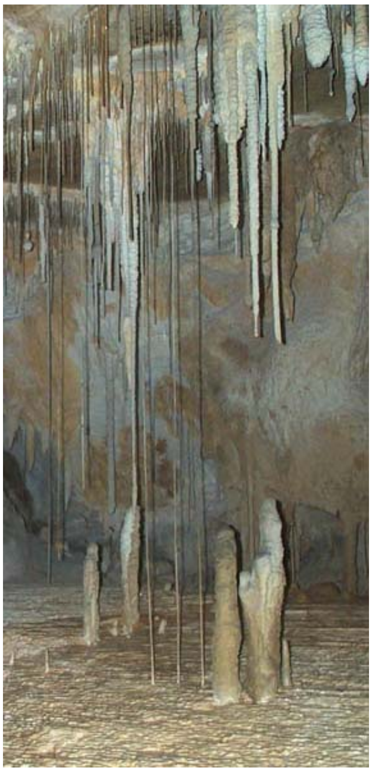
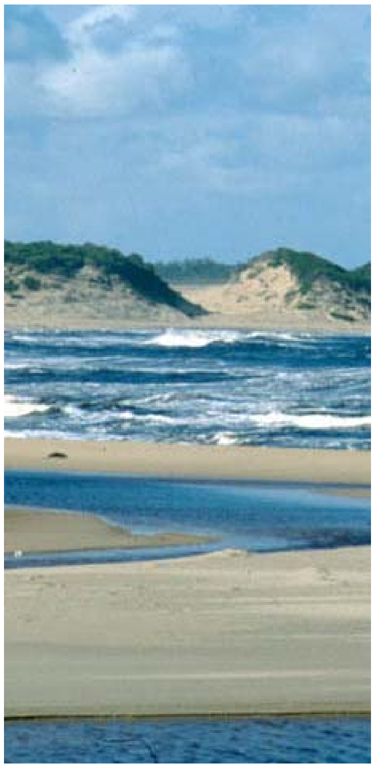
A REVIEW OF THE GEOCONSERVATION VALUES

OF THE

TASMANIAN WILDERNESS WORLD HERITAGE AREA

Chris Sharples

Nature Conservation Report 03/06

Nature Conservation Branch,
Department of Primary Industries, Water and Environment
2003

Tasmania

Front Cover: The front cover images depict several significant elements of the World Heritage geoconservation values of the Tasmanian Wilderness World Heritage Area (TWWHA):

Left: Speleothems in Exit Cave (TWWHA), Australia's longest mapped cave. Several different attributes of the TWWHA karst systems have outstanding universal value. Exit Cave exhibits an extraordinary diversity of karst phenomena, including evidence of distinct multiple phases of karst development stretching over roughly 400 million years, evidence of hydrothermal, sulphuric acid and glacial influences on cave development at different times, cave passages of very large scale and length, outstanding speleothem displays, and speleothems providing evidence of environmental changes spanning multiple Late Cainozoic glacial phases. The diversity and expression of multiple karst values in Exit Cave gives this cave outstanding universal value in its own right.

Centre: The upper Weld River in the TWWHA (shown here just upstream of the karstic Weld River Arch) is part of an almost entirely undisturbed fluvial geomorphic process system in which natural processes are operating at natural rates and magnitudes of change throughout a large old growth – forested catchment basin. Extensive regions displaying undisturbed ongoing geomorphic process systems such as this are a major geodiversity theme of World Heritage significance in the TWWHA. The undisturbed upper – middle Weld River catchment also contains extensive well-developed and diverse karst systems of large scale, including Tasmania's (and Australia's) currently second-deepest cave, which constitute another important undisturbed geomorphic process system of World Heritage significance.

Right: The eroding and receding barrier beach of Nye Bay, on the high-energy south-western TWWHA coastline. This beach is part of the longest sandy and rocky temperate zone coastline of its type free of significant anthropogenic process disturbances (other than global sea level rise related to anthropogenic climate change) in the southern hemisphere temperate zone. Due to their lack of human process disturbances (other than sea level rise) these sandy TWWHA shores have outstanding universal value as – amongst other things - "benchmark" undisturbed coastal geomorphic systems against which to compare processes on more disturbed coasts elsewhere. In particular, the foredune erosion evident in this photo is considered to be a response to sea level rise in the Twentieth Century, and undisturbed shores such as this provide a rare opportunity to monitor and study the effects of sea level rise on sandy shores whose geomorphic behaviour is not complicated by the effects of the many other anthropogenic process disturbances that influence coastal behaviour along much of the world's sandy shores.

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ISSN 1441-0680

Recommended citation:

SHARPLES, C., 2003: *A Review of the Geoconservation Values of the Tasmanian Wilderness World Heritage Area*; Nature Conservation Report 03/06, Department of Primary Industries, Water and Environment, Tasmania.

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SUMMARY

The Tasmanian Wilderness World Heritage Area (TWWHA) was nominated for, and inscribed on, the World Heritage List during 1989. The nomination, which incorporated a smaller area previously inscribed on the World Heritage List in 1982, was partly based on geological, geomorphic and soil phenomena (geodiversity) of world significance ("outstanding universal value"). In respect of geodiversity, the 1989 nomination recognised World Heritage value primarily in assemblages of features and processes that collectively contribute to themes of global significance. Although in some cases individual sites or phenomena were considered to be of World Heritage value in their own right (eg, Exit Cave), in general it was the diversity, extent and inter-relationships between sites or processes belonging to a theme of world significance that were the major geodiversity factors endowing the TWWHA with World Heritage values.

Since the 1989 nomination a considerable amount of new scientific data has been collected in the TWWHA, the theoretical development of Geoconservation as a discipline has provided more rigorous methods of identifying and assessing geoheritage values, and the UNESCO World Heritage criteria have themselves been slightly revised. For these reasons a review of the geoconservation values of the TWWHA is now timely.

The collation of all previous inventories of Tasmanian geoheritage sites and systems into the Tasmanian Geoconservation Database (TGD) during 1996, and the ongoing updating and review of this database by an expert technical panel, has provided a particularly relevant and useful tool for this review of the geoheritage values of the TWWHA. With the exception of a few new geoheritage features and systems identified during the present study, the TGD provides a collation of all those sites, features and systems that have been identified to date as having geoheritage significance in the TWWHA, both prior to and since the 1989 TWWHA nomination.

The present project has involved a review of the geoheritage aspects of the 1989 TWWHA nomination, and new data collected since 1989 has been reviewed to identify any new geoconservation values (at all levels of significance) that are now evident. These reviews indicate that the main World Heritage geodiversity themes identified in 1989 are justified, although some minor values identified in the 1989 nomination could not be justified on available information as having outstanding universal value. Additional features contributing to the significance of World Heritage themes have been identified or better understood since 1989, and some World Heritage themes have gained greater prominence in the light of new information. It is notable, however, that no entirely new World Heritage geoconservation themes or values that were not at least flagged in the 1989 nomination, have been identified for the TWWHA during this review. It is likely that this is at least partly because most scientific research conducted in the TWWHA since the 1989 nomination has been directed towards facilitating better management of those very World Heritage value themes for which the TWWHA was inscribed in the World Heritage List. That is, the focus of research has been upon improving understanding and management of the known values, rather than identifying completely new values, if any, that may be potentially present.

On the basis of the present (2002 - 2003) review, the geodiversity themes of the TWWHA that can be considered to be of World Heritage value (that is, "of outstanding universal value") mostly qualify under criterion (i) of the current World Heritage Convention Operational Guidelines, namely:

> "(i) 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;" (UNESCO 1999, p. 10-11, paragraph 44)

Some features and themes additionally qualify under criterion (iii), namely:

> "(iii) contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;" (UNESCO 1999, p. 10-11, paragraph 44)

The geomorphic and soil features of the TWWHA form the basis for biological habitats, and thus can be considered to contribute to (primarily biological) World Heritage values under criteria (ii) and (iv). However, this review (and the original 1989 TWWHA nomination) has only specifically identified geodiversity-based values related to biological habitat under criterion (iv), in those cases where the special geological, geomorphic or soil characteristics of habitats have played a particularly critical role in the evolution or existence of biota of outstanding universal value in those habitats:

> "(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; " (UNESCO 1999, p. 10-11, paragraph 44)

An important outcome of the present review is that it has re-emphasised the fact 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. 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[1], 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).

It is also noteworthy that the most important 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[2].

Geodiversity Themes of World Heritage Significance

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. Consequently the present review has devoted 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.

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 listed below[3]:

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[1] The extent of some northern hemisphere blanket bogs outside Europe is poorly known, hence firm comparative figures are unavailable for these.

[2] One bedrock geology theme in Tasmania which is considered (Large 1992, p. 118) to rank amongst the best at world levels is the scale of volcanic – hosted massive sulphide (VHMS) metallic mineralisation in the Cambrian-age Mount Read Volcanics of western Tasmania; however, the most important mineralisation in this rock unit lies outside the TWWHA, and unsurprisingly has not been subject to formal geoconservation significance assessments.

[3] See fuller explanations in Section (3.0).

Ongoing Natural Geomorphic and Soil Process Systems Theme

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, and in some parts of the TWWHA without effective disturbance inherited from past Aboriginal activities. These constitute an extensive, diverse and globally rare suite of on-going "benchmark" geomorphic and soil processes that have outstanding universal value (under Criterion i) in consideration of the fact that contemporary human activities have significantly disturbed natural geomorphic and soil processes in nearly all other comparable-sized areas in the temperate climatic zone regions of the world. The most nearly comparable undisturbed temperate environments elsewhere are subject to significantly different ongoing geomorphic processes influenced by present-day glacial processes. The high sensitivity of most of these process systems to human disturbance underscores their value as undisturbed systems. The undisturbed process system sub-themes that are of particular importance in the TWWHA include:

- *Ongoing Fluvial Geomorphic Process Systems*
  Undisturbed temperate fluvial process systems (including catchments) cover extensive parts of the TWWHA, and include a wide diversity of fluvial process systems including alpine, forested, karst-influenced and peat-land fluvial systems. Many of these systems have been strongly affected by past glacial and periglacial processes. These systems occur on a variety of bedrock substrates ranging from dolerite sheets and flat-lying sedimentary rocks to limestones and metamorphic and/or structurally complex dolomites, quartzites and schists which include the most extensive and well-expressed fold structure-influenced temperate fluvial system in Australia, namely the strike ridges, valleys and gorges of the Gordon River basin. Together, these diverse systems comprise the largest area of undisturbed temperate fluvial geomorphic process systems free of contemporary glacial and intense periglacial process influences[4] in the southern hemisphere and possibly globally. The undisturbed *Ongoing Fluvial Geomorphic Process Systems* sub-theme is for this reason of outstanding universal value, both in its own right and as an important contributor to the over-arching *Ongoing Natural Process Systems* theme.

  Unfortunately, the largest individual ongoing fluvial process system in the TWWHA, the Gordon River system, is partly disturbed by recent human activities and as such it's World Heritage value as an ongoing fluvial process system must be considered to be under threat. However, some of the Gordon's major tributary catchments (including the Denison, Maxwell and Olga river systems) remain entirely undisturbed. Numerous smaller individual undisturbed catchments contribute to the outstanding universal value of this sub-theme, whilst several catchments (the New-Salisbury River Basin and the Sorell – Pocacker – Spero Rivers tectonically-influenced peat-land fluvial system) are sufficiently important as to individually justify World Heritage significance in their own right (see further below).

- *Ongoing Blanket Bog Peat Land Soil Systems*
  The peat lands of the TWWHA comprise large parts[5] of the most extensive blanket bogs in the southern hemisphere, with large proportions of the system displaying undisturbed 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 TWWHA blanket bogs are also of a significantly different type to many other extensive

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[4] That is, they do not include contemporary glacio-fluvial (and intense periglacial) systems, in contrast to the most nearly comparable undisturbed temperate fluvial regions – in New Zealand and southern South America – where glacial and strong periglacial erosion, and glacio-fluvial outwash processes in many rivers, result in markedly different seasonal water flow, sediment transport and channel morphology regimes.

[5] Large parts of the Tasmanian blanket bogs also occur outside the TWWHA boundary.

examples elsewhere in the world, in that they are not primarily *sphagnum* bogs. Peat mounds at some locations are an associated and contributing phenomenon of national significance. The *Ongoing Blanket Bog Peat Land Soil Systems* sub-theme is of outstanding universal value in its own right, and as a contributor to the overarching *Ongoing Natural Process Systems* sub-theme.

- *Ongoing Coastal Geomorphic Process Systems*
  Almost the entire coast of the TWWHA displays ongoing high energy embayed rocky and sandy coastline geomorphic processes undisturbed 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 undisturbed by human activities other than those causing global sea level rise. The TWWHA sandy coastlines occur on the longest temperate zone "Roaring Forties" coast[6] undisturbed by human activities in Australia and probably the world, and so are of outstanding universal significance under Criterion (i) as the most extensive of only a few comparable stretches of temperate coastline globally where undisturbed natural sandy coastline processes can be observed. The *Ongoing Coastal Geomorphic Process Systems* sub-theme is of outstanding universal value both in its own right, and as a major contributor to the over-arching *Ongoing Natural Process Systems* World Heritage theme.

- *Ongoing Karst Geomorphic Process Systems*
  The TWWHA (and adjacent areas) karsts have outstanding universal value as 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. They have an exceptional scale of development (including some of the longest and deepest mapped caves, with some of the largest chambers, in the southern hemisphere) on a diversity of substrates (limestones and dolomites), in a diversity of topographic contexts (alpine to coastal); and they also provide habitat for significant cave-adapted fauna (Criterion iv). The scale of karst development on dolomite in Tasmania is globally unusual. The *Ongoing Karst Geomorphic Process Systems* sub-theme is of outstanding universal value both in its own right and as a significant contributor to the over-arching *Ongoing Natural Process Systems* World Heritage theme.

- *Ongoing Lacustrine Geomorphic Process Systems*
  A large number of undisturbed lakes with undisturbed catchment areas exist in the TWWHA, and have a wide variety of origins, including numerous glacial lakes, lakes on river floodplains including outstanding meromictic lakes such as those on the Lower Gordon River, karstic or glacio-karstic lakes such as Lakes Timk & Sydney, and both oligotrophic and dystrophic types. 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 (see "*Late Cainozoic Ice Ages*" and "*Outstanding Biological Habitats*" World Heritage themes). However, the value of the Lower Gordon meromictic lakes as ongoing process systems is threatened by artificial disturbance of the Gordon River's hydrology by hydro-electric development upstream.

- *Ongoing Periglacial Geomorphic Process Systems*
  Modern day active periglacial phenomena are limited to restricted alpine areas within the TWWHA, but provide important examples of modern – day temperate zone periglacial

[6] Temperate-zone sandy coasts (especially those in the "Roaring Forties" zone) 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.

processes in areas uninfluenced by contemporary glacial processes. Although of limited extent and diversity, and not clearly of outstanding universal value as an individual sub-theme in its own right, the *Active Periglacial Geomorphic Process Systems* sub-theme contributes significantly to the outstanding universal value of the over-arching *Natural Process Systems* World Heritage theme.

Apart from the intrinsic nature conservation value of these undisturbed process systems, the practical value of maintaining such undisturbed process systems as "benchmarks" or baseline sites is exemplified by the sandy coastal geomorphic systems of the TWWHA, which are likely to be particularly important in the coming decades as sites where the coastal effects of sea level rise can be directly monitored in locations where those effects are not complicated by the numerous other disturbing influences that human activities have had on many of the world's comparable coastlines.

"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. Nonetheless, the importance of certain geomorphic and soil features in providing habitat for important species of outstanding universal value is sufficient to warrant identifying these values as a World Heritage theme in their own right (under criterion (iv).

A number of important geomorphic features have been shown to have been important glacial or interglacial refugia for species of World Heritage significance (caves, lakes, alpine areas), and some have provided isolated environments within the TWWHA that have resulted in significant genetic and phenotypic variation in modern populations across the region (especially offshore island, caves, lakes and mountain tops).

Notable examples of significant landforms under this theme include karst caves, glacial and meromictic lakes, isolated mountaintops, offshore islands, and the unique environment of Bathurst Harbour, whose unusual biological habitats are strongly dependant on the origin of the Harbour as a flooded river/plain system.

Late Cainozoic "Ice Ages" and Climate Change Record Theme

Tasmania's tectonic stability, maritime climate and diversity of 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 sensitive and well-preserved[7] temperate – zone record of a major stage of earth's history, the Late Cainozoic "Ice Ages". The scale, diversity, sensitivity and degree of preservation of the Late Cainozoic geomorphic and geological record in the TWWHA is of outstanding universal value in a global context (Criterion i). 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, fluvial and coastal features are also known in the TWWHA 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.

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[7] Tasmania's maritime climate has resulted in more sensitive geomorphic responses to Late Cainozoic climatic changes than are found in more continental environments, whilst tectonic stability has resulted in better preservation of this record compared to the most comparable other undisturbed temperate maritime environments such as New Zealand and Patagonia, which are tectonically active orogenic zones; see also Section (3.2.2).

Important contributing elements (sub-themes) of the *Late Cainozoic Ice Ages and Climate Change Record* World Heritage theme in the TWWHA include:

- *Glacial and Glacio-fluvial Landforms*
  The highland areas and associated valleys of the TWWHA preserve an extensive and diverse assemblage of glacial landforms and deposits, together with related glacio-fluvial landforms and sediments (including extensive glacio-fluvial river terraces). These result in a spectacular glacial landscape which is one of the dominating aesthetic features of the TWWHA and is of outstanding universal value for exceptional natural beauty under Criterion (iii). At least as important, however, is the fact that the tectonic stability, maritime climate and diversity of geological, topographic and climatic environments within the TWWHA (compared to other glaciated temperate environments elsewhere) mean that the record of Late Cainozoic glaciation in the TWWHA is in important respects the most complete and sensitive record of temperate-zone Late Cainozoic glaciation available globally, which gives it outstanding universal value in its own right, as well as for its contribution to the broader *Late Cainozoic Ice Ages Record* World Heritage Theme, under Criterion (i).

- *Glacio-karstic Phenomena*
  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, 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 which is absent or not as well preserved in areas outside caves. This degree of inter-action between glacial and karst processes is rare in southern temperate glacial environments, and gives the glacio-karstic landforms and sedimentary deposits of the TWWHA outstanding universal value in their own right, as well as in contributing to the broader *Late Cainozoic Ice Ages Record* World Heritage Theme, under Criterion (i).

- *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 large 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.

- *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 studies have shown that the coastal regions of the TWWHA display an extensive suite of well-preserved uplifted Pleistocene marine terraces, palaeo-shorelines and associated marine and coastal aeolian (dune) deposits that preserve a record of climatic, tectonic and sea-level changes associated with the Late Cainozoic Ice Ages theme. 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 (see below). Much scientific work remains to be done to fully interpret these features, but the results of work to date and the extent and diversity of Pleistocene coastal features known to

exist, ensures that these coastal landforms have outstanding universal value under Criterion (i) as a record of processes and environmental changes during the Late Cainozoic.

Parts of the TWWHA coast such as Port Davey also strongly exemplify the characteristics of coasts formed by the (interglacial) flooding of terrestrial landscapes formerly exposed during glacial phases. Port Davey – Bathurst Harbour is an outstanding example of a "ria" coast, or flooded fluvial landscape.

Although it is not clear that the Late Cainozoic Coastal Landforms sub-theme can be attributed outstanding universal value in its own right, the information available from the study of these features complements that available from the glacial and glacio-karst landforms of the TWWHA, thereby contributing significantly to the *Late Cainozoic Ice Ages Record* World Heritage Theme that is of outstanding universal value for the diversity of phenomena relating to the Ice Ages theme to be found within the TWWHA (i.e., the glacio-karst and coastal features provide a record of aspects of the "Ice Ages" theme that complements and adds to the glacial record rather than simply repeating it).

Many of the coastal features resulting from this complex geomorphic history (including numerous terraces and the flooded landscape of Port Davey – Bathurst Harbour) contribute significantly to the outstanding aesthetic values of the TWWHA (Criterion iii).

- *Cainozoic Sedimentary and Palaeobotanical Record*
  Cainozoic sediments including lacustrine and fluvial deposits have yielded palynological and palaeobotanical evidence which contributes strongly to understanding environmental changes during the Late Cainozoic "Ice Ages" phase of Earth's History. Of particular note is the Quaternary sedimentary record in the now-infilled but formerly lacustrine Darwin meteorite Crater, which provides one of the longest unbroken sedimentary records for the Quaternary in the TWWHA. Whilst the Cainozoic sedimentary and palaeo-botanical record of the TWWHA is not necessarily of World Heritage value in itself, it contributes significantly to the Late Cainozoic Ice Ages theme which is overall of World Heritage significance.

Diverse Karst Landform and Process Systems Theme

Whilst aspects of the TWWHA karst systems are significant under the Ongoing Processes theme (for undisturbed ongoing karst processes) and the Cainozoic Ice Ages Theme (for outstanding examples of glacio-karst interactions), the karst systems of the TWWHA are also of outstanding universal value as a theme in their own right because of the scale and diversity of well-developed and well-expressed phenomena which they display that are significant under Criteria (i), (iii) and (iv) of the current World Heritage criteria.

The karst systems of the TWWHA have an exceptional scale of development (including some of the longest and deepest mapped caves, with some of the largest chambers, in the southern Hemisphere) on a diversity of substrates (limestones and dolomites), in a diversity of topographic contexts (alpine to coastal); and they provide palaeokarst evidence of at least 4 successive phases of cave development over a time span of around 400 million years, including phases of hydro-thermal cave development as well as development in response to normal meteoric waters. Karst systems of the TWWHA have very high aesthetic values (criterion iii) in virtue of landform scale and speleothems.

The karst systems of the TWWHA are also related to and provide the basis of other World Heritage values in that they contain important sub-fossil deposits including Pleistocene megafauna, they include important Pleistocene Aboriginal occupation sites which are of cultural World Heritage significance, and they provide habitat for significant cave-adapted fauna (some of which evolved in the caves in response to glacial climatic conditions).

Geodiversity Sites and Areas within the TWWHA that are individually of World Heritage Significance

Whilst most of the numerous individual features or sites contributing to the World Heritage themes listed above do not have World Heritage significance in isolation, but rather as contributing components of broader World Heritage themes, a number of sites or features belonging to these themes exemplify the important characteristics of their theme to such a high degree that they can arguably be attributed World Heritage value in their own right. Whilst all features or areas contributing to World Heritage geodiversity themes are worthy of appropriate management to protect the geoconservation values of their themes, the individual sites and areas listed below, which are exemplars of World Heritage geodiversity themes that are so well developed as to be *individually* of World Heritage value, should for that reason be accorded especially high priority for protective management of their geodiversity values. These individual sites or areas include:

- *Exit Cave*
  Significant for ongoing karst processes relating to undisturbed ongoing processes theme (Criterion i), glacio-karst interactions relating to the Cainozoic Ice Ages theme (Criterion i), multiple phases of palaeokarst development (including possible hydrothermal development) relating to the diverse karst theme (Criteria i & iii). Exit Cave is of World Heritage significance in its own right because of the exceptional diversity and scale of development of characteristics contributing to these themes. Undisturbed karst processes in Exit Cave were formerly under threat due to quarrying, however the cessation of quarrying and a successful program to restore the operation of natural processes has abated this threat.

- *Mt Anne (North East Ridge) Glacio-karst*
  This site is also included in a broader "Weld River Catchment Basin Fluvial and Karst" site (below) which is highlighted as of individual outstanding universal value for its extensive area of ongoing natural fluvial and karst processes; however the Mt Anne glacio-karst is in itself of so outstanding a character that it is considered to have outstanding universal value in isolation. Significant for ongoing karst processes relating to the undisturbed Ongoing Geomorphic Processes theme (Criterion i), for glacio-karst interactions relating to Cainozoic Ice Ages theme (Criterion i) and for its exceptional scale of development and characteristics relating to "Diverse Karst Landform and Process Systems" theme (Criteria i & iii). Mt Anne North East Ridge karst system is of World Heritage significance because of the exceptional scale of development of characteristics relating to these themes.

- *Lake Pedder* (the natural lake).
  Outstanding universal value under Criterion (i) as a globally unique landform produced by glacio-fluvial processes (part of the *Late Cainozoic Ice Ages* World Heritage theme). Outstanding universal value under Criterion (iii) as a superlative glacial landform, and for its exceptional natural beauty and aesthetic importance. Despite inundation, the glacio-fluvial lacustrine geomorphology remains currently intact and ongoing geomorphic processes are potentially restorable, thus the outstanding universal value of the lake arguably remains intact; however current inundation of the lake beneath a hydro-electric impoundment represents a long term threat to its World Heritage values.

- *New-Salisbury River Basin Fluvial and Karst Process Systems*
  Largest entire (source to sea) ongoing fluvial process system (catchment basin) effectively undisturbed by either Aboriginal or European human disturbances in the TWWHA. Outstanding universal value under Criterion (i) as the most extensive entirely undisturbed ongoing temperate fluvial process system in Australia and probably comparable to the best examples globally. A diversity of bedrock substrates in different parts of the catchment (dolerite sheets and flat-lying sedimentary rocks to the east, folded and metamorphosed quartzite/schist associations to the west, and pristine karst systems developed on dolomite to the west and limestone in the east/central part)

enhance the value of this area for exemplifying a variety of undisturbed fluvial and karst process types within the one large undisturbed catchment basin. The extensive high-relief hill flank karst of the Precipitous Bluff – Salisbury River (Vanishing Falls) area, within this catchment basin, is particularly important as potentially the most extensively developed undisturbed Ordovician limestone karst in the TWWHA, and includes Tasmania's most spectacular karst stream sink at Vanishing Falls. Satellite Lake - within the New River catchment - is an undisturbed ongoing lacustrine geomorphic process system which has high potential significance for Holocene palaeo-climatic and palaeo-environmental studies based on lake sediments in a pristine lake (significant as part of Late Cainozoic Ice Ages theme).

- *Weld River Catchment Basin Undisturbed Karst Process System*
  This system lies in a large undisturbed old-growth forested fluvial catchment basin and comprises extensive moderate to high relief areas of Precambrian dolomite containing known karst development at large scales. Much of the dolomite is unexplored, and has considerable potential for further extensive as-yet unexplored karst systems. The system includes the Mt Anne (North East Ridge) Glacio-karst system identified above as having World Heritage value in its own right, which includes the second-deepest cave currently known in Australia. The scale of the karst area, in its context of an undisturbed catchment basin, makes this karst the most extensive known and potentially intensely karstified area within the TWWHA, and thus one of few ongoing undisturbed karst systems of such extent globally.

- *Birches Inlet – Sorell – Pocacker- Spero River Tectonically-influenced Peat Land Fluvial System*.
  Ongoing peat-land fluvial process system displaying outstanding assemblages of river terraces and related marine terraces (at Birches Inlet / Macquarie Harbour) exemplifying tectonic control of fluvial system development with excellent preservation of features due to peat land processes. Significant under Criterion (i) as an outstanding tectonically-influenced on-going peat land fluvial process system, and under Criterion (iii) as a superlative natural phenomenon.

- *Lower Gordon levee-flood basin-meromictic lakes.*
  Significant under Criterion (i) as an outstanding ongoing fluvio-lacustrine process system, and under Criterion (iv) as significant habitats. However, the World Heritage values of these lakes under the *Ongoing Natural Processes* and *Outstanding Biological Habitats* themes are under threat as a result of human disturbance of Gordon River fluvial process system.

- *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.

- *Cynthia Bay Thule-Baffin Moraines*
  The Cynthia Bay Thule-Baffin moraines have outstanding universal value in their own right under Criterion (i) 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.

Themes and sites requiring further significance assessment

The following themes and sites were cited as contributing to the World Heritage value of the TWWHA in the 1989 nomination, however their significance was not established. Further assessment is required to confirm or reject the World Heritage significance of these features (see section 4.5.1):

- *Ordovician Stratigraphy/palaeo-environment theme*
- *Permo-Carboniferous Glaciation theme*
- *Gondwana Break-up Theme*
- *Weld Valley Group (& correlates in TWWHA – eg, Jane Dolomite, Hastings Dolomite) dolomites and mixtites Theme*
- *Denison Range Cambro-Ordovician fan-delta flysch sequence*
- *Adamsfield Trough tectonic melanges*

In addition, a number of localised site features have been assigned "world" level significance, as individual sites, on the Tasmanian Geoconservation database subsequent to 1989. These features do not contribute to any broader themes of World Heritage significance identified to date, and further review of their significance as isolated sites is needed before they can be cited having World Heritage significance in their own right (see section 4.5.1). These sites are:

- *Collingwood River White Schist*
- *Reward Creek mineralisation*
- *Adamsfield Workings Mineralogy*

World Heritage Geoconservation Values in Reserves Adjoining the TWWHA

Twenty one small reserves adjoining the TWWHA have been created since 1989, many of them as an outcome of the Tasmanian Regional Forest Agreement (1997). These have been assessed to determine the degree to which they possess geoheritage features that are of World Heritage value, in particular because of inclusion of features contributing to the World Heritage Themes (above) that have been identified within the present TWWHA boundaries. The World Heritage geodiversity values that can be identified within each of these reserves are summarised below (the specifics of the identified values are described in Section 3.3).

Most of these areas have previously been recommended for inclusion in the TWWHA (DPWH 1990). All of the 21 reserves contain features contributing to one of more of the recognised TWWHA World Heritage geodiversity themes, which is unsurprising since they adjoin areas of the TWWHA with these values and many were reserved due in part to their undisturbed natural condition. Hence they are all recommended for inclusion in an extended Tasmanian Wilderness World Heritage Area boundary on this basis.

New Reserved Area	World Heritage Geodiversity values
Mole Creek National Park	
Several discrete reserved areas outside TWWHA	*Karst* theme and sub-themes: integral portions of Mole Creek Karst, one of the most extensive and well-developed karsts in Tasmania, which is an outstanding exemplar of the TWWHA World Heritage karst values.
Cradle Mountain – Lake St Clair National Park additions	
Dove River	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: essentially undisturbed fluvial process area. *Glacial and Glacio-fluvial Landforms* sub-theme: potential for glacial landforms and deposits.

Mersey Valley (two small blocks at Lees Paddocks)	*Glacial and Glacio-fluvial Landforms* sub-theme: glacial landforms and deposits.
Franklin – Gordon Wild Rivers National Park additions	
Navarre Plains	*Glacial and Glacio-fluvial Landforms* sub-theme: glacial landforms and deposits.
Beech Creek (very small area)	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: undisturbed old-growth forested fluvial process area.
Beech Creek – Counsel River (large area)	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: large undisturbed old-growth forested fluvial process area. *Glacial and Glacio-fluvial Landforms* sub-theme: potential for glacial landforms and deposits.
Counsel River (small area)	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: undisturbed old-growth forested fluvial process area.
Tiger Range	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: undisturbed old-growth forested fluvial process area; also part of a prominent strike ridge belonging to the TWWHA strike ridge and valley fluvial landform system which contributes significantly to the fluvial process sub-theme.
Nelson Falls	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: possibly partly disturbed by past logging for smelter fuel (requires further assessment), however area includes outstanding undisturbed waterfall landforms which contribute to the fluvial geomorphic process theme.
Southwest National Park additions	
Hartz "Hole"	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: integral part of large undisturbed old-growth forested upper Picton fluvial system. Possible but undemonstrated contribution to *Karst* theme and sub-themes, *Glacial and Glacio-fluvial Landforms* sub-theme, and potentially *Glacio-karstic Phenomena* sub-theme.
South-east of Cockle Creek	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: several small undisturbed catchment areas. *Ongoing Blanket Bog Peat Land Soil Systems* sub-theme: deep blanket bogs in Blowhole Valley. *Ongoing Coastal Geomorphic Process Systems* sub-theme: undisturbed rocky coastline. *Late Cainozoic Coastal Landforms and Sediments* sub-theme: Blowhole Valley relict headland bypass dune system.
Little Florentine River	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: undisturbed old-growth forested fluvial process area. *Glacial and Glacio-fluvial Landforms* sub-theme: glacial landforms & deposits in unusual topographic position. *Karst* themes, *Glacio-karstic Phenomena* sub-theme: unconfirmed potential karst and glacio-karst features.

Styx River	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: undisturbed upper catchments of Styx River. *Karst* theme and sub-themes: well developed karst in Precambrian dolomite, including the only polygonal karst currently known in Tasmanian Precambrian dolomite.
Blake's Opening	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: area completes inclusion of entire undisturbed Manuka Creek catchment in the TWWHA, plus several other smaller undisturbed catchment areas. *Karst* theme and sub-themes: incorporates most of Mt Picton – Blake's Opening dolomite into TWWHA, which has known karst, and potential for the deepest caves in Australia. *Glacial and Glacio-fluvial Landforms* sub-theme: contains pre-Last Glaciation glacial deposits at Blake's Opening. *Glacio-karstic Phenomena* sub-theme: potential for glacio-karst phenomena (unconfirmed).
Cook Rivulet / Creek	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: undisturbed old-growth forested fluvial process area.. *Karst* theme and sub-themes: high probability of karst in Precambrian dolomite. *Glacial and Glacio-fluvial Landforms* sub-theme: glacial landforms present. *Glacio-karstic Phenomena* sub-theme: good likelihood of glacio-karstic phenomena.
Farmhouse Creek	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: undisturbed old-growth forested fluvial process area. *Karst* theme and sub-themes: likely catchment of adjoining TWWHA karst area. *Glacial and Glacio-fluvial Landforms* sub-theme: glacial landforms and sediments present.
East Picton	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: important undisturbed old growth - forested fluvial process area. *Glacial and Glacio-fluvial Landforms* sub-theme: potential glacial features (unconfirmed).
Hastings Caves (**note:** *not* to be confused with Hastings Caves State Reserve, which adjoins but is not the same area as this proposed extension area; see also further below.)	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: several undisturbed catchment areas. *Karst* theme and sub-themes: well developed karst in Precambrian dolomite. *Glacial and Glacio-fluvial Landforms* sub-theme: low altitude terminal moraine deposit complex in Hot Springs Creek valley.
D'Entrecasteaux River	Little-known area which includes areas disturbed by historic logging and possibly burning.; *Karst* theme and sub-themes: probable plains karst (unconfirmed by highly likely). *Glacial and Glacio-fluvial Landforms* sub-theme potential glacial and glacio-fluvial features (unconfirmed but likely). *Glacio-karstic Phenomena* sub-theme: glacio-karstic phenomena possible but unconfirmed.

Catamaran River	*Ongoing Fluvial Geomorphic Process Systems* sub-theme: includes areas disturbed by historic logging and probably firing, but also includes undisturbed old-growth forested fluvial process areas. *Glacial and Glacio-fluvial Landforms* sub-theme: speculative (only) possibility of glacial features.
State Reserve addition	
Devils Gullet	*Glacial and Glacio-fluvial Landforms* sub-theme: part of World Heritage Central Plateau Glacial Terrain, glacial sediments and landforms likely to be present. *Periglacial Landforms* sub-theme of *Late Cainozoic Ice Ages* theme: periglacial slope deposits present, periglacial mass movement features (related to known features nearby) may be present.

Other Areas Adjacent the TWWHA with Features Contributing Significantly to TWWHA World Heritage Geoconservation Themes

It is strongly recommended that the following existing reserve abutting the Hastings Caves recommended TWWHA extension (above) be also incorporated within the TWWHA boundaries as a logical rationalisation of the TWWHA boundary (see Section 3.4):

- *Hastings Cave State Reserve*: Very well developed and accessible exemplar of karst developed in Precambrian dolomite, including ongoing hydrothermal karst processes that are poorly represented within the current TWWHA boundaries. This addition would contribute significantly to the TWWHA *Karst* theme and sub-themes, and this area has previously been recommended for inclusion in the TWWHA (DPWH 1990).

The following additional areas, mostly adjacent the existing TWWHA or recommended TWWHA extensions (above), contain major exemplars of or extensions to World Heritage geoconservation value themes recognised within the existing TWWHA boundaries. Most (but not all) of these areas have previously been recommended for inclusion in the TWWHA (DPWH 1990). It is recommended that the implications of the management and tenure of these areas for the integrity of recognised TWWHA geoconservation values be considered with a view to ensuring sympathetic cross-tenure management and, where appropriate, possible future rationalisation of land tenures and / or TWWHA boundaries (see descriptions of values in Section 3.4):

- *Riveaux Karst (Middle Huon Valley)* (outstanding karst and probable glacio-karst)
- *Mole Creek Karst* (additional parts of karst outside existing reserve boundaries)
- *Melaleuca Conservation Area Blanket Bogs, Peat Mounds and Undisturbed Coast* (values contiguous with equivalent values within adjacent TWWHA boundary)
- *Birches Inlet – Sorell – Pocacker / Spero River Tectonically-Influenced Peat Land Fluvial System* (additional portions of outstanding TWWHA fluvial geomorphic system, extending beyond existing TWWHA boundary)
- *Tyndall Range – West Coast Range Glacial Areas* (outstanding "type area" for glaciation in Tasmania)
- *Mt Field National Park – Junee River Karst* (outstanding glacial, karst, & glacio-karst features)
- *Mt Cripps – Vale of Belvoir Glacio-karst* (outstanding karst, glacial and glacio-karst phenomena)
- *Non-contiguous Magnesite Karst Areas* (globally rare well-developed magnesite karst, which is currently entirely unreserved in Tasmania, yet contributes strongly to the TWWHA *Diverse Karst Landform and Process Systems* theme)
- *Non-contiguous Tertiary Plant Fossil Sites* (Scattered suite of small Cainozoic palaeo-botanical sites of world significance)

A brief summary of key threats to the integrity of geoheritage in the TWWHA, and appropriate management responses, is provided in Section (4.3) of this report, whilst Section (4.5) highlights key areas for further research and assessment that are required to support protection of TWWHA geoconservation values. Section (4.6) identifies a number of elements of geodiversity in the TWWHA that have been recommended for new or upgraded listing on the Tasmanian Geoconservation Database (TGD).

1.0 INTRODUCTION

Scope

This report reviews the geoconservation values of the Tasmanian Wilderness World Heritage Area (TWWHA),with particular emphasis on the identification and review of geoconservation values of World Heritage significance.

The concept of geoconservation (and the related terms "geodiversity" and "geoheritage") are discussed in more detail in Sections (2.1) and (2.2) of this report. In essence, the focus of geoconservation is on the conservation of bedrock (geological) landform (geomorphic) and soil features and processes for their own intrinsic value as natural systems, because of the essential and integral role they play in permitting biological systems to exist and flourish, and for a range of other utilitarian, aesthetic and scientific values they have to humans. From the perspective of geoconservation, Nature Conservation can be seen as having at least two primary, interdependent and complementary aspects, namely *Geoconservation* and *Bioconservation*.

The current TWWHA was successfully nominated for inclusion on the UNESCO World Heritage List in 1989 (DASETT 1989) as an expanded re-nomination of the smaller Western Tasmanian Wilderness National Parks World Heritage Area that had been recognised since 1982. Although the term was not used in the 1989 nomination, geoconservation values formed a significant part of the World Heritage values for which the TWWHA was inscribed on the World Heritage List (see Section 2.3 below). However, subsequent to the 1989 TWWHA nomination, a great deal of new scientific research and data gathering has taken place in the TWWHA, and in addition there have been significant advances in the theory and practice of geoconservation significance assessment and management in Tasmania and overseas (see Sections 2.2 & 2.4). As a result of these advances, both a more comprehensive database and a more rigorous theoretical basis upon which to assess the geoconservation values and significance of the TWWHA is now available than was the case in 1989 (in particular, the collation of all previous inventories of Tasmanian geoheritage sites and systems into the comprehensive "Tasmanian Geoconservation Database" during 1996, and the ongoing updating and review of this database by an expert technical panel, has provided a particularly relevant and useful tool for this review of the geoheritage values of the TWWHA; see Section 2.4). Moreover, the criteria for assessing World Heritage values have themselves also been updated since 1989 (see Section 2.3.3), and there is consequently a need to review the values of the TWWHA in the light of the new updated criteria (until such a review is conducted, the old World Heritage criteria will continue to formally apply to the TWWHA: PWS 1999, p. 22).

Partly for these reasons, one of the ten key focus areas of the current Tasmanian Wilderness World Heritage Area (TWWHA) Management Plan (PWS 1999, p. 32-33, 51-52, 74-75) is to review the recognised conservation values of the TWWHA, and to update, re-evaluate and add to these as appropriate in the light of more recent information, including research that has occurred since the nomination of the World Heritage Area. The Management Plan requires that the conservation values of the TWWHA be reviewed at all levels, ie. at regional, state and national significance levels as well as at the level of World Heritage values (PWS 1999, p. 32-33; 52). However World Heritage values have priority in the management of the TWWHA, and where new World Heritage level values are identified, or previously recognised values are better understood, the improved knowledge may facilitate identification of more appropriate boundaries and management prescriptions for the area.

The project reported upon in this volume comprised a review of the geoconservation values of the TWWHA that is intended to satisfy the relevant key focus area of the TWWHA Management Plan in respect of geoconservation values. The main aims of the project were as follows:

1. To review the geoconservation values which were identified in the1989 Tasmanian Wilderness World Heritage Area (TWWHA) nomination (DASETT 1989) in the light of updated scientific information and significance assessment procedures available in 2002.

2. To review geoscientific reports and similar work conducted in the TWWHA (especially subsequent to the existing TWWHA nomination), and on the basis of such information determine whether additional geoconservation values (at all levels from local to world significance) can now be identified that were not previously identified in the 1989 TWWHA nomination.

3. Identify ongoing and future research priorities for the TWWHA, targeting critical gaps in knowledge, which will improve understanding of, and the ability to successfully manage and protect TWWHA geoconservation values.

4. Identify and investigate threats or threatening processes to geoconservation values in the TWWHA.

The scope of this report encompasses all the areas and reserves within the boundaries of the TWWHA as nominated in 1989, and as subsequently inscribed on the UNESCO World Heritage list. The report also considers the values of a number of small reserves contiguous with the TWWHA, that have been created since 1989 (many of them as an outcome of the Tasmanian Regional Forest Agreement 1997). These include the 15 contiguous reserves listed on p. 15 of the 1999 TWWHA Management Plan (PWS 1999), and portions of the Mole Creek Karst National Park that lie outside the TWWHA boundary (see Section 3.3). Some consideration is also given to the degree to which World Heritage geoconservation values extend beyond the TWWHA boundaries to other areas not currently reserved, or in non-contiguous reserves (See Section 3.4).

Structure of this report

Brief summaries of the history of Geoconservation in Tasmania, and of the philosophy and methods of geoconservation significance assessment, are presented in Sections (2.1) and (2.2); this is considered warranted because, firstly, geoconservation values have played a major historical role in the development of perceptions of environmental values in Tasmania and Australia (Section 2.1), yet until recently most of the theoretical development of conservation value assessment methodologies has focussed on bioconservation, hence there is a need to explicitly establish the methodological rationales for geoconservation (Section 2.2).

The geoheritage values which were cited in the 1989 TWWHA nomination (DASETT 1989) as justification of World Heritage value are listed in Section (2.3.2), and the degree to which those values were justified (in the nomination) under the World Heritage Criteria then in force is briefly reviewed and assessed.

The current (updated) World Heritage Criteria (UNESCO 1999) are reproduced in Section (2.3.3) The available scientific data pertaining to themes of potential World Heritage significance in the TWWHA is identified in Section (2.4), including a review of new data that has become available subsequent to the 1989 nomination.

Section (3.2) identifies geoheritage values of World Heritage significance that can be justified in the TWWHA under the current criteria and in the light of currently available data. Descriptions, condition and integrity, and justification of each value are detailed in Section (3.2.2). The geoheritage values of new reserve areas proposed for addition to the TWWHA are reviewed in section (3.3), and recommendations for additions to the TWWHA are made in section (4.2). Specific relevant geoheritage features of the TWWHA which are listed in the Tasmanian Geoconservation Database are noted in Appendix (A1.0), and recommendations for additions to the TGD based on the current assessment are noted in Section (4.6).

Some geoheritage values listed in the 1989 nomination have been assessed to not be of World Heritage significance, and these are noted in Section (2.3.2). However, some geoheritage values identified in the 1989 nomination – which were not adequately justified in that nomination – require further assessment for confirmation or rejection of their World Heritage value; these are listed as requiring further assessment in Section (4.5).

Threats to established World Heritage geoconservation values, and appropriate management responses, are identified in Section (4.3). Some opportunities and constraints for interpretation and presentation of World Heritage geoconservation values are briefly noted in Section (4.4). Important areas of scientific research aimed at improving understanding and management of identified World Heritage geoconservation values, or at better assessment of World Heritage values in the TWWHA generally, are identified in Section (4.5).

Glossary of terms and acronyms

DPIWE Tasmanian Department of Primary Industries, Water and Environment.

Geodiversity "The natural range (diversity) of geological (bedrock) geomorphological (landform) and soil features, assemblages, systems and processes. Geodiversity includes evidence for the history of the earth (evidence of past life, ecosystems, and environments) and a range of processes (biological, hydrological and atmospheric) currently acting on rocks, landforms and soils." (Eberhard 1997b, p. v).

Geoconservation "The identification and conservation of geological, geomorphological and soil features, assemblages, systems and processes (geodiversity) for their intrinsic, ecological or heritage values." (Eberhard 1997b, p. v).

Geoheritage " Those components of geodiversity that are important to humans for purposes other than resource exploitation; things we would wish to retain for present and future generations." (Eberhard 1997b, p. v).

TGD Tasmanian Geoconservation Database (see Section 2.1)

TGDRG Tasmanian Geoconservation Database Reference Group (see Section 2.1)

TWWHA Tasmanian Wilderness World Heritage Area as nominated (DASETT 1989) and declared by UNESCO.

WHA World Heritage Area as informally referred to in the current Management Plan (PWS 1999); comprises the declared TWWHA plus contiguous reserves that have not yet been formally added to the TWWHA.

Acknowledgments

Whilst the information, assessments and review contained in this report are based partly only on a recent literature review, this is by no means their sole source. Beginning with a 1971 visit to the natural Lake Pedder (Figure 1) prior to it's inundation, over thirty years of bushwalking, liloing, caving, climbing, flying and BASE jumping in the Tasmanian Wilderness World Heritage Area have all played a part in familiarising me with the values described in this report. Numerous discussions - some over many years - with Max Banks, Grant Dixon, Rolan Eberhard, Ian Houshold, Kath Jerie, Kevin Kiernan, Mike Pemberton, Kerry Bridle and others have provided me with a great deal of the geological, geomorphic and pedological information and understanding that has allowed the production of this review. Much of the philosophical and methodological discussion of geoconservation principles provided in Sections (2.1) and (2.2) is a summary of a longer document that I have previously "published" on the World Wide Web (on the Tasmanian Parks and Wildlife Service website), but which has not previously been available in a traditional paper form.

2.0 THE BASIS FOR THE IDENTIFICATION OF GEOHERITAGE AND GEOCONSERVATION VALUES IN THE TASMANIAN WILDERNESS WORLD HERITAGE AREA

2.1 Purpose of Geoconservation Significance Assessment Procedures, and their History in Tasmania

During the years since the 1989 TWWHA nomination, the concept of "Geoconservation" has undergone considerable theoretical and practical development, both within Tasmanian land management agencies and overseas. In Tasmania, considerable work during the 1990's was devoted to improving the rigor and justifiability of geoconservation significance assessment procedures, and to the collection of inventory data on features and natural systems of geoconservation significance throughout Tasmania, including within the TWWHA (e.g., Dixon 1991). As noted in the Introduction (Section 1.0), these developments provide the basis for a review of TWWHA World Heritage geoconservation values using data and procedures that have been considerably improved since 1989. This and the following sections (2.1 & 2.2) provide an introductory outline of the developments in geoconservation theory that have taken place in Tasmania since 1989[8].

Defining "Geoconservation"

The term "geoconservation" is being increasingly used in Australia, Europe and elsewhere to refer to the conservation of geological (bedrock) features, landforms and soils for their nature conservation values.

Geoconservation can be defined as: *the identification and conservation of geological, geomorphological and soil features, assemblages, systems and processes (geodiversity) for their intrinsic, ecological or heritage values*. (Eberhard 1997b, p. v)[9]. Geodiversity can be defined as: *The natural range (diversity) of geological (bedrock), geomorphological (landform) and soil features, assemblages, systems and processes. Geodiversity includes evidence for the history of the Earth (evidence of past life, ecosystems, and environments) and a range of processes (biological, hydrological and atmospheric) currently acting on rocks, landforms and soils* : Eberhard 1997b, p. v).

One of the important things to grasp about this definition of geoconservation is that it defines geoconservation as an approach which is philosophically distinct from some other earth science - based approaches to land management, such as 'Environmental Geology'. The latter discipline essentially focuses on utilitarian or anthropocentric values; that is, it seeks to predict, prevent or mitigate the degradation of landforms, soils and water quality by geomorphic hazards such as

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[8] More detailed theoretical discussion and bibliographies of geoconservation theory and practice are available on the Tasmanian Parks and Wildlife Service website (the geoconservation pages can be accessed at http://www.geoconservation.info)

[9] The writer considers the term 'Geoconservation' preferable to the alternative 'Geological Conservation', partly because it is shorter, but more importantly because the term 'Geological Conservation' can easily be construed to refer primarily to the conservation of *bedrock* geological features only (eg, fossil sites and other important bedrock exposures), whereas the use of the prefix 'geo-' is more likely to be broadly interpreted to encompass geomorphology (landforms) and soils as well as bedrock features. Similarly, roughly equivalent terms such as 'Earth Science Conservation' and 'Geological Heritage Conservation' are too restrictive since they imply that the reasons for conserving 'earthy' things lie purely in their scientific (research and education) or heritage values to humans, respectively, thereby downplaying the importance to conservation of the fundamental role they play in underpinning all ecological processes, and of their intrinsic values.

landslips, soil erosion, or karst subsidence, so as to minimise the impact such hazards may have on human aspirations for use of the land.

In contrast to this philosophically utilitarian approach, the focus of geoconservation is on preventing degradation in order to conserve bedrock, landform and soil systems for their value as natural systems, as well as for their utilitarian or scientific value to humans; that is it incorporates an ecocentric view of conservation values as well as an anthropocentric one. This approach also implies that nature conservation should be seen as having at least two primary and complementary aspects, namely *geoconservation* and *bioconservation*. All too often in the past it has been the case that nature conservation has been seen as being synonymous with bioconservation alone, neglecting the fundamental and essential role that the non-living substrate - bedrock, landform systems, soils and associated waters - plays in natural processes including ecological processes, and neglecting also the fact that non-living parts of the natural environment can be considered to have intrinsic value just as the living parts can (Sharples 1995a). No approach to nature conservation which ignores geoconservation makes sense, or indeed is possible[10].

The concept of geoconservation is an advance on the older "geological monuments" or "geological heritage" approach of the Geological Society of Australia, which (officially) still recognises geological features as having value or significance only in terms of their value for research and education. Whilst geoconservation incorporates the idea of protecting geological features for their research and educational value (i.e., their scientific values), it goes beyond this by recognising that natural geological, geomorphic and soil systems have intrinsic value beyond their value to science, and are also important as the fundamental natural systems upon which all ecological processes are based. Further, whereas the geological heritage approach tends to focus on small sites, geoconservation emphasises the importance of broader natural processes in maintaining the features and systems which are of interest.

In spite of the above, geoconservation actually involves little in practical terms that has not been done before. Many agencies in many places have sought to protect karst and river systems, minimise soil erosion, prevent unnatural dune blow-outs, preserve important geological sites, and many other things which can now be lumped together under than banner of geoconservation management. Indeed, many of the earliest conservation reserves in Australia were Cave Reserves, set aside for reasons which could today be described as their geoconservation value, and some of Australia's major conservation controversies such as those over Lake Pedder (Figure 1) and the Franklin River have revolved around landform conservation which is an aspect of geoconservation. The merit of the idea of "geoconservation" is that it puts all these things into a unified conceptual framework and presents them as a logical, inter-related theme which is meaningful and pertinent to land managers, and philosophically consistent with their more familiar bioconservation tendencies.

The Basic Aims of Geoconservation

Two basic aims of geoconservation can be identified; phrased in more general terms, these could easily be also seen as aims of nature conservation generally:

Maintenance of Geodiversity

Geoconservation aims to retain significant representative or outstanding examples of the diversity of bedrock, landform and soil features and processes; that is, of "geodiversity" (e.g., see Kiernan

[10] In practice, the measures undertaken by land managers in response to degradation threats will often be similar under both a geoconservation-oriented approach and a more utilitarian approach such as that exemplified by 'environmental geology'. However this will not always be the case, and the difference in philosophical approach can have practical consequences. For example, the quarrying of a relict, or inactive, cave system might conceivably be managed in such a way as to have no significant impact on local water quality or regional landscape amenity, and thus might be considered acceptable from a purely utilitarian perspective. However, such quarrying might destroy a cave of significant scientific or intrinsic value, and thus be unacceptable from a geoconservation perspective.

1991b, 1995). This aim incorporates the traditional "geological heritage" goal of conserving features for their research and education values, but is much broader than this and also encompasses maintaining the diversity of the natural systems which underpin ecological processes and biodiversity, and simply maintaining the richness of the earth's geodiversity for its intrinsic value. An important aspect of this aim is the conservation of 'relict' features - those aspects of our geoheritage that are no longer forming, such as bedrock features, glacial landforms or palaeosols - which illustrate the effects of past processes and cannot be regenerated if they are destroyed.

Maintenance of natural rates and magnitudes of change
This aim is based on the idea that geological, geomorphic and soil *processes* are both important aspects of nature in themselves, and also fundamentally underpin ongoing natural ecological processes. It follows that a major aim of geoconservation - as of conservation generally - should be to allow natural geological, geomorphic and soil processes to continue to operate, change and evolve at natural rates and magnitudes[11] (Houshold *et al.* 1997 in: Eberhard 1997b). The aim is to maintain natural change as opposed to allowing artificially accelerated changes to occur. The formulation of this idea in terms of maintaining processes at natural rates and magnitudes of change is intended to emphasise that we are not trying to maintain a static "museum - piece" natural environment, but rather we are trying to maintain the capacity of natural systems to continue to evolve, develop and adapt in natural rather than artificially altered or accelerated ways.

Both of these aims are implicit in many formulations of the aims of geoconservation, and of nature conservation more generally. In particular, the current World Heritage criteria (UNESCO 1999) can readily be interpreted as implying these aims. For example, in stating that World Heritage places must "be outstanding examples representing major stages of earth's history" (UNESCO 1999, p. 10-11), Criterion (i) is clearly implying that *representative exemplars* of major elements of earth's geodiversity are of World Heritage value. Similarly, the same criterion refers to "significant on-going geological processes in the development of landforms", in which it is implicit that such processes are of World Heritage value because they are examples of major elements of geodiversity whose natural processes continue to function at natural (rather than artificially altered) rates and magnitudes of change.

The Sensitivity of Geodiversity

There is a widespread misconception, which still prevails amongst some land managers, that rocks and landforms are mostly robust, so that no special management of their values is necessary. Whilst this is true of some features, there are many aspects of geodiversity which are highly sensitive to disturbance. A sampling of examples includes:

- Important fossil or mineral sites of limited extent, whose scientific value may easily be destroyed by uncontrolled excavation or over-enthusiastic amateur or scientific collecting.

[11] To give an example of what this means in practice, consider aggradation (sedimentation) in caves: this was a major natural process in Tasmania under the conditions of the Last Glaciation, which resulted in many underground karst systems becoming wholly or partially filled by glacial and periglacial debris. However, during the present interglacial many of these cave fills have again been partly removed by natural erosion, and aggradation is now much less significant as a natural process in Tasmanian caves. Thus the appropriate geoconservation - oriented management approach for Tasmanian caves is to seek to avoid artificially triggered erosion in cave catchments which could result in renewed aggradation. By contrast, in a present day glacial environment with natural aggradation occurring in caves, it would be inappropriate to seek to stop such aggradation; indeed, to do so might have other consequences such as allowing colluvial deposits outside the caves to build up to levels of un-naturally high instability, which could result in slope instability hazards of larger - than - natural scale. Similar examples may be found in the management of mass movement, fluvial, coastal and aeolian systems.

- Active karst and fluvial landform systems whose ongoing processes may be degraded by activities such as quarrying or excessive vegetation clearance in their catchment, resulting in changes to hydrological regimes, sediment budget, water chemistry and a range of other parameters which may in turn destroy landforms and extinguish biological communities living within the karst or fluvial landform systems. Similarly, sandy coastal landforms are inherently mobile systems whose natural processes can be dramatically altered by artificial disturbances that modify their sediment budgets, such as building groynes or seawalls, and planting exotic dune vegetation species.

- Inactive (relict or 'fossil') landforms, such as Pleistocene sand dunes and glacial moraines in Tasmania, are significant aspects of our geoheritage that tell us about past environmental conditions. Since they were formed by processes no longer acting, they cannot be regenerated if destroyed, and their defining forms can be destroyed if disturbed by excavations or artificially accelerated erosion.

- Many soil types are sensitive to a range of accelerated erosion and other degradation hazards. Good examples from a geoconservation perspective are the sensitivity of limestone soils, and the susceptibility of the globally rare blanket peat bog soils of western Tasmania to destruction by improper fire management.

It is the sensitivity of many natural elements of geodiversity to artificial disturbance which makes it essential that any comprehensive nature conservation strategy or goals should give due attention to the conservation management requirements of bedrock, landform and soil features.

The Distinction between "Sensitivity" and "Vulnerability" in Geoconservation

Although the terms 'sensitivity' and 'vulnerability' are sometimes used interchangeably, a useful distinction can be made between these terms, based on the widely accepted use of the term 'vulnerability' in the IUCN Criteria for threatened, vulnerable and endangered biological species. The distinction is that 'sensitivity' refers to the inherent susceptibility of a feature to damage, whereas 'vulnerability' refers to the actual (contingent) likelihood of damage occurring, given existing or likely land use.

Thus, fine gypsum hairs growing on a cave wall are inherently highly sensitive, since even a human breath may destroy them, but may not be considered vulnerable if they occur in a wild and difficult cave which is only rarely visited by even the most experienced cavers. The same features would be considered highly vulnerable in a cave passage subject to regular uncontrolled visitation.

Some General Distinctions between the Sensitivities of Bedrock, Landform and Soil Features

Although it can be dangerous to generalise, some broad distinctions between the characteristic sensitivities of the geoconservation values of bedrock features, landforms and soils can be identified. These are outlined below. Although there are numerous exceptions to these generalised distinctions, they have broad implications for the types of management appropriate to the conservation of bedrock features, landform systems and soils that are considered to have significant geoconservation value. These broad distinctions are:

- *Geological (bedrock) Sites*
  Where bedrock features (e.g., fossil sites, stratigraphic type sections or exposures of important structural relationships) are considered to have geoconservation values, those values reside essentially in the *contents* of the rocks - their internal structures and constituents which provide evidence of past processes - independently of relationships to the present land surface. Bedrock geological features are for the most part only indirectly involved in ongoing surface and ecological processes, to the extent that they condition the development and character of the landforms and soils which are the active interface between the earth and the surficial

environment (albeit this distinction is weaker in the case of groundwater processes, for example).

Thus, in some cases the geoheritage (scientific and educational) values of bedrock sites may be enhanced by artificial disturbances such as excavations which better display their contents. Note however that *excessive* excavation can destroy site values. A further exception occurs where naturally weathered surfaces display the bedrock contents better than a freshly broken surface (such as the spectacular exposure of silicified fossils on weathered limestone surfaces).

- *Geomorphic (landform) Features and Systems*
  In contrast to purely bedrock features, landforms are defined by their surface contours, and in the case of active landform systems, are dependant upon ongoing natural processes for the maintenance of their integrity. Furthermore, all landforms - whether active or relict - are integral to ongoing surface processes, which are also the basis of ecological systems.

  Therefore, in contrast to features valued purely for their bedrock characteristics, the disturbance of significant landform contours (e.g., by excavation) will by definition degrade their geoconservation values, and may also interfere with ongoing geomorphic and ecological processes. Interference with the natural rates and magnitudes of change in ongoing geomorphic processes may degrade landform system values.

- *Soil Sites and Systems*
  Soils are defined by the nature of their profiles relative to surface and bedrock, and are also integral to ongoing natural surface processes.

  The geoconservation values of soils are therefore degraded by activities which disturb their profiles and their ongoing soil-forming processes. Such disturbances may include soil erosion, compaction, puddling, mixing and large scale excavations, whilst changes to vegetation cover and hydrological regime may also degrade soil-forming processes. For instance, removal of native vegetation has the potential to decrease native invertebrate habitation by 50%, with major impacts on soil processes. Such degradation may in turn impact on groundwater and other ecological processes.

Degrees of Sensitivity
Particular elements of geodiversity cannot be simply classified as either 'robust' or 'sensitive' to disturbance; rather, any element of geodiversity will be sensitive to some types of disturbance and robust in the face of others. Hence, in assessing the sensitivity of particular features or processes, it is necessary to identify the disturbing activities in terms of which the assessment is being made.

A 10 – point "Scale of Sensitivity" has been developed for use with the Tasmanian Geoconservation Database, which endeavours to assign degrees of relative sensitivity to particular elements of geoheritage according to the type and scale of disturbances that would degrade their geoheritage values. The Scale of Sensitivity is provided in Appendix One (Section A1.2).

History of Geoconservation in Tasmania

Early conservation actions such as the reservation of outstanding caves and scenic landscapes could be broadly regarded as the beginning of geoconservation work in Tasmania. Indeed, the importance of geoheritage in conservation in Tasmania is nothing new, with geoheritage themes such as karst (eg, at Hastings Caves) and glacial landforms (eg, at Mt Field National Park) having been the basis for early reservation of those places. However, it has only been in recent decades that the idea of "geoconservation" has been explicitly formulated as a unifying theme drawing together some concepts which had previously been applied, albeit in less systematic ways.

The development of concepts of geoconservation in Tasmania has to some extent parallelled similar developments overseas, most particularly in Europe (eg, O'Halloran *et al.* 1994, Barettino *et al.* 1999, Gray 2003); however the theoretical and practical development of geoconservation in Tasmania is widely acknowledged to have been in the forefront of progress in this area globally (see Gray 2003). A comparison of Tasmanian progress in geoconservation up to 1995 with approaches elsewhere, can be found in Dixon (1995a).

The first work explicitly directed at the recognition and conservation of Tasmania's geodiversity was centred around the "Geological Monuments" approach of the Geological Society of Australia.

Figure 1: The original Lake Pedder, a lake formed during the Pleistocene when glacio-fluvial sediments impeded the Serpentine River, seen here in a 1972 vertical airphoto immediately prior to being inundated beneath a much larger hydro-electric lake which was (with dubious justification) also named "Lake Pedder". The original lake had both globally unique geoconservation values, and was a wilderness lake of outstanding aesthetic beauty. It's inundation produced an unprecedented outcry in Australia, and is widely acknowledged to have been the event which kick-started environmental politics in Australia. At the same time, the loss of this outstanding element of Tasmania's geodiversity also started a process leading to the development of concepts of geoconservation in Tasmania (Sharples 2001). Photo © Department of Primary Industries, Water & Environment, Tasmania.

This early work was based mainly on recognition of the scientific, research and educational value of outstanding bedrock features and some landform sites as heritage which informs us about the Earth's past development, and focussed on sites rather than ongoing natural processes. This approach resulted in the preparation of two inventories of significant geological and landform sites (Jennings *et al.*1974, Eastoe 1979).

However, whilst the "Geological Monuments" (or "Geological Heritage") approach to geoconservation is of undoubted importance, it tends to focus on geological or landform features and sites as "static" evidence of past processes, and as such tends to have only marginal relevance to the broader issues of environmental management and the conservation of ecosystem processes, in which the management of ongoing natural processes is critical. At least partly for this reason (arguably) geoconservation has generally remained something of an oddity in Australia, mostly divorced from mainstream nature conservation programs, and so it has had low priority within land management agencies such as Parks and Forestry Services.

In contrast, the historically high profile of nature conservation issues generally in Tasmania created a political and intellectual environment conducive to the development of a broadly-based and management – relevant approach to geoconservation. The presence of a large area of wilderness in Tasmania has meant that nature conservation issues generally have dominated the Tasmanian political agenda since the late 1960's, with the controversial flooding of the globally unique Lake Pedder landform assemblage in Tasmania's south-west, for hydro-electric development, being widely regarded as the issue that effectively launched environmental politics as a major force in Australia generally (Sharples 2001). Conservation continued to dominate Tasmanian politics through the 1980's, with the Franklin River Dam and forestry issues being major controversies which changed Tasmanian society and politics in many ways. A number of Tasmanian geologists and geomorphologists were involved in these controversial issues, in both professional and activist roles at various times, and some of these professionals were later instrumental in developing the discipline of geoconservation in Tasmania.

Against this background, an approach to geoconservation has evolved in Tasmania over the last 20 years which better integrates geoconservation with the broader concerns of nature conservation generally, by emphasising the importance not only of significant "static" sites and features of geoheritage value, but also of the fact that ongoing geomorphic and soil processes both maintain the soil and geomorphic systems themselves, as well as maintaining ecosystem processes (including biological processes) as a whole. This approach incorporates the "geological monument" - style recognition of the scientific value of bedrock and landform features in informing us about the past, but additionally highlights the fact that bedrock, landforms and soils form the essential and integral basis of the broader ecological systems on which most nature conservation concern has been focussed. This process- oriented approach to geoconservation has made the importance of the discipline more readily understandable to land managers, and has resulted in significant funding of geoconservation work, particularly within the Tasmanian Parks & Wildlife Service, DPIWE Nature Conservation Branch, the Tasmanian Forest Practices Unit, and Forestry Tasmania.

During the mid-1980's, the Forestry Commission (now Forestry Tasmania) began to take conservation issues seriously, and with the establishment of the Forest Practices Unit in 1986 a geomorphologist was appointed to co-ordinate landform conservation management in the forestry industry. Prior to this, a major study of the Mole Creek karst had been undertaken on behalf of Forestry Tasmania and the Parks & Wildlife Service (Kiernan 1984, 1989a), and this was one of the first Tasmanian geoconservation studies to highlight not only the intrinsic and scientific value of an outstanding landform complex, but also the need for proper management of the ongoing fluvial, soil and karst processes which sustain that landform complex and its ecological processes, and determine the rates and magnitudes at which these continue to develop and change.

Concurrently, political events created a climate in which concerned Tasmanian geoscientists were able to further press the case for geoconservation to be recognised as an important land management issue. In particular, geomorphic values (especially karst and glacial landforms) were recognised as having major conservation and heritage significance by the 1987 Helsham Inquiry into Tasmanian forest conservation values (Helsham *et al.*1988), which led directly to the identification of World Heritage geomorphic values in the 1989 TWWHA nomination (with which the present review is concerned). In 1988, worrying bank erosion on the World Heritage – listed Gordon River caused the Tasmania Parks and Wildlife Service to employ an Earth Scientist, and later concerns regarding damage to Exit Cave (in the TWWHA) by quarrying resulted in the additional appointment during 1991 of a geomorphologist to work on karst issues.

The ensconcement of earth scientists in land management agencies during the 1980's led to an acceleration of geoconservation work during the early 1990's, as these officers sourced funding and initiated projects to improve knowledge of Tasmanian geodiversity, its natural processes and management requirements. Section (2.4) provides a listing of geoheritage inventories for Tasmania (including the TWWHA) which were compiled during the 1990's as a result of the increased attention being paid to geoconservation during the last decade.

The Tasmanian Geoconservation Database

In 1996 (through the processes leading to the Tasmanian Regional Forest Agreement) funding became available for a project to amalgamate all existing Tasmanian geoheritage inventories into one unified electronic database, known as the Tasmanian Geoconservation Database or "TGD" (Dixon & Duhig 1996). Whilst this database provides only very brief descriptive details of each geoheritage site or system, it does cite the relevant references and, most importantly for the present review, provides an assessment of the conservation significance of each site or system, in a format which is readily applicable to assessments of World Heritage values (and to assessments of other levels of significance).

The custodian of the TGD is the Earth Science Section, Nature Conservation Branch, Tasmanian Department of Primary Industries, Water and Environment. A formal review panel, comprising a range of experts on Tasmanian geology, geomorphology and soils, was established in 1999 with the approval of the General Manager, Resource Management and Conservation Division, DPIWE. This panel is known as the Tasmanian Geoconservation Database Reference Group (TGDRG), and meets regularly to review and update the TGD.

Because the TGD includes all examples of Tasmanian geodiversity that have to date been identified – and accepted by a review panel - as having special geoconservation significance, and because the database incorporates an assessment of geoheritage value or significance in accordance with the methods of geoconservation significance that have been developed over the last decade (at levels from local to world significance), it has proven an up to date, comprehensive data source, and an ideal tool for conducting this review of World Heritage Values. Appendix (A1.0) provides a listing of all TWWHA geoheritage sites and systems listed on the TGD, and this provides, in part, a basis for the assessment of World Heritage values in Section (3.0) of this report.

2.2 The Assessment of Geoconservation Significance

The previous section (2.1) outlined the basic aims or purposes of geoconservation – that is, why it is necessary or appropriate to consider geodiversity and geoheritage in any properly comprehensive approach to conserving natural values. This section provides some outline of the principles and procedures by which we can identify those elements of geodiversity to which it is appropriate to give priority in nature conservation programs.

2.2.1 *The Concept of Significance as a Basis for Assessing Geoconservation Values*

Strictly speaking, geoconservation is not *in itself* a research science, but rather an approach to practical land management which is distinguished by the particular natural *values* that it endeavours to conserve. If anything geoconservation could be considered a branch of practical ethics which uses science as the basis for ethical decision - making processes. The practice of geoconservation involves making value judgements - ethical judgements - as to what aspects of nature it is important to conserve, and then using rigorous science to identify those aspects, and determine the best means of conserving them.

A central issue in geoconservation - as in conservation generally - is therefore to determine what things are to be considered *significant*. In effect, judging a natural thing to be significant means judging that its conservation is meaningful or important to the realisation of the aims of geoconservation (Section 2.1). The need for a concept of significance arises from the recognition that we cannot conserve everything in a natural state, and that humanity has a right to exploit natural resources to fulfil our own legitimate needs and purposes. However, geoconservation ethics propose that this should not be done in such a way that the diversity of natural geological, geomorphic and soil features and processes (geodiversity) is unnecessarily reduced by the elimination of entire classes of natural phenomena, nor in such a way that (at least) representative examples of natural systems are no longer able to unfold or evolve in their own ways (i.e., at natural rates and magnitudes of change). We therefore need a means of identifying which things we should conserve in their natural state in order to fulfil the aims of geoconservation, and conversely which things can be justifiably altered and exploited by human society to serve the legitimate needs of society. The assignment of conservation *significance* is a widely used means of identifying those things which have the highest priority for conservation.

It is the writers contention that the identification of particular things as having conservation significance takes place by a two stage process (whether those making the identification recognise this or not). We firstly make a *value* judgement - which is ultimately a subjective judgement - as to what it is about natural phenomena that is of value and worth conserving. We then – ideally - use objective criteria to identify, using scientific methods, what specific things best exemplify those values, and are therefore of the highest priority for conserving.

Various writers have advocated a wide variety of reasons for valuing and conserving natural geological, geomorphic and soil phenomena. In the writers opinion, most value sets advocated in the literature can be grouped under one of three broad headings (Sharples 1995a):

Reasons to value geodiversity:

- *Intrinsic values*: the valuing of things simply for what they are, rather than for any other purpose they might serve;

- *Ecological or natural process values*: the value of things in maintaining natural processes including ecological processes; and

- *Anthropocentric (or "geoheritage") values*: the direct value of things to humans for purposes which do not decrease their intrinsic or natural process values[12]. Such values include the research and educational value of geodiversity, its aesthetic or recreational value, the social value of landforms which contribute to the "sense of place" of a community, and so forth.

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[12] The significance of this wording is that the geoconservation value of rocks, landforms and soils is here being contrasted with the utilitarian resource values which can be realised by their removal, processing or manipulation for purposes such as mining, agriculture, settlement, and so on.

All three of these value sets relate directly to one or both of the aims of geoconservation as identified above (section 2.1). Once any of these value sets have been accepted - in what is essentially an ethical judgement - as being worthy of conserving, it is possible to draw up objective criteria by which those natural phenomena whose conservation would best serve the protection of each value can be identified in a rigorous and scientific way.

For example, if we hold geodiversity to have intrinsic value, then we can argue that this implies a need to identify good representative examples of each element of geodiversity for conservation purposes. We can develop a classification system to define important representative elements of geodiversity (Kiernan 1997a in: Eberhard 1997b), and use a systematic method such as Georegionalisation (Houshold *et al.* 1997 in: Eberhard 1997b) to assist in identifying the best available representative examples in a scientifically rigorous way[13]. Such methods of identifying representative elements of geodiversity may also serve to satisfy some of the conservation requirements of ecological and geoheritage value perspectives.

Again, if we accept the value of geodiversity in ecological processes then we need to determine the role which particular elements of geodiversity play in ecological processes. Such a determination is a matter of scientific research and monitoring, which allows us to determine whether the disturbance, degradation or destruction of a "geo-phenomenon" will result in an unacceptable degree of change or degradation to the broader natural environment and ecological processes of which it is part; if so then it is a thing of *significant* geoconservation value which should be managed accordingly to avoid such detrimental effects.

Use of the concept of significance to identify World Heritage values in this report

The approach to identifying elements of World Heritage significance taken in this report complies with the "two stage" process described above, and indeed is the process required by the World Heritage criteria and guidelines (UNESCO 1999). That is, a judgement (ultimately subjective) is first made as to what values are to be regarded as significant, and scientific data is then used (in an objective comparative fashion) to identify those elements of geodiversity which provide examples of the chosen values that are significant at a world level.

In regard to the first stage, the values that have been agreed upon as those conferring World Heritage significance are those which have been formulated as the current World Heritage criteria (UNESCO 1999, see also this report Section 2.3.3). These values are specific formulations of aspects of the three underlying value sets identified above, namely intrinsic, natural/ecological process and anthropocentric values.

The second stage of the process consists of the use of available scientific data to identify, in a comparative way, which elements of geodiversity in the TWWHA provide exemplars of World Heritage values that are significant at a world level, i.e., that are amongst the best expressed or developed examples of their type globally. The scientific data used for this second stage is described in Section (2.4), and Section (3.2.2) provides the World Heritage assessments undertaken using this data.

Identifying good exemplars

It is implicit in the above discussion of significance that "significant" elements of geodiversity are the “best” examples of their class of feature, or comparable to the best. The essential criteria by which the “excellence” of a feature as an example of its class are assessed are:

[13] Note that "intrinsic values" are inherently unquantifiable; the use of representativeness is a surrogate for intrinsic value which cannot be perfect or absolute, but which we can nonetheless expect will identify the most valuable conservation estate of "intrinsically valuable" elements of geodiversity that we are likely to achieve by any scientifically rigorous and defensible means.

- the excellence or degree to which it displays the key characteristics of its type (i.e., we identify the best - developed or best - expressed representative examples of each class of thing or element of geodiversity); and:

- its condition or integrity, i.e., the degree to which its natural values have or have not been degraded by artificial disturbance.

Representative and Outstanding Exemplars
However, it has become customary in geoconservation to not just classify significant features as being "best" examples, but rather to classify them as being either *outstanding* and/or *representative* exemplars of their class (e.g., Joyce & King 1980, Davey 1984, Dixon 1991):

- an *outstanding* feature is one which exemplifies an aspect of geodiversity through a feature which is rare, unique, an exceptionally well-expressed example of its type, or otherwise of special importance; whilst:

- a *representative* feature may be either rare or common, but is considered significant as a well-developed or well-exposed example of its type.

That is, *outstanding* features are "best" examples, whereas "representative" features are simply ones that are sufficiently well expressed and have sufficient integrity as be considered significant. Although some early approaches to geological heritage focused mainly on individual features that were considered outstanding, the *aims of geoconservation* cannot be adequately fulfilled if attention is focused solely on this approach. Although outstanding features are typically those which it is easiest to gain public and institutional support for protecting, there are several inherent problems in focussing solely on this approach (Davey 1984, Sharples 1995a):

- Firstly, current scientific interests and cultural fashions may make a certain feature seem outstandingly significant which in the future may be considered less important, and vice versa. 'Outstandingness' is commonly a subjective and culture-dependant judgement which is likely to be only ephemeral (albeit some things may be outstanding in more objective ways - for example, the biggest thing is objectively the biggest - but the 'most' spectacular, beautiful or interesting things are clearly only so in a purely subjective sense).

- Secondly, the basic geoconservation aim of maintaining geodiversity (for its intrinsic, scientific, and other values) implies that we need to manage for the conservation of (at least) phenomena *representative* of all aspects of the geodiversity of a region. Outstanding features alone will only encompass a very incomplete sampling of the features characteristic of a region.

- Thirdly, the geoconservation aim of maintaining natural rates and magnitudes of change - so as to maintain the ecological value of geodiversity - is better served by a system of features and processes representative of all aspects of the geodiversity of a region than by a more arbitrary selection of outstanding features. A system of representative bedrock, landform and soil types also supports biodiversity by protecting a fuller range of habitat substrates.

For these reasons, it is more useful to focus on identifying features of representative significance, although particular features may still be identified as 'outstanding' in order to highlight cases of special importance. Such an emphasis on representativeness 'dovetails' neatly with the approach described above to incorporating consideration of intrinsic values into geoconservation significance assessment, and is implicit in the idea of valuing geodiversity.

Because of the historical emphasis on outstanding features in early geoconservation inventories, many inventories are still heavily weighted towards outstanding features. However, with a growing emphasis on systematic inventory studies (see below), it is envisioned that the balance will gradually shift towards more representative databases.

Nonetheless, it is arguable that features of "outstanding" significance should continue to be inventoried as such, because they provide indicators of the potential endpoint of the development of features or systems (Houshold *et al.* 1997).

Assigning "levels" of significance

It is common practice in nature conservation, including geoconservation, to assign different "levels" of significance to things as a means of differentiating between things which are judged to be of greater or lesser importance or priority for conservation. Whilst there may be some philosophical objections to this approach, it has proven useful as a means of prioritising nature conservation efforts, responsibilities and funding. The approach is consequently used by, for example, the Australian Heritage Commission and many State conservation agencies. In particular, it is explicit in the concept of World Heritage, which refers to heritage of only the highest (global) significance levels. Thus, judging "levels of conservation significance" is unavoidable if we wish to assess whether certain themes or areas are of "World Heritage value".

The Operational Guidelines for the Implementation of the World Heritage Convention (UNESCO 1999) provide criteria which define, for the purposes of that convention, the highest priority (World) level of significance that can be assigned to natural (or cultural) heritage. Those criteria are described in Sections (2.3.2) & (2.3.3) below, and form the basis for world heritage significance assessments in this report. However, this report assesses features of all significance levels in the TWWHA, not only world significance levels, and so it is necessary to be able to define "lower priority" significance levels for the purposes of this document. Moreover, it is simpler to appreciate the meaning of "World Heritage" or "world significance" levels if they are considered and defined alongside other significance levels.

In Australian geoconservation practice, features of geoconservation significance have for several decades now been customarily assigned to levels of significance ranging from "local" to "world" significance (eg, Rosengren 1984, Dixon 1991, Sharples 1993, Joyce 1995, 1997). This method of assigning significance levels was used in the compilation of the Tasmanian Geoconservation Database (Dixon & Duhig 1996), and is continued in the present document[14]. In this method, significance levels are defined as follows (after Rosengren 1984, Sharples 1993):

World ("global" or "international") **significance:** Phenomena that are rare in the world, and/or by the nature of their scale, state of preservation or display are comparable with excellent examples known internationally. May be illustrative of processes occurring or having effects at an inter-continental or global scale.

Equivalent to "World Heritage value" as defined by the Operational Guidelines for the Implementation of the World Heritage Convention (UNESCO 1999).

National significance: Phenomena that are unusual or unique nationally, and/or by the nature of their scale, state of preservation or display are comparable with examples known nationally. May be illustrative of processes occurring or having effects at a continental or national scale.

[14] Philosophical and procedural problems can be identified with the means of assigning levels of significance used in this document; however no satisfactory alternative means of assigning differing levels of significance to a wide range of phenomena is available at the time of writing.

State significance: Phenomena that are important in the context of the geological, geomorphological or pedological development of the State, and/or which are amongst the best developed, expressed or preserved examples of their type (class) in the state.

Regional significance: Phenomena that are important within the context of a region. Regions may be arbitrarily defined on political or administrative boundaries, or on the grounds of characteristic geological, landform and/or soil features. May include phenomena that are amongst the best developed, expressed or preserved examples of the features that characterise the region.

Local significance: Phenomena that, whilst not unique to a local area, are amongst the best developed, expressed or preserved examples of their type (class) within a local area defined on geographic grounds, such as a valley, catchment basin, or the administrative boundary of a city or town.

Unknown significance: Unknown significance may be assigned where a phenomenon is insufficiently well known to allow comparison with other examples of its type, or where insufficient data exists on the distribution and quality of other examples of its type.

It is important to note that whilst this system of assigning significance levels is typically used as a means of prioritising conservation efforts, it is not intended to express a “high” to “low” significance hierarchy. A thing that is of only local significance is not properly speaking of “low” significance compared to something of world significance: rather, it is a thing that has high significance in a local (but not world) context. Things that are properly speaking of “low” significance are things that do not have notable significance at any level.

In summary, the essence of the above system of assigning levels of conservation significance is that a feature, area or value is considered to be significant at the (spatially defined) level where it is amongst the best representative (or outstanding) exemplars of its type or class. Thus, a feature which is of (outstanding or representative) local significance is likely to be of a type (class) which is relatively well represented at a state-wide level, but which is the best example in its local area. In contrast a feature of (outstanding or representative) state significance will be one of the best examples of its type (class) in the state, and a feature of (outstanding or representative) world significance will be one of the best examples of its type (class) in the world.

Appropriate Levels of Classification for Assessment of Geoconservation Significance

It is implicit in the preceding discussions that a key consideration in assessing the geoconservation significance of a thing is to determine the appropriate level of classification at which to conduct that assessment. Classifications of various sorts – i.e., the identification of classes of features or systems which are comparable - form the basis for defensible methods of significance assessment, as discussed above and elaborated further below in the subsection "Procedures for Assessing Geoconservation Significance and Values".

Classifications of natural phenomena are generally hierarchical, with the higher levels in a classification being more broadly defined, and lower levels being defined by a greater number of more specific criteria. Thus, a classification of "mountains" might start with "all mountains" at the highest level, then subsidiary classifications might be based on genesis, form or composition. For example, a sub-class of mountains might be "residual mountains", a subclass of residual mountains might be "dolerite mountains", and subclasses of residual dolerite mountains might be "glacially-eroded" or "peri-glacially eroded". And so on, to finer and finer distinctions forming lower levels in the classification hierarchy.

The problem for geoconservation assessment is, at what level in a classification hierarchy should an appropriate comparative assessment of phenomena be carried out to find the best representative exemplars? After all, if we consider any feature or object at a detailed enough level of classification, then every object could be said to be globally unique and therefore of outstanding universal significance or World Heritage Value! If we consider sand grains in terms of their detailed microscopic surface textures or morphologies, no two sand grains will be alike, thus we would have to say that each and every sand grain is globally unique and consequently of World Heritage significance! This "every sperm is sacred" approach is clearly nonsense, and results from attempting to assess world level significance at an inappropriately detailed level of classification.

The appropriate level of classification at which to compare examples of phenomena for the purpose of a geoconservation significance assessment depends on the level of significance (see preceding sub-section) which is being considered. Thus, an assessment to identify features of world significance should compare features at a higher level of classification, whereas an assessment to identify features of local significance would compare features at more detailed – or lower – level of classification. *The level of classification which is appropriate for assessing features at a given level of significance will be the level of classification that is defined by characteristics or properties of the features that vary significantly and thus can be meaningfully compared at that level of significance, but not at lower levels of significance*.

For example, comparison of the geoconservation significance of mountains at a world significance level might consider characteristics (classification levels) such as height or rock type, as these vary significantly across the world. On this basis, Tasmanian dolerite mountains can be seen to be globally unusual, such that a well expressed example in good condition may be a representatively significant exemplar at a global level if it can be shown to be as good or better an exemplar as the few other examples available in Antarctica and South Africa. In contrast, "dolerite" rock type is less useful as a classification level for identifying the most significant Tasmanian mountains at a State level of significance, since dolerite mountains are common in Tasmania. Classifying a mountain as "dolerite composition" is still necessary, since other mountain rock types also exist in Tasmania, however it is not *sufficient* for establishing high geoconservation value at a State Level by comparative assessment of available examples. For that, recourse must be made to finer, more detailed levels of classification of Tasmanian mountains. To identify significant dolerite mountains in the state context, we must consider not just "dolerite mountains", but "block-faulted or residual" dolerite mountains, "glaciated or periglacially-eroded" dolerite mountains, and perhaps other detailed elements of classification.

The levels of classification used to assess World Heritage geoconservation values of the TWWHA in this report are therefore levels at which meaningful variability exists at a global level. One of the most important such classification variables at a World level that has been used in this report for assessing World Heritage value is the degree to which geomorphic and soil processes continue to function in natural ways unmodified by human disturbance.

Assignment of significance to themes or assemblages, and to component sites (wholistic vs reductionist significance assessment)

It is generally inadequate to manage specific individual features (e.g., an individual cave or stretch of river bank) within active landform or soil systems in isolation from other components of the systems of which they are part. Active landform and soil systems need to be considered and managed as integrated assemblages or systems, rather than as isolated features, because they are all linked by the effects of ongoing processes.

Similarly, although it is sometimes the case that the geoconservation values of individual relict (inactive) features, for example a geological exposure or a glacial moraine, can sometimes be protected in isolation from their surrounding, this too is not always the case. In many cases, particular relict features form part of broader assemblages of relict features having a common origin. Such features have less meaning considered in isolation, and their full scientific significance only becomes apparent in the context of the larger assemblage of related features. Thus, whilst a glacial cirque produced by past glacial processes may be of some interest in isolation, its full significance only becomes apparent when it is considered in the context of an assemblage of related features, such as the over-deepened rock-basins, rochés moutonnées, eskers, moraines and outwash deposits, which the same glacier produced. Without the evidence provided by the assemblage of related features, the information which any one isolated feature can give us about past processes is limited. Thus, whilst each relict feature may be capable of being protected on an individual site basis, it is still important to aim for the protection of a fully representative assemblage of related features, rather than just one or two individual components of the total related assemblage.

For these reasons, the emphasis in this report is more on the identification of related assemblages of features, or process systems, as being of (World Heritage) geoconservation significance, than upon the identification of individually significant features in isolation.

However, this approach raises questions about the significance levels that can be assigned to individual features in an assemblage, as opposed to the assemblage as a whole. It could be argued that if a particular geodiversity theme in Tasmania, say "Cainozoic Glacial Features", is deemed to be of world significance as a theme, then all component features (individual landforms, sites, deposits, etc) that contribute to that theme must therefore be of world significance. However, this appears to lead to seemingly absurd conclusions such as that, say, minor and degraded features within an assemblage of features are *individually* of World Heritage value simply because the assemblage of which they are part is *collectively* of World Heritage value.

In practice, some previous assessments have assigned world significance levels to certain geodiversity themes in the TWWHA, and to certain specific landforms belonging to such themes, but have assigned lower levels of significance to many other sites belonging to the same themes (DASETT 1989, Dixon 1991, Dixon & Duhig 1996, TGD 2001). For example, it has been strongly argued that the Tasmanian Cainozoic glacial landform systems (as a theme, or an assemblage of sites) are of World Heritage significance (DASETT 1989), and indeed several specific glacial sites were identified by Dixon (1991) and Dixon & Duhig (1996) as having world level significance (eg, Cynthia Bay Moraines, Mt Anne Northeast Ridge Glacio-karst). However other sites within the same theme were only assigned National, State or lower levels of significance (eg, Lake Tahune Glacio-karstic Cirque, Lake Sydney Glacio-karstic Lake, Lake Adelaide Glacial rock basin lake).

Thus, rather than making a "top-down" assignment of high value to all specific or individual components of a theme or assemblage that is considered to have high value as a whole, it appears to be more commonly held that values may be enhanced in a "bottom-up" fashion. That is, a whole (theme or assemblage) may collectively have values over and above the sum of the values of its individual components. This wholistic approach has been taken explicitly to assessing the significance of karst and glacial landform values in Tasmania (Helsham *et al.* 1988, Houshold & Davey 1987). A similar approach is arguably applicable to many aspects of natural heritage, in which whole communities or ecosystems may be held to have values over and above the values of individual component organisms.

In the case of landform themes or assemblages, some landforms or deposits contributing to the theme may be poorly expressed or degraded examples of their type, and it may be that only a proportion of the contributing features will be sufficiently well expressed examples of their class, or in sufficiently good condition, as to make a significant contribution to a World Heritage theme of which they are a part. Thus it does appear difficult to argue that an intermediate recessional moraine, almost obliterated by erosion and similar to a dozen others nearby, contributes to a glacial theme to the same extent as does a well-preserved and well-expressed terminal moraine marking the maximum ice limit of a major glacial phase.

Some ways in which individual components of a geodiversity theme or assemblage may contribute to a whole whose heritage value is greater than the sum of its parts include:

- an assemblage of inter-related features may gain significance from the inter-relationships and/or diversity of component types displayed. For example, one uplifted marine terrace may be of limited significance by itself, but a related series of such terraces may have great value because, taken together, they tell a detailed story of repeated climatic and sea level changes over a long period. Again, a suite of otherwise unexceptional karst systems developed in an unusually wide diversity of topographic situations (e.g., from alpine through to coastal environments) may have great value for displaying –*in toto* – an unusually wide range of topography and altitude - dependent characteristics; or

- an assemblage of "ordinary" features whose ongoing contemporary development is occurring in a context of negligible human disturbance may collectively be of high significance simply because of the rarity of such undisturbed integral natural process systems; or

- the regional and topographic extent of related occurrences of some elements of geodiversity may be significant in cases where the elements are of a sort which rarely occur over such broad areas, or in such a diversity of situations (eg, the extensive blanket bog soils of western Tasmania derive some of their significance from the fact that such soils only have relatively restricted occurrences elsewhere in the southern hemisphere, and are not normally found on such steep slopes (as well as flatter ground) as in Tasmania).

Thus, the assessment of geoconservation significance of themes and sites within the TWWHA presented in this report adopts the view that:

> Whereas a geodiversity theme, or a broad assemblage of related elements of geodiversity, may be assigned an overall significance level (eg, World Heritage significance or value), individual component features contributing to that theme may be assigned a variety of levels of significance depending upon the degree to which they display key aspects of the overall theme, and the degree to which their key features are well preserved or degraded. Some characteristics can lead to an assemblage of features having higher significance, as a whole, than any of its component features considered individually.

2.2.2 *Procedures for Assessing Geoconservation Significance and Values*

The practical implementation of geoconservation requires that significant and sensitive elements of geodiversity - those requiring special management prescriptions - be identified on the ground. Most importantly in the present context, it is necessary to be able to identify specific features , assemblages and systems as having geoconservation values in order to justify recognising and managing an area such as the TWWHA for its natural heritage values rather than for (say) its resource extraction value.

The basic procedures for assessing geoconservation significance of particular features or systems have been outlined above. However, such assessments may proceed in one of two ways, namely an ad hoc approach or a more desirable strategic approach:

Ad Hoc Identification of Values

The ad hoc approach involves the assessment of geoconservation values at a particular site or area during the planning or assessment of specific activities or projects that may disturb that area (such as the assessment of individual logging coupes or development sites immediately prior to development taking place).

This ad hoc approach is a short term strategy which has a number of disadvantages:

- It may be difficult to make reliable assessments of the significance of features at a particular site in isolation from a systematic comparison between similar sites over a much broader region.

- The initiation of ad hoc assessments of geoconservation values often depends upon field managers or planners being able to recognise the possible existence of geoconservation issues and then request specialist advice. This approach cannot be totally reliable since it depends upon the knowledge of non-specialists, who cannot be expected to unfailingly recognise possible geoconservation issues at the outset of a planning process.

- Perhaps most importantly, the ad hoc approach doesn't allow for long term planning and regional zoning with geoconservation values in mind (as is implied, for example, by reservation or giving an area World Heritage status). The assessment of values will typically come after a decision to undertake a development has been made, so that the discovery of highly sensitive features may require the alteration of long term plans at short notice or, if development activities have already reached a committed stage, may result in degradation of the significant features anyway.

Continued use of the ad hoc approach is inevitable in many areas due to the lack of more comprehensive databases upon which a more strategic approach could be based. However the limitations of the ad hoc approach mean that an ongoing effort to develop a more strategic approach, involving early systematic identification of geoconservation values over broad regions, and appropriate zoning that indicates areas of highest priority for conservation, is most desirable as a means of minimising potential conflict between conservation and development goals.

Strategic Identification of Values - Inventories

A strategic approach to the identification of geoconservation values involves the systematic and comparative assessment of geoconservation values over broad regions, allowing appropriate zoning (such as, for example, National Park or World Heritage Area status) to be developed to indicate features and areas of high conservation significance, as distinct from areas more or less suitable for various types of development activities.

The strategic approach can only be applied in areas where an adequate scientific database of basic geological, geomorphic and soil information exists, so that the collection of such basic data is a necessary component of a strategic approach to the identification of geoconservation values.

The strategic identification of geoconservation values has been and is being undertaken in the form of compiling inventories of significant elements of geodiversity at three levels of detail (Sharples 1995a), namely:

- Reconnaissance Inventories
- Systematic or Thematic Inventories
- Detailed Inventories

Reconnaissance Inventories

Reconnaissance assessments are "first pass" assessments which identify significant features in a fairly unsystematic way, on the basis that they have geoconservation values that are in some way obvious. A reconnaissance inventory of significant features is usually compiled on the basis of literature reviews and consultation with relevant experts, with only limited fieldwork since the inventory is based on identifying features which stand out as significant on existing knowledge. Insofar as reconnaissance assessments inherently tend to have a bias towards outstanding features and sites, a reconnaissance inventory can be a reliable, albeit incomplete, identification of the most outstanding significant sites. However, reconnaissance inventories are less likely to encompass a representative range of exemplars of a theme. Most inventories of sites of geoconservation significance compiled to date in Tasmania have been compiled in a reconnaissance fashion (see Section 2.4), and the 1989 identification of World Heritage values in the TWWHA (DASETT 1989) was arguably a reconnaissance assessment.

Systematic and Thematic Inventories
The preparation of systematic or thematic inventories involves making a comprehensive comparative assessment of all the features and systems in a specific region, or in a given theme (eg, fossil sites, stratigraphic sites, karst, glacial, fluvial, organic soils, etc), so as to systematically identify the most significant representative elements of geodiversity in the region and/or theme. This approach involves assembling data on all the relevant known features in the region or theme, and systematically comparing them all so as to identify which are the best representative examples of their type (i.e., the best developed and/or expressed).

The preparation of systematic inventories is fundamentally based on the idea that the best approach to geoconservation management is to aim at protecting geodiversity by first identifying the best *representative* (not merely outstanding) examples of each element of geodiversity.

Although time consuming, a systematic and thematic inventory approach provides comprehensive data over large areas, and allows more rigorous and defensible assessments of the significance of particular features to be made. A systematic data inventory covering the whole of Tasmania has been compiled for karst phenomena (Kiernan 1995), and a recently completed state wide georegional classification of fluvial geomorphic systems (based on Jerie *et al.* 2001, 2003) will provide the basis for a state-wide assessment of fluvial geodiversity significance. It is possible to discern a logical move in Tasmanian geoconservation inventory work from reconnaissance to systematic inventories, with reconnaissance inventories for most of the state (except private land) having been compiled during the 1990's, and current work focussing more on systematic thematic work. Other geodiversity themes in Tasmania which have particularly high priority for future systematic and thematic inventory work, due to their ecological or geoheritage importance in Tasmania and to their commonly high sensitivity to disturbance, include coastal landforms, soils, and sensitive bedrock site types such as fossil and mineral occurrences.

Two (related) approaches to the preparation of systematic and thematic inventories are being developed in Tasmania, which can be referred to as the 'Classification - based Approach' and the 'Geo-Regional Approach'.

The classification - based approach involves developing a systematic classification of a particular geodiversity theme (e.g., karst systems, fluvial systems), compiling inventories of all the known occurrences of each class within the geodiversity theme that are defined by such a classification, and then identifying the best representative examples of each element or occurrence of each class on the ground. This detailed exercise could be undertaken for karst systems in Tasmania based on the inventory data and classification system provided by Kiernan (1995). Similar classifications have been prepared for coastal and glacial landforms in Tasmania (Kiernan 1996, 1997a), however data inventories of Tasmania's coastal and glacial landforms are still far from adequate. With particular relevance to World Heritage geoconservation values, Kiernan (2001a) has provided a good example of the application of a systematic (classification-based) geoconservation value assessment, in the form of a detailed assessment of the geoconservation significance of the (original) Lake Pedder (see also Section 3.2.2).

The related but somewhat distinct geo-regional approach is fundamentally related to bio-regional approaches in nature conservation, and hopefully will at some stage be integrated with these. The geo-regional approach involves systematically identifying regions of similar distinctive basic characteristics in terms of their "system controls", i.e., the independent geological and landforming processes variables that exert over-arching controls on the types of landforms that will develop in a given place (Houshold *et al.* 1997). Each "geo-region" identified by such a systematic analysis should constitute a region containing distinctive and characteristic elements of geodiversity, such that a comprehensive nature conservation program will aim to identify and conserve representative examples of each geo-region. In terms of present day processes including ecological processes, fluvial (running water) geomorphic systems are by far the most dominant in Tasmania from a nature conservation perspective. Kathryn Jerie (Earth Science Section, Nature Conservation Branch, DPIWE) has recently completed a three year project to prepare a fluvial geo-regionalisation of Tasmania (Jerie *et al.* 2001, 2003). The next stage will be to use this regionalisation to identify the best exemplars of each fluvial georegion. These representative regions will in effect comprise a suite of exemplars of the major elements in Tasmania's fluvial (geomorphic) geodiversity.

Detailed Inventories
These comprise information about particular significant and sensitive systems at a level adequate to make specific management prescriptions for those particular systems. Such inventories are generally based on detailed studies of particular systems; examples include detailed studies of the Exit Cave, Mole Creek and Junee-Florentine karsts, which are currently being used by Forestry Tasmania and the Parks and Wildlife Service to guide management of those areas (see Section 2.4).

2.2.3 *Practical Management Approaches*

For the purposes of this report, it is implicit that the management of geoconservation values within the TWWHA will be by protection of their values through reservation and appropriate management to avoid any modification to their natural ongoing processes or features. Nonetheless, for the purpose of completing this introductory discussion of geoconservation principles, it can be noted that management of significant natural phenomena by protective reservation is not necessarily the only appropriate option for their conservation, although it is desirable in certain circumstances. In fact, four broad options for the management of significant elements of geodiversity can be identified; which of these is appropriate in particular circumstances depends on a range of factors including the degree of significance attributed to a feature, its degree of sensitivity to disturbance, and the nature of any other associated conservation values (e.g., wilderness, biodiversity, aesthetic or scenery values):

1. *Protection/Reservation*
The exclusion of artificial disturbances from a significant site or area may occur through formal or informal reservation, and is appropriate when the values are of sufficiently high significance as to warrant preservation, and/or of sufficient sensitivity that disturbance would inevitably degrade the values. The protection of undisturbed natural ongoing landform and soil processes, whose values lie in the maintenance of their processes in a "wilderness" state, free of artificial disturbance as far as is possible, provide clear examples of geoconservation values whose successful maintenance requires protection and reservation.

The fact that one of the major world heritage values of geodiversity in the TWWHA is that undisturbed natural processes are ongoing over large regions (see Section 3.2.2) constitutes one of the major justifications for managing those values by reservation in National Parks, rather than by any of the other options noted below. That is, it is implicit that only by the exclusion of human activities capable of significantly modifying natural landform and soil processes can these particular (and major) world heritage values be successfully maintained.

2. *Special Prescriptions*
Some significant features exhibit a lesser degree of sensitivity, so that their values can be adequately protected in areas subject to development activities provided these are conducted with special modifications to avoid degradation of the significant values. Examples might include significant bedrock exposures that can be protected by the use of buffer zones or reduced intensity operations.

3. *General Prescriptions*
Some significant features have values that are relatively robust to many artificial disturbances, for example structural landforms whose conservation values reside primarily in their large scale form. The values of such features can be protected in the context of many development activities. The appropriate management prescriptions which should apply to development activities in such areas are those general prescriptions to maintain overall environmental amenity which should apply to any responsibly conducted development activities.

4. *Precautionary Management*
In some cases the management requirements of an area may be unknown, due either to poor understanding of the natural processes affecting the response of a significant phenomenon to disturbance, or because there are indications that significant and sensitive features may be present but insufficient survey work has been done to confirm or refute the existence of such features. In accordance with the widely accepted Precautionary Principle of conservation practice, potentially disturbing activities in such places should ideally be deferred until the necessary investigations have been undertaken to establish the conservation management requirements of the place.

2.3 The Identification of Geoconservation Values of World Heritage Significance in the TWWHA

2.3.1 *Introduction*

This section reviews the geoconservation values of the TWWHA that were identified in 1989 as being of World Heritage value or contributing to the World Heritage values of the TWWHA (sub-section 2.3.2).

Those values were identified under World Heritage criteria that have subsequently been updated, and were assessed using data and methods that have subsequently been improved upon and made more rigorous. Section (2.3.3) describes the current World Heritage criteria (which have superseded those used in 1989), Section (2.4) reviews new scientific data pertaining to the TWWHA that has become available since 1989, and the preceding section (2.2) has described current geoconservation significance assessment methods that have been formalised since the 1989 nomination. Together, the new World Heritage criteria, new scientific data, and more rigorous assessment methods provide the basis for Section (3.0), which is in effect a re-evaluation of the geoconservation values of the TWWHA, and as such supersedes the 1989 evaluation reviewed in Section (2.3.2).

2.3.2 *1989 World Heritage Criteria and a Review of World Heritage Geoconservation Values Identified in the TWWHA Nomination*

The 1989 TWWHA nomination (DASETT 1989) identified geoconservation values of World Heritage significance in terms of four criteria for natural properties of outstanding universal value, as adopted by the World Heritage Committee and laid out in the operational guidelines for implementation of the World Heritage Convention at that time. These criteria have been subsequently been updated, as discussed in Section (2.3.3) below, and the review of the geoconservation values of the TWWHA presented in this report (Section 3.0) has been conducted in the light of the updated criteria.

Nonetheless, in reviewing the World Heritage values upon which the 1989 TWWHA nomination was justified, it is appropriate to begin by reviewing those values in the light of the criteria that applied at that time. This subsection presents such a review, following which the original geoconservation values identified as justifying the nomination are reviewed in section (3.0) of this report in the light of the new (updated) criteria.

1989 World Heritage Criteria

For natural properties, outstanding universal value (ie, World Heritage significance) was (in 1989) recognised when a natural heritage property was found to meet one or more of the following criteria:

(i) be outstanding examples representing the major stages of the earth's evolutionary history; or

(ii) be outstanding examples representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment; as distinct from the periods of the earth's development, this focuses upon ongoing processes in the development of communities of plants and animals, landforms and marine and fresh water bodies; or

(iii) contain superlative natural phenomena, formations or features, for instance, outstanding examples of the most important ecosystems, areas of exceptional natural beauty or exceptional combinations of natural and cultural elements; or

(iv) contain the most important and significant natural habitats where threatened species of animals and plants of outstanding universal value from the point of view of science or conservation still survive.

Sites or areas meeting the above criteria also had to meet conditions of integrity to qualify as World Heritage, namely:

- The areas described in (i) above should retain all or most of the key interrelated and interdependent elements in their natural relationships; for example, an "Ice Age" area would be expected to include the snow field, the glacier itself and samples of cutting patterns, deposition and colonization (striations, moraines, pioneer stages of plant succession, etc.).

- The areas described in (ii) above should have sufficient size and contain the necessary elements to demonstrate the key aspects of the process and to be self-perpetuating. For example, an area of "tropical rainforest" may be expected to include some variation in elevation above sea level, changes in topography and soil types, river banks or oxbow lakes, to demonstrate the diversity and complexity of the system.

- The areas described in (iii) above should contain those ecosystem components required for the continuity of the species or of the objects to be conserved. This will vary according to individual cases; for example, the protected area for a waterfall would include all or as much as possible, of the supporting upstream watershed; or a coral reef area would be provided with control over siltation or pollution through the stream flow or ocean currents which provide its nutrients.

- The areas described in (iv) above should be of sufficient size and contain the necessary habitat requirements for the survival of the species.

  In the case of migratory species, seasonable sites necessary for their survival, wherever they are located, should be adequately protected. The committee must receive assurances that the necessary measures be taken to ensure that the species are adequately protected throughout their full life cycle. Agreements made in this connection, either through adherence to international conventions or in the form of other multilateral or bilateral arrangements would provide this assurance.

A Review of the World Heritage Geoconservation Values identified in the 1989 TWWHA Nomination

The 1989 TWWHA nomination (DASETT 1989) did not refer to "geoconservation", "geoheritage" or "geodiversity", since these terms were not commonly used in Tasmania prior to the 1990's. However, the nomination identifies significant geomorphological and geological values that easily fall within the meaning of "geoheritage" or "geoconservation values" as these terms are used today and in the context of this report. The nomination identified geoconservation values relating to three of the four criteria (listed above) for natural properties, and these are summarised below. It should be noted that the 1989 TWWHA nomination also identified Aboriginal cultural values in relation to three of the World Heritage criteria for cultural properties. These cultural values are substantially related to the geomorphic values identified in the nomination, in that much of the (World Heritage value) evidence of Aboriginal culture in western Tasmania during the Last Glaciation has been preserved in caves - and is associated with glacial deposits and landforms - which themselves form part of the natural World Heritage values identified in the nomination.

The nomination document notes at the outset (DASETT 1989, p.27) that two broad characteristics of the TWWHA underpin the World Heritage justification as a whole, which are paraphrased as follows:

(i) *The wilderness character of much of the nomination area is emphasised as a key value, whose importance is asserted to be that the TWWHA is one of few comparably extensive temperate wilderness areas globally*. Although not explicitly noted on p 27, one significant implication of this, which is brought out on p. 42 of the nomination, is that it implies that natural processes (both physical and biological) are continuing to operate at natural rates and magnitudes of change, in a fashion mostly undisturbed by present-day human activities.

This means that the TWWHA is of significant value in a world context as the largest temperate region in Australia, and one of only a few such areas in the world, where essentially unmodified natural processes continue to operate and to provide a benchmark against which more disturbed environments can be compared. The undisturbed, or wilderness, character of the TWWHA greatly enhances the value of all its natural features and processes, whether considered individually or in combination.

However there are some caveats on the value of the TWWHA as a place where natural processes continue undisturbed by human activities. In the first place it is likely that past Aboriginal activities including firing have had some impacts on some biological processes, and hence upon some dependant geomorphic and soil processes (e.g., see Jackson 1968, Bowman & Jackson 1981), albeit the degree of Aboriginal impact on geomorphic and soil processes in the TWWHA remains unclear and somewhat controversial. Secondly, more recent activities such as roading, hydro-electric impoundments and recreational activities have had impacts on natural processes in the TWWHA including downstream fluvial processes in areas such as the Lower Gordon River (e.g., see Bradbury *et al.* 1995).

Notwithstanding these, it still remains true that the degree of human interference with the nominated area is minor compared with most comparable temperate terrestrial regions globally, and hence it remains arguable that the nominated area exhibits a system of natural processes (including geological, geomorphic and soil processes) that are of world significance for their low level of human interference.

(ii) *The TWWHA incorporates a wide range of identifiable values and processes. These can be identified and assessed separately in a reductionist fashion, however they are all integral parts of the system, with interlinkages and interdependencies which collectively enhance the World Heritage value of the system as a whole*. The nomination (DASETT 1989, p. 27) cites wilderness as an overarching theme to which all other individual values of the TWWHA contribute and enhance. As noted above, in the context of geoconservation values this over-arching theme is important because of its implication that ongoing natural geomorphic processes are continuing in an undisturbed fashion.

Individual sites may not necessarily be the most outstanding examples of a particular phenomenon, but a group of sites viewed as an inter-related complex may well be outstanding for the way in which a variety of different values co-exist and inter-relate. For example, the interaction between karst processes and glacial systems has produced a globally rare set of "glacio-karst" landforms whose natural heritage value is arguably greater than the sum of the glacial and karst values considered in isolation.

The World Heritage value of the TWWHA is, in part, seen as being derived from this wholistic perspective; it is the inter-relationship of many component values, including both cultural and natural values, in a wilderness context that provides a high degree of integrity and sustainability to the whole, which gives the TWWHA much of its World Heritage value (DASETT 1989, p.27, PWS 1999, p. 23).

With these underpinning characteristics in mind, the geoconservation values of World Heritage significance that were identified under natural property criteria in the 1989 TWWHA nomination (DASETT 1989, p. 30-47) are summarised or paraphrased (*in italics*) and reviewed below. The following discussion essentially reviews the degree to which the various values cited as supporting the TWWHA nomination were justified in the nomination (DASETT 1989) as World Heritage values, under the 1989 World Heritage criteria; the later Section (3.0) of this report revisits the cited values and reviews their justification under the current (1999) World Heritage Criteria (UNESCO 1999) using current scientific data and geoconservation significance procedures.

Criterion (i) ***Outstanding examples representing the major stages of the earth's evolutionary history.***

World Heritage geoconservation values that were identified under this criterion related primarily to the geological record of certain major phases of Earth history that are well represented in Tasmanian bedrock sequences, and to the evidence of Quaternary climate change preserved in certain Tasmanian landform complexes, in particular glacial and karst landform systems.

Bedrock Geology Values

Cambrian tectonic melanges of the Adamsfield Trough are stated to be "superb", and are compared with the Western USA melanges. However, no other supporting or comparative evidence is provided justifying World Heritage significance.

Denison Range (Denison Group) fan-delta sedimentary sequences are stated to be one of the best fan-delta sequences globally. No supporting or comparative evidence is provided.

Ordovician limestone sequences are stated to comprise the best stratigraphic sequence of its age in Southern Hemisphere. Although no supporting or comparative evidence is provided in the nomination document (DASETT 1989), the Ordovician sequences are indeed recognised as being the longest and most complete sedimentary record of the Ordovician Period in Australia at least (Burrett *et al.* 1984). However, the longest and most complete exposures of the Ordovician stratigraphic sequences in Tasmania lie outside the TWWHA (at Mole Creek and Florentine Valley), hence given the current TWWHA boundaries it is difficult to justify these sequences as contributing to the World Heritage values of the TWWHA.

*The Parmeener Supergroup Sedimentary Sequence– Dolerite Associatio*n is cited as well exposed accessible evidence of continental break-up and fossil Gondwanan flora/fauna. The Parmeener Supergroup is also cited as important for the record of Permo-Carboniferous glaciation – a major stage in Earth's history. However no supporting or comparative evidence is provided to allow comparison with the equivalent associations in Antarctica and South Africa, and it is unclear whether those portions of the Parmeener – Dolerite Association within the TWWHA include features as important as those parts elsewhere in Tasmania

Whereas the above geological values undoubtedly present outstanding evidence of major stages of the Earth's evolutionary history, a number of other geological features presented as support for the TWWHA nomination under Criterion (i) (DASETT 1989, p. 31-32) appear, upon review, to be unlikely to actually fulfil the criterion. These appear to be significant at State or National levels, but don't clearly constitute or contribute to themes of World significance. These include:

Precambrian rocks with multiple fold phases Comparable phenomena occur globally and no case is made for the TWWHA examples being special.

Eclogites and gneissic rocks are stated to be "rare and unusual", but this is really only true in a Tasmanian context – in a global context they aren't particularly unusual.

The Late Proterozoic Weld River Group Dolomites are cited as an "unusually thick" sequence of dolomite, but why this gives it World Heritage value is not clear (ie, "size" alone is not necessarily a criterion of significance). However the dolomites are also cited as having "unusual" karst features, and this aspect does contribute to TWWHA World Heritage values under geomorphological (karst) themes (see below).

The Darwin meteorite crater (with long Pleistocene lake sediment record of flora) and impact glass strewn field are stated to be of world significance. The crater and impactite glass are not clearly of world significance, being fairly ordinary examples on the global scale and also having no obvious relationship to major phases of Earths evolution; however the long Pleistocene sediment record within the crater is potentially of World significance (see Section 3.2.2) although no evidence of this was provided in the 1989 nomination.

The Lake Edgar Fault is cited, but whilst it is a good example of a fault scarp on State and National levels, it is not shown to be outstanding globally and also is not clearly representative of important stages in Earth's evolutionary history.

Deposits from every geological age are cited as being present in WHA, however the significance of this is doubtful since it is based on essentially arbitrary time period definitions and in any case the TWWHA includes nothing from the (very long) Archaean or early Proterozoic parts of the Precambrian Period[15].

These latter features are significant features in a Tasmanian or Australian context – that is they are of state or national significance – but in terms of World Heritage they are best regarded as supporting values that enhance the overall suite of World Heritage values, rather than having World Heritage significance in their own right.

Quaternary Climate Change history – Geomorphological Values

Glacial Features

Tasmania's Late Cainozoic glacial record (expressed in landforms and sediments) is cited as an outstanding geomorphic legacy representing globally important evidence of a major stage in the earth's evolutionary history, namely the Late Cainozoic "ice ages". The Late Cainozoic has been a period of generally cool global climates, that have alternated repeated between glacial and interglacial phases. Prior to the onset of cool glacial climates in mid-Tertiary times, circa 36 my BP, similar glacial climates had not occurred on Earth since the Late Permian Period, circa 250 million years before present.

The examples of Late Cainozoic (ie, Late Tertiary to Quaternary Periods) glacial geomorphology in Tasmania are stated to be of major international significance for the following reasons (DASETT 1989, p. 32):

- Quaternary glacial processes in southern temperate latitudes were not only of different character to polar glacial processes, but were also of a different character to those in northern temperate latitudes, due to the much greater maritime influence at southern temperate latitudes compared to the more continental northern temperate latitudes; and

- Tasmania is one of only three areas preserving evidence of southern temperate glacial histories (the others being New Zealand and the Patagonian Andes); and

- Of the three areas, only Tasmania has been mostly tectonically stable through the Late Cainozoic. In consequence of this stability, Tasmania has an excellent record of Middle to

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15 Unless re-worked detrital zircon grains yielding a radiometric age of circa 3,200 million years, that have been extracted from younger Proterozoic rocks of the Jubilee region of the TWWHA, are counted.

Early Pleistocene-age glaciation which is more fragmentary in other areas where tectonic instability has disrupted glacial records; and

- In 1989 there was evidence of at least 3 and possibly 6 separate Late Cainozoic glaciations in Tasmania, which on a world scale was considered a major sequence of glacial evidence (subsequently further evidence of additional glaciations has been identified, which increases the value of Tasmania's glacial evidence); and

- The Cainozoic glacial systems within Tasmania show considerable variation, from maritime glaciological conditions with low snowlines 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 quartzite, dolerite and flat-lying sedimentary bedrock types. These variations in glacial types and expression within Tasmania complement one another to form a suite of features whose diversity enhances their scientific and intrinsic value.

In terms of Criterion (i), these attributes make Tasmania's glacial record an outstanding example (the best available for southern temperate latitudes with their distinctive types of glacial processes) of a major stage of the Earth's evolutionary history (the Late Cainozoic "ice ages"). Ongoing glacial research subsequent to the 1989 TWWHA nomination has further supported the World Heritage significance of Tasmania's glacial landforms, whose significance at a world level can now be considered well established and robust.

The 1989 nomination did not differentiate between particular glacial features in particular locations in Tasmania; rather it is implicit that the entire suite of glacial geomorphic features, as a whole, contributes to the World Heritage values. This potentially creates issues of integrity and contiguity for the TWWHA area itself, since not all known complexes of glacial features in Tasmania are wholly or even partly within the TWWHA. Indeed, some major glacial complexes such as those at Mt Field and Ben Lomond, lie both entirely outside and disconnected from the TWWHA area. However, it is evident that the TWWHA contains a sufficiently large portion of Tasmania's glacial features as to qualify for World Heritage significance.

In many areas of the TWWHA the integrity of the glacial systems within the nominated World Heritage area is high, in that all or most related components of the glacial landform systems, from high altitude erosional features such as cirques to distal features such as outwash deposits, are incorporated within the nominated area. This is the case at, for example, the Arthur and Southern Ranges, Frenchman's Cap, and a variety of other glacial centres. In these places the high integrity of the glacial assemblages is enhanced by the fact that most or all components of the glacial systems are typically in essentially unmodified and undisturbed natural condition (although an exception occurs beneath the Frankland Range where the outstanding glacial Lake Pedder is currently drowned - albeit not physically destroyed - beneath an artificial impoundment).

However in some important glacial areas such as the Central Plateau, Huon-Picton, Upper Derwent and King Valleys, high altitude erosional landforms and depositional features from the Last Glaciation are encompassed by the World Heritage Area boundaries, but some depositional features related to earlier glacial phases – which are crucial components of the integral glacial landform systems – in many cases lie largely beyond the nominated World Heritage Area boundaries, and are commonly situated in State forest or other non-reserved tenures. In some cases, significant glacial features beyond the TWWHA boundary have been disturbed and partly degraded by roading, dam building and other artificial disturbances, thereby affecting the integrity of the glacial assemblages as a whole. Thus the integrity of the glacial systems in the WHA under Criterion(i) is high in some areas, but lower in others.

In general, although the TWWHA nomination did not cite detailed evidence, sufficient justification (reasons) to assert World Heritage significance for TWWHA glacial features were cited as to provide a strong case for World Heritage value.

Glacio-Karstic Features

The 1989 TWWHA nomination (DASETT 1989) further identified the interaction between glacial features (significant under criterion i) and karst landform systems (significant under criterion ii; see below) as being highly significant in a world context. Research has shown that the Cainozoic development of Tasmanian karst landforms has been strongly influenced and modified by glacial processes (see Section 2.4). The 1989 nomination identified Mt Anne and Mt Bobs as notable examples of glacio-karst interactions, and subsequent work has identified major glacial influences on a wide range of other karst systems in or close to the TWWHA, including at Lune River, Junee-Florentine and Mt Cripps (Section 2.4).

The 1989 TWWHA nomination stated that glacio-karstic interactions are rare in southern temperate latitudes, and that in this context the extensive scale and variety (or diversity) of glacio-karstic process interactions and landform development in Tasmania is outstanding at a world level. On this basis, the glacio-karstic landforms of Tasmania are justified as outstanding examples at a world level of an important aspect of the "Cainozoic Ice Ages" stage of the Earth's evolutionary history.

As is the case with Tasmania glacial systems generally, whilst some important glacio-karst systems lie entirely within the TWWHA and thus fully comply with World Heritage integrity requirements, others are partly or wholly outside the TWWHA (eg, Mt Cripps), and in some cases occupy separate regions that are not contiguous with the current TWWHA (eg, Junee – Florentine karst). Nevertheless, some of the most important and well-developed examples (e.g., Mt Anne Northeast Ridge and Mt Bobs) are within the TWWHA and thus justify World Heritage value.

Extra-Glacial Features

The 1989 TWWHA nomination identified a range of "extra-glacial" landforms – which were not formed by direct glacial action but which reflect Late Cainozoic climate changes in other ways – as having significant world heritage values. The "extra-glacial" features identified comprised periglacial features including widespread slope mantles, fluvial landforms such as alluvial terraces reflecting changed climatic conditions, and coastal terraces and other features reflecting changing sea levels that correspond to changing climates through Late Cainozoic times.

However, although the 1989 nomination (DASETT 1989, p. 33) argued that such "extra-glacial" terrestrial processes are elsewhere poorly developed at southern temperate latitudes (ie, in New Zealand and South America), it is unclear to what degree this is actually the case. It is probably more important that they complement the glacial record, providing more depth and diversity to the record of the Cainozoic Ice Ages than could be obtained from glacial features alone.

Criterion (ii) ***Outstanding examples representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment; as distinct from the periods of the Earth's development, this focuses upon ongoing processes in the development of communities of plants and animals, landforms and marine and fresh water bodies.***

The 1989 TWWHA nomination (DASETT 1989) identified the following ongoing geomorphic and soil processes as having World Heritage significance in terms of Criterion (ii):

Karst Geomorphology and Hydrology

The nomination briefly argued that the ongoing karst processes of the TWWHA are of world significance under criterion (ii) (DASETT 1989, p. 41-42) on the grounds that:

- *The ongoing karst processes are essentially undisturbed by human activities, which is globally rare situation and constitutes an international asset.* This justification equally applies to all ongoing geomorphic processes in TWWHA – see Section (3.2.2) – and its validity is supported by the clearly extensive area of wilderness in the TWWHA (including highly karstic areas, eg, the Weld Valley). This justification provided strong reason to consider the karst systems of the TWWHA to be of World Heritage significance under Criterion (ii).

- *Karst diversity involved is very wide – various different carbonate substrates, topographical situations, climatic variability across Tasmania and climatic variation through Late Cainozoic time all influence diversity of present karst processes*. No comparative evidence was provided to support the claim that the karst geodiversity of the TWWHA is high in a world context (i.e., that it is comparable to the most diverse karsts globally).

- *The TWWHA provides well expressed examples of karst landform processes ongoin*g. Whereas the fact of ongoing natural karst processes clearly contributes to a World Heritage value under Criterion (ii) as noted above and below, this statement implies that World Heritage value also inheres in the *well expressed* nature of those processes. This is a slightly different justification: whilst clearly valid at some level, no comparative evidence was provided to support the claim that the karst landform processes of the TWWHA are comparable to the best exemplars of their types in a world context (which is a key issue in World Heritage significance assessment).

In addition, other characteristics of the TWWHA karsts relating to their past development, although not directly relevant to Criterion (ii), were stated to contribute to their diversity, and hence to their world significance under this criterion. These included:

- Significance of glacio-karst interactions.
- Sub-fossil deposits in caves (incl. megafauna).
- Caves important Pleistocene Aboriginal occupation sites – which are of cultural world heritage significance.
- Karst record of major significance in determining other aspects of landscape significance.

Again, however, although these features clearly contribute to the diversity of the TWWHA karsts, no comparative evidence was provided that the karst geodiversity of the TWWHA is high in a world context, which is the key issue in respect of World Heritage significance.

The World Heritage significance of TWWHA karst was adequately justified in the 1989 nomination on the basis of undisturbed natural processes, and is likely to be justified on the basis of diversity and degree of expression, although these latter characteristics were not clearly demonstrated in the 1989 nomination.

Other Geomorphological Processes

Periglacial processes continue on higher summits, and fluvial, aeolian and marine processes are ongoing in an essentially undisturbed environment – this is globally significant for all the ongoing processes in the area and allows the area to have world value as a benchmark site against which to compare the effects of human activity elsewhere (DASETT 1989, p. 42). Although only cited briefly, in the light of the earlier argument for the importance of the wilderness environment of the TWWHA (DASETT 1989, p. 27), the fact that its wilderness character provides an extensive, global – rare temperate "benchmark" environment in which ongoing geomorphic processes continue to operate in an undisturbed fashion means that this argument for World Heritage value under Criterion (ii) seems to be clearly justified.

The current review (this report) shows that, despite their very brief mention in the 1989 nomination, the "other" ongoing undisturbed geomorphic processes of the TWWHA (especially soil, fluvial and coastal ("marine") processes) are just as important as the ongoing karst processes (which were more emphasised and explicitly justified in the 1989 nomination – see above) in giving the TWWHA much of its outstanding universal value (see Section 3.2).

Organic soils

The 1989 nomination stated that ongoing development of the most extensive blanket bogs in the southern hemisphere (with associated unusual peat mounds) gave the TWWHA World Heritage value. It was noted that blanket bog development was ongoing in essentially undisturbed environment, which as noted above provided a key justification for the World Heritage significance of all the TWWHA geoconservation themes.

These assertions have been reviewed in Section (3.2.2) of this report, and are considered to be justified.

Integrity under Criterion (ii)

The 1989 TWWHA nomination argued that the integrity requirements of the specified geomorphic and soil processes were met by large size and diverse range of environments in the nominated area. This is true in general for the specified ongoing processes (see Section 3.2.2), but is not valid for some processes in some specific areas of the TWWHA. For example, the integrity of the Lower Gordon River fluvial process system has been significantly threatened by hydro-electric development and tourist boat operation. Nonetheless, the majority of the TWWHA area remains sufficiently undisturbed by human activities that, with some exceptions, the integrity requirements for ongoing geomorphic and soil processes under Criterion (ii) have easily been met.

Criterion (iii) ***Superlative natural phenomena, formations or features, for instance, outstanding examples of the most important ecosystems, areas of exceptional natural beauty or exceptional combinations of natural and cultural elements.***

Landscape

The TWWHA nomination (DASETT 1989, p. 44 - 45) identified the landscapes of western Tasmania as having exceptional natural beauty, some aspects of which are of international renown. Although landscape is not in itself a purely geoconservation value - because landscape values depend just as much on factors such as flora, cultural values and varying personal perceptions as they do on landforms, soils and rocks – the nomination cites geomorphic and geological features as primary factors contributing to the world heritage quality of the landscapes of western Tasmania.

Major geological and geomorphic features cited as contributing to the landscape values of the TWWHA include numerous glacially-sculpted peaks and lakes, distinctive dolerite and quartzite mountains, karst landforms such as those of the upper Weld River valley, high energy coastal landforms, and the broad lowland plains (which although not stated in the nomination justification, are the result of combinations of differential erosion across a variety of bedrock types, and erosion to differing base level surfaces over time).

The 1989 nomination argued that the (geologically and geomorphically-based) TWWHA landscapes were of World Heritage quality by simply asserting that they are "excellent", "superb" or "magnificent", but no real justification for these judgements were given. It is arguable, however, that the degree to which the TWWHA landscapes have attracted national and international interest over the last thirty years, have directly influenced major political decisions and community opinions, and have featured in a wide variety of photographic publications, could all be taken as evidence to justify their outstanding aesthetic beauty. If this is accepted, the degree to which geological and geomorphological features dominate many classic photographic images of the TWWHA – and thus can be said to contribute significantly to the outstanding aesthetic value of the TWWHA landscapes - is virtually unarguable, and some such justification could easily have been used in the 1989 nomination.

Specific geological and geomorphic elements that were cited as contributing to the outstanding landscape values of the TWWHA were:

Karst features

Aspects of the TWWHA karst systems were held to be "excellent", "superb" and "magnificent" (DASETT 1989, p. 46), although no real argument was given to justify such assertions or show them to be of World Heritage quality. Nevertheless, aspects such as the large scale of karst development at places such as Exit Cave, the Weld Valley and Mt Anne Northeast Ridge, and well developed speleothem displays in a variety of caves, can arguably be taken as good evidence of their contribution to the World Heritage landscape values of the TWWHA.

Glacial features

Aspects of the TWWHA glacial systems (including erosional and depositional features) are stated to be "superlative", "superb" or of "great significance" (DASETT 1989, p. 46), although no real argument is given to justify such adjectives or show them to be of world heritage quality. Nonetheless, even a cursory sampling of widely admired photographic images of the TWWHA landscapes demonstrates that glacial landforms – especially cirque lakes and glacially-sculpted peaks – are a major theme in many outstanding examples of TWWHA landscape photography, and are clearly widely appreciated as outstanding aesthetic features.

Other Geomorphological formations

A number of other geomorphic features are asserted to be "superb", "magnificent" and "superlative" (DASETT 1989, p. 47), but no more specific justification is provided. These include:

- Well expressed erosion surfaces
- Super-imposed river gorges
- Wide moorland-floored valleys with glacial outwash (eg, Vale of Rasselas)
- New River Lagoon and barrier beach
- Various elevated marine terraces
- Coastal sea caves and geo
- Ria coast at Port Davey & Bathurst Harbour

Again, whilst no specific justification for these features contributing to landscape values of outstanding universal value was provided, the degree to which some of the listed features, such as the Gordon River Splits (super-imposed river gorges) and the coastal landforms of the TWWHA have been repeatedly featured in published landscape photography could arguably taken as evidence of their outstanding landscape values.

Integrity under Criterion (iii)

The integrity conditions for the landscape value of the identified geoheritage phenomena were considered to be satisfied by the large extent of areas of unmodified wilderness that protect the identified values. Given that the outstanding aesthetic value of the TWWHA landscapes is accepted, the lack of visual intrusion by discordant artificial elements - which is characteristic of most of the TWWHA due to its wilderness quality - clearly justified their integrity under Criterion (iii).

Criterion (iv) ***The most important and significant natural habitats where threatened species of animals and plants of outstanding universal value from the point of view of science and conservation still survive.***

A variety of habitats were nominated as having World Heritage value under this criterion. Whilst bedrock, landform and soil substrates necessarily form an integral part of all biological habitats, a number of specific geomorphic (landform) types or soil types were singled out for mention as the habitat of biological species of outstanding universal value. These included:

- Alpine (mountain-top) habitats in general, and more specifically including:
- High altitude dolomite karst habitats at Mt Anne;
- Riparian (riverside) habitats in general, and more specifically including:
- Riparian limestone cliffs (Franklin & Lower Gordon Rivers);
- Alkaline pans (soil features) of the south-west moorlands;
- Coastal habitats; and
- Lakes (alpine lakes; dystrophic, oligotrophic and transitional types; meromictic lakes and coastal lagoons).

These landform and soil types were nominated under Criterion (iv) as habitats for biological species, rather than for their value as landforms and soils in their own right; thus it is arguable as to whether they have actually been nominated as features of geoconservation significance under Criterion (iv). This distinction is, however, largely immaterial given that most or all of the above landform and soil types are also parts of landform systems explicitly nominated for geoconservation values under other criteria (see above).

Conclusion – The Justification of World Heritage Geoconservation Values in the 1989 TWWHA nomination

The1989 TWWHA nomination (DASETT 1989, p. 27 & 42) provided a strong case for the importance of the wilderness character of the TWWHA in providing the basis for the region being a globally – rare temperate environment where natural geomorphic and soil processes continue to operate at natural rates and magnitudes over an extensive region; the 1989 nomination thereby made a good (albeit rather briefly argued) case for the ongoing blanket bog soil, fluvial, karst and coastal geomorphic process systems of the TWWHA having World Heritage geoconservation values under Criterion (ii) of the 1989 World Heritage Criteria.

The assertion that individual features of the TWWHA should be considered in a wholistic way as contributing to over-arching themes of World Heritage significance (DASETT 1989, p. 27) was also a strong point of the nomination, which allowed many features that would not individually have World Heritage significance to be validly considered as important contributors to over-arching themes of World Heritage significance. In order for this argument to justify World Heritage values, however, it is important to establish that the various individual features and values do indeed contribute to some over-arching ("wholistic") themes that are themselves of World Heritage significance[16]. The nomination did not achieve this for some of the individual features cited, for example some bedrock geology features. However the 1989 TWWHA nomination explicitly and convincingly cited the contribution of a range of TWWHA values to its wilderness character as the most important instance of such a wholistic theme (DASETT 1989, p. 27). Given that wilderness implies ongoing natural geomorphic processes, then as noted above the range of natural ongoing geomorphic processes cited in the nomination clearly provided a strong justification for the TWWHA having World Heritage values under Criterion (ii) of the 1989 criteria.

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[16] If isolated features, un-related to any particular theme and not individually of outstanding universal value in their own right, can be argued to contribute to some poorly-defined "collective" World Heritage value, then the whole argument would become meaningless since any individual features, anywhere, could be argued to contribute to a World Heritage value. The entire planet would then become a single World Heritage site. Whilst this is not necessarily an unreasonable view, it would defeat the purpose of the World Heritage Convention, which is to identify places of special value which warrant special protection compared to other places.

The nomination also made a strong, explicitly justified, case for the importance of the glacial features of the TWWHA (and by implication, related glacio-karst and other "extra-glacial" features) having World Heritage significance. These features collectively contribute to a "Cainozoic Ice Ages" theme under Criterion (i) of the 1989 World Heritage Criteria, and the 1989 TWWHA nomination provided a solid, comparative justification for the World Heritage significance of Tasmania's glacial (and related) features as a theme.

In many other respects, however, the 1989 TWWHA nomination gave only very brief evidence and justification for some of the World Heritage geoconservation values cited; in the case of many elements of geodiversity cited, other than those noted above, the nomination simply made unsupported assertions that they have World Heritage value. For many of the features and themes cited as contributing to World Heritage values, no comparative evidence was cited to establish that they are comparable to the best exemplars of their type globally (which is ultimately what is required for a justification of World Heritage values). Whilst many of the features or processes cited contribute collectively or "wholistically" to themes (wilderness / ongoing natural processes, Cainozoic Ice Ages) whose World Heritage significance was adequately justified, some others do not comfortably do so (eg, many of the bedrock geology features cited). Hence the World Heritage significance of some features cited cannot be considered to have been established by information and justifications provided by the 1989 TWWHA nomination.

It appears implicit in the TWWHA nomination, although it is not stated, that earlier deliberations on the World Heritage values of areas included in the 1989 TWWHA nomination that were exhaustively scrutinised during the prior Commission of Inquiry into the Lemonthyme and Southern Forests, also known as the "Helsham Inquiry" (Helsham *et al.* 1988), are to be taken "as read". Although the majority opinion expressed in the Inquiry's final report (Helsham *et al*. 1998) was that only five small areas outside the original 1982 World Heritage Area were of World Heritage Quality, this conclusion was disputed by one of the three Commissioners (Peter Hitchcock), and by many of the Commission of Inquiry's consultants, who considered that additional areas qualified as World Heritage. This dissenting view ultimately prevailed in the Australian Governments decision to nominate the enlarged area now listed as the TWWHA (DASETT 1989), and it appears implicit in the nomination that the World Heritage values argued during the Helsham Inquiry deliberations and supported by the dissenting Commissioner were taken to have established the justification for the most important World Heritage geoconservation values of the TWWHA, in particular karst, glacial and glacio-karst values. Since a number of large extensions to existing National Parks occurred following the Helsham Inquiry, and were at least in partly justified on the grounds that the Inquiry's deliberations (if not its majority opinion) had shown them to have World Heritage values, then the extension of the TWWHA in 1989 to cover those National Park extensions may have been taken to be simply formalising a judgement of World Heritage value that had already been exhaustively argued as an outcome of the Helsham Inquiry. If this interpretation is correct, the authors of the1989 TWWHA nomination (DASETT 1989) may have recognised that there was no longer a need to provide detailed justification of the World Heritage values of those areas and hence, did not in many cases do so.

2.3.3 *Current (updated) World Heritage Criteria*

Subsequent to the preparation of the 1989 TWWHA World Heritage nomination and listing of the nominated area on the World Heritage List, the criteria for identifying World Heritage values have been updated (UNESCO 1999). However, until such time as the values of the TWWHA have been reviewed in the light of the new criteria, the 1989 criteria (as reviewed in Section 2.3.2 above) remain the ones which formally apply (PWS 1999m, p.22).

This report comprises a part of the process of reviewing the values of the TWWHA in the light of the new (updated) criteria (UNESCO 1999), so that the latter can be formally applied to the TWWHA. This sub-section lists the current (updated) World Heritage criteria for natural properties, and the integrity and contiguity conditions for these (UNESCO 1999). These are the basis for the review and identification of geoconservation values of World Heritage significance in the TWWHA contained in the following sections and Appendix of this report.

Criteria for inclusion of natural properties on the World Heritage List

This report is concerned primarily with the geoconservation values of "natural heritage". Some Aboriginal cultural heritage values of World Heritage significance are closely related to geoconservation values (e.g., Aboriginal occupation and art sites in karst caves), however this relationship is not directly addressed in this report. Under article 2 of the World Heritage Convention, natural heritage for the purposes of the World Heritage List is defined as (UNESCO 1999, p. 10, paragraph 43):

> "natural features consisting of physical and biological formations or groups of such formations, which are of outstanding universal value from the aesthetic or scientific point of view;
>
> geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation;
>
> natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty."

A natural heritage property (as defined above) is considered to be of outstanding universal value (ie, to be of World Heritage value) for the purposes of the World Heritage Convention if it meets one or more of the criteria in paragraph 44 of the Operational Guidelines, and also fulfils the conditions of integrity (UNESCO 1999, p.10-11, paragraph 44). In principle a site could be listed on the World Heritage List if it fulfils just one criterion plus the relevant integrity conditions, although in practice most listed places have fulfilled more than one of these criteria. The criteria to be met are that the site(s) or place(s) should:

44 (a) (i) 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; or

(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; or

(iii) contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; or

(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;

Whilst the intent of the new criteria is essentially the same as that of the earlier criteria under which the 1989 TWWHA nomination was accepted and listed (as reviewed in Section 2.3.2 above), the new criteria represent a partial rewording and re-organisation of the earlier criteria, presumably undertaken to clarify their intent.

Criteria (i) and (ii) have been significantly altered compared to the criteria under which the 1989 TWWHA nomination was drawn up (DASETT 1989). In the earlier version of the Operational Guidelines, Criteria (i) and (ii) could both apply to geodiversity and/or to biodiversity, but the distinction was that Criterion (i) applied to features or systems representing the effects of past natural processes, whilst Criterion (ii) referred to presently ongoing processes and process systems. In contrast, the current criteria have been re-organised so that Criterion (i) focuses on geodiversity (including both features representing past processes, and ongoing geological or geomorphic processes), whereas Criterion (ii) focuses essentially on biodiversity (albeit ecological processes are referred to, which necessarily involve non-living as well as living things).

The wording of Criterion (iii) has been simplified in the new version, and whilst it may still be read as referring to superlative values other that aesthetic or scenic values, considered in conjunction with the new integrity conditions (below) the intention of Criterion (iii) now seems to be restricted almost entirely to the recognition of features of great aesthetic or landscape value. As such, however, many geological, landform and soil features may be crucial contributing components to landscapes of World Heritage aesthetic beauty (ie, of "outstanding universal value").

The wording of Criterion (iv) has only been slightly changed. The intent of this criterion is clearly the recognition of biological habitats of outstanding value. Whilst elements of geodiversity clearly underpin all biological habitats, it would probably misinterpret the intent of the criterion if it were used to recognise a feature primarily for its geodiversity values; the intention is clearly that the value of geodiversity is only recognised under this criterion to the extent that it underpins a biological species or community that is of outstanding universal value.

In addition to the four criteria for natural properties of World Heritage value (UNESCO 1999, para. 44), the updated Operational Guidelines for Implementation of the World Heritage Convention also place emphasis on evaluating the World Heritage values of nominated sites relative to other sites of the same type; thus, paragraph 60 of the updated Operational Guidelines reads:

60 Each natural site should be evaluated relatively, that is, it should be compared with other sites of the same type, both inside and outside the State Party's borders, within a biogeographic province or migratory pattern.

Although it is not explicitly stated in the Operational Guidelines, it seems implicit in paragraph 60 that World Heritage sites should be outstanding - or at least amongst the best - exemplars of their type in order to qualify for World Heritage listing.

In summary, under the new criteria most sites, features or systems of World Heritage geoconservation value will be recognised under criteria (i) or (iii), and will be amongst the best representative or outstanding examples of their type. Whilst some elements of geodiversity could arguably fall under criteria (ii) or (iv), it is evident that the intent of these latter criteria is focused on biodiversity values, and geodiversity values are only relevant to these criteria insofar as they underpin or contribute to the biological values.

Integrity conditions for natural properties on the World Heritage List

Properties meeting one or more of the above criteria must also fulfil the following conditions of integrity (UNESCO 1999, para 44(b)) in order to be considered of "outstanding universal value" (ie, of World Heritage value):

(i) The sites described in 44(a)(i) should contain all or most of the key interrelated and interdependent elements in their natural relationships; for example, an "ice age" area should include the snow field, the glacier itself and samples of cutting patterns, deposition and colonisation (e.g. striations, moraines, pioneer stages of plant succession, etc.); in the case of volcanoes, the magmatic series should be complete and all or most of the varieties of effusive rocks and types of eruptions be represented.

(ii) The sites described in 44(a)(ii) should have sufficient size and contain the necessary elements to demonstrate the key aspects of processes that are essential for the long-term conservation of the ecosystems and the biological diversity they contain; for example, an area of tropical rain forest should include a certain amount of variation in elevation above sea-level, changes in topography and soil types, patch systems and naturally regenerating patches; similarly a coral reef should include, for example, seagrass, mangrove or other adjacent ecosystems that regulate nutrient and sediment inputs into the reef.

(iii) The sites described in 44(a)(iii) should be of aesthetic value and include areas that are essential for maintaining the beauty of the site; for example, a site whose scenic values depend on a waterfall, should include adjacent catchment and downstream areas that are integrally linked to the maintenance of the aesthetic qualities of the site.

(iv) The sites described in paragraph 44(a)(iv) should contain habitats for maintaining the most diverse fauna and flora characteristic of the biographic province and ecosystems under consideration; for example, a tropical savannah should include a complete assemblage of co-evolved herbivores and plants; an island ecosystem should include habitats for maintaining endemic biota; a site containing wide-ranging species should be large enough to include the most critical habitats essential to ensure the survival of viable populations of those species; for an area containing migratory species, seasonal breeding and nesting sites, and migratory routes, wherever they are located, should be adequately protected; international conventions, e.g. the Convention of Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention), for ensuring the protection of habitats of migratory species of waterfowl, and other multi- and bilateral agreements could provide this assurance.

(v) The sites described in paragraph 44(a) should have a management plan. When a site does not have a management plan at the time when it is nominated for the consideration of the World Heritage Committee, the State Party concerned should indicate when such a plan will become available and how it proposes to mobilize the resources required for the preparation and implementation of the plan. The State Party should also provide other document(s) (e.g. operational plans) which will guide the management of the site until such time when a management plan is finalized.

(vi) A site described in paragraph 44(a) should have adequate long-term legislative, regulatory, institutional or traditional protection. The boundaries of that site should reflect the spatial requirements of habitats, species, processes or phenomena that provide the basis for its nomination for inscription on the World Heritage List. The boundaries should include sufficient areas immediately adjacent to the area of outstanding universal value in order to protect the site's heritage values from direct effects of human encroachment and impacts of resource use outside of the nominated area. The boundaries of the nominated site may coincide with one or more existing or proposed protected areas, such as national parks or biosphere reserves. While an existing or proposed protected area may contain several management zones, only some of those zones may satisfy criteria described in paragraph 44(a); other zones, although they may not meet the criteria set out in paragraph 44(a), may be essential for the management to ensure the integrity of the nominated site; for example, in the case of a biosphere reserve, only the core zone may meet the criteria and the conditions of integrity, although other zones, i.e. buffer and transition zones, would be important for the conservation of the biosphere reserve in its totality.

(vii) Sites described in paragraph 44(a) should be the most important sites for the conservation of biological diversity[17]. Biological diversity, according to the new global Convention on Biological Diversity, means the variability among living organisms in terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part and includes diversity within species, between species and of ecosystems. Only those sites which are the most biologically diverse are likely to meet criterion (iv) of paragraph 44 (a).

[17] It is notable that the wording of the first sentence of Integrity condition (vii) seems to suggest that World Heritage sites cannot be listed purely for geodiversity values, but must always be important sites for the conservation of biological diversity. This seems to imply that sites which have high geoconservation values can only be inscribed on the World Heritage List if they *also* have high value for biological conservation. In reality, however, some sites have in fact been inscribed on the World Heritage List solely for geological values. It seems that the wording of Integrity condition (vii) is flawed, and the writer hopes that this wording will be improved in the future!

In summary, the integrity conditions for places of World Heritage value require that the place includes all or most of the system components necessary to sustain the features that are of World Heritage value, with appropriate boundaries and buffer zones to enable the features or systems of World Heritage value to be self-sustaining and capable of being protected in the long term. World Heritage places should have an adequately resourced management plan which aims to protect their World Heritage values and should be ensured of appropriate long term protection of a legislative, regulatory, institutional or traditional sort.

Contiguity requirements for nominations to the World Heritage List

Basic principles of nature conservation and reserve design suggest that, from a management and ecological perspective, contiguous areas are to be preferred over discontinuous or fragmented ones. Notwithstanding this, it is not essential under the existing World Heritage Criteria (UNESCO 1999) for a World Heritage Area to be a single contiguous area. Paragraph (19) of the Operational Guidelines (UNESCO 1999, p.5) states

"State Parties may propose in a single nomination a series of cultural or natural properties in different geographical locations, provided that they are related because they belong to:

(i) the same historico-cultural group or
(ii) the same type of property which is characteristic of the geographical zone
(iii) the same geomorphological formation, the same biogeographic province, or the same ecosystem type

and provided that it is the series as such, and not its components taken individually, which is of outstanding universal value."

2.4 A Review of Relevant Available Geoscientific Data

The successful 1989 TWWHA nomination was necessarily based on the limited scientific information that had been collected up until that time. Partly because of the relatively inaccessible nature of much of the nominated region, only limited scientific research (much of it aimed at possible future hydro-electric, forestry and mining developments) had been undertaken in the region prior to it's listing as World Heritage. However, since the inscription of the enlarged TWWHA on the World Heritage List in 1989, there has been a need for improved information to enable better understanding and management of the area's heritage values, and this has led to a considerable increase in the amount and diversity of scientific research undertaken in the World Heritage Area.

Additionally, it was only in the lead-up to the 1989 TWWHA nomination – and particularly during the Helsham Inquiry – that serious efforts were made identify, assess and inventory the heritage values of the geodiversity of the TWWHA region in a logical and consistent way. Subsequent to 1989, there has been a considerable body of further work undertaken in this area, which now allows a far more detailed assessment of heritage values to be undertaken.

This section provides an overview of some relevant geological, geomorphic and soils research and mapping that has been undertaken in and adjacent the TWWHA both before and after 1989. Progress in the development of geoheritage assessment methods has been described in Section (2.1) above, and geoheritage inventory work that has occurred over the same period is noted below. These data and methods are used in the review of TWWHA geoconservation values presented in Section (3.0) below. Relevant scientific work is here reviewed in categories related to the thematic geodiversity categories used in Section (3.0).

Geoheritage Inventory Work

Considerable work over the last two decades or so by a number of Tasmanian earth scientists has resulted in the compilation of a considerable body of inventory and management information regarding geodiversity, geoconservation and geoheritage in Tasmania. Whilst geoheritage inventories also exist for mainland states of Australia, these are largely focussed on bedrock geology and site-specific physical features. The focus in Tasmania has extended beyond this traditional "geological monuments" approach by placing considerable emphasis on geomorphic and soil *systems*, and by recognising the importance of geomorphic and soil *processes* as integral parts of nature conservation generally. The geoheritage inventory work, in particular, has been a major focus of work in Tasmania, which has drawn heavily on the results of the various scientific investigations noted in following sub-sections

Geoheritage Inventory work prior to 1989

Early (pre-1989) geoheritage inventory work was mainly focussed on the "Geological Monuments" approach of the Geological Society of Australia (see Section 2.1). This early work was based mainly on recognition of the scientific, research and educational value of outstanding bedrock features and some landform sites as heritage which informs us about the Earth's past development, and this approach resulted in the preparation of two inventories of significant geological and landform sites (Jennings *et al.*1974, Eastoe 1979).

However, during the 1980's Kiernan (1984, 1989a) also provided the first detailed inventory of a significant geomorphic system, the Mole Creek Karst, which went beyond the "research and education" focus to consider natural process and intrinsic landform values.

A symposium held in 1990 by the Royal Society of Tasmania was important for drawing together all the scientific information on the natural heritage values – including geoheritage - of the TWWHA that had been collected up until roughly the time of the 1989 nomination (Smith & Banks 1993), and continues to provide an excellent summary of the natural heritage of the TWWHA.

Geoheritage Inventory work after 1989

The employment of a number of earth scientists in Tasmanian land management agencies (especially the Parks & Wildlife Service, the (then) Forestry Commission and the Forest Practices Unit) during the 1980's led to an acceleration of geoconservation work during the early 1990's, as these officers sourced funding and initiated projects to improve knowledge of Tasmanian geodiversity, its natural processes and management requirements. Of particular relevance to the identification of World Heritage values was the development of defensible methods of assessing conservation significance levels (see Section 2.1 & 2.2). These methods were used to compile a variety of inventories of Tasmanian geoheritage, incorporating assessments of significance.

Most of these inventories were "reconnaissance inventories" in the sense described in Section (2.2), however they nonetheless constituted an important record of the most readily identifiable elements of significant geoheritage on public land in Tasmania. Of particular relevance to the present project was an assessment and listing of World Heritage values in proposed extension areas adjoining the TWWHA (DPWH 1990), many of these areas being recommended by the present report for inclusion in the TWWHA (see Section 3.3), or being noted as requiring sympathetic cross-tenure management of World Heritage values (Section 3.4). Dixon's (1991) inventory of geoheritage in the TWWHA was an important early geoheritage inventory which listed many of the sites contributing to World Heritage values, as well as sites of notable but lesser significance within the same region. Further reconnaissance inventories were compiled for reserved and some unreserved public lands throughout Tasmania by Bradbury (1993, 1994, 1995) and Dixon (1994, 1995b, 1996, 1997), whilst Sharples provided reconnaissance geoheritage inventories of State forests throughout Tasmania, and some public lands in north-western Tasmania (Sharples 1992, 1994a, 1994b, 1995b, 1996a, 1996b, 1997). Between them, these inventories have provided a reconnaissance coverage of most public land in Tasmania, however private land remains poorly assessed at even the reconnaissance level.

During 1996 all these reconnaissance inventories were amalgamated into a single electronic database, the Tasmanian Geoconservation Database (Dixon & Duhig 1996). This database has subsequently undergone further updating and review, and is managed by an expert reference group (see Section 2.1).

Development of more systematic and thematic geoheritage inventories began during the 1990's, with Kiernan's *Atlas of Tasmanian Karst* (Kiernan 1995) providing the first comprehensive and uniform state-wide data set on a particular geodiversity theme. Recent work on fluvial landform systems (Jerie *et al.* 2001, 2003) and mapping of coastal landforms (Sharples 2000) similarly provide comprehensive data sets on Tasmanian river systems and coastal landforms for use in preparing systematic significance assessment of these landform systems state-wide.

Eberhard (1994, 1995) provided detailed geoheritage inventories and management recommendations for highly significant karst systems in the Junee – Florentine Valleys (outside the TWWHA), and has recently provided a detailed GIS-based inventory and management strategy for the Mole Creek Karst, which partly falls within the TWWHA and is of clear World Heritage value (Eberhard 2003). Cullen (1998a) has provided a detailed description and inventory of sandy barrier beaches of the TWWHA which provides part of the basis for the assessment of their World Heritage values in the present report (Section 3.2.2).

Fluvial Geomorphic mapping and research

Research and mapping prior to 1989

Although river hydrology in Tasmania was intensively studied during the 20th Century, and considerable hydrological data was collected for hydro-electric development planning and other purposes, there was very little detailed study of river or fluvial landform development processes in Tasmania prior to 1989. The few detailed studies of fluvial geomorphology that were undertaken related to areas outside the TWWHA (eg, Goede 1965), and in general, most of what was known or surmised about the geomorphic history and development of Tasmanian fluvial systems was based on interpretation of regional – level observations, with little detailed data to support it.

Nevertheless, by the mid-1960's a number of broad conclusions had been reached about the history and large - scale geomorphic processes of Tasmanian river systems. These included recognition of the influence of Tertiary basalts on modifying drainage patterns (eg, Nye 1924); the identification of a stepped series of erosion surfaces in the Tasmanian landscape as representing major and ancient phases of fluvial denudation, into which rivers have subsequently incised deeply (eg, Twidale 1957, Davies 1959); the observation that many Tasmanian river valleys are too large, and contain more coarse sediment than can be explained by present day discharge rates - implying greater discharges in the past (eg, Goede 1965, Davies 1965); and identification of numerous instances of past river capture that have modified the drainage system during its history (eg, Nicolls 1960, Fish & Yaxley 1966). Davies (1965) produced a broad synthesis of the major styles of structural (bedrock) control on Tasmanian river networks, in which he identified the strong influence of fold structures in producing the characteristic "trellised" and strike valley drainage patterns characteristic of much of southwest Tasmania, contrasting with the influence of fault structures in producing rectilinear drainage patterns in areas underlain by flat-lying rock units. Davies also highlighted the fact that many large western rivers cut directly across fold structures, producing some of the spectacular gorges that are a famous feature of the TWWHA; he attributed this to superimposition of drainage patterns inherited from flat-lying rocks which formerly covered the folded rocks and have subsequently been removed by erosion.

Some probably incorrect ideas about drainage development in the TWWHA were also current around the 1960's, for example Carey's (1960) ideas that geologically – recent tectonic tilting had modified drainage patterns in the southwest region and had thereby produced the original Lake Pedder (Fish & Yaxley 1966, p. 255). This idea was superseded by Davies (1967) glacigenic interpretation of Lake Pedder, but has continued to be believed by some geologists up to the present and was recently again debunked by Kiernan (2001a, p. 22).

Despite this, by the late 1980's it was nevertheless clear that the major tectonic movements associated with the Late Cretaceous – Early Tertiary separation of Tasmania and Antarctica, and the subsequent opening of the Tasman Sea, had indeed produced tectonic tilting and large scale horst and graben structures in Tasmania which must have played a major early role in modifying and determining the broad pattern of the present major Tasmanian river networks. This tectonism must have resulted in a major increase in landscape relief, hydraulic gradients and the rates of fluvial denudation during the Early Tertiary.

However, whilst much of the early work focussed on the geomorphic history and development of Tasmanian river systems, there was very little work undertaken on modern river forms and ongoing fluvial processes, either in the TWWHA or elsewhere in Tasmania. This constitutes a major gap in our knowledge of Tasmanian river systems which is critical in understanding the sensitivity of fluvial systems to disturbance, yet remains a poorly studied area to the present.

Research & mapping after 1989

In general, the geomorphic history and development of Tasmania fluvial systems during the Tertiary and Quaternary is only a little better known today than it was in the 1960's, as is our understanding of ongoing Tasmanian fluvial geomorphic processes. This is due at least in part to the ongoing lack of focus on fluvial geomorphology in Tasmania, with no more than a handful of detailed fluvial geomorphic studies having been conducted since 1989.

Improved dating of Tertiary basalts, and in some cases mapping of pre-basaltic river valleys flooded by volcanic lava, has been undertaken (eg, Everard 1989), however the potential of such information to fill in the picture of Tertiary river development in Tasmania has yet to be realised. The ages and significance of major erosion surfaces in Tasmania – which such basalt data also has the potential to help elucidate - remain little better understood today than they were in the 1960's (Houshold *et al.* 1999, p. 67). New palaeobotanical and geomorphic data on major climate changes during the Tertiary (eg, Hill 1990, Macphail *et al.* 1991), and during Quaternary glacial and interglacial phases, have highlighted the fact that higher river discharges and erosion rates during humid Early Tertiary climates, and during meltwater-dominated glacial phases, can account for the over-sized valleys and coarse fluvial deposits found in Tasmanian river systems today, however the implications of these climatic changes for Tasmanian rivers have rarely been explored in detail. Similarly, the effects on river processes and morphology of long-suspected climatic variations in Tasmania during the Holocene have yet to be confirmed or studied in detail.

Earlier recognition of the effects of karst and glacial processes on fluvial geomorphic history in Tasmania (eg, Jennings & Sweeting 1959, Goede 1969, Colhoun & Augustinus 1984) has been confirmed with study of further examples (eg, Eberhard 1994, 1997a, Kiernan *et al.* 2001), however the additional information available from these karst and glacial studies has yet to be fully integrated into a more detailed synthesis of fluvial geomorphic development in Tasmania through the Cainozoic.

Only a handful of studies of modern fluvial geomorphic forms and processes have been undertaken in Tasmania since 1989. Of these, one important group of studies have been undertaken in the TWWHA, namely detailed studies and monitoring of fluvial landforms in the Lower Gordon River system (Soutberg 1991, Bradbury *et al.*1995). These studies were initiated as a direct response to the impacts of hydro-electric development and tourist boats on the river landforms, and have resulted in establishment of other fluvial landform monitoring projects in and near the TWWHA (eg, Bradbury & Dixon 1998). Further studies of the fluvial geomorphology of the Gordon River below the Gordon Dam have also been undertaken in the last few years with the aim (amongst other things) of identifying likely geomorphic impacts on the Gordon River of changed hydro-electric power station operations resulting from proposed linkage of Tasmania's hydro-electric grid to the national electricity grid (Koehnken *et al.*2001).

Most recently (2002 – 2003), studies of the influences of tectonism and peat soils on fluvial landform development in the TWWHA have been undertaken by Kathryn Jerie and Ian Houshold (DPIWE) in the Birches Inlet region (Jerie *et al.* 2003, Appendix 8), following earlier recognition of unusually well developed flights of fluvial terraces associated with rivers in that area (Bradbury 1996). Evidence is emerging that the blanket bog peat soils characteristic of the TWWHA have a significant influence on fluvial geomorphic processes, potentially adding a new dimension to the significance of both ongoing fluvial and ongoing blanket bog soil process systems in the TWWHA (K. Jerie, DPIWE, *pers. comm.*).

Whilst the Gordon River studies were undertaken in response to threats to a known geoheritage value of the TWWHA, and the Birches Inlet studies have led to recognition of a new facet of fluvial geoheritage values in the TWWHA (see Section 3.2.2), very few other detailed fluvial geomorphic studies – especially process studies - have yet been undertaken elsewhere in the TWWHA, although some monitoring of river bank morphology is occurring in a few places, such as rivers draining into Port Davey.

On the other hand, concern over river management in areas of agricultural, forestry and urban development has grown during the last decade, resulting in a number of fluvial landform mapping projects and studies of fluvial landform sensitivity outside the TWWHA. These have included several river styles mapping projects (see Jerie *et al.* 2003 for a list of Tasmanian river styles assessments) and a study aimed at improving stream geomorphology management in forestry areas (Wells 2002). Although mainly focussed outside the TWWHA, information from these projects is likely to ultimately contribute to knowledge of the diversity and proper management of TWWHA fluvial systems.

However, from the perspective of assessing the geoconservation or geoheritage significance of fluvial geomorphic systems in the TWWHA, two issues are of keystone relevance (see Section 2.2), namely:

- the diversity of fluvial landform systems in the region, and the ability to determine their representativeness and rarity or otherwise; and

- the integrity of natural processes in the TWWHA fluvial systems, that is, the degree of artificial process disturbance (pre- or post-European settlement).

From the perspective of managing and protecting natural fluvial geomorphic systems in the TWWHA, a further keystone issue is:

- knowledge and understanding of the natural geomorphic processes that form and maintain fluvial landform systems; this knowledge is critical in assessing the sensitivity of fluvial systems to a variety of potential disturbances.

In regard to fluvial system diversity, a major recently completed DPIWE study has classified and mapped Tasmanian fluvial landform systems (state-wide) into fluvial "georegions" defined according to fundamental geomorphic "system controls" (Jerie *et al.* 2001, 2003). This represents a major advance in assessment of the geoconservation values of the TWWHA, since it provides objective characterisation of the diversity ("fluvial geodiversity") of fluvial landform systems in

Tasmania, including the TWWHA, and consequently will allow more rigorous comparative geoconservation significance assessments of fluvial geomorphic systems in the TWWHA and elsewhere (see also Section 2.2).

Given the potential to be able to objectively assess the representativeness and rarity or otherwise of fluvial systems in the TWWHA that the fluvial georegionalisation of Jerie *et al.* (2001, 2003) provides, the other key information needed for assessments of the geoconservation significance of fluvial landform systems is data on their integrity, that is, the degree to which their natural processes continue to operate, or have been artificially modified. The general lack of historic (and potentially in many areas, pre-European) modification of river systems in the TWWHA indicates that their integrity is likely to be high in many areas, however studies of the Gordon River (see above) have highlighted that there has been significant fluvial process modification in the Lower Gordon area due to hydro-electric development and tourist boat operations (Bradbury *et al.* 1995).

Extensive degradation of peat soils due to fire has also occurred in parts of the TWWHA south of Macquarie Harbour and on the Central Plateau (Pemberton 1988, Cullen 1995), resulting in extensive destruction of peat soils, erosion of Tertiary alluvial sediments and Quaternary periglacial mantles, and likely consequent modification of fluvial processes. It is likely that some of this peat degradation predates European influences and, given that Aboriginal firing is known to have occurred widely in the TWWHA, it is possible that pre-European (Holocene) anthropogenic modification of fluvial geomorphic processes has occurred in some of the blanket bog areas of the TWWHA (Jerie *et al.* 2003, Appendix 8). Lack of scientific data on the extent of pre-European anthropogenic influences on fluvial processes in the TWWHA constitutes an important gap in understanding of the significance of fluvial geoconservation values in the TWWHA (see also Section 4.5).

Finally, and as noted above, lack of detailed understanding of the ongoing fluvial geomorphic processes that form and maintain natural fluvial landforms in the TWWHA remains a large knowledge gap which needs to be filled in order to improve ability to recognise the sensitivity of TWWHA fluvial systems to various disturbances (e.g., fire), and thus to be able to appropriately manage disturbances in the TWWHA so as to maintain the natural integrity of TWWHA fluvial systems.

Karst mapping and research

Research and mapping prior to 1989

Karst features, especially speleothem-decorated caves, have been of significant interest to Tasmanian's since the 19th Century, so much so that Tasmania's first cave conservation reserve, at Wet & Honeycomb Caves (Mole Creek), was declared as early as 1894 (Dyring 1995). Cave tourism of various sorts has occurred in Tasmania since the 19th Century, but cave exploration and karst mapping accelerated significantly after World War II with the establishment of the Tasmanian Caverneering Club by Professor Sam Carey. As a result, there was significant exploration, mapping and scientific research undertaken in some major karst areas such as Ida Bay, Junee-Florentine and Mole Creek prior to 1989.

One of the first major conceptual revolutions in the scientific understanding of Tasmanian karst was the recognition of the influence of glaciation on the development of Tasmanian karst systems. This was ultimately to be a key factor in ascribing World Heritage value to the western Tasmanian karsts. The earliest suggestion that glacial processes had influenced karst evolution in Tasmania was probably the speculation by Jennings & Sweeting (1959) and Jennings & James (1967) that decanting of glacial meltwaters from glacio-fluvial fans had driven the underground breaching of a drainage divide at Mole Creek. Around the same time Goede (1969) similarly noted that glacial processes had been an important influence on the development of Exit Cave. Subsequent work has shown that glacio-karst process interactions were widespread in Tasmania, however some of the most important pre-1989 work in this area was on glacio-karst systems of impressive scale and complexity at Mt Anne (Kiernan 1990a,b) and Mt Bobs (Kiernan 1989b).

The first major Tasmanian study of karst heritage management issues was completed for the Mole Creek Karst in 1984 (Kiernan 1984, republished as Kiernan 1989a). As well as providing the first thorough review of practical management issues for a Tasmanian karst area, this report identified specific areas of karst considered to be of sufficiently high conservation significance as to warrant protective reservation (Kiernan 1984, p. 288; Kiernan 1989a, p.113).

Apart from Exit Cave and Mole Creek, some cave exploration occurred in the TWWHA area prior to 1989 in locations such as Judd's Cavern (Wargata Mina), the NE Ridge of Mt Anne, Precipitous Bluff, and along the lower Gordon and Franklin Rivers (Middleton 1979). The discovery of Aboriginal cultural material in caves along the Lower Gordon and Franklin Rivers was a key factor in the success of the original 1982 World Heritage Area nomination, and karst values, especially glacio-karst, made a major contribution to establishing the World Heritage significance of the extended TWWHA region during the Helsham Inquiry (Helsham *et al.* 1988) and subsequent TWWHA nomination (DASETT 1989).

Kiernan & Eberhard (1993) provided a summary of the knowledge of karst geomorphology (and biology) up until 1989.

Research & mapping after 1989

The declaration of the TWWHA in 1989, incorporating Exit Cave which was recognised as having World Heritage value in its own right, resulted in a flurry of mapping and scientific work in Exit Cave (Houshold & Spate 1990, Houshold 1992, Kiernan 1991a, 1993). The scientific work was driven by management needs, since the presence of a working limestone quarry intersecting known cave passages created a need to understand the relationships between Exit Cave and the quarry. Not only did this work greatly improve knowledge of the processes and values of Exit Cave, leading to the closure of the adjacent quarry, but it also generated a further conceptual advance, namely the first real recognition of the important role of previous (pre-Cainozoic) phases of cave development (palaeokarst) in determining major aspects of Cainozoic cave development (Houshold 1992).

Since 1989 continuing research on glacio-karstic interactions has made it clear that glaciation has influenced karst development in Tasmania over much greater areas and time frames than was initially apparent. Whilst evidence of glaciations prior to the last having affected Tasmanian karst development has been recognised since at least the early 1980’s (Goede & Harmon 1983, Kiernan 1983), it was not until the 1990’s that it became clear that there has been a long history of glaciation significantly modifying karst processes over multiple glacial stages and over large areas of the central-southern-western Tasmanian landscape (Eberhard 1997a, Kiernan *et al.* 2001).

Understanding of the complexities and value of Tasmanian karst systems has benefited from at least three further substantial conceptual advances since the 1989 TWWHA nomination. Firstly, there has been a recognition of the influence on Cainozoic karst processes of a legacy of multiple “palaeokarst” phases extending back to at least 350 million years before present. Although the presence of limited ancient (Devonian) palaeokarst in Tasmania had been recognised for decades at Eugenana in northern Tasmania (Burns 1964), it was probably not until the intensive investigations of Exit Cave after 1989 that it became clear that the Cainozoic development of several major cave passages at Exit Cave has followed much older infilled (“palaeokarst”) passages, and that sulphuric acids generated by weathering of the sulphide-bearing palaeokarst deposits are partly responsible for the enormous scale of parts of the cave (Kiernan 1991a, Houshold 1992, Clarke 1995, Osborne & Cooper 2001). Subsequent work has recognised that similar palaeokarst phenomena are present in other Tasmanian caves, and represent at least 4 distinct phases of karst development at intervals extending back to Late Devonian times.

Secondly, and still somewhat tentatively, there has been recognition of evidence for ancient hydrothermal processes having played a role in the evolution of some palaeokarst systems in the TWWHA (which in turn have influenced Cainozoic cave development is noted above). Large coarse crystalline quartz vughs in dolomite at Mt Weld are thought to have been formed by a post-Carboniferous hydrothermal karstification event - and have in turn provided a focus for contemporary cave development (R. Eberhard & C. Sharples *unpublished data*, Bottrill *et al.* 1999, Calver *et al.* 2003) - whilst Osborne & Cooper (2001) suggest that one of the phases of palaeokarst development at Exit Cave was a hydrothermal cave development phase which has had important consequences for the present phase of cave development.

Thirdly, the significance of humic acids in Tasmanian karst development has been recognised (Houshold *et al.* 1999), and may partly account for the significant scale of karst development in the (normally-less-soluble-than-limestone) Precambrian dolomite carbonate rocks of the TWWHA. This factor is potentially very important, as the presence of significant quantities of humic acids in the TWWHA environment is related to extensive blanket bog development in TWWHA, with the degree of blanket bog development itself constituting a significant World Heritage value of the TWWHA (see relevant sections in this report). The influence of humic acids may be a key factor in the global uniqueness and diversity of the TWWHA karsts.

During the 1990's, work on cave speleothem trace element compositions as dateable indicators of past environmental conditions was progressed by Albert Goede and Joel Desmarchelier, and highlighted the potential that the TWWHA karst systems have for providing sensitive records of past environmental changes during the Cainozoic (contributing significantly to the *Late Cainozoic Ice Ages and Climate Change Record* World Heritage theme).

Other notable karst phenomena described from the TWWHA subsequent to 1989 (albeit recognised earlier) includes tower karst (rare in temperate climatic zones) on Precambrian dolomites in the Lightning Plains - Maxwell River valley – Algonkian areas (Dixon 1992, Kiernan 1995, vol. 2 p. 47, 58).

Karst and cave exploration in parts of the TWWHA progressed slowly subsequent to 1989, however many areas of evident high cave exploration potential have remained almost entirely unexplored up to the present, largely due to the difficulties of access to these remote undisturbed areas for gear-laden cavers. Most parts of the extensive high relief dolomite and limestone karsts of the Weld Valley and Precipitous Bluff – Mt Bobs belt remain unexplored, a large topographic depression in dolomite in the upper New River basin has only been briefly visited at the surface on one or two occasions, the potentially very high relief extension of limestone inland from Surprise Bay has apparently not been examined on the ground, and the high relief dolomites of Red Rag Scarp (Mt Picton) have remained largely unexplored despite a cave depth potential of over 500 metres (which could yield Australia's deepest caves). Even the (comparatively accessible) known high relief extension of limestone south-westwards from Exit Cave has rarely been explored for evidence of karst.

On the other hand, reconnaissance geological mapping and karst exploration in the New and Salisbury River catchments (Dixon & Sharples 1986, Eberhard *et al*. 1991) has provided a basis for identifying those catchments as undisturbed fluvial and karst process systems of potential World heritage significance in their own right (see Section 3.2.2).

Of particular importance to assessing the geoheritage significance of Tasmanian karst was the publication in 1995 of *An Atlas of Tasmanian Karst* (Kiernan 1995), which mapped all Tasmanian karst areas known to that date, and summarised information about each of them in a uniform format. This Atlas has provided a consistent and comprehensive database on Tasmanian karst that is especially useful for comparative heritage significance assessments. Digital versions of the Atlas have subsequently been edited and upgraded.

One of the most important developments for the management of TWWHA karsts has been the Natural Heritage Funded Mole Creek Karst Integrated Management Strategy (Eberhard 2003), which involved additional karst exploration and mapping, and has established a framework to progress management of that very significant karst across the boundaries of TWWHA and of National Park, State forest and private freehold tenures. Detailed management planning has been undertaken for the Mole Creek Karst National Park (partly TWWHA) and the Hastings Caves State Reserve (adjacent the TWWHA). Work has also recently commenced on a detailed karst exploration and mapping project for the Mt Picton – Riveaux karst, which straddles the South West National Park – State forest boundary in the middle Huon area, and for which a variety of future management options (including potential partial or complete incorporation in the TWWHA) are on the table.

Coastal Geomorphic mapping and research

Research and mapping prior to 1989

The coastal geomorphology of the TWWHA had received only limited attention prior to 1989. Davies (1965, 1973, 1978) provided important early insights into regional geomorphic characteristics of the TWWHA coast, emphasising in particular the effects of its high degree of exposure to wave energy generated by constant south-westerly swells (Davies 1978), tectonic (faulting) controls on the gross form of its long straight south-west coast from South West Cape to Cape Sorell (Davies 1965), the relatively limited availability of sand sources to build beaches (as compared to the abundant glacio-fluvial sand sources north of Cape Sorell), and the highly embayed and compartmentalised nature of the entire TWWHA coast, which greatly limits the effect of littoral drift on sand movement within this region (Davies 1973). Sanders (1968) investigated the development of shore platforms which are well developed on many parts of the TWWHA coast. Kiernan (1987) briefly noted evidence of higher Last Interglacial sea levels in the form of sea caves up to 12m above present sea level on Ile du Golfe, and identified glacial outwash from South Cape Rivulet valley as the likely source of sands in South Cape Bay and dunes at Blowhole Valley. A study of the entire Tasmanian coast by the Tasmanian Conservation Trust (TCT 1980) involved collection of a number of physical and biological datasets on the TWWHA coastline, of which one of the most important was the production of an airphoto - interpreted 1:50,000 scale map of the landform types of the entire Tasmanian coast compiled by Revel Munro (Munro 1978). The TWWHA parts of this map were reproduced in a SW Tasmania Resources Survey publication (TCT/SWTRS 1979), but in general this valuable dataset was little used prior to 1989. However, Munro's original paper map was subsequently digitised during 2000 (Sharples 2000) to form part of a digital coastal geomorphic map & data set now held by the Tasmanian Department of Primary Industries, Water & Environment (DPIWE).

Both Davies' and Munro's studies were simply parts of broader Tasmania-wide regional studies, and little detailed or focussed study of TWWHA coasts occurred prior to 1989. Probably largely for this reason, the potential for coastal landform features of World Heritage value received only brief mention in the 1989 TWWHA nomination.

Research & mapping after 1989

Following the inscription of the TWWHA on the World Heritage List in 1989, the need for better scientific knowledge to guide management of the TWWHA led to the initiation of several research projects on coastal geomorphology by the Earth Science Section of the (then) Parks & Wildlife Service. An preliminary survey of the geomorphology of the entire TWWHA coast was commissioned (Baynes 1990), and this highlighted a number of major characteristics of the coastline including the presence of prominent rock-cut marine terraces representing former higher relative seas at several levels up to 80 metres above the present shoreline, a suite of prograded barrier beach complexes, and prominent active dune erosion on many of these complexes.

Baynes' report highlighted a need for further studies of the beach and dune complexes of the TWWHA, and subsequent detailed geomorphic mapping and studies of these (Cullen 1998a, Pemberton & Cullen 1999) showed that these systems have preserved information critical to unravelling the Pleistocene and Holocene (post-glacial) climatic, environmental and pre-European cultural history of Tasmania. In the light of these studies it has become apparent that the TWWHA barrier beach/dune systems comprise the most extensive assemblage of sandy coastal landforms in the south-eastern Australian region whose geomorphic processes are today still virtually undisturbed by human activities[18], which makes these landforms particularly significant as benchmark geomorphic process sites (Cullen 1998a). Threats to the integrity of natural geomorphic processes on the TWWHA sandy coasts have been identified – in particular, the incipient spread of the coastal weeds marram grass and sea splurge to the TWWHA coast (Cullen 1998b) - and are being actively managed (eliminated) to protect the integrity of these benchmark process sites.

Geological and geomorphic investigations of TWWHA islands have been undertaken by Pemberton (1990), Banks (1993) and Dixon & Houshold (1996). These studies allowed Dixon (1996) to identify a range of coastal geoheritage features including a large scale suite of coastal mass movement landforms on De Witt Island, unusual soils and rare biogenic minerals, most of which have been listed on the Tasmanian Geoconservation Database (see Section 2.1 & Appendix A1.0).

Geological mapping in part of the TWWHA at Birches Inlet, and elsewhere in Macquarie Harbour and Cape Sorell (McClenaghan & Findlay 1989, 1993 p. 9-13), identified unusually well-developed uplifted marine terraces at a variety of levels, some of which are probably related to nearby river terraces in the Sorell River region south of Birches Inlet that together comprise an unusual landform complex of World Heritage value (Jerie *et al.* 2003, Appendix 8; Bradbury 1996; see this report Section 3.2.2: *Fluvial Geomorphic Process Systems* sub-theme). However, understanding of these features is still at an early stage, and the relationships between the terraces at Macquarie Harbour, and those previously identified elsewhere in the TWWHA by Baynes (1990) remains unclear.

Kiernan (1997) has produced a description and classification of Tasmanian coastal landforms that is intended to form a basis for more systematic identification of coastal landforms of geoconservation significance (see Section 2.2).

Glacial Geomorphic mapping and research

Research and mapping prior to 1989

Early investigations into Tasmanian glacial landforms were conducted by an enthusiastic amateur, Arndell Lewis, in the early Twentieth Century (e.g., Lewis 1924), however progress in Tasmanian glacial studies was limited prior to the 1980's, with clear evidence for only one phase of Cainozoic glaciation being recognised in Tasmania over much of that period (e.g., Jennings & Banks 1958, Derbyshire 1968). However, a renaissance of interest in Tasmanian glaciation occurred in the early 1980's, and within a few years clear evidence for at least three distinct Cainozoic glaciations was recognised (Kiernan 1980, 1983a, 1985, Augustinus & Colhoun 1986). Much of this work was initially focussed on the West Coast Range, which had high precipitation and ice throughput rates during glacial phases, and hence contains some of the best developed and expressed glacial landforms and deposits in Tasmania, which serve as an informal "type site" for Tasmanian glaciations (Colhoun 1985). Kiernan and Hannan's subsequent mid-1980's work on glacial

[18] Other than the globally - extensive effects of human-induced enhancement of the Greenhouse Effect.

landforms of the Central Highlands (Kiernan 1985, 1989c, 1990c, 1992) and Mersey – Forth valleys (e.g., Hannan & Colhoun 1987), together with studies of areas such as Mt Anne (Kiernan 1990a, b) and some observations on other southern ranges (Davidson 1971, Colhoun & Goede 1979, Kiernan 1987, 1989b) provided a great deal of the theoretical basis for arguing the World Heritage glacial values of the TWWHA in the Helsham Inquiry (Helsham *et al.* 1988) and the 1989 TWWHA nomination (DASETT 1989).

Research & mapping after 1989

Glacial landform studies have continued on the West Coast Range (e.g., Fitzsimons *et al.* 1993), Cradle Mountain area, Pieman Valley, Vale of Belvoir, Western Tiers region, Mt Field, Picton Valley, Frankland Range (Kiernan 2001a) and elsewhere during the 1990's, and the list of identifiable glacial phases in the Cainozoic of Tasmania has been extended, back to a possible very early glacial phase of Late Eocene or Early Oligocene age (Macphail *et al.* 1993). Kiernan (1996) has produced a general description and systematic classification of Tasmanian glacial landforms that is intended to form a basis for more systematic identification of glacial landforms of geoconservation significance (see Section 2.2). Most recently, a review of existing data by Kiernan (2001a), using the classification – based approach developed in Kiernan (1996), has shown the original Lake Pedder to be a glacigenic landform of undoubted World Heritage value, and one which still exists intact beneath the Huon – Serpentine Impoundment (Tyler 2001, Kiernan 2001b).

However, the glacial landforms of some outstanding glaciated regions of the TWWHA remain almost entirely un-studied, including the Arthur Ranges, Frenchman's Cap and much of the Southern Ranges.

One of the key realisations that has emerged from the last several decades of glacial research in Tasmania, is the profound degree to which Cainozoic glaciation has influenced the Cainozoic landform development of Tasmania generally. Not only are directly-glaciated mountain ranges and glacial sediment deposits a major feature of the Tasmanian landscape, but glaciation, and glacial climatic conditions, have strongly influenced fluvial landform development (valley shapes and sizes, meltwater flows, bedload supplies, modified drainage patterns, etc), slope evolution (large scale periglacial processes and slope mass movement processes, erosion and sediment supply to rivers), coastal landform development (effects of changing sea levels, large glacigenic sand supplies to coasts), karst development (widespread glacio-karst processes) and inland aeolian processes (extensive cold arid-climate aeolian landforms in north-western, north-eastern and central Tasmania). See relevant discussions elsewhere in this report for further details.

Soil mapping and research

Research and mapping prior to 1989

Although the presence of widespread peat soils in southwest and western Tasmania had been long known (Nicolls & Dimmock 1965), the geoconservation significance of these extensive "blanket bog" peat soils was probably not fully appreciated until the late 1980's when the first systematic regional-scale soil surveys of the region were published, highlighting the presence and vulnerability of blanket bog peats in western Tasmania (Pemberton 1986, 1989). The blanket bogs were cited in the 1989 TWWHA nomination as having World Heritage value in virtue of being the most extensive blanket bog peat soils in the southern hemisphere (DASETT 1989, p.43).

Other unusual soil (or "soil-related"?) phenomena that were known from the TWWHA region prior to the 1989 nomination were the "alkaline pans", visually prominent features that within the TWWHA are known from areas of carbonate bedrock (Brown *et al.* 1982, Jarman *et al.* 1988, Dixon 1992). Alkaline pans were cited in the 1989 nomination as contributing to World Heritage values as biological habitats, however it is arguable that they also have geoconservation significance as soil features.

Research & mapping after 1989

It was apparent in the 1980's that the blanket bog soils, and a variety of other soils in highly valued alpine areas of the TWWHA, are extremely vulnerable to human disturbance and have already been considerably degraded in some areas by deliberate firing, cattle grazing and other causes (Pemberton 1988, Cullen 1995, Pemberton & Cullen 1995). Subsequent to the 1989 inscription of the TWWHA on the World Heritage List, the resulting incentive to protect the World Heritage values of these vulnerable soils, and of their associated landscapes and biological communities, has resulted in ongoing management, research and rehabilitation initiatives.

Cullen (1995) undertook a detailed study of alpine soil degradation due to past fires and stock grazing in the Central Plateau part of the TWWHA, which has provided a basis for subsequent management prescriptions and projects designed to revegetate the worst affected areas and prevent further degradation.

The management of blanket bog peats has proven a controversial issue during the 1990's, since there is evidence that repeated firing is responsible for, and needed for the maintenance of, many of the native vegetation communities of the TWWHA. At the same time, however, excessive burning has also been shown to be responsible for blanket bog peat soil degradation and erosion, and subsequent fluvial landform disturbance. Hence, effort has been and continues to be invested in researching peat land hydrology and Holocene fire regimes in the TWWHA with a view to determining appropriate fire regimes which will maintain TWWHA vegetation communities without destroying blanket bog soils (e.g., Bridle *et al.* 2003). Work has also commenced to research the influence of blanket bog peat soils on fluvial landforms in the TWWHA, again with an ultimate view to establishing appropriate fire management regimes in the TWWHA (K. Jerie, *pers. comm.*).

A variety of other smaller scale soil features of geoconservation significance have been recognised and studied within and adjacent the TWWHA subsequent to 1989. These include globally rare "peat mounds" at Louisa Plains, Melaleuca and Birches Inlet – Moore's Valley (Macphail *et al.* 1999), and unusual soil types on Maatsuyker Island that are influenced by shearwater (mutton bird) activities (Pemberton 1990). However, blanket bog peat soils have been the major focus of interest in soils in the TWWHA to date, and the variety of other soil types and features found in the TWWHA remains relatively poorly known.