much less degraded by exploitation. Reliable figures for the comparative extent of blanket bogs in various regions of the world are hard to obtain, and it is possible the Russian examples are the most extensive. However, whilst the Tasmanian blanket bogs may be the most extensive and least disturbed examples of any sort in the southern hemisphere, they are also probably the most extensive effectively undisturbed examples of their (marginal environment, non-\textit{sphagnum}) type anywhere globally.

\textsuperscript{35} That is, whilst many individual patches of blanket bog soil in the TWWHA might be considered individually “ordinary”, the extent of the entire assemblage of such patches imparts world significance to the theme.

\textsuperscript{36} Pemberton (1988) and SDAC (1996, p. 2.13) conservatively estimate that 1000 km\textsuperscript{2} (100,000 ha) of blanket bog has been degraded in south-west Tasmania (mostly in the region south of Macquarie Harbour), in addition to which a large area has been degraded around the Pieman River in north-west Tasmania (outside the TWWHA). At a rough estimate, it is likely that around 200,000 ha total (about 30%) of western Tasmania blanket bog has been degraded, leaving roughly 550,000 ha (about 70%) more or less intact.
Whilst peat mounds have occasionally been recorded in British peat bogs (Lindsay et al. 1988, p. 74), the peat mounds associated with the Tasmanian blanket bogs are possibly unique in the southern hemisphere (Macphail et al. 1999). The association of these features with the TWWHA Blanket Bogs contributes additional value to their world-level significance.

Comments
The western Tasmania blanket bogs (as a theme) were briefly cited as contributing to World Heritage values in terms of World Heritage Criterion (i) in the 1989 TWWHA nomination (DASETT 1989) (see Section 2.3.2) and were subsequently (as “site” OLG30) assigned significance at World level in the Tasmanian Geoconservation Database (Dixon & Duhig 1996). A small number of component sites on the TGD (see Appendix) were individually assigned significance levels ranging from Regional to National (Dixon & Duhig 1996).

The present review confirms the World significance of the blanket bog theme under the current World Heritage criteria (see Section 2.3.3; UNESCO 1999).

Individual sites or systems of World Heritage significance in their own right
Individual sites or areas contributing to the blanket bog theme generally have been attributed with significance at Regional and State levels, whilst the Louisa Plains and Melaleuca peat mounds have been attributed with National level significance by the Tasmanian Geoconservation Database Reference Group (TGD 2001). However, no individual blanket bog features or sites have been attributed World Heritage significance in their own right; rather it is the great extent of undisturbed blanket bog systems of the TWWHA that collectively give those systems World Heritage significance.
Sub-Theme:

**Ongoing Coastal Geomorphic Process Systems**

The TWWHA has a long, mostly oceanic, coastline from just south of Elliott Bay to South East Cape (see Figure 12). A shorter stretch of more sheltered coastline in Macquarie Harbour is also included within the TWWHA, however this is of different character to the oceanic shoreline and has not here been assessed for outstanding universal values. The assessment following refers only to the long mostly oceanic coastline of the TWWHA.

**Description**

The TWWHA has 755 kilometres of mainly oceanic shoreline (as mapped at 1:25,000 scale)\(^{37}\), of which 119 kilometres are sandy (beach) shores and the remainder mostly bedrock shores ranging from low gently sloping rocky shores with extensive shore platforms to towering sea cliffs. "Muddy" (clay/silt/sand/pebble) shores in Quaternary sediment deposits are present in a few sheltered locations, such as parts of the shore of New River Lagoon. The greater part of the coast is underlain by folded and metamorphosed Precambrian-age quartzites, phyllites and schists, however east of New River Lagoon a wider variety of coastal bedrock types are present, including Cambrian ultramafics, Cambro-Ordovician conglomerates, Ordovician limestones, Permo-Carboniferous tillite, Triassic sandstones and coal measures, and Jurassic dolerite.

The south-west facing portion of the TWWHA coast from near Elliott Bay south to South West Cape exhibits a relatively straight plan form at a large scale, which is likely to be tectonically controlled by large Cretaceous -Tertiary fault structures associated with the offshore Sorell Basin (Davies 1965, Corbett & Brown 1976). At a smaller scale this coast exhibits embayments such as Nye Bay and Mulcahy Bay whose existence are at least partly determined by differential erosion in response to structural and lithological variations within the Precambrian meta-sedimentary rocks which underlie the entire coastal stretch. The largest and deepest embayment on this coastal stretch is Port Davey – Bathurst Harbour, which is a well-developed ria, or drowned river valley system, in which the dendritic pattern of former river valleys can be discerned, and even a drowned strike ridge gorge (at The Narrows) can be identified. This river system was active during glacial climatic stages, including the last when sea level stood roughly 120 metres below its present level.

The south-facing TWWHA coast from South West Cape to South East Cape has a more irregular and deeply embayed form than the southwest – facing part, and is fringed by a notable archipelago of moderate-sized islands representing residual erosional landforms (see Figure 13). The greater physiographic complexity of the south coast compared to the south-west coast of the TWWHA can be attributed partly to a lack of very large scale simple structural controls, which permits greater geomorphic influence of smaller-scale lithological and structural variations in the bedrock (eg, resistant quartzite headlands between embayments underlain by more erodible schist and phyllite bedrock are a prominent feature of the section between South West Cape and Louisa Bay).

Geological, geomorphic and soil descriptions of the rocky TWWHA coasts and some rocky offshore islands have been provided by Sanders (1968), Baynes (1990), Pemberton (1990), Banks

---

\(^{37}\) Based on the 1:25,000 scale digital (GIS) Tasmanian Shoreline Geomorphic Types data set (Sharples 2000). Coastal lengths cited include islands, islets, lagoons connected to the sea, the sheltered ria coast at Bathurst Harbour, the Cox's Bight beach (not formally a part of the TWWHA) and the stretch of reserved coast from near South East Cape to Recherche Bay (not formally a part of the TWWHA, but recommended for inclusion – see Section 3.3), but does not include parts of the Macquarie Harbour shoreline that lie within the TWWHA but are a separate coastal process system to that for which outstanding universal significance is asserted here.
Figure 12: Sandy barrier and pocket beaches of the TWWHA coastline. Note the embayed nature of the TWWHA coastline, which results in a high degree of compartmentalisation such that little longshore transport of sediment due to littoral drift occurs; rather each embayment forms a "cell" within which sediment movement is predominantly onshore-offshore, with each embayment being effectively a self-contained system. The sediment budget and coastal process system of each embayment is dominantly determined by the south-westerly swell wave regime and adjacent hinterland fluvial sediment sources, and is essentially unaffected by distant human disturbances other than the globally-ubiquitous effects of climate change and sea level rise. NOTE: “TWWHA” boundary shown includes proposed extensions listed in Section (3.3).

(1993) and Dixon & Houshold (1996). These studies identified and described a range of coastal features including rocky shore platforms, uplifted marine terraces, coastal mass movement landforms (especially on De Witt Island), unusual soils and rare biogenic minerals, some of which have been listed on the Tasmanian Geoconservation Database (see Section 2.1 & Appendix A1.0).

However, some very important coastal geomorphic values under the Ongoing Processes World Heritage theme relate in particular to the softer sandy shores, which are subject to faster rates of natural geomorphic change than the rocky shores, are inherently more sensitive to human process disturbances, and thus are of particular value where these processes are undisturbed. These are described further below.

The TWWHA coastline is directly exposed to a powerful and constant south-westerly oceanic swell wave regime, and receives the highest cumulative wave energies of any Tasmanian coastal section (Davies 1965, 1978). See Figure (13). However, past sand supplies (eg, glacial outwash) to the TWWHA coast were more restricted than the large glacial sand sources disgorging to the continental shelf north of Macquarie Harbour, and most sand on the TWWHA coast is probably ultimately derived from relatively small glacial outwash sources such as those washed down the New River and South Cape Rivulet (Kiernan 1987), and to lesser quantities of river-
Figure 13: This view, looking west along the rocky southern coast of the TWWHA from near Surprise Bay, illustrates the irregular plan form and large islands characteristic of that coast. The high wave energies evident in this photo are generated by TWWHA coastline's exposure to constant south-westerly oceanic swells generated in the "Roaring Forties" region, and are an important factor in the characteristic coastal geomorphic processes of the region.

Figure 14: Nye Bay, a sandy barrier beach on the south-west TWWHA coastline. This sandy shoreline is exposed to no anthropogenic geomorphic process disturbances other than the effects of global climate change and incipient growths of marram grass (Ammophila arenaria) and sea spurge (Euphorbia paralias), both of which are present in only low numbers and are being actively controlled. This and other TWWHA beaches provide ideal "benchmark" locations to monitor the effects of sea level rise on sandy coasts free of the complicating effects of other human disturbances. The foredune erosion which is evident along this shore – including very large blowouts that have created large gaps in the foredune - is thought to be a result of sea level rise; however no monitoring of coastal change at this site has yet been initiated.
transported sand available from periglacial and fluvial erosion in the hinterland. The proportion of the TWWHA coast occupied by sandy beaches is thus considerably less than is the case for other Tasmanian coast stretches of comparable length (Davies 1965). See Figure (12).

The highly embayed nature of the TWWHA coast greatly limits littoral sediment drift on the TWWHA coast, which is thus a highly compartmentalised coast with beaches occupying embayments that are each individual compartments or “littoral cells” (Davies 1973). Little sand is exchanged between compartments (embayments) through longshore drift, and sediment movement within each embayment is predominantly onshore-offshore in response to storm erosion events and the "cut and fill" cycle.

The beaches within each TWWHA coastal embayment are mostly barrier beaches that formed as spits closing off embayments subsequent to the post-glacial transgression which ended 6,500 years ago (Cullen 1998a). Pocket beaches are also present in small embayments. Older Pleistocene sands exposed behind some of the present day barrier beaches indicate previous beach and dune building episodes during earlier interglacial climatic phases (Cullen 1998a, Pemberton & Cullen 1999).

Probably due to their direct exposure to very strong prevailing onshore westerly and south-westerly winds, the foredunes behind some TWWHA beaches are amongst the highest behind any Tasmanian beaches, reaching heights up to 30 metres at places such as Nye Bay (see Figure 14). Cliff-top dunes have developed in places, as at South Cape Bay where such dunes are found above rocky shore platforms and cliffs (Cullen 1998a). The sandy coasts of the TWWHA include a diversity of geomorphic types, including reflective, dissipative and intermediate beaches on a variety of barrier and embayment morphologies (Cullen 1998a).

Foredunes along some TWWHA beaches exhibit multiple palaeosols (buried soil horizons) indicative of repeated phases of dune stabilisation, erosion and mobility (Pemberton & Cullen 1999), whose causes are likely to be natural events such as periods of more frequent large storms or cyclic vegetation dieback due to nutrient depletion. Carbon dating of four dune palaeosols at Nye Bay have established that at least that many phases of dune stabilisation followed by remobilisation of sand have occurred within the last 700 years (Pemberton & Cullen 1999). Large transgressive dunes and sheets of sand have at times blown kilometres inland from deflated coastal foredunes at places such as Nye Bay, Towterer Beach and South Cape Bay. Indeed, sands blown up Blowhole Valley during the Late Pleistocene/Early Holocene from South Cape Bay to Recherche Bay may constitute one of the largest headland bypass dune systems in Tasmania (albeit this system is not currently active and much of the sand movement probably occurred prior to the rising post-glacial seas reaching their present level; Cullen 1998a).

Many TWWHA beaches currently exhibit wave-scarped foredune fronts (Cullen 1998a), and large currently active foredune blowouts and unvegetated transgressive dunes are active at places such as Nye Bay (see Figure 14). The TWWHA beaches and foredunes appear to be currently undergoing another phase of major erosion and dune sand mobilisation, and dune fronts at some beaches such as Nye Bay are thought to have receded 10 – 20 metres within the last century, based on extrapolating truncated foredune and palaeosol slopes (M. Pemberton pers. comm.). Although the timing of onset of the current phase of coastal dune erosion throughout the TWWHA is unknown, the dune recession being observed is consistent with that which is expected to occur in response to the current phase of renewed global sea level rise resulting from anthropogenic enhancement of the Greenhouse Effect (Church & Gregory et al. 2001), and is taking place in Tasmania’s most energetic coastal environment (Davies 1978) which is where such effects of sea level rise would be expected to become apparent first.

**Condition & Integrity**

The entire coastline of the TWWHA displays ongoing coastal geomorphic processes free of any significant modification by modern human activities other than the incipient effects of global sea level rise resulting from the enhanced Greenhouse Effect (and the latter is affecting all coastlines...
globally). Of particular importance are the sandy barrier beach coastlines of the TWWHA which are highly sensitive to human disturbance, yet whose ongoing geomorphic processes remain unmodified by human activities other than those remote activities causing global sea level rise.

No infrastructure - such as roads, buildings, seawalls, groynes or the like – is present on any part of the TWWHA coast, with the exception of walking tracks and a few rough campsites adorned with flotsam and jetsam at some beaches, and a jetty with associated huts at the (sheltered) Melaleuca Inlet. It is unlikely that these are causing any significant modification of coastal geomorphic processes. Small quantities of anthropogenic flotsam and jetsam are present on most TWWHA shores (in common with most shores globally), but are not thought to be causing any significant modification of coastal geomorphic processes. Minor impacts (erosion) on dunes at South Cape Bay associated with human disturbance around the Lion Rock campsite have been noted (Cullen 1998a, p. 22), however this is being actively addressed by excluding walkers from affected areas with signs and fencing, and the use of a sand ladder to minimise walker impacts where the track ascends the dune face.

The most important threat to the integrity of coastal processes in the TWWHA is the possibility of invasion by the weed species marram grass (*Ammophila arenaria*) and Sea Spurge (*Euphorbia paralias*). Both have infested many beaches and foredunes in other parts of Tasmania, and marram grass in particular is known to have major impacts on sand budgets, sediment movement and beach/dune morphologies on sandy coasts (Cullen 1998b). Whilst the TWWHA coast remains almost entirely free of these weeds, incipient infestations of marram grass and/or sea spurge have appeared at several TWWHA beaches during the last decade, including Nye Bay (Sea Spurge) and Towterer Beach (marram) (Cullen 1998b). Known occurrences have been actively removed and an active management regime of monitoring and removing incipient weeds on TWWHA beaches is in place. It is unlikely that the incipient growths detected to date have significantly affected geomorphic processes, and it is the intention of the TWWHA Management Plan (PWS 1999) to maintain a program of monitoring and removing these coastal weeds in the TWWHA.

Another potential modification to coastal geomorphic processes in the TWWHA could conceivably result from increased supply of sandy sediment to the coast from rivers draining areas of quartzose substrate exposed by erosion following peat soil fires, such as have occurred at the De Witt Range, Lost World Plateau, and elsewhere (see *Ongoing Blanket Bog Peat Land Soil Systems* sub-theme above, and Pemberton 1989). However, whilst no studies or monitoring of this issue have been carried out in the TWWHA, no evidence has been noted of large slugs of sediment resulting from accelerated substrate erosion during the last century or so moving down the rivers and streams flowing to the TWWHA coast. It seems unlikely that accelerated sand supply from rivers is significantly modifying the sand budget of TWWHA coasts, however further investigation of this issue is recommended (see Section 4.5).

Given the highly compartmentalised nature of the TWWHA coast (see above), it is highly unlikely that disturbances to sediment budget and geomorphic processes in coastal areas beyond the TWWHA boundaries, for example at Ocean Beach or Recherche Bay, could propagate to or impact on coastal processes along the TWWHA coast. Other than sea level rise, there are no

---

38 “Remote activities” refers to industrial, agricultural and other activities world-wide that are causing global climate change and sea level rise by modifying the composition of the atmosphere (IPCC 2001).

39 Whereas the compartmentalised nature of the TWWHA coast prevents significant movement of sandy sediment along the coast, weed seeds or rhizome fragments liberated during foredune erosion at the (highly infested) Ocean Beach, north of the TWWHA, are able to drift southwards down the TWWHA coast on ocean currents (Cullen 1998a). These currents do not significantly affect sand movement, which mostly occurs in the near-shore zone where ocean currents are overwhelmed by wave-generated littoral drift currents in relatively shallow waters. Whereas sand does not remain in suspension for long enough to be carried further from shore to where ocean currents are more important than wave-generated littoral drift currents, seeds and rhizomes will do so and hence can migrate along the TWWHA shoreline.
Geoheritage Values – Tasmanian Wilderness World Heritage Area

anthropogenic process disturbances known (or considered likely) to be significantly modifying coastal geomorphic processes along the TWWHA coast. Given the high level of integrity of coastal processes within the TWWHA, and active management of the few incipient disturbances that are present, the ongoing coastal processes of the TWWHA coast - particularly its more sensitive sandy shorelines – evidently retain a high level of natural integrity.

Whilst the suspected impact of global sea level rise due to the anthropogenically enhanced Greenhouse Effect may be seen as the exception to this statement, that impact will be felt globally, and thus does not lower the natural integrity of the TWWHA coast relative to any comparable coasts elsewhere. Indeed, given the lack of any other significant anthropogenic process disturbances, the TWWHA coastline provides a unique "benchmark" natural system in which to monitor and study the coastal effects of sea level rise in an environment free of the "noise" created by other human disturbances, which complicate attempts to isolate and identify sea level rise impacts on other coasts subject to a diversity of human process disturbances (see also Section 4.5.2).

The integrity conditions for natural World Heritage properties (UNESCO 1999, paragraph 44(b)) are met by the Ongoing Coastal Geomorphic Processes theme in the TWWHA because:

- **Integrity criterion 44(b) (i) (Inclusion of key inter-related elements):** The highly embayed and compartmentalised nature of the TWWHA coast means that it comprises numerous fully self-contained coastal process systems ("littoral cells"), each of which includes all the key inter-related elements of the coastal process system (e.g., the beaches, dunes, spits, backshore dunes, shore platforms, rocky headlands, etc). The river systems draining to these coastal embayments – which supply sediment and partly control coastal and estuarine processes – are also fully contained within the TWWHA.

- **Integrity criterion 44(b) (v) (Management Plan):** Management of ongoing coastal geomorphic process systems within the TWWHA are subject to (and specifically protected by) a statutory management plan (PWS 1999).

- **Integrity criterion 44(b) (vi) (Adequate long term protection):** The ongoing coastal geomorphic process systems within the TWWHA are protected by legislation, since nearly all portions of the TWWHA that contain undisturbed ongoing coastal geomorphic process systems are of National Park land tenure, and subject to the provisions of the Regional Forest Agreement (Land Classification) Act 1998, which specifies that one legislative purpose of National Parks is the conservation of geological diversity (which is defined in the legislation to include geomorphic processes). The highly compartmentalised nature of the TWWHA coast ensures that most coastal disturbances outside the park will not impact on coastal processes within the park; where such impacts are possible (as in the case of marram grass and sea spurge infestation), a management regime to actively monitor and remove such incipient impacts is in place.

**Justification**

The TWWHA coast is the most extensive temperate-zone coast of its type displaying ongoing rocky and sandy coastal geomorphic forms and processes unmodified by human activities other than the globally-ubiquitous incipient effects of global climate change and sea level rise. As such, the TWWHA Ongoing Coastal Geomorphic Process Systems have outstanding universal value under Criterion 44(a)(i) (UNESCO 1999) as an example of "significant on-going geological processes in the development of landforms".

40 Note that these three integrity criteria from UNESCO (1999, para 44(b)) are the only ones pertinent to the Ongoing Coastal Geomorphic Process Systems sub-theme, because it is here attributed outstanding universal value under Criterion 44(a) (i) of the Current World Heritage criteria only (see Section 2.3.3).
Distinctiveness
The TWWHA coast is a high energy, highly compartmentalised rocky and sandy coast fully exposed to the strong wind and wave action of the "Roaring Forties" temperate-zone climatic regime. The undisturbed nature of the sandy parts of the coast is particularly significant, since sandy coasts are highly sensitive to human disturbance of coastal processes. The compartmentalised nature of the coast results in numerous littoral cells each of which may be considered a distinct coast process system substantially independent of others along the coast.

Temperate-zone sandy coasts display significantly different characteristics to tropical and polar zone beaches, being exposed to generally higher wind and wave energies than the latter, and so building broader, gentler-angled beaches with much more extensive dune systems than are normally found on polar or tropical beaches (Short 1996, 12).

Comparative Assessment
The distinctive characteristics of the TWWHA coast mean that comparative assessment, for the purposes of World Heritage value assessment, should focus on other undisturbed temperate zone high energy compartmentalised rocky and sandy coasts. Few comparable coasts exist. Similar sandy coasts in south-eastern Australia are less exposed to "Roaring Forties" weather patterns, and moreover comparable lengths of those coasts show considerably higher levels of human disturbance, with more closely-spaced human disturbances such as coastal roads, towns, etc. The most extensive temperate zone high energy wilderness coasts elsewhere – those of south-west New Zealand and Patagonia are of a significantly different type, being both predominantly hard-rock highly invaginated fjord – dominated coasts with ongoing active glacial processes in hinterland areas. Possibly the most closely comparable coasts to those of the TWWHA are those of South Africa and Namibia (Tinley 1985), however these include long coastal stretches in which little compartmentalisation occurs – so that longshore drift processes are major determinants of sandy coast processes in distinct contrast to the TWWHA beaches – and moreover, there are no coastal stretches of comparable length to the TWWHA coast which are entirely free of human coastal settlements, roads or other disturbances.

It can readily be concluded that the TWWHA coast is almost certainly the most extensive length of undisturbed coast, of its distinctive type, in the world.

Comments
Whilst the contribution of ongoing undisturbed coastal (or "marine") processes to the World Heritage values of the TWWHA received only very brief mention in the 1989 nomination (DASETT 1989, p. 42; see this report Section 2.3.2 "Other Geomorphological Processes"), subsequent work highlights that the ongoing coastal geomorphic process values of the TWWHA give the coastal landform systems of the region considerable global value as benchmark or "baseline" sites for studying undisturbed temperate zone coastal processes, and consequently as sites for monitoring and studying the effects of global sea level rise in a situation where the effects of sea level rise are not complicated by "noise" from other anthropogenic coastal disturbances (as is the case for most or all temperate-zone sandy coastlines elsewhere).

Individual sites or systems of World Heritage significance in their own right
Some individual coastal features contributing to the Ongoing Coastal Geomorphic Processes sub-theme have been listed on the Tasmanian Geoconservation Database and attributed geoheritage significance at levels ranging from Local to State levels (see Appendix A1.0). However no individual TWWHA coastal sites or features have been identified as being of World Heritage significance in their own right (i.e., in isolation from the whole assemblage of TWWHA coastal landform systems). Rather, it is the totality of TWWHA coastal process systems that have World Heritage significance in virtue of the significant extent of those systems – especially sensitive sandy systems - that retain a high degree of natural integrity.
Sub-theme:

Ongoing Karst Geomorphic Process Systems

Whereas the Glacio-karst Phenomena sub-theme and Diverse Karst Landform and Process Systems theme (following) focus on the value of the scale and diversity of TWWHA karst; this theme focuses specifically on the outstanding universal value of extensive undisturbed karst areas with natural ongoing processes.

Description

The extent of carbonate rock (potential karst) substrates in the TWWHA is depicted on Figure (15). Considerable areas of Precambrian dolomite and Ordovician limestone karst exist in the TWWHA (Kiernan 1995), and occupy a variety of topographic situations ranging from alpine (Mt Anne), hill flank (Weld Valley, Salisbury River / Precipitous Bluff), valley-floor (Olga / Hardwood, Vale of Rasselas), and riverine (Lower Franklin – Gordon Rivers) to coastal (Surprise Bay) situations.

High effective precipitation in the TWWHA combined with significant relief in many areas has ensured significant scales of karst landform development which is ongoing in the temperate – zone maritime – climate environment of the TWWHA.

In regard to the Ongoing Karst Geomorphic Process Systems sub-theme, the key characteristic of the TWWHA is that these karst processes are ongoing in an environment which is predominantly undisturbed by anthropogenic process disturbances (see Ongoing Natural Geomorphic and Soil Process Systems theme). In addition to the natural integrity that this implies for the karst geomorphic processes themselves, it additionally implies a high degree of natural integrity for cave invertebrate habitats which are significant under the Outstanding Biological Habitats theme (below).

Condition & Integrity

Because water is a key element in karst processes, the anthropogenic disturbance processes likely to affect karst in the TWWHA are in many instances the same disturbing processes as may affect fluvial geomorphic processes, and these have been discussed under the Ongoing Fluvial Geomorphic Process Systems sub-theme above. Some of the most extensive karst systems in the TWWHA exist in the catchments of the fully old-growth forested valleys of the Weld River and New / Salisbury Rivers and, as with the fluvial processes in those valleys, are considered to be free of any significant effective anthropogenic process disturbances (see further discussion below). Other large valley floor karsts such as those in the Olga-Hardwood and Maxwell River valleys are partly mantled by blanket bog peat lands which do not show significant historic process disturbances and are probably largely free of effective ongoing process disturbances inherited from past Aboriginal activities (see Ongoing Blanket Bog Peat Land Process Systems sub-theme discussion).

Karst systems are also subject to potential physical and process disturbances related to tourism, adventure recreation and other visitor impacts. These disturbances are important issues for a number of TWWHA karsts, including those at Mole Creek, the Lower Gordon and Franklin Rivers and Exit Cave ("Ida Bay"), however a characteristic feature of most of the TWWHA karsts is that their remoteness from access means that they have for the most part been subject to very little visitation and exploration, and hence remain for the most part unexposed to visitor impacts. This aspect considerably enhances the value of the undisturbed ongoing karst processes in most of the TWWHA karsts.

Limestone quarrying at Exit Cave ("Ida Bay": see Figure 15) has also caused disturbance of processes within the cave in the past (Houshold 1992), however a unique rehabilitation program specifically designed to restore natural processes in Exit Cave has been in place for over ten years.
Figure 15: Carbonate bedrock areas (karst and potential karst) of the TWWHA, indicating several important karsts within or adjacent the TWWHA. This map (from Kiernan 1995) uses four categories of karst defined by Kiernan (1995), ranging from the highly karstic Category A ("known or likely to be intensely karstified") to the little-karstic Category D ("possibly karstified"). Most known well-karstified areas are graded category A or B.

NOTE: "TWWHA" boundary shown includes proposed TWWHA extensions listed in Section (3.3).
Geoheritage Values – Tasmanian Wilderness World Heritage Area

(Gillieson & Houshold 1996, Gillieson 1996 p. 290-296), and regular monitoring has demonstrated that karst processes in the cave are returning to a natural state (I. Houshold pers. comm.).

Despite a limited number of karst landform and process disturbances, the condition of karst landforms and processes is essentially undisturbed over by far the greater portion of the TWWHA.

The integrity conditions\(^{41}\) for natural World Heritage properties (UNESCO 1999, para 44(b)) are met by the Ongoing Karst Geomorphic Process Systems sub-theme in the TWWHA because:

- **Integrity criterion 44(b) (i) (Inclusion of key inter-related elements):** The majority of extensive karst areas within the TWWHA (see Figure 15) are entirely contained within the TWWHA together with their entire catchment areas (compare Figures 15 & 5). Particularly important and extensive undisturbed karst systems for which this is true include the Weld River valley and New / Salisbury River karsts, which are discussed further below.

  However, this integrity condition is not met for several important karsts which straddle the TWWHA boundary, particularly:
  - Mole Creek karst
  - Hastings karst
  - Mt Picton – Riveaux karst

  Recommendations for incorporating parts of these karsts into the TWWHA and / or managing their karst values in sympathy with the TWWHA karsts are made in Sections (3.3), (3.4) and (4.2) of this report. With these exceptions noted, the overall high degree of inclusion of entire karsts with their catchments gives the TWWHA adequate integrity under this criterion to comprehensively represent an inter-related assemblage of karst landforms, and to allow maintenance of ongoing natural karst geomorphic processes.

- **Integrity criterion 44(b) (v) (Management Plan):** Management of the ongoing karst geomorphic process systems within the TWWHA are subject to (and specifically protected by) a statutory management plan (PWS 1999).

- **Integrity criterion 44(b) (vi) (Adequate long term protection):** The ongoing karst geomorphic process systems within the TWWHA are protected by legislation, since the TWWHA comprises lands of declared National Park, Conservation Area and Forest Reserve land tenure, and these are subject to the provisions of the Regional Forest Agreement (Land Classification) Act 1998, which specifies that one legislative purpose of these reserve categories is the conservation of geological diversity (which is defined in the Act to include geomorphic processes).

**Justification**

The TWWHA encompasses the entire carbonate bedrock substrates and fluvial catchments of a diversity of extensive undisturbed temperate-zone maritime-climate karsts. Due in part to high rainfalls and significant relief in many areas, karst processes remain highly active in many of these undisturbed karsts. Whilst more extensive undisturbed tropical karsts (with significantly different process regimes) exist in areas such as New Guinea, the karsts of the TWWHA are probably the most extensive temperate-zone maritime-climate karsts of their type globally, that (as is significant for TWWHA fluvial processes) are not influenced by ongoing present-day glacial or orogenic processes and that are predominantly free of effective anthropogenic process disturbances. The TWWHA (and adjacent areas) karsts have outstanding universal value as extensive temperate-zone karsts.

\(^{41}\) Note that these three integrity criteria from UNESCO (1999, para 44(b)) are the only ones pertinent to the Ongoing karst Geomorphic Processes sub-theme in respect of its outstanding universal value under World Heritage criterion 44(a) (i) (see Section 2.3.3).
Figure 16: At a large scale, karst landscapes in the TWWHA are commonly typified by broad flat-floored strike valleys, such as the Davey-Olga-Gordon-Franklin valley, or the upper Gordon River Vale of Rasselas (shown here), in which more soluble limestones have become recessive in the landscape compared to adjacent erosion-resistant quartzites and conglomerates. These large-scale karst landforms contribute strongly to the characteristic fold structure – influenced landscapes of the TWWHA (see Figure 4), however in other parts of the TWWHA the preservation of greater relief on limestones and dolomites has permitted the development of very long and deep cave systems.

Figure 17: At smaller scales, some of the well-recognised features of karst systems in the TWWHA include extensive caves and speleothem development, such as this example of a delicate "pendulum" straw in Exit Cave.
undisturbed ongoing karst process systems (Criterion i) that are continuing to develop at natural rates and magnitudes of change in a wide diversity of contexts. On these grounds, the ongoing karst geomorphic process systems of the TWWHA have outstanding universal value under Criterion 44(a)(i) (UNESCO 1999) as an example of "significant on-going geological processes in the development of landforms".

Comments
The ongoing karst process systems of the TWWHA were justified to be of World Heritage value in the 1989 TWWHA nomination (DASETT 1989), on the grounds discussed in Section (2.3.2) of this report. To a significant extent, the intellectual arguments for the TWWHA karsts having World Heritage value were also established during the Helsham Inquiry (Helsham et al. 1988, Household & Davey 1987) that shortly preceded the 1989 TWWHA nomination. The World Heritage significance of the TWWHA ongoing karst process systems was well established in and prior to the 1989 TWWHA nomination (DASETT 1989), hence only a brief discussion and justification of the TWWHA karsts has been provided here.

Individual sites or systems of World Heritage significance in their own right
Several areas within the TWWHA, with significant known karst development, are of sufficient areal extent and vertical relief, within undisturbed catchment basins, as to provide outstanding exemplars of the Ongoing Karst Geomorphic Process System theme which are arguably of World Heritage significance in their own right; these are described below. Two additional (partly overlapping) karst systems, Exit Cave and the Mt Anne (North East Ridge) Glacio-karst, are also identified as having outstanding universal value in their own right under the Diverse Karst Landform and Process Systems theme: these are described separately under that theme.

Weld River Catchment Basin Karst Process System
The upper – middle Weld River catchment has been noted above (Ongoing Fluvial Geomorphic Process Systems) as one of the largest fully old-growth forest catchment basins in the TWWHA where contemporary geomorphic process disturbances are absent and any effective process disturbances inherited from Pleistocene or early Holocene Aboriginal activities (especially firing) are negligible today. Within this undisturbed catchment basin (covering 322 km²), 140 km² (43%) of the catchment area comprises Precambrian dolomites of the Weld River Group, which Kiernan (1995) has mainly classified as Category A karst (known or likely to be intensely karstified) with a few small areas of Category B karst (known or likely to be substantially karstified). See Figure (18). These extensive dolomites exhibit moderate to very high relief (on Mt Anne NE Ridge), and although little explored, are intensely karstified in a number of locations where they have been explored.

Known karst development within the Weld River undisturbed catchment includes Annakananda cave on the Mt Anne NE Ridge, Australia's second deepest cave at 373m depth (Kiernan 1995); the Weld River Arch (see Figure 19) through which the entire Weld River flows underground; a nearby uvala which is nearly a kilometre long and 300 metres wide; and the 236m deep Arrakis cave on the slopes of Mt Weld (see Figure 18). Given the known karst, and the areal extent and vertical relief on the Weld River basin dolomites, it is virtually certain that a considerable degree of as-yet unexplored karst development exists in the Weld Valley, all of it in an undisturbed state within an undisturbed fluvial catchment. In many respects, the Weld Valley karst probably has the highest potential for extensive karst development of any carbonate bedrock area within the TWWHA. This all gives the Weld karst particularly high intrinsic value, and potential scientific

42 Whilst more extensive areas of both limestone and dolomite bedrock exist in the TWWHA, for example in the Maxwell River, upper Gordon River and Olga – Hardwood Rivers areas (see Figure 15), these larger areas are predominantly very low relief valley-bottoms (they are in fact mostly strike valleys), and as such have only limited potential for karst development (particularly caves and subterranean hydrological systems), other than insofar as their large-scale low relief landscape expression is in itself karstic.
Figure 18: Map depicting the extent of highly karstic and potentially highly karstic Precambrian dolomites within the undisturbed, fully old-growth forested upper Weld River catchment basin, which has previously been highlighted as a major undisturbed fluvial catchment within the TWWHA (see sub-section Ongoing Fluvial Geomorphic Process Systems). The extensive and undisturbed nature of the fluvial catchment enhances the outstanding universal value of the large-scale undisturbed karst, and extensive karst substrate (dolomite) within that catchment.
importance as an undisturbed "benchmark" karst system under the *Ongoing Karst Geomorphic Process System* theme.

In addition, the Weld Valley (and adjacent Styx Valley) dolomites host significant crystalline silicification (Calver 1989), to a degree not found in correlated dolomites elsewhere in Tasmania. Some crystalline vughs in the dolomite are sufficiently large as to constitute enterable (and spectacular) "crystal caves", as on the slopes of Mt Weld (Kiernan 1995). Calver *et al.* (2003, p. 37) consider these "crystal caves" to be features of post-Carboniferous hydro-thermal origin. Although this enhances the significance of the karst under the *Diverse Karst Landform and Process* theme rather than the *Ongoing Karst Geomorphic Process System* theme, it nonetheless adds significant value to the Weld River karsts.

As a very extensive karst area, with moderate to high relief, known large-scale karst development and high potential for extensive as-yet unexplored karst in an extensive effectively undisturbed catchment basin, the Weld River basin Precambrian dolomite karst is arguably the most outstanding exemplar of the *Ongoing Karst Geomorphic Process System* theme in the TWWHA. As such, it has World Heritage significance under that theme in its own right as one of the most extensive undisturbed temperate climate karst systems globally. The Weld River basin karst as described here includes the Mt Anne (NE Ridge) Glacio-karst, an overlapping site that has previously been assigned world level significance on the Tasmanian Geoconservation Database (TGD), and which is described separately as a World Heritage site in its own right, under the *Glacio-karstic Phenomena* sub-theme (below).

The condition of the Weld karst is excellent (undisturbed karst and catchment), and the integrity conditions for World Heritage properties (UNESCO 1999) are easily met since the entire karst system and associated fluvial catchment are contained within the TWWHA, which has a Management Plan (PWS 1999) that specifically protects karst and is governed by legislation that specifically provides for protection of geomorphic processes (the *Regional Forest Agreement (Land Classification)* Act 1998).

*Precipitous Bluff – Salisbury River Karst Process System*

The New / Salisbury Rivers undisturbed fluvial catchment – which is described above under the *Ongoing Fluvial Geomorphic Process* sub-theme as an entire undisturbed source – to – sea catchment basin of outstanding universal value in its own right - also contains within it a very important extensive, high relief Ordovician limestone karst, in the Precipitous Bluff – Salisbury River area (see Figure 15 and compare Figure 6). This karst is of particular value under the *Ongoing Karst Geomorphic Process Systems* sub-theme as an extensive undisturbed karst system.

After the Weld catchment dolomite karsts described above, the extensive area and high relief of the limestones in this undisturbed catchment give them perhaps the next – highest potential for extensive karst development in an undisturbed catchment of any karst within the TWWHA (and as such, perhaps the highest potential for an Ordovician limestone karst). Karst exploration to date has only taken place within a small portion of this extensive limestone area, at Precipitous Bluff and Vanishing Falls (Salisbury River), however the existence of extensive karst development in those places has been demonstrated (Eberhard *et al.* 1991), and indeed Vanishing Falls is arguably the most spectacular karst stream sink in Tasmania.

This karst is noted here as an important natural geomorphic process system which adds to and considerably enhances the outstanding universal significance of the New / Salisbury Rivers undisturbed fluvial catchment basin, which has been identified under the *Ongoing Fluvial Geomorphic Process System* sub-theme as a catchment of World Heritage significance in its own right.
Sub-theme:

Ongoing Lacustrine Geomorphic Process Systems

Description

A large number (some hundreds) of undisturbed lakes with undisturbed catchment areas exist in the TWWHA, and have a wide variety of origins, including glacial cirque and trough lakes, hundreds of lakes in icecap – abraded depressions on the Central Plateau, lakes dammed by glacio-fluvial outwash and periglacial deposits, sinkhole (karstic) lakes, glacio-karstic lakes such as Lakes Timk & Sydney, floodplain lakes including outstanding meromictic lakes such as those on the Lower Gordon River, deflation hollow lakes on the Central Plateau, fault scarp "sag ponds", coastal dune ponds, and others. Apart from their geomorphic significance as undisturbed lacustrine environments, many of these lakes contain undisturbed sedimentary deposits providing sensitive records of Quaternary environmental change, and provide important habitat for a range of biota. Limnologically, TWWHA lakes range from oligotrophic to dystrophic types.

The lakes of the TWWHA include Australia's deepest lake, the 167m deep glacial Lake St. Clair (Derbyshire 1971, Kiernan 1992), and the globally outstanding (natural) glacio-fluvially impounded Lake Pedder (Kiernan 2001a): see Figure (1).

However, whilst there has been a moderate amount of limnological study of lakes in the TWWHA, there have been only a few studies of the geomorphic development of TWWHA lakes, for example the outstanding glacio-karstic Lake Timk (Kiernan 1990b), and virtually no study of ongoing geomorphic processes in TWWHA lakes.
**Condition & Integrity**

Despite the lack of detailed study, it is clear that the majority of the hundreds of lakes in the TWWHA are in geomorphically pristine condition, being free of artificial physical disturbance and having undisturbed catchments which in many cases are mantled with old growth forest or undisturbed alpine grasslands and herb fields. A good example of a moderately large pristine glacial cirque lake is Satellite Lake, which lies within the undisturbed New River catchment (see *Ongoing Fluvial Geomorphic Process Systems* sub-theme). This lake has high potential significance for Holocene palaeo-climatic and palaeo-environmental studies based on lake sediments, due to having a pristine catchment and lake basin, in a catchment undisturbed even by walker, which eliminates most extraneous signals from sediment records. As such, Satellite Lake (and many others like it in the TWWHA) has outstanding universal value under Criterion (i) as an undisturbed lacustrine process system and for its potential sedimentary record of Holocene climatic changes (significant as part of the *Cainozoic Ice Ages* theme).

There are however some disturbed lacustrine systems in the TWWHA, the most significant of which are summarised below; as is the case with ongoing fluvial geomorphic processes in the TWWHA, hydro-electric development has been one of the most important disturbing factors:

- A number of TWWHA lakes have been modified by Hydro-electric development, including Lake St. Clair which was raised several metres in 1937 by a dam at its outlet. This has modified its lacustrine processes and caused extensive shoreline erosion (Dixon 1994a).

- The largest water body within the TWWHA boundaries is an artificial lake, the Huon-Serpentine Impoundment (see Figure 5), which was dammed in 1972 as part of the middle Gordon hydro-electric development. This impoundment flooded the original Lake Pedder (see Figure 1), however work by Tyler (2001) and Kiernan (2001b) has shown that the natural lake geomorphology (landforms) remain intact beneath the impoundment, and that natural lacustrine processes in the lake are capable of restoration should the impoundment be drained.

- Lacustrine processes in the meromictic lakes of the Lower Gordon River area have been modified by the artificial modification of the hydrology of the Lower Gordon River due to hydro-electric development upstream (see also below, and *Ongoing Fluvial Geomorphic Process systems* sub-theme).

- Work by Kate Harle has shown that some TWWHA lakes contain measurable concentrations of heavy metals in their recent bottom sediments, which derive from former atmospheric pollution from the Queenstown Mine smelter, west of the TWWHA. These concentrations are highest in lakes nearest Queenstown, and attenuate to the east. Whilst these heavy metals may have affected the limnology of some lakes, it is questionable whether lacustrine geomorphic processes are affected; indeed, these sediments arguably confirm the significance of TWWHA lake sediments as sensitive records of the regional palaeo-environment.

**Justification**

Despite disturbance of a number of significant TWWHA lakes, and a general death of lacustrine geomorphic studies within the TWWHA, it is clear that the large number and diversity of undisturbed lakes within undisturbed catchments contributes strongly to the outstanding universal value of the TWWHA under UNESCO (1999) Criterion (i), both as an extensive assemblage of undisturbed lacustrine geomorphic process systems contributing to the *Ongoing Natural Geomorphic and Soil Process Systems* theme, and as an enormous resource of Holocene and Pleistocene palaeo-environmental information (in lake sediments) contributing to the *Late Cainozoic Ice Ages* theme. The outstanding aesthetic beauty of many TWWHA lakes is also a
major contributor to TWWHA values under Criterion (iii), and some lakes (at least) are significant under Criterion (iv) as *Outstanding Biological Habitats* (see below).

**Individual sites or systems of World Heritage significance in their own right**

The natural Lake Pedder is a (disturbed and endangered) lacustrine geomorphic process system of outstanding universal value in its own right, and is discussed under the *Glacial and Glacio-fluvial* sub-theme below (because of its glacio-fluvial origins). In addition, the following individual features exemplify the values of the *Ongoing Lacustrine Geomorphic Process Systems* sub-theme to such a high degree that they arguably have World Heritage value in their own right (not simply as features contributing to the overall theme):

*Lower Gordon levee-flood basin-meromictic lakes.*

Bradbury (1994) considered that the Lower Gordon River floodplain meromictic lakes, including Lake Morrison, Lake Fidler and Sulphide pool were lakes of outstanding geoheritage significance at a world level, and they have been listed as such on the Tasmanian Geoconservation Database (TGD 2001). These are floodplain lakes formed behind levees, whose meromictic status is maintained by the intrusion of a salt wedge up the Lower Gordon estuary (Bowling & Tyler 1984, Tyler & Bowling 1990). In the case of Lake Morrison, intrusion of the salt wedge is thought to be via karst conduits in underlying limestones, making it possibly the only karstic meromictic lake in the world (Bradbury 1994). The meromictic status of these lakes provides a stratified range of habitats for more than 200 taxa of diatoms, and bottom sediments in the lakes are important records of Quaternary palaeo-environmental changes. The Lower Gordon meromictic lakes (including their sediments) have outstanding universal value in their own right under Criterion (i) as globally rare *Ongoing Lacustrine Geomorphic Process Systems* and as palaeo-environmental records contributing to the *Late Cainozoic Ice Ages* theme, and under Criterion (iv) as *Outstanding Biological Habitats*.

The World Heritage values of these lakes are under threat as a result of human disturbance of Gordon River fluvial process system, since the change in the flow regime of the Lower Gordon River, due to upstream hydro-electric development, is affecting the natural intrusion of the salt wedge which maintains meromixis (Bowling & Tyler 1984); see also *Ongoing Fluvial Geomorphic Process Systems* sub-theme.

**Sub-theme:**

**Ongoing Periglacial Geomorphic Process Systems**

**Description**

Modern day active periglacial phenomena are limited to restricted mountain – top alpine areas within the TWWHA, but provide examples of modern – day temperate zone periglacial processes in areas uninfluenced by contemporary glacial processes. There has been very little geomorphic study of contemporary periglacial processes in the TWWHA, however known contemporary periglacial features in the TWWHA include prominent periglacial terracing (or :"stone stripes"), for example on the Boomerang and Moonlight Ridge, in which alpine vegetation plays an important binding role. Other contemporary periglacial phenomena in the TWWHA include polygonal ground, active nivation cirques on Frenchman’s Cap and Mt La Perouse, minor frost-shattering of boulders and a limited range of other small-scale geomorphic phenomena related to frost heave in alpine soils.
These small-scale periglacial phenomena are sensitive to disturbance, including alpine fires (which may destroy binding vegetation) and trampling pressure from walkers, and require careful management of these disturbances to ensure the ongoing integrity of their processes.

**Condition & Integrity**

Many Tasmanian alpine (mountain-top) contemporary periglacial process environments remain in excellent undisturbed condition (e.g., The Boomerang). The most significant disturbance of these processes has probably occurred on the Central Plateau, where widespread soil erosion due to fires and grazing (Cullen 1995) is likely to have reduced the potential scope of periglacial activity by removing significant parts of the periglacial process substrate (i.e., the alpine soils). Perhaps ironically, revegetation of these degraded alpine soils is now inhibited by frequent frost heave in the bared soils, which is in itself a periglacial process.

On some other mountain tops, significant but localised degradation of contemporary periglacial features has occurred through trampling erosion on un-hardened walking tracks and routes.

**Justification**

The limited areal extent and small scale and diversity of ongoing periglacial geomorphic processes in the TWWHA suggests that it may be difficult to justify World Heritage significance for ongoing periglacial processes in the TWWHA, in their own right, particularly in the absence of any substantial scientific studies that might identify significant aspects of those processes. However, as undisturbed ongoing geomorphic processes within a region characterised by a variety of other broad-scale undisturbed ongoing geomorphic processes, the ongoing periglacial geomorphic process systems of the TWWHA contribute to the overall outstanding universal value of the *Ongoing Natural Geomorphic and Soil Process Systems* theme under Criterion (i).
Theme:

Outstanding Biological Habitats
No detailed review of the contribution of the geomorphic and soil systems of the TWWHA to biological habitats has been undertaken during this review; rather the recent reviews of TWWHA flora and fauna values provided by other workers provide a key source of information justifying this theme. The Outstanding Biological Habitats geoheritage theme is listed here simply to highlight its significance as an important element of the TWWHA World Heritage values which derive their significance from the geological, geomorphic and soil characteristics of the TWWHA.

A variety of landform and soil systems in the TWWHA are indispensable in providing habitat for fauna and flora which is itself of outstanding universal value. Further, a number of important geomorphic features of the TWWHA have been shown to have been important glacial or interglacial refugia for species of World Heritage significance, and some have provided isolated environments within the TWWHA that have resulted in significant genetic and phenotypic variation in modern populations across the region (eg, mountain-tops, caves, lakes and islands).

For such reasons, these landform and soil systems collectively have outstanding universal value as "the most important and significant habitats for in-situ conservation of biological diversity" under World Heritage Criterion (iv) (UNESCO 1999) in that, without these unique geomorphic and soil habitats, the habitat-dependant biological species which are themselves of outstanding universal significance would not exist.

Some of the key TWWHA landform and soil systems providing indispensable habitat for flora and fauna of World Heritage value in the TWWHA include:

- Karst cave systems (see Ongoing Karst Geomorphic Process Systems sub-theme); considerable study of karst cave invertebrate faunas of the TWWHA has been undertaken due to their unusual and highly sensitive nature.

- Off-shore islands (see Ongoing Coastal Geomorphic Process Systems sub-theme).

- Lakes, such as the outstanding Lower Gordon meromictic floodplain lakes (see Ongoing Lacustrine Geomorphic Process Systems sub-theme).

- Bathurst Harbour (a broad shallow deeply embayed flooded riverine landscape with restricted access to the sea, in which tannic terrestrial water runoff from surrounding lands creates a unique coastal marine environment which is habitat for a number of unusual species; see Late Cainozoic Coastal Landforms and Sediments sub-theme).
**Theme:**

**Late Cainozoic “Ice Ages” and Climate Change Record**

**Description**

The highland topography of the TWWHA is dominated by spectacular rugged mountain forms resulting from multiple phases of Late Cainozoic glaciation (see for example Figures 20, 21 & 22). These glaciated landforms comprise some of the most widely recognised and often - photographed landscapes of the TWWHA, and contribute strongly to its distinctive character. However, these highland glacial forms are merely the most obvious aspects of an extensive heritage of landforms and sedimentary deposits that provide a detailed record of repeated climatic and environmental changes through the Late Cainozoic, and especially the Quaternary Period. Other features in this assemblage of related phenomena include glacial deposits such as valley moraines, glacio-fluvial outwash terraces and sediments, complex landforms and deposits resulting from interactions between glacial processes and karst systems, periglacial landforms including cliffs and slope mass movement deposits, relict lunette dunes on the Central Plateau that were formed under more arid past conditions, and coastal terraces and deposits recording repeated sea level changes related to sequences of glacial and interglacial climatic phases.

Together, these and other features provide a complex and detailed record of environmental change and landscape evolution over the major (and still ongoing) phase of the Earth's geological history which is known as the "Late Cainozoic Ice Ages". This major phase of Earth's history began circa 36 million years ago with the final tectonic separation of Australia from Antarctica, leading to initiation of the cool southern circumpolar ocean current. This event initiated the first major phase of climatic cooling and glaciation on Earth since the end of the great Permo-Carboniferous glaciations, circa 250 million years ago. The mid-Tertiary Period transition from a formerly warm, humid climate in Tasmania, to a cooler, more seasonal climate is discernable in palaeo-botanical (plant fossil) evidence in Tasmania (Macphail et al. 1991), and in the appearance of cold climate sediments in the Tasmanian geological record (e.g., Macphail et al. 1993, Augustinus & Idnurm 1993). Subsequent to the large scale transition of the Earth's climate to a cooler climate for reasons fundamentally related to plate tectonic influences on ocean circulation, global climatic conditions have repeatedly alternated between cooler (glacial) phases and less-cool (interglacial) phases, for reasons partly determined by regular variations in solar energy influx due to periodic variations in the Earth's orbital motion (known as the Milankovitch cycles: Hays et al. 1976).

Tasmania’s tectonic stability, temperate maritime climate and diversity of geological, topographic and climatic environments have resulted in the preservation within the TWWHA of a suite of glacial, periglacial, glacio-fluvial, glacio-karstic, coastal and other landforms and deposits which collectively constitute a record of repeated climatic and environmental changes and developments during the Late Cainozoic “Ice Ages” that is globally unique for a variety of reasons described in the "Justification" below. Although some elements of this heritage of sedimentary and landform records of the Late Cainozoic Ice Ages are found throughout Tasmania, the best and most extensive development of glacial and related phenomena are found in and adjacent the TWWHA. This is because western Tasmania (including the TWWHA) has always been the highest precipitation region in Tasmania, during both glacial and interglacial Late Cainozoic phases, and hence received the greatest throughput of ice during glacial phases, leading to the most prominent highland glacial erosion, and the largest glacial sediment deposits\(^{43}\).

---

\(^{43}\) Prevailing snow-bearing winds probably came from much the same (westerly) direction as today during glacial phases (Kiernan 1990c), and ice accumulation decreased eastwards across Tasmania due to a marked west to east climatic gradient resulting from the effects of decreased precipitation, increasing temperatures and increasing insolation (total sunlight hours) towards the east (Davies 1962, Colhoun & Peterson 1986).
The Late Cainozoic glacial systems of the TWWHA show considerable variation or diversity, ranging from more maritime glaciological conditions in the west to more continental conditions with higher snowlines further east, and also in terms of geological substrates giving widely variable glacial landform types on quartzites, dolerite, flat-lying sedimentary bedrock and karstic carbonate rock substrates. Kiernan (1996) has provided a description and classification of the considerable diversity of glacigenic landform types found in Tasmania, and the TWWHA specifically. In addition, the Tasmanian Late Cainozoic geomorphic and sedimentary record contains good evidence of multiple glaciations – at least four (and probably considerably more) distinct glacial advances during the Quaternary alone (see Kiernan 1996, p. 74 - 75 for a summary of known Tasmanian glacial advances for which evidence was available in 1996).

Intensive research and mapping of glacial and glacio-fluvial landforms and deposits has been undertaken in a number of key areas of the TWWHA (see Section 2.4), although mapping remains limited and preliminary in some prominent glaciated TWWHA regions such as Frenchman's Cap and the Arthur Ranges. However, whilst the mapping that has been done is available in a variety of published and unpublished sources (see Section 2.4), up to date mapping has not yet been collated into a unified state-wide (or TWWHA-wide) map resource (in contrast to fluvial, karst and coastal landform systems, for which a basic level of state-wide geomorphic mapping is now available in digital (GIS) formats: see Ongoing Natural Geomorphic and Soil Process Systems sub-theme descriptions above). Nonetheless, Kiernan (1996) has provided a detailed classification and description of the diversity of glacial landforms and sediments found in Tasmania, which provides a basis for assessing their geoheritage value.

Further discussion of sub-themes within the overall Late Cainozoic “Ice Ages” and Climate Change Record theme, and identification of a number of specific features of particularly outstanding significance, is provided following the justification of this overall theme below.

44 Derbyshire et al. (1965) provided an early glacial map of Tasmania, however much new glacial landform mapping would now need to be added to this.
**Condition & Integrity**

Because glacial (and intense periglacial) processes are not ongoing in Tasmania at the present time, the condition or conservation status of the relict (or "fossil") landforms and sediments that contribute to the Late Cainozoic Ice Ages theme is not determined by the integrity of their ongoing processes (in contrast to the Ongoing Natural Geomorphic and Soils Process Systems theme above), but rather by the degree to which the defining physical forms, spatial relationships and fabric (contents) of those features have been artificially disturbed and degraded or otherwise (see also discussion of The Sensitivity of Geodiversity in Section 2.1 above). Such disturbance may occur through mechanical disturbance (e.g., excavations or covering) or through artificial disturbance of other ongoing geomorphic processes which accelerate the natural erosion of a relict glacial landform, for example.

Because of the wilderness character of the TWWHA and its general lack of deliberate mechanical artificial disturbance (see Ongoing Natural Geomorphic and Soil Process Systems), the great majority of landforms and sedimentary deposits related to the Late Cainozoic Ice Ages theme in the TWWHA remain in undisturbed natural condition. However, artificial disturbance and degradation of some of these features has occurred in a number of locations within the TWWHA, including:

- The raising of the level of the glacial trough Lake St. Clair, by construction of a dam at its outlet in 1937, has caused severe artificial shoreline erosion which has physically impacted on both the glacial trough and the "Thule-Baffin" moraine complex at its southern end (Dixon 1994a, Kiernan 1996).

- The outstanding glacio-fluvial Lake Pedder (Figure 1) has been inundated beneath the artificial Huon – Serpentine hydro-electric impoundment (Figure 5), albeit the glacio-fluvial and lacustrine landforms remain intact beneath the impoundment (Tyler 2001, Kiernan 2001a, b).

- Roading and building construction on the outstanding "Thule-Baffin" moraine complex at the Cynthia Bay Visitor Centre (Lake St. Clair) has locally modified and degraded the surface form of some of these features.

- Excavation and filling associated with road-making has locally modified the form of glacial and glacio-fluvial sediment deposits in several locations, such as along the Lyell Highway and Scott's Peak Roads, albeit this has also provided improved exposure of the sedimentary materials within these features, permitting access to their contents for scientific study.

- Soil erosion related to grazing and burning on the Central Plateau (Cullen 1995) has caused accelerated erosion of some Quaternary glacial and periglacial features in that extensively glaciated region.

- Trampling erosion on walking tracks and routes in some alpine areas has caused localised erosion of glacial features and deposits in some popular bushwalking areas.

However, instances of glacial landform degradation such as these - whilst important and warranting appropriate management decisions to minimise further degradation - are of restricted extent in the TWWHA. The great majority of glacial and related landforms and deposits within the TWWHA show no discernable anthropogenic degradation of their form and fabric. Hence, due to the predominantly undisturbed wilderness character of the TWWHA, the great majority of features contributing to the Late Cainozoic Ice Ages theme remain in excellent natural condition within the TWWHA.
Figure 21: The 300 metre high east face of Frenchman's Cap, in the TWWHA, is a glacial headwall which is thought to be the highest absolutely vertical to overhanging cliff face in Australia.

The integrity conditions\(^{45}\) for natural World Heritage properties (UNESCO 1999, para 44(b)) are met (albeit imperfectly) by the *Late Cainozoic Ice Ages* theme in the TWWHA, because:

- **Integrity criterion 44(b) (i) (*Inclusion of key inter-related elements*):**
  The TWWHA does not everywhere contain all the inter-related landforms and deposits contributing to the *Late Cainozoic Ice Ages* theme. The most notable instance of this is the fact that, whilst the most notable examples of highland glacial erosion features (cirques, peaks, etc) are nearly everywhere entirely contained within the TWWHA (due partly to their obvious and outstanding aesthetic values), related but less spectacular down-valley elements of the same glacial landform systems, such as valley – bottom moraines, till and outwash deposits, sometimes extend beyond the TWWHA boundaries into adjoining areas including State forest and private freehold. This is the case in, for example, the Picton, middle Huon, Derwent, Pieman and Mersey River valleys. This is significant from the point of view of the scientific record of Late Cainozoic climate and environmental change contained in these assemblages, since it is axiomatic in glacial geomorphology that whilst highland glacial erosion features

\(^{45}\) Note that these three integrity criteria from UNESCO (1999, para 44(b)) are the only ones pertinent to the *Late Cainozoic Ice Ages* theme in respect of its outstanding universal value under World Heritage criterion 44(a) (i) (see Section 2.3.3).
provide the spectacular glacial scenery, it is the down-valley glaciogenic sedimentary deposits which contain the greatest amount of scientific information (e.g., see Kiernan 1983a). Not only are the stratigraphic sequences within down-valley sedimentary deposits more sensitive records of change, but very often valley deposits distant from glaciated highlands are the only places where records of glaciations preceding the last are to be found (since the highland areas are eroded afresh during each glaciation, thus erasing much of the evidence of previous glaciations).

An additional issue which leaves the glacial landform assemblages of the TWWHA less complete than is desirable, is the exclusion of the West Coast Range, especially the Tyndall Range area, from the TWWHA. This area had the highest precipitation and highest ice throughput in Tasmania during glacial climatic phases, and the resulting large scale of glacial landform development and sedimentary deposition has made it the most intensely studied "type area" for Cainozoic glaciation in Tasmania (e.g., see Colhoun 1985).

Thus, in some areas significant inter-related parts of the TWWHA Late Cainozoic Ice Ages theme geomorphic and sedimentary record are not fully contained within the TWWHA. This is a significant issue which creates a need for sympathetic management of glaciogenic features in areas beyond the TWWHA, in order to adequately protect TWWHA values under this theme.

Nevertheless, it is not everywhere the case that full inter-related suites of glaciogenic features are not contained within the TWWHA. Glacial landform and deposit assemblages such as those of the Arthur Ranges, much of the Southern Ranges, Frenchman's Cap region, upper Franklin River basin, Denison – Spires area and other glaciated areas are probably nearly or fully contained within the TWWHA, providing at least presentative samples of a full range of inter-related glaciogenic features within the TWWHA.

Although imperfect, the inclusion of some entire inter-related glaciogenic landform and sedimentary deposit assemblages gives the TWWHA adequate integrity under this criterion.

- **Integrity criterion 44(b) (v) (Management Plan):** The Late Cainozoic Ice Ages theme geomorphic and sedimentary features within the TWWHA are subject to (and specifically protected by) a statutory management plan (PWS 1999).

- **Integrity criterion 44(b) (vi) (Adequate long term protection):** The Late Cainozoic Ice Ages theme geomorphic and sedimentary features within the TWWHA are protected by legislation, since the TWWHA comprises lands of declared National Park, Conservation Area and Forest Reserve land tenure, and these are subject to the provisions of the Regional Forest Agreement (Land Classification) Act 1998, which specifies that one legislative purpose of these reserve categories is the conservation of geological diversity (which is defined in the Act to include geomorphic features).

In summary, the Late Cainozoic Ice Ages theme geomorphic and sedimentary features of the TWWHA are in generally good condition, and have sufficient (albeit imperfect) integrity as to satisfy the requirements of the World Heritage integrity criteria (UNESCO 1999).

**Justification**

The inter-related assemblages of the Late Cainozoic Ice Ages theme geomorphic and sedimentary features of the TWWHA have outstanding universal value under Criterion 44(a)(i) (UNESCO 1999) as "outstanding examples representing a major stage of earth's history". Additionally, the glacial landscapes of the TWWHA, including in particular numerous glaciated mountains and ranges, contribute to the outstanding universal value of the TWWHA under Criterion 44(a)(iii) (UNESCO 1999) as "areas of exceptional natural beauty and aesthetic importance".
Figure 22: Dove Canyon, a narrow slot canyon in the northern part of the TWWHA, was incised by energetic meltwater flows from the snout of a glacier which, during the Last Glaciation, terminated a little way upstream of this point.

The justification of the World Heritage value of the TWWHA *Late Cainozoic Ice Ages* theme was established in the 1989 TWWHA nomination (DASETT 1989) and was thoroughly argued during earlier exhaustive deliberations during the Helsham Inquiry (Helsham *et al.* 1988). These justifications remain valid and are elaborated below:

**Distinctiveness**

The TWWHA preserves an extensive and diverse assemblage of inter-related geomorphic and sedimentary features providing a record of the climatic and environmental changes of the Late Cainozoic Ice Ages phase of Earth's history, in a temperate-zone, maritime – climate, tectonically-stable environment which is predominantly undisturbed by human activities, such that the assemblage of features remains in excellent natural condition.

Whilst the glacial aspects of this suite of phenomena have been best studied to date, and were emphasised in the 1989 TWWHA nomination, extensive suites of related glacio-karstic, periglacial, glacio-fluvial, coastal, palynological and palaeo-botanical features are also known in the TWWHA which contribute strongly to this theme and which have potential to yield a great deal of additional scientific understanding of this theme in future.
Many of the landforms contributing to this theme additionally contribute to World Heritage values in virtue of their aesthetic importance (Criterion iii) as the only well-developed mountainous glacial/periglacial landscapes in a tectonically stable southern temperate environment that is not undergoing contemporary "orogenic" (mountain-building) activity.

The distinctive temperate-zone maritime glacial environment of Tasmania is significant because the climatic context in which glaciation occurs exerts considerable influence on the nature and behaviour of glaciers, and on the types of geomorphic and sedimentary record they leave (Kiernan 1996, p. 48). For example, whereas minor climatic changes are likely to have little effect on the terminal positions of polar continental glaciers such as those of Antarctica, a similar degree of change in a more temperate and maritime climate such as that of Tasmania will be reflected in a much larger movement of a glaciers terminal position, which will leave a more sensitive sedimentary and geomorphic record of the change (ibid.). The temperate maritime glaciers of Tasmania were of significantly different types to polar glaciers, and have provided a more sensitive response to Late Cainozoic climatic changes than the more continental glaciers found in most northern hemisphere temperate glaciated climatic zones. Colhoun and Kiernan (in Helsham et al. 1988, p. 240) both considered northern hemisphere temperate glacial environments to be quite unlike southern temperate ones.

Tasmania has also been a more marginal temperate glacial environment than the other most nearly comparable temperate maritime glacial environments, those of South America (Patagonia) and New Zealand. Whereas both New Zealand and Patagonia have retained some active glaciers during the present interglacial climatic phase, Tasmania has not. Thus, Colhoun (in Helsham et al. 1988, p. 240) considered Tasmania to be the most marginal area in the southern hemisphere where multiple glaciations can be demonstrated. Tasmania has only been glaciated during the more intense cooling phases, and so provides a glacial record differentiating more sensitively between glacial and interglacial climatic phases than do the more continuously-glaciated environments of New Zealand and Patagonia.

The tectonic stability of Tasmania is also an important characteristic distinguishing it from New Zealand and Patagonian glacial environments, both of which have been and have remained tectonically (orogenically) active during the Late Cainozoic. Tectonism tends to rejuvenate depositional areas, leading to erosion and removal of sedimentary records. Thus Kiernan (in: Helsham et al. 1988) considered that the record of glaciation in tectonically-stable Tasmania is more complete for a large part of the Quaternary than is the record for Patagonia, and a 1 million year gap in the Quaternary terrestrial glacial record for New Zealand is represented only by marine sediments, as a result of tectonic movements (Kiernan 1996, p. 64).

**Comparative Assessment**

Polar and continental glacial environments produce glaciers, glacial landforms and deposits quite unlike those of temperate maritime glacial environments. Moreover, the temperate maritime glacial environments of the southern hemisphere (Tasmania, New Zealand and Patagonia) are quite different to more continental northern hemisphere glacial environments.

Thus, the glacial records of temperate maritime Tasmania, New Zealand and Patagonia are distinctively sensitive records of Late Cainozoic climatic and environmental change, involving distinctive glacial phenomena, at a global level. All three are also relatively undisturbed environments, which enhances the value of their geomorphic and sedimentary heritage. Of these three locations, Tasmania is the most marginal glacial environment, and the only tectonically stable one, giving it globally unique value in providing the most complete and sensitive glacial record for a large part of the Quaternary. Tasmania is the only one of these three comparable locations not currently glaciated.
On the basis of their globally distinctive characteristics, and the sensitivity and completeness of their record, the inter-related assemblages of the *Late Cainozoic Ice Ages* theme geomorphic and sedimentary features of the TWWHA have outstanding universal value under Criterion 44(a)(i) (UNESCO 1999) as "outstanding examples representing a major stage of earth's history".

Comments
The World Heritage significance of the glacial, glacio-karst and related features contributing to the *Late Cainozoic Ice Ages and Climate Change Record* theme was thoroughly debated during the Helsham Inquiry (Helsham et al. 1988), and was perhaps the single most clearly and rigorously justified World Heritage value enunciated in the 1989 TWWHA nomination (DASETTE 1989; see this report Section 2.3.2). It is here considered that the outstanding universal value of the *Late Cainozoic Ice Ages and Climate Change Record* theme was and is well established. Hence, less detail on this theme is provided in this review, as compared to the *Ongoing Processes* theme which was less clearly justified in the 1989 nomination.

Numerous individual sites, features and systems contributing to the *Late Cainozoic Ice Ages* theme have been listed on the Tasmanian Geoconservation Database (Dixon & Duhig 1996, TGD 2001), at significance levels ranging from local to world level (see Appendix A1.0). Some of these – especially those that have been assigned world level significance on the TGD – are further discussed in following sections.

Important elements (sub-themes) of the *Late Cainozoic Ice Ages and Climate Change Record* theme in the TWWHA are discussed further in the following pages.

Sub-Theme:

*Glacial and Glacio-fluvial Landforms*

The preceding discussion of the *Late Cainozoic Ice Ages and Climate Change Record* was focussed primarily on glacial and glacio-fluvial landforms. Hence their integrity, significance and justification as a theme of World Heritage significance is not repeated here, except to point out that they are considered in the present review as one sub-theme, of outstanding universal value in its own right, which contributes strongly to a broader *Late Cainozoic Ice Ages* theme but is only one of several sub-themes contributing to that theme. Other contributing sub-themes are described below.

*Individual sites or systems of World Heritage significance in their own right*

However, within this sub-theme, several individual areas or systems arguably have World Heritage value in their own right (not merely as features contributing to the overall theme or sub-theme). These are:

*Lake Pedder* (the original lake)

Lake Pedder (see Figure 1) is a large natural lake formed by impoundment of the Serpentine River behind a barrage of glacio-fluvial sediment derived from the adjacent Frankland Range (Davies 1967, Kiernan 2001a). The lake was widely valued for its aesthetic beauty, which was based to a large degree on its outstanding geomorphic features such as its extra-ordinarily wide sand beach and large mega-ripples (visible on Figure 1). When the Lake was in 1972 inundated beneath a large artificial hydro-electric impoundment, the Huon-Serpentine Impoundment\(^\text{46}\) (see Figure 5), its flooding provoked an outcry that is widely regarded as having launched environmental politics in

\(^{46}\) The enlarged impoundment was officially named "Lake Pedder", however this name is not used here for the artificial impoundment in order to avoid confusion with the original natural Lake Pedder.
Australia. Despite being artificially inundated, Lake Pedder still lies within the boundaries of the TWWHA.

Geomorphic investigations by Tyler (2001) and Kiernan (2001b) have shown that the landforms of Lake Pedder, including the surrounding blanket bog peat soil mantle, remain intact and that the natural geomorphic and biological processes of the lake are restorable if the artificial impoundment were ever to be drained. The lake basin has not been buried beneath "metres of silt" as some geomorphically-naive critics have suggested it would be.

Kiernan (2001a) has provided an assessment of the geoheritage significance of the natural Lake Pedder, which is perhaps the most detailed comparative classification-based geoheritage significance assessment ever undertaken to date (compare this report Section 2.2.2). Kiernan found that, as a large lake formed by glacio-fluvial processes: "A search for counterparts reveals Lake Pedder to be unique at a world scale. A number of its genetically-related landforms and its component landforms are also revealed as being significant at international and national levels. Lake Pedder is a place of immense geoconservation significance that on the basis of its geomorphological values alone would seem easily to meet the criteria for inclusion on the List of the World's Natural and Cultural Heritage." (Kiernan 2001a, p. 13).

Lake Pedder has been listed on the Tasmanian Geoconservation Database (TGD 2001) as being a significant landform at world level. On the basis of Kiernan's detailed geoheritage assessment (Kiernan 2001a), the natural Lake Pedder is here considered to have outstanding universal value in its own right under World Heritage Criterion 44 (a) (i) (UNESCO 1999), as a globally unique landform produced by glacio-fluvial processes (part of the Late Cainozoic Ice Ages theme), as well as an outstanding potentially-ongoing lacustrine process system under the Ongoing Lacustrine Geomorphic Process Systems sub-theme of the Ongoing Natural Geomorphic and Soil Process systems theme. Lake Pedder also has outstanding universal value under Criterion (iii) as a superlative glacio-fluvial landform, and for its exceptional natural beauty and aesthetic importance.

Despite inundation, the glacio-fluvial lacustrine geomorphology remains intact and hence retains ongoing World Heritage value as a glacio-fluvial landform under Criterion (i). On the other hand, its aesthetic value and ongoing lacustrine processes, whilst potentially restorable, are not currently accessible or active. Hence, in respect of these latter values, current inundation of the lake beneath a hydro-electric impoundment represents a long term threat to its World Heritage value and integrity (Kiernan 2001a, p. 43-44).

Central Plateau Glacial terrain
The Central Plateau is an extensive ice-abraded plateau exemplifying a glacial landscape formed by ice caps that have covered large areas of the plateau on multiple occasions during the Cainozoic. It has outstanding universal value in its own right, under Criteria (i & iii), as the only ice-abraded plain of significant size in Australia and as the dominating glacial landform feature in Tasmania. As such it is an outstanding feature within the Glacial and Glacio-fluvial Landforms sub-theme of the Late Cainozoic "Ice Ages" and Climate Change Record theme, and it has been assigned World level significance on the Tasmanian Geoconservation Database (TGD 2001, see Appendix A1.0).

Cynthia Bay Thule-Baffin Moraines
An impressive array of at least 25 terminal and latero-terminal moraine ridges, some extending continuously for up to 3.6 km, occur in the TWWHA at the southern end of Lake St. Clair (Kiernan 1991c, 1992; see Figure 23 below). The moraines are generally low features (not exceeding 10m height), regularly spaced with steep distal faces, which Kiernan (1991c, 1992) considered were formed by brief cyclic (annual or slightly longer) advances of an active ice front during a phase of general retreat of the Derwent Glacier during the late Last Glacial Stage.
Kiernan (1991c, 1992) considered the Cynthia Bay moraines to closely resemble "Thule-Baffin" moraines that have formed on the wasting margins of cold (polar) continental ice caps in Greenland and Baffin Island. The Cynthia Bay moraines are unusual features in the context of the temperate maritime glacial environment of Tasmania, in that they represent a type of moraine generally characteristic of colder and more continental glacial conditions. No moraines of similar type have been identified in more maritime glaciated areas of Tasmania's west coast region, and they are quite unlike the broader more massive moraines formed further down the Derwent Valley during earlier glaciations (Kiernan 1992, p. 56). The development of Thule-Baffin type moraines at Lake St Clair during the Last Glaciation appears to have been facilitated by slightly more continental glacial conditions at Lake St Clair than further to the west.

The Cynthia Bay Thule-Baffin moraines were assigned Representative and Outstanding significance at World level on the Tasmanian Geoconservation Database (Dixon & Duhig 1996, TGD 2001). The moraines have outstanding universal value in their own right under Criterion 44 (a) (i) of the current World Heritage criteria (UNESCO 1999), as an outstanding example of landforms produced during the Cainozoic Ice Ages stage of the earth's history (Late Cainozoic Ice Ages theme). The assessment that they are outstanding landforms is justified because they represent features normally characteristic of polar continental glacial environments, which in this case have formed within a generally temperate maritime glacial environment. This situation is likely to be globally unusual and justifies significance at a World level.

The Cynthia Bay moraines are well preserved and expressed over a large area south of Lake St Clair (see Figure 23), and the entire landform assemblage is contained within the TWWHA boundary, as are all of the up-valley glacial landforms and deposits relating to the glacial phase that produced these moraines. Some mechanical disturbance by roading and building construction has occurred within the TWWHA, in a narrow corridor along the Lake St Clair access road and at the Cynthia Bay park Visitor Centre and accommodation areas. Shoreline erosion at Lake St Clair, artificially triggered by raising of the lake level for hydro-electric development (Dixon 1994a, Kiernan 1996), has also artificially disturbed the moraine forms and fabric along the lake shore.
However these disturbances affect only a small proportion of the moraine complex, the great majority of which remains essentially undisturbed by human activities. All the key elements of the Cynthia Bay Thule-Baffin moraine complex are thus legislatively protected and governed by a management plan, and the features themselves are in most parts well preserved, such that the moraine complex clearly satisfies the integrity conditions for the World Heritage List (UNESCO 1999, para 44(b)).

Sub-theme:

Glacio-karstic Phenomena

Description
The Late Cainozoic glacial record in the TWWHA is particularly notable for the extensive degree of interaction that occurred between glacial and karst processes. Major examples were highlighted in the 1989 TWWHA nomination (DASETT 1989), but research since that time has shown the extent of glacio-karst interaction to be considerably greater than was then established. These interactions resulted in many of the major characteristics and patterns of development of the TWWHA karst systems being determined by glacial processes, and resulted in extensive sedimentary deposits and ancient speleothems being preserved within caves that provide a sensitive record of glacial and interglacial environmental change over multiple Late Cainozoic glaciations which is absent or not as well preserved in areas outside caves.

One of the earliest revolutions in the understanding of Tasmanian karst phenomena (see section 2.4) was the realisation that changed glacial-phase drainage and water flow patterns, together with the supply of large quantities of sediment to caves during glacial phases, was responsible for significant modification of karst systems at Mole Creek and Exit Cave during glacial phases (e.g., Jennings & Sweeting 1959, Jennings & James 1967, Goede 1969). Similar glacial control of karst development has now been demonstrated for many other karsts within and adjacent the TWWHA, and it is now recognised that glacio-karst interactions of various sorts are pervasive amongst karsts within and adjacent the TWWHA (e.g., Nelson River: Kiernan 1983, Mt Cripps: Shannon et al. 1991). It has also been shown that sedimentary deposits preserved and protected from erosion within Tasmanian caves provide an environmental record spanning not just the Last Glacial phase, but multiple glaciations preceding it (e.g., Eberhard 1997a).

Two of the most highly-developed glacio-karsts in Tasmania are those of the Mt Anne NE Ridge/Lake Timk area of the Weld valley (Kiernan 1990a,b), and Mt Bobs (Kiernan 1989b), both in undisturbed alpine and old-growth forested catchments within the TWWHA. At Mt Anne, Kiernan (1990b) showed that pre-glacial karst landforms had determined the pattern of glaciation at Lake Timk. Annakananda Cave, in the Mt Anne NE Ridge glacio-karst is the second deepest known cave in Australia, highlighting the extensive scale of development of that glacio-karst. At Mt Bobs, the glacial Lake Sydney is also a karst lake with underground drainage, and Kiernan (1989b) showed that glacial erosion and deflection of meltwaters had played a major role in conditioning the patterns of karst development in that area.

Condition & Integrity
As is the case for glacial and karst systems of the TWWHA per se, the most important glacio-karst environments of the TWWHA remain in excellent undisturbed condition, and have a high level of integrity in terms of the UNESCO (1999) World Heritage integrity requirements. This is particularly the case for some of the most outstanding glacio-karsts, including those of the Mt Anne NE Ridge area (which falls within the Weld Valley undisturbed karst process region – see Ongoing...
Karst Geomorphic Process Systems sub-theme discussion) and Mt Bobs (which lies in undisturbed old growth forest and alpine environments, with an undisturbed catchment).

It should be noted, however, that one of the other most important and extensive glacio-karst systems in Tasmania is the Mt Cripps – Vale of Belvoir glacio-karst (Kiernan 1995), which is in mostly undisturbed condition and which lies adjacent but immediately outside the TWWHA boundaries (see Figure 15). Given the World Heritage significance of glacio-karst in Tasmania, this highly developed glacio-karst system clearly contributes significantly to the World Heritage value of Tasmania's glacio-karst, despite its exclusion from the TWWHA boundaries.

**Justification**

The glacial and karst landform systems of the TWWHA are each individually of outstanding universal value in their own right under Criterion (i) (UNESCO 1999), in respect of the Late Cainozoic Ice Ages theme, the Ongoing Karst Geomorphic Process Systems sub-theme, and the Diverse Karst Landform and Process Systems theme. The significant degree of interaction between these individually significant themes, in the form of glacio-karst phenomena, wholistically enhances the significance and value of both and gives the glacio-karst landforms and sedimentary deposits of the TWWHA outstanding universal value under World Heritage Criterion (i) in their own right, in addition to their contributing to the broader Late Cainozoic Ice Ages Record World Heritage theme and other themes. This assessment is reinforced by comparative assessment of the most nearly comparable glaciated regions of the world, those of New Zealand and South America:

Other glaciated karsts occur in the world, however for the most part these occur in climatic regions where both the karst and glacial phenomena are of significantly different style to that of Tasmania, for example, the extensive tropical glaciated karsts of the New Guinea cordillera (Hope et al. 1976). The significance of the TWWHA glacio-karsts is partly based on the fact that glaciated karst is otherwise rare in the temperate maritime glacial environments of which Tasmania is an outstanding exemplar. Although some glaciated karst exists in New Zealand, Kiernan (1990b, p. 18) notes: "Rapid tectonic uplift and extensive glaciation by geomorphologically very active glaciers has meant that little glaciated alpine karst of pre-Last Glacial age escaped effective erasure during the Last Glaciation in New Zealand. Little if any karst occurs at comparable latitudes in South America."

Thus, as is the case for purely glacial phenomena per se (see above), Tasmania's tectonic stability compared to the other most nearly comparable glacial environments of New Zealand and South America (Patagonia) has made Tasmania's heritage of glacio-karst interactions in a temperate maritime glacial environment globally unique and of outstanding universal value. It is significant not only for its extent and scale of development, but also for the fact that the TWWHA glacio-karst heritage is unique amongst temperate glaciated environments in spanning multiple Late Cainozoic glaciations.

**Comments**

The World Heritage value of the TWWHA glacio-karsts was argued at length during the Helsham Inquiry (Helsham et al. 1988), and was emphasised and justified in the 1989 TWWHA nomination (DASSETT 1989). Their World Heritage value is well established.

**Individual sites or systems of World Heritage significance in their own right**

Within this sub-theme, one particular glacio-karst system stands out as exemplifying the characteristics of the theme to such a high degree that it arguably has World Heritage value in its own right (not simply as a feature contributing to the overall sub-theme). This system is the Mt Anne (North East Ridge) glacio-karst:

145
Mt Anne (North East Ridge) glacio-karst
The Mt Anne glacio-karst (Kiernan 1990a,b) has been assigned Representative & Outstanding significance at World Level (TGD 2001: site WED25) due to the exceptional scale of karst development relating to glacial influences (the deepest cave at the site, Annakananda, is the second deepest cave in Australia: Kiernan 1995). This is perhaps the best development of glacio-karst phenomena in Tasmania and is especially notable in that its upper parts are the most extensive ongoing alpine karst process system in Australia today (Kiernan 1995). This system is thus an outstanding exemplar of the glacio-karst World Heritage sub-theme. This site also forms part of the undisturbed Weld River Valley Ongoing Karst Geomorphic Process System which is considered individually to be of outstanding universal value as an exemplar of the Ongoing Karst Geomorphic Processes sub-theme (see above).

Sub-theme:

Periglacial Landforms
Extensive high altitude Pleistocene periglacial landforms, mass movement features, colluvial deposits and other features, on a diversity of markedly different substrates including quartzite and dolerite, provide a record of environmental conditions during the Late Cainozoic Ice Ages that extends well beyond the geographical boundaries of the glacial features. As such, these provide an important complement to the record provided by the glacial features themselves (Criterion i), as well as being responsible for some of the most aesthetically outstanding landforms of the TWWHA other than glacial landforms (Criterion iii). For example, many dolerite cliffs which contribute significantly to the outstanding landscape values of the TWWHA, such as Precipitous Bluff, are probably the result of periglacial rather than glacial erosion.

However, in contrast to glacial landforms and deposits, there has been relatively little detailed scientific study of the origins, development and geomorphic processes governing Pleistocene periglacial landforms in Tasmania, either within the TWWHA or elsewhere. Consequently, it is difficult to assess the geoheritage significance of the TWWHA periglacial geomorphic phenomena. Thus, whilst it is clear that the extensive periglacial phenomena of the TWWHA are an important element of the geomorphic features contributing to the Late Cainozoic Ice Ages theme, at the present time they are perhaps best regarded as a sub-theme which contributes to the outstanding universal value of the Late Cainozoic Ice Ages theme as a whole, but one which cannot on available information be attributed outstanding universal value in its own right.

Sub-theme:

Late Cainozoic Coastal Landforms and Sediments
The uplifted coastal landforms of the TWWHA were not well documented at the time of the 1989 TWWHA nomination, but subsequent reconnaissance studies have emphasised the fact that the coastal regions of the TWWHA display an extensive suite of well-preserved uplifted Pleistocene marine terraces, palaeo-shorelines and associated marine sediment and coastal aeolian (dune) deposits that preserve a record of climatic, tectonic and sea-level changes associated with the Late Cainozoic Ice Ages theme.

Baynes (1990) identified probable uplifted marine terraces in the TWWHA at altitudes up to 80 m ASL, such as the outstanding rock-cut platforms around Isolated Hill (several kilometres inland of Mulcahy Bay), which probably represent Late Interglacial or earlier coastlines. Uplifted sea caves on Ile du Golfe (Kiernan 1987) occur up to 12m above present sea level and probably represent Last Interglacial sea caves. Well preserved sequences of marine terraces at Birches Inlet and
elsewhere around Macquarie Harbour (McClenaghan & Findlay 1989, 1993) are probably related to outstanding sequences of fluvial terraces nearby within the TWWHA (Jerie et al. 2003), which are a tectonically-influenced fluvial geomorphic system of outstanding universal value in its own right (see Ongoing Fluvial Geomorphic Process Systems sub-theme discussion).

Cullen (1998a) and Pemberton & Cullen (1999) have identified Pleistocene (Last Interglacial?) palaeo-shorelines in some sandy coastal areas of the TWWHA, and have investigated the geomorphic development of TWWHA barrier beaches, focussing primarily on Late Holocene histories. Glaciogenic sands at South Cape Bay have partly been blown inland at Blowhole Valley, forming a now-inactive headland bypass dune system which, when it was active in the Pleistocene and Early Holocene, was one of Tasmania's largest headland bypass dune systems (Kiernan 1987, Cullen 1998a).

Parts of the TWWHA coast such as Port Davey also strongly exemplify the characteristics of coasts formed by the (interglacial) flooding of formerly exposed terrestrial landscapes. Port Davey and Bathurst Harbour is an outstanding example of a "ria" coast, or flooded Last Glacial phase fluvial landscape, in which the dendritic pattern of river valleys, and even a flooded strike ridge gorge ("The Narrows") can be identified.

However, whilst there has been some detailed study of uplifted Pleistocene coastal landforms and sediments elsewhere in Tasmania (eg, Bowden & Colhoun 1984, Murray-Wallace & Goede 1991, 1995), studies of Pleistocene coastal landforms and deposits in the TWWHA remains at an early reconnaissance stage, with for example the ages and relationships between a variety of prominent marine terraces around the TWWHA coast remaining uncertain. Whilst the extent and diversity of uplifted and flooded coastal landforms and sediments of apparent Pleistocene age within the TWWHA is impressive, and there can be little doubt that these have the potential to contribute significantly to understanding of the Late Cainozoic Ice Ages theme in the TWWHA, the limited scientific understanding of these features to date makes it difficult to attribute them outstanding universal value in their own right at the present time.

Thus, whilst it is clear that these coastal phenomena are an important element of the diversity of geomorphic features contributing to the Late Cainozoic Ice Ages theme, at the present time they are perhaps best regarded as a sub-theme which contributes significantly to the outstanding universal value of the Late Cainozoic Ice Ages theme under Criterion (i), but one which cannot on available information be attributed outstanding universal value in its own right.

However, many of the Late Cainozoic coastal landforms of the TWWHA also contribute significantly to the outstanding aesthetic value of the TWWHA under Criterion (iii), for example the flooded ria coastline of Port Davey. The Bathurst Harbour part of this same ria coast is also an Outstanding Biological Habitat under Criterion (iv), which owes its unique habitat characteristics to the fact that it is a broad flooded formerly-terrestrial plain behind a very narrow flooded strike ridge gorge which now provides the only connection to the sea for this unique marine environment.

Sub-theme:

Cainozoic Sedimentary and Palaeobotanical Record
The TWWHA encompasses a variety of Late Cainozoic sedimentary environments which contain palynological and palaeo-botanical records complementing the important long palaeo-environmental records preserved in karst cave sediments and speleothems (see above). The palynological and palaeo-environmental records of the TWWHA are especially important because most of them exist in undisturbed environments unmodified by post-European settlement anthropogenic disturbances.
As noted in the discussion of the Ongoing Lacustrine Geomorphic Process Systems sub-theme (above), the TWWHA contains hundreds of undisturbed lakes of various origins, each of which contains a Late Cainozoic (mainly Quaternary) sedimentary record. Whilst many of the glacial highland lakes contain only Holocene sediments, lakes of different origins at lower altitudes often contain much longer sedimentary records spanning multiple Late Cainozoic glacial phases. An outstanding example is the Darwin Meteorite Crater, in the Andrew River area of the TWWHA. Whilst not necessarily an outstanding meteorite crater at a global level, this landform is also an infilled lake containing a long uninterrupted Quaternary sedimentary record dating back to the time of meteorite impact 730,000 years ago (Ford 1972, Fudali & Ford 1979). Palynological analysis of sediments within the Darwin Crater has yielded an outstanding unbroken record of vegetation changes spanning at least five Quaternary glacial and interglacial phases (Colhoun in: Burrett & Martin 1989, p.413-414), and the palynological record at this site has consequently been identified as being outstanding at a world level of significance on the Tasmanian Geoconservation Database (TGD 2001). The numerous other lacustrine sedimentary environments within the TWWHA constitute a complementary palaeo-environmental record of the Quaternary, at least, whose scientific information potential has barely begun to be tapped.

Sediments of Tertiary age in the TWWHA provide a further palaeo-botanical record extending well back into the Tertiary Period (Hill 1990). A number of Tertiary sediment deposits in Tasmania have yielded a palaeo-botanical record of the mid-Tertiary transition from warm humid to cooler climates associated with the onset of the Late Cainozoic Ice Ages phase of earth history (e.g., Macphail et al. 1991), and as such provide a key element in the Tasmanian record of the Late Cainozoic Ice Ages theme. A conservation significance assessment of some Tasmanian Cainozoic plant fossil sites has been undertaken (Hill 1995, Jordan & Hill 1998), and some sites have been identified as being of world and national level significance (TGD 2001). Unfortunately, however, whilst some significant Tertiary palaeo-botanical sites identified by Hill (1995) and Jordan & Hill (1998) are located within the TWWHA (e.g., the Coal Head site at Macquarie Harbour), the majority of the most important Late Cainozoic sites that they identified, such as the Little Rapid River and Monpeelyata sites, are located outside the TWWHA.

Whilst two conservation significance assessments to date have identified several Tasmanian Quaternary and Tertiary palynological and palaeo-botanical sites as being significant at a world level, and the Cainozoic Sedimentary and Botanical Record sub-theme is consequently likely to be of outstanding universal significance in its own right if all Tasmanian sites are considered, the fact that some of the most important known sites to date are located outside the TWWHA raises questions as to whether this sub-theme can yet be demonstrated to be of outstanding universal value within the existing TWWHA boundaries.

For the present, this review concludes simply that the Cainozoic Sedimentary and Botanical Record sub-theme within the TWWHA contributes significantly to the overall World Heritage significance of the Late Cainozoic Ice Ages theme under World Heritage Criterion (i) (UNESCO 1999), but may not have sufficient integrity in respect of Tertiary Period sites within the TWWHA to be attributed outstanding universal value within the TWWHA. This assessment may change in future if further world-significance sites are identified within the TWWHA, or if some of the most significant Tertiary sites outside the TWWHA can be brought into the TWWHA, perhaps as non-contiguous extensions of the TWWHA (see Sections 3.4, 4.2).
Theme:

Diverse Karst Landform and Process Systems

Previous discussions have identified the karst geomorphic systems of the TWWHA as having outstanding universal value (World Heritage significance) in their own right under both the *Ongoing Natural Geomorphic and Soil Process Systems* theme and the *Late Cainozoic Ice Ages and Climate Change Record* theme (*Glacio-karstic phenomena* sub-theme). However, the World Heritage significance of the TWWHA karsts arguably extends beyond these elements of their values, hence they are also identified here as being significant as a *Diverse Karst Landform and Process Systems* theme, which encompasses their values as ongoing natural process systems and as glacio-karstic systems, but also recognises the contribution of additional values to their overall World Heritage significance.

This *Diverse Karst Landform and Process Systems* theme focuses in particular on the World Heritage significance of the extent, scale and diversity of karst phenomena in the TWWHA. Kiernan & Eberhard (1993) have provided an outline description of the karst geodiversity of the TWWHA as it was understood in 1989, albeit subsequent work has expanded upon this in some respects.

Description

The undisturbed nature of ongoing karst processes in the TWWHA, and the extensive influence of glacio-karstic processes, are elements of the karst geodiversity of the TWWHA that have been described above, and contribute to the *Diverse Karst Landform and Process Systems* theme. Additional elements of karst diversity in the TWWHA include:

In virtue of large areas and thickness of carbonate bedrock, high relief and high rainfall, the TWWHA has some of the deepest and longest cave systems in Australia, including Australia's second deepest cave (Annakananda at 373m deep: Kiernan 1995)\(^{47}\). In some areas of the TWWHA such as the northwest flanks of Mt Picton (Calver & Everard 2002), high relief on carbonate bedrock gives a potential for caves up to 500m deep to exist. With over 20 kilometres of mapped passage, Exit Cave is the longest mapped cave in Australia (Kiernan 1995). The scale of some chambers in Exit Cave is very large (cross-sections greater than 30 x 30 metres), partly due to speleogenesis related to sulphuric acids produced by weathering of pyritic palaeo-karst sediments, which is a further element in the diversity of TWWHA karsts (see below).

Karst in the TWWHA is developed in a wide range of topographic contexts (Kiernan 1995), ranging from Australia's only major alpine karst (Mt Anne NE Ridge), to extensive hill flank karsts (eg, Weld Valley and Precipitous Bluff – Salisbury River); plains karsts (e.g., upper Gordon River / Vale of Rasselas, Olga – Hardwood valley), including tower karst at Lightning Plains/Maxwell River (Dixon 1992, Kiernan 1995, vol. 2 p. 47, 58); riverine karsts (Lower Gordon – Franklin Rivers) and coastal karst (e.g., Surprise Bay).

Whilst the major TWWHA carbonate bedrock substrates are mainly limited to Ordovician limestone and Precambrian dolomites (with some minor Devonian limestone karst), the scale of karst development in the (less soluble) dolomites is unusual, and may be related to an abundance of humic acids in soil waters in the TWWHA (Houshold *et al.* 1999), which is in turn partly related to the blanket bog peat soils of the TWWHA that are of World heritage significance in their own right (see *Ongoing Blanket Bog Peat Land Soil Systems* sub-theme).

\(^{47}\) Australia's deepest cave, Niggly Cave at 375m depth (Eberhard 1994), is located in the Junee River Karst just outside the TWWHA boundary.
Karst landform development in the TWWHA has occurred in at least four major phases over the last 400 million years (Clarke 1995, Osborne & Cooper 2001), and a diversity of karst processes have played roles in karst development over that time, including glacio-karstic processes (see Glacio-Karstic phenomena sub-theme), ancient hydrothermal processes producing speleo-genesis at Exit Cave and quartz-crystal lined caves in the Weld Valley (Osborne & Cooper 2001, Calver et al. 2003), sulphuric acid speleogenesis related to weathering of palaeo-karst sediments (Kiernan 1991a, Houshold 1992, Clarke 1995, Osborne & Cooper 2001), humic acid karst development (Houshold et al. 1999) and sea water solution (Kiernan 1995), all in addition to “normal” karst processes involving meteoric waters and carbonic acids produced in soil ground waters. See also karst research review in Section (2.4).

Some TWWHA karst sites, of which Exit Cave is an outstanding example, exhibit complex karst landforms and sediment deposits produced by an inter-play of many of these factors over time.

The diverse karst systems of the TWWHA are the site of a variety of contained values, including Aboriginal cultural heritage (occupation sites, artefacts, artwork) of World Heritage significance, extinct marsupial megafaunal sub-fossils of considerable scientific significance, and important cave-adapted invertebrate faunas. The outstanding universal significance of these contained values have been established elsewhere, however their dependence on the karst for their existence or preservation provides additional reasons to ascribe World Heritage significance to the TWWHA karsts under Criterion (iv) (UNESCO 1999).

**Condition & Integrity**

The condition, degree of disturbance and integrity of the TWWHA karsts (under the UNESCO (1999) integrity criteria) has been described above under the Ongoing Karst Geomorphic Process Systems and Glacio-karstic Phenomena sub-themes. On the same grounds as these (overlapping) sub-themes, the condition and integrity of the Diverse Karst Landform and Process Systems theme is adequate to fulfil the requirements of the World Heritage integrity criteria (UNESCO 1999), and in many respects is excellent.

Nevertheless, it is worth noting that despite their scale and integrity, the TWWHA boundaries do not encompass several major aspects of Tasmanian karst diversity which if included would potentially enhance the value of the Diverse Karst Landform and Process Systems World Heritage theme. Notable exceptions to the diversity of Tasmanian karst systems represented in the TWWHA include:

- **Magnesite Karst:** Northwest Tasmania includes areas of well-developed karst in magnesite carbonates, which include large scale ongoing hydrothermal karst processes and Tertiary-age palaeokarst, in surface catchments which in several cases (e.g., upper Lyons River) are undisturbed (Houshold et al. 1999). Well-developed magnesite karst is globally rare, and this Tasmanian magnesite karst, were it included in the TWWHA, would be a major and significant additional element contributing to the Diverse Karst Landform and Process Systems World Heritage theme (see also Sections 3.4 & 4.2).

- **Permian & Tertiary – age Limestone Karsts:** Significant karst is found in Permian and Tertiary-age limestones in north-eastern Tasmania and on the Bass Strait Islands (Kiernan 1995), but only minor poorly-developed examples of these are known or likely to occur in the TWWHA. However, the Permian- and Tertiary-limestone karsts of Tasmania are probably not so well-developed or unique as to constitute a critical gap in the karst diversity represented in the TWWHA.

- **Junee River Karst System:** One of Tasmania’s largest and most important Ordovician limestone karst systems, the Junee Karst system (Eberhard 1994) which includes Australia’s
deepest cave (Niggly Cave 375 metres depth), is situated partly in State forest and partly in the Mt Field National Park, immediately adjacent but outside the TWWHA (see Figure 15).

- **Ongoing Hydrothermal Karst Process Systems:** Ongoing hydrothermal karst process systems including warm springs are present in a number of Tasmanian karsts, including the magnesite karsts noted above, in the Hastings Karst outside the present TWWHA (Sharplees 1994a), at Smithton, Kimberley and in several other locations (Kiernan 1995). However known ongoing hydrothermal karst processes are minor within the TWWHA itself, and this is a significant gap in the representation of karst values within the TWWHA. A proposed extension of the TWWHA boundary to include the Hastings Cave State Reserve (see Sections 3.4 & 4.2) would bring one significant ongoing hydrothermal karst system into the TWWHA, and inclusion of magnesite karst (see above) would bring in another.

- **Other elements:** The discussions of the Ongoing Karst Geomorphic Process Systems and Glacio-karst phenomena sub-themes have noted a number of other highly significant karst systems excluded from or only partly included in the TWWHA. These represent not so much elements of karst diversity that are entirely missing from the TWWHA, but rather are major exemplars of important elements of karst diversity that are also present elsewhere in the TWWHA but are so well-expressed as to warrant World Heritage status (e.g., Mt Cripps / Vale of Belvoir glacio-karst), or else are important karsts which straddle the TWWHA boundary, creating difficulties for the management of their World Heritage Values (e.g., Mole Creek, Riveaux / Mt Picton and Hastings karsts).

**Justification**

The Diverse Karst Landforms and Process Systems of the TWWHA have outstanding universal value under Criterion 44(a)(i) (UNESCO 1999) as "outstanding examples representing major stages of earth's history....significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features". Additionally, the scale and diversity of the karst systems and landscapes of the TWWHA, including decorated caves, extensive plains karsts, and other landscape features, contribute to the outstanding universal value of the TWWHA under Criterion 44(a)(iii) (UNESCO 1999) as "superlative natural phenomena..." and as "...areas of exceptional natural beauty and aesthetic importance". Many caves and associated hydrological systems are also of outstanding significance as Outstanding Biological Habitats (Criterion 44(a)(iv), UNESCO 1999)\(^{48}\).

The justification of the World Heritage value of the TWWHA karsts as undisturbed ongoing process systems (under the Ongoing Karst Geomorphic Process Systems sub-theme) and as significant glacio-karst systems (under the Glacio-Karstic Phenomena sub-theme) was adequately established in the 1989 TWWHA nomination (DASETT 1989; see this report Section 2.3.2). However, whilst the overall diversity of TWWHA karst systems was also identified as a World Heritage value of those systems (DASETT 1989, p. 41), comparative evidence to support this assertion was not provided in the nomination (see this report Section 2.3.2). However, it is the conclusion of the present review that the diversity of karst systems in the TWWHA, including but not limited to their undisturbed processes and glacio-karstic attributes, is itself of World Heritage significance, for the reasons outlined below:

**Distinctiveness**

The Diverse Karst Landforms and Process Systems of the TWWHA include a large scale and wide diversity of karst environments, phenomena, landforms and processes (as above) in the context of an extensive mostly undisturbed formerly-glaciated temperate-zone maritime-climate region which is not today actively glaciated nor orogenically active. This situation is globally unusual or unique.

\(^{48}\) Justification not elaborated in this (geoheritage) review, but considered valid; see Outstanding Biological Habitats discussion.
Comparative Assessment

Although longer and deeper caves exist in the northern hemisphere (e.g., caves over 1700m deep are present in France, Mexico and the Caucasus, and caves with several hundred kilometres of mapped passages exist in western USA and elsewhere), the TWWHA has the deepest and longest caves in Australia, and the scale (depth and length) of TWWHA cave systems are outstanding at a global level for a non-orogenic karst region (i.e., a karst area not currently subject to major tectonic uplift which creates extreme cave depth and length potentials). The presence of this scale of cave development in a predominantly undisturbed temperate climate environment is also globally unusual, due to the degree of human settlement and exploitation of karst regions in most temperate-climate parts of the world.

Because the TWWHA encompasses an uninterrupted range of landscape units and fluvial catchments extending from the coast to high alpine regions, the karst environments within the TWWHA are correspondingly diverse. This is a characteristic shared by few other karstic regions in the world, which are typically predominated by a particular type of karst environment49.

Another globally significant aspect of the TWWHA karsts is the degree of karst development in the (less soluble) dolomites, which in the TWWHA have a scale of karst development as great as that in the more soluble limestones. Although karst in dolomite is not globally rare, it is typically less well developed than limestone karst due to the normally lower solubility of dolomite compared to limestone (Ford & Williams 1989, p.30). The large scale of dolomite karst development in the TWWHA may be partly due to the diversity of karst solvents available in the TWWHA, including abundant humic acids which are a characteristic feature of the TWWHA and are partly related to its blanket bog peats which are themselves of World Heritage significance. One notable distinctive aspect of dolomite karst in the TWWHA, apart from its large scale, is the presence of tower karst in the Lightning Plains – Maxwell River area, which is a normally-tropical karst landform that is rare in temperate climates50.

In essence, the justification of the outstanding universal value (World Heritage significance) of the Diverse Karst Landform and Process Systems theme is that the TWWHA karsts are globally unique in a number of ways, including in being the most extensive temperate-zone maritime-climate undisturbed ongoing karst process systems not subject to ongoing glacial and orogenic processes globally (see Ongoing Karst Geomorphic Process Systems sub-theme), in having an extensive and diverse glacio-karst record in a tectonically-stable temperate maritime glacial environment (see Glacio-karstic Phenomena sub-theme), in having a large scale of karst development in a non-orogenic tectonically-stable region, and in having an outstanding diversity of karst phenomena and environments for a single extensive karstic region. Taken together, these attributes mean that the TWWHA contains an exceptional diversity and scale of karst phenomena for an environment of its type (temperate, maritime, tectonically–stable, undisturbed) globally, which justifies the Diverse Karst Landform and Process Systems of the TWWHA as having outstanding universal value under Criteria (i) & (iii) of the World Heritage criteria (UNESCO 1999). The scale and diversity of the

49 For example, the very extensive karsts of central New Guinea are predominantly formed where Tertiary limestones have been uplifted in the currently active orogenic zone of the New Guinea cordillera; hence these tropical karsts are predominantly inland, high relief, high altitude karst (like some in the TWWHA), but not plains or coastal karsts (unlike some others in the TWWHA). (Albeit spatially separate and lithologically unrelated karst occurs in other environments elsewhere in New Guinea, such as in reefal coastal limestones on the Huon Peninsula.)

50 Note that tower karst also occurs in the magnesite karst of north-west Tasmania, where it is at least in part exhumed palaeo-karst that actually formed under a warm humid climate in Early or Middle Tertiary times, was buried beneath alluvium and has only been re-exposed in geologically recent times (Houshold et al. 1999). A similar explanation for the TWWHA tower karst, were it found to be valid, might explain the apparent anomaly of "tropical" karst forms in the temperate TWWHA climate.
TWWHA karsts and features such as speleothem displays, also contribute to the outstanding aesthetic value of TWWHA landscapes under Criterion (iii).

**Individual sites or systems of World Heritage significance in their own right**

Two specific TWWHA karst areas were previously identified as having world significance in their own right, namely the Exit Cave Karst System and the Mt Anne (North East Ridge) Glacio-Karst / Weld Valley Karst System. Exit Cave was highlighted in the Helsham Inquiry (Helsham et al. 1988) and both were noted in the 1989 TWWHA nomination (DASETT 1989) as important elements of the World Heritage karst values, and were identified as having world significance by Dixon (1991). Both have subsequently been listed on the Tasmanian Geoconservation Database (Dixon & Duhig 1996, TGD 2001) as features of world level significance.

This review supports the World Heritage significance of these sites, in their own right, under the "diverse karst" theme:

**Exit Cave**

Exit Cave (in the TWWHA at the "Ida Bay" karst area – see Figure 15) is an outstanding cave system of exceptional scale, complexity and diversity. The cave is developed in a gently domed anticline of Ordovician-age limestones, with the main trunk passage aligned along the anticline axis (Sharples 1979, Sharples & Klootwijk 1981). With over 20 kilometres of passage it is the longest mapped cave in Australia (Kiernan 1995), and some of its stream passages are of exceptional "cathedral-like" scale. It exhibits extensive speleothem displays including delicate gypsum "hair", and contains palaeokarst deposits representing four separate phases of karst development over roughly 400 million years (Clarke 1995, Osborne & Cooper 2001). The development of the present cave system has been partly conditioned by re-incision along old infilled palaeo-karst passages, and partly by glacio-karst processes (Goede 1969). Various phases of karst development have been driven by not only "classic" meteoric water / carbonic acid karst solution, but also by sulphuric acid dissolution resulting from weathering of pyritic palaeo-karst in-fills (Kiernan 1991a, Houshold 1992, Clarke 1995, Osborne & Cooper 2001), hydrothermal processes (Osborne & Cooper 2001) and probably humic acids. The cave system contains Pleistocene sediments and speleothems spanning multiple glaciations, extinct marsupial megafauna sub-fossils, and an endemic invertebrate cave fauna.

Limestone quarrying adjacent Exit Cave has caused disturbance of processes within the eastern passage of Exit Cave in the past (Houshold & Spate 1990; Kiernan 1991a, 1993; Houshold 1992), however following closure of the quarry a unique rehabilitation program specifically designed to restore natural processes in Exit Cave has been in place for over ten years (Gillieson & Houshold 1996, Gillieson 1996 p. 290-296), and regular monitoring has demonstrated that karst processes in the cave are returning to a natural state (I. Houshold pers. comm.). Notably, the catchment and passages of the western part of the cave system were not affected by quarrying and provide examples of undisturbed karst processes which are being used as a baseline against which to monitor the restoration of natural processes in the eastern passages.

Although partly disturbed by prior limestone quarrying, the entire surface water catchment of Exit Cave is contained within the TWWHA boundaries and, as noted above, innovative rehabilitation techniques have been employed over the last ten years in a so-far successful effort to return the catchment, and catchment water quality, to a close-to-natural condition. All known cave passages and their contents are contained within the TWWHA, although there is a possibility that some minor subterranean drainage from the cave may spring or seep from the system into State forest.

---

51 Karst in the Exit Cave area has often been referred to as the "Ida Bay" karst, although this is something of a misnomer since Ida Bay is several kilometres away and is not underlain by limestone!
land tenure to the north of the system. If so, however, this would only be a small and "downstream" component of the cave hydrology that would not affect upstream parts of the system within the TWWHA. As is the case for the TWWHA as a whole, Exit Cave is managed under the TWWHA management plan (PWS 1999), which specifically provides for its protection, and is legislatively protected by National Park status and the provisions of the Regional Forest Agreement (Land Classification) Act 1998, which states that a purpose of National Parks is to protect "geological diversity" (which is defined in the Act as including landforms and geomorphic processes). The condition and integrity of the Exit Cave karst system is thus adequate to fulfill the integrity requirements for World Heritage properties (UNESCO 1999; see this report Section 2.3.3).

The World Heritage significance of the Exit Cave was argued during the Helsham Inquiry by consultants to the Inquiry (Houshold & Davey 1987, p.82), and the majority opinion of that Inquiry was that the Exit Cave system, in its own right, was a system of World Heritage significance (Helsham et al. 1988, vol. 1, p. 214). The World Heritage significance of the cave was asserted in the 1989 TWWHA nomination (DASET 1989), and subsequent scientific work leading to and following the decision to close an adjacent limestone quarry because of its impact on World Heritage karst values has significantly enhanced understanding and appreciation of the cave's outstanding universal value (e.g., Houshold & Spate 1990; Kiernan 1991a, 1993; Houshold 1992).

The Exit Cave karst system is justified as having outstanding universal value in its own right under Criterion (i) as a "significant geomorphic ... feature" and under Criterion (iii) as a "superlative natural phenomenon" (UNESCO 1999), since it is an outstanding exemplar of the scale and diversity of the attributes that give World Heritage significance to the TWWHA karsts as a whole. These include its undisturbed karst processes (Ongoing Karst Geomorphic Process Systems sub-theme), glacio-karstic influences on its development (Glacio-Karstic Phenomena sub-theme) and its diversity of other phenomena including physical scale and multi-phase history of varying karst process types that are significant for the TWWHA karsts as a whole under the Diverse Karst Landform and Process Systems theme.

Mt Anne (NE Ridge) Glacio-karst

This system has been described above as being of outstanding universal value in its own right under the Glacio-karstic phenomena sub-theme, and forms a part of the broader Weld River Catchment Karst System which is described and justified to be of outstanding universal value in its own right under the Ongoing Karst Geomorphic Processes sub-theme.

The Mt Anne (NE Ridge) Glacio-karst is further noted here as having outstanding universal value in its own right under the Diverse Karst Landform and Process Systems theme, in virtue of not only its undisturbed and glacio-karstic attributes, but also in virtue of its large scale of development in dolomite bedrock, which are additional elements of the TWWHA karst geodiversity that are of outstanding universal value under Criteria (i) & (iii) (UNESCO 1999).
Other Potential World Heritage Geodiversity Themes and Sites

A number of features cited in the 1989 TWWHA nomination (DASETT 1989) as contributing to World Heritage values have been rejected in the present review. These are noted and reasons for their rejection as contributing to World Heritage values are given in Sections (2.3.2) and (3.2.1) above.

The following additional geological themes were identified as contributing to the World Heritage significance of the TWWHA in the 1989 nomination (DASETT 1989), however their World Heritage significance was not justified in that nomination (see Section 2.3.2). The themes may prove to be of World Heritage significance, however further review is required to establish this, and these themes are listed in section (4.5.1) as warranting further review and assessment of their geoconservation values in a global context. These themes are:

- Ordovician stratigraphy / palaeo-environment theme
- Permo – Carboniferous glaciation theme
- Gondwana break-up theme
- Weld Valley Group dolomites and mixtites
- Denison Range Cambro-Ordovician fan-delta flysch sequence
- Adamsfield Trough tectonic melanges

In addition, subsequent to 1989 the following individual sites within the TWWHA have been assigned world level significance on the Tasmanian Geoconservation Database (Dixon & Duhig 1996, TGD 2001). However, they do not contribute to any currently-identified over-arching World Heritage themes, and it will be necessary to carefully review their significance before accepting (or rejecting) these sites as being individually significant World Heritage sites. These sites (also listed for further review in Section (4.5.1) are:

- Collingwood River White Schist
- Reward Creek mineralisation
- Adamsfield Workings mineralogy
3.3 World Heritage Geoconservation Values of New Reserve Areas Adjacent the TWWHA

Since the TWWHA was inscribed on the World Heritage List in 1989, a total of 21 new reserves or reserve extensions have been created contiguous with the TWWHA, as a result of several processes including the 1997 Tasmanian Regional Forest Agreement (RFA) between the State and Commonwealth governments. These areas (listed in PWS, 1999, p. 15, 17 & 19) do not currently form part of the listed Tasmanian Wilderness World Heritage Area. In addition to these, the Mole Creek Karst National Park, proclaimed in 1996, includes several pre-existing reserves that lie outside the TWWHA (as well as the former Marakoopa Cave State Reserve which lies within the TWWHA). The TWWHA Management Plan (PWS, 1999, p. 74) provides that the heritage values of these various reserves be reviewed in order to determine whether they should be considered for World Heritage nomination (i.e., for addition to the existing declared TWWHA). The areas are listed below (see also Figure 24), and an assessment of their contribution to World Heritage geoconservation values is provided.

Most of these areas have previously been assessed as having World Heritage geoconservation values and have previously been recommended for addition to the TWWHA (DPWH 1990). It is concluded that all these areas contribute to geoconservation-based World Heritage values to some degree, which is not surprising since they mostly comprise areas that were reserved due to being relatively undisturbed and adjacent existing reserves. A few (e.g., Nelson Falls, Catamaran River, D’Entrecasteaux River) are partly disturbed in respect of certain geomorphic values, however all make some worthwhile contribution to the World Heritage values of the TWWHA.

Mole Creek National Park (several discrete pre-existing reserved areas outside TWWHA that became National Park in 1996)

Only a small portion of the Mole Creek karst (limestone bedrock: see Figure 15) lies within the listed 1989 TWWHA boundary, although parts of the allogenic karst catchment are also within the boundary. This proposed extension area comprises several additional discrete conservation reserves within the Mole Creek karst system. Parts of the proposed extension areas have previously been recommended for inclusion in the TWWHA (DPWH 1990).

Karst themes and sub-themes:
These areas contribute significantly to the World Heritage karst themes and sub-themes (see Section 3.2.2), in that they are all integral portions of the Mole Creek karst system which is one of the most extensive and highly developed karst systems in Tasmania, and as such is an outstanding exemplar of the TWWHA karst themes and sub-themes. Although parts of the karst are compromised by disturbance, significant portions are undisturbed and contribute to the Ongoing Karst Geomorphic Processes sub-theme of the Ongoing Geomorphic and Soil Process Systems World Heritage theme (see Section 3.2.2); the extensive scale and diversity of karst at Mole Creek contributes to the Diverse Karst Landform and Processes Theme; and the karst includes some of the first glacio-karstic phenomena recognised in Tasmania (see Section 2.4), which contribute to the Glacio-Karstic Phenomena sub-theme of the Late Cainozoic Ice Ages and Climate Change Record World Heritage theme (see Section 3.2.2).

See also discussion of the Mole Creek Karst System in Section (3.4).
Figure 24: Map indicating the location of the proposed additions to the TWWHA described in this section.
Geoheritage Values – Tasmanian Wilderness World Heritage Area

**Dove River** (addition to Cradle Mountain – Lake St Clair National Park; RFA\(^{52}\))

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

*Ongoing Fluvial Geomorphic Process Systems* sub-theme

This area includes alpine and forested portions of small upstream catchments which are mostly undisturbed, and contribute to the World Heritage significance of this sub-theme.

*Glacial and Glacio-fluvial Landforms* sub-theme

This area lies adjacent to one of Tasmania's best known glacial landscapes at Cradle Mountain. Although detailed glacial studies of this region are ongoing (M. Thrush *pers. comm.*), the area was over-ridden by an ice cap during the Maximum Cainozoic Glaciation (Kiernan 1990c) and may contain glacial landforms which contribute to the World Heritage significance of this sub-theme.

**Mersey Valley - two small blocks at Lees Paddocks** (addition to Cradle Mountain – Lake St Clair National Park; added 1991)

Parts of this proposed extension area have previously been recommended for inclusion in the TWWHA (DPWH 1990).

*Glacial and Glacio-fluvial Landforms* sub-theme

These blocks, which are surrounded by the TWWHA, lie in the floor of the classically-shaped glacial trough of the upper Mersey Valley, and are thus integral parts of a large glacial landform that contributes significantly to the World Heritage value of this sub-theme. The blocks are additionally likely to contain sediments of glacial or glacio-fluvial origin, contributing further to this sub-theme.

**Navarre Plains** (addition to Franklin – Gordon Wild Rivers National Park)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

*Glacial and Glacio-fluvial Landforms* sub-theme

This area contains numerous moraine ridges, till and glacio-fluvial outwash sediments relating to at least two phases of Late Cainozoic glaciation (Kiernan 1985, Fig. 7.2; 1991c). These features contribute significantly to the World Heritage value of this sub-theme.

**Beech Creek - very small area** (addition to Franklin – Gordon Wild Rivers National Park)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

*Ongoing Fluvial Geomorphic Process Systems* sub-theme

This area is a small upstream portion of the undisturbed old growth-forested catchment of the Hanlon Creek (Counsel River tributary) / Gordon River watershed. As such it contributes to the World Heritage significance of this sub-theme.

\(^{52}\) (Note: “RFA” = reserve addition created upon commencement of *Regional Forest Agreement (Land Classification) Act 1998*).
**Beech Creek – Counsel River - large area** (addition to Franklin – Gordon Wild Rivers National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

**Ongoing Fluvial Geomorphic Process Systems** sub-theme
This area encompasses large parts of the upstream, undisturbed old growth-forested catchments of Beech Creek, Hanlon's Creek and Counsel River, and as such contributes very significantly to the World Heritage value of the *Ongoing Fluvial Geomorphic Process Systems* sub-theme.

**Glacial and Glacio-fluvial Landforms** sub-theme
The Beech Creek valley portions of this area have untested potential to include glacial landforms and deposits from glaciers that may have flowed off the Wylds Craig massif during the Maximum Cainozoic glaciation.

**Counsel River - small area** (addition to Franklin – Gordon Wild Rivers National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

**Ongoing Fluvial Geomorphic Process Systems** sub-theme
This area is a small portion of the undisturbed old growth-forested Counsel River catchment. As such it contributes to the World Heritage significance of this sub-theme.

**Tiger Range** (addition to Franklin – Gordon Wild Rivers National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

**Ongoing Fluvial Geomorphic Process Systems** sub-theme
This area is a small undisturbed old growth-forested upstream portion of the (downstream highly disturbed) Florentine River catchment. As such it contributes to the World Heritage significance of this sub-theme.

This area is additionally part of a very prominent strike ridge forming an integral part of the strike ridge and valley fluvial landscape of the TWWHA (see Section 3.2.2), and as such additionally contributes to the World Heritage values of this sub-theme.

**Nelson Falls** (addition to Franklin – Gordon Wild Rivers National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

**Ongoing Fluvial Geomorphic Process Systems** sub-theme
This area includes forested fluvial catchment areas which may have been (at least in part) subject to disturbance due to logging for smelter fuel in the past (for the Queenstown smelter). Further investigation is required to determine the degree of disturbance that has occurred to fluvial processes in this area.
However, the area does include a notable waterfall landform and process system which has not been physically (morphologically) degraded; and hence contributes to the *Ongoing Fluvial Geomorphic Process Systems* sub-theme to a degree.

**Hartz “Hole”** (addition to Southwest National Park; added 1991)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

The Hartz "Hole" is an undisturbed area on the eastern side of the Picton River valley upstream of the Farmhouse Creek tributary and southwest of Hartz Mountains, which is completely surrounded by the Southwest National Park and the TWWHA as listed in 1989.

There has never been any field mapping of bedrock geology or geomorphology within this area, even at a reconnaissance scale (the oddly uniform geology indicated on current 1:250,000 geological mapping that covers the area is merely inferred, and is likely to be at least partly incorrect). Nevertheless, the area demonstrably contributes significantly to one TWWHA geoconservation theme of World Heritage significance, and potentially may contribute to several others:

**Ongoing Fluvial Geomorphic Process Systems** sub-theme:
The area is a substantial integral part of the upper Picton River fluvial geomorphic system (catchment and channels), which is entirely forested and undisturbed above Farmhouse Creek (see Section 3.2.2, Figure 5) and as such is one of the largest individual undisturbed fluvial catchments in the TWWHA (albeit the downstream half of the Picton catchment beyond the TWWHA is disturbed by roading and forestry). The Hartz "Hole" therefore contributes significantly to this sub-theme (see Section 3.2.2), and indeed to not incorporate it into the TWWHA would anomalously leave the area as the only "gap" in the TWWHA coverage of the large pristine upper Picton fluvial geomorphic system.

Whereas other geoconservation values of the Hartz "Hole" (below) are only speculative on current knowledge, the significant contribution of the area's ongoing fluvial systems to the TWWHA World Heritage values can be confidently asserted.

**Karst** theme and sub-themes:
It is possible that Ordovician limestone underlies part of the Picton Valley floor within the Hartz "Hole", as is known to be the case downstream of Farmhouse Creek (Forsyth *et al.* 1995, Kiernan 1995). If so there is potential for karst systems in the area which may contribute significantly to the *Karst* World Heritage theme and sub-themes (see Section 3.2.2).

**Glacial and Glacio-Fluvial Landforms** and **Glacio-karstic Phenomena** sub-themes:
Pleistocene glacial depositional landforms, tills and outwash sediments are known in several parts of the upper, middle and lower Picton Valley (Sharples 1994a), and there is undemonstrated potential for glacial features related to an upper Picton valley glacier of pre-Last Glaciation antiquity to exist within the Hartz "Hole". Given the possibility that limestone could also underlie part of the area, there is additional potential for significant glacio-karst processes to have occurred within the area. Potential glacial features in the Hartz "Hole" area could therefore conceivably contribute significantly to the *Glacial and Glacio-fluvial Landforms* sub-theme and may potentially contribute to the *Glacio-Karstic Phenomena* sub-theme (see Section 3.2.2).
South-east of Cockle Creek (addition to Southwest National Park; added 1991)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

This area includes Blowhole Valley and the hills and coast to the south-east, including the area from the southern shores of Recherche Bay (Cockle Creek) to Big Trumpeter Bay near South East Cape. This area contributes significantly to four TWWHA geoconservation themes of World Heritage significance.

Ongoing Fluvial Geomorphic Process Systems sub-theme:
Although parts of this area have been logged in historic times (Kostoglou 1993), the area includes several small probably undisturbed catchments south and south-west of Blowhole Creek, which are contiguous with undisturbed parts of the existing TWWHA and therefore contribute significantly to this sub-theme (see Section 3.2.2).

Ongoing Blanket Bog Peat Land Soil Systems sub-theme:
The floor of Blowhole Valley is mantled by deep peat blanket bogs (overlying aeolian sand sheets of Late Pleistocene / Early Holocene age; see below) which contribute significantly to this sub-theme (see Section 3.2.2).

Ongoing Coastal Geomorphic Process Systems sub-theme:
This area includes a substantial length of mostly rocky coastline between South East Cape (Big Trumpeter Bay) and the southern shores of Recherche Bay. Although some disturbance has occurred in the Cockle Creek area (southern Recherche Bay), the larger rocky proportion of this coastline (from Fisher Point southwards) is a wholly undisturbed coastal stretch contiguous with the undisturbed TWWHA coast from South East Cape westwards, and thus shares the World Heritage values of this sub-theme (see Section 3.2.2). Indeed, this stretch of undisturbed coast is an important addition to the TWWHA coast as it encompasses the last stretch of wholly undisturbed coastline between the existing undisturbed TWWHA coast and the predominantly disturbed coastline from Recherche Bay northwards.

Late Cainozoic Coastal Landforms and Sediments sub-theme:
The inland part of this area encompasses the Late Pleistocene/Early Holocene stabilised dunes and sandsheets which form the Blowhole Valley headland bypass dune system (Cullen 1998a), which is one of the largest relict headland bypass dune systems in Tasmania and contributes significantly to this sub-theme (see Section 3.2.2).

Little Florentine River (addition to Southwest National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

Ongoing Fluvial Geomorphic Process Systems sub-theme:
This area comprises the undisturbed old growth – forested upstream headwaters of the Little Florentine River adjoining the existing TWWHA, and as such contributes significantly to this World Heritage sub-theme.

Glacial and Glacio-fluvial Landforms sub-theme
Although glacial landforms have not been documented (or searched for) within this area, the area lies up-valley of known deposits of glacial sediments in the Little Florentine Valley and elsewhere near the Gordon River Road (Brown et al. 1982a; Kiernan et al. 2001, Fig. 1). It is thought that an anomalously extensive glacier flowed from the northern side of Mt Mueller down the north west-facing Little Florentine Valley (Kiernan et al. 2001, Fig. 1), hence this area is likely to contribute
significantly to the *Glacial and Glacio-fluvial Landforms* sub-theme through evidence of Late Cainozoic glaciation in an unusual topographic position (glaciers in Tasmania are thought to have generally been less prone to accumulation on north-western slopes due to excessive insolation and ablation on slopes of such aspect; hence a glacier in this situation is unusual and significant in the context of this sub-theme).

*Karst and Glacio-karstic Phenomena* theme and sub-themes

Precambrian dolomite bedrock is present within this area (Brown *et al.* 1995). Although no karst phenomena have been documented in the area to date (Kiernan 1995), there has been little or no karst exploration either. Hence the potential exists for karst landforms, and potentially glacio-karst phenomena, within this area, which if present would contribute significantly to the World Heritage significance of this theme and sub-themes.

**Styx River** (addition to Southwest National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

This area comprises a strip of undisturbed land adjoining the existing TWWHA in the upper headwaters of the Styx River southeast of Mt Mueller. This area contributes significantly to two TWWHA geoconservation themes of World Heritage significance:

*Ongoing Fluvial Geomorphic Process Systems* sub-theme:

The area includes undisturbed old growth – forested upstream portions of the Styx River catchment, and therefore contributes to the World Heritage value of this sub-theme (see Section 3.2.2).

*Karst* theme and sub-themes

This area includes a substantial area of Precambrian dolomite of the Weld River Group (Brown *et al.* 1995). Recent exploration within this area (Sharples & Duhig 2003) has demonstrated that karst is well developed in dolomite straddling the boundary between this reserved area and adjacent State forest. Features identified within the reserved area include a cave, sinkhole lake, karst pinnacles and, most significantly, an area of very well developed polygonal karst ("egg-carton" karst) centred at about 459 700mE 5258 350mN (AGD66 datum) and straddling both the reserve and adjoining State forest. Whereas a handful of polygonal karst areas are known in Ordovician limestones in Tasmania, this is the only polygonal karst yet identified in Precambrian dolomite in Tasmania. Considerable karst development is evident, hence the area contributes strongly to the World Heritage significance of the *Karst* theme and sub-themes (Section 3.2.2).

The area lies a few kilometres from highly developed karst in the same dolomites in the upper Weld River part of the TWWHA (see *Ongoing Karst Geomorphic Process Systems* sub-theme in Section 3.2.2).

**Blake's Opening** (addition to Southwest National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

This extension area straddles the middle Huon River around Blake's Opening and includes Blake's Opening, the northern slopes of Mt Picton from Red Rag Scarp downhill, and much of the eastern half of the Manuka Creek catchment north of Blake's Opening.
This area contributes significantly to three TWWHA geoconservation themes of World Heritage significance:

**Ongoing Fluvial Geomorphic Process Systems** sub-theme:
The area includes the large eastern part of the Manuka Creek catchment (thereby completing the inclusion of the entire undisturbed Manuka Creek catchment in the TWWHA), and the undisturbed catchments of several tributary creeks flowing into the Huon River from the flanks of Mt Picton. The area therefore contributes significantly to the World Heritage significance of this sub-theme (see Section 3.2.2)

**Karst** themes:
This extension area covers most of the large Mt Picton – Blake's Opening Precambrian dolomite area (Calver 1997, Calver & Everard 2002), which was almost entirely outside the 1989 TWWHA boundary. Although little-explored for karst, the dolomite exhibits large sinkholes and some identified caves at the unconformity on Red Rag Scarp and on slopes below. With almost 500 metres of vertical relief on the dolomite between Red Rag Scarp and Blake's Opening, the area has clear potential to host vertical caves deeper than any so far discovered in Australia. Known and potential karst within this area contributes (and has the potential to contribute very significantly) to the **Karst** World Heritage theme and sub-themes.

**Glacial and Glacio-Fluvial Landforms** and **Glacio-karstic phenomena** sub-themes:
Pleistocene glacial sediments pre-dating the Last Glaciation and deposited by a former glacier that flowed down Manuka Creek from Gallagher Plateau are well exposed within the extension area at Blake's Opening, and provide clear evidence of multiple phases of Pleistocene glaciation in the TWWHA (Colhoun & Goede 1979). The Huon Glacier over-rode the Blake's Opening dolomites (see above), hence there is clear but as-yet unstudied potential for significant glacio-karst interactions to have occurred within the area. The Blake's Opening glacial features contribute significantly to the World Heritage value of these sub-themes (see Section 3.2.2).

**Cook Rivulet / Creek** (addition to Southwest National Park; RFA)
This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

**Ongoing Fluvial Geomorphic Process Systems** sub-theme:
This area on the lower southern slopes of Mt Picton is a portion of the undisturbed old growth – forested upper catchment of Cook Creek (or Rivulet), downstream of the undisturbed headwaters of the creek and upstream of disturbed (logged) portions of the lower catchment. The area thus contributes significantly to the World Heritage value of this sub-theme.

**Karst** theme and sub-themes:
A large portion (more than half) of this area is underlain by Precambrian dolomite on moderately sloping hill flanks (Forsyth et al. 1995). A large glacio-karstic uvala has been previously documented nearby in the same dolomite area within the adjoining TWWHA (Kiernan 1989b, McNeill 1993). Although no karst has yet been documented within this extension area, there is clear potential for significant karst, contributing to the World Heritage value of this theme and sub-themes.

**Glacial and glacio-fluvial** sub-theme and **Glacio-karstic phenomena** sub-theme:
Glacial cirques are present in the headwaters of Cook Creek (Kiernan 1989b). Kiernan (1989b) and Sharples (1994a, Vol. 2, p. 29) have documented a large moraine lower down Cook Creek

---

53 The deepest Australian karst cave discovered to date is Niggly Cave (Florentine Valley) with a depth of a mere 375 metres (Eberhard 1994).
valley. Kiernan (1989b, Fig. 1) has airphoto-interpreted moraines within this extension area, and it seems certain that glacial features contributing to the World Heritage value of the Glacial and glacio-fluvial sub-theme are present in this area. Additionally, given the known presence of dolomite in this area, and a nearby known glacio-karstic uvala in the TWWHA immediately south of the extension area (Kiernan 1989b, McNeill 1993), there is evidently high potential for this area to also contribute significantly to the World Heritage value of the Glacio-karstic Phenomena sub-theme.

**Farmhouse Creek** (addition to Southwest National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

**Ongoing Fluvial Geomorphic Process Systems** sub-theme:
This area immediately north of Mt Bobs is a portion of the undisturbed old growth – forested upper catchment of Farmhouse Creek, downstream of the undisturbed headwaters of the creek and upstream of disturbed (logged) portions of the lower catchment. The area thus contributes significantly to the World Heritage value of this sub-theme.

**Karst** theme and sub-themes:
Current (reconnaissance) geological mapping suggests that karstic carbonate bedrock adjoins but may not lie within this area (Forsyth *et al.* 1995, Kiernan 1995). The area may be important to the World Heritage karst values for protecting part of the catchment of significant karst (Kiernan 1989b).

**Glacial and Glacio-fluvial Landforms** sub-theme:
Moraines and glacial sediments exist in this area (Kiernan 1989b), which therefore contributes to the World Heritage significance of this sub-theme.

**East Picton** (addition to Southwest National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

**Ongoing Fluvial Geomorphic Process Systems** sub-theme:
This undisturbed old growth – forested area immediately upstream of the Picton River – Farmhouse Creek confluence is the downstream end of the entirely undisturbed upper part of the Picton River catchment (see Section 3.2.2, Figure 5). It is highly significant to the World Heritage value of this sub-theme since it completes protection of the maximum possible area of the important undisturbed upper Picton River catchment.

**Karst** theme and sub-themes:
This area provides undisturbed catchment for the upper end of an area of riverine Ordovician limestone outcropping along the Picton River immediately downstream (Forsyth *et al.* 1995, Kiernan 1995), albeit this potentially karstic area is mostly situated outside the TWWHA.

**Glacial and Glacio-Fluvial Landforms** sub-theme:
Pleistocene glacial depositional landforms, tills and outwash sediments are known in several parts of the upper, middle and lower Picton Valley (Kiernan 1989b, Sharples 1994a), and there is undemonstrated potential for glacial features related to a Hartz Mountains and/or upper Picton Valley glacier of pre-Last Glaciation antiquity to exist within the East Picton area, which therefore has unexplored potential to contribute to the World Heritage value of this sub-theme.
Hastings Caves (addition to Southwest National Park; RFA)

This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

This area comprises a strip of land on the north-west side of the broad Lune River Valley, which adjoins and links the prior Southwest National Park boundary to the (older and formerly isolated) Hastings Caves State Reserve, but does not include and should not be confused with the latter (see also Section 3.4). This area contributes significantly to three TWWHA geoconservation themes of World Heritage significance:

**Ongoing Fluvial Geomorphic Process Systems** sub-theme:
The area includes undisturbed old growth – forested portions of the Lune River, Mesa Creek, Hot Springs Creek and Creekton Rivulet catchments upstream of all known fluvial disturbances, and therefore contributes to the World Heritage value of this sub-theme.

**Karst** theme and sub-themes:
Recent (2003) fieldwork by I. Houhold and C. Sharples (currently unpublished) has demonstrated that the Precambrian dolomite bedrock and dolomite karst previously known in the adjoining Hastings Caves State Reserve (see Section 3.4) extends into the Hastings Caves extension to the Southwest West National Park in the upper valley of Hot Springs Creek. Several vertical shafts, numerous dolines, a major karst spring and siliceous sediments interpreted as palaeo-karst deposits, have all been identified in a portion of this extension area approximately 1 kilometre northwest of Newdegate Cave (in the adjoining Hastings Caves State Reserve). One shaft has been explored recently (C. Sharples personal observations) and has yielded several hundred metres of pristine cave passage to date, with further leads remaining to be explored. This makes it already the fourth longest known cave in the Hastings Karst. Considerable karst development is evident, hence the area contributes significantly to the World Heritage value of the Karst theme and sub-themes (Section 3.2.2).

Karst is also developed within the proposed extension area in Ordovician limestones at Mesa Creek, and is likely to be present in Precambrian dolomites in the Creekton Rivulet headwater portion of the area. These karsts therefore similarly contribute to the TWWHA karst themes.

**Glacial and Glacio-fluvial Landforms** sub-theme:
Recent (2003) fieldwork by I. Houhold and C. Sharples (currently unpublished) has identified a large till deposit in this extension area, on the floor of the Hot Springs Creek valley upstream of the Hastings Caves State Reserve (centred around 486 450mE 5197 400mN, AGD66 datum), which is interpreted as a terminal moraine complex deposited by a glacier flowing off the south side of Adamson's Peak during a Pleistocene glacial phase prior to the Last Glaciation. This represents glacial action to an unusually low altitude for Tasmania, and thus contributes significantly to the World Heritage significance of the Glacial and Glacio-fluvial Landforms sub-theme (see Section 3.2.2). The till overlies karstic dolomite (see above), thus additional significant elements contributing to the Glacio-karst Phenomena sub theme are possible.

D'Entrecasteaux River (addition to Southwest National Park; RFA)

This (dangerous) area lies immediately south of the highly significant Exit Cave system (see Section 3.2.2), but has been virtually unvisited by geologists or geomorphologists in recent decades. The area encompasses parts of the broad low-lying D'Entrecasteaux plains which have been logged from tramways and probably burnt in historical times (Kostoglou 1993), and hence may not contribute significantly to the Ongoing Fluvial Geomorphic Process Systems sub-theme.
Geoheritage Values – Tasmanian Wilderness World Heritage Area

Karst theme and sub-themes:
The extension area is interpreted to be, and most probably is, underlain by Ordovician limestone contiguous with the Exit Cave Ordovician limestone immediately to the north (Forsyth et al. 1995). The area is considered to be an extensive plains karst area, and thus probably contributes to the World Heritage value of the Karst theme and sub-themes.

Glacial and Glacio-fluvial Landforms and Glacio-karst Phenomena sub-themes:
Adjoining areas of the TWWHA exhibit glacial landforms including moraines (Davidson 1971, Sharples 1994a, vol. 2, p. 37), and the proposed extension area is interpreted as a limestone plain mantled by glacial and/or glacio-fluvial outwash sediments. As such, it contributes to the World Heritage significance of the Glacial and Glacio-fluvial Landforms sub-theme. Given the probability that glacial sediments overlie limestone in this area, there is a likelihood that glacio-karstic phenomena are present, which would contribute to the World Heritage value of the Glacio-karstic Phenomena sub-theme.

Catamaran River (addition to Southwest National Park; RFA)
This area lies south-east and downstream of a plain (in the TWWHA) likely to be underlain by Ordovician limestone (Kiernan 1995), and therefore does not contribute to World Heritage karst themes. Whilst upstream areas of the Catamaran River valley are glaciated (Davidson 1971), there is as yet no evidence of glacial phenomena as far downstream as the proposed extension area, although glacial sediments in this area are conceivable.

Ongoing Fluvial Geomorphic Processes sub-theme
Much of this area comprises plains and low hills of low dense regrowth that have been partly logged from tramways and probably burnt in historic times (C. Sharples personal observations, Kostoglou 1993), however the western (upstream) side of the area comprises undisturbed old growth – forested areas adjoining the pristine South Cape Rivulet catchment of the TWWHA. On this basis, parts (at least) of the proposed extension area contribute to the World Heritage value of the Ongoing Fluvial Geomorphic Processes theme.

Devils Gullet (addition to Devils Gullet State Reserve; RFA)
This proposed extension area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

This small area comprises a section of the deeply incised Fisher River valley tributary of the Mersey River, immediately downstream of the prior Devils Gullet State Reserve, which is part of the incised escarpment edge of the Central Plateau glacial terrain. Ongoing fluvial processes in Devils Gullet State Reserve are partly disturbed by roading and the damming of Lake Mackenzie at the head of Fisher River (upstream of the State Reserve), which has diverted water and modified the fluvial discharge regime in Fisher River within the State Reserve.

Glacial and glacio-fluvial Landforms sub-theme
This area has been over-ridden by the Central Plateau ice cap during the maximum Late Cainozoic glaciation (Kiernan 1990c), and forms an integral part of the escarpment bounding the Central Plateau Glacial Terrain, which is a dominating glacial landform of World Heritage significance in its own right (see Section 3.2.2). Hannan & Colhoun (1987) have documented till deposits in the Fisher River valley immediately adjacent (a few hundred metres outside) the proposed extension, and have inferred that the ice limits of the Arm Glaciation (younger than the Maximum Cainozoic Glaciation) in the Mersey Valley lay with the proposed extension area. Although they did not document glacial landforms or sediments within the proposed extension area, these are likely to be present given their existence immediately adjacent (Hannan & Colhoun 1987), and this
interpretation was previously made by Jennings & Burns (1958). The role of this area as part of the Central Plateau Glacial Terrain, and the likelihood of glacial landforms and/or deposits in this area, contributes to the World Heritage significance of the Glacial and glacio-fluvial Landforms sub-theme.

Periglacial Landforms sub-theme of the Late Cainozoic Ice Ages theme. Although underlain by Jurassic dolerite and Permo-Triassic sedimentary bedrock, much of the proposed extension area is mantled by doleritic periglacial slope deposits of probable Last Glacial age (Jennings & Burns 1958). Further upstream on Fisher River, within the prior Devils Gullet State Reserve, large periglacial mass movement features in the dolerite slope deposits have modified drainage, forcing the river underground for a section. These features contribute to the World Heritage significance of the prior State Reserve under this sub-theme. It is uncertain whether similar mass movement features are present within the proposed extension, however contiguous periglacial deposits are present and form part of the same periglacial landform system, thereby contributing to the World Heritage value of this sub-theme.

3.4 Other Areas Adjacent the TWWHA with Significant Features Contributing to TWWHA World Heritage Themes

It has become apparent during this review that several other places which mostly lie adjacent the TWWHA - in addition to the new reserves described in Section (3.3) above – also contain outstanding exemplars of and/or extensions of those elements of geodiversity that have been assessed within the TWWHA as having World Heritage geoconservation values. Some of these areas have previously been assessed as having World Heritage geoconservation values and have previously been recommended for addition to the TWWHA (DPWH 1990)\(^{54}\). These areas are listed below, with brief details of the contribution of each to the TWWHA World Heritage themes described in Section (3.2) above:

**Hastings Caves State Reserve**

This area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

The Hastings Caves State Reserve is an old reserve, originally declared for its karst landforms, which was formerly isolated from the Southwest National Park but now directly abuts the latter since the intervening strip of land has been reserved and added to the National Park as an outcome of the 1997 Tasmanian Regional Forest Agreement (as the "Hastings Caves" area described in Section 3.3 above, and not to be confused with the adjoining "Hastings Caves State Reserve" described here!). See Figure (15).

Hastings Caves State Reserve was declared nearly a century ago for its well developed cave systems in Precambrian dolomite, one of which – Newdegate Cave – is amongst Tasmania's best known and most popular tourist show caves. The degree of karst development in the Hastings Caves State Reserve is comparable to any dolomite karst within the existing TWWHA, and hence provides an important – and well known and accessible – exemplar of the same karst phenomena which contribute to the World Heritage geoconservation values of the TWWHA under the Karst themes (see Section 3.2.2). The Hastings Caves State Reserve also includes one of Tasmania's best known ongoing hydrothermal karst systems, including several warm springs. Known ongoing

\(^{54}\) Some additional areas adjoining the TWWHA and not listed here, were also assessed previously as having World Heritage values and were recommended for addition to the TWWHA (DPWH 1990). These further areas have not been listed here, however their potential values should also be taken into consideration in any further future assessment of appropriate TWWHA boundary rationalisations.
hydrothermal karst systems are poorly represented within the current TWWHA boundaries, and
the inclusion of Hastings Caves State Reserve would add this significant additional element of karst
diversity to the TWWHA, thus adding to the outstanding universal value of the *Diverse Karst
Landform and Process Systems* World Heritage theme (see Section 3.2.2).

Given that karst values are present in the adjoining Hastings Caves extension to the Southwest
National Park (see Section 3.3), extension of the TWWHA boundary to encompass both the
contiguous National Park extension discussed above (Section 3.3) and the Hastings Caves State
Reserve would significantly contribute to the TWWHA World Heritage karst themes. This logical
boundary extension would avoid the anomalous situation of leaving the Hastings Cave State
Reserve outside but immediately adjoining the TWWHA boundary despite its clear possession of
the same World Heritage values.

**Riveaux Karst (Middle Huon Valley)**

This area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

Ordovician limestone occurs in a fault block in the middle Huon River valley below Mt Riveaux
and downstream of Blake's Opening (Calver & Everard 2002), where it's existence has only been
known for about a decade (Kiernan 1995, vol. 2, p.90). Karst exploration in the area – which is
now generally referred to as the "Riveaux Karst" has only occurred within the last few years (I.
Several large caves have been discovered, and although these are on State forest land tenure the
caves and catchment are undisturbed and old growth - forested apart from a recently constructed
forestry road which has been partly rehabilitated as a result of concerns over the karst. The
undisturbed caves, cave contents and catchment are considered so significant and sensitive that
"unofficial" ongoing cave exploration is currently being actively discouraged by Forestry Tasmania
and DPIWE pending decisions on the future management of the karst. However, a major "official"
karst survey has been funded for 2004, by Forestry Tasmania and DPIWE, with the aim of
gathering information to allow a more rigorous heritage assessment and study of management
requirements for the karst to be carried out (I. Houshold & R. Eberhard, *pers. comm.*).

The mapped geological structures (Calver & Everard 2002) strongly suggest that the Ordovician
limestone is in direct faulted contact with the Precambrian dolomite of the Blake's Opening
extension to the Southwest National Park, immediately west of the Riveaux limestone area (see
Section 3.3 above), albeit this has not been demonstrated since the putative contact is masked by
unconsolidated slope deposits. If true, however, this raises the possibility of a direct subterranean
hydrological link between the Riveaux limestone and Blake's Opening dolomite karsts, such that
disturbances in one of these karsts could be transmitted directly to the other by subterranean karstic
hydrological connections. It would also be a highly unusual situation in situation in Tasmania,
where the only other comparable dolomite-limestone contact is inferred at Hastings, and is
probably partly responsible for the Hastings warm springs hydrothermal karst system noted above
(Sharples 1994a).

The dolomite karst part of this area has potential for caves in excess of 500 metres deep, and both
the dolomite and the limestone karsts of the Mt Picton – Riveaux area are also known to be
associated with Late Cainozoic glacial deposits related to several glaciations (Colhoun & Goede
1979, I. Houshold *pers. comm.*), giving rise to a likelihood of glacio-karstic phenomena being
present. Given the significance of features already discovered to date, the Mt Picton – Riveaux
dolomite / limestone karst region has potential for an unusual scale and diversity of karst
phenomena in an undisturbed geomorphic process environment, making the World Heritage values
of the area very significant under all *Karst* themes and sub-themes (Section 3.2.2).

55 The karst area has also been referred to as the "Roadend Creek Karst" (Kiernan 1995) and the "Hustling
Creek Karst" (Clarke 2002).
The likely direct physical and hydrological contact between the Blake's Opening and Riveaux karsts suggests that a common tenure and management regime, or sympathetic cross-tenure management regime, would be the appropriate means of managing these adjacent karsts. Irrespective of this potential link, however, the undisturbed nature, significant extent and contents of the Riveaux karst and catchment, and its proximity to the recommended Blake's Opening TWWHA extension (Section 3.3) means that the karst contributes significantly to karst World Heritage themes of the adjacent TWWHA.

Mole Creek Karst
Parts of this area have previously been recommended for inclusion in the TWWHA (DPWH 1990). The Mole Creek karst geomorphic system is one of the most extensive and well developed karsts in Tasmania (Kiernan 1984, 1989a; Eberhard 2003), and is a highly significant exemplar of the karst World Heritage geoconservation values of the TWWHA (see Section 3.2.2). However, only a portion of the karst system is located within conservation reserves and the (existing and recommended extensions of) the TWWHA (see Section 3.3 & Figure 15). Large contiguous, hydrologically connected and equally significant portions of the karst are situated on adjoining freehold and State forest land tenures outside the TWWHA boundary (Eberhard 2003). For example, the large and deep, recently-discovered pristine “Shooting Star” cave, with its outstanding speleothem displays, lies partly in State forest, however its catchment is partly in the adjoining TWWHA (Eberhard 2003, Gray 2003, p. 359-360).

The integrated nature of the entire karst means that effective management and protection of the World Heritage values of the Mole Creek karst cannot be successful unless the freehold and State forest portions of the karst are managed in sympathy with the TWWHA portions. A major process has been under development over the last three years to create a framework for cross tenure management of the Mole Creek Karst (the Natural Heritage Trust Mole Creek Karst Integrated Catchment Management Strategy: Eberhard 2003, Gray 2003, p. 359-360), and will be pursued further under a Meander Valley Partnership Agreement between the Meander Valley Council and the State government (R. Eberhard pers. comm.). The draft Mole Creek National Park Management Plan also recommended extending reserve status to an important part of the State forest section of the karst, in the Croesus and Lynds Cave area.

Melaleuca Conservation Area Blanket Bogs, Peat Mounds and Undisturbed Coast
This area, which is a large area surrounded but excluded from the TWWHA in the Port Davey – south coast area, has previously been recommended for inclusion in the TWWHA (DPWH 1990). The area has traditionally been excluded because of small scale alluvial tin mining and prospects.

The Melaleuca Conservation Area contains small areas that have been disturbed by tin mining, however the great bulk of the area is mantled by effectively undisturbed blanket bog peat soils which are significant under the Ongoing Blanket Bog Peat land Soil Process Systems World Heritage sub-theme. Of particular note is that the Melaleuca Conservation Area contains one of the two most important clusters of peat mounds known in south-west Tasmania, the other being within the TWWHA at Louisa Plains (Macphail et al.1999). These are rare features which contribute considerably to the World Heritage significance of the Ongoing Blanket Bog Peat land Soil Process Systems sub-theme (see Section 3.2.2).

The sandy barrier beach shore at Coxes Bight, within this Conservation Area, is an undisturbed sandy portion of the TWWHA coastline (Cullen 1998a), which contributes strongly to the World Heritage significance of the Ongoing Coastal Geomorphic Process Systems sub-theme (see Section 3.2.2). The exclusion of this stretch of coast from the TWWHA leaves the only gap in the otherwise continuous TWWHA coast between Elliott Bay and South Cape Bay (see Figure 12),
creating an inappropriate anomaly for management of this long and highly significant undisturbed coastline.

Quaternary sediments at Melaleuca also contain a fossil flora which contributes significantly to the World Heritage value of the Cainozoic Sedimentary and Palaeobotanical Record sub-theme (Section 3.2.2).

**Birches Inlet – Sorell – Pocacker / Spero River Tectonically-Influenced Peat Land Fluvial System.**
This area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

The review of the Ongoing Fluvial Geomorphic Process Systems sub-theme (Section 3.2.2) justified the Birches Inlet-Sorell-Pocacker-Spero River tectonically-influenced peat-land fluvial system as having outstanding universal value (i.e., World Heritage significance) in its own right. However, the system is only partially encompassed by the existing National Park / TWWHA boundaries, with significant parts of the system – and thus significant World Heritage values - extending beyond the TWWHA into Conservation Area land tenure in the Wanderer River area and elsewhere (see Figure 9). Downstream parts of several of the river systems involved, such as the Spero River, are in excellent undisturbed condition with large areas of undisturbed old growth forest ensuring that natural fluvial processes are intact in those areas beyond the TWWHA boundaries.

The highly significant nature of this fluvial system requires that the entire system, including catchments upstream and downstream of the TWWHA portions of the system, be managed appropriately and in sympathy with the TWWHA portion of the system.

**Tyndall Range – West Coast Range Glacial areas**
This area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

The Tyndall Range directly adjoins the TWWHA boundary in the West Coast Range area. This area had the highest precipitation and highest ice throughput in Tasmania during glacial climatic phases, and the resulting large scale of glacial landform development and sedimentary deposition has made it an intensely studied "type area" for Cainozoic glaciation in Tasmania (e.g., see Colhoun 1985 & this report Section 3.2.2). As such, it is one of the most significant Late Cainozoic glacial areas anywhere in Tasmania. Apart from the scientific significance of the outstanding scale and extent of glacial landforms and deposits in this area, which contribute very strongly to the World Heritage value of the Glacial and Glacio-fluvial Landforms sub-theme under Criterion (i) (see Section 3.2.2), the large scale of alpine glaciated landscapes in the Tyndall Range has also made it a much photographed area with very high aesthetic values characteristic of the TWWHA, that are of World Heritage significance under Criterion (iii) (UNESCO 1999).

**Mt Field National Park - Junee River Karst**
The National Park portion of this area has previously been recommended for inclusion in the TWWHA (DPWH 1990), subject to further assessment of appropriate boundaries.

Mt Field National Park lies a few kilometres outside the TWWHA, from which it is separated by State forest. However, the National Park contains aesthetically outstanding glacial landforms which were amongst the first glacial landforms recognised in Tasmania (Lewis 1922, 1923), and which strongly contribute to the World Heritage Glacial and Glacio-fluvial Landforms sub-theme of the nearby TWWHA under criteria (i) and (iii) (UNESCO 1999).
The National Park also contains part of one of the most extensive and well-developed Ordovician limestone karsts in Tasmania, the Junee River Karst including Australia's deepest known cave, Niggly Cave at 375 metres deep (Eberhard 1994). See Figure (15). This karst crosses into adjoining State forest, where a management zoning scheme is in place to protect the most critical parts of the Junee River Karst system (Eberhard 1994). The large scale of development and diversity of its other karst attributes makes this karst highly significant under the World Heritage karst themes (Section 3.2.2). In particular, glacio-karst phenomena are well developed in the Junee River Karst, due to interaction with the Mt Field glacial processes (Eberhard 1997a, Kiernan et al. 2001), and these contribute significantly to the Glacio-karstic Phenomena World Heritage sub-theme in the adjacent TWWHA.

Although Mt Field National Park and the Junee River Karst system are not contiguous with the TWWHA boundary, they are only a few kilometres away and contain highly significant karst and glacial features that relate and contribute strongly to the World Heritage values of the TWWHA, and which thus warrant sympathetic management with the TWWHA karst and glacial values.

Mt Cripps – Vale of Belvoir Glacio-karst
This area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

A large area of Ordovician limestone immediately adjacent the TWWHA in the Mt Cripps – Vale of Belvoir region (see Figure 15) exhibits well developed plains and hill flank karst in a predominantly undisturbed environment ranging from alpine grass and sedge-lands (Vale of Belvoir) to old growth forest (Mt Cripps). Extensive karst development at Mt Cripps includes caves up to 500 metres long and a very well-developed polygonal karst in undisturbed forest (Shannon et al. 1991), while the Vale of Belvoir exhibits numerous sinkholes and sinkhole ponds in a limestone plain mantled by glacial sediments (Kiernan 1995). Both karsts have been glaciated on multiple occasions during the Late Cainozoic (Derbyshire et al. 1965, Augustinus & Colhoun 1986, Kiernan 1990c), and the Vale of Belvoir is of particular significance as it is one of only a couple of locations in Tasmania where Cainozoic glacial sediments dated to pre-Pliocene (mid-Cainozoic?) age have been identified (Augustinus & Idnurm 1993), thus providing rare direct evidence of the earliest phases of the Late Cainozoic Ice Ages glacial advances in Tasmania. Lake Lea, in the Vale of Belvoir, is a limestone-floored glacio-karstic lake with elements of karst hydrology, yet probably at least partly owes its origin to glaciation.

The Mt Cripps – Vale of Belvoir area exhibits well developed karst, glacial and glacio-karst phenomena in a largely undisturbed environment immediately adjacent the TWWHA. These karst and glacial phenomena are outstanding exemplars that contribute significantly to the Ongoing Karst Geomorphic Process Systems, Glacial and Glacio-fluvial Landforms and Glacio-karstic Phenomena World Heritage sub-themes, and to the Diverse Karst Landforms and Process Systems World Heritage theme.

Non-contiguous Magnesite Karst Areas
The review of the Diverse Karst Landform and Process Systems theme (Section 3.2.2 above) noted that Tasmania possesses globally-rare karst systems developed in magnesite carbonate bedrock in north-western Tasmania, which display large scale ongoing hydrothermal karst processes and Tertiary-age palaeo-karst (Houshold et al. 1999). None of these magnesite karsts are currently reserved for conservation or included within the TWWHA boundary, yet several well-developed magnesite karsts occur in undisturbed old-growth forested catchments and hence have the potential to be major contributing elements to both the Ongoing Karst Geomorphic Process Systems sub-theme and Diverse Karst Landform and Process Systems theme. The global rarity of well-developed magnesite karst suggests that inclusion of a well-developed undisturbed magnesite karst into the TWWHA would constitute a major augmentation of these significant World Heritage themes. An appropriate candidate may be the upper Lyons River magnesite karst area (Houshold et
Geoheritage Values – Tasmanian Wilderness World Heritage Area

*al.* 1999), which includes a major undisturbed karst warm spring, a variety of other karst landforms and palaeo-karst features, is situated in an undisturbed old-growth forest catchment, and immediately adjoins (but is excluded from) the existing Savage River National Park.

This karst system has high priority for effective conservation management (since no Tasmanian magnesite karst has any formal conservation reserve status as yet), and the incorporation of the area as a non-contiguous extension of the TWWHA would be one possibility for both recognising its important contribution to Tasmanian World Heritage values and also providing a framework for appropriate management of this important element of Tasmanian karst geodiversity.

**Non-contiguous Tertiary Plant Fossil Sites**

Tasmanian Tertiary and Quaternary – age palynological and palaeo-botanical sites provide key elements of the *Cainozoic Sedimentary and Palaeo-botanical Record* sub-theme of the *Late Cainozoic "Ice Ages" and Climate Change Record* World Heritage theme, of which a variety of geomorphic and sedimentary features in the TWWHA constitute a globally outstanding record of World Heritage significance (see *Late Cainozoic "Ice Ages" and Climate Change Record* theme discussions in Section 3.2.2). However, although most geomorphic elements of this theme are well represented in the TWWHA, in the case of Tertiary-age palaeo-botanical evidence many of the most important Tasmanian sites contributing to this theme are located outside the TWWHA boundaries (see Hill 1995, Jordan & Hill 1998), for example at the Little Rapid River, Regatta Point and Monpeelyata sites.

The palaeo-botanical sites outside the TWWHA are all small sites comprising limited areas of Tertiary-age fossil-bearing sediment deposits. The significance of sites such as these to the World Heritage *Late Cainozoic "Ice Ages" and Climate Change Record* theme is such that there is a case for recognising a suite of outstanding sites outside the contiguous TWWHA boundary as contributing to an important World Heritage theme whose other key elements are well represented within the TWWHA. These could comprise a system of non-contiguous sites worthy of recognition and management in sympathy with the TWWHA.